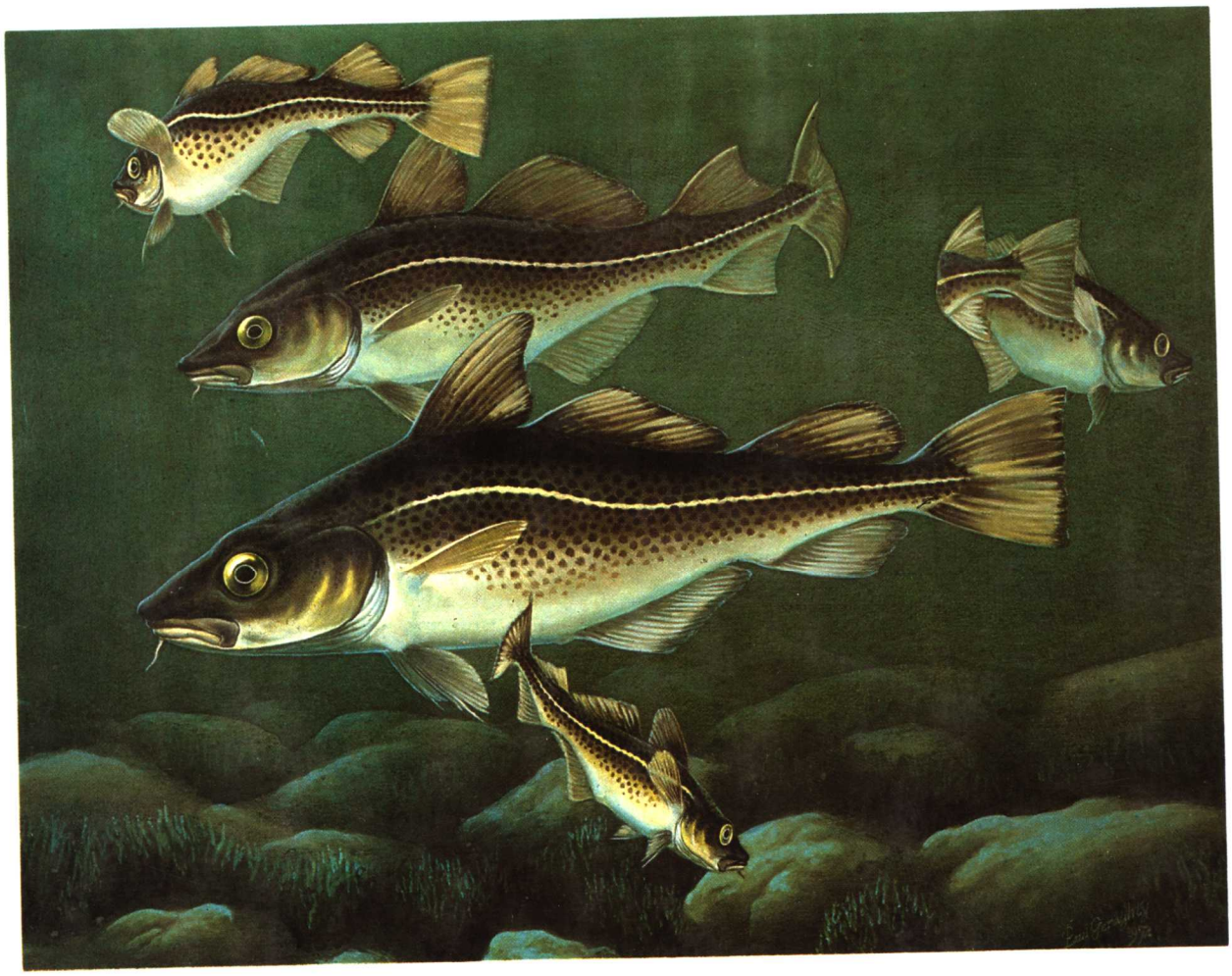
ATLANTIC FISHES OF CANADA



W. B. Scott and M. G. Scott

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and

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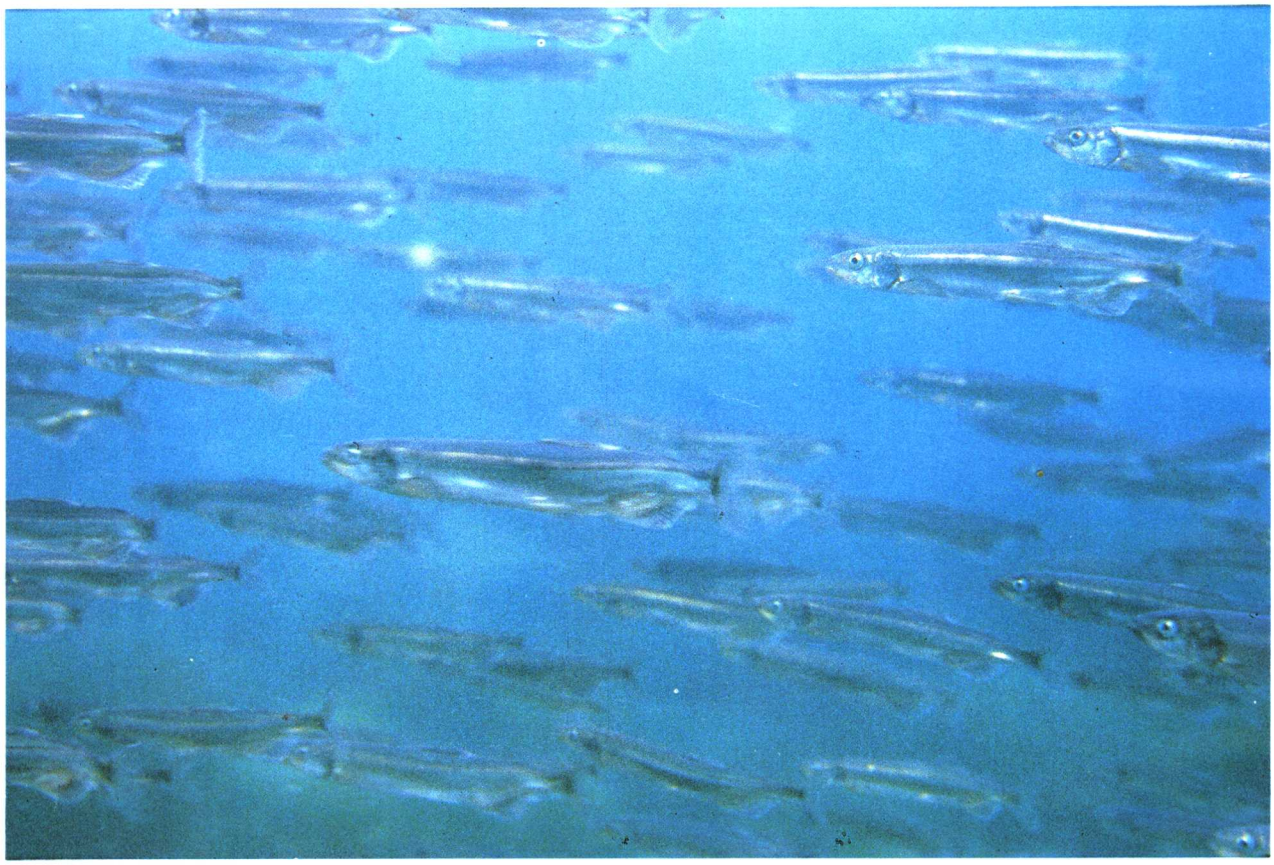

