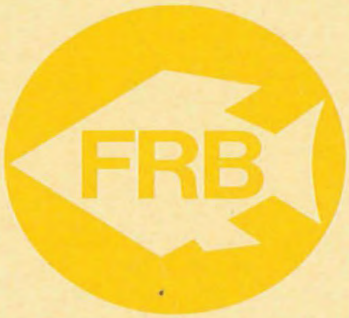
REVIEW 1965/1966



FISHERIES RESEARCH BOARD OF CANADA

REVIEW

of the

FISHERIES RESEARCH BOARD OF CANADA

1965-1966

OTTAWA • CANADA
1967

Contents

Members of the Board

The members of the Board during the calendar years 1965 and 1966 were

F. Ronald Hayes, PH.D., D.SC.; Hon. Degrees: LL.D.(Dalhousie), D.SC.(Memorial), F.R.S.C.; *Chairman*

C. W. Argue, C.B.E.; Dean of Science, and Head, Department of Biology, University of New Brunswick, Fredericton, N.B. (1965)*

J. M. R. Beveridge, PH.D., M.D.; Hon. Degrees: D.SC.(Acadia), F.R.S.C.; President, Acadia University, Wolfville, N.S. (1968)

D. B. DeLury, PH.D., F.A.S.A., F.A.A.S.; Chairman, Department of Mathematics, University of Toronto, Toronto, Ont. (1965)

O. F. Denstedt, PH.D.; Gilman Cheney Professor, Department of Biochemistry, McGill University, Montreal, Que. (1968)

M. K. Eriksen; Director, Prince Rupert Fishermen's Co-operative Association, Prince Rupert, B.C. (1967)

H. A. Favre, D.SC.; Dean of Science, University of Montreal, Montreal, Que. (1969)

G. Filteau, PH.D.; Head, Department of Biology, University of Laval, Quebec, Que. (1968)

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

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

J. H. G. LeBlanc, M.B.A.; Secretary General, Quebec United Fishermen, Youville Station, Montreal, Que. (1967)

L. E. Marion, PH.D.; Hon. Degrees: D.SC.(Laval, Ottawa, Queen's, Montreal, Paris, British Columbia, Carlton, R.M.C., McGill), LL.D.(Toronto), 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. McLean; McLean Bros. Fisheries, Wheatley, Ont. (1968)

I. McT. Cowan, PH.D., F.R.S.C.; Dean of Graduate Studies, University of British Columbia, Vancouver, B.C. (1965)

M. O. Morgan, M.A.; Dean of Arts and Science and Acting President, Memorial University of Newfoundland, St. John's, Nfld. (1970)

R. L. Payne, Jr., M.S.; General Manager, J. H. Todd and Sons Ltd., Vancouver, B.C. (1968)

G. L. Pickard, M.B.E., D.PHIL., F.R.S.C.; Director, Institute of Oceanography, University of British Columbia, Vancouver, B.C. (1967)

Hazen A. Russell; President, Bonavista Cold Storage Company Limited, St. John's, Nfld. (1968)

S. Sinclair, PH.D., F.A.I.C.; Head, Department of Agricultural Economics and Farm Management, University of Manitoba, Winnipeg, Man. (1966)

R. G. Smith; President and Executive Officer, National Sea Products Limited, Halifax, N.S. (1966)

W. M. Sprules, PH.D.; Special Assistant to Deputy Minister, Department of Fisheries, Ottawa, Ont. (1968)

W. L. Williamson; Consultant (Conley's Lobsters Ltd.), St. Andrews, N.B. (1968)

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

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*Appointment terminates at end of year indicated.

ORGANIZATION

Honorary Board

The long and successful history of the Fisheries Research Board of Canada is attributed to the program and policy advice it receives from its independent advisory board. This board is a direct outgrowth of the honorary Board of Management established under the federal Minister of Marine and Fisheries in 1898 to encourage and supervise marine biological research. With growth in the scope of responsibilities and membership, the board became the Biological Board of Canada in 1912 and the Fisheries Research Board of Canada in 1937. Although the honorary board-type of program direction is unique among Canadian federal agencies responsible for research on living renewable resources, its example has been followed by two of the largest research organizations in other fields: the National Research Council (1917) and the Defence Research Board (1947).

Function. Under the the control of the Minister of Fisheries, the Board "has charge of all Dominion fishery research stations in Canada, and has the conduct and control of investigations of practical and economic problems connected with marine and freshwater fisheries, flora and fauna, and such other work as may be assigned by the Minister." It is the only organization in the federal government with scientific research responsibilities in this field.

Membership. The Board consists of a full-time Chairman, appointed by the Governor-in-Council, and not more than eighteen members appointed by the Minister of Fisheries who serve without pay. The majority of members must be scientists; the remainder represent the federal Department of Fisheries and the fishing industry. At the end of 1966 there were nine scientific members, residents of British Columbia, Ontario, Quebec, Nova Scotia, and Newfoundland, all being distinguished specialists in disciplines related to the Board's work. Seven members were leaders of the fishing industry with intimate knowledge of the high seas, coastal, and inland fisheries of Canada. Representation from the Department of Fisheries was at a professional and senior level.

Chairman. The first full-time Chairman of the Board was appointed on amendment of the Fisheries Research Board Act in 1953. "The Chairman is the chief executive officer of the Board and has supervision over and direction of the work of the Board and of the persons appointed for the purpose of carrying out the work of the Board."

Meetings. At its annual meetings in Ottawa, and at special meetings as necessary, the Board sets objectives and policies, reviews and guides broad research programs, and determines the laboratory and staff organization requirements to carry out these programs.

Executive Committee. The administrative responsibilities of the Board are delegated to an Executive Committee consisting of the Chairman and four to six members elected from the full Board and approved by the Minister. The Executive Committee establishes the level and distribution of capital facilities (such as laboratories and research vessels), operating funds, and research staffs required to carry out the Board's work. The appointments and remuneration of scientific,

Minister of Fisheries

Fisheries Research Board of Canada

Chairman, appointed by Governor-in-Council
Up to 18 honorary members
appointed for 5-year terms by the Minister
(Executive, Regional Advisory,
and Special Committees)

Office of the Chairman,
and *Editorial Division,*
Ottawa

Research Establishments

Biological Station, Nanaimo, B.C.

Research Laboratory, Vancouver, B.C.

Freshwater Institute, Winnipeg, Man.

Arctic Biological Station, Ste. Anne de Bellevue, Que.

Biological Station, St. Andrews, N.B., and Substation, Ellerslie, P.E.I.

Atlantic Oceanographic Group, Dartmouth, N.S.

Research Laboratory, Halifax, N.S., and Technological Station, Grande-Rivière, Que., and Technological Unit, St. John's, Nfld.

Biological Station, St. John's, Nfld.

technical, and other staff are reviewed by a Personnel Subcommittee of the Executive Committee. All of the Executive Committee's proposals involving money and staff are subject to approval by the Minister of Fisheries, to review by the Treasury Board, and to the availability of government funds.

Advisory Committees. The scientific programs are regularly reviewed by committees of the Board. There are separate Advisory Committees for the Eastern, Central–Arctic, and Western regions of Canada. These Advisory Committees visit Board laboratories and field operations to review operations and scientific programs. They make recommendations to the full Board for program and operational improvement.

Special Committees. Special committees of Board members and other experts are set up from time to time to deal with continuing or ad hoc problems. A standing committee deals with policy matters relating to the Board's publications. An ad hoc committee on Board–University relations was active in 1965; it was replaced in 1966 by a standing committee on University Grants.

Office of the Chairman

F. Ronald Hayes, PH.D., D.SC.(Liverpool); Hon. degrees: LL.D.(Dalhousie), D.SC.(Memorial), F.R.S.C., *Chairman*

W. R. Martin, PH.D.(Michigan), *Assistant Chairman*

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., SIGMA XI, *Oceanographic Consultant* and Secretary of the Canadian Committee on Oceanography; from April 1, 1966

G. F. M. Smith, PH.D.(Toronto), *Biological Consultant*

E. G. Bligh, PH.D.(McGill), *Technological Consultant*; to August 1966

N. Tomlinson, PH.D.(California), *Acting Technological Consultant*; from September 1966 (seconded for one year from Vancouver Laboratory)

J. S. Willmer, PH.D.(Liverpool), *Research Personnel Consultant*; from December 1, 1965

The Chairman of the Board is assisted in Ottawa by a small scientific and administrative staff. This staff provides secretarial services and conducts staff studies for the Board; it guides the administration of the operating units of the Board in accordance with Board policies, Executive Committee decisions, Ministerial and financial authorities, and government regulations; it maintains liaison with associated scientific and otherwise related agencies, including the Scientific Secretariat of the Privy Council Office, the National Research Council, and research branches of the departments of Agriculture; Forestry; Energy, Mines and Resources; and Indian Affairs and Northern Development: it is intimately associated with the Department of Fisheries in joint accommodation at the Sir Charles Tupper Building, Confederation Heights: it maintains administrative ties with the Treasury Board, and the departments of Public Works and Transport. The total staff in the Office of the Chairman at Ottawa, 20, is less than 3% of the full time staff employed by the Board.

Editorial Division. The Board's Editorial Division, also located in Ottawa, was partially separated from the Office of the Chairman in 1966. Its respon-

sibilities include general surveillance, evaluation, and documentation of all reports on research carried out by the Board or under its sponsorship. The Editorial Division has particular responsibility in the field of primary scientific publication and maintains various publication media, the most important of which is the Journal of the Fisheries Research Board of Canada. This Journal has become a leading international vehicle for scientific publication of aquatic research.

Senior officers of the Editorial Division are as follows:

J. C. Stevenson, PH.D.(Toronto), *Editor*
G. I. Pritchard, PH.D.(North Carolina State), *Associate Editor*
R. H. Wigmore, M.SC.(McGill), *Assistant Editor*; from April 1, 1965
R. L. MacIntyre, *Publication Production Supervisor*

Laboratories

The Fisheries Research Board has no laboratories in Ottawa. Its researches are completely decentralized: they are carried out from laboratories at locations where they can conveniently serve the major fisheries of Canada, and, at the same time, maintain close relationships with other government agencies and universities having parallel interests. In 1966, these establishments were administered by Directors at: Nanaimo, Vancouver, Winnipeg (transferred from London in July, 1966), Ste. Anne de Bellevue (transferred from Montreal in February, 1965), St. Andrews, Halifax, Dartmouth, and St. John's (see organization chart on page 8). The wide differences in size and function of these establishments is shown graphically in the figure in the next section. The breakdown by regions, by establishments, and by the five main types of research provides a general picture of Board operations. Summary reports of the research carried out by each laboratory during the 1965–1966 period are included in this Review.

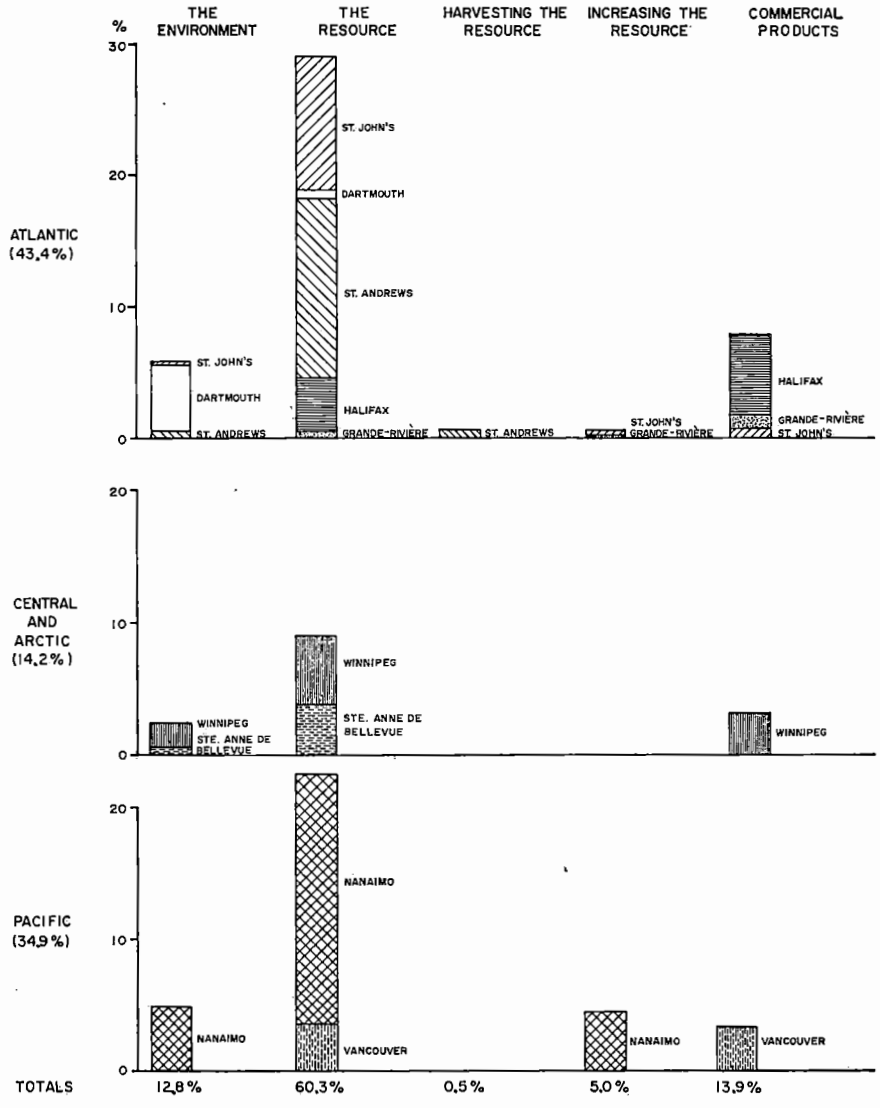
To facilitate field operations, the laboratories operate a total of 16 research-type fishing vessels ranging from inshore and lake craft to large, ocean-going ships (three) specially designed and equipped to carry out biological and oceanographic investigations.

Operating Costs

The Board's operating budget for the fiscal year 1966–67, excepting costs of new construction, was $9,332,000. The accompanying chart indicates the approximate percentages of the operating costs that were spent on each area on the main classifications of research: the environment, the resource, harvesting the resource, increasing the resource, and commercial products.

Research on the environment is directed toward increasing our knowledge of it and of its effects on the resource. It includes studies of temperature, oxygen content and salinity of waters, and systems of recording them; effects of these factors on survival, growth, and behaviour of fish; plankton; degree and effects of pollution from municipal and industrial wastes and from insecticides, and methods of control; and interrelations of water currents with all these factors.

The resource, whether of concern only to Canada or to international fishery commissions as well, is studied as to the extent of its various components and where they are found at different times; studies also include changes in stocks



OTTAWA HEADQUARTERS :	OFFICE OF THE CHAIRMAN	3.1%
	EDITORIAL DIVISION	1.8%
	UNIVERSITY SUPPORT	2.6%
	TOTAL	7.5%

Percentages of total operating costs spent on the main types of research by the Board and the various establishments.

because of fishing and natural causes, and effects of these changes on availability and maximum sustainable yield.

Harvesting the resource is investigated with the object of increasing the efficiency of the operation, both through studies of fish behaviour in the presence of fishing gear and by devising new gear and techniques for capture.

Means of increasing the resource are sought through studies of the influence of environmental changes and of artificial rearing on production. The possibility of increasing production through the introduction of new species by transplantation and by developing means of utilizing fish that are not already exploited is also investigated.

Efforts to improve and increase commercial products include investigations of all phases of the holding and processing of fish between catching and marketing and of possibilities of preparing entirely new products from them.

Personnel Establishment

Of the Board's personnel establishment of 762 full-time positions in 1966–67, about 32% were scientific, 36% were technical, and 32% were support (administrative, clerical, maintenance, and vessel). In addition, provision is made for the employment of short-term staff, including university students, to bolster the work force during periods of peak activity. This short-term employment totals about 100 man-years.

Reporting

The Board puts considerable emphasis on the importance of its scientists' publishing the results of their research in recognized scientific journals. In addition, the Board's achievements are interpreted and reported in a number of ways for use by fishing companies and fishermen, national committees and international commissions concerned with the management of fisheries, and the general public. Primary scientific articles and interpretive reports published during 1965 and 1966 are listed in a later section of this *Review*.

Communication of research results to the fishing industry involves use of various media other than the printed word, such as radio, television, exhibitions, and direct contact with fish processors and fishermen. Courses for fishery officers and contributions to widespread fisheries conferences are used to inform interested users of Board research in government and industry. Board scientists assume responsibility for scientific advice, at both national and international levels, on management and development of Canadian fisheries.

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*

Labrador, Northeast Newfoundland, and Gulf Cod

A. W. May, PH.D.(McGill);
on educational leave to March 6, 1966
M. Wiles, PH.D.(Leeds)

Newfoundland Cod South and East, Groundfish Statistics, and Sampling

A. M. Fleming (*see above*)
A. T. Pinhorn, M.SC.(Memorial)

Haddock, Cod of South Grand Bank and Flemish Cap

R. Wells, B.A.(Memorial)

Redfish

E. J. Sandeman, M.SC.(Memorial)

Pleuronectids

T. K. Pitt, M.A.(Toronto)

Groundfish Biology and Distribution

W. Templeman (*see above*)

Pelagic Fishes

V. M. Hodder, M.SC.(Memorial);
on temporary transfer to Nanaimo from September 1, 1966
A. S. Hourston, PH.D.(California);
on temporary transfer from Nanaimo from September 1, 1966
G. H. Winters, B.SC.(Memorial);
from May 2, 1966

Salmon

A. A. Blair, PH.D.(Toronto)
A. R. Murray, B.A.(Saskatchewan)

Commercial Invertebrates

H. J. Squires, PH.D.(Durham)
M. C. Mercer, B.SC.(Memorial)

The main subjects of research were the commercial groundfishes (especially cod), salmon, herring, capelin, lobster, squid, and hydrography. The studies were especially directed toward:

- Age and growth, reproduction, success of survival of year-classes, distribution, and the effects of the fishery on the stocks of cod, haddock, redfish, American plaice, and Greenland halibut.

- Studies of herring and capelin distribution, age, growth and maturity; and the effects on the herring stocks of the rapidly increasing fishery.

- Oceanic distribution of Atlantic salmon and introduction of pink salmon to Newfoundland.

- Life history and distribution studies of lobster and squid; forecasting of squid abundance.

Groundfish Sampling and Statistics

Biological samples, and data on distribution, catch, and effort were collected from the Labrador and Newfoundland coastal commercial cod fisheries and from the commercial fisheries for various species of groundfish. This program provides records for the study of changes that are occurring in the stocks.

The total landings in Newfoundland of the main commercial groundfish in 1966 (650 million lb) were 7% above the landings in 1965 and 12% above those of 1964. Of this landed weight, 64% was cod, 15% American plaice, 12% redfish, 6% Greenland halibut, 2% greysole, and the remaining 1% yellowtail, wolffish, halibut, pollock, and hake. Increased effort by an enlarged fleet of otter trawlers in the offshore fisheries was chiefly responsible for the increased landings, especially of American plaice with landings 50% higher than in 1964, and redfish with landings 80% higher than in 1964. Cod landings were 8% below the 1964 level, the result of a poor summer fishery in many inshore localities.

Cod

In the coastal cod fisheries the catch per unit effort and average size of fish caught continued to decline generally, apparently as a result of more intense fishing of the stocks in many offshore and inshore localities. Investigations have shown the dependence of trap and handline gears on young, small fish and the relative scarcity of the older ages in catches by these gears. However, older ages, above 10–11 years, still contribute significantly to the catches by longline and gillnet.

The distribution and abundance of cod in the offshore areas were investigated during half-hour tows on otter-trawl survey cruises by the *A. T. Cameron* as follows:

Eastern Grand Bank	April 1965, August 1966
Southwestern Grand Bank	May 1965, May 1966
Gulf of St. Lawrence	November 1965, October 1966
Northern Labrador	October 1966

The *Investigator II* carried out a similar survey on St. Pierre Bank in June 1965.

On the eastern edge of the Grand Bank between 44° and 45°N, in April 1965, up to 12,000 lb of cod (mainly 3 years old, less than 18 inches long) were caught per tow in 60–100 fath, temperatures from 0 to 2 C; and in August, over 3000 lb of cod (mainly 2 and 4 years old) were caught in a tow in 125 fath, temperature 3.6 C. These cod would reach commercially acceptable sizes within 1–3 years.

Although depths from 30 to as great as 175 fath were fished on the various cruises, no other large catches were made in any other set in all areas surveyed.

Studies of cod fecundity in the offshore and in the southern inshore areas of Newfoundland showed that egg production ranged between $\frac{1}{4}$ million and 11 million eggs per mature female, depending upon fish size. The dry-weight method apparently yielded more accurate fecundity estimates than the volumetric method.

The otolith method of age determination was examined in detail and was found to be valid for the Labrador area.

Haddock

During otter-trawling surveys by the *A. T. Cameron* in May 1965 and 1966 on the Grand Bank, and by the *Investigator II* in June 1965 on St. Pierre Bank in depths of from 30 to 150 fath, catches of haddock were very small. The fish were mainly young and immature but there was no evidence of a strong new year-class in the stocks. Catches from the commercial fishery continued at a low level. Very favourable environmental conditions are necessary for the production of a strong year-class by the small spawning stock remaining.

Redfish

Survey cruises were made by the *A. T. Cameron* between Burgeo and St. Pierre banks in February 1965, in the Gulf of St. Lawrence in November 1965, and on the Nova Scotian Shelf in November 1966. On the northern side of the Laurentian Channel in the Burgeo Bank area, catches of up to 7000 lb per half-hour tow were taken in 125 fath. These catches were mostly of small redfish of sizes similar to the year-classes contributing to the recent increased landings in the Gulf of St. Lawrence where indications were that the abundant small fish would support the commercial fishery for possibly two more years. Prospects for the future there were poor because there was no evidence of the recruitment of new year-classes.

On the Nova Scotian Shelf catches of 5000 lb per half-hour tow were taken on the seaward edge of the central part of the shelf generally in depths somewhat greater than 200 fath. Except for moderate catches of about 200 lb per half hour on the east side of Sambro Bank, redfish were not found in commercial quantities in the deeper depressions of the shelf.

During a cruise to the West Greenland area in July–August 1965, in the Labrador Sea about halfway between Labrador and Greenland, 15 redfish were caught by longline at 100–250 fath over depths of 1600–1700 fath. These were mature *Sebastes mentella*, superficially similar to the Labrador type, and were heavily infested with the copepod parasite *Sphyrion lumpi*.

American Plaice

From continued studies of spawning in plaice from Labrador, the Northeast Newfoundland Shelf, and the Grand Bank, it was evident that old, large fish spawn first and that plaice in shallow water spawn earlier than those in deep. Fifty per cent of female plaice from these regions are mature at 12–14 years of age and 40–50 cm in length. On the Flemish Cap 50% of the females are mature at 5–7 years of age and 20–29 cm in length.

Greenland Halibut (Turbot)

The landings of Greenland halibut in 1966 (36 million lb) were more than twice those of 1965, with the greatest amounts being caught in Trinity Bay which seems to have a relatively large population. The Trinity Bay commercial catch was composed principally of 8- to 12-year-old fish.

A research program begun in 1965 was intensified in 1966 and surveys were conducted on the biology and distribution of the species in White, Notre Dame, and Trinity bays, while fishing gillnets and longlines. The average Greenland halibut caught by the gillnets were smaller than those caught by longlines. Catches in gillnets of 7-inch mesh were 25% higher than those in 6-inch mesh.

Herring

Prior to 1964, except for a minor fishery by purse seiners in the Bay of Islands area for a short period of years, most herring were caught by gillnets and were processed for food or used for bait. From 1959 to 1964 the annual landings of 6–9 thousand tons were the lowest since 1875. In 1964–65 expansion of reduction processing of herring began following good catches by large purse seiners in the western and southwestern Newfoundland areas. In 1965 the landings were over 14 thousand tons. The 1966 landings of nearly 32 thousand tons were the greatest since 1948.

Concurrent with the expansion in the fishery, herring investigations were intensified. Preliminary analyses indicated that fish from the south and west coasts were smaller and younger than during the period of record catches (1942–48) and that there were fewer year-classes contributing appreciably to the present run than at that time. A change in spawning time in these areas was also evident. Spring spawners predominated in this area in the late 1940's but autumn spawners became the dominant group. This change in spawning habits, and the changes which had occurred in the areas of major catches, suggested that extensive changes had taken place in the composition and location of the run over the past two decades.

Capelin

Capelin were sampled in 1965 and 1966 from representative areas of the Newfoundland and Labrador coast, and the Grand Bank, to evaluate any differences which might indicate separate stocks. Although no significant differences in anal and pectoral fin-ray and in vertebral counts could be found among these areas, the capelin from the south coast of Newfoundland were the smallest and youngest, the Grand Bank and Labrador capelin were the largest, and those from the east coast of Newfoundland were intermediate in size.

In 1965, 3-year-olds (the 1962 year-class) dominated the spawning schools and this year-class was even more dominant in 1966 as 4-year-olds. This suggests not only a very successful 1962 year-class but also a relatively poor 1963 year-class. Accompanying the dominance of 4-year-olds in the spawning schools in 1966 was an increase in the average size and fat content of the capelin.

Atlantic Salmon

During a cruise of the *A. T. Cameron* in 1965 in the Labrador Sea and West Greenland area, 39 salmon were caught in surface drift-nets: 6 in the Labrador Sea on July 19–20; 15 on or near the West Greenland coastal banks from the northern peak of Store Hellefiske Bank off Rifkol to off Cape Desolation, August 5–20; 13 over oceanic depths west of Cape Farewell, August 22; and 5 in the Labrador Sea on August 23.

The *A. T. Cameron* re-fuelling at Faeringehavn, West Greenland.

Between March 21 and April 16, 1966, 38 Atlantic salmon were taken by the *A. T. Cameron* in 6 surface drift-net sets (each about 21 nets) over oceanic depths east of the Northeast Newfoundland Shelf in temperatures of 3.7–6.1 C. No salmon were caught in a set at 9.2 C. The greatest numbers of salmon were caught closer to, rather than more seaward from, the 1000-fath isobath. On May 1, 1966, 7 salmon were taken in a similar surface set by the *A. T. Cameron* off the southwestern slope of the Grand Bank at a temperature of 5.4 C.

PINK SALMON

From 1964 to 1966 there were 3 transplants of pink salmon eggs from Lakelse River, British Columbia, to North Harbour River, Newfoundland, the number of eggs planted being 3.4 million in 1964, 3.3 million in 1965, and 5.9 million in 1966. The rate of survival to the migrant fry stage was 83% in 1965 and 91% in 1966 which means the freshwater environment is suitable. The main predator of the fry in both the river and the estuary was the brook trout but some fry were found in the stomachs of eels, Atlantic salmon smolts, cod, and sculpins.

The return of 638 adults in 1966 from 2.9 million fry and 3.4 million eggs is a considerable improvement over previous returns of 49 adults in 1964 from 2.2 million fry and 2.5 million eggs and 1 adult in 1961 from 0.1 million fry and 0.25 million eggs. The distribution of the 638 adults accounted for in 1966 was as follows: 419 in the home stream of North Harbour River, 40 in Colinet River, 178 in the commercial salmon fishery of St. Mary's Bay, and 1 on a spinner in

salt water off Branch River at the outer end of St. Mary's Bay. Of the 419 fish that returned to North Harbour River, 213 were females so that, at 1600 eggs per female, one tenth of the eggs planted in 1964 would be replaced. The plant of 5.9 million eggs in 1966 was almost double the size of any of the previous plants so that the returns in 1968 may give some indication of the number of eggs required to establish a run in Newfoundland waters.

Lobster

Comparison of fishing rates among areas on the Newfoundland west coast was made by measuring lobsters from the commercial catch and estimating the proportion of first-year recruits in the catch. This estimate was based on the growth increment of the moulting of lobsters from sublegal to legal sizes which was determined in Port au Port Bay, Bay of Islands, and St. John Bay. Fishing rate estimates from proportions of first-year recruits in the commercial catch showed that some areas, principally on exposed coasts where storms often destroy gear, were underfished. Other areas such as North Arm, Bay of Islands, were fished to the point of full recruit exploitation annually.

Preliminary distribution studies showed that no lobsters were found on near-shore banks of about 20 fath off the Newfoundland west coast.

Comparison of moulting of lobsters in nature (estimated from biological samples) with lobsters held through the moulting period in cages or held and marked before release indicated a significant amount of moult suppression occurring in held lobsters.

