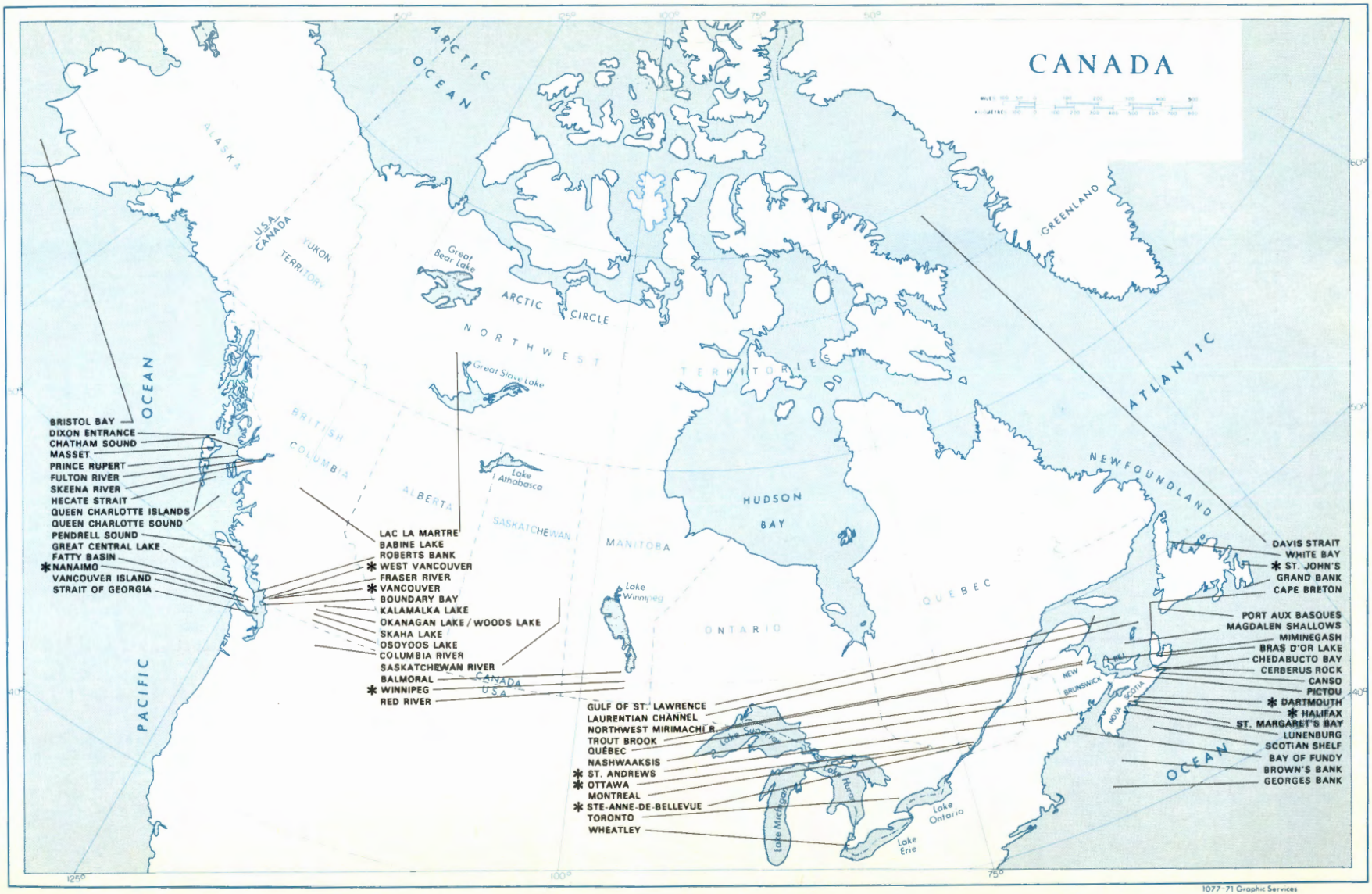
REVIEW

1969-1970

The Fisheries Research Board of Canada

OTTAWA 1971



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REVIEW
OF THE

FISHERIES RESEARCH BOARD OF CANADA

1969-1970

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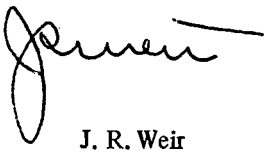
FOREWORD

The Fisheries Research Board of Canada has the unique responsibility and technical background to develop the whole field of research on Canada's aquatic renewable resources. It is an interdisciplinary organization, uniting experience and motivation in diverse sciences for the benefit of fisheries and aquatic resources generally. Its relatively small staff of talented scientists has brought the organization to a position commanding international recognition. This has resulted mainly from accomplishments in meeting the problems that arose because of the rapid change in Canadian fisheries from rather primitive harvesting operations to modern food industries.

In this era of scientific activity, fisheries research and aquatic science offer as complex a challenge as can be found in any field of investigation. The FRB program is designed to assist in conserving, increasing, and making better use of renewable aquatic resources, which include fishes, marine mammals, shellfish, other invertebrates, and aquatic plants. Its program also includes increasing attention to the biological fitness of the aquatic environment, a need which has been emphasized during the past two years in Canada as in other parts of the world.

Currently the Board's research program is considered under three main headings: Commercial and Recreational Fisheries Research, Environment Research, Products and Processing Research. Other important activities are included under Support of University Research, and Administration and Research Services. Some of the highlights of activities during 1969–1970 in these areas are listed in the next section; the research components are discussed in greater detail in the body of the Review.



J. R. Weir
Chairman

SOME 1969–1970 ACTIVITIES

Commercial and Recreational Fisheries Research

The general objective of the Commercial and Recreational Fisheries Research program is to facilitate effective research on the harvesting and management of aquatic renewable resources for the benefit of commercial and recreational fisheries. The program can be described as: research on harvesting (behavior, detection, and capture) and management (habitat, ecology, physiology, chemistry, abundance, and population dynamics) of marine mammals, fishes, shellfish, and aquatic plants; and on increasing these resources through transplants, fish farming, and new methods of propagation. Among interesting developments, the following are mentioned:

- On the Atlantic coast, surveys by research vessels have indicated poor haddock recruitment on the Scotian shelf since 1964. This information combined with analysis of fishing intensity was used as the scientific basis for establishing a quota on haddock catches in 1970, through the International Commission for the Northwest Atlantic Fisheries.

- The Atlantic herring fishery, developed explosively in recent years, has been based partly on accumulated older fish. As these are gradually harvested, the fishery is depending more on new recruits and the catch per unit fishing effort is decreasing. Research shows that a number of fairly distinct stocks are involved, distinguished by geographical distribution and migrations, spawning time, body form, rate of growth, and biochemical structure. In 1970, 80,000 herring were tagged at three locations, and recoveries show extensive movements from southwest Newfoundland into the Gulf of St. Lawrence in spring, and out of the Gulf in the fall.

- Blood proteins of salmon caught off west Greenland showed that about half the salmon present were of North American origin; the other half came from Europe. Salmon tagged during the controversial drift-net fishery off Port aux Basques, Newfoundland, in May and June mostly returned to Canadian mainland rivers.

- Encouraging results came from introducing Pacific pink salmon into North Harbour River, Newfoundland, by transplanting eyed eggs from 1959 through 1966. In 1969 a run of 1116 adult fish from natural spawning returned to their home stream, while 106 were known to go to other rivers and the commercial fishery took another 800.

- Arctic char tagged in the mouth of the Kuujjua River on the west side of Victoria Island, N.W.T., migrated at least 60 miles. The river population is exploited by summer and winter domestic fisheries, as well as by a summer sport fishery, the local catch being about 70,000 lb annually.

- On the Pacific coast an X-ray spectroscopy system has been developed for use in identifying the area of origin of different salmon stocks.

● Experimental utilization of shallow "winterkill" lakes for trout-rearing on the Prairies was extended. Rainbow trout planted in the spring of 1969 as fingerlings were harvested in late autumn at an average weight of 14 oz. The net yield is up to 125 lb per acre as compared to about 3 lb per acre for other commercial fish in that region. The color and flavor of the trout is much better than that of most rainbow trout sold commercially.

● Recoveries in 1969 of young harp seals tagged in the Gulf of St. Lawrence confirm that some Gulf-born animals join, perhaps permanently, the Newfoundland "Front" herd at one year of age. The sustainable yield of the combined Gulf and Front herds is estimated to be about 175,000 young animals, if present restraints on killing of older animals are maintained.

Environmental Research

The objective of the Environmental Research Program is to understand, maintain, restore, and enhance the aquatic environment in its biological aspects. The program can be described as: research on biological aspects of oceanography and limnology, as related to productivity of marine and inland waters and to fitness of the aquatic environment; detection, dispersion, and degradation of man-made pollutants in water; and ecological changes and tolerance.

The 1969–1970 studies included attention to various pollution crises and investigations of the ocean and freshwater environment. A few examples are:

● In 1969, massive water pollution and fish kills were caused by elemental phosphorus from a plant in Placentia Bay, Newfoundland. Research by FRB concentrated into a period of a few months showed that elemental phosphorus is extremely toxic to fish, that it accumulates in fish tissues, and that an abnormal red coloration of herring was caused by destruction of red blood cells. New analytical techniques had to be developed to detect elemental phosphorus in minute quantities in sea water.

● Oil pollution, caused in February 1970 by destruction of the oil-tanker *"Arrow"* after hitting rocks at Chedabucto Bay, N.S., gave rise to the development by FRB of a rapid method for distinguishing between various bunker oils, and definition of the role of microorganisms in oil pollution. Field teams of FRB personnel from St. Andrews, N.B., Dartmouth, N.S., and Ste. Anne de Bellevue, Que., evaluated the effects of oil pollution on fauna contributing to local fisheries, including lobsters, clams, and scallops, as well as on seals.

● Many young harp seals in the Gulf of St. Lawrence in 1969 were contaminated by oil, and the subsequent history of tagged animals was traced. Oil-fouled seals reached the Strait of Belle Isle, showing that mortality was not always immediate, but dead seals were reported both around Cabot Strait and in the Strait of Belle Isle.

● Serious concern, over the discovery in December 1969 of dangerous levels of mercury in fish from the Saskatchewan River, had expanded by summer 1970 into a

nation-wide pollution problem. FRB has been heavily involved in a priority program to determine the extent and degree of mercury contamination in many species of fish and marine mammals and sediments.

- Studies of the phytoplankton, zooplankton, and bottom fauna of northern waters, combined with physical oceanography, are aimed at understanding the factors controlling arctic productivity and providing a baseline for northern pollution control studies. Such work is timely because of the threat of pollution from accidental oil spills and from other industrial developments in the Arctic.

- FRB scientists made major contributions to the International Joint Commission on Pollution of the Lower Great Lakes including an assessment of the present state of eutrophication, recent historical changes, and recommendations on dealing with enrichment by phosphates and other pollutants.

- A 1969 cruise on CNAV *Endeavour* from Esquimalt, B.C., to Tokyo and return, continuously monitoring chemical and biological components, extended knowledge of how oceanic variability may affect commercial fish production.

- FRB scientists participated in the Around-the-Americas *Hudson 70* expedition, which ended on October 16, 1970. Interest was aroused by the finding that dark fixation of ^{14}C is a large component of total carbon fixation, especially at low latitudes.

Products and Processing Research

The general aim of the Products and Processing Research program is to discover and develop new and improved products derived from aquatic renewable resources, and to improve the handling, storing, and processing technology of such resources. The program is described as: research on functional properties of aquatic products and on their handling, storage, and processing.

Examples of the 1969–1970 activities under this program are:

- In 1970 the first Canadian plant to produce fish protein concentrate (FPC) was completed at Canso, N.S. Based on the isopropanol process developed by FRB, recent modifications permit more economical handling of fatty species such as herring.

- Although earlier research on fish preservation led to many successful commercial applications, spoilage of chilled fish has continued to plague the fish industry. Recent experiments at sea and on shore show that rapid chilling after capture, and the use of refrigerated sea water or adequate icing, can prevent these losses.

- Establishment in 1968 of the Freshwater Fish Marketing Corporation has encouraged research to develop new products from Canada's lakes and streams. In 1969, pilot-plant experiments resulted in utilization of over one million pounds of suckers in the preparation of pet foods; palatable sausages and fish patties were also made from this

species. Improvements were developed in the processing of smoked goldeye and whitefish.

- On the West coast the problem of waste-water disposal from fish plants has been attacked by developing methods for economically utilizing the wastes. Some plants have already adopted the techniques.

- Of special significance to man's health is the discovery that molluscs have potential as dietary depressors of blood cholesterol.

- A portable refrigerated fish plant, weighing less than a ton, has been designed for use on remote northern lakes and is expected to replace sheds and icehouses.

Support of University Research

Research at selected Canadian universities is supported with development grants, scholarships, staff exchanges, publication services, and the use of ships and laboratories for research and for student training. The objective is to encourage the development of university centers of research excellence and sound professional training in sciences related to aquatic renewable resources.

Administration and Research Services

Administration and Research Services are involved in data processing, report preparation, scientific publication facilities, libraries, accommodation, repair shops, vessels, and administrative services as they relate to the control and operation of the Board.

Honors and Awards

The Board's Chief Scientist, Dr. W. E. Ricker, was honored in 1969 by receiving from the American Fisheries Society at its 99th Annual Meeting the first Award of Excellence, which included a medal and $1,000 prize, "in recognition of excellence of contributions to fisheries and aquatic science." In 1970 Dr. Ricker received the Flavelle Medal of the Royal Society of Canada to mark his "original research of conspicuous merit in the biological sciences." He was also given an honorary degree of Doctor of Science from the University of Manitoba.

Dr. H. L. A. Tarr was honored by a special award for "outstanding contributions and world-recognized leadership in pure and applied research in the fishery field" at the 1970 Annual Meeting of the Pacific Fisheries Technologists Society.

Dr. L. M. Lauzier was elected a Fellow of the Royal Society of Canada in 1970. Mr. A. W. Lantz received the W. J. Eva award from the Canadian Institute of Food Technology.

THE FISHERIES RESEARCH BOARD OF CANADA

The Fisheries Research Board of Canada is a federal agency whose role is to provide information on the most effective means of utilizing the aquatic environment and maintaining its biological fitness, and to conduct investigations of practical and economic problems connected with marine and freshwater fisheries, and Canada's living aquatic resources. The oldest government-supported scientific organization in North America supervised by an independent advisory board, it is a lineal descendant of the honorary Board of Management established in 1898 under the federal Minister of Marine and Fisheries to encourage and supervise marine biological research. With growth in scope of responsibilities and membership, the Board was reconstituted as the Biological Board of Canada in 1912, and as the Fisheries Research Board of Canada in 1937. In 1970 its total staff complement was 839 and its annual budget was 16.1 million dollars.

The present board consists of a full-time Chairman, appointed by the Governor in Council, and up to eighteen members appointed by the Minister of Fisheries and Forestry. At the end of 1970 ten members were from Canadian universities, seven from the fishing industry, and one from the Department of Fisheries and Forestry. The Board sets objectives and policies, reviews and guides broad research programs, and advises on questions referred to it.

Research establishments are located at Nanaimo, Vancouver, and West Vancouver, British Columbia, at Winnipeg, Manitoba, at Ste. Anne de Bellevue, Quebec, at St. Andrews, New Brunswick, at Dartmouth and Halifax, Nova Scotia, and at St. John's, Newfoundland. Smaller permanent establishments are maintained at St. John's, Newfoundland, and at Ellerslie, Prince Edward Island. Several temporary and seasonal field stations are also operated. Summary reports of research carried out by each laboratory during the 1969–1970 period form the major part of this Review.

OFFICE OF THE CHAIRMAN

The Chairman, as Chief Executive Officer, maintains an office in Ottawa concerned with the management of decentralized laboratories across Canada, and with policy and program planning. He is supported by a Deputy Chairman (Operations), a Deputy Chairman (Policy and Planning), Scientific Advisers, and a Director of Administration. This staff serves as a secretariat to the advisory Board and its committees and has responsibility for implementing decisions in accordance with governmental and ministerial policies. The staff also operates the university grants and scholarships program. Coordination of programs, liaison with other agencies, and scientific advisory services are provided through the Office of the Chairman.

Organizational Changes

In May 1969, Dr. J. R. Weir became Chairman of the Fisheries Research Board, on the retirement of Dr. F. Ronald Hayes. Dr. Hayes had served with distinction as the Chief Executive Officer since 1964.

Much has happened in the Board recently, both with regard to personnel and to structure. Under the Government Organization Act (1969), which became effective on April 1, 1970, the Board ceased to be a "separate employer" and its employees were placed under the Public Service Commission.

An Atlantic Region, composed of FRB establishments at St. John's, Newfoundland, at Dartmouth and Halifax, Nova Scotia, at St. Andrews, New Brunswick, and at Grande-Rivière, Quebec, was created in the fall of 1969. The Office of the Regional Director (Research) was established in Halifax to direct FRB programs in the Atlantic Region and coordinate these with related federal, provincial, university, and industry programs. As a result of the Government's manpower adjustments the Station at Grande-Rivière was closed in March of 1970, and a number of the staff were transferred to Halifax, N.S.

The Ottawa Headquarters organization was changed in the latter part of 1970, with the appointment of an additional Deputy Chairman. One Deputy is now responsible for operations, and the other for policy and planning.

The post of Pacific Regional Coordinator, Research, was established in 1970, for coordination of FRB operations on the West Coast, liaison with other Ministry Services, and integration of these activities into the Board's whole program.

A Program Head was appointed at the new FRB facility at West Vancouver, British Columbia, which became operational in the fall of 1970.

OFFICE OF THE EDITOR

The Office of the Editor is responsible for primary scientific publication and maintains various publication series. The monthly *Journal of the Fisheries Research Board of Canada* is recognized as a leading international vehicle for the publication of aquatic research results.

The steady flow of scientific and technical information that is the main product of FRB's research program has been maintained. Communication between scientists in the Board's fields of interest is principally through the *Journal* and other recognized primary journals. Achievements are reported to the fishing industry and to national and international bodies in the *Journal, Bulletin* series, *Circulars, Technical Reports,* and interpretive articles in trade journals.

An important policy change was the introduction of page charges for material published in the *Journal*. Recovery of part of the costs of publishing Bulletins was also introduced. Articles on FRB investigations published in other primary periodicals, which have been bound as sets of collected reprints called *"Studies"*, are listed in each issue of the *Journal*. The binding and distribution of sets of studies was discontinued at the end of 1969.

Results of investigations by FRB scientists were made available in an increasing number of printed reports and sub publications in the two-year review period. In addition to the 212 articles by FRB staff in the Journal, they also published 194 articles in other primary journals. In the subpublication series, 126 Technical Reports were distributed, and 415 titles were added to the Translations series. The establishments issued 20 Circulars directed principally to the fishing industry, 61 interpretive articles were published by Board scientists, and 111 Manuscript Reports were produced.

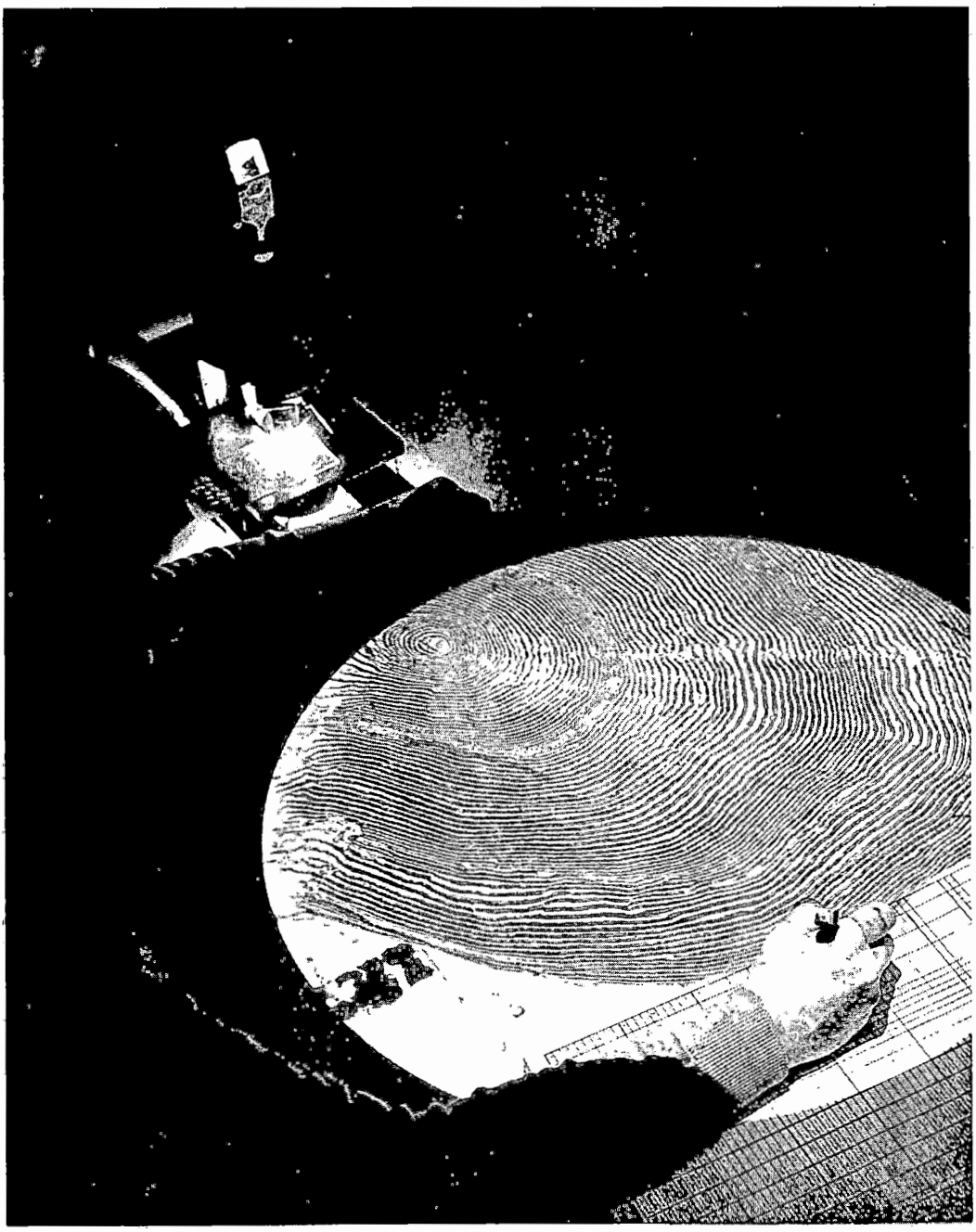
Five new Bulletins were issued in 1969 and two in 1970, one of the latter being an addition to the important group of authoritative works on Canadian fishes. A French edition of Bulletin 151, which had appeared earlier in English, and a French translation of the preface to Bulletin 164, were published. A number of Bulletins are being translated and a large number of new Bulletins are being processed.

An index was prepared and issued for the Manuscript Report series, and included 1189 numbers.

The Annual Reports and biennual Review for 1967 and 1968 were produced and distributed widely. Through subscriptions, sales or publication exchange arrangements, FRB publications are distributed to more than 100 countries.

The April 1969 issue of the Journal was dedicated to Dr. T. W. M. Cameron, a distinguished Canadian parasitologist and member of the Board from 1954 to 1963.

The Office of the Editor also acts as a central documentation unit for the Board, handles exchange agreements, and controls publication distribution.



Microprojection equipment is used to study scales, which reveal age, racial origin, and growth rate of fishes

BIOLOGICAL STATION
NANAIMO, BRITISH COLUMBIA

The Nanaimo Biological Station contributes both to the commercial and recreational fisheries and to the environmental quality programs of the Fisheries Research Board. Its functions, in the implementation of these programs, are:

- To increase knowledge and understanding of the biology of aquatic organisms of economic importance and of biological processes affecting the production and utilization of aquatic resources

- To increase knowledge and understanding of the aquatic environment; particularly of those qualities and processes which determine its capacity to produce living aquatic resources

- To discover and develop means of maintaining and increasing the benefits obtainable from the aquatic resources through both recreational and commercial fisheries by:

  increasing the productive capacity of the environment
  augmenting the supply of resources by new or improved cultural techniques and by transplants of suitable species and races
  inauguration or improvement of methods of farming aquatic resources
  efficient and economical harvesting and more effective management of the harvesting process
  providing scientific support for the protection of Canada's interests in the fisheries of international waters

- To increase knowledge and understanding of the effects of pollution on the aquatic environment and on aquatic organisms, and to assist in the control and prevention of harmful effects of pollution

A few of the highlights of the Nanaimo Station's work in 1969 and 1970 have been:

- Completion of a survey of rockfish species of the northeast Pacific and separation of the Pacific ocean perch, the most important species, into two major stocks

- Explanation of the causes of the recent failure of British Columbia herring stocks

- Development of techniques for identification of temperature and feeding rate giving optimum growth and food conversion in salmon

- Discovery of chemical means for rapid separation of salmon of different origin, applicable to analysis of commercial catches

- Development of diagnostic services enabling the resumption of the export of salmonid eggs to United States hatcheries

- Verification that sockeye salmon originating in the spawning channels at Babine Lake are similar in quality and survival to naturally produced fish

- Demonstration that the carefully controlled addition of nutrients to a nutrient-poor lake can increase the growth of young sockeye salmon without producing blooms or other undesirable effects

- Confirmation that a hatchery technique developed at Nanaimo gives, for pink salmon, survival that is better than nature up to emergence, and about as good during marine life

- Verification that the Pacific environment can fully support adult Atlantic lobsters and enable them to grow and reproduce normally

- Identification of the brown stain in pulp mill effluent as a serious inhibiter of normal biological production in long marine inlets

Increasing Knowledge of the Biology of Aquatic Resources

Investigations which have this as their immediate objective include:

Groundfish

Principal objectives of these studies have been to study the ecology and population dynamics of the commercially important species of groundfish to define the status of the stocks and monitor the effects of fishing. Emphasis is placed on: (1) species which contribute to the long-established trawl fishery off the British Columbia coast; (2) rockfish species which are taken not only by the domestic fishery but also by the fleets of foreign vessels operating off the British Columbia coast.

Collection of catch and effort statistics and samples for age and growth permit estimation of trends in abundance, growth, and mortality. Total catch of all trawl-caught species in 1969 and 1970 was 38 and 29 million lb, respectively, considerably less than the peak catch of 55 million taken in 1966. In 1969 and 1970 commercial abundance was lower than in previous years for both Pacific cod and Pacific ocean perch which is the most important rockfish. This was partially the effect of fishing but also because of reduction of apparent strengths of year-classes entering the fishery. In Pacific cod the largest year-class in recent years was that of 1962 and those produced since have been considerably weaker. In Pacific ocean perch, a longer-lived species, year-classes entering the commercial fishery since that of 1952 have been relatively weak, and that particular year-class is past its peak contribution.

Pacific ocean perch have been subdivided into two major stocks, a British Columbia type and a Gulf of Alaska type on the basis of differential growth and dominant year-classes. The boundary is Dixon Entrance. A further new rockfish species, *Sebastes caenaematicus*, has been described from British Columbia waters.

Assessment of the status of Pacific cod stocks in Canadian waters has been hampered in the past by lack of a means of aging them but recently a method was developed which depends upon examining magnified images of their scales, and its reliability was proved. Ages of Pacific cod are now obtained routinely by the new method.

Pelagic Fishes

The objectives of this investigation include: (1) determination of the causes of the recent decline in herring abundance, and the parts played by the fishery and the environment; (2) determination of the conditions for maximum and optimum sustainable yield to assure that overfishing does not cause similar declines in future; (3) knowledge of the distribution and growth of wild larval herring, and determination by laboratory studies of the effect of environmental factors on the survival of eggs and larvae, food, nutrition, and growth; (4) determination of the location of any offshore concentrations of herring, and their relation to the inshore spawning stocks currently exploited.

A sharp decline in herring catches occurred between 1964–65 and 1967–68. From 1966 to 1968 spawn deposition declined to between 85 and 104 miles as compared with the 25-year average of 199 miles. As a result in 1968–69 and 1969–70 essentially all fishing was prohibited. Also, to promote understanding of the causes of the failure, the herring research program was reviewed and expanded to provide a multidisciplinary approach by drawing in specialists in parasitology, microbiology, environmental physiology, and population dynamics. In 1969 spawn deposition increased again to 124 miles, in 1970 to 293 miles. While the 1970 figure, represents a spawning stock size well above average, the total stock (catch + spawning stock) is still somewhat below average. The increase in abundance was greater in southern British Columbia stocks than in northern. At the same time as the decline in abundance, there was a decrease in the average age of the fish with a greater representation from fish in their second year. Population models indicate that the abrupt decline in abundance which led to the closure of the fishery in 1967–68 may be the result of overfishing on stocks already affected by low recruitment. The recruitment of two poor year-classes (1962 and 1963), had reduced the abundance of spawners to a very low level at a time when the rate of exploitation was increased. This situation is not unique in the history of the fishery. Never before, however, has it been accompanied by an appreciable exploitation of young fish. With the ranks of immature and newly maturing fish depleted by the fishery, no appreciable recovery in the abundance of spawners could be anticipated until the progeny of the postclosure spawnings mature (1970 for most southern stocks and 1971 for most northern stocks). The spawn depositions to 1970 followed the patterns predicted by the models, and some populations could have supported a small fishery in 1970–71; this however would not have been large enough to be commercially viable. Unfortunately survival conditions for the 1969 year-class apparently were poor. If this causes the year-

class to be appreciably weaker than its immediate predecessors the rate of recovery may be slowed.

The offshore survey, begun in 1968, using a midwater trawl along the lower west coast of Vancouver Island was expanded in 1969–70 to cover a full year and include Hecate Strait and Queen Charlotte Sound. Herring appeared to be confined to the region of the coastal banks: few were found in water deeper than 60–70 fath and none in water deeper than 100 fath. No new stocks were located. The herring found appeared to be part of known inshore spawning stocks. On the lower west coast of Vancouver Island the largest concentrations were found on La Pérouse Bank and on Swiftsure Bank. In Hecate Strait smaller quantities of herring were located than on the west coast. There were more herring in the northern part of the region than in the southern. In Queen Charlotte Sound only limited quantities of herring were located, mostly on the last cruise, in April. The reason for the limited catch is not clear, particularly since spawning reports indicate the stocks in this region are increasing.

During 1969–70 larval herring from artificially fertilized eggs were reared at 9 C and 20 ‰ salinity on different diets. In 1969, maximum growth and survival rates were obtained from a diet of zooplankton and newly hatched brine shrimp nauplii. Some larvae on this diet grew to 28 mm in 104 days. In 1970 larvae were fed three separate diets at two different rates. These were brine shrimp nauplii, zooplankton, and brine shrimp nauplii plus zooplankton, at rates of three organisms, and six organisms/day per larvae. By the end of the third week mortality had risen to more than 60%, and was 10% greater at the lower rate of feeding than at the higher. After 3 weeks, mortality levelled off with only small, daily losses of 1–2% until the end of the 18-week experiment. The heavy early loss was attributed to the inability of some larvae to initiate feeding. Mortality was lowest among larvae fed the mixed brine nauplii and zooplankton diet. The 90% mortality level was reached in 68 days on this diet and in 32 and 42 days on the other two diets. At both rates of feeding, growth averaged about 0.2 mm/day on both the zooplankton and zooplankton plus brine shrimp diets. Those larvae that survived quadrupled in size on these two diets, attaining lengths of 33–36 mm and fully metamorphosing to juvenile herring.

The juvenile herring survey showed that the region from Pedder Bay to Sooke along the lower east coast of Vancouver Island was a center of very high abundance for juvenile herring. Herring congregated here in October prior to migrating seaward in November.

The population dynamics group at Nanaimo also undertook studies on the status of the Newfoundland herring stocks following the increase of the catch from 10,000 tons in 1964–65 to 144,000 tons in 1967–68. Investigations showed that the bulk of the increase in catch was taken on the southwest coast from a stock of predominantly autumn–winter spawning fish which does not appear to have been a major producer in the past. Most of the remaining increase came from a formerly important spring-spawning stock in Fortune Bay. At least three other stocks also contributed to the seine catch. Estimates of abundance and exploitation indicated that by 1967–68 this rapidly expanding fishery was exploiting the southwest coast stock at or beyond the sustainable

yield level, and suggested that similar conditions obtained for the larger minor stocks. Continued expansion of this fishery could seriously jeopardize its future.

Salmon Stock Assessment

The objective of this project is to assess the age, size, and sex composition of sockeye, pink, and chum salmon stocks of major commercial importance in British Columbia. These data are essential for effective management of the salmon stocks.

The total catch of sockeye in 1969 was well below that of 1968. More than half of the Skeena catch was represented by 4-year-olds from the 1965 brood year whereas catches from Rivers and Smith inlets were composed mostly of 5-year-olds. For chums, unlike 1968 wherein catches were composed mostly of 4-year-olds, 1969 catches contained relatively high proportions of 3-year-olds.

Statistical evaluation of the sampling of British Columbia catches of sockeye, chum, and pink salmon indicated the sampling of all species could be reduced while maintaining the required level of accuracy in the results.

Salmon Scale Studies

The object of these studies is to develop additional means of distinguishing between salmon from different sources from the characteristics of their scales and, for this purpose, to investigate the mechanisms producing these characteristics.

A study of the scale characters of sockeye salmon originating in small nursery areas of the Skeena River system has suggested a possibility of separating Skeena River stocks spawning at a low elevation far inland from other stocks in the system. Scale patterns also provided some insight into the productivity of the nursery areas where Skeena River juveniles were reared.

Studies suggest that both the number and spacing of circuli on scales of young sockeye salmon are influenced by the feeding interval. Fish fed to satiation daily had both more circuli and more widely spaced circuli than those fed every 7 days. Scales of young sockeye starved continuously from 5 to 7 months formed neither circuli nor checks during the period. There was a positive correlation between the number of checks on scales of young sockeye and the number of months they were fed to satiation daily. Correlations between the nucleus radius of the scale and (a) the number of circuli, (b) length, and (c) fish weight suggests egg size may affect the size of the scale nucleus and subsequent formation of circuli.

Ecology and Production of Freshwater Fishes

The fish community of Lynn Creek, a small coastal stream on Vancouver Island, is under study to explain the basis for coho smolt production. Particular attention is given to the coho and cutthroat trout populations which dominate the fish community. Analysis of foodchain relations, fish distribution and abundance in the system, and

behavioral interaction shows that the coho and trout populations compete for food and space. Severity of competition is partly relieved by dissimilarities in (1) reproductive timing and duration of stream residence prior to seaward migration, (2) feeding behavior in similar habitats, and (3) social behavior involving reduced effectiveness of interspecific communication of aggressive state.

Shrimps and Crabs

Field work was completed by mid-1969 on a project to investigate the biology and dynamics of an exploited shrimp stock near Comox which had begun in 1965. Analysis is now in progress. During the final year, experimental trawling and vertical plankton hauls were continued to determine distribution and abundance of adult and larval stages of the two main species. *Pandalus jordani* and *P. hypsinatus* and of their growth rates and reproductive cycles. In 1969, as in 1965 and 1967, the fishery was supported by one age-class utilized between 1½ and 2 years of age, in contrast to 1966 and 1968 when more older shrimps were present.

Early in 1969 a study of Dungeness crab (*Cancer magister*) stocks on Roberts Bank and in Boundary Bay was begun; its objectives are to determine distribution, migration, and soft-shell or molting seasons. Work to date has shown concentrations of juveniles in certain localities, and that the soft-shell period is approximately from June to September. Tag returns to date (93 of 170 released) reveal insignificant movement at Roberts Bank. Thus crabs are expected to remain in the area and fishermen should not suffer loss if a summer closure is enacted to protect the crabs until the meat yield is back to normal after molting. Bottom sediment monitoring at 14 stations adjacent to the coal shipping site at the Roberts Bank superport was started early in 1970.

Clams and other Molluscs

The purpose of these studies is to assess the molluscan resources of the British Columbia coast and provide the biological knowledge needed for their management.

Regular sampling of the razor clam population at Masset, Queen Charlotte Islands in 1969 and 1970 showed that major spawning occurs in July and the clams attain a shell length of about 10 mm by the end of the first winter. However, significant settlement also results from minor spawnings which occur from early May to October. Settlement on North Beach was low in 1969 (maximum density 13 clams/ft^2), but excellent in 1970 (maximum density 39 clams/ft^2). In 1970 moderate numbers of small clams were found on South Beach.

Measures of growth and mortality rates of butter clams latitudinally along the British Columbia coast and at different tidal levels on intertidal beaches showed that growth rate was most rapid in the Strait of Georgia and decreased with northward distribution. Growth was faster at the low-tide line than above. Mortalities, which were due mostly to the moon snail *Polinices lewisi*, were less than 5% in northern plots, but as high as 70% at the low-tide line in the Strait of Georgia.

A triennial survey to assess fluctuations in clam population on Seal Island in the Strait of Georgia was carried out in 1970. Legal-size butter clams (shell length 65 mm and over), which comprised 91% of the population, had a mean density of 9/sq yard, slightly higher than in the past 10 years. Mean density of sublegal-size clams was the lowest recorded in the study, 0.85 clam/sq yard.

A temperature of 15 C, salinity of 25–30‰ and a food regime of 10,000–20,000 algal cells/day was found to provide optimum conditions for growth and survival of butter clam larvae. Optimum temperatures for growth and survival of horse clam, *Tresus capax*, larvae was 10–15 C. The larval stages of the rock borer, *Zirphaea pilsbryi* were determined. Mortalities of juvenile butter clams planted in three areas of the Strait of Georgia were very heavy, 90% in one plot and 99% in five others.

Physiology

The broad aim is to determine the energy requirements of salmon for maintenance, activity, growth, and feeding in relation to size, quantity of food, and environmental factors such as temperature, light, and salinity. Such studies provide information on the energy expended in migration, and thus on the consequences of delays and changes of environment. Knowledge of the most efficient conditions for growth is, of course, valuable in fish culture.

The discovery that there were unique combinations of ration and temperature which would produce either maximum growth or maximum conversion efficiency from food to fish flesh, depending on appropriate definable levels, prompted the development of multi-environmental controlled tanks. Although supporting evidence was not available on the optimum levels for all the environmental factors chosen, judicious selection was possible from knowledge of metabolic rates and general growth phenomena.

Experiments have been conducted using (*a*) hatchery-raised yearling sockeye, (*b*) wild yearling sockeye smolts, (*c*) hatchery-raised pink fry, and (*d*) wild chum and pink fry. Fastest growth was obtained with cultured pink fry which doubled their weight every 2 weeks (average of 5% per day) for the first 2 months. Sockeye yearlings grew at about half this rate – as a result of genetic and size influences. The combination of wild chums and pinks grew poorly despite good feeding responses. Marketable pink salmon weighing 10 oz could be produced in about 8 months.

At 15 C (59 F) appetite was found to increase rapidly 7–10 hr after satiation feeding. From studies of the effect of temperature on rate of digestion it was deduced that good appetite occurs when the stomach is about 90% empty. This has provided a rationale for maximizing food intake for any temperature conditions.

In general there is enough evidence for the success of environmental and ration control as a means of maximizing growth to predict that the production of any species of fish which is amenable to artificial culture could be greatly improved.

Physiological Ecology

Objectives of the program are to obtain an understanding of (1) the biology of commercially important aquatic species, particularly early development, (2) the biological processes affecting their production, and (3) influence of environmental conditions on these processes and on survival. These studies provide information on the effects of natural environmental change on fluctuations in abundance. They also provide a baseline for studies on the effects of pollution. The objectives are pursued in two areas of inquiry:

Egg and larval studies on marine fish

Effects of salinity and temperature on developmental success (from egg fertilization to yolk sac exhaustion in larvae) were completed on flathead sole (*Hippoglossoides elassodon*) and initiated on Pacific herring (*Clupea harengus pallasi*). Salinity and temperature tolerance boundaries and optima were estimated, in most cases, for rate of development, percent total and viable hatch, larval size at hatching and post-hatching development. Both species appear particularly well adapted to develop successfully over a broad range of salinity and temperature conditions in the external environment. Direct effects of salinity and temperature on egg development are probably not involved in the recent decline of British Columbia herring stocks.

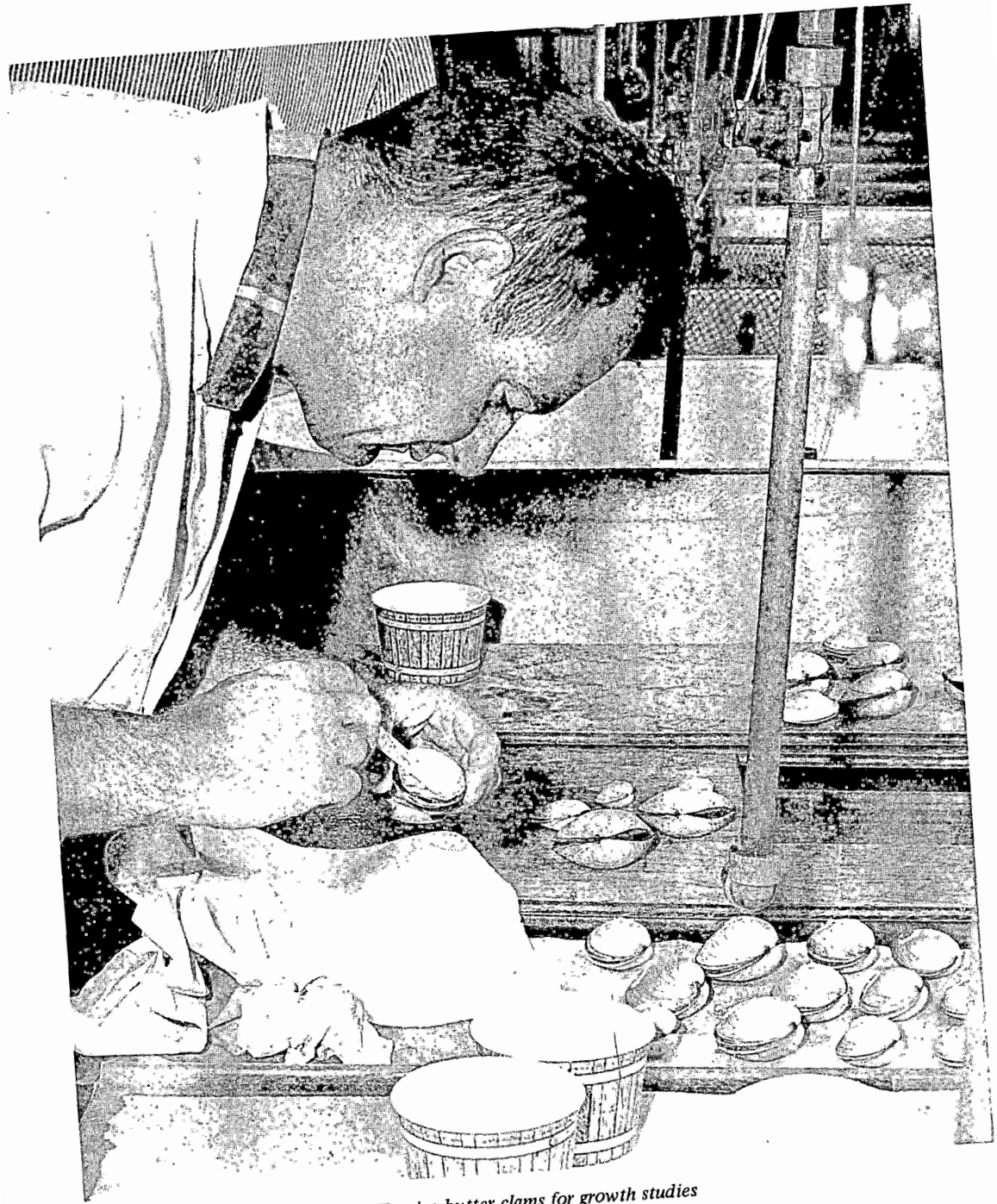
Juvenile coho salmon

Swimming capacity of juvenile coho salmon (7.5–9.5-cm total length) in fresh water was determined with respect to temperature history (acclimation) and unacclimated (acute) temperature experience. Optimum performance (5.8 body lengths/sec) occurred at a combination of acclimation and acute temperature levels near 20 C. At least 50% of optimum swimming capacity is achieved over virtually the whole range of thermal tolerance. Young coho appear capable of greater performance in warmer environments (17–20 C) than sockeye salmon juveniles.

Ecological Genetics

Investigations in ecological genetics have recently been started. The long-term objective is to study the inheritance of traits which regulate behavior, growth, and survival in economically important fishes. These studies will provide important information for use in management of the resource and in programs of artificial propagation, and mariculture. Initial studies have dealt with anadromous salmonids.

New methodology and facilities were developed in connection with these studies. Experimental rearing and testing facilities suitable for culturing large numbers of small groups of fish were constructed. Also under study were data acquisition techniques which could be used to accumulate data electronically and tagging methods to distinguish small organisms. A method of chemical tagging using X-ray fluorescence spectroscopy was developed.