School of capelin, Bryant's Cove, Nfld

FOREWORD

The Department of Fisheries and Oceans, in co-operation with the University of Toronto Press and the Canadian Government Publishing Centre, DSS, is proud to present *Atlantic Fishes of Canada*, written by Dr W.B. Scott and M.G. Scott.

Canada's fish fauna has been said to be the best documented in the world. Supporting evidence lies in a group of bulletins on Canadian fishes, the first of which was *Fishes of the Pacific Coast of Canada* by Clemens and Wilby, published in 1946 by the Fisheries Research Board of Canada. Recognizing the value and success of the book, the board encouraged production of bulletins covering other areas of Canada. Thus followed Leim and Scott's *Fishes of the Atlantic Coast of Canada* in 1966, McPhail and Lindsey's *Freshwater Fishes of Northwestern Canada and Alaska* in 1970, Hart's *Pacific Fishes of Canada* in 1973, and Scott and Crossman's *Freshwater Fishes of Canada* in 1973. These books have all served as internationally recognized reference works for years, and some have been reprinted repeatedly.

Fishes of the Atlantic Coast of Canada had been out of print for more than a decade. It was obvious there was a need to publish a completely rewritten version reflecting the numerous advances in knowledge, and there was still a consistent demand for it. Dr Scott and his colleague and wife Mildred G. Scott were approached to undertake the task. They were both well known and highly respected, and Dr Scott had already coauthored two of the previously published and popular bulletins on Canadian fishes.

The revised manuscript was many years in the making, with the writing being done at the Huntsman Marine Science Centre in St Andrews, New Brunswick, and strong supportive work by the Department of Fisheries and Oceans, Biological Station, St Andrews, New Brunswick, and the Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto.

Knowledge of our aquatic faunas is fundamental to the understanding of our aquatic resources and their wise management. In completing the book and placing it in the hands of a new generation of Canadians, the Scotts have made a major contribution to fisheries knowledge and carried on Canada's proud tradition of being a world leader in fisheries science. It has certainly been a pleasure to have worked with them in bringing the project to fruition.

John Camp
Acting Director
Scientific Publications
Communications Directorate
Department of Fisheries and Oceans

'Science's only hope
of escaping a Tower of Babel calamity
is the preparation from time to time
of works which summarize and which popularize
the endless series of disconnected
technical contributions.'

Carl L. Hubbs
Copeia 1935

BACKGROUND INFORMATION

Introduction

Atlantic Fishes of Canada is intended as a replacement volume for *Fishes of the Atlantic Coast of Canada*, which was published in 1966 as Bulletin 155 of the Fisheries Research Board of Canada.

The major portion of the present book is concerned with the biology, distribution, and/or economics of the fishes occurring off our Atlantic coast. Most accounts are well documented, necessitating an extensive reference list, which we hope will prove useful in itself.

A checklist and keys are also presented for students or anyone concerned with the kinds and identification of fishes making up the fauna of the region.

Many changes have occurred since 1966, not only in the state of our knowledge of the fauna and its biology but also in the management of the resource. Changes in the management are well documented in the section 'Atlantic Coast Fisheries and Fisheries Research in the Last 25 Years.'

A brief review of the ichthyology of Atlantic Canada was presented in the bulletin published in 1966 and has not been repeated. That section, entitled 'Historical Review,' included most of the comprehensive texts on Atlantic fishes published up to 1966, and of interest to Canadians. Several excellent volumes have appeared since that date. The monographic series *Fishes of the Western North Atlantic*, published by the Sears Foundation for Marine Research, Yale University, is continuing and now consists of eight parts. One whole part, number seven (1977), is devoted entirely to the lanternfishes, family Myctophidae, and it is recommended that reference be made to this part for detailed information on the members of the family. A brief account of those species known to occur off the Canadian coast, with distinguishing characteristics, is presented in the text here.

The Food and Agriculture Organization of the United Nations (FAO) has published many items of interest to Canadians; for example the *Species Identification Sheets for Fishery Purposes*. One of these, a six-volume treatise covering the 'Western Central Atlantic,' was published in 1978; another six-volume set, covering the 'Eastern Central Atlantic,' in 1981. FAO also publishes a fisheries synopsis series which includes such titles as *Sharks of the World* (1984), *Scombrids of the World* (1983), and *Billfishes of the World* (1985).

A three-volume publication, entitled *Fishes of the North-eastern Atlantic and the Mediterranean*, was published by UNESCO from 1984 to 1987.

The regions of the Atlantic Ocean treated by these FAO and UNESCO publications may seem far removed from Canada but many fishes occurring in Canadian waters also occur in the areas of the Atlantic Ocean covered by these texts; hence they are useful sources of additional information. The section 'Oceanography of the Region,' included below, discusses some of the factors involved in the changing distribution patterns of fishes.

Much still remains to be known about fishes in waters of the Canadian Atlantic area. Anyone who has additional information concerning the fishes mentioned in this book, or knows of the occurrence of fishes in parts of the region other than those stated, or has caught an unfamiliar fish and wishes to have it identified, is urged to communicate with the authors.

Acknowledgments

Preparations for the present volume were begun while we were working at the Royal Ontario Museum in Toronto. The work continued after relocating at the Huntsman Marine Laboratory, St Andrews, New Brunswick. We are most appreciative of the assistance and moral support provided by the staffs of both organizations.