In conjunction with a study of lobster habitat (sedimentation, rock types, topography, and shoreline) five species of sculpin were investigated. Sampling seasonally by scuba diving since 1964 showed the time of spawning, embryonic development, and hatching of the shorthorn (*Myoxocephalus scorpius*). Small lobsters were obtained from stomachs of shorthorn sculpins in North Arm, Bay of Islands.

Oysters

In cooperation with the Department of Fisheries 10 barrels of seed and 30 barrels of adult oysters were transplanted from P.E.I. to Two-Guts barachois pond in 1965. Growth was substantial: mortality over the first winter was about 20% in adults and 4% in seed oysters; however, the condition of the oysters improved slightly after the first year.

Seaweed

Preliminary assessment of Irish moss (*Chondrus crispus*) beds for harvesting in Port au Port Bay, Newton (Bonavista Bay), and St. Mary's Bay was discouraging. Very large amounts of drifted seaweed of mixed species on the Newfoundland west coast were observed.

Squid

During research operations in Conception and Trinity bays in 1965 squid were not caught over deep water or farther than 2 miles from shore. However, it

was demonstrated that squid could be taken at many places other than traditional squid jigging grounds, and that an active program of search, using lights, etc., would produce more squid than could be realized by restricting fishing to these traditional grounds.

Tagging squid (*Illex illecebrosus illecebrosus*). Tagging needle being thrust through fin.

HYDROGRAPHY

In July–August 1965, the usual 6 hydrographic sections were taken across the Labrador Current from Labrador to the southern Grand Bank. In 1966, because of lack of offshore vessel time, the survey of the 6 sections taken since 1951 was reduced to one—St. John's to Flemish Cap. At the station 2 miles off Cape Spear hydrographic observations were taken monthly or more often throughout the year.

RESEARCH LABORATORY, HALIFAX, NOVA SCOTIA

(including Technological Unit, St. John's, Newfoundland, and Technological Station, Grande-Rivière, Quebec)

D. R. Idler, D.F.C., PH.D.(Wisconsin), *Director*
C. H. Castell, M.S.A.(Toronto), *Assistant Director* (1965)
R. G. Ackman, PH.D.(London), *Assistant Director* (1966)
P. M. Jangaard, M.ENG.(N.S. Tech. Coll.), *Scientific Liaison Officer*
I. Jean Rattray (Miss), *Executive Assistant*
M. A. Stephanopoli, B.L.SC.(Ottawa), *Librarian*

Process and Product Research

H. E. Power, B.E.(N.S. Tech. Coll.)
A. L. Wood, B.E.(N.S. Tech. Coll.)
Margaret L. Morton, B.SC.(St. Francis Xavier); to June 30, 1966
Ruth E. Sinclair, B.SC.(Mt. Allison); from May 6, 1966

Deterioration and Prevention

R. G. Ackman (*see above*)
M. G. Cormier, B.SC.(Moncton); to July 31, 1966
Shirley N. Hooper, B.SC.(New Brunswick); from October 17, 1966
J. C. Sipos, M.A.(Toronto)
C. H. Castell (*see above*)
N. Dambergs, ING. CHIM.(Nancy)
Barbara A. Moore, B.SC.(Dalhousie); to September 2, 1966
Doris M. Spears, M.SC.(Dalhousie); from September 10, 1966
W. J. Dyer, PH.D.(McGill), F.C.I.C.
Doris I. Hiltz, B.SC.(Acadia)
S. Y. Lo, M.SC.(McGill); to September 2, 1966
Sandra C. Nowlan, M.SC.(Cornell); from March 7, 1966
Saroja K. Kamra, PH.D.(Indian Inst. Sci.); from September 13, 1965

Exploration Research

P. H. Odense, PH.D.(Oklahoma)
Theresa M. Allen, B.SC.(Ottawa); to September 24, 1966
Carol M. Bishop, B.A.(Oxford)
J. R. Dingle, PH.D.(Toronto), F.C.I.C.
J. A. Hines, B.SC.(St. Francis Xavier)
H. Brockerhoff, PH.D.(Cologne)
R. J. Hoyle, M.A.(Cantab.)
Pei Chu Hwang, M.SC.(McGill); from December 8, 1965
M. Yurkowski, M.SC.(Saskatchewan); to July 1, 1965
H. S. Shieh, PH.D.(McGill)
R. F. Addison, PH.D.(Queen's, N. Ireland); from November 14, 1966
Carol A. Tocher, PH.D.(Washington); to August 26, 1966

Improvement of Resource

D. R. Idler (*see above*)
H. C. Freeman, M.SC.(Acadia)
Nadine R. M. Kimball, B.SC.(Dalhousie); from July 1, 1965
Heather C. Macnab, B.S.A.(Toronto)
Beryl Truscott, M.SC.(Queen's)
A. Saito, D.T.(Osaka)
M. S. Mounib, PH.D.(Aberdeen)
Joanne S. Eisan, M.SC.(Dalhousie)
D. G. Ellis, B.SC.(Queen's)
M. W. Gilgan, PH.D.(Wisconsin); from October 4, 1965
M. Elizabeth Trerice, M.SC.(Dalhousie); from September 12, 1966
J. E. Stewart, PH.D.(Iowa)
J. W. Cornick, M.S.A.(Toronto)
Diane M. Foley, B.SC.(Mt. St. Vincent); to May 31, 1966
Wanda D. Tacreiter, M.SC.(Cracow); from May 24, 1966
M. F. Li, PH.D.(Alberta)
Carol W. Flemming, B.SC.(Mt. Allison)
R. M. MacKelvie, PH.D.(British Columbia); from November 1, 1965
G. K. Campbell, M.SC.(New Brunswick)
P. J. Ke, M.SC.(Memorial); from August 15, 1966

Visiting Scientists

A. S. Grimm, PH.D.(Glasgow), National Research Council postdoctoral fellow; from October 28, 1965, to January 27, 1967
A. Kanazawa, PH.D.(Kyoshu), research fellow, Department of Education, Japanese Government; from September 1, 1965, to August 31, 1966
Ruta Lucis, PH.D. candidate, McGill; September 1965 to August 31, 1966
K. A. Savagaon, B.SC.(Bombay), Colombo Plan trainee; from October 7, 1966

TECHNOLOGICAL STATION, GRANDE-RIVIÈRE, QUEBEC

R. Legendre, M.ENG.(McGill), *Director*

H. P. Dussault, M.SC.(McGill)
T. C. Leung, B.SC.(Dalhousie)
M. Barbara Wojtowicz, PH.D.(Warsaw); from March 31, 1966

TECHNOLOGICAL UNIT, ST. JOHN'S, NEWFOUNDLAND

W. A. MacCallum, M.SC.(Dalhousie), *Scientist-in-Charge*

Dorothy A. Chalker, B.SC.(Memorial); to September 23, 1966
Rosamund M. Gover, B.SC.(Memorial); to July 30, 1965
J. T. Lauder, B.SC.(Dalhousie)
Coty Lasola, B.SC.(St. Thomas); to February 25, 1965
Joan M. Murphy, B.SC.(Toronto); to August 5, 1966
Teresita U. Tan, B.SC.(San Carlos); from November 21, 1966

The research concerned mainly:

• Improving or preserving quality of fresh and frozen fish and shellfish through studies on: rancidity; flavor changes in iced and frozen swordfish and mackerel; superchilled storage of cod; effective *p*H on fillet quality; proteolytic enzymes in fish muscle; protective coatings for frozen fish; freezing, thawing and refreezing of cod, flounder, and redfish; radiation and chemical preservatives.

• Manipulation of the resource: Detection and prevention of diseases of fish and shellfish; distribution of lobster pathogen in natural environment; preventing mortality in lobsters by lowering temperature; demonstrating that lobster must be wounded to be infected; simple method of predicting meat content of lobsters; possible means of distinguishing resistant from disease susceptible oysters; isolation of a pathogenic bacteria from rainbow trout; diagnosis of diseases in hatcheries; endocrinology of fish and shellfish; hormones concerned with fish reproduction; potent new mineral-regulating steroid isolated from fish; impaired hormone metabolism in dying fish; studies on molting of lobsters; long-term preservation of Atlantic salmon spermatozoa.

• Freeze-drying of fish products; cost analysis of fish protein concentrate and water thawing.

• Biochemistry of fish and shellfish included: isoenzymes as genetic markers of fish populations; postmortem processes in fish and shellfish muscle; composition of sperm proteins; metabolism of testes and ovaries; amino acids of cod muscle; composition of marine oils; nutrition of marine lipids; chemical composition of seaweeds; metabolism of marine bacteria.

DISEASES OF FISH AND SHELLFISH

Gaffkaemia, a blood disease of lobster. The causative agent of this disease, *Gaffkya homari*, was detected in lobsters captured in five widely separated areas of the Canadian Atlantic coastal region. The incidence of infection ranged from 2 to 40% with an overall average of 5%. The infective agent was therefore either resident in the local lobster populations or sustained in a reservoir (animate or inanimate) which was at least as widespread as the lobsters. Infection studies with

crabs showed that *G. homari* does not lose virulence in the crab but, fortunately, it is not a highly developed pathogen for the crab.

The minimum numbers of a virulent strain of *G. homari* required to cause a fatal infection are 3–4 or fewer per lobster, so that the animal has no apparent resistance to this organism. *In vitro* and *in vivo* experiments showed that *G. homari* grows exceptionally well in lobster hemolymph, is unaffected by the agglutinin present in the lobster's hemolymph, does not appear to be phagocytized to the same extent as other bacteria, and although it is phagocytized it is apparently released back into the system rather than cleared from the hemolymph. These features plus its ubiquitousness make *G. homari* unique and an effective lobster pathogen.

The only factor which alleviates the seriousness of the disease is the organism's strict dependence on temperature. The growth rate *in vitro* parallels the time from infection to the death of the lobster. The time to death for 90% of the animals is 5 days at 20 C; 16 days at 15 C; 30 days at 10 C; 86 days at 7 C; and 135 days at 5 C. It is possible that lower temperatures will inhibit the growth and infectiveness of the organism completely.

Transmission studies indicated that the mode of transmission of the organism must include the wounding of the animal. Attempts to transmit the disease orally failed. The gastric fluid was shown to be lytic for *G. homari* and other organisms.

Withdrawing hemolymph sample from lobster.

Other organisms which were isolated from the lobster's hemolymph included Brevibacterium, Achromobacter, Micrococci, and Pseudomonads. Infection experiments with these organisms were negative, indicating that they are probably incidental and harmless agents for the lobster.

Relation of number of cells and protein in blood to meat yield in lobster. The method developed for counting lobster hemocytes was used in conjunction with hemolymph protein determinations to work out a relationship between these values and the amount of muscle in the lobster. The hemolymph protein correlates well with the muscle quantities. This measurement will be useful in nutritional studies and in surveying wild stocks. Measurements made on wild stocks showed that wild stocks vary markedly from one area to another.

Oyster tissue culture. The existence of multinuclei in the cells and some evidence of a mitosis were found in normal oyster cultures of oyster heart explants. The primary cells could be useful in *in vitro* infection studies. The presence of multinuclei suggests that certain precautions should be taken when evaluating the results, especially in viral infection studies with the oyster cells, to avoid a misidentification of the parasite.

Distinguishing a resistant from a susceptible oyster population. In addition to the interfacial ring test, agar gel diffusion technique further demonstrated the serological difference between Malpeque disease resistant and disease susceptible populations of oysters from the Atlantic Coast of Canada. The consistency of this finding was repeatedly tested with the two groups of oysters.

Oyster hemagglutinin. Oyster hemagglutinin was found to be heterogeneous. Its general properties, such as heat stability, optimum *p*H, erythrocyte preference, and the effect of ultracentrifugation were determined. This information is important in the differentiation of the host's naturally occurring hemagglutinin and the hemagglutinin produced by infecting agents, which must be done in any infection studies.

Fish tissue culture. Some naturally occurring substances, such as ascitic fluid, animal sera, and embryo extract, were found to be essential for maximum proliferation of rainbow trout gonadal cells, but ascitic fluid caused early cell degeneration. This latter finding was extremely important for avoiding erroneous conclusions in our studies of virus propagation and cytopathogenic effect using this fish cell line.

Fish diseases. A pseudomonad was isolated from skin lesions of rainbow trout. The pathogenic effect observed was apparently due to the extracellular bacterial proteinase. A 114-fold increase in the specific activity of the proteinase was achieved by fractionation. The enzyme was active over a wide *p*H range, 4.4–10, and was not completely inactivated by heating for 60 min at 98 C. The temperature optimum for proteolytic activity was approximately 45 C.

A kidney disease of salmonids was diagnosed in three Maritime hatcheries and recommendations for therapy were forwarded to the Fish Culture Branch authorities. Examination of a selection of wild salmon, trout, and sticklebacks taken from the headwaters of the severely afflicted Margaree Station failed to reveal that any of these fish were carriers of the responsible organism. Characterization

of the causative agent (believed a Corynebacterium) was underway in the latter part of 1966.

Populations of rainbow trout tissue-culture lines were initiated for the study of Infectious Pancreatic Necrosis Virus.

Physiology of cod blood and liver. Lactate dehydrogenase, glutamic-pyruvic transaminase, and glutamic-oxalacetic transaminase levels of cod serum were not altered significantly during heavy feeding or starvation. Extractable activities in liver decreased during starvation and increased sharply during regeneration of the liver. The activities increased noticeably in cod serum and liver extract after one freeze-thaw cycle.

Quality of Fresh and Frozen Fish

Rancidity studies. Muscle tissues from different species of fish and marine animals differ widely in their susceptibility to oxidative rancidity. Neither the amount of fat present nor the degree of its unsaturation, although involved, are the limiting factors. Of more importance is the presence of oxidation catalysts and mechanisms in the tissues that inactivate or retard the action of these catalysts.

Cod muscle is extremely resistant to rancidity. Well wrapped fillets were held in storage for 3 years at −16 F (−25 C), over a year at 10 F (−12 C), and for more than 100 days at 26 F (−3 C) without any significant increase in TBA (thiobarbituric acid) values or rancid odors. Except where oxidation catalysts had been purposely added, the only rancid cod fillets we encountered were poorly wrapped or unwrapped fish that had undergone extensive dehydration.

Several things protect cod muscle lipids against oxidation. The relatively rapid formation of free fatty acids during storage brings about conditions in the muscle that affect metal ions in such a way that they are no longer available as oxidation catalysts. This was shown by following the effect of free fatty acid formation in stored frozen fish; by adding hydrolyzed marine lipids to fresh cod muscle; and by inducing rapid lipid hydrolysis in the muscle through the addition of snake venom containing active phospholipidase. In each case the effective concentration of free fatty acid required to inactivate the metal ions was approximately of the same order.

In addition to this effect of free fatty acids, fresh fish muscle and muscle from other marine animals have components that bind or otherwise inactivate heavy metal ions. The specific metals that are affected and the metal-binding capacity varies widely in different species of fish. For example: 150–200 ppm Cu^{++} added to lobster muscle brings about less rancidity than 15–20 ppm Cu^{++} added to cod muscle; and scallop muscle was shown to be more than a thousandfold more sensitive to iron ions than was the muscle of certain other species of fish.

In general the most active catalysts were V^{++}, Fe^{++}, Cu^{++}, and Fe^{+++}. Relatively ineffective for lipid oxidation in cod muscle were Cd^{++}, Co^{++}, Ni^{++}, and Zn^{++}, which were more effective for flounders and for the more fatty species such as ocean perch and herring. We now have curves showing the effect of various concentrations of 11 heavy metal ions on muscle taken from 12 species of fish.

During the winter and early spring, cod muscle is more susceptible to Cu^{++}-induced rancidity than the muscle of these same fish caught during the summer and early fall. The summer-caught fish have a much longer induction period of

copper-induced rancidity. This is not so for iron; and if anything, the summer-caught cod are more sensitive to Fe^{++} or Fe^{+++} than fish caught during the winter and spring.

The addition of tocopherol (the most widespread natural antioxidant in fish) protected the muscle lipids against oxidation induced by Cu^{++}, much less against oxidation induced by Fe^{++}, and hardly at all against V^{++}.

The thiobarbituric acid (TBA) reaction is widely used as a measure of rancidity in fatty foods and as a measure of "peroxidation" in animal tissues. Traces of V^{++}, Fe^{++}, and Fe^{+++} interfere with this test, giving spurious values to substrates where they have been added. The lower and dark muscle of many species of fish normally contain sufficient metal ion to interfere with the TBA reaction. These errors can be controlled by carrying out a portion of the TBA procedure under an atmosphere of nitrogen or by the addition of chelating agents.

Quality in iced and in frozen swordfish. Nucleotide degradation in relation to flavor changes: iced, dressed swordfish showed no loss in quality by taste panel testing up to 15 days, and was acceptable at 19 days though showing some spoilage changes after that time. Hypoxanthine (Hx) formation was insufficient to contribute any bitter flavor but inosine monophosphate (IMP) decreased rapidly between 15 and 19 days parallel to the taste scores. Changes in the red muscle were considerably earlier, though the relation of this to the "strong" flavor of the dark muscle is not clear. In frozen swordfish, quality remained excellent for at least 5 months at −26 C but rapidly deteriorated at −4.5 C (1 week). At −9.5 C, unacceptability was reached at 11–16 weeks on the basis of toughening of texture and appearance of stale, rancid, oily flavors. Nucleotides showed no change at −26 C; IMP decreased and Hx rose slightly at the higher temperatures, but these changes were insufficient to affect taste. Thus, the frozen storage deterioration was apparently not related to nucleotide degradation.

Quality and nucleotide changes in mackerel. The postmortem dephosphorylation of IMP to Hx via inosine was slower in iced mackerel than in iced cod and related species, indicating a less active enzyme system in the mackerel, but was not so slow as that in iced dressed swordfish. As with swordfish, the sequence of changes occurred earlier in the red than in the ordinary muscle. The nucleotide degradation changes and quality deterioration were hastened by (a) transportation from the trap at ambient temperature (4–16 C), as in commercial practice, instead of in ice, (b) subsequent storage at temperatures of 0 C, or (c) thawing of frozen material at 5 C or at 18 C. Statistical analysis of flavor scores, and IMP and Hx contents for several different lots of mackerel subjected to a variety of postmortem commercial handling conditions showed a highly significant linear relationship between both IMP level and flavor, and Hx level and flavor. Only traces of bitterness were noted at the Hx levels reached in spoiling mackerel (1.5–2 μmole/g), but the development of a tastelessness following the loss of the fresh characteristic mackerel flavor may be attributed to the concomitant loss of IMP from the muscle. It was noted also that ascorbic acid prevented darkening of the flesh and inhibited TBA development.

Pin bones in cod and haddock fillets. Scott, of the Royal Ontario Museum, at our instigation, and using samples of fillets and of whole fish supplied by us,

completed the preliminary study of the possibility of distinguishing cod from haddock fillets by pin bone structure. The rib bones appear to be sufficiently different for identification, but the reliability of the method under practical conditions should be checked if interest from the fishing industry warrants.

Superchilled storage of cod. Fish held under superchill temperatures was of lower quality than fish held in melting ice until after 10 days storage. Although iced fish became unacceptable after 14 days, the superchilled fish remained acceptable for up to 31 days. The major difference in quality between iced and superchilled fish for the first 10 days storage was in the texture of the cooked muscle.

Reducing the storage temperature of round cod to just below the point where the water in the muscle begins to freeze can increase the storage life, as measured by a taste panel, from approximately 14 days to between 26 and 31 days. Storage of fish in air without ice causes dehydration which, because of processing difficulties and reduced yield, would make this method of storage unacceptable for commercial use. Storage in ice in −3 C and −0.5 C air caused no dehydration. Fish stored in −3 C air yielded cooked fillets which were acceptable after 31 days storage, although the texture was soft and coarse. If the fish was stored in −0.5 C air in ice, the taste panel found the cooked fillet acceptable after 26 days storage; however, the commercial storage life of this fish would probably be limited to approximately 21 days because of development of ammonia odors on cooking and slight yellowing of the uncooked fillet.

Fillet pH and quality. The uptake of buffer solutions by cod muscle and the extent of resultant change in homogenate *p*H indicated only superficial penetration of buffer by dip treatment. Thawed, texture-deteriorated cod fillets improved in texture, taste, and grade if they were dipped in sodium bicarbonate solution to give a homogenate *p*H of 7.2 prior to cooking. Thawed-dipped fillets were rated organoleptically, however, slightly inferior to fillets cooked directly from the frozen state. The presence of bicarbonate was only rarely identified by the taste panel. Intravenous injection of buffers into cod 1 hour before killing resulted in a slightly improved control of muscle homogenate *p*H within narrow limits during iced storage of headed and gutted fish. Postmortem intramuscular injection of acid and alkaline phosphate buffers had no demonstrated effect on homogenate *p*H, organoleptic, and TMA values for cod, but the introduction of foreign flavors was confusing to the taste panel. Postmortem intramuscular injection of bicarbonate buffer did not enhance the useful storage life of frozen cod fillets at −6 C. Injected fillets rated somewhat lower than controls in organoleptic trials during the first week of storage, but in subsequent taste panel studies, injected fillets scored slightly but consistently higher in texture, taste, and grade. TMA and homogenate *p*H were not altered by injection. Higher extractable protein values indicated a slight advantage of injected fillets over controls during the first two weeks at −6 C. Prolonged storage abolished this advantage.

Enzymes as indicators of quality. Lactate dehydrogenase (LDH), glutamic-pyruvic transaminase (GPT), and glutamic-oxalacetic transaminase (GOT) activities did not change significantly in fillets or water-soluble muscle extracts of cod and haddock upon freezing. LDH decreased during frozen storage, however, more

rapidly at −6 C than at −29 C. No predictable fluctuations in LDH were observed during iced storage of untreated and irradiated (150–300 Kr) haddock fillets. The LDH activity of water-soluble extracts of cod and haddock flesh remained relatively unaltered during iced storage under reasonably sterile conditions.

Non-bacterial deterioration of fish and shellfish. Factors affecting the quality of gillnetted cod have been studied by simulating gillnetting conditions in experiments performed on tank-held cod at Grande-Rivière. Fish held or netted under controlled conditions were sampled for lysosomal enzyme activity (acid phosphatase and cathepsins), and were examined organoleptically. The results indicated that several factors contribute to the rapid deterioration in quality of gillnetted fish: wave-motion, temperature, and extent of struggling or strangulation are the most important.

With the exception of cathepsin, the lysosomal enzyme levels in cod muscle are low. Cod muscle cathepsin was isolated and its activity towards "natural" muscle protein substrates tested. Its action on the structural proteins of muscle, actomyosin and tropomyosin, is slight, and its activity is more likely directed towards the connective tissue or stroma proteins thereby bringing about the softening of the flesh, characteristic of poor quality gillnetted cod.

Preservation of fillets by gamma irradiation. The laboratory studies of the preservation of fresh fillets by irradiation was followed up by testing under commercial conditions with the co-operation of a local fish producer, the Atomic Energy of Canada Ltd., and the Fish Inspection Laboratory at Halifax. Results of these tests confirmed laboratory findings that treatment of iced fillets with low doses (75,000–150,000 rad) of gamma radiation provides a useful extension of the storage life. However, higher doses caused the product to be rejected because of irradiation odors and flavors.

Bactericidal effect of acetylated monoglycerides as protective coating on frozen fish. Hot dip coatings of acetylated monoglycerides were applied to frozen fish samples. The surface microflora were reduced but far from eliminated by the treatment. Used in conjunction with antibiotic dips, the process should provide a safe and effective coating for frozen fish products.

Quality of Newfoundland fish. A continuation of work on trap-caught cod (*Gadus morhua*) showed that muscle glycogen at mid-season and immediately after killing was 6- to 8-fold that at the start and end of the season. The mid-season is a period of about 4 weeks within the May–August Newfoundland shore fishery and is normally associated with lower quality. The effect of this nutritional difference carried over into the frozen product and resulted in differences in texture, thaw-drip, and *p*H. Correlation was found among all three; thus, patterns in quality may be predicted by *p*H and thaw-drip measurements.

The energy reserves at killing appear to play a significant part in slowing the toughness process in fish frozen before rigor mortis. Thus high ATP levels at the time taste panels were conducted coincided with absence of toughness.

The textural quality of Grand Bank cod, taken during normal dragging operations, was found to be more influenced by the method of capture than by handling and commercially-practiced freezing and storage procedures.

Twice-frozen flounder had characteristics similar to those detected in once-frozen material when they were examined for moisture, thaw-drip, solubility of the proteins in salt solution, and development of rancidity (TBA test).

Chemical and organoleptic assessment showed no evidence of significant rancidity in unprocessed blocks of frozen cod stored unwrapped, as in commercial practice, or during subsequent thawing, refreezing, and storage. Off-white color detected in the fatty tissue under the skin of some thawed flounder (*Hippoglossoides platessoides*) was associated with fish of higher total lipid. Thawed cod, flounder, and redfish (*Sebastes marinus mentella*), freshly frozen at sea, were found to carry no spoilage odors on thawing. Cod lost some resiliency on thawing. Thawed flounder and redfish were comparable in texture with iced landings.

Handling of cod, flounder, and redfish. Trap fish, frozen pre-rigor, were of substantially better quality after 12 months cold storage at −23 C than the same fish frozen in-rigor. In-rigor freezing cannot always be avoided and in these instances fish should be kept chilled and on-the-bone up to the time of filleting and freezing. A study of commercial-type handling (no ice was used at the traps) showed significant reduction in yield of firm fillets for freezing as compared with yields resulting from handling and filleting pre-rigor iced fish. The preference for handling pre-rigor iced fish also applied to texture after single-freezing and storage; at 28 weeks these fish graded 13–19 points higher than those of commercial-type handling. Pre-rigor freezing of blocks for later thawing and refreezing was also shown to be preferable to commercial-type handling for twice-frozen fish. Still better results followed storage of the fish at −40 C before and after thawing. Fish handled commercially without ice for a few hours prior to block freezing were also very acceptable for cold storage and later thawing and refreezing.

Thawing and refreezing of fish, frozen initially pre-rigor at sea, resulted in acceptable or better quality in Grand Bank cod and very good quality in flounder and redfish after 1 year in cold storage.

Bank cod, treated with sodium tripolyphosphate after thawing and filleting, then refrozen and cold-stored, were of considerably better texture and developed less thaw-drip than twice-frozen untreated fillets.

Dielectric, water (at 18–22 C), and humidified air (at 21 C) thawing methods could not be distinguished in terms of effect on the fish at filleting or after refrozen storage. Cod, flounder, and redfish from combination dielectric-seawater thawing developed salty tastes which were accepted in redfish but not in cod and flounder. Substitution of tap water for sea water for finish-thawing resulted in equal sensory evaluation of the product from the dielectric and combination dielectric-water methods.

Holding cod 12 and 16 hr, and flounder 16 and 48 hr, after partial thawing did not affect texture or taste scores of refrozen fillets.

An engineering and economic study was made of commercial-scale water and combination dielectric-water thawing methods. When fish are caught at a mean rate on the Grand Bank of 35,000 lb per day, and 3 days total steaming time and 2 days port time are allowed, it may be slightly more profitable to freeze part of the yearly catch at sea and thaw it ashore (in Newfoundland) than to

land all the fish in ice. These studies showed that the dielectric thawer was useful for reprocessing blocks of vessel-frozen skins-on untrimmed fillets but not so well suited technically and economically as the conveyor-type water thawer for reprocessing blocks of heads-on gutted flounder, whole redfish, and heads-off gutted cod in Newfoundland.

ENDOCRINOLOGY AND PHYSIOLOGY OF FISH AND SHELLFISH

Sex hormones in fish. 11-Ketotestosterone is a naturally occurring androgen in salmonid fishes. Studies in the living animal suggested an important route of synthesis not involving testosterone and it has now been established that adrenosterone is a very significantly better precursor with both gonadal and interrenal tissue. The production of 11β-hydroxytestosterone by normal gonadal tissue was observed for the first time.

Testosterone was isolated and measured for the first time in blood of elasmobranchs. It was present in female skate, but at lower levels than in males. A glucuronide form of the steroid was detected in male *Raja radiata* but not in *R. ocellata*, while a "sulphate" conjugate was present in both. The concentration of both the free steroid (approx 10 μg/100 ml plasma) and the glucuronide form (approx 5.5 μg/100 ml) are many times higher in the male skate than in the normal human male. Adrenocorticotrophin depressed free testosterone in the male and increased testosterone glucuronide in the female *R. radiata.*

Studying the function of a new steroid in the species (skate) in which it was isolated.