Tagging butter clams for growth studies

Results of studies in which male and female sockeye salmon from different streams in the Babine Lake system were crossed, demonstrate a genetic basis for the stock concept. Genetic differences in survival and in response to current in juvenile fish were observed. Maternal effects were also shown to have a considerable effect on survival of juveniles. Analysis of environmental variables suggests that density dependent factors, especially parasitism, are in part responsible for the observed maternal effects.

X-ray spectroscopy studies of juvenile and adult sockeye salmon collected in different geographic areas demonstrated the presence of recognizable inorganic chemical differences among the samples in trace quantities. A method of ascertaining the area of origin of fish taken in the catch was developed and is currently being tested. The results also indicated the normal background range of chemical elements associated with heavy metal pollution.

Salmon Hybridization

The objective of this study is to determine the ways in which characteristics of Pacific salmon (e.g., rates of growth, incubation time, size at hatching, etc.) are transmitted. For this purpose offspring of a series of inter- and intra-specific crosses of sockeye, pink, and chum salmon have been examined. Among the three species, the time from fertilization to hatching is affected more by the male than by the female parents. Chum males produce earliest-hatching offspring and sockeye males the latest. Amongst groups of eggs fertilized by the same male, those from chum females hatch soonest and those from pink females, latest. Size of the newly hatched larvae is determined almost entirely by the female parents. Chum females produce the largest larvae (chum eggs are larger than those of pinks or sockeye). The growth rate of embryos while still in the egg, however, is determined more by the male parents than by the females. Fastest pre-hatch growth rates are associated with chum males and females; slowest with sockeye males and pink females. Because sockeye, pink, and chum salmon can be crossed readily and produce viable offspring, it should be possible to breed salmon capable of exploiting new or changed freshwater environments.

Ethology

Direction finding in migrating Pacific salmon is a complex interaction between environmental factors and sensory and integrating systems of the fish. To study this interaction in sockeye salmon in the field, a cooperative project between the Fisheries Research Board (FRB), the University of Wisconsin (U of W) and the Resource Development Branch of the Fisheries Service (FS) was initiated in 1969. Sockeye salmon were intercepted during their migration through Chatham Sound (U of W), the lower Skeena River (FS) and Babine Lake (FRB), and marked with ultrasonic transmitters. Signal range varied from ¼ to 1 mile, dependent on water, weather, and bottom conditions. Individually marked sockeye salmon were followed in the three areas, and their paths plotted. Tracks lasted up to 76 hr over distances of more than 100 km. Environmental conditions were monitored during each track.

Results to date indicate that sockeye salmon migrate with individual average speeds of 1.4–3.6 km/hr in salt water (Chatham Sound) and 1.0–2.6 km/hr in fresh water (Babine Lake). The somewhat higher speeds in salt water are probably due to tidal influences. In salt water, migration generally continues through the night, while in fresh water sockeye salmon often stop or slow down considerably during the dark period, to start again as soon as the sun rises. Directed migratory routes can be maintained in both habitats under both clear and overcast skies either during day or night.

Although laboratory experiments have shown that Pacific salmon can use the sun for direction finding, the sonic tracking results strongly suggest that these fish must be able to make use of noncelestial cues to keep on course during densely overcast periods.

Microbiology

The objective of this program is to gain an understanding of the factors governing the survival, abundance, and health of important species utilized in the commercial and recreational fisheries through investigation of contagious diseases affecting the species, and elucidation of the host's defense mechanisms and to find means of applying this knowledge to disease control in fish culture operations and in nature.

Given an adequate dose of antigen, sockeye salmon held at 13–15 C all produced circulating antibodies by 3 months following a single intraperitoneal injection of heat-killed kidney disease bacteria in adjuvant. The response was specific for the pathogen. Because elevated levels of antibody were present for at least 15 months following the treatment, long-term protection against specific infectious diseases may be possible by this method with a minimum of handling. Results indicate that heat-killed antigen conferred only questionable protection to challenge with living pathogen, and trials with other preparations of the antigen are indicated.

A study of the bacterial ecology of salmon eggs incubating in the Qualicum River and Robertson Creek spawning channels has been terminated. The following genera have been identified: *Pseudomonas* (25), Group I, II, III; *Cytophaga* (18); *Chromobacterium* (5); *Aeromonas* (3) (no furunculosis organism); *Klebsiella* (3); *Enterobacter* (2); *Acinetobacter* (2); *Vibrio* (2); *Sarcina* (1). Three cultures were placed in the family *Enterobacteriaceae*. Tentatively, the results suggest that salmon eggs usually have a characteristic microflora and that there are no obligate or primary bacterial pathogens of salmon eggs. Bacterial invasions, usually by *Pseudomonas* spp. probably follow debilitation or death of the egg by physical or chemical factors.

Diagnostic services related to fish diseases were provided with increasing frequency to the British Columbia Fish and Game Branch, Fisheries Service, Vancouver Public Aquarium, industry, the public, as well as to local FRB establishments. New viral diagnostic services were developed and as a result a provincial hatchery was certified as being free of viral hemorrhagic septicemia ("Egtved disease") so that shipments could legally be made to the United States. Several fish kills and epizootics have been investigated and reported, for example, the death of hundreds of thousands of adult whitefish at Kootenay

Lake, fungal infections of spawning Girrard River rainbow trout and a multispecies kill at Nitinat Lake.

Vibrio anguillarum has been isolated from epizootics among chinook and pink salmon held at West Vancouver. Vibriosis has not previously been reported in cultured fish in Canada. Other diseases investigated in the hope of developing suitable control measures as an aid to aquaculture included an unidentified species of myxobacterium causing a bacteremia resulting in heavy losses in juvenile chum and chum-pink hybrids, and a contagious disease of unknown aetiology has caused devastating mortalities in cultured pink salmon at Nanaimo.

Parasitology

The objectives of parasitological studies are (1) to assess the effects of parasitism on fish and (2) to use parasites as biological tags for the identification of the geographic origins of salmon stocks taken on the high seas or in coastal fisheries. Diagnostic services for identification of parasites occurring in fisheries products are provided to the Fisheries Service, to industry, and to the public.

Those sockeye smolts migrating from Babine Lake which are infected with the tapeworm *Eubothrium salvelini* (20–30%) average 5 mm shorter and 1 g lighter than noninfected smolts and show spring or "plus" growth on their scales more rarely. Also, infected smolts, when tested in an experimental swimming tunnel, fatigued more rapidly than uninfected smolts. These results suggest parasitism may be important in relation to subsequent smolt survival. If the *Eubothrium* infection rate is affected by sockeye density, this parasite could adversely affect the Babine sockeye development program. To enable controlled laboratory study of the effects of *E. salvelini* on young sockeye, the life cycle of the parasite is being studied; copepods of the genus *Cyclops*, but not *Diaptomus*, were found to be the intermediate host in which the larval stage (plerocercoid) normally infective to fish develops.

Studies on the effects of *Salmincola californiensis*, a parasitic copepod of potential danger in salmon culture, have shown that contrary to previous beliefs the parasite feeds quite commonly on the blood of its young salmon host. Establishment of a laboratory stock of infected salmon has been accomplished by transfer of the parasite from wild, naturally infected sockeye smolts to laboratory-reared uninfected smolts.

Parasitization of the eye of *Atheresthes stomias*, arrow-toothed flounder, with the copepod *Phrixocephalus cincinnatus* results in blindness of the infected eye (usually the right one). However monocular fish appear to be quite capable of normal feeding, and very few fish suffer binocular blindness, so that the overall effects on the host population appear to be negligible.

Continuing studies on using parasites as natural tags to identify the origin of salmon stocks have shown that infection with the protozoan *Myxobolus* sp. in the hindbrain and spinal cord of sockeye varies according to river system. It is apparently absent from some

principal sockeye-producing river systems in Alaska (Karluk, Kenai, Wood, Naknek), abundant in Rivers Inlet sockeye and comparatively scarce in Babine Lake and some Fraser River tributaries. Thus *Myxobolus* sp. appears potentially useful as a salmon stock discriminant, particularly when used in combination with other stock differentiating characteristics.

The discovery of *Brachiella lageniformis* (parasitic copepod) on the gills of hake, *Merluccius productus*, from British Columbia lends support to the theory of the North Pacific origin of the genus *Merluccius*. This parasite was previously known only from hake, *M. Hubbsi*, from the coast of Argentina.

Increasing Understanding of Productivity of the Aquatic Environment

Investigations which have this as their immediate objective include:

Fisheries Oceanography

The objectives of this program are to provide oceanographic information of direct value to the management of fisheries. The program is divided up into a number of smaller projects as follows:

Meterological data were used to determine wind driven transport on the coast of British Columbia using a 2 degree grid, 300 miles wide and extending from the Columbia River to southeast Alaska. Relations between these data and fisheries data, such as groundfish catches and sockeye salmon migrations, are being studied.

Techniques suitable for commercial operations were developed for the bulk capture of zooplankton.

Fifteen thousand pounds of frozen zooplankton was distributed to aquaria, fish hatcheries, and retail stores for comparison with imported frozen brine shrimp. Replies indicate that Fraser estuary zooplankton is often preferred to frozen brine shrimp and that a demand for this product continues to exist.

Data on pomfret (*Brama raii*) in the Gulf of Alaska are being assembled from all sources. Preliminary analysis of results suggest a single widespread stock.

Data on fur seals in relation to oceanographic features have shown a positive correlation between annual variations in fur seal distributions and surface transport.

Biological Oceanography

The purpose of this program is to study long-term changes in the biological oceanographic environment of the North Pacific Ocean. Biological data from Ocean Weather Station P, American Mail Line vessels (with the University of Washington), and from the

1969 Trans-Pacific cruise of CNAV *Endeavour* are being brought together to describe large scale variations in the North Pacific. A new program involving the use of a 200 KHz echo sounder on Line P has been initiated in order to study changes in the shallow scattering layer of the Gulf of Alaska.

Stream Ecology

In the past, studies of the production of fish-food organisms in streams, and of the effects of pollutants and erosion on stream benthos, have been hindered by the lack of a technique for unselectively sampling living and nonliving substrate materials.

A simple and inexpensive method has therefore been devised which allows the collection, in shallow streams, of biotic and abiotic materials in the size range 50 microns to 200 mm. Collected materials are wet-seived and the volumes passed by successively finer sieves are plotted as cumulative curves against a logarithmic size scale. In addition, the densities, size distribution, vertical stratification, and identities of the invertebrates in the samples are recorded. In this way precise quantitative description can be made of the physical and benthological features of stream habitats so that assessment can be made of the biological effects of siltation of spawning beds, and of logging, industrial, and agricultural practices in watersheds.

Increasing the Productive Capacity of the Environment

Investigations which have this as their immediate objective include:

Salmon Development Projects

The objectives of these projects are, to provide biological data needed for the management of the Skeena River pink and sockeye salmon fisheries, and to measure changes in sockeye production resulting from the Babine Lake Sockeye Development scheme, and to reveal causes of success or failure so that improvement and rational development of salmon culture techniques and their application may proceed. The aims of particular studies have included: (1) testing the assumption that sockeye salmon fry produced in an artificial spawning channel will grow and survive equally as well as fry produced naturally; (2) determining the extent of lake nursery area used by sockeye, particularly those from the Fulton River and artificial spawning channel; (3) developing ways of increasing survival of hatchery produced salmon subsequent to their release into the wild with emphasis on the influence of time and method of release, size, food availability, and predation; (4) measuring the relationship between age of parents and age of progeny in substocks of variable age at maturity; (5) measuring postlacustrine mortality rates on smolts, by size of smolt; (6) measuring the effects of cestode parasite, *Eubothrium salvelini*, on sockeye production in Babine Lake.

The Fisheries Research Board counting station on the Babine River recorded 662,000, 4- and 5-year-old sockeye and 166,000 jacks as compared with 634,000 and

154,000 respectively in 1969. More than 166,000 pink salmon, the largest escapement to Babine since 1943, were also recorded in 1970.

Sockeye smolts leaving Babine and Nilkitkwa Lakes numbered 46 million in 1969 and 43 million in 1970, and represented egg-to-smolt survivals of approximately 5.5% and 5.0% respectively.

In 1967 and 1968 about 150,000 smolts were sorted in size categories and tagged distinctively with coded magnetic wire as part of a study on smolt-to-adult mortality in relation to size at seaward migration. In 1969 recoveries were obtained from 65, 5-year-old, 477, 4-year-old, and 33, 3-year-old (jack) sockeye. Similar numbers have been recovered from 4- and 5-year-olds in 1970. Results thus far suggest that large smolts survived better at sea and returned after fewer years than did small ones.

The success of the Babine Lake Sockeye Development Project depends on the effectiveness of artificial spawning channels to produce fry, and the capacity of the lake nursery area to support them. Tests of fry produced in an artificial spawning channel have demonstrated that these fry possess the qualities necessary for growth and survival in Babine Lake, for migration to sea, and for their return as maturing adults. Large numbers of both channel-produced fry and wild fry from three spawnings were marked distinctively, and released into the lake. Comparison of their performance showed: (1) channel fish were consistently smaller on the average throughout the period of lake residence. This was attributed largely to their late entry into the lake and consequent reduced growing period; (2) neither this difference in size nor their channel origin appeared to have any substantial effect on survival from the fry to seaward migrant stage. Channel fish survived at a rate comparable to that of wild fish in 1 year (9 and 10%) at a greater rate in another (19 and 15%) and at a lesser rate in a third year (29 and 33%); (3) almost all channel-produced fish migrated to sea after 1 year in the lake — the usual occurrence for Babine Lake sockeye. Extensive examination of the lake population of nonanadromous sockeye (kokanee or residuals) produced no evidence of loss or reduction of anadromy on the part of channel-produced fish; (4) incomplete returns of marked adults have demonstrated that channel fish can survive at sea and return with a substantial degree of homing.

Studies of the diel and seasonal activities of young sockeye have produced new information on how their nursery area is utilized and have provided a sound basis for future examination of the lake's potential as a sockeye producer. The lake distribution of marked fry from the Fulton River and of the young sockeye population as a whole was observed throughout three summers. The fry dispersed rapidly and widely into the 80 mile long main basin. But their distribution was neither uniform nor static. Feeding was largely confined to the periods of evening and morning twilight when the fish were at or close to the surface. By day, they occupied the deep, cool waters of the hypolimnion and fed little. The average growth rate in August was 2.9% in weight/day on a daily food intake of 6.9% of body weight. Smaller rations and lesser growth rates were observed both earlier and later in the growing season.

Lake Fertilization

The purpose of this program is to enhance the production of sockeye salmon by the addition of nutrients to a lake in which the natural nutrient supply probably limits salmon production. Great Central Lake (area 12,600 acres) on Vancouver Island was chosen for these studies and 100 tons of dissolved nitrates and phosphates were added in carefully controlled amounts during the period May–October, 1970. As a result of these additions, the rate of primary production was increased but the standing stock of primary producers remained virtually unchanged. Thus water clarity was unaffected by the nutrient additions. On the other hand, the standing stock of secondary producers (zooplankton) was increased approximately 10 times and by October 1970 the young salmon, which feed off the zooplankton, had grown twice as fast as in 1969. From these results it appears that small, sustained additions of dissolved nutrients can have a marked beneficial effect on the productivity of ultra-oligotrophic lakes.

Competition between sockeye and other lake fish for the beneficial effects of lake fertilization has shown that the threespine stickleback feeds on some of the same food organisms as are used by young sockeye salmon. Adult lake trout may also benefit from lake fertilization since young sockeye are among food organisms taken by these predators.

Augmenting the Supply of Resources

Investigations which have this as their immediate objective include:

Experimental Hatcheries

The main objective of this investigation is, at present, the evaluation of an incubation method for Pacific salmon developed upon criteria deduced from ecological studies on their larval stages.

Following encouraging preliminary tests, which terminated at the fry stage, ultimate testing was initiated in 1968 on the pink salmon stock of the Tsolum River, Vancouver Island. Incubation in the newly built hatchery and in the hatchery stream was successful and a comparison of the survival rates from egg to migrant fry obtained under the two treatments showed the hatchery to have been about 6 times more efficient than the stream environment. In the spring of 1969 equal numbers of the naturally and the artificially produced fry were selectively marked by the removal of fins and released into the stream. Upon return from the ocean in 1970 marked fish were recovered from the fishery and the stream. On the basis of the proportions of fish from the two sources observed in the marked fish population at the time of release and at recapture, it is concluded that the rates of survival from fry to returning adult were virtually the same in both groups.

Since the original gain in survival obtained in the hatchery was retained to the adult stages the greatly increased numbers of fry produced by the hatchery method were demonstrated to have been fully comparable in viability and survival potential to naturally produced fry.

Salmon Culture

These studies are being undertaken to improve Pacific salmon culture techniques by defining the limits of tolerance of eggs, milt, and young to artificial manipulation in spawn-taking, incubation, and culturing. Under artificial culture conditions, the milt of one male sockeye can be used to fertilize the eggs of at least 60 female sockeye, and the milt of one male pink can be used to fertilize the eggs of at least 90 female pinks. Water uptake in eggs just removed from a mature sockeye female is usually complete within 40 min of their immersion in fresh water. The average increase in volume of individual sockeye eggs during hardening is 14%. In fresh water at about 10 C, the susceptibility of freshly-taken sockeye eggs to fertilization declines very rapidly: after 5 min of immersion only a very few eggs could be fertilized by fresh milt. Freshly-taken unfertilized sockeye eggs can be packed in containers for at least 30 min to a depth of 21 inches without impairing their subsequent fertility.

Chinook and Coho Salmon

The purpose of this study is to investigate the status and exploitation of chinook and coho salmon by Canada and the United States, and to assess the contribution made to these fisheries by certain United States hatcheries.

These cooperative United States–Canadian programs for evaluating production and contribution to fisheries of chinook and coho salmon from Columbia River and Puget Sound–Washington coast hatcheries continued and were terminated in 1969. During 1964–69, approximately 1,250,000 chinook salmon and 1,600,000 coho salmon in Canadian catches were examined for marks and for biological data.

Unadjusted for marking mortality, four brood year (1961–64) hatchery stocks of Columbia River "fall" chinook salmon contributed an estimated average of approximately 160,000/brood year to United States and Canadian commercial sport fisheries during 1963–69. Since the rate of marking mortality, though variable, probably averaged about 50%, these estimates should be increased by a factor of two. Thus about 0.6% of the number of juvenile fish released from the hatcheries (213 million in 1962–65) were taken in the fisheries. The overall catch–escapement ratio varied with each brood, but averaged about 8:1.

The coho evaluation studies involved three brood year (1964–66) stocks of Puget Sound–Washington coast hatcheries, and two (1965 and 1966) of the Columbia River hatcheries. Coho salmon are taken in the fisheries almost exclusively during their third year of life, having entered the sea early in their second year. Corrected estimates of total catches in United States and Canadian fisheries in 1968 of the Puget Sound–Washington coast fish, and of the Columbia River fish, were 583,000 and 1,100,000 respectively. These estimated catches amounted to approximately 5–6% of the number of yearling coho released from the hatcheries. Data are not yet available on catches in 1969 (1966 brood year stocks) of hatchery coho in United States fisheries, but it is estimated that Canadian fisheries (principally the west coast of Vancouver Island troll fishery and the Strait of Juan de Fuca net fishery) took about 140,000 Puget Sound–Washington coast hatchery fish, and about 22,000 Columbia River hatchery fish.

On the average, Canadian fisheries appear to take about a third of the "fall" chinook salmon and 5–10% of the coho salmon produced by Columbia River hatcheries, and 50–60% of the coho salmon produced by the Puget Sound–Washington coast hatcheries.

Lobster

The objective of this project is to predict whether an increasing population of Atlantic Ocean lobsters could be successfully introduced into the Pacific, and, if so, to determine the most promising techniques to employ.

First estimates based on 3 year's trapping data with the adult coterie at Fatty Basin, Vancouver Island, indicated that monthly loss due to death and emigration was low (about 2% for females, males higher); frequency of berried females was high (ca. 60%); and molting incidence and growth were normal. Serum protein values from animals at liberty for 3 years were the same as those observed in "ecologically suitable" areas on the east coast. This further indicates that the Pacific environment can adequately support viable, physiologically normal adult lobsters.

Attempts at Fatty Basin to sample larval lobsters from the 1969 hatch produced only six Stage I animals. This low return was attributable almost entirely to inadequate sampling. In 1970 a small test using a different sampling design based on only a fraction of the number of samples taken in 1969, resulted in 27 Stage I larvae.

An odd assortment of information on the productivity, physical, planktonic, geological, and microbiological features of Fatty Basin has been collected as a result of studies undertaken by visiting experts. An investigation into the agonistic behavior of adult lobsters in tanks was completed. Ten adult European lobsters (*Homarus gammarus*), including berried females, were successfully shipped from England to Nanaimo. The eggs hatched during the summer and a number were reared through the fourth larval stage.

Rearing juvenile lobsters in pens and cages at Fatty Basin after hatching has proven successful. Juvenile animals have been maintained in these enclosures for more than 3 years. Growth was excellent; annual survival was highest in individual cages (in excess of 95%) while that in concrete pens was 20%(year 0–1) and 33%(year 1–2). This raises the possibility of successful farming of lobsters in pens and enclosures.

Freshwater Crayfish

The native freshwater crayfish is under study to evaluate its potential commercial value, particularly as an export product. Preliminary studies are aimed at development of suitable aquaculture techniques, including evaluation of various diets, control of breeding, and space requirements. Survival, growth, and reproduction in the laboratory is being compared with that in large, outdoor culture facilities, and in natural populations.

The following investigations also contribute substantially to this objective, although they are primarily concerned with more basic studies as physiology and microbiology.

Investigations which have this as their immediate objective include:

Sablefish

This investigation, aimed at determining whether the culture of sablefish (black cod) is commercially possible, has confirmed that they are easy to keep under conditions designed to simulate a fish farming operation. They are essentially disease free except for susceptibility to eye infections leading to blindness, and some reduction of this has been achieved. They thrive on a mixed diet of whole frozen herring and frozen dogfish chunks with no additives; there is reason to believe that they would also thrive on other simple, inexpensive diets. They gain about a pound for every 5 lb of food, so it takes about 40 lb of food to put on the 8 lb required to attain commercial size. If a commercial operator could get the food for about 1 cent per lb the food costs could be 40 cents for rearing a fish that would sell for more than $1.25 without processing. Although more investigation is needed the economic prospects for sablefish farming are quite promising.

Oysters

The objective of this investigation is to add to the knowledge of the biology of oysters and to apply this knowledge to improvement of their culture, harvesting, and sanitation.

Oyster spatfalls were again forecast for Ladysmith Harbour and Pendrell Sound. In the latter area in 1969 there was a spatfall of commercial intensity early in the summer for which the industry was not prepared. Larvae which occurred later in the season failed to set primarily because of low salinity occasioned by heavy runoff from exceptionally heavy snowfall from the previous winter. In 1970 there was a commercial spatfall and about 150,000 shell strings were exposed from rafts. In Ladysmith Harbour there was no significant spatting in either year.

Artificial cultch has been developed to a point where industry was able to begin testing it in 1970.

Bacteriological studies show that oysters, polluted to the degree normally experienced in British Columbia waters, can be purified within a 48-hr period at all times of the year. This is done by harvesting into shucking baskets (usually of 4 ft^3 capacity) and relaying these to a nonpolluted area for the necessary time prior to shucking. This is a more economical and time saving method than the normal relaying procedure and results in oysters with cleaner shells.

A survey of 62 species of British Columbia bivalves has shown that 12 of them harbor the spirochaete genus *Cristispira*.

Rafts made of ferro-concrete logs have been shown to be applicable to raft culture and oyster seed collecting operations, being resistant to shipworm attack.

Improving Harvesting of Aquatic Resources

The following investigations contribute substantially to this objective, although they are primarily concerned with more basic studies: Salmon Stock Assessment, Groundfish, Pelagic Fishes, Shrimps and Crabs, Chinook and Coho Salmon, Fisheries Oceanography, and Clams and other Molluscs.

Protecting Canada's Interests in International Fisheries

The following investigations contribute substantially to this objective, although they are primarily concerned with more basic studies: Groundfish, Pelagic Fishes, Chinook and Coho Salmon, Ecological Genetics, and Parasitology.

Increasing Knowledge Required for the Control of Pollution

Investigations which have this as their immediate objective include:

Estuarine Ecology

The objective of this program is to understand and quantify the effects of forest industry effluent on estuarine ecology so that preventative or remedial measures may be devised to counter practices which lower biological production.

Several effects can now be demonstrated: at Port Alberni a brown stain is discharged with the pulp mill wastes. This stain restricts light penetration to the extent that net photosynthetic production rarely occurs in the mixed layer above the halocline within the harbor, and seldom, if ever, occurs in the saline layer below the halocline for a distance of 25 km (15 miles) seaward.

Respiration of a considerable biota concentrated immediately below the halocline results, in the absence of photosynthetic production, in severe oxygen depletion.

This layer, as it moves up-inlet, becomes entrained and mixed into the low salinity surface layer, thus contributing to the oxygen sink.

The large discharge of dissolved organics by the pulp mill contributes to a heterotrophic production pathway: bacteria–Protozoa–Crustacea–fish. This pathway to some extent compensates for losses in the primary production pathway: phytoplankton–zooplankton–fish.

Logging and Stream Ecology

The objectives of this program are: to determine the impact of current logging practices on the productive capacity of salmon streams by assessing if damage is being done by current logging practices and to determine how operations might be changed to minimize damage to the stream's capacity to produce salmon; determining the speed of recovery from any environmental damage due to logging; studying methods of improving or rehabilitating streams after logging.

Through the cooperation of MacMillan Bloedel Limited a small, unlogged watershed producing chum and coho salmon has been set aside on the west coast of Vancouver Island as the site for a study on the long-term effects of logging. The program has started with a study of "baselines" on stream production and this program will continue for 3–4 years after which the watershed will be logged. An intensive study will then be carried out during the logging process and during the recovery period. In 1970, studies were also conducted on two salmon and trout streams comparing the abundance, growth, and feeding habits of fish populations, insect drift and temperature in recently clearcut stream sections with sections in adjacent timbered areas.

The following investigations contribute substantially to this objective, although they are primarily concerned with more basic studies: Physiological Ecology, Stream Ecology, and Physiology.

*Research workers prepare (*top*) radioactive cortisol for injection (*bottom*) into sockeye salmon to study endocrine changes which occur during maturation of Pacific salmon*

VANCOUVER LABORATORY
VANCOUVER, BRITISH COLUMBIA

The following projects were emphasized:

- Successful application of the technique of partial freezing of noneviscerated sockeye salmon that enabled transport of 1.8 million fish from Bristol Bay to British Columbia canneries; improving color of canned salmon by addition of a harmless carotenoid pigment; progress in devising a multiple fiber optics probe for color-sorting of raw salmon in cans prior to processing; preparation of dogfish meal and a study of its nutritive value and experimental use of dogfish presscake in mink rations

- Erection of a small laboratory on an industry leased site where problems of immediate concern to the fishing industry, particularly those on abatement of odor and use of liquid effluents, are in active progress. Results include design of an efficient scrubber for gaseous effluents, of a method for recovery of useful protein from "low solids" liquid waste waters, and pioneering research on techniques such as concentration of solids by reverse osmosis, and growth of microorganisms that form potentially valuable substances in such effluents

- Experiments have been initiated concerning application of laboratory research on hormones and physiology of salmon in attempts to establish runs of pink salmon in "off-years"; the effects of certain herbicides on juvenile salmon is reported and further studies are in progress; progress has been made in research in the areas of preservation of fresh and frozen fish, in examining the possibility of utilization of potential resources such as those of seaweeds and sea urchins, on ability of phytoplankters to degrade certain potential pollutants, on identification of a number of enzymes of fish that are of importance in postmortem changes in fish, and in the area of chemical speciation of fish

Products and Processing

Fish Preservation

Preservation at sea and on shore

Improvement of quality and increase in yield of products obtained from the commercial catch, constitute an important segment of the work of this laboratory.

Research into methods of holding fish for prolonged periods at sea by means of partial freezing culminated, in 1970, in the transportation of 1.8 million lb of sockeye salmon from Bristol Bay, Alaska, to canneries in Prince Rupert and Steveston, B.C. This was the first full scale application of a method which involves holding the fish in refrigerated sea water (RSW) containing 5% added salt, thus permitting the temperature of

storage to be lowered to 25 F. Transportation of these fish to distant canneries was necessitated by the inability of those in Bristol Bay to cope with the exceptionally large run of salmon to that area. If a method of storage suitable for use in the vessels available had not been devised, these valuable fish would have been wasted.

An investigation of weight changes in fish during storage at sea has shown that the magnitude of weight losses suffered by cod is influenced by the amount of ice used between layers of fish as well as by the depth of fish in pens. Losses decrease with an increase in the amount of ice used between layers of fish. It has been found that such decreases in weight loss are reflected in an increased yield of fillets. The common commercial practice of only "poke" icing halibut has been shown to result in weight losses that can be reduced or eliminated by the use of a small additional amount of ice between the fish. Commercial scale experiments with sockeye salmon have demonstrated that the yield of canned product from fish stored in RSW is appreciably greater than that from others stored in ice. This difference apparently reflects the different weight changes the fish undergo when stored in the two media – small gains in RSW, losses in ice. Comparison of the quality of canned salmon prepared from fish stored 4 or 5 days in RSW with that of others stored in ice has shown them to be nearly indistinguishable. A somewhat smaller quantity of free oil in the cans from RSW stored fish was the only important difference found, and results of preliminary investigations of this difference indicate it is probably related more closely to storage temperature than to storage medium and may possibly be eliminated by careful control of the temperature of the RSW. Delay in chilling sockeye and pink salmon has been found to cause a number of quality defects in the canned product in addition to a reduction in yield. The defects include decreased volume of free oil, increased volume of free liquor, increased curd, increased cleaning defects (resulting from proteolysis of the visceral cavity of the fish and red discoloration of the flesh), and odor and flavor defects. All the defects increase in severity with increased delay.

The quality of halibut and cod frozen at sea (pre- or inrigor) has been compared with that of similar fish frozen ashore after storage in RSW and in ice for various periods. The sea-frozen fish were distinctly superior to the others, particularly in flavor and odor, both initially and after lengthy holding in frozen storage.

Further studies of chalkiness in halibut are in progress in an attempt to ascertain if the previously demonstrated influence of feeding on the occurrence of the condition may bring about seasonal variations in its incidence and if fish from different geographic areas differ in this respect. When such information is obtained it may enable the fishery to be conducted in such a manner that the incidence of chalky fish landed can be reduced.

Botulism

In collaboration with the Inspection Branch, Department of Fisheries and Forestry, Central Region, a survey was carried out to ascertain the distribution of *Clostridium botulinum* in lakes located in Alberta, Saskatchewan, Manitoba, Ontario, and the North West Territories.

Various species of fish were sampled from a total of 36 lakes. Approximately 1200 alimentary tracts from fish caught during the winter season were examined in this laboratory for the presence of *C. botulinum* types. The results of mouse protection tests on enrichment cultures prepared from the contents of alimentary tracts of each fish sample indicate the presence of *C. botulinum* in the following lakes: Winnipeg and St. Martin (Manitoba); Descharme, Lac la Ronge, Mountain, and Pinehouse (Saskatchewan); Lake of the Woods (Ontario); Great Slave and Rutledge (North West Territories).

In conjunction with the *C. botulinum* survey on fish from lakes, a *C. botulinum* survey was made on alimentary tracts from marine fish of the genus *Sebastodes*. The initial results of mouse protection tests on enrichment cultures revealed that *C. botulinum* cells or spores were present in the alimentary tracts of rockfish caught at a depth of 211 fath. Relations between different bacteria which occur in fish are being investigated, with particular emphasis on *C. botulinum*, a producer of lethal toxin. Other possible food poisoning organisms and fish spoilage organisms are also being studied. It has been found that germination and outgrowth of *C. botulinum* spores is substantially affected by the presence of certain normally harmless aerobic bacteria. There is now evidence that use of ethylenediaminetetraacetic acid (EDTA) as a preservative may alter the influence of different bacteria upon one another. Results indicate that in the presence of fish flesh, certain food poisoning organisms can tolerate higher concentrations of EDTA in fish flesh than they can in nutrient medium.

Toxic marine strains of *C. botulinum* were shown to accumulate a starchlike polysaccharide during growth on sugar-containing media. In the absence of external nutrients the organism utilized the stored material as a sole source of carbon and energy for continued growth, spore formation, and toxin production. This knowledge is valuable as an aid in the isolation and identification of the organism from suspected marine products and, in addition, contributes to our understanding of the basic physiology of the cell.

Canned Salmon

Color sorting of salmon for canning

This collaborative program with the British Columbia Research Council continued on a contract basis. The sorting instrument which had a successful trial during the 1968 season was used again in the same cannery in 1969 and 1970 at the request of the management and at considerable expense to them. The results were analyzed and again it was found that with this instrument pale salmon could be sorted out successfully prior to canning. The cannery sales department claimed that they were able to obtain a higher price as a result of the sorting. A multiple probe is presently being developed to enable automatic sorting of open filled cans rather than of whole fish.

Color improvement

Because color is such an important quality attribute in canned salmon, a program was initiated to find ways of increasing the red color of pale salmon when processed.

Some success was achieved by dipping steaked salmon in a solution containing an acceptable carotenoid pigment (canthaxanthin) and ascorbic acid (vitamin C). Canned chum and pink salmon when so treated exhibited an attractive red color. However, such a process does not lend itself to existing cannery processes and the investigation is presently directed toward devising a practicable method of treatment under existing cannery conditions.

Pigmentation of canned salmon

Indirect pigmentation of salmon muscle by feeding the fish canthaxanthin was described previously. Direct pigmentation of canned salmon would be greatly facilitated if the low solubility and poor protein binding properties of available commercial synthetic coloring agents such as canthaxanthin could be overcome. A number of cationic and anionic derivatives of canthaxanthin with potential surfactant properties were considered, and one of these (4,4′-bis(pyridiniummethylcarbonylhydrazino)-canthaxanthindiylidene dichloride) was synthesized and proved to have the required color and surfactant properties, binding irreversibly to proteins bearing a net negative charge. Synthetic approaches to the preparation of metastable surfactants are in progress for the purpose of preparing hydrophobic complexes of water insoluble pigments and proteins. These studies have general implication in preparing suitable carriers for drugs solubilized with difficulty.

Odor and flavor

Organoleptic criteria are currently employed in grading of canned salmon, and there is a need for a more positive method of determining both the desirable and undesirable chemical components that contribute to odor and flavor. A method has been developed, using gas chromatography, which can clearly show differences between good and poor products. Currently, work is directed towards the identification of the molecular components that show most marked change with respect to quality.

Frozen fish

Myosin is the principal structural protein of muscle and the fundamental mechanisms which can lead to its denaturation, and the attendant toughness of frozen fish, were therefore studied. It was found that native fish myosin contained no disulfide bonds and that the basic mechanism of myosin denaturation was initiated by the oxidation of some of the very labile sulfhydryl groups in the molecule. The disulfide bonds formed upon oxidation are then able to react with sulfhydryl groups in other myosin molecules in a sulfhydryl–disulfide exchange reaction leading to the formation of myosin aggregates or polymers. Further interaction within the polymers by hydrogen and hydrophobic bonds leads to the formation of firm aggregates which are insoluble in salt solutions up to 1 M. Heavy metal concentrations as low as 10^{-6} M accelerated the aggregation.

A class of chemicals known as cryoprotectors like dimethyl sulfoxide (DMSO), glycerol, dextran, and others have been widely used to overcome tissue damage caused by

freezing of biological materials such as blood cell elements, spermatozoa, heart, kidney, skin, cornea, and ovarian minces. Since the effect of these cryoprotectors had not been tried on cold-stored fish muscle, an investigation was carried out on the effect of two of them, and also of an ionic agent, magnesium sulfate ($MgSO_4$). The reason for the inclusion of $MgSO_4$ was because previous work in this laboratory had demonstrated an absorption of magnesium ions in fish stored in refrigerated sea water, and also because $MgSO_4$ retards the development of toughness in cold-stored fish muscle when injected into fish antemortem.

Fish muscle immersed in $MgSO_4$ solution at −10 C for 12 weeks retarded muscle deterioration as determined by release of free fatty acids, to a statistically significant degree compared to untreated muscle. Immersion in DMSO solution produced least visual deterioration in appearance and texture unlike the white soft and swollen texture of muscle immersed in the other solutions.

Utilization of Dogfish

Investigations into the use of dogfish for animal feeds has continued. The Poultry Science Department of the University of British Columbia has concluded the feeding trials initiated to determine the value of dogfish meal as a poultry feed. The results show that this meal is a poor source of protein in relation to other available fish meals. A set of trials to determine whether mink can use frozen dogfish presscake has been initiated in cooperation with the University of British Columbia Department of Animal Science.

Chemistry of Seaweeds

The amount of readily accessible kelp available on the British Columbia coast is conservatively estimated to exceed 1.5 million tons annually. The chemical composition of some of the 500 known species is being assessed to appreciate the potential of this renewable resource.

An extraction procedure using an homogeneous mixture of chloroform–methanol–water has proved useful in isolating and separating the low molecular weight components into water-soluble and insoluble fractions which are subsequently tested for antibacterial activity. The water-insoluble fraction from the common red alga *Rhodomela larix* inhibited the growth of *Sarcina lutea* and *Pseudomonas perfectomarinus*. As these fractions constitute over 50% of the dried weight of most seaweeds they are being examined for useful chemicals.

The polysaccharides of seaweeds are an important source of industrial gelling agents such as alginates, carrageenan and agar. The food reserve polysaccharide of the red alga *Rhodymenia pertusa* has been shown by periodate oxidation, methylation, and proton magnetic resonance studies to possess a ramified structure of 1,4-linked α-D-glucopyranose residues bearing branch points at C-6. The physical properties of this marcomolecule approximate to those given by glycogen. In a similar manner the cell-wall glucan of this alga was shown to consist of a linear structure of 1,4-linked β-D-glucopyranose

residues. The use of proton magnetic resonance to assess the overall anomeric configuration in polysaccharides which are sparingly soluble or insoluble in water has been demonstrated by studies on the corresponding permethylated derivatives. Preliminary studies on the sulfated galactan from *R. pertusa*, which contains D- and L-galactose, indicates that its structure is unlike that of agar or carrageenan.

New methods to elucidate the structures of algal polysaccharides are being devised. Gas–liquid chromatographic studies have proved effective in demonstrating the presence of 3,6-anhydrogalactose together with galactose in sulphated galactan polysaccharides and the percentage of D- and L-galactose in the hydrolysate of these polymers is being examined with the combined aid of enzymes and proton magnetic resonance spectroscopy.

Vitamins Formed by Phytoplankters

An interest in the nutritive value of algae promoted a study of the production of fat-soluble vitamins by phytoplankters cultured under controlled conditions. The unicellular red alga (*Porphyridium cruentum*) was found to contain α-tocopherol (vitamin E), phylloquinone (vitamin K_1), ubiquinone-10 (coenzyme Q_{10}), plastoquinones A and C. The production of these vitamins and quinones was markedly reduced when the algal growth was stimulated by glycerol.

Utilization of Sea Urchins

Sea urchin eggs and gonads are used extensively in Japan and other countries in the Orient as roasted, salted, fermented, or canned products. For the years 1957 through 1962, production of fermented sea urchin roe and milt in Japan averaged over 1500 tons/year. Imports have been made from South Korea, North Korea, Taiwan, and Okinawa. It appears that the production is limited by catch rather than demand, as one of the Japanese producers is presently looking to Australia as a source of supply.

In the coastal waters of British Columbia, three species of sea urchin occur. The largest and most abundant is the giant red sea urchin (*Strongylocentrotus franciscanus*) and this is the species which would be harvested, at least at first, should a commercial operation be started to utilize these animals. Studies were carried out aboard the charter vessel *Great Northern 3* to determine the best methods of harvesting sea urchins and the time of year when maximum yield of eggs and gonads can be obtained. Continued studies on the feasibility of commercial utilization of sea urchins will involve investigations into methods of storage and shipment of the eggs and gonads and processes for preparing roasted, salted, and fermented products.

Enzymes

Research on biosynthesis and degradation of nucleic acids and related compounds proceeded. Systems capable of forming the essential building blocks for synthesis of nucleic acids, namely uridylic and inosinic acids, were demonstrated in salmon liver and

immature testes. Formation of both ribonucleic acid and deoxyribonucleic acid by salmon liver nuclei, and of the latter by a partially purified polymerase enzyme from immature salmon testes, was also demonstrated. Enzymes capable of degrading the flavorous nucleotide inosinic acid to inosine were partially purified from cod muscle and salmon testes. Mature salmon testes were used to prepare a highly purified deoxyribonuclease, the potency of which was greater than that of any similar enzymes so far purified from other sources.

Cyclic 3′,5′-nucleotide phosphodiesterase, the enzyme which catalyzes the conversion of cyclic 3′,5′-nucleoside monophosphates to 5′-nucleoside monophosphates, was partially purified from trout brain. The properties of this enzyme were similar to those reported for other organisms, and appeared to be associated with synaptic vesicles.

Examination of phosphomonoesterase activity in extracts of the green marine alga, *Enteromorpha linza*, indicated that a nonspecific acid phosphatase was the predominant, if not the only, phosphohydrolase activity present.

The enzymes responsible for glycogen synthesis in trout liver (glycogen synthetase and the branching enzyme) have been partly purified.

The action of fish enzymes on muscle lipids, an important form of energy storage in salmonid fish, is being examined in relation to their physiological function in the live fish, as well as in connection with the postmortem changes taking place during storage of frozen salmon.

Evidence was obtained for the presence in fish muscle of a lipolytic activity toward long chain triglycerides that is capable of hydrolyzing depot fat which, in fish, is composed of triglycerides containing predominately fatty acids with 12–24 carbons. The proper emulsification of the substrate is of critical importance in demonstrating this activity in vitro and it was found that a phospholipid fraction isolated from fish muscle acts as a proper dispersing agent. The characteristics of the enzyme were compared with those involved in mobilizing depot fat in mammals.

To elucidate further the function of the red lateral line muscle in the energy metabolism in fish, particular attention was focused on the effect of coenzyme A and carnitine on the oxidative activity of mitochondria from various fish tissues. The similarities between mitochondria from fish heart and lateral line muscle appear of special interest as they provide further evidence that fatty acid oxidation plays a prominent role in the energy metabolism of fish red muscle.

The phospholipase D of *P. cruentum* was shown to resemble the corresponding enzyme from higher plants in several, but not all properties. A survey was made for the occurrence of L-threonine dehydratase (deaminase) in 17 phytoplankter species and the enzyme found in seven of these species was extensively characterized. In general, the deaminase was found to be an allosteric enzyme specifically regulatable by L-isoleucine and similar to the corresponding enzyme from bacteria previously studied by other workers.

The postmortem role of proteolytic enzymes in fish muscle is not completely understood. Since the use of hemoglobin as an experimental substrate proved unsatisfactory a soluble globin formed by splitting off the heme group and using the globin moiety rather than the entire hemoglobin molecule as the substrate was used. An assay using this soluble globin and muscle proteinase from sockeye salmon (*Oncorhynchus nerka*) proved satisfactory.

As most muscle proteinases have *p*H optima in the region of *p*H 3.5–4.5 and the *p*H of fish muscle does not usually go much below about *p*H 5.8, studies were carried out with the objective of determining if muscle proteinases with *p*H optima above *p*H 6 exist in fish. The *p*H-activity curves for the proteinases found in extracts of the muscle of four marine fishes (sockeye salmon, chinook salmon, Pacific halibut, and lingcod) were determined. For salmon and lingcod, the maximum activity was found between *p*H 3.0 and 3.5. Almost no activity was found above *p*H 5. In the case of Pacific halibut, activity was found above *p*H 5. However, the optimum *p*H for proteolysis was in all cases clearly below *p*H 4.5.

The Environment

Pollution Abatement

Two trailer units were installed on land leased from a fish processing company at Steveston, B.C., and these were equipped as laboratories to study certain problems of immediate concern to the fishing industry. This small unit is presently being used to continue a study of fish plant processing wastes in order to obtain necessary background information for design of treatment facilities for partial purification of low solids content plant effluents. Considerable progress has been made in this area, and a study of the possible use of "reverse osmosis" as one purification method is in progress. In addition, research has resulted in the design of an improved odor abatement unit for fish meal plants which has performed satisfactorily on both Atlantic and Pacific coasts.

Collaborative experiments with the Department of Chemical Engineering, University of British Columbia, showed that the effluent from sulfite mills can be utilized by certain bacteria to produce acetic acid, propionic acid, and Vitamin B_{12} . Preliminary design estimates indicate that the process is feasible, and that a 100 ton/day pulp mill could anticipate daily production of 2000 lb of acetic acid, 3500 lb of propionic acid, and 1 lb of Vitamin B_{12} , and simultaneously achieve a moderate reduction in the chemical oxygen demand of the waste liquor. Recent research has shown that the yield of Vitamin B_{12} can be substantially increased. The low solids content fish plant effluents mentioned above have been shown to form excellent culture media for growth of microorganisms that produce products of potential industrial value such as proteolytic enzymes.

Effects of a Herbicide on Salmon Fry

The herbicide Tordon 22 K (Dow Chemical) 4-amino-3,5,6-trichloropicolinic acid in an "inert" carrier, is being used in British Columbia to clear Hydro right-of-ways. An investigation of the effects of this herbicide on salmon was initiated with the following preliminary results. Coho fry in fresh water survived 7 weeks in a 25 ppm concentration of Tordon 22 K, but were killed within 24 hr when exposed to between 30 and 60 ppm; fry in water containing 12.5 and 25 ppm Tordon 22 K ceased to grow in length and in weight and there was a suggestion that fish in 25 ppm were thinner (relative to length) than fish in 0 or 12.5 ppm after 7 weeks treatment; there were no apparent differences between electropherograms of the plasma proteins or the hemoglobins from the three groups of fry, but hematocrits were 40–45% in control fish, 32–43% in 12.5 ppm fish and 22–37% in 25 ppm fish after 7 weeks; histological examination showed liver damage, absence of liver lipid and possibly thyroid damage in both groups of fry exposed to Tordon 22 K; the integument of the caudal fins of both groups of fish exposed to Tordon 22 K was disintegrating after 3 weeks exposure and was badly disintegrated after 7 weeks. This investigation is continuing, and another investigation which deals with the effects of Tordon 22 K on sexually maturing adult coho, on the viability of their sex products and on the liver synthesis of lipovitellin has been initiated.

Action of Planktonic Algae on Pollutants

The ability of planktonic algae to degrade certain of the aromatic constituents of pulp and paper mill effluents was investigated. Nine species of 22 studied showed varying degrees of catabolism leading to production of $^{14}CO_2$ from the aromatic ring of the amino acid phenylalanine. This catabolic activity was randomly distributed among the algal classes, but appeared to be particularly common in pennate diatoms and absent in centric diatoms.

Studies on the utilization or organic nitrogen compounds (urea, purines, pteridines) as nitrogen source for phototrophic growth of a marine cryptomonad continued. These studies are relevant to pollution ecology in that such components may be expected to occur in domestic and farmyard sewage. It was found that uric acid and several pteridines were degraded by the chemical action of sea water and light without any biological agency. Apart from pollutants, pteridines may be expected to leach into sea water from fish skin in which they are known to occur, and results suggest that their photolysis in sea water may play an important ecological role in their turnover in the marine environment.

Function of Hemoglobins

Hemoglobins and other heme proteins carry out one of the most vital biochemical functions of extracting and transporting molecular oxygens in fish, as in other living forms. During their life cycles, fish are exposed to far greater fluctuations in environmental oxygen tension than mammals and are accordingly endowed with a greater array of hemoglobins of varying oxygen affinities. Any foreign material discharged into the environment that selective processes have not compensated for by the formation of different proteins, and that adversely affect the functions of this class of proteins, can profoundly affect the energetics and other vital activities. For a better understanding of the means by which this can be accomplished, a knowledge of the structure–function

relation is necessary. Continuing studies on salmonid hemoglobins have explained the tetrameric structure, the molecular basis for the existence of multiple hemoglobins, some of which have been shown to be intimately associated with characteristic transformation in preparation for adult life. The effect of structure and agents affecting oxygen affinity are being investigated.

Commercial and Recreational Fisheries

Egg Yolk Proteins

Three proteins, which account for more than 99% of the total yolk protein of coho salmon eggs, have been shown to be a phospholipoprotein, a phosphoprotein similar to the lipovitellin and phosvitin of avian and amphibian egg yolk, and a so-called, "simple" protein that is a unique constituent of fish eggs and contains neither lipid nor phosphorous. The molecular weights of these proteins are approximately 390,000, 27,000, and 30,000 respectively.

The simple protein was found to be a yolk protein rather than a livetin (serum proteins which are present in large amounts in avian and amphibian yolk and in trace amounts in teleost yolk).

Increasing the Resource

As part of a general plan to establish a small run of salmon at the West Vancouver site for research purposes the feasibility of using Cypress Creek water in conjunction with hatchery techniques was studied. Egg to fry survival was 80% for pink, coho, sockeye, and chum salmon. Stocks of 3-year-classes of coho and 2-year-classes of pink salmon, from fry to sexually mature fish, were also reared in captivity for experimental purposes. The successful rearing of these two species in captivity demonstrate that farming of these fish and probably the other species of Pacific salmon is possible. An additional benefit is that we are now in a position to investigate the physiology of coho and pinks at any stage in their life cycle.

Two projects were initiated to investigate the possibility of establishing off-year runs of pink salmon. The first was an attempt to accelerate sexual maturation of pink salmon by subjecting them over a 10-month period to the photoperiod regime that they experience over their 22-month life cycle failed to shorten their maturation cycle. Attempts are now being made to lengthen this cycle by subjecting them over 34 months to the photoperiod regime that they are normally exposed to over a 22-month period. The second was an attempt to establish small "hatchery-based" odd and even year runs of pink salmon in this location. This appeared feasible because of the excellent egg to fry survival. Eggs were obtained from Fraser River pink salmon in the fall of 1969 and the resultant fry released in the early spring of 1970. Similarly fertilized pink salmon eggs were obtained from Thompson Inlet in the fall of 1970 and are now being incubated.

Coho and sockeye fry, which normally spend their first year in fresh water, were successfully reared in seawater ponds to the smolt stage. This raises the possibility that the numbers of these two species could be increased significantly by having hatcheries, with adjacent seawater rearing pens, situated on coastal streams which normally would not support runs of coho or sockeye salmon. The fry would be reared in sea water and liberated as smolts.

Biochemical Speciation

Electrochemical properties of fish proteins are being used as diagnostic tools for several purposes. Based on the frequencies of several genetically linked polymorphic isoenzymes as population parameters, the Pacific herring and Pacific ocean perch from different geographic areas off the coast of British Columbia are being investigated. In collaboration with the FRB Biological Station at Nanaimo, both electrochemical and morphological characteristics have been used to explain the hitherto confused. *Sebastes aleutianus–S. melanostomus* complex and a new species of rockfish, *S. caenaematicus* in the northeast Pacific ocean has been described. In collaboration with the Tropical Fish Culture Research Institute at Malacca, electrophoretic characteristics of four species of *Tilapia*, cultured extensively in Africa and the Far East for food, have been described. Much improved methods have been described for the selection of proper genetic strains of parental species used in monosex culture.

In collaboration with the Fish and Wildlife Branch of the British Columbia Department of Conservation and Recreation, studies have been carried out on the genetic differences between headwater and lake migratory rainbow trout in the Kootenay Lake system. A new genotype, expressed in a hitherto undescribed liver lactate dehydrogenase, which functions in the main energy yielding biochemical reactions, has been found. Using this criteria, segregation of the two populations are in progress for the purpose of breeding pure genotypes. Preliminary evidence indicates a correlation between the enzymatic activity and superior swimming ability, a desirable feature from the sports fishery standpoint.

Endocrinology

The gonadotropic hormone which regulates sexual development in fish is being prepared from salmon pituitary glands and used in several studies. In 1969 experiments were initiated on the induction of precocious sexual development in juvenile pink salmon.

The purpose of this study is to attempt to establish an off-year run of pink salmon in streams where only one year-class is present. Attempts to transplant pink salmon from one river to another are thought to have failed because "each stock of pink salmon has evolved to meet a particular set and sequence of life history events." Thus, present experiments are aimed at providing off-year stock to replace the missing line in a particular river using the offspring of the fish in the line which is present. Success has been achieved in accelerating male pink salmon to sexual maturity a few months after hatching by administration of gonadotropic hormone. Ovarian development in female pink salmon was accelerated to the point where deposition of yolk in the eggs had commenced. The

ability of spermatozoa from accelerated male pink salmon to fertilize normal ova is being examined in cooperation with the Nanaimo Station.

Other experiments on the biological activity of salmon gonadotropin have included an experiment on the hormonal control of sexual development in the male catfish with the University of Delhi and an investigation on the activity of salmon gonadotropin in the lizard with the University of California (Berkeley). The purpose of these studies is to delineate the range of animals which respond to fish gonadotropin and establish the stage in vertebrate phylogeny where reproductive development became controlled by two distinct gonadotropins as in man and other mammals.

During October 1969, experiments were carried out at the Oceanic Institute, Hawaii, on the induction of sexual development in the mullet. The mullet is farmed extensively in the Orient and other parts of the world; however, it does not breed in captivity and stocks are obtained by netting young fish at sea. This procedure is not reliable and also prevents manipulation of the genetic composition of the stock. Results to date indicate that injection of salmon gonadotropin into mullet may prove to be a means of inducing them to reproduce successfully in captivity.

Changes in the environment of salmonids are reflected in the secretion and metabolism of the steroid hormones, cortisol, and cortisone. The effect of the migration from sea to fresh water on metabolism in maturing sockeye salmon was investigated by capturing sockeye salmon at sea and transferring them into seawater aquaria. They were then introduced into fresh water at the time that they would have normally entered the river. Results indicated a decrease in the metabolic clearance rate of cortisol after transfer to fresh water. This fall in metabolic clearance rate preceded the rise in metabolic clearance rate which occurs as the fish approach sexual maturity. Experiments in cortisol metabolism during maturation have been extended to include cortisone metabolism by injecting the two hormones labelled with two different radioactive isotopes into the fish simultaneously. Results indicate that the tracer dose of cortisol is rapidly converted to cortisone. Cortisone is cleared more slowly. Comparison of the production rates of the two hormones indicated that when the fish is at rest most of the cortisol is converted to cortisone, but in stressed fish a significant proportion of the cortisol is not metabolized via cortisone. In higher vertebrates cortisol is biologically active whereas cortisone is not. Thus, conversion of cortisol to cortisone represents inactivation of the hormone and studies are now underway to determine the tissues in the salmon where this occurs.

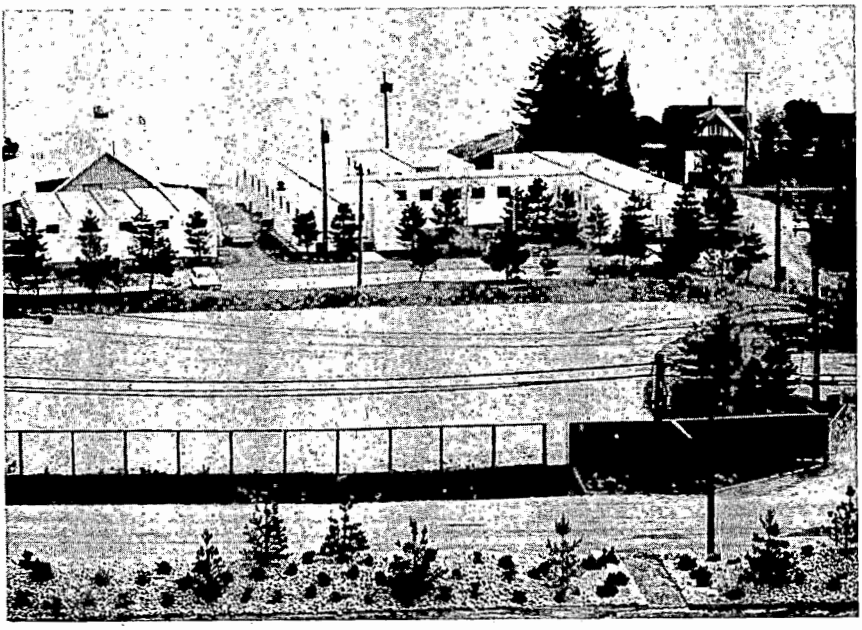
For determinations of cortisol and cortisone in the small amounts of plasma obtainable from juvenile salmonids a method was developed, which utilized the corticosteroid binding ability of certain plasma proteins.

In a study on the effects of sex hormones in salmon it was found that administration of male sex hormones, the androgens, evolved a striking increase in skin thickness, a marked shrinkage in the size of the stomach and a degeneration of the liver and kidney. The female sex hormones, the estrogens, produced similar, but weaker responses in the

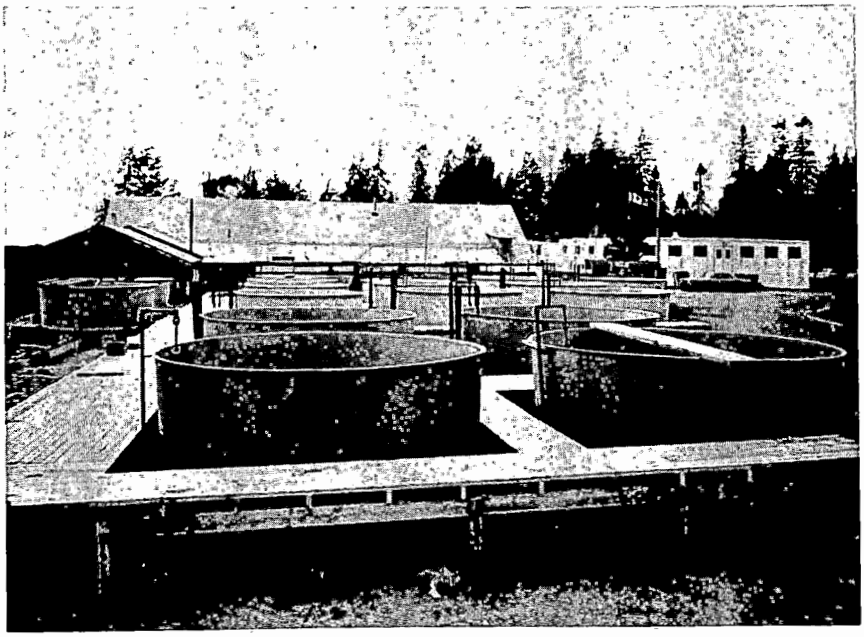
skin, stomach, and kidney. On the other hand, the liver of females receiving estrogen administration were visibly activated. Experiments in cell-type identification in the pituitary of the Pacific salmon continued. Of the seven cell types characterized, the specific functions of four were recorded. These were the gonadotroph, somatotroph, corticotroph, and the cells producing prolactin. Attempts to identify the thyratrophs clearly were not successful. Additional studies to establish the functions of the last of these cell types are in progress.

Algal Ecology

There has been considerable speculation in the ecological literature on the causes of finding planktonic algae in dark oceanic depths and the winter survival of arctic algal populations. A principal contributory factor apparently overlooked by the ecologists may be their capacity to survive prolonged periods of continuous darkness. Over 80% of 31 pure cultures of marine planktonic algae showed viability and unimpaired capacity for growth in the light after 12–24 weeks of continuous darkness. Similar results were obtained at 20 and 0–4 C, with the lower temperature favoring longer survival of most species, but definitely detrimental to the viability of two species. The inability of these two species to maintain viability at 0–4 C may be due to their origin in warmer waters (Gulf Stream, Sargasso Sea). The observed darkness survival, of most planktonic algae tested, may partially explain the above-mentioned ecological findings. The mechanism of darkness survival may involve cellular transformation to a sporelike stage capable of "germination" on exposure to light.



Sight of new Pacific Environment Institute, West Vancouver. Trailers are used for laboratory and office facilities



Outdoor facilities at West Vancouver include fish-holding tanks for experiments on various pollutants.

PACIFIC ENVIRONMENT INSTITUTE
WEST VANCOUVER, BRITISH COLUMBIA

Work reported here is essentially that conducted by the Pacific Oceanographic Group (POG) (excluding the biological component) at the Nanaimo Station. Staff of POG were transferred to West Vancouver in 1970 to become the nucleus of the Pacific Environment Institute.

Northeast Pacific Oceanography

Studies of the waters extending to approximately 200 miles off the coasts of British Columbia and Washington, initiated in the autumn of 1967, were continued. They provide oceanographic information for ecological studies as well as giving the seasonal and annual variability in oceanic and continental shelf waters. Preliminary analysis of the data indicates that the vertical temperature structure is extremely complex in some areas; many small inversions occur, particularly between depths of 100 and 300 m. The horizontal distributions of temperature and salinity are characterized by many cells and tongues, indicating a relatively slow meandering movement of these waters. Temperatures of the bottom waters overlying the continental shelf off Vancouver Island were about 1.0 C degree higher in April 1969 than in September 1967, and in October and April 1968.

Continuous current and temperature observations from the drill rig SEDCO-135-F were continued until May 1969, at which time Shell Canada Limited concluded test-drilling operations on the continental shelf off the coast of British Columbia. Preliminary analysis of the data shows that off the west coast of Vancouver Island the net flow at 100 m depth was at a rate of 3.0 nautical miles/day during the period February 12–30, 1969. The maximum speed recorded was 1.08 knots. There was a suggestion of a weak clockwise tidal component.

The regular program of oceanographic observations at Ocean Station P (50°N lat, 145°W long) and along Line P was maintained. In early 1969 the program was enlarged to include observations from CCGS *Quadra* as well as from CCGS *Vancouver*. The collection of data and ship positioning was facilitated by the use of a salinity–temperature–depth (STD) system, an STD digitizer, a data acquisition system, and satellite navigation equipment.

For the first time, bottom currents were measured using a free-fall current meter system. Preliminary analysis of the velocity records indicates that the mean bottom velocity for the period May 29–31 was 0.015 knot, 073°; for the period June 4–7 it was 0.002 knot, 277°.

In 1970, the current meter program was expanded with a moored-buoy system to include current observations at 700 and 500 m depths, well below the permanent halo-

cline; at 110 m, below the thermocline, but just at the top of the halocline; and at 25 m, in the surface-mixed layer or alternately in the thermocline.

Coastal Oceanography

Strait of Georgia

Studies in the Strait of Georgia consisted mainly of continuous current velocity measurements at the surface, 50 and 200 m depths, from three moored buoys in the central part of the strait, analysis of drift observations for surface circulation in the Fraser River plume area, and completion of a one dimensional hydrodynamical-numerical model of the Strait of Georgia–Juan de Fuca Strait system. The studies provide current information to agencies concerned with pollution and fisheries studies.

The results of the analysis of the current velocity data obtained at 200 m depth during the latter part of 1968 indicate that oceanographic events in the Strait of Georgia have time scales from a few hours to several days, and therefore demonstrate the effectiveness of relatively long series of observations.

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

Fatty Basin and contiguous waters

Oceanographic studies were initiated in May 1969 in Fatty Basin, located on the west coast of Vancouver Island, in support of the lobster transplant program. Continuous current, temperature, and wind observations, as well as several synoptic surveys were carried out in Fatty Basin, in the connecting channels and in the surrounding waters. Drift cards were also released.

In 1970, studies to determine the flushing rate of surface waters in Alberni Inlet and to define the surface circulation in Trevor Channel, Junction Passage, and Useless Inlet in Barkley Sound were carried out in close cooperation with Tidal and Current Surveys division of the Marine Sciences Branch.

The surface tidal circulation in the channel connecting Useless Inlet and Fatty Basin is modified by meteorological conditions existing in Barkley Sound. During calm periods, surface velocities are proportional to the rate of change of tidal height. However, during periods of relatively strong westerly winds, the flood current is approximately twice the predicted flow and the ebb current about one-half the predicted flow. During the easterly winds, the ebb flow was greater than the flood flow. Drift cards released on the ebb tide in the channel between Fatty Basin and Useless Inlet moved out into Barkley Sound and were recovered in Sechelt Channel, Imperial Eagle Channel, and Alberni Inlet. Some moved out of Barkley Sound northward toward Amphitrite Point and Long Beach. Two were retrieved on the Washington–Oregon coast. One card recovered at sea indicated a drift of about 12 miles/day.

Daily seawater observations

During 1969 and 1970, surface sea temperature observations were continued at 17 shore stations. Starting in July 1969, the collection of seawater samples for the laboratory analysis of salinity was replaced at all but one station by in situ measurement of seawater density by hydrometer. This changes the accuracy of the salinity from ±0.05 ‰ by conductivity to ±0.5 ‰ by hydrometer.

In 1969, seawater temperatures at most stations were below normal during January, February, August, and September. Near-normal temperatures prevailed in the spring and early summer until June, when eight of the stations reported above-normal temperatures. Normal temperature conditions were generally prevalent in October and November, except in Hecate Strait, where above-normal temperatures were observed.

Pollution

Effects of wood solids on water quality

Experiments were continued in the laboratory on the effects of wood particles on water quality. Leaching, mineralization, and bacteriological degradation tests were carried out with different wood particle sizes under various conditions of salinity, temperature, and water quality. Although the tests are not complete, indications are that the degradation of wood particles in the sizes tested is very slow.

Hydrodynamical properties of wood particles of different sizes and of different species are being tested to determine sedimentation behavior in coastal waters.

Pulpmill pollution in coastal waters

Oceanographic surveys were continued in areas receiving pulp mill wastes on the east and west coasts of Vancouver Island. Observations in Muchalet Inlet showed that no serious adverse effect on water quality is occurring from Kraft pulpmill wastes dispersed through a diffuser at Gold River. However, the sulfite waste from the Port Alice pulp mill continues to depress oxygen levels in surface waters of Neroutsos Inlet.

Wind flushing in Departure Bay

Observations on water properties and currents were conducted in Departure Bay during the summer of 1968. It was confirmed that westerly winds move surface water out of the bay, and cold, saline subsurface water moves to the surface to replace the water transported seaward. A simple hydrodynamical-numerical model developed by Marine Sciences Branch, Department of Energy, Mines and Resources, Ottawa, showed reasonable agreement with observed data.

FRESHWATER INSTITUTE
WINNIPEG, MANITOBA

The Freshwater Institute is responsible for FRB research related to Canada's lakes and rivers and their freshwater fishery resources. Its programs are classified under three general categories of activity with objectives as follows:

- Environmental Research: (*a*) to provide the fundamental ecological understanding necessary to prevent degradation of Canadian freshwater ecosystems; (*b*) to determine the extent and degree of pollution of fresh waters; (*c*) to determine the effects of pollutants (and potential pollutants) on fish and other aquatic organisms and the biological transformations and transport of such substances in freshwater ecosystems; (*d*) the development of new analytical techniques for detection and surveillance of freshwater pollution; and (*e*) the development of methods for the prevention of water pollution and restoration of already polluted fresh waters.

- Commercial and Recreational Fisheries Research: (*a*) to provide a sound basis for improved management of fisheries on natural freshwater fish populations so as to achieve maximum sustained yields; (*b*) to develop fish farming and other aquacultural methods which will serve to increase the fisheries resource.

- Products and Processing Research: (*a*) to discover and develop new and improved freshwater fish products; and (*b*) to improve the handling, storage, and processing technology of freshwater fish products.

The main activities during 1969–70 were as follows:

- Environmental Research: eutrophication (studies on the cause and control of the biological and ecosystem changes resulting from nutrient pollution in the lower Great Lakes and other Canadian waters); the mercury pollution problem (mercury levels in fish, biological transformations in aquatic ecosystems, effects on aquatic organisms, and improved methods of analysis)

- Commercial and Recreational Fisheries Research: studies leading to development of fish farming in small prairie lakes; statistical analysis of fisheries data and experimental fisheries under controlled conditions to develop improved management techniques

- Products and Processing Research: development of new products from unutilized species of fish; development of new refrigeration equipment and methods; studies on improved methods for quality control

An artist's concept of the new Freshwater Institute building being erected on the University of Manitoba campus. The complex will be completed in late 1972

Eutrophication

Great Lakes studies

Major contributions were made to the 1969 Report to the International Joint Commission on Pollution of the Lower Great Lakes. These included an assessment of the state of eutrophication, development of recommendations on control measures, culture experiments, and service on the editorial committee.

Monitoring of chlorophyll in the surface waters of the Great Lakes has continued on all ship cruises. In addition, a program was initiated in 1969 to measure lake-wide rates of photosynthetic carbon uptake throughout the year and estimates of zooplankton production. Lake-wide studies on the effect of nutrient addition on the waters of lakes Erie and Ontario showed that phosphate and nitrate brought about the most pronounced responses in terms of algal growth, but with markedly varying results depending on locality and time of year. Although only statistical trends were discernable in the overall data, the effect of phosphate addition was more pronounced in Lake Ontario than in Lake Erie. The addition of bicarbonate did not result in any detectable response. The net effect on algal growth brought about by the addition of nitrilotriacetate (NTA), in concentrations of 0.1 mg/liter, ranged from nil to slightly positive.

The development of phytoplankton populations in Lake Ontario was found to be correlated with shoreline and associated temperature effects. Spring populations of the diatoms *Asterionella, Melosira,* and *Stephanodiscus* typically developed first in nearshore waters, later spreading out into the main body of the lake with time delays ranging from weeks to months.

In conjunction with the Lakes Division of the Department of Energy, Mines and Resources a series of tests was conducted on the biological sampling efficiencies of 12 different types of grabs and corers. The standard Ekman dredge and the new FRB multiple corer gave the best overall results. A separate study of chironomid and other insect remains in a sediment core collected from the western basin of Lake Erie showed evidence of increased eutrophication in the upper part of the core. This constitutes the first assessment of the presettlement trophic state of Lake Erie.

Zooplankton abundance in lakes Superior, Huron, and Ontario showed a strong positive correlation with the phosphorus loading rates for each lake.

Experimental lakes

During 1969, living and laboratory accommodations were constructed for a maximum of 30 staff on a year-round basis. The Meteorological Branch of the Department of Transport constructed a land-based meteorological station and the Department of Energy, Mines and Resources provided a lake-based meteorological tower, weir installations for measurement of water flow, and ground-water wells.

Base-line limnological data (phytoplankton and zooplankton populations, primary production, and nutrient chemistry) have been accumulated since 1968 on selected lakes. Less extensive measurements have also been made on general chemistry, nutrient budgets, precipitation, and the abundance and distribution of benthic plants and animals. Some of these data are summarized in the February 1971, issue of the Journal of the Fisheries Research Board of Canada. In general, the lakes are dilute in terms of dissolved inorganic ions and low in productivity. Nutrient enrichment experiments have shown that the main chemical factors limiting growth in the various lakes are (in decreasing order of importance): phosphate, nitrogen salts, and available iron. There is considerable variation from lake to lake in the content of humic substances. The waters are typical of lakes on the Precambrian Shield.

One of the smaller lakes has been fertilized with weekly addition of nitrate and phosphate salts during the open water period since June 1969, at a rate corresponding to the loading rates of phosphorus and nitrogen for Lake Erie. During the first year of study phytoplankton populations increased from an average of 4 micrograms/liter chlorophyll to an average of 40 micrograms/liter chlorophyll, with values during the second year rising to as high as 60–100 micrograms/liter chlorophyll. The major algal groups responding to the treatment were green algae and desmids, with blue-greens third in importance. No invasion of the bloom-forming species of blue-green algae was observed up to the fall of 1970. Parallel experiments in plastic tubes located within the lake during the enrichment showed that phosphorus, nitrogen, and carbon (in decreasing order of importance) were the major limiting factors. As a result of the fertilization, the *p*H of the lake has risen from initial values in midsummer of 6.5 to 7.0 up to values as high as 10.5 during 1970. There has been a depletion of inorganic carbon in the surface waters during summer.

Regional limnological studies

The Freshwater Institute's staff have taken lead responsibility for limnological studies in the Okanagan basin under a Federal–Provincial agreement for study under The Canada Water Act. A study of factors limiting algal growth in lakes of the Okanagan basin showed that in lakes Kalamalka, Woods, and Okanagan, phosphorus was more important as a growth-limiting nutrient than nitrogen. In Skaha and Osoyoos lakes the reverse was true. Other nutrients were not in limiting supply. In Okanagan Lake midge larvae and oligochaete worms were found to have increased approximately four and 35 times, respectively, in abundance, relative to measurement made in the 1930's. Although Okanagan Lake is still oligotrophic, these results indicate that significant changes have taken place, possibly due to human influences. Several deformed midges were found among the benthic animals collected from Okanagan Lake, similar to those reported earlier in samples from the western end of Lake Erie. The cause of the deformations is still unknown. Tests with several insecticides and polychlorinated biphenyls (PCB) have yielded negative results.

During 1969 a 1-year limnological survey of Lake Winnipeg was completed to assess its present level of eutrophication, based on measurements of all major chemical and

biological components. There was an approximately 100-fold decrease in the levels of orthophosphate and a 300-fold decrease in the levels of nitrate in passing from the southern to the northern end of the lake. Chlorophyll concentrations in the south basin were generally in the range of 5–50 micrograms/liter during midsummer, whereas in the north basin they rarely exceeded 5 micrograms/liter. The turbidity and nutrient content of the Red River appears to exert a dominant influence in the southern end of the lake.

Laboratory investigations

A new method was developed and tested for the detection of inorganic carbon in water samples at levels down to 5–10 micromoles/liter.

An improved method based on staining reactions and fluorescence under high wavelength ultraviolet light was developed for sorting samples of benthos from sediments. This greatly reduces the time required to sort samples rich in detritus. A multiple corer for sampling invertebrates in soft sediment was constructed and tested and also a new type of insect emergence trap for streams that collects exuviae as well as adults. An improved method of calculating invertebrate production was published.

Nitrilotriacetate (NTA)

With a federal control on phosphates in detergents coming into effect, attention has been focused on NTA as the most promising substitute. Experiments to test the environmental acceptability of NTA are being carried out.

Following experimental tests on the effects of NTA on algal growth in 1969 (which showed only a slight positive response) an enlarged testing program was undertaken in 1970 to determine the effects of NTA on the aquatic ecosystem. This involved the use of plastic tube experiments in two lakes of different water hardness supplemented by acute toxicity tests on representative freshwater invertebrates and fish. Analysis of the results is in progress.

A new method was developed for the detection of NTA in samples of natural water. The method, based on gas chromatography of the trimethyl ester of NTA, is free of environmental interference from chelating substances and other contaminants and can be used down to levels as low as 10 micrograms NTA/liter.

The toxicity of NTA for rainbow trout was found to be very low. Trout were kept at 20 C in solutions of 200 mg NTA/liter with no apparent harm for 16 days, and for over 30 days in a concentration of 400 mg NTA/liter, buffered with hydrochloric acid to a *p*H of 7.8. There is a behavioral change in fish kept in this concentrated solution; initially the trout were more irritable than the controls, but subsequently they showed better growth, apparently due to appetite stimulation. Histological examination of the tissue is underway.

Mercury Pollution

The discovery of mercury in Canadian freshwater fish in November 1969, aroused much concern over the potential health hazard associated with consumption of fish from certain inland waters. The Freshwater Institute was immediately approached to take a leading role in investigating the problem and to assist the Fish Inspection Branch in ensuring that contaminated fish did not reach the market. Scientists of varied disciplines were called upon to initiate research programs on: (1) degree, extent, and sources of mercury pollution in Canada; (2) development of reliable methods for determining total and organic mercury in aquatic specimens; (3) the dynamics of mercury in the aquatic environment; (4) the physiological and biochemical effects of mercury of aquatic life; (5) the cleanup of the aquatic environment and the disposition of the resources.

A fast, reliable method for the determination of residue levels of total mercury (ppm) in fish tissue was developed. Analysis of marine and freshwater fish collected from coast-to-coast indicated many areas of mercury contamination in Canada. Contaminated fish have been found wherever there is a mercury-cell chlorine manufacturing plant. Fish were held in cages above and below the expected entrance of mercury in the South Saskatchewan River, and downstream fish showed marked accumulation of mercury in kidney, liver, and muscle tissue. A similar study done in winter time indicated little mercury pickup at low temperatures. A check sample program for mercury analysis on fish tissue was conducted involving over thirty laboratories; most laboratories are now performing satisfactory analysis.

A fast method for analysis of methyl mercury was also developed. It is currently being submitted to a number of analytical checks. The use of this method indicates that Canadian fish, including the caged fish, are contaminated with methyl mercury only. Analysis of fish exposed to other mercurials dissolved in water indicate no formation of methyl mercury.

Preliminary experiments with live fish in aquaria have shown that mercuric sulfide added to river sediments is mobilized and picked up by fish in a few weeks. The rate is greater with mercuric chloride. Metallic mercury added to sediments shows up in fish at high levels after 1 week. The nature and composition of a sediment influences the mobilization rates of mercury compounds which it contains.

The incorporation of fish or fish meal contaminated with mercury into animal feeds is an important question and feeding tests are underway with poultry, mink, and hogs. There is a 25% reduction of mercury content when fish is reduced to meal. The studies are carried out in collaboration with scientists at University of Manitoba, University of Saskatchewan, and several federal and provincial agencies.

Samples of fish food organisms were collected from Clay Lake, northwestern Ontario; this lake is known to be highly contaminated with mercury. The highest mercury levels occurred in bottom-living and bottom-feeding invertebrates. Planktonic organisms

There are many small prairie lakes with an abundance of fish food but they are devoid of fish due to oxygen depletion during winter. Rainbow trout fingerlings planted in these lakes in the spring grow well and yield marketable fish in 6 months. These fish were harvested from a 40-acre lake

had relatively low concentrations of mercury, above 0.05 ppm (on fresh weight basis) as compared with an average of 0.5 ppm in bottom-feeding invertebrates.

The lethal and sublethal effects of various levels of mercury compounds on rainbow trout were determined in flow-through aquaria. Mercuric chloride showed 96-hr TL_m values of 0.40, 0.30, and 0.25 mg Hg/liter mercury at 5 C, 10 C, and 20 C respectively. At 20 C, 0.1 mg Hg/liter depressed active metabolism by 10%; at 5 C there was no significant effect. Phenylmercuric acetate (PMA) was about 12 times more toxic than mercuric chloride.

The rate of uptake in presence of mercuric chloride was directly related to concentration and to increasing temperature. For 96-hr exposure, the concentration factors ranged from 3.8 to 26. The concentration factor in the presence of PMA was much higher, reaching 140 for a 7-day exposure to a solution containing 0.006 mg Hg/liter.

Elimination of mercury from fish tissue appears to be influenced by temperature and initial mercury level in tissue.

The effect of mercury at very low concentrations on olfaction of fish has also been studied. The normal electrical responses from the olfactory bulbs of rainbow trout in the presence of hand-rinsed water, a well-known repellent to salmon, are blocked (although reversibly) by brief, 10 sec treatment with mercuric chloride at a concentration of 10^{-4} M ($HgCl_2$). They are irreversibly blocked by longer 1 hr treatment with a mercuric chloride solution of lower concentration, 10^{-5} M $HgCl_2$. The blocking effect of $HgCl_2$, however, is completely antagonized by the presence of sodium thiosulfate, a compound used to neutralize chlorine present in city water. The effect makes city water unusable for sublethal and physiological studies with mercury compounds until a substitute method of removing chlorine is devised.

Preliminary studies of other heavy metals as possible pollutants in fresh water have been initiated.

Pesticide Pollution

The widespread occurrence of organochlorine pesticide residues is an important environmental quality problem. A survey was made of the extent of DDT contamination in various commercial freshwater fish species of the larger commercially exploited lakes in Canada. This showed that the levels were below the safe tolerance level for human consumption in all samples except fall-caught coho salmon, and in some whitefish, from Lake Huron. However, the harmful effects of these residues on the fish themselves requires further study and methodology is being developed for assessing the overall effects of other pesticides in the aquatic environment.

Fish Farming

Throughout the prairie provinces are vast numbers of small shallow lakes. These bodies of water, known as winterkill lakes, contain no fish due to depletion of oxygen in the water during the long period of winter ice cover. However, they contain great quantities of fish food organisms (mainly amphipods of the genus *Gammarus*). Preliminary experiments in 1968 demonstrated that rainbow trout planted in such lakes in early summer attained a marketable size by autumn and indicated the possibility for a new kind of fish farming. Studies to develop this unique kind of fish farming have been expanded during 1969 and 1970. In the spring of 1969, three small lakes in western Manitoba were planted with 2½-inch rainbow trout fingerlings. Harvesting was carried out in October and the average weight of the trout harvested was about 14 oz; 70% of the fish planted were harvested. The total yield in the lake which was stocked heaviest was 125 lb/acre. (Only about 3 lb/acre of fish is obtained from commercially fished lakes in the prairie region.) The color and flavor of the trout obtained was much superior to that of rainbow trout now imported and available commercially. These trout when stored at −15 F were shown to have a shelf life of more than 11 months without a detectable decline in quality. These results indicated excellent prospects for the development of commercial rainbow trout farming in these types of waters so abundant throughout the prairie provinces. These results stimulated great public interest and resulted in more than 1000 requests for information.

In 1970 the experimental program was expanded and 17 winterkill lakes of various depths and sizes were stocked with rainbow trout at various densities. Studies were carried out on the growth rate, survival, and production of trout and at the same time studies were made on the natural trout food (*Gammarus lacustris*). The objective of these studies is to determine the optimal stocking densities for lakes of this type so as to optimize trout production while utilizing most effectively the natural trout food on a continuing basis. Harvesting has been completed and yields of rainbow trout range up to more than 100 lb/acre. The growth rate of the trout was somewhat lower than in 1969, likely the result of the smaller size of fish when they were planted and the fact that the lakes were not ice free and ready for stocking until 3 weeks later than in 1969. It was found that the trout survived and grew well in even very shallow lakes – less than 6 ft in depth. Analysis of results of this year's experiments will provide better management information for the fish farming industry which is now developing.

More than 200 individual farmers bought and stocked the rainbow trout fry in their small winterkill lakes in 1970. As a result more than 50,000 lb of rainbow trout have been delivered to the Freshwater Fish Marketing Corporation to date. These fish are now being marketed by the Corporation and are finding ready acceptance on the market at premium prices. Prospects for extensive development of this new industry in the future are most encouraging.

A new hatchery and artifical pond complex is now under construction. This will provide necessary facilities for undertaking work on selective breeding and for future expansion of studies designed to further stimulate this promising new development in fish farming.

Management

Fishery statistics for Great Slave Lake since 1945 have been analyzed. A report is in its final stages and new management regimes will soon be implemented on the basis of these studies. Studies of a new native fishery at Lac la Martre in the Northwest Territories were carried out to provide baseline information on fish populations which will be used in future management of this fishery. A computational computer program for the improved handling of Canadian freshwater fisheries statistics of a research nature has been developed; and working closely with the Freshwater Fish Marketing Corporation and the Fisheries Service, programs for the handling of production data have been devised. This data is now available for use by the provincial fishery agencies and by the federal fisheries service.

A detailed survey of the present status of the N.W.T. sports fishery and its potential has been carried out at the request of the Government of the Northwest Territories to assist them in their planning for future tourism development.

Experimental Fishery

The full-scale management experiment on Goldsand Lake in northern Manitoba (begun in 1965) to assess various methods of fishery management continued.

Selective harvesting of northern pike (*Esox lucius*) continued in 1970 to affect control of the pike-whitefish tapeworm, *Triaenophorus crassus*, and to increase recruitment and production of more valuable commercial fishes such as walleye and whitefish. Walleye (*Stizostedion v. vitreum*) were again exploited after a 1-year rest, but only lightly to provide information on some measure of population density and size of fish.

In 1970 fish catch was down for the second consecutive year from 30,000 in 1968 to 21,000 fish. A significant difference from the previous year was the paucity of small pike, which suggest that recruitment to the fishery is being significantly reduced. The catch of walleye remained quite low, about 9000 fish, but small walleye continued to be fairly numerous. The 1970 catch of whitefish, by number, was up about 1.6 times that of the previous year due to an abundance of small (½-lb) fish which are vulnerable to the small-mesh pike exploitation nets. The most significant change in the fish population at Goldsand Lake was the abundance of white suckers (*Catostomus commersoni*). For the first time in 5 years the catch, by number, of this species exceeded that of pike. The 1970 catch, by number, of white suckers was 1.5 times greater than pike.

About 27,000 walleye fry were planted in a 30-acre lake tributary to Goldsand Lake in the spring of 1970. This experiment was part of a plan to augment walleye production in Goldsand Lake by rearing fingerlings in a controlled nursery area from

which all other fishes were excluded. Walleye eggs, from Goldsand Lake stock, were incubated and hatched at the Goldsand Lake substation. Although the planting appeared successful, no walleye fingerlings were recovered in late August. Low water levels in the nursery lake and abnormally high summer temperatures contributed, at least in part, to the failure of this experiment.

Products and Processing Research

Products

The popularity and economic importance of smoked goldeye to the prairie fishing industry are well known, but variability in quality and in processing techniques are still a problem. A study was undertaken to determine the processing techniques which will produce a product of consistently high quality. Prefreezing and low temperature smoking are recommended. In cooperation with the Faculty of Home Economics, University of Manitoba, the effects of 12 different Canadian woods on the flavor of smoked whitefish have been studied. Good flavors were produced with red maple, red oak, trembling aspen, white ash, and birch but poor flavors were produced with diamond willow and burr oak. Some of the conditions which can affect the quality of canned whitefish were studied. Parameters investigated have included spawning cycle, sex, location of catch, and fresh versus frozen fish. There was no noticeable effect except that of frozen fish giving a firmer, preferred product.

Patties and breaded portions were developed from sucker and maria stimulating increased market potential of these presently underutilized species. Technical assistance was provided to the Department of Indian Affairs and Northern Development in the preparation of meal from beluga whales and in plant design. The Government of the Northwest Territories was also assisted in the development of products for the Rankin Inlet cannery.

Refrigeration Engineering

The design, construction, and testing of all components of a portable refrigerated fish storage facility have been completed. Field trials were carried out on Lake Winnipeg, at Molson Lake, Manitoba, and an operating test was completed this summer at Kaminak Lake, 120 miles west of Rankin Inlet, N.W.T. The complete success of this latter operation demonstrated the usefulness of this type of equipment in conducting fishing operations on fly-in lakes in northern Canada.

A high velocity blast freezer unit has been designed, constructed, and is ready for testing. Design and performance are being evaluated in an effort to produce an optimized unit for the efficient freezing of whole or dressed freshwater fish.

Biophysical Engineering

The present inspection method used for estimating the number of fish which contain cysts in any given shipment is wasteful of fish, and is not totally reliable. The

detection of cysts by means of ultrasonics is possible and research has concentrated on development of techniques to improve the efficiency of the method and on the development of electronics hardware to make the detection system automatic.

The temperature of the fish should be raised to 55 F, preferably by dielectric heating, for no less than 15 sec; this can be done without any loss of quality.

An automatic detector which uses a four transducer mosaic has been designed; the laboratory model has a detection efficiency of 85% or more whenever two or more cysts are present in the sample.

Biochemistry and Microbiology

Common objective methods for determining freshness in marine fish products are practically useless when applied to freshwater fish. A quality test developed by German scientists, and based on fluorescence of fish muscle, was tried on freshwater fish. The intensity of fluorescence was found to correlate inversely with time after death, disappearing completely after rigor dissolved. The method offers possibilities but needs to be developed.

A study of the effect of polyphosphate treatment on drip prevention in freshwater fish is not yet complete, but results obtained so far indicate that the treatment is effective for several species.

Although hypoxanthine is formed in frozen fish, the rate of formation is so low in comparison with that in iced fish that poor frozen-storage conditions are not likely to affect the hypoxanthine level in any significant way, at least in whitefish. Thus the hypoxanthine level can be said to represent the quality of the product at the time it was frozen.

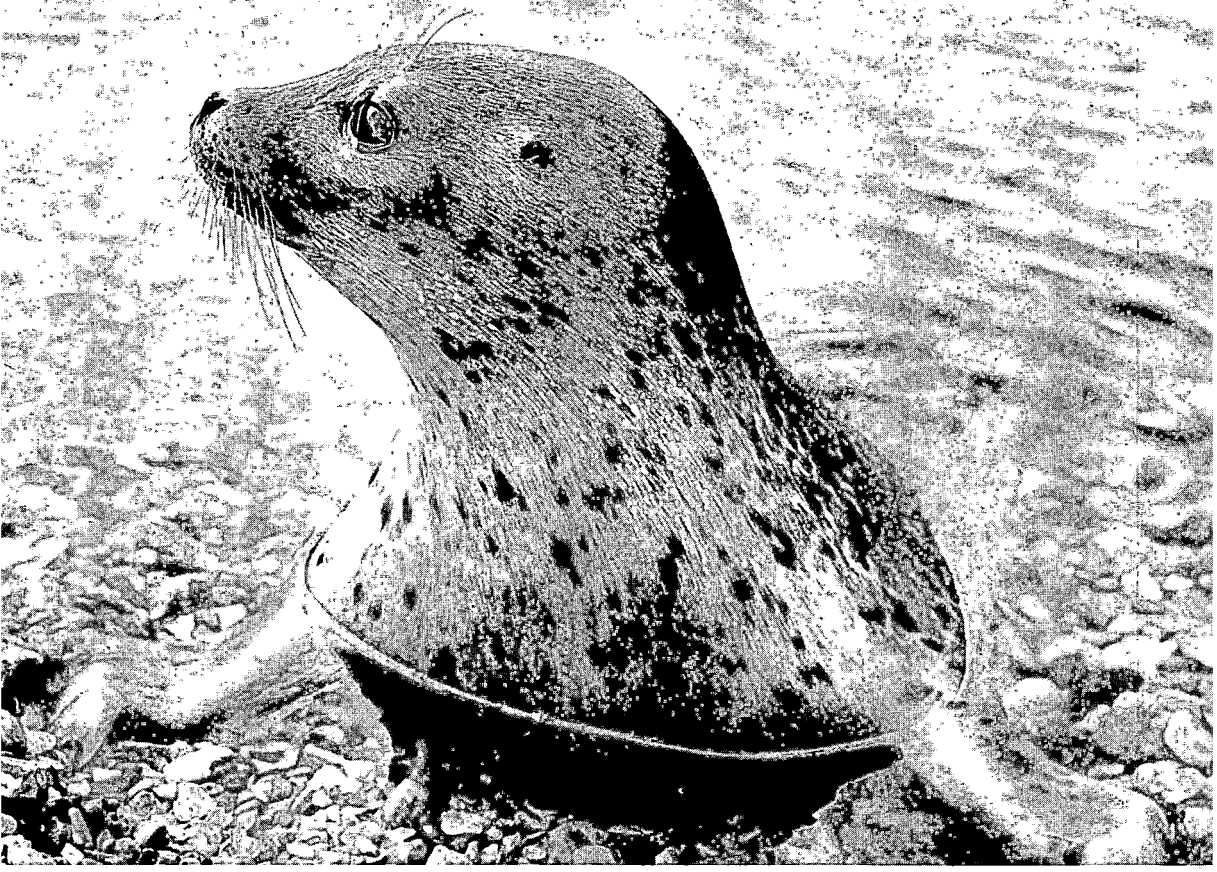
The flavor and odor of rainbow trout obtained from fish farming operation in Manitoba showed definite decline on the average after 14 months of storage at −15 F. Shorter storage life in some samples is explained by individual variation between fish.

An investigation studied the relation between total bacteria and fecal contaminants on the surface of fish and those of the water in which they were caught. The results indicated that fish either do not pick up or else eliminate fecal organisms from their slime.

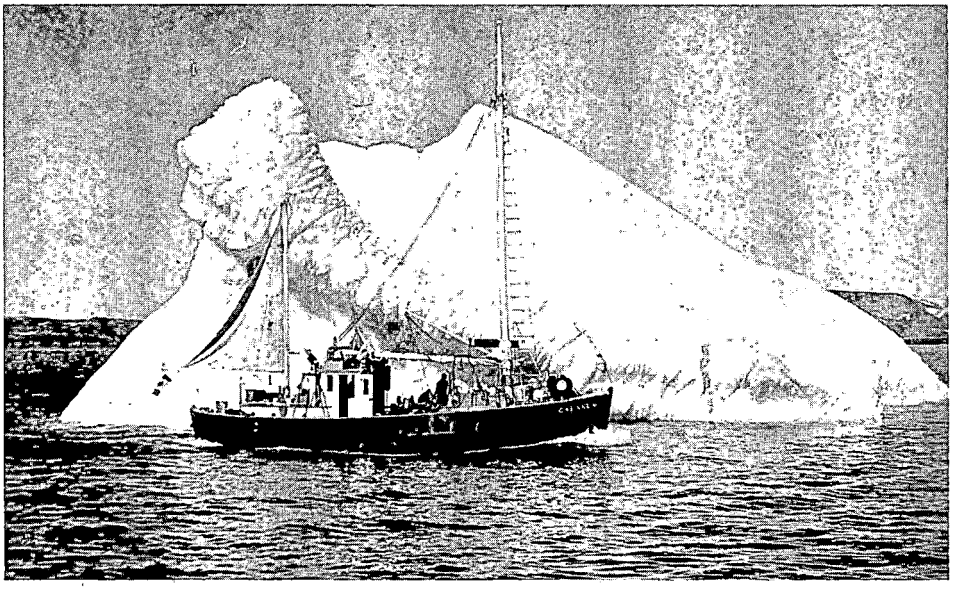
Some lakes in the prairie provinces yield fish with a muddy odor and taste; these fish are unmarketable. Analysis has revealed that these fish contain a substance which gives the same reaction under gas chromatography as a compound identified as "geosmin" which is produced by streptomyces and which conveys a musty, potato-like odor.

The intensity determined by gas chromatography appears to correlate with taste-panel assessment of the muddy odor.

Research in biochemical genetics has been concentrated on investigations of the physical chemistry and genetics of specific proteins in several freshwater fish species. Once the existence and genetic basis of the multiple forms of any specific protein is determined it is a relatively simple matter to apply this knowledge to the discrimination of species as well as races or stocks of fish within species. Studies of coregonid fishes, sponsored jointly by the Freshwater Institute and the Department of Zoology, University of Manitoba, have revealed that many members of this family have multiple forms of hemoglobin, lactate dehydrogenase, malate dehydrogenase, and L-glycerol-3-phosphate dehydrogenase. A genetic analysis of the multiple forms of lake whitefish (*Coregonus clupeaformis*) lactate dehydrogenase has been completed, and studies of the genetics of lake whitefish L-glycerol-3-phosphate dehydrogenase are also nearly complete. An investigation of multiple malate dehydrogenase isozymes in walleye (*Stizostedion v. vitreum*) has been carried out. This study has shown that walleye have multiple genetic loci for this enzyme and that one locus has at least three alleles. It is anticipated that these results could prove very useful in evaluating the success of transplanting stocks of this game fish.



A young ringed seal was netted in Milne Inlet, north of Baffin Island, during a narwhal survey. The seal was studied and later released



The research vessel M.V. Calanus *is used for research in Canada's northern waters. The* Calanus *is shown here steaming past an iceberg in Frobisher Bay, N.W.T.*

ARCTIC BIOLOGICAL STATION
STE. ANNE DE BELLEVUE, QUEBEC

The most important activities of the Arctic Biological Station are as follows:

- Studies of life histories, growth rates, and population dynamics of marine mammals of the Pacific and Atlantic coasts to meet the requirements of three international commissions concerned with conservation of North Pacific fur seals, Atlantic harp, and hood seals, and North Atlantic whales. Investigations are also carried out on several arctic species including walrus, ringed seal, bearded seal, white whale, and narwhal, which can continue to benefit northern communities if exploited wisely

- Studies of life histories, population dynamics, and factors limiting production of marine and anadromous fishes of the Canadian arctic and sub-arctic, to provide information on maximum sustainable yield to domestic, recreational, and commercial fisheries

- Studies of the phytoplankton, zooplankton, and benthos of northern waters, combined with some physical oceanography, aimed at an understanding of the factors controlling arctic productivity and providing a baseline for northern pollution studies

Marine Mammals

Harp Seal

As a result of agreements between Canada and Norway, the fishery for harp seals on the east coast of Canada now takes mainly young seals. Research has therefore concentrated on improving estimates of annual production and maximum sustainable yield. An aerial photographic survey carried out in March 1970 showed greater numbers of harp seals whelping on the "Front" off southern Labrador than in the Gulf of St. Lawrence by a ratio of about 5:3. The results of a capture–recapture tagging experiment in the Gulf involving nearly 2000 young harp seals, when considered together with ships' catches and the known distribution of whelping patches, suggest a production of about 125,000 seals in the Gulf and therefore a production of about 210,000 on the Front.

Analysis of large numbers of age samples continues to provide assessment of the degree of survival of young harp seals. Comparison of survival after high and low catches of young in successive years has allowed an estimate of annual production of about 200,000 seals on the Front and 125,000 in the Gulf which corresponds very closely to estimates obtained by other methods.

In 1969 many young seals found in the northern Gulf were contaminated with oil. Tagging experiments carried out by the Arctic Biological Station and observations made

by the Conservation and Protection Branch of the Ministry around Prince Edward Island identified the source of contamination as Bunker "C" oil released in Northumberland Strait in late January 1969. The tagging showed that young harp seals up to an age of 4–6 weeks migrated 200 miles north, with few deaths resulting from the contamination; however, their subsequent death rate may have been higher.

Grey Seal

Continuing predation by the grey seal on netted herring and mackerel in eastern Nova Scotia has led to a detailed investigation of the population status of this species. Local fishermen, trained as collectors, have substantially increased the take of specimens necessary for a meaningful study of the grey seal's life history, and counts of the young produced in known breeding colonies have led to a better estimate of total numbers. Over 900 weaned and newly molted young have been branded and this program will be continued until a significant number of seals has become sexually mature. Recoveries of branded seals will provide a more accurate estimate of mortality rates and will add to future studies of behavior.

The recapture of several specimens branded as pups in 1963 and 1964 has allowed verification of a method for determining age based on incremental lines in the cementum of the canine teeth.

In March and April 1970, following the sinking of the tanker *Arrow*, the area of eastern Cape Breton Island affected by the oil spill, and Sable Island, were examined for seals. About 500 grey and harbour seals were seen, most of which were contaminated with oil. However only 24 dead grey seals were found, 11 of which came from Sable Island. The observations showed a scarcity of seals in an area where normally up to several thousand are seen. Oil may have been the decisive factor in causing them to disperse, but it is also possible that the unusually heavy air and boat traffic may have been partly to blame.

Harbor Seal

In the Maritime Provinces the population of harbour seals has been considerably reduced by a bounty system which has been in force for many years. Adequate collections of specimens are being made in conjunction with the grey seal study to provide for an assessment of the population of this species. A study is being made of a breeding colony at Sable Island, which produces about 200 pups annually.

Ringed Seal

In 1969 an aerial survey of molting ringed seals hauled out on the fast ice in the Broughton Island area of eastern Baffin Island was carried out in conjunction with counts of animals made from the ground. To complete the study further specimens were collected in Cumberland Sound in 1969 and in Broughton Island in 1970. Population parameters derived from the data will help in determining populations of ringed seals in other areas of the arctic.

Fur Seal

Under the terms of the Interim Convention on Conservation of North Pacific Fur Seals, pelagic fur seal research was carried out for the eleventh and twelfth consecutive years. In April and May 1969 a chartered fishing vessel was able to sample 291 seals off the coasts of British Columbia and Washington, but in January–March 1970 the same vessel and crew were able to sample only 180 seals in the same area owing to stormy weather.

The scope of this research was increased by coding all past and present data under a new system agreed to by investigators from both the United States and Canada.

White Whale (Beluga)

A successful method of tagging devised in 1967 has provided knowledge on migrations on the Hudson Bay area but so far it has not proved possible to tag more than a few white whales in other localities in the Canadian arctic. In July 1969 attempts at tagging white whales were again successful at Seal River, Manitoba, with 893 tagged, but in the Mackenzie Delta only 18 whales were tagged. Recoveries in Hudson Bay from the 1969 tagging experiment were seven in 1969 and one in 1970, again ranging from Churchill, Manitoba to Repulse Bay, N.W.T.

In view of the demonstrated mercury contamination of white whales from Churchill the source of the contamination is important. Although no tags have been recovered from the Nelson River, the large herd in the estuary of that river, 100 miles south of Churchill, seems the most likely source since mercury compounds have been discharged into the Saskatchewan River system, tributary to the Nelson. Alternative sources in James Bay are more distant.

Fin, Sei, and Humpback Whales

Research has concentrated on providing better estimates of sustainable yields of fin and sei whales for the east coast whaling industry. Almost every whale landed at the three whaling stations has been sampled for data on age and maturity, and a series of tagging cruises has been carried out. In February 1969 tropical waters of the western Atlantic, including the Caribbean, were searched for whales at the southern limit of their range. Six sei and 33 humpback whales were marked. In May and June 1969, 5 sei, 4 humpback, and 34 fin whales were tagged in the Gulf of St. Lawrence and its approaches, but so far no tags have been returned from this experiment. In April 1970, 11 humpback whales were tagged in Bermudian waters with the cooperation of the U.S. Navy. The results of all these tagging programs have not yielded enough information and other methods of tracking whales, such as the use of radio tags, are now being assessed.

Marine and Anadromous Fishes

Depletion fishing of small selected areas in Coronation Gulf, N.W.T., proved effective in measuring population abundance of benthic invertebrates and small benthic fishes. Gear efficiency varied from as high as 82% for starfish to as little as 2.5% for some species of fish.

Locations suitable for similar population studies were examined in Frobisher Bay in 1970. Estimates of relative abundance of several species of invertebrates and fish resulted from this initial survey. High speed fishing with an Issacs-Kidd trawl in moderate depths at several locations caught numerous larval cottids and amphipods in Frobisher Bay and a more varied assortment of larval fish and invertebrates from the waters of Coronation Gulf.

Range extensions of four species of fish (*Cyclopterus lumpus, Hippoglossoides platessoides, Triglops murrayi,* and *Artediellus uncinatus*) northwards into Frobisher Bay were found.

A specimen of *Acantholumpenus mackayi,* a relict species with its distributional center in the Sea of Japan, was added to the small collection already available from Tuktoyaktuk harbour.

The data obtained from a small sample of arctic char from the Pelly Bay test fishing in 1970 indicate that this area has been heavily fished in the past and is not capable of higher sustainable yields. Char stocks in the Tree River continue to improve and, depending upon the 1970 catch returns, may be exploited more heavily in the future.

Biological Oceanography

Marine Ecology Study, Frobisher Bay

Regular observations were carried out at the same station in Frobisher Bay throughout 1969 and 1970. The resulting meteorological and oceanographic data, combined with similar data collected in 1967 and 1968, show that total primary production may be nearly doubled in years when higher spring temperatures and early breakup of the sea ice occur. However, primary production is still low by North Atlantic standards. Studies carried out in winter on the nutrients and pigments in sea ice show that phosphate consumption rises in March and continues until at least late May. In part this can be attributed to photosynthetic activity of diatoms and phytoflagellates since chlorophyll *a* levels rise during this period. With the beginning of melting, chlorophyll *a*, representing survivors of the ice flora, is released from the underside of the ice and may contribute significantly to the development of the new crop of phytoplankton. The arctic flora accumulates greater quantities of reserve materials such as starch and oil than the flora of North Pacific or equatorial seas. These substances are eventually liberated into the sea where they join other abundant organic aggregates, believed to result from the disintegration of fecal pellets from zooplankton.

Approximately 300 species of benthic invertebrates, almost a third of which are polychaetes, have been identified from the collections made in the area of the station. The predominant epifaunal forms are ascidians, sponges and polychaetes which represent about 87% of the total wet weight of the standing stock. Echinoderms replace polychaetes in order of importance when the standing stock is expressed as dry weight.

OFFICE OF THE ATLANTIC REGIONAL DIRECTOR, RESEARCH HALIFAX, NOVA SCOTIA

The position of Atlantic Regional Director, Research, was created in September 1969 and Dr D. R. Idler, formerly director of the Halifax Laboratory, was appointed as the first Regional Director. The Regional Director is responsible for integrating the activities of all the Board's Atlantic establishments which include laboratories at Halifax and Dartmouth, Nova Scotia, St. Andrews, New Brunswick and St. John's, Newfoundland. He is responsible for the planning and integration of programs and maintenance of liaison and collaboration with industry, universities, and governmental departments and agencies with common interests. The Regional Director is also responsible for the operations of the Board's Atlantic fleet which consists of nine fisheries research vessels.

As a result of recommendations put forward by the task force on pollution in the Altantic Region, a pollution research laboratory has been established jointly by the Fisheries Research Board and the Resource Development Branch of the Fisheries Service. Laboratory facilities have been procured and were installed on a site at the Bedford Institute in Dartmouth as a part of the Marine Ecology Laboratory. Scientists have been recruited for the unit and several research programs initiated. The majority of the programs will initially be concentrated in the fields of tolerance and pollutant chemistry such as the effects of pollutants on flora and fauna and on commercial marine products. Later the base will be broadened to include ecology and oceanography. A similar unit is planned for Newfoundland.

The nine vessels operated by the Board on the Atlantic coast range in size from 50 to 177 ft in length, and employ a total of 60 personnel. Scheduling of the larger vessels for multistation use and operational and maintenance cost control of the fleet is carried out by a Vessel Manager. This office is also responsible for the charter of submersibles and other vessels as required to maintain scientific programs.

A number of meetings have been held with personnel from the Economics Branch of the Fisheries Service in order to establish a statistics unit for the Atlantic Region. The purpose of this unit is to obtain more complete records of catches and landings of all species and to augment the biological sampling programs. These data will be of great value in estimating catch per unit effort and the areas of catch and will be used to calculate the maximum sustainable yields of various commercially exploited species. This will in turn permit better management of the fisheries resources in the future.

A regional approach has been taken to better coordinate research and development studies in the field of fresh fish preservation. To accomplish this goal, meetings have been held between personnel from Fisheries Research Board and the Fish Inspection Branch and Industrial Development Branch of the Fisheries Service.

Similar intradepartmental meetings have also been taking place in order to co-ordinate more effectively research and development on oysters and salmon.

Herring research was greatly expanded in 1969 since concern was voiced by scientists and members of the industry over the possible effect on the stocks of the rapidly increasing catches. All Fisheries Research Board laboratories in the Atlantic Region are involved in various phases of the study and a herring coordinator has been appointed. A very successful tagging program was carried out in 1970 with a total of approximately 80,000 herring being tagged in Newfoundland, Magdalen Islands, and Northern New Brunswick. A substantial number of tags has been recovered and has confirmed an extensive movement of herring into the Gulf of St. Lawrence in the spring and out again in late fall.

The solution to the massive water pollution and subsequent fish kills caused by elemental phosphorus from a newly established plant at Long Harbour, Placentia Bay, Newfoundland in 1969 involved the efforts of a large number of scientists and support staff from all Fisheries Research Board laboratories in the Atlantic Region. Bioassays established that elemental phosphorus is extremely toxic to fish, that it accumulates in fish tissues, and that the "Red Herring" symptoms are caused by destruction of the red blood cells. New analytical techniques were developed to detect elemental phosphorus in the part per billion range.

The company was forced to close down the plant for about 2 months in order to construct effluent treatment facilities and large settling ponds, and the mud on the harbor bottom near the plant was dredged. The routine monitoring has been taken over by the Resource Development Branch of the Fisheries Service in St. John's, but Fisheries Research Board scientists are still involved in an advisory capacity.

The scientific liaison officer is responsible for the dissemination of scientific and technical information to the industry and general public and to keep the Regional Director and Fisheries Research Board scientists informed of new developments in the fishing industry in Canada and abroad. A number of articles on Fisheries Research Board research has been written as circulars or have appeared in magazines and newspapers. Personal contact with members of the fishing industry was maintained through frequent visits to the plants and through meetings such as the one on flounder biology and processing technology held in St. John's in January 1970. A large number of requests for information on fisheries research and technology is also processed.

BIOLOGICAL STATION
ST. ANDREWS, NEW BRUNSWICK

Research at St. Andrews is divided into two broad categories:

- Research aimed at improving the management and harvesting of commercial and recreational fisheries, by such investigations as physiology, life histories, population dynamics, stock assessments, and behavior of a variety of species of groundfish, pelagic fish, anadromous fish, and invertebrates

- Research on the aquatic environment, with particular emphasis on quality assessment and control

On August 24, 1970, the Huntsman Marine Laboratory (HML) was officially opened at St. Andrews. Its aim is to promote teaching and research in the marine sciences. The FRB at St. Andrews, which fostered, encouraged, and was largely instrumental in the formation of the HML, is proud of this unique organization in Canada – a consortium of 19 Canadian universities, the Fisheries Research Board, the New Brunswick Department of Fisheries, and the International Atlantic Salmon Foundation. While the HML enjoys a separate corporate identity, it is planned that there will be much FRB–HML integration at the operational level

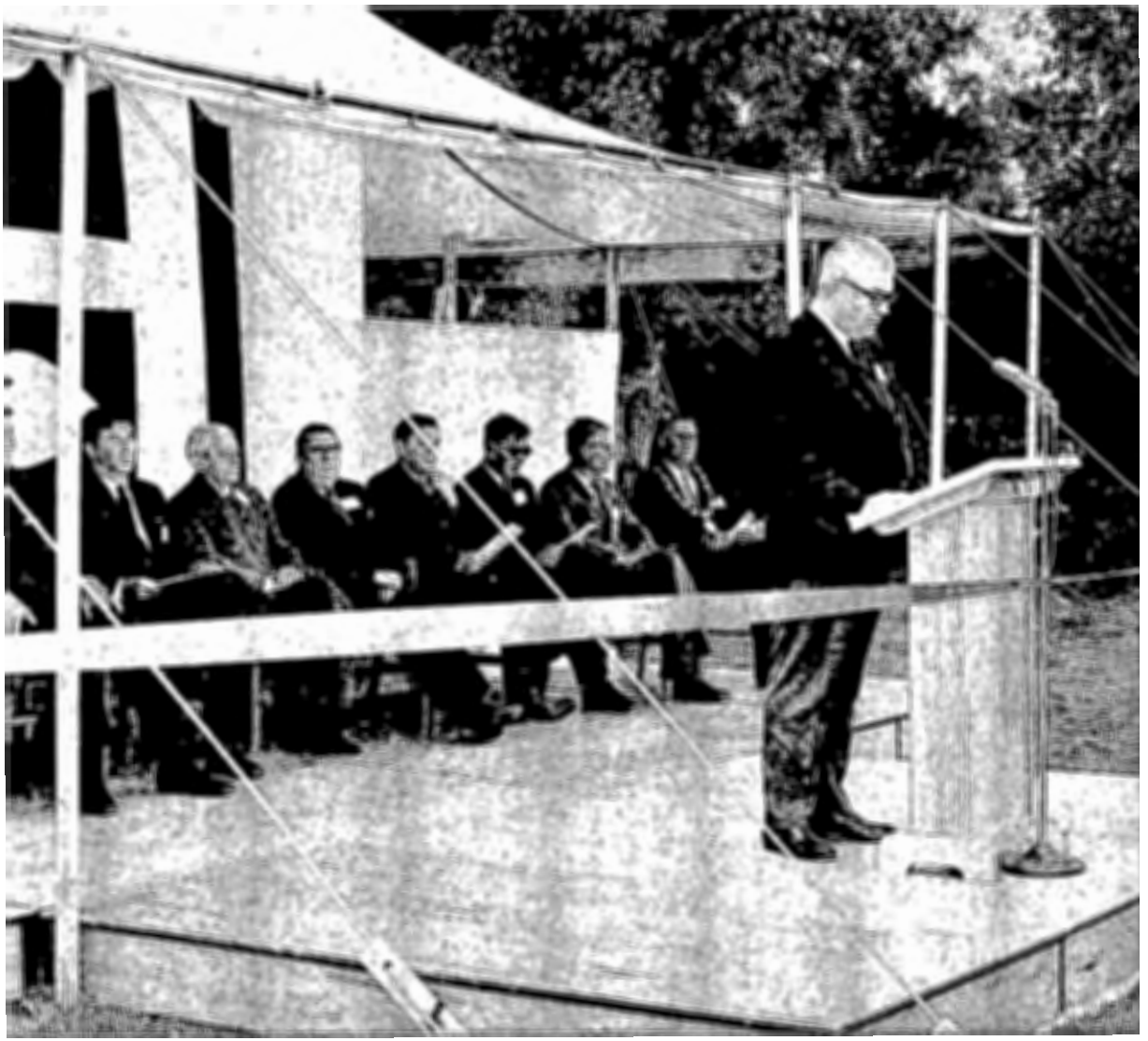
Particular emphasis was placed on the development of new underwater methodologies, including the use of research submersibles, in fisheries research

Pelagic Fish

Herring

Canadian Atlantic herring fisheries increased fivefold during the 1960's, in association with a change from traditional fixed-gear fisheries for food, to mobile operations for a meal and oil industry. Landings from the Bay of Fundy region peaked at about 600 million lb in 1968 and have since declined drastically. The expansion is still continuing in the Gulf of St. Lawrence where landings in 1970 are expected to approximate 400 million lb, about double what they were in 1968.

Growth studies of three different groups of sardines from 1965–68 indicated that Bay of Fundy sardines are recruited from three different spawning populations outside the area. The Nova Scotia herring stocks are generally considered to be biologically distinct from the Georges Bank stocks but there is still some doubt about the parental stock of New Brunswick sardines.



Dr. J. R. Weir, Chairman FRB, addressing guests on the occasion of the official opening of the Huntsman Marine Laboratory in St. Andrews, August 24, 1970. Platform guests show (from left) – Hon. W. S. Bird, Lieutenant Governor, Province of N.B.; Dr J. M. Anderson, Director FRB St. Andrews; Dr A. G. Huntsman; Hon. E. Richard, Minister of Fisheries, N.B.; Mr W. M. Carter, Exec. Director, International Atlantic Salmon Foundation; Hon. W. W. Meldrum, Minister of Education, N.B.; Dr F. Depocas, NRC; Dr H. B. Hachey, Mayor, St. Andrews

In the Gulf of St. Lawrence the fisheries are supported by both spring- and autumn-spawning populations which may mix on feeding and winter habitats; but there is no evidence for mixing on spawning grounds. Spring and autumn spawners probably return to their first spawning ground year after year.

There is no longer any doubt that herring stocks fished in the Gulf of St. Lawrence are exploited also by fisheries outside the area. The complexity of the stock stiuation makes it difficult to identify individual components but recaptures of tagged fish are providing useful information. In cooperation with the Biological Station at St. John's, Newfoundland, more than 80,000 herring were tagged in 1970: 25,000 off the south coast of Newfoundland (March), 35,000 at Magdalen Islands (May), and 20,000 off the Gaspé coast (August). More than 700 recoveries have already been made.

The Perry submersible *Shelf Diver* was used during September 1969 to survey herring spawning beds in the Trinity–Lurcher area off southwest Nova Scotia. No beds were found, probably because the eggs had already hatched, but the system was evaluated and found to be promising.

In late September–early October, 1970, as part of an international joint survey, the submersible *Pisces I* was used to observe herring spawning beds on Georges Bank. Spawning beds were observed on five separate dives in an area subject to a strong rotary permanent tidal system. Egg beds were found on a flat level gravel plain which was being slowly traversed along a north–south axis by a system of sand dunes graded in size from 2 inches to 30 ft and lying east and west. Particle size for the rounded gravel varied from ¼ inch to 2 inches with interspersed larger cobbles. The width of individual egg beds was of the order of ½ mile and, on a newly laid bed, eggs formed an almost complete firm cohesive mat not more than 2 cm in thickness. Larval herring were observed on the bottom, forming a 4-inch thick densely aggregated swarm some tens of yards across. A hatched-out egg bed was underlaid by a deoxygenated black gravel substrate rich in organic matter. Red hake proved to be a major fish predator on eggs; other suspected fish predators were seen as evidence of local heavy predation. Hermit crabs were abundant on the fresh egg bed.

The distribution of larval herring in the Bay of Fundy and Gulf of Maine indicates two important recruitment areas – the northern edge of Georges Bank and the southwest coast of Nova Scotia. Larval collections from quarterly cruises over a 3-year period (1967–69) demonstrate the importance of autumn spawnings in both areas. Spawnings occur in other areas and seasons but, by comparison, are insignificant. Initial growth of autumn-hatched larvae is slow. By spring of the following year they are only 30–45 mm long and have drifted away from spawning grounds. They are concentrated at the entrance to the Bay of Fundy during the winter months and subsequently disperse throughout the region.

Tuna

Giant (over 500 lb) bluefin tuna were tagged with sonic tags in St. Margaret's Bay in cooperation with the Woods Hole Oceanographic Institution. The tags telemetered fish

and water temperatures for studies of temperature regulation. A total of 11 fish were followed for 57 hr and 130 miles.

Swordfish

Swordfish grow rapidly and are thought to reach weights of 4, 15, 40, 70, and 113 kg in successive years. Tag returns indicate increased recoveries after using a special harpoon on free swimming fish (13%) than when fish are released from longlines (2%). The returns also suggest that swordfish return to the same area of the continental shelf each year (average 45 miles, between release and recovery for fish at liberty a year or more).

Examination of the gills and gastro-intestinal tracts of swordfish showed presence of *Contracaecum incurvum* and *Hirudinella marina* in the stomach, *Fistulicola plicatus* in the rectum, and *Tristoma coccineum* and *T. integrum* on the gills. The incidence of the latter monogenetic trematodes and related species in other areas suggest that they may be useful as biological tags.

Sharks

A total of 412 sharks of various species were tagged during 1969–70, and six recoveries recorded. Returns suggest a seasonal movement by blue and possibly mako sharks in an anticlockwise direction between the Gulf Stream and continental shelf of as much as 1000 miles.

New Fish Records

Records of unusual occurences of fish species include northern wolffish (*Anarhichas denticulatus*), squaretails (*Tetragonurus atlanticus* and *T. cuvieri*), moonfish (*Vomer setapinnis*), small scale pomfret (*Brama raii*), oilfish (*Ruvettus pretiosus*), long-nose grenadier (*Coelorhynchus carminatus*), planehead file fish (*Monacanthus hispidus*), menhaden (*Brevoortia tyrannus*), chub mackerel (*Scomber colias*), cavalla (*Scomberomorus cavalla*), tarpon (*Megalops atlantica*), big scale pomfret (*Taractes longipinnis*), scup (*Stenotomus chrysops*), tilefish (*Lopholatilus chamaeleonticeps*), lesser deepsea angler (*Cryptopsaras couesi*), a berycoid fish (*Gephyroberyx darwinii*), and an unidentified angler (*Himantolophus* sp.).

Groundfish

In 1969–70 the imposition through the International Commission for the Northwest Atlantic Fisheries (ICNAF) of international quota controls on the haddock fishery on Georges and Nova Scotia banks stimulated the assessment of stocks of groundfish exploited by Canadians.

Codfishes

Studies of the southern Gulf of St. Lawrence cod fisheries showed that sizes and ages of fish landed commercially, have remained fairly stable during 1969 and 1970 and the stock still make an annual winter migration out of the Magdalen Shallows to congregate along the edge of the Laurentian channel off Cape Breton. Cod were abundant in this area in the winter but were not heavily exploited by Canadian fishermen.

Assessment of the eastern Nova Scotia Banks haddock stock (ICNAF Division 4V-W) indicated that the traditional, mainly Canadian, fishery has been exploiting this population close to its maximum yield under present mesh regulations. The large Soviet fishery of 42,876 metric tons in 1965 was evidently based almost entirely on haddock aged 1–4, prior to any significant contribution of these year-classes to the traditional fishery. This resulted in a substantial loss in yield of between 9000 and 46,000 metric tons from the eastern Nova Scotia Banks haddock stock and was an important contributory factor to the current very low adult stock abundance. Abundance in 1967–69 was only one-third of that in 1956–57. Research vessel surveys of pre-recruits indicate that the 1966–69 year-classes, which will recruit to the traditional fishery in 1970–73, are poor, thus no substantial improvement in the fishery can be expected prior to 1974. As fishing mortality remains substantial it is likely that stock abundance will continue to decline unless further regulatory measures are enforced.

Demonstration of overexploitation of the Browns Bank–Bay of Fundy (ICNAF Division 4X) haddock stock through cooperative USA–Canada research programs led to ICNAF quota regulations for the 1970–72 period. Most recent studies indicate the annual quota of 18,000 metric tons is too high to prevent further stock decline, as all year-classes recruiting since that of 1963 have been poor. Improved recruitment is unlikely prior to 1974.

Quota regulations of ICNAF Subarea 5 (12,000 metric tons), and Division 4X haddock fisheries, and proposals for regulation of the Divisions 4V-W haddock fishery, include closed area provisions during the spawning season. These were formulated, and are being reviewed, in the light of results of joint USA–Canada studies of variation in spawning time and location. Variation in fecundity in these haddock stocks is being related to changes in environment and population density.

Flatfish

Work on niche diversity indicated that greysole occupied at least three diversified ecological niches which changed with fish age and size; a pelagic larval stage persisted up to a year; a deep water stage where the metamorphosed fish settled from 100–250 fath deep in the Nova Scotia Banks area and remained there separated from the rest of the main stock until they were up to 5 years of age; and finally the adult stage where they moved onto the shallower commercial fishing grounds.

Underexploited Species

Research vessel catches on the Scotia Shelf for 1958–69 were analyzed to give relative abundances of each species caught. These data indicate large underutilized stocks of argentine, skates, sand lance, dogfish, and squids.

Sand lance (*Ammodytes dubius*) investigations indicate: maximum size of fish on the Nova Scotia Banks varies with locality and is determined by local environmental conditions; local concentrations are fairly static, geographically; there is a correlation between research catches and tides, best catches being made at slack water, possibly a result of the fish's behavior in relation to tidal currents.

The sub-arctic boreal lanternfish, *Benthosema glaciale* (Reinhardt), was the predominant species in a diverse collection of mesopelagic fishes, containing both arctic and tropical elements, taken by midwater trawl off the central Scotian Shelf. Biological investigations of *B. glaciale* established an ageing technique using otoliths, showed a lifespan of at least 4½ years and a maximum length of 68 mm, and described its vertical migrations. Such studies of mesopelagic fishes are important in view of increasingly numerous statements on the potential of this resource for commercial exploitation.

Species Associations

Sea raven (a piscivorous fish) consume numbers of young cod whose growth and maintenance in turn is largely dependent on supplies of euphausiids and pandalid shrimp that the cod must share with longhorn sculpin. To assess energy flow in this production system, effects of temperature and meal size on rates of stomach emptying have been determined for sea raven fed yearling cod, and yearling cod fed pandalid shrimp and euphausiids. Results indicate that equal percentages of different meal sizes are digested in equal times. Temperature increase greatly accelerates rate of gastric emptying between 2 and 10 C with both cod and sea raven (Q_{10} = 5.5 and 4.0), but the acceleration slows between 10 and 15 C (Q_{10} = 1.2 for both species). Concurrent bomb calorimeter studies of natural fish foods in Passamaquoddy Bay have shown that the energy content of pandalid shrimp changes seasonally by 10%.

Anadromous Fish

Atlantic salmon commercial catches in 1970 for the Gulf of St. Lawrence coast of mainland Canada (Cape Gaspé to northern tip of Cape Breton) were the lowest recorded in the last 100 years. This continues a decreasing trend started about 1965, from 1.4 million lb to a low of 0.7 million lb in 1970. It contrasts with an upward trend of much larger landings in the Davis Strait–West Greenland area, which impinged on the same year-classes (3.4 million lb in 1964 and 4.7 million lb in 1969). This distant-water fishery in 1970 gives early promise of approximating the 1969 landings; if an inverse relation with the Gulf of St. Lawrence fishery exists, the latter is unlikely to increase greatly in 1971.

Recaptures of fish tagged as smolts from 1964 to 1966 indicate that hatchery-reared smolts of early-run parentage were subject to higher exploitation (82%) in home fisheries than similar smolts of late-run parentage (73%) and wild smolts (77%) from the Northwest Miramichi. On the average, about 50% of the recoveries were recorded as grilse in home waters (one-quarter of the grilse were registered as spawning escapement), 8% were taken in Greenland, 40% were used as large salmon in Canada, and only 2% of the large salmon were recorded as escapement.

Smolt runs from the Northwest Miramichi River in 1969 and 1970 were estimated at 10–15 thousand smolts, about half as many as in 1967 and 1968. Returns of grilse from the 1969 smolt run have been about one-third of the number recorded from the 1968 smolt run. The 1968 smolts, besides being more abundant, experienced a survival rate about twice as high as previously recorded (about 5%). There was comparative lack of high water as well as freedom from copper–zinc pollution during the 1968 season of smolt descent.

Underyearling recruitment in upper freshwater reaches of the Northwest Miramichi in 1969 was low, following the low run and poor dispersal of grilse and salmon in the drought year of 1968. Recruitment in the lower 15 miles, subject to mine-originating copper–zinc pollution, was negligible in 1969 and 1970, lethal metal concentrations having impinged several times on both year-classes. In late May 1970, an accidental spill at the mine resulted in a substantial kill of descending smolts and some ascending adult salmon and sea trout. An expected low adult run in 1970 has been the lowest in 20 years of record (under 1000 grilse and salmon). Depressed runs of adults up to 1975 or 1976 may well be expected to follow these weak year-classes.

Following aerial application of the organophosphate insecticide Fenitrothion (= Sumithion) to the Trout Brook (Miramichi system) and Nashwaaksis (Saint John system) basins in 1969 and 1970, stream invertebrates utilized as food by juvenile salmon and brook trout were reduced to levels below those recorded following DDT spraying, and did not recover during the usual period of summer high population densities.

Differing gene pools for salmon of several different river populations have been established by examination of electrophoretic patterns of blood transferrins. A realistic foundation for future work in genetics and selective breeding of salmon for desirable physical and behavioral traits has been established.

Estuarial paths of salmon migration have been studied, using ultrasonic telemetry techniques, in the industrialized Miramichi area and the adjacent, unsettled Tabusintac. Paths of fish in the Miramichi reflected avoidance of some effluents, as distributed by tidal mixing. Upstream progress was slower than in hydrographically comparable parts of the Tabusintac. During exceptionally warm summer weather (surface water temperature up to 28 C) in late July, 1970, upstream progress of salmon through the Miramichi estuary virtually ceased.

Lobster

The feeding habits of lobsters were studied by examining stomachs of 1750 lobsters collected by divers in Northumberland Strait. Diet varied with season, type of bottom and size of lobsters. Major components were starfish, crabs, polychaetes, sea urchins, mussels, tunicates, and fish. Contrary to popular belief, most food was taken alive with little evidence of either scavenging or cannibalism.

The lobster population on an artificial rock reef built in 1965 probably reached its maximum in 1969, about two-thirds that of good natural grounds. Most recruitment was by immigration, with some evidence of larval settlement in 1969. The rocks would probably have been used more efficiently if spread over two to three times the area. Drainage tiles show some promise as cover for lobsters.

Effluent from a bleached kraft mill near Pictou, N.S., seriously affects a relatively small area. Underwater surveys and plankton towing from 1968 to 1970 showed that apparently normal adults and larvae were present in areas where surface waters were discolored by effluent. Although lobster stocks in the area have declined recently, this decline is paralleled in other areas. On the evidence available, the decline cannot be attributed to the effluent.

Underwater surveys in the vicinity of the oil tanker *Arrow* which sank in Chedabucto Bay showed the bottom from low tide to 70 ft was clean with normal flora and fauna. In one area where conditions were unusual, a few small patches of Bunker C oil ballasted with sand were found at depths to 12 m. Lobsters smeared with Bunker C oil or fed smeared bait did not readily become tainted. Smeared lobsters placed in clean running sea water became free of gross contamination within a few hours. From these findings, it was correctly predicted that the spring lobster fishery could proceed virtually as normal.

The effects commercial raking for Irish moss has on lobster stocks were investigated principally off North Rustico, P.E.I., in cooperation with the P.E.I. Department of Fisheries and the Industrial Development Branch of the Department of Fisheries and Forestry. Scuba surveys showed that lobsters were half as abundant on moss beds as on typical lobster bottom. Divers towed by moss rakes observed 1628 lobsters in the rake paths. Only 29 (1.8%) were known to be seriously damaged. Closer examination of rake paths revealed damaged lobsters under rocks. Numbers damaged varied seasonally and geographically. Moss rakes do more damage than hitherto believed but it appears that profits from moss raking outweigh damage to lobster stocks.

At Miminegash, P.E.I., a limit of 250 lobster traps per boat has shortened the fishing day by 50%, reduced the number of traps 25%, lowered the rate of exploitation 10%, reduced fishing costs and increased the size composition. Other effects have been masked by declining stocks, rising prices, and diversion of fishing effort to unusually lucrative scallop and Irish moss fisheries.

Special underwater towed sled, designed and built at St. Andrews, which is used for flying over bottom for extended survey missions. Particularly useful in assessment of Irish moss beds (off P.E.I.) and effect of commercial moss raking on lobster fishery

Weak and injured lobsters suffered 17% mortality during 3 months' winter storage as compared to 6% for vigorous lobsters. Rigorous culling would reduce commercial losses appreciably. During 3 months' summer storage, lobsters with drainage tiles for cover survived better, did not develop objectionable algal growths and did not turn black because of egg absorption as did those without cover. Molting, growth per molt, and meat yield were not related to quantity of food. Unexpectedly, lobsters molting in captivity suffered only 2% mortality and cannibalism has been insignificant.

Molt frequency and size increase of *Homarus* are influenced by sex, day length, and temperature. From 10 to 20 C, there is a linear relation between temperature and molt frequency, but no change in size increase per molt. From 10 to 15 C, day length affects molt frequency and size increase. Although most males molt as readily as females in long and short days, approximately 10% of males exposed to short days enter a protracted plateau in early premolt. A plateau may appear in long days, but is always of short duration.

Morphogenesis of pleopod setae led to a technique for rapid premolt staging and prediction of molt in lobsters. This is useful in molt studies, and has potential value in reducing commercial losses of molting lobsters.

Changes in integumental structure have been identified for premolt, postmolt, and intermolt lobsters, and stages of the molt cycle have been described.

Susceptibility of lobsters to pollution by yellow phosphorous was studied following the Placentia Bay incident. Exposure to contaminated mud from the pollution site revealed that lethal effects are cumulative and irreversible. Blood, excretory organs, and hepatopancreas (tomalley) show degenerative changes.

"School" and "native" lobsters from Nova Scotia differ in color and size composition but not in sex or molt stage. With the U.S. Bureau of Commerical Fisheries, physiological, serological, and parasitological studies are continuing to determine whether "school" lobsters migrate from offshore grounds.

Snow Crab

With support from the Industrial Development Branch, studies of the snow crab (*Chionoecetes opilio*) were continued. Expansion of the fishery and exploitation of new ground resulted in landings of 18.5 million lb in 1969. In 1970, with fewer vessels and poor market conditions, landings fell about 25%.

Tag returns to 60% in moderately fished areas in 1969 indicated that exploitation in heavily fished areas was very high. Lower returns in 1970 reflected decreased fishing effort. Most tagged crabs moved less than 10 miles.

In the laboratory, time to complete a molt varied from 3 to 9 hr in relation to size. Lost legs were regenerated in three molts. From the megalopa larval stage both sexes

reach maturity (60-mm carapace width) in about nine molts. Females stop molting at maturity but males continue, reaching commercial size in two molts and maximum size in two further molts.

Females, molting to maturity, mate when soft. Hard-shelled males as small as 60-mm carapace width mated successfully. The fishery, which takes only males over 100-mm carapace width, probably leaves enough males for reproduction.

Larval development in the laboratory was observed through all stages at 15 C. After release of larvae, females may lay fertile eggs without mating. Several batches of fertile eggs may be produced from one mating.

Trap experiments showed that few commercial crabs buy many nonmarketable crabs could escape through 1½- to 1 5/8-inch spaces. Escape hatches could be important in conserving small crabs.

A towed camera sled developed to assist in assessments of crab populations yielded promising results and should allow rapid surveys over wide areas.

Scallop

Studies of scallop drag efficiency, size selection, and mortality of discards were continued.

A photographic survey of Digby scallop grounds in 1969 confirmed the scarcity of scallops and provided no evidence of pre-recruits. Poor fishing will probably continue for 1 or 2 years. A survey with the submersible *Shelf Diver* showed a transition with depth from the coast, from boulder-strewn lobster bottom, through sand and gravel dunes and ridges (bar clam habitat), to traditional scallop beds of coarse gravel, sparsely inhabited by scallops.

The Georges Bank fishery has had poor recruitment since the last large year-class entered the fishery in 1956–60. Catch per unit effort fell from 475 lb/hr in 1961 to 100 lb/hr in 1965, and in 1969 fell below 100 lb/hr for the first time. In 1969 numerous young scallops (under 50 mm diameter) were reported from the Northern Edge, and in 1970 these were heavily exploited by Canadian vessels. Scallop populations were surveyed by bottom photography and an 8- x 14-mile area of high density of young scallops was located. Population densities and distribution within this high density area are being determined from photographs. With the Inspection Branch of the Department of Fisheries and Forestry, scallop meats were sampled to estimate variation within the catch and between boats and ports of landing. Number of meats per lb landed in August 1970 varied between 13 and 80, the smallest scallops being landed at Lunenburg.

Ocean Clam

Shortages of shellfish products have led to increased demands for ocean clams (*Arctica islandica*). It has been established that ocean clams appeal to the raw half-shell

trade. Tests indicated that undesirable flavors and dark colors result primarily from high temperature during processing. These studies and liaison work have aided development of a fishery off Lunenburg County, Nova Scotia, which in 1970 yielded 300,000 lb of ocean clams. Growth studies indicate that 15 years are required for clams to reach marketable length of 2 inches.

Paralytic Shellfish Poison

In 1969 and 1970 clams (*Mya arenaria*), mussels (*Mytilus edulis*) and rough whelks (*Buccinum undatum*) were responsible for shellfish poisonings in the St. Lawrence estuary. Of 21 individual cases four were fatal.

Systematic sampling of ocean clams indicates that paralytic shellfish poisoning is not likely to be a serious problem with this species.

Statistical Services and Data Processing

The 1130 IBM computer installed in 1968 has been fully integrated into the research activities of the Station. Analysis of commercial and research cruise data for the groundfish investigation, examination of levels of metal pollution, and salmon run information from the Curventon fence, stock identification, and assessment studies for herring have been expedited by the use of the computer.

Behavior

Lobsters

The acute sense of smell of lobsters is being investigated in a special laboratory apparatus in which the response of the animals approximates their normal search-behavior when downstream from baited traps.

The concentration threshold for a variety of chemical substances and food odors is considerably lower for starved than satiated lobsters. Fresh cod extract is more attractive to lobsters than fresh herring, which in turn is more attractive than aged extract from fish of either type.

Chemical signalling between different members of a lobster population appears to be mediated either by a single pheromone, released in different amounts by males and females at different stages of the life cycle, or by more than one pheromone. The urine of all lobsters is attractive to some extent to both mature males and females and the chemical nature of the pheromone(s) is being investigated by various separatory, chromotographic and mass spectrographic techniques.

In relation to pollution studies, it has been shown that lobsters do not avoid bleached kraft mill effluent (BKME) at concentrations up to 20%. BKME introduced upstream from lobsters did not elicit behavioral responses. It is therefore unlikely that dilute BKME would have immediate direct effects on movement of lobsters in nature.

Acoustics

Atlantic cod have been shown to be physiologically very sensitive to acoustic stimuli. Since underwater recordings have confirmed that otter trawls in operation are very noisy, it now seems likely that cod are capable of detecting the approach of trawling-gear and of making locomotor manoeuvers to avoid capture. Laboratory experiments, to determine which of the acoustic parameters is the provocative stimulus, are in progress.

In the field, methods using free-swimming fish and sonic tracking gear, and methods using tethered fish, strain switches and direction indicators, have been evaluated as means of detecting locomotor responses in front of trawls.

Salmon

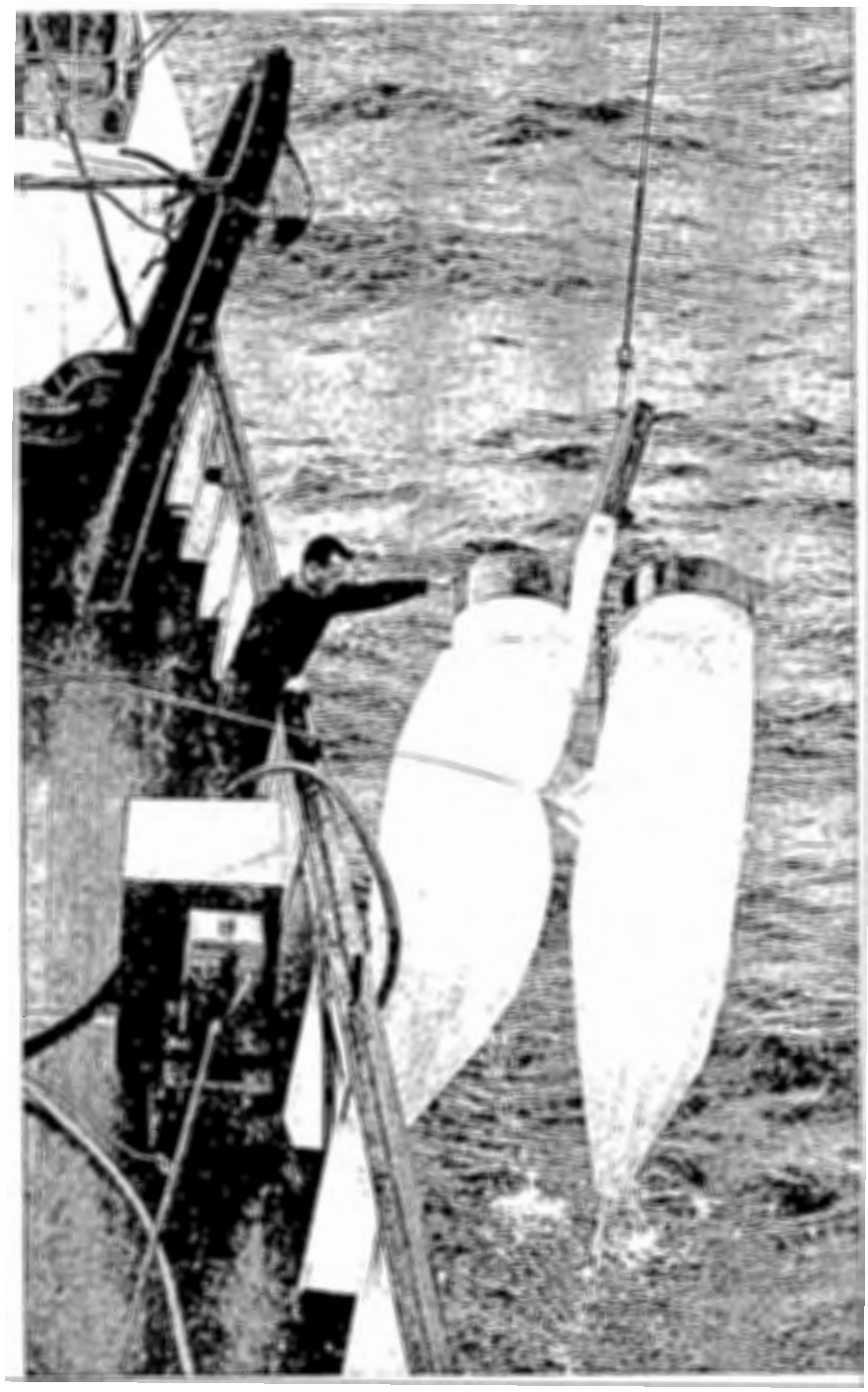
Gustatory and olfactory chemoreceptive pathways in Atlantic salmon parr have been determined electrophysiologically. External receptors in the snout region are sensitive to salts and weak acids and insensitive to neutral amino acids and simple sugars, whereas taste buds are sensitive to all four types. Discharges from neuromasts and taste buds differ in temporal patterns and in susceptibility to blocking agents (Hg^{++}, Pb^{++}) and a potentiating agent (Cu^{++}). Salmon are "visual feeders" but gustatory senses are also employed in food selection. Food pellets treated with dilute solutions of Hg^{++} were rejected while most inert carriers treated with aliphatic acids are ingested. Anosmic fish and those with olfactory organ intact showed similar discrimination.

Frequency of oscillatory potentials, evoked by amino acids, is 2–3 times higher from olfactory mucosa than from the olfactory bulb. Different amino acids vary in stimulatory effectiveness but cross-adaptation studies of mucosal activity indicate that similar receptor sites are probably being used by most amino acids. Preliminary studies indicate a degree of temperature sensitivity in the mucosal receptors.

Ethology

Social and territorial behavior of juvenile Atlantic salmon in rivers could be more important in determining the production of smolts migrating each year from the rivers than was previously suspected.

In a laboratory stream the growth of smaller, and subordinate young salmon was suppressed, despite an excess of food, until the larger, and older dominants died or emigrated.



Bongo net (for plankton sampling) going over the side during joint Canada–USA–USSR survey cruise in west Atlantic

Growth of 3- and 4-year-old smolts migrating from the Northwest Miramichi River was found to be suppressed until the year immediately preceding emigration. The age at which growth accelerated corresponded to the age at which those fish would have reached sufficient size to become socially dominant. The growth of the youngest smolts was not suppressed during their 2 years of river life, probably because they lived separately from, and therefore did not have to compete socially with, the bigger fish.

If suppressed growth in a portion of the population is a behavioral rather than a genetic or environmental effect, rivers where smolts are all of one age are producing less than their maximum number of salmon. The rivers where smolts range over 2 or 3 years of age are producing nearer their maximum.

Physiology

Osmotic and Ionic Regulation

The epidermis covering the exposed, posterior part of salmon scales provides osmotic protection from the external medium. Herring scales lack this protection and when subjected to different osmotic concentrations, their reflected color changes because of changes in alignment and spacing of silvery crystals.

Plasma osmotic concentrations in nonexercised cod are about 345 mosmols/kg in summer and 380 in winter. Corresponding values for trawl-captured cod are 385 and 415. Plasma Cl^-, Na^+, Mg^{++}, and Ca^{++} levels generally increase during exercise; K^+ levels decrease. Tissue levels of Mg^{++}, Ca^{++}, and K^+ generally decrease during exercise while Na^+ increases. Severe exercise and resulting osmotic imbalance may affect survival, particularly at low temperatures.

Photoperiod-Endocrinology

Unequal lighting from left and right sides did not affect the pattern of regenerating scales or the amount and distribution of silvery material on regenerated or unregenerated scales of blinded salmon or unblinded controls.

Salmon subjected in the spring to a constant photoperiod of 13 hr light/day or to natural photoperiod, smoltified and grew rapidly before and after entering sea water. Those subjected to the reciprocal (complement) of natural photoperiod grew rapidly but, unlike smolts, developed high condition factors in fresh water. In sea water they ate less, grew more slowly, and had lower efficiencies of food conversion than those subjected to natural or constant photoperiod. Photoperiod probably acts through the endocrine system to affect smolting and growth patterns. Manipulation of photoperiod and salinity offers promise for controlling timing of smoltification and for accelerating growth.

Total fat content and liver and muscle glycogen levels were significantly higher in salmon smolts subjected to decreasing daylength in the spring than those levels in smolts subjected to normal photoperiod. Blood glucose levels in smolting salmon rise as a result of strenuous exercise and remain high for many hours during recovery in fresh water.

Recovery to pre-exercise levels is much faster in sea water. Naturally produced smolts caught at a counting fence and retained in a holding pound had low muscle and liver glycogen levels and elevated blood glucose and lactate levels, suggesting they were approaching fatigue. Those caught as they entered the pound had glycogen reserves and blood glucose and lactate levels close to those in unexercised smolts. Following transportation in a tank truck, many hatchery smolts died. Those surviving had unusually high or low blood glucose and high lactate levels. Parr from the same shipment had normal glucose and lactate levels. Thus, smolts are delicate fish and should be handled as little as possible.

Cardiovascular-Respiratory Physiology

Two groups of proprioceptors were found on the gills of the sea raven and Atlantic salmon. Receptors associated with gill filaments respond to filament displacement and those located near gill rakers respond to displacement of the rakers. Branchial divisions of cranial nerves IX and X innervating the gills contain both classes of receptor fibers. No O_2 receptors were found.

Sea ravens respond to hypoxia by increasing breathing rate, amplitude, and blood pressure. Bilateral section of cranial nerves IX and X resulted in a fall in dorsal aortic PO_2 but did not abolish hypoxic responses. Perfusing blood of low PO_2 into the dorsal aorta gave hypoxic responses as did perfusion of high PO_2 blood into the dorsal aorta while exposing the gills to hypoxia. Thus, it appears there are both central and peripheral oxygen receptors.

Pollution

The principal task was detection, identification, measurement, and study of biological effects of industrial wastes, chemicals, and economic poisons entering the environment.

Polychlorinated Biphenyls (PCB)

These have recently been recognized as worldwide industrial pollutants which accumulate in animals. PCB's are practically water insoluble but can be solubilized by certain nonionic surfactants. Lethal threshold of a commercial PCB preparation, Aroclor 1254, solubilized by Corexit 7664, was 0.01 mg/liter for the marine crustacean *Gammarus oceanicus*. Observation suggested that molting or freshly molted animals were particularly vulnerable. Preliminary experiments indicated that Aroclors solubilized by Corexit 7664 were acutely toxic to Atlantic salmon (*Salmo salar*) parr at 3–4 mg/liter.

Oil Pollution

Toxicity of several commercial oil dispersants to aquatic animals has been determined. Four-day median lethal for salmon (*Salmo salar*), winter flounder (*Pseudopleuronectes americanus*), and lobster (*Homarus americanus*) ranged from 6 to 10,000 mg/liter.

It has been shown that aquatic animals take up residual fuel oil (Bunker C). Up to several hundred micrograms per gram wet weight was found in fish and shellfish from Chedabucto Bay (the *Arrow* incident) and after exposure to Bunker C oil in the laboratory.

Yellow Phosphorus Pollution Incident

An emergency project carried out with the Pelagic Fish Group revealed an extreme toxicity of yellow phosphorus to herring (*Clupea harengus*) and Atlantic salmon (*Salmo salar*) parr. No incipient lethal level was found for herring, and mortality was observed at a concentration of yellow phosphorus as low as 2.5 micrograms/liter. Incipient lethal level of yellow phosphorus to salmon parr was 18 micrograms/liter. Poisoned fish turn red and show signs of extensive hemolysis. Oxidation of yellow phosphorus, dispersed in water, is a first-order reaction with half-life of 2–7 hr. Adsorption of phosphorus on bottom mud substantially decreases its rate of oxidation.

Mercury Pollution

American eel (*Anguilla rostrata*), chain pickerel (*Esox niger*), white perch (*Roccus americanus*), yellow perch (*Perca flavescens*), brook trout (*Salvelinus fontinalis*), and Atlantic salmon (*Salmo salar*) from New Brunswick contained 0.05–1.56, 0.20–1.18, 0.56–0.80, 0.15–0.79, 0.06–0.10, and 0.07–0.15 ppm of methylmercury, expressed as mercury on wet weight basis, respectively. With only two exceptions, levels of methylmercury in marine fish from the Bay of Fundy and Nova Scotia Banks were below 0.1 ppm.

Some of the freshwater sampling locations could be directly dissociated with an industrial activity in the area, while others were probably polluted by airborne mercury.

Sublethal Effects

Laboratory work revealed that sublethal levels of chlorinated hydrocarbon and organophosphate insecticides have a pervasive effect on fish behavior, affecting such systems as the ability to learn both a simple conditioned reflex and a more complex operative routine in the shuttlebox arrangement, adenosine triphosphatase and cholinesterase activity in brain tissue, and the vulnerability of salmon parr to predation by trout.

An experimental sublethal dosage of DDT given to 4000 tagged, wild, Northwest Miramichi smolts resulted in 50% as many returns of grilse as from a similar number of smolts given identical handling but without DDT. Moreover, a higher percentage of the DDT-treated fish were recaptured as strays in other freshwater streams.

Fishing Gear and Underwater Technology

The ability to predict the engineering performance and behavior of otter trawls was considerably advanced by a theoretical analysis of the force-shape complex of trawl lines,

based on measured variables and using a computerized, iterative technique. An instrument package for measuring variables at the trawl doors (three attitude angles, two tensions, and spread) has been designed, and construction in our laboratory has commenced.

The application of underwater technology to fisheries biology has been explored on a wide front at St. Andrews. "Traditional" scuba-diving techniques were used for observations in such diverse fields as lobster storage and growth experiments, scallop assessment and behavior, artificial reefs for lobster, Irish moss harvesting in relation to lobster ecology, shellfish ecology, and fishing gear performance. Trials with submersibles *Shelf Diver* and *Pisces I* in 1969 and 1970 respectively, proved the value of such vehicles in making quantitative evaluations of herring spawning and scallop beds.

In addition, St. Andrews has made significant advances in underwater photographic survey methods. The towed underwater research plant (TURP), a manoeuverable diving sled for carrying two scuba divers and automatic camera, has been constructed and used successfully. The Edgerton, automatic, underwater camera has been improved by decreasing the firing interval from the original 12 to 6 sec and by remaining operable until the battery charge has dropped to 5 v, with correspondingly increased underwater service per lowering. This camera may now be fired on command of an odometer wheel or other external, underwater control device. The towed underwater automatic camera sled (TUACS) for making photographic observation traverses of the sea floor at speeds up to 5 knots has been constructed and is in service. This carries the automatic camera and electronic flash on a shock-absorbing mount at a nearly constant distance above the sea floor. The drifting underwater collapsible camera sled (DUCCS), a compact, light-weight, low-speed unit, has proven useful for photographic observations of the sea floor in rough weather. The self-trimming camera vehicle for midwater observations requires further development for improved stability. A closed-circuit hydraulic flume for observing animals under conditions of controlled flow and for testing underwater instruments has been designed.

Fisheries Oceanography

Circulation

Studies of circulation patterns on the continental shelf from Gulf of Maine to Labrador were continued to evaluate long-term variations and their relations to fisheries. Approximately 23,000 drift bottles and seabed drifters were released and over 5000 were recovered. Percentage rates of recovery were 17.41 for bottles and 23.53 for drifters.

An unusually strong southwesterly drift of surface water, averaging 7–9 miles/day, characterized circulation over the Scotian Shelf and in Gulf of Maine in the winter of 1969.

Water Properties and Environmental Relations

The trend to warmer water temperatures on the Atlantic coast, first noted in the summer of 1968, continued through 1969 and 1970. The mean annual temperature at St. Andrews (7.6 C) was the highest since 1955. The temperature of the warm, deep layer of Cabot Strait increased from approximately 4.3 C in 1966 to 5.4 C in 1969.

Studies of run-off conditions, flushing times and physical characteristics of the waters in Miramichi estuary were made in relation to effects of environment on salmon movements. Total flushing time from fresh water to the lower part of the estuary was 10.5–11.0 days in July 1969.

Texture measurements on cooked scallops indicate superior quality when frozen prerigor

Aseptic collection of bottom samples in survey of incidence of Clostridium botulinum Type E on Canadian fishing grounds

HALIFAX LABORATORY
HALIFAX, NOVA SCOTIA

The program, with overall supervision exercised from the Halifax Laboratory, includes the research needs of the FRB Atlantic Technological Program and investigations at the cellular and molecular levels. The work was carried out at three locations; Halifax, Grande-Rivière (to the end of 1969), and St. John's, Newfoundland. For convenience the main areas of research in 1969–70 have been considered under the following headings:

- Manipulation of the resource: detection and prevention of diseases of fish and shellfish, endocrinology of fish and shellfish, biochemistry of reproductive processes, and the biochemistry of shellfish digestive processes as a preliminary to nutritional studies

- Exploration studies: comparative biochemistry of fish and shellfish, biochemical genetic bases for population identification, biochemistry of marine species with emphasis on underexploited species, food web transfers with special interest on the lipids, and metabolite identification

- Deterioration and prevention: improving the quality of fresh and frozen fish and shellfish through studies on new methods of preservation, vacuum unloading devices for trawlers, nonbacterial spoilage, new indices for quality assessment, effect of freezing rate on quality, reasons for discoloration in flounder and plaice, freezing of scallops (prerigor), and the implication of biochemical findings in live and dead fish and shellfish in terms of the quality of the final product

- Environmental studies: (1) the massive fish mortalities resulting from the emission of elemental phosphorus (Pel) from the phosphorus plant in Long Harbour, Newfoundland diverted 25% of the program's 1969 resources. Most of the effort was concentrated into a period of a few months. Work included: development of a new and rapid quantitative method for Pel detection, studies on the toxic effects of Pel on numerous species, demonstration of the rate of uptake by marine species and subsequent stability of Pel in the tissues, illustration of Pel concentration in tissues rich in lipids, analyses of bottom muds, water, and biological specimens from Long Harbour; (2) oil pollution at Chedabucto Bay gave rise to development of a rapid method for distinguishing between various Bunker C oils and a study of the role of microorganisms in oil pollution

- Process and products: Food and Drug Directorate approval for commercial manufacture of gadoid Fish Protein Concentrate (FPC) announced October 14, 1970, was based upon data acquired with material made by the Halifax Process at the Halifax Laboratory. Further work resulted in: a modified FPC, FPC from various other species, data on enzymes of potential commercial value, studies on an underwater adhesive (Mussel Byssal Threads), crustacea waste utilization criteria, freeze-drying data, and an assessment of sterols found in marine forms

Disease Studies

Malpeque disease of oysters

Electron microscopic examinations of oyster tissue from the disease susceptible strain, which had been exposed to the disease infected area for a period of 1–2 years, were done. No viral particles were observed in the specimens prepared from the oyster tissue by organic solvent (Fluro-Carbon) fractionation and ultracentrifugation. A longer term in vivo infection program of this disease is in progress to resolve the question of the cause of Malpeque disease.

Infectious pancreatic necrosis

At the request of the Resource Development Branch of the Fisheries Service, several batches of salmonid fry and fingerlings were examined for the presence of the infectious pancreatic necrosis virus. The susceptibility of Atlantic salmon to this virus was amply confirmed. Specimens from the Freshwater Institute at Winnipeg and from a National Parks hatchery in Alberta have been similarly examined.

In experiments designed to investigate virus transmission via the egg it was found that virus multiplication occurred in excised (yolkless) embryos when incubated in a nutrient medium. No muliplication took place in parallel experiments using intact animals although they had indeed been infected. Reasons for this disparity are under investigation.

Gaffkemia in lobsters

Investigations on the mode of action of the causative agent of this economically important disease were continued. Gaffkemia was shown to be a wasting type of disease in which death occurred through depletion by the pathogen of body reserves such as heart and hepatopancreas glycogen and adenosine triphosphatase (ATP) as well as blood nonprotein nitrogen, lactic acid, and glucose.

The inability of the natural defence mechanisms of the lobster to eliminate the pathogen was hypothesized to be due to the nature of the bacterial surface (protective capsule). Studies using bacterial strains of varying virulence have shown, however, no direct relation of degree of virulence to capsule size.

The possible stimulation and/or enhancement of the naturally occurring bactericidal activity of lobster blood against the pathogen *Gaffkya homari* was studied also. A rapidly induced (several days) but short lived, dose dependent increase in bactericidal activity was demonstrated in lobster blood after vaccination with a nonpathogenic pseudomonad. The vaccine, however, conferred no protection for the lobster against *G. homari*.

Experiments aimed at the elucidation of the nature and specificity of naturally occurring lobster hemagglutinins were carried out. The hemagglutinin withstood freezing, was nondialysable, heat labile and required Ca++ to withstand even modest temperatures. Activity was stable only over a *p*H ranging from 7.5 to 8.0. Partial purification has been carried out by ammonium sulfate fractionation and separation on Sephadex G75 columns. A comparison of activity titers indicates that the hemagglutinin principle is separate from the bactericidal principle in lobster blood.

Reported heavy mortalities of lobsters associated with gaffkemia in commercial live holding facilities during the summer months was investigated and recommendations made. The data obtained from these studies has aided the understanding of the nature and extent of these epizootics and thus permitted the recommendation of improved control measures.

Red crab

Information on temperature and disease resistance of this potentially economically important species was required. Mortality rates at water temperatures between 12 and 18 C were determined. The species appears to be more tolerant of high temperatures than the Queen crab. Results indicated that a temperature of 14 C was useful for short term (1 week) storage but for longer storage periods a temperature of 12 C or lower should be used. Crab serum, in vitro supported much less growth than did lobster serum, in vitro.

Lobster storage and shipment

The use of a plastic webbing material to reduce mortality of lobsters during air shipment was evaluated with cooperation from the Freshwater Institute in Winnipeg. The interim outlook for the commercial use of this material is good, based upon survival rates and prevention of transmission of gaffkemia.

Antiviral agent(s) from shellfish

Since the ocean and its inhabitants might become important sources of new and better antimicrobials the antiviral activity of the extracts from various shellfish have been studied in an amphibian virus (LT-1) and fish cells system. All oyster, mussel, and soft-shell clam tested to date possessed the activity to inhibit the amphibian virus. Both virucidal and virustatic activities appeared to be present in the shellfish tissue. Work is in progress to study the mode of function and to purify the active component(s) in the extract.

Endocrinology and Physiology of Fish

The major androgens in testicular and peripheral plasma of Atlantic salmon (*Salmo salar*) were quantified during the late stages of sexual development. 11-Ketotestosterone was the principal steroid in both peripheral and testicular plasma; the concentration increased substantially as maturation advanced. Testosterone levels in peripheral plasma

remained comparatively low and relatively stable but in testicular plasma there was a trend towards increased levels with advancing maturation. The quantities of 11-ketotestosterone were isolated and tentatively identified in plasma. This is the first time this steroid was isolated from blood of a fish. 11β-Hydroxylation in testes to date has been demonstrated only in salmon and mammalian tumors. The results confirm previous in vitro studies which suggested that in the testes 11-hydroxytestosterone is a precursor of 11-ketotestosterone.

Early investigations failed to demonstrate conclusively that the hormone aldosterone occurred in fish. This steroid, which occurs in man at only about 7 nanograms/100 ml of plasma, is a potent mineral regulating hormone and was expected to play a prominent role in anadromous species of fish in the regulation of their mineral balance with respect to change in the mineral content of their environment. Recently aldosterone was isolated from the plasma of Atlantic herring (*Clupea harengus harengus* L.) and assays in four species of teleosts demonstrated that its concentration is frequently even lower than those reported for man. This explains the difficulty of its detection in earlier studies where sufficiently sensitive methods for detection and identification were not available.

Application of histological and histochemical methods has shown that the yellow bodies distributed throughout the kidney of the Atlantic sturgeon (*Acipenser oxyrhynchus*) are interrenal tissue. When these yellow bodies were incubated with pregnenolone plus progesterone in vitro, cortisol, cortisone, corticosterone, 11-deoxycortisol, 17α-hydroxyprogesterone, and progesterone were isolated as transformation products. Incubation of the yellow bodies with cholesterol gave cortisol and other steroids. Testosterone, cortisol, cortisone, and corticosterone were found in plasma samples taken from male Atlantic sturgeon. Conjugated testosterone was not detected in sturgeon plasma, in contrast to findings with salmonids and elasmobranchs. This is the first report of the occurrence of steroids in the plasma of a chondrostean. In a recent study it was established, contrary to the findings of others, that while the hagfish (*Myxine glutinosa*) produced typical corticosteroids, the quantities were very small. Cortisol, cortisone, and corticosterone have now been identified in hagfish plasma; the levels were only 0.07, 0.03, and 0.02 microgram/100 ml, respectively. By injecting ACTH the levels of cortisol and cortisone were increased to 0.12 and 0.98 microgram/100 ml, respectively. It is now possible to conclude that corticosteroids occur throughout the vertebrates.

The gluconeogenic action of certain corticosteroids and the negative nitrogen balance induced by this class of steroid hormones indicate the involvement of these agents at some biochemical site concerned with the conversion of protein to carbohydrate. The effect of these glucocorticosteroids in enhancing glutamic pyruvic transaminase activity in the livers of the higher animals is known; however, the mechanism whereby glucocorticosteroids control transaminase activity is generally thought not to exist below the reptiles. Contrary to this belief, the glutamic pyruvic transaminase activity of rainbow trout (*Salmo gairdneri*) livers was increased significantly by injections of cortisol.

1α-Hydroxycorticosterone was first identified in this laboratory in a species of skate. No species of elasmobranch (sharks, skates, rays) has yet been found in which 1α-hydroxycorticosterone is not a principal corticosteroid (18 species). 1α-Hydroxylated steroids have not yet been found in other species of fish but the recent isolation, by others, of 1α-hydroxylated steroids from urine of hypertensive human infants suggests a wider significance. In addition to the salt retaining activity of 1α-hydroxycorticosterone, this steroid has now been shown to be active in two bioassays that measure glucocorticoids.

The liver of skate (*Raja radiata*) is capable of rapidly metabolizing the sex hormone testosterone. Incubations of testosterone with liver tissue yielded a number of metabolites most of which were more polar than testosterone. No evidence was obtained for the conversion of testosterone to testosterone glucuronide (a steroid conjugate in skate plasma).

In order to obtain evidence for the origin of plasma testosterone and testosterone glucuronide in skate, blood samples from the testes and the caudal artery were analyzed. The results obtained indicated that both of these compounds are synthesized by the testes.

It is known that the binding affinity or strength (association constant) of a protein to a steroid hormone is one of the principal factors that determines its metabolism and thereby its biological activity. The association constants of the plasma proteins for the principal steroid hormones in several species of fish have been determined and will be of value in understanding the metabolism of these hormones. In general, the binding affinities of the steroid hormones in fish were found to be low when compared to those found in man. In the fish investigated, protein binding of corticosteroids, similar to the transcortin (a protein) binding of corticosteroids in man, does not exist. This is significant, for transcortin binding methods, as used for mammals, give erroneous results when applied to fish. All the fish studied had a sex hormone binding protein of high binding affinity.

Lobster Molt Hormones

Sensitive methods for the detection of ecdysterone, the hormone controlling molting in insects, are being developed for use in studies on lobster molting. A method has been established for the chemical estimation of ecdysterone in amounts from approximately 10 micrograms to 50 nanograms. The ecdysteroid is converted by dilute sulfuric acid to a derivative which fluoresces in ultraviolet light. Ecdysteroids other than ecdysterone produce similar fluorescence and thus would be measurable by the same method. The technique is approximately as sensitive as insect bioassay, gives more quantitative results, but lacks the specificity of the insect bioassays for molt hormones.

The general methods for the formation of radioactive derivatives (acetates and acetonides) of ecdysterone and inokosterone for use on submicrogram quantities of these materials has been established reasonably well. Appropriate thin-layer and paper chromatographic methods of purifying the original compounds and their derivatives have also been developed. It is intended that these would be applied to a double isotope derivative method for identifying submicrogram amounts of ecdysteroids.

Small groups of animals have been treated with selected doses of ecdysterone and inokosterone from commercial sources to determine the effect of these compounds on the lobster molting process. Both compounds induce an accelerated development of the premolt characteristics of the animal. Inokosterone appeared to be one-half as effective on a weight basis which suggests that only one of the two stereoisomers present in the commercial material is active. Both compounds have led to the death of the treated animals, normally at molt or very late premolt, in the doses which induced the development of premolt characteristics. Trials on larger groups of animals are in progress to establish a dose response curve.

Reproductive Physiology

Biochemistry of reproductive process

Carbon dioxide fixation by cod (*Gadus morhua*) testes was examined by incubating testicular tissue in the presence of $^{14}CO_2$. The results suggested a carbon dioxide fixation with pyruvate by the testicular tissue. A study of the enzyme activity of the testicular tissue elucidated the presence of malic enzyme, phosphoenolpyruvate carboxykinase and propionyl CoA carboxylase. The carboxykinase may play an important part in regulating biosynthesis in the testes of fish.

Malic enzyme activity, as determined by the exchange incorporation of $H^{14}CO_3^-$ into malate, was found in the mitochondria and in the cytosol of cod testes. The results demonstrated the presence of two malic enzymes, requiring nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP) respectively, in the mitochondria and also in the cytosol. It is possible that the presence of two malic enzymes, requiring NAD and NADP respectively, in one compartment may play an important role in replenishing C-4 dicarboxylic acids, through carboxylation of pyruvate to malate, and in the generation of NADP. We have succeeded in isolating the NADP-enzyme, but found that, depending on the method of separation, the addition of NAD had either an inhibitory effect or no effect on the activity of the NADP-enzyme. It was concluded that the mitochondria of cod testes have a factor which combats the inhibitory effect of NAD on the activity of the NADP-malic enzyme.

Previous work on the metabolism of pyruvate in the gonads of cod prompted the study of the activities of two aminotransferases, i.e., aspartate and alanine aminotransferases, because of their possible regulatory role in gonadal metabolism. The activity of these enzymes was examined in four fractions, i.e., mitochondria, cytosol, microsomes, and nuclear fraction. In any one fraction, of the testes or the ovaries, the specific activity of aspartate aminotransferase was higher than that of alanine aminotransferase. In the testicular tissue the specific activity of aspartate or alanine aminotransferase was highest in the mitochondria, followed by the cytosol, the microsomes then the nuclear fraction. In the ovaries, the specific activity of alanine aminotransferase, followed the same pattern, whereas that of aspartate aminotransferase was highest in the mitochondria followed by the nuclear fraction, the cytosol and then the microsomes.

Biochemistry of Digestion

Digestive enzymes of lobsters and scallops

As one part of the work on the physiology and nutrition of shellfish, the digestive enzymes present in lobster gastric fluid were studied. Lipase, nucleases, a phosphatase, a carbohydrase, and a variety of proteinases were found. The presence of proteinases of very low molecular weight (one-half that of the mammalian enzymes) was particularly striking. Among the proteinases there were acidic and alkaline enzymes, a carboxypeptidase, and a trypsinlike enzyme. The carbohydrase, chitobiase, and a phosphatase were surprisingly high in specific activity.

In the extract of digestive glands of scallops, the activity of at least three (on the basis of *p*H optima and molecular weight) proteolytic enzymes, carboxypeptidase A and B, ribonuclease, deoxynuclease, alpha-amylase, and lipase were demonstrated. The proteinases, active around *p*H 3.0, predominate over the trypsinlike enzymes. The high activity of these enzymes, tested on different substrates, suggests that the digestion of protein occurs mainly in the digestive diverticula of the scallop. No seasonal variations (April–October) in the level of the enzyme activity were observed.

Digestion of polyunsaturated marine fatty acids

The digestion of esters of these polyunsaturated marine fatty acids by the pancreatic lipase of mammals is slower than the rate for animal or vegetable fatty acid esters. The position of the double bond nearest to the carboxyl group of the fatty acid was shown to be responsible for this effect. Hydrogenation abolishes this hindrance, but even in raw marine oils the effect will have no influence on the digestibility.

Effects of marine oil diets

Groups of weanling rats were fed diets containing raw herring oil, hydrogenated herring oil, or a control diet containing corn oil. All rats were started on the control diet, then two groups were abruptly switched to raw herring oil or hydrogenated herring oil diets, while two other groups were gradually changed over to a marine oil diet, and a fifth group was kept on the control diet. After 30 days, the rats were sacrificed and their hearts were examined histologically for signs of heart lesions. While other fat diets have been reported to produce heart lesions, none were found in any of the control rats nor in any of the rats on marine oil diets.

Snow crab

The tolerance level of the snow crab to low salinities was determined. Below a salinity of 22.5% death occurred within 24 hr. At higher salinities the crabs survived when kept in a temperature range of from 2 to 10 C. These values indicate the minimum conditions required for live transport of the crabs in refrigerated sea water or for live holding in tanks prior to processing.

Exploration Studies

Biochemical Studies of Atlantic Herring Populations

The escalation of the Atlantic herring fishery has caused concern over the ability of the herring stocks to sustain this fishery. Biochemical studies of the herring were carried out as part of the overall Atlantic herring program to aid in the assessment of herring stocks and assist in determining the migration paths of this species. Starch gel electrophoresis and histochemical staining were the basic tools for the isoenzyme studies.

Several herring enzymes display polymorphism, among them lactate dehydrogenase (LDH), a tetramer with mutant A and B subunit forms; malate dehydrogenase (MDH), recently shown to be a dimer; aspartate aminotransferase (AAT), a dimer; phosphohexose isomerase (PHI), a dimer; phosphoglucomutase (PGM) and esterase. The frequencies of occurrence of mutations in 38 population samples of Atlantic herring has been determined for four of these enzymes: LDH, MDH, AAT, and esterase, Where possible the allele frequencies of the mutant forms has been reported and in the case of the esterase system the frequency of occurrence of each esterase band has been noted. The degree of correlation between the sampled populations have been determined and the initial results suggest a movement of spring herring from the Bay of Fundy south shore to Yarmouth and along the southern Nova Scotia coast in the summer and fall. There are also indications of herring migrating out of the Gulf of St. Lawrence in the late fall to wintering areas off the southern coast of Newfoundland. The degree of correlation between samples of Georges Bank herring and Nova Scotia inshore herring populations was low, suggesting separate populations.

Isoelectric focusing

This method could supplement conventional methods of electrophoresis used to identify fish or shellfish. The technique of isoelectric focusing was applied to fish and shellfish isoenzyme systems. The isoelectric points of the lactate dehydrogenases of several fish species, cod, herring, haddock, etc. were determined by isoelectric focusing in a polyacrylamide supporting medium. Mutant subunits were shown to possess different isoelectric points, indicating a change of a charged amino acid in the polypeptide chain. The procedure was modified to permit demonstration of malate dehydrogenase and aspartate aminotransferase activity after isoelectric focusing. The isoelectric focusing gel may be stained with amido black for total protein and the resolution of proteins in the tissue extract is far greater than that in starch or acrylamide electrophoresis.

Comparative histology of mollusc adductor muscles

The histology of the adductor muscles of several species of molluscs have been compared and in particular the ultrastructure of adductor muscles of the file yoldia (*Yoldia limatula*), the scallop (*Placopecten magellanicus*), the oyster (*Crassostrea virginica*), the ocean quahaug (*Arctica islandica*), and the astarte (*Astarte undata*) have been examined.

The muscles of these molluscs reveal differences related to the function of the muscle for the particular species (sessile, burrowing, swimming, etc.). A transverse 50 Å periodicity was found in all the thick filaments of the adductor muscles while a surface diagonal or helical periodicity was observed in some preparations and is probably associated with the 'catch' mechanism of these muscles. Paracrystals or paramyosin and tissue homogenates of adductor muscles gave rise to the same transverse periodicity but no diagonal striations were observed, further suggesting this was a surface feature.

Biochemistry of Marine Species

Muscle cathepsins

The catheptic activity of fresh muscle from 10 species of Atlantic fish was determined on hemoglobin substrates and on the endogenous protein substrates (autolytic activity). The enzymes of all species show similar *p*H optima and similar response to the varied test conditions, temperature, and substrate composition. Sturgeon, herring, cod, and smelt belong to the group of high catheptic activity and plaice and haddock have a very low muscle proteolytic enzyme activity.

The hemoglobin-splitting activity of the enzymes in lobster claw muscle is 15–25 times higher than in tail muscle of the same individual. Preliminary observations on the catheptic enzymes in the lobster claw muscle before, during, and after the molt, show essential differences in the level of the activity and warrant further study.

Carbohydrate chemistry

The investigation of the neutral sugars in dolphin milk, has shown that in addition to the expected lactose, two inositols occur, both in the free state. As it is known that young mammals have very high inositol levels relative to the adult, it is important to have found what may be a method of providing this in a direct form. As far as can be ascertained, free inositols are not found in the milk of land mammals.

Scallop metabolite

Trigonelline, the N-methyl betaine of nicotinic acid, has been found associated with its isomer homarine (N-methyl picolinic acid) in scallop muscle, and isolated by column chromatography. Homarine is widely distributed among invertebrate species, but the occurrence of trigonelline in a bivalve mollusc has not heretofore been reported.

New assay for pancreatic lipase

In the course of a study on marine enzymes an assay for digestive lipases was developed which is highly specific and more sensitive except for radioactive techniques than the existing methods. It is anticipated that the assay will find use in the clinical diagnosis of pancreatitis.

Lipid metabolism in lobster

The lobster, *Homarus americanus*, can synthesize triglycerides by pathways established for vertebrates.

Lipoxidase analysis of marine oils

Marine oils contain polyunsaturated fatty acids conforming to ω3 and ω6 methylene-interrupted patterns. Adherence to these structural details may confer a degree of essential fatty acid activity. Although these fatty acids may be determined individually by gas–liquid chromotography, it was thought that the ω3 and ω6 structure and potential biological activity could be determined for the whole oil by an enzymatic assay with soybean lipoxidase. In a collaborative study with the Food and Drug Directorate polyunsaturated fatty acids in eight samples of raw oils from freshwater and marine fish, and two from marine mammals, were compared by the two methods. The results agreed well and confirmed that lipoxidase forms only one peroxide group per fatty acid molecule despite the presence of fatty acids with up to six double bonds in marine oils.

Lipids in commercially important species

Queen crab muscle was found to be low in lipid, less than 1% but rich in phospholipids. The viscera, on the other hand, contained over 10% lipid. Fatty acid compositions for muscle and viscera reflected differences between phospholipid or triglyceride origins. Shell contained only small amounts of lipid of which a proportion was modified in meal production. The shell and unused tissues from the commercial production of crab meat pose a waste disposal problem that is becoming more acute as landings of this species increase. By-product dry meals marketable for animal feeding have been prepared under two conditions. Although these samples had about the same corrected protein levels (25%), one had a high (approx 10%) and one had a low (approx 2%) fat level. The five principal lipid fractions of cod muscle, two neutral lipids, and three phospholipids, have been isolated from male and female fish and studied for fatty acid composition. Several important fatty acids varied markedly by type of lipid but showed only small differences with sex. This finding supports the view that cod flesh lipids are essentially cellular in function and suggests that sex of a fish need not influence the role of lipids in the various deteriorative processes undergone by cod flesh in fresh or frozen storage.

Unusual fatty acids in marine lipids

In midwinter, smelt from Jeddore Harbour, near Halifax, contain up to 10% fatty acids of odd-numbered chain lengths, an exceptional value for any species of Canadian fish so far investigated. In smelt collected at the same time of year from Digby, Pictou, and the Miramichi estuary, and from the adjacent waters of Musquodoboit Harbour and Porter's Lake, odd-numbered fatty acids amounted to only the normal 2–3% of the total. The excess acids follow the same metabolic pathways as the normal amounts of these acids. An electrophoretic comparison of numbers of smelt from Jeddore Harbour, the Miramichi estuary, and Heney Lake in Gatineau County, Quebec, revealed a unique

absence of mutant forms of several common isoenzyme systems. For this reason, and from preliminary assessment of stomach contents, the seasonal occurrence of odd-numbered fatty acids in Jeddore Harbour smelt is believed to reflect unknown dietary factors peculiar to the one area. An unusual fatty acid, *trans*-6-hexadecenoic, was first identified in animals in the fat of the Atlantic leatherback and other marine turtles. Subsequently, it was detected also in the fats of the ocean sunfish. These specific sources pointed to a dietary origin, probably from jellyfish. Most coelenterates are very low in fat, but in a metridian selected for investigation on the basis of a high fat content not only was the anticipated fatty acid found, but also the corresponding fatty alcohol, *trans*-6-hexadecanol.

Isoprenoid fatty acids

It has been shown that the methyl-branched hydrocarbon pristane, a common constituent of the marine environment and marine lipids in general, is virtually absent from freshwater fish oils. Four out of the possible eight diastereomeric forms of the related pristanic acid have been detected in marine oils. The two not previously known were in lesser proportion than those derived directly from phytol and show that slow biological oxidation of pristane takes place. In collaboration with Bristol University the complete stereochemistry and gas–liquid chromatographic behavior of several of the shorter-chain derived isoprenoid acids has been worked out. A comparison of isoprenoid fatty acids in periwinkles, oysters, and quahaugs showed that the former degrade their heavy intake of phytol to 4,8,12-trimethyltrideconoic acid. This accumulates in 100-fold excess over the usual primary product, phytanic acid. In filter feeders the proportions of 4,8,12-trimethyltridecanoic, pristanic, and phytanic acids paralleled the more equitable distribution found in marine vertebrate lipids. There was little distinction in any of the mollusc species between proportions of these acids in triglycerides and phospholipids and the distribution suggests that they participate in the normal fatty acid pool of saturated acids in association with acids of similar effective chain length, for example 4,8,12-trimethyltridecanoic with myristic.

Halosphaera taxonomy

Halosphaera viridis is an interesting phytoplankter which has at times a very large (pinhead size) pelagic cyst stage. A natural bloom in Newfoundland waters permitted a study of the fatty acid compositon which supported the recent morphological classification of *H. viridis* with the Prasinophyceae instead of the Chlorophyceae. Comparisons of the fatty acids from this natural bloom with fatty acids from cultured *Dunaliella tertiolecta* (Chlorophyceae) and *Tetraselmis sp.* (Prasinophyceae) suggested that cultured unicellular algae retain the important fatty acid characteristics of natural blooms and may be used as a reliable guide to their contributions to the food chain.

Crustacean fatty acids in the food web

Examination of two species of the larger euphausiid zooplanktonic Crustacea from Nova Scotian waters showed total lipid to be in the 1–3% range. The lipids were prepon-

derantly phospholipids with some triglyceride and low levels of unsaponifiable material. The fatty acids showed typical marine lipid patterns but were differentiated in detail for the two species by relationships conforming to recorded herbivorous and carnivorous diets. Examination of the total fatty acids of a copepod, *Temora longicornis*, collected in Newfoundland waters showed a high proportion of myristic acid to palmitic acid. This has been observed by others in the Calanidae and therefore may be a means of differentiating the lipids of copepods from those of the larger euphausiids. All of the fatty acids found in the lipids of important commercial species which might prey upon these copepods, with the exception of the C_{20} and C_{22} acids with one double bond, were present. The fatty acids from Newfoundland spring sea water associated with the copepods showed details corresponding to an ostensible plant origin. Unexpectedly high proportions of the oxidation-resistant insoluble fatty acids such as stearic and arachidic were found in the water.

Herring oils

Studies started in 1965 revealed two annual patterns in the iodine values of Atlantic herring oils produced commercially in Nova Scotia and Newfoundland waters. A reproducible systematic decline in iodine value of 20 units through July and August in the southwestern Nova Scotia fishery, and of 10 units from December to the end of March in the southwestern Newfoundland fishery, are believed to have a common origin in basic biochemical changes in fatty acids taking place in the fish. These short-term patterns were superimposed on year to year iodine value variations of ±5 units. The majority of iodine values for these oils were in the 135–105 range. The free fatty acids in freshly produced commercial herring oils were shown by the long-term study to seldom exceed 0.2–0.3% when fresh fish were reduced. A separate study showed that rapid phospholipid hydrolysis before reduction was the principle source of these fatty acids, but that any very extensive lipid hydrolysis involved triglycerides as well. Some evidence for slow post-reduction chemical processes was also obtained.

Deterioration and Prevention

Quality of Fresh and Frozen Fish

Fresh fish preservation

Studies on the spray application of ethylene diamine tetraacetic acid (EDTA) to haddock fillets under essentially commercial conditions have shown that the treatment will lengthen the refrigerated storage life. The average extension was about 3 days with the sodium EDTA treatment at about 300 ppm. The calcium salt was less effective. The treatment was not consistently effective. When combined with vacuum packaging the sodium EDTA gave about doubled shelf life (16 days at melting ice temperatures) for the EDTA inhibits certain spoilage organisms which are not inhibited by the absence of oxygen. The combination thus is effective in delaying spoilage as measured by taste panels.

The preservation of haddock fillets by radio pasteurization with gamma rays has been given further attention from the microbial spoilage aspect. The pseudomonads were the normally predominating organisms during spoilage of the aerobically stored unirradiated fish while the achromobacters were the numerically predominant organisms in the samples given 100 krad doses and stored at 3 C. However, at spoilage the proportions of the different genera of achromobacters changed markedly. Also, some pseudomonads were present at the time of spoilage of the irradiated fillets in significant numbers. The level of these was below that which normally would be detected due to the high total level of organisms.

Mechanical trawler unloading

Previous evaluation of a vacuum unloading system for trawlers showed that 86% of the fish were damaged in the process. Additional studies showed that adjustment of the equipment and training of the hold workers allowed a decrease in the number of damaged fish to an essentially negligible level of 4%.

Nonbacterial spoilage

Experiments made with homogenized muscle during the previous years have indicated that a more complete understanding of the nature of the changes that occur in frozen fish, as they deteriorate slowly during storage, requires a better knowledge of the interaction between the lipid and the nonlipid components of the muscle. With this as a background, some of the changes taking place simultaneously in whole frozen fillets from 14 species of commercial fish and in the muscle of lobster, shrimp, and scallops were studied.

The gadoids (fish of the cod family) differed from the other species studied in that they produced dimethylamine (DMA) in the frozen muscle. The amount of DMA produced differed widely with the different species. It was also found that there was always a direct relation between the amount of DMA produced and the reduction of extractable protein in the muscle. Further evidence was uncovered to indicate that the enzymic reaction resulting in the production of DMA from trimethylamine oxide in the muscle also catalyzed the oxidation of free fatty acids in the muscle. The products of the oxidation of the fatty acids probably combined with the protein to form a very insoluble polymer. This would be a principal cause of the tough texture that develops in long stored or improperly stored frozen fish muscle.

It was also found that the center of the activity for the production of DMA is in the thin lateral band of red muscle that extends along the exterior surface of the fillet. When this red muscle was removed from the fillet prior to freezing, the production of DMA was inhibited almost completely; the decrease in extractable protein was correspondingly retarded and the free fatty acids accumulated in amounts beyond those found in the fillets in which the red muscle had not been removed.

These results apply to cod, haddock, pollock, cusk, hake, and other members of the gadoid fish. Other patterns of spoilage take place in the nongadoid species and in the shellfish and crustaceans. In addition to extending knowledge regarding the changes taking place in stored frozen fish, these findings have potential practical value. They indicate to the producer the very great differences in the keeping qualities of our commercial species, but, more important, they suggest ways of controlling frozen storage deterioration.

Thaw drip reduction in American plaice fillets

Polyphosphate dips were effective in reducing drip in fresh iced fillets of American plaice and this effect was retained during frozen storage, the thaw drip being reduced to 9–12% from about 16% in the controls after 6–9 months at –18 C. A similar reduction was obtained even with summer caught American plaice (with normally high drip levels), perhaps sufficient to allow its commercial processing.

Biochemical changes in prerigor cod muscle at 0–4 C

Glycolytic activity, and adenosine-triphosphate (ATP) dephosphorylation, in prerigor cod muscle, increased with decreasing temperatures between –1 and –2.5 C, going through a maximum rate between –2.5 and –3.4 C, and then declining towards –4 C. Deamination of the adenine nucleotides was also most rapid near –3 C. Enzymic reactions in unfrozen prerigor muscle at 0 C are considerably slower than in frozen muscle (held between –1 and –4 C) but the rate is considerably increased by grinding immediately postmortem. Thus, at the temperatures at which superchilled fish are held, these enzymic reactions will be accelerated and could significantly affect some quality parameters, for instance, in superchilling fish on board vessels.

Quality of iced, frozen, and thawed scallops

Results continue to show that prerigor scallop meats, either iced, frozen, or thawed yield a superior quality cooked product. In iced meats, texture as assessed by taste panel or instrumental means, shows a marked firming as the meat enters rigor followed by a postrigor relaxation. In meats frozen after various periods in ice and cooked either without prior thawing or after thawing overnight at 2–3 C, the meats frozen prerigor remained comparable to the unfrozen ones, but those frozen "inrigor" or "postrigor" were objectionably firm and also tasteless. There was a tendency to poorer texture in the thawed meats and to earlier manifestation of rigor mortis (confirmed by the nucleotide changes). Several objective texture parameters measured on the cooked scallop meats (Instron Tester) were most useful in following the patterns of texture change. Attempts to improve the quality of the postrigor frozen scallops by agents such as polyphosphate have so far been unsuccessful. Storage tests indicated that the desirable texture and taste of the prerigor frozen product was retained for at least 1½ years at –40 C.

In this species, the texture changes and postmortem biochemical degradation of nucleotides and glycogen both indicate that the rigor process is slow, giving adequate time for prerigor freezing of scallop on board or as landed up to 4–5 days on ice.

Octopine in scallop muscle

Octopine, a condensation product of arginine and pyruvate, appears to be a principal end-product of glycolysis in scallop adductor muscle, thus demonstrating in this species a major deviation from the classic glycolytic pathway whereby pyruvate is reduced to lactate, as in fish and mammalian muscle. Little or no octopine is detectable in fresh muscle dissected from live scallops, but on subsequent iced storage, octopine accumulates steadily, concomitant with nucleotide catabolism and a reciprocal decrease in arginine, to ultimate levels of about 1% in 6–10 days. High activity of octopine dehydrogenase, an NAD^+ enzyme, in scallop muscle, coupled with negligible lactic dehydrogenase activity, substantiates these findings. Maximum levels of octopine may be reached considerably in advance of organoleptic rejection; hence, octopine content seems limited as an index of quality to confirmation of freshness.

In scallops iced from 0 to 20^+ days, the content of octopine, and of other glycolytic and nucleotide metabolites, was not changed during rapid freezing (plate freezer). On the other hand, thawing, particularly of prerigor quick-frozen scallops, under conditions similar to those in commercial practice, resulted in marked nucleotide and glycolytic breakdown, complete hydrolysis of arginine phosphate, degradation of ATP to adenosine monophosphate (AMP), sharp increase in hypoxanthine content and formation of octopine (20–40% of the ultimate levels reached). Organoleptic changes leading to loss of the tender-soft prerigor texture and of initial sweet flavor paralleled the biochemical changes.

Adenosine deaminase in scallop muscle

The adductor muscle of scallop, especially the smaller "catch" part, was found to contain adenosine deaminase, an enzyme that produces inosine during postmortem degradation of nucleotides in the iced muscle. It differs from muscle of higher animals, such as fish, in which an analogous enzyme produced, instead, inosine monophosphate (IMP), a flavor enhancer. The enzyme is readily extracted with water, has been partially purified, and had some of its kinetic properties determined. It will not by itself deaminate adenylic acid to IMP (the process in fish muscle); there is, however, some evidence that adenosine triphosphate can stimulate this reaction and also suppress the normal deamination of adenosine. This may explain the atypical appearance of IMP occasionally found in some scallop meats.

Nucleotide degradation in iced fillets

The pattern of postmortem decay of adenine nucleotides in samples of Atlantic fishes was investigated. In all cases, the flavor enhancer, IMP, reached a maximum level within 2 days in iced fillets. In haddock and halibut it remained at a high level for 5–7 days, but in cod, pollock, American plaice, and winter flounder it generally decayed to approximately zero within about 4 days. A few random analyses of retailed fresh fish, which would normally be at least 4 days old, confirmed these results. Hypoxanthine appeared too soon in American plaice and winter flounder to make it useful as a storage

time indicator, but it might serve in the cases of the other species. There were, however, considerable variations in the rates of appearance and disappearance of the various degradation products, such as IMP and hypoxanthine, among six winter flounders examined simultaneously. These could well have been due to the rather small observed *p*H differences among the fillets, in turn caused by differences in physiological states, and indicate the need for caution and much more information before attempting to use this kind of data for quality index purposes.

Quality of Newfoundland Fish

Capelin

Capelin (*Mallotus villosus*), a relatively unexploited species abundant in Newfoundland, is of interest in connection with possible future meal, oil, and canned fish production. The proximate composition of whole beach-spawning capelin was determined, the ranges on a wet weight basis being: fat, 8.1–1.8%; moisture, 77.1–82.3%; crude protein, 15–12.9%. Lipid decreased over the short spawning season with a much less marked increase in moisture and decrease in nitrogen and protein during the same period. These changes may parallel results in commercial meal reduction plants that reportedly require 7 and 9 tons of capelin to produce 1 ton of meal at the start and near the end, respectively, of the season. It was shown, concurrently, that oil of a quality comparable to herring oil can be produced from these fish.

In research on methods to decrease the cost of production of canned capelin, hand shears were shown to increase the heading rate for these fish to about four times that prevailing in Newfoundland plants.

Iced and frozen flounder

Quality for freezing whole or storing in ice; storage life of iced fish – Newfoundland industry is increasingly dependent on landings of flat fishes for the successful operation of the processing and freezing plants. Downgrading or rejection at the plants of fillets prepared from relatively freshly-caught iced American plaice prompted research into biochemically and organoleptically measureable changes in both raw and cooked fillets of these fish. Studies of various bleeding and gutting cuts and lengths of towing times of the trawl net, as these may affect the incidence of dark-colored or bruised fish (and thus affect processing costs), showed slash-gutting, complete gutting, and a bleeding cut at the head or at the tail (bobtailing) to result in similar quality of the fillet prepared from plaice iced for 4 days. Quality was superior to that of fillets of fish stored in ice without bleeding or gutting. Extension of time of trawling from ½ to 3 hr appeared to have considerably less effect on increase in the incidence of bruising than did failure to bleed or gut the fish. It was shown that for nominally unbruised "live" Grand Bank plaice, trawled in April and in early December and bled by slash-gutting or by heading and gutting, the bleeding time in clean 10 C (50 F) sea water need not exceed 5–10 min. On freezer trawlers, where the time and conditions provided for bleeding can be a matter of extreme importance, provision can be made for a combined washing and bleeding time of 15–20 min, with the fish reaching the freezers at a temperature of about 8 C (46 F).

Trimethylamine (TMA) values and odor assessment showed that raw slash-gutted, iced plaice have a minimum combined storage life as whole fish and as fillets (stored in plastic bags) of 8 days and a maximum of 12 days. Preliminary results indicate that the storage life based on taste panel evaluation will exceed these times.

Discoloration in flounder – American plaice, frozen whole and cold stored commercially, developed yellow and golden-brown colors in the subdermal layer of the thawed fish. The more markedly pigmented fillets are unacceptable for packing. Recent studies have shown that fish frozen with skins on, as received from the cod end and slash-gutted or after storage in ice and immediately thawed, yield a significant proportion of golden colored fillets. Control fish, filleted and skinned before freezing and immediate thawing were of normal color in the subdermal layer. Chemical procedures which have shown the presence of carotenoids in the skin of American plaice are presently being employed to determine whether carotenoids contribute to the golden-yellow color. Other procedures are directed to the identification of noncarotenoid pigments.

Yellowtail flounder, recently reported to occasionally having greenish flesh, an attribute considered unacceptable to the commercial fish plant operator. Pigmented areas have been observed on the skin side of fillets from both the blind and eyed side of fish with no apparent preference for a specific area. Present work centers on the chemical identity of this color, and the reason for its occurrence. There is evidence to show that fish in which the iron content is higher than normal may be more susceptible to "greening." Other evidence suggests that the color may be a pigment–protein complex, with origin in the food chain. To date, all the off-colored fish reported have been from a fairly well defined zone.

Iced and frozen redfish

Light color in fillets from redfish (*Sebastes marinus mentella*) is a desirable attribute in marketing this species. Whole redfish allowed to proceed through rigor in ice then filleted and frozen, were shown to be significantly lighter in color than fillets prepared from prerigor frozen whole fish.

Environmental Studies

"Red Herring" Pollution Crisis (Elemental Phosphorus)

Phosphorus toxicity

Yellow phosphorus is lethal to trout (*Salvelinus fontinalis*), salmon (*Salmo salar*), cod (*Gadus morhua*), and smelt (*Osmerus mordax*) at concentrations as low as 0.5 microgram/liter.

After a few hours of exposure to yellow phosphorus, salmon and trout show a bright red coloration around the head and fin regions. The blood of these salmonids shows evidence of extensive hemolysis and the hematocrits approach zero. In contrast cod and smelt show no evidence of external redness and there is no reduction in hematocrits.

Uptake of elemental phosphorus

Elemental phosphorus (Pel) was rapidly assimilated by cod exposed to sea water containing Pel. In a 16 hr exposure to sea water containing 70–80 parts per 1000 million, Pel was concentrated 1000-fold in the liver, from 10 to 25 times in white muscle, and about 50–100 times in the dark or red muscle. The degree of concentration was even higher with more dilute initial concentrations in the sea water. The Pel distribution was roughly in proportion to the tissue lipid content.

In cod muscle, containing Pel picked up by in vivo exposure to contaminated sea water, it was found that processing procedures, including icing, freezing, and frozen storage, salting by pickle or kench followed by drying, and cooking resulted in only a partial reduction of the initial levels of Pel. Some 25–90% remained in the tissue, obviously not a significant reduction from the viewpoint of possible injury to health of the consumer. Processing and storage by any of the usual commercial procedures thus cannot be relied upon to yield a safe product.

Analytical method

As a result of needs arising from the Long Harbour phosphorus pollution disaster, a rapid and sensitive method for the analysis of elemental phosphorus was developed. Phosphorus is extracted into a suitable organic solvent, isolated by gas–liquid chromatography, and measured in a highly sensitive and specific flame photometric detector. Phosphorus in water at levels as low as 10^{-12} g/liter can be measured in a few minutes and the methodology has been extended to include muds and biological samples. With the cooperation of the Department of Fisheries and Forestry, St. John's, Nfld., thousands of water samples from Long Harbour were examined to establish and monitor the distribution of elemental phosphorus down to the parts-per-thousand-million level.

Phosphorus deposit survey operations

The presence of elemental phosphorus in Long Harbour, Newfoundland, required extensive surveys of bottom deposits which were carried out by divers from other laboratories and agencies. All analyses, however, were carried out in the Halifax Laboratory. Some samples were bucket or grab hauls, but the majority were cores which required sectioning and individual treatment of the sections. In all, over 500 analyses were carried out on Long Harbour bottom deposits. Mud samples with as high as 5% by weight elemental phosphorus were found in the vicinity of the ERCO wharf, and lower levels were found over a substantial area of the inner harbor. After each of two dredging operations further surveys were carried out that indicated after a year local deposits of elemental phosphorus still existed in the vicinity of the ERCO wharf.

Oil Pollution

Project Oil

A two-dimensional thin-layer chromatographic technique was evolved which could distinguish between certain Bunker C oils of distinct origins through separation of polynuclear aromatic compounds into distinct groups. The procedure requires only simple equipment and chemicals and is suitable for use in the field. This was part of this laboratory's contribution to "Project Oil."

Biodegradation of oils

A number of bacteria have been isolated from mud samples taken at sites in the large oil spill at Chedabucto Bay. These are being assessed for their ability to degrade aliphatic and aromatic hydrocarbons as part of a continuing study to assess the role of microorganisms in the biodegradation of oils spilled in north temperate to arctic waters.

Tissue Culture Detection of Water Pollution

In contrast to specific chemical determinations the cells cultured in vitro are sensitive to various pollutants, such as pesticides, herbicides, and heavy metals etc. This bioassay system will be a useful monitoring tool for water quality. The factors affecting the sensitivity of this system to the pollutants, such as growth phase of cell, initial cell density, and culture medium have been investigated. Under present experimental conditions as little as 10–30 parts per billion of mercuric chloride can be detected by this system.

Process and Products

Fish Protein Concentrate (FPC)

A process has been developed for producing from lean fish muscle a protein concentrate having improved emulsifying properties. This bland white powder can be used to replace some or all of the beef in a recipe for frankfurter sausages. A small sample submitted to Canada Packers Limited received favorable comment. Application has been made to patent the process, but it has not been tested on a pilot plant scale.

Fish protein concentrate (FPC) has also been made from deboned dogfish, skate, sand lance, and from deboned filleting scrap from flounder and redfish (ocean perch). These materials will be used for feeding studies to provide data for the extension of the approval already given for gadoid FPC.

Since the fluoride level and ash content of FPC are related to the bone content, it is useful to know the amount of bone in the product. A method was developed for this determination which is based upon the density difference of bone and the tissue proteins.

Enzymes of Potential Commercial Value from Invertebrates

In a survey of enzymes of potential commercial value in invertebrate species of the Canadian Atlantic coast, high β-glucuronidase activity (similar to presently used commercial materials) was found associated with the digestive glands of several abundant and readily harvestable species of gastropod molluscs, with lower levels of activity in bivalve molluscs, crustaceans, and echinoderms. Arylsulfatase activity was very high in scallop, clam, and a freshwater mussel. Easily obtainable species of Gastropoda, as well as scallop and clam wastes, may be suitable commercial sources of these enzymes.

Mussel Byssal Threads

The byssal threads of mussels are of interest in that this is the mechanism used by this animal to attach itself to smooth or rough, wet surfaces. An understanding of the biological process could lead to the use of the material directly and/or to the development of wet surface adhesives modelled on this biological model. The threads adhere well to wet plastic.

Chemical analysis of this material is incomplete but indicates that it is composed largely of protein but has a significant carbonhydrate component. The material contains hydroxyproline in amounts suggestive of an elastin.

Crustacean Wastes

Wastes from pink shrimp and snow crab processing were dried and incorporated in the diet of speckled trout at the 20% level. The shrimp waste was shown to contribute a significant pigmentation to the flesh within 12 weeks. The crab waste contributed very little to the pigmentation of the trout flesh.

Dried crab waste, however, was shown to contribute to the pigmentation of chicken eggs when fed at the 10% level. The level of pigmentation was not as excessive as that reported for shrimp wastes. The proteins in the crab waste appear to be useful for poultry nutrition.

Freeze-Drying

Organoleptic evaluation of samples of freeze-dried cod prepared with a variety of raw material and process variable combinations showed that the first effect detectable was a change in the texture. The product was toughened most by high drying surface temperatures. This toughening effect occurred upon freeze-drying of raw scallops and precooked shrimp.

Sterols of Marine Life

A comprehensive study of Atlantic fauna and flora was done to increase the consumption and value of products from this source. For years marine plants and animals

have been known to be a rich source of many rare sterols and during the past few years several previously undescribed sterols have been isolated at this laboratory. A new C_{26}-sterol, 22-*trans*-24-norcholesta-5,22-dien-3β-ol has been isolated from the scallop, *Placopecten magellanicus* (Gmelin). To our knowledge this is the first naturally occurring sterol that has been identified as C_{26}-compound. This sterol may be a fairly ubiquitous compound, occurring in many marine sterol mixtures along with cholesterol and various other sterols.

The seasonal distribution of desmosterol, a sterol of potential economic value, which was previously isolated for the first time from red algae (dulse), as its principal sterol, has been determined. June, July, and August are the best months to harvest dulse to obtain desmosterol.

There also is evidence that nonedible invertebrates are a potential source of valuable sterols (i.e., desmosterol from barnacles).

Studies on the hypocholesterolemic effect of these sterols have been carried out with a hope that some may be found which will be a therapeutic value to man. A comparison of diets fed to chicks to which cholesterol or scallop sterols were added showed that high blood cholesterol levels resulted only from diets including cholesterol. There was no significant change in plasma cholesterol when scallop sterols were incorporated into the basal diet.

FRB scientist on board the Hudson '70 *cruise operating equipment to record high frequency sounds from whales*

MARINE ECOLOGY LABORATORY
BEDFORD INSTITUTE, DARTMOUTH, NOVA SCOTIA

The research program of the laboratory is directed to the study of processes underlying marine production. The study is designed to develop knowledge in four main areas:

- Prediction of the productive capacity of a water body
- The means of increasing efficiency of harvest of the natural production
- Assessment of the effects of pollutants on natural productivity
- Use of the information of production processes in development of systems of marine culture

In ecology, as generally in the environmental sciences, it is rarely possible to carry out a major environmental manipulation to test hypotheses about production. The development of knowledge about the natural systems therefore depends on a more complex methodology involving description of natural models, comparison among models, laboratory study, and simulation. The laboratory has chosen a model system, St. Margaret's Bay, for basic description and measurement of production parameters. Subsequent research has followed two main pathways: (1) Field studies to compare the model system with others which differ in identifiable ways, and (2) laboratory studies that have afforded manipulation of identified processes or mechanisms.

Problems with prediction of productivity, and its management for more efficient harvest, is dependent on adequate description of natural systems. Research projects tend to emphasize field studies and projects concerned with assessment of pollution effects, and aquaculture tends to focus attention on specific mechanisms. Some of the laboratory work in the past 2 years has been in association with these aspects. Fuller use of field and laboratory techniques is being made by the various programs. This has led to an increased interest and ability to formulate the acquired information into simulation models of the ecosystem. Manipulations of models in the form of either equation systems, or computer models, is proving of value in the selection of parameters of the complex natural systems, which deserve priority study because of their importance in regulation or sensitivity to manipulations.

Accomplishments in the main projects pursued in 1969–1970 are described in more detail below.

Basic Model: St. Margaret's Bay

The Field Program

This bay, approximately 40 square miles in area, situated about 25 miles from the laboratory continued to be a principal study area. Many of the investigations have reached important turning points. In particular, the principal features of the physical oceanography have been described and the main driving forces for water circulation and flushing have been identified. Primary production has been measured for phytoplankton and the limits of reliability of various methods for predicting it have been established. Production has been measured for attached seaweeds, one major macrozooplankton organism, one of the marine worms important in fish diets, and for the principal resident fish species.

The temperature–salinity structure of the Bay has sharp variations within short periods of time. Nevertheless, the gross features are repeated with seasonal regularity: (1) in spring a thin, low-salinity, rapidly warming, surface layer overlies the bulk of water that is of uniform temperature and salinity; (2) in summer, a pronounced pycnocline separates a salinity-stratified surface layer from a temperature-stratified and thicker lower layer; (3) in autumn, the water is of homogeneous temperature and salanity; (4) in winter, the lowest temperature and salinity are at the surface, but both gradually increase with depth. In transition between winter and spring (late March) a midwater temperature minimum was observed and probably recurs regularly.

The tides are the principal movers of water in the Bay. Tidal currents of about 0.5 knot occur at the surface in the mouth of the Bay, but decrease with depth and towards the head. Tidal excursions vary from 0.5 to about 1km/cycle, setting up an anticlockwise circulation.

The water in the Bay is primarily of oceanic origin with a residence time of about one month. The lower-salinity upper-layer exchange is enhanced by addition of direct precipitation and land runoff and its residence time may be as low as 7 days. The deeper layers appear to exchange more slowly, but the estimated time varies, depending on the model used in calculation.

In the classical two-layered system, the deep water is continuously renewed in an average period of a month. However, if the main exchange is through the anticlockwise circulation at the surface that is generated by the tides, the deep water residence time may be longer and the water may be renewed occasionally over short time periods. There is evidence that both mechanisms occur. Estimates of relative importance have not been made, but are of significance to the level of biological production of inlets.

Physical study has shown reliable information can be obtained with relatively few oceanographic stations. However, changes are intermittent and rapid, suggesting a need for relatively short time-intervals between observations. The main perturbations result from regional rather than local meterological events, verified by comparisons with nearby

Bedford Basin (see below), and is of considerable utility in describing and predicting for coastal systems.

In biological studies of the Bay, the 3-year mean rate of carbon fixation (C^{14}) by the plytoplankton was 193 ± 60 g C/m^2 per year (3049 Kcal/m^2 per year), comparable with rates in the main fishing areas in the North Sea and on Georges Bank. Seaweeds, mainly *Laminaria*, have a total production at least 50% greater than that of the phytoplankton. It is greater than anticipated and may be a feature of similar open bays and coastal regions throughout the world. Revision upwards of previous estimates of the basic production of organic material available to food chains is necessary in such areas.

Seaweed contributes directly to the food chains, through grazing by sea urchins that in turn are a significant item in lobster diets. Naturally eroding fronds of the *Laminaria* also contribute food to the benthic detritovores such as annelid worms and gastropod molluscs. The largest contribution to the system seems to be through the quantities of organic compounds released from seaweeds into the water, to be taken up by the zooplankton or the benthic filter feeders.

Of particular interest in food chain studies is the efficiency of energy transfer among the various trophic levels. A new method for studying photosynthetic efficiency has been evolved and an integrating radiometer has been built and field-tested. It permits rapid measurement of photosynthetic efficiency over considerable areas and provides a strong basis for comparative studies.

Relation of photosynthetic production to that of the animals is inhibited by deficiencies in the actual methods of measurement. For example, workers at the laboratory have established nonphotosynthetic primary production (carbon fixation) processes appear to be of more importance in nature than has been generally accepted, especially when nutrient levels are low or when there is a deficiency in the supply of chelating agents. Zooplankton production, which has proven generally difficult to measure, is being assessed through a variety of methods, using biochemical products of intermediary metabolism as indices of biomass and rates of growth. Results show a high degree of predictability of the relation between biomass and growth in nature when information on the sizes of the organisms involved is given.

In general, organism size and spatial distribution appear to be the most important parameters controlling production efficiency at various trophic levels. This conclusion, based on model calculations has directed a considerable percentage of the field effort in St. Margaret's Bay towards measurement of the distribution parameters. Significant components of the patchiness of the phytoplankton can be explained in terms of the distribution of small-scale water masses. Since these physical characteristics are predictable, it is of increasing interest to extend these studies to further stages in the marine food-chain systems and to other areas.

The total production of one of the main zooplankton organisms, *Sagitta*, was estimated to be about 200 mg C/m^2 per year (2.3 Kcal/m^2 per year), or about 1/10 of 1%

of the phytoplankton production. The animal is an important predator, feeding actively on smaller zooplankton and on the pelagic larvae of such fish as the herring. Analysis of sampling data and models of the population dynamics of the species showed that the population consists of several subpopulations, but maintenance of the present level of the total stock in the Bay depends on recruitment from populations which must be produced in the colder coastal waters of the shelf. This perhaps results from the physical drain imposed on the resident population by the relatively high flushing rates of the surface-water layer of the Bay.

Life history and distribution studies of the marine worm *Pectinaria* have indicated that its production in any potentially suitable region of the bottom is dependent on both abundance and the variable age and size structure of the populations from place to place. Production ranged from 0.03 to 7.6 Kcal/m^2 per year. Information on variations in production with abundance and structure of the population suggest that it is possible to calculate a properly weighted production estimate for the Bay as a whole using data on probability of occupancy of different sediment types and the distribution of sediment types themselves.

Measurements of production of the principal resident fish species, the American plaice (*Hippoglossoides platessoides*), have been made on a population that has not been fished, and which appears to have reached a steady-state high density. Individuals are slow-growing compared with other species in fished areas. For the major plaice-bearing areas of the Bay, the production of fish-flesh stayed more or less constant from area to area at about 2.5 g/m^2 per year (0.25 g C/m^2 per year) despite considerable differences in size and age-compositions of the stocks. In terms of their overall trophic efficiency in the St. Margaret's Bay system, these preliminary calculations put the fish at about the same level as *Sagitta*, the major zooplankton carnivore. Our present evidence indicates that we are relatively underestimating the production of the fish species, because of deficiencies in sampling of the younger age-groups.

Special Studies of Production Mechanisms

To understand the significance of differences in production efficiency among various organisms in a system, it is necessary to study some of the underlying mechanisms in considerable detail. This requires laboratory study and analyses supplemented by theoretical analysis and computer simulation. The laboratory programs are currently underway.

Phytoplankton culturing

Studies of dinoflagellate cultures have shown the importance of humic acids on plankton blooms. Lower molecular fractions are important in biological "conditioning" of water. The positive effects are interpreted in terms of chelating effects and direct physiological "stimulants" increasing metabolic rates and efficiencies. Studies are being extended to other complex organic compounds that are dissolved in sea water, especially those derived from the decomposition of the large seaweeds.

Zooplankton cultures

Zooplankton organisms exist in a wide variety of shapes, sizes, and life history patterns making it difficult to base over-all production indices on generalizations. Problems arise in the relation of growth and reproductive efficiency to food abundance and quality, and the conditions which lead to somatic growth or reproduction. The general group probably should be separated into various types on a combination of physiological and ecological criteria. Efforts during the last 2 years have led to the successful culture of several of the more important organisms found locally, and the initiation of studies of their feeding and metabolic responses. Of particular interest are several highly specialized but apparently successful predator–prey relations developed in the pteropods, and a study of conditions that promote the production of "blind end" food chains as opposed to those supporting large carnivore populations.

Energetics of fish production

Under present exploitation rates, the various stocks of fish cannot be considered in isolation from one another. Predator–prey and potential competitive situations exist in a complex manner. Despite varying success of various individual stocks, over-all production appears to respond in a more or less regular and possibly predictable fashion. Of particular interest is the division of food energies between growth and metabolism in different species in similar environments. Species being considered are the mackerels and tunas which have developed efficient structures and are highly successful in the same areas as the more common and unspecialized herring.

Distribution and abundance of food are important in controlling production efficiency. These effects are mediated and moderated in fishes by the interaction of the fish behavior pattern with an existing environmental situation. Studies are being made on the influence of food abundance and availability, on food selection, activity, appetite, and growth of individual fish.

Comparative Coastal Embayment Studies

Given the existing information on St. Margaret's Bay, it is feasible to begin making meaningful comparisons with other inlets, on the basis of at least gross physical and biological parameters. Such comparisons are necessary for the long-term process of establishing the relative importance of various parameters to productivity. However, there is a shorter-term and immediate need for such information by the management levels of government. The results are useful for pollution assessment, for recreational and tourism planning, and for potential aquaculture development. The most urgent of these requirements is that of pollution and this consideration has been the chief one in choosing the Bedford Basin–Halifax Harbour area, and the Canso Strait–Chedabucto Bay area as regions for special attention.

Bedford Basin–Halifax Harbour

A joint biological–physical study of this system was undertaken by the Bedford Institute in 1968 with preliminary sampling for phytoplankton production patterns and water-quality measurements. The nutrient load of the water is high, probably in large measure due to the heavy raw sewage input to the area from the fringing urban development. Maximum phytoplankton production was also higher than in St. Margaret's Bay, but with a considerably different species composition.

Following these observations, an intensive study program has been developing. On the basis of the results to date, the Bedford Basin seems to be generally a three-layered system. The bottom layer is below the level of the entrance sill between the Basin and Halifax Harbour. Water in this deep part of the basin appears to exchange only very slowly and possibly intermittently with the overlying water and at times is almost completly anaerobic. This condition is probably aggravated by the organic pollution input.

In the two surface layers, the physical exchange processes resemble those of St. Margaret's Bay, with inflow in the lower layer and a surface outflow. The tidal component of the mixing and circulation forces is less important than wind and freshwater discharge. The upper dynamic part of the system on occasion, may become three-layered rather than two with the inflowing water at an intermediate level.

Biologically, the surface waters are not only more productive per unit area than the unpolluted St. Margaret's Bay, but the efficiency of the primary productivity is also greater. The mechanisms may be related to several factors including a different nutrient ratio, higher humic acid content, different species composition and seasonal production pattern of phytoplankton, and higher bacterial load. There is a vigorous zooplankton development in the surface layers, but the basin is virtually devoid of benthic producers. Fish species are similarly confined to the upper pelagic zones.

Canso Strait–Chedabucto Bay

Work in this area began on an opportunity basis in 1968, with a background physical oceanographic survey, a sediment distribution survey, and some sampling of the benthos and zooplankton. Further sampling was continued in 1969 to develop a description of the seasonal distribution. Most of this work was confined to the Canso Strait area, south of the Causeway.

This program was overshadowed in February 1970 with the grounding of the Liberian oil tanker *Arrow* on Cerberus Rock in Chedabucto Bay, near the entrance to the Canso Strait. The subsequent oil spillage coated nearly 200 miles of coastline with Bunker C oil. Staff of the Marine Ecology Laboratory examined and sampled the area immediately following the announced grounding and about one-quarter of the staff was involved in the subsequent scientific survey and clean-up operation, many in a major way for several months. Results of special importance to the laboratory productivity program are still emerging from the continuing study. Oil from the spill was dispersed and mixed downward into the water column as particles ranging from 0.01 to 3.0 mm in diameter. In late March, these were largely restricted to surface waters, but in late April were dispersed to depths of over 80 m. It is estimated that the amount of oil so dispersed was

about 1500 tons or 10% of the total tanker cargo. Particles were detected in the water as far away as Halifax, and the beaches on the north side of Sable Island were coated by an unknown re-coagulation process from the water column.

The fate of the dispersed material has not been fully established. However, it is clear that zooplankton organisms were one of the most important agents in the degradation process. Large amounts of dispersed oil appear to have been ingested by the plankton and passed out in the fecal pellets which sank to the bottom. It is not clear whether any metabolic breakdown of the oil takes place in the guts of the zooplankton, hence whether any food energy is derived from the passage. However, the particles did not appear to harm the organisms, except for some indications of ingestion of particles large enough to block the gut. Under the conditions prevailing, main bacterial action on the particles may have been taking place subsequent to passage as fecal pellets.

Studies of the effects of the heavy Bunker C oil on the littoral fauna indicated that the main problem was one of smothering and starvation or physical destruction of the environment, rather than toxic chemical effects. In areas where the oil scum was sufficiently thin, soft-shell clams appeared able to establish siphon holes through it, and oily residues were found in the mantle cavities of living animals after several months. Such organisms are, of course, rendered unpalatable.

The staff was heavily involved in the assessment of the effects of the oil deposition and subsequent clean-up, and on the dynamics of the beaches and other littoral zone habitats. In general, it was established that physical-mechanical cleaning of the areas was highly preferable to use of chemicals or dispersants. There is still some apprehension about the effects of bulldozer removal in areas where the natural rate of supply of new beach material is very low. Rocks and extensive marsh areas could not be cleaned.

Other Embayment Studies

The laboratory has been involved in examination of other coastal situations, mostly associated with pollution problems. The Pictou Harbour area in Nova Scotia was resurveyed, following the opening of the industrial effluent treatment facilities at Boat Harbour. There was a significant change in the composition of the bottom communities off the harbour. It is not clear whether this is a result of the greatly increased organic content of the effluent waters as they are mixed into the salt water, or whether it is primarily a result of the changed pattern of water circulation following construction of the East River Causeway. It is likely that both causes are involved.

Following the spills of elemental phosphorus into Placentia Bay, Newfoundland, laboratory scientists were involved in reassessment of the water circulation and flushing and sedimentation rates for Long Harbour, and in an assessment of the damage to the marine invertebrate community. Subsequently, the staff has been involved in checking the results of the harbour dredging which has attempted to remove the accumulated phosphorus sedimentary layer, and in laboratory analyses of the metabolic pathways by which the phosphorus effects on the animals were mediated.

Preliminary studies have been made of several estuaries and inlets in Prince Edward Island. A major field study of the benthic communities in the oyster-growing areas around Ellerslie have been completed. Certain inlets near Summerside and Charlottetown have been inspected to assess the requirements of surveys in connection with possible pollution and eutrophication effects. Other inlets in Prince Edward Island and Nova Scotia have been examined for shellfish rearing potential (see below).

Coastal Studies

Larval Fish Surveys

Experience with St. Margaret's Bay surveys for macrozooplankton and ichthyoplankton have resulted in the development of considerable expertise in such work. This experience is directly applicable to the development of larval fish surveys for estimating adult spawning stock abundance. Surveys were undertaken in 1968 and 1969 in connection with the herring stocks of the Scotian Shelf area. A number of stocks exist along the coast as fall spawners and they are distinct from stocks of the Bay of Fundy or Newfoundland–Gulf of St. Lawrence areas. Scotian Shelf stocks are of significant size but appear to be smaller than those supporting the major eastern Canadian fisheries. Their contribution to the offshore European fishery of the Scotian Shelf is not known, but spawning off the Canso area were indicated by the surveys and supported by evidence from interviews with fishermen.

Acoustic Fish Surveys

Information on fish abundance is important to scientists for production measurement and to management at government levels, in connection with control of catch and effort for conservation and economic development objectives. In addition a detailed and timely knowledge of local fish distributions and abundance is important to industry in planning fishing strategy to maximize economic return.

In the belief that certain practical modifications and system development of echo-sounding techniques would serve all of these needs, acoustic survey problems have been an important component of the total program. Acoustic equipment and electronic systems for sensing, analyzing, and recording fish echoes have been built up over the past 4 years. In 1969, elements of these systems were compared in field operations with others being developed in England and Norway, and were shown to be the best suited to our purposes. With subsequent refinements, the equipment has been tested on an opportunity basis in actual surveys for demersal fish abundance on the Scotian Shelf.

The results to date are promising. Under carefully controlled conditions, correlations of catch and count are very high. However, the acoustic apparatus can be used to sample for abundance in parts of the water column not fished with conventional fishing gear, can sample in areas difficult for fishing, and can cover much greater areas in short periods of time. Judicious survey design incorporating both sounders and fishing gear can increase the survey information from research vessels.

Initial results of studies on the usefulness of acoustic surveys for guiding commercial operations verify that differences in the degree of local concentrations or aggregations significantly affect present commercial catches. They also indicate a surprisingly strong persistence pattern in both the degree and spatial positioning of local aggregations. These surveys will provide information on the spatial distribution of sample surveys required for giving abundance and catch estimates within specified statistical limits.

Other Bio-Acoustics Work

Development studies and possible application of acoustic survey systems to other species, especially pelagic species such as herring, are restricted by the low level of support available to the programs. However, studies of the parameters of acoustic reflections from a variety of pelagic animals are being undertaken, including large pelagic fish, the meso-pelagic fishes of the deep-scattering layers, and large zooplankton.

Shrimp Abundance and Production

Northern shrimps, *Pandalus borealis*, are one of the potentially important resources of the coastal area and are currently gaining wide commercial and governmental interest. Areas of shrimp abundance were predicted on the basis of the particle size distribution of the sediments. Sediment maps, potentially useful in shrimp and crab fishery explorations, have been prepared for some regions of the coastal shelf and their existence made known to provincial and federal administrators.

In the face of a developing fishery for shrimps, the current difficulties in calculating production rates for this trophic level of the food-web system becomes a problem of considerable practical importance. As a by-product of geochemical studies of the bottom sediments, the content of trace metals such as zinc, copper, lead, manganese, chromium, cobalt, and nickel in the shrimp exoskeleton and flesh has been determined. It appears from the study that the ratios in flesh compared with carapace vary with area, but also with size within areas, suggesting that this geochemical method may be applicable to growth rate determinations, hence production rate estimates in these relatively long-lived representatives of the zooplankton.

Exploratory sampling of the deep-scattering layer above the Scotian continental slopes off Halifax has shown the presence of several species of large pelagic shrimps. Information on the relative seasonal distribution of their availability is being developed in conjunction with vertical-haul stations employing large Issacs-Kidd trawls.

Gulf of St. Lawrence Studies

The Gulf is a region of special interest to the laboratory. It is a major source of fish catches on the east coast; a major estuarial system, receiving freshwater outflow from the St. Lawrence River, the Great Lakes, and the many tributaries that drain the industrial

heartland of the continent; along with the Gulf of Mexico, it is a major recipient of industrial and domestic effluent; it is a major trade route, and especially subject to all the hazards of modern marine commerce, including oil spills; it is also an important mediator of the climate of eastern Canada, but an area which is showing signs of undergoing change from an ice-covered to ice-free environment as a result of hydro-electric river control. It is thus a demonstration area in which it may be possible to assess the impact of the developing technological society on a large portion of the biosphere. As far as possible, the laboratory encourages and cooperates in ecological studies of the system.

Of particular interest to the development of background knowledge of this area is a number of physical-oceanographic studies and surveys. These are carried on from the Bedford Institute by the coastal oceanography group. Close coordination and, when possible, operational support is maintained with the Gulf of St. Lawrence Canadian International Biological Program, and with ice-forecasting studies sponsored by the Meteorological Branch of the Department of Transport.

In addition to the above, scientists have been developing three special studies of the Gulf.

Geology and Geochemistry

Intensive field collections of cores of the superficial sedimentary deposits and studies of the geomorphology of the Gulf were continued up to mid-1969. From that time, effort has been devoted entirely to analysis and reporting of the data. A detailed sediment map (1:750,000) of the river and gulf has been prepared and arrangements are being made for special publication. A similar study of the geochemistry of the sediments is being carried out. The combination gives not only a picture of depositional and erosional zones and bottom types of importance in fisheries, but permits an assessment of rates and patterns of addition of many of the metallic pollutants.

Production Mechanisms

It is generally accepted that biological production processes are ultimately dependent on physical conditions. However, production measurements in most cases represent integration over a considerable period of time and space so that only correlations of measurements of physical and biological events averaged over rather large time and space scales have often been attempted. The relations appear to satisfactorily explain major zoogeographic differences, but are of very limited application in the area of predictions which might be utilized in planning human activities.

In this latter sphere, the short time and space scales that determine fish larval survival and recruitment, provide for major food production differences, influence fish or fish-food migration routes, and aggregation patterns are of considerable importance and interest. Developments in oceanographic sensing and sampling methods over the past 5 years have led to the identification in the Gulf of St. Lawrence of meso-scale water masses which seem likely to be associated with important events of this sort.

Investigations during 1969 and 1970 have shown that the meso-scale events are persistent and concern features of the gulf circulation. Biological sampling shows that biomasses of organisms, and events within given masses, which usually appear as gyres of surface water, are different from those in the "less organized" general water masses in which the gyres occur.

Identification and study of associated physical, chemical, and biological events at these intermediate scales pose formidable sampling problems. These problems will have to be overcome before it is possible to interpret the high heterogeneity and variability that is exhibited in all the biological sampling to date. During 1970 a concerted program of study of spatial and time variations in physical and biological parameters was undertaken in the biologically important Magdalen Shallows area of the Gulf.

Pollution Effects

Because the Gulf of St. Lawrence is the recipient of such potentially large discharges of industrial and domestic effluent from freshwater outflow, in addition to the air-borne sources brought to the area from the Northeast and Central United States and Canada in the predominantly southwestern summer air circulation, a special program of environmental survey and monitoring is being undertaken in that area. The first special oceanographic cruise for assessing pollution levels was undertaken in mid-1970 and involved sampling of the water column, biological organisms, and sediments. Preliminary results show a distribution of elements which is in accordance with our predictions based on the general circulation patterns. Residence times of various compounds in the water column, organisms, and sediments are dependent on a large number of factors, which are the subjects of continuing study.

Oceanic Studies

The major effort in oceanic studies was associated with *Hudson'70.* This cruise afforded an opportunity to conduct experiments in three oceans and their associated water masses and enabled the testing of hypotheses concerning the factors affecting marine productivity.

In collaboration with scientists from other laboratories, measurements of dissolved oxygen, nitrate, phosphate, silicate, titration alkalinity, and *p*H were taken to delineate and characterize chemically the major water masses of the Atlantic and Pacific oceans. Similar measurements were made in the Chilean fjords and the Drake Passage.

The survey also allowed comparison of a number of available methods for measuring primary production in waters of different productivity. Samples were collected from 282 stations to study distribution, and experiments were carried out on the growth of particulate matter (algal and detrital). Determinations were made on adenosine triphosphatase, deoxyribonucleic acid, particulate carbon, chlorophyll, C^{14} uptake, and particle spectra with the Coulter Counter. Analysis so far indicates that incidence of non-

photosynthetic production (indicated by dark uptake of C^{14}) of phytoplankton is higher in tropical and subtropical waters, apparently related to low nutrient concentration of these water masses. In these water masses, the supply of chelating substances also appears to be an important factor limiting production.

In the cooler waters of both the northern and southern hemisphere occur a group of planktonic copepods that undergo regular seasonal migration, coming into the surface water to feed at the time of maximum plant production, storing large quantities of energy within their bodies in the form of fat (probably wax esters) and then sinking into the deeper water to complete their life cycle in virtual starvation. Not only do these copepods provide an energy pipeline between midsurface waters and the relatively poor, middepth region, but also, when they become associated with specific water masses, may have considerable value as indicators of water movement if rate and utilization of their stored fat could be measured.

Rhincalanus gigas was chosen for the *Hudson'70* study as perhaps the most useful of the southern ocean submergent species. Plankton tows above, in, and below the Antarctic intermediate water were made from 30 to 55°S in the Atlantic and from 63 back to 15°S in the Pacific. Its distribution extended north to 30°S in the Antarctic intermediate water of the Atlantic, more than 1200 miles from the Antarctic convergence where it last occurs in the surface zone. Southward successively younger stages were found with higher fat content and physiological evidence of extreme starvation in the northern limits of its range, reliance on stored fat or on energy substrate in deep water, and rapid growth with fat storage during the Antarctic spring bloom. It would be premature to attempt more than a preliminary evaluation of the results to date.

Pollution Studies

The effects of pollutants on production systems are becoming a major concern in most of the ecological studies of the laboratory. This has been a natural development, and was the original reason for the choice of the relatively unpolluted and unfished area, St. Margaret's, as the basic study model. Aside from the general concern to understand the natural processes well enough to judge the importance of changes, however, the experience gained in this area has been essential to the formulation of intelligent sampling plans and methods in other areas. Given this background, the immediate demands for information on areas where pollution is now an apparent problem have largely determined the choice of comparative study areas.

A limited capacity to assess the general physical and ecological properties of most of the smaller marine bay systems is available at this laboratory, enabling staff to offer advice on necessary safeguards against pollution damage. However, many of the effects of pollution are complex and subtle. Protection requires an appreciation of the immediate toxic effects on animal and plant physiology, as well as of the effects of accumulations over periods of time. Where pollution compounds have already become widely dispersed in the environment, or are capable of such dispersion, information is needed to permit calculation of the probability that they will turn up directly in our foods, or will alter the parameters on which food production depends.

The solutions to these problems are not essentially separable from the solutions sought by the general laboratory program. They do require special attention to the collection and analysis of particular information and the reporting of its significance to certain operating and managing levels of government.

To satisfy these requirements, a special Environmental Quality Research Group was established in the laboratory during 1970. Its terms of reference are to carry out research that can lead to the identification and assessment of effects of pollutants in the marine environment. The research group is also charged with the development of techniques and sampling systems which can be used to monitor potentially deteriorating situations.

The research group is concerned with techniques of chemical analysis for certain pollutants, tolerance to various toxic compounds, toxicology of certain others, and sampling for levels of various pollutants in natural food chains. An important part of the activity of the group is the development of fast and efficient computer-based information-retrieval systems which can make data available for local use.

Mariculture

It is generally considered that estuarial areas are potentially the most vigorous production areas of the world. An obvious application of scientific knowledge of natural production processes is in the development of marine aquaculture, or what is frequently called mariculture. Experience in the world to date has been that mariculture, indeed all aquaculture, is technically feasible but generally so labor-intensive as to be a viable activity only in developing areas where labor is cheap and food relatively expensive, or where special luxury items are involved. The same is true in Canada, where it appears that culture of only two species show promise of early payoff: oysters and salmonids.

The east coast oyster research program has been a responsibility of the laboratory since 1968. Principal activities during the past 2 years have been in the area of advice and assistance to new industrial ventures to apply known research results, and examination of the problems of introductions of new desirable shellfish that are free of diseases and parasites.

Close liaison, exchanges of material, information and advice have been offered to two commercial ventures. One is a commercial oyster hatchery in Prince Edward Island, now completing its second successful year of operation, based on techniques developed at the oyster station at Ellerslie. The second was advice to an Indian Band at Eskasoni, Cape Breton, in their efforts to utilize part of their reservation area in Bras d'Or Lake for oyster culture. Techniques in manipulation of adult brood stock, predictions of spat-fall, spat catching, and shell-string rearing were successfully applied in an area with low natural production, probably due to poor bottom conditions. Conditions at the end of the first 4 months of the operation promise not only a technically but also a commercially successful operation.

A new trial introduction of the European oyster, *Ostrea edulis*, was undertaken in 1969. Adults from a stock known to be more tolerant of winter conditions were introduced at Ellerslie into strict quarantine with subsequent isolated hatchery-rearing of the juveniles for a period of several weeks. Several thousand healthy seed oysters were then exposed to storage in nature. Growth and survival have been excellent and sexual development normal. Testing of growth and survival in southern Nova Scotia waters was undertaken in 1970 in cooperation with the Nova Scotia Department of Fisheries. If the present successful record is maintained, there would appear to be promise for a very large extension of the Maritime coast line for commercial oyster culture.

Other oyster culture activities have involved the preservation of several strains of disease-resistant oysters from populations which have since been decimated by disease, or subjected to genetic mixing in rehabilitation programs. It is expected that these strains may represent valuable genetic resevoirs from which to begin studies in selection, should oyster culture activities realize their apparent commercial potential in the near future.

BIOLOGICAL STATION
ST. JOHN'S, NEWFOUNDLAND

The main research efforts were directed toward:

- Studies of biology and population dynamics of cod, redfish, American plaice, and Greenland halibut

- Oceanic distribution, tagging, serology, and parasites of Atlantic salmon especially in relation to the Greenland and high-seas fisheries

- Population dynamics, and stock separation in herring

- Studies on haddock, capelin, lobster, crab, squid, and the introduction of Pacific pink salmon to Newfoundland

- Monitoring of hydrography of the Newfoundland area

Groundfish

Fishery

Projects to monitor fisheries and environmental effects on the principal groundfish stocks were continued in a number of principal landing ports. Additionally, stock surveys were carried out using the research ship *Marinus* in the outer coastal areas and the *A. T. Cameron* in the offshore areas.

Commercial landings of the principal groundfish species in Newfoundland totalling 680 million lb (round) in 1969 were at approximately the same level as in 1968, with cod and flounders forming the bulk. However, cod landings were nearly 50 million lb lower and flounder landings 35 million lb higher than in 1968. Yields of cod from inshore waters were generally low, particularly in Labrador, where in 1969 the total was only about 20% of the 1960–68 average.

The 1970 fishery indicates lower landings of cod but higher landings of flounders than in 1969. In the inshore fisheries increased versatility and mobility of small boats have resulted in increased catches of other groundfish species (Greenland halibut, plaice, witch, and wolffish) in addition to cod.

Cod

The decrease in inshore landings, particularly in Labrador and eastern Newfoundland, is attributed largely to the intense offshore international trawler fishery.

Consistent with the intensified fishery in the eastern area are higher total mortality and growth rates and reduced average age of cod. Catch-effort assessments indicate that cod stocks in the area (ICNAF Subareas 2 and 3) are near or beyond the point of maximum sustained yield. Small long-term gains to landings might be expected with increase in otter-trawl mesh size from the present 4½ to 5 inches.

Recruitment has been fairly regular for the past few years although regional differences in year-class contribution are evident. In the inshore summer fisheries, particularly by cod traps, the 1964 and 1965 year-classes were dominant in 1969 and 1970. Research vessel catches in various areas in 1969–70 indicated the 1967 year-class to be dominant off southern Labrador, whereas it was poorly represented on southern parts of the Grand Bank where the 1966 and 1968 year-classes were dominant, and on St. Pierre Bank where the 1966 year-class dominated. The 1964 year-class which contributed heavily to commercial catches from the eastern parts of the Grand Bank in 1967 has largely disappeared from the fishery in that region.

Haddock

Research vessel cruises to the southern part of the Grand Bank (ICNAF Divisions 3N and 3O) in 1969 indicated that the adult haddock stock is very low and no significant quantities of commercial-sized haddock were caught. Catches of pre-recruit haddock indicated that the most recent year-classes up to 1968 were very poor.

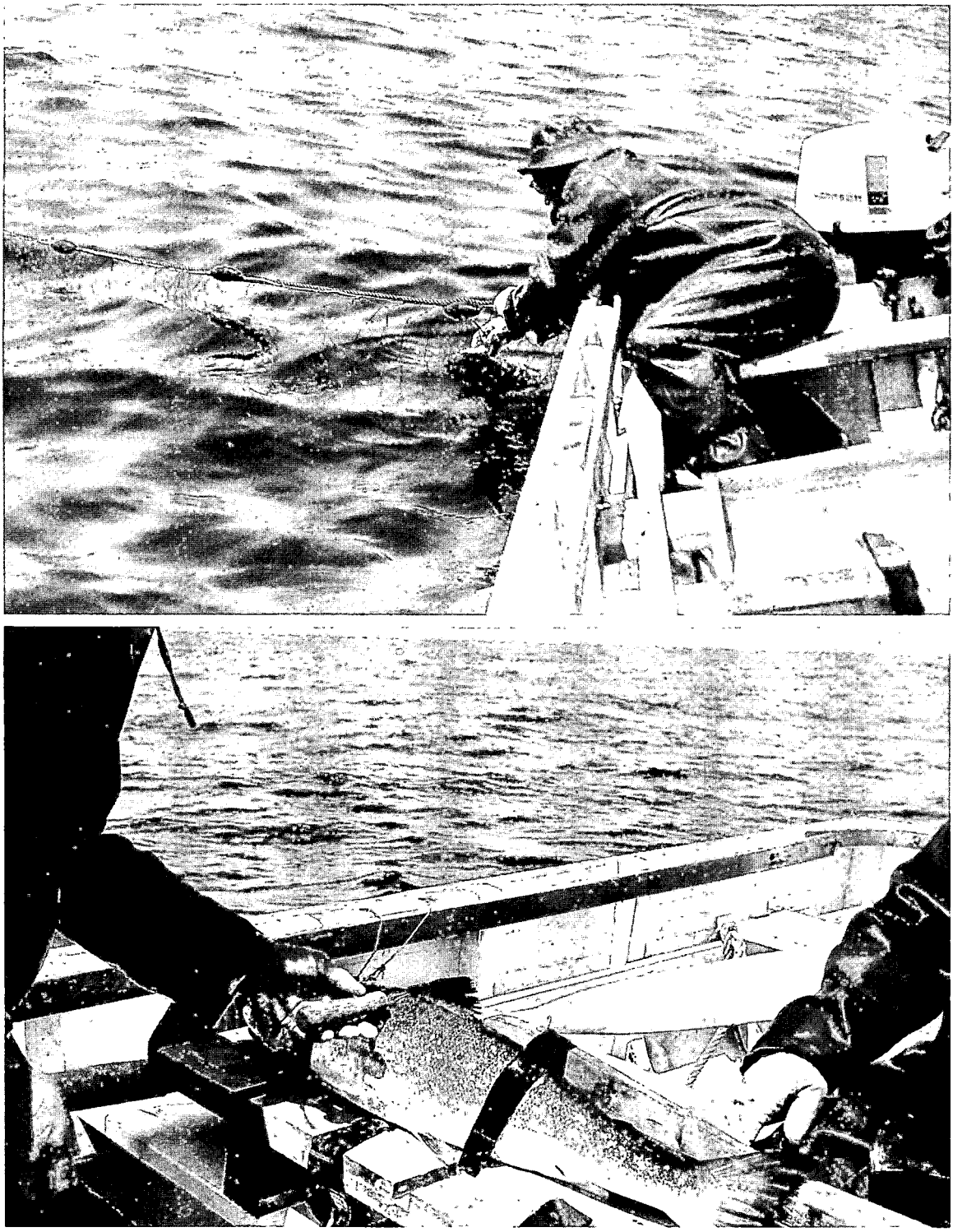
On St. Pierre Bank (ICNAF Division 3Ps) in 1969 catches of haddock were almost solely composed of the 1966 year-class. The 1967 and 1968 year-classes were extremely scarce.

During a cruise in 1970, the 1966 year-class was still an important contributor but catches of pre-recruit fish indicated that the 1969 year-class was fairly good. However, year-classes of 1967 and 1968 seem to be very poor.

In 1970, reports of significant quantities of haddock were received from several areas of the south and east coasts of Newfoundland. Early in the inshore fishing season they contributed significantly to catches by cod trap. Analyses of the vertebral samples failed to indicate the origin of these fish.

American Plaice

Analysis of otter-trawler statistics of American plaice catches for 1954–69 indicates: (*a*) the total fishing effort expanded rapidly from about 10,000 hr in 1954 to nearly 175,000 hr in 1969, (*b*) an increase in the landings from around 20 million lb to a little over 200 million lb, (*c*) Canada's share of the catch has declined from about 80% up to 1962 to less than 50% in 1968–69, (*d*) the catch per hour of Newfoundland-based trawlers has decreased from about 2000 lb/hr in 1954 to less than 900 lb in 1969, (*e*) the maximum sustainable yield was probably reached in 1967–68.



Tagging Atlantic salmon at sea. A small boat is used to patrol the drift nets so that salmon are removed soon after they are caught

Yellowtail Flounder

This species has gradually increased in abundance on the Grand Bank since the early 1960's. In 1965 about 4 million lb were landed by Newfoundland otter trawlers and in 1969, 22 million lb were taken. This increase in abundance can be related to a slight increase in water temperatures and a reduction in numbers of species with the same food spectrum, possibly haddock.

Greenland Halibut

Recoveries from 247 Greenland halibut tagged near the mouth of White Bay, October 1969 indicate an offshore movement during winter and spring. Recoveries during April and May 1970 were by European factory ships fishing on the continental shelf about 120 miles from the tagging site. All summer and autumn recoveries were from White Bay and Notre Dame Bay up to 50 miles from the tagging site.

Redfish

Echo-sounder surveys accompanied by baited handline fishing in 1969 confirmed the existence of numerous redfish almost continuously distributed from the northern part of the Grand Bank and southern Labrador to Greenland. These redfish were *mentella* in appearance, were usually within the depth zone 75–150 fath and were found over water from 200 to over 1500 fath (deepest water present on the vessel track from Newfoundland to Greenland).

An echo-sounder survey by the *E. E. Prince* in 1970 from Hamilton Inlet Bank to Flemish Cap, from the edge of the slope to depths greater than 1000 fath, showed records similar to those previously confirmed as redfish. Attempts at identifying the source of the echoes as redfish on this cruise were not successful and only twice fish were taken from the depths at which the echo targets were most plentiful. Both of these were, however, redfish.

An echo-counting system (designed and constructed by R. Dowd of the Marine Ecology Laboratory) was operated throughout the survey and counts of the number of targets in 50 m levels were obtained throughout the trip.

Pelagic Fishes

Herring

The purse seine fishery for herring, operating mostly along southwestern Newfoundland from November to April, accounts for 95% of the Newfoundland landings annually. The yield increased from 125,000 tons in 1967–68 season to 185,000 tons in 1968–69, and 199,000 tons in 1969–70. Increasing proportions of herring landed in Newfoundland are caught at Magdalen Islands and off northwestern Nova Scotia, 4000 tons (1967–68), 22,000 tons (1968–69) and 32,000 tons (1969–70). In 1969–70 an estimated 15% increase in fishing intensity produced an 8% increase in catch.

In autumn 1969 water temperatures 2–3 C above normal in the upper 90 m undoubtedly inhibited movement and concentration of herring schools into the southwestern Newfoundland fjords where they could be readily located and fished by seiners. Landings in October–December 1969 were 16,000 tons lower than in the same period in 1968 although there was an increase in the seiner fleet.

Indications from larval surveys along southwestern Newfoundland in autumn 1969 are that late summer and early autumn spawning is insignificant and south coast waters cannot be considered as a major spawning area for large numbers of autumn-spawning herring which over-winter in south coast fjords.

In a study of herring migration samples of herring from the Magdalen Islands in November, and southwestern Newfoundland shortly after, were not significantly different in length, age, and maturity condition, vertebral numbers, fin-ray numbers, and *Anisakis* nematode infestation. The results support the hypothesis that the winter fishery along southwestern Newfoundland is largely dependent on herring concentrations which migrate eastward in the autumn from the southern Gulf of St. Lawrence.

Twenty-five thousand herring were tagged with internal tags and released in La Poile Bay, Newfoundland in early March 1970. By September 30, 1970, recoveries were as follows: 391 in southwestern Newfoundland to mid-April, 64 at Magdalen Islands in April–May, and 70 in the southwestern Gulf of St. Lawrence (American Bank, Gaspé, Chaleur Bay) in June–September. This confirms the westward movement of the herring schools after they leave southwestern Newfoundland in the spring.

Significant differences in numbers of gillrakers and fin rays between spring- and autumn-spawning herring, which over-winter along southwestern Newfoundland, are attributed largely to environmental conditions. Autumn-hatched larvae develop when surface water temperatures are decreasing, whereas those hatched in spring or early summer develop when the temperatures are increasing. This indicates that spring- and autumn-spawning herring are not a homogeneous group but constitute distinct breeding populations developing at different times of the year under different environmental conditions.

Research surveys in summer and autumn 1969 revealed no significant herring concentrations in bays of eastern Newfoundland and Labrador. Maturity condition indicated that eastern Newfoundland herring were predominantly spring spawners and the Labrador herring mostly late summer and early autumn spawners. Age composition of eastern Newfoundland samples revealed the dominance of the 1963 year-class as predicted from an abundance of 1-year-olds in 1964.

Capelin

A survey in June 1969 to study abundance, distribution, and spawning characteristics revealed the presence of large concentrations of spawning capelin on the

southern and western parts of the Southeast Shoal of the Grand Bank. Catches over 6000 lb were obtained in 30-minute otter-trawl hauls. Bottom water temperatures were 3.1 to 4.5 C in 24–30 fath. The fat content of samples ranged from 1.3 to 2.6%.

Sand Lance

Analyses of meristic and morphometric data of sand lance in the Newfoundland area indicated that specimens taken on the Grand Bank and St. Pierre Bank were slender with relatively short heads and high meristic numbers whereas those from Trinity and St. Mary's bays were deep bodied with relatively long heads and lower meristic numbers. The offshore lance were consequently assigned to the species *Ammodytes dubius* and those from inshore to *Ammodytes hexapterus*.

Mackerel

The capture of juvenile mackerel in Conception Bay, Newfoundland, in November 1968 represents the first documented record of the occurrence of 0-group mackerel in eastern Newfoundland waters. This indication of possible sporadic mackerel spawning in the eastern or southern Newfoundland area was confirmed by the capture of prespawning and spawning mackerel in Placentia Bay in early July 1970. Although there is considerable year-to-year variation in the temperature pattern and thickness of the warm surface layer in summer in the bays of southern and eastern Newfoundland, surface water temperature conditions are suitable for mackerel egg and larval development in some years.

A research vessel cruise to the southern part of Labrador in August 1969 revealed mackerel to be unusually abundant in many areas and specimens were caught as far north as Black Island (53°46′N). The previously authenticated northern range limit was Triangle Harbour (52°50′N).

Anadromous Fishes

Atlantic Salmon

The Atlantic salmon research program is directed entirely toward studies of salmon in the sea, and the effects of high seas and coastal fisheries on salmon stocks. Evaluation of techniques for stock identification received high priority, and included studies of salmon scales as well as other morphometric and meristic characters, tagging, parasite studies, and biochemical systematics.

Drift-net tagging experiments were conducted off Port aux Basques, Newfoundland and at West Greenland in 1969. Over 40% of the tags applied at Port aux Basques have been returned, virtually all from the Gulf of St. Lawrence and rivers flowing into the Gulf. Tags applied at West Greenland have been returned from the Greenland fisheries, from Canada, and from the United Kingdom and Irish Republic.

Tagging in 1970 was carried out in the Miramichi drift netting area, in the Labrador Sea, and off West Greenland.

Experimental fishing with different mesh sizes and types of twine was conducted in conjunction with the tagging experiments. Preliminary results indicate that fish taken by monofilament nets are in better condition for tagging and suffer a lower tagging mortality than those caught in synthetic polyfilament nets.

Investigation of various protein systems in Atlantic salmon revealed that qualitative differences were present in two of the blood serum protein systems, allowing identification of fish taken on the high seas as either North American or European. A sample taken at West Greenland in 1969 was classified as 43% North American and 57% European. This result was substantiated by examination of smolt ages and parasite counts, and by comparison with a sample of tagged fish of North American origin recovered at West Greenland.

Work on salmon parasites was confined to species which earlier studies had indicated might be useful as biological tags. It was concluded that specimens of the larval nematode *Anisakis* in salmon from both sides of the Atlantic were of the same species. North American salmon at West Greenland appear to contain fewer *Anisakis* larvae than European fish from the same area. On the other hand, the incidence of the tapeworm *Eubothrium crassum* appears to be higher in North American fish. Preliminary work on variations in *Anisakis* abundance in Canadian rivers indicates that identification of stocks which have been to Greenland seems possible. Thus salmon caught in the Miramichi and Chaleur Bay areas harbor *Anisakis* populations similar to those in North American salmon taken at Greenland.

Biochemical studies on parasites of salmon and other species revealed that this technique could be used to identify species of larval forms of various parasites.

A program of commercial sampling was begun to provide quantitative descriptions of sizes and ages of salmon taken in various commercial fisheries, in particular to allow estimation of one- and two-sea-winter salmon in catches so that effects of West Greenland fishing may be elucidated.

Pink Salmon

Following transplants of 3.4 million eggs in 1964, 3.3 million in 1965, and 5.9 million in 1966, the largest run of returning adults occurred in 1967, from the 1965 transplant (5334 to the river and about 3000 from commercial fisheries). No transplanting has been carried out since 1966.

Returns from natural spawning only occurred for the first time in 1969 (from the 1967 spawning). These were disappointingly low, 1116 returns to the river plus about 1500 to the commercial fishery and other rivers from 5334 spawning adults in 1967.

Returns in 1970 are the progeny of 1353 spawning fish in 1968. An exact count is not available as the counting facility was damaged in flood conditions during the spawning run. However, it appears that the fish spawning in 1968 were at least replaced in 1970, on the basis of redd counts in the spawning channel and river.

Commercial Invertebrates

Queen Crab

The Industrial Development Branch and the Fisheries Research Board cooperated on an extensive program of exploratory fishing for queen crabs in the Newfoundland–Labrador area. In 1969 three vessels surveyed likely areas on the south and east coasts of Newfoundland; in 1970 one vessel examined many of the remaining areas. Excellent results were obtained in White, Notre Dame, and Placentia bays (max 700 lb/trap).

In an experiment in Trinity Bay in 1969 a total of 2400 crabs was tagged. Recoveries have shown no appreciable movements of tagged crabs.

Lobsters

The growth of lobsters tagged with a ferromagnetic tag and those tagged with the "sphyrion tag" were found to be similar. The very small size of the ferromagnetic tag and its nature of insertion minimizes any possible detrimental effects of these tags on the growth of the tagged lobster so we may conclude that adverse effects of the much more easily handled "sphyrion tag" are also minimal.

Aquarium experiments with larval lobsters have shown delays in time of molting of lobster larvae held over sandy bottom compared with larvae held over rocky bottom. Indications are that this delay in molting time, while most evident in 4th–5th state molts, was also present in earlier stages.

Squid

In 1970 as in 1969 the Newfoundland fishery was practically a complete failure. In 1970 squid appeared at a few places on the south coast of Newfoundland. Through cooperation with the Department's Bait Service, biological samples were obtained.

Attempts in February–March 1969 were unsuccessful at locating young juveniles and/or spawning concentrations of *Illex* in the area of the continental shelf from Delaware to Florida.

In 1970, during two research vessel cruises (May and July) to the southwestern area of the Grand Bank, St. Pierre Bank, and Scotian Shelf, the distribution, abundance, and biology of squid were studied with special reference to characterizing the migrating

populations by size, distribution, and parasite burden. Most squid were found in the area of the Eastern Gully of the Grand Bank in both trips.

Hydrography

In July–August 1969 the usual six hydrographic sections were occupied from Labrador to the southern Grand Bank. At Station 27, 2 miles off Cape Spear, hydrographic observations are taken monthly or more often throughout the year.

Placentia Bay Pollution

Herring Movements

Dead and dying "red" herring were first reported from Long Harbour in February 1969, and were reported from various parts of Placentia Bay until April; red herring were also reported in St. Mary's Bay in April. Analysis of these reports and results of associated fish surveys using the *Investigator II*, *Marinus*, and *A.T. Cameron* in February–March revealed how herring affected by pollution (suspected and later confirmed to be phosphorus discharged into Long Harbour in the effluent of the ERCO plant) spread widely from the initial point of contact.

Large schools of herring entering Placentia Bay in January moved through the polluted area in Long Harbour in early February where heavy mortalities occurred. However, survivors both unaffected and affected continued northward to the head of the bay then southward on the western side in March, many dying enroute. As spawning time approached a return migration occurred over the same route but with the proportion of "red" herring greatly reduced. Large schools of herring re-entered the Long Harbour area in early April and large numbers died. The survivors proceeded out on the eastern side of the Bay and entered St. Mary's Bay in late April, where spawning eventually occurred.

Red Herring Symptoms

The most obvious symptoms observed in red herring were the intense red coloring of the dermis and the water consistency of the blood. Subsequent hematocrit determinations gave values of 0–7% for red herring compared with 37–57% for normal herring. There was extensive destruction of the erythrocytes, with dispersal of cytoplasmic and nuclear material through the serum. Other gross symptoms included jaundiced liver, red fluid, and cellular debris in the eyes, yellowish to bright green intestines, and general absence of food in the stomachs. The symptoms did not conform with any known diseases but were similar to those caused by arsine and phosphine poisoning in man. This led to consideration of the chemicals in the effluent of the phosphorus plant in Long Harbour and confirmation of phosphorus poisoning of the herring.

Other Species

In research cruises in March and June in Placentia Bay, cod, haddock, American plaice, witch and yellowtail flounder, and Greenland halibut were caught. The fish exhibited no abnormal redness. Hematocrits of cod indicated normal values and histological examination of various organs revealed no definite abnormalities.

Examination of redness in fins of cod thought to be evidence of phosphorus poisoning indicated the condition was common in all areas both in and remote from Placentia Bay. The redness was evidently the result of hemorrhaging caused during catching and handling and was normal for all gears and areas studied.

MEMBERS OF THE BOARD

The members of the Board during the calendar years 1969 and 1970 were:

F. R. Hayes, Ph.D., D.Sc.; Hon. Degrees: LL.D.(Dalhousie), D.Sc.(Memorial); F.R.S.C.; *Chairman*, retired May 1969

J. R. Weir, Ph.D.; Hon. Degree: D.Sc.(Manitoba); F.A.I.C., F.A.A.A.S., F.R.S.A.; *Chairman*, from May 1969

B. Blais, General Manager, St. Lawrence Sea Products Co., Quebec, Que. (1972)*

D. A. Chant, Ph.D.; Chairman, Department of Zoology, University of Toronto, Toronto, Ont. (1974)

R. H. Common, D.Sc., Ph.D.; F.A.I.C., F.R.I.C.; Chairman of the Department of Agricultural Chemistry, Macdonald College, Que. (1973)

R. D. Connor, Ph.D.; Dean of Science, University of Manitoba, Winnipeg, Man. (1971)

D. F. Corney, President, Freshwater Fish Marketing Board, Winnipeg, Man. (1971)

E. S. Deevey, Ph.D.; F.A.A.A.S.; Killam Professor of Biology, Dalhousie University, Halifax, N.S. (1973)

H. A. Favre, Ing.Chim.Dipl.(Swiss Federal Institute of Technology), E.P.F., D.Sc.; Dean of Science, University of Montreal, Montreal, Que. (1974)

G. Filteau, Ph.D.; Head, Department of Biology, University of Laval, Quebec, Que. (1973)

F. E. J. Fry, M.B.E., Ph.D.; F.R.S.C.; Professor, Department of Zoology, University of Toronto, Toronto, Ont. (1969)

E. L. Harrison, Executive Vice-President, B.C. Packers Limited, Vancouver, B.C. (1973)

W. S. Hoar, Ph.D.; Hon. Degrees: D.Sc.(Memorial, New Brunswick); F.R.S.C.; Head, Department of Zoology, University of British Columbia, Vancouver, B.C. (1970)

R. R. Logie, Ph.D.; Assistant Deputy Minister, Fisheries Service, Department of Fisheries and Forestry, Ottawa, Ont. (1974)

L. E. Marion, C.C., M.B.E., Ph.D.; Hon. Degrees: D.Sc.(Laval, Ottawa, Queen's, Montreal, Paris, British Columbia, Carleton, Royal Military College, McGill, Poznam), LL.D.(Toronto, Saskatchewan), D.C.L.(Bishop's); F.R.S., F.R.S.C., F.C.I.C.; Dean, Faculty of Science, University of Ottawa, Ottawa, Ont. (1970)

M. O. Morgan, M.A.; Hon. Degrees: LL.D.(Mount Allison, New Brunswick); Vice-President Memorial University of Newfoundland, St. John's, Nfld. (1970)

J. B. Morrow, Vice-President, National Sea Products, Lunenburg, N.S. (1973)

L. H. Omstead, Jr., Omstead Fisheries Limited, Wheatley, Ont. (1973)

T. P. Pallant, Prince Rupert, B.C. (1972)

G. L. Pickard, M.B.E., D.Phil.; F.R.S.C.; Director, Institute of Oceanography, University of British Columbia, Vancouver B.C. (1972)

C. C. Pratt, President, Steers Limited, St. John's, Nfld. (1972)

W. M. Sprules, Ph.D.; Director, International Fisheries Branch, Department of Fisheries and Forestry, Ottawa, Ont. (1969)

The Deputy Minister of Fisheries and Forestry is also invited to attend meetings of the Board and the Executive Committee.

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* Appointment expires at end of year indicated.

STAFF

Office of the Chairman

F. R. Hayes, Ph.D., D.Sc.(Liverpool); Hon. Degrees: LL.D.(Dalhousie), D.Sc.(Memorial); F.R.S.C.; *Chairman*, retired May 1969

J. R. Weir, Ph.D.(Minnesota); Hon. Degree: D.Sc.(Manitoba); F.A.I.C., F.A.A.A.S., F.R.S.A.; *Chairman*, from May 1969

W. R. Martin, Ph.D.(Michigan); *Deputy Chairman (Operations)*

D. A. Munro, Ph.D.(Toronto); *Deputy Chairman (Policy and Planning)*, from August 1970

J. A. Rogers, A.C.B.A.; *Director of Administration*

W. E. Ricker, Ph.D.(Toronto); F.R.S.C.; *Chief Scientist*, stationed at Nanaimo, B.C.

J. P. Tully, M.B.E., Ph.D.(Washington); F.R.S.C.; *Oceanographic Consultant* and Secretary of the Canadian Committee on Oceanography, retired September 1969

C. J. Kerswill, Ph.D.(Toronto); *Program Coordinator–Commercial and Recreational Fisheries*, from August 1970

K. S. Ketchen, Ph.D.(Toronto); *Acting Biological Consultant*, to June 1969, seconded from the Biological Station, Nanaimo

M. Waldichuk, Ph.D.(Washington); *Oceanographic Consultant* and Secretary of the Canadian Committee on Oceanography, from September 1969 to July 1970, seconded from the Biological Station, Nanaimo

F. D. McCracken, Ph.D.(Toronto); *Acting Biological Consultant*, from August 1969 to June 1970, seconded from the Biological Station, St. Andrews

M. P. Shepard, Ph.D.(Toronto); *Adviser, Pacific*, from September 1970, seconded from the Biological Station, Nanaimo

R. W. Trites, Ph.D.(British Columbia); *Adviser, Atlantic*, from September 1970, seconded from Marine Ecology Laboratory

G. F. M. Smith, M.B.E., Ph.D.(Toronto); *Biological Consultant*, from March 1970, seconded to International Fisheries Branch, Department of Fisheries and Forestry, Ottawa

L. M. Lauzier, D.Sc.(Laval); F.R.S.C.; *Program Coordinator–Environmental (Oceanography and Limnology)*, from July 1970

J. S. Willmer, Ph.D.(Liverpool); *Program Coordinator–Products and Processing*

G. I. Pritchard, Ph.D.(North Carolina State); *Program Coordinator–Aquaculture*

Office of the Editor

J. C. Stevenson, Ph.D.(Toronto), *Editor and Director of Scientific Information*

L. W. Billingsley, Ph.D.(McGill), *Associate Editor*

R. H. Wigmore, M.Sc.(McGill), *Assistant Editor*

R. L. MacIntyre, *Chief of Publication Production*

J. Camp, *Administrator of Scientific Documentation*

Biological Station
Nanaimo, British Columbia

K. R. Allen, M.A.(Cantab.), *Director*; seconded to Ottawa August 1969 to April 1970

K. S. Ketchen, Ph.D.(Toronto), *Assistant Director*; to August 1969; *Acting Director* August 1969 to April 1970; *Assistant Director* from April 1970

G. L. Robins, Ph.D.(Liverpool), *Scientific Assistant to Director*

I. J. Strong, B.A.(British Columbia), *Executive Assistant*; to September 1970

Environmental Research Group

T. R. Parsons, Ph.D.(McGill), *Head*; lake fertilization
R. A. Bams, Phil.D.(Leiden), eggs and alevins
J. I. Manzer, M.A.(British Columbia), biological oceanography
R. J. LeBrasseur, Ph.D.(Glasgow), biological oceanography
O. D. Kennedy, B.Sc.(Halifax), biological oceanography
C. D. McAllister, M.A.(British Columbia), biological oceanography
J. C. Mason, Ph.D.(Oregon State), ecology and production of freshwater fish
J. H. Mundie, Ph.D.(London–Imperial College), stream ecology
D. W. Narver, Ph.D.(Washington), logging and stream ecology
R. R. Parker, Ph.D.(British Columbia), estuarine pollution
W. P. Wickett, M.A.(British Columbia), fisheries oceanography
W. E. Barraclough, M.A.(British Columbia), fisheries oceanography
J. D. Fulton, B.Sc.(British Columbia), lake fertilization

Fisheries Biology Group

S. J. Westrheim, M.Sc.(Washington), *Head*, groundfish
W. A. Kennedy, Ph.D.(Toronto), groundfish
F. C. Withler, M.A.(British Columbia), salmon hybridization
H. Godfrey, M.A.(British Columbia), chinook and coho
H. T. Bilton, B.A.(British Columbia), salmon stock assessment
J. McDonald, M.A.(British Columbia), salmon development
H. W. D. Smith, M.Sc.(Washington), Babine sockeye
M. P. Shepard, Ph.D.(Toronto), international salmon studies; seconded to Ottawa September 1970
K. V. Aro, B.A.(British Columbia), international salmon studies
F. H. C. Taylor, Ph.D.(California), pelagic fishes
D. N. Outram, B.A.(British Columbia), pelagic fishes
D. B. Quayle, Ph.D.(Glasgow), marine invertebrates
N. Bourne, Ph.D.(Toronto), marine invertebrates
T. H. Butler, M.A.(British Columbia), shrimp and crab
R. J. Ghelardi, Ph.D.(Scripps), lobster investigation
A. S. Hourston, Ph.D.(California), population biology

Experimental Biology and Pathology Group

L. Margolis, Ph.D.(McGill), *Head*, parasitology
Z. Kabata, D.Sc.(Aberdeen), parasitology
N. P. Boyce, M.Sc.(Calgary), parasitology
J. R. Brett, Ph.D.(Toronto), physiology
J. E. Shelbourn, M.Sc.(British Columbia), physiology
G. R. Bell, Ph.D.(Western Ontario), microbiology
T. P. T. Evelyn, Ph.D.(British Columbia), microbiology
D. F. Alderdice, Ph.D.(Toronto), physiology ecology
J. R. Calaprice, Ph.D.(California), genetics
C. Groot, Ph.D.(Leiden), ethology

Pacific Oceanographic Group

M. Waldichuk, Ph.D.(Washington), *Head*, pollution; to September 1970
S. Tabata, D.Sc.(Tokyo), physical oceanography; to April 1970
L. F. Giovando, Ph.D.(British Columbia), physical oceanography; to April 1970
P. B. Crean, M.A.Sc.(Toronto), physical oceanography; educational leave October 1969–October 1971; to September 1970
A. J. Dodimead, M.Sc.(British Columbia), continental shelf and near ocean studies; to September 1970

Scientific Support Services

G. L. Robins, Ph.D.(Liverpool), *Head*, scientific support services
W. H. Bell, M.Sc.(Hawaii), P.Eng., engineering research and development; to September 1970
J. S. Ford, B.Sc.(British Columbia), P.Eng., engineering research and development
J. A. C. Thomson, M.Sc.(McGill), computations
E. A. Young, B.A.(British Columbia), B.I.Sc.(Toronto), *Librarian*
R. M. Humphreys, fish culture

Seconded

C. S. Wong, Ph.D.(Scripps), seconded from Department of Energy, Mines and Resources

Non-Staff

H. P. Arai, Ph.D.(University of California, Los Angeles), visiting scientist
M. N. Arai, Ph.D.(University of California, Los Angeles), visiting scientist
J. McInerney, Ph.D.(British Columbia), visiting scientist
E. Triplett, Ph.D.(Stanford University, California), visiting scientist
T. Yusa, Ph.D.(Tohoku), on FRB contract
Y. Kitano, B.Agr.(Hokkaido), exchange scientist from Japan
G. Hewitt, Ph.D.(Victoria University of Wellington, New Zealand), National Research Council fellowship
M. C. Healey, Ph.D.(British Columbia), National Research Council fellowship
C. J. Berkeley, Hon. LL.D.(Victoria), F.C.I.C., honorary research associate
R. E. Foerster, Ph.D.(Toronto), honorary research associate
F. Neave, Ph.D.(British Columbia), F.R.S.C., honorary research associate

Vancouver Laboratory
Vancouver, British Columbia

H. L. A. Tarr, Ph.D.(McGill; Cantab.), F.R.S.C., *Director*
N. Tomlinson, Ph.D.(California), *Assistant Director*
Z. S. Wozny, *Executive Assistant*; from May 1969
A. D. J. Hackie, B.L.A.(McGill), *Librarian*

Biochemistry and Physiology

N. Tomlinson, Ph.D.(California), biochemistry of muscle, storage, and processing of fish
H. Tsuyuki, Ph.D.(Wisconsin), chemistry of fish speciation
E. Bilinski, D.Sc.Agr.(Louvain), lipid biochemistry
W. E. Vanstone, Ph.D.(McGill), physiology of salmonids
E. M. Donaldson, Ph.D.(British Columbia), endocrinology
D. E. Kramer, Ph.D.(California), enzymology, storage, and processing of fish
J. R. McBride; M.A.(British Columbia), histophysiology
U. H. M. Fagerlund, M.Sc.(Abo), endocrinology
R. E. E. Jonas, B.A.(Madras), lipid biochemistry
E. Roberts, B.Sc.(Manitoba), chemistry of fish speciation
S. E. Geiger, B.A.(British Columbia), biochemistry of muscle, storage, and processing of fish
J. R. Markert, B.Sc.(British Columbia), physiology
R. E. Hurst, B.Sc.(Victoria), biochemistry
S. N. Williscroft, B.Sc.(British Columbia), chemistry of fish speciation; from April 1969

Chemistry

R. J. Bose, Ph.D.(Minnesota), flavors, mass and NMR spectrometry
J. N. C. Whyte, Ph.D.(Edinburgh), algal polysaccharides
M. D. Peters, B.Sc.(British Columbia), flavors and attractants

Microbiology and Food Technology

H. L. A. Tarr, Ph.D.(McGill; Cantab.), microbiology, nucleic acid metabolism
N. J. Antia, Ph.D.(Zurich), organic chemistry phytoplankton
G. A. Strasdine, Ph.D.(British Columbia), industrial fermentations; botulism
M. Yamamoto, Ph.D.(British Columbia), enzymes
H. A. Buttkus, M.A.(California), amino acids, proteins
J. W. Boyd, B.S.A.(British Columbia), fish preservation
B. A. Southcott, B.S.A.(British Columbia), fish preservation
P. J. Schmidt, B.E.(Saskatchewan), color of fish flesh

Engineering

S. W. Roach, B.A.Sc.(British Columbia), mechanical engineering

F. G. Claggett, B.A.Sc.(British Columbia), chemical engineering

Non-Staff

P. Ingram, Ph.D.(Glasgow), National Research Council postdoctoral fellow; from October 1968 to September 1969

W. W. Philleo, Ph.D.(Hawaii), National Research Council postdoctoral fellow; from August 1969 to July 1970

J. R. Botta, B.Sc.(Agr.) (British Columbia), postgraduate student, FRB grant; from September 1969

C. D. Brown, M.Sc.(British Columbia); from September 1970

J. D. Funk, B.Sc.(British Columbia), postgraduate student, FRB grant; from April 1969

M. A. Giles, B.Sc.(Manitoba), postgraduate student, FRB grant; from August 1967

A. F. Landymore, B.Sc.(British Columbia), postgraduate student, FRB grant; from June 1968

B. Mason, B.Sc.(British Columbia), postgraduate student, FRB grant; from September 1968 to April 1970

M. Don-Paul, M.Sc.(Bombay); from May 1970

Pacific Environment Institute
West Vancouver, British Columbia

M. Waldichuk, Ph.D(Washington), *Program Head*; from September 1970

W. H. Bell, M.Sc.(Hawaii), P.Eng., engineering research and development

P. B. Crean, M.A.Sc.(Toronto), physical oceanography

A. J. Dodimead, M.Sc.(British Columbia), physical oceanography

L. F. Giovanda, Ph.D.(British Columbia), physical oceanography

S. Tabata, D.Sc.(Tokyo), physical oceanography

Freshwater Institute
Winnipeg, Manitoba

W. E. Johnson, Ph.D.(Wisconsin), *Director*

E. G. Bligh, Ph.D.(McGill), *Assistant Director*

S. E. Schick, *Executive Assistant*

K. E. Marshall, B.Sc.(London) *Librarian*

L. C. Dugal, D.Sc.(Laval), *Scientific Assistant to Director*; from April 1970

Eutrophication

J. R. Vallentyne, Ph.D.(Yale), *Scientific Leader*

F. A. J. Armstrong F.R.I.C., chemical limnology; to November 1970

J. Barica, Ph.D.(Prague), analytical chemistry; from October 1969

G. J. Brunskill, Ph.D.(Cornell), biogeochemistry

A. L. Hamilton, Ph.D.(British Columbia), aquatic insects

R. D. Hamilton, Ph.D.(Miami), microbiology; from June 1969

F. P. Healey, Ph.D.(California), algal physiology; from October 1970

S. Holmgren, Fil.lic.(Uppsala), phytoplankton ecology; from January 1969 to May 1970

K. Patalas, D.Sc.(Wroclaw), zooplankton communities; from December 1969

D. Povoledo, M.D.(Padua), molecular ecology

O. A. Saether, Cand.real.(Oslo), bottom fauna; from May 1968

D. W. Schindler, D.Phil.(Oxford), production ecology

J. G. Stockner, Ph.D.(Washington), phytoplankton ecology

Canada Centre for Inland Waters
Burlington, Ontario

R. A. Vollenweider, Ph.D.(Zurich), *Chief, Lakes Division*
W. A. Glooschenko, Ph.D.(Oregon), phytoplankton ecology; from April 1970
A. Nauwreck, Fil.dr.(Uppsala), plankton ecology; from March 1970

Fisheries Technology

E. G. Bligh, Ph.D.(McGill), *Scientific Leader*
F. A. J. Armstrong, F.R.I.C. heavy metal pollution; from November 1970
J. W. Clayton, Ph.D.(Saskatchewan), protein chemistry
L. C. Dugal, D.Sc.(Laval), chemistry of quality
M. Freese, M.Sc.(McGill), biophysical engineering
D. C. Gillespie, Ph.D.(Western Reserve), microbiology
A. W. Lantz, B.Sc.(Alberta), products and processing; to October 1970
S. V. Manohar, Ph.D.(McGill), postmortem biochemistry
K. R. Scott, B.A.Sc.(Toronto), refrigeration engineering
J. F. Uthe, Ph.D.(Western Ontario), pesticide residues
M. Yurkowski, Ph.D.(Guelph), nutritional biochemistry

Fish Population Dynamics

L. Johnson, Ph.D.(Leeds), *Scientific Leader*
T. J. Hara, Ph.D.(Tokyo), physiology; from February 1969
M. C. Healey, Ph.D.(Aberdeen), fish ecologist; from September 1970
G. H. Lawler, Ph.D.(Toronto), experimental fisheries
A. H. Lawrie, M.A.(Toronto), fisheries surveys; to April 1969
P. J. Lee, Ph.D.(McMaster), mathematical statistics
J. C. MacLeod, Ph.D.(Minnesota), fish physiology; seconded to Ottawa September 1970
E. Scherer, Ph.D.(Giessen), fish physiology
D. P. Scott, Ph.D.(British Columbia), fish physiology
L. A. Sunde, M.Sc.(British Columbia), experimental fisheries

Non-Staff

A. Otsuki, Ph.D.(Tokyo), chemical limnology, National Research Council postdoctoral fellow; from September 1969 to September 1971.

Arctic Biological Station
Ste. Anne de Bellevue, Quebec

C. J. Kerswill, Ph.D.(Toronto), *Director*; to July 1970
A. W. Mansfield, Ph.D.(McGill), *Acting Director*; from August 1970
C. A. Lepine, B.Sc.(Loyola), *Executive Assistant*
J. A. Currie, B.S.(Toronto), *Librarian*

Marine Mammals

A. W. Mansfield, Ph.D.(McGill)
M. A. Bigg, M.Sc.(British Columbia); from July 1970
E. D. Mitchell, Ph.D.(California, Berkely)
G. C. Pike, M.A.(British Columbia); to December 1968
D. E. Sergeant, Ph.D.(Cantab.)

Biological Oceanography

E. H. Grainger, Ph.D.(McGill)
A. S. Bursa, Ph.D.(Krakow)
J. W. Wacasey, Ph.D.(Michigan State)

Fisheries

J. G. Hunter, Ph.D.(McGill)
K. M. Muth, M.S.(Marine); to May 1969

Office of the Atlantic Regional Director, Research
Halifax, Nova Scotia

D. R. Idler, D.F.C., Ph.D.(Wisconsin), *Regional Director*; from September 1969
H. E. Power, B.E.(Nova Scotia Technical College), P.Eng., *Assistant to Regional Director*; from January 1970
T. D. Iles, B.A.(Wales), *Herring Coordinator*; from October 1970
C. Jackson, *Executive Assistant*; from March 1970
P. M. Jangaard, M.Eng.(Nova Scotia Technical College), P.Eng., *Scientific Liaison Officer*; from September 1969
W. H. Sparling, *Research Vessel Manager*; from September 1969

Biological Station
St. Andrews, New Brunswick

J. M. Anderson, Ph.D.(Toronto), *Director*
F. D. McCracken, Ph.D.(Toronto), *Assistant Director*; seconded to Ottawa from August 1969 to July 1970
J. S. Scott, Ph.D.(St. Andrews), *Acting Assistant Director*; from August 1969
A. Weinsieder, M.S.(Vermont), *Assistant to Director*; to August 1969
B. G. Weinsieder, B.A.(New Brunswick), B.L.S.(Toronto), *Librarian*; to August 1969

Anadromous

P. F. Elson, Ph.D.(Toronto), ecology of salmon
M. W. Smith, Ph.D.(Toronto), ecology of Atlantic anadromous fishes; to January 1970
D. Møller, Ph.D.(Oslo), stock identification by biochemical genetics; to September 1970
J. W. Saunders, M.Sc.(Laval), ecology of salmon and trout
J. H. C. Pippy, M.Sc.(Memorial), parasitology of fishes; to January 1969
A. B. Stasko, Ph.D.(Toronto), orientation in salmon migration and sonic tracking; from September 1970

Behavior

J. M. Anderson, Ph.D.(Toronto), neurophysiological effects of insecticides
D. W. McLeese, Ph.D.(Toronto), physiological behavior of Crustacea
U. Buerkle, M.Sc.(McGill), hearing in fish; on educational leave from September 1969 to May 1970
A. M. Sutterlin, Ph.D.(Massachusetts), fish neurophysiology
P. E. K. Symons, Ph.D.(Leiden), salmon behavior and ecology
R. H. Peterson, Ph.D.(Carleton), fish neurophysiology; casual, from September 1970

Fisheries Oceanography

L. M. Lauzier, D.Sc.(Laval), environmental factors for fishes; to July 1970

Gear Research

P. J. G. Carrothers, S.M.(Massachusetts Institute Technology), engineering studies in fishing gear; on sabbatical leave from July 1969 to July 1970

Groundfish

A. C. Kohler, Ph.D.(McGill), population and growth studies of groundfish
J. S. Scott, Ph.D.(St. Andrews), ecology of underutilized fishes, parasitology
R. G. Halliday, Ph.D.(Glasgow), groundfish ecology and stock assessment
A. V. Tyler, Ph.D.(Toronto), fish metabolism and inter-species associations

Invertebrates

D. G. Wilder, Ph.D.(Toronto), lobster stocks
J. C. Medcof, Ph.D.(Illinois), underexploited molluscs
D. J. Scarratt, Ph.D.(Wales), lobster ecology
D. E. Aiken, Ph.D.(Alberta), lobster growth
J. F. Caddy, Ph.D.(London), biology of scallops and other molluscs

J. Watson, Ph.D.(Durham), crab populations and ecology

Pelagic

S. N. Tibbo, M.S.(Toronto), ecology and life history of herring and tuna

B. E. Barrett, Ph.D.(New Hampshire), herring ecology; to August 1969

J. S. Beckett, M.A.(Cantab.), swordfish and tuna; on educational leave to April 1969

S. N. Messieh, Dip.H.S.Oceanog.(Alexandria, Cairo), herring growth

T. D. Iles, B.A.(Wales), herring population and recruitment; casual, from January 1970 to October 1970

Pollution

J. B. Sprague, Ph.D.(Toronto), pollution biology; on sabbatical leave to September 1969; to September 1970

V. Zitko, C.Sc.(Slovak Academy Sciences), pollution chemistry

W. K. T. Besch, Ph.D.(Giessen), biological indicators in pollution; to October 1969

Physiology

R. L. Saunders, Ph.D.(Toronto), cardiovascular-respiratory physiology of fishes

Data Processing and Statistical Services

A. Sreedharan, M.S.(Massachusetts), statistics

Non-Staff

J. T. P. Baker, M.Sc., graduate student; (McGill University)

J. S. Bleakney, Ph.D., guest investigator; (Mount Allison University)

Q. Bone, Ph.D., guest investigator; Marine Biol. Assoc. Lab., Plymouth

J. Burns, M.Sc., graduate student; (University of New Brunswick)

M. J. A. Butler, M.Sc., graduate student; (McGill University)

S. Corey, Ph.D., guest investigator; (University of Guelph)

D. J. Davis, Ph.D., guest investigator; Nova Scotia Museum

E. Denton, Ph.D., guest investigator; Marine Biol. Assoc. Lab., Plymouth

K. Dormaar, M.Sc., graduate student; (University of Guelph)

D. J. Faber, Ph.D., guest investigator; Canadian Oceanographic Identification Centre

J. Fields, graduate student; (McGill University)

K. Fisher, M.Sc., graduate student; (University of Toronto)

M. Forsyth, M.Sc., graduate student; (University of Ottawa)

J. Freelander, M.Sc., graduate student; (McGill University)

D. G. Garnett, B.Sc., graduate student; (McGill University)

D. E. Gaskin, Ph.D., guest investigator; (University of Guelph)

J. Geraci, Ph.D., guest investigator; (McGill University)

B. Hannah, M.Sc., graduate student; (University of Illinois)

G. M. Hare, B.Sc., graduate student; (University of New Brunswick)

H. H. Harvey, Ph.D., guest investigator; (University of Toronto)

C. T. Hatfield, B.Sc., graduate student; (Queen's University)

C. Iles, Ph.D., guest investigator; Wales

D. Jackson, M.Sc., graduate student; (Carleton University)

N. Khan, M.Sc., graduate student; (University of Ottawa)

E. Kott, Ph.D., guest investigator; (Waterloo Lutheran University)

P. Lamourieux, M.Sc., graduate student; (McGill University)

J. Lewis, Ph.D., guest investigator; (McGill University)

R. A. Liversage, Ph.D., guest investigator; (University of Toronto)

J. Marsden, Ph.D., guest investigator; (McGill University)

D. F. Mettrick, Ph.D., guest investigator; (University of Toronto)

J. Middlemiss, APICS summer student; (Mount Allison University)

J. Patterson, M.Sc., graduate student; (McGill University)

K. W. Peterson, Ph.D., and M. Peterson, Ph.D., guest investigators; (Mount Allison University)

D. Pocock, M.Sc., graduate student; (McGill University)

P. M. Powles, Ph.D., guest investigator; (Trent University)

B. Price, M.Sc., graduate student; (University of Toronto)

L. Rowe, B.Sc., graduate student; (University of Waterloo)
D. Sanger, Ph.D., guest investigator; (University of New Brunswick)
W. Schaffer, M.A., graduate student; (Princeton University)
P. Schluger, Ph.D., guest investigator; (University of Pennsylvania)
W. B. Scott, Ph.D., guest investigator; Royal Ontario Museum
P. Shepheard, Ph.D., National Research Council postdoctoral fellow; St. Andrews
D. Schindler, M.Sc., graduate student; (University of Ottawa)
S. B. Singh, Ph.D., guest investigator; (Dalhousie University)
D. Snow, B.Sc., graduate student; (McGill University)
J. B. Sochasky, B.Sc., graduate student; (University of Guelph)
W. B. Stallworthy, Ph.D., guest investigator; (Mount Allison University)
J. Theodorides, Ph.D., guest investigator; Laboratoire d'Evolution, Paris
V. G. Vethamany, Ph.D., guest investigator; (Dalhousie University)
E. Waywell, M.Sc., graduate student; (University of Guelph)
C. Wendt, Ph.D., guest investigator; Department of Fisheries, Sweden
D. J. Wildish, Ph.D., National Research Council postdoctoral fellow; (London University)
K. Wilson, B.Sc., graduate student; (University of New Brunswick)
N. Wolfson, Ph.D., guest investigator; (McGill University)

Halifax Laboratory
Halifax, Nova Scotia

(including Technological Unit, St. John's, Newfoundland, and Technological Station, Grande-Rivière, Quebec; to March 31, 1970)

D. R. Idler, D.F.C., Ph.D.(Wisconsin), *Director*; to September 1969
J. E. Stewart, Ph.D.(Iowa), *Acting Director*; from September 1969 *Assistant Director* to September 1969
R. G. Ackman, Ph.D.(London), *Assistant Director*; from January 1970
H. E. Power, B.E.(Nova Scotia Technical College), P.Eng., *Assistant to Director*; to January 1970
P. M. Jangaard, M.Eng.(Nova Scotia Technical College), P.Eng., *Scientific Liaison Officer*; to September 1969
I. J. Rattray, *Executive Assistant*
M. A. Stephanopoli, B.L.Sc.(Ottawa), *Librarian*

Process and Product Research

L. W. Regier, Ph.D.(California), fish processing, fish protein concentrate
H. E. Power, B.E.(Nova Scotia Technical College), fish protein concentrate; to January 1970
R. Legendre, M.Eng.(McGill), chilling and freeze-drying; from Grande-Rivière March 1970
A. L. Wood, B.E.(Nova Scotia Technical College), P.Eng., chilling and freeze-drying; to July 1970
A. Saito, D.T.(Osaka), flavors, odors, colors
N. Damberts, Ing.Chim.(Nancy), fish protein concentrate
P. M. Wiseman, B.Sc.(Acadia), isolation of natural products; to August 1970

Deterioration and Prevention

R. F. Addison, Ph.D.(Queen's, Belfast), postmortem biochemical changes; to March 1970
S. N. Hooper, B.Sc.(New Brunswick), seasonal changes in lipids
C. H. Castell, M.S.A.(Toronto), processed quality
D. M. Bishop, M.Sc.(Dalhousie), processed quality; to April 1969
W. J. Dyer, Ph.D.(McGill), F.C.I.C., preservation of fish and shellfish (fresh and frozen)
D. I. Hiltz, B.Sc.(Acadia), preservation of fish and shellfish (fresh and frozen)
S. C. Nowlan, M.Sc.(Cornell), preservation of fish and shellfish (fresh and frozen)

Exploration Research

P. H. Odense, Ph.D.(Oklahoma), comparative biochemistry
Y. M. MacDougall, B.Sc.(St. Francis Xavier), comparative biochemistry; to September 1969
T. C. Leung, B.Sc.(Dalhousie), comparative biochemistry; from Grande-Rivière March 1970
J. R. Dingle, Ph.D.(Toronto), F.C.I.C., physical changes of protein
J. A. Hines, B.Sc.(St. Francis Xavier), physical changes of protein
H. Brockerhoff, Ph.D.(Cologne), metabolism and metabolic control
M. B. Wojtowicz, Ph.D.(Warsaw), metabolism and metabolic control; from Grande-Rivière March 1970
R. J. Hoyle, M.A.(Cantab.), metabolism and metabolic control
P. C. Hwang, M.Sc.(McGill), metabolism and metabolic control; to January 1970
H. S. Shieh, Ph.D.(McGill), lipids, metabolism, food chain
R. G. Ackman, Ph.D.(London), lipids, metabolism, food chain
J. C. Sipos, M.A.(Toronto), lipids, metabolism, food chain
M. J. Paradis, M.Sc.(Ottawa), lipids, metabolism, food chain, from September 1970.
M. S. Mounib, Ph.D.(Aberdeen), fish reproduction
J. S. Eisan, M.Sc.(Dalhousie), fish reproduction

Manipulation of Resource

H. C. Freeman, M.Sc.(Acadia), fish endocrinology
D. A. Horne, M.Sc.(Dalhousie), fish endocrinology
C. J. Sangalang, B.Sc.(Philippines), fish endocrinology
B. Truscott, M.Sc.(Queen's), fish endocrinology
M. W. Gilgan, Ph.D.(Wisconsin), shellfish endocrinology
M. E. Zinck, M.Sc.(Dalhousie), shellfish endocrinology; to March 1970
G. L. Fletcher, Ph.D.(California), fish physiology; to March 1970
J. E. Stewart, Ph.D.(Iowa), shellfish diseases and nutrition
B. Arie, M.Sc.(Tel Aviv), shellfish diseases and nutrition
J. W. Cornick, M.S.A.(Toronto), shellfish diseases and nutrition; from March 1969
G. S. Traxler, B.Sc.(Washington), shellfish diseases and nutrition; from January 1969
M. F. Li, Ph.D.(Alberta), shellfish diseases and nutrition
R. M. MacKelvie, Ph.D.(British Columbia), fish diseases and nutrition
C. M. Bentley, B.Sc.(Reading), fish diseases and nutrition; to August 1970
H. Artsob, M.Sc.(McGill), fish diseases and nutrition; to August 1969

Instrumentation

D. G. Ellis, B.Sc.Ch.Eng.(Queen's)

Special Staff

D. R. Idler, D.F.C., Ph.D.(Wisconsin), *Group Leader*, fish endocrinology, by special arrangement

Non-Staff

M. W. Weisbart, Ph.D.(British Columbia), National Research Council postdoctoral fellow; to August 1969
D. A. Taylor, B.Sc.(British Columbia), Cardinal Proteins Limited, fish protein concentrate; January to March 1970
T. M. Allen, B.Sc.(Ottawa), graduate student, FRB grant
C. M. Morrison, M.Sc.(Dalhousie), graduate student, NRC grant
D. Darrow, B.Sc.(Acadia), graduate student, FRB grant
R. A. Laycock, Ph.D.(Liverpool), on contract to Atomic Energy of Canada Limited and FRB
W. H. Owen, Ph.D.(Sydney), National Research Council postdoctoral fellow; from November 1969 to November 1970
T. T. Huong Nguyen, B.Sc.(Guelph), Colombo Plan trainee; from May to August 1969

Technological Unit
St. John's, Newfoundland

W. A. MacCallum, M.Sc.(Dalhousie), *Unit Chief*, refrigeration engineering
D. K. Shaw, Ph.D.(Capetown), biochemistry

of fresh and frozen fish, emphasis on carbohydrate biochemistry

R. J. Striha, M.Sc.(Victoria), biochemistry of fresh and frozen fish; from July 1970

G. W. Moss, B.Sc.(McGill), biochemistry of fresh and frozen fish; to December 1969

K. M. Kane, B.Sc.(Memorial), quality of frozen fish

J. T. Lauder, B.Sc.(Dalhousie), quality of frozen fish

Technological Station
Grande-Rivière, Quebec
(Closed March 31, 1970)

R. Legendre, M.Eng.(McGill), *Director*; to March 1970

H. P. Dussault, M.Sc.(McGill), preservation of fresh fish; to April 1969

T. C. Leung, B.Sc.(Dalhousie), comparative biochemistry; to March 1970

M. B. Wojtowicz, Ph.D.(Warsaw), preservation of fresh fish; to March 1970

Marine Ecology Laboratory
Bedford Institute
Dartmouth, Nova Scotia
(including Biological Substation Ellerslie, P.E.I.)

L. M. Dickie, Ph.D.(Toronto), *Director*
M. Blaxland, *Executive Assistant*

Environmental Oceanography

R. W. Trites, Ph.D.(British Columbia), physical oceanography to September 1970

D. H. Loring, Ph.D.(Manchester), geology and geochemistry

R. W. Sheldon, Ph.D.(Manchester), geology and geochemistry

E. M. H. Hassan, Ph.D.(New York), physical oceanography; from July 1969

I. W. Duedall, M.Sc.(Oregon State), chemical oceanography

D. P. Krauel, M.Sc.(Dalhousie), physical oceanography

Biological Oceanography

K. H. Mann, Ph.D.(Reading), D.Sc.(London), biological productivity

W. H. Sutcliffe, Ph.D.(Duke), zooplankton productivity

R. J. Conover, Ph.D.(Yale), zooplankton

A. Prakash, Ph.D.(British Columbia), phytoplankton

R. E. Drinnan, B.Sc.(London), estuarine culture

M. L. H. Thomas, Ph.D.(Dalhousie), estuarine ecology; to October 1970

T. C. Platt, Ph.D.(Dalhousie), primary productivity and zooplankton

D. V. Subba Rao, Ph.D.(Andhra India), primary productivity, National Research Council postdoctoral fellow; to October 1969

R. J. Miller, Ph.D.(North Carolina), benthic communities, National Research Council postdoctoral fellow; from October 1969

D. L. Peer, M.Sc.(Saskatchewan), benthos

Population Studies

B. S. Muir, Ph.D.(Toronto), population parameters

V. M. Brawn (Srivastava), Ph.D.(British Columbia), trophic relations

E. Alliot, Doc.Spec.(Marseilles), fish physiology; Canada Council postdoctoral fellow, Dalhousie University; to September 1969

D. D. Sameoto, Ph.D.(Queens), population dynamics

J. C. Smith, M.Sc.(British Columbia), fish metabolism

Fisheries Oceanography

L. M. Dickie, Ph.D.(Toronto)

P. C. Beamish, Ph.D.(British Columbia), bioacoustics; from March 1969

S. Paulowich, instrumentation

Environmental Quality

D. C. Gordon, Ph.D.(Dalhousie), biological oceanography; from October 1970

G. L. Fletcher, Ph.D.(California), physiology; from April 1970

R. F. Addison, Ph.D.(Queens Belfast), organic chemistry; from April 1970

S. R. Kerr, Ph.D.(Dalhousie), food chain dynamics; from April 1970

M. E. Zinck, M.Sc.(Dalhousie), biochemistry; from April 1970

Non-Staff

S. Poulet, Ph.D.(Marseilles), plankton; from May 1970

J. Anibie, Ph.D.(Paris), biological oceanography, FAO fellow; from March to September 1970

K. McKay, M.Sc.(Dalhousie), pelagic fish

J. C. McKinnon, M.Sc.(London), energetics

Biological Station
St. John's, Newfoundland

W. Templeman, O.B.E., Ph.D.(Toronto), F.R.S.C., *Director*

A. M. Fleming, M.A.(Toronto), *Assistant Director*

O. E. Wheeler, *Executive Assistant*

Groundfish

R. Wells, M.Sc.(Memorial), cod, northern and gulf

A. M. Fleming, M.A.(Toronto), cod, eastern, and groundfish statistics

A. T. Pinhorn, M.Sc.(Memorial), haddock and cod, southern

E. J. Sandeman, M.Sc.(Memorial), redfish; to December 1969

T. K. Pitt, M.A.(Toronto), pleuronectids

W. H. Lear, M.Sc.(Memorial), pleuronectids; to December 1969

W. Templeman, O.B.E., Ph.D.(Toronto), fish distribution and systematics

Pelagic Fishes

V. M. Hodder, M.Sc.(Memorial), herring, mackerel

G. H. Winters, M.Sc.(Memorial), herring, capelin, lance

L. S. Parsons, B.Sc.(Memorial), herring, mackerel

Anadromous Fishes

A. W. May, Ph.D.(McGill), Atlantic salmon, pink salmon

A. R. Murray, M.A.(Saskatchewan), Atlantic salmon; to July 1969

O. L. Nyman, Fil.Lic.(Uppsala), Atlantic salmon, biochemical genetics; to September 1970

A. A. Blair, Ph.D.(Toronto), pink salmon; to March 1970

J. H. C. Pippy, M.Sc.(Memorial), Atlantic salmon parasitology; transferred from St. Andrews, January 1969, educational leave from September 1970

W. H. Lear, M.Sc.(Memorial), Atlantic salmon; from January 1970

Commercial Invertebrates

E. J. Sandeman, M.Sc.(Memorial), crabs, shrimp; from January 1970

H. J. Squires, Ph.D.(Durham), lobsters, crabs, to July 1969

M. C. Mercer, M.Sc.(Memorial), cephalopods; educational leave from September 1969

G. P. Innis, M.Sc.(Memorial), lobsters

C. J. Pauls, B.Sc.(Memorial), crabs; May 1969 to September 1970

PUBLICATIONS AND REPORTS

The Board publishes two major scientific printed series – the monthly *Journal of the Fisheries Research Board of Canada,* and the irregular *Bulletin* series. The *Journal* increased in volume to 3379 pages in 1969 with 38% of the 304 articles published coming from Board scientists; the decrease to 2487 pages in 1970 brought the volume to midway in size between the 1966 and 1967 volumes. Again, 38% of the 254 articles were contributed by Board scientists. Nine bulletins were published in the 1969–70 period, including the 381-page work on the freshwater fishes of northwestern Canada and Alaska; two others were French editions of English bulletins.

The *Studies* for 1969 (photoreproductions of articles of primary research published by Board scientists in other scientific and technical periodicals) were bound in two parts. This concluded the binding of studies, although they continue to be listed each month in the *Journal* along with the name of the originating establishment.

The *Annual Report* for 1969 and for 1970 followed the popular format of the last few years. The previous *Review* covered the years 1967 and 1968; the present *Review* is for the years 1969 and 1970.

The issue numbers of various publications and reports of the Board for 1969 and 1970 were as follows: *Journal*, Vol. 16, 1–12, and Vol. 27, 1–12; *Bulletins* 1968–174 plus 151 and the preface to 164 in French; *Studies* 1263–1456, 1496–1504, 1513; Statistical Series of Circulars for the Biological Station, Nanaimo, 27 and 28; General Series of Circulars of the Biological Station, Nanaimo, 87–89; Circulars of the Research Laboratory, Vancouver, 41–46; General Series of Circulars of the Biological Station, St. Andrews, 54 and 55; Circulars of the Research Laboratory, Halifax, 35–38; Circulars of the Biological Station, St. John's, 16 and 17; Circular of the Office of the Atlantic Regional Director, Research, Halifax, 1.

Technical Reports 79, 86, 88, 90–150, 152–159, 161–175, 177–191, 193–198, 201, 203, 305–208, and 214 were issued in 1969 and 1970. These reports are research documents of sufficient importance to be preserved but not appropriate for scientific publication at the time of issue. They may be cited in publications, though they are of manuscript status.

The *Journal* and the *Bulletin* series are available by purchase. Issues as they appear are listed, with prices, in the daily checklists published by Information Canada, and also in the monthly and annual catalogues of Canadian Government publications. Applications for purchase of publications should be made to: Information Canada, Ottawa, Canada. The *Annual Report* and *Review* are available on request from the Office of the Editor.

Circulars and *Technical Reports* may be obtained while the supply lasts, on request from the Board establishment that issues them. Reprints of both *Journal* articles and of articles by FRB scientists published in other periodicals, may be obtained, if available, only from the author or originating FRB establishment listed below:

Fisheries Research Board of Canada
Biological Station
P.O. Drawer 100
Nanaimo, British Columbia

Fisheries Research Board of Canada
Vancouver Laboratory
6640 N.W. Marine Drive
Vancouver 8, British Columbia

Fisheries Research Board of Canada
Pacific Environment Institute
4160 Marine Drive
West Vancouver, British Columbia

Fisheries Research Board of Canada
Freshwater Institute
501 University Crescent
Winnipeg 19, Manitoba

Fisheries Research Board of Canada
Arctic Biological Station
P.O. Box 400
Ste. Anne de Bellevue, Quebec

Fisheries Research Board of Canada
Biological Station
St. Andrews, New Brunswick

Fisheries Research Board of Canada
Marine Ecology Laboratory
Bedford Institute
P.O. Box 1006
Dartmouth, Nova Scotia

Fisheries Research Board of Canada
Halifax Laboratory
P.O. Box 429
Halifax, Nova Scotia

Fisheries Research Board of Canada
Biological Station
St. John's, Newfoundland

Inquiries concerning exchange of Board publications should be addressed to: Office of the Editor, Fisheries Research Board of Canada, 116 Lisgar Street, Ottawa, Canada K1A 0H3.

In addition to the publications and reports already mentioned for sale or general distribution, the Board prepares Manuscript Reports for its own use. Numbers 931, 989, 990, 1000–1038, 1031–1102, 1104, 1106, 1107, and 1109 were listed during 1969 and 1970. These reports may be consulted at libraries of Board establishments by arrangement with their Directors; they are not available for distribution outside the Board.

Interpretive Articles are by Board scientists and interpret work already published in primary journals. These articles are published in various technical publications, but are not included in the *Studies* series; they are included in the annual indexes of the *Journal*.

In the list of articles and publications that follows, these abbreviations are used: *MS Rep.* – Manuscript Report of the Fisheries Board of Canada; *Tech. Rep.* – Technical Report of the Fisheries Research Board of Canada; *FRBS* – articles in the *Studies* series; *FRBA* – articles in the Interpretive Articles series; the designation "(F)" following an article indicates it was published in French.

Primary Publications of Board Research

Reports chiefly on investigations financed by the Board, published in recognized scientific journals, and based on hitherto unpublished data.

Ackman, R. G. 1968. The flame ionization detector: further comments on molecular breakdown and fundamental group responses. J. Gas. Chromatogr. 6: 497–501. [FRBS 1265]

1969. Temperature effects in the calculation of equivalent chain length values for multiple-branched fatty acid esters and ketones on polar and non-polar open tubular columns. J. Chromatogr. 42: 170–175. [FRBS 1331]

1969. Gas–liquid chromatography of fatty acids and esters, p. 329–381. *In* J. M. Lowenstein [ed.] Methods in enzymology. Vol. 14. Academic Press, Inc., New York and London. [FRBS 1396]

1970. Effect of terminal "groups" on gas–liquid chromatographic retention times of long-chain compounds: a case of tail *versus* dog. J. Chromatogr. 47: 534–536. [FRBS 1449]

Ackman, R. G., R. F. Addison, and C. A. Eaton. 1968. Unusual occurrence of squalene in a fish, the eulachon *Thaleichthys pacificus*. Nature 220: 1033–1034. [FRBS 1286]

Ackman, R. G., R. F. Addison, S. N. Hooper, and A. Prakash. 1970. *Halospaera viridis:* fatty acid composition and taxonomical relationships. J. Fish. Res. Bd. Canada 27: 251–255.

Ackman, R. G., and C. A. Eaton. 1970. Biochemical implications of seasonal trends in the iodine values and free fatty acid levels of commercially produced Atlantic coast herring oils. J. Fish. Res. Bd. Canada 27: 1669–1683.

Ackman, R. G., C. A. Eaton, J. C. Sipos, S. N. Hooper, and J. D. Castell. 1970. Lipids and fatty acids of two species of North Atlantic krill (*Meganyctiphanes norvegica* and *Thysanoëssa inermis*) and their role in the aquatic food web. J. Fish. Res. Bd. Canada 27: 513–533.

Ackman, R. G., and S. N. Hooper. 1969. The "load effect" in open-tubular GLC: relationships among methyl *trans*-11-octadecenoate and *cis* isomers with similar retention times. J. Chromatogr. Sci. 7: 549–553. [FRBS 1351]

1970. Branched-chain fatty acids of four freshwater fish oils. Comp. Biochem. Physiol. 32: 117–125. [FRBS 1395]

1970. Analyses of fatty acids from Newfoundland copepods and sea water with remarks on the occurrence of arachidic acid. Lipids 5: 417–421. [FRBS 1423]

Ackman, R. G., S. N. Hooper, M. Kates, A. K. Sen Gupta, G. Eglinton, and I. Maclean. 1969. Phytanic acid L-menthyl esters gas–liquid chromatographic separation of diastereoisomers. J. Chromatogr. 44: 256–261. [FRBS 1385]

Ackman, R. G., M. Kates, and R. P. Hansen. 1969. Diastereoisomeric composition of pristanic acids of marine and terrestrial origin. Biochim. Biophys. Acta 176: 673–675. [FRBS 1323]

Ackman, R. G., P. J. Ke, W. A. MacCallum, and D. R. Adams. 1969. Newfoundland capelin lipids: fatty acid composition and alterations during frozen storage. J. Fish. Res. Bd. Canada 26: 2037–2060.

Addison, R. F., and R. G. Ackman. 1969. Separation of triglycerides and free fatty acids on Sephadex LH-20. Anal. Biochem. 28: 515–522. [FRBS 1330]

1970. Direct determination of elemental phosphorus by gas–liquid chromatography. J. Chromatogr. 47: 421–426. [FRBS 1424]

Addison, R. F., R. G. Ackman, and J. Hingley. 1969. Free fatty acids of herring oils: possible derivation from both phospholipids and triglycerides in fresh herring. J. Fish. Res. Bd. Canada 26: 1577–1583.

Allen, K. R. 1969. An application of computers to the estimation of exploited populations. J. Fish. Res. Bd. Canada 26: 179–189.

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

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

1969. Limitations on production in salmonid populations in streams. H. R. MacMillan Lectures in Fisheries, Symp. Salmon Trout Streams 1968: 3–18. [FRBS 1334]

Anderson, G. C., T. R. Parsons, and K. Stephens. 1969. Nitrate distribution in the subarctic northeast Pacific Ocean. Deep-Sea Res. 16: 329–334. [FRBS 1355]

Anderson, J. M., and M. R. Peterson. 1969. DDT: sublethal effects on brook trout nervous system. Science 164: 440–441. [FRBS 1324]

Anderson, J. M., and H. B. Prins. 1970. Effect of sublethal DDT on a simple reflex in brook trout. J. Fish. Res. Bd. Canada 27: 331–334.

Antia, N. J., E. Bilinski, and Y. C. Lau. 1970. Identification and characterization of phospholipase D in a unicellular red alga (*Porphyridium cruentum*). Can. J. Biochem. 48: 643–648. [FRBS 1427]

Antia, N. J., and J. Y. Cheng. 1970. The survival of axenic cultures of marine planktonic algae from prolonged exposure to darkness at 20 C. Phycologia 9: 179–183. [FRBS 1448]

Antia, N. J., J. Y. Cheng, and F. J. R. Taylor. 1969. The heterotrophic growth of a marine photosynthetic cryptomonad (*Chroomonas salina*). Proc. Int. Seaweed Symp. 6: 17–29. [FRBS 1403]

Arai, H. P. 1969. A new trematode of the genus *Lepidophyllum* (Digenea: Steganodermatidae) from a cottid fish, *Hemilepidotus hemilepidotus*. J. Fish. Res. Bd. Canada 26: 799–803.

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

Bams, R. A. 1969. Adaptations of sockeye salmon associated with incubation in stream gravels. H. R. MacMillan Lectures in Fisheries, Symp. Salmon Trout Streams 1968: 71–87. [FRBS 1333]

1970. Evaluation of a revised hatchery method tested on pink and chum salmon fry. J. Fish. Res. Bd. Canada 27: 1429–1452.

Barraclough, W. E., R. J. LeBrasseur, and O. D. Kennedy. 1969. Shallow scattering layer in the subarctic Pacific Ocean: detection by high-frequency echo sounder. Science 166: 611–613. [FRBS 1386]

Beare-Rogers, J. L., and R. G. Ackman. 1969. Reaction of lipoxidase with polyenoic acids in marine oils. Lipids 4: 441–443. [FRBS 1405]

Beck, B., and A. W. Mansfield. 1969. Observations on the Greenland shark, *Somniosus microcephalus*, in northern Baffin Island. J. Fish. Res. Bd. Canada 26: 143–145.

Beckett, J. S., and S. N. Tibbo. 1968. Recent changes in size composition of Canadian Atlantic swordfish catches. Int. Comm. Northwest Atl. Fish. Redbook 1968 Pt. III: 62–66. [FRBS 1282]

Bell, G. R., G. E. Hoskins, and J. W. Bagshaw. 1969. On the structure and enzymatic degradation of the external membrane of the salmon egg. Canadian J. Zool. 47: 146–148. [FRBS 1297]

Bernard, F. R. 1968. Sexual dimorphism in *Polinices lewisi* (Naticidae). Nautilus 82: 1–3. [FRBS 1315]

1969. The parasitic copepod *Mytilicola orientalis* in British Columbia bivalves. J. Fish. Res. Bd. Canada 26: 190–191.

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

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

Bilinski, E., and R. E. E. Jonas. 1970. Effects of coenzyme A and carnitine on fatty acid oxidation by rainbow trout mitochondria. J. Fish. Res. Bd. Canada 27: 857–864.

Bilinski, E., and Y. C. Lau. 1969. Lipolytic activity toward long-chain triglycerides in lateral line muscle of rainbow trout (*Salmo gairdneri*). J. Fish. Res. Bd. Canada 26: 1857–1866.

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

Bourne, N., and D. E. McAllister. 1969. The black hagfish, *Eptatretus deani*, from British Columbia. J. Fish. Res. Bd. Canada 26: 3246–3248.

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

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

Brawn, V. M. 1969. Buoyancy of Atlantic and Pacific herring. J. Fish. Res. Bd. Canada 26: 2077–2091.

Brett, J. R. 1969. Temperature and fish. Chesapeake Sci. 10: 275–276. [FRBS 1430]

1970. Fish – the energy cost of living, p. 37–52. *In* Marine aquiculture. Selected papers from the Conference on Marine Aquiculture, Oregon State University Press, Corvallis, Oreg. [FRBS 1415]

Brett, J. R., and D. A. Higgs. 1970. Effect of temperature on the rate of gastric digestion in fingerling sockeye salmon, *Oncorhynchus nerka*. J. Fish. Res. Bd. Canada 27: 1767–1779.

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

Brockerhoff, H. 1969. Esters of phenols as substrates for pancreatic lipase. Biochim. Biophys. Acta 191: 181–183. [FRBS 1371]

1969. Action of pancreatic lipase on emulsions of water-soluble esters. Arch. Biochem. Biophys. 134: 366–371. [FRBS 1374]

Brockerhoff, H., R. J. Hoyle, and P. C. Hwang. 1970. Digestive enzymes of the American lobster (*Homarus americanus*). J. Fish. Res. Bd. Canada 27: 1357–1370.

Brunskill, G. J. 1969. Fayetteville Green Lake, New York. II. Precipitation and sedimentation of calcite in a meromictic lake with laminated sediments. Limnol. Oceanogr. 14: 830–847. [FRBS 1438]

Brunskill, G. J., and R. C. Harriss. 1969. Fayetteville Green Lake, New York. IV. Interstitial water chemistry of the sediments. Limnol. Oceanogr. 14: 858–861. [FRBS 1439]

Brunskill, G. J., and S. D. Ludlam. 1969. Fayetteville Green Lake, New York. I. Physical and chemical limnology. Limnol. Oceanogr. 14: 817–829 [FRBS 1437]

Brunskill, G. J., S. D. Ludlam, and W. H. Diment. 1969. A comparative study of meromixis. Verh. Int. Ver. Theor. Angew. Limnol. 17: 137–139. [FRBS 1436]

Buerkle, U. 1969. Auditory masking and the critical band in Atlantic cod (*Gadus morhua*). J. Fish. Res. Bd. Canada 26: 1113–1119.

Buhler, D. R., and W. E. Shanks. 1970. Influence of body weight on chronic oral DDT toxicity in coho salmon. J. Fish. Res. Bd. Canada 27: 347–358.

Butler, D. G., W. C. Clarke, E. M. Donaldson, and R. W. Langford. 1969. Surgical adrenalectomy of a teleost fish (*Anguilla rostrata* LeSueur): effect on plasma cortisol and tissue electrolyte and carbohydrate concentrations. Gen. Comp. Endocrinol. 12: 503–514. [FRBS 1337, title only]

Butler, T. H. 1968. The shrimp fishery of British Columbia. FAO Fish. Rep.: 521–526. [FRBS 1328]

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

Buttkus, H. 1969. Reaction of cysteine and methionine with malonaldehyde. J. Amer. Oil Chem. Soc. 46: 88–93. [FRBS 1314]

Caddy, J. F., 1970. A method of surveying scallop populations from a submersible. J. Fish. Res. Bd. Canada 27: 535–549.

Caddy, J. F., and E. I. Lord. 1968. Recent developments in the Georges Bank scallop fishery. Int. Comm. Northwest Atl. Fish. Redbook 1968 Pt. III: 89–93. [FRBS 1284]

Calaprice, J. R. 1969. Production and genetic factors in managed salmonid populations. H. R. MacMillan Lectures in Fisheries, Symp. Salmon Trout Streams 1968: 377–388. [FRBS 1335]

Calaprice, J. R., and F. P. Calaprice. 1970. Marking animals with micro-tags of chemical elements for identification by x-ray spectroscopy. J. Fish. Res. Bd. Canada 27: 317–330.

Carrothers, P. J. G. 1968. Field identification of synthetic fibres used in fish nets. Int. Comm. Northwest Atl. Fish. Redbook 1968 Pt. III: 49–52. [FRBS 1281]

Carter, N. M. 1970. Index et catalogue des ouvrages publiés par l'Office des recherches sur les pêcheries du Canada et des publications connexes, 1900–1964. [French Preface only; English edition (Index and List of titles, Fisheries Research Board of Canada and associated publications, 1900–1964) published in 1968.] Fish. Res. Board Can. Bull. 164F: 16 p.

Castell, C. H., and D. M. Bishop. 1969. Effect of hematin compounds on the development of rancidity in muscle of cod, flounder, scallops, and lobster. J. Fish. Res. Bd. Canada 26: 2299–2309.

Castell, C. H., W. Neal, and B. Smith. 1970. Formation of dimethylamine in stored frozen sea fish. J. Fish. Res. Bd. Canada 27: 1685–1690.

Castell, C. H., B. Smith, and W. Neal. 1970. Effects of transition metal ions on the extractable protein of fish muscles. J. Fish. Res. Bd. Canada 27: 701–714.

Chen, F. Y., and H. Tsuyuki. 1970. Zone electrophoretic studies on the proteins of *Tilapia mossambica* and *T. hornorum* and their F_1 hybrids, *T. zillii*, and *T. melanopleura*. J. Fish. Res. Bd. Canada 27: 2167–2177.

Cheng, J. Y., and N. J. Antia. 1970. Enhancement by glycerol of phototrophic growth of marine planktonic algae and its significance to the ecology of glycerol pollution. J. Fish. Res. Bd. Canada 27: 335–346.

Clayton, J. W., and W. G. Franzin. 1970. Genetics of multiple lactate dehydrogenase isozymes in muscle tissue of lake whitefish (*Coregonus clupeaformis*). J. Fish. Res. Bd. Canada 27: 1115–1121.

Clayton, J. W., and J. H. Gee. 1969. Lactate dehydrogenase isozymes in longnose and blacknose dace (*Rhinichthys cataractae* and *R. atratulus*) and their hybrid. J. Fish. Res. Bd. Canada 26: 3049–3053.

Dambergs, N. 1969. Isopropanol–water mixtures for the production of fish protein concentrate from Atlantic herring (*Clupea harengus*). J. Fish. Res. Bd. Canada 26: 1919–1923.

1969. Isopropanol–water azeotrope as solvent in the production of fish protein concentrate from herring (*Clupea harengus*). J. Fish. Res. Bd. Canada 26: 1923–1926.

Dambergs, N., and L. W. Regier. 1970. Estimation of bone material in fish protein concentrates. J. Fish. Res. Bd. Canada 27: 591–595.

Donaldson, E. M., and U. H. M. Fagerlund. 1968. Changes in the cortisol dynamics of sockeye salmon (*Oncorhynchus nerka*) resulting from sexual maturation. Gen. Comp. Endocrinol. 11(3): 552–561. [FRBS 1310]

1969. Cortisol secretion rate in gonadectomized female sockeye salmon (*Oncorhynchus nerka*): effects of estrogen and cortisol treatment. J. Fish. Res. Bd. Canada 26: 1789–1799.

1970. Effect of sexual maturation and gonadectomy at sexual maturity on cortisol secretion rate in sockeye salmon (*Oncorhynchus nerka*). J. Fish. Res. Bd. Canada 27: 2287–2296.

Dowd, R. G., E. Bakken, and O. Nakken. 1970. A comparison between two sonic measuring systems for demersal fish. J. Fish. Res. Bd. Canada 27: 737–742.

Drozdowski, B., and R. G. Ackman. 1969. Isopropyl alcohol extraction of oil and lipids in the production of fish protein concentrate from herring. J. Amer. Oil Chem. Soc. 46: 371–376. [FRBS 1350]

Duedall, I. W. 1967. A nonwetting surface on glass. Amer. J. Phys. 35: iii–iv. [FRBS 1275]

1968. Partial molal volumes of 16 salts in sea water. Environ. Sci. Technol. 2: 706–707. [FRBS 1273]

1968. A mercury dispenser. J. Chem. Educ. 45: 393. [FRBS 1274]

Dunn, R. S. 1970. Further evidence for a three-year oocyte maturation time in the winter flounder (*Pseudopleuronectes americanus*). J. Fish. Res. Bd. Canada 27: 957–960.

Dunn, R. S., and A. V. Tyler. 1969. Aspects of the anatomy of the winter flounder ovary with hypotheses on oocyte maturation time. J. Fish. Res. Bd. Canada 26: 1943–1947.

Dyer, W. J. 1968. Deterioration and storage life of frozen fish, p. 429–447. *In* Prof. J. Hawthorne [ed.] Low temperature biology of foodstuffs. Pergamon Press, Oxford, New York. [FRBS 1290]

1969. Effect of brining and polyphosphate on yield and quality, p. 167–171. *In* R. Kreuzer [ed.] Freezing and irradiation of fish. Fishing News (Books) Limited, London, England. [FRBS 1366]

Dyer, W. J., and D. I. Hiltz. 1969. Nucleotide degradation in frozen swordfish muscle. J. Fish. Res. Bd. Canada 26: 1597–1603.

Dyer, W. J., D. F. [I.] Hiltz, R. G. Ackman, J. Hingley, and G. L. Fletcher. 1970. In vivo assimilation by cod muscle and liver tissue of elemental phosphorus from polluted sea water. J. Fish. Res. Bd. Canada 27: 1131–1139.

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Saunders, R. L. (St. Andrews)
Scarratt, D. J. (St. Andrews)
Schaffer, W. (St. Andrews)
Scherer, E. (Winnipeg)
Schick, S. E. (Winnipeg)
Schindler, D. (St. Andrews)
Schindler, D. W. (Winnipeg)
Schluger, P. (St. Andrews)
Schmidt, P. J. (Vancouver)
Scott, D. P. (Winnipeg)
Scott, J. S. (St. Andrews)
Scott, K. R. (Winnipeg)
Scott, W. B. (St. Andrews)
Sergeant, D. E. (Ste. Anne de Bellevue)
Shaw, D. K. (Halifax)
Shelbourn, J. E. (Nanaimo)
Sheldon, R. W. (Dartmouth)
Shepard, M. P. (Ottawa)
Shepheard, P. (St. Andrews)
Shieh, H. S. (Halifax)
Singh, S. B. (St. Andrews)

Sipos, J. C. (Halifax)
Smith, G. F. M. (Ottawa)
Smith, H. W. D. (Nanaimo)
Smith, J. C. (Dartmouth)
Smith, M. W. (St. Andrews)
Snow, D. (St. Andrews)
Sochasky, J. B. (St. Andrews)
Southcott, B. A. (Vancouver)
Sparling, W. H. (Atlantic Regional)
Sprague, J. B. (St. Andrews)
Squires, H. J. (St. John's)
Sreedharan, A. (St. Andrews)
Stallworthy, W. B. (St. Andrews)
Stasko, A. B. (St. Andrews)
Stephanopoli, M. A. (Halifax)
Stevenson, J. C. (Ottawa)
Stockner, J. G. (Winnipeg)
Strasdine, G. A. (Vancouver)
Striha, R. J. (Halifax)
Strong, I. J. (Nanaimo)
Subba Rao, D. V. (Dartmouth)
Sunde, L. A. (Winnipeg)
Sutcliffe, W. H. (Dartmouth)
Sutterlin, A. M. (St. Andrews)
Symons, P. E. K. (St. Andrews)

Tabata, S. (West Vancouver)
Tarr, H. L. A. (Vancouver)
Taylor, D. A. (Halifax)
Taylor, F. H. C. (Nanaimo)
Templeman, W. (St. John's)
Theodorides, J. (St. Andrews)
Thomas, M. L. H. (Dartmouth)
Thomson, J. A. C. (Nanaimo)
Tibbo, S. N. (St. Andrews)
Tomlinson, N. (Vancouver)
Traxler, G. S. (Halifax)
Triplett, E. (Nanaimo)
Trites, R. W. (Ottawa)
Truscott, B. (Halifax)
Tsuyuki, H. (Vancouver)
Tully, J. P. (Ottawa)
Tyler, A. V. (St. Andrews)

Uthe, J. F. (Winnipeg)

Vallentyne, J. R. (Winnipeg)
Vanstone, W. E. (Vancouver)
Vethamany, V. G. (St. Andrews)
Vollenweider, R. A. (Winnipeg)

Wacasey, J. W. (Ste. Anne de Bellevue)
Waldichuk, M. (West Vancouver)
Watson, J. (St. Andrews)
Waywell, E. (St. Andrews)
Weinsieder, A. (St. Andrews)
Weinsieder, B. G. (St. Andrews)
Weir, J. R. (Ottawa)
Weisbart, M. W. (Halifax)
Wells, R. (St. John's)
Wendt, C. (St. Andrews)
Westrheim, S. J. (Nanaimo)
Wheeler, O. E. (St. John's)
Whyte, J. N. C. (Vancouver)
Wickett, W. P. (Nanaimo)
Wigmore, R. H. (Ottawa)
Wilder, D. G. (St. Andrews)
Wildish, D. J. (St. Andrews)
Williscroft, S. N. (Vancouver)
Willmer, J. S. (Ottawa)
Wilson, K. (St. Andrews)
Winters, G. H. (St. John's)
Wiseman, P. M. (Halifax)
Withler, F. C. (Nanaimo)
Wojtowicz, M. B. (Halifax)
Wolfson, N. (St. Andrews)
Wong, C. S. (Nanaimo)
Wood, A. L. (Halifax)
Wozny, Z. S. (Vancouver)

Yamamoto, M. (Vancouver)
Young, E. A. (Nanaimo)
Yurkowski, M. (Winnipeg)
Yusa, T. (Nanaimo)

Zinck, M. E. (Dartmouth)
Zitko, V. (St. Andrews)