The Board of Trustees and the directors of the Royal Ontario Museum (W.M. Tovell, J.E. Cruise, and T.C. Young Jr.) were most supportive. The help of the staff (and former staff) and the use of the collections of the Department of Ichthyology and Herpetology have been invaluable. We are particularly indebted to E.J. Crossman, A.R. Emery, R. Winterbottom, Erling Holm, Marty Rouse, Peter Buerschaper, and Eldon Smith.

The Board of Directors and the executive directors (T.W. Moon and R.G. South) of the Huntsman Marine Laboratory – renamed the Huntsman Marine Science Centre in 1987 – have provided support in many forms for which we are most grateful. The staff always assisted cheerfully, each in his or her own unique way. We would like particularly to express our thanks to M. Brown, B. Glebe, W. Hogans, L. Johnson, D.F. Markle, K. Miller, G. Pohle, I. Pohle, F. Purton, R. Small, Marilyn Stuart, K.J. Sulak, L. Van Guelpen, and the late Carroll Wright. Special thanks must be extended to those who typed the manuscript, particularly to Janet Stewart, who also helped with collation of references; and to Brenda Fullerton, Cindy Mitchell, and Debra Ann Foulkes. We owe much to Marlene Wilbur, who not only typed tirelessly on the manuscript but was constantly cooperative and cheerfully helpful in many ways.

Completion of this volume would have been impossible without the willing help and cooperation of a great many people. We are especially grateful to the director and staff of the Biological Station, Department of Fisheries and Oceans at St Andrews, which has served as a focal point for the project, particularly in the early years, and has provided many essential services in recent years. We are most appreciative also of the cooperation provided by the staffs of the biological stations at St John's, Nfld; St Anne de Bellevue, Que; the Marine Fish Division and the Marine Ecological Laboratory at the Bedford Institute of oceanography, Dartmouth, NS; and more recently the Gulf Region Laboratory at Moncton, NB. Thanks also to the many fisheries officers of the Department of Fisheries and Oceans who willingly supplied information.

We would also like to express most sincere thanks to the staff at the Communications Directorate, Information and Publications Branch, Department of Fisheries and Oceans, especially J. Watson, J.M. Reinhart, J. Camp, and G. Neville, for constant and cheerful help.

Publications of this scope rely heavily on the assistance of librarians. For their cheerful and untiring service we extend sincere thanks to Darlene Warren, Joyce Taylor, and Joanne Cleghorn, St Andrews Biological Station library; to Betty Sutherland, Bedford Institute of Oceanography library; and to Julia Matthews and Pat Trunks of the Royal Ontario Museum library. We are grateful also for the help of the late Ruth Garnett.

We extend special thanks to John Gilhen of the Nova Scotia Museum, whose constant help and thoughtful assistance in providing information on Nova Scotia fishes have been invaluable. Don E. McAllister, National Museum of Natural Sciences, National Museums of Canada, Ottawa, generously made available unpublished data and made the collection accessible to us, for which we are grateful.

The staff of the International Observer Program is deserving of special mention. Constant and enthusiastic interest in the fishes caught by domestic and foreign vessels fishing in Canadian Atlantic waters provided records and information on fishes that would not have been reported otherwise.

The following individuals have given valuable assistance by providing specimens or information, by reviewing manuscripts, or by discussion of fishery problems; to all we extend sincere thanks: K. Able, D.B. Atkinson, R. Bowering, J.C. Carscadden, W.M. Carter, J.H. Caruso, Brian Coad, Larry W. Coady, D. Clay, R.H. Cook, the late Alberte Courtmanche, Simon Courtenay, M.J. Dadswell, L.R. Day, J.C. Delbeek, W.R. Driedzic, K. Frank,

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The illustrations are from numerous sources. Many drawings were prepared originally by D.R. Harriott for *Fishes of the Atlantic Coast of Canada*, Fisheries Research Board of Canada Bulletin 155 (1966). Many additional drawings were prepared by Peter Buerschaper, Paul Geraghty, and Peter McWhirter. The painting of the Atlantic whitefish, *Coregonus huntsmani*, was prepared by Michael Dumas; the drawing of the basking shark carcass by Allan C. Fleming. We are grateful to the International Pacific Tuna Commission, La Jolla, California, for the use of the painting of the swordfish, executed by George Mattson. Aleta Karstad prepared the illustrations of the radiated shanny and the winter flounder and has our sincere thanks.

Finally, we are most grateful to P.W.G. (Bill) McMullon and Frank Cunningham of the Photographic Section, Biological Station, DFO, St Andrews, for their skillful use of photographic techniques. They took most of the black and white photographs, prepared the map on page xxviii, and were always helpful with advice and guidance. Some excellent photographs were also taken by R.E. Merrick of the Nova Scotia Museum and made available to us by John Gilhen of the Nova Scotia Museum. The color photograph of capelin, *Mallotus villosus*, on a Newfoundland shore was provided by K. Frank and W.C. Leggett. The color photographs of the Atlantic salmon and monkfish were taken by Gilbert van Ryckevorsel.

C.R. Mann, Institute of Ocean Sciences, Sidney, BC, contributed the section on 'Oceanography of the Region'; and R.G. Halliday, Marine Fish Division, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, wrote the section entitled 'Atlantic Coast Fisheries and Fisheries Research in the Last 25 Years.' We thank them for their contributions.

Our thanks to Lorraine Ourom, University of Toronto Press, for kind and conscientious editorial service. Detailed credits for all illustrations are listed at the back of the book.

It is possible that we have overlooked individuals who provided assistance in the early stages of manuscript preparation. We offer apologies and trust they will understand and forgive.

Atlantic Coast Fisheries and Fisheries Research in the Last 25 Years

Fisheries off the Atlantic coast of Canada, and indeed throughout the world, have been subject to radical changes in the last 25 years, perhaps greater than in any similar time-period in the past. Major technological advances (the most important of which actually occurred in the 1950s with development of the factory-freezer stern trawler), expansion of distant-water fleets to massive tonnages in the 1960s especially by eastern European countries, experiments with international fisheries management, and extension of national fisheries jurisdictions to 200 miles almost worldwide in the 1970s brought rapid and continuous change to the nature of fisheries and the regulatory framework within which they were conducted. These developments, and the expanded scientific research activities which accompanied them, have generated much in the way of new knowledge and new perceptions of the nature of fishery resources off Canada's Atlantic coast. The previous version of this book was based on knowledge accumulated to about 1960; much has happened since.

The importance of Canadian Atlantic coast fisheries. World fish catches increased most rapidly from the late 1950s, when they were about 30 million tonnes, to 1970, when they reached 70 million tonnes, but have not changed greatly since. Canada has consistently been among the more important fishing nations of the world, but the Canadian ranking, in terms of volume of catch, has declined from about 7th up to the early 1960s to about 15th from the early 1970s. Present Canadian catches of ca. 1.4 million tonnes are much lower than those of the leading fishing nations, Japan and the USSR, which catch ca. 10 million tonnes annually. These nations are, however, serving large domestic markets while Canada primarily serves foreign markets and has consistently been one of the leading fish exporting countries in the world. Indeed, since 1978, Canada has been the top fish exporter in terms of dollar value.

Most of Canada's fish catches are made off its Atlantic coast, and the Atlantic predominance has been increasing. Around 1960, about 65 percent of the 1 million tonnes caught annually originated from the Atlantic, and the figure has risen to about 85 percent of the 1.4 million tonnes caught annually in the early 1980s. In terms of market value the increase has been from 55 to 70 percent over the same period. Pacific coast catches are dominated by salmon, which has a high value per tonne compared to that of the groundfish and pelagic species predominant in Atlantic coast catches, and this explains the difference in percentage of the Canadian total accounted for by volume and by value.

Despite the important position Canada holds as a fishing nation, fisheries cannot be considered important in terms of the national economy. Fisheries have consistently (from the 1950s) contributed about 1 percent to the gross domestic product from commodity-producing industries, which currently amounts to a contribution by fisheries of a little more than 1 billion dollars. In terms of the Atlantic regional economy and employment opportunities, however, fisheries are much more important, accounting for about 15 percent of the gross domestic product in Nova Scotia, Newfoundland, and Prince Edward Island. In Atlantic Canada there are over 50 000 registered fishermen fishing from over 30 000 fishing vessels. These fishermen supply almost 300 fish-processing establishments, providing employment for about 22 000 fish-plant workers.

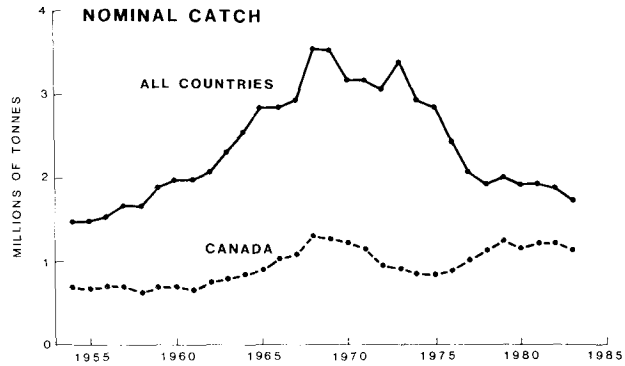

Figure 1. Catches reported from waters adjacent to Canada's Atlantic coast, Labrador to the Gulf of Maine (including some areas outside 200 miles and in the United States fishing zone), i.e. NAFO Subareas 2–5, derived from NAFO Statistical Bulletins

Northwest Atlantic catch trends. The fisheries based in Atlantic Canada are 'local' in that they are restricted to the coast and to the continental shelf adjacent to it. Canadian vessels have ranged as far as Greenland in the north and the Mid-Atlantic Bight off the United States coast in the south, but the normal range of Canadian fishing activities has been from Labrador to Georges Bank. Canadian fishermen have shared this area with fishermen from the United States and from many distant-water fishing nations. Total catches* of all countries combined increased from 1.5 million tonnes in the mid-1950s to a peak of 3.5 million tonnes in 1968–69 but then declined, particularly after 1975, so that recent catches have been slightly less than 2 million tonnes (Fig. 1). The increase in catches through the 1960s kept pace with increasing world catches and the area contributed about 5 percent to world totals. Its contribution declined from 1970 and now amounts to less than 3 percent. Canada's catches increased too, from about 700 000 tonnes around 1960 to over 1.2 million tonnes in 1968–70; and Canada shared the declining catch trends of the early 1970s (Fig. 1). The expanding Canadian fishing capacity in the 1960s did not match that of its competitors and the Canadian catch share declined from about 45 percent in 1955 to 30 percent in 1973–75. Subsequent to 1975, however, Canada

* The catches referred to are from NAFO Subareas 2–5 and hence include some catches from waters outside Canada's jurisdiction, i.e. from United States and international waters.

experienced a rapid increase in catches, contrary to the general trend, and these have stabilized at about 1.2 million tonnes (the 1968–70 level) since 1979. Proportional share increased rapidly, of course, and exceeded 60 percent from 1979.

Introduction of new technology. Until the 1950s the fishing banks off Canada's coast were exploited by local fleets from the United States and Canada and by the salt-cod fleets of France, Portugal, and Spain which had fished the Labrador–Grand Banks grounds for several centuries. Local fleets landed fresh fish on ice as well as fish preserved at sea in salt, but distances were too great for European fleets to supply home markets with fresh fish from the northwest Atlantic. The introduction of the factory-equipped freezer stern trawler in the latter part of the 1950s changed the nature of the fishery, not only in the northwest Atlantic but throughout the world. The *Fairtry*, conceived and built in the United Kingdom, was the first such vessel, and combined the concepts of stern trawling with on-board filleting machinery, freezing capability, and fish-meal reduction plant. Her maiden voyage in 1954 was to the Grand Banks, where she was soon joined by vessels of USSR and West German origin which mimicked her design features. These vessels were highly successful and, by removing the constraint placed on distant-water fishing by the limited time fish can be preserved on ice, opened the way for development of diversified high-volume fisheries in the northwest Atlantic and almost anywhere in the world's oceans, and allowed a doubling of northwest Atlantic and world catches in the 1960s.

Other technological innovations enhanced the value of the stern trawler. Synthetic twines came into widespread use in trawl construction in the late 1950s replacing manila and other natural fibres. Their additional strength allowed construction of trawls which could more readily stand the additional strains of being pulled up stern ramps rather than being pulled manually over the gunwales of side trawlers. Synthetic twines provided other benefits to the fisheries, of course, since their strength allowed nets to be constructed of finer twines, which produced less drag through the water. Thus bigger nets could be used and synthetics were easier to use and did not rot. Development of highly successful one-boat midwater trawling in the late 1960s, largely by the West Germans, rounded out the capabilities of the factory trawler by greatly increasing its efficiency to catch pelagic species such as herring, mackerel, and capelin.

Canada has tended not to be among the forerunners in fisheries development. The last of the dory schooners, the *Theresa E. Connor*, made its final trip to the Grand Banks in 1962, side trawlers having increasingly taken over the offshore fishery. Introduction of large stern trawlers, which dominate the Canadian groundfish fleet of today, did not occur in a big way until 1966–68, about 10 years after the arrival of the modern European fleet. These vessels were smaller than their European rivals, most being about 600 gross registered tons (grt), and were wet-fish vessels as were their side-trawling predecessors. They were perfectly satisfactory for most local fishing, and it was not until the 1980s that Canada acquired freezer trawlers to exploit the shrimp and cod resources off the more distant reaches of the Labrador coast. In 1986 the first factory-freezer trawler, the *Cape North*, joined the Canadian Atlantic fleet, processing at sea being considered a necessity for production of the top-quality products demanded in some markets. Canada was quicker to adopt midwater trawling technology, utilizing it effectively for redfish fishing in the early 1970s. The Canadian purse seine fleet was greatly expanded in 1965–67 to support development of a herring reduction industry. The fishery was converted to one for human food production in the mid-1970s and fleet size has been gradually decreasing in recent years. These were, and still are, highly efficient 'overnight' boats but most are not suited to offshore fishing because of their small size and lack of adequate refrigeration or freezing capacity to maintain the catch in good condition.

Expansion and diversification of fisheries. When the new distant-water fleets appeared in the late 1950s, they competed directly with existing participants in traditional fisheries for cod, redfish, haddock, and flatfish, but in addition developed new fisheries. A most significant development of the early 1960s was the expansion of small-mesh-gear fisheries, spearheaded by the USSR and concentrating in the southern part of the area, particularly on the hakes. The international fisheries regulatory body for the northwest Atlantic, the International Commission for Northwest Atlantic Fisheries (ICNAF), from its establishment in 1950 had introduced a series of bottom-trawl construction regulations, particularly regarding netting

mesh-size. These required the use of large mesh-sizes, initially 114 mm but now 130 mm, when fishing for cod, haddock, and flatfishes, to reduce wastage of small unmarketable fish caught and discarded at sea. The USSR had a use for the small-bodied hakes, particularly silver hake, and associated species which were caught with mesh-sizes of 40 mm or even less. Catches of juvenile cod, haddock, and other traditional species, taken incidentally in these large-volume small-mesh-gear fisheries, no doubt hastened the decline in their abundance already being brought about by heavy exploitation in directed large-mesh fisheries.

The USSR also pioneered development of offshore herring fisheries in the 1960s. Combined with Canadian development of large coastal herring fisheries to support a fish-meal industry, this gave herring a new importance. As groundfish catches declined from the mid-1960s, herring catches increased to reach almost 1 million tonnes in 1968–69. Thereafter, herring catches also declined but the international fleet directed its attention to other pelagic species, with emphasis first on mackerel, then capelin. This maintained catches of these pelagic species (in the whole of the northwest Atlantic) in the range of 1.0–1.2 million tonnes until 1975, after which there was a rapid collapse of catches to recent levels of little more than 200 000 tonnes. Invertebrate fisheries assumed more importance through the 1970s, squids being of primary importance in an international fishery context.

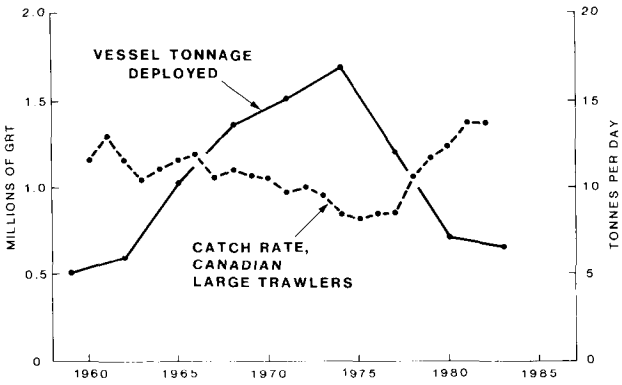

Figure 2. Gross registered tonnage (vessels greater than 50 grt) deployed in the northwest Atlantic from triannual ICNAF/NAFO lists of fishing vessels (left axis), and catch (tonnes) per day of Canadian otter trawlers greater than 150 grt in NAFO Subareas 2–4, Labrador to Scotian Shelf (right axis)

Squid catches peaked in 1979 at almost 200 000 tonnes (in all of the northwest Atlantic) and have since declined greatly.

Fishing vessel tonnage is a poor measure of effective fishing power but it can indicate general trends. About 0.5 million grt of vessel (excluding inshore vessels of less than 50 grt) were deployed in the northwest Atlantic in 1959 (Fig. 2). The tonnage increased steadily to 1.7 million grt in 1974. Separate figures are not available for the area directly off Canada's coast but the trends in fishing effort and catch were much the same. In the first phase of fishery expansion to the mid-1960s catches increased almost in proportion to expanding fishing effort, but no component of the resource could support the increasing fishing capacity for long. Despite continuing diversions to new species, total landings peaked in 1968. Fleet capacity increased a further 25 percent between then and the peak level of 1974, but total catch was gradually declining. Given the spectrum of species which could effectively be exploited, the productive capacity of the ecological system was being exceeded when catches reached 4.5 million tonnes from the northwest Atlantic as a whole and 3.5 million tonnes off the Canadian coast.

International fishery regulation. The course of events was anticipated by fisheries administrators and scientists from the early 1960s and methods for regulatory control of expanding international fishing effort in the northwest Atlantic were extensively debated by ICNAF. Collapse of the haddock stocks in the late 1960s precipitated action and ICNAF embarked on a scheme of regulatory control of catch levels which came into effect in 1970. While ICNAF had authority to propose total allowable catch (TAC) restrictions it could not allocate shares among countries participating in the fishery. This stumbling-block was removed in 1971 with an amendment to the ICNAF convention, which paved the way for widespread introduction of TAC regulation. By 1974 all species subject to directed fishing had been placed under TAC control.

Although TAC controls were intended, in most cases, to reduce exploitation rates below then current levels, and hence TACs were set lower than immediately previous catch levels, on the whole they were still set too high and did not stem declining trends in stock sizes. There was an increasingly precipitous decline in catches in the mid-1970s. Much of the damage had been done

before controls were instituted. The Canadian groundfish industry was on the verge of collapse and required large-scale financial assistance from the government. Whether cooperative international management efforts would have been generally successful in rehabilitating the fisheries will not be known as other events overtook ICNAF efforts. ICNAF certainly developed the philosophical and practical basis for fisheries regulation which was subsequently used with some success by Canada.