A new steroid. 1α-Hydroxycorticosterone was isolated for the first time from the blood and interrenal gland of elasmobranch, genus *Raja.* Limited quantities of the substance are available in crystalline form. It has mineralocorticoid but not glucocorticoid activity for adrenalectomized rodents and stimulates sodium transport by toad bladder. Metabolism, production, protein binding, and quantities of the steroid in body fluids were determined. The formation of the steroid is inhibited by Metapirone. 1α-Hydroxylation does not occur at 37 C and it is therefore unlikely that the new steroid will be found in warm-blooded animals. The substance was found in all elasmobranchs (10) studied to date (early 1967).

Hormones and the death of fish. Sexually immature cod that are dying have an impaired hormone metabolism similar to that found previously in dying spawned Pacific and Atlantic salmon. Impaired metabolism is thus separated from maturation and the spawning act and serves as an indicator of approaching death.

Destruction of steroids. Steroids are frequently purified by thin-layer chromatography (TLC) on silica gel prior to quantitation. It was established that steroids can survive TLC and then be destroyed during elution from the gel with methanol, concentration of the eluate, and rechromatography. The most effective procedure found for protection of the steroid is the use of a relatively non-polar eluting agent such as dichloromethane:methanol (9:1). All batches of gel are not equally destructive.

Corpuscles of Stannius. These are tiny bodies found in the kidneys of teleost fishes. Little is known of their function. It was established that they can form progesterone from pregnenolone and convert the former to 11-deoxycorticosterone.

Lobster endocrinology. The principal endocrine glands (x- and y-organs, and the androgenic gland) of the lobster were located through a histologic and anatomic comparison with those reported in other crustaceans. The precise physiologic function of these tissues in the lobster had not been established at the time of writing.

An enzyme which catalyses the formation of testosterone from 4-androstenedione was detected in lobster tissues. The enzymic activity was detected in all tissues tested but was greatest in the testis, vas deferens mucosa, and androgenic gland.

The hormone(s) responsible for stimulating limb regeneration, and likely molting, in crustaceans was detected in solvent extracts of hemolymph from de-eyestalked lobsters, but not in those of normal intermolt lobsters. The hormone was detected through a limb-bud regeneration bioassay with green crabs (*Carcinus maenas*) as test animals. The bioassay, still under development, appears to be rather insensitive. After partial purification, the lobster hormone seems to resemble the insect molting hormones, ecdysones. To permit a more adequate comparison of the hormone with that of insects, an insect bioassay for ecdysone was started.

Long-term preservation of Atlantic salmon spermatozoa. All attempts to recover viable salmon sperm after quick or slow freezing were unsuccessful. The survival of the cells was determined by microscopic examination, by their

motility upon dilution with water, and ultimately by their ability to fertilize eggs. A step-wise examination of the total freezing procedure allowed certain conclusions. Dimethyl sulphoxide or ethylene glycol could safely be added as a protective agent but glycerol rapidly inactivated the sperm cells. Without an extender, neither agent afforded protection to the cells against freezing damage. Two extenders, a modified physiological saline and a citrate-dextrose-sodium chloride solution, were found to be satisfactory diluents to the extent that the sperm stored in them fertilized eggs upon dilution with fresh water. Sperm cells diluted with an equal volume of the modified saline containing 5% ethylene glycol were fertile (70%) after 38 days storage at −0.5 C. A sample of sperm in the saline and 5% dimethyl sulphoxide was fertile (*80%*) after storage for *28 days at −6.5 C.* A longer storage life might well be possible but eggs of the Atlantic salmon were no longer available and the fertility at a later date could not be tested. Samples of sperm containing higher levels of glycol to permit storage at lower temperatures without freezing gave a fertility rating of only 5%. Although preservation of sperm measured in weeks or months cannot be considered an alternative to frozen storage, spermatozoa held in this manner conceivably could be used for cross-breeding of certain salmonids.

Anaesthetics. Isobutyl alcohol as an anaesthetic for lobsters was shown to be superior to methyl pentynol. No side effects were observed during its use and it is effective in concentrations between 1.5 and 14 ml per litre of sea water. The recommended concentrations are between 1.5 and 7.0 ml per litre for isobutyl alcohol while the recommended levels of methyl pentynol are between 3 and 6 ml per litre. Methyl pentynol, however, must be used with caution since it can cause paralysis or death at the higher levels.

Low concentrations of chloroform or diethyl ether in sea water were very effective anaesthetics for both sand shrimps (*Crangon septemspinosus*) and green crab (*C. maenas*). Unfortunately, chloroform appears to have cumulative toxicity to the crab. Isobutanol and methyl pentynol are anaesthetics for the lobster but are not effective with the green crab, and, in fact, act as irritants. Neither M.S. 222 nor high magnesium ion concentrations were effective on the green crab or sand shrimp.

Biochemistry of Fish and Shellfish

Amino acids of cod muscle. The patterns of free and protein-bound amino acids have been determined in the skeletal muscle of the Northwest Atlantic cod. Well-defined samples in sufficient numbers were used. No drastic differences in the protein-bound amino amino acid patterns as compared with the East Atlantic or European cod were detected.

Histology of fish and shellfish tissues. The morphology of the digestive tract of the cod was described. An electron microscope study showed that the intestinal epithelium possesses a brush border of microvilli, often lined with spirochaete-like microorganisms, especially in the rectal area of the intestine. A new cell type, pear-shaped and striated in appearance, was found among the goblet cells of the epithelium. It was especially prevalent in the epithelium of the pyloric caeca. The results of this study will form the basis of an understanding

of the digestive physiology of the cod and the role played by intestinal enzymes in the deterioration of fish quality.

The ultrastructure of freshly killed and fixed cod skeletal muscle tissue was examined. The typical features of a striated muscle cell were apparent but in addition there were indications of branching and reorientation of the actin filaments at the N band. Continuity was observed between the I band material, the area between the transverse tubules and the sarcoplasmic reticulum of the triad, and the space between the inner and outer mitochondrial membranes.

Lactate dehydrogenase isoenzymes. Herring: Mutant forms of the two sub-units of LDH in herring were found. The distribution of LDH genotypes in samples of herring populations from St. Andrews, Grande-Rivière, and Halifax conformed to the Hardy Weinberg law. Thus, LDH isoenzymes may be used as genetic markers to characterize herring populations.

Cod: There are three basic LDH sub-units in cod tissues, those characteristic of eye, skeletal muscle, and heart muscle. Several mutant forms of the heart muscle sub-unit have been found, and the distribution of genotypes in populations from Grande-Rivière, Halifax, and the North Sea have conformed to the Hardy Weinberg law. Deviation from the expected distribution was found in the St. John's population sample, indicative of a mixed population. The gene frequency again appears to be useful as a population characteristic.

Other species: LDH polymorphism has been found in other species and may be used for population studies. Several species show the presence of additional sub-units, especially in eye or brain tissue.

Aspartate aminotransferase isoenzymes. This enzyme in herring is present in a soluble and a mitochondrial form. The soluble form acts as a dimer and mutant forms of the sub-units have been found. Again the distribution of genotypes in samples of herring populations from St. Andrews, Grande-Rivière, and Halifax conformed to the Hardy Weinberg law.

Enzymes of postmortem processes in muscle. Inosine monophosphate, an important flavor-enhancing substance, is formed in cod muscle during catching and postmortem storage. This has been found to be caused by the presence of an enzyme that deaminates adenosine monophosphate, and the properties of the enzyme have been shown to be similar to a corresponding one found in mammalian muscle. It can be extracted with water from pre-rigor but not from post-rigor cod muscle. Post-rigor muscle requires the use of salt solutions which also extract the proteins of the contractile system.

Thin-layer chromatography of perchloric acid extracts of lobster muscle indicated that postmortem degradation of the nucleotides was similar to that found in cod and higher animals. Other evidence suggests, however, that the activities of one or more of the enzymes involved differ considerably from the corresponding ones in cod.

Composition of sperm head proteins of cod. The proteins extracted from the sperm heads of cod were fractionated on Sephadex. Five main fractions were collected. There was no striking difference in the amino acid composition in the various fractions. This shows that the protein extracted is chemically homo-

geneous but varies in chain lengths. The amino acid composition confirmed older studies that in this regard cod is an exception to the rule. Its sperm head proteins do not classify as protamines but belong to the lysine-rich histones.

Metabolism of testes and ovaries of fish. Three reactions were shown to occur when cod testicular tissue was incubated with pyruvate; reduction of pyruvate to lactate, oxidative decarboxylation of pyruvate, and fixation of carbon dioxide with pyruvate. The latter two reactions may play a role in regulating the metabolism of the testes.

Cod testicular tissue incorporated all three carbons of pyruvate in lipids, proteins, and nucleic acids.

Studies have also indicated that 2,4-dinitrophenol and *p*-nitrophenol could be used to establish differences in the metabolism of the different species.

Cod ovarian tissue metabolized pyruvate essentially by the same routes found in the testicular tissue.

The O_2 uptake of both ovarian and testicular tissue of cod increased when an exogenous substrate (^{14}C-labelled pyruvate, acetate, or glyoxalate) was added. The addition of malonate promoted the O_2 consumption in both tissues. Malonate depressed the evolution of $^{14}CO_2$ by cod testicular tissue from added radioactive substrate, and freezing increased the effect. On the other hand, addition of malonate to ovarian tissue enhanced the formation of $^{14}CO_2$. The effect of freezing on the ovaries varied from a slight decline in the oxidation of pyruvate to a considerable rise in the oxidation of acetate.

Metabolism of sperm and eggs of fish. Metabolism of pyruvate, acetate, and glyoxalate: Evidence was found for the reduction of pyruvate to lactate in both isotopic and enzymic studies. In addition, pyruvate underwent an oxidative decarboxylation and fixation with CO_2. The C-1 atom of glyoxalate was oxidized in preference to C-2, and this was particularly the case under anaerobic conditions. Acetate was oxidized more rapidly than glyoxalate, and more rapidly than the corresponding atoms (C-2 and C-3) of pyruvate. An active transaminase system was indicated by the formation of amino acids from added pyruvate or glyoxalate.

Lipid biosynthesis by salmon sperm from acetate, pyruvate, and glyoxalate: Experiments with salmon sperm incubated with ^{14}C-labelled acetate, pyruvate, or glyoxalate, showed that any carbon atom in any position of these substrates can be incorporated into the total lipid extract. The incorporation was highest with glyoxalate, less with pyruvate, and least with acetate. In all cases the incorporation was more in the glycerol fraction than in the fatty acid or the non-saponifiable fraction. Only sperm incubated with glyoxalate could incorporate this substrate into cholesterol. Malonate enhanced the incorporation from all three substrates in all lipid fractions, whereas succinate suppressed the lipid biosynthesis from pyruvate, and acetate, but not from glyoxalate.

Fixation of carbon dioxide by cod sperm: When sperm was incubated in the presence of $^{14}CO_2$, ^{14}C was incorporated in keto, amino, and other organic acids in the supernatant layer, and in lipids, proteins, and nucleic acids of the residue. Addition of pyruvate to the incubation medium caused an increase in the fixation of $^{14}CO_2$, whereas malonate depressed the ^{14}C incorporation. The enzyme activity of the acetone powder of cod sperm showed the presence of

malic enzyme and also the operation of the purine cycle so that cod sperm can fix carbon dioxide by at least these two routes.

Composition and origin of marine oils. Several hitherto unreported monoethylenic fatty acids were discovered in herring oil. The complete isomer pattern in different chain lengths was correlated with the activity of a single enzyme specifically removing hydrogen atoms from saturated fatty acids at positions 9 and 10 carbon atoms removed from the carboxyl group.

Study of a number of herring oils having a range of iodine values showed that although percentages of individual fatty acids might vary markedly from sample to sample, there were "groups" of related fatty acids exhibiting either constant proportions or proportions varying in relation to iodine value. Thus, total saturated fatty acids increased with increasing iodine value, but hexadecanoic acid was always nearly 60% of these totals. The ratio of hexadecanoic acid to the sum of hexadecenoic and octadecenoic acids was more consistent than the ratio to hexadecenoic acid alone, suggesting that the two monounsaturated acids are to some extent interchangeable in herring oils. A number of similar relationships were explored in the polyunsaturated fatty acids, the most important observation being that as iodine value increases the fatty acids of "linolenic" type became more prominent than those of "linoleic" type.

The origin of phytanic (3,7,11,15-tetramethylhexadecanoic) and associated isoprenoid acids in marine oils was investigated in collaboration with scientists from the Department of Scientific and Industrial Research, New Zealand, and the National Research Council, Ottawa. Two diastereoisomers were demonstrated with advanced gas-liquid chromatographic techniques and it was shown that the ratios of the two isomers in marine fish, and to a lesser extent in marine mammals, differ completely from the ratios common in terrestrial animals. Investigations are being extended to a wider variety of aquatic organisms to clarify the reason for this difference.

The activity of the endogenous enzymes involved in liberating oil from cod livers was demonstrated by elimination of bacterial effects through irradiation sterilization and the use of antibiotics. Seasonal variations in the proportion of fatty acids liberated were related to the fat content of livers. Isopropyl alcohol at suitable concentrations inhibited cellular decomposition in cod livers as well as lipolytic activity.

A comparative study of the fatty acid composition of Atlantic herring oils led to discovery of a general relationship for deriving the percentage of polyunsaturated fatty acids in marine oils or lipids from one of the simplest properties, the iodine value.

The fatty acid composition of Atlantic finwhale oil was found to differ from Antarctic finwhale oil in having high proportions of eicosenoic and decosenoic fatty acids. Further investigation of dietary lipids showed that these acids originate in depot fats of herring and capelin, and particularly in a North Atlantic zooplankter, *Meganyctiphanes norvegica*, which is believed to have a fatty acid composition unique in this respect.

Previous studies on the nitromethane concentration of unsaturated methyl esters of marine origin led to a simple procedure for concentrating these esters

as a generally applicable aid to the gas chromatographic identification of fatty acids.

The potential value of Atlantic herring oils with iodine values as low as 95–105 to the Canadian edible oils industry was publicized in a symposium on Canadian marine oils.

Digestion of fat by marine animals. Lobster and cod digest fats by splitting off the fatty acids bound on the outer positions of glycerol. In lobster the fat is then resynthesized. In fish a large part of the fat undergoes further breakdown to glycerol and fatty acid before it is deposited; this is also the course of fat assimilation in mammals.

Structure of fats of aquatic animals. The distribution of fatty acids within fat molecules is asymmetrical. In fish and invertebrates the polyunsaturated acids are found accumulated mainly in position 2 and then in position 3 of the glycerol. In the fat of seals, whales, and polar bear, however, these acids occur mainly in position 3 and do not, in this respect, take the place of the linoleic acid found in terrestrial mammals.

Incorporation of marine fats into the fats of mammals. Analyses of minks and rats fed on mackerel showed that marine polyunsaturated fatty acids can replace the usual essential acids (linoleic, arachidonic) as structural units of mammalian phospholipids. The depot fats, however, resembled in structure that of seals rather than that normal for terrestrial mammals.

The pancreatic lipase of mammals digests esters of marine polyunsaturated fatty acids only very slowly, but this fact has probably little influence on the digestibility of marine fats.

Phytoplankton. The concentrations of the B vitamins have been determined in dulse (*Rhodymenia palmata*) by microbiological assay. Dulse is widely distributed along the Nova Scotia and New Brunswick coast and is the only commercially available edible seaweed in Canada.

Sterol was isolated from Irish moss (*Chondrus crispus*) harvested in Nova Scotia. The principal sterol was identified as cholesterol by thin-layer chromatography, gas-liquid chromatography, infrared spectra, and chemical constants of the sterol and its derivatives. The total and free sterol content of the dry seaweed were 0.012% and 0.011%, respectively. The crude sterol contained 1.75% of a provitamin D.

Marine Bacteria

Formation of formaldehyde from betaine, dimethylglycine, and sarcosine. Formaldehyde was demonstrated as an intermediate of betaine, dimethylglycine, and sarcosine oxidation in previous work with the marine bacterium, *Achromobacter* sp. By using a trapping agent, formaldehyde was isolated as the dimedone derivative when intact bacterial cells were incubated with betaine, dimethylglycine, or sarcosine. It was apparent that three methyl groups of betaine were converted to formaldehyde by the isolated marine bacterium.

PRODUCTS AND PROCESSING

Freeze-drying. A preliminary investigation of the freeze-drying of Atlantic cod steaks was completed. Drying time varied directly with sample thickness, inversely with temperature, was influenced by state of rigor in thinner samples only, and was not affected by sex of fish, rate of freezing, or dryer pressure.

Quality depended upon state of rigor (in slow-frozen samples only), thickness of sample and, to a lesser degree, upon sample temperature and dryer pressure, but was not significantly affected by sex of fish or rate of freezing.

Acceptable freeze-dried cod steaks could be consistently produced from all except post-rigor, slow-frozen fish.

Section of the pilot plant area used for the production of fish protein concentrate.

Cost of producing F.P.C. (Fish Protein Concentrate) by Halifax process. A study of the cost of producing F.P.C. in the Halifax area was made by Stone and Webster Ltd. of Toronto at our request. This study indicated the possibility of producing F.P.C. from cod trimmings for a price of between 32.7 cents per lb and 17.0 cents per lb with a capital cost of between 1.6 million and 1.3 million dollars, depending on production conditions.

LIAISON WITH INDUSTRY

The Scientific Liaison Officer made visits to fish plants in Newfoundland, Prince Edward Island, New Brunswick, and Nova Scotia. As a result of this

personal contact, there was a steady increase in the number of inquiries by mail, telephone, and visits. Papers were presented at several meetings attended by industry. The mailing list for circulars was revised and greatly expanded. Liaison with the industry had directly resulted in improved use of resources in at least two instances, shrimps and fish skins. Considerable interest developed in water thawing, fish protein concentrate, and nutritional data for fish meals.

ATLANTIC OCEANOGRAPHIC GROUP, DARTMOUTH, NOVA SCOTIA

L. M. Dickie, PH.D.(Toronto), *Director*; from July, 1965
M. Blaxland, *Executive Assistant*; from August, 1965

Environmental Oceanography

R. W. Trites, PH.D.(British Columbia)
D. H. Loring, PH.D.(Manchester)
R. F. Platford, PH.D.(Saskatchewan)
B. L. Blackford, M.SC.(Mass. Inst. Tech.); to September, 1965
I. W. Duedall, M.SC.(Oregon); from June, 1966

Biological Oceanography

R. J. Conover, PH.D.(Yale); from September, 1966
A. Prakash, PH.D.(British Columbia)
Vivien M. Brawn (Srivastava), PH.D. (British Columbia); from August, 1965
E. Kott, PH.D.(Toronto); from July, 1965
D. L. Peer, M.SC.(Saskatchewan)
T. C. Platt, M.A.(Toronto); from June, 1965

Fisheries Oceanography

J. E. Paloheimo, M.A.(Toronto); from August, 1966
E. Bakken, Cand.real(Bergen); from May, 1966
S. Paulowich; from April, 1966

Visiting Scientists

Dr D. J. G. Nota, Wageningen, Holland; from July 8 to September 9, 1965, and May 23 to June 3, 1966
Dr E. R. Baylor, Woods Hole Oceanographic Institution, Woods Hole, Mass.; from July 11 to July 27, 1966

In 1965 the Atlantic Oceanographic Group, formerly part of the Biological Station, St. Andrews, was established as an independent marine research laboratory, located in the Bedford Institute of Oceanography at Dartmouth, N.S. The change in status marked the beginning of a new, expanded program of study of the processes underlying marine production. With such a major change of scope and emphasis, the main effort during the period under review has been concentrated on planning, recruiting for, and organizing future programs. Emphasis in the research is being placed on increasing knowledge of the structure and dynamics of the environment and biological resources, and the effects of these characteristics on harvesting of the resources. The main projects undertaken in 1965–66 included

• Environmental Studies: physical oceanography of near-shore areas, and coastal regions including the Gulf of St. Lawrence; geomorphology and geochemistry of marine sediments in the Gulf of St. Lawrence; sea water chemistry in model and natural systems; phytoplankton, especially dinoflagellate growth requirements and their relations to red-tide phenomena and paralytic shellfish poisoning; field sampling in primary productivity (phytoplankton abundance, production rates, and nutrient chemistry); field sampling for abundance and distributions of benthic organisms; caloric values of benthic organisms and fish food; seasonal changes in physiology of zooplankton related to feeding.

• The Resources: nature of the distribution and abundance of different size and species components of an unexploited benthic fish community; chemical indices of metabolic and productivity levels in relation to feeding and environmental changes.

• Harvesting the Resource: characteristics of the distribution of concentrations of common fishes in relation to sampling by otter trawls; mathematical studies of the nature of predator-prey relations; electro-acoustic instrument and system development for measuring abundance of demersal fishes.

THE ENVIRONMENT

Physical oceanography. Water circulation patterns in the Gulf of St. Lawrence were studied by means of radio drift buoys with parachute drogues set in the surface layer, the intermediate layer, and in the deeper waters. The speed and direction of the water in the three layers were different and variable. Surface movements were rapid, strongly influenced by wind, and showed the presence of gyres, possibly formed under the influence of coastal configurations. Movements in the region of the thermocline were weaker and in 1965 on the Magdalen Shallows were insignificant over a period of 10 days. Movements in the area of Cabot Strait in 1966 were rather irregular, indicating a need for frequent position fixing if the apparently complex movements are to be outlined.

Preliminary attempts at electrical analogue modelling of the Gulf of St. Lawrence system demonstrated that surface circulation patterns of the general type observed were created by wind stress. A second, more complex model was designed to include variations in depth and density, but was abandoned when it became evident that inclusion of important boundary conditions and density structure required at least an order of magnitude decrease in grid spacing, and therefore, at least a thousand-fold increase in the number of components.

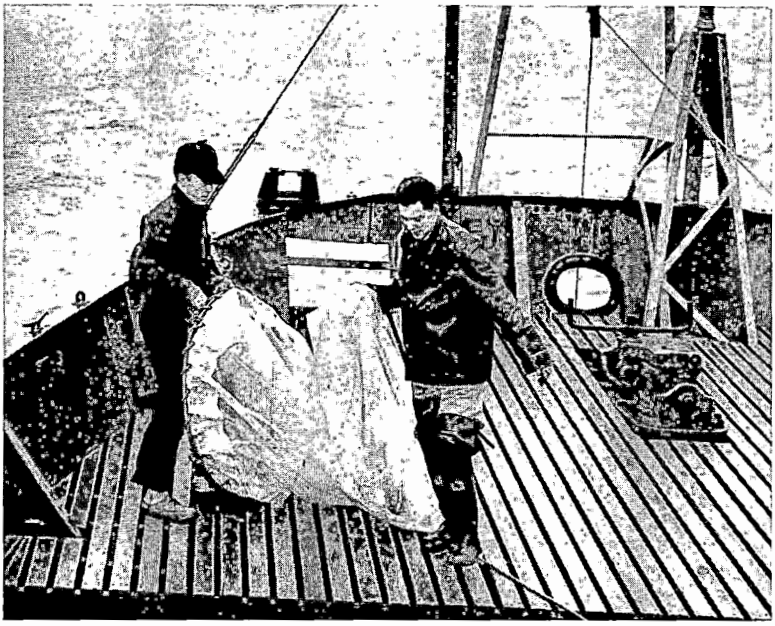
A study of small-scale structure of the surface waters of St. Margaret's Bay was undertaken in association with the Woods Hole Oceanographic Institution. Continuous horizontal temperature and zooplankton sections were made in association with Rhodamine dye, aluminum powder, and smoke float releases. The apparently Laingmuir-type circulation pattern was reflected in regular 5–10 m horizontal temperature fluctuations of as much as 1 and 2 centigrade degrees and in the dye and powder movements. The zooplankton distribution appeared to be correlated with the temperature fluctuations.

Near-shore studies in physical oceanography have included embayments where the influence of freshwater discharge plays a relatively minor role, and estuaries where freshwater run-off is the key factor in dynamics and circulation. In one shallow coastal plain estuary (Cheticamp, N.S.) the mouth varied in size because of the opposing action of barrier beach formation under wave action, and the erosional action of the river discharge. On occasions the mouth was completely closed. In a similar estuary (Margaree, N.S.) where the opening was stabilized by breakwaters, the discharge tended to be intermittent, because of tidal action, when freshwater outflow was small but the discharge became more regular with less complete mixing during periods of high run-off. In a third area (Pictou, N.S.), with relatively little river discharge and a different topographical

configuration, tidal action caused quite thorough mixing but the relatively large basin produced a low rate of flushing. Comparative embayment studies started at a later date include the much larger St. Margaret's Bay.

Geomorphology and geochemistry. A 4-year extensive study of the morphology, sedimentation, and geochemistry of the bottom in the Gulf of St. Lawrence revealed characteristics of the original formation, and the past and present erosional and distributional patterns of the sediments. Results indicate that Pleistocene scouring, modified by several distinct contemporary sedimentary environments, is responsible for the basic morphology. Geochemical and mineralogical studies of $CaCO_3$ in the sedments show that shell fragments and calcareous foraminifera are the main carbonate sources only in those sediments containing less than 5% $CaCO_3$. Carbonate concentrations of up to 30%, observed in two regions, are related to erosion of bedrock and submerged reefs. At least four distinct mineralogical associations were identified and appear to be related to depositional conditions. Studies of "free" iron and related metabolic cations indicate that the retention and mobilization of many of them are related to the formation and dissolution of iron compounds under present physical-chemical conditions.

Chemistry. Determination of partial molar volumes of major salts in sea water is basic to density calculations, geochemical studies, and predictions of pressure effects. The partial volumes of major salts are known but no information is available on non-conservative salts such as calcium carbonate, sodium silicate, and calcium phosphate. A dilatometer was constructed for making these measurements.



Oceanographers prepare to lower a plankton net to sample marine life in Atlantic waters.

Continuing studies of the activity coefficients in model seawater systems (H_2O–0.5 m NaCl–0.05 m $MgSO_4$) indicate that the coefficient of the $MgSO_4$ is only 0.13 at 25 C, which is further evidence of the oceanographic peculiarities of the chemically interesting magnesium ion.

Dinoflagellate growth requirements. Laboratory cultures of dinoflagellates have shown the dependence of growth rates and culture "maturity" on temperature, salinity, various nutrient salts, and on a "humic" factor derived from land run-off. Observations of "red-water" and blooms of dinoflagellates related to paralytic shellfish poisoning also illustrate the additional importance of stability of water masses and of high sunlight intensities on initiation of the blooms.

Benthic communities. Sorting and analyses of samples of benthic organisms in the sediments of the Gulf of St. Lawrence were virtually complete by 1967. The samples provide quantitative information on the distribution and abundance of some 50 groups of animals, 13 of which may be classed as "common." Several species show strongly contagious distributions within "stations" on the basis of the 0.1 m^2 Van Veen bottom grab, whereas others show small variations within stations but major station-to-station differences. The variance within stations appears strongly related to the dispersal behaviour of adults and larvae. Between-station variations appear related to sorting coefficients and mean particle sizes of sediments.

Caloric content of the bottom fauna. Determinations of caloric values of dominant forms in bottom samples showed a regular pattern of distribution of energy per unit area in the standing crops irrespective of species and size compositions of the component animals.

The Resource

Studies of an unexploited population of American plaice. The population of American plaice in St. Margaret's Bay, N.S., has been protected from commercial otter-trawling for many years. Sampling of the stock, initiated in 1966, showed a relative constancy of biomass from station to station within the Bay, but marked heterogeneity of the size-composition. The fish are slow growing and appear to have a high natural mortality rate in relation to that of exploited populations in the Gulf of St. Lawrence.

Harvesting the Resource

Heterogeneity in commercial fish distributions. The uneven local distribution of commercial fishes was a source of major difficulty in assessing abundance from commercial or research vessel catch data. Analyses of research vessel catches have confirmed that among haddock these aggregations are significant with respect to the area covered per $\frac{1}{2}$-hr tow. Theoretical models were developed to show how such characteristics affect fishing success. The results indicate the extent to which a knowledge of such variations could be used to improve fishing efficiency.

Mathematical models of fish growth in relation to feeding were developed on the basis of empirically derived physiological parameters. The results suggest that maximum sustained yields depend upon the grazing efficiency which may differ

significantly among sizes and species, and generally are higher among smaller fish. The results also indicate the importance of distribution of food and fishes on production in a predator-prey system.

An electro-acoustic system for counting echos from demersal fishes and compiling the results on a detailed geographic grid was built and found to perform satisfactorily in preliminary trials on redfish.

