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in Review

2007

Canada

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Cover Photos © courtesy of Neil MacKinnon

These photos were taken in 2007 during an oceanographic expedition in the Barrow Strait aboard the CCGS DesGroseilliers. *The mission was part of the ongoing Arctic flow-through research: Canadian Archipelago Throughflow Study – Barrow Strait. On August 4, the team had just finished sampling water with Niskin bottles and a CTD* when this iceberg drifted close to their line.*

Back cover photo: Jim Hamilton, a scientist in Ocean Physics, in DFO's Ocean Sciences Division at BIO, aboard the launch as it approaches the iceberg

** A CTD is an instrument that measures the conductivity, temperature, and depth of water in a continuous profile. This CTD is also fitted with a device that measures fluorescent particles in the water.*

The photographer, Neil MacKinnon, is a Mechanical Technician in Ocean Physics, Ocean Sciences Division of DFO, at BIO.

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Introduction

The Bedford Institute of Oceanography (BIO) is a major oceanographic research facility, established in 1962 by the Government of Canada and located in Dartmouth, Nova Scotia, on the shore of Bedford Basin. It has grown to become Canada's largest centre for ocean research. Scientists at BIO perform research mandated by the Canadian government to provide advice and support to government decision-making on a broad range of ocean issues including sovereignty, defence, environmental protection, health and safety, fisheries, and natural resources. Integrated coastal and oceans management is an expanding activity of the Institute. Other activities, such as environmental planning, are also carried out.

Fisheries and Oceans Canada (DFO) is represented by four divisions within its Science Branch including the Canadian Hydrographic Service (CHS), five divisions of the Oceans and Habitat Branch, the Aquaculture Coordination Office, and the Canadian Coast Guard Technical Services for technical and vessel support. Together they provide scientific knowledge and advice on issues related to climate, oceans, the environment, marine and diadromous fish, marine mammals, shellfish, and marine plants. As well, they are responsible for the fish habitat management protection program, environmental assessments, integrated coastal and oceans management, species-at-risk coordination, and oceans planning initiatives.

Natural Resources Canada (NRCan) is represented by the Geological Survey of Canada - Atlantic (GSC Atlantic), Canada's principal marine geoscience facility. Its scientific research expertise focuses on marine and petroleum geology, geophysics, geochemisty, and geotechnology. The GSC Atlantic is also the source of integrated knowledge and advice on Canada's coastal and offshore landmass.

The Route Survey Office of Maritime Forces Atlantic, Department of National Defence (DND), supports ocean surveillance activities. Surveys are conducted in areas of the sea floor of specific interest to DND, in cooperation with the CHS and the GSC Atlantic.

In support of the Canadian Shellfish Sanitation Program, the Shellfish Section of Environment Canada (EC) conducts sanitary and water quality surveys and analyzes the samples at the microbiology laboratory at BIO.

Altogether, approximately 650 scientists, engineers, technicians, managers, support staff, and contractors from a variety of disciplines work at BIO.

This review highlights some of the ongoing research activities at the Institute as well as some of the activities dealing with the management of ocean uses.

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Climate Change Research

Climate Variability and Change in the Northwest Atlantic

Kumiko Azetsu-Scott, Glen Harrison, Erica Head, Ross Hendry, William Li, John Loder, Alain Vézina, Dan Wright, Igor Yashayaev, and Philip Yeats

Warming of Earth's climate system is now unequivocal and most of the observed warming since the mid-20th century is very likely due to increasing greenhouse gas concentrations in the atmosphere. This is the conclusion of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) released in 2007. Observations show increases in air and ocean temperatures, decreases in snow and ice coverage, and rising sea levels. The Labrador Sea plays a pivotal role in the changing large-scale ocean climate system. The Labrador Sea is also particularly vulnerable to climate change, since it lies in a transition zone between the Arctic to the north and the warm subtropics to the south. DFO scientists at BIO are monitoring climate change in the Labrador Sea while exploring the impacts of climate variability and climate change on the physical and chemical properties and the ecosystems of this important ocean region.

HOW OCEAN CIRCULATION IS AFFECTED BY AND AFFECTS CLIMATE CHANGE

Ocean circulation plays a key role in the global climate system as it transports and circulates heat throughout the world's oceans. In the low latitudes of the Atlantic, surface waters are warmed by solar radiation and become saltier through evaporation. Ocean currents like the Gulf Stream carry these surface waters northward to the Labrador and Nordic seas, where they lose heat to the atmosphere, becoming cooler and denser. This dense water sinks (deep-water formation), flows southward, and eventually returns to the surface (upwelling). An individual water parcel can take centuries to complete this loop. Through this process, known as the Global Conveyor Belt (Figure 1), the ocean circulation moderates the Earth's climate by redistributing heat from equatorial to polar regions.

The intensity of this large ocean circulation cell is governed by the rate at which surface waters can be converted into denser waters to feed into the deep return flow. Cold winter winds mix the upper layer of the ocean, homogenizing its properties and releasing heat stored in the water to the overlying atmosphere. Temperature affects water density: density increases as the temperature decreases. Vertical overturning, or convection, can contribute to the mixing when surface waters are cooled enough to become denser than the underlying layers. In severe winters the surface waters of the Labrador Sea can become dense enough to produce mixed layers that extend as

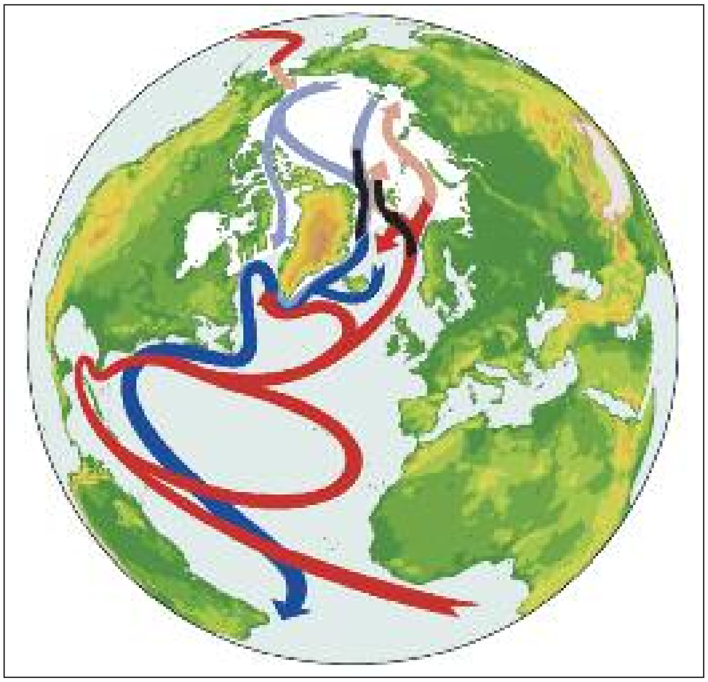

Figure 1. The Global Conveyor Belt representing the large-scale circulation in the Atlantic and Arctic oceans: upper level flows (red) transport warm and saline water from tropical regions to the north, cooling as they go; if surface water becomes denser than water at depth, deep convection occurs and contributes to a deep equatorward flow (blue); slow upwelling in the ocean interior completes the loop. (Diagram courtesy of Greg Holloway, Institute of Ocean Sciences, Sidney, B.C.)

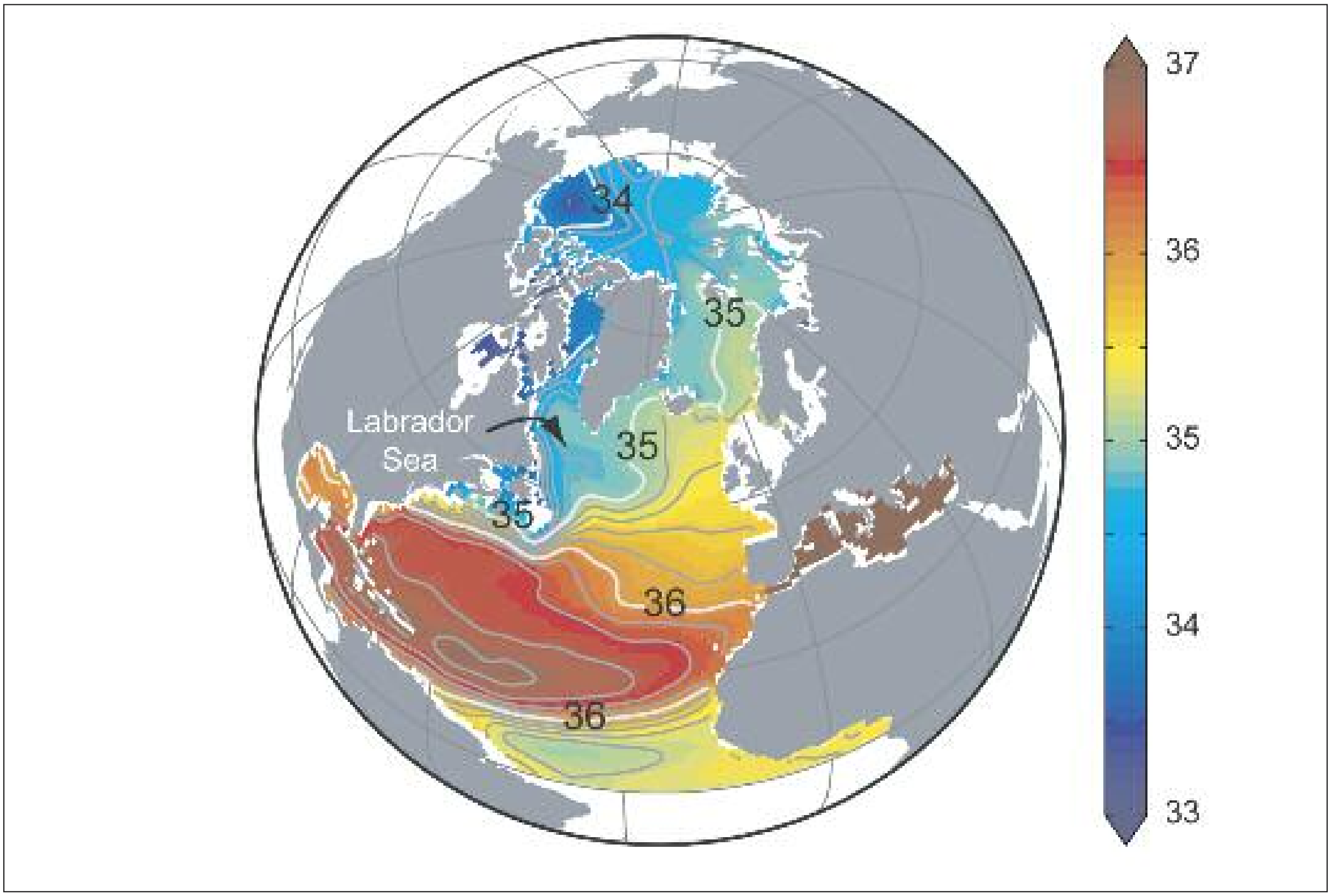

Figure 2. Salinity at 200 m depth: exports of fresh water and ice from the Arctic contribute to the low salinities in the Labrador Sea.

deep as 2 km. This deep convection forms a distinct water mass called Labrador Sea Water that spreads into the northern North Atlantic and the slope regions off eastern Canada. The depth of convection is strongly affected by the great variability in wintertime North Atlantic atmospheric conditions on interannual and decadal time scales. Successive severe winters over the Labrador Sea lead to the formation of deep, cold, and dense mixed layers while mild and moderate winters lead to shallower, warmer, and less dense mixed layers.

Salinity has an affect on water density as well: increasing the salinity also increases the density. The salinity of the upper layers of the Labrador Sea is determined mainly by a balance between low-salinity waters and ice from the Arctic Ocean in the north and saltier waters from the south. Increased fresh water input from the Arctic lowers the salinity of the upper layers of the northern North Atlantic, leading to decreased surface-layer density and a reduction in the intensity and depth of vertical overturning. The contour labelled 35 (35 grams of salt per kilogram of seawater) in the map of salinity at 200 m depth in Figure 2 marks a distinctive boundary between the fresh (and cool) waters to the north and west and the saltier (and warmer) waters to the south and east.

The recent IPCC report indicates that it is very likely that the global warming from increasing greenhouse gas concentrations will be accompanied by surface freshening at high latitudes as a result of increased precipitation and ice melt. Warmer temperatures and lower salinity would give lower surface-water densities, tending to reduce vertical overturning. Computer models suggest it is very likely that the Global Conveyor Belt will slow down during the 21st century. Although sea-surface temperatures in the North

Atlantic are generally expected to increase, a slower conveyor belt will result in a decrease in northward heat transport by the ocean circulation. Some models predict that in the midst of a generally warmer world the slowing of the ocean conveyor belt could actually lead to slight decreases in sea-surface temperatures in parts of the eastern North Atlantic.

While this article emphasizes the connection between climate and large-scale ocean circulation, the recent IPCC report projects other changes that will influence ocean areas important to Canada (*see* other articles in this Review). Warming is expected to be greatest at high northern latitudes and we can expect to see a continued reduction in summertime sea-ice cover in the Arctic and an increased export of icebergs from the glaciers of Greenland and northern Canada. Sea level will continue to rise both from the thermal expansion of a warmer ocean and from the melting of land-fast ice. Models also predict that mid-latitude storm tracks could move several degrees poleward, giving fewer but more intense mid-latitude storms with corresponding increases in extreme wave heights.

THE IMPACT OF CLIMATE VARIABILITY AND CHANGE ON MARINE ECOSYSTEMS

Most marine ecosystems cannot exist without light and mineral nutrients because these are required by phytoplankton (small marine algae) which are at the base of the marine food web. Phytoplankton live in the surface mixed layer where there is enough light for photosynthesis. The nutrients that they need for growth are provided by vertical mixing between the surface and deeper layers. Increasing levels of greenhouse gases, global warming, and resulting changes in the physical properties, structure, and circulation of the ocean will affect the structure and productivity of these ecosystems.

At a minimum, warmer ocean conditions will lead directly to elevated metabolism (photosynthesis, respiration, and reproduction) and changes in the geographic distribution of marine life. Ecosystem response to climate change, however, will be complex, non-linear, and difficult to predict. Lower surface-water densities in a warmer and wetter climate will tend to produce shallower mixed layers. Reductions in vertical mixing and exchange could reduce the supply of nutrients to the surface layers. Recent analyses of global trends in phytoplankton suggest that shallower mixed layers and reduced mixing (increased stratification) from climate change will enhance productivity at high latitudes (near the poles) by increasing light which will stimulate growth, whereas productivity at low latitudes (near the equator) will be diminished because of a reduction in vertical mixing of nutrients. Changes in circulation pathways could also affect the nutrient supply to a particular ocean area.

Ocean plants need carbon dioxide (CO_2) for photosynthesis, but the extra anthropogenic CO_2 added to the ocean from fossil fuel combustion does not affect ocean productivity because natural levels in the ocean are high enough to keep photosynthesis running at its maximum rate. On the other hand, the increasing amounts of atmospheric CO_2 taken up by the ocean form carbonic acid; there has been a related global increase of ocean surface acidity by approximately 30% over the past 200 years. Increased acidity could have negative impacts on marine shell-forming organisms and other species that depend on them. It could also affect nutrient availability, metal toxicity, and enzymatic and other biochemical reactions. There are serious concerns about the ability of marine ecosystems to adapt to such a rapid change.

It is clear that climate change is occurring and that there are potential impacts on ecosystems in ocean areas of importance to Canada. Our challenge is to identify, monitor, understand, and develop a capacity to predict these changes to help manage our marine ecosystems and marine living resources in an era of increased human impact.

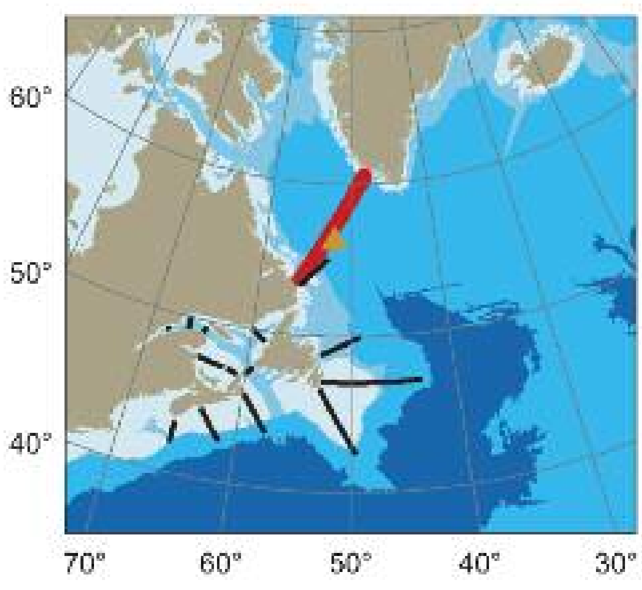

Figure 3. Monitoring activity in the Canadian Atlantic zone includes a grid of Atlantic Zone Monitoring Program sections and the highlighted Labrador Sea AR7W section occupied annually since 1990. Ocean Weather Station (OWS) Bravo monitored oceanographic conditions in the west-central Labrador Sea from 1964 to 1974.

BIO AND THE LABRADOR SEA

Since the founding of BIO in 1962, scientists from the Institute have carried out many studies in the Labrador Sea aimed at understanding the regional circulation and the deep convection that occurs during severe winters. Extensive measurements were carried out from CSS *Hudson* in 1966, a period which showed exceptionally warm and saline conditions and shallow wintertime mixed layers. Data from the U.S. Coast Guard Ocean Weather Station (OWS) Bravo (Figure 3) showed a renewal of deep convection during the exceptionally cold winter of 1971-1972. No regular monitoring of oceanographic conditions remained after the 1974 abandonment of OWS Bravo, but BIO continued to visit the area on occasional research cruises.

Starting in 1990, DFO Maritimes Science Branch began annual surveys of hydrographic and chemical properties in the Labrador Sea as a contribution to the World Ocean Circulation Experiment (WOCE). Our line of stations from Hamilton Bank on the Labrador Shelf to Cape Desolation on the Greenland Shelf (Figure 3) was designated as the WOCE Atlantic Repeat Hydrography Line 7 West (AR7W). The chemistry program was focused on the oceanic carbon cycle. Deep convection is the conduit for atmospheric gases such as carbon dioxide to pass from the surface mixed layer to deeper levels. This "solubility pump" is one way the oceans act as a sink of atmospheric CO_2 so atmospheric concentrations increase more slowly than they otherwise would. Measurements of dissolved and particulate biogenic (organic) carbon, bacteria, phytoplankton, and zooplankton have been included since 1994 to study the role of biology in the ocean carbon cycle and to detect and assess impacts of climate change on the regional ecosystems. Observations show that the carbonate shells from phytoplankton transport about half of the biogenic carbon from the surface layers to the interior of the Labrador Sea. This "biological pump" is also an important sink of atmospheric CO_2.

Primary productivity and plankton biomass in the northern North Atlantic, including the Labrador Sea, experience large-scale spatial and temporal variability linked to changes in the physical environment. Also, changes in both deep convection and horizontal circulation pathways can alter the supply of nutrients necessary for primary productivity. For example, Atlantic waters are high in nitrate, while Arctic waters are high in silicate. Recognizing the links between the Labrador Sea and regional Canadian ecosystems, the AR7W survey is now a core element of DFO's program of monitoring ocean climate.

The AR7W surveys support DFO's ecosystem monitoring mandate and deliver high-quality physical, chemical, and biological data to global ocean observing systems. They are a BIO contribution to Canadian and international scientific efforts to understand the ocean processes contributing to climate variability and global climate change.

RECENT FINDINGS

Physics and Chemistry

The resumption of regular Labrador Sea surveys on the AR7W line in 1990 was propitious because the 1990s proved to be an exceptional decade in the Labrador Sea. A sequence of severe winters in the early 1990s, peaking in 1993–1994, led to the deepest convection yet observed. The Spring 1993 survey (Figure 4) revealed that deep convection during the preceding winter had created a uniform pool of 2.8°C water extending deeper than 2 km. Recent winters have been exceptionally mild and the upper levels of the Labrador Sea have become warmer and more saline. By the time of the most recent Spring 2007 survey (Figure 4), the upper 2 km of the Labrador Sea had warmed from 1993 conditions by more than 0.5°C. The warming is related to reduced deep convection during the last 14 years, partly due to warmer air temperatures and reduced heat losses to the atmosphere, and partly due to increases in the amounts of warmer and more saline waters of Atlantic origin relative to cold and fresh waters of Arctic origin. One scenario of global warming has increased melting of Arctic ice driving a freshening of the northern North Atlantic but there is no sign of this in our Labrador Sea measurements to date.

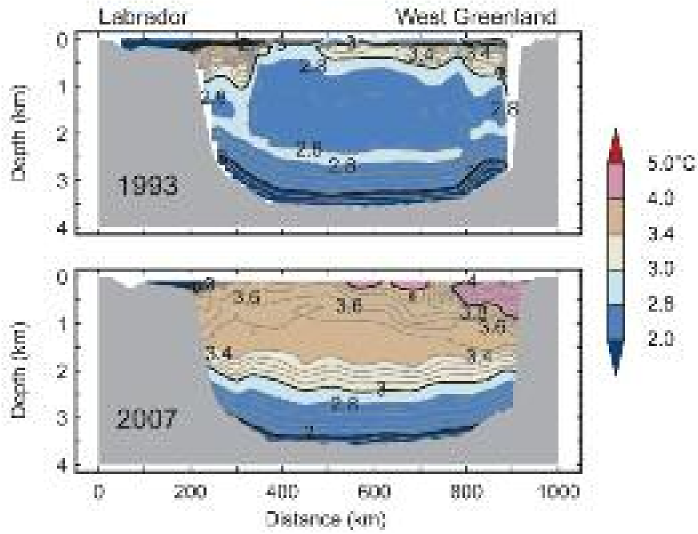

Figure 4. Labrador Sea temperature measurements show dramatic changes in the upper 2 km from 1993 to 2007.

Altimetric satellite measurements have detected an 8-cm rise in

Figure 5. This large tabular iceberg was observed during the 2007 occupation of AR7W. It probably originated in the glaciers on the east coast of Greenland, was carried into the Labrador Sea by the southward currents on the east coast of Greenland, and continued into the Labrador Sea with the northward-flowing West Greenland Current. This iceberg will eventually melt and contribute fresh water to the Labrador Sea.

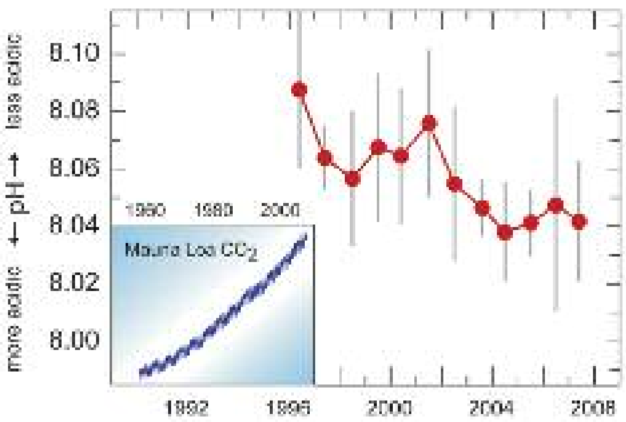

Figure 6a. The depth range of 150-500 m in the central Labrador Sea has become more acidic (lower pH) as it adjusts to increasing concentrations of atmospheric CO_2, such as measured at Mauna Loa by the Scripps Institution of Oceanography (inset). Acidity is expressed on a logarithmic scale in pH units, with more-acid conditions giving lower pH values. Pure water has a pH of 7 and pre-industrial ocean surface pH values are estimated to be about 8.2.

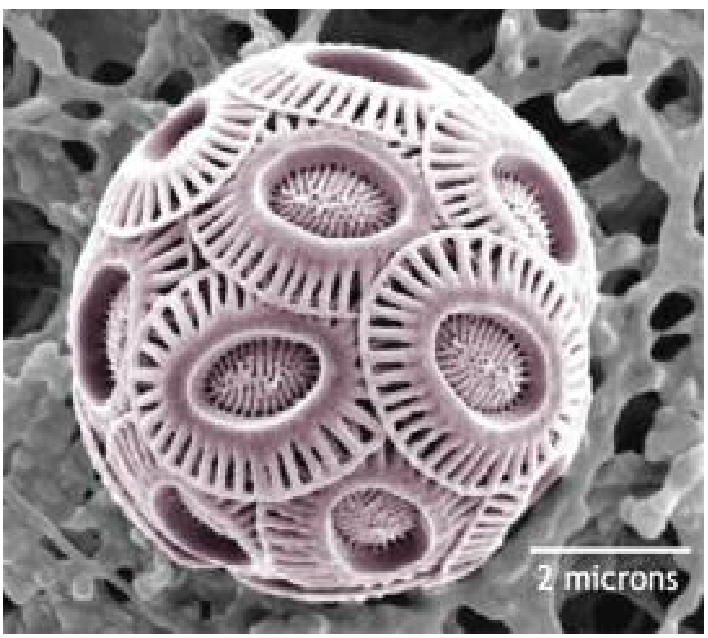

Figure 6b. Scanning electron microscope image of a single-celled photosynthetic marine organism (the coccolithophore *Emiliania huxleyi*) shows the organism has a calcium carbonate shell that is vulnerable to increasing ocean acidity. Such phytoplankton are at the base of the marine food web. A micron is one millionth of a meter, smaller than the naked eye can see. Photo courtesy of Dr. Markus Geisen, Marketing & Grafik

sea level in the Labrador Sea from 1994 to 2007. This is directly related to the thermal expansion of sea water associated with the observed warming. Increases in salinity have tended to increase density and decrease volume during this period; if salinity had not increased, the rise in sea level would have been 50% greater than actually observed.

CO_2 has a higher solubility at cold water temperatures, so cold Canadian waters may be particularly affected by the threat of ocean acidification. The Labrador Sea is a particularly good sink of atmospheric CO_2 because of the deep mixing that occurs there during winter convection. Measurements from the AR7W surveys show that the Labrador Sea has become noticeably more acidic over the past decade (Figure 6).