During ICNAF's most active management phase in the first half of the 1970s, the Third United Nations Conference on the Law of the Sea was developing a consensus on the rights of coastal states to renewable resources off their shores. Discussions had reached such a stage by 1976 that Canada was in a position to declare a 200-mile fisheries zone effective 1 January 1977. This placed most of the fishery on banks off the Canadian coast within national jurisdiction. (Canada had already declared Bay of Fundy and Gulf of St Lawrence waters to be exclusive fishing zones in March 1971.) Canada had argued at the Law of the Sea Conference for coastal-state jurisdiction to the edge of the continental shelf but this position did not receive general support. As a result the southern and eastern parts of the Grand Bank, as well as the Flemish Cap, lie outside Canada's jurisdiction. This was a primary reason for continuation of arrangements for international fisheries management in the northwest Atlantic. It is much in Canada's interest to have effective control of fishing in areas adjacent to its waters, as fish on either side of its 200-mile boundary belong to the same stocks, and actions outside affect fishing success inside the boundary. A new international convention came into effect in 1979, creating the Northwest Atlantic Fisheries Organization (NAFO), tailored to the new era of 200-mile jurisdictions, to replace ICNAF. Transition of responsibilities took place during 1979 with the ICNAF convention being terminated at the end of the year and NAFO taking its full responsibilities on 1 January 1980.

Canadian fishery regulation. Canada's approach to fisheries management from 1977 did not differ greatly from that used by ICNAF. A new strategy of fishing at a lower exploitation rate than that which gave maximum sustainable yield came into effect in 1977. Although this had been agreed to the year before in ICNAF, it had been at Canadian instigation. The biggest change lay in the increased effectiveness of controls on fishing activities, however. Foreign-vessel licensing and surveillance activities by Canada replaced flag-state controls which in some cases had left considerable room for improvement. From 1978, total catches stabilized at just under 2 million tonnes (Fig. 1). Canadian catches, which began to increase from 1976, just prior to extended jurisdiction, increased rapidly in 1977–79 and leveled off thereafter at 1.2 million tonnes, close to the peak level of 1968. In part, Canadian fishery resurgence resulted from Canada's new status; almost all resources which could be utilized by Canada were reserved for that purpose. The consensus of the Third Law of the Sea Conference was that only fish surplus to coastal-state requirements need be allocated to other countries. In contrast, national catch allocations in the ICNAF context had been based on formulas giving much weight to historical catch levels. The rapid increase in the Canadian fishery was fueled, however, by a recovery of traditional groundfish species, particularly cod and to a lesser extent haddock, to levels approximating those of the early 1960s. An integrated view is provided by fishing success of the Canadian groundfish trawler fleet. In the early 1960s catch rates of these vessels were about 12 tonnes per day fished (Fig. 2). By 1975 the rate had declined to 8 tonnes per day, precipitating, along with rapidly increasing fuel costs, the groundfish industry crisis of 1974–75. By 1980 daily catch rates were again exceeding 12 tonnes. Certainly this fleet is composed of, on average, larger and more powerful vessels now than in 1960, but it is also fishing under many more regulatory controls, which reduce effectiveness when measured in tonnes caught. More emphasis is now placed on fish quality and species marketability.

The year-classes of cod and haddock being fished in 1977 and the years immediately following were spawned in the early to mid 1970s. They proved to be of greater abundance by the time they entered the commercial fishery than had their immediate predecessors. Whether this was a result of management actions by ICNAF or Canada, or of a naturally occurring change in the marine environment which allowed better survival during early life-history stages, has not been determined. Regardless of the reasons, after extension of jurisdiction the groundfish sector of the Canadian fishery did benefit quickly from a greatly increased supply of readily available resources. The economic problems which befell the industry in the early 1980s, which again

required large-scale government financial intervention, were not related to supply.

Pelagic fish resources and the related fisheries have fared differently. There was no resource recovery in the latter half of the 1970s and, for herring and mackerel, the abundance declines which began in the late 1960s have continued through the early 1980s. Capelin stocks, however, have shown clear signs of recovery beginning about 1980. Canadian fishery interest has been primarily in the herring. Declining herring stocks in the early 1970s precipitated the institution of TAC regulations, first introduced for the major stocks in the Gulf of Maine–Bay of Fundy area for 1972. Resultant low catch volumes could not support a viable fishery for reduction purposes. Low prices paid required a high volume of catch and, with the number of purse seine units increasing even after catches had peaked, crisis rapidly followed. Major government intervention in the mid-1970s converted the herring fishery from meal to human food production, which increased the value of herring caught and thus improved the economics of fishing. Good European markets for Canadian products as a result of collapse of northeast Atlantic herring stocks further aided rehabilitation of the Canadian fishery. Continuing resource decline (and recent resurgence of northeast Atlantic herring stocks) has, however, undermined the initiatives of the late 1970s and the Canadian herring industry is again in troubled times.

Invertebrate fisheries have been included in the above statistics on northwest Atlantic fisheries but most have been conducted solely by coastal states, largely within territorial seas, and hence have been little affected, at least in a direct way, by the major international developments affecting finfish fisheries. Notable exceptions are the offshore resources of sea scallop and lobster in the Georges Bank area, which, nonetheless, are fished only by coastal states. In the new Canadian zone squid was the only species which had been subject to the international trawl fisheries. Expansion of squid fisheries, both by Canadians in coastal Newfoundland waters and by foreign fleets along the edge of the Scotian Shelf, peaked in 1979 with catches of 162 000 tonnes from these areas but catches declined to only a few hundred tonnes by 1983. Similar abundance cycles have been observed in historical Newfoundland coastal fisheries, and the present low squid abundance is viewed as a natural, rather than a fishery-induced, event.

Large pelagic species – a special case. The large oceanic fish species are subject to specialized fisheries with a separate history from that for shelf seas fisheries. In a Canadian context the most important species are swordfish and bluefin tuna, which are summer visitors to Canadian waters and while there are subject to domestic fisheries. Swordfish fishing in the northwest Atlantic was conducted from the turn of the century by Canadian and United States fishermen using harpoons, often as an adjunct to other fisheries, but was revolutionized by the introduction of directed longline fishing in 1962–63. Initiation of the Japanese oceanic tuna longline fisheries in the northwest Atlantic in 1961–62 took swordfish as a by-catch, and in total the resource was being fully exploited. Existing mercury-content regulations for foodstuffs in the United States and Canada were applied to swordfish in 1971, preventing sale of most swordfish and bringing an abrupt end to a lucrative fishery. The cessation was short-lived as ways around the regulations were soon found, and revision of mercury regulations in 1978–79 opened up additional fishing opportunities. Canadian domination of the fishery which existed from 1940 to 1971 has not been regained, however.

Until 1960, Canadian bluefin tuna catches were restricted to the sports fishery and incidental trap catches of large fish in coastal waters. In the early 1960s Canadian purse seiners participated in the fishery for juvenile bluefin in New York Bight, until then prosecuted solely by the United States purse seine fleet. The biggest fishery expansion resulted from catches made by the United States fleet, however, and from oceanic longline catches of medium-sized fish by Japan. Total Atlantic catches peaked in 1964. The International Commission for the Conservation of Atlantic Tunas (ICCAT) was established in 1969 to deal with management of tunas (and 'tuna-like fishes,' which includes swordfish). Regulations controlling exploitation of bluefin tuna were first applied in 1975 and northwest Atlantic catches have been limited to well below historical levels from 1982. Fishing directed at the spawning stock in the Gulf of Mexico has been banned. These measures are only now resulting in observable improvement in stock status, and it will be some years before this benefits Canadian fisheries, the success of which depends on the abundance of large fish, older than about 14 years.

Jurisdictional boundary issues. Extensions of

fisheries jurisdictions by coastal states in the northwest Atlantic raised a number of boundary questions, as some areas were claimed by more than one party. Canada and Denmark had agreed on a continental shelf boundary between Greenland and Canada in 1973 and there was no dispute that the fisheries zone boundary should coincide with that for the continental shelf.

The intention of the United States and Canadian governments at the time of extension of fisheries jurisdictions was to negotiate a comprehensive maritime resource and boundary settlement in the Gulf of Maine area. An interim agreement on fisheries maintained the regulatory status quo in 1977 while negotiations proceeded. Negotiations continued into 1979 but did not resolve the question of boundary location. Two interrelated agreements were reached, one submitting delimitation of the maritime boundary in the Gulf of Maine area to binding dispute settlement and the other an Agreement on East Coast Fishery Resources, the agreements to come into force simultaneously. The latter provided a framework for management of fisheries in the area of interest to fishermen of the two countries. The fisheries agreement met strong opposition from United States fishing interests, and in 1981 the president indicated that it would not be ratified by the United States. The maritime boundary question was then separated from fisheries considerations and a treaty was concluded towards the end of 1981 which referred the matter to binding settlement by a chamber of the International Court of Justice. The chamber rendered its decision in October 1984, placing the boundary through the deeper parts of the Gulf of Maine Basin and across Georges Bank, thus putting the northeastern sector of Georges Bank in Canadian waters.

In the seven years from expiry of the 1977 interim agreement until the chamber's decision, the United States and Canada applied their own fishery regulatory controls on their nationals fishing the disputed area on Georges Bank but these were not necessarily consistent with each other or with conservation requirements. The boundary decision created a new situation which allows unilateral resolution of some aspects of conservation problems but there are transboundary resources that still require coordinated efforts by the United States and Canada if conservation and rational management are to occur. This problem remains to be resolved.

The fisheries zone boundaries between Canada and the French islands of St Pierre and Miquelon remain an outstanding issue. After extensions of jurisdiction in 1977 a continuation of orderly fishing by both countries in the vicinity of these islands was aided by various ad hoc arrangements, while negotiations on long-term solutions proceeded. This has not necessarily meant that both parties have been pursuing the same objectives through their regulatory controls, however, and as in the Gulf of Maine area the situation limits the extent to which conservation problems can be addressed effectively.

FISHERIES RESEARCH

Canadian fisheries research institutions. In Canada, fisheries lie within federal jurisdiction, and it is the federal government which has been responsible for most of the fisheries research conducted in Atlantic Canada. The organization of fundamental importance in shaping the history of research on fish and fisheries has been the Fisheries Research Board of Canada (FRB). Established by act of Parliament in 1937, the FRB inherited from its predecessors a biological research facility on the Atlantic coast at St Andrews, NB, originally established in 1908. With Newfoundland's entry into confederation with Canada in 1949, its government laboratory, which had been responsible for fisheries research in Newfoundland in one form or another from 1931, was taken over by the FRB. These two laboratories have provided focal points for research on Atlantic marine fish and fisheries.

In the early 1960s, establishment of the Bedford Institute of Oceanography in Dartmouth, NS, provided for a major expansion in marine science on the Atlantic coast and a new FRB laboratory, housed in the facility, provided a new emphasis on general marine ecology, including the ecology of marine fishes. This was part of a general broadening of FRB programs, which included a strong emphasis on man-made environmental problems. As a result, research related specifically to fisheries, which had preoccupied the board in the 1950s, was not receiving very much more support from the federal government in the mid-1970s than it had in 1960, despite the rise and fall of the international northwest Atlantic fishery.

Universities took an increasing interest in marine science during the period from 1960. Particularly noteworthy, in the present context, was the creation of the Huntsman Marine Laboratory (HML) at St Andrews in 1969. Run by a board of

directors on behalf of a consortium of central and eastern Canadian and American universities and government agencies, the laboratory promotes teaching and research in marine sciences. In the late 1970s, federal contracting for ichthyological identification services from the laboratory allowed it to support a small, but full-time, staff with systematic expertise which was much needed within the Atlantic region. This initiative has recently developed into creation of an Atlantic Reference Centre run by HML, with federal government financial support. The centre, which has taken over historical reference collections previously supported by the St Andrews Biological Station, provides a reference service and a focus for research on the systematics of marine organisms. The province of Quebec has, from time to time, supported research on marine species as a result of the unique situation where some federal responsibilities for marine fisheries were delegated to it. In general, however, the provinces have not engaged in marine fisheries research.

In 1973, the FRB was divested of its responsibilities for its research stations, becoming an advisory body to the minister of fisheries, and its stations were amalgamated into the then Fisheries and Marine Service of the Department of the Environment. There was little immediate impact on the stations, but the way was paved for a radical organizational change in 1975–76, which resulted in regional administration of federal fisheries research. In 1976 there were two research branches associated with two organizational regions for Atlantic fisheries. With increasing decentralization, these have evolved to four, with headquarters in Quebec City, PQ; Moncton, NB; Halifax, NS; and St John's, Newfoundland.

The following account of trends in research programs, and of the availability of biologists and research vessels to conduct them, is restricted to include only marine fishes and the related fisheries. There has been, of course, a substantial amount of research on anadromous species, invertebrates, and marine mammals, the history of which is different from that for marine fishes, but that is outside the scope of this book.

Canadian research facilities and programs. Federal research staff directing their attention to fisheries, as already mentioned, did not change greatly between 1960 and 1975. Extension of fisheries jurisdiction, and the expanded Canadian responsibilities for research that it implied, were recognized, however, by a substantial increase in manpower and monies directed towards marine fisheries research.

Acquisition of information and new knowledge in fisheries biology depends on an ability to make observations at sea. Biologists have traditionally used fishermen extensively as proxies in this regard. Fishing logbook systems which record the location and amount of fishing, and species and quantities caught, have long served as a fundamental aspect of data collection programs. Fishermen are one of the best sources of information, particularly when it comes to unusual events and catches of unusual specimens. The use of the commercial fleet as a source of scientific data and as a research platform was greatly extended, starting in 1977, with the introduction of observer programs. Established as a scheme to place observers on foreign vessels in the new Canadian zone, as a way both to ensure compliance with regulations and to collect biological and fisheries data, the program expanded to include domestic fleets in 1980. A purely scientific observer scheme was subsequently adopted by NAFO for the area outside 200 miles. In the 1980s, observer coverage has been in the order of 10 000 sea days per year, giving coverage of 50–75 percent of foreign-vessel days in the Canadian zone and of 10–20 percent of sea days of domestic trawlers over 100 feet in length. Coverage of foreign fishing outside 200 miles has been nominal.

Commercial vessel observers, in addition to their deterrence effect, provide much more detailed observations on fishing operations than could be expected in captain's logbooks, allowing analysis of fisheries data for stock assessment purposes on finer spatial and temporal scales. Data on by-catches and discard practices are particularly difficult to obtain from other sources, and observers provide a greatly improved sampling of the catch for biological characteristics such as size and age compositions.

Many of the observations a biologist needs to make at sea cannot, nonetheless, be made from commercial fishing vessels. Vessels dedicated to research, and equipped with specialized gear and instrumentation, are required. Of the variety of vessels operated by the FRB Atlantic coast stations prior to 1958 the largest were the *Harengus* (25.6 m, 84 ft) based in Halifax and the *Investigator II* (25.0 m, 82 ft) based in St John's. Rigged as side trawlers,

these vessels were operated offshore at times, but their lack of facilities and seaworthiness was a severe limitation. The *A.T. Cameron*, a 53.9-m (177-ft) steel side trawler designed for research purposes and commissioned in 1958, was the first truly offshore Canadian Atlantic coast fisheries research vessel. The 39.6-m (130-ft) steel stern trawler *E.E. Prince* was added to the fleet in 1966. The *Investigator II* was laid up in 1970 because of financial constraints and never reactivated. The *Harengus* was decommissioned in 1976 after 30 years of service. Given the size of the fishing areas off the Atlantic coast and the importance of the fishery resources, Canada's offshore fisheries research capability has to be considered inadequate until the late 1970s.

Expansion of research as a result of extension of jurisdiction included expansion of the research vessel fleet. Long-term charters were immediately arranged for two fishing vessels which were converted for research purposes. The 80.2-m (263-ft) *Gadus Atlantica* came on charter in late 1977 and the 53.3-m (175-ft) *Lady Hammond* in early 1978. A building program was also initiated which resulted in the commissioning of two new research trawlers, sister ships of 50.3 m (165 ft), the *Wilfred Templeman* and the *Alfred Needler*, in 1982. The *A.T. Cameron* was decommissioned in the same year after 25 years of excellent service. Thus, there was an approximate doubling of offshore research capability subsequent to 1977 and a further increase in 1982, the present offshore fleet consisting of five stern trawlers in the range 39.6–80.2 m (130–263 ft).

With acquisition of an offshore research capability in the late 1950s, emphasis was placed on description of the distribution and biological parameters (e.g. growth, maturation cycle) of groundfishes. In the early 1970s, emphasis was placed on obtaining fishery-independent estimates of abundance of fishable stocks, and on estimation of recruiting year-class strengths, primarily for stock-assessment purposes. It had been common practice to depend on fishing success of the commercial fleet (expressed in terms such as catch per day fished) to provide an indicator of fish-stock abundance. The imposition of regulatory controls modified fishing patterns, however, and catch rates did not necessarily reflect fish abundance in the same way as they had before. Anticipating (correctly) that research vessel abundance estimates would become critically important, ICNAF initiated a standardized international bottom-trawl survey program in the early 1970s which was intended to cover all of the fishing grounds in the northwest Atlantic. Expansion of the research fleet in the late 1970s allowed greatly expanded coverage under this program on both a geographic and a seasonal basis.

The first major field study addressing the factors causing variability in year-class strength in fish stocks was initiated when the *E.E. Prince* became available in 1966. It involved seasonal sampling of planktonic egg and larval stages in the southern Gulf of St Lawrence over a 10-year period. This served as a pilot study for a more intensive 5-year ichthyoplankton research program initiated on the Scotian Shelf as part of the expansion of research after extension of jurisdiction. A similar program was initiated on an international cooperative basis on the Flemish Cap, and there has been more recent work on a small scale on the Grand Bank. Almost nothing was known of the biology and ecology of the early life-history stages of offshore fishes in Canadian waters prior to these initiatives.

The third major area of expanded research activity resulting from the extended jurisdiction program involved a return to basic biological studies. These had been largely neglected in the preceding 10-year period when all efforts concentrated on fish-stock assessment as a basis for solving the serious management problems of the 1970s. Primary topics are the ecology of juveniles, filling in the gaps in knowledge between planktonic and adult stages; definition of stock structure and migration patterns; and trophic relationships, laying the basis for consideration of ecological interactions in fisheries management practice.

In summary, acquisition of an offshore research capability in the late 1950s, augmented in the mid-1960s, gave a substantial improvement to Canada's fisheries research capacity. This improvement happened about the beginning of the period under review. Research emphasis was increasingly on population dynamics, analysis of the effect of fishing, and prediction of catch levels, in support of massive international efforts to control exploitation, but research resources did not change greatly for much of the review period. In response to extension of fisheries jurisdiction and the increased managerial responsibilities that implied, Canada substantially increased its fisheries research capability after 1977. In terms of professional research staff and data-collection capabilities at sea, the increase approximates a tripling of previous levels.