ST. ANDREWS, NEW BRUNSWICK BIOLOGICAL STATION

J. L. Hart, PH.D.(Toronto), F.R.S.C., *Director*
J. C. Medcof, PH.D.(Illinois), *Assistant Director*
A. Weinsieder, M.S.(Vermont), *Assistant to Director*; from August 30, 1965

Lobster

D. G. Wilder, PH.D.(Toronto)
D. W. McLeese, PH.D.(Toronto)
D. J. Scarratt, PH.D.(Wales)
J. Watson, PH.D.(Durham); from September 27, 1966

Oyster

R. E. Drinnan, B.SC.(London)
M. L. H. Thomas, M.S.A.(Toronto)
W. B. Stallworthy, PH.D.(Toronto); casual, June 21–July 16, 1965

Groundfish

F. D. McCracken, PH.D.(Toronto)
L. M. Dickie, PH.D.(Toronto); to July 1, 1965
A. C. Kohler, PH.D.(McGill)
P. M. Powles, PH.D.(McGill)
A. V. Tyler, M.A.(Toronto); on educational leave from October 3, 1966
A. R. Emery, M.SC.(Toronto); to February 2, 1965
J. S. Scott, PH.D.(St. Andrews); from November 5, 1966

Pelagic

S. N. Tibbo, M.A.(Toronto)
B. E. Barrett, PH.D.(New Hampshire); from June 15, 1966
R. D. Humphreys, M.A.(British Columbia); to May 7, 1966
J. S. Beckett, B.A.(Cambridge)
W. B. Scott, PH.D.(Toronto); casual, July 4–September 3, 1966

Gear Research

P. J. G. Carrothers, S.M.(Mass. Inst. Tech.)

Fish Behaviour

F. W. H. Beamish, PH.D.(Toronto); to December 1, 1965

Scallop

N. F. Bourne, PH.D.(Toronto); to June 16, 1965
J. F. Caddy, PH.D.(London); from February 4, 1966

Fisheries Oceanography

L. M. Lauzier, D.SC.(Laval)

Anadromous

K. R. Allen, M.A.(Cambridge); from November 1, 1965
M. W. Smith, PH.D.(Toronto)
P. F. Elson, PH.D.(Toronto)
R. L. Saunders, PH.D.(Toronto)
J. W. Saunders, M.SC.(Laval)
P. E. K. Symons, PH.D.(Leiden); from September 1, 1965
J. H. C. Pippy, M.SC.(Memorial); from June 3, 1966

Pollution

J. B. Sprague, PH.D.(Toronto)

Mathematical Statistics

J. E. Paloheimo, M.A.(Toronto); on educational leave from October 1, 1965, to August 15, 1966
W. R. Knight, PH.D.(Toronto); casual, May 17–August 18, 1965, and May 9–August 23, 1966

Non-Staff

J. S. Alabaster, PH.D., guest investigator; 1966
D. P. Dehadrai, PH.D.(Delhi), National Research Council postdoctoral fellow; to February 1966
R. S. Dunn, B.SC., graduate student; 1966
R. G. Halliday, PH.D.(Glasgow), National Research Council postdoctoral fellow; from October 1966
R. A. McKenzie, M.A.(Toronto); Industrial Development Service and Fisheries Research Board Contracts 1965 and 1966
T. W. Rowell, B.SC., graduate student; 1966
A. J. Waterman, PH.D., guest investigator; 1966

Research at the St. Andrews Station is aimed at providing information applicable to sound management and full utilization of marine and freshwater resources available to Maritime fisheries. It may be considered under the following categories:

- Environment; studies of the environment based on observations of marine circulation and water properties in the sea, sediment on the bottom, and changes brought about by human interference.
- Resource; an important part of investigations at St. Andrews including exploration for new fish stocks and new fishing areas, all phases of the biology of species comprising the stock, and population studies which look at size and continuity of the stock and at mass responses to fishing stresses.
- Harvesting.
- Increasing the resource; trials of positive methods of increasing production of lobster and oyster.
- Utilization.

The work was organized and carried out on the basis of the following species and subject investigations: lobster, oyster and clams, groundfish, pelagic fishes, scallop, behaviour, gear engineering, fisheries oceanography, andromous fishes, and pollution. There is much interlocking of interest among categories and investigations, and co-operative study between groups is frequent.

ENVIRONMENT

Surface and bottom movements of water. Recoveries of 706 out of 7509 drift bottles released indicated general surface circulation patterns in 1966. For example, the surface circulation in the Bay of Fundy area was "closed" for the fourth consecutive year so that there was little exchange of water between it and the Gulf of Maine. Recoveries also showed that the north-easterly drift along the west coast of Newfoundland reached 8–13 km a day and seemed to be stronger than previously estimated.

There were 357 recoveries from 6251 seabed drifters put out in 1966 to indicate water movements along the bottom. In Northumberland Strait drifter recoveries gave clear indication of convergence in the Wood Island–Pictou area which had been suspected previously from stratification patterns in the water. Bottom water moved into the Bay of Fundy along the southeast shore and out past Grand Manan and along the shore of Maine.

During the last six years, 62 surface drift bottle recoveries have been recorded from Europe. Recently a higher proportion than formerly of drift bottles crossing the Atlantic has been recovered from southern Europe, and those recovered along the British Isles are taking longer to reach their destinations.

Water properties. Surface water temperatures at all fixed monitoring stations were somewhat higher in 1966 than in 1965, but except in the Gulf of St. Lawrence, they were below long-term averages. Similarly at Prince Station 5 at

the entrance to Passamaquoddy Bay both bottom and surface temperatures were above those of 1966 but below the long-term (34-year) averages.

The general distribution of water masses in Cabot Strait in 1966 resembled that of the cold-water period of the 1930's with a reduced volume in the deep warm layer and a relatively low maximum temperature within the deep layer.

Alteration in the environment. In a variety of situations, alterations of the environment induced by human enterprise were examined or anticipated.

Dissolved oxygen in the estuary of the Restigouche River in October was in general near saturation. However, it lowered to 89–94% at low tide in the channel between the sulphite pulpmill and Campbellton. These observations were made in October when river discharge was close to average and water temperatures were between 4 and 6 C.

Monitoring metal ion load in the Northwest Miramichi River in 1966 showed that toxic levels caused by mine wastes were close to the average over the last 6 years. This must be regarded as part of the environment for Miramichi salmon until better control measures are operational. It is noteworthy that in March and April the river should be regarded as poisonous to fish.

Water leaving tailings ponds for the precipitation of metal ions from mining operations is highly alkaline as it enters Little River of the Miramichi System. It gains in acidity, dropping in *p*H from 9.7 to 3.0 after only 5.1 km of flow and is still a lethal *p*H 3.3 after 23.2 km.

In Wabush Lake in West Labrador widespread direct lethal effects on fish of pollution from an iron mine are unlikely. Any ferrous iron in the effluent would be oxidized quickly to non-toxic ferric iron with the result that any deleterious effects would stem from suspended material which rapidly settles out. In the August in which studies were made the lake was not stratified and oxygen concentrations were close to saturation throughout. *p*H was well within the range of tolerance. Settling solids from the mining operations may be expected to change bottom characteristics and thus reduce productivity on a long-term basis.

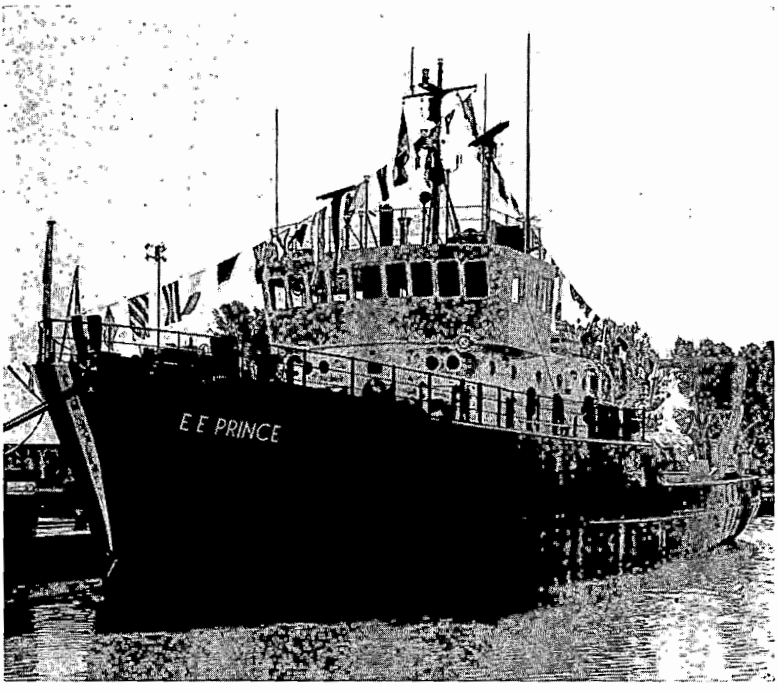
Sedimentation and bottom studies. In Malpeque Bay marked changes in both the amount and species content of bottom biomass were observed during 4 years at 2 of 37 observation sites. Changes were unfavourable to productive oyster growing. In general, biomass decreased as depth increased. Rock substrates were most productive. Muddy sand, sand, gravel, sandy-mud, and mud followed in order of decreasing faunal biomass.

Laboratory tests demonstrated that a marine worm (*Nereis virens*) and a clam (*Cumingia tellinoides*) which are part of the natural fauna of oyster beds play active parts in reducing silt accumulation.

Eelgrass can be reduced or eliminated on oyster grounds by mechanical cutting or by use of herbicides. Effects of mechanical cutting are variable. Autumn cutting induces winter mortality. Herbicides when applied properly control eelgrass effectively and have no evident side effects on fauna but the public health aspects of their use remain to be assessed. As eelgrass on oyster grounds both encourages silting and interferes with harvest, practical control measures are required.

Silting interferes with fish in fresh water, also. In the autumn of 1965 repairs to an unsurfaced road near the head of Hayes Brook in the Ellerslie system led

to heavy silt accumulation which natural water flows did not flush out. The lowest standing crop of trout in 20 years of study was encountered in 1966. This observation parallels one from Ellerslie Brook in 1958–59 when the lower part of the brook was silted in, reducing the abundance of trout in 1960.



The new fisheries research vessel CGS *E. E. Prince* operating out of St. Andrews.

Resource

Exploration. Exploratory fishing for lobsters gave no indication of large unused segments of the stock. In 1965, only 196 lobsters were taken by 192 trawl tows of $\frac{3}{4}$–1 hour duration along the edge of the continental slope. Only 10 lobsters were caught in 192 trap hauls in deeper water off western Nova Scotia. Further tests in 1966 yielded only 24 lobsters from 115 trawl tows off southern Nova Scotia. Although returns were small off Nova Scotia, promising catches were made farther to the south along the edges of Georges Bank at similar depths and water temperatures. United States fishermen were working these grounds at the beginning of 1967.

Lobster trap fishing in July and August of 1966 yielded only 83 lobsters, half of them less than legal size, from 486 trap hauls on offshore grounds beyond those fished by commercial fishermen between Grand Manan and German Bank.

The existence of extensive stocks of bar clams in Malpeque Bay, P.E.I., too deep to harvest by gear in current use, was confirmed by a newly designed hydraulic sampling dredge.

Good trawl catches of argentines were made south of Sable Island and along the southern edge of Banquereau in an area unexplored previous to 1966. These fish were 25–30 cm long. Just as in 1965, catches were good along the edge of the continental shelf off LeHave, Browns, and Georges banks in depths between 150 and 275 m.

Exploratory trawling for herring close to the 200 m contour from Georges Bank to Sable Island produced poor catches in seven cruises in 1965 and 1966. The best catches were made near Corsair Canyon, Georges Bank. A lined No. 41 Yankee trawl was over eight times as productive as a Dutch herring trawl.

Ten kinds of sharks were captured incidental to the new longline fishery for swordfish in 1966. All kinds except porbeagle and mako sharks have generally been discarded in the past but improving technology and expanding markets may add additional species to the fishery.

Surveys in 1965 of scallop fishing areas in the southern Gulf of St. Lawrence showed potential areas for commercial fishing — off Cape Bear and Boughton Island, and on restricted grounds south of the Magdalen Islands. Grounds immediately west of Pictou Island showed the abundance of scallops to be borderline for commercial utilization.

Scallop surveys in the Bay of Fundy in 1966 showed poor catches on traditional fishing grounds. Good catches were made beyond 22 km (12 miles) offshore but the small size and inferior quality of meats reduce incentive to exploitation. Most scallops were 10 years old and very few young were observed except off Gullivers Head.

Lobsters and crabs. Tagging and marking experiments on lobsters at Miminegash, P.E.I., showed the percentage growth per moult to be 13.6%. Moulting frequency depends upon size. Failures to moult were 18% among sub-legal lobsters, 44% among canners, and 72% among markets. Sub-legal lobsters released in June suffered a 65% mortality during the following two months. Legal-sized lobsters showed a 45% mortality.

Lobster food intake almost doubles with an increase of temperature from 10 to 20 C. Food consumption as a percentage of lobster weight was less for larger lobsters than for smaller ones. Newly moulted lobsters at 15 C consumed nearly three times as much food as hard-shelled lobsters of similar size.

Field observations showed first and second stage larva to be at the surface more in daytime than at night. For third and fourth stage, preferences were not significant. Laboratory observation on the response of fourth stage larvae to changing light in the presence of a thermocline gave confusing results.

Lobster larvae hatched in sea water of 31.4‰ salinity avoid fresh water. They do not pass readily into water of salinity 21.4‰, which is above the lower critical level for their survival. This may promote survival where surface waters are diluted by rainfall as in British Columbia inlets or by polluted fresh water of pulpmill effluents.

A survey for lobster larvae off Pictou, N.S., showed few larvae within 3 km of the harbour entrance but concentrations of up to 200 per tow farther out.

For comparison with lobster tolerances, the lethal threshold for salmon parr of bleached kraft mill effluent (BKME) was determined and found to be between

12 and 15%. Tests with lobster larvae were complicated by salinity (fresh water) effects but gave similar results. Results of tests with adult lobsters were extremely variable but it is evident that the adults are highly resistant to BKME under the favourable conditions that might be expected at sea. Further tests showed that biological treatment of BKME is effective in reducing toxicity to salmon but not necessarily, or quickly, so for lobsters.

Sphyrion tags, each consisting of a stainless steel anchor joined to a vinyl spaghetti label by polyethylene monofilament inserted in the joints between carapace and first abdominal segment, did not cause excessive mortality. The tag remained in place effectively after moulting.

Spider crabs, *Chionoecetes opilio*, do not tolerate high water temperatures. At 20 C, half died within 2 hours and at 16 C half died within 430 hours.

Oyster. The epidemic of so-called Malpeque disease that devastated mainland oyster populations over the last 12 years had shown no further spread by 1967. Oysters at Shippegan and Bras d'Or Lake are still susceptible. However, mortalities observed at Bras d'Or Lake in 1965 are attributed to low salinities where the oysters were held.

In both 1965 and 1966 spatfall was generally light throughout the Maritimes except in the Bras d'Or Lake region. Spat settlement on scallop shells was better during the second week of exposure on spat collecting strings.

At Ellerslie in 1965, oysters on trays were found to grow slowest on the bottom and faster at mid-water.

Groundfish. Fishing success, and sizes and ages of fish landed provide the most useful information on stocks of commercial fishes. A critical analysis of our coverage of information on these subjects indicated that, because of changing practices, a continued effort must be made toward complete coverage. Information obtained on fish landings and fish sizes are the basis for Canadian biological studies and international research.

Systematic sampling of commercial landings in the southern Gulf of St. Lawrence showed that while total landings were going up, cod landings had declined slightly since 1962. Research catches show that cod were smaller in 1966 than in 1965.

Studies of egg and larvae stages of groundfish in the Gulf of St. Lawrence showed cod eggs to be more evenly spread in 1966 than in 1965. The larvae of yellowtail flounder were abundant during the summer although no eggs were found in early collections.

Haddock stock surveys were continued through 1965 and into 1966. No great changes in stocks were observed but the anticipated contributions of the 1962 and 1963 year-classes did not materialize. Depletion of heavy unsampled catches by foreign fishing fleets in 1965 may be involved.

Size distributions, and anal and dorsal fin-ray counts both showed yellowtail flounder stocks on the Magdalen Shallows to be different from those on the Nova Scotian Banks. Fish from the Nova Scotia Banks were larger and had more rays in their anal fins. No great difference in these characters was found among samples of yellowtail from different parts of the Nova Scotia Banks.

Incipient lethal levels for expected effluents from a smelter planned at Belledune, N.B., using small winter flounders as test animals were copper, 0.85 mg/liter Cu; silver, 0.87 mg/liter Ag; lead, 15 mg/liter Pb; cadmium, 20 mg/liter Cd; zinc, 20 mg/liter Zn; and fluorine, 44 mg/liter as H_2SiF_6 (believed produced by low *p*H). Gypsum in heavy suspensions killed fish.

For the first time, infections by *Ichthyosporidium* sp. were recorded from the livers of yellowtails. The fish were taken on the Nova Scotia Banks.

American plaice grow notably fast in Passamaquoddy Bay where female fish reach a length of 53 cm by age 12. On the Magdalen Shallows where growth is slow, plaice are only about 47 cm at that age. However in slower-growing areas, fish live to be older and reach a greater final size.

Cod accept increasing amounts of food as water temperatures increase from 2 to 15 C but convert the food ingested into flesh better at 2 and 5 C than at the higher temperatures. Digestion rates in young winter flounders and cod are influenced by the size of the food particles.

In winter flounders, food consumed, fat content and weight of liver, and gonad weight are closely correlated. Fish fed less than a critical amount show suppressed follicular development in their ovaries.

Pelagic fishes. Landings and fish sizes are analysed to provide a gauge of fisheries. Pelagic fish landings in the Maritimes and Quebec during 1966 included 221,000 metric tons (m t) herring, 11,000 m t mackerel, 4,400 m t swordfish, 230 m t tuna, and 110 m t shark. Herring landings were up by 50% in Yarmouth County and 31% in Chaleur Bay. Swordfish landings were down. Tuna landings also fell off with the diversion of purse seiners to the herring fishery. Shark landings were small but twice those of the previous year.

Herring hatched in 1963 were most important in catches both in southwest Nova Scotia and southern New Brunswick in 1966. In Nova Scotia the 1963 year-class was superseded in importance by 1961 fish in April. In New Brunswick, also about April, the 1963 year-class began to be outnumbered by 1964 fish.

During 1966 postlarval herring, 24–41 mm, were abundant in Passamaquoddy Bay at 8–25 m depth. Very few postlarval herring were taken outside the Bay in the Bay of Fundy.

Internal tags were found to be the most effective way of tagging herring. These can be made of magnetic stainless steel and recovered by magnets in reduction plants.

Mackerel grow quickly during their first 3 years of life but thereafter the annual increase in length is small.

Most of the recoveries of the mackerel tagged in Nova Scotia and off Prince Edward Island were made quickly and showed short migrations. However, three returns in 1966 were made well to the eastward, the fish having travelled about 18 km per day. This confirms a migration deduced from fishing experience.

The average weight of swordfish landed had been declining at a rate of 9% annually since 1963. In 1966 it continued to decline at a lesser rate, but in that year reduction was associated with a change of fishing grounds to warmer Gulf stream water where fish are generally found to be smaller.

In February 1965, 47 young swordfish, 18–111 mm, were found near abrupt horizontal gradients of either temperatures or salinity off the United States coast

and in the Caribbean. Temperatures ranged from 23.7 to 25.6 C and salinities from 35.81 to 36.60‰.

Tuna come from three sources in the Canadian fishery. They are landed as incidental catches in the swordfish fishery and are taken by traps and purse seiners. Longlines set for swordfish take a variety of tuna species but traps and seiners have taken mostly bluefins. There were no seine-caught landings in 1966.

Tag recoveries from large pelagic fishes show that some swordfish, sharks, and bluefin tunas survive the stresses of tagging. Both long and short migrations are striking. Among the 18 returns, the only swordfish recovery showed a movement of only 10 km in 641 days. A dusky shark travelled over 2,000 km from Georges Bank to Tortugas in 276 days, and a 76 cm bluefin tuna crossed the Atlantic from off New Jersey to the Bay of Biscay in 377 days.

Capelin occurred abundantly in the Bay of Fundy from February to April 1965 and were taken in research catches again in 1966. Capelin taken in April 1965 were approaching a spawning condition. Samples were examined in detail for comparison with other stocks.

Scallop. In 1965, scallop landings reached an all-time high at 19 million lb. About 40% of the catch came from grounds off the Virginia coast following the discovery of readily exploitable concentrations. In 1966, landings dropped to about 18 million lb. Although a similar proportion of the landings came from the Virginia grounds, there was no evidence of a significant decline in abundance on Georges Bank which had been the mainstay of the fishery.

Plankton collections at the proper season in Passamaquoddy Bay did not indicate significant numbers of scallop-like larvae. However, early post larval stages were found in Penobscot Bay epifauna on a colonial bryozoan which in turn was fixed to the shells of living adult scallops. None was found elsewhere.

Juvenile scallops in the laboratory can attach themselves to a new surface in 7 minutes, so the young animals in nature may be quite mobile. Even at a commercial size some scallops occasionally continue to attach themselves to the substrate by the byssus. In their 4th year at 50–60 mm length, 50% became attached to hard surfaces in the laboratory.

Free swimming by adult scallops subsides after about 6 hours in a laboratory container. Among tagged scallops planted on a smooth stretch of bottom in the St. Croix estuary, however, dispersion continued for some months. The axes of dispersion corresponded with the directions of tidal currents in the inlet.

Shock marks on scallop shells suggest that many young scallops, small enough to pass through the meshes of the drag, are injured by fishing operations but escape.

Salmon. Salmon catches in the Maritimes area continued to rise in 1966. The commercial catch was slightly lower than in 1965 but was still higher than in any other year since 1950. The angling catch increased over that of 1965 by almost 30% and was the highest for many years. The decline in the number of large salmon at the counting fence on the Northwest Miramichi continued and the number in 1966 was the lowest on record.

At the counting fence, 3-year-old smolts were found to migrate downstream first. With the advance of the season, 2-year-old smolts increased in relative

numbers. Young female salmon become smolts younger on the average and migrate earlier in the year. More than half the male smolts had mature testes; the proportion that were mature increased with age and reached 90% in 4-year-olds. The proportion of 4-year-old smolts was significantly higher in 1966 than in 1965.

Lack of clear-cut results at this stage from the study of the effects of merganser control on salmon catches emphasizes the complexity of the problem and the dependence of results on highly variable and complicated environmental factors.

A new program for studying effects of environmental factors on trout and salmon production in small tributaries of large rivers was established in 1966 in Trout Brook and the Nashwaaksis River. Movements and mortalities of fish in both directions were monitored in relation to physical and biotic conditions, and the history of spraying with insecticides.

From about 42,000 salmon smolts tagged in the Maritimes in 1965, 98 small salmon were recovered in Greenland during 1966. Drift nets off the coast took 3 of these and the rest were taken in nets along shore. This brought the total of smolts tagged in Canada and recovered in Greenland to 130. Of 223 salmon tagged in Greenland by Scottish and Danish biologists in September of 1965, one was captured in southwest Newfoundland near Cabot Strait. Mathematical studies of the salmon population indicated that the Greenland fishery would be unlikely to produce any great change in world Atlantic salmon production. There would be, however, a reduction in the catches of large salmon in home waters. Canadian rivers would likely be the most affected. Grilse fishing would suffer no direct effects.

The acanthocephalan *Pomphorhynchus laevis*(?) appeared to be the most promising of the many parasites examined for use as a natural tag in separating fish of North American and European origin on Greenland fishing grounds. The study of parasites for this and other purposes was being actively pursued.

Salmon reared from early running parents tend to produce offspring which are early-run, at least as grilse. Returns of 276 tags from plantings of nearly 15,000 hatchery-reared smolts of known early- and late-run parentage showed that early-run parents produced 87% early-run progeny compared with 19% from late-run parents. Descendants of early-run fish had a higher percentage return to the fishery and a higher proportion in anglers' catches. Of 276 tags returned, 21 came from Greenland fisheries.

Salmon fry grew faster on the whole in water of 6‰ salinity than at 12‰ or in fresh water in 1966. Between 5 and 16 C, growth rate was positively related to temperature. Experiments in 1965 showed that moderate salinity reduced mortality among salmon fry under favourable diet conditions but increased deaths when the fish were stressed by a thiamine deficiency induced by a diet of raw herring.

Salmon smolts grow better in dilute sea water (15‰) or in fresh water than in full sea water (30‰). Optimum temperatures for growth are lower in salt water. At any salinity, feeding falls off at temperatures above 17 C, but effects are more marked in salt water. Prolonged feeding on herring led to disability and death.

Non-protein nitrogen in salmon smolt blood serum is more concentrated in salmon held in full sea water than in 15‰ sea water or fresh water. Smolts appear, however, to adjust to a wide range of salinities without large changes in the level

of their serum protein. It is inferred that proteins are of little importance in osmoregulation.

The osmotic concentration of salmon blood as measured by freezing point depressions is increased by ambient salinity and by satisfactory diet. Freezing point depressions at 30‰ were 0.78 on liver-trout chow diet, 0.75 on herring-liver-trout chow diet, and 0.70 on herring diet.

When salmon parr are starved for 1 or 2 days, larger individuals display increased aggressive characteristics by nipping at other fish in the aquarium, threatening them, and chasing them. The increase in aggression is mainly directed toward other large individuals. Smaller fish also show increased aggressiveness. After the 2nd day aggressiveness decreases, possibly as a result of weakness. This behaviour may provide a mechanism by which young fish adjust the population density to available food.

Tests of new insecticides as possible substitutes for DDT in forest spraying against budworm showed Zectron and Phosphamidon to be relatively non-toxic to fish. Sumithion is of moderate toxicity. Malthion is more toxic but still only a quarter as toxic as DDT. Zectron, Phosphamidon, Sumithion, and Malathion have the major advantage of being expected to disappear in the natural environment.

From 1 to 10 mg/liter of ferrous iron in solution killed small salmon in 3 or 4 hours. Results must be stated in approximate terms since ferrous iron is not stable in water, quickly oxidizing to non-toxic ferric iron. The threshold for short-term lethal action seems to be about 0.3 mg/liter ferrous iron.

A lethal threshold of 300 mg/liter suspended solids was indicated by tests with the iron mine effluents and the native minnow at Wabush Lake. An initial concentration of 3500 mg/liter suspended solids killed fish in less than 2 hours. Concentrations of 450–600 mg/liter cause 50% mortality in about 1 day. An average concentration of 90 mg/liter suspended solids caused only slight mortality in 10 days.

Harvesting

Lobster trap limits. Fishing practices at Miminegash, P.E.I., under a 250 trap limitation in 1966 were compared with unrestricted fishing in 1965. The rate of exploitation at 85–86% showed no real change. Fishermen fished for shorter days, 5 hours instead of 8 or 9, with the time saved used for maintenance or other occupation. The number of boats increased by about 10%. Catch per boat fell, partly because of the increased number of boats, and partly because of a decline in stock size. The most successful fishermen caught more than three times as many lobsters as the least successful. The total number of traps declined by 26.3% and the number of hauls by 13.1%.

Fouling. Damage by silt to gear and oyster bottom depends heavily on binding by fouling organisms. Most important of these are the filamentous colonial diatoms, *Schizonema* spp. Other groups involved are mussels, worms, amphipods, barnacles, hydroids, and green algae. Knowledge of timing of settlement and kinds of fouling organisms is important in relation to commercial collection of oyster spat and maintenance of boats and other equipment in salt water. Prevailing methods of combating fouling have been evaluated.

Ability of fish to avoid gear. Swimming endurance of cod, redfish, and winter flounder increased with temperature at swimming speeds up to about four body lengths per second and for haddock up to about three body lengths per second. At higher swimming speeds, the advantage of warmer water was less pronounced. At 8 C, a common test temperature, winter flounder displayed greatest endurance.

Cod have high auditory sensitivity from 18 to 283 cycle/sec. This was determined by training cod to miss a heart beat in response to sound stimuli, and then subjecting them to sounds varying in pitch and loudness.

Headline of instrumented trawl with underwater recording cameras (attached to the line with the floats), an underwater recording pitometer to measure pressure (instrument held), and a headline height transducer carrier (triangular instrument).

Gear development. During 1965 and 1966 data were accumulated for trawls in action by using instruments developed over preceding years. Data concern tensions, dimensions, and angles of most parts of the nets, boards, and warps in relation to vessel speed in water and to speed in relation to the shore.

Increasing the Resource

Lobster reef. By the spring of 1966 the artificial lobster reef installed during 1965 in Northumberland Strait had developed its own fauna of bryozoans and hydroids with some sponges, tunicates, and starfish. By autumn, growth may have been sufficient to support an overwintering lobster population. At one time, 51 lobsters were counted and the population was estimated as about 60 with about 35% of them being legal size.

Oyster hatchery. The first major rearing of oyster larvae, in April 1966, was very successful. After a period of growth in the hatchery spat put out under field conditions grew very well, averaging about 37 mm at 4 months. Later in the year,

Spawning of oysters is triggered by raising the temperature in which they are kept.
(Department of Fisheries of Canada Photo)

several commercial-scale rearings were achieved. Spat produced in 1965 continued to grow and survive well on trays. At 18 months they averaged 5 cm in length.

The hatchery is at once involved in solving urgent problems of day-to-day operations and conducting trials to guide commercial operations. When lead coils in heat exchangers were tracked down as the cause of oyster sterility, polyethylene was substituted. Toxic food cultures were avoided by substituting batch for continuous culture. Progress continues in developing culture methods for food for larvae and spat and in simplifying proven methods. An ideal cultch material is still being sought. Effort to find or design more suitable mechanical components for the hatchery continued. The Station contributed to the design of a mobile hatchery to explore the oyster culturing potential of other areas in the Maritimes.

Utilization

Lobster. A reasonable proposal for increasing returns from the lobster fishery is to retain small lobsters and grow them to legal size or to more valuable market size. In general, however, deaths overbalanced growth in trials at culture. Inmature lobsters held in ample space (0.4 m^2 each) survived in 1966 with no net loss in weight.

A survey showed that in 1965 lobster held by fishermen had losses of 130 metric tons (m t) weak and 24 m t dead. Of shipped lobsters, 477 m t weakened and 54 m t died. Loss by death during storage was estimated at 350 m t of which 61% was in tidal pounds. Tagging in tidal pounds showed deaths of slightly weak lobsters to be 40% higher than of those classed as vigorous.

Ninety-two per cent of lobsters held in trays in running sea water 5 cm in depth at 10 C survived for 30 days. In general increasing temperature or decreasing water depths reduced survival. Detailed information can be applied to short-term holding units.

Blue mussels. Fatness of mussels as a measure of desirability was found to fall sharply in all areas studied in late June and early July, presumably with spawning, and to rise through summer and autumn.

Paralytic shellfish poisoning. A survey of cases of deaths reported as resulting from paralytic shellfish poisoning confirmed 75 out of 90 on the Quebec shore of the Gulf of St. Lawrence. Most cases came from eating soft-shelled clams. Paralytic shellfish poisoning is as important in Quebec as around the bay of Fundy and risks of fatal illness are significant.

Fat content of herring. In the Bay of Fundy region small herring tended to have lower fat content than larger fish. No seasonal trends in fat content were evident in Bay of Fundy or Nova Scotia herring. In the Gulf of St. Lawrence, however, spring spawning herring showed a rapid increase of fatness in late May and early June but little change thereafter.

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K. M. Muth, M.S.(Maine); from June 15, 1966

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The Arctic Biological Station is responsible for marine, freshwater, and anadromous fish studies in the Canadian arctic and subarctic, and for aquatic mammal research in both arctic and northwest Atlantic waters. Biological oceanography and limnology are an integral part of the work, and give an insight into the environmental factors limiting production of the aquatic fauna.

Highlights of recent activities and accomplishments of the Station include:

- Completion in 1965 of a 3-year limnological and fisheries survey of Great Bear Lake, showing its relatively low productivity.

- Completion in 1966 in the vicinity of Pond Inlet, northern Baffin Island, of a 3-year study of the narwhal, whose biology was little known.

- Continuation in the Gulf of St. Lawrence and off the Labrador coast of the investigation of harp seal populations, which have been found to be discrete and therefore subject to separate management.

- Start in 1966 of an intensive study of occurrence, migration, and population density of large North Atlantic whales, because a small-scale fishery for the fin whale had developed since 1964 with shore stations in Nova Scotia and Newfoundland.

- Start in 1966 of a new investigation of the ringed seal with special emphasis on its population dynamics in various areas across the arctic.

THE ENVIRONMENT

Great Bear Lake. Analysis of Great Bear Lake phytoplankton collected in water samples and nets, 1963 to 1965, gave 250 species but all were scarce, as

expected from the extremely low level of nitrates, phosphates, and other nutrients found in water analyses. Freshwater algae predominated, but the presence of some marine diatoms and silicoflagellates suggested an earlier occurrence here of saline pro-glacial waters. Extra-cellular starch grains, perhaps produced by Chlorophyta, occurred with the phytoplankton; but the quantity was small—up to 10,000 grains per liter—compared with previously reported quantities in marine habitats of about 9,000,000 grains per liter.

Arctic marine waters. Relating the distributions of 200 species of pelagic copepods (Calanoida and Cyclopoida) collected in northern Canadian waters to depth, water movements, and water masses, showed that there is greatest species diversity in waters strongly influenced by the Atlantic and Pacific Oceans, and least diversity in unmixed arctic waters. A group of eight copepods may be used as the chief indicators of "arctic" water at the surface of the North Atlantic.

Exploration

Marine fish. In 1965 exploratory fishing with long-lines, gill nets and otter trawl from the research vessel *Salvelinus* showed that Greenland cod (*Gadus ogac*) were fairly plentiful in Cambridge Bay harbour and saffron cod (*Eleginus gracilis*) were generally distributed in shallow coastal water. The distributional ranges of the flounder (*Hippoglossoides robustus*) and the wolffish (*Anarhichas orientalis*), previously unreported east of Chukchee and Bering Seas, were extended eastward to Bathurst Inlet.

In 1965 narwhal investigators found that the Greenland shark (*Somniosus microcephalus*) was abundant in waters around northern Baffin Island. This species is a potential source of food for local dogs and a possible export product for human consumption.

Freshwater and anadromous fish. Arctic char (*Salvelinus alpinus*) is the dominant freshwater and anadromous species in coastal and high arctic areas.

Fish Populations

Cambridge Bay. A tagging and recapture program with the Greenland cod (*G. ogac*) at Cambridge Bay gave a population estimate of 12,000 fish within the harbour. Until 1966, at least, this species had not been reported in offshore arctic waters and there was no evidence of migrations or exchange with other coastal bays. The average survival of year classes is 5–7 years; it is therefore unlikely that stocks could withstand extensive fishing.

In marine waters offshore from Cambridge Bay fish populations consisted mainly of small forms, predominantly the arctic cod (*Boreogadus saida*); the fish biomass was estimated at 3 lb per acre, and the invertebrate biomass at 4 lb per acre.

Tree River. Extensive fishing in the Tree River removed approximately 150,000 lb of arctic char over a 3-year period. Restriction of the fishery to angling since 1964 at an intensity of about 5000 lb or one-third the estimated sustainable annual yield has already allowed some recovery of the standing stock through recruitment. Fishing success increased from a catch of 0.16 fish per rod hour in

1965 to 0.46 fish in 1966. In 1965 the record char for Canadian angling, weighing 27 lb 4 oz, was taken here.

Keyhole Lake. The standing crop of landlocked arctic char in 120-acre Keyhole Lake (a typical small arctic lake on Victoria Island) was estimated to be 50 lb per acre from a tag and recovery program started in 1963 and concluded in 1965.

Great Bear Lake. In Great Bear Lake there is low production of all fish species. The lake trout, important as a sport fish, is the only one with widespread distribution; but it grows slowly and does not reach sexual maturity until 14 years old when it weights about 5 lb. At 30 years of age the weight may be only 16 lb and the length 36 inches. Other species including whitefish, lake herring, grayling, and yellow pickerel have limited distribution and low productive capacity, partly because they do not maintain an annual breeding cycle. Without proper management all stocks could be fished down quickly to uneconomic levels.

Harp Seal

Investigations of Canadian harp seals for 15 years to provide a sound basis for managing the fishery included aerial surveys to give the number of whelping adults and their young, tagging newborn seals and analyzing recaptures made during the ensuing brief fishery, and following in different areas the range of ages of females at which sexual maturity is reached to indicate separateness of stocks, since a heavily-exploited stock reproduces at a higher rate than a lightly-exploited stock.

Harp seals are divided into two stocks or herds, one whelping and moulting in the Gulf of St. Lawrence, the other east of Newfoundland and Labrador. These herds mix in summer in arctic waters.

The Gulf herd produces about 350,000 pups per year and the total population before pupping is about $1\frac{1}{2}$ million. It has never been overfished and the original population probably never exceeded 2 million. Now 85,000 young and 15,000 older animals are taken annually by Canadian ships, aircraft, and landsmen. The Department of Fisheries imposed a quota of 50,000 young seals for ships and aircraft in the southern Gulf in 1965. The maximum sustainable yield is about 95,000 young and 18,000 older animals per year.

The east coast of Labrador or "Front" herd once numbered about 2 million animals and produced about 430,000 pups per year. In recent years production of pups has been reduced to about 200,000 annually. Apparently some animals enter it from the Gulf herd. Recent annual "Front" catches of 180,000 young and 30,000 older animals are considered to be excessive.

Hood Seal

Hood seals living in Canadian North Atlantic waters are an offshoot from animals living farther north, probably in Davis Strait. Numbers reaching southern Labrador fluctuate greatly from year to year and over longer periods, apparently under the influence of the climatic cycle. The species is even scarcer in the Gulf which may be too warm. There is evidence that they are not hunted excessively; however, the catch includes more adult females than adult males.

Grey Seal

Population and behaviour studies of grey seals have been carried on for several years in the Gulf of St. Lawrence and off eastern Nova Scotia to assist management authorities in reaching a decision on the need for, and method of, stock reduction. The species is an important vector of parasitic nematodes in codfish and damages salmon nets. Observations in 1965–66 indicated that controlled killing of several hundred animals would be desirable and feasible during the breeding season in January. This information was used by the Department of Fisheries in allowing a limited kill on the Basque Islands, N.S. in January 1967, after such action had been requested by local salmon fishermen.

Scientist observing grey seals on Sable Island, Nova Scotia, in January to determine the adult sex ratio and pup production.

Ringed Seal

Previous intensive research of the ringed seal off Baffin Island ended in 1958 and there is now a need for new biological studies over a wide area of the arctic. In 1966 ringed seals came under intensive population study in Cumberland Sound where there is relatively heavy exploitation. Later the work will extend northward to Home Bay where the species appears to be under-utilized, to assess the significance of hunting pressure as a factor limiting stock size. Many birth lairs were found about 15 miles from the nearest land, whereas the earlier work indicated they were restricted to land-fast ice much closer to shore. Records of catch statistics and related information were improved by providing Eskimo hunters with illustrated booklets containing labels, maps, and containers for jaw samples which are used to age the seals. This produced 2000 jaws, which will give a distributional record of different age classes and their mortality rates.

Narwhal

The new information on the physiology of reproduction of narwhal, obtained from specimens caught in 1965 during netting operations off northern Baffin

Island, will be useful for population estimates. Conception occurs in mid-May and the length of the gestation period is about 14 months; this was determined from measurements of well-developed foetuses from two pregnant females compared with foetal measurements recorded in the literature.

Measuring narwhal specimen at Koluktoo Bay, northern Baffin Island, during 3-year study of this single-tusked aquatic mammal.

White Whale

The total population of white whales on the west coast of Hudson Bay was estimated at 5,000–10,000 by an aerial survey in July 1965, made to provide information on which to base quota recommendations for a local fishery.

Large North Atlantic Whales

An extensive survey and tagging program to provide information with which to manage an Atlantic coast fishery started in 1964 for large whales (mainly fin whales) was initiated in 1966. In a 3-month period starting July 17, a 165-ft chartered vessel first operated off Nova Scotia, Newfoundland, Labrador and west Greenland, then cruised southward to Venezuela, Puerto Rico and Bermuda. Tags were applied to 76 fin whales (of 283 sighted), 62 sperm whales, and 30 whales of seven other species. Fin whales were seen only within the continental shelf, from Cape Cod northward to 57°N on the Labrador coast. Two independent estimates of the stock size of fin whales were by *tagging and recapture*, based on four recoveries at Nova Scotia and Newfoundland whaling stations—6790; by *strip*

census, based on sightings adjusted for the area carefully searched, visibility, etc. —6620. Assuming a 12% exploitation rate for sustained yield (as used in Antarctic fin whaling) the allowable annual catch from the above populations would be about 800. This first approximation to a quota was used to control the 1967 fin whale fishery.

SEA LAMPREY CONTROL EXPERIMENT STATION
SAULT STE. MARIE, ONTARIO

J. J. Tibbles, PH.D.(Wisconsin), *Director*
A. K. Lamsa, M.SC.(Western Ontario), *Assistant to Director*
R. S. Williams, *Executive Assistant*

Chemical Control

W. A. Davis, B.S.A.(O.A.C.)
K. A. Wilson, B.S.A.(O.A.C.)
A. K. Lamsa (*see above*)

Stream Surveys

S. M. Dustin, M.SC.(Michigan)

Electric Trawl

D. P. Dodge, B.S.A.(O.A.C.)

Emphasis in the research was placed on controlling the sea lamprey in Lake Superior with a selective toxicant, assessing the effect of this control measure with electrical barriers, and preparing for the advance of control into the remaining Great Lakes.

Sea lamprey control on the Canadian side of the Great Lakes was the responsibility of the Fisheries Research Board of Canada acting, under contract, as agent of the international Great Lakes Fishery Commission after 1955.

In 1956 the headquarters for the Lamprey Control unit was transferred to the newly established Biological Station in London, Ontario, while a sub-headquarters unit was maintained in Sault Ste. Marie. Early in May 1965, arrangements were finalized for consolidation of the sea lamprey work of the Fisheries Research Board of Canada at Sault Ste. Marie, Ontario. Plans for construction of a new office building and transfer of headquarters for the Sea Lamprey Control Experiment from the London Biological Station to Sault Ste. Marie were announced at the Annual Meeting of the Great Lakes Fishery Commission in June 1965. Plans for office accommodation were drafted in June and construction started in July. Personnel were transferred from London in August and September, and temporary headquarters at Sault Ste. Marie were established. The new building, located on land leased from the St. Lawrence Seaway Authority on St. Marys Island immediately below the Canadian locks, was completed by the end of November 1965.

On July 1, 1966, the Department of Fisheries took over responsibility for the Lamprey Control unit.

ELECTRICAL BARRIERS

Electrical barriers, once employed to control the sea lamprey, are now used to assess the effects of the lampricide treatments on the lamprey population by collecting a portion of the spawning run of adult sea lamprey entering the streams in the spring. Consisting of pairs of pipe electrodes which stretch across the river

and are connected to an electrical outlet, these devices are designed to sample the number of lampreys returning upstream. This sample indicates the size of the lamprey population in the lake and can be compared from year to year to assess the overall effect of the control program.

Eight electrical barriers were operated on the Canadian side and 16 were operated on the United States side of Lake Superior. In 1962 there was a sharp decline in the number of adult spawning lamprey collected at these barriers—to about 20% of the average catch for the preceding 5 years. The catch in 1965 remained relatively stable for the fourth consecutive year. Evidence from the fishery on both sides of the lake confirmed that the feeding phase lampreys in Lake Superior were considerably less abundant from 1962 to 1965 than before. The decline in the number of lampreys at the assessment barriers and the apparent decrease in the lake population can only be attributed to the application of the selective lampricide to streams with sea lamprey populations.

Since the reduction of the lamprey population in Lake Superior, there has been an improved survival of lake trout, and older fish have become more abundant. In the fall of 1964, substantial numbers of mature lake trout were observed on spawning grounds in Western Lake Superior and in 1965 naturally produced trout fingerlings were taken by experimental fishing for the first time since 1959.

As a preliminary to the advance of chemical control measures into Lake Huron, electrical barrier sites were selected on 11 tributary streams. During the fall of 1964, assessment barriers were constructed on three of these—the Root and Garden rivers near Sault Ste. Marie, and the Harris-Naiscoot combination on the east shore of Georgian Bay. The Still River barrier was built and was operational by the early spring of 1965. At the end of the barrier operating season, electrical barriers were constructed on the Echo River, a tributary to Echo Lake near Sault

Electrical barrier in stream at St. Joseph's Island, Lake Huron, is used to assess sea lamprey spawning runs. High voltage signs warn passersby to keep their distance.
(Department of Fisheries of Canada Photo)

Ste. Marie, the Two Tree River on St. Joseph Island, the Mad River, a tributary to the Nottawasaga River near Camp Borden, and the Bayfield River, a tributary to the main body of Lake Huron south of Goderich.

Stream Surveys

Stream surveys, with electro-shocking gear or the lampricide TFM, were performed in Lake Superior to determine the effectiveness of stream treatments with lampricide and for monitoring selected streams for newly established runs, while surveys of the lower Great Lakes were performed to determine the number of lamprey-infested streams and the distributional pattern of ammocoetes in these streams as a preliminary to lamprey control. By 1966, sea lamprey had been found in 38 Lake Superior, 38 Lake Huron, 1 Lake St. Clair, 6 Lake Erie, and 22 Lake Ontario streams.

Stream Treatments

Six streams with a total flow of 3675 ft^3/sec tributary to the Canadian side of Lake Superior were treated in 1965 with 24,416 lb of the selective lampricide TFM and 491 lb of the synergist Bayer 73. No ammocoetes were found in the 101 miles of stream in the Big Pic watershed although they were relatively abundant during the first treatment in 1963. Lamprey were scarce in the Batchawana, Chippewa, and Sable river treatments and moderately abundant in the Pancake and Michipicoten rivers.

Lamprey Tagging

Adult sea lamprey have been collected at night by towing a modified beam trawl behind a small boat in the propeller wash of the outboard motor. Eight hundred and twenty-five of these lamprey were tagged with a Petersen tag and released in the area of capture below the locks in the St. Marys River at Sault Ste. Marie to determine the direction and extent of migration and whether or not there was a significant recruitment from Lake Huron into Lake Superior. Thirty-four lamprey were recaptured in 1965—5 in Lake Superior, 13 in the lower St. Marys River, and 16 in Lake Huron.

FRESHWATER INSTITUTE, WINNIPEG, MANITOBA

W. E. Johnson, PH.D.(Wisconsin), *Director*; from August 1, 1966
S. E. Schick, *Executive Assistant*; from March 1, 1966
W. A. Kennedy, PH.D.(Toronto), *Director of London Biological Station*; to July 31, 1966
R. B. Rush, *Executive Assistant*; to January 15, 1966

EUTROPHICATION

J. R. Vallentyne, PH.D.(Yale), *Scientific Leader*; from September 1, 1966
A. L. Hamilton, PH.D.(British Columbia); from December 9, 1966

FISHERIES TECHNOLOGY

Biochemistry

E. G. Bligh, PH.D.(McGill), *Scientific Leader*; from August 1, 1966
L. C. Dugal, D.SC.(Laval), *Scientist-in-Charge, London Technological Unit*; to July 31, 1966
J. F. Uthe, M.A.(Saskatchewan)

Processing and Products

A. W. Lantz, B.SC.(Alberta)

Engineering

M. Freese, M.SC.(McGill); from November 1, 1965 (seconded to Division of Applied Physics, National Research Council, Ottawa)
K. R. Scott, B.A.SC.(Toronto); from July 1, 1966

FISH POPULATION DYNAMICS

Experimental Biology

L. Johnson, PH.D.(Leeds), *Scientific Leader*; from August 1, 1966
D. P. Scott, PH.D.(British Columbia)

Goldsand Lake

L. A. Sunde, M.SC.(British Columbia)

Heming Lake

G. H. Lawler, PH.D.(Toronto)

Great Slave Lake

J. J. Keleher, M.A.(Toronto)

Lake Superior

A. H. Lawrie, M.A.(Toronto)
B. G. H. Johnson, M.SC.(Western Ontario)

The Freshwater Institute was established on the campus of the University of Manitoba in September, 1966. The Institute includes the staffs of the former London Biological Station fisheries group which was reorganized as the Fish Population Dynamics Section, and the London Technological Unit which became part of the Fisheries Technology Section.

As the name implies, the Freshwater Institute is a centralized operation having responsibility for all Board research related to Canada's inland lakes and rivers, and their fishery resources. In addition to laboratory research, field research is carried on in a wide variety of lakes stretching from Great Slave Lake and Great Bear Lake in the Northwest Territories to the St. Lawrence and the Great Lakes. The Institute is composed of three major research sections having the following general objectives:

• Eutrophication: multidiscipline fundamental research on mechanisms and processes of biological production and decomposition in lakes, with emphasis on the effects of nutrient enrichment. The developing research of this section, aimed at gaining a fundamental understanding of eutrophication, is part of a coordinated Canadian program dealing with the problem of pollution on the Great Lakes; research will be carried out in the laboratory, on small experimental lakes, and on the Great Lakes.

• Fisheries Technology: fundamental and applied biochemical, chemical, microbiological, and engineering studies to provide scientific and technical information required for development of the most effective utilization of freshwater fishery products.

• Fish Population Dynamics: studies of life history, population dynamics, and ecology of freshwater fishes and the fish production capacity of lakes.

FISHERIES TECHNOLOGY

Processing and products. There has been increased interest in special products from freshwater fish, and many products have been prepared and assessed. The preparation of these products from species of low economic value has been documented in the Board's Bulletin No. 151, "Special Products from Freshwater Fish."

The use of slush ice for chilling and transporting smelt gave promising results. The uniformly high quality and shape of the fish greatly facilitated mechanical processing and handling. The method showed potential for other species of freshwater fish.

A collaborative experiment with the Department of Fisheries of Canada and Atomic Energy of Canada Limited indicated the possibility of doubling the useful storage life of whitefish in ice by Cobalt-60 irradiation.

Triaenophorus detection. With the help of the National Research Council, it was found that present candling methods for the detection of parasitic cysts in whitefish fillets could not be significantly improved. A new research investigation was begun wherein modern physical techniques were studied as means of detecting cysts in whole whitefish.

Biochemistry. Hypoxanthine formation in iced yellow pickerel and whitefish was followed to assess its use as a chemical index of quality. The hypoxanthine level increased gradually in the course of storage and the average level for a group of fish was directly proportional to the number of days in ice. Although the rate of formation varied for individual fish, the test holds promise as a quality index for groups of these two species.

Compilation of data on the nutritive values of Canadian fishery products is well advanced and more reliable and comprehensive values for copper, magnesium, cholesterol, and fatty acids are being obtained. This information will be made available in a handbook.

Fish meal and oil. Experimental lots of fish meal were prepared from alewife, sheepshead, tullibee (cisco), and maria (burbot) to assess the feasibility and potential of producing meal from freshwater fish. Yields of meal ranged from

13 to 17%. Detailed chemical and biological analyses showed that the meals were of high nutritional value and that they compared favourably with marine fish meals.

The oils also were of high quality and in most respects the fatty acid compositions were similar to marine fish oils.

Analyses for pesticide residues showed that the residue contents of all the meals were well below tolerance levels.

Fish Population Dynamics

The Population Dynamics Section is responsible for investigating factors affecting fish production in fresh water. This work is being approached from several directions: the observation of the effects of a fishery on natural populations (Great Slave Lake), the effects of lamprey predation and the rehabiltation of the lake trout population by stocking with hatchery-reared fish (Lake Superior), the effects of highly controlled fishing on the parasite *Triaenophorus crassus* and a study of the population changes brought about by the fishing (Heming Lake and Goldsand Lake), and the study of the physiology and ecology of the fish species of most concern (Experimental biology). It is expected that considerable expansion will take place in this last area as the section expands.

Experimental biology. Fluctuations in thermal resistance times of speckled trout, tested at the Maple Ontario Laboratory of the Department of Zoology, University of Toronto, at constant acclimation and test temperatures, indicated a periodicity apparently diel and semi-diel in frequency. Developing and testing various mathematical models under differing basic hypotheses occupied most of 1965 and 1966.

Goldsand Lake. A research program directed at the experimental control of *Triaenophorus* in whitefish by heavy exploitation of pike commenced in 1965. The plan that year was to survey the lake, sample the main commercial fishes, conduct a census of the commercial fishery, test pike, whitefish, and ciscoes for rates of infestation of *Triaenophorus*, and establish a camp. Of about 1000 pike tested, 68.1% were infected with *Triaenophorus*, and of about 1000 whitefish tested, 92.7% were infected.

Pike exploitation by the research crew commenced in 1966 with 11,500 pike killed and an additional 1000 pike marked and released. Most pike were captured in pound nets and gill nets but hoop nets, seines, trawls, trammels, and angling were used or experimented with. The total catch of other species included 2955 whitefish, 66 ciscoes, 3509 walleye, 7494 white suckers, 129 longnose suckers, 20 perch, and 91 burbot. All species of commercial importance were individually weighed and subsamples were drawn from the catch for age, growth, maturity, stomach content, and parasite studies.

Heming Lake. Field work was carried out on schedule with little disruption resulting from the change of headquarters from London, Ontario, to Winnipeg, Manitoba.

Approximately 10,000 new tags were applied to pike, sucker, and perch during the field season. Over 7000 recaptures were handled, and paired fins were removed as an accessory mark for estimating tag loss—the effect of removing both fins would not be evident until fishing began in 1967. From an analysis of

tag return data it was found that 2% of the tagged fish lose their tags in the first season, 8–10% in the second season, and an even higher rate in the ensuing years.

None of the tags used at Heming Lake were suitable for tagging small fish and minnows. An attempt was made to mark fish by total immersion in biological stains and then releasing fish in the lake and recapturing them after they had had an opportunity to mix with unmarked fish. Bismarck Brown Y, Nile Blue Sulphate, and Neutral Red were tested under laboratory conditions and in the field; Bismarck Brown Y was superior to the other stains because mortality was lower and the stain did not fade so rapidly as with the other stains.

Great Slave Lake. A computer tape system for processing catch, size, and age data was largely completed; most of the commercial fishery data were in a retrievable form and were summarized. Indications were that the system is not entirely project limited and, therefore, has an application beyond the immediate needs of Great Slave Lake.

The commercial production of lake trout and whitefish over the 10-year period 1954–1964 amounted to 112 million lb. This gives a yield of very close to 0.8 lb per surface area per annum; however, this production was not obtained uniformly from the lake as a whole. Catch per unit effort, size, and age composition generally declined over the period; lake trout were more affected in this way than whitefish. Attention was paid to achieving quantitative descriptions of these changes and the relationships between them.

Lake trout studies at a field station on a lake in the Northwest Territories.

Peripheral studies on the biology of the northern lamprey and the grayling were carried out.

Lake Superior studies. The Canadian fishery in Lake Superior continued to operate under a quota for lake trout in 1965 and 1966. Employees of the Fisheries Research Board, and commercial fishermen under an agreement with the Board, sampled more than 90% of the lake trout production in both years. Other species such as whitefish, rainbow trout, and speckled trout were also sampled as time permitted. The status of the lake trout population continued to show a steady, though not spectacular, improvement with respect to average size, availability, and freedom from lamprey predation. The increase in availability was largely owing to the accumulation of planted trout as well as a minor improvement in their survival as a result of decreasing lamprey predation. In an effort to reach a better estimate of mortality rates a number of lake trout were tagged in Nipigon Bay during the summer of 1966. Although it was not possible to tag so many trout as desired the results confirm existing estimates of exploitation rates and will permit a measure of the extent of movement of the trout. A significant increase in the speed and accuracy of producing tabular data for use by the Great Lakes Fishery Commission and co-operating agencies was achieved by the development of computer programs to process data stored on punch cards.

VANCOUVER LABORATORY, VANCOUVER, BRITISH COLUMBIA

H. L. A. Tarr, PH.D.(McGill; Cantab.), F.R.S.C., *Director*
Neil Tomlinson, PH.D.(California), *Assistant Director* (seconded to Ottawa from September 1, 1966)
Hiroshi Tsuyuki, PH.D.(Wisconsin), *Acting Assistant Director*; from September 1, 1966
A. D. J. Hackie, B.L.S.(McGill), *Librarian*

Biochemistry and Physiology

Neil Tomlinson (*see above*)
Hiroshi Tsuyuki (*see above*)
Edward Bilinski, D.SC.AGR.(Louvain)
William E. Vanstone, PH.D.(McGill)
E. M. Donaldson, PH.D.(British Columbia); from August 16, 1965
D. E. Kramer, PH.D.(California); from October 11, 1966
J. R. McBride, M.A.(British Columbia)
U. H. M. Fagerlund, M.SC.(Abo)
R. E. E. Jonas, B.A.(Madras)
Eve Roberts, B.SC.(Manitoba)
Shirley E. Geiger, B.A.(British Columbia)
J. R. Markert, B.SC.(British Columbia)
W. C. Hadaway, B.SC.(British Columbia); from November 1, 1966

Chemistry

Michael Smith, PH.D.(Manchester); to July 8, 1966
R. J. Bose, PH.D.(Minnesota); from January 4, 1966
T. G. Oikawa, M.SC.(British Columbia)

Microbiology and Food Technology

H. L. A. Tarr (*see above*)
N. J. Antia, PH.D.(Zurich)
G. A. Strasdine, PH.D.(British Columbia); from June 7, 1965
H. A. Buttkus, M.A.(California)
Joan E. Roy, M.SC.(British Columbia)
John W. Boyd, B.S.A.(British Columbia)
Burnett A. Southcott, B.S.A.(British Columbia)
P. J. Schmidt, B.E.(Saskatchewan)

Engineering

S. W. Roach, B.A.SC.(British Columbia)
F. G. Claggett, B.A.SC.(British Columbia)

Non-Staff

Robert P. Klett, PH.D.(Heidelberg), National Institutes of Health, Bethesda, Maryland; to October 31, 1965
G. H. Berry, B.S.A.(British Columbia), International Pacific Salmon Fisheries Commission; to December 31, 1965
Todor Todoroff, PH.D.(Aachen), International Pacific Salmon Fisheries Commission; to December 31, 1965
Tomoo Nakano, PH.D.(Tohoku), National Research Council postdoctoral fellow; to November 13, 1965
Fumio Yamazaki, PH.D.(Hokkaido), National Research Council postdoctoral fellow; from November 30, 1966

The following research projects received emphasis:

• Partial freezing of groundfish in salt-fortified refrigerated sea water to improve quality; conditions responsible for postmortem development of "chalky" halibut; studies on the organism causing botulism in fish products; formation and control of "curd" in canned salmon; colour sorting of salmon intended for canning; cold storage of dogfish; desiccation of frozen fish; reactions of muscle proteins with products of fat oxidation; preservation of herring for reduction and antioxidant treatment of herring meal intended for bulk storage.

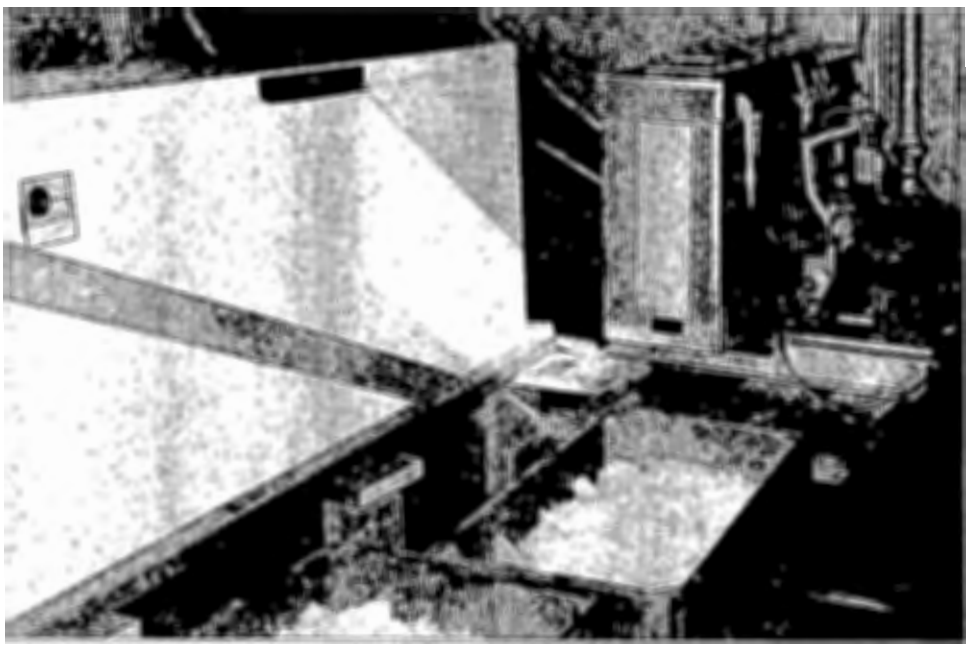
• Biochemical studies on live salmon continued and were expanded. They included studies of maturation and migration of smolts; effect on their tissues of feeding maturing sockeye salmon as part of a general study of post-spawning

survival; studies on mode of action and purification of certain protein hormones of salmon pituitary glands, and causes of high cortisol concentrations in blood of maturing salmon.

• Investigations of production of antibacterial agents by marine phytoplankters continued; biochemical classification of fish by means of muscle or haemoglobin protein patterns was expanded to use other techniques; systems responsible for control of glycogen and glucose concentrations in fish organs, for postmortem breakdown of muscle fats (phospholipids), for formation of deoxyribonucleic acid and nucleotides in salmon testes, and for metabolism of sugar phosphates and nucleotides were studied; and a new investigation of the chemistry of fish flavours was implemented.

Preserving Fresh Fish

Partial freezing for preserving groundfish. Expansion of the groundfish fishery made it imperative that the landed quality of these fishes be maintained and improved. It was found that partial freezing of grey (true) cod, lingcod, lemon sole, sablefish, and halibut in sea water containing added salt (25–29 F) exerted a very favourable effect in suppressing visceral autolysis ("belly burn") and development of undesirable odours. The texture of the cooked flesh of partially frozen fish was in general equal to that of fish preserved by icing or holding, for reasonable periods, at 30 F in refrigerated sea water (RSW). However, grey cod flesh tended to become soft and fragile and to exude free liquid, and this method would therefore be of limited value with this species. As was previously reported



Vertical plate freezer and cold storage cabinet installed in the hold of the M.V. *Great Northern No. 3.*

for salmon, fish held partially frozen were found to be particularly susceptible to the development of a somewhat rancid odour, which could largely be prevented by exclusion of air from the holding tanks.

Halibut. Studies of chalkiness in halibut flesh continued with a detailed study of the relation of the development of postmortem acidity to fishing methods and handling. In the range of *p*H 6.8–5.7, where the lower value indicates higher muscle acidity, free liquid (drip), which formed steadily in chilled fish postmortem, was highest with the more acid flesh. Maximum acidity occurred after 1 or 2 days, and the *p*H thereafter slowly increased. Chalkiness was shown to be strictly related to the postmortem acidity of the flesh. Thus at *p*H of 6.0 or below, all fish were chalky; between *p*H 6.0 and 6.2 there was considerable variability in the incidence of the condition, and above *p*H 6.2 chalkiness did not occur.

Chalkiness occurred more frequently in trawl-caught halibut that were killed immediately upon landing than in others similarly caught but held 10 hours in circulating sea water before being killed. The acidity was lower in the flesh of the fish held 10 hours. This finding may explain the greater incidence of chalkiness observed in trawl-caught than in longline-caught halibut.

Microbiological investigations. Studies of *Clostridium botulinum* type E were expanded. The spores of a "Minnesota" strain germinated, outgrew, and produced toxin in homogenized flesh of Pacific salmon, sole, and cod. Approximately 2000 minimum lethal doses of toxin were produced per gram of homogenized cod muscle after 2 days at 86 F and the toxin was neutralized by type E antitoxin. A system permitting rapid (60 min) germination of the spores was developed. This made possible a study of the effect of environmental conditions and known inhibitors on germination, and the actual mechanisms involved. Chemically defined and natural substances, some of which occur in fish, were compared for their abilities to support germination. Extracts of fresh cod flesh, which have a comparatively low free amino acid and high free peptide content, strongly support spore germination. When the chilled flesh is held, the free peptide content decreases and the free amino acid content increases, with a decrease in the ability of the tissue to support germination. The relationship between amino acid and peptide content, and the ability of fish flesh to support spore germination was still unexplained in 1967. A chemically defined medium capable of supporting growth and spore formation of *C. botulinum* type E was developed, and this may permit exact studies regarding the formation of toxin from defined precursors.

Studies showed that certain commercial fish spreads were not bacteriologically sterile. This is frequently true of meat spreads, as the fat present tends to protect certain non-spore forming bacteria from heat destruction. A gram positive non-spore-forming rod, and coccoid organisms were isolated regularly. This type of minor bacterial contamination is difficult to overcome but is, fortunately, considered harmless by food regulating authorities.

Processed Fish

Canned salmon. Studies of factors affecting the formation of "curd" in canned salmon were resumed. An exhaustive investigation of all factors which might be

responsible for this defect, including area of capture, postmortem age, handling, and maturity, had not revealed any consistent correlations. Useful progress was made in suppressing curd formation by the introduction of simple additives normally used in foods, but further studies would have to be made to ascertain whether such treatment is industrially acceptable.

A study was made of the "binding" of oil in canned salmon, a phenomenon which lowers the apparent oil content of the drained liquid, especially in fish stored for about 10 days in ice or in refrigerated sea water. This binding is obviously superficial and of no nutritional significance since mild centrifugation releases the bound oil.

Salmon colour. A collaborative project was initiated under contract with the British Columbia Research Council for the purpose of attempting to develop instrumentation for the in-cannery colour sorting of fresh salmon prior to canning. Three progress reports were received from the Council during 1966. An experimental reflectometer capable of giving reliable predictions was constructed and its conversion to a "probe" type of instrument to permit cannery use was begun. This Laboratory carried out investigations to establish the relation between colour of fresh and canned salmon of different species which is essential for instrument development.

Dogfish. As part of a Department of Fisheries program for marketing dogfish, frozen storage studies were undertaken. Pacific dogfish carcasses were found to have a high oil content and this, coupled with the fact that there is a pronounced layer of superficial red muscle rich in blood pigment, makes the frozen muscle susceptible to oxidative rancidity. Rancid odors were detected in frozen carcasses which were thawed after 22 days at 14 F and 70 days at −4 F, but not in 180 days at −22 F. Slight fading of the desirable pink colour of belly flaps was observed after 50 days at −4 F and 160 days at −22 F. A slight "souring" was detected in belly flaps held 99 days at −4 F. It was concluded that reasonable quality of carcasses and belly flaps could possibly be maintained at −4 to −10 F for 3–5 months.

Desiccation of frozen fish. Two types of cartons with and without cellophane inner liners were used in packaging sole fillets for frozen storage "desiccation" tests. Throughout the storage tests it was observed that the loss in weight from frozen fillets packaged in cartons with cellophane inner liners was approximately one tenth that lost from those packaged without cellophane inner liners.

Muscle Proteins

The thermal stabilities of fish myosins, the principal proteins of muscle, are much much lower than those of mammalian muscle. Myosin from cod muscle is more unstable than that from trout muscle. However, in many other respects myosins are very similar. It is well known that fat oxidation and resultant free fatty acid formation tends to accelerate myosin denaturation in frozen fish muscle. It was found that one typical product of unsaturated lipid oxidation in fish muscle (malinaldehyde) reacts with the amino acids of fish myosin under frozen conditions (−4 F) as rapidly as at 68 F. When heated at 110 C (230 F) a fatty acid

ester (methyl linolenate) and fish myosin react to form an uncharacterized brown product. This type of reaction is a typical "browning reaction" and is undoubtedly of primary importance in causing the browning of dehydrated and lyophilized fish and fish meals.

Fish Meal

Although herring often reaches reduction plants in good condition, there are occasions when sudden gluts or transportation problems cause quality deterioration or loss of fish. A study of possible preservation techniques was undertaken. It was found that refrigerated sea water (RSW) gave best preservation. Nitrite-formaldehyde mixtures and chlortetracycline were less effective in the concentrations used. The chief drawback to use of RSW is the initial cost of equipment. If such equipment is available, the operation costs are much lower than for the chemical preservative treatments.

The absolute necessity for antioxidant treatment became obvious with bulk storage of herring meal where very large amounts are stored under industrial conditions. Although butylated hydroxytoluene (BHT) usually proved effective for somewhat short storage periods, cooling (by turning) proved essential in some cases for more prolonged storage. Experiments showed that ethoxyquin is a better antioxidant than BHT and now that its addition is permitted, it is hoped that its use will make prolonged storage of the meal without turning of the piles possible.

Experiments were initiated in order to make a thorough study of protein wastes from fish plants. Avoidance of pollution, economic methods of recovery, and nutrient value of the recovered products were on the plan of study.

Development and Maturation of Salmon

Smolting. The importance of this resource stimulated initiation of further research into some of the physiological and biochemical problems involved. Studies on chemical changes in smolting coho salmon at Big Qualicum River, completed in 1966, showed that there was no change in growth (length and weight) or chemical composition during the winter months. The ratio of weight:length$^{3.25}$ was 7.0:1. From April 14 until seaward migration commenced, the following changes (measured in per cent increase per day) occurred: weight, 4.5; length, 1.5; skin guanine, 4; and total nitrogen 5.0. The weight:length$^{3.25}$ ratio decreased to 6.2:1. Samples of the migrating coho were held in live boxes at sea (27‰ salinity) from May 25th and sampled until July 20. The following daily increases occurred: weight 1.6; length, 0.4; and total nitrogen, 1.8. The skin guanine content (6 $\mu g/mm^2$) and weight:length$^{3.25}$ ratio (6.2:1) remained constant.

Changes Involved in Sexual Maturation. In attempts to elucidate some of the poorly understood changes that occur in maturing and spawning salmon, and how these may affect post-spawning survival, thorough studies of the tissues of these fish were begun. Feeding adult sockeye salmon during gonad development prevented (thyroid) or reduced (pancreas, kidney) corresponding degenerative changes that occurred in unfed fish, but it did not prevent gradual degeneration of the skeletal muscle. In spent salmon only the thyroid showed a beneficial

response to feeding. It would appear that starvation is not responsible for the degenerative alterations, but that, in some manner associated with gonad development, endocrines control the changes. The water and sodium content increased, and the potassium content decreased to about the same extent, in the flesh of fed and unfed fish during sexual maturation.

A thorough histological study of the pituitary gland of sexually maturing sockeye salmon was completed and the changes in cell types during maturation were recorded. It was concluded that the sockeye pituitary contains six different hormone-producing cell types.

A study of the water-insoluble egg yolk proteins for five species of Pacific salmon using zone electrophoresis was completed. Similar results were obtained for coho and spring salmon and for sockeye and pink salmon, chum salmon being midway between the two groups.

Endocrinology. A successful method was worked out for determination of the adrenocorticotrophic hormone (ACTH) during the many steps of its purification by chromatography on oxycellulose and by gel filtration. The relationship between the pituitary gland and other endocrine organs of fish was investigated by use of hypophysectomized trout. Hypophysectomy reduced the plasma cortisol level from 8.1–1.6 μg per 100 ml and prevented the increase in cortisol which is normally caused by stress. This established that pituitary secretions control interrenal function in trout. Injection of a steroid, dexamethasone, into normal trout also reduced the plasma cortisol concentration to 1.6 μg per 100 ml, again indicating a feedback mechanism between interrenal function and the pituitary gland. This drug, which is known to interfere with release of ACTH from the pituitary, reduces stress-induced increases in plasma cortisol in sockeye salmon. A histological study of the various endocrine organs of hypophysectomized trout was initiated to ascertain what tissue alterations occur as a result of the hormonal imbalance.

The cortisol concentration in the blood of resting, captive, sockeye salmon remained low during gonad maturation and for some time after spawning. This has been found to apply also to many fish in their natural habitat, both in the river and on the spawning grounds. High cortisol concentrations are induced by fright and some disease conditions. In spring, salmon disease produced cortisol concentrations in excess of those found in sockeye salmon under similar conditions.

Marine Phytoplankton

Studies on production of substances of biochemical and pharmacological interest by marine phytoplankters, the culture of which was previously reported, were continued. A wide spectrum of antibacterial activity was found. Thus, two antibacterial products were isolated from one species (*Isochrysis galbona*) and were tentatively identified as derivatives of chlorophyll *a*. Only one of 16 species examined (*Monochrysis lutheri*) possessed a potent bacterial-toxin type of phospholipase (lecithinase C). A study of certain enzymes was made and it was found that enolase occurred in most species, while the occurrence of two distinct types of aldolase activity yielded some useful clues to algal evolution.

Securing a sample from a culture of marine phytoplankters for microscopic study.

PROTEINS AND FISH CLASSIFICATION

Fish blood contains a number of different haemoglobins which are completely species specific and constant. However, these proteins are comparatively unstable so that it was necessary to develop a micro zone electrophoresis technique which could be applied at sea or in field laboratories. The absolute necessity for this was apparent when it was found that in some species of fish the blood haemoglobins could change within 3–5 hours after sampling. Application of the electrophoretic separation method to blood haemoglobins of ground fish at sea, including those of 24 rockfishes, was of great value in identification of a new species of *Sebastodes*. Moreover, the results indicated that this species exists as two genetically distinct variants, the frequency of occurrence differing with the geographic location. Similar genetic polymorphisms occurred in haemoglobins of certain other rockfish varieties.

With other genera of fish hitherto examined, the muscle protein patterns showed a marked and consistent species specificity, but this failed to hold true with rockfishes. This would appear to indicate an exceptionally close genetic relationship in this genus. On the other hand, muscle protein patterns were definitely established as valuable criteria of classifying many species of fish and of determining sub-species. Thus a study of blackcod (*Anoplopoma fimbria*) revealed definite genetic polymorphism.

A survey of the iron-containing blood serum proteins (transferrins) of certain scombroid fishes of the Pacific Ocean from Baja California to the

northern coast of South America was made. These proteins were used in population analysis studies of these fishes. Thus, field tests indicated that there is a comparatively uniform population of yellowfin and skipjack tuna in the above area.

Most of the problems encountered in the use of proteins separated by zone electrophoresis for studies of chemical structure were resolved. Studies of certain of these proteins continued using modern techniques including determination of amino acid "end groups," studies of "peptide maps" of enzyme hydrolysates, and investigations of total amino acid compositions. Oxygen equilibrium studies on fish haemoglobins were also carried out.

ENZYMES

Many important postmortem changes in fish muscles and organs are mediated by enzymes; hence, studies of several such changes were begun. Sugars and related compounds have considerable significance in producing fish flavour and in causing processing changes. It was found that in live trout a reduction in liver and heart glycogen and an increase in blood glucose in response to severe disturbance (e.g. struggling) are mediated to a large extent by secretion of adrenalin and related compounds (catecholamines) released into the blood stream. It was uncertain whether or not these substances cause reduction in muscle glycogen under stress conditions.

Studies on enzymes responsible for postmortem formation of free fatty acids in fish muscle continued. These enzymes, which hydrolyse lecithin, occur in the "particulate" fraction of the red muscle, and the activity of the microsomal fraction is four to six times that of the mitochondria. Increases in glycerylphosphorylcholine in trout muscle during frozen storage approximately paralleled increases in free fatty acid formation. Free choline, formed during cold storage, may arise from the breakdown of glycerylphosphorylcholine.

Studies on the formation of deoxyribonucleic acid in salmon testes proceeded. Using slices of very immature testes it was found that the known enzyme pathways of deoxyribonucleic acid (DNA) formation from preformed purine and pyrimidine bases are present in this tissue. However, DNA was not formed if the tissue slices were lightly homogenized or exposed to vacuum treatment. Evidently these treatments either disturbed one or more of the enzyme systems required for synthesis of DNA, or liberated enzymes that degraded it more rapidly than it was formed. *De novo* biosynthesis of purine and pyrimidines in the testes slices from smaller molecules that are normally used for synthesis of these compounds (formate, carbonate, and glycine) could not be demonstrated under conditions used for DNA formation from the bases themselves.

Studies on the mode of formation of sugar phosphates in fish muscles continued. A purine nucleoside phosphorylase enzyme first studied several years ago was purified over 100-fold from lingcod muscle and the existence of three separate such enzymes (isoenzymes) was demonstrated. The muscle was shown to possess a very much weaker pyrimidine nucleoside phosphorylase also. Very unstable enzyme systems capable of synthesizing many different nucleoside and deoxynucleoside di- and tri-phosphates from the corresponding monophosphates were demonstrated in soluble extracts of immature salmon testes.

MISCELLANEOUS

A mass spectrometer was installed and operated successfully. Flavour studies were initiated with attention being paid to the stability of certain sulphur compounds that appear to affect flavour both undesirably and desirably depending on conditions. Thus the basis of stability of dimethylpropiothetin and related sulfonium salts was studied.

Because of the increasing tendency to export coho salmon to Great Britain for subsequent smoking, it was noted that these fish, especially the larger ones, are much more likely to contain soft gelatinous areas in the muscle than are spring and chum salmon. Examination indicates that this is due to the presence of a myxosporidian parasite, probably *Henneguya salminicola.*

BIOLOGICAL STATION
NANAIMO, BRITISH COLUMBIA

(including Pacific Oceanographic Group)

P. A. Larkin, D.PHIL.(Oxon), *Director*; to September 30, 1966
W. E. Ricker, PH.D.(Toronto), F.R.S.C., *Acting Director*; from October 1, 1966
K. S. Ketchen, PH.D.(Toronto), *Assistant Director*
I. J. Strong, B.A.(British Columbia), *Executive Assistant*

SALMON AND EXPERIMENTAL INVESTIGATIONS

F. C. Withler, M.A.(British Columbia), *Program Supervisor*; to June 21, 1966
R. R. Parker, PH.D.(British Columbia), *Program Supervisor* for Salmon Investigations; from June 22, 1966

Salmon Stock Assessment

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Skeena Salmon

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H. W. D. Smith, M.SC.(Washington)
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Early Sea Life of Salmon

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Chinook and Coho

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Experimental Hatchery Studies

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Special Salmon Projects

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Physiology

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J. E. Shelbourne, M.SC.(British Columbia); from October 31, 1966
L. S. Smith, PH.D.(Washington); May 5–June 15, 1965
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Effects of Environmental Changes

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Behaviour

C. Groot, PH.D.(Leiden); to March 31, 1966

Salmon Stream Biology

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Parasitism and Disease

L. Margolis, PH.D.(McGill)
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N. P. Boyce, B.SC.(British Columbia); educational leave to May 1967

Pollution

M. Waldichuk, PH.D.(Washington); to January 25, 1966

Salmon Consultant

F. Neave, PH.D.(British Columbia), F.R.S.C.; to September 15, 1966

MARINE COMMERCIAL FISHERIES

K. S. Ketchen (*see above*), *Programme Supervisor*

Herring and Other Pelagic Fishes

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D. N. Outram, B.A.(British Columbia)

Distant Seas Groundfish

S. J. Westrheim, M.SC.(Washington)
F. T. Pletcher, M.A.(British Columbia); to August 23, 1965

Near Seas Groundfish

K. S. Ketchen (*see above*)
W. A. Kennedy, PH.D.(Toronto); from September 1, 1966
J. A. C. Thomson, M.SC.(McGill); to July 31, 1966
V. M. Hodder, M.SC.(Memorial) (seconded from St. John's from September 1, 1966)

Crustaceans

T. H. Butler, M.A.(British Columbia)
R. J. Ghelardi, PH.D.(Scripps); from May 3, 1965

Mammals

G. C. Pike, M.A.(British Columbia)

Shellfish and Other Invertebrates

D. B. Quayle, PH.D.(Glasgow)
N. Bourne, PH.D.(Toronto); from June 1, 1965
M. J. Tynen, PH.D.(Wales); from April 6, 1966

Statistical Services and Population Model Studies

A. S. Hourston, PH.D.(California) (seconded to St. John's September 1, 1966)
J. A. C. Thomson, M.SC.(McGill); from August 1, 1966
K. R. Allen, M.A.(Cantab.); to July 1, 1965

Instrumentation Research and Development

W. H. Bell, B.A.SC.(British Columbia), P.ENG.

PACIFIC OCEANOGRAPHIC GROUP

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W. E. Johnson, PH.D.(Wisconsin), *Acting Program Supervisor*; to July 31, 1965 (Seconded to Office of the Chairman from August 1, 1965)
M. Waldichuk, PH.D.(Washington), *Program Supervisor*; from January 26, 1966

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Biological Oceanography

T. R. Parsons, PH.D.(McGill)
W. P. Wickett, M.A.(British Columbia)
R. J. LeBrasseur, M.A.(British Columbia)
W. E. Barraclough, M.A.(British Columbia); from January 27, 1965
C. D. McAllister, M.A.(British Columbia); from July 1, 1965; educational leave to May 1966

VOLUNTEER INVESTIGATORS

C. J. Berkeley, F.C.I.C.
Mary Needler Arai, PH.D.(U.C.L.A.)
H. Arai, PH.D.(U.C.L.A.)
Y. Kitano, B.AGR.(Hokkaido), exchange scientist from Japan

Emphasis in the research was placed on salmon, pelagic fish, groundfish, crustaceans and other invertebrates, marine mammals, theoretical population studies, oceanography, pollution, and development of instruments and gear. The studies considered mainly:

• Forecasting the size of salmon runs; distribution and identification of stocks at sea; natural and artificial hatching areas and behaviour of young salmon; storage of eggs and sperm; transplantation of stocks from the east coast; and physiology of salmon.

• Abundance of herring stocks and survival of year-classes; and studies of fish associated with sound scattering layers.

• Groundfish research on the shallow coastal banks of British Columbia; and offshore and distant-seas investigations in deep water areas.

• Population studies of shrimp; shipment of lobsters from the east coast; distribution and identification of invertebrates off British Columbia.

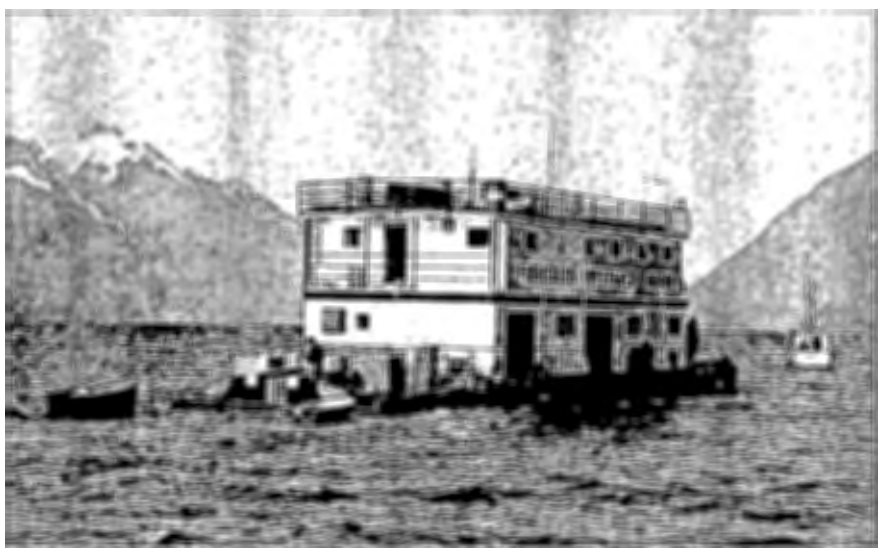
• Studies of differences in maturation rates of different seals; and distribution of seal and whale stocks.

• Computer programs for estimating sizes of stocks.

• Collection and analyses of nutrient and zooplankton data; and physical oceanography of the North Pacific, Strait of Georgia, and inlets along the west coast.

• Pulpmill and domestic pollution studies.

• Expansion of data processing facilities; and improvements and additions to Nanaimo Station installations.



Barge-lab "Valella" brings excellent laboratory facilities to remote coastal inlets.

High-Seas Salmon Studies

High-seas salmon studies were conducted to determine the feasibility of forecasting the abundance of North American salmon runs from longline fishing in

offshore waters of the Gulf of Alaska several months in advance of the commercial fishing season. Estimates were made of the density of maturing salmon from longline catch per unit of effort, while racial differences in scale characters, meristic counts, and parasite content were used to determine the proportions of different stocks present. The program involved a cooperative longline fishing program during April, May, and June of 1965 by three United States vessels and three Canadian vessels; Japan conducted gillnetting and longlining in the western part of the Gulf of Alaska toward the end of May; in addition, there were two 10-day longline cruises, one in mid-January and another toward the end of August. In 1966 longline fishing and tagging were conducted by three Canadian vessels from late March to late August.

It was found that high-seas catches gave a reasonably good advance indication of the relative abundance of major North American sockeye stocks, but a poor indication of pink stocks. During their final year at sea almost all British Columbia salmon are confined to the Gulf of Alaska (east of the area of high-seas commercial fishing operations by Japan). The Gulf of Alaska is also an important wintering area for sockeye originating in Bristol Bay in the Bering Sea, and for chums from most of the important producing areas of both Pacific coasts of Asia, the Bering Sea, and the arctic coast of North America.

Further information was obtained on the migration of major maturing stocks of salmon from the high seas to coastal spawning areas by the analysis of tag and recovery data resulting from the tagging operations in the northeast Pacific Ocean in 1962. For sockeye and pink salmon, the species for which data are most abundant, travel rates increased with increasing size of the individual, and with the progression of the season.