Although the recent trends to warmer, more saline, and more acidic conditions are striking, it is a challenge to separate long-term climate change from the energetic natural interdecadal variability in the Labrador Sea. For example, historical measurements of hydrographic properties from OWS Bravo and infrequent research surveys show that in the late 1960s the upper 2 km of the Labrador Sea were even warmer than presently observed (Figure 7). We need to continue to monitor the physical and chemical properties of the Labrador Sea and seek a better understanding of the processes that cause them to change.

Biology

Biological systems are inherently complex and include a large number of interacting components. It is difficult to separate cause and effect, making it a particular challenge to identify and interpret long-term ecosystem impacts under a changing climate. In high- latitude oceans such as the Labrador Sea, seasonal changes over the annual growth cycle cause enormous biological variability. This makes it difficult to detect year-to-year change in AR7W survey observations made within one short window of time every year. Remote sensing of ocean colour by the satellite-based SeaWiFS (Sea-viewing Wide Field-of-view Sensor) helps monitor the seasonal evolution of the microscopic phytoplankton that form the base of marine food webs and are key drivers of global biogeochemical cycles. Satellite maps showing ocean colour over space and time indicate that phytoplankton bloom in spring along the system boundaries (Labrador and Greenland shelves) and in late summer in the central Labrador Sea basin (Figure 8). In a similar way, maximum abundance of young zooplankton that feed on phytoplankton is observed along the shelf/slope boundaries in spring.

Despite this variability, recent warming trends in the Labrador Sea have been accompanied by detectable changes in biota and in oceanographic properties that influence their growth and distribution. A distinct shallowing in the depth of the spring/summer surface mixed layer has been observed over the past decade, resulting in more favourable light conditions for phytoplankton growth. Changes have also been observed in the inventories of nutrients necessary for primary productivity. Nitrate, a nutrient used by all phytoplankton species and essential for protein synthesis, has been increasing in the Labrador Sea while silicate, a nutrient used principally by diatoms for shell construction, has been declining. These

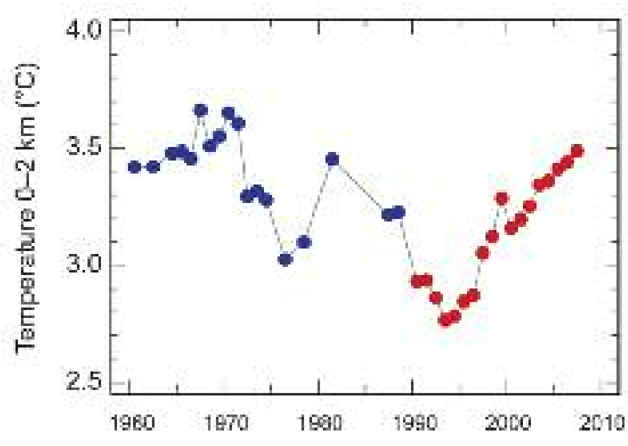

Figure 7. The mean temperature of the upper 2 km of the west-central Labrador Sea is nearing the record-high values of the late 1960s. (Blue circles represent historical measurements; red circles represent findings from AR7W.)

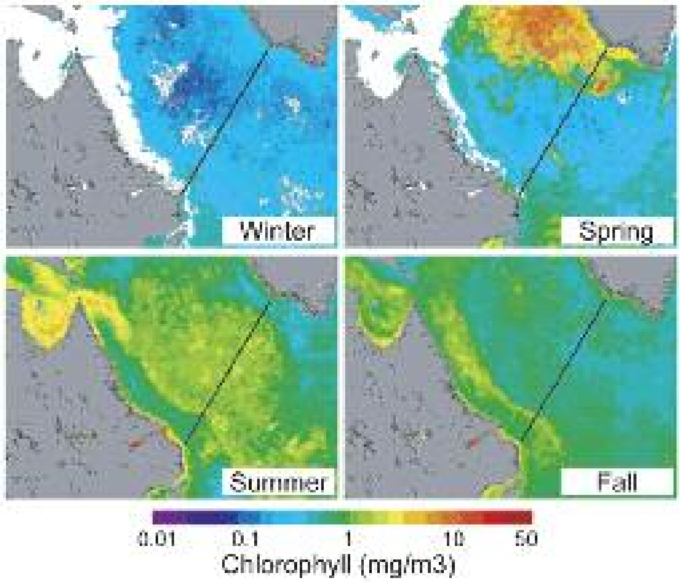

Figure 8. Shown are seasonal changes in the distribution of phytoplankton (chlorophyll a) in surface waters of the Labrador Sea (the line is the AR7W line).

changes in nutrient concentrations suggest that the relative contribution of Arctic waters (high in silicate) to the Labrador Sea is decreasing while the contribution of Atlantic waters (high in nitrate) is increasing, consistent with other evidence.

If light is the limiting factor, shallower mixed layers and reduced mixing would favour an increase in phytoplankton production and biomass. However, no significant changes in the overall biomass of Labrador Sea phytoplankton have been detected over the past decade of observations. This apparent paradox could be explained by a re-organization in the composition of the phytoplankton community. The dominance of silicate-requiring diatoms may be giving way to an assemblage that includes greater contribution from other cell forms. It is tempting to attribute the decline in diatoms to shallower mixed layers and changing nutrient conditions but the explanation is not yet clear. Perhaps the smaller forms are responding to more favourable light conditions (due to shallower mixed layers) or to decreased competition for other growth resources with the decline of larger forms.

Trends have been observed also in other components of the plankton food web. Whereas phytoplankton are confined largely to the upper 100 m, bacteria are found throughout the water column with highest concentrations at the surface. The overall abundance of bacteria has remained relatively stable for the last decade, but near-surface vertical carbon fluxes estimated by bacterial production have been declining. Warmer ocean waters might be expected to enhance bacterial production over time, so declining production probably indicates a response to other factors. Possibly the phytoplankton have changed the rate at which they produce the substances necessary for bacterial growth. This would be an example of how climate-related signals can be propagated by ecological transfers.

NEW DIRECTIONS

Monitoring and prediction technology

While traditional shipboard measurements will continue to be needed to provide high-quality hydrographic and chemical measurements as part of a climate monitoring system, emerging ocean-measurement technologies offer exciting new possibilities. Satellite altimetry has proved its worth in monitoring global sea-level change and will continue to be an important tool. A new international venture called Argo has recently met its ambitious goal of having 3,000 globally distributed, autonomous, profiling floats providing real-time measurements of temperature and salinity from the surface to 2000-m depth at 10-day intervals. Argo floats deployed in the Northwest Atlantic as part of DFO's Canadian Argo Program contribute to this international effort (Figure 9). The combination of altimetric satellites and Argo provides an unprecedented dataset for initializing and testing the next generation of global ocean and coupled models. The international Global Ocean Data Assimilation Experiment is now developing computer models to provide improved oceanic and atmospheric forecasts by assimilating both

Figure 9a. Adam Hartling (left) and Richard Boyce prepare to deploy an Argo float on board CCGS *Hudson* in October 2007. The"3000" marked on the float celebrates its part in the achievement of the International Argo Program's goal of having 3,000 active floats in the global ocean that was finally met in October 2007.

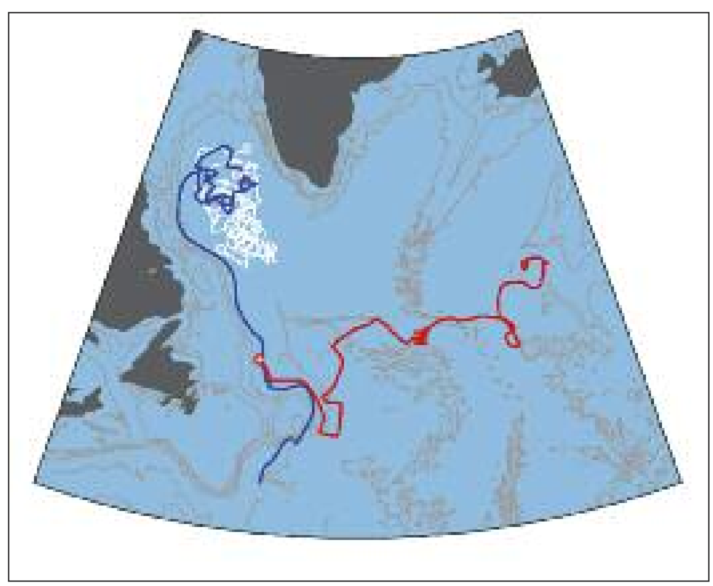

Figure 9b. Image indicates two-year-long trajectories of some of the Canadian Argo floats launched in 2005. Circles mark the launch sites of each float. Note the contrast between the distances covered by floats caught up in the fast flowing Labrador Current (blue) and North Atlantic Current (red) and the more confined circulation in the central Labrador Sea (white).

Figure 10. Copepods are small crustaceans that are an important source of food for fish and sea birds. *Calanus hyperboreus* shown here is an Arctic species also found in the Labrador Sea. Its body length of approximately 6.5 mm makes it one of the larger copepods.

Argo and altimetric satellite data.

Recent developments in ocean modeling at DFO Maritimes offer opportunities for interpreting past observations and predicting future changes. An ocean circulation model of the North Atlantic forced by realistic atmospheric variability has simulated the observed large-scale decadal variability in upper-level Labrador Sea temperature shown in Figure 6 and tested new biological models for representing seasonal variations in North Atlantic productivity. Finer resolution models that include the effects of eddies on oceanic conditions have been used to interpret seasonal variations in near-bottom conditions over the Labrador slope. A reanalyses project has started to test the ability of both fine and coarse resolution models to represent ocean changes on scales ranging from regional to global. These reanalyses will help develop weather and climate change prediction systems that couple our ocean models with Environment Canada's atmospheric models. We are also developing higher-resolution models for shelf regions that can be nested within these larger-scale models to interpret and predict ocean climate variability affecting coastal ecosystems.

Ecosystem models face additional challenges in that they need to represent complex systems with the capacity to change in response to changes in environmental forcing. A newly developed ecosystem model that attempts to capture some of the complexity and adaptive nature of ecosystems was recently used to hindcast ecological conditions in the Labrador Sea over the past 55 years. The simulation suggests a weak but statistically insignificant trend in phytoplankton biomass over the last 15 years which broadly agrees with observations. The next step will be to identify the model processes responsible for this trend (or absence of trend) and compare with inferences from real world observations. Only when we can match insights from the model with insights from the analysis of the observations (physical, chemical, and biological) will we be in a reasonable position to project future trends from these models.

Oceanography can be dangerous in winter in the north. In December 2002, off southern Labrador, the CCGS *Hudson* was caught in an overnight freezing spray storm that deposited about 30 tons of ice on her decks - not enough to capsize her, but enough to slow her down. The next day it was all hands on deck - seamen, officers, cooks, and scientists - to beat, chip, and shovel the ice off, so that she could safely resume her homeward journey.

A Need for Predictions of Climate Change and Potential Impacts

Understanding and predicting ocean climate change is of particular importance in the Northwest Atlantic because it is a region where there may be competing influences from large-scale atmospheric changes and changes in the ocean's overturning circulation, including Arctic outflows. Multiple branches of the Labrador Current that flow equatorward off eastern Canada provide efficient conduits linking the North Atlantic overturning circulation, Arctic outflows, and continental shelf regions extending from Baffin Bay to the Gulf of Maine. Studies are needed to identify how well this complex oceanographic regime is represented in coupled atmosphere-ocean models presently used to provide large-scale climate change scenarios. Reliable projections of changes in shelf waters and the coastal ocean will require regional models that downscale from improved larger-scale models.

From the perspective of ecological impacts, emphasis in the future will be expanded to consider not only how climate will affect and be affected by the local oceanography and ecosystems of the Labrador Sea, but also how oceanographic and ecosystem changes in the Labrador Sea will influence downstream processes and properties. For example, changes in water mass properties and circulation of Arctic and Atlantic waters entering and exiting the Labrador Sea strongly influence the composition and production of Labrador Sea zooplankton populations that, in turn, contribute to the composition and production of zooplankton on the Newfoundland and Nova Scotia continental shelves. How climate change will affect these large-scale communications is at present unknown.

Figure 11. A daylight arrival at the eastern end of the 2006 AR7W mission allowed the ship's company this view of the rugged terrain of Cape Desolation on the West Greenland coast.

SUMMARY

Predicting climate change and its impacts on the ocean waters and marine ecosystems affecting Canadians is a formidable scientific challenge. Describing and understanding recent and ongoing changes provide an essential foundation for developing the models to make these predictions. DFO's ocean climate monitoring programs contribute to this foundation with a perspective that includes our regional Atlantic Canada ecosystems, the larger North Atlantic ecosystem, and the global climate system.

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IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. (http://www.ipcc.ch/ipccreports/ar4-syr.htm)

Changes in Arctic Sea Ice and Ocean Fluxes Passing through the Canadian Arctic Archipelago

Simon Prinsenberg, Ingrid Peterson, and James Hamilton

It is now generally accepted that as part of climate change, the extent and thickness of Arctic sea ice are decreasing. Indeed, the extent of Arctic ice in September 2007 was the lowest in the last 30 years, the period for which satellite imagery was available to accurately document it. In addition, for the first time over that 30-year period, all three Northwest (NW) Passage routes through the Canadian Arctic Archipelago (CAA) were ice free for several weeks in 2007. Through a mooring and modeling program, DFO's Ocean Sciences Division personnel are investigating the interaction of the ocean and ice environments of the CAA with the atmosphere and are simulating the changes in these environments due to climate change and the impacts of these changes on navigation, the marine ecosystem, and the lifestyle of Arctic indigenous people.

Normally, the eastern part of the NW Passage within the CAA becomes ice free in August and September and is used for domestic shipping to re-supply eastern communities of Canada's northern Arctic. The western section of the NW Passage has until 2007 remained mostly

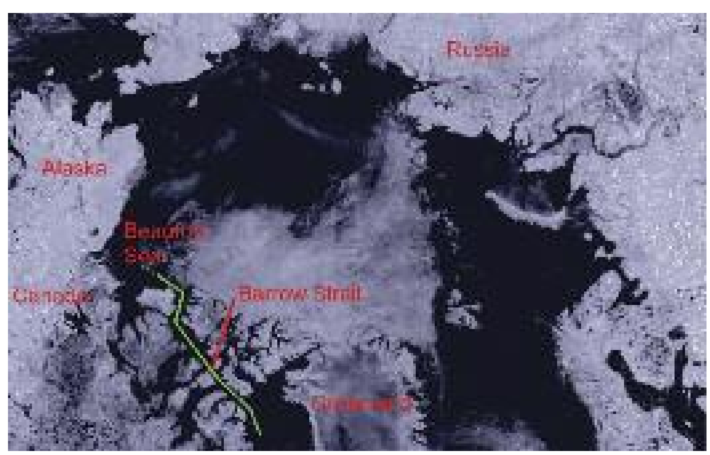

Figure 1. Composite image of September 4, 2007, showing the summer minimum Arctic sea-ice extent of 2007 including the ice-free NW Passage (green line) – image courtesy of W. Chapman, Polar Research Group, University of Illinois (http://arctic.atmos.uiuc.edu/cryosphere)

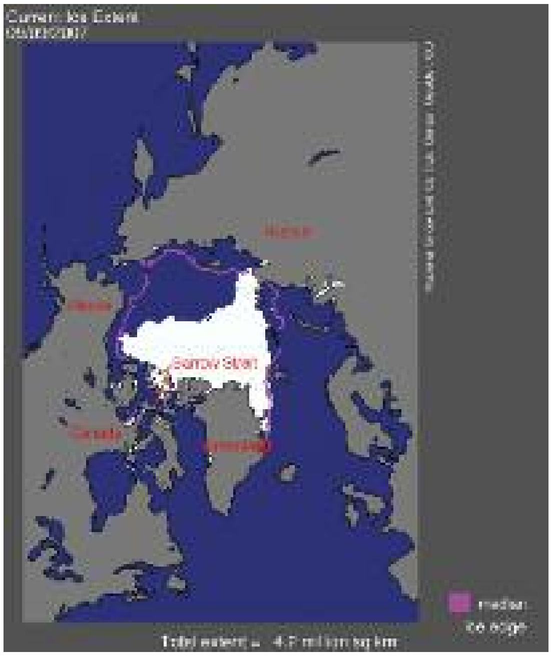

Figure 2. Arctic ice extent of September 9, 2007, compared to the September medium (pink line) for 1979-2000 (National Snow and Ice Data Centre, http://nsidc.org)

covered with first-year ice formed locally and with multiyear (MY) ice entering from the Beaufort Sea. MY ice has survived at least two summers' melt. It is thick and hard and represents a major hazard to shipping. Computer models suggest that if the Arctic sea ice continues to retreat north, as it has in 2007, the flux of MY ice into the region could stop, thus improving navigation through the NW Passage.

The satellite composite image from September 4, 2007 (Figure 1), shows the ice extent left in the Arctic after the severe 2007 ice reduction off the Alaskan and eastern Siberian coasts and the large ice transport from the Arctic through Fram Strait, located east of Greenland. The summer minimum ice extent of 2007 was one-third less than the 20-ice-year mean of 1979-2000 (Figure 2), a reduction in ice extent of 2.5 million km^2, equal to the area of the province of Quebec and the Atlantic Provinces. The cause of the large ice reduction is related to changes in the Arctic weather. An unusually high atmospheric-pressure region persisted over the western Arctic and Greenland and a low-pressure region sat over most of Siberia. This pressure distribution caused clear skies over the Arctic, increasing solar radiation that reached ice and water surfaces, and brought in warm air masses from the south between the high and the low pressure regions. Both processes enhanced the ice melt off the coasts of Alaska and eastern Siberia.

In addition, the remaining ice was pushed to the European side of the Arctic by the wind created by the pressure distribution, generating a large ice transport out of the Arctic east of Greenland. Freeze-up is expected to begin slowly in fall 2007 as the extra heat absorbed in the summer by the ocean will likely delay the onset of ice growth, resulting in thinner ice later in the season.

The summer minimum ice extent has been declining steadily over the past 30 years (Figure 3). For some years it recovered a bit, but overall the extent shrank 10.2% per decade. Researchers modeling the decline of the Arctic sea ice due to global warming were predicting that the Arctic could be ice free in the summer by the end of the 21st century. By 2005, model simulations and observations indicated that summer ice could disappear as early as 2050. After watching the record low of 2007, scientists are now considering that the Arctic might be ice free even sooner.

Mooring data collected at Barrow Strait in the CAA since August 1998 by BIO scientists are important to validate numerical models and to understand the interaction processes among ocean, ice, and atmosphere, and to understand the relationship between the Arctic surface water transport that passes through the Archipelago and the circulation and vertical ventilation of the north Atlantic Ocean. This knowledge and data will help us validate global numerical models that are used to simulate changes in the ocean and ice environments of the Arctic and Atlantic Oceans that are due to global warming.

At the mooring site, Barrow Strait is 65 km wide and reaches depths of 285 m. The mooring instrumentation includes Acoustic Doppler Current Profilers to monitor ocean currents and ice drifts, Upward Looking Sonars to monitor ice drafts, and current-temperature-depth (CTD) units to monitor water column properties at different depths. Tide gauges and the CTD profiler called ICYCLER, developed at BIO, also have been used. Eight years of data have been processed and show large seasonal and inter-annual variabilities in ocean and ice fluxes (transports). The average monthly volume transport over the eight-year time series peaks seasonally, in summer and in winter. The heights of the peaks vary in response to weather severity in the Arctic Ocean rather than local wind forcing in Barrow Strait.

Both mobile and land-fast pack-ice conditions occur for ten months of the year at the mooring site. (Land-fast ice freezes along the coast and extends from land to sea; it is not mobile.) Land-fast ice conditions occur normally in March and April and in some severe winters during the months of May and June. Land-fast ice conditions did not occur during the 2003 winter for the entire two-month period of March-April. During mobile ice conditions, the

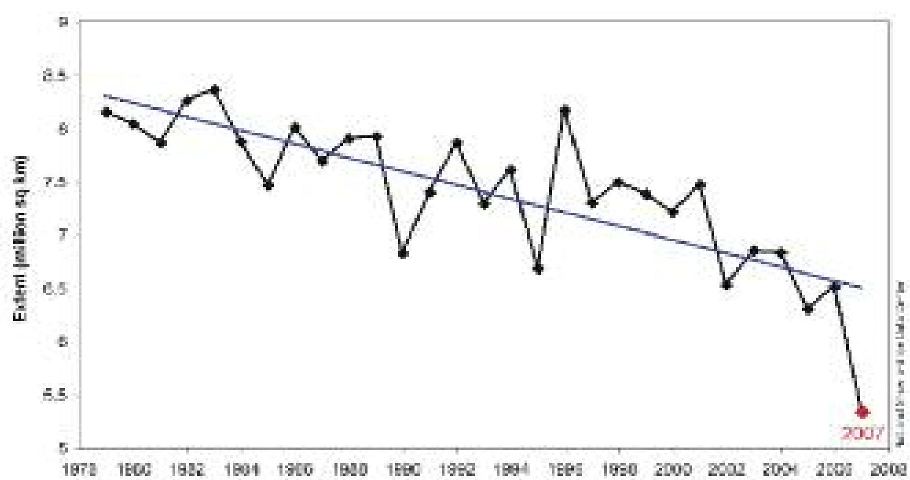

Figure 3. Arctic sea ice extent (September) shows that the rate of ice decline has increased significantly in recent years. (National Snow and Ice Data Centre, http//:nsidc.org)

August 2007, CCGS *Des Groseilliers* encounters an iceberg from Baffin Bay for the first time over eight summer surveys

mean velocities are up to 50 cm/sec and directed towards Baffin Bay moving along with the Arctic Surface waters passing eastwards through Barrow Strait. Maximum ice velocities can reach 150 cm/sec when tidal, mean, and wind-forced ice-drift components all act in the same direction. Maximum ice velocities towards Baffin Bay are generally greater than those towards the Arctic as they move along with the average eastward ocean currents.

Data on ice draft (ice thickness below the sea surface) are available for two ice seasons: 2003-04, when the pack ice at the mooring site remained mobile throughout the winter and 2005-06, when land-fast ice conditions occurred, thus reflecting a more normal ice season based on the past. With global warming, however, mobile ice conditions such as those seen in 2003-04 may become more prevalent. The overall maximum draft of ice ridges passing the mooring site was 24 m, but drafts more commonly were as much as 16 m for the 2003-04 winter and up to 13 m for the 2005-06 winter. The larger monthly maximum drafts attained in the 2003-04 season probably reflect the increased ridging that can occur when the area of mobile ice upstream of the site is larger, and can generate more and larger compression forces. Once land-fast ice conditions were established at the mooring site in February, 2006, the sonar monitored the same slowly growing ice.

The large Arctic ice reduction in 2007 was not expected, but scientists now suspect that the interaction between ice-melt processes, not just their sum, are weakening the sea ice and thereby are reducing its ability to cope with the warming of recent decades. It is hard to quantify the impacts of this year's record low ice extent on Arctic indigenous communities and wildlife, but it is likely that those species depending on sea ice, such as the polar bear, were affected. Coastal communities depending on coastal ice for their traditional methods of hunting and travel would have to adjust to the lack of ice. In the NW Passage, the delicate marine ecosystems that depend on the seasonal land-fast ice cover will be impacted. Biological production in these ecosystems is started by ice algae and promotes a benthic community, while areas with a mobile ice cover rely on phytoplankton as the base, resulting in pelagic communities. Thus the change in pack ice properties of the NW Passage might affect not only the local hunting routes (unsafe skidoo trails between islands), but also the availability of marine animals to hunt. The ice-free NW Passage of 2007 will force Canadian regulators and resource managers to deal with this issue much sooner than expected.

Deployment of an Upward Looking Sonar to monitor ice drafts

Deployment of an Acoustic Doppler Current Profiler to monitor ice drifts and ocean currents

"What is happening to my ice and seals?" The habitat and food of the polar bear will be compromised by the melting of Arctic sea ice.

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Creeping Up: Preparing for Higher Sea Levels in Atlantic Canada

Donald Forbes[1], Michael Craymer[2], Réal Daigle[3], Gavin Manson[1], Stéphane Mazzotti[4], Charles O'Reilly[5], George Parkes[3], Robert Taylor[1], Keith Thompson[6], and Tim Webster[7]*

Most people living, working, or playing along the coast in Atlantic Canada have little awareness of a long-term rise in sea level. Dramatic high water levels during major storms (as in January 2000 and December 2004 in the southern Gulf of St. Lawrence and Hurricane Juan in 2003 in Halifax) may lead to some surprise and concern, but these generally are considered isolated events. Yet geological evidence of rising sea levels is widespread along the coast and historical indicators such as Acadian aboiteaux (sluices) beneath saltmarsh deposits or submerged mooring rings at the 18th century Fortress of Louisbourg point to a long-term persistent rise in the mean sea level relative to the land. Tide-gauge records extending back to 1895 in Halifax and to 1911 or earlier in Charlottetown show the same pattern. Some of this apparent rise in sea level results from vertical land motion (subsidence) and some represents a true rise in the regional and global sea level.

The latest assessment by the Intergovernmental Panel on Climate Change (IPCC), the Fourth Assessment Report (AR4), *Climate Change 2007*, published in 2007 (http://www.ipcc.ch/), cites updated information on global sea-level rise over the past 50-100 years and provides the latest estimates of potential rise in mean sea level over the coming 100 years. For the global ocean as a whole, the latest literature assessed in the IPCC report indicates that sea level rose 0.17±0.05 m during the 20th century, an increase over the rate in the 19th century. Climate model projections of global mean sea-level rise (mean for 2090-2099 relative to 1980-1999) range from 0.18-0.26 m for the scenario of lowest greenhouse gas emissions to 0.38-0.59 m for the status quo. At the low end, this is equivalent to (or possibly less than) the present rate of rise. At the high end, it is less than projected in the 2001 IPCC Third Assessment Report, but still represents more than three times the rise observed during the 20th century. Furthermore, these estimates exclude the effects of any future acceleration in the flow rates of glaciers draining the Greenland and Antarctic ice sheets. For Atlantic Canada, the IPCC AR4 indicates that the regional sea-level rise related to ocean warming and thermal expansion may be very close to the global mean, but the geographical distribution of sea-level rise from glacier, ice-cap, and ice- sheet melting may be somewhat different, in part due to gravitational effects.

What does this sea-level rise mean for coastal residents and adaptation policy in communities around the Maritimes? Maritimers are already dealing with rising sea levels and, in some cases, are not well prepared. The challenge is likely to grow over coming decades, regardless of any mitigation achieved through cuts in global, national, or local emissions of greenhouse gases.

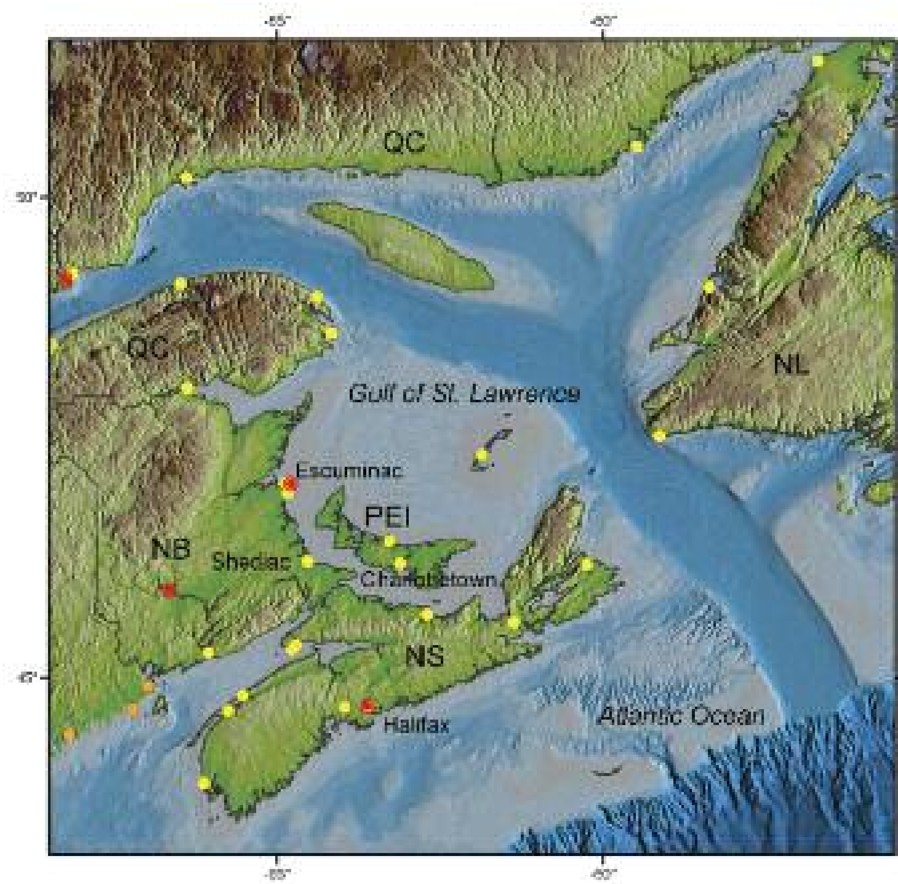

Figure 1. Study area in Atlantic Canada: map shows sites with tide-gauge records in Canada (yellow dots) and Maine, USA (orange dots) and sites with continuous GPS monitoring for land motion (red squares).

Staff from NRCan at BIO and elsewhere, in partnership with others in Environment Canada, DFO, provincial agencies, universities, and colleges, have worked over the past few years to evaluate risks and provide guidance to community planners and decision-makers in the three Maritime Provinces. Related work has been undertaken also in Newfoundland and Labrador and in Arctic communities in Nunavut and the Northwest Territories. One current project, a partnership with the Halifax Regional Municipality (HRM), aims to provide appropriate scientific advice for land-use planning, setback guidelines, minimum foundation levels, and security for critical infrastructure, as input to the forthcoming Halifax Harbour Plan. Using an extensive data set on coastal processes and erosion rates, this project will be extended to support natural-hazard, land-use, and sustainable-development planning along Nova Scotia's Eastern Shore, an area of accelerating suburban and exurban development.

Earlier projects were a multi-partner effort focused on Charlottetown and the central North Shore of Prince Edward Island and another along the southeast Gulf coast of New Brunswick within the jurisdictions of the Beaubassin and Kent South planning commissions. These documented wide-spread flooding and erosion hazards related to current rates of sea-level rise combined with surge and wave impacts from severe storms. Rising sea levels throughout the Maritimes are enhanced by regional subsidence, an ongoing legacy of past glaciation. The absolute rates of vertical land motion are determined using gravity and global-positioning-system (GPS) measurements. Differences in subsidence rates among sites can be estimated from differential rates of relative sea-level rise (which is the rate of sea-level rise against the land, measured by tide gauges, representing the combination of land motion and true sea-level rise). Rates of land subsidence as high as 20 cm/century (2.0 mm/yr) or more occur in parts of Nova Scotia but the subsidence diminishes northward through New Brunswick. Because the rates of land subsidence are of the same order as rates of sea-level rise, this has important implications for projections of future sea-level rise and associated impacts in coastal communities across the region. Tide-gauge records from Escuminac and Shediac, New Brunswick, were analysed in relation to equivalent record intervals in the longer time series at Charlottetown. The differences among the trends when normalized in this way provided a basis for estimating the crustal motion component at these locations. The relative sea-level rise ranged from 32 cm/century at Charlottetown to approximately 24 cm/century at Escuminac, corresponding to a difference of 8 cm/century in the rate of land subsidence between these places, assuming that the regional rate of absolute sea-level rise differs little across this distance in the southern Gulf of St. Lawrence (Figure 1).

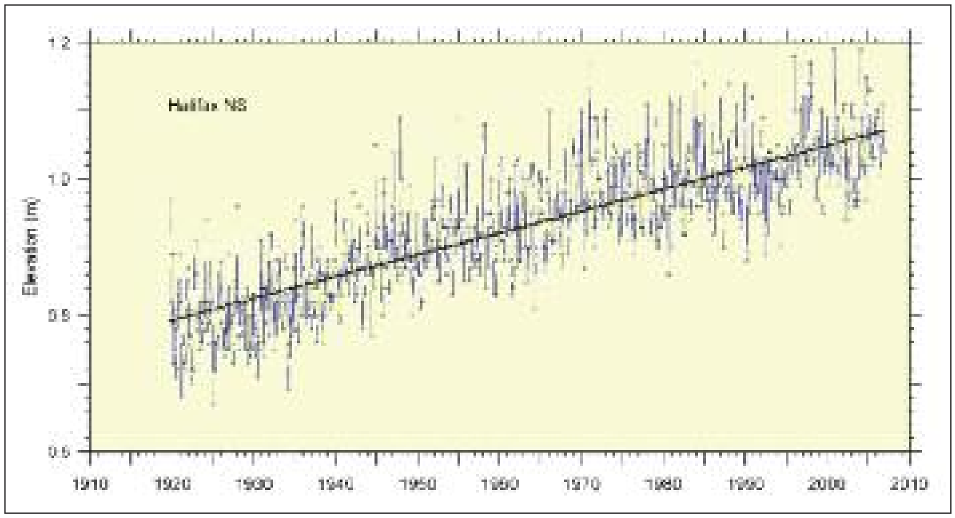

Figure 2. Monthly mean water levels recorded by tide gauge in Halifax Harbour, Nova Scotia, from 1919 to 2006: mean relative sea level (solid line) is rising at 32 ± 1.3 cm/century (3.2 ± 0.13 mm/year).

At Halifax, the rate of relative sea-level rise averaged 32 ± 1.3 cm/century (the same as Charlottetown) from 1919 to 2006 (Figure 2). Measurements of vertical land motion at a continuous GPS site near the front door of BIO (Figure 3) show that the crust in this area is sinking at 17 ±15 cm/century. This value is the latest International Terrestrial Reference Frame 2005 solution from the International Earth Rotation and Reference Systems Service. Other solutions for this site are similar with smaller errors and the uncertainty will diminish as the GPS record length is extended and systematic errors reduced in the coming few years.

Coastal flooding and other effects of severe storms are exacerbated by climate change and rising sea levels. Record flooding at Charlottetown and in southeastern New Brunswick occurred during a winter storm on January 21-22, 2000. Sea ice was present in the southern Gulf of St. Lawrence at the time, precluding much wave damage, but ice push onshore overtopped wharves and some coastal dunes, causing significant damage to homes, a lighthouse, breakwaters, and other harbour facilities (Figure 4) (http://gsc.nrcan.gc.ca/coast/storms/index_e.php). This event

Figure 3. GPS antenna on pillar is set in bedrock above the front entrance to BIO, overlooking Halifax Harbour. This active control station operated by the Geodetic Survey Division of NRCan has been recording the position every second on a continuous basis since 2002. Weekly solutions are computed and used to estimate horizontal and vertical crustal motion.

Figure 4. Navigation infrastructure was destroyed by ride-up of ice 40 cm thick during storm of January 21, 2000, in Robichaud, New Brunswick - photo courtesy of Michael Campbell, Environment Canada.

Figure 5. Aftermath of Hurricane Juan in Halifax Harbour: waves propagating up the harbour at high water undermined the outer track of the Canadian National rail yard along the Dartmouth waterfront, toppling rail cars and sending some into the harbour.

was followed by a succession of storms under open-water conditions affecting coasts in the southern Gulf of St. Lawrence (October 29, 2000; November 8, 2001; December 27, 2004; among others). High waves combined with storm-surge flooding caused severe erosion and damage to coastal properties, two national parks, harbour infrastructure, and coastal habitat for endangered species. In the Halifax region, on the outer Atlantic coast of Nova Scotia, the most severe storm in recent years was Hurricane Juan, which made landfall just west of Halifax on September 29, 2003, raising the water in Halifax Harbour to a record level as high waves were driven directly up the harbour, causing unprecedented damage to shore-zone infrastructure in the urban core (Figure 5). This storm also caused major damage in coastal communities to the east and west of Halifax, in addition to severe wind damage along a north-south swath across the province and on through Prince Edward Island.

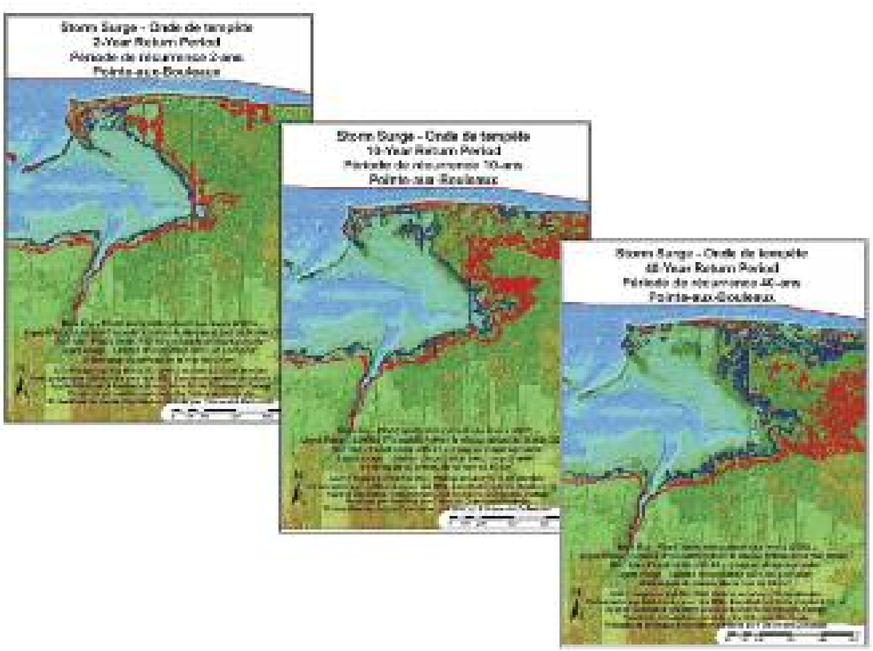

Figure 6. This example of flood hazard mapping in southeastern New Brunswick shows change in frequency for a given flood extent as a function of projected relative sea-level rise over the coming century (Source: Daigle et al., 2006).

The January 2000 storm in the Gulf of St. Lawrence and Hurricane Juan in the Halifax region represent benchmark storms for assessing future flood risk under rising sea levels and other climate-change effects. An approximate upper limit for coastal flooding can be estimated by superimposing the storm surges (observed water levels minus predicted tide) associated with these record storms on a high-tide level adjusted to predictions of local relative sea-level rise (local subsidence plus regional sea-level rise). This exercise faces a number of challenges:

- the range and uncertainty in the IPCC projections of global mean sea level, which depend on the global development pathway (scenario) and the range and error bars on the model predictions;
- potential for additional sea-level rise due to accelerated glacier outflow from the Greenland and Antarctic ice sheets;
- uncertainty in the ratio of regional sea-level response to the global mean sea level, which will vary with changes in the ratio of Antarctic to Greenland melt;
- uncertainty in the estimate of local subsidence.

Despite these challenges, we are now better able to estimate the likely range of increased sea level over coming decades up to 2090-2099.

In addition to higher extreme water levels, rising sea level also increases the frequency of flooding at less extreme but critical levels. This was observed in Charlottetown, where the threshold level for flooding along the waterfront was not exceeded in the 50 years of the tide-gauge record prior to the record storm of January 21, 1961, but was then exceeded seven times in the following 45 years.

Mapping of flooding hazards associated with rising sea level requires high-resolution topography that is not usually available from existing survey data. We have pioneered the use of LiDAR (airborne laser altimetry) in this region to create digital elevation models (DEMs) for large areas of Prince Edward Island, southeastern New Brunswick, and Nova Scotia. In conjunction with estimates of future water levels, these DEMs have been used to map flood hazards in coastal regions (Figure 6). The maps demonstrate that levels of inundation, including flooding of homes and critical infrastructure such as roads and bridges, will occur progressively more frequently as mean sea level rises. These maps provide a solid foundation for planning purposes, particularly where new development is proposed and planning strategies such as setbacks are required.

At the same time, it is important to recognize that shorelines are not stable. They change, sometimes rapidly, in response to severe storms or storm sequences, higher wave action with rising sea levels, and changes in sediment supply that may be triggered by shore development or protection as well as natural fluctuations in erosion and sediment transport. In some areas, waterfront development is going ahead in places where dramatic shoreline changes have occurred over the past 100 years. In most cases, neither the developers nor the future buyers are likely to understand the precarious state of the shoreline. Elsewhere, shoreline erosion is eating into roads and building foundations, providing dramatic evidence of coastal retreat (Figure 7).

Increasingly, planners, politicians, and the general public are coming to understand the potential impacts of climate change in the coastal zone and elsewhere. They are beginning to understand that our current vulnerability to storm events along the coast is likely to increase if appropriate adaptation measures are delayed. Vulnerability is a function of exposure to a hazard and the extent to which adaptation measures can be and are adopted to reduce the impacts. The 2007 IPCC AR4 included a number of key findings related to coastal vulnerability:

- Coasts will be exposed to increasing flooding and erosion risks over coming decades.
- Impacts of climate change on coasts are exacerbated by increasing human pressures.
- Adaptation costs for vulnerable coasts are much less than the costs of inaction.
- Sea-level rise has substantial inertia and will continue beyond 2100 for many centuries - this inevitable rise in sea level conflicts with current development patterns and trends.

We are working in partnership with planners in the HRM to build resilience to climate change into the planning process for Halifax Harbour and eventually for all coastal areas in the municipality, using the lessons learned in the Prince Edward Island and New Brunswick projects, as well as insights from the IPCC AR4. The philosophical basis for this partnership can be summarized in the following points:

- Information is the foundation for robust adaptation.
- Science can and should inform the planning process.
- We are already challenged by present climate and some conventional development practices are maladaptive.
- The environmental challenges will increase over coming decades.
- Climate-change adaptation needs should be integrated into everyday planning.
- Community engagement is critical.

Robust scientific information can help to increase coping capacity in the face of these challenges. The work described here is helping to build a solid foundation of science on which effective policy and planning decisions can be based to build resilience in our coastal communities.

Figure 7. Time sequence shows erosion threatening cottages in 1999 and 2000 followed by severe damage and removal of two cottages by 2004, North Shore, Prince Edward Island

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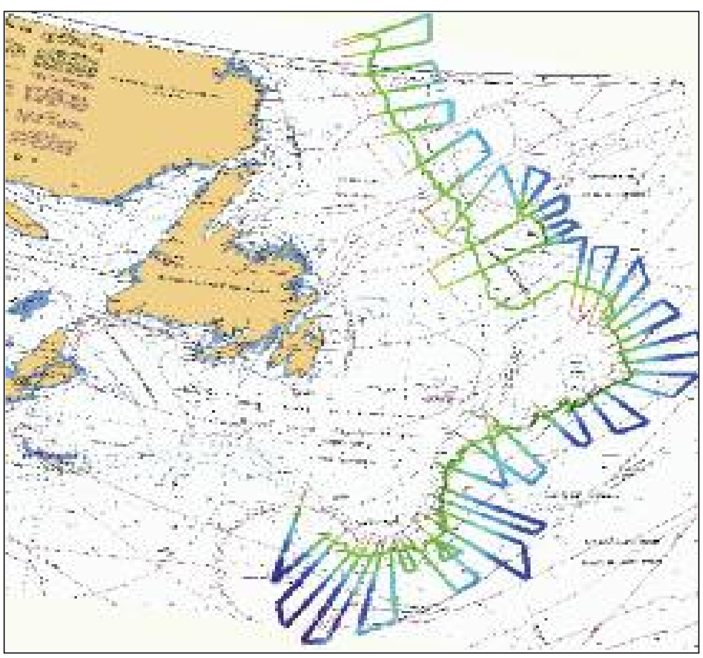
BIO Research in Partnership

Activities Toward Delineating Our Continental Shelf under Canada's UNCLOS Program

Richard MacDougall

The United Nations Convention on the Law of the Sea (UNCLOS) is a comprehensive attempt by the international community to regulate all activities in the world's oceans, including all aspects of the resources and uses of the oceans. For this, UNCLOS divides the seafloor into zones of national and international jurisdiction, with each coastal State's authority diminishing seaward. It recognizes the right of a coastal State to the resources of the seabed and water column offshore to 200 nautical miles (nm) and, under special circumstances, to the resources of the seabed of the continental shelf beyond 200 nm. With this goal of establishing the extent of its offshore jurisdiction beyond the existing 200 nm limit, Canada is in the process of data collection and research to establish the outer limits of the continental shelf in the Atlantic and Arctic oceans. This scientific component of Canada's UNCLOS program is being directed by an interdepartmental management board consisting of one director each from the Geological Survey of Canada and the Canadian Hydrographic Service and the Director, Oceans and Environmental Law, Department of Foreign Affairs and International Trade, with the program office located at BIO.



Long green line represents the 2500 contour; blue lines represent profiles every 30 nm.

UNCLOS both confirms the sovereign rights of coastal States in their continental shelf and provides the criteria for establishing the outer limits of the continental shelf. These can be established by applying whichever combination of two formulae of entitlement and two formulae of constraint is most advantageous to the coastal State. The entitlement formulae are commonly known as the bathymetric (60 nm from the foot of slope) and sediment (distance from foot of slope to the point where the sediment thickness is 1% of the distance to the foot of slope) formulae. The coastal State can also choose the most advantageous constraint formula, either 350 nm from the baselines of the Territorial Sea (points on the coast line defining the general direction of the coast line) or 100 nm from the 2500 metre depth contour.

A coastal State intending to establish the outer limits of its continental shelf is obligated to submit particulars to the Commission on the Limits of the Continental Shelf (CLCS) along with supporting scientific and technical data, within 10 years of that State's ratification of UNCLOS. Canada ratified UNCLOS in November 2003 and therefore must present its submission to the CLCS by the end of 2013. In making the submission, Canada is seeking international recognition of the area over which Canada has sovereign rights, for the purpose of exploring and exploiting the natural resources, including oil and gas, of the seabed and subsoil.

Canada estimates that its continental shelf beyond 200 nautical miles in the Atlantic and Arctic oceans covers approximately 1.75 million square kilometres or the size of the three prairie provinces combined. Of this, an area of approximately 0.75 million square kilometres is in the Arctic.

The 2004 federal budget provided $69 million over 10 years to cover the costs of the seismic (geophysical surveys that map geological structures beneath the seabed) and bathymetry (water depth) surveys needed over the ten-year period to establish the outer limits of the continental

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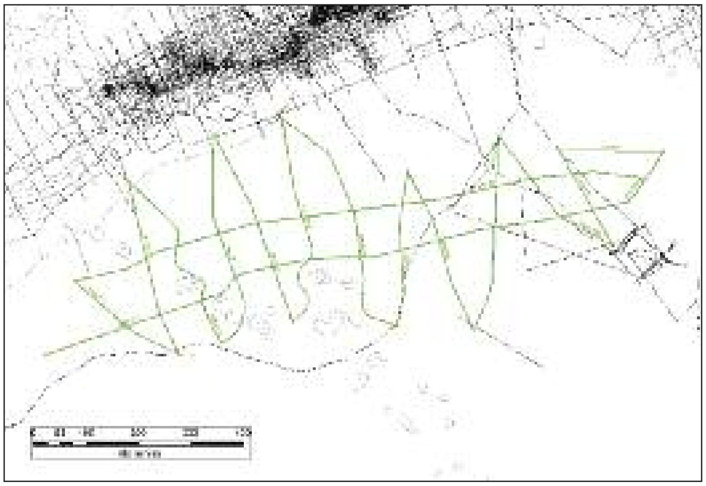
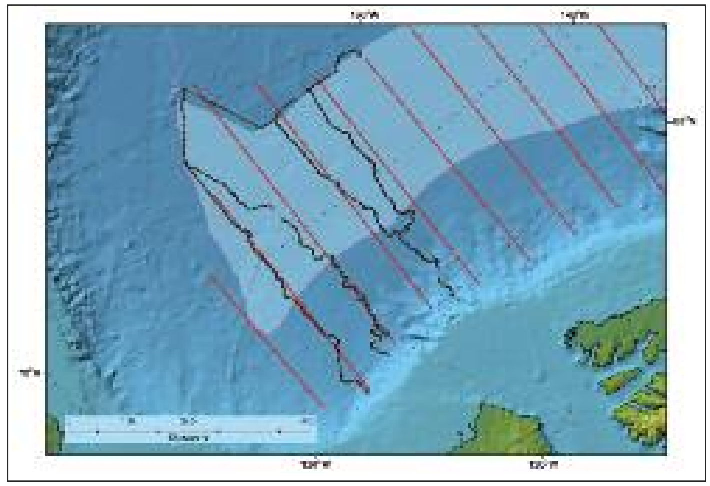


Green lines are 2007 seismic lines; black are pre-existing seismic lines.



Red lines represent planned seismic and bathymetric activity; black lines represent surveys achieved.

shelf. The data required includes determining the foot of the slope of the continental shelf, mapping the 2500 metre depth contour, and measuring sediment thickness to determine the point where the sediment thickness is 1% of the distance to the foot of the slope. Bathymetric and seismic surveys are also required to determine if submerged elevations are a natural prolongation of the continental shelf.

Data collection began in March 2006 with the LORITA (LOmonosov RIdge Test of Appurtenance) project, a joint Canada-Denmark expedition to conduct seismic and bathymetric surveys on Lomonosov Ridge. The objective was to collect scientific evidence that would help determine if Lomonosov Ridge was a natural prolongation of the continental shelf. Despite losing 65-70% of the season to bad weather, the primary objective of collecting the seismic data was achieved. Little bathymetry was collected due to weather.

Also in 2006, a $2 M contract was awarded to conduct bathymetric surveys off the Grand Banks of Newfoundland. Multibeam echo-sounder profiles were run perpendicular to the continental shelf every 30 nautical miles to supplement existing data in determining foot of slope. The 2500 metre contour was also mapped from southern Labrador to the Laurentian Channel. Applying the bathymetry formula and the 2500 metre depth contour plus 100 nm constraint formula will maximize Canada's continental shelf off the Grand Banks.

There were several initiatives in 2007, the second full year of data collection for Canada's UNCLOS project. A March-April bathymetric survey was based at CFS Alert to collect data not possible during LORITA. Time lost due to weather (primarily fog due to open water off Ellesmere Island) that impacted helicopter flying exceeded 95% and little of the primary objective was achieved.

A $6M contract for a seismic survey off the Scotian Shelf in June-August resulted in the collection of 6900 km of multi-channel seismic data to determine sediment thickness. This survey was designed to tie into and use all available existing seismic data. In this area, the sediment formula and the 350 nm constraint formula will be applied to maximize Canada's extended continental shelf.

Canada also participated in a Swedish-Danish International Polar Year project that included a survey north of Greenland which planned to collect additional seismic and bathymetric data on Lomonosov Ridge. The scientific work was conducted from the Swedish icebreaker, *ODEN*, escorted by the Russian nuclear icebreaker, *50 Let POBEDY*. Ice conditions were severe—100% covered in multiyear ice, 3-5 metres thick with pressure ridges to 6 metres—and after losing several seismic streamers, the vessels moved to plan B, an area off Greenland, and did not come into the Canadian waters.

A seismic and bathymetric survey in the western Arctic on board the CCGS *Louis S. St-Laurent* took advantage of light ice conditions and collected 3000 km of seismic and 7800 km of bathymetry data using the ship. The ship's helicopter was used to obtain 180 spot depths on a 20-km grid between the 50-nm-spaced ship tracks during a 6-week survey (September-October). In this area, applying the sediment formula and the 350 nm constraint formula will maximize the area of Canada's continental shelf.

Collaborative programs with Denmark continued and discussions were held with the United States and Russia concerning our respective programs in the Arctic and possible collaboration.

As of December 2007, data collection in 65% of the Atlantic and 15% of the Arctic areas has been completed and the project is on target. An evaluation of the project is being conducted in 2008 to determine if there need to be course corrections to mitigate risk and ensure that Canada will complete the mapping and have a credible submission ready for the December 2013 deadline.

The Cold, Harsh Reality of Marine Geoscience Research in the Arctic

Robbie Bennett, Dustin Whalen, John Shimeld

Over the past few years, interest in the Canadian Arctic has greatly increased and news stories about the region are appearing on an almost daily basis in the worldwide media. Topics garnering public attention include climate change, oil and gas exploration, international boundary disputes, sovereignty issues, and security concerns. The Canadian Speech from the Throne on October 16, 2007, relayed plans to address northern issues through an increased Canadian presence in the Arctic, scientific research, and improved infrastructure.

Map of Canada displaying the study area for Arctic marine geoscience research conducted by BIO scientists

Renewed Canadian interest in the Arctic is a step towards improving our knowledge of the north; however, working in the Arctic is much different from working in the rest of Canada. Sea ice covers the waterways of the Canadian Arctic for most of the year but there is also considerable seasonal variability of the ice cover, making the prediction of ice cover difficult. It is mostly dark in the Arctic for the months of November to February with an average winter temperature of -37° C and extreme lows of -62° C. Poor weather and visibility during the winter make air travel unreliable while shipping of supplies and equipment is time-consuming and expensive. Some areas of the Arctic are accessible by road only during the winter months when ice roads allow shipping of items that are too large to be carried by aircraft. Overtaxed or non-existent logistical support also contributes to the increased time and money required to work in the Arctic.

Added to these challenges is the immense scale of the Canadian Arctic. The Arctic comprises about 40% of Canada's landmass; it holds about two-thirds of Canada's total coastline; and numerous seasonally ice-covered waterways wind around 36,563 islands. The nature and size of the Arctic environment require the use of specialized research vessels such as icebreakers for the offshore areas and shallow-draft coastal vessels for field work in nearshore areas. Each of these types of vessels is in short supply in the Arctic and so they are sometimes hard to obtain and are expensive to operate. Expenses for the large icebreakers are further compounded by rising fuel costs and the fact that all Canadian icebreakers are stationed far away from the Arctic in Quebec City, Quebec; Dartmouth, Nova Scotia; or Victoria, British Columbia.

The icebreaker, CCGS *Amundsen*

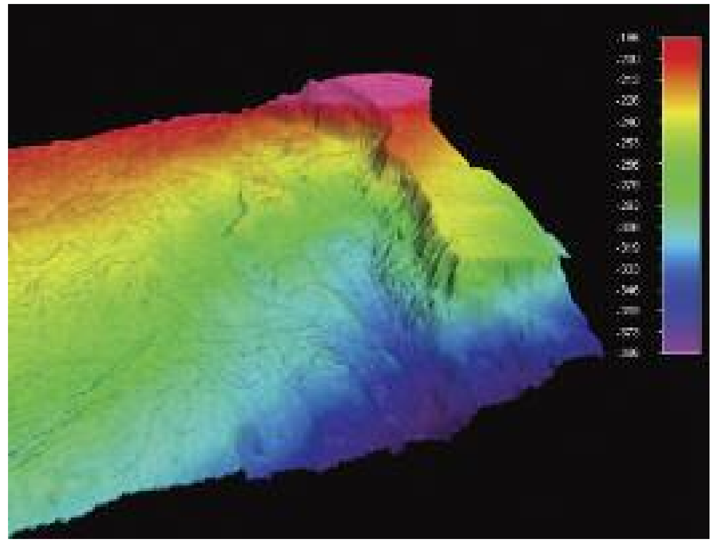
Even with all of these impeding factors, BIO researchers conduct successful field work in the Arctic every year. Two ongoing programs provide important data to support marine geoscience research relating to seabed geohazards, coastal erosion, and continental shelf mapping. These programs are the Geoscience for Ocean Management program run by the Geological Survey of Canada (NRCan) and the United Nations Convention on the Law of the Sea (UNCLOS) program run jointly by the Department of Foreign Affairs and International Trade, DFO through the Canadian Hydrographic Service (CHS), and NRCan through the Geological Survey of Canada (GSC).

The Arctic component of the Geoscience for Ocean Management program provides geoscience knowledge to support economic development of the Northwest Passage while maintaining environmental integrity. This work helps to fill coastal and marine geoscience knowledge gaps related to hydrocarbon exploration and production activities. Key gaps identified in recent consultations with stakeholders such as the National Energy Board, Inuvialuit, and the oil industry are coastal and nearshore stability, ice scouring, subsea and coastal permafrost, seabed foundation conditions, shallow gas hazards, artificial island stability, and benthic ecosystem sensitivity.

In the offshore areas of the Beaufort Sea and Northwest Passage, the Canadian Coast Guard ships *Nahidik* and *Amundsen*, and other vessels are used to collect various types of geophysical data and seabed samples. Both the *Nahidik* and *Amundsen* employ multibeam sonar technology that allows for high-resolution imaging of the seabed. This has been the main tool for identifying seabed geohazards in the Arctic since 2001. A number of seabed features have been identified that have implications for oil and gas exploration including ice scour, mud volcanoes, gas vents, and slope failures. Informed of these potential hazards by this research, oil and gas operators can engineer their operations and adopt safe practices that will preserve the Arctic environment through the prevention of exploration-related accidents.

Coastal and nearshore research encompasses much of the Arctic coastline; however, the bulk of the work is concentrated in the nearshore region of the Beaufort Sea along the coastline of the modern Mackenzie Delta. The work is focused on improving our understanding of coastal processes, rising sea level, subsidence, and potential geohazards in permafrost-affected areas. Field work is performed from the ice surface in the winter and from various small coastal vessels up to the 53-m-long CCGS *Nahidik* in the ice-free summer months. Sediment coring, ground-penetrating radar, and GPS elevation surveys to measure ground subsidence are performed in the winter to take advantage of industry infrastructure (ice roads and camps) in the area. However, summer field work often entails camping for long periods in remote areas accessible only by boat or helicopter. Multibeam, side-scan sonar, sub-bottom profiler data, and data from underwater oceanographic observing stations (current meters, ocean-bottom seismometers, and wave gauges) have identified a number of potential geohazards such as strudel scours (caused by a downward jet of water draining through a hole in the ice during the spring freshet), and enhanced our understanding of fine-grained Arctic delta processes.

UNCLOS establishes the 200-nautical-mile Exclusive Economic Zone within which coastal states exercise jurisdiction of the water column, seabed, and subsoil. Beyond 200 nautical miles, Article 76 of UNCLOS permits coastal states to submit claims for an Extended



Three-dimensional multibeam image of slope failure scarp on the Beaufort Shelf edge; the scarp is approximately 70 m high and is located in about 250-metre water depth. Image generated by Jason Bartlett of the Canadian Hydrographic Service.

Box coring through the ice in the Beaufort Sea onboard the *Amundsen*

Ice camp for UNCLOS researchers located north of Ellesmere Island in the Canadian High Arctic

Continental Shelf (ECS) within which they exercise jurisdiction over the resources of the seabed and subsoil (and not the water column). Researchers with the GSC and the CHS are acquiring, compiling, and interpreting geophysical datasets that will form the basis of the Canadian ECS claim. These datasets, which include measurements of the bathymetry and the thickness of sedimentary rocks along the slope, rise, and abyssal plain of the continental margin, will be used by the Department of Foreign Affairs and International Trade in the legal submission to the UN.

A range of geophysical methods are used to define the ECS including echosounding, seismic surveying, and measurements of the Earth's gravitational and magnetic fields. Acquisition of these data over the Arctic Ocean during the spring requires camps of three to twenty people on the sea ice, and these are among the most complex and expensive field operations ever mounted by either the GSC or CHS. Tens of thousands of kilograms of equipment, shelter, fuel, and people are mobilized to the sea ice using a range of fixed-wing aircraft and helicopters flying from the High Arctic Canadian Forces bases of Alert and Eureka. During late summer, some of the most powerful icebreakers in the world are used to operate within the thick multiyear icepack which, despite dramatic thinning in recent years, still poses extreme challenges along the Canadian Arctic margin. The Canadian Coast Guard Ship *Louis S. St.-Laurent*, the Swedish icebreaker *Oden*, the Russian nuclear icebreaker *50 Let Pobedy*, and the American icebreaker *Healy* have been used, or will be used, for acquisition of seismic reflection, seismic refraction, and bathymetry data in a range of conditions from open-water leads to nine-tenths multiyear pack ice.

Sea Ice off Canada's East Coast

Charles Tang

Off the east coast of Canada, sea ice begins to form in northern Baffin Bay in mid-October. As air temperature continues to drop with the approach of winter, the sea-ice cover spreads southward along the coast. Sea ice reaches northern Labrador in late November, and northern Newfoundland in mid-January. By early April, the southern ice edge reaches its southernmost position at 48°N before it starts to retreat north. The seasonal change of the mean ice concentration from December to July is shown in Figure 1. Between years, there is a large variation. In years of heavy ice, sea ice covers a large part of the Grand Banks. In years of light ice, sea ice does not reach the Newfoundland coast.

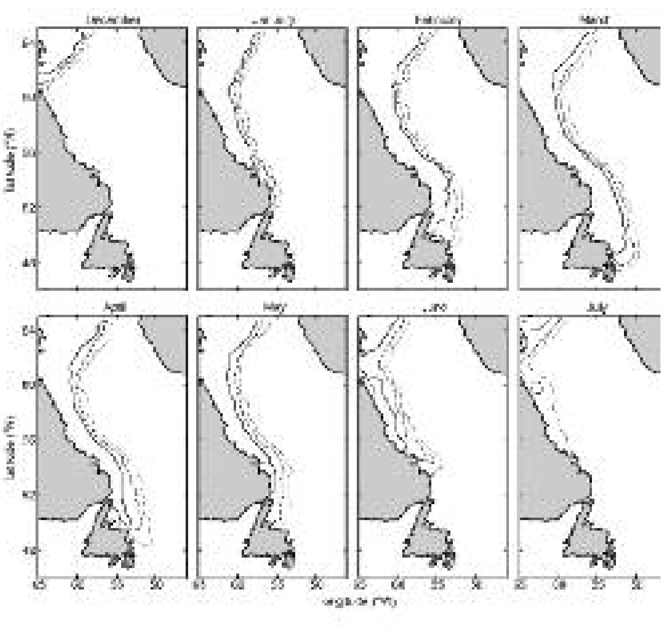


Figure 1: Shown is the seasonal evolution of ice concentration, observed at the beginning of the indicated months. On the scale of 0 (no ice) to 1 (complete ice cover), the lines represent: 0.1 (dotted), 0.5 (dashed), and 0.9 (solid).

The presence of sea ice in coastal waters can impose a threat to the safe operation of offshore oil and gas exploration and production, shipping, and fishing. A case in point is the Hibernia oil field in northeastern Grand Banks (47° N, 48° W). The oil field lies within the range of sea-ice limit. Sea ice can be found within 40 km of Hibernia approximately one year in two. The average and maximum lengths of ice stay are one week and nine weeks, respectively. The average thickness is 1 m. Sea ice is of great concern to the offshore platform operators of Hibernia. In the design of the offshore structure, both the response to extreme ice events and the behaviour under normal operating conditions must be considered. During production, a set of procedures including surveillance, forecasting, monitoring, and avoidance of sea ice and icebergs must be followed for safe operation.

The aim of east coast sea-ice research at BIO is to understand the thermodynamics and dynamics of sea ice that are important for ice formation, growth, melt, and drift. Based on our knowledge of the ice-ocean processes, the causes of the short-term, annual, and interannual variability of sea ice and the impact of the variability on the ocean are investigated. Another aim is to develop a capability to predict the ice cover and ice movement on different spatial and temporal scales. Understanding of the variability on time scales of 50 to 100 years can lead to improved estimates of the impact of climate change on ice condition.

Field observation, analysis of satellite data, and numerical modeling are the primary tools used by scientists to study sea ice. Field measurements can be carried out either from research vessels (Figure 2) or helicopters. Ice beacons deployed on ice are used to monitor the movement of ice floes. Temperature, salinity, and current profiles below sea ice can be obtained by lowering instruments through manually drilled holes in ice. The data are used to study heat, water, and momentum exchanges between ice and the upper ocean. Ice thickness can be measured *in-situ* or by an electromagnetic device towed by helicopter. Satellite data can provide information over a large area on a regular basis. Figure 3 is a satellite image taken on March 4, 1995, showing sea ice on the

Figure 2. Work on ice during a cruise to northeast Newfoundland Shelf: CCGS *Hudson* is in the background

Labrador and Newfoundland shelves and in the Gulf of St. Lawrence. Many interesting features can be found in the image. The picture shows that sea ice is primarily confined to the continental shelf. This is related to the fact that water in the open ocean is relatively warm due to winter convection, which mixes the surface water with the warm and salty deep water, resulting in the warming of the surface water and hence no ice formation. Ice floes blown off the shelf by offshore winds are quickly melted in the Labrador Sea water. The image also shows that the ice edge has many eddies of a few tens of kilometres in size. The structure reflects the unstable nature of the edge of the Labrador Current. The effect of the ocean currents on sea ice can clearly be seen at the eastern edge of the Grand Banks where a 150-km-long filament of sea ice hugs the shelf edge.

Numerical models have been developed to simulate and forecast sea-ice concentration, thickness, and movement over the shelf. The models are also used to study fundamental ice-ocean processes and interactions. Figure 4 shows ice concentration and ice velocity for March 19, 1997, from an ice forecast model. A storm centered at 50°N, 48°W passed the southern Labrador Sea with wind speeds up to 20 ms^{-1} in a cyclonic pattern. Wind is the major driving force of ice motion. The model simulation indicates sea ice on the northeastern Grand Banks moves eastward at a speed of 0.8 ms^{-1} (70 km d^{-1}). Such a high speed changed the ice condition on the northeastern Newfoundland Shelf very quickly. The information can be used by offshore oil, shipping, and fishing indus-

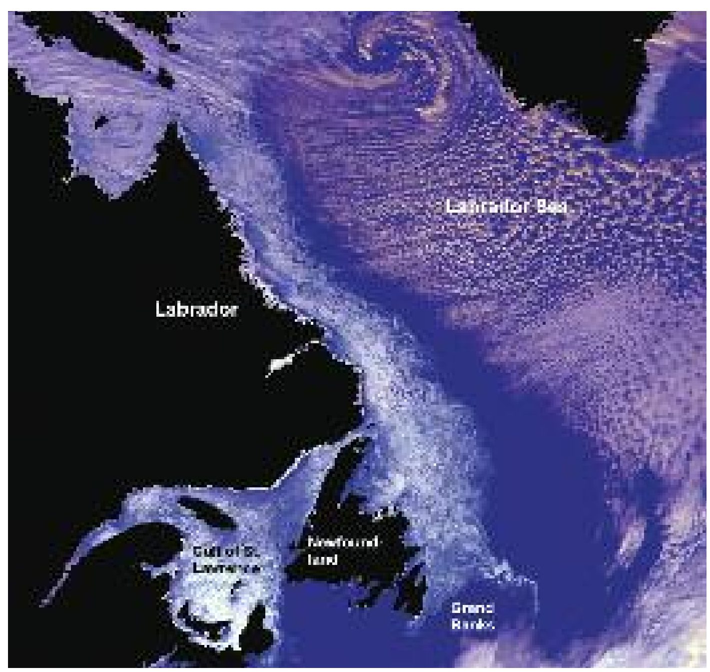


Figure 3. Satellite infrared image of the Labrador Sea and the Gulf of St. Lawrence was taken on March 4, 1995. Sea ice off the coast is indicated in white. Most of the Labrador Sea is covered by cloud. (Image courtesy of Ingrid Peterson)

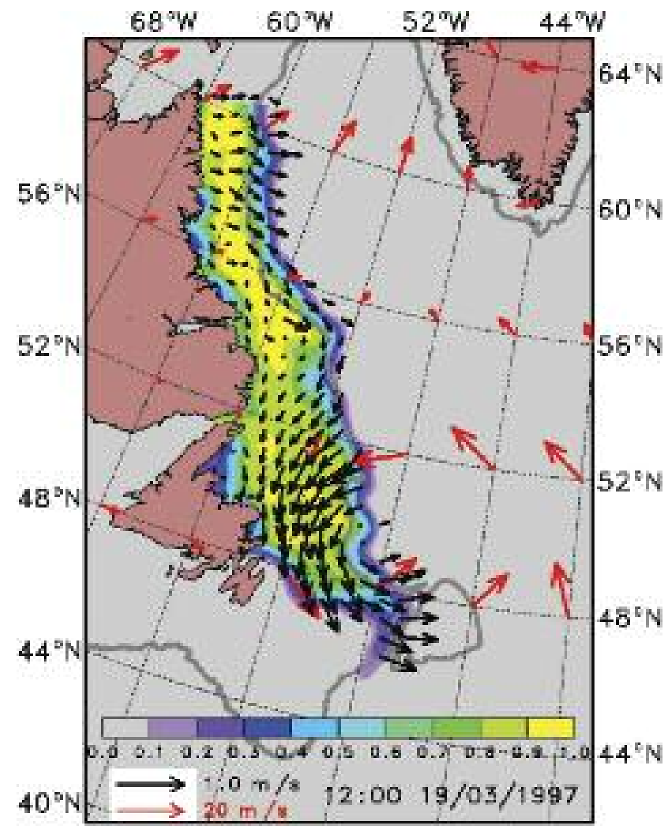


Figure 4. Ice concentration and velocity from an ice forecast model for March 19, 1997: colour contours indicate ice concentration (0 for no ice to 1 for complete ice cover), red arrows indicate surface wind and black arrows indicate ice speed and direction. The scales are given in the lower left corner. The grey line is the 1000 m bathymetry contour.

tries in planning daily operations and developing contingency measures.

The changes in sea-ice cover are mainly controlled by heat, water, and momentum exchanges between sea ice and water, and horizontal advection by ocean currents. Surface cooling in winter removes heat from the water column and lowers the water temperature. When the sea surface temperature drops below the freezing point, sea ice starts to form. Further cooling causes the sea ice to grow in thickness. Around the ice edge, the relatively warm water of the open ocean melts the ice. The rates of ice growth and melt vary with time and location. The balance of ice growth and melt in conjunction with advection by ocean currents determines the changes of sea-ice concentration and thickness. The thermodynamic processes can be studied by using coupled ice-ocean models. Figure 5 shows total growth/melt over the 60-day period between mid-January and mid-March from a model simulation. Net growth is found over the inner shelf and net melt is found over the outer shelf and slope. The maximum melt occurs along a narrow strip at the offshore ice edge off the northern Labrador coast. The model result reveals that ice melt does not occur only at the southern ice edge in spring as commonly believed, but also along the eastern ice edge through the winter.

Significant progress has been made in east coast sea-ice research at BIO over the past 25 years. Continuing efforts in modeling, data collection, and analysis allow us to develop better tools for research and gain better understanding of the dynamics and variability of sea ice, which are necessary to tackle sea-ice related environmental issues such as climate change, hydrocarbon exploration, fisheries, and ecosystems.

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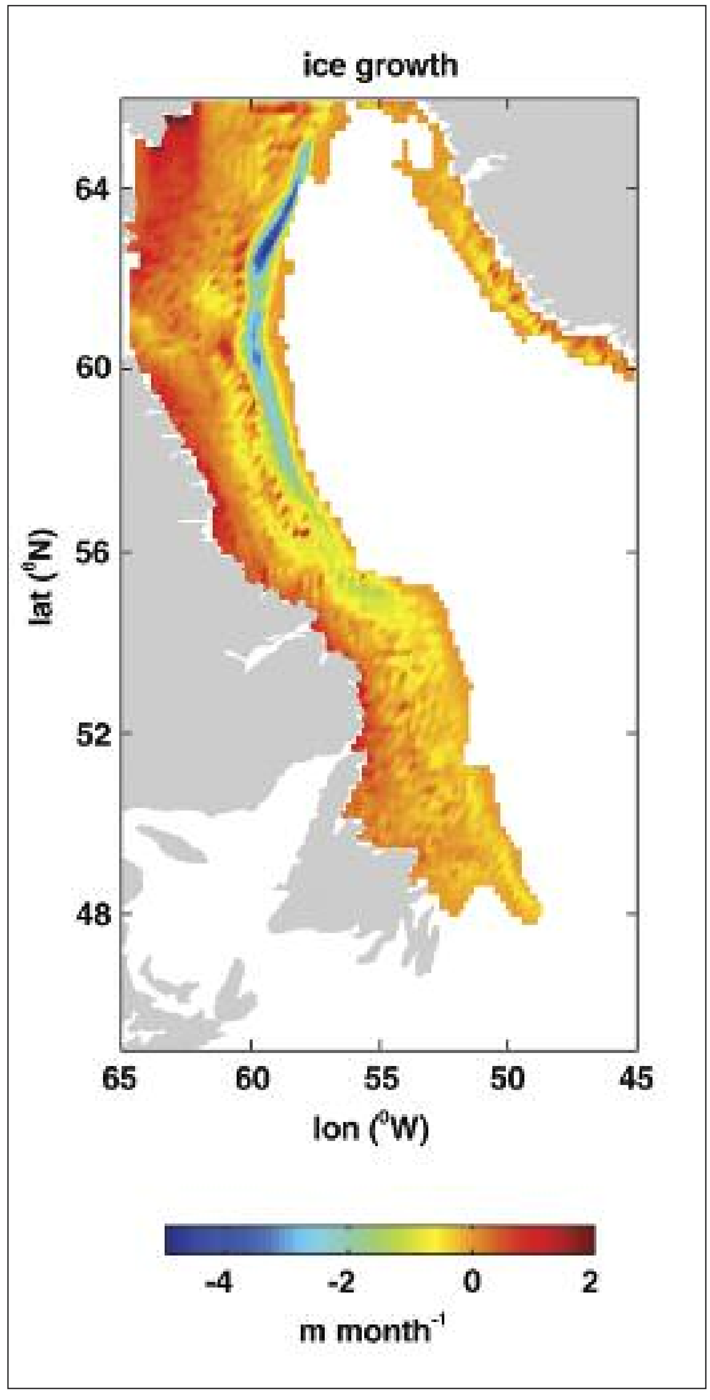

Figure 5. Ice melt (negative values) and growth (positive values) between mid-January and mid-March from a coupled ice-ocean model of the Labrador Sea and the shelf regions

Oil Spill Countermeasures in the Ocean - New Technologies and Research Directions at BIO

Kenneth Lee, Paul Kepkay, Zhengkai Li, and Thomas King

Figure 1. The wave tank at BIO is equipped with a computer-controlled wave maker to produce progressive non-breaking regular waves and breaking waves. It has been upgraded into a flow-through system to simulate movement of oil drops due to coexistence of waves and currents and to investigate dilution effects on toxicity of physically and chemically dispersed oil on pelagic and benthic species.

The Centre for Offshore Oil and Gas and Energy Research (COOGER) provides national co-ordination for DFO research programs on the environmental and oceanographic impacts of offshore petroleum exploration, production, and transportation. An important area of their work involves oil-spill remediation. Despite advances in technologies, accidental oil spills can and will occur. During November and December of 2007 alone, major accidental releases of crude oil occurred in the North Sea off Norway and the Yellow Sea near South Korea, and a massive spill of fuel oil was observed in the Black Sea (involving five sunken ships). Open-water spills such as these and the multitude of accidental smaller spills associated with operations in the industrial sector are very difficult and expensive to remediate. For the protection of the marine environment and its living resources, the public and environmental resource managers are demanding more efficient and cost-effective oil-spill countermeasures.

In response to this demand, COOGER has collaborated with the U.S. Environmental Protection Agency (EPA), the National Risk Management Research Laboratory, and other agencies to develop a coordinated research program on the remediation of oil spills. The research, co-funded by NRCan's Panel of Energy Research and Development, the EPA, the US National Oceanic and Atmospheric Administration, and the US Minerals Management Service has been focused on:

1) the combined action of wave energy and chemical dispersants on the breakup of oil slicks,
2) the utilization of oil mineral aggregate (OMA) formation to disperse oil in open water, and
3) the development of new technologies capable of monitoring the dispersion of oil in situ.

WAVE ACTION AND CHEMICAL DISPERSANT - THE BIO WAVE TANK

Waves can break up oil into small droplets, disperse the oil to low concentrations, and trigger the breakdown of the oil by bacteria existing in the sea. This dispersion effect of waves can be enhanced by the addition of chemical dispersants that reduce the interfacial tension between oil and water, breaking up oil slicks in much the same way as detergents are used to clean up oil and grease in dishwater. However, the utility of chemical dispersants has been the subject of a considerable amount of debate due to two uncertainties: efficacy and effects. Efficacy, or the effectiveness of chemical dispersants on different types of oil under different environmental conditions, has proven to be important when attempts have been made to correlate dispersant effectiveness with wave conditions. Effects-based research has been focussed on the biological impacts generated by the toxicity of the

Figure 2. COOGER and Canadian Coast Guard collaborative field trial on combating oil spill on pack-ice conditions by delivering minerals and mixing using prop-wash from the ice-breaker, CCGS *Martha L. Black*

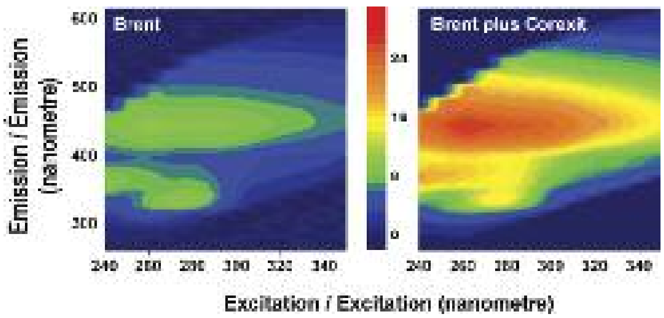

Figure 3. The contour plots illustrate Brent Blend and IFO 300 crude oils dispersed in seawater (left) and dispersed in seawater with the addition of the chemical dispersant Corexit 9500®.

Figure 4. Summer students and COOGER staff recovering time-series samples from various depths within the wave tank to determine chemical dispersant effectiveness

dispersants themselves and by the toxicity of chemically dispersed oil.

To address the uncertainties involved in the determination of efficacy and effects, an international research program has been coordinated by COOGER to determine the efficiency of different dispersants under different wave conditions and the potential chronic and sublethal effects of chemically dispersed oil on pelagic and benthic biota. To meet this objective, a wave tank facility has been designed and constructed at BIO (Figure 1) to accurately determine efficacy and effects under realistic conditions representing the natural environment.

It is known that the effective dispersion of oil slicks by the addition of oil dispersants requires some mixing energy. The first phase of wave-tank research has been a series of experiments on chemical dispersant efficiency as a function of wave energy. The wave tank facility at BIO is unique in that it has a computer-controlled wave generator that allows a variety of wave types representative of the natural environment to be produced. The hydrodynamic regime within the wave tank has been carefully characterized by advanced fluid mechanics technologies, including Acoustic Doppler Velocimetry, a three-dimensional velocity measurement device, and the application of FLUENT, a data processing/computer simulation package. In addition, oil dispersion and droplet size have been measured using a suite of state-of-the-art instruments, including laser in-situ scattering and transsiometry (LISST) (which measures dispersed oil droplet size ranging from 2.5 to 500 microns); ultraviolet epi-fluorescence microscopy (which measures dispersed oil droplet size ranging from 1.0 to 50 microns and the morphology of the droplets); and, to quantify oil dispersion effectiveness, ultraviolet excitation-emission matrix spectroscopy (EEMS) (which characterizes the ultraviolet fluorescence fingerprints of oils in seawater and facilitates identification and monitoring of chemically dispersed oil in the open ocean).

Support for the use of chemical oil dispersants is based on the premise that the oil would be dispersed or diluted within the water column to concentrations below toxicity threshold limits. To fully evaluate this process, the BIO wave-tank facility was designed to be operated in flow-through as well as batch mode to support simulated studies on the influence of tides and currents on oil dispersed at sea.

The work to date has clearly demonstrated that the efficacy of chemical dispersion depends on wave conditions and, even at this early stage, the results can be used to establish operational guidelines for dispersant application to real-life oil spills. A second wave of new work will focus on investigating the biological effects of chemical dispersant application, in particular on the most sensitive life stages of fish, such as larvae and juveniles.

OIL-MINERAL AGGREGATES

The formation and dispersion of OMA has been proposed by COOGER as another novel oil-spill countermeasure. An oil-mineral aggregate is the agglomeration of oil droplets or mineral fine colloids in suspension. This remediation process not only facilitates the dilution and mixing of oil spilled into the environment, but it could also eliminate potentially toxic components of the oil. Laboratory experiments and shoreline field trials have demonstrated that OMA enhances the natural dispersion of oil spilled in the environment and reduces its environmental persistence. More specifically, chemical analyses following surf-washing operations after the *Sea Empress* spill in the U.K. have shown that OMA formation can actually enhance the biodegradation of residual oil as small oil droplets are stabilized by mineral fines[1] and the oil-water interface (where microbial activity is predominant) is enlarged. With respect to toxicity, previous field studies in Svalbard, Norway conducted by DFO have shown that OMA within the immediate vicinity of a spill site can be dispersed to levels below regulatory toxic thresholds. As a result, the overall effect of OMA formation and its dispersion is to minimize negative environmental impacts and protect local fisheries habitat.

The goal of new research on OMA by COOGER is to establish the operational feasibility of aggregate formation in the remediation of oils spills, either on its own or in combination with other strategies. As an example, the delivery of mineral fines and mixing using prop-wash from ice-breakers is currently under investigation by COOGER and the Canadian Coast Guard to evaluate OMA formation as a primary oil spill countermeasure for use in dynamic pack-ice conditions (Figure 2). In addition, results from recent wave-tank studies suggest that OMA formation in seawater can augment the efficacy of chemical oil dispersion by encouraging the formation of

[1] The finest fraction of suspended sediments and clay minerals in the size range of microns and sub-microns

denser and smaller OMA that tend to remain suspended in the water column. Even without the combined effect of OMA formation and chemical dispersion, the sequestering of toxic components by the irreversible adsorption of oil onto the surface of mineral fines in OMA may reduce their bioavailability and protect the biota after dispersion of an oil spill.

OIL SPILL MONITORING BY NEW TECHNOLOGIES

The application of new technologies has been central to the ongoing work of COOGER on the monitoring of oil-spill dispersion. In particular, the application of LISST along with EEMS has yielded a number of interesting results so far.

EEMS has been used to characterize the fluorescence fingerprints of crude oils in seawater (Figure 3). When chemical dispersant is mixed with oil prior to its dispersion in seawater, the fingerprint is altered radically due to an increase in fluorescence at higher emission wavelengths. When the wealth of information available in an excitation-emission matrix spectrum is simplified, the response of the oil to dispersant can be expressed in terms of either a slope or an intensity ratio that can be used as a simple and rapid means of identifying the most dispersible fractions of an oil mixed into the ocean after the application of dispersant to an oil spill.

ASSISTING NATURE

The oil spill countermeasure technologies being developed at BIO are based on enhancement of natural processes such as oil dispersion and biodegradation that exist in our oceans for the remediation of contaminant petroleum hydrocarbons. Unfortunately, in the event of accidental spills the natural rates of recovery are generally limited by environmental factors. The addition of chemical dispersants and mineral fines can be considered as a means of providing nature with a helping hand. Data obtained from the controlled oil-spill countermeasure experiments conducted in the wave tank will be used for the development of operational guidelines for use by spill responders for the selection and implementation of the appropriate oil-spill response tool for the conditions encountered. The development of analytical instruments and protocols to monitor oil-dispersion effectiveness and biological effects at BIO will enable oil-spill responders to verify the efficacy and operational end-points for their operations.

Figure 5. Processing samples collected from the wave-tank experiment in the COOGER Organic Chemistry Laboratory

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Deep-water Fauna of the Continental Slopes

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The Gully, the largest marine canyon in eastern North America, is located to the east of Sable Island, at the edge of the Scotian Shelf. The site of Atlantic Canada's first Marine Protected Area (MPA), it is home to over 13 species of cetaceans including the endangered northern bottlenose whale. The canyon is over 65 km long, 15 km wide, and extends from shallow (approximately 200 m) sandy banks to the continental rise (>2,500 m). It separates Sable Island Bank from Banquereau. The bedrock geology of The Gully is mostly sandstones, siltstones, and mudstones. Surficial sediments range from gravels in the shallow water to the north, to muddy sand in deep water. Inherently, the diversity of canyon depths and geology supports higher species-richness than is seen in a comparable area on the banks. In addition, the unique physical oceanographic features of a canyon, with enhanced water and sediment transport onto and off the banks, tend to attract different species to the deep waters of the canyon than are seen on the adjacent continental slope.

During 2007, The Gully was investigated in a two-part research initiative. In part 1, DFO scientists from BIO and the Northwest

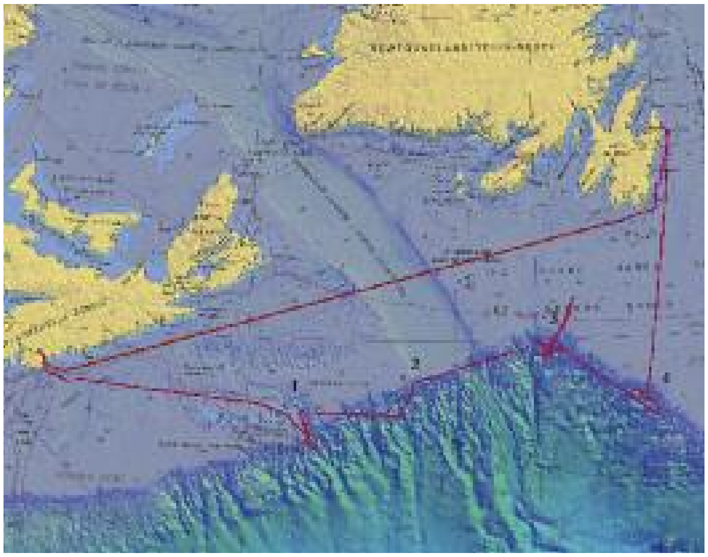

Figure 1. The 2007 ROPOS mission cruise track, departing from Halifax to 1) The Gully Marine Protected Area, 2) The Stone Fence Coral Conservation Area, 3) Haddock Channel, and 4) Debarres Canyon

Figure 2. Deployment of ROPOS to explore the fauna in the deep waters of The Gully MPA

Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador (NL) and scientists from Memorial University, NL explored the seabed fauna in the deep waters of the continental slopes. The field program (July 7-29) was funded by the International Fisheries and Oceans Governance Fund, the Natural Sciences and Engineering Research Council of Canada, and DFO Science Branch and High Priority Funds. It involved deployment of a deep-water submersible known as ROPOS (Remotely Operated Platform for Oceanographic Science) from CCGS *Hudson* in four areas of operation: The Gully Marine Protected Area, the Stone Fence Lophelia Conservation Area, and on the southwest Grand Banks at Haddock Channel and Desbarres Canyon (Figure 1). The ROPOS submersible (Figure 2), owned by the Canadian Scientific Submersible Facility and on contract to DFO for this mission, collected over 3000 digital images, over 10,000 frame grabs, and hundreds of hours of colour video coupled to ROV (remotely operated vehicle) positional data. The overarching objectives were to increase knowledge of deep-water coral and associated species along the continental slopes in Atlantic Canada.

Exploration of The Gully focused on two areas, the deep water outside of the shelf break between 1,000 and 2,500 m depth, and the walls of the largest feeder canyon. Scientists were excited to see the diversity of organisms, including extensive areas colonized by xenophyophores – large, single-celled marine protozoans (Figure 3). Although they have been found throughout the world's oceans, they had never before been recorded off Atlantic Canada. Worldwide, there are approximately 42 recognized species of xenophyophores, the largest of which can reach 20 cm in diameter. They are delicate organisms, and the ones seen in The Gully very much resemble a muddy sponge. They are benthic deposit feeders and are clearly the dominant benthic species at some localities in The Gully. In the past, xenophyophores have been difficult to study because they are so fragile. Neither the full extent of their range nor the role they play in the

Figure 3. Xenophyophores, the world's largest single celled protozoans, can reach up to 20 cm in diameter.

Figure 4. The ogre fish (*Anoplogaster cornuta*), while fearsome in appearance, only reaches 15 cm in length.

Figure 5. The amphipod, *Pegohyperia sp.*, was previously unreported in the region until recently caught in September of 2007 during mesopelagic trawls in The Gully.

bioturbation (processing) of Gully sediments is fully understood.

Video from the mission is currently being analyzed. The positional data gathered for each organism seen in the video will provide a clearer picture of how these relatively understudied deep-sea creatures distribute themselves, and what factors, whether biotic (e.g., reproductive strategies, species assemblages, etc.) or abiotic (e.g., sediment type, temperature, geological formations, etc.), affect this distribution.

The second part of the initiative in 2007 was a mesopalagic survey (September 6-19) of the ecosystems within The Gully, both to aid MPA management and as an example of a submarine canyon ecosystem. The mesopelagic zone is that area roughly from 200 to 1,000 m deep, where little light penetrates. The surface waters over The Gully are not remarkably productive but exceptional productivity at great depth is revealed by the presence of deep-diving cetaceans. Part of this mission's goal was to better understand the processes which create the food that attracts these whales, while preparing a first description of the fauna within the mesopelagic zone of the MPA.

The fauna was sampled with a midwater trawl deployed from the CCGS *Templeman* and towed at depths down to 1,700 m. The work focused on fish (Figure 4), squid, and the larger crustaceans, particularly decapods, euphausids, and hyperiid amphipods (Figure 5). Additional sampling was undertaken at one station outside The Gully, which was regularly sampled during extensive surveys by BIO scientists in the 1980s, to compare the canyon fauna with that of the open ocean and to look for long-term changes in the mesopelagic community off Nova Scotia.

As with the ROPOS mission to The Gully, there were unexpected discoveries. Included among these is a rare species of deep-sea nemertean, never before recorded from Canadian waters, which by most accounts resembles a "salmon fillet" (Figure 6). Little is known about pelagic nemertean biology worldwide. Research is ongoing but the crustacean catches may yet yield specimens of species previously unknown to science. They also show a localized concentration of shrimp-like euphausids, or "krill", in the portion of The Gully where bottlenose whales most often feed.

Figure 6. A pelagic Nemertean, *Dinonemertes sp.*, previously unreported in Atlantic Canada

Figure 7. The coiled egg casing of *Kronborgia sp.*, a flatworm parasitic to shrimp

Figure 8. *Paragorgia johnsoni*: a coral previously thought to occur much farther south of Nova Scotia

Samples taken for "genetic barcoding" during both the ROPOS and mesopelagic missions to The Gully will give researchers a first look at the genetics of some of these unique species, while in other cases they will act as a forensic tool to point taxonomists towards identifications. These genetic tools have already allowed the team to correctly identify what appeared to be a form of coral but is the hard egg casing (>15 cm) produced by a parasitic flatworm that had not previously been reported from our region (Figure 7).

From these two missions, our list of previously unreported species in Atlantic Canadian waters, or species completely new to science currently stands at about 40. This includes at least ten species of coral, six species of echinoderms, and six species of amphipods (Figures 8, 9, and 10). Analysis of preserved samples, video, and high-resolution images collected during these missions will undoubtedly lead to even more discoveries as this information continues to be distilled over the months ahead.

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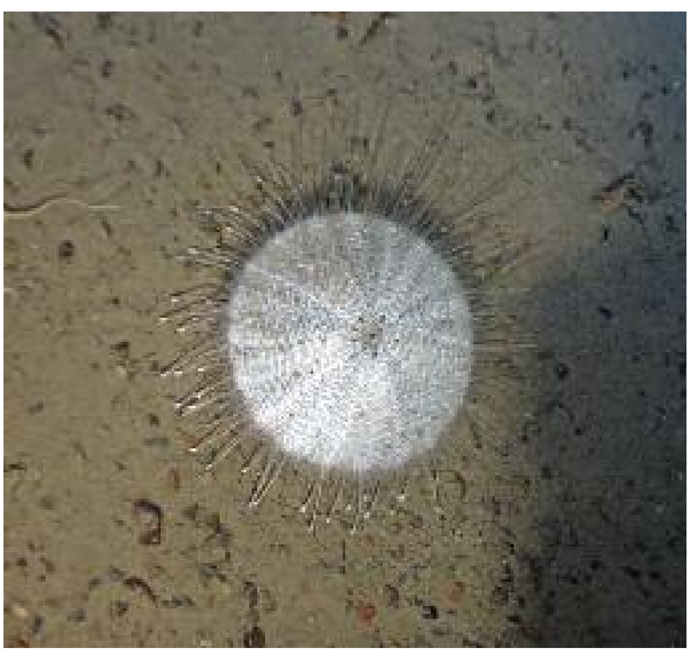

Figure 9. *Araeosoma fenestratum*, a dinner-plate-sized urchin that had not previously been reported in Atlantic Canadian waters

Figure 10. This amphipod recently identified as *Epimeria tuberculata* is a first sighting for Atlantic Canada.

New Multibeam Bathymetry Surveys in the Bay of Fundy

D. Russell Parrott, Brian J. Todd, John Shaw, and Eric Patton

INTRODUCTION

The Bay of Fundy (Figure 1) is an estuarine embayment with the largest tides in the world (according to current hydrographic research data). The tidal range increases from about 4 m at the mouth of the bay to a maximum of 17 m at the head. These extremely large tides generate strong currents that range from an average of 0.7 $m.s^{-1}$ at the mouth of the bay to about 1.8 $m.s^{-1}$ at the head.

In 2006, a consortium formed by the Geological Survey of Canada (GSC), the Canadian Hydrographic Service (CHS), and several universities commenced a project to map the bay with multibeam sonar systems. This type of mapping yields high-resolution elevation models of the seafloor and also provides backscatter strength, a property that can indicate the nature of the material on the seafloor. To complement the multibeam coverage, selected adjacent intertidal and land areas were mapped using terrestrial LiDAR (Light Detection And Ranging), an optical remote-sensing technology that also provides very high-resolution elevation models.

Figure 1 shows the extent (about 10,000 km^2) of multibeam sonar bathymetric mapping as of 2007. The bathymetric mapping will be completed in 2008 and benthic surveys to test and evaluate the bathymetry data are planned for 2009. Bottom-current and sediment-transport measurements are planned for March 2008. The objective of these integrated geoscientific and biological investigations is to produce a series of 1:50,000-scale maps of the Bay of Fundy showing seafloor topography, backscatter strength, geology, and benthic habitats (i.e., bottom environments with distinct physical, geochemical, and biological characteristics).

GEOLOGICAL HIGHLIGHTS

The new imagery contains a wealth of information relating to geological processes in the bay. Fields of elongated glacial landforms (Figure 2) attest to a powerful stream of glacial ice that exited the bay during the last glacial period (about 14,000 years ago). Strong imprinting of the seafloor by icebergs over large areas reflects the subsequent breakup and retreat of the glaciers.

One of the most spectacular geological features is the Margaretsville dune field, a field of trapped very large sand dunes (up to 21 m high) in the central Bay of Fundy (Figure 3). These dunes are trapped in the sense that they are situated on a relatively immobile gravelly substrate and are unable to migrate due to lack of sediment availability. Scouring and incision around the bases of the dunes likely arise as a result of the dunes' stationarity. These and other features, many of them enigmatic, will be examined in more detail by surveys in the coming years.

HARNESSING TIDAL POWER IN THE BAY

Minas Channel (Figure 4) was the focus of schemes to harness tidal power as long ago as 1910. The channel was surveyed with geophysical systems in the 1960s because of plans to construct a tidal dam. The dam was never built, partly due to predicted environmental effects that were thought to be serious and widespread. Effects would have included significant alterations of tidal ranges throughout the Bay of Fundy and the Gulf of Maine. With revived interest in renewable energy, Minas Channel is the subject of an engineering study for electricity generation by turbines located on the seafloor. The new imagery and other data are contributing to the process of selecting sites for the turbines.

Investigators gathering information in the 1960s in connection with plans for the tidal dam referred to Minas Channel as a "scour trench" because strong, constricted tidal currents (up to 3.5 $m.s^{-1}$)

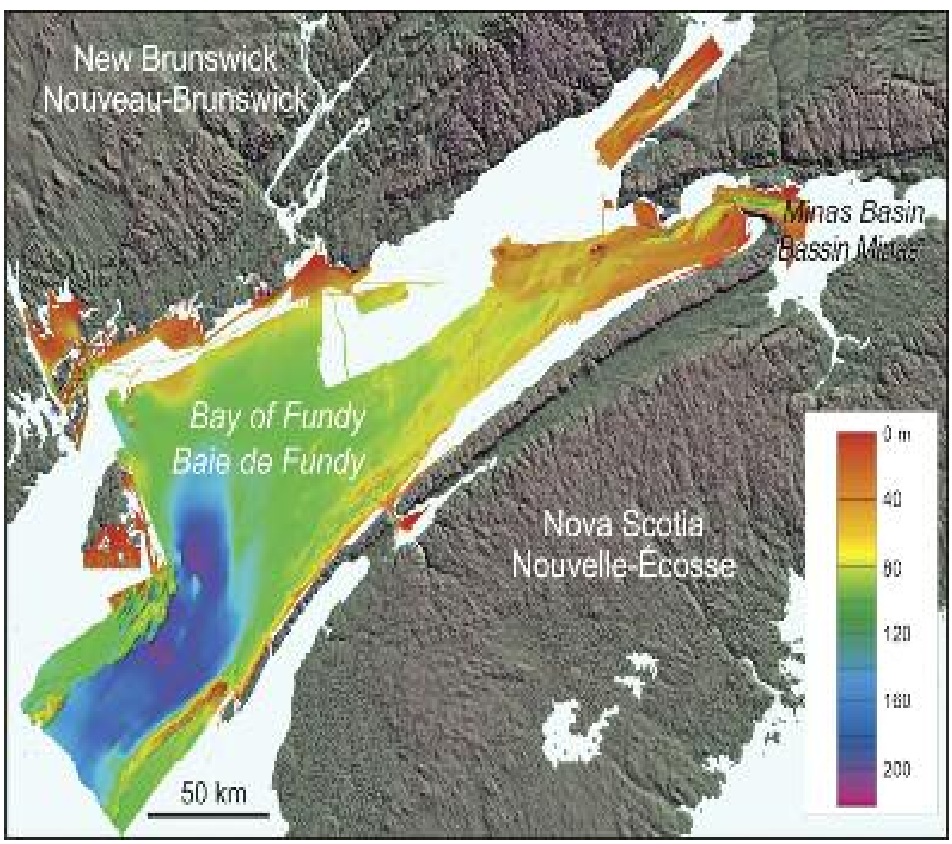

Figure 1. Extent of multibeam sonar bathymetry data collected in the Bay of Fundy during recent GSC/CHS surveys: red denotes shallow water and blue denotes deep water.

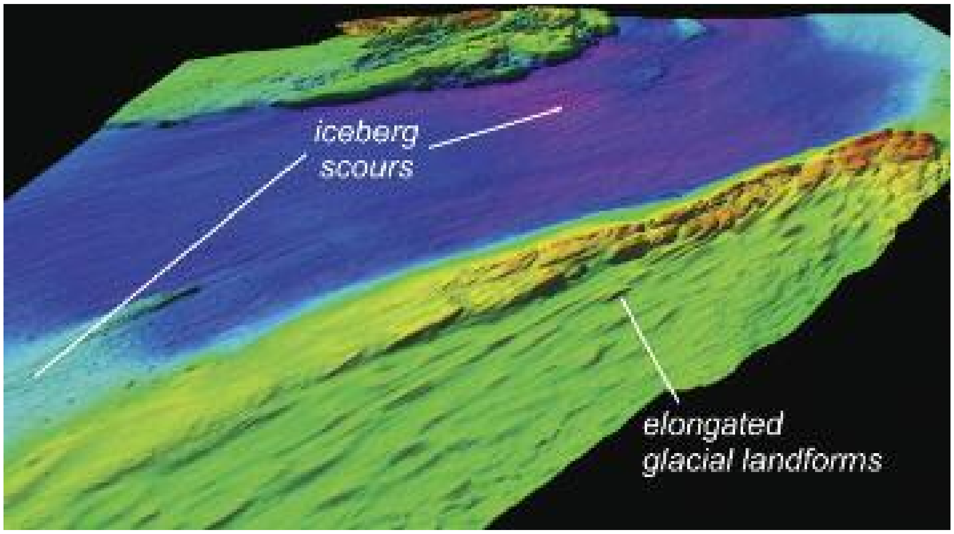

Figure 2. Oblique aerial view of Grand Manan Basin at the mouth of the Bay of Fundy shows elongated glacial landforms on either side of the basin and seabed sediment scoured by icebergs on the basin floor. Width of view is approximately 40 km.

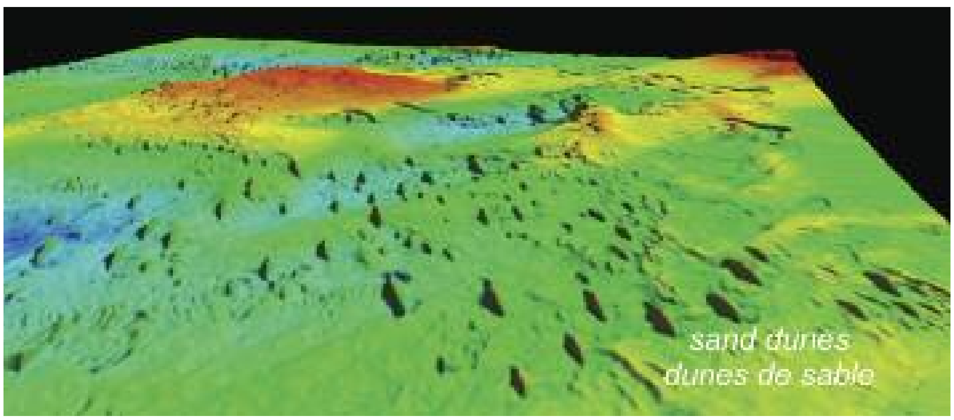

Figure 3. Oblique aerial view of field of trapped sand dunes in the central Bay of Fundy: width of view is approximately 8 km.

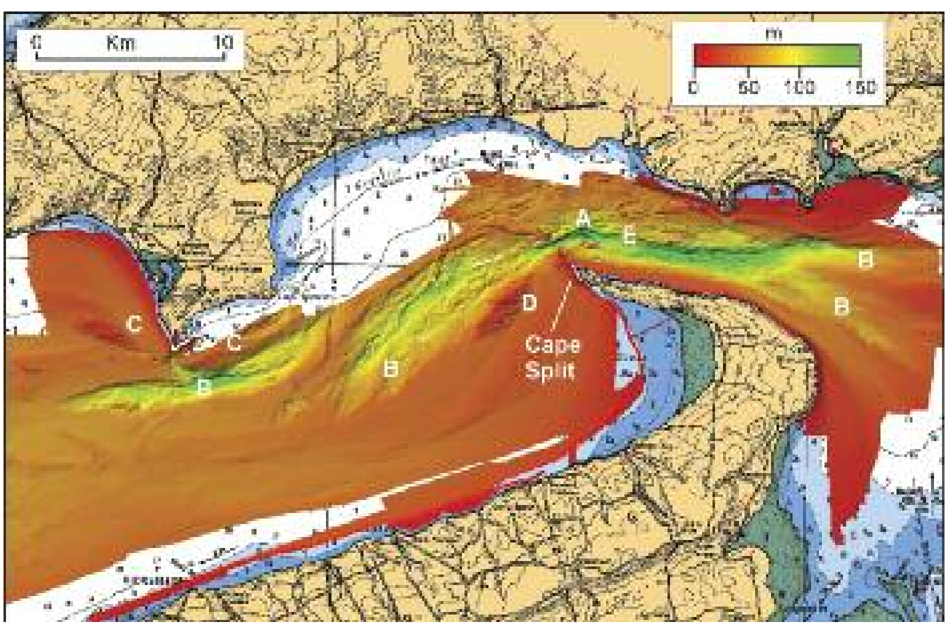

Figure 4. View of Minas Channel, Nova Scotia, and surrounding areas. See the text for explanation of the lettering. Colours assigned to water depth range from red (shallow) to green (deep). Background imagery is part of Canadian Hydrographic Service chart 4010.

have scoured the thick sediments to great depths, exposing faulted bedrock at the seafloor over a large area. The multibeam surveys have revealed great complexity in the scour trench. The trench is 170 m deep just north of Cape Split (Figure 4, A). The trench splays to the east and west into a series of separate, finger-like troughs (B) that have been eroded into the Quaternary sediments.

Minas Channel is notable for other current-formed features, particularly the twinned sets of sand wave fields that appear off headlands. A pair of these "banner banks" is on either side of Cape Advocate (C) and adjacent to Cape Split (D and E). The orientation of the bedforms in the Scots Bay sand wave field (D) shows migration towards the south at the west side of the field, and migration towards the north on the east side. This huge sand body is entirely surrounded by hard gravel seafloor, so that the dune field appears to be a self-contained system, probably trapped in a large tidal eddy. The apparent twin of the Scots Bay field is a 3-km-long, 20-m-thick body of gravel ripples (E), trapped inside the deep trough north of Cape Split.

Two further points can be made about this fascinating region. First, it is well known that the range of the Fundy tides has been increasing for more than 7,000 years. However, evidence from inside Minas Basin suggests that the basin had a low tidal range as late as about 3,500 years ago. If this is correct, then the Minas Channel scour trenches developed after Minas Basin experienced an increase in tidal range. Second, the total volume of Quaternary sediment removed in these trenches is conservatively estimated at 4 km^3. This large volume has never featured in estimates of sediment sources in the bay made by earlier researchers. This may lead to a rethinking of the origin of the vast amounts of suspended sediments in the bay, and indeed the even larger amounts that have been deposited in the deep salt marshes and extensive mud flats that characterize this part of the Bay of Fundy.

Although the Bay of Fundy has been scientifically studied for decades, the new mapping data provide fresh insight into the complexity of the bay's workings. These data will underpin the balancing of biological resources with the development of tidal power within the Bay of Fundy.

Where the People Meet the Ocean: Nearshore Oceanography at BIO

Gary L. Bugden and Timothy G. Milligan

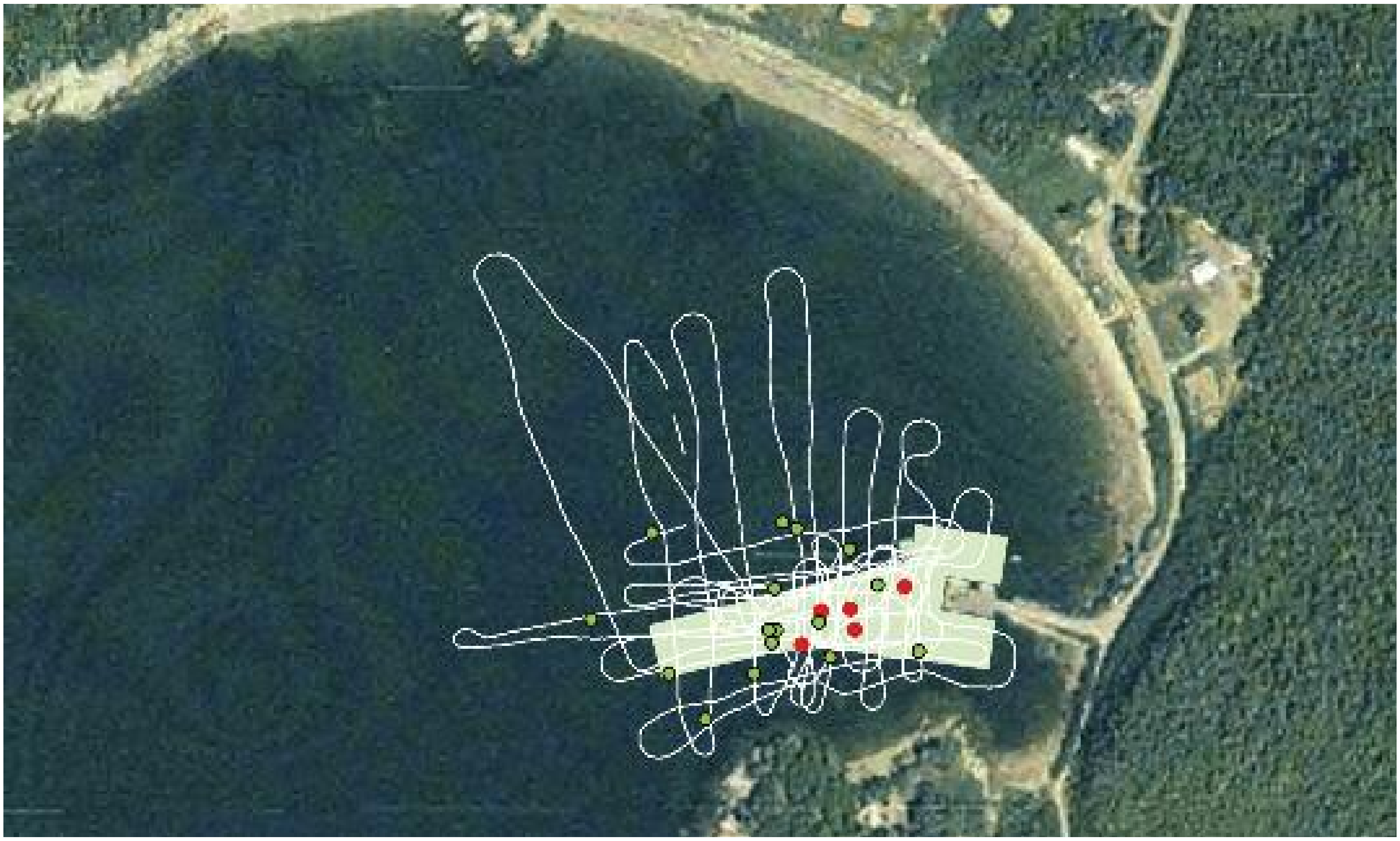

Figure 1. GIS presentation of Seeleys Cove: the aerial photograph shows the cove, beach, and wharf. The light green area is the area under consideration for dredging; the white line is the track of the survey vessel which measured water depth and sub-bottom sediment characteristics. The red dots are sediment core locations and the green dots are surficial grab-sample locations.

More than 40% of the world's population—about 2.5 billion people—live within 100 km of the coastline. Here, near the continent-ocean boundaries, occurs the majority of the interaction between humans and the ocean. As the human population increases in coastal areas, so does the pressure on coastal ecosystems through habitat alteration, increased pollution, and demand for coastal resources.

Planning for sustainable use of the coastal zone frequently reveals significant gaps in our knowledge of this complex and heterogeneous region. Filling these gaps often requires multi-disciplinary programs that involve innovation in instrumentation and methodology. Researchers from DFO's Science Branch and NRCan's Geological Survey of Canada (GSC) at BIO often work together on these projects and the following describes some of the nearshore studies recently undertaken by these scientists.

The Seeley's Cove Small Craft Harbour facility is located on the southwest coast of New Brunswick and serves as a staging point and wharf for several local lobster fishing operations (Figure 1). The approach channel to the wharf has been dredged several times in the

Figure 2. Tim Milligan stands aboard the research vessel used in the Basin Head, PEI study. Main photograph shows the vessel configured for bathymetric and water-quality sampling. The inset shows the vessel configured for mooring deployment. Note the small electric outboard motor.

Figure 3. Brent Law of ERD operating the Microcosm Erosion Chamber to selectively erode flocs from the undisturbed surface of the core just acquired by the mini slo-corer.

past, with the most recent major operation occurring more than 40 years ago. In recent years, larger-hulled vessels have encountered difficulty using the wharf at times other than high water. Pressure from the users of the facility to dredge the channel resulted in Public Works and Governments Services Canada (PWGSC) commissioning a modeling study. This study determined that dredging would not be economically feasible as the channel would fill in again in two to three years. This finding disagreed with local knowledge which suggested that results of previous dredging operations had persisted for a much longer period. With funding from PWGSC and equipment from BIO, the authors set out to gain an understanding of the sediment dynamics in Seeley's Cove and to directly measure the sediment infill rate. Sub-bottom acoustic profiles of the previously dredged channel were obtained by the GSC while incidentally testing a new piece of equipment intended for deployment in the Beaufort Sea later in the year. Ecological Research Division (ERD) researchers collected sediment cores of the channel infill material, surficial grabs from the surrounding area, and used radionuclide dating techniques to directly estimate the channel infill rate. Initial results support local knowledge. A report is in preparation which will combine these measurements with Geographic Information System (GIS) analysis of historic bathymetric surveys to re-evaluate the feasibility of a dredging project which will re-establish the channel in this Small Craft Harbours facility.

In October 2005, DFO designated Basin Head as a Marine Protected Area (MPA). Basin Head is shallow coastal lagoon approximately 5 kilometres long, located on the eastern tip of Prince Edward Island, near the town of Souris. The lagoon is surrounded by both agricultural land and an extensive sand dune system. Many different types of animal and plant life exist in the area. Most notable is a unique type of Irish moss found nowhere else in the world. Irish moss is a marine plant commercially harvested throughout the Maritimes. The type in Basin Head is unique because it does not attach to the bottom and is significantly larger than the normal plant found elsewhere. As well, it has a higher concentration of carrageen, an important thickening agent in products we use every day. As part of the development of a management plan to provide long-term protection for the area, a numerical circulation model of the basin is being developed by the Ocean Sciences Division (OSD). This model is designed to answer such questions as:

What are the water circulation and flushing rates of the lagoon and how do they vary with tidal amplitude, freshwater discharge, and wind forcing?

What changes in circulation and flushing rates might be expected due to modifications of the existing entrance to the lagoon or if a second entrance to the lagoon is opened by a storm event?

What are the anticipated impacts of sea-level rise and climate change?

To assist in model calibration and validation, a bathymetric survey and mooring program were carried out in the basin to provide depth, temperature, salinity, and flow data to calibrate the model. As a large portion of the basin is less than 1 m deep and the provisions of the management plan do not permit the operation of internal combustion engines in the Basin, an electrically powered flat-bottomed skiff was used as a survey vessel (Figure 2). For mooring deployment and recovery in the deeper portions of the Basin, the vessel was creatively jury-rigged with a bow-mounted A-frame. The end result of this venture into the realm of marine architecture raised a few eyebrows but in the final analysis got the job done. Circulation model development continues using the data acquired. Recently there have been alarming decreases in the amount of the unique Irish moss in the basin and further field work is underway to monitor the discharge rate and water quality of the streams running into the basin.

As part of a larger interdepartmental study led by the GSC that is examining the extent and the potential risks associated with gold mine tailings in Nova Scotia, researchers from BIO have been studying the impact of mine tailings on fish habitat in the marine environment. Historical gold mine tailings in Nova Scotia contain high concentrations of the metals arsenic and mercury. These tailings were routinely deposited directly into lakes, swamps, streams and the ocean between the 1860s and 1940s. In 2005, the discovery of high arsenic levels in soft-shelled clams near coastal gold mine sites in Guysborough County led to the closure of the recreational clam fishery in the area of Isaac's and Seal harbours. The mechanism for the uptake of arsenic and mercury by marine benthic organisms is not well understood. One possible pathway is the ingestion of metal-bearing flocs, which are loose agglomerations of organic and inorganic material found primarily in salt water. Flocs, or marine snow, are a preferred food source for suspension-feeding organisms like clams and scallops as they provide an efficient way of ingesting high-quality carbon. Unfortunately, flocs also collect metals and other surface-active contaminants. Flocs are notoriously difficult to sample as they readily break up and disperse when disturbed, becoming part of the background sediment in suspension and making it impossible to determine their metal content. To sample undisturbed flocs from the bottom, the OSD designed and built a mini slo-corer which uses weights and a mechanical damping system to slowly push a 15-cm-diameter core barrel into the sediment. By slowly lowering the core barrel into the sediment, the sediment-water interface remains intact, allowing the flocs sitting on the sediment surface to be retrieved without breaking them up. Once on board, the core is removed from the corer and fitted with a

Microcosm Erosion Chamber. This chamber provides a method to apply increasing shear stress to the sediment surface while collecting the material that is resuspended at a particular stress level. The sediment that is resuspended is then analysed for trace elements, including arsenic and mercury. This new, specially designed instrumentation was used to collect flocs from the sediment-water interface at Seal Harbour. Results show that both arsenic and mercury are concentrated in the surface "fluff" layer making them available for ingestion by marine benthic organisms (Figure 3).

Recently, concern has been expressed about an apparent increase in suspended particulate matter (SPM) in the waters of Northumberland Strait, between Prince Edward Island, and Nova Scotia and New Brunswick. A limited number of measurements made in the fall of 2005 yielded suspended sediment concentrations that were significantly higher than previously published values. Subsequently, a more complete survey was undertaken in collaboration with Northumberland Strait fish harvesters. Results from this survey showed that SPM values during calm conditions were similar to those from 30 years earlier. SPM values appeared to increase during storms and periods of high runoff, which could explain the high values detected in 2005. To understand the results of the two sampling programs, contemporaneous and historical satellite remote sensing data were analysed to determine the spatial distribution of SPM in the Northumberland Strait. The MERIS (MEdium Resolution Imaging Spectrometer) satellite sensor provided a representation of the surface SPM concentrations in the Northumberland Strait that agreed closely with the samples collected at the same time by the fish harvesters. The higher spatial resolution of MERIS as compared with older sensors proved to be of great use in this nearshore region. The imagery indicated that the primary sources of SPM in the strait appeared to be the shoreline near headlands where there were high currents (Figure 4). This is presumably due to factors such as sea-level rise and poor land-development practices as opposed to construction of the PEI Confederation Bridge which had been postulated as the major culprit.

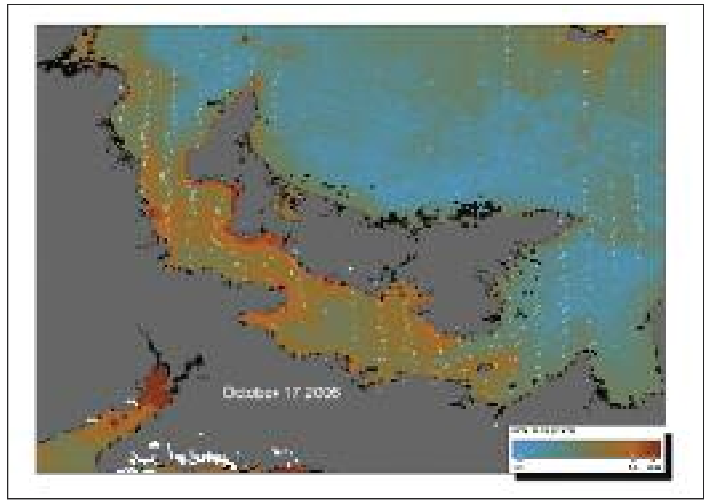

Figure 4. Surface SPM concentration in the Northumberland Strait derived from MERIS: the white arrows show the predicted tidal currents at the time the image was acquired. High SPM values are seen to originate near the coast in regions of enhanced tidal currents.

All of these nearshore projects share some common features. They use sophisticated techniques, often taken directly from leading edge scientific research programs, to address applied problems, sometimes in water shallow enough to stand in. The results of the studies are often of great interest to the stakeholders and the general public. The studies often include the use of innovative platforms and instrumentation to obtain the measurements required. Many of the projects span departmental and regional boundaries as well as disciplines. Future progress will depend on cultivation of this sort of interdepartmental and regional cooperation. This exciting area of study will continue to gain importance as more people make their way down to the sea.

The Inshore Ecosystem Research Project

Alida Bundy (Population Ecology Division, DFO), Cornelia den Heyer[1] (Fishermen and Scientists Research Society [FSRS]), and Patty King (FSRS)

INTRODUCTION

The Inshore Ecosystem Research Project was a collaborative project between DFO and the Fishermen and Scientists Research Society (FSRS), funded through Phase 1 of the Oceans Action Plan (OAP). Established by the Government of Canada in 2005, the OAP is a legislative and policy framework to modernize management of our oceans. The objectives of the research project were to draft Volume 1 of DFO's *Inshore Scotian Shelf Ecosystem Overview and Assessment Report* (EOAR) and to identify potential Ecologically and Biologically Significant Areas (EBSAs) in support of Integrated Oceans Management for Sustainable Development, a pillar of the OAP.

The Inshore Ecosystem Research Project focused on waters within the 12-nautical-mile limit of the Scotian Shelf, from Cape Sable to Cape North (Figure 1). Although inshore areas are recognized as nursery and feeding areas for many marine species, we have insufficient scientific information to meaningfully contribute to either integrated management of the inshore or to definitions of EBSAs. In order to address this data gap, the DFO-FSRS Inshore Ecosystem Research Project collected new baseline data. This new data was collected through eight research activities, the findings of which will be incorporated into the final Inshore Scotian Shelf EOAR. These research activities were:

1. the 2006 Workshop on Inshore Ecosystems and Significant Areas of the Scotian Shelf,
2. analyses of DFO databases and data archiving,
3. monitoring of environmental and oceanographic data,

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4. the Grey Seal Pup Survey,
5. Fishery-Independent research,
6. At-Sea Catch analysis,
7. the video of bottom habitat using Underwater Reconnaissance and Coastal Habitat Inventory (URCHIN), and
8. local ecological knowledge (LEK) survey of commercial fishermen.

FINDINGS

A data synthesis workshop was held in March 2007 to explore the data acquired from the various project components and to discuss preliminary results. Clear patterns in this data were consistent with what is already known about the inshore, such as the CTD (conductivity, temperature, depth) data from the Fishery-Independent research that emphasized the role of the Nova Scotia current in the inshore, demonstrated cool water temperatures, and, when moving from east to west, showed an increase in salinity and decrease in stratification. The preliminary catch analyses of the plankton tow, beach seine, trap, and gillnet catch data indicate no systematic variation along the shore for zooplankton, invertebrates, fish, or seabirds. There also was no apparent cline (gradual change) in species richness or productivity (catch rate) from east to west, though such a cline might be expected, given the results from the CTD analysis. Preliminary analysis of fish and invertebrate communities identified by the underwater video survey for Port La Tour showed differences between sites that have high exposure to the forces of the ocean and those with low exposure. Differences in abundance and species composition with exposure within bays were also evident in the preliminary analysis of the beach seine catch and the analysis of beach seine data from a similar project at Acadia University.

Results derived from the Fishery-Independent CTD data, FSRS recruitment traps, and gillnet sampling all identify inshore-offshore trends in water properties and biota. Increasing depth, integrated chlorophyll, stratification, and salinity are accompanied by changes in species composition. Taken together, these data suggest that there are three zones within the 12-mile limit: the coastal fringe, mid-depths (between 10 and 40 m), and offshore (greater than 40 m). Although this is to be confirmed by further analysis, identification of these depth zones, and their associated habitats and biota, will be a valuable tool for the integrated management of the inshore.

The project revealed that many of the species caught by our sampling were ubiquitous, such as lobster and rock crab, suggesting consistency in community composition and diversity along the inshore Scotian Shelf. Further, the results indicate that the areas sampled during the Fishery-Independent research also were representative of the broader area

CONCLUSIONS AND NEXT STEPS

The synthesized data provides a valuable baseline that spans the geographic breadth of the inshore Scotian Shelf. The DFO-FSRS Inshore Ecosystem Research Project can thus contribute knowledge towards conservation and management of the inshore Scotian Shelf through the Science Expert Knowledge (SEK) derived during the 2006 workshop and the LEK surveys, the objective of identifying potential EBSAs was met. Finally, the data collected during this project can help us describe ecologically significant species, but further research to identify these species and their functional role in the ecosystem is required.

The DFO-FSRS Inshore Ecosystem Research Project has provided a rich data set for deepening our understanding of species distributions and use of the inshore. Next steps include the integration of results across such components as the at-sea catch data, the DFO database data, and the fishery-independent data; comparisons with historical data; and comparisons of fishery-independent results with those from the underwater video survey. The LEK studies will provide a longer time dimension to the project which, together with the retrospective analysis of DFO databases and other historical data, may identify and increase our understanding of changes in the Scotian Shelf ecosystem. The data gaps identified through the DFO-FSRS Inshore Ecosystem Project will also serve to focus future research.

Ecosystem research and monitoring are critical for integrated management of the oceans. In the inshore, where there has been no consistent funding of research and monitoring, multi-disciplinary collaborative projects such as the DFO-FSRS Inshore Ecosystem Project can provide the necessary baseline data. In addition to DFO and FSRS, the Inshore Ecosystem Project benefited from the participation of researchers from the Canadian Wildlife Service and Acadia University. Future work on the inshore will continue to involve a wide range of partnerships with government agencies, the academic community, and stakeholders.

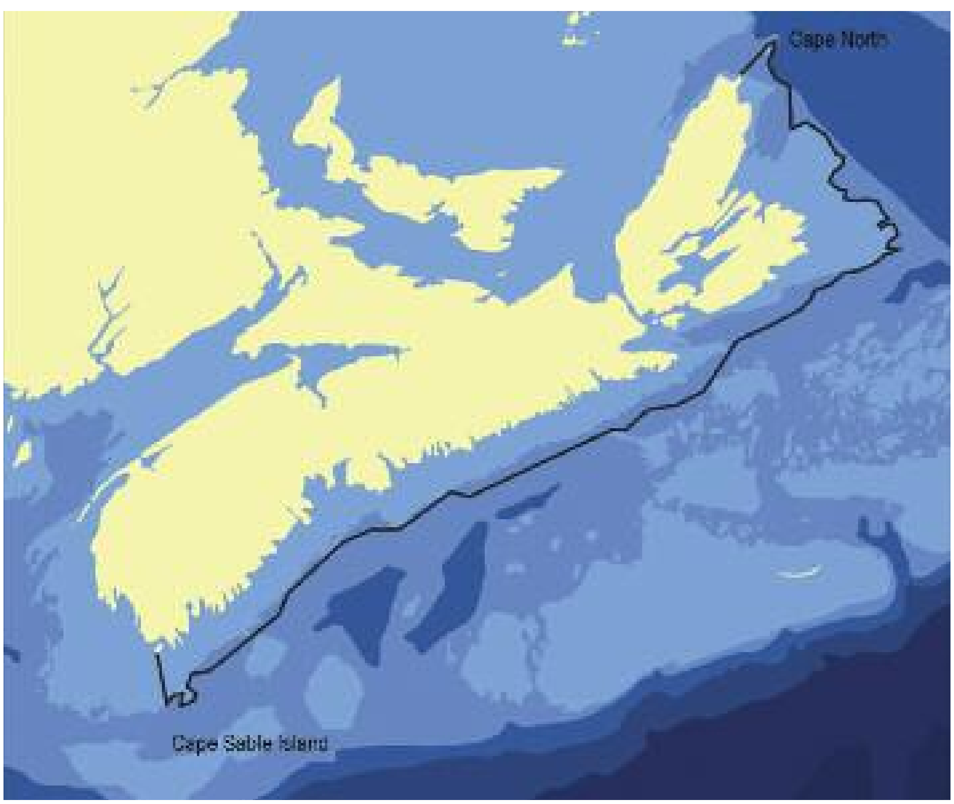

Figure 1. Map of Nova Scotia, Canada, showing the 12-mile offshore line

Figure 2. Beach seining at Gabarus Bay, Cape Breton, Nova Scotia

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Oceans and Aquatic Management

Tidal Power – Exciting Developments in Renewable Energy

Ted Currie and D.R. Duggan

Many regions of Canada, including the provinces of Nova Scotia and New Brunswick, are exploring and developing new alternate sources of energy, in attempts to offset the effects of greenhouse gases emission, combat climate change, and establish secure supplies of energy sources. As well, power generating infrastructure is ageing and public utilities are planning replacement options for the next 30 years. Both provinces currently generate some electricity using hydro, wind, and nuclear energy, but the majority of generating stations are dependent on coal and oil. Another reason for the interest in exploring alternate sources of power is the projected cost of all fossil fuels.

The Nova Scotia government has legislated that by 2013 almost 20% of the province's electricity must be generated through renewable energy sources such as hydro, wind, tidal, biomass, and solar. As a result there has been a renewed interest in exploring ocean renewable energy sources including tidal power. In 2006, the Electric Power Research Institute prepared a number of reports to assess the areas for tidal power development which identified the Bay of Fundy as one of the areas with the highest potential in North America (http://archive.epri.com/oceanenergy/attachments/streamenergy/reports/Tidal_003_NS_Site_Survey_Report_REV_2.pdf).

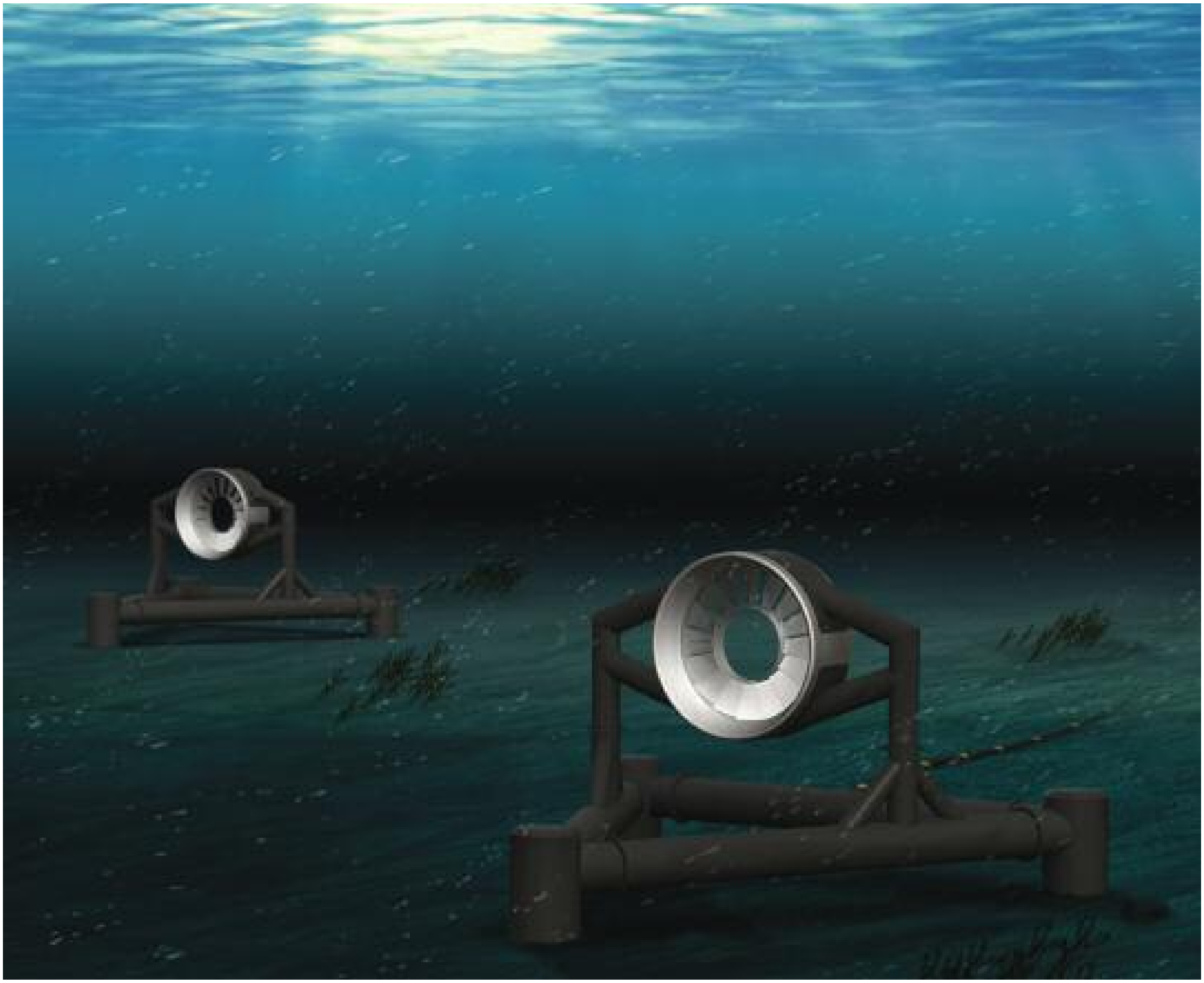
OpenHydro turbine prior to deployment in the UK – photo courtesy of Nova Scotia Power Incorporated

Indeed, the Bay of Fundy has the largest tidal range in the world. For more than a century, scientists and business interests have been investigating ways to harness some of this tidal energy. Several studies were conducted in the 1970s and 1980s, many of which were led by scientists at BIO. Some of these same scientists are currently involved in research to assess the feasibility of converting tidal power into electricity.

To evaluate the viability of tidal power generation in the Bay of Fundy, in 1984 Nova Scotia Power Incorporated (NSPI) constructed a prototype project on the Annapolis River. This facility is one of only three tidal power generating stations in the world and the only one in North America. The NSPI technology is similar to a hydro dam on a river, and uses a dam to create a head pond to capture the flow of water. Although the Annapolis River tidal plant does not generate electricity continuously and alternate sources of energy are required for approximately 12 hours of the day, it does produce up to 20 megawatts of power. To put this into perspective, one megawatt is considered enough electricity to power 300 homes. By comparison, each of the units at the NSPI Tufts Cove facility, powered by fossil fuels, can generate 150 megawatts.

Although the technology has been proven, and the Annapolis facility has been a success, a larger facility has not been constructed in the Bay of Fundy. The construction of large-scale dams and causeways in tidal waters poses a number of concerns including interference with navigation and fishing, barriers to fish migration, deposition of sediment, and changes in tidal regimes. These concerns are further complicated by the anticipated rise in sea level and effects of climate change.

Nonetheless, the success of the project raises exciting possibilities for generating electricity from the tidal power. Technologies have advanced over the past 25 years and new designs that will have fewer adverse impacts on the ecosystem include in-stream turbines. Some of the recent designs appear similar to wind turbines but are mounted on the seabed. Technologies of this type



An artist's rendition of tidal power devices on the seabed – image courtesy of Nova Scotia Power Incorporated

would continue to generate electricity on both a rising and falling tide. A small-scale tidal in-stream power turbine was successfully deployed at Race Rocks in British Columbia (http://www.racerocks.com/racerock/energy/tidalenergy/tidalenergy.htm).

In 2007, the province of Nova Scotia initiated a Strategic Environmental Assessment (SEA) to assess the socio-economic and environmental feasibility of offshore renewable energy development in the province with a focus on tidal power. The SEA includes extensive public consultation throughout Nova Scotia which will continue through 2008. Some of the issues to be considered include interference with fishing, navigation, tourism, and recreation, and impacts of the underwater cable.

At this time, NSPI and other developers are exploring the feasibility of a demonstration-scale project of these in-stream turbines in the Bay of Fundy. Researchers from BIO (NRCan and DFO's Oceans and Habitat Branch and Canadian Hydrographic Service) have assisted in the collection of baseline information regarding tides, currents, sediments, and bathymetry to identify high potential locations for a facility.

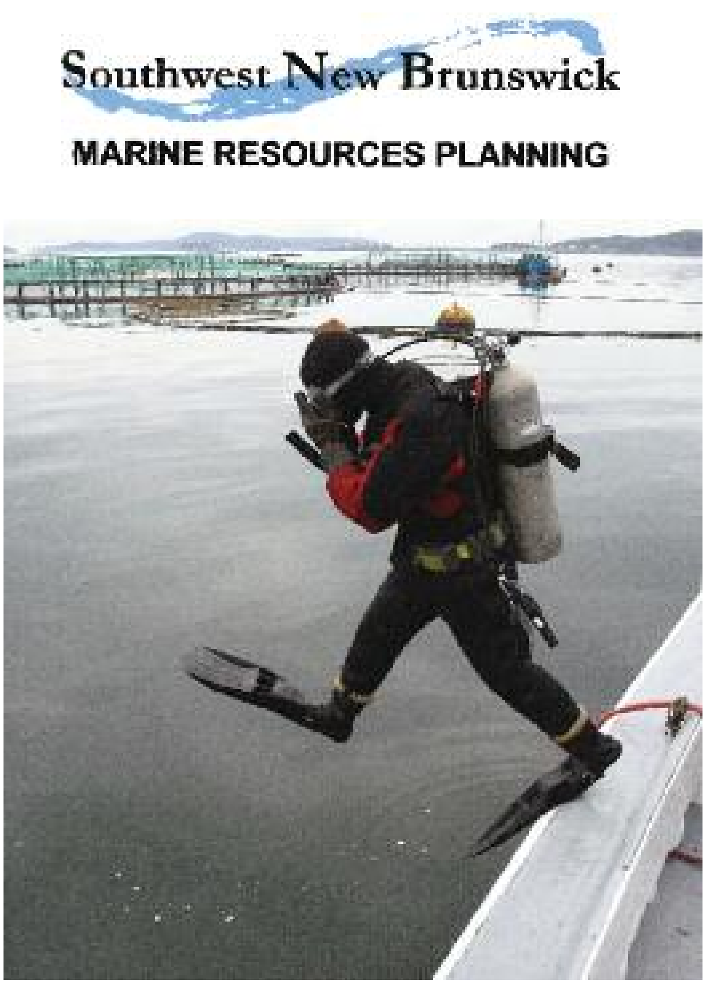
The placement and operation of an in-stream tidal power project will likely require approvals under the *Fisheries Act* and will also be subject to the *Canadian Environmental Assessment Act*. The Oceans and Habitat Branch will be representing DFO in the review process and has formed a departmental working group to assist in the planning. For questions or comments about the role of DFO in ocean renewable energy visit (http://www.dfo-mpo.gc.ca/oceans-habitat/index_e.asp).

The upper Bay of Fundy is a very harsh environment and the new technology will have to first prove itself against strong currents, high tides, turbid water, and seasonal problems like ice and floating debris. Designs that can withstand these types of conditions will be able to function anywhere.

The potential to harness tidal power in the Bay of Fundy has intrigued scientists and entrepreneurs for more than a century. The new in-stream tidal technology represents an exciting development for Nova Scotia, not just for the generation of a sustainable and environmentally friendly form of electricity, but it also holds the potential of a new marine-based industry.

"Have Your Opinion Heard": Citizens Lead Development of Integrated Marine Resources Management Plan in Southwest New Brunswick

Susan Farquharson and D. R. Duggan



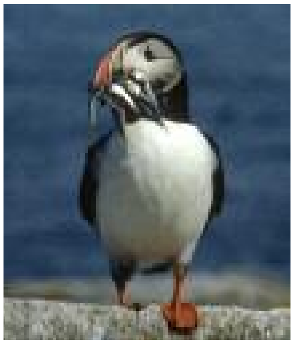
Courtesy of the Grand Manan Whale Seabird Research Station

A new approach to management of marine resources has begun in the Bay of Fundy. The ***Southwest New Brunswick Marine Resources Planning Initiative*** will develop a comprehensive management plan for the marine resources and marine space in the Southwest New Brunswick (SWNB) section of the Bay of Fundy.

The Bay of Fundy is renowned for its rich physical and biological features. These have supported a number of coastal communities through significant economic activities such as commercial fishing and harvesting, salmon aquaculture, fish processing, shipping, the energy industry, ferry transport, and tourism. These economic activities must make room for the expectations of coastal landowners and recreational users, and all has to carry on without degrading the health of the bay or damaging its wildlife or habitats.

As people make more demands on the Bay of Fundy, conflicts arise over what the best use of its limited resources and space should be and how the bay should be protected. The variety of stakeholders, with often competing interests, led to efforts aimed at improving the dialogue among them. A first Bay of Fundy Stakeholders Forum in September 2001 proved to be useful for information sharing; however, the need to go beyond this to a proactive planning mechanism was recognized. DFO, through the Oceans and Habitat Branch, and the New Brunswick Department of Agriculture, Fisheries and Aquaculture launched discussions in early 2004 to improve marine resources planning and management in the southwestern part of the Bay of Fundy. The concept of developing a Bay of Fundy Marine Resources Planning initiative and draft Terms of Reference were presented at the May 2004 Bay of Fundy Stakeholders Forum, and the initiative was launched in September. The plan is to be a tool for managing current and future marine activities which will allow people to make a living at the same time the health of the Bay of Fundy is protected and sustained.

In phase one of the initiative, a Planning Process Committee was created. The committee comprises individuals with a demonstrated



Courtesy of Nell Halse

Courtesy of the Grand Manan Whale Seabird Research Station

Allan and Joseph Abbott, longline fishing for dogfish in the Bay of Fundy – photo courtesy of Marc Johnston

knowledge of the issues and concerns of the relative marine resource sectors of the area, and includes representatives from the above industries, conservation and economic development organizations, First Nations, local government, and the sponsoring provincial and federal government departments. A public survey that completed phase one indicated that issues previously identified, such as aquaculture, better fishery management, and protection of the ecosystem, are still considered priorities for more effective management and that there was public support for moving forward with phase two.

An intensive public engagement process to provide input to plan development is underway in phase two. Susan Farquharson and a team of local individuals dedicated to moving from the current conflict-based processes to dialogue-based resource planning have been tasked with leading the Marine Resources Plan development. Ongoing engagement activities include presentations to groups and organizations, one-on-one meetings with users of the marine environment from all backgrounds, eight Community Consultation Forums scheduled between February 5 and April 1, 2008, and the development of communication tools to encourage citizen input to the plan.

Along with the public engagement process is a parallel effort by the Technical Working Group to compile data and information. Scientists and GIS technicians from the province of NB along with DFO scientists from the St. Andrews Biological Station and BIO are busy merging and compiling data ranging from fishing effort to marine plants to shipping lanes. This data will provide a critical backdrop for informed decision-making in the area.

This new approach to marine resources management requires that the Marine Resources Plan be built on the public input. Those who want their opinion heard or to otherwise become involved should visit (www.bofmrp.ca). The public is encouraged to make the most of this history-making opportunity in marine management and make sure their opinions are considered in the final Marine Resources Management Plan in SWNB Bay of Fundy.

Courtesy of Fiona Cuthbert

Musquash Estuary Marine Protected Area: An Evolving Management Regime

Penny Doherty and D.R. Duggan

The Musquash Estuary Marine Protected Area (MPA) is New Brunswick's first MPA. It was designated under Canada's *Oceans Act* in December 2006. Although its designation is a major achievement, the ongoing management of the Musquash Estuary MPA also is a challenge. Its first year as an MPA has brought forth many management issues, including maintaining the ecological integrity of the MPA, clarifying roles and responsibilities of provincial and federal regulators, and communicating the MPA conservation measures to all affected parties.

The Musquash Estuary MPA is located approximately 20 km west of the city of Saint John and covers, roughly, 7.4 km^2. A relatively undisturbed area, the estuary comprises a diversity of habitat types, from expansive salt marshes to rocky subtidal features, all nurturing related biological communities. Overall, the highly productive estuary provides a rich habitat for many species of wildlife and is highly valued by the surrounding populace.

Conservation and fishing organizations largely were responsible for bringing the Musquash Estuary to the attention of the federal government as a proposed MPA in 1998. The Musquash Estuary Planning Group was formed, comprised of interested parties including conservation organizations, industries, federal and provincial government departments, First Nations groups, coastal land owners, and community members. Through the efforts of the planning group, Musquash Estuary was accepted as an Area of Interest in the MPA Program of the *Oceans Act* in 2000. The planning group, which developed into the Musquash Advisory Committee following MPA designation in 2006, worked closely with DFO throughout the designation process.

Collaboration was the cornerstone of the Musquash Estuary MPA designation process and is the crux of MPA management. Prior to designation, the Province of New Brunswick transferred the administration and control of submerged provincial Crown lands in the estuary to the Government of Canada so that the entire estuary could be managed as an MPA. Under the *Oceans Act* the MPA boundary could extend only to the low water mark. However, to ensure that the salt marshes and mudflats in the intertidal area surrounding the MPA were managed within the same spirit of the MPA, New Brunswick transferred these lands also to the federal government.

Musquash Estuary – photo courtesy of David Thompson

Although the MPA regulations which prohibit the disturbance, damage, destruction, or removal of any living marine organism or any part of its habitat within the MPA cannot be applied to the intertidal area because it is outside the MPA boundary, the provisions of other federal and provincial laws, regulations, and policies will play an important role in managing activities in this area. In addition, research, monitoring, and management objectives for the MPA are applied also to the intertidal area. The Province of New Brunswick and DFO are working together to further define the roles and responsibilities of federal and provincial regulators in the MPA, and to determine the most appropriate manner in which to manage activities in the intertidal area.

Human activities permitted in the Musquash Estuary MPA will be limited to those whose sustainability has been demonstrated. Emphasis will be placed on maintaining health of all species and on the conservation of ecosystem functions and processes. A precautionary approach and the most current scientific knowledge will provide the basis for management decisions. Protection levels in the MPA's three management zones vary according to the ecological features of the zone, the zone's importance in meeting the overall objectives for the MPA, and its capacity to accommodate human activities. Different activities may be permitted within the three management zones, provided they do not compromise the ecosystem objectives of the MPA. To assist proponents in carrying out permitted activities within the MPA, DFO has developed a guideline document detailing the required information for activity plans and an internal process for reviewing proposed plans.

The Musquash Estuary MPA is connected with the broader Bay of Fundy and Gulf of Maine ecosystem and the surrounding landscape within the Musquash watershed. Although activities outside the MPA boundary may have a negative impact within the MPA, the Musquash Estuary MPA Regulations and general prohibitions do not apply to these activities. Therefore, the MPA tool alone cannot address all issues of concern in this area, especially those outside federal oceans jurisdiction. There is an ongoing need for all interests to work together in addressing the potential impacts on the MPA of activities in the Musquash watershed and adjacent coastal waters. DFO is collaborating with the province of New Brunswick, landowners, MPA users, and other stakeholders to encourage

This sunken barge in the Musquash Estuary MPA could be hazardous to MPA users.

compatible land and coastal water uses in the Musquash watershed and waters adjacent to the MPA.

The transfer of administration and control of lands to the federal government also raises potential liability issues. DFO has undertaken a project to identify hazards in the MPA and intertidal area and to communicate associated risks to users. Some of the measures underway include attaching a buoy to a sunken barge in the MPA, posting signs around old derelict vessels in the intertidal area, doing a survey of potential dangers in the MPA and intertidal area, and developing a map identifying the location and description of these hazards.

One of the key challenges in protecting the ecosystem in the MPA is to communicate to a variety of audiences the conservation measures of the MPA. Provincial regulatory agencies involved with the watershed, coastal adjacent waters, intertidal area, and MPA need to be informed of MPA conservation measures and general prohibitions, and to incorporate these measures into their existing regulatory frameworks. Landowners in the Musquash watershed, industry representatives, users of the MPA, and other stakeholders also need to be aware of conservation measures because they can all contribute to the protection of the MPA. A communications strategy has been developed to target key audiences using communications products such as brochures, meetings, and presentations.

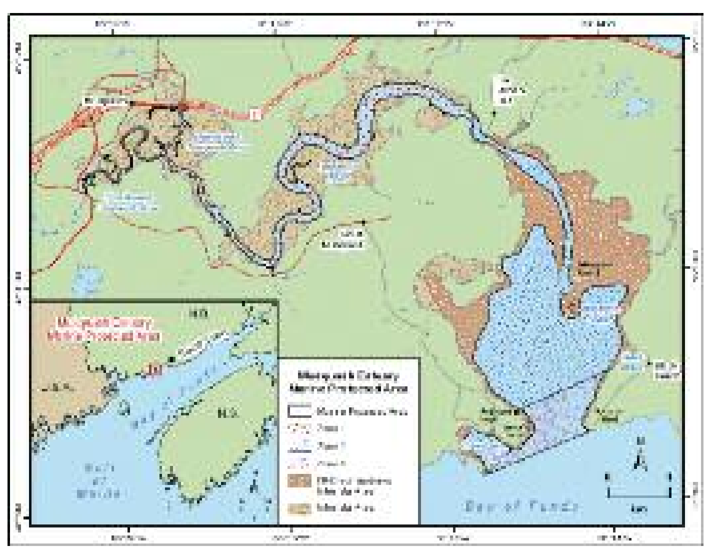
The primary goal of managing the MPA is to maintain its ecological integrity. An ecosystem-based approach is used to manage human activities in the MPA. The goal of this approach is to preserve the integrity of the ecosystem by restoring and/or maintaining ecosystem components, functions, and properties at appropriate temporal and spatial scales. In cooperation with the MPA management team at BIO, scientists at the St. Andrews Biological Station are developing a research and monitoring program to increase the understanding of the Musquash ecosystem, and allow us to monitor the effectiveness of the MPA.

A framework identifying performance indicators and operational strategies for monitoring various components of the MPA ecosystem has been developed. DFO researchers will map benthic habitat, ecotypes, and animal and plant species distribution within the MPA and intertidal area and monitor:
1) the health and acreage of ecotypes to ensure they are being protected from anthropogenic impacts,
2) the health of certain indicator organisms to ensure water and sediment quality is being maintained,
3) human activities to assess their impacts on living resources, and
4) the number and distribution of exotic species.

All of these activities will help determine a baseline of environmental quality for the MPA and intertidal area against which future assessments of the ecosystem structure and function can be made.

Monitoring of the MPA must be in line with management needs so that monitoring results will provide MPA managers with information for adaptive management and informed decision-making. Thus, the management of the MPA will take a “learning by doing” approach that incorporates flexibility into the process. Planning and ongoing management will be adaptive and responsive to improved knowledge of the Musquash Estuary ecosystem as it becomes available, and to changing environmental conditions. The management and effectiveness of the MPA will be monitored and evaluated regularly.

While DFO has the lead jurisdictional responsibility, the vision and objectives for the MPA can be achieved only through the coordination, cooperation, and partnership among all relevant organizations and interests. Management planning must be both inclusive and transparent, and supported by all affected organizations and individuals, to ensure the shared accountability for the protection of the MPA. A wide range of stewardship actions can be taken by individuals, groups, and communities to raise awareness of the MPA, and to monitor and conserve the Musquash Estuary ecosystem. DFO encourages and has been pursuing collaborative activities and habitat stewardship opportunities for the Musquash Estuary. Effective protection and management depends on open and informed decision-making. Thus, there is ongoing need for collaboration in protecting the Musquash Estuary MPA.



The Musquash Estuary Marine Protected Area with its three management zones: note that the MPA boundary (shown within the bold lines) extends to the low water mark and does not include the intertidal area. Figure courtesy of Stan Johnston

Technical Support

Research Voyages in 2007

Donald Belliveau

Researchers at BIO utilize the following research vessels based at the Institute and operated by the Canadian Coast Guard (CCG), Maritimes Region:

CCGS *Alfred Needler*, a 50-m offshore fisheries research trawler;
CCGS *Hudson*, a 90-m offshore research and survey vessel;
CCGS *Matthew*, a 50-m coastal research and survey vessel.

In addition, BIO scientists conduct field programs on CCG research vessels from other DFO regions, vessels of opportunity (e.g., CCG buoy tenders and icebreakers, commercial fishing ships, and survey ships), and research vessels of other countries. The CCGS *Creed*, based in Quebec Region, was used by both the Canadian Hydrographic Service (CHS) and NRCan's Geological Survey of Canada (GSC) for multibeam survey work in the Gulf of St. Lawrence and Bay of Fundy. Surveys normally conducted on the CCGS *J.L. Hart*, a 20-m inshore research vessel, were conducted on a series of charter vessels in 2007 because the *Hart* was removed from service and the replacement vessel was not yet available.

The CCGS *Alfred Needler's* principal role is in stock assessment surveys. The programs planned for the *Needler* were conducted on the *Wilfred Templeman* and the *Teleost* out of St. John's, Newfoundland and Labrador because the *Needler* was out of service for her Transitional Life Extension, an extended refit that will upgrade the vessel's systems as well as add considerable oceanographic science capabilities in preparation for the planned reduction from three to two trawlers. The *Needler* is expected back in service in July 2008.

The CCGS *Hudson* started her year in early April. The first cruise was for the Maritimes Region annual spring Atlantic Zone Monitoring Program (AZMP). This cruise collects data on water properties, temperature, salinity, nutrients, dissolved oxygen, and plankton biomass for the annual *State of the Ocean Report* and focused research projects. The second cruise serviced moorings in Orphan Basin and Flemish Pass off Newfoundland. The vessel then sailed to the Labrador Sea to service oceanographic moorings and collect conductivity, temperature, and depth data in oceanographic survey operations, as part of Canada's contribution to global climate studies. NRCan used the ship in June for geophysical research in the Laurentian Channel and on the Newfoundland Shelf. They conducted sidescan surveys, piston coring, bottom photography, grab sampling, and seismics for geophysical research. In July, ROPOS—the Remotely Operated Platform for Oceanographic Science, a 6,000-m-capable ROV (remotely operated vehicle)—was installed on the *Hudson* for the second time. With ROPOS, researchers were able to explore parts of The Gully, the Stone Fence, and areas off Newfoundland with video and still imagery and to collect biological and geological samples under operator control. In August, some moorings in The Gully were retrieved and then the ship went to the Terra Nova offshore oil field for investigation into the impacts of "produced" water on the environment around the platform. "Produced" water is recovered with the oil as it is brought from deep underground. Unfortunately, a new crane for the foredeck of the *Hudson* could not be installed in time for a joint NRCan-University of Quebec program in the Canada Basin and the September cruise was cancelled for this year. The Maritimes Region fall AZMP cruise was conducted in October. The *Hudson* was on display at the BIO Open House, October 17-21. From late October to mid-November, oceanographers from the Institut Maurice Lamontagne in Quebec Region conducted their fall AZMP/Ice Forecast cruise in the Gulf of St. Lawrence. From late November to mid-December, the *Hudson* was used to conduct the fall AZMP cruise of the Northwest Atlantic Fisheries Centre in St. John's. This cruise had been moved from the *Hudson* to the *Teleost* earlier in the year as a cost-reduction measure, but was moved back at the last minute due to problems on the *Teleost*. On the *Hudson*'s return trip from St. John's, a mooring that had not come to the surface in October was dragged for, and successfully recovered. The season concluded December 10 when the ship was docked at BIO for the winter.

The CCGS *Matthew* is primarily a hydrographic vessel which can carry two hydrographic launches and conduct surveys with its high resolution Kongsberg EM710 multibeam system. The 2007 field season was a significant one for the *Matthew* survey platform, as this was the first time that both launches were equipped with multibeam capability (Kongsberg EM3002) which greatly increased the efficiency of inshore survey operations. After a delay in April/May, the *Matthew* began its field season in mid-May with a trip to the Bay of Fundy for a joint NRCan/CHS program. In June, the *Matthew* moved to the north

Nachvak Fiord is located in the heart of the Torngat Mountains National Park in Labrador. This view looks up the valley at the head of the fiord, just after the *Matthew* had turned around after running a sounding line the entire length of this spectacular waterway. Photo courtesy of Michael Lamplugh

coast of Newfoundland (Cape Freels and Fogo Island). For the Cape Freels survey, the *Matthew*'s multibeam system collected bathymetry data and acoustic water-column information, as part of a fisheries ecology research program. The ship headed for the Labrador coast in July. A three-year project using multibeam surveys to discover and chart a safe inshore navigation corridor up the northern Labrador Coast along the very rugged and shoal-infested area between Cape Mugford and Cape Chidley was completed. An unprecedented 22-day stretch of fair weather allowed this goal to be reached. In addition to completion of the more than 350-km route, the *Matthew* flotilla was used to chart McLellan Strait and Grenfell Sound. This approximately 20-km-long narrow passage between the Atlantic Ocean and Ungava Bay has rarely been transited. In October, the *Matthew* returned to the south coast of Newfoundland where surveys were conducted off Brunnette Island. The vessel arrived back at BIO in time for Open House, when the CHS and GSC Atlantic showcased

Crew on the *Matthew* have observed killer whales (Orcas) in Newfoundland and Labrador waters on several occasions over the years. The Orcas are usually heading north in July and August so they are seen as they transit through the ship's work area. In 2007, hydrographer Michael Lamplugh finally had the opportunity to get some photographs. This pod comprised three females and two calves.

the work they perform aboard the vessel. NRCan staff used the vessel starting in late October for a ground-truthing survey in the Gulf of St. Lawrence, conducting geophysical activities including seismics, grab samples, and gravity coring. On November 8, the *Matthew* returned to BIO for the winter.

Replacement of our ageing scientific research fleet is a high priority. Plans are underway to replace the *J.L. Hart*; preliminary design work was started in 2006. Delivery is expected in 2009. Two replacement trawlers, one for each of the east and west coasts, were announced in the spring 2005 federal budget. Contracts have been let to start the preliminary design, with delivery planned for 2010/2011. The replacement for the *Hudson* is moving ahead with completion of the Statement of Requirements expected in early 2008 and delivery of the ship in 2013.

Electronic and Informatics Support to Science at BIO

Jim F. Wilson

From their workshop in the Vulcan Building at BIO, the Marine Electronics Group of the Canadian Coast Guard (CCG) Integrated Technical Services Electronics and Informatics Division has been providing electronics support for science programs for more than 40 years.

This group of dedicated technicians supports the complex electronic systems of the Canadian Hydrographic Service (CHS), as well as other electronic systems on vessels used by the BIO science community. Specifically, they are responsible for the maintenance and repair of navigation systems, informatics support for computers on board research vessels, and provision of at-sea technical support for the CCGS *Matthew* and CCGS *Hudson*. Typical field seasons involve four hundred or more sea days per year for the two ships. Through a comprehensive training program conducted by Integrated Technical Services, technicians maintain competencies related to computer software and hardware, navigation systems, and specialized echo-sounding equipment, such as the multi-beam sounders used by the CHS.

Installation of EM710 Transducer Array on the CCGS *Matthew*

The group carries out major installations, including the EM710 Multi-beam system on CCGS *Matthew* and the annual installation and work-up of the computer systems, portable reference stations, GPS Rover backpacks, and wind- and solar-powered systems for navigation systems in remote sites.

As well, science programs benefit from maintenance performed by the Marine Electronics Group on navigation data distribution systems, uninterruptible power supplies, acoustic pingers, deep-sea echo-sounding systems, acoustic sensors, hull-mounted, variable-depth acoustic rams, and Electro Fishers.

During 2007, the Marine Electronics Group was responsible for outfitting the newly refitted, 31-foot, CHS survey launch, *Pipit*. This involved the installation of the shallow-water, EM3200 multi-beam echo-sounding system, hull sensors, antennas, and a suite of onboard electronics. Once the installations were complete, the group

Replacing 12 Khz Transducer, Main Ram, CCGS *Hudson*, February 2007

Launch Electronics – CSL *Pipit.*

commissioned all the systems and sub-systems prior to trials by the CHS. The launch will be part of the hydrographic surveys conducted by the CCGS *Matthew*.

As an integral part of the Vessel Life Extension of the CCGS *Alfred Needler*, the Marine Electronics Group has been tasked with the installation of a wide array of new electronic systems, including a scientific echo-sounding system (EK-60), a trawl monitoring system (Scanmar), a seafloor classification system (SeaScan), an acoustic doppler current profiler, and a navigation data remote display system.

Always working behind the scenes, the Marine Electronics Group is vital to the CHS and science programs at BIO. The work performed preparing specifications, overseeing contracted work, updating engineering drawings, and performing much of the actual physical installations, speaks highly of the dedication and the expertise of these electronic technicians.

New Laboratory Nears Completion – Van Steenburg Project and Jetty Extension Begin

Brian Thompson

Approximately three years after the groundbreaking for the new laboratory building, equipment and staff have been moved into the building. The building consists of five stories, and was built to conform to the topography of the site. Visual compatibility with the existing buildings at BIO was also an important architectural consideration.

The building includes about 4,500 square metres of useable space. Three of its five levels contain both labs and workstations: approximately 60 office workstations have been provided for staff along with 72 lab modules in various single, double, triple, and quadruple configurations. Two meeting rooms also have been included. The entrance level of the building accommodates freezers for biological samples and meets chemical storage requirements, while the uppermost floor (penthouse) houses the building's ventilation system. The facility is directly connected to the main BIO complex through the van Steenburgh Building, while access to the jetty and seawall is available through a new pedway.

The new lab was designed and constructed with energy efficiency in mind, using heat recovery technology and taking full advantage of BIO's Energy Centre. The Energy Centre extracts cool water from the Bedford Basin, thus minimizing the requirement in summer to provide additional chilling for the lab building's air conditioning system. The name of the new facility will be the Katherine Ellis Building.

Reconfiguration of the Strickland and Vulcan buildings got underway during the year, in association with the van Steenburgh Building refurbishment. The Strickland Building renovations involved converting former laboratories to temporary or swing work space, required to accommodate staff displaced while construction is being carried out on the van Steenburgh Building. Similarly, both temporary and permanent relocations and fit-ups of some workshops in the Vulcan Building were necessitated by the van Steenburgh construction.

The next phase of the van Steenburgh project involves demolition and removal of the entire interior of the existing building. Tenders were awarded for this work which is expected to be completed by early spring 2008. Following this, a contract will be tendered for the removal of the exterior walls and reconstruction of the building to meet current building codes. This will provide a modern and highly functional work environment.

In 2007, a contract was awarded to extend the jetty by 33 metres and to upgrade the jetty's electrical system. Construction work is progressing well and the concrete caissons should be completed and available for use by spring 2008.

Coordinating and facilitating the creation of temporary swing space, temporary moves, and fit-up at the Institute have presented many logistical challenges for the staff of DFO (Science and Real Property, Safety and Security branches) and Public Works. Successes achieved have been possible only through a high level of cooperation by all involved parties.

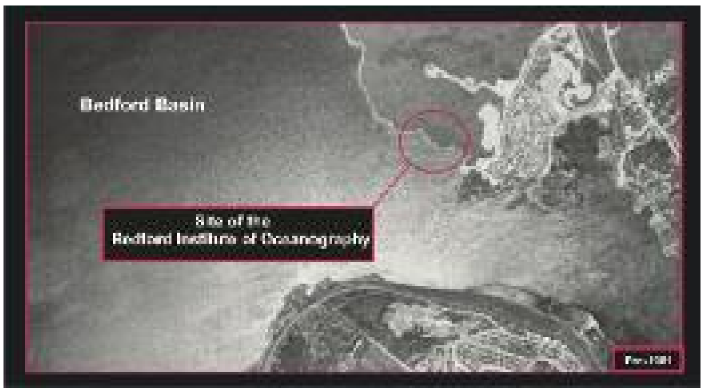
Lab modules in the new laboratory building

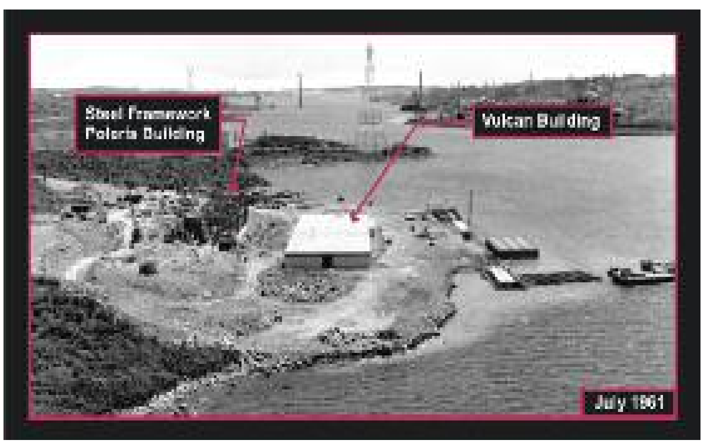
Work underway in the Vulcan Building to accommodate shops relocated from the van Steenburgh Building

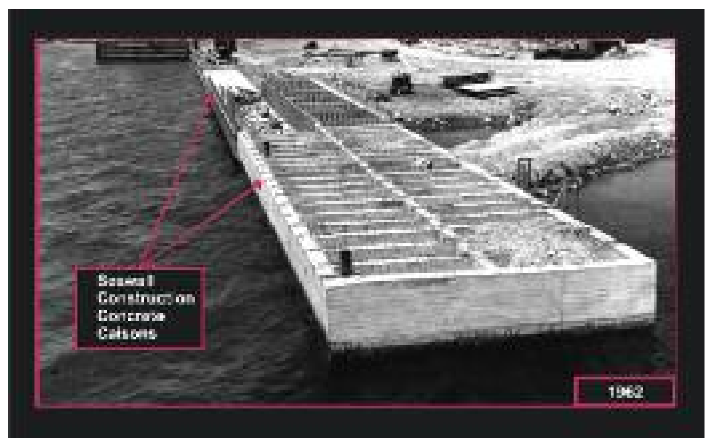
The Birth, Development, and Revitalization of a World-Class Facility

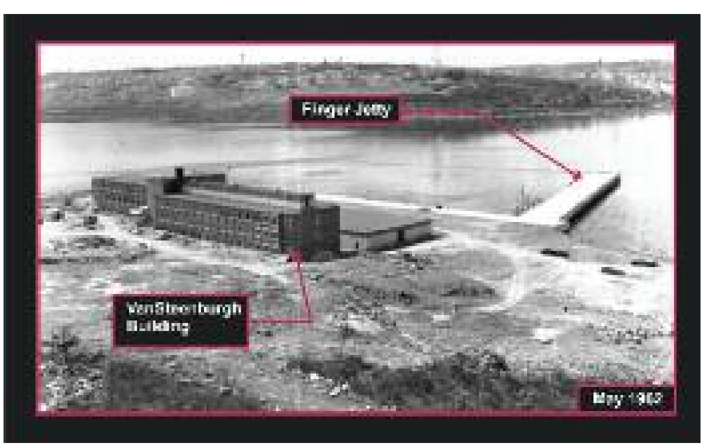
Brian Thompson

Over more than four decades, we have seen many changes in the physical appearance of the BIO site as new facilities and infrastructure were built and existing ones were reconstructed. The following photographs were taken during the period of 1960-2007 and show the evolution of the BIO campus from the initial shoreline development for the jetty and the Vulcan building to the most recent construction of the new laboratory building.

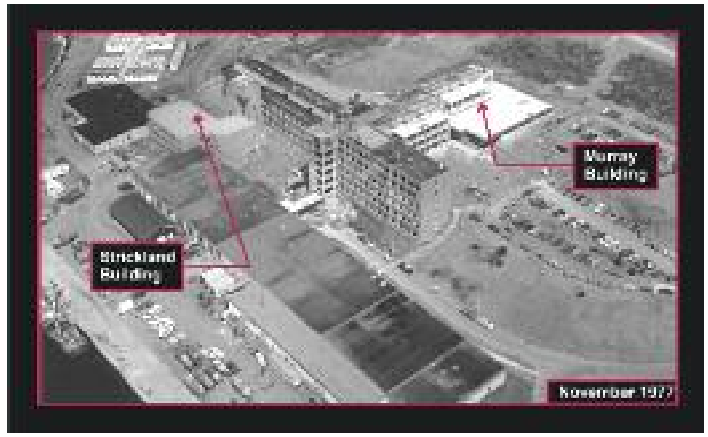


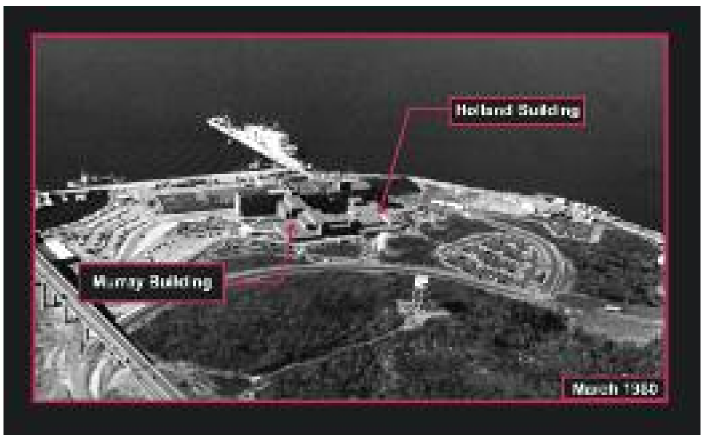


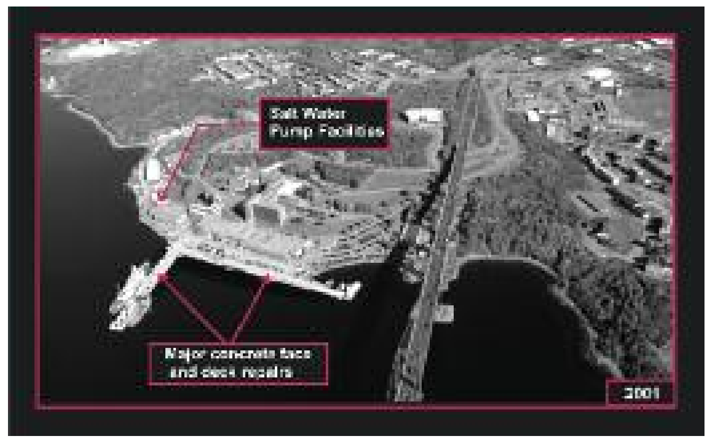





VanSteenburgh (North)
A. Murray MacKay Bridge Construction
5th & 6th floor additions to Polaris Building
Fish Lab
July 1968


Murray Building
Strickland Building
November 1977


Holland Building
Murray Building
March 1980


Salt Water Pump Facilities
Major concrete face and deck repairs
2001


New Energy Centre
New Lab Building
November 2007

Outreach

BIO Open House 2007: Celebrating 45 Years of Marine Science that Benefits Maritimers, Canadians, and the World

Bruce Anderson, Claudia Currie, Richard Eisner, Francis Kelly, Jennifer Hackett, Carl Myers, and Tom Sephton

More than 20,000 visitors from around Atlantic Canada came to learn about marine science from the experts.

During the period of October 17-21, BIO bustled with welcoming staff and eager visitors to the Institute's Open House. It had been five years since the last BIO Open House celebrated the 40th Anniversary of this oceanographic research centre. Not building renovation, nor torrential rains, nor even a complete building evacuation due to a false fire alarm could thwart the enthusiasm of over 20,000 visitors as they discovered the **ABC**s of ocean science through:

Attending exciting and provocative lectures (the 12 lectures attracted 1,000 people);

Boarding and touring the oceanographic research ships, the CCGS *Hudson* and *Matthew*;

Chatting with 350 of BIO's 650 marine researchers and technologists at the 66 exhibits.

The opening ceremony was held in the BIO auditorium on October 17. Master of Ceremonies was René Lavoie, Scientist Emeritus, who presented Institute research highlights from the past year. DFO's Associate Deputy Minister of Science, Dr. Wendy Watson-Wright, and Dr. Marc D'Iorio, Director General of NRCan's Geological Survey of Canada, represented BIO's two largest departments. Musical highlights were *O Canada* performed by soloist Rebecca Hiltz Leblanc, and touching renditions of *Farewell to Nova*

A highlight of the opening ceremonies was the Lakeview Elementary School Choir performing their original song, *We love the Ocean*, inspired by the BIO Open House.

2007

It took over a year of preparation and more than 450 volunteers to make this free open house a success.

Scotia and *We Love the Ocean* by Lakeview Elementary School's Grade 4 Choir. The latter song was composed for the event by Choir Director, Maureen MacMullen. The ceremony kicked off a tour of the exhibits by VIPs, media, family, and friends.

During School Days, October 18-19, 130 classes of eager students and teachers visited from all over Nova Scotia. On Elementary Day, the excited chatter of 1,800 students filled the Institute as the young visitors got to see and touch both live and dead sea creatures, pan for gold, sit in the Coast Guard rescue chopper, and walk through the *Oceans Wild* Fin Whale. The next

Visitors of all ages were captivated from the variety of hands-on experiences including meeting Rex, panning for gold, touching sharks, discovering tunicates (invasive species), and sitting on the North Pole.

day, 1,650 junior and senior high school students asked many questions and got to tour the CCGS *Hudson* which had just returned from a research cruise. Later, many colourful letters of appreciation were received from students and teachers.

Friday concluded with a public lecture by Open House keynote speaker Bob Fournier of the Department of Oceanography at Dalhousie University. Professor Fournier recounted past states of ocean knowledge and reminded us that there is still so much to learn.

The doors were opened to the general public between 9am-3pm on Saturday and Sunday, October 20 and 21. They were offered a pair of two-hour route tours lined with exhibits. Local media had captured the public's interest in the Open House, especially in the woeful tale of Rex, a lobster as old as BIO, and in the up-close opportunity to see and touch dead fish and sharks. Visitors were impressed by the enthusiasm of the staff when describing their displays, including the newest permanent display—a 3-D model of Halifax Harbour. They showed special interest in International Polar Year, which was the theme of many of the public lectures.

The 2007 Open House was the 8th for BIO, including the official opening of the Institute on October 25, 1962 and formal open houses in 1975, 1980, 1984, 1990, 1998, and 2002. Anticipate the next Open House to coincide with BIO's 50th (golden) anniversary in 2012.

About 3,500 students and teachers from all over Nova Scotia visited this five-day event.

Education Outreach at the Geological Survey of Canada (Atlantic) in 2007

Jennifer Bates, Sonya Dehler, Gordon Fader, Rob Fensome, David Frobel, Nelly Koziel, Bill MacMillan, Bob Miller, Michael Parsons, Patrick Potter, John Shimeld, Bob Taylor, Dustin Whalen, Hans Wielens, and Graham Williams

Education outreach by the Geological Survey of Canada (GSC) (Atlantic) of NRCan is primarily as a contributing member to the EdGEO, Video, and Education committees of the Atlantic Geoscience Society (AGS). Other members of these committees include provincial geological surveys, museums, science centres, universities, and schools. Aside from active participation on these committees, GSC Atlantic staff give invited talks at schools, universities, and libraries, and judge at science fairs.

GSC's Graham Williams (centre) and Rob Fensome (right) providing hands-on learning in the classroom - photo courtesy of Mamie Wilks

EdGEO is a national program that supports local workshops on Earth science for Canadian teachers. The Nova Scotia EdGEO Workshop Committee is working to build a new year-round program for educators. As the initial step, in 2007 the Nova Scotia committee divided its program between a field-based workshop in August and hands-on sessions at the Association of Science Teachers (AST) annual conference in Halifax. An annual contribution to the Social Studies Teachers Association (SSTA) conference and several thematic mini-workshops throughout the year in schools and in university education courses would round out the new Nova Scotia EdGEO program. These changes provide flexibility for current presenters and growth for new session organizers. Perhaps, best of all, teachers now have more professional development opportunities.

The 2007 field-based workshop (the 15th since 1994) was held in Wolfville. Sandra Barr and Ian Spooner of the Department of Earth and Environmental Science, Acadia University, led 22 educators through an informative and relevant field trip titled *Rocks, Sand, Mud, and Scenery: How Earth History Controls the Human Environment in the Vicinity of Wolfville, Nova Scotia*. Tracy Webb, a teacher at Horton High School, summarized the best teaching resources and activities from her many years of leading the Grade 12 geology class. The success of this session confirmed that the inclusion of a teacher in the program is important and relevant to K-12 educators. The first evening, the group gathered in the faculty club for a relaxed dinner and social. Ian gave a presentation on the popular yet complex topic of climate change, a talk that generated lively discussion.

Financial support for the August workshop came from the National EdGEO Committee. In-kind support was generously provided by the GSC Atlantic, Acadia and Dalhousie universities, the Nova Scotia Department of Natural Resources (NSDNR), Nova Scotia Museum of Natural History (NSMNH), the Nova Scotia Community College (NSCC), several Nova Scotia schools and school boards, and the Atlantic Science Links Association.

The EdGEO group saw these fossil footprints of a large labyrinthodont amphibian on the beach at Horton Bluff in the Wolfville area. These tracks (or perhaps similar) were discovered in 1841 by William Logan, the founder and first director of the Geological Survey of Canada.

This painting by Judi Pennanen represents the paleoenvironment of the Triassic Wolfville Formation. The ancient landscape was well vegetated and featured braided streams and alluvial fans. Painting reproduced courtesy of the Atlantic Geoscience Society

At the October AST conference held at Halifax West High School, GSC staff Sonya Dehler, Rob Fensome, and Graham Williams offered a hands-on session titled *Dancing Continents, Wingless Birds, and Nova Scotia Rocks* for teachers of grades 9-12. Their session outlined a time line focused on Nova Scotia and some of the local highlights, such as Earth's oldest reptiles. The integral role of plate tectonics in the evolution of life and continents was told through the eyes of flightless birds, whose distribution today reflects their continental drifting. A booth in the conference display area allowed EdGEO members the opportunity to meet teachers and tell them about the EdGEO program and AGS publications and videos.

The success of the Nova Scotia EdGEO Workshop Program depends upon the knowledge, experience, enthusiasm, and dedication of its committee. Presenters and committee members represent both the geoscience and education communities, including the NSDNR, the NSCC, the NSMNH, Dalhousie University, the NS Association of Science Teachers, various private and public schools and school boards in the province, and GSC Atlantic staff.

The sixth season of the *Beyond "The Last Billion Years"* public talk

This Photoguild of Nova Scotia geological-site field trip to Avondale was guided by (front row) the GSC's Rob Fensome (3rd from right) and Hans Wielens (first right). Photo courtesy of and ©Elio Dolente series was held at BIO. Five talks were presented but the new venue did not draw the large crowds as in previous years at the NSMNH. The museum has a dedicated audience that regularly attends such events. The fall 2007 season was absorbed into the BIO Open House talk series, but the next season of the *Beyond "The Last Billion Years"* will return to the NSMNH.

The AGS is now a member of the Halifax Young Naturalists Club (YNC). As such, the AGS Education Committee organizes one month's program each year for the club members who range in age from eight to fourteen. GSC Atlantic staff were active in the program. Bob Taylor led a trip to Lawrencetown and Conrad's beaches; Graham Williams led an excursion to York Redoubt using a mapping activity developed by Patrick Potter; and Graham also gave a talk at the NSMNH on climate warming from a geological perspective. The collaboration with the YNC provides an opportunity to engage young people in geoscience and its prominent role in our surroundings.

On Earth Day, April 22, the paintings by New Brunswick artist, Judi Pennanen, depicting the geological history of the Fundy Basin were unveiled at the Fundy Geological Museum in Parrsboro, NS. Commissioned by the AGS, four of the watercolours highlight life and landscapes in the time of the Wolfville, Blomidon, North Mountain, and McCoy Brook formations while the fifth features a prosauropod dinosaur. A first draft of an accompanying booklet is in the review stage. This visual concept, started by AGS Education Committee member Randy Miller of the New Brunswick Museum, is attracting interest from geoscience museums.

Collaboration continues between the AGS and the Photoguild of Nova Scotia (PGNS). Elio Dolente won both the Atlantic Geoscience Society Award (best geological photograph) and *The Last Billion Years* Award (best Atlantic Canada geological photograph). As usual, Rob Fensome of GSC Atlantic organized a field trip to introduce the PGNS members to the many photogenic geological sites in the province.

These activities and programs are possible only because of the dedicated members of the Nova Scotia Branch of the AGS Education Committee, who come from the aforenamed educational and geoscience organizations and also include educators and interested individuals from private life.

GSC Atlantic staff are also active members of the AGS Video Committee. After its successful release of *Halifax Harbour: A Geological Journey*, this committee is concentrating on promotion of its materials. The Halifax Harbour video was shown continuously at the 2007 BIO Open House and is for sale in the Halifax area and the BIO Gift Shop. Other Committee activities underway are: the development of an online teachers' guide for the Halifax Harbour video; partnership with the Fundy Geological Museum, the Joggins Fossil Institute, and the Cape Chignecto Provincial Park on development of a video highlighting the geological history and resultant spectacular sights of the Bay of Fundy region; and support for a video on the Shubenacadie Canal led by the Shubenacadie Canal Commission.

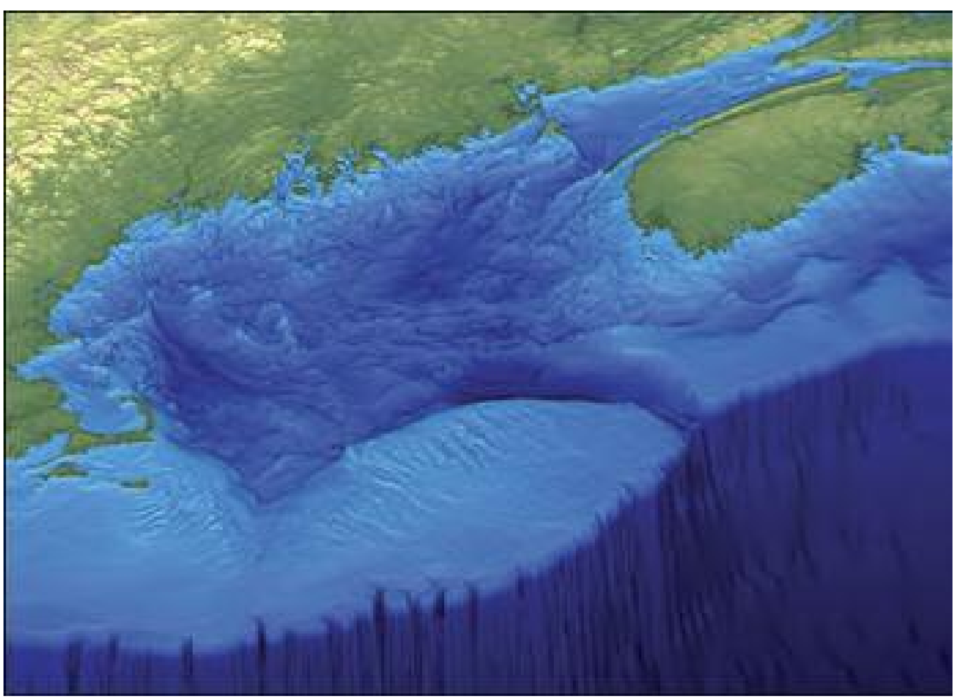
Several GSC Atlantic staff are contributing to a project dedicated to the development of a book on the geology of Canada. This book, *Four Billion Years and Counting: Canada's Geological Heritage* (FBY) represents a tremendous effort: no other book on the subject will bring together the expertise of so much of the Canadian geoscience community, through contributions of text, graphic images, and photographs; the co-ordination of manuscript development; reviews; and co-publication between the Canadian Federation of Earth Science and a commercial publisher. The FBY book will be a cornerstone of Canada's celebration of the International Year of Planet Earth (IYPE) in 2008. Another undertaking for IYPE is *Geotime Trails*. These are hiking or walking trails of a length meant to represent Earth's age of 4.6 billion years. Along the route, signage highlights aspects of Earth's geological history with an emphasis on those that are relevant to the local area. Other planned projects include a competition for high school students, a website about careers in Earth science, fact sheets, and other education resources and activities. The IYPE website (http://www.iypecanada.org/) provides updates on the projects and activities happening across Canada throughout 2008-09.

Retrospective

Research Highlights

NEW ECOSYSTEM RESEARCH INITIATIVE IN THE GULF OF MAINE AREA

DFO Science is funding new five-year regional Ecosystem Research Initiatives (ERI) to advance the science foundation for ecosystem-based management. The Maritimes Region has opted to focus its ERI on the Gulf of Maine Area (GoMA). The choice of GoMA is motivated by the challenging management issues that are emerging in this area and by the developing opportunities to collaborate with the Canadian marine science research community and our US colleagues on shared research questions. The GoMA ERI will work in three areas: (1) influence of climate change on oceanography and ecosystems; (2) spatial patterns in benthic communities; and (3) impact of ecosystem interactions on harvest strategies and species dynamics. The program is being developed and supervised by a joint St. Andrews Biological Station-BIO scientific committee overseen by a cