Arctic Biological Station

REVIEW

1980-1985

Fisheries and Oceans
Pêches et Océans

Canada

In Septembre 1986, changes in departmental organization resulted in the Arctic Biological Station now reporting directly to the newly opened Maurice Lamontagne Institute of the Department of Fisheries and Oceans at Mont-Joli, Québec. In keeping with the research mandate of MLI, ABS, with a new orientation, will now intensify research in northern Québec and will be increasingly involved in oceanographic research in the Gulf of St. Lawrence.

This review of activities at ABS covers the period from 1980 to 1985. Copies of the review can be obtained from:

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An inuksuk points the way. These man-like structures were built by Inuit in years past as beacons to guide travellers across the arctic tundra.

INTRODUCTION

This comprehensive review of recent Arctic Biological Station (ABS)activities describes for the general public and our scientific and business clientele some of the arctic and marine mammal research being undertaken by the Department of Fisheries and Oceans (DFO). Although detailed reports of research activities are prepared as part of an annual Review and Planning Process, they are not widely circulated and are not in a form suitable for public dissemination. To fill a general need for such information, we have prepared this review which we hope will serve as an informative introduction to the wide variety of research being carried out by us at ABS.

The Arctic Biological Station originated as the "Eastern Arctic Investigations" set up by Dr. M.J. Dunbar at McGill University in 1947. With financial support provided by the Fisheries Research Board of Canada, and the service of the research vessel *Calanus,* Dunbar and his small group of research students set out to study the physical and biological oceanography of Ungava Bay and other waters of the eastern Canadian Arctic and to search for marine resources that could be developed for the benefit of the Inuit. In 1955 this McGill organization came under the direct management of the Fisheries Research Board (FRB) and was renamed the Arctic Unit. It was provided with a full-time director and several permanent scientific staff positions, and its mandate was expanded to cover the marine and freshwater resources of the entire Northwest Territories. Responsibility was also undertaken for investigation of the marine mammal resources of eastern Canada, especially the heavily exploited harp seal herds.

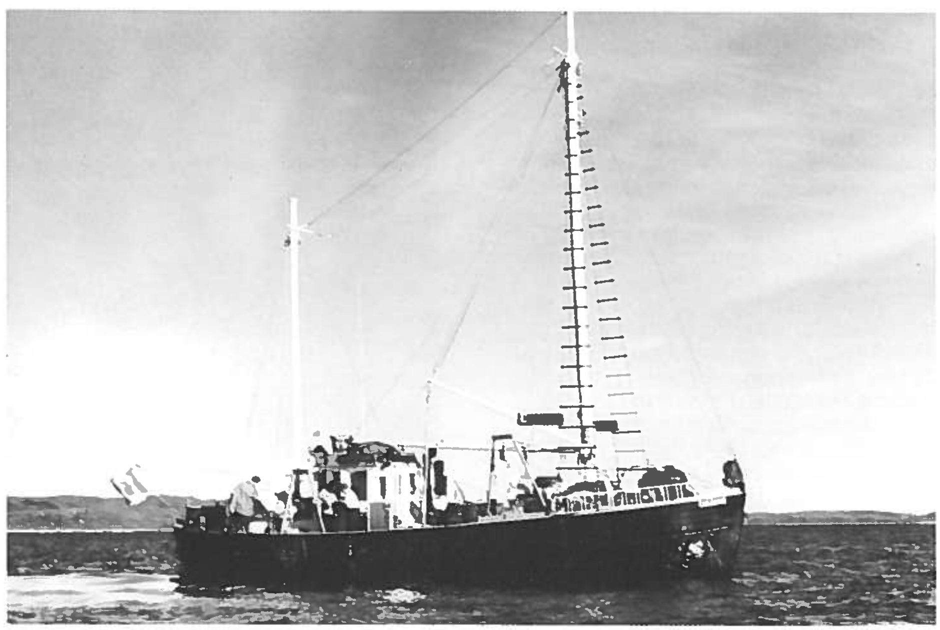
In 1963 FRB was notified that the lease on the McGill property housing the Arctic Unit would lapse in 1965. In choosing a new location the Board recognized that Montréal is the major gateway to the eastern Canadian Arctic and that there were advantages to remaining within or near the city. When it was found that government-owned land was available at Ste-Anne-de-Bellevue, it was decided to erect a new building there. In 1965 the Arctic Unit moved to its present site and changed its name to the Arctic Biological Station.

In 1967 responsibility for research on arctic freshwater fishes was transferred to the Freshwater Institute, Winnipeg, leaving ABS responsible primarily for marine biological research in the Arctic and for research on marine mammals of the East Coast. The latter responsibility was broadened in the same year to include the marine mammals of the West Coast.

In spite of the vast geographic area involved, entailing difficult and costly logistics, full-time scientific staff has never exceeded ten. During the 1950s and 1960s, most effort was spent on wide-scale surveys and life history studies of the more important fish and marine mammal species, and on the distribution and abundance of the major species of plankton and benthos.

After 1970, an increasing number of studies involved environmental impact assessment related to hydroelectric and non-renewable resource developments, particularly offshore drilling for oil and gas. This occupied much of the time and effort of the scientific and technical staff, and many continuing programs were temporarily shelved. However,during this period it became possible to expand and to develop a more experimental approach to envi-

Dr. M.J. Dunbar of McGill University established the "Eastern Arctic Investigations" in 1947. This eventually evolved into the Arctic Biological Station.



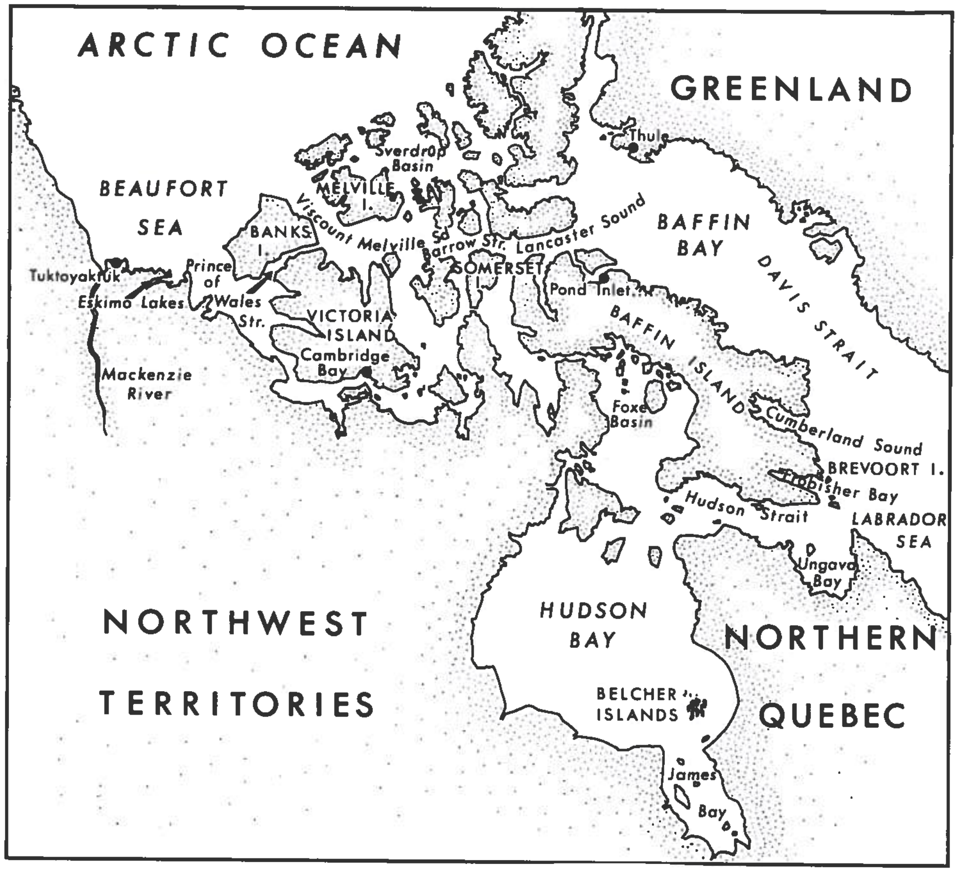
M.V. Calanus, a veteran of over three decades of arctic marine research.

ronmental problems, especially in the fields of microbiology and invertebrate physiology. This broadened the scope of the Station's activities considerably.

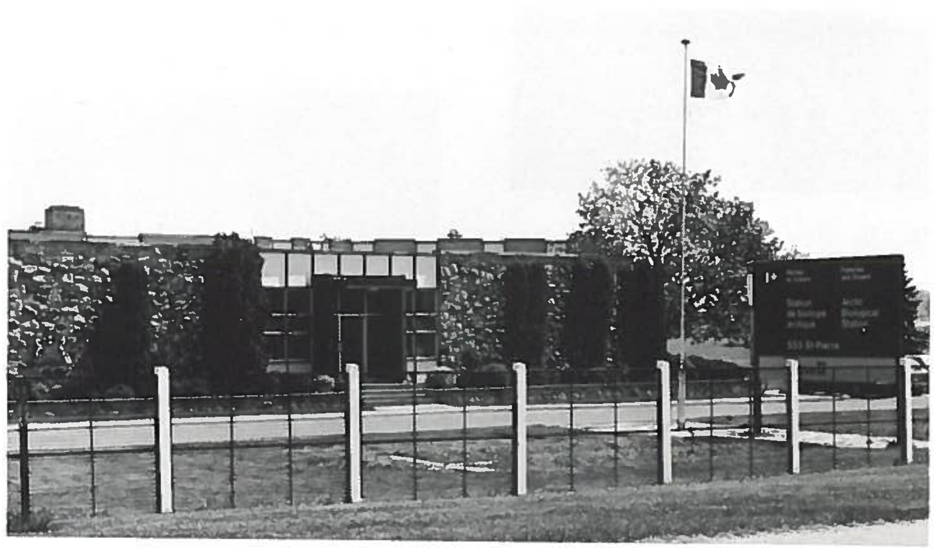
A major change in organization in 1972 saw FRB absorbed into the Fisheries and Marine Service of the Department of the Environment. When the Fisheries and Marine Service reorganized its regional structure in 1977, ABS became part of the new Québec Region, losing responsibility for research on marine mammals on both the west and east coasts, but still retaining a major interest in the Arctic and in the marine mammals of the Gulf of St. Lawrence. In 1979, the Fisheries and Marine Service separated from the Department of the Environment to become the present Department of Fisheries and Oceans.

Additional changes in responsibilities of ABS have resulted from the increasing role of the Western Region, headquartered in Winnipeg, in managing marine mammals in the Northwest Territories. By mutual agreement between the Western and Québec regions in late 1981, management responsibility for the coastal fisheries of Northern Québec, technically a Western Region responsibility, was ceded to the Québec Region. The ABS now acts as the northern research arm of Fisheries Management in the Québec Region. It also has a firm commitment to carry out research on marine mammals, coastal and estuarine fishes and biological oceanography in Northern Québec as well as to continue its studies on the arctic marine ecosystem for which it has particular expertise. These studies include a biological oceanography program, presently being carried out in southern Baffin Island, and the study of several species of seals and whales in the high Arctic. The Station also retains its mandate for the study of seals and whales in the Gulf of St. Lawrence.

In November 1984 DFO announced that as part of an expenditure reduction program, ABS would close on 1 April 1985. Scientific programs and associated staff were to be transferred to other departmental establishments. However, after considering advice from many sources and after carefully reviewing the situation, the Minister of Fisheries announced in February 1985 that the Station would remain open. The Minister stated that the principal reason underlying his decision to retain ABS was the need to maintain a clearly visible commitment to marine science research in the Department's arctic jurisdiction. "Although other DFO laboratories have significant arctic responsibilities," the Minister said, "this is the only laboratory largely dedicated to arctic marine science issues."



The Arctic Biological Station has been active in marine research throughout the Canadian Arctic.



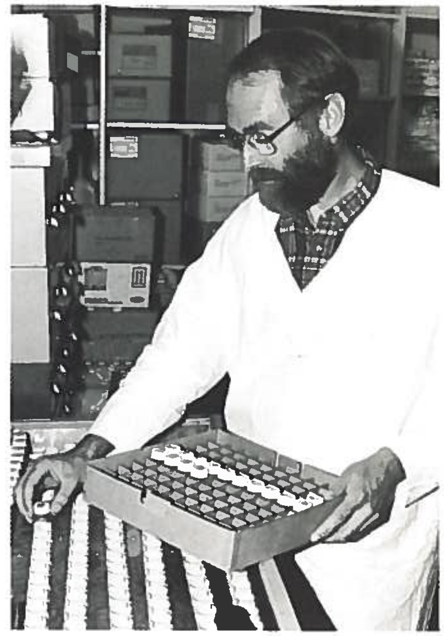
The headquarters of the Arctic Biological Station is located in Ste-Anne-de-Bellevue, Québec.

THE ARCTIC BIOLOGICAL STATION AND ITS FACILITIES

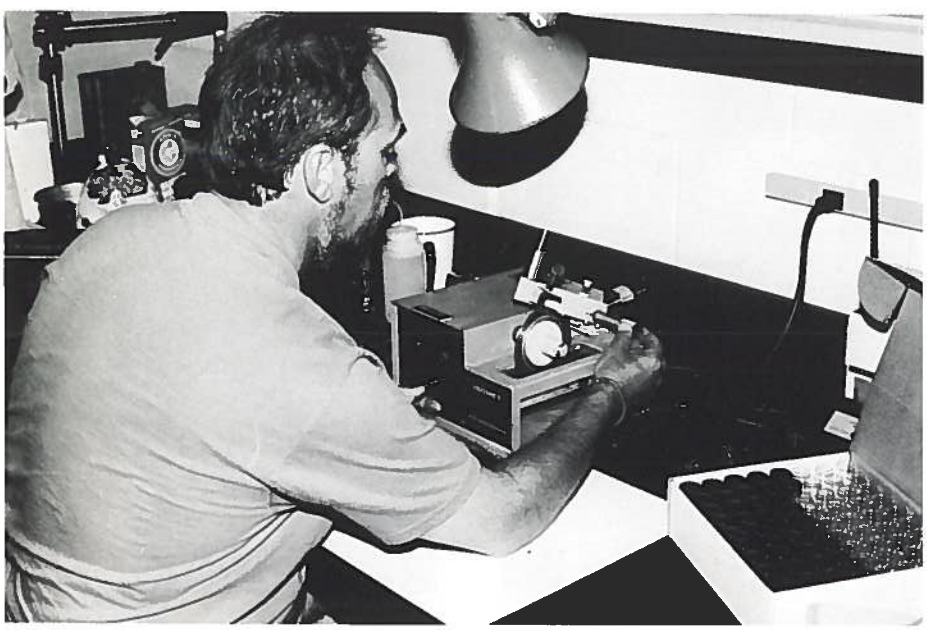
The Arctic Biological Station is well-located at Ste-Anne-de-Bellevue to take advantage of Montréal as the centre for air transportation to the eastern Arctic. Jet aircraft have dramatically improved the speed and regularity of service and it is now possible to bring living animals to the laboratory in good condition.

Only one small laboratory was present in the original building. However, increasing demands for information on the physiological responses of arctic marine plants and animals to changes in the environment, both natural and man-made, necessitated the construction of more suitable laboratory facilities. The substantial funding that became available in the early 1970s to carry out environmental impact studies, made it possible to set up several laboratories for experimental work on marine bacteria, phytoplankton, and various species of invertebrate macrozooplankton as well as two temperature-controlled rooms, one of which contains a 4000-litre circulating sea water system. Space restrictions have meant that experimental work on fish, other than larval forms, has not been possible.

Vidar Neuhof checking shrimp in circulating sea water tanks in ecophysiology cold room.



Ross Harland loads a scintillation counter with samples obtained during studies on arctic marine bacteria.

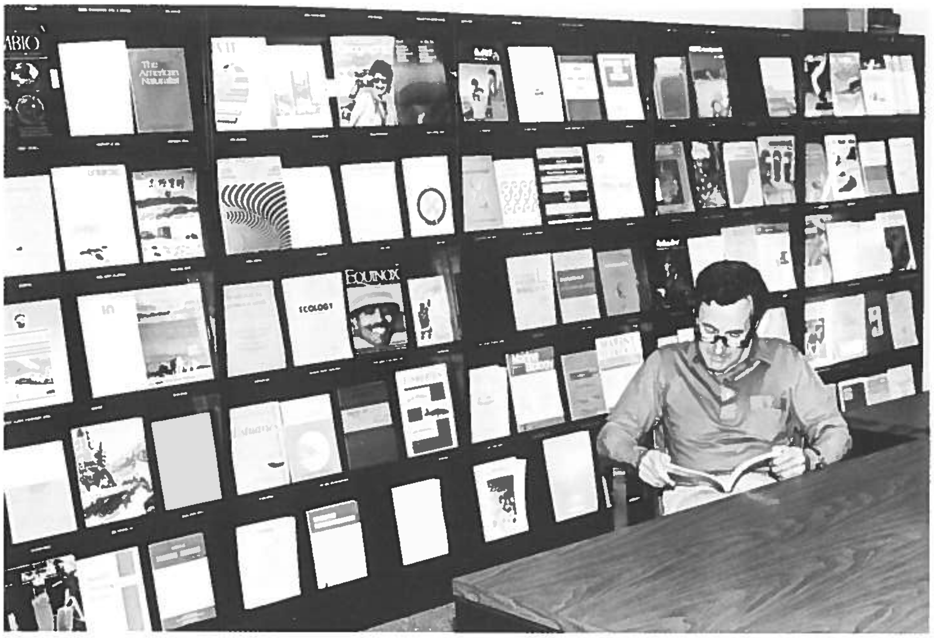


Wyb Hoek sections a seal's tooth in order to determine the animal's age.

While a great deal of information is obtained from experiments in the field, much biological material collected there is preserved. Processing of fish and marine mammals is carried out in two "wet" laboratories, while smaller organisms, such as plankton can be worked on in the individual scientist's and technician's rooms. Several precision tooth-cutting machines provide sections of teeth and other calcified tissues for determining the age of individual animals.

A second building houses a workshop, a generator to supply emergency power to laboratories and essential equipment, and a marine mammal processing room. In addition, the building provides space for the preparation and storage of the large amounts of field equipment and supplies necessary to conduct field programs in remote areas.

Other facilities available at the Station include a drafting room, a photographic darkroom, a small conference room and a library. Information systems are of fundamental importance to good research. To meet this need



A small specialized library helps scientists such as Ted Grainger keep up to date in their field.

ABS has a small but excellent collection of books on marine biology, with special emphasis on the polar regions and marine mammals. In addition, about 85 pertinent scientific periodicals are regularly received, and bound back-issues of most of these are available. The library receives many governmental and non-governmental reports pertaining to marine science, marine mammals, fisheries and the Arctic. In recent years an increasing number of documents has been acquired in microfiche or microfilm format. A reader-printer is available to read and copy this material.

Although the library is principally used by the Station's research staff, it also serves as a valued resource for students at local colleges and universities, as well as for members of the general public with fisheries-related questions or interests. Interlibrary loan requests have also been increasing steadily in recent years.

The scientific literature and a great deal of other pertinent information is indexed on computerized data bases maintained by government agencies and private companies. A computer

Librarian June Currie is well equipped to carry out computerized literature searches and obtain needed books and articles through her electronic network.

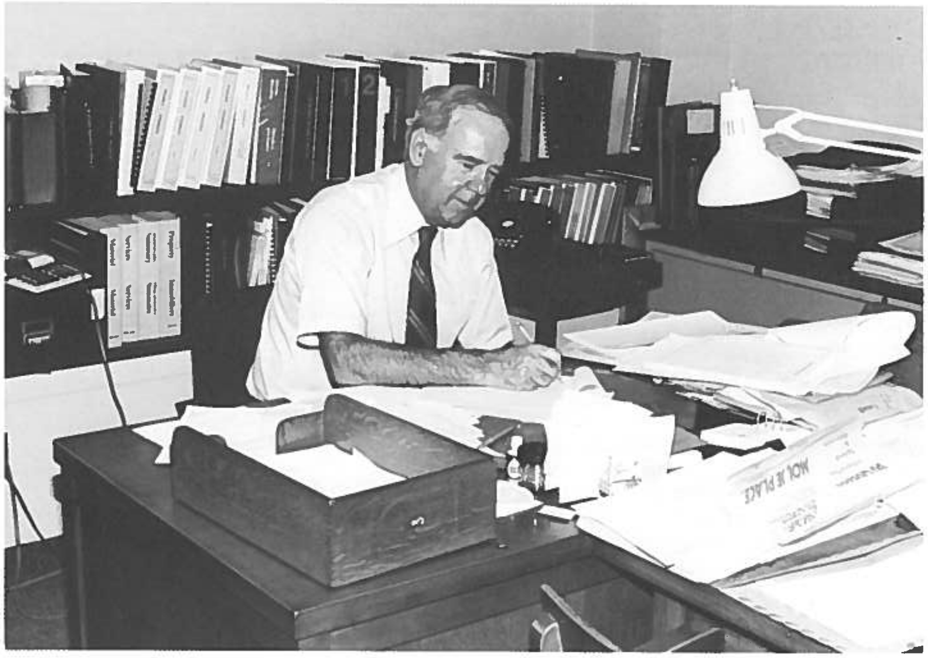
Lucie Morin prepares a report on a word processor.

terminal in the library permits rapid searches of these data bases. The terminal is linked to departmental and other libraries across the country, permitting more rapid and efficient processing of interlibrary loan requests.

Storage and processing of data is facilitated by several terminals linked to mainframe computers. Much of the programming and analysis of data is now carried out locally on recently acquired microcomputers,thereby reducing the amount of expensive time needed on mainframe computers.

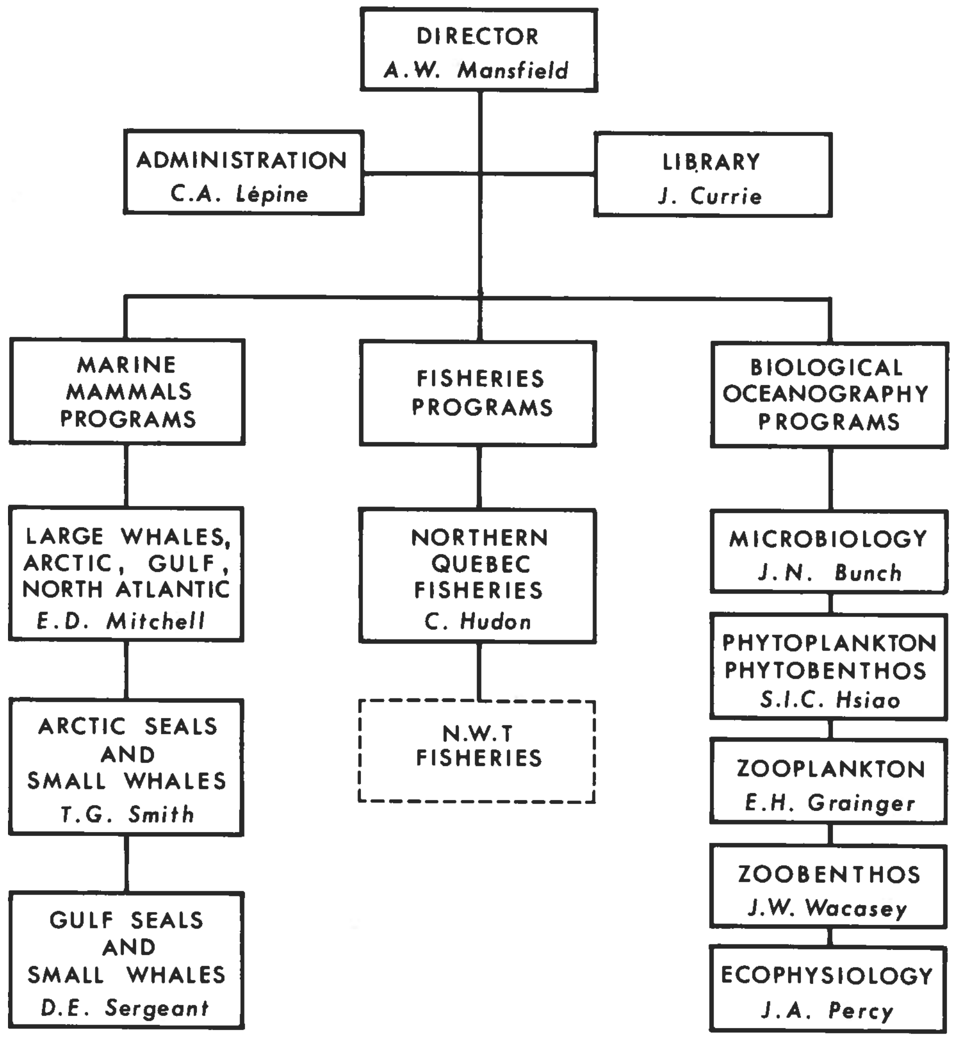
A research project is not complete until the results are published in a report, scientific journal or book. The whole process of manuscript preparation has improved dramatically with the advent of word processors, two of which are available for scientific and administrative needs.

It will be evident from a glance at the map of Canada that field operations, conducted in remote areas of the Arctic over 3200 km from Montréal, require good planning and logistical support if they are to succeed. While planning is the task of the scientific and technical staff, much logistic support and all administrative services involved in running the scientific program of the Arctic Biological Station are provided by a permanent administrative staff of six.



Charles Lépine ensures the smooth running of the administrative machinery at the Arctic Biological Station.

The Arctic Biological Station is involved in three broad areas of northern marine research: marine mammal biology, fisheries biology and biological oceanography. Within these three disciplines, nine research groups carry out studies on specific components of arctic and subarctic marine ecosystems. Although some of the research groups have both a taxonomic and a geographic orientation (e.g. the arctic mammals group and the St. Lawrence mammals group both deal with seals and whales) the following descriptions of the principal research activities are based on a strictly taxonomic arrangement to simplify the presentation. Selected publications are cited in the text and fully referenced in Section 6 for those readers interested in obtaining more information about particular studies.



The Arctic Biological Station has three main research divisions, each consisting of several research groups.

A field team loading up their "kamotiks" in preparation for a collecting trip out onto the sea ice of Frobisher Bay.

Biological Oceanography

Biological Oceanography is comprised of five research groups dealing with microbiology, phytoplankton, zooplankton, zoobenthos and invertebrate physiology. Research is concerned with the principal processes, the controlling factors and the rates of primary and secondary production, the nature and magnitude of energy exchanges within the ecosystem, and the availability of invertebrates as food for marine fish, birds and mammals. Because of a common focus on trophic relationships, the research programs are closely integrated. The groups usually work together in the same area and share field facilities, equipment and personnel. In recent years, all groups have been involved in long-term field work in the Beaufort Sea region of the western Arctic and in Frobisher Bay and the waters of south-eastern Baffin Island in the eastern Arctic. Individual research groups have also carried out long and short-term field programs in many other arctic and subarctic areas.

Phytoplankton

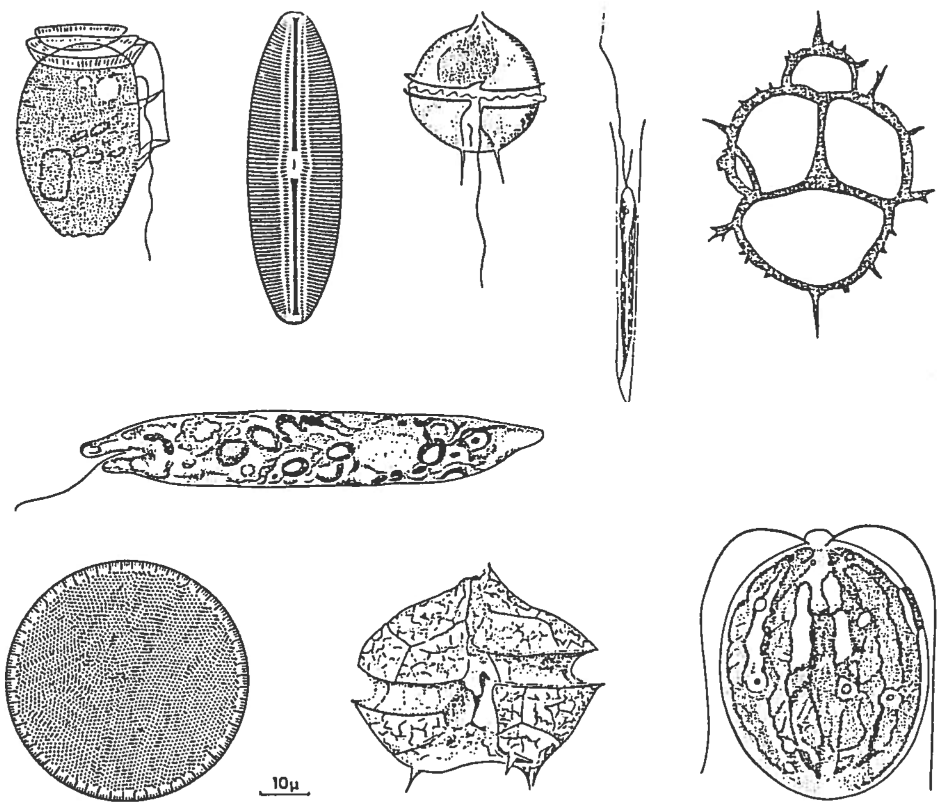
Phytoplankton floating in the water and microalgae attached to the sea ice are the major primary producers in arctic seas. These microscopic marine plants, in the process known as photosynthesis, use light energy to synthesize organic matter which is then transferred through the food chain to higher animals. Studies to date have examined the species composition, standing stock, horizontal and vertical distribution, productivity and growth of marine phytoplankton in several areas.

Microalgal cells are present in sea ice when it begins forming in late October. During the early period they are few in number and scattered through the ice so that no visible layer of organisms is present (Hsiao 1980). By late March a large population exists in the ice and by April or May when the ice thickness approaches two metres, coloured bands are visible in the bottom several centimetres. These are caused by diatoms, green flagellates, dinoflagellates, blue-green algae and chrysophytes growing on or trapped within the ice. The ice flora of Frobisher Bay consists mainly of diatoms, with most being pennate forms. Dinoflagellates, flagellates and chrysophytes are not abundant and no blue-green algae have been observed.

Seasonal cycles of reactive nutrients in arctic sea ice have been described (Grainger 1977). Nitrate reaches maximum levels of more than 14 μg-at L^{-1} and phosphate more than 4 μg-at L^{-1} in the lower few centimetres of the ice. At the same time, chlorophyll is found at the remarkably high concentration of 0.3 g L^{-1}. All these occur in much greater concentrations in the ice than in the water below. Sea ice microalgae play an important role as primary producers in the arctic marine ecosystem and they provide a major food source for ice-associated invertebrate fauna, which in turn are a food source for marine fishes, birds and mammals.

Population Growth

To study growth of natural populations, phytoplankton collected during the summer in Frobisher Bay at depths of 0, 5, 10, 15, 20 and 25 m were enclosed in dialysis bags and incubated at the collection depth (Hsiao 1985). Growth rates and generation times of phytoplankton in Frobisher Bay vary from month to month and from year to year as well as with species, depth, period of incubation, and environmental conditions. The greatest growth occurs at 10 m in July-August and at 5 m in late August-early September. Growth rates range from 0.06 to 1.12 divisions per day and generation times vary from 21.4 to 404.7 hours per division.



A wide variety of phytoplankton organisms forms the base of the food chain in arctic seas.

Quantitative composition, vertical distribution and standing stock

To examine the relationships between environmental factors and seasonal changes in microalgal communities, studies of species composition, vertical distribution and standing stock have been conducted in selected arctic locations during ice and open water seasons. Recent studies have been undertaken in Frobisher Bay (Grainger and Hsiao 1982), Brevoort Harbour and Cornelius Grinnell Bay in southeastern Baffin Island (Hsiao and Trucco 1980), and in Hudson Bay (Hsiao et al 1984). This baseline information can be used for monitoring the marine ecosystem in these areas. It is also useful for comparisons with other regions.

A plug of ice taken from the bottom of the ice hole provides a sample of the plants and animals living within the bottom few centimetres of the ice.

Production of organic matter

The conversion of carbon dioxide to organic carbon compounds by marine plants is the starting point for the transfer of energy through the marine food chain. The rate at which this primary conversion process occurs largely determines the size of the animal communities that can be sustained in an area. Long-term changes in production can cause fluctuations in the size and nature of the dependent communities. Time-area studies of production can therefore be of great importance for fisheries and marine mammal management.

Production rates are measured *in situ* by monitoring the uptake by the algae of small quantities of radioactive carbon isotope (^{14}C) injected into sealed flasks containing natural phytoplankton populations. The ^{14}C uptake rates are correlated with environmental factors such as temperature, salinity, nutrients and solar energy. In winter the rates vary from 0.9 to 3.7 mg C m^{-3} h^{-1} for sea ice from 1.0 to 5.6 mg C m^{-3} h^{-1} for phytoplankton in Frobisher Bay and from 0.7 to 8.0 mg C m^{-3} h^{-1} for phytoplankton in the waters adjacent to Brevoort Harbour. A study of marine primary production in Frobisher Bay (Grainger 1979) represents the first multi-year, year-round study of this kind done in the Canadian Arctic. Primary phytoplankton production, with annual values estimated at 41 to 70 g C m^{-2}, is regulated mainly by light, which is controlled in early summer by ice and snow cover, and less importantly by nutrients (chiefly nitrogen) and temperature. The production of plants in the ice is estimated to be about 10% of annual phytoplankton production.

Phytoplankton samples are incubated in sealed bottles at various depths in the water to measure production rates.

Carbon assimilation patterns

The ^{14}C fixed by phytoplankton is rapidly incorporated into a variety of organic compounds. The proportion transformed into lipid, protein, polysaccharide and low molecular weight metabolites varies among species and under different environmental conditions. Until recently, little information has been available about the pattern of ^{14}C incorporation in arctic phytoplankton.

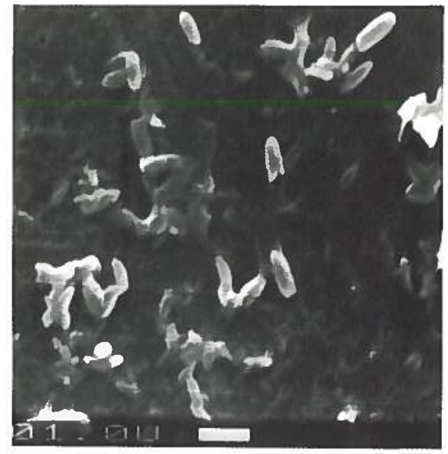
Natural populations of marine phytoplankton and sea ice microalgae from Frobisher Bay have been incubated *in situ* under natural conditions during late winter and summer (Hsiao 1984). When nutrients are adequate, ^{14}C assimilation into metabolites generally increases with increasing light intensity and temperature but decreases with the length of incubation; similarly polysaccharide production increases with increasing light intensity and incubation time particularly at higher temperatures. However, the proportion of protein produced increases with decreasing light intensity and temperature, and the correlation is enhanced by longer incubation time. The incorporation of ^{14}C into lipid is not correlated with any of these factors.

Natural populations of sea ice microalgae can assimilate only about 1.2% of the total fixed ^{14}C into lipid during late winter at low light intensities and low sea water temperature. Phytoplankton in the water column beneath the ice, incubated under the same conditions, can accumulate about twice as much lipid as sea ice microalgae (2.4%). These values are low in comparison with results from other localities.

Microbiology

Bacteria derive energy and food from one of two mechanisms: autotrophic bacteria produce organic food with energy they obtain by oxidizing reduced inorganic forms of hydrogen, nitrogen (eg. ammonia and nitrites) and sulphur to more stable oxidized forms such as water, nitrates and sulphates; heterotrophic bacteria utilize organic carbon for growth and multiplication in the same manner as protozoa and higher animals. These bacteria play a major role in the cycle of carbon in the sea. They are involved in the decomposition of dead plants and animals and their wastes. They mineralize the ensuing organic material to carbon dioxide, water, and reduced forms of inorganic nutrients. Dissolved organic material constitutes the largest amount of carbon in the world's oceans and is available mainly to bacteria and fungi. In utilizing this carbon, bacteria multiply and form particulate biomass which is available to protozoa and many invertebrates, particularly those which forage in and on the sediments.

Some heterotrophic bacteria can also degrade and mineralize fractions



Scanning electron micrograph of marine bacteria supported on membrane filter. The white bar is 1.0 μm or 1/1 000 000 of an inch long.

of petroleum, pesticides, herbicides and other organic compounds which enter the sea as a consequence of man's activity. The world's oceans are slowly cleansed of contaminants in this way, provided the input is not too great.

At the Arctic Biological Station, interest is focused on the roles of heterotrophic bacteria in arctic and temperate marine waters and sediments. Surveys have been made in the Beaufort Sea, Lancaster Sound, Frobisher Bay and along the eastern continental shelf of Canada from the high arctic islands to the Grand Banks of Newfoundland (Bunch 1979, Bunch et al 1983b, Bédard and Bunch 1983). With funds largely provided by the petroleum industry, data have been assembled to assess the turnover and mineralization of organic carbon in water and sediment, the formation of reduced nutrients and bacterial biomass, and the relationship of these activities to phytoplankton.

and the sedimented material retrieved from sedimentation traps deployed in the water column. These experiments are leading to an appreciation of the contribution of heterotrophic bacteria to the carbon budget in the waters of Frobisher Bay.

Labelled organic substrates such as ^{3}H-thymidine and ^{14}C-glutamic acid, and more recently ^{3}H-glutamic acid, are used for measurements of rate of incorporation. No single organic substrate is consumed by all bacteria and the portion of the flora consuming a particular substrate varies with the season.

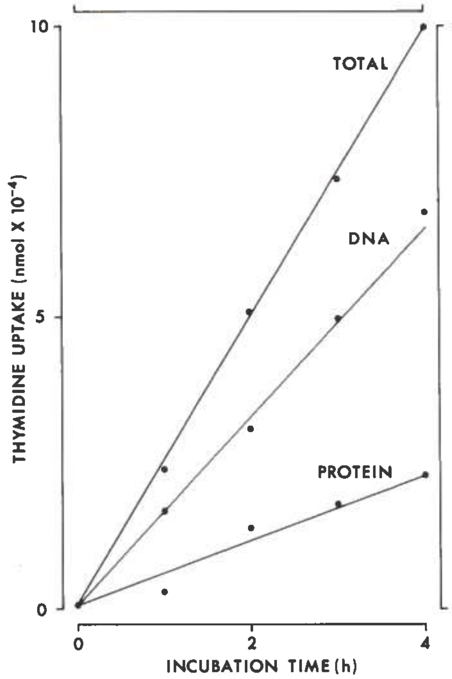
The time required for bacteria to double at various levels of the water column varied from 9 to 250 h during August 1984. Since the standing crop reached a maximum during this time, grazing by predators would appear to be the factor limiting further population growth. This suggests that during a 24-h period on 3 August, for example, a minimum of 4.6 $\mu g\ m^{-3}$ of carbon in the form of bacterial biomass was consumed by predators in the top 10 m of the water column. This carbon originates from soluble photosynthetic products extruded by phytoplankton into the water column and, without bacteria to consume it, would be unavailable to higher trophic levels. A close relationship therefore exists between bacteria and phytoplankton.

A short cruise was undertaken in the Gulf of St. Lawrence during the early part of September 1984. Preliminary data suggest that bacterial activity in the Gulf is probably comparable to activity at Frobisher Bay during the same time. Rates of bacterial activity in the Gulf were not influenced by experimentally increasing the water temperature by 10°C, suggesting that the bacterial flora was inactive. More activity was seen in the area near the Saguenay River than around Anticosti Island.

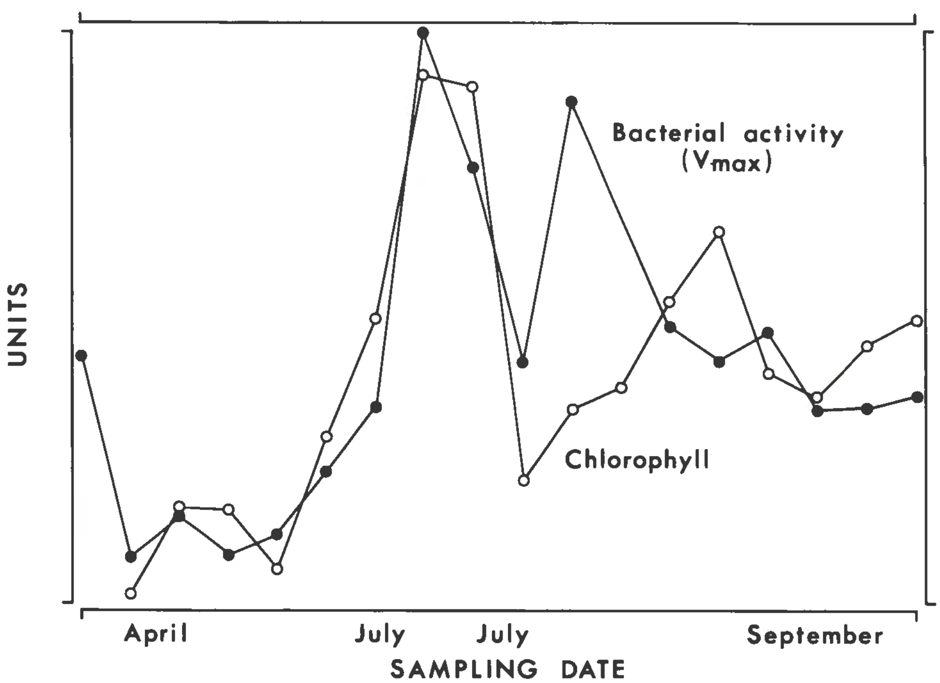
François Dugré lowers a water sampling bottle through an ice hole at Cape Hatt.

Bacterial production studies

Experimental work at Frobisher Bay has included measurements of numbers of heterotrophic bacteria, their activity and rates of multiplication. Measurements were made on samples from the water column, the sediment,



Incorporation of ^{3}H-thymidine into bacteria in a water sample from Frobisher Bay during the summer. Total denotes incorporation of thymidine into whole cells while curves for DNA and protein represent incorporation into these fractions. The rate of incorporation of thymidine into DNA is a measure of the rate of cell multiplication.



Seasonal variations in the bacterial activity in the water of Frobisher Bay are closely related to the fluctuations in phytoplankton populations expressed here as chlorophyll.

Petroleum studies

The effects of petroleum on the flora and fauna of arctic marine waters and sediments are poorly understood. The Baffin Island Oil Spill (BIOS) project, part of the Arctic Marine Oilspill Program, was carried out to compare the effects of chemically dispersed and non-dispersed petroleum releases in cold marine waters. This four-year project, which began in 1980 at Cape Hatt in northern Baffin Island, was supported by Canadian and foreign government agencies and the petroleum industry. During the project, physical, chemical and biological studies were undertaken in four experimental and control bays by a number of investigators.

Members of ABS studied the effects of the petroleum releases on the microbial flora of the water column and sediment. Baseline data on bacterial numbers and activity were obtained in the summer before the releases (Bunch et al 1981), and studies continued during and after the releases (Bunch et al 1985). The dispersed petroleum was released near the sea floor and had a transient and minimal effect on microbial activity in the water, as it was rapidly diluted and flushed out of the experimental bay (Bunch et al 1983a). A small amount of dispersed petroleum entered the sediment, but no effects on microbial activities were detected. Petroleum without dispersant was released as a surface slick in another experimental bay at high tide. Favourable winds ensured that the slick beached in the intertidal zone of the bay. No effects on microbial activities in the water or sediment were observed at that time.

In the year following the release of dispersed petroleum, increased amounts of organic carbon were observed in the sediment of that bay relative to the control bay. One year later, a similar observation was made in the experimental bay where the slick of petroleum had beached. In the two years between the beaching and the observation of increased organic carbon, petroleum from the intertidal zone had been entering the sediment due to the action of ice and water. Increased levels of organic carbon in the sediments of both bays were distinct from and considerably larger than the concentrations of petroleum. Bunch and Cartier (1984) suggested that the petroleum affected the macroflora and fauna of the sediments and thereby altered the level of organic carbon. This resulted in changes in bacterial numbers and activity in both experimental bays. The knowledge gained through the BIOS project will assist in determining the effectiveness, and the potential ecological risks, of treating petroleum spills with chemical dispersants in cold marine waters. The results of all studies will be available in a forthcoming issue of *Arctic.*

Aerial view of oil being released into a boomed bay at Cape Hatt during the BIOS study.

Microbiological samples are processed in the field laboratory set up at Cape Hatt during the BIOS program.

Zooplankton

Zooplankton comprises many kinds of aquatic animals, ranging in size from tiny protozoans, too small to be seen without magnification, to such creatures as jelly-like medusae, sometimes measuring more than a metre across. Like the microscopic plants of the phytoplankton, they all share a passive floating habit. Although unable to go anywhere in particular along horizontal planes, the plankton shows remarkable feats of movement upward and downward, rising to near the surface then descending into deep water. Such movements may be the means by which some planktonic animals become established within the lower levels of the winter ice cover of the arctic seas. There, a distinct ice fauna is found to exist, comprising a dozen or more species of several taxonomic groups.

The long-term objective of the zooplankton investigation is to contribute to our understanding of the biology of the arctic marine zooplankton and sea ice fauna, particularly their role in the food chain.

Production studies

The late 1970s brought to an end the first phase of plankton and plankton-related work in Frobisher Bay in the eastern Arctic, and in the estuarine Eskimo Lakes in the western Arctic. These two locations were studied over several seasons in order to provide year-round data, of a kind not previously available, on a range of biological and physical features from representative arctic localities, to determine levels of secondary production, and to identify the major controlling factors.

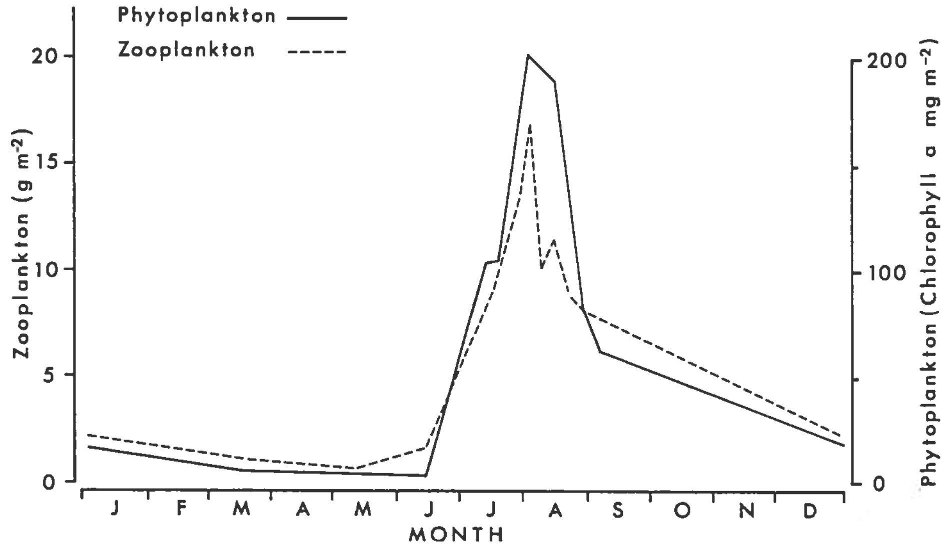
Zooplankton, like the phytoplankton, show wide seasonal variation in quantity. Standing stocks in coastal waters increase by as much as ten times between late winter and mid-summer, rising most rapidly in July then falling off more gradually through autumn and early winter to reach their lowest level in June. This conspicuous seasonal pattern of high biomass in summer and low biomass in winter characterizes both the plant and animal plankton of far northern seas. It is related to well defined seasonal variations in air temperature, snow and ice cover, sunlight and plant nutrient levels.

A study of zooplankton in the estuarine waters of the Eskimo Lakes, which form a nearly land-locked extension of the Beaufort Sea, showed a division of the 43 species present into groups dependent mainly on salinity and the origin of inflowing waters, freshwater forms entering from upstream and marine forms from the sea (Evans and Grainger 1980). The mean annual biomass of 80 mg m^{-3} (wet) is an especially low standing stock and is in accordance with the very low primary productivity and phytoplankton standing stock (Grainger and Evans 1982). Low levels of subsurface light throughout the summer and a chronic shortage of phosphate are major factors limiting primary production in this especially oligotrophic estuary.

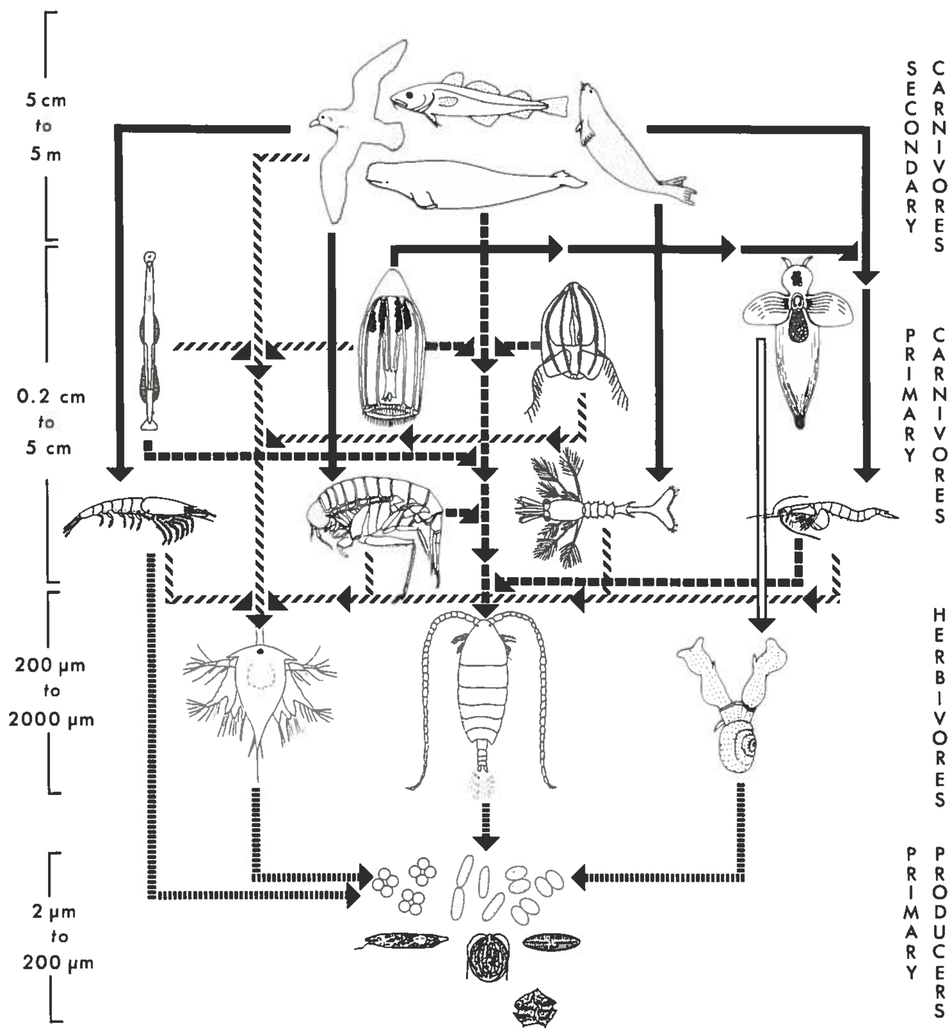
A third area from which seasonal

data have been collected is the Belcher Islands in southeastern Hudson Bay. Primary productivity there is also low in terms of marine waters in general (Grainger 1982). A major controlling factor is the planktonic grazers, among which ciliates play a larger role than previously recognized in far northern marine systems.

In response to the proposed use of Brevoort Island as a staging site for oil exploration off southeastern Baffin Island, a marine biology survey was carried out in the summer of 1979, funded by Esso Resources Canada and Aquitaine Company of Canada Limited. Zooplankton work (Grainger et al 1980) provided quantitative information on zooplankton stocks and on their availability to predators. Special attention was given to nocturnal concentration near the surface and predation by pelagic larval fishes.



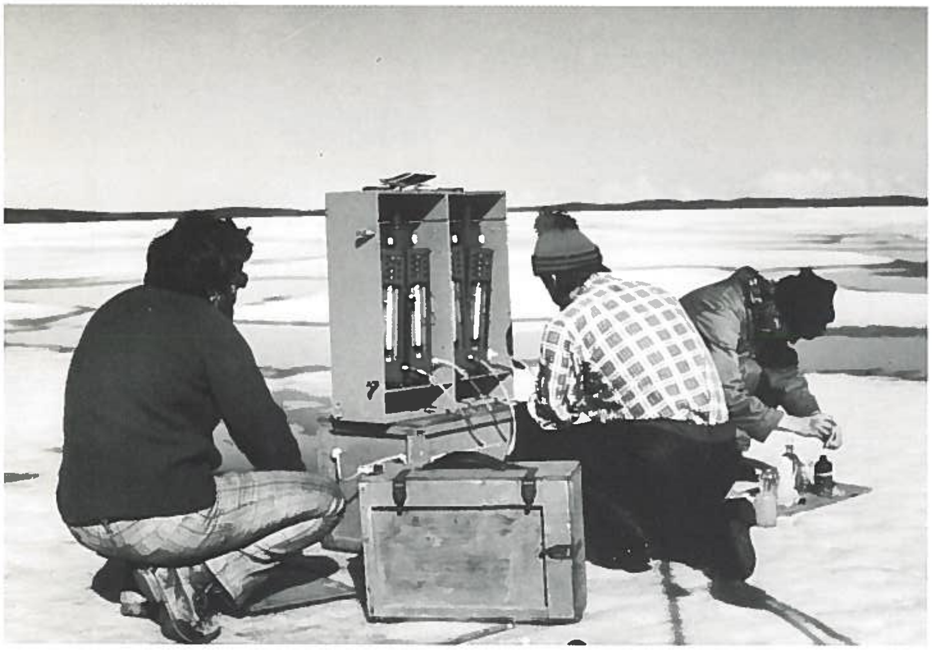
There is a marked seasonal cycle in the abundance of both plants (measured as chlorophyll a) and zooplankton in the waters of Frobisher Bay.



The marine food web in Frobisher Bay showing the importance of zooplankton in the transfer of energy between marine plants and commercially important marine vertebrates.

Sea ice studies

Study of the ice fauna began during the early 1980s, following earlier examination of ice nutrients, pigments and (as part of phytoplankton studies) the ice flora. The animal component of the ice biota was especially poorly known. It was apparent, however, that it played a role in an ice-water food chain, starting with ice-dwelling diatoms and including herbivorous invertebrates in the ice, carnivorous invertebrates (mainly crustaceans) at the ice-water interface, and under-ice predators such as the arctic cod and the ringed seal. Some 20 species of animals have been found within the lower levels of the ice in Frobisher Bay (Grainger and Hsiao 1982). Nematodes, copepods and polychaetes are the dominant forms, occurring at times in vastly greater concentrations than in the water below: for example, as many as 3×10^5 individuals per m^2 in the lower 3 cm of the ice. At least 12 species of copepods have been found (Grainger and Mohammed 1984), some of which appear to pass a large part of their life cycle within the ice. One of these is *Arctocyclopina pagonasta*, a new genus and species of cyclopoid copepod.

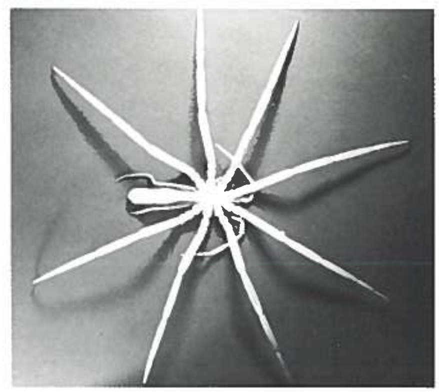


Water samples collected at various depths under the ice are used for a variety of chemical and biological measurements.

Zoobenthos

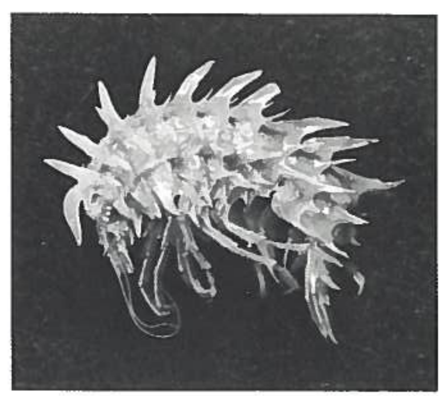
The marine zoobenthos program studies the fauna (primarily invertebrates) that live in, on, or near the bottom of the sea, in order to understand their role in arctic marine ecosystems. The zoobenthos is not an isolated entity, but is closely linked to the other components of the ecosystem, such as phytoplankton, zooplankton, microorganisms and fish. It is desirable to define and quantify these ecological relationships and to evaluate the factors responsible for the regulation of populations.

Zoobenthic sampling by ABS has been conducted over much of the Canadian Arctic, yielding over 1100 species of invertebrates, and revealing many communities with a diverse and widely distributed fauna. Quantitative studies, initiated in 1967, have been carried out in Frobisher Bay, James Bay, the Eskimo Lakes, the southern Beaufort Sea, and to a lesser extent at Brevoort Island, Pond Inlet, and in the vicinity of Cambridge Bay. These have provided an insight into factors that affect the distribution and abundance of benthic invertebrates, which has led to a better understanding of the structure and dynamics of arctic zoobenthic communities.



*A benthic sea spider **Colossendeis proboscidea** collected in the Arctic.*

When ice and open water are present helicopters are the only feasible means of reaching oceanographic stations.



*A bizarrely ornamented arctic amphipod, **Paramphithoe hystrix**.*

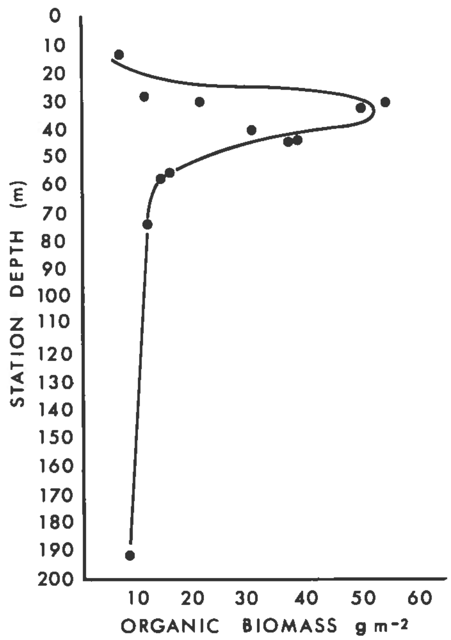
Community biomass

Of the communities that have been measured, those in Frobisher Bay consistently have the highest biomass values. A characteristic feature of upper Frobisher Bay, an area of about 1400 km², is the high tidal amplitude. The mean amplitude is 7.8 m and the maximum approaches 11 m. This results in well-mixed waters in the upper part of the bay, and provides sufficient nutrients to maintain a moderately productive ecosystem. The coastline is rocky with a few sandy beaches. The large tidal amplitude exposes wide areas strewn with rocks and boulders. The coarse gravel-sand substrate of the intertidal zone grades into finer sediments with fewer and smaller rocks in the subtidal depths.

Good estimates of community biomass have been obtained from the intertidal zone down to water depths of 192 m; however, the most frequently sampled depths are those from 15 to 60 m. Water temperatures (below 0°C) and salinities (30-33‰) at these depths fluctuate little throughout the year and have little influence on community biomass, which varies with depth.

The composition and biomass of these communities have been studied intensively (Wacasey et al 1979, 1980). Conversion factors, permitting crude dry weights to be expressed as organic weights and caloric equivalents, have been determined for over 100 species (Atkinson and Wacasey 1983). Good estimates of total community biomass can be obtained by applying these factors to the dry weights of the 10% of the species (10-20 species) that account for 90% of the total biomass.

Although the biomass varies from one sampling period to another, no consistent seasonal pattern is evident. The community seems to be dynamically stable; that is, the individual populations fluctuate, but the net change in community biomass is minimal since some species increase as others decline.



The biomass of bottom animals varies with depth in Frobisher Bay, with the greatest amounts occurring at 35 m depth.

Biomass is generally highest (≈ 50 g m⁻² ash-free dry weight) in water depths of 25 to 45 m. The detrital input to the bottom community is being examined to see if it is a factor responsible for this distribution.

A grab deployed through a lead in the ice by Joe Lovrity is used to collect samples of bottom sediments and animals.

Detrital fallout

Detritus produced in the water column falls to the bottom and is utilized by the benthos. The input of detritus is being examined by means of funnel traps deployed on the bottom at a representative 40 m deep station in Frobisher Bay. This study is providing information about the composition and biomass of the benthic community at the site, the nature and amount of organic material reaching the bottom and some of the factors influencing the rate of detrital deposition.

Most of the particulate matter produced in the water consists of fecal pellets of zooplankters, dead and live cells of plankton, and some inorganic material. The heavier particles, such as fecal pellets, reach the bottom within 24 hours since the distance involved is less than 30 m. Less than 20% of the particulate matter is organic because much of the material passes through the zooplankton in the water column before it reaches the bottom.

The annual fallout is about 70 g m^{-2} ash-free dry weight of organic material. About 26% falls during the month of August, 34% during June, July and September, and the remaining 40% during the period from October to June. An estimated 3.3 g m^{-2} ash-free dry weight of organic material reach the bottom in each of the eight winter months.

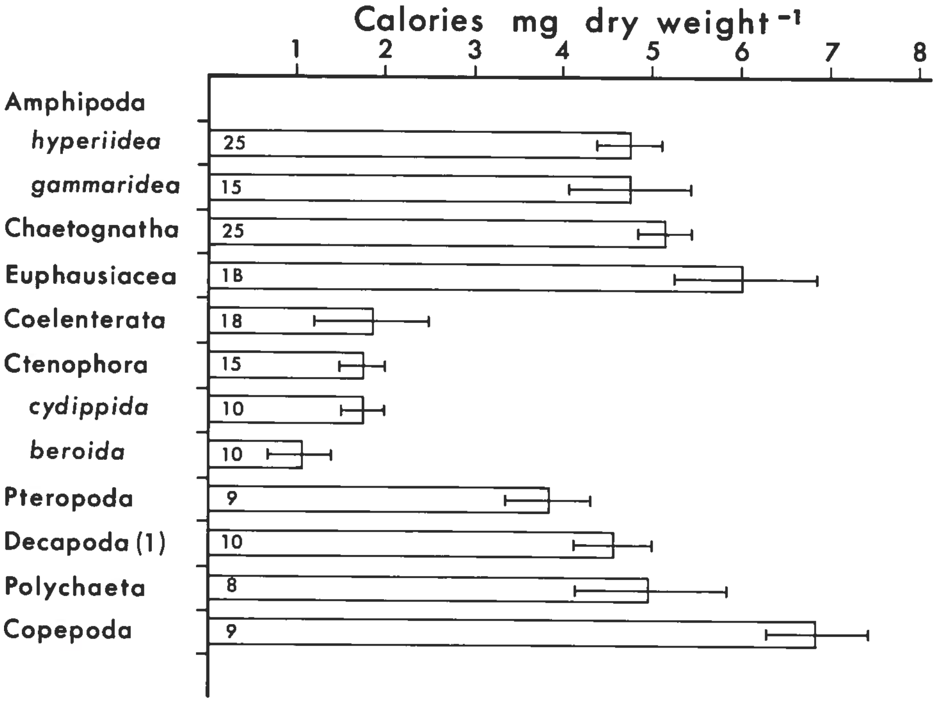
The low winter fallout reflects the scarcity of plankton in the water at this time. The amount of organic material reaching the bottom in August is about six times the monthly winter level, and the monthly amount for June, July and September is about three times the monthly winter value. This pattern of fallout is similar to that for primary production, except that the peak of detrital fallout lags behind the peak of primary and secondary production.

The benthic biota at the detrital trap station is diverse, with all trophic levels represented. Over 250 species of invertebrates have been collected in the area with a total biomass of about 50 g m^{-2} ash-free dry weight. At least 150 different species can be expected to occur in a typical 0.33 m^2 sampling area, 50% of which will be polychaetes and amphipods. The dominant groups in terms of weight are bivalve molluscs, sponges, polychaetes, ascidians, barnacles and occasionally ophiuroids, echinoids and holothuroids. The biomass of suspension feeders accounts for at least 50% of the total, suggesting that much of the detritus is being utilized by this group.

Ecophysiology

Physiology is the study of the biological processes such as growth, respiration and excretion that take place within living organisms. Ecophysiology seeks to understand how such life processes are influenced by changes (sometimes called stresses) in the animal's environment. Arctic marine organisms may be subject to a variety of environmental stresses such as great seasonal changes in the availability of food, wide fluctuations in salinity and the introduction of various types of toxic pollutants. At the Arctic Biological Station ecophysiological studies are primarily concerned with determining how these environmental stresses, be they natural or man-made, influence the survival, functioning and in particular the energy utilization of marine organisms.

A winter field site. The biological oceanography group is particularly interested in seasonal cycles in biological and oceanographic processes.



The caloric energy present in different groups of marine zooplankton is a good indication of their nutritional value to predators.

Bioenergetics

In marine ecosystems, species of macrozooplankton (organisms greater than about 2 mm in length) play an important role in the transfer of energy from smaller microplankton to larger marine vertebrate carnivores such as fish, seabirds and marine mammals. In arctic and subarctic seas the general pattern of trophic relationships among the common species is known. However, there is little quantitative information about the amounts of energy present and the rates of utilization and exchange. Even less is known about the manner in which physiological processes underlying this secondary production are influenced by the pronounced seasonality of the arctic environment.

Energy utilization by the dominant macrozooplankton species present in Frobisher Bay is being studied by a combination of ecological and physiological studies. The ecological studies provide information about the partitioning of energy among the different macrozooplankton species as well as about the population structure and biomass of the dominant forms at different times of the year and in different years (Percy and Fife 1983a).

In the upper 50m in Frobisher Bay three species, the ctenophore *Mertensia ovum,* the chaetognath *Sagitta elegans* and the hyperiid amphipod *Parathemisto libellula* consistently account for most of the biomass and more than 90% of the caloric energy of the macrozooplankton community (excluding copepods). Large numbers of the euphausiid crustaceans *Thysanoessa inermis* and *T. raschi* are present below about 60 m. Sampling at various depths has provided information about abundance, biomass and energy content, population size structure, growth rate and vertical distribution of these key species (Percy and Fife 1985).

Physiological studies carried out in the laboratory and the field are providing information about energy requirements and the partitioning of this energy among different biological processes such as growth, metabolism, and reproduction in selected species. The biochemical composition (water, lipid, protein, carbohydrate and ash) and energy content of the common species have been measured at different times of the year (Percy and Fife 1980a, 1980b, 1981, 1983b). The metabolic rates (oxygen consumption and ammonia excretion) of selected species are being measured at different times of the year, both *in situ* in the natural habitat and in the laboratory. Results thus far indicate that the metabolism of *Mertensia ovum* declines by approximately 30% in the winter.

Comparable studies of seasonal changes in metabolism and biochemical composition are also being carried out on selected species of benthic amphipods (Percy 1979, 1980)

The influence of salinity on arctic marine crustaceans
Habitat salinity is often an important factor regulating the distribution of marine organisms. Some species are stenohaline and tolerate little variation in salinity, while others are euryhaline and can exist in waters of widely varying salinity. Although salinity in much of the Arctic Ocean is relatively high and unvarying there are biologically important habitats characterized by a widely fluctuating salinity. Two such habitats, within river estuaries and immediately beneath annual sea ice, are the foci of the following studies.

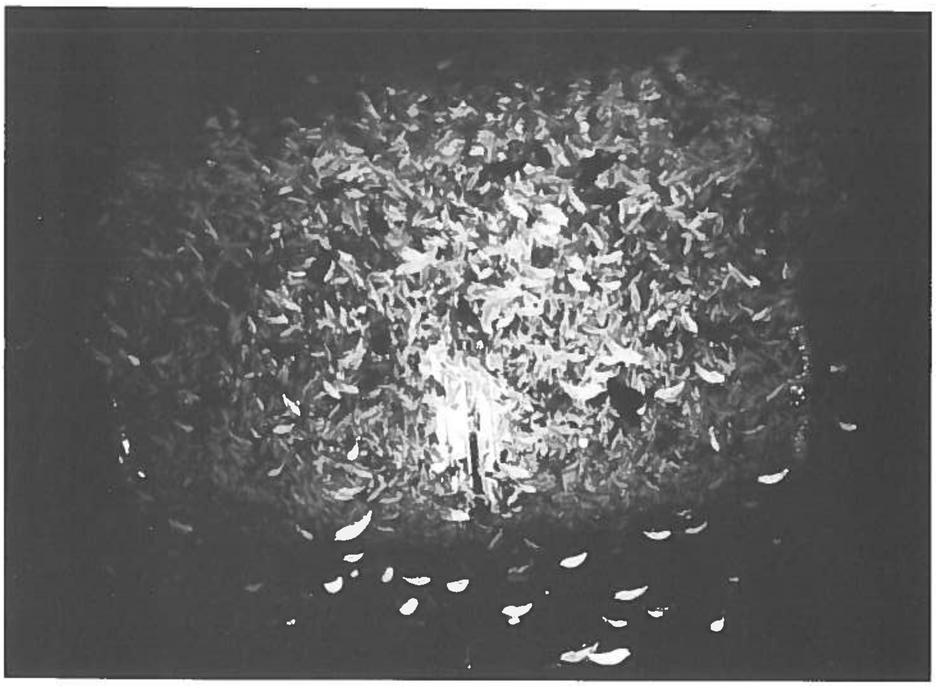
Three large marine isopods, *Mesidotea entomon, M. sibirica* and *M. sabini* are common in the coastal waters of the Beaufort Sea adjacent to the Mackenzie River Delta. They form an important component of the benthic community, acting as both predators and omnivorous scavengers and serving as food for a variety of fish, birds and marine mammals. The occurrence of all three species in the same area has provided an opportunity for comparative studies of their osmoregulatory physiology and their distribution in relation to salinity (Percy and Fife 1980c, Percy 1983, 1985).

Mesidotea entomon is restricted primarily to the warm, brackish nearshore estuarine zone in water depths of less than 10 m; *M. sibirica* is commonly encountered at intermediate depths of 5-25 m; while *M. sabini* is the most marine of the three species and occurs at depths between 10 m and 441 m.

The physiological studies tend to confirm the importance of salinity as a factor in the distribution of these three species. *M. entomon* is the most effective osmoregulator and *M. sabini* the least. In all three species the haemolymph is hyperosmotic in dilute sea water and isosmotic at higher salinities. All three species reduce their integumental permeability to water as the salinity declines, but the capability to alter the permeability increases in proportion to the euryhalinity of the species.

The sub-ice community is another important component of the arctic marine ecosystem. Several species of amphipods characteristically occur in large numbers in the sub-ice habitat. The larger animals browse the rich algal layer and shelter in crevices while smaller ones penetrate into the ice matrix itself via brine channels. Considerable variation in salinity occurs in this habitat, ranging from very high salinities within the brine channels and in areas of brine drainage to almost fresh water immediately under the ice during the spring melt. Clearly, particular physiological adaptions are required, and not all species of amphipods are able to cope with the osmotic stress of this habitat. A comparative study is presently underway of the salinity tolerance, osmoregulatory capabilities and metabolic responses to salinity change of two common sub-ice species, *Onisimus glacialis* and *Onisimus litoralis,* and a typically benthic species *Anonyx nugax.*

***Anonyx nugax** is a large bottom dwelling amphipod that is common in many arctic areas.*



A baited trap suspended in arctic seas rapidly attracts thousands of scavenging amphipods.

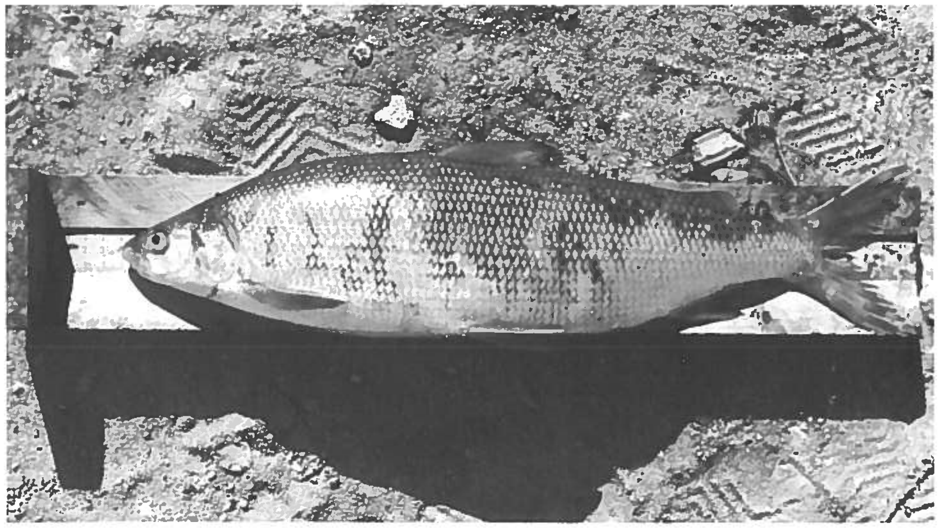
Petroleum hydrocarbons
The potential for oil pollution in the Arctic grows steadily but the exact nature of the possible threat to the environment has proven difficult to define. Undoubtedly some of the broad generalizations about petroleum impacts derived from decades of study in other regions are equally valid in the Arctic. Most clearly require modification or extrapolation because of the many unique features of polar ecosystems. Although there are still major information gaps that make prediction of impacts difficult, there is a growing understanding of the effects of petroleum on arctic organisms and ecological processes (Percy 1982, Percy and Wells 1984, Wells and Percy 1985). Studies thus far at ABS have focused primarily on the sublethal physiological effects (metabolism, activity, behaviour) of crude oil on arctic marine crustaceans. Similar studies are also being conducted on larval fish inhabiting shallow coastal embayments, a habitat particularly vulnerable to marine oil spills.

Northern Fisheries

Studies on northern marine and anadromous fishes are providing information on the distribution, abundance, production and yield of the important species, and on their relation to the arctic marine ecosystem. This information is crucial to an understanding of their ability to tolerate environmental disturbance resulting from man's exploitation of petroleum, mineral and hydroelectric resources. Fish play a dominant role in the economy of northern peoples living in the major river basins draining to the Arctic Ocean, Hudson Bay and Ungava Bay. Anadromous species are the most heavily exploited since they can be caught in large numbers in rivers and coastal waters during their journeys to and from the sea. It is this characteristic which places many stocks in potential conflict with man's development of the North. By contrast, there are few uniquely marine species of potential food value, except at the fringes of the Arctic in the Beaufort Sea in the west and in eastern Hudson Strait in the east, where several species with limited commercial possibilities exist.

In earlier years, studies of northern fish resources were primarily oriented towards management needs and much information was acquired and put to practical use. Since 1970, with the advent of the Mackenzie Valley Pipeline Program and the James Bay Hydroelectric Development Project, most studies have looked at the more immediate problem of environmental impact on a scale never before visualized, at least in Canada. The susceptibility of anadromous fish to damming of rivers has been of great concern to northern peoples who depend on these resources. The James Bay and Northern Québec Agreement represents one outcome of this concern and will require continuing effort on the part of management and research staff to document changes in the fisheries and provide stock assessments and estimates of potential yields.

In northern Québec, DFO is primarily concerned with marine and estuarine fishes while the Province of Québec has the responsibility for managing freshwater and anadromous fish stocks. However, the Department participates indirectly in the management of freshwater fish stocks through its mandate to protect and maintain fish habitat.



Whitefish is an important resource species in some areas of the Canadian Arctic and Northern Québec.

Northwest Territories Fisheries

A study of the fishes of Brevoort Harbour and the nearby waters of south-eastern Baffin Island, carried out in 1979 as part of an environmental impact study related to offshore hydrocarbon development in Davis Strait, brought to an end over two decades of marine fish surveys in the Northwest Territories. These wide-ranging surveys, extending across the whole Arctic, provide a comprehensive overview of the zoogeography of arctic marine fish species. Station locations and supporting oceanographic data have been published (Hunter and Leach 1983a, 1983b) while the extensive data on the fish collections have recently been archived in the computerized files of the Ichthyology Unit, National Museum of Natural Sciences, in Ottawa. These data have been used to prepare a distributional atlas of the marine fishes of Arctic Canada (Hunter et al 1984). The extensive collections of arctic fish acquired by ABS over the years have also been deposited with the National Museum to make them accessible to interested researchers.

In recent years the ABS fisheries program has tended to focus more specifically on the fisheries resources of the coastal areas of northern Québec.

A biologist collects fish samples from a gill net during a fisheries survey of a northern lake.

Northern Québec Fisheries

Northern Québec is a vast region with a marine coastline that extends from southern James Bay to north-eastern Ungava Bay, a distance of over

A counting fence is used to monitor the annual migrations of fish in a river in Northern Québec.

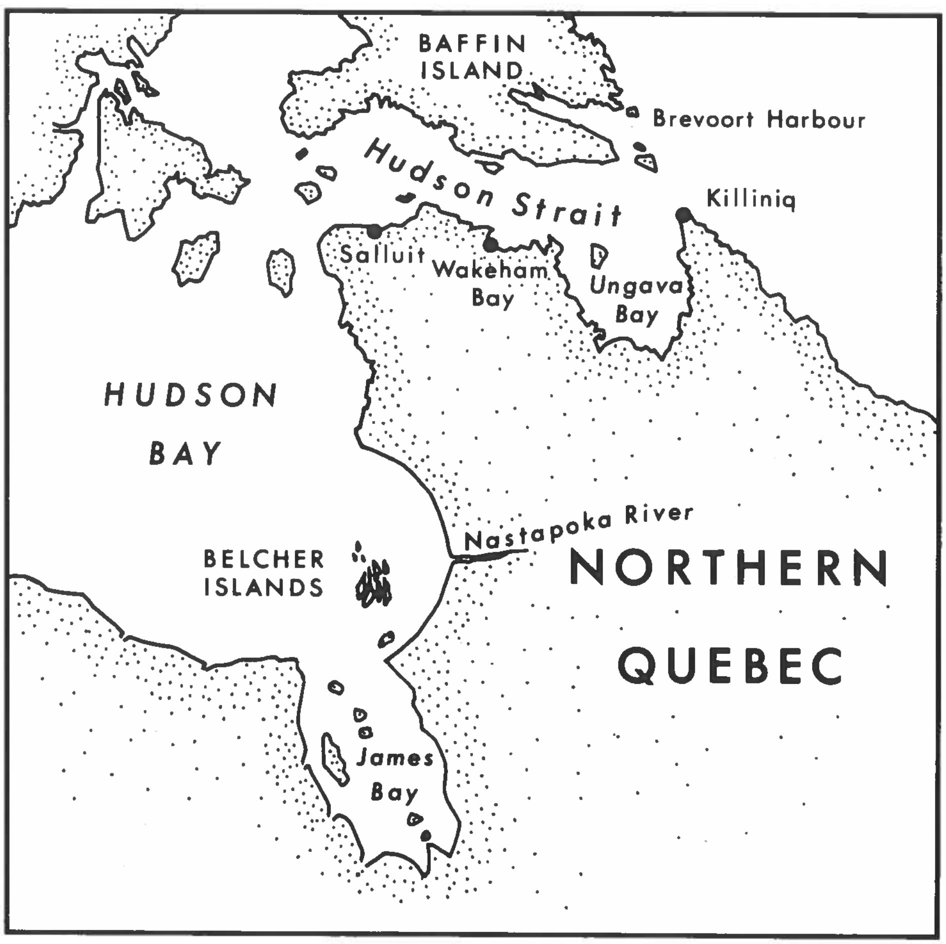
2500 km. Several species of fish found at sea and in estuaries along the coast represent an important food resource for numerous Cree and Inuit communities. In spite of the importance of this fishery resource, systematic exploration and research in James Bay and Hudson Bay only began in the 1970s.

The Station first undertook field studies in eastern James Bay and southeastern Hudson Bay between 1973 and 1976. The principal objective was to obtain information necessary to evaluate the effects of hydroelectric development on coastal marine and anadromous fishes. These studies also provided information on estuarine fish communities and on the ecology of anadromous whitefishes (Morin et al 1980, 1981, 1982).

Comparison of fish communities in estuaries along the coast reveal patterns in the distribution of different species that provide insight into the primary factors regulating the coastal fish populations. One of the hypotheses suggested by the above studies is that climatic conditions along the coast of James Bay and Hudson Bay limit the occurrence of several species, particularly in northern Hudson Bay where growing seasons are short and of variable duration. This has been confirmed by analysing the abundance, growth and reproduction of three species of anadromous whitefishes, *Coregoninae*, in several rivers in eastern James Bay and southeastern Hudson Bay.

These studies have both theoretical and practical applications: they further our understanding of how reproductive traits evolve in northern environments; they show how changes in production at lower trophic levels caused by environmental perturbations influence the presence and abundance of fish species; and they provide the first account of the life cycle of anadromous whitefishes, the major exploitable fish resources in James Bay and southern Hudson Bay. Such an understanding of whitefish ecology and adaptive life history is essential for their proper management and exploitation.

In 1983, DFO began a five-year program to develop the fisheries potential of Québec. As part of this program, ABS has undertaken responsibility for research activities on fish and marine mammal stocks of importance to the native peoples in Northern Québec. In 1984, the Station supported the Makivik Corporation (which provides research services to the Inuit under the James Bay and Northern Québec Agreement) in the development of an Atlantic cod fishery at Killiniq (Port Burwell) and in research into ways to enhance the production of arctic charr in the rivers of Ungava Bay. Research at Killiniq has so far concentrated on determination of the age structure and stock affinity of the Atlantic cod population, as well as a study of the distribution, abundance and biology of inshore epibenthic decapods (shrimp), important food items for fish and marine mammals. The research project on arctic charr used aerial photos, maps, interviews with Inuit fishermen, and ground surveys by researchers to identify important factors limiting the production of this species in the rivers flowing into Ungava Bay. One of the most common factors discovered is the lack of clear access for arctic charr in shallow rocky rivers during years of low flow caused by low summer rainfall. The solution to this is an enhance-



Fisheries studies are being actively pursued in several areas in Northern Québec, especially in Ungava Bay and James Bay.

ment procedure that has been recognized and endorsed by the Inuit themselves: the construction of weirs and clear channels in the rivers to guide charr to their upriver spawning and overwintering sites.

In 1985, ABS acquired a research scientist and a biologist to augment its fisheries research activities. Research is continuing at Killiniq to establish a system for monitoring the exploited cod stocks and to determine the potential for exploiting alternative species. Projects in James Bay have begun to explore the marine fish species that inhabit coastal and deep waters and to study the demography of a coastal anadromous population, providing information necessary for management policies.

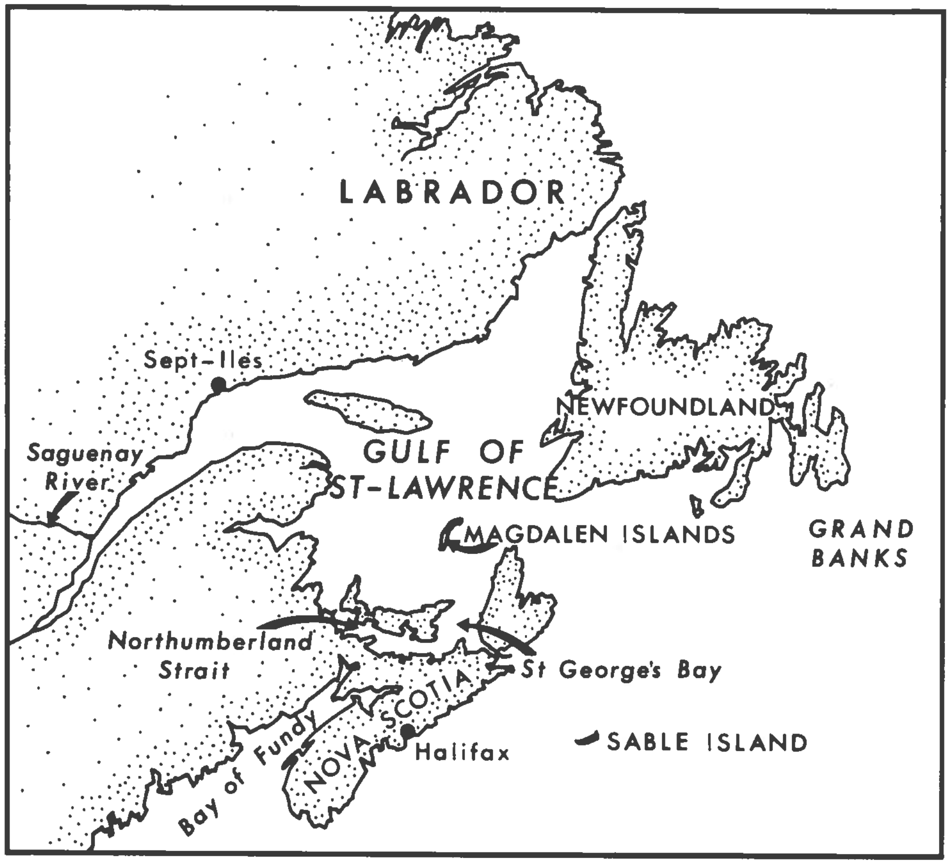
Marine Mammals

Marine mammal studies in the Arctic are aimed at providing information on the distribution, abundance, production and yield of seals and whales. The relationship of mammals to the rest of the arctic marine ecosystem, particularly with respect to feeding and predation and their ability to tolerate environmental disturbance resulting from exploitation of resources such as oil, gas and minerals, is also being examined.

With increasing human populations in the North there is an urgent need for DFO to learn as much as possible about the fisheries resources on which many northern residents depend. Traditionally, marine mammals have been the mainstay of the Inuit economy, providing food, fuel and clothing for men and food for their dogs. They are still of fundamental importance to the Inuit, and until recently served both as an article of trade (skins and ivory) and as a source of food. Although the value of skins has declined drastically in the last three years as a result of the ban on importation of seal skins by the European Economic Community, hunting pressure on stocks will continue to rise, and effective management procedures will be required to limit the kill.

The rising level of education of Inuit and Dene (Indians) and their increased political awareness has resulted in the negotiation of one major land claims agreement (the James Bay and Northern Québec Agreement, 1976) and may lead to others in the near future. Such agreements call for reliable scientific information on the levels of stocks and their yields.

Northern peoples are becoming acutely aware of the environmental problems that may result from the



In recent years the Arctic Biological Station has been actively involved in marine mammal studies in the Gulf of St. Lawrence and in Canadian east coast waters.

An Inuk woman removes the blubber from a sealskin with an "ulu", a traditional and highly effective knife.

exploitation of resources such as oil, gas and minerals. Seismic activity associated with offshore drilling, the drilling operations themselves (as in the Beaufort Sea, the Sverdrup Basin, and on the Baffin Shelf), projected pipelines and the use of supertankers are all of great concern in northern communities. It is essential that DFO continues to provide scientific information so that sound environmental impact assessments can be made.

Research on arctic marine mammals has changed considerably in the past two decades. In the 1960s studies dealt with assessment of populations hunted by the Inuit. The 1970s were mostly taken up with short-term, impact-related studies. Now, in the 1980s, the growing realization of the limitations of short-term research and the weakness of the standard methods of population assessment are resulting in new directions and approaches in marine mammal research (McLaren and Smith 1985).

A humpback whale. These and stocks of other large whales require careful monitoring of their population sizes.

Marine mammal studies on the East Coast are aimed at providing information on the distribution, abundance, production and yield of whales and seals, their effect on fisheries, and their relation to the marine ecosystem in the northwest Atlantic Ocean and the Gulf of St. Lawrence. Much of the early effort was devoted to providing data to the International Whaling Commission (IWC), which regulates the level of catch of all whales of commercial importance in the world's oceans. Canada withdrew from membership in IWC in 1982, following a 10-year period during which no commercial whaling took place in Canada. However, there is still a large backlog of biological data resulting from the east coast fishery which ended in 1972 that needs to be analysed and published in various scientific journals.

Canada also plays a leading role in seal research under the Northwest Atlantic Fisheries Organization (NAFO). The controversy surrounding the harp seal hunt has been widely publicized. While the ethics of killing newborn white-coated pups have been widely debated, and remain a matter of personal conviction, the actual levels of catch have generally been accepted as ecologically reasonable. Catch quotas were based on the results of a long-term research program, much of which was carried out by ABS. A much reduced research program continues in the Gulf of St. Lawrence, with the major effort being carried out by the Northwest Atlantic Fisheries Centre at St. John's, Newfoundland, which now has the responsibility for assessment of the stocks of both harp and hooded seals.

While international commitments are important, there are also domestic problems needing solution. The grey seal is a good example. This species, which may number about 100 000, is of great concern since it preys on the cod, herring, mackerel and salmon that are the mainstay of inshore fisheries. It is also a principal vector of the codworm, or sealworm, which infests the flesh of groundfish, making them less marketable. The urgent demands of fishermen to eradicate this predator have been partially met by controlled killing and the institution of a bounty. However, there is much opposition to this kind of control. Continued research on this species is the only way to provide the data necessary for rational management that will be acceptable to the majority of people concerned.

Although responsibility for much of the research on the grey seal has been transferred to the Scotia-Fundy Region, ABS still maintains a program in the Gulf of St. Lawrence and will continue to analyse and publish information collected in earlier years.

Marine mammal studies on the West Coast also formed part of the Station's mandate from 1967, but this responsibility was reassigned to the Pacific Region in 1978. The species principally concerned were the north Pacific fur seal, the killer whale, the harbour seal and the Steller sea lion.

Seals

Seals are an integral part of the marine ecosystem on Canada's east coast and even more so in much of the Arctic. They are of considerable ecological and economic importance and as a consequence ABS has been actively pursuing research on several species in both areas for many years. The following three species are being studied intensively.

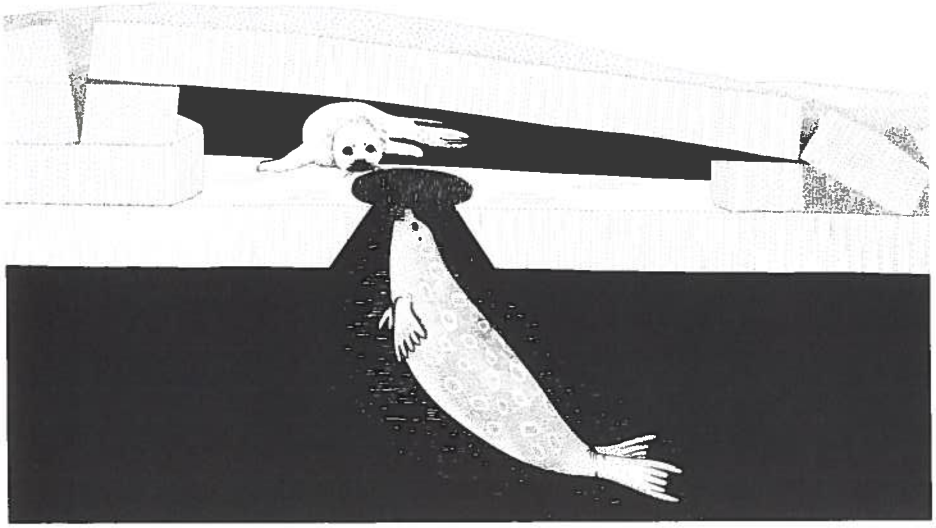
Ringed Seal

The ringed seal, the only species adapted to year-round life in ice-covered waters, is widely distributed throughout the Arctic. It is a small seal, adult males rarely weighing more than

Ringed seals are an important resource species for Inuit throughout the Canadian Arctic.

100 kg. In the past, the ringed seal formed the backbone of the economy of the coastal Inuit, but its importance has declined drastically in recent years as a result of the ban on importation of seal skins to the European Economic Community.

Research on ringed seals in Amundsen Gulf and the southeastern Beaufort Sea has been conducted annually since 1971. A monograph dealing with age structure, reproduction, feeding, bioenergetics and population dynamics is presently nearing completion. The results show that ringed seals vary in their annual rates of reproduction, apparently as a result of significant changes in body condition, suggesting that ringed seal populations are food-limited.



Subnivean lairs hollowed out beneath drifted snow provide protection for newborn ringed seals.

Studies presently underway in Barrow Strait are attempting to assess breeding habitat in quantitative terms and to relate changes in the distribution and quality of fast ice to changes in population parameters. The results should provide a detailed view of the relationship between ice conditions and breeding habitat, which can be used to monitor the annual status of ringed seal populations. Other studies seeking to derive energy budgets for free-ranging ringed seals occupying the fast ice are also being undertaken. Instrumentation, including radiotelemetry, is being used to obtain the required data. The role of the subnivean (under-snow) birth lair as a thermal shelter and refuge from predation by polar bears (Smith 1980) is also being evaluated.

The studies described are largely dependent on the involvement of graduate students. Collaborative research on ringed seals, bearded seals and polar bears is being carried out in the Canadian Arctic with the Canadian Wildlife Service, and in both the Canadian Arctic and Svalbard (Norway) with the University of Oslo and the Norsk Polarinstitutt.

Since the early 1970s there have been continuing efforts to discover, delineate and develop the offshore petroleum reserves of the Canadian Arctic. Widespread public concern about the possible effects of these activities on the ecosystem resulted in an unprecedented surge of environmental impact research in many northern areas. There was particular concern about the potential effects of spilled oil on marine mammals. This led to studies being undertaken to determine the impact on ringed seals of immersion in and ingestion of crude oil (Smith and Geraci 1975). The results show that ringed seals are surprisingly robust animals since they suffered only minor and reversible damage from a 24-hour immersion in Norman Wells crude oil. Furthermore, ingestion of low levels of oil over a long time did not produce any marked adverse effects (Geraci and Smith 1976a, 1976b).

Other environmental impact studies have looked at the effect of different types of development. As part of the Arctic Islands Pipeline Project the possible impact of pipeline crossings on ringed seals of the high Arctic was studied (Smith et al 1979). Large-scale surveys of Barrow Strait showed varying densities of ringed seals, with the best breeding habitat being found in the channels between the islands.

During the Eastern Arctic Marine Environmental Studies program (EAMES), surveys of breeding habitat were made along the eastern Baffin Island coast between Cumberland Sound and Frobisher Bay, and detailed behavioural studies were carried out (Smith 1980, Smith and Hammill 1980, Smith and Hammill 1981). It was demonstrated that ringed seals are territorial in their fast ice breeding areas and exhibit a polygynous social structure.

The arctic fox, though essentially a terrestrial mammal, plays an important part in the marine ecosystem since it is an important predator of the ringed seal. It is also a major source of income to the Inuit, who trap it during the winter for its valuable pelt. Ringed seal pups, especially in the nearshore breeding habitat, are an important source of nourishment for foxes in springtime.

The population dynamics of arctic foxes in Amundsen Gulf were studied over a four-year period (Hammill 1980). Marked changes were observed in the population age structure which were correlated with similar fluctuations in the overall reproductive rate of the ringed seal population, apparently caused by changes in availability of food resources. In years when ringed seals are readily available in the spring, predation is high and large numbers of fox cubs are produced. This tends to damp out the wide fluctuations in numbers so characteristic of inland fox populations and most likely explains the consistently high yields from fox trapping on Banks and Victoria Islands.

Arctic fox are predators on seal pups and are an important source of cash income in many Inuit villages.

Harp Seal

The harp seal is a highly migratory species that breeds on ice floes in the Gulf of St. Lawrence and off the coasts of southern Labrador and northeastern Newfoundland (the "Front"), and spends the summer along the western coast of Greenland and in the eastern Canadian Arctic, particularly Lancaster Sound. Until 1983 the harp seal formed the basis of a very large commercial hunt, principally for the fur of the new-born "whitecoat". Since 1955, ABS has had a continuing involvement in the monitoring of the population of this species.

Recent estimates of production of harp seals are based on several sources. A capture-recapture experiment involving tagged animals in the Gulf of St. Lawrence and on the Front gave an estimate of pup production in 1978-80 of 482 000, with confidence limits of 369 000 and 583 000 (Bowen and Sergeant 1983). This estimate was raised to 534 000 ± 66 000 as a result of a second experiment, so far unpublished, in 1983. Statistics on the catch of harp seals in Greenland show a decline from about 22 000 in 1950 to 5500 in 1970, and a rise again to 17 000 in 1982 and 18 000 in 1983. Since the catch in Greenland comes entirely from the western Atlantic herds, and is composed mostly of animals in their first and second years, it gives an index of escapement of young from the hunt. Unfortunately these catch data cannot be corrected accurately for effort since there was some increase in the number of motor boats and improvement of rifles between 1970 and 1983, but the number of hunters did not change significantly.

There is additional independent evidence that the production of harp seals has been increasing. In the Gulf of St. Lawrence, ABS staff sampled the winter catch of harp seals at Les Escoumins, Québec, in 1969, 1971, and annually from 1978 to 1985 . The samples, which vary in size from 125 to 300, have been analysed for age frequency distribution, female reproductive rates, and food consumption. Following the imposition of quotas on the catching of harp seals in 1972, age-class strengths reached a peak with the age-classes of 1975 to 1977. The latter age-class has remained dominant since that time. An apparent decline in recruitment and survival of more recent age-classes has resulted in an increase in the mean age of the population. In spite of these changes in population structure, the age at which females attain sexual maturity has remained constant for a long time, with a median age varying around 4 years. This value was observed not only before quotas were established in 1972, when the population was reduced by overhunting, but as recently as 1984. There is no evidence during this period of density-dependent changes in the reproductive rate.

Tagging seals for later identification is an important technique for studying many aspects of their biology.

A harp seal and pup on the ice floes of the Gulf of St. Lawrence.

There are large annual variations in food consumption, particularly of capelin, the dominant prey species. When these fish are scarce they are replaced in the diet by a variety of other fish, cephalopods and crustacea.

Grey Seal

The grey seal is a large, relatively sedentary species that frequents the Gulf of St. Lawrence and the coastal areas of the Maritime Provinces and Newfoundland. The adult males, known locally as "horseheads", are large dark animals easily recognized by their long, rounded noses.

Grey seals present a continuing problem because of their role as the principal vector or final host of the cod-worm or sealworm, a parasitic nematode known variously under the scientific names *Porrocaecum, Terranova, Phocanema* or, most recently, *Pseudoterranova decipiens.* The larvae of this parasite encyst in the muscle of commercially important fish, particularly ground-fish such as cod,

Fred Bruemmer

Male, female and pup grey seals. These animals are a major host for codworm, creating considerable problems for Canadian Atlantic fisheries.

and when present in large numbers render the fish unmarketable. Over the last 20 years the number of grey seals has increased, particularly at Sable Island off the east coast of Nova Scotia. Over the same period, codworm incidence has also greatly increased in the ground-fish populations on the neighbouring banks.

Grey seals in eastern Canada are known to whelp mainly at Sable Island and in the Gulf of St. Lawrence, with additional small colonies along the outer coast of Nova Scotia north of Halifax. The production at Sable Island, which reached nearly 6000 in 1984, is known with reasonable accuracy since nearly all living pups have been tagged. The grey seals in the Gulf of St. Lawrence whelp mainly on pack ice, especially in Northumberland Strait and St. George's Bay, during January and early February. Grey seals also whelp on Ile Le Corps-Mort, southwest of the Magdalen Islands, and on Amet Island in Northumberland Strait. There is evidently no whelping along the south coast of Newfoundland.

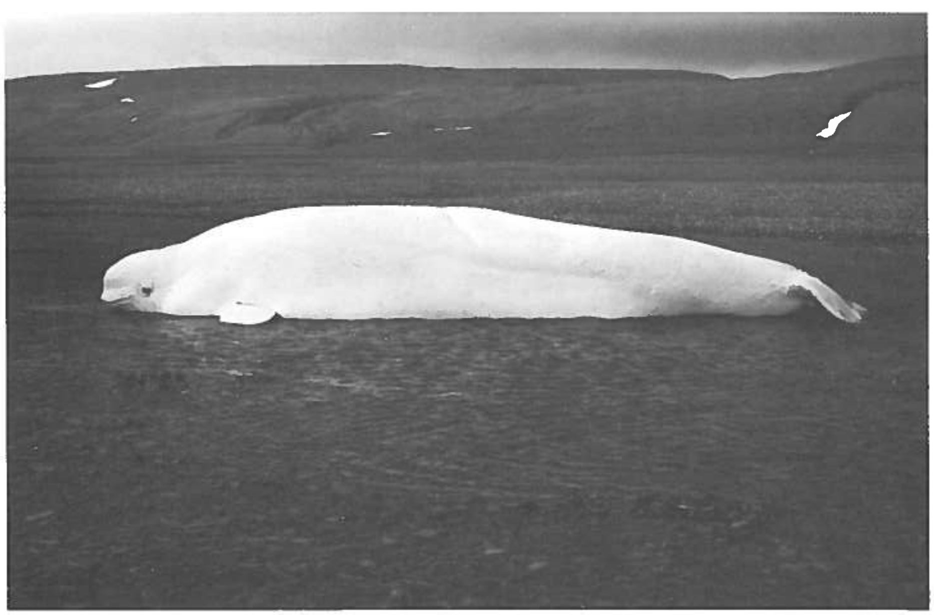
In January and February 1984 and again in 1985, helicopters were used to tag grey seals at Amet Island and Ile Le Corps-Mort and also on the ice in Northumberland Strait and St. George's Bay. About fourteen hundred pups were marked with plastic rototags in 1984 and nearly 2000 in 1985. Production of young was estimated from data on tag returns obtained from the bounty kill of grey seals in the Gulf of St. Lawrence and from observations of young-of-the-year at Sable Island. Since experiments using double-tagged animals have shown only a small loss rate of tags (5%), and since all living pups at Sable Island have been tagged, it has been assumed that the majority of untagged seals taken for the bounty or observed at Sable Island must have been born on the ice in the Gulf or at other unknown breeding localities. The data from the two sources have been combined to give estimates of pup production of approximately 12 300 $\pm$ 2100 in 1984 and 16 000 $\pm$ 2500 in 1985. This wide divergence in estimates is obviously not a result of population growth (which is known to be increasing by about 12% annually at Sable Island), but is most likely to be a result of incomplete tag returns.

Whales

Canada is fortunate in that its Atlantic, Pacific and Arctic coastal waters are frequented by many species of large and small whales. Although the nation is no longer involved in commercial whaling, small whales such as the beluga and narwhal still figure prominently in the culture and economy of many native communities in the Arctic. In addition, there is an increasing interest in observing whales in their natural habitat. Canada affords many such opportunities. Heightened general awareness of whales and the plight of many species has resulted in growing public concern for their conservation. However, conservation can only be effective if it is based on sound knowledge of whale biology and a substantial understanding of the environmental requirements of whales. Research leading to well-informed resource management policies provides the only effective means of harmonizing potential conflicts. For more than three decades ABS has been actively involved in research on Canada's whale populations.

Beluga

The beluga, or white whale, is a small arctic toothed whale found throughout the north polar regions. It is slate grey to pinkish brown in colour when born, but changes to a bluish grey colour when immature and then a brilliant white in adulthood. There are five major stocks in the Canadian Arctic, plus an apparently isolated southern stock at the confluence of the Saguenay River and the St. Lawrence



Belugas are the most abundant whale species in the Canadian Arctic.

Estuary. ABS is actively involved in research on these animals in both areas.

Arctic populations: in the Arctic, belugas spend the winter in leads of open water within or near the edge of the pack ice. As the ice disperses during the spring and summer months they migrate from their wintering areas to certain river estuaries where they congregate in large numbers for six to seven weeks during mid-summer. The largest summer concentrations occur in western Hudson Bay and in the Mackenzie Delta. Lesser concentrations occur in the high Arctic, in southeastern Baffin Island, and along the coast of northern Québec.

Studies are being carried out on belugas in Cunningham Inlet, a river estuary on northern Somerset Island in Lancaster Sound where up to 1500 individuals are present from early July until mid-August. The extensive vocal repertoire of the beluga has now been well documented and studies on the relation between vocalizations and the activities of the herd are continuing.

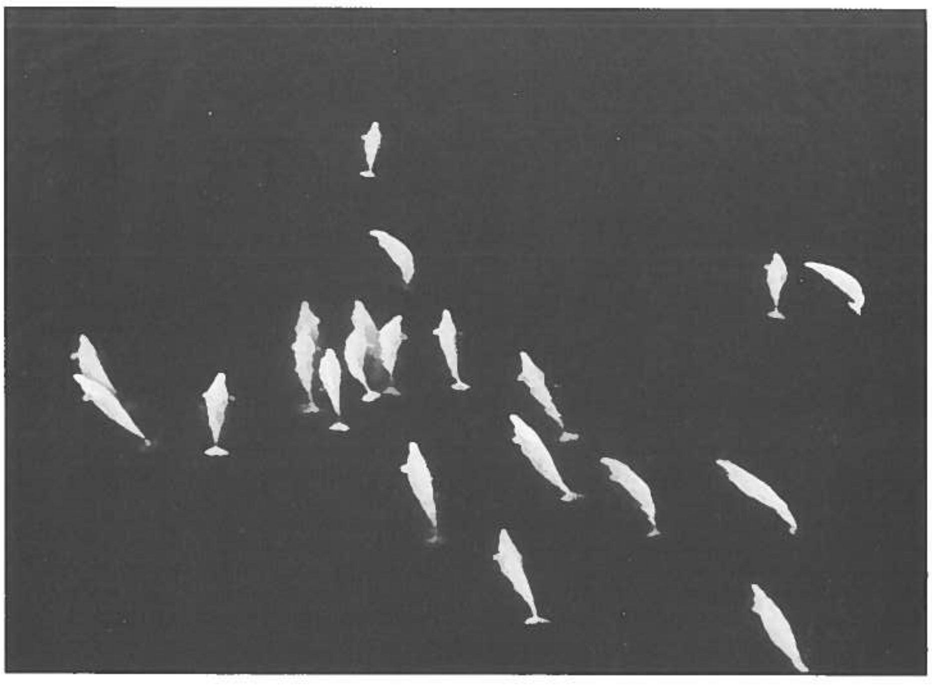
The World Wildlife Fund Canada, through its "Whales Beneath the Ice Program", has provided additional support for these studies, which have been expanded to include the much reduced stock of belugas found along the coast of eastern Hudson Bay, principally at the Nastapoka River. Since this stock, unlike the high Arctic one, is heavily exploited, the study will try to assess the effects of hunting on beluga behaviour. Further DFO studies currently underway are focusing on the age structure, female reproductive rate and size of this population as a basis for effectively managing the hunt. Similar studies are also being carried out from field laboratories at Wakeham Bay (Kangiqsujuaq) and Salluit on the stocks of belugas that frequent the coast of Hudson Strait in spring and fall. It appears likely that these animals are part of the population that is found in Hudson Bay in summer.

An observation tower set up in a tidal estuary is used to study beluga behavior at close range.

Studies of the catch history of belugas (Mitchell and Reeves 1981) include reconstruction of the exploitation of the eastern Hudson Bay and Hudson Strait populations. If sufficient information on annual hunting kills and losses can be obtained, these data will be used together with current estimates of population parameters to simulate the populations' responses to exploitation and their potential for recovery under different management regimes.

An important part of the estuarine research program on belugas is a physiological investigation of the dynamics of epidermal growth. Seasonal changes in epidermal cell proliferation rates and related behavioural observations appear to confirm the suggestion that belugas undergo a form of moult during their sojourn in the comparatively warm water of these estuaries.

In addition to these studies, ABS staff have made aerial surveys of belugas in Lancaster Sound, Prince Regent Inlet and Barrow Strait in the high Arctic. The results indicate a population of 6300-18 600 belugas summering in these areas (Smith et al 1985).



Each summer large numbers of belugas congregate in river estuaries in many areas of the Canadian Arctic.

Gulf of St. Lawrence population: the belugas in the St. Lawrence estuary form an apparently isolated resident population which has decreased a great deal due to hunting in the last 100 years. A recent historical study estimates an initial population size of at least 5000 animals, and suggests several factors that may have impaired the population's recovery since the 1950s, particularly over-exploitation and habitat degradation (Reeves and Mitchell 1984). The St. Lawrence population is now fully protected from hunting.

From 1982 to 1985 studies were carried out to determine the size of the population, its current trend and the effects of man's activities on the animals' welfare. The St. Lawrence estuary has much commercial and recreational boat traffic, and also receives polluted waters from the Great Lakes and the St. Lawrence River. These factors, combined with the relatively short period of ice cover, result in a markedly different habitat from the arctic localities being studied.

In August 1982 visual aerial surveys were conducted from a helicopter in an area about 100 km long, centered on the Saguenay-St. Lawrence confluence, which was believed to contain most of the animals in the population. This area was resurveyed by aerial photography in 1984 and again in 1985. Diving times observed from a small craft showed too high a variance to permit a correction factor to be estimated, but some upward adjustment of numbers was made possible by comparing repeated images of groups of whales in overlapping photographs. The three surveys gave mean estimates of population size between 400 and 530, but confidence limits were so wide (360-715 in 1982 and wider in 1984 and 1985) that it is unlikely that similar surveys in the next few years will be able to demonstrate changes in population size.

Gross annual reproductive rate was measured directly by counting calves at the end of the calving season in August. The figure of 8% obtained is equivalent to the lower end of the range estimated for arctic beluga populations. Estimates of the percentage of grey, immature animals are also low compared with arctic populations. It is not yet clear whether this difference is intrinsic (a similar low reproductive rate was recorded from beluga catches in 1938 and 1939) or is a result of human activities.

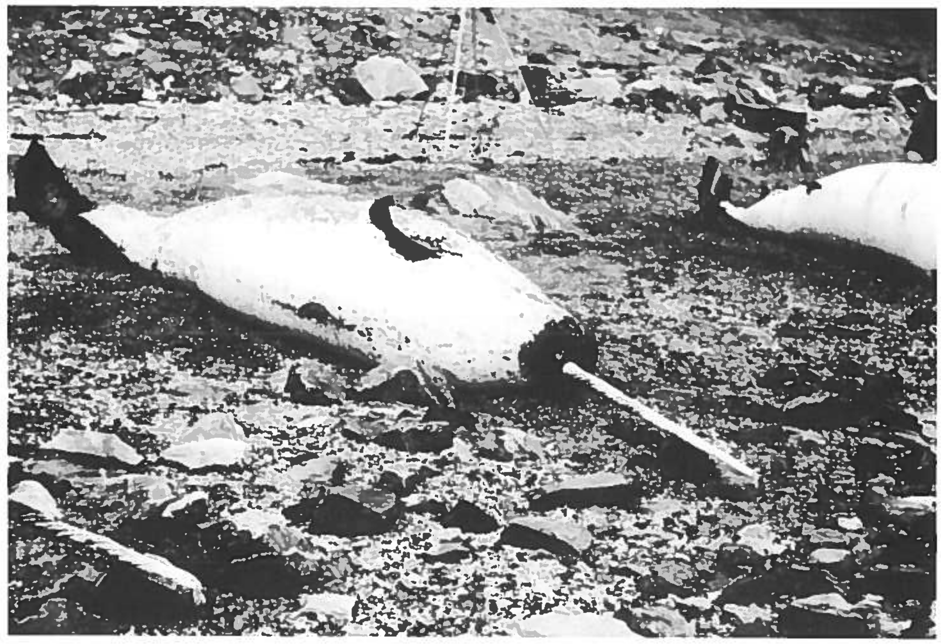
The possible effects of human activities are many (Reeves and Mitchell 1984), but two are of particular concern at the present time. Disturbance or deliberate harassment by small craft is an activity that is likely to be stressful to the animals involved, especially to calves and their mothers, but there is no way of assessing this at present. Of more concern is the widespread pollution by organochlorine chemicals, especially polychlorinated biphenyls (PCBs), which occur in very high concentrations in the tissues. From our knowledge of their effects on other mammals, such pollutants might be expected to lower the reproductive rate. This assumption could be tested by studying the reproductive condition of the dozen or so belugas stranded each year in the St. Lawrence estuary, but this would likely be a slow process since few are fresh enough for adequate autopsies to be carried out.

changes occur with age. Newborn young are slate grey in colour, but as they grow older large patches of white appear on the ventral surface and gradually extend up the flanks. In old animals, especially males, the body is almost white ventrally, with mottled flanks and a dark back and head.

In Canada, the narwhal is virtually limited to the eastern Arctic where it is found in close association with pack ice, especially in Davis Strait, Baffin Bay and Lancaster Sound. Recent aerial surveys carried out by ABS staff estimate that about 18 000 animals summer in Lancaster Sound and adjoining waterways (Smith et al 1985). An additional unknown number spend the summer in the Thule area of northwestern Greenland, in Foxe Basin, and in southeastern Baffin Island.

The biology of this species in Canadian waters has recently been described in detail by Hay (1984). Adult females appear to attain sexual maturity at 6 to 8 years, if the method of age determination based on growth layers in the unerupted tooth and lower jaw bone (dentary) is correct. Calves are born about mid-July as the narwhals are entering their summering areas. Breeding is believed to occur in mid-April, which indicates a gestation period of about 15 months. The lactation period lasts for about two years, resulting in a calf being produced about once every three years.

Narwhals appear to feed heavily in pack ice and at the edge of the fast ice, but very little in their summering areas. Arctic cod *Boreogadus saida*



The narwhal with its curious spiralled tusk is found in many areas of the eastern Canadian Arctic.

Biologists take measurements and tissue samples from a beluga recently captured by Inuit hunters.

Narwhal

The narwhal is perhaps the most remarkable of all the Odontocetes, or toothed whales, since the male bears an enormously elongated tusk up to 3 m in length that projects forward from the left upper jaw (Reeves and Mitchell 1981). Occasionally two tusks develop which are usually of unequal size. Females, though normally tuskless, may also develop one or even two tusks. As in the beluga, striking colour and Greenland halibut *Reinhardtius hippoglossoides* are the most common prey species. Halibut and other species such as polar cod *Arctogadus glacialis,* indicate that narwhals are capable of feeding in deep water.

Predation by both killer whales (Steltner et al 1984) and polar bears undoubtedly accounts for some natural mortality in narwhals. Also, entrapment in ice, which is known to occur occasionally (Mitchell and Reeves 1981, Sergeant and Williams 1983), probably has some impact on the populations, but the available data are insufficient to quantify this component of natural mortality.

During the last 10 years about 300 narwhals have been harvested annually in the Canadian Arctic (maximum quota for 21 villages is 542). The greater proportion of these are males which are valued for their tusks. Ivory prices reached a peak of nearly $200 per kilogram in 1982 but have since declined drastically owing to the ban imposed on the importation of narwhal ivory by the European Economic Community in 1983. Tusks now sell for between $150 and $300 depending on condition and length. The skin or muktuk, which is rich in vitamin C, is a preferred food of the Inuit, and some of the meat is used for human consumption and dog food.

A number of whaling stations operated on the East Coast until 1972 when Canada ceased commercial whaling.

Narwhal tusks are becoming increasingly valuable and are eagerly sought by Inuit hunters.

North Atlantic Whales

The North Atlantic, like other ocean basins, contains a fairly typical assemblage of whale species. These include the large, slow moving northern right whale, and the family of fast moving finner whales or rorquals. The latter range in size down from the 24 m long blue whale, through the fin, sei, humpback and Bryde's whale to the diminutive 8 m long minke whale. One former North Atlantic species, the gray whale, may have been extirpated by man as late as the 18th century (Mead and Mitchell 1984); however a substantial population remains in the North Pacific. All these species belong to the Mysticeti, or baleen whales, in which the teeth are replaced by a series of several hundred fringed, horny plates (baleen) which hang down from the roof of the mouth and serve as a strainer for sifting zooplankton and small fish. Among the toothed whales, or Odontoceti, the largest is the sperm whale which is abundant in the North Atlantic, as are many species of mid-sized and smaller odontocetes, the porpoises and dolphins.

During the period 1964-1972, a commercial whaling operation was conducted in Nova Scotia and Newfoundland, mainly for fin and sei whales. Nearly every whale caught was sampled to provide data for studies on age, growth, reproduction and feeding. Several cruises, totalling nearly 400 days of sea time were also undertaken in the Northwest Atlantic and Gulf of St. Lawrence to tag and census whales of all species, and to provide information on their distribution, abundance and migrations.

Following the closure of the east coast commercial whaling operation in 1972, a three-year study of the behaviour of blue, fin and minke whales was carried out at Les Escoumins, near the mouth of the Saguenay River in the St. Lawrence estuary. This was followed in 1976 by a brief expedition to the same location to attempt to track a whale by radiotelemetry. A radio tag was successfully implanted in a fin whale and its transmissions were received intermittently over the next 28 hours. Unfortunately the tracking boat and aircraft lost contact with it after this time (Ray et al 1978).

Further field studies of large whales at Les Escoumins were discontinued until 1985 when a refurbished launch was used to observe their feeding behaviour in detail and to identify the food organisms by direct sampling with nets. Information was also obtained on diurnal behaviour, to see if and when whales sleep, and on the daily and seasonal movements of individually identified whales.

Analysis of data from all these activities continues, while related studies are underway on the nature of growth layers in the hard tissues of various species of odontocetes, including the killer whale (Mitchell and Baker 1980) and the narwhal (Bada et al 1983).

Historical studies of whaling records are also being undertaken in order to obtain estimates of initial population size, to generate catch data useful in simulating populations under different levels of exploitation, and to aid in evaluating the current status of particular species.

Fin whales are abundant off the East Coast and in the Gulf of St. Lawrence and were the mainstay of the now defunct Canadian whale fishery.

Fin whale: while in operation, the east coast fishery took about 3500 fin whales, and the research program has been mainly directed toward this species. The western North Atlantic population is comprised of a Newfoundland/Labrador stock and a Nova Scotia stock. Those whales found in the St. Lawrence are thought to be a component of the Nova Scotia stock that migrates along the Scotian Shelf in spring and early summer. The population in the St. Lawrence was estimated in the early 1970s to be about 350 individuals, with about 2800 in the rest of the Nova Scotia population.

Approximately 500 fin whales were taken within hunting range of the whaling station at Sept-Iles between 1905 and 1915, suggesting that the population using these grounds during summer was at least this size in 1905. It is likely that most fin whales leave the Gulf in winter. They are probably driven out by ice, although winter mortalities suggest that some fail to reach open water before freeze-up.

Sei whale: this species is evidently restricted to one small population, separate from another population in the Labrador Sea, that makes early and late summer movements along the Nova Scotian coast. The Canadian fishery took over 800 sei whales from this stock between 1966 and 1972. Nine sei whales were tagged, three of which were killed in the fishery four and five years later. Calculations from these mark-recovery experiments indicate that the population numbered between 1400 and 2200 animals, whereas results of the census data indicate that there could have been as few as 870 whales at that time.

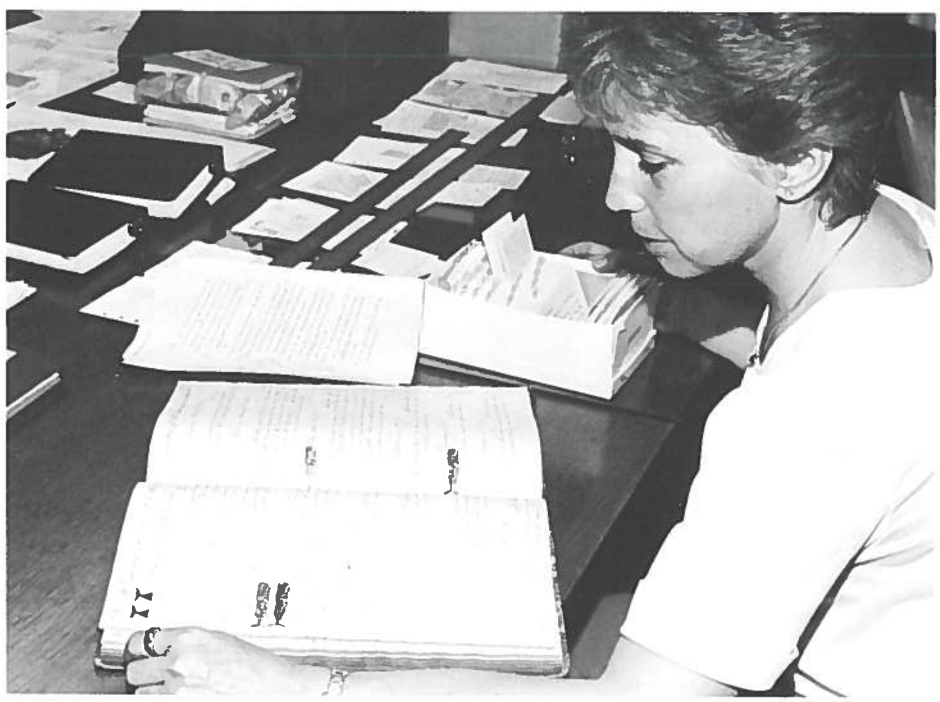
Humpback whale: estimates from censuses and tagging indicate that approximately 1400 humpbacks were present in the Northwest Atlantic in the 1960s, and perhaps 1800 in the early 1980s. A long history of the commercial exploitation of this species has provided the data to calculate a minimum population of approximately 4700 humpbacks in 1865, while population modelling suggests an even higher figure (Mitchell and Reeves 1983).

Blue whale: this species is seldom seen except in the estuary and Gulf of St. Lawrence where a small population in the low hundreds feeds close inshore during the summer and fall months.

Northern right whale: this species is also rarely sighted in surveys; however a small population occurs in the Bay of Fundy in August and September and in the vicinity of Brown's Bank, off the southern tip of Nova Scotia.

Minke whale: this, the smallest of the rorquals, is abundant inshore but hard to count and tag. A local fishery in Newfoundland was restricted to inshore waters and took relatively few animals.

Sperm whale: this, the largest of the odontocetes or toothed whales, is one of the most abundant species offshore. The commercial whaling operation landed relatively few sperm whales, all of which were males. Tag-



Anne Evely seeks information from old whaling logs that provide important information about population trends of these long-lived marine mammals.

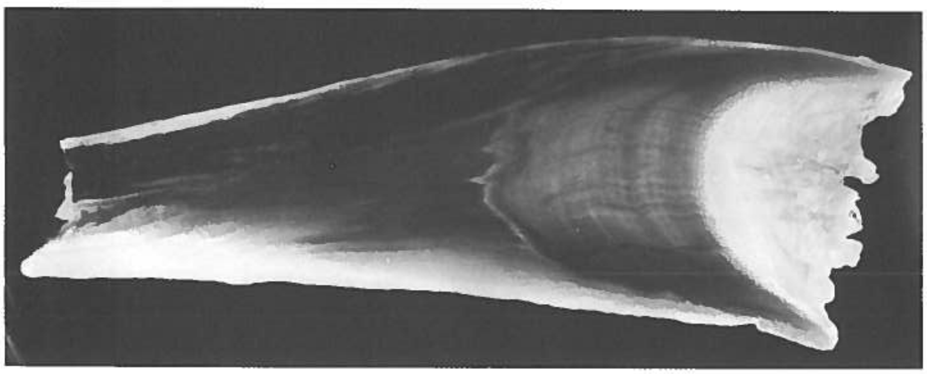
ging indicates that there may be only one stock or population in the North Atlantic; thus Canada was probably fishing the same population as Iceland and Spain. Most of the sperm whales taken off Nova Scotia were sexually mature males (Mitchell and Kozicki 1984, Mitchell 1983) on their northward migration to Davis Strait.

Bowhead

The bowhead, like its close relative the northern right whale, is a large, black baleen whale that attains a length of approximately 20 m. It is well adapted to living in ice and carries probably the thickest coat of blubber of any whale. The skin, or muktuk, is rich in vitamin C and is considered a great delicacy by the Inuit. Meat and bones have long been used by Thule Eskimos and their descendants (Mitchell and Reeves 1982) for food, fuel and housing.

Historically, bowhead whales were separated into four or five stocks in a nearly circumpolar distribution, but numbers are now much reduced from over three centuries of commercial whaling by European and American whalers.

The earlier population studies on North Atlantic whales conducted by ABS were extended in 1973 to include work on bowhead whales (Mitchell and Reeves 1980). Opportunistic vessel and aircraft surveys yielded few records of this species in the eastern Canadian Arctic, but a recent ABS survey in northern Baffin Island was able to locate a small concentration of bowheads in Admiralty Inlet, a few of which were photo-identified. Historical studies (Mitchell and Reeves 1981, Reeves et al 1983) indicate that, in the eastern Canadian Arctic, a once large population numbering in the tens of thousands had been fished out by pelagic whalers by about 1914, only a few hundred individuals of which remain in Davis Strait and Baffin Bay at the present time. In the Beaufort Sea in the western Canadian Arctic, early whalers (Reeves and Mitchell 1985) also exploited the bowhead population very heavily (Breiwick and Mitchell 1983) but few were taken by Canadian Inuit. At present the status of the species is uncertain since the western and eastern Arctic populations are probably recovering at only a very low rate. The finding of growth layers in the waxy accumulation in the ear of bowheads (Mitchell 1984) may allow their age to be determined, leading to more useful population models (Breiwick et al 1981).



Growth layers in the "earbone" of whales provide important clues to an animal's age.

ENVIRONMENTAL CONCERNS

The decade of the 1970s saw a dramatic increase in exploratory and developmental activities in the Arctic associated with the search for non-renewable resources such as hydrocarbons (oil and gas) and minerals, and the development of hydroelectric power. One of the first major projects proposed was the Mackenzie Valley Pipeline to carry natural gas from fields in the Mackenzie Delta and the shallow offshore waters of the Beaufort Sea to the major pipeline network in the south of Canada. A further development was the proposed use of icebreaking supertankers to transport liquified natural gas (LNG) and oil to eastern markets via the Northwest Passage through Prince of Wales Strait, Viscount Melville Sound and Lancaster Sound.

The possible impact of such enormous projects on the environment is a major concern to the Federal Government which has primary responsibility for the lands and natural resources of the Northwest Territories and Yukon and their offshore waters. This concern led to the establishment in 1973 of the Environmental Assessment and Review Process (EARP) as a formal mechanism for evaluating the environmental effects of major projects undertaken or supported by the Federal Government, or carried out on federal lands. For all arctic projects, the Federal Government acts as the initiator and the oil companies, for example, as the proponents. If it is determined that significant impacts might result from the proposed project, then the Government issues guidelines for the preparation of a detailed Environmental Impact Statement (EIS) which the proponents must prepare, usually after several years of field research. The EIS is then reviewed by the various government departments involved, including DFO. The resulting reports are presented to a Panel, appointed by the Federal Environmental Assessment Review Office (FEARO) for each project. The Panel calls for responses from government and the general public and reviews these at public hearings. The Panel then recommends whether the project should proceed or not.

In the last 15 years, ABS has been concerned with all stages of these major arctic projects for which expertise in marine science is required. The list includes the Mackenzie Valley Pipeline, the Arctic Islands Pipeline, the Arctic Pilot Project (shipment of LNG from Melville Island through Lancaster Sound), and exploratory oil drilling projects off the coast of Labrador and in Lancaster Sound, Davis Strait, Hudson Bay and the Beaufort Sea. The latter project, which is regional in concept, has involved the construction of artificial islands for much of its exploratory work, and proposes transporting oil either by a pipeline up the Mackenzie Valley, or by icebreaking supertankers through the Northwest Passage.

Apart from the need to prepare written information for the preparation of guidelines, the review of environmental impact statements and the development of departmental position statements, individual scientists have undertaken many field studies relevant to all of the projects listed. Such studies were first carried out by ABS in the early 1970s. Investigations on the marine ecology of the Mackenzie Delta and the Tuktoyaktuk Peninsula were followed by participation in the Beaufort Sea Project, in which studies ranged from the ecology of bacteria to the distribution of bowhead whales. This was followed by the Eastern Arctic Marine Environmental Studies program (EAMES) in Davis Strait and Baffin Bay, which involved ABS participation in studies of bacteria, plants, invertebrates, fishes and marine mammals.

A recently concluded collaborative study is the Baffin Island Oil Spill (BIOS) project, carried out at Cape Hatt, northern Baffin Island, as part of the Arctic Marine Oilspill Program (AMOP). This four-year project to investigate the effects of dispersants on oil spills involved one of the station's scientists with specialized knowledge of arctic marine bacteria.

It is worthwhile making a few comments about these essentially *ad hoc* environmental studies and short-term research projects. Initially the Federal Government was called upon to carry out some of these studies since the requisite expertise was not available elsewhere. The Beaufort Sea Project was a good example of joint studies between government and industry. This situation changed as private environmental consultants flourished and rapidly built up competence. It soon reached the point where their expertise in some areas became better than the Federal Government's. Obviously, this places the proponents in a stronger position to press their case unless government is willing to enhance its own competence in these areas. This has now been partly accomplished by funding under the Northern Oil and Gas Action Plan (NOGAP) which endeavours to fill in the gaps in government research programs relevant to arctic hydrocarbon development. The Arctic Biological Station received substantial NOGAP funding in 1984 for studies on ringed

Panarctic Oil

Tankers and other large vessels may one day be a common sight in the Arctic. There is concern about their environmental impact – particularly in the event of accidents.

seals, bowhead whales and general marine ecology, and is being supported currently for continuation of the ringed seal work.

Not all of the environmental studies undertaken by the Station have been concerned with hydrocarbon development. In 1973-75, a fisheries program was carried out on three of the rivers flowing into eastern James Bay, one of which is now part of the giant La Grande hydroelectric complex. More recently, samples of the under-ice plankton were collected off the mouth of Great Whale River in eastern Hudson Bay. The scheme for development of the hydroelectric potential of this river has now been shelved temporarily in favour of further development in James Bay. A proposal to divert some of the waters flowing into James Bay to meet the escalating agricultural and domestic needs of the United States has been publicized recently and will demand a substantial increase in government support of environmental programs if such a proposal is ever taken seriously.

While environmental studies related to hydrocarbon and hydroelectric development have required much of the Station's effort, some studies related to environmental pollutants have been carried out; these have mostly concerned marine mammals. Levels of man-made organic pollutants such as DDT and PCBs occur in only very small amounts in the tissues of arctic animals, as one might expect from their remoteness from agricultural and industrial activities (Addison and Smith 1974). However, heavy metals such as mercury are often found at surprisingly high levels. The ability of marine mammals to concentrate mercury and other metals in the liver, especially with increasing age, is a general phenomenon which appears to be unrelated to the activities of man (Smith and Armstrong 1975, 1978).

The situation is not markedly different for several species of marine mammals that are found in the St. Lawrence River (Sergeant and Armstrong 1973, Sergeant 1980). However, in the beluga, low levels of mercury have been found in the liver, but high levels of DDT and PCBs have been found in the blubber, with especially high levels in a suckling calf. It has been speculated that such contaminants are having a deleterious effect on the beluga population, but this has yet to be proven.

Following transfer of responsibility for freshwater fisheries research in the Northwest Territories to the Freshwater Institute in 1967, virtually all of the subsequent research carried out by ABS having management implications has concerned marine mammals. More recently, ABS has undertaken studies of fish populations in northern Québec.

In 1967 Canada had an active whaling industry on the East Coast based on fin, sei, humpback, sperm and minke whales. A similar operation on the West Coast closed down the same year, but east coast whaling remained active in Newfoundland and Nova Scotia until November 1972, when it was terminated by ministerial decree. Staff of ABS studied almost every whale landed in this "fishery", as well as carrying out sighting surveys and a marking program in the North Atlantic from the West Indies to western Greenland. The scientist in charge of the investigation played a major role in representing Canada on the Scientific Committee of the International Whaling Commission (IWC) by participating in many discussions and evaluations of northern hemisphere whaling issues. Canada was one of the original signatories to the International Convention on Whaling, which led to the formation of the International Whaling Commission shortly after the end of the Second World War. Canada withdrew from membership in IWC in 1982.

Although important in economic terms, Canada's whaling industry was overshadowed by the east coast fishery for harp and hooded seals. Management of the seal fishery was complicated by the fact that most of the hunting took place in waters just outside Canada's jurisdiction. Therefore all the early regulations were essentially gentlemen's agreements between Canada and Norway, the other principal exploiter of the seal resource. A major step forward in management procedures occurred in 1967 when the convention establishing the International Commission for the Northwest Atlantic Fisheries (ICNAF) was amended to bring harp and hooded seals under its aegis. From then on, management procedures were adopted annually by the Commission, based upon recommendations received from its standing committee on research.

In 1971 Canada and Norway entered into a bilateral agreement on the conservation of Northwest Atlantic harp seal stocks, which was amended in 1975 to include hooded seals, bearded seals and walruses. The resulting Canada-Norway Sealing Commission was primarily involved in negotiating the detailed aspects of management, such as allocation of quotas and opening and closing dates, but was also concerned with improving the humaneness of the hunt.

In 1977, with the extension of fisheries jurisdiction to 200 miles offshore by Canada and Denmark (Greenland), management of the harp and hooded seal populations that formed the basis of the fishery became the responsibility of the two countries. This change was marked by the replacement of ICNAF by a new organization, the Northwest Atlantic Fisheries Organisation (NAFO). In spite of the change in jurisdictional basis of the new organization, the mechanism for the generation of scientific advice has remained essentially unchanged. Following the establishment of Total Allowable Catches (TACs) of harp and hooded seals, and the allocation of the TACs between Canada and Denmark (represented by the European Economic Community), Canada convened meetings with Norway to discuss allocations within the Canadian fisheries zone. This was basically the management situation until 1983 when Norway ceased sealing in the Northwest Atlantic owing to the ban on the importation of seal skins to countries within the EEC. Canadian sealing virtually ceased in 1985 for the same reason.

The intense publicity given to the harp seal hunt since 1964 has placed a continuing burden on DFO to provide improved estimates of population size and sustainable yield. The Arctic Biological Station was responsible for virtually all harp and hooded seal research in the Department from 1955 until 1979. In that year, the Newfoundland Region took over responsibility for research on the Front off southeastern Labrador and northeastern Newfoundland while ABS carried on with studies in the Gulf of St. Lawrence.

The Northwest Atlantic Fisheries Organization is not the only body that deals with research and management of the seal fisheries. Since 1977 Canada has had a domestic scientific forum, the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC), which provides advice to management based on recommendations made by its various subcommittees, one of which is concerned specifically with marine mammals. Thus Canadian material presented at meetings of the NAFO Scientific Council is usually reviewed first by the Marine Mammals Subcommittee of CAFSAC. The subcommittee also reviews research proj-

A sealing vessel manoeuvers close to a herd of seals. The once lucrative sealing industry on the Canadian east coast has virtually ceased as a result of public opposition to the hunt.

Sealskins being pegged out on the arctic tundra to dry in the summer sunshine.

ects concerned with other species of seals and whales of specifically Canadian interest: the grey seal and the beluga, both inhabitants of the Gulf of St. Lawrence, are good examples. Both species are currently studied by ABS.

In the Northwest Territories, management and most research on marine mammals is wholly the responsibility of DFO's Western Region, based at the Freshwater Institute, Winnipeg. However ABS still maintains a program concerned with the ecology and population dynamics of the ringed seal, particularly in Barrow Strait and Amundsen Gulf, and the behaviour and vocalizations of the beluga, also in Barrow Strait and Lancaster Sound. Aerial assessments of both the white whale and narwhal populations have also been carried out in the Lancaster Sound area in recent years, providing basic information for management of these species.

In northern Québec, DFO is primarily concerned with marine and coastal fishes and marine mammals while the Provincial Government has the responsibility for managing freshwater and anadromous fishes.

Little research has been carried out in northern Québec by ABS in the last 10 years. Technically, the coastal waters of northern Québec are part of the Northwest Territories. In 1981 the Western Region ceded management responsibility for the coastal regions of northern Québec to the Québec Region. This was followed in 1983 by a significant increase in funding under the Québec Fisheries Development Program, which has permitted ABS to implement new programs on marine and anadromous fishes and marine mammals, and to support other programs already being carried out by the Research Department of Makivik Corporation, which represents Inuit interests under the James Bay and northern Québec Agreement. Data from these programs will be used in support of the management of such species as arctic charr, Atlantic cod, beluga and walrus.

Locally caught fish are an important component of the daily diet in many northern communities.

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ORGANIZATION AND STAFF 1980-1985

The Arctic Biological Station is a research laboratory of the Government of Canada, operated by the Department of Fisheries and Oceans (DFO). It forms part of the Québec Region of DFO and is responsible to the Director General at regional headquarters in Québec City.

Listed below are present and past members of the staff, as well as graduate students, summer students and contractors who have worked on projects of interest to us.

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L.G. McMullon (retired)

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Ménard, L., *Microbiology*
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O'Rourke, A., *Microbiology*
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Pontbriand, D., *Zooplankton*
Saumier, M., *Phytoplankton*
Poulin, R., *Zoobenthos*
Shea, J., *Physiology*
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Verburg, M., *Arctic Small Whales; Gulf of St. Lawrence Mammals*
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Wyszkowski, M., *Arctic Small Whales; Phytoplankton*

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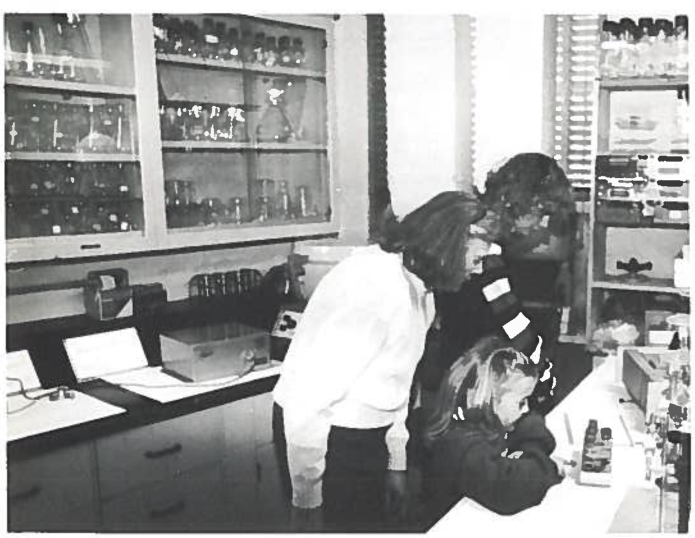

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