Information for International Negotiations

Beginning in October 1965, Canada and the United States renewed discussions of management problems caused by joint exploitation of pink salmon stocks by fishermen of both countries in the Fraser River and Puget Sound area (covered by a Protocol to the Fraser River sockeye treaty) and of salmon of all species in the region of northern British Columbia and southeastern Alaska. The movements of the southern pinks were subjected to several years of intensive cooperative study that ended with a final report in 1965; the staff of the Nanaimo Station provided background information regarding the status of the stocks in the northern region and what is known of their movements. The discussions resulted in proposals for cooperative research with the United States in the northern area.

Still another international committee continued to examine all aspects of coho and chinook salmon interaction between Canada and the United States, and much background material was prepared for its use.

Distribution and Growth of Salmon at Sea

Analyses of previous years' catch data provided additional information on the seasonal distribution of immature and maturing sockeye in the northeastern Pacific Ocean. Both immatures and fish in their final ocean year move southward during the winter. Some overlap occurs in the areas occupied by the two groups,

with immatures occurring farther south. In the spring and summer, immatures migrate northward and westward into the western Gulf of Alaska, while maturing individuals proceed to the coast.

A study was begun on the seasonal and annual changes in the sizes of sockeye and chum salmon in the northeastern Pacific, using length data obtained during extensive longline surveys in 1962, 1963, and 1965. The consistency with which fish of each age in a given year differed in length from fish of similar age in other years at comparable times indicates that environmental conditions in the ocean, rather than different growth characteristics of different stocks, mainly account for the year-to-year differences in fish size.

Early Sea Life of Pink Salmon

Studies on the early marine life of pink salmon in central British Columbia were continued during 1965 and 1966. From marking experiments it was found that natural mortality is high during the first 40 days of sea life, varying from 55 to 77% of the entering population. The average rate of natural mortality during the remaining 410 days at sea was much lower on a day-to-day basis, but in total it varied from 78 to 94% of the population alive at 40 days.

A considerable part of the early mortality is due to predation by juvenile coho salmon. Squids also prey upon young pinks, but to what extent is not known. Parasitic copepods are a direct cause of mortality which may be important in some years, and internal helminths are also suspect. Losses by bird predation are considered of little importance.

In 1966 the returning Bella Coola pink salmon, some of which were marked as fry by removal of the adipose fin, entered fisheries as far north as Whale Channel (100 miles north of Namu) in substantial numbers. Some strayed into areas quite removed from the Bella Coola system. The furthest stream sampled was the Kynoch where three marked fish were found in 1539 examined. The mouth of this river is about 100 water miles from that of the Bella Coola.

Effectiveness of Spawning Channels for Salmon

Large spawning channels on the Fulton River are designed to add to the supply of sockeye fry in the main basin of Babine Lake. In order to evaluate this facility it is necessary to know what part of Babine Lake is used as a nursery area by young sockeye from the Fulton River, and how the distribution, growth, and survival of sockeye produced in the spawning channel compare with sockeye produced naturally in the river. Fry from the river and from the channel were marked distinctively during their May and June migration into the lake. Marked and unmarked fish were captured throughout the main lake area from June through October in a special purse seine, using a small aluminum drum seiner. Dispersal of both groups of fry was rapid and extensive. The main body of fry moved southward first and by mid-July marked fish were recovered as far as 42 miles south of the Fulton River. Subsequently the population shifted to the north and by fall sockeye were most abundant in the northern half of the main lake basin. "Channel" and "river" fish were of comparable size as fry and grew at the same rate. However the channel fish, because of their later entry into the

lake, were smaller on the average throughout the season. No difference in survival rate could be demonstrated between marked "channel" and "river" fish.

Skeena River Management and Biological Research

In 1965 the Department of Fisheries took on the responsibility for Skeena Salmon Management Committee operations at Prince Rupert (including test fishing) and in 1966 it assumed responsibility for a large part of the escapement enumeration work. The operation of the Babine fence, escapements to the lake, and estimates of sockeye smolt output remain a Research Board responsibility because these are tied in with research programs on the lake.

In 1965 a smolt run of 26 million smolts (4.6 million early, 21.4 million late) was estimated to have migrated from Babine Lake. The total in 1966 was 37 million; 20 million were early and 17 million were late. The 1965 and 1966 totals represent egg-to-smolt survivals of about 2.8% and 2.7% respectively—both somewhat lower than the 9-year average of 3.2%.

Babine escapements of salmon and steelhead in 1965 and 1966 were as follows:

	Sockeye		*Chinook*					
	Large	*Jack*	*Large*	*Jack*	*Pink*	*Coho*	*Chum*	*Steelhead*
1965	580,000	64,000	1,200	2,000	67,000	20,000	0	52
1966	389,000	182,000	1,600	2,500	47,000	7,200	2	60

The 1965 coho escapement was about twice as large as any measured prior to that time.

The age composition of sockeye in Babine sub-stocks was assessed annually beginning in 1962. Returns from the 1962 brood year were essentially complete in 1967 and the first sequence of parent-progeny relationships could then be evaluated.

In order to relate smolt survival to size, 47,000 smolts were tagged with a fine wire implanted in the nose cartilage in 1966.

Primary Productivity of Babine Lake

Carbon-14 *in situ* experiments were used in 1966 to compare the rates of carbon fixation by phytoplankton within various regions of Babine Lake. Primary productivity in 1966 was slightly lower in the North Arm (outlet) and Morrison Arm (an inlet) than in the main lake region. Morrison Lake, a major tributary, was much lower in rate of photosynthesis, *p*H, alkalinity, compensation depth, and total dissolved solids than any part of Babine Lake. An unusually high rate of photosynthesis at one part of the main lake in September may have been related to the decomposition of salmon carcasses in a nearby stream. Carbon fixation at Babine Lake was much less per unit area than in the majority of 24 sockeye salmon lakes in southwestern Alaska, but it was as good as most when put in terms of the volume of the euphotic layer because the depth of light penetration was considerably less at Babine Lake. Compared to the 24 Alaskan lakes Babine ranked first in alkalinity, third in TDS and fifth in *p*H.

Behaviour of Young Sockeye in a Lake

A 145 kc echo sounder (Sea Scanar by Honeywell) was operated from a 20-foot cruiser on Babine Lake. Targets were identified as sockeye fry by catches made with nets. The echo sounder greatly extended our knowledge of the horizontal distribution of young sockeye and revealed a daily vertical movement. From late July to the middle of September the fry at midday occurred in a band 150–200 feet below the surface; by late afternoon this band had ascended to about 50 feet; near sunset they ascended rapidly and arrived at the surface just after sunset where they remained for about $\frac{1}{2}$ hour; then they dispersed into the 10–40 foot stratum where they remained until dawn; at dawn they began a slow descent to midday depths.

Cowichan River Chinook and Coho Studies

Seaward movements. Chinook salmon fry captured in downstream migrant traps exhibited a range of fork length from 38 to 50 mm (average 42.3–43.7) in March and April and 48 to 86 mm (average 56.1–77.1) in late May and June. Fry captured by seining were larger than fry caught in traps upstream of the seining location.

Juvenile chinook salmon were first observed in mid-April of 1966 in the Cowichan estuary, and were captured by seining from May 15 to July 31. Little change in average size was evident during this period of availability.

Chinook salmon fingerlings and coho yearlings were caught during their early sea life in Cowichan Bay after May 15 and up to October; the largest catches were in June and July. The average fork length of the chinooks increased from 79 mm on May 31 to 170 mm by the end of September.

Chinook and coho tagging. Young salmon during their first sea year were tagged in Cowichan Bay in 1965 and 1966. Of 1720 small coho (average 126 mm) tagged in 1965 with a Carlin tag, 4.1% were returned from sport and commercial fisheries. Recoveries during the first ocean year were mostly from Cowichan Bay and Saanich Inlet. Later recoveries were widely dispersed, including 32 from the Strait of Georgia and 14 from outside Juan de Fuca Strait. The most northerly recoveries were from Esperanza Inlet on the west coast of Vancouver Island and Cape Lazo on the east coast of Vancouver Island. About 2310 chinook salmon with a mean length of 109 mm were also tagged in 1965. Few recoveries have been made to date (early 1967).

Monitoring Biological Characters of Salmon Stocks

Sampling of the British Columbia commercial catches of sockeye, pink, and chum salmon was continued in 1965 and 1966. All major stocks were sampled weekly throughout the fishing season; length, weight, sex, and ages were determined. Reporting is now on a current basis. For chums, 1960 was a good brood year on most parts of the coast.

Special sampling of Rivers Inlet sockeye escapements was continued after 1963 as a part of an intensive study in that region by the Department of Fisheries. In the escapements of 1963 and 1964 there was some segregation by age on the spawning grounds at Owikeno Lake, with most of the 4-year-old

spawners found in streams tributary to the lower portion of the lake. In 1963, most 5-year-olds were found in streams tributary to the upper lake region, but in 1964 they were evenly distributed. In both years the sockeye of both ages were smaller in the lower lake region than in the upper lake region. The gill-net fishery tended to select the larger 4- and 5-year-olds from these stocks.

Studies on chinook salmon from three major rivers revealed differences in total age, life-history type, size at a given age, fecundity at a given size, flesh colour, and number of pyloric caeca.

Salmon Scale Studies

On scales of pink, chum, and sockeye salmon caught throughout the Gulf of Alaska at various times of the year, the annual ring began to form between early November and January. Many sockeye and pink salmon had completed their annulus sometime in December or January, whereas chum salmon completed theirs later in February or March.

Scale readings and vertbrae counts are used to identify stocks from which high-seas-caught salmon originate.

Among 159 central British Columbia pink salmon that had been marked as fry and subsequently recovered in the commercial fisheries after one winter in the sea, the scales of about one third showed a second check near the center of the scale in addition to a clear-cut annulus. This confirms the prevailing diagnosis of these checks as supplementary or "false" checks.

The characteristics of pink salmon scales from the Glendale River in British Columbia were compared with those of pink salmon transplanted from this source to Newfoundland. The transplanted pinks had significantly fewer and more widely spaced circuli anterior scales than did their siblings in the Glendale River. The transplant scales were much more similar to those of pinks from central Alaska.

Hardiness of Salmon Fry in Hatcheries and in Nature

Experiments were conducted over several years to improve the survival of hatchery-reared sockeye and pink salmon fry by releasing them from dark gravel-bottomed tanks. These proved unsuccessful, but observations suggested that the key to improvement might be in the size of the fry produced. From time of hatching to time of fry migration, sockeye alevins require mechanical support in order to remain effortlessly in an upright position. Lacking this support, a righting response occurs involving considerable swimming activity. Since their only source of energy is the yolk reserve, any activity additional to normal growth and maintenance reduces the supply available for these two functions. The absorption rate of the yolk material is not noticeably affected by increased muscular activity, nor is the rate of morphological development or the time of emergence; hence the energy used in swimming is subtracted from what is available for growth, and the result is smaller fry—the observed weight deficit is of the order of 20%.

Tests of swimming performance and vulnerability to predation showed that performance is directly related to size of fry, so that at the time of emergence and migration, hatchery fry are at a significant disadvantage compared to fry that have no unsatisfied thigmotactic demand. A modified hatchery technique was started, aimed at preservation of yolk material and expected to produce fry of normal size.

Chinook Salmon Cooperative Hatchery Evaluation Program

In 1965 the fourth and last experimental release of marked and unmarked chinook fingerlings was made from the 12 hatcheries participating in the Columbia River hatchery evaluation program. The marked and unmarked fish of the broods of 1961–1964 released to date number 213 million, approximately 50 million per year. Of these 30,931,192 have been marked.

In British Columbia almost 150,000 chinook salmon from commercial catches were examined for marks in 1965, and about 250,000 in 1966. About 1% of these were marked fish. More than 94% of these marks were from the troll fishery off the west coast of Vancouver Island. In addition, during the 2 years, 1965 and 1966, biological information (length, weight, age, and flesh colour) was obtained from about 63,000 fish.

Preliminary estimates of the total Canadian and United States catches of chinooks reared and released by the 12 hatcheries are 130,000 in 1964 and 140,000 in 1965; this includes both marked and unmarked. Of these, British Columbia contributed 35% in 1964 and 29% in 1965. Adjustments for marking mortality had not been made at the time of writing, but they should increase these estimates quite substantially.

Almost complete returns of marks from the 1961 brood are available: 0.49% of the number released. Of these, 80% were caught and 20% returned to spawning streams. However, considerable variation exists in survival rate; the 1962 brood made only about half as large a contribution to the fishery as did that of 1961; at the time of writing, the 1963 brood resembled 1961 rather than 1962.

Sockeye and Pink Salmon Hybrids

In the fall of 1966 at Lakelse Lake, the eggs and milt of several sockeye and pink salmon were used to obtain "pure" and "hybrid" lots of eggs. Portions of the four lots were incubated under three different temperature regimes; under each regime they hatched in the following order: pink ♂ × sockeye ♀; pink ♂ × pink ♀; sockeye ♂ × sockeye ♀; sockeye ♂ × pink ♀. The larvae hatching from the hybrid eggs were smaller, in both cases, than those hatching from either the pure sockeye or pure pink eggs. However, the fry developing from the early hatching hybrid larvae had by May, 1967, grown larger than those from any of the other three lots, perhaps because of the longer feeding period since hatching.

Fertility of Stored Salmon Eggs and Sperm

Eggs and milt of sockeye and pink salmon were tested at Lakelse Lake in 1966 to determine the time available for transportation of sex products in experiments requiring cross-fertilization of widely separated races or species of salmon. Eggs and milt were stored at 8–9 C without added water. Sockeye eggs and milt retained their initial fertility for 11–12 hours; pink salmon eggs maintained theirs for 8 hours, and pink salmon milt for 30 hours. The sex products held under the experimental conditions maintained some fertility for much longer; for example, a few sockeye eggs were still fertile after 175 hours. Comparison of these results with other work suggested that cooler storage would prolong the highly fertile period.

Transplantation of Pink Salmon to Newfoundland

In 1965 and 1966 the third and fourth large shipments of eyed pink salmon eggs were flown to Newfoundland where they were planted in a prepared channel of the North Harbour River. Both shipments came from the Lakelse River, a tributary of the Skeena. The 1965 shipment of 3.3 million produced 3.0 million sea-going fry; the 1966 planting numbered 5.8 million eggs from which fry emerged in the spring of 1967.

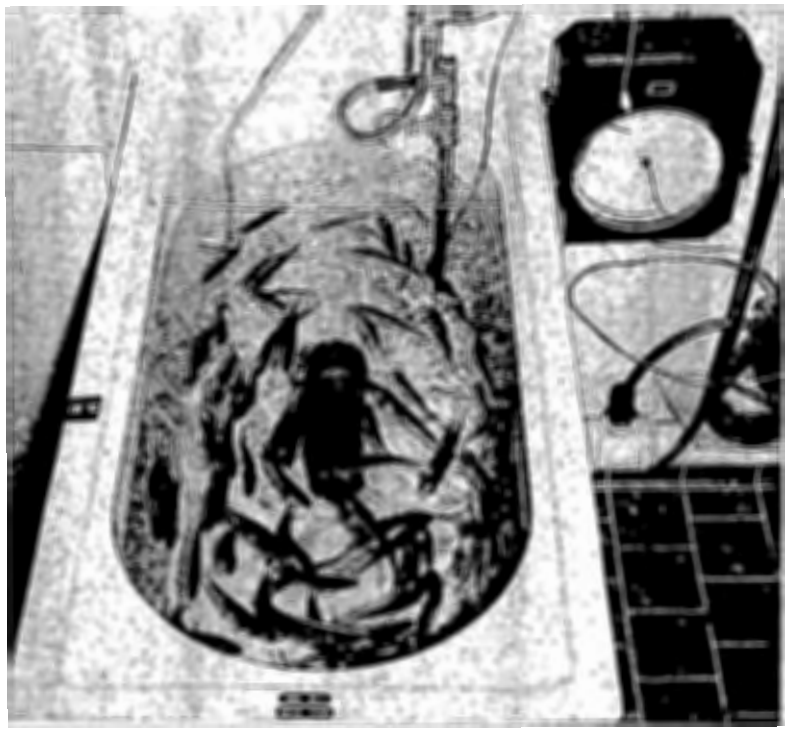
Only 47 returning adult pink salmon were found in 1964 following a 1962 planting of 2.5 million eggs from the Glendale River. In 1966, however, 627 adult pinks were recovered from a 1964 planting of 3.4 million eggs from the Lakelse. The 1966 recoveries were found mainly in the North Harbour River (418), but also in the nearby Cabinet River (32), and in commercial fishermen's catches in St. Mary's Bay (177).

Physiology of Salmon and Trout

Metabolic rate. A second fish respirometer provided opportunity for studies on metabolic rates and circulatory systems of large fish under a wide range of conditions. For adult sockeye it was found that the greatest scope for activity occurred at 15 C. The relationship between weight and metabolic rate at 5, 15, and 20 C was determined on sockeye from 3 to 1500 g. At each temperature, active metabolic rate, unlike the standard rate, was found to be independent of weight.

Nutrition. In nutrition studies of fingerling sockeye, temperatures from 1 to 20 C were used. When rations were 6% of body weight per day, best growth

occurred at 15 C. A progressive shift in the optimum to lower temperatures occurred with decreased rations, so that for a 1.5% ration the best growth was at about 7 C.



Temperature acclimatization studies on fish for food and growth studies.

Collection of data began on the growth and food conversion efficiency in juvenile coho salmon as affected by temperature. Conversion efficiency in fingerlings 1–6 months old was highest between 6 and 18 C, although the temperature associated with maximum growth appears to vary with age.

Circulation. Successful multiple cannulation of the dorsal aorta, ventral aorta, and subintestinal vein in rainbow trout and coho salmon was achieved. When moderately active or at low oxygen tension, blood pressure increased 10–15%. Resistance of the gills may reduce arterial systolic pressure from 50 mm Hg in the ventral aorta to 25 mm Hg in the dorsal aorta.

Body temperature. Deep muscle temperatures of coho salmon as affected by activity and environmental temperature were recorded. Little rise in internal temperature caused by activity was noted. The temperature of the fish closely followed environmental temperature changes of 10 C with up to a 10-min lag.

Salmon Behaviour

In 1965 the sockeye smolt orientation data were prepared for publication. Detailed studies were made of migration behaviour of sockeye smolts under

natural conditions, using sonar and time-lapse photography, and also of sockeye fry as they migrate out of the breeding rivers into the lake.

Preliminary orientation tests with sockeye fry, of both the Fulton and Babine rivers, revealed directional tendencies, under experimental conditions, which correlated with the direction in which the concentrations of the deep small targets changed with time of season.

HERRING

The British Columbia herring catch swung sharply from well above average in 1964–65 to below average in 1965–66 (from 241 to 181 thousand tons; 10-year average = 201). Indications were that 1966–67 stocks and catches would be lower yet. This phase of reduced abundance is a result of two or three poor year-classes of recruits in most stocks. The decline was not uniform and the stock spawning on the lower east coast of Vancouver Island was particularly hard hit: its spawnings in both 1965 and 1966 were poorer than any previously observed. Though most of the catch was still taken in fall and winter, the summer herring fishery continued to expand.

Tagging. Tagging was done in August and September 1965; six taggings with releases totalling 11,828 were made off Swiftsure Bank. Recoveries to date suggest that about two thirds of the fish caught there in late summer belong to the Strait of Georgia stocks, and the remainder to stocks of the lower west coast of Vancouver Island.

The 1965–66 recoveries from the northern taggings in 1964 yielded 2380 tags. They showed that herring near the southwest tip of the Queen Charlotte Islands are of the same stock as those on their southeast coast; herring on the remainder of the west coast of the Queen Charlotte Islands did not mix with stocks on the east coast or in Hecate Strait; herring from the north coast of the Queen Charlotte Islands mixed to a limited extent with stocks in Hecate Strait.

Larval surveys. Herring year-class strength is apparently determined during the larval period. Surveys were made in the islands region of the Strait of Georgia to determine the distribution and abundance of herring larvae in 1965 and 1966. Few larvae were taken, however, in the regular season. They occurred mainly in the upper 30 m, and their food was mainly eggs and nauplii of copepods.

Hatching success. Using eggs spawned naturally on eelgrass, laboratory experiments were made to determine the effect of egg density on hatching success. The percentage of normal, free-swimming larvae produced was highest at the "very light" and "light" categories of intensity, averaging 82 and 75% respectively. "Heavy" spawning produced hatches of only 23%. Larvae hatched in the laboratory survived and grew on a diet of *Artemia* nauplii but starved when fed on barnacle nauplii.

Salmon taken. An intensive survey of the numbers of salmon taken incidentally in herring operations in the Strait of Georgia during the 1963–64 and 1964–65 seasons was completed. Adult salmon taken in herring operations averaged 12,500 per season; of these 5,300 were chinook, 1,100 coho, and the remainder mostly chums. In addition the herring fishery averaged 27,000 small

salmon ("grilse") per season, mainly coho. Some local areas produce large catches of grilse at particular times. When lights were used to attract herring, more than three times as many adult salmon and grilse were taken.

Sound Scattering Layers

In July 1965 the *G. B. Reed* made a cruise to the west coast of the Queen Charlotte Islands to study the fish associated with sound scattering layers. Twenty-six midwater trawl hauls were made in the open ocean and nine on the Bowie Seamount. The animals taken were mainly lanternfishes of four species. Viperfish were the next most numerous. Four other species of lanternfish, five species of argentinids and one species of dragonfish were caught occasionally. Small catches of rockfish and halibut were made on the seamount.

Groundfish

Groundfish research is divided into two main sections. One of these (near-seas investigation) is concerned with the species which contribute to the long-established trawl fishery of British Columbia, mainly on the shallow coastal banks. The other (offshore and distant-seas investigation) is concerned with resources in deep water, and particularly in regions to the north and west of British Columbia, which, though as yet unutilized by North American fishermen, are the object of a rapidly expanding fishery by the Soviet Union and Japan. Both sections of the groundfish investigation are providing scientific background for management of the fisheries, and for encouraging the utilization of new stocks by the Canadian industry.

Production and abundance. A large part of the research on near-seas stocks involved collection and analysis of catch-and-effort statistics for the purpose of measuring changes in abundance of the more important species (Pacific cod, petrale sole, English sole, rock sole, and longcod). Sampling conducted at the major ports of landing provides material for the size and age composition of catches and indicates changes in recruitment, growth, and mortality.

Total production of groundfish by British Columbia trawlers reached record highs of 45 million lb in 1965 and 55 million in 1966. The increases were due to the combination of good market conditions and an increased abundance of Pacific cod, which made up over 58% of the catch. The cod fishery, dependent as it is on only one or two age-groups, is subject to sharp fluctuations which are of considerable economic significance. Studies were started to obtain means of forecasting fishing success.

General increases in landings of several other species also occurred, the most notable being the increase in Pacific ocean perch to 3.1 million lb in 1965 and 5.4 million lb in 1966.

Exploration. The near-seas investigations included two exploratory fishing programs in 1966. The first, sponsored by the Industrial Development Service of the Department of Fisheries, discovered several "new" fishing grounds in southern Hecate Strait. The second, utilizing the *G. B. Reed*, failed to find commercial concentrations of groundfish on Hecate Strait grounds not usually fished by

British Columbia trawlers during winter months. A search for spawning grounds of rock sole was also unsuccessful.

Age and growth. Age and growth studies on stocks of petrale sole, rock sole, and English sole were continued as part of the assessment of long-term changes in the fisheries. Information on petrale sole to 1965 was recently summarized in Fisheries Research Board of Canada Bulletin No. 153; 1966 information indicated a continued low level of recruitment to the stock.

Offshore and distant-seas stocks. The *G. B. Reed* cruises in August–September, 1965 and 1966, from southeastern Alaska to Oregon completed the initial summer survey, begun in 1963, of Pacific ocean perch distribution. The region from Oregon to western Alaska was covered. Depth distribution of perch was similar throughout this large area, with maximum catches at 100–139 fath (183–254 m). Major areas of high abundance included: western Gulf of Alaska (Kodiak Island to Unalaska Island); southeastern Alaska; and southwestern Vancouver Island. Sizes of adult fish taken declined northward and westward, reflecting slower growth rates. For example, the mean length of age 2 fish was 36 cm off Oregon, Washington, and British Columbia; 34 cm off southeastern Alaska; and 30 cm in the Gulf of Alaska (Yakutat to Unalaska Island). The principal age-groups in all areas were 10–16.

A cruise in February and March 1965 investigated winter distribution and abundance of ocean perch off southwest Vancouver Island, Yakutat, and Kodiak Island. In all three regions the bathymetric abundance maximum had shifted 40–60 fath (80–120 m) deeper than in summer. Also, catch rates were lower and female ocean perch less prevalent in the catches.

Many other rockfish species were encountered during these surveys and identification problems are gradually being resolved. The examination of both morphological and biochemical characteristics of the various groups was begun, the biochemical studies at the Vancouver Station. A description of a previously unrecognized rockfish species, for which the name *Sebastodes reedi* was proposed, was prepared. It is abundant off British Columbia, but occurs mostly on grounds too rough for ordinary commercial trawling. A number of rockfish range extension records, including some species new to British Columbia, were published.

Crustaceans

Crabs and shrimps. The British Columbia catch of crabs was 3,501,000 lb in 1965, and 4,538,000 lb in 1966. The 1965 catch was down in all coastal areas, particularly in the Queen Charlotte Islands region which yielded 1,444,000 lb; but in 1966 this region produced 2,801,000 lb, the best year since 1961. Field investigations of crabs were suspended, but the basis for forecasting abundance was to be re-examined.

In 1965, a detailed study of a commercial *shrimp* ground near Comox was started. This ground was discovered by exploratory work from the Nanaimo Station in 1954, and after that was fished every winter. In 1963 and 1964 fishing was very poor but late in 1965 the ground produced more pink shrimps than ever before, 362,000 lb compared with 164,000 lb in the previous best year (1957–58). A search for the causes of these fluctuations was begun. Experi-

mental trawling revealed migrations, growth, and spawning times, as well as the distribution and depth of shrimps of the three commercial age-groups.

Lobsters. The project to test the feasibility of establishing a lobster population in Fatty Basin (Barkley Sound) was started in 1965. Following a small trial transplantation in 1965 to assess problems of shipping and handling, 1500 adult lobsters from the east coast were shipped to Fatty Basin in June 1966. Subsequent surveys with traps indicated extensive movement within the Basin from the original release sites, but there was little evidence of emigration. The lobsters appeared to be healthy and growing satisfactorily. Some females were carrying fertilized eggs as a result of breeding prior to transplantation; however, a few had definitely mated in the Basin. Embryonic growth was normal. Growth increments of a small number of *larval* lobsters which survived shipment in 1965 were similar to what occurs on the east coast.

Molluscs and Other Invertebrates

Oysters. Spatfall forecasts are made annually for Ladysmith Harbour and Pendrell Sound. At Ladysmith a small spatfall occurred at the extreme head of the harbour in 1965 and a modest one in 1966; however, in this area there were still reserves of seed accumulated from the 1958 spatfall. In Pendrell Sound there were heavy sets in both years and considerable quantities of seed were collected, mainly for export.

The Denman Island oyster disease was again monitored at Henry Bay. In 1965 the highest rate of infection was less than 20%, somewhat lower than in the previous year. In 1966 the maximum rate was 12%.

Mussels. The study of the copepod parasite *Mytilicola orientalis* was continued. It has been found that rate of infection of mussels on a long float varies with distance from shore or depth of water, or both. This may indicate that the larvae remain near the bottom during the pelagic stage.

Raft culture of oysters. Trials of oyster raft culture were begun on a pilot scale. Pendrell Sound seed (1965) was held on the experimental oyster reserve in Ladysmith Harbour in preparation for the plantings in early 1967. A new raft design using plywood pontoons was tested and shown to be not so satisfactory as the log raft.

Razor clams. Razor clam beaches at Wickaninnish Bay and at Masset were again checked for the young of the year. There was, as usual, no sign of spat on Long Beach in Wickaninnish Bay in either 1965 or 1966. A population study of adult razor clams was carried out at Masset.

Clam digger. Tests were conducted with a manual hydraulic clam digger which was shown to dig clams faster and more efficiently than the clam fork. The investment required is small and the digger could be used profitably in British Columbia.

Clam transplantation. In 1962 Japanese little-neck clams (*Venerupis japonica*) were planted in Naden Harbour and Masset Inlet in an attempt to introduce the species to the Queen Charlotte Islands. In 1965 in Naden Harbour

there was a modest survival but no sign of breeding and very little growth. Survival in Masset Inlet was very poor and only a few live specimens were found, with no evidence of breeding. Failure of this experiment is probably due to low water temperatures.

Clam borer. Information on the life history of *Polinices* is being accumulated. Newly hatched young were located for the first time; they were found on fronds of *Ulva.* Held in aquaria, the young *Polinices* were able to drill the shells of clams 3 mm in length within 6 months of hatching, when about 5 mm in diameter, so the period during which an algal diet is required is probably short. Prey attraction experiments demonstrated that neither whole clams nor clam meat had much attractive power. Enzyme activity was shown to be involved in the boring action and details of the morphology of the accessory boring organ have been worked out.

Shellfish poisoning. The year 1965 was marked by a local outbreak of paralytic shellfish poisoning which caused one death and four cases of illness. This occurred on June 1 in Malaspina Inlet and the causative organism was found to be *Gonyaulax acatenella.* Toxicity in the butter clam persisted, chiefly in the siphon, until the present time (early 1967), but all other affected species lost all toxicity within 4–6 weeks. Tests on canning toxic butter clams were carried out with the assistance of the Department of Fisheries and it was shown that a non-toxic product could be produced from clams with a toxicity as high as 1000 μg if the whole siphon were removed.

Abalones. Studies on abalones during 1965 and 1966 were limited to a tagging program to determine growth rates and migration patterns. Preliminary evidence indicates growth rate is slow and movements are not extensive.

Distribution and systematics. More information on the distribution of invertebrates was obtained from offshore cruises and from the Bering Sea. An updating of the checklist of British Columbia's marine fauna was begun. The number of lamellibranchs known has increased by about 40% since 1933.

Marine Mammals

Whales. The 1965 whale catch from the Coal Harbour Whaling Station consisted of 9 blue, 83 fin, 18 humpback, 604 sei, and 151 sperm whales. In 1966 blue and humpback whales were protected, and the catch consisted of 134 fin, 354 sei, 229 sperm, and 2 bottlenose whales. The catch of fin whales was greater than predicted by available population models, suggesting some mixing of local and pelagic stocks.

Fur seals. Collections continued to be made on the high seas as planned by the International North Pacific Fur Seal Commission. A special feature of the 1965 work was the search for seals in November and December in the Gulf of Alaska and the Bering Sea. Effects of gonadotrophic hormones in stimulating first ovulation in fur seals were investigated, as part of a study which seeks an explanation for earlier maturity of fur seals on Robben and Commander Islands. Samples of tagged seals were obtained from Japan and the USSR for this study.

Fur seal sightings by salmon, whaling, fur seal, and oceanographic research vessels have been analysed. Upon leaving the Pribilofs in the late fall, the seals approach the North American continent mainly south of 50°N and thence fan out over a wide expanse of coastal area. They return to the Pribilofs in the spring along a route paralleling the continental rim.

Harbour seals. The harbour seal population within the 2 or 3 years before 1967 was hunted briskly because of good market demand for skins. Information on age, growth, pelage, reproduction, and stock size was obtained from a contract study with the University of British Columbia.

Sea lions. British Columbia sea lions are now reduced to about 4000 individuals following several years of commercial use. Biological information on the stock was obtained, but estimation of sustained yield is hampered by the difficulty of obtaining representative samples of the stock.

Tolerance of Environmental Stress

Eggs of the Pacific cod were examined for their rate of development, their survival to hatching over a range of 2–10 C and 19–31 S (salinity), and the size of the larvae at hatching. Maximum survival and larval size were estimated provisionally at 6 C, 10 ‰ S. A significant salinity–temperature interaction indicated that maxima in the above characteristics at higher salinities would be coupled with higher temperatures. Pacific cod eggs were also found to be markedly euryhaline.

A similar study on the English sole (*Parophrys vetulus*) produced the following results:

	Calculated levels			
	S, ‰		*Temp, C*	
Characteristic	*Mean*	*Range*	*Mean*	*Range*
Minimum incubation period		23.0–27.0		
Maximum larval length	28.1		7.9	
Total hatch (maximum)	25.6	25.2–26.2	9.0	8.9–9.4
Viable hatch (maximum)	25.9	24.9–26.9	8.4	7.9–8.5

The acute toxicity of a new formamidin acaricide was compared with that of hexachlorocyclohexane, used in control of ambrosia beetle infestation of cut timber. Although considerably less toxic than hexachlorocyclohexane, the acaricide formulation had a potentially high residual toxicity which might in time build up to dangerous levels.

Theoretical Population Dynamics

Recent studies in theoretical population dynamics include work on computer simulation of salmon stock sizes, catches, and reproduction; a new method of computing von Bertalanffy growth equations that avoids some of the limitations

of previous methods; computer programs for estimating age distribution of whale populations from length data and age–length key, and for estimating the abundance of exploited whale populations from catch effort and age distribution; simulation of long-term cyclical effects of environmental factors on various kinds of stock–recruit relationships.

Parasitology

The investigations in parasitology are related to faunal studies, the use of parasites as "tags" to determine ocean distribution of specific stocks of sockeye salmon, and the effects of parasitism on fishes.

Work continued on a monograph of the morphology, taxonomy, distribution, abundance, and ecology of the parasites of Pacific salmon. The parasite faunas of other species of fishes also were examined—34 to the early part of 1967.

The life-span of *Tubulovesicula lindbergi*, a trematode parasite of potential use in determining the ocean distribution of North American sockeye, was shown experimentally to last at least 31 months in chum salmon.

The absence of *Philonema oncorhynchi* in adult sockeye from the main upriver Fraser sockeye stocks was vertified. This absence is a potential mark of identification of the main Fraser River stocks on the high seas because *Philonema* is present in virtually all sockeye from other major North American stocks. This nematode exists in two forms, morphologically indistinguishable. One has a prolonged life history, geared to that of its anadromous host, and the other apparently has an annual life cycle in completely freshwater salmonoids. The "freshwater" form may infect the young of anadromous sockeye, but the parasite dies in less than a year after seaward migration of the smolt, without having reached maturity.

The hosts involved in the life cycle of the trematode *Lecithaster gibbosus* are the snail *Thais* (first intermediate host), copepods (second intermediate host), and various fishes, including salmons (final hosts). Copepods have been infected with cercaria obtained from naturally infected *Thais* and reared to the infective stage, and young salmon have been infected by them experimentally. Massive infection was attempted to investigate its effects on young pink salmon.

Microbiology

Bacterial flora of salmon eggs. Seventy bacterial isolates from living and dead salmon eggs were obtained and characterized. The dominant organisms were Myxobacteria. The study of their relationship to egg mortalities in nature was begun.

Gaffkaemia. Some lobsters transplanted to the Pacific coast apparently carried with them the bacterial disease gaffkaemia. This disease, before unknown in the wild condition on the Pacific coast, was transmitted experimentally to native crabs and prawns (*Cancer* and *Pandalus*) by injection of cultures isolated from diseased lobsters.

Kidney disease. The causative bacterium was isolated and identified from two stocks of experimental sockeye. In experiments on transmission by contact, 74–78 days were required for the appearance of advanced kidney disease in sockeye held in salt water at summer temperatures (11–15 C).

Sealing-off cultures for microbiological studies. The cultures are frozen with CO_2 then dried by vacuum pump before the sealing to prevent contamination.

In the search for treatments for kidney disease, it was found that therapeutic levels of the broad-spectrum antibiotic chloramphenicol were rapidly attained in liver, kidney, and muscle tissues of coho and sockeye salmon held in fresh water after a single feeding at a rate of 50 mg of drug per kg of fish. In similar experiments with cohoes in salt water only traces of the antibiotic occurred in these tissues.

In attempts to devise a more suitable growth medium for the kidney disease bacterium, it was found that a number of human plasma proteins could be substituted for whole blood but known bacterial growth factors, singly or in combination, failed to support growth.

Oceanography of the North Pacific

Primary production. The collection of primary production and nutrient data at Ocean Weather Station P continued during 1965–66. In addition, primary production observations were made during cruises of the *G. B. Reed* and from vessels chartered by the Salmon Investigation.

Chlorophyll *a* and nutrient data collected during 1965–66 show that although the level of nutrients remains high throughout the year, a small but significant decrease occurs during the period August–October. This decrease is not sufficient to limit the level of primary production in the area but reflects an increase in the standing stock of phytoplankton caused by a probable decrease in zooplankton grazing during the same period.

Nitrate data, first routinely collected in 1965, indicate that the concentration of this nutrient may occasionally become growth limiting to primary producers in the area.

Zooplankton. Zooplankton collected in 150-m net hauls at Station P reached a minimum in 1963 and 1964. The wet weight of the standing crop decreased from 2.5 g/m^3 to less than 0.5 g/m^3 from 1958 to 1963–64. After that time there was a gradual increase in standing crop to approximately double the 1964 values. The species composition largely remained unchanged; some Transitional Zone species, notably salps, were present in the 1965 samples.

Physical oceanography. Oceanographic work included: participation in the *Boreas* Expedition (January 26–April 1, 1966) of the Scripps Institution of Oceanography; bathythermograph, surface salinity, and primary productivity observations during April–July and November–December from vessels engaged in salmon longlining; continued observations at Station P and line P, and a short review of temperature and salinity structures and circulation between Station P and the Pacific coast.

On the *Boreas* Expedition the coldest water was found off the southern tip of Kamchatka and in the Okhotsk Sea (−1.8 C). Lowest salinities were associated with the westward-flowing Alaskan Stream. There was a marked southward flow along the Kamchatka coast. Geostrophic calculations give a speed of 1.25 knots, while observations from ship drift suggest 1.8 knots. Such speeds indicate that there is winter acceleration since summer data indicate much slower currents.

Minimum temperatures in the eastern subarctic were recorded in the latter part of March during 1966, as compared with mid-February during 1965. Winter surface temperatures for the 2 years were very similar, those in 1966 being slightly higher (by less than 0.5 C at Ocean Station P). Maximum temperatures were recorded in the last week of July, 1966, with a 2-day secondary maximum in late August. In 1965, maximum temperatures were reached in the latter part of September. Maximum temperatures differed by about 2 C, those in 1965 being higher.

Surface salinity distributions for 1966 were fairly typical for the area. There was recirculation in the Gulf of Alaska, starting at about Longitude 165°W, during the winter months. A tongue of relatively low salinity water extended westward from the northern tip of Vancouver Island during July and through at least part of August.

Temperature distributions between Station P and the Pacific coast, at the top of the halocline (seasonal waters) and at its bottom (non-seasonal waters), show two major changes. In the southwestern portion of the region there are meridional shifts in the isotherms which may be accompanied by meridional and zonal shifts along the coast. The years 1955–66 were classified as cold, warm, and intermediate by computing the areas of water warmer than 7 C for the seasonal zone, and warmer than 6.5 C for the non-seasonal zone. The classification of waters at the top of the halocline (after 1962, winter surface temperature data were used) showed 1958 and 1963 as the warmest years. As in 1958, the warm conditions in 1963 were common for the whole North American coast. Isothermals of the lower zones had not retreated to the positions observed in 1955 through 1957, at least until 1967.

There is an area along an axis of about 46°N lat, between about 140° and 160°W long, where relatively large (1.0–1.5 C) temperature inversions regularly

occur. These inversions are apparently generated locally, probably by lateral mixing and by differential advection, or both, and are also dissipated en route. They probably account for many of the inversions occurring between Station P and the coast.

Surface transport in relation to biological phenomena. Mass transport in the North Pacific Ocean for the years 1946–1949 and 1962–1966 was computed, extending the series to 21 years. Southward wind-driven surface transport at the divergence of the West Wind Drift near North America is positively related to zooplankton abundance off California in the following year, and is negatively related to their abundance in the following year in the western Bering Sea. At Station P both salinity and zooplankton abundance vary with wind-driven recirculation from the Alaskan Stream into the Gulf of Alaska. It appears that the quality of water reaching an area as well as the total transport to that area, is an important factor influencing the oceanic biological environment.

Wind-driven surface transport onto the coast in the first 6 months of each year is directly related to pink salmon catches of the following year in Statistical Areas 7 and 8 of the central British Columbia coast. It is postulated that in the same way the abundance of food organisms is altered "downstream," as shown above, so that the availability of food for young pink salmon entering Hecate Strait varies directly with the onshore transport, and that the young fishes survive proportionately.

The same populations of pink salmon vary directly with summer rainfall and with the timing of the upstream movement of adults in the major streams in the brood year. Drought and delay go together, and result in poor return and catch 2 years later. The above two factors, one in the sea and the other in fresh water, explain much of the variability in the Central Area pink salmon catches.

Strait of Georgia Studies

Primary production. The level of primary production in terms of total biomass was very similar in 1965 and 1966, in spite of different meteorological conditions during the years. The time at which production started in the spring, and the type of production that occurred, varied more than the total amount of plant material produced.

Zooplankton. The biomass of zooplankton in the euphotic zone changed seasonally, with maxima during April and September. During spring *Calanus plumchrus* is dominant; it is then developing from egg to pre-adult, and is an important food for many larval and juvenile fishes. Later it descends below 200 m. The fall zooplankton maximum consists predominantly of *Pseudocalanus minutus* and the ctenophore *Pleurobrachia.*

During both 1965 and 1966 there were two areas with a high level of production: beneath the Fraser River plume and in a small area north of Texada Island. The separation of the Strait into areas of high and low production may be misleading, however, unless the production of benthic communities is also taken into consideration. From sedimentation studies in Departure Bay it appears that approximately half the annual primary production of plant material sinks to the bottom, but only a small fraction of this is permanently retained in the sediment.

Young fishes. Stomach contents of larval and juvenile fish indicate that young salmon are highly diverse feeders, but that post-larval, juvenile, and adult herring are very specific in their diet, feeding almost exclusively on *Calanus plumchrus*. During April large numbers of post-larval lingcod were found in the Fraser River plume together with pink and chum salmon fry. The latter tended to be concentrated along the edge of the plume and in pockets of cloudy water separated from the plume. During June and July, larval eulachon (6–12 mm) were very abundant in the plume and were being consumed by nearly every other species of fish sampled as well as by the ctenophore *Pleurobrachia*. Two species of lamprey (*Entosphenus tridentatus*, 130–200 mm; *Lampetra ayresii*, 90–180 mm) were caught in the surface waters of the plume, the latter being present in nearly every tow taken during June and July. From lamprey scars observed on the sides of some juvenile salmon and herring, it seems likely that the lampreys may cause significant mortalities among the young salmon.

Experimental plankton dynamics. Under experimental conditions nocturnally feeding sub-mature *Calanus pacificus* have a higher growth efficiency, ingest more food at a given concentration, and can utilize higher concentrations of food than can *Calanus* feeding continuously at their equilibrium rate. This results from the fact that feeding declines with time, reaching an equilibrium value after about 4 days. Also, data on diurnal variations in the growth of diatoms in culture suggest that, in a light–dark cycle, carbon per cell or per unit volume is at a maximum near sunset. Nocturnally feeding *Calanus* ingest at a maximum rate at this time, thus maximizing the ratio of food intake to the energy expended in feeding.

Physical oceanography. To determine the effect of tide on the Fraser River discharge, drogues were released in batches of three at the mouth of the river at or near high- or low-water slack, and were tracked for from 6 to 30 hr. During most of the tracking, wind effects could be regarded as insignificant. Drogues released at the surface at low-water slack mainly veered northward and then northeastward on the succeeding large flood tide. Those released at high-water slack unexpectedly gave varied and confusing results as to direction. Surface-current speeds varied from 0.3 to about 3.5 knots, the latter near the mouth of the river. Aerial observations and colour photography assisted in locating water mass boundaries, internal waves, and water from sewer outfalls.

With the assistance of the Geodetic Survey of Canada, second-order precise levelling was carried out from Woodward Landing to Sand Heads, and in the Tsawwassen area. This will be of value in the study both of the flow at the mouth of the Fraser River and of the oscillations in the central Strait region.

Fundamental to an understanding of the physical oceanography of the Strait of Georgia is a knowledge of the tides and tidal streams. A simple one-dimensional mathematical model was found to yield good agreement between the distributions of tidal amplitudes for M_2 and K_1 components along the Strait and available gauge data. Comparison of the limited number of current measurements with the calculated velocities for a series of sections across the Strait indicated the latter to be at least of the right order of magnitude. A further calculation employing G. I. Taylor's method for a rotating rectangular inlet afforded a qualitative indication

of the effect of Coriolis force on the amplitudes and phases associated with the tides and tidal streams.

OCEANOGRAPHY OF INLETS

Nanoose Bay and Saanich Inlet. During 1965 and 1966 intensive time series studies of production processes were carried out in these two semi-isolated environments. Much exploratory information was obtained from Nanoose, but the results obtained from Saanich Inlet were generally more illuminating. Grazing experiments with zooplankton revealed the size spectra of food particles available and the biomass of material consumed in various size categories. Using a modification of Ivlev's equation relating ration to the concentration of food available, maximum and minimum concentrations of certain types of food were determined for several zooplankters. Also, the quantity of specific sizes of zooplankton required by juvenile salmon at different stages of growth were determined. Although juvenile salmon will select *Calanus plumchrus* as their preferred food, the standing stock of *C. plumchrus* would have had to be very much greater than what was present in Saanich Inlet during the latter part of the study period if the salmon were to have obtained all their ration from this organism alone. The only organisms of a similar size and present at a sufficient concentration at that time to meet the food requirements of the salmon were furcilia stages of *Euphausia pacifica.*

These observations were combined into a general picture of the pathways of trophic exchange from phytoplankton to juvenile salmon. A dimictic *Chaetoceros* bloom was a good source of food for the large euphausiids (but a poor source for *Calanus* and the small copepod *Pseudocalanus minutus*). After eating sufficient amounts of this easily obtainable food, the euphausiids laid large quantities of eggs from which furcilia, feeding off a second bloom consisting of μ-flagellates, developed to concentrations of around 8000/m^3.

Current-meter studies at the mouth, and sea level studies from the head to the mouth, of Saanich Inlet were carried out in cooperation with the Canadian Hydrographic Service in order to compare the daily net exchange of water in and out of Saanich Inlet with the biological events.

Burke Channel. Observations of salinity, temperature, currents, turbidity, and extensive biological observations (zooplankton, stomach content, predator concentrations, etc.) were carried out during March to June, 1962 through 1966. There are longitudinal and cross-channel gradients of properties in all parts of the system, the most predominant being in North Bentinck Arm. The shore configurations modify the circulation patterns near bays and points, producing gyres and back eddies, which are major features of the area. At the junctions of various channels there are marked cross-junction "jets" which are directly related to the residual flow.

Turbidity profiles in the channel suggest that there is a sequence of events leading from a surface turbid layer to a subsurface maximum. Turbidity is associated with runoff, plankton blooms, wind-driven transport, and surface mixing. A longitudinal gradient of turbidity prevails, particularly during the large

runoff of early spring, with the greatest turbidity at the head and the lowest to seaward.

Barometric pressure (from continuous recordings) oscillates with a period of 3–6 days. Rapid changes in pressure are accompanied with changes in mean sea level and at times, with winds. Winds play an important role in the overall surface transport. Diurnal winds down-channel in the morning are generally weaker than the winds up-channel in the afternoon. At times strong winds blow persistently out of the inlet for 1–3 days. The resulting surface transport causes cataclysmic changes in distribution of everything from salinity to fish. During periods of winds, large numbers of small pink salmon fry have been observed moving toward the beaches, sometimes swimming or drifting with the current, and at other times swimming against it.

Pollution Investigations

Pulpmill pollution. Pulpmill pollution continues to be of primary concern. Oceanographic observations were conducted in a number of areas of actual or potential pulpmill pollution: Crofton, Port Alberni, Port Alice, Gold River, Duncan Bay, Squamish, Union Bay, and Powell River.

In Alberni Inlet, a monthly oceanographic program was initiated in 1965 to study the seasonal variation of oceanographic conditions under the influence of the pulp mill. Low dissolved oxygen concentrations of less than 4 mg/liter at nearly all depths in Alberni Harbour during August 1965 were not reached in the summer of 1966 when runoff was higher and air temperatures were lower. Collection of sediment in Alberni Harbour was concluded in April 1965. The total average solids from all stations rose from 6.8 kg/m^2 per month in 1963–1964 to 10.8 kg/m^2 per month in 1964–1965, an increase in keeping with increased mill production. Sampling and analysis of gases in sediments continued during 1965–1966. The average monthly volumes throughout the harbour tended to be higher than in the previous year, while the average yearly H_2S concentrations of all stations followed the same distribution pattern as in 1964–1965.

Surveys to study sediments and gas formation were made in the summer of 1965 at the following actual or prospective pulpmill sites on the British Columbia mainland: Port Mellon, Woodfibre, Squamish, Powell River, Ocean Falls, Kitimat, and Port Edward. Comparable studies were conducted in 1966 at five sites on Vancouver Island. Chemical analyses of the sediments and gases, particularly in relation to pulpmill pollution, were continued.

Domestic pollution. A cooperative study, involving Federal and Provincial agencies, was completed in June 1965 using aerial photography to study surface currents, supported by current-measuring ships at anchor, at the approaches to Victoria in Juan de Fuca Strait. The results of this study, which was coordinated by the British Columbia Pollution Control Board, were used by the consulting engineers for a comprehensive plan on sewerage and sewage disposal for the Greater Victoria area. In support of this study, different types of targets for aerial photography were compared during an oceanographic survey in Cordova Bay during May 1965. Aerial photographs taken of dye solutions, strips of paper, aluminum dust, and packages of dye during three stages of the tide (ebb, low-

water slack, and flood) permitted evaluation of dispersion rates in surface waters of Cordova Bay.

A study was initiated in August 1965 to evaluate seasonal variations of oceanographic characteristics, including nutrients and plant pigments, in Victoria Harbour and its extension, the Gorge and Portage Inlet. The salinity in Portage Inlet was higher than that in the bottom waters of Victoria Harbour during August; this is one of the few known examples of a "negative estuary" on the Pacific coast of Canada. In Portage Inlet during late summer of 1965 and 1966 the nitrate concentration was zero while the phosphate was high (>6 μg-at/liter). At that time phosphate increased to more than 20 μg-at/liter, in the presence of zero nitrate, at the mouth of Colquitz River, a tributary stream. Nitrates reached peak concentrations in December with more than 70 μg-at/liter in the Colquitz River, 32 μg-at/liter in Portage Inlet, and 28 μg-at/liter in Victoria Harbour. Phosphates were comparatively low at this time, being 5, 3, and 1.5 μg-at/liter, respectively. Two peaks in chlorophyll *a* were evident at Portage Inlet stations: 23 mg/m^3 in April and 7.5 mg/m^3 in August. Minima of 0.5–1.5 mg/m^3 were recorded at all stations in October and December at all stations during both 1965 and 1966.

Annual monitoring surveys in the Fraser River estuary, Burrard Inlet, and Howe Sound continued to provide a fund of information on year-to-year changes in the waters off the Lower Mainland. Although increasing urbanization had resulted in more domestic sewage, and industrialization had increased the amount of trade wastes, the pollution parameters examined (dissolved oxygen, *p*H, alkalinity) had not shown large changes, except in localized areas near pulpmill outfalls.

Data Processing

The data processing facilities at the Nanaimo Station underwent considerable expansion. In 1965 a 407 Accounting Machine was installed. This made it possible to do in Nanaimo all preliminary tabulations of salmon sampling data (all species, inshore and offshore), salmon racial studies, high-seas salmon tagging data, salmon stomach contents, groundfish age-length relationships, and effects of fishing effort on groundfish. Tables for data records were produced directly on multilith stencils by the 407. More detailed computations were done by contract at computing centers, but, starting in 1967, most of this work was in Nanaimo with the 1130 Computing System delivered in December 1966.

In January 1966 all continuing data files on IBM cards were copied onto magnetic tapes to be stored in a vault in another building as a safeguard against the possible loss of these data.

Apparatus Research and Development

Major projects in the engineering research and development group during 1965 and 1966 included: a reflection photometer for reading the number of laminae in whale ear plugs as an aid to age determination; a water tunnel (maximum test section velocity in excess of 2 m/sec) for respiratory studies on fish; extensive examination of infra-red and low-level visible light systems capa-

bilities and limitations for *in situ* observations of fish; design and construction of a large water tunnel for stamina studies. Other projects were photocell instrumentation of an activity respirometer, an improved thermistor chain, underwater camera modifications, event recorder instrumentation, examination of hydrophone systems, and general arrangement design for tank experiments on crabs. In addition, design or initial construction was begun on a small stamina tunnel, a photo-electric smolt counter incorporating a feedback control on the light source to maintain the sensitivity at a pre-set level as water turbidity changes, a plankton size distribution device, and a brine-shrimp counter. Project examinations were made for various investigations on such things as heat transfer in spawning channels, specific gravity determinations for fish eggs, aspects of vessel equipment, analog programs for population dynamics studies, and similar engineering problems.

FACILITIES

Improvements and additions to Nanaimo Station facilities during 1965 and 1966 included: recovery of 3 acres of waterfront property from tideflats by filling; dredging of a harbour, 23 ft deep; construction of a 204-ft deep-sea wharf; a new entrance road to the waterfront; a field camp trailer installation at Fulton River; a field camp and lobster hatchery at Fatty Basin; a boathouse and boatways at Donald's Landing; the connection of the Station's septic tanks to the city sewer system; the installation of an IBM 1130 Computer; and the acquisition of the small vessels *Tahlok*, *Decibar*, and *Navicula*.

PUBLICATIONS AND REPORTS

The Board maintains two major scientific publications—The *Journal of the Fisheries Research Board of Canada* and the *Bulletin* series. The *Journal* increased in volume from 1615 pages in 1965 to 2039 pages in 1966, the first year of monthly issues. A total of 174 articles were published in 1966, 54% of which were contributed by Board scientists and 18% by scientists from Canadian universities. Ten new *Bulletins* were published in the two-year period covered by this *Review*, including the 485-page work on the Fishes of the Atlantic Coast of Canada.

The *Studies* for 1965 and 1966 (collections of reprints of articles published by Board scientists in other scientific and technical periodicals) were bound in two parts for each year.

The *Annual Reports* for 1965 and 1966 followed the shortened and popularly written format developed for the 1964 report. The first *Review*, which included detailed information on the researches of Board establishments, covered the year 1964. The present *Review* is for the years 1965 and 1966.

A special publication entitled "Aquatic Pollution Studies" was prepared for presentation in September 1966 to the National Research Council on the occasion of the 50th anniversary of that organization. It included selected scientific papers by Board scientists on aquatic pollution research in Canada during the period 1902 to 1966.

The issue numbers of various publications and reports of the Board for 1965 and 1966 were: *Journal*, Vol. 22, 1–6 and Vol. 23, 1–12; *Bulletins*, 149–155; *Studies*, 928–1109; Statistical Series of Circulars for the Biological Station, Nanaimo, 14–27; Circulars of the Pacific Oceanographic Group, Biological Station, Nanaimo, 73 and 74; Circulars of the Research Laboratory, Vancouver, 34–36; General Series of Circulars of the Biological Station, St. Andrews, 44–50; Circulars of the Research Laboratory, Halifax, 20–27; Circulars of the Biological Station, St. John's, 12 and 13.

The *Journal* and the *Bulletin* series are available by purchase. Issues as they appear are listed, with prices, in the daily checklists published by the Queen's Printer, and also in the monthly and annual catalogues of Canadian Government publications. Applications for purchase of publications should be made to: The Queen's Printer, Ottawa, Canada. The *Annual Report* and *Review* are available free of charge.

Circulars may be obtained from the Board Establishment that issues them while the supply lasts. Separates of articles not published by the Board (*Studies* and others) are not for sale, but may sometimes be obtained from the authors.

Enquiries concerning exchange of publications should be addressed to: Editor, Fisheries Research Board of Canada, 116 Lisgar Street, Ottawa 4, Canada.

In addition to publications for general distribution, the Board prepares Manuscript Reports primarily for its own use. In 1965–1966, the Biological

Series reports were 802–899, and the Oceanographic and Limnological reports were 186–228. These are not available for distribution outside the Board, but interested persons may consult them at the libraries of the Board's stations on arrangement with the Director of the station.

In the following listing of articles in the above publications, these abbreviations are used:

MS Rept. Biol.—Manuscript Report, Biological Series, of the Fisheries Research Board of Canada.

MS Rept. Oceanog. Limnol.—Manuscript Report, Oceanographic and Limnological Series, of the Fisheries Research Board of Canada.

FRBS—Articles in the Studies Series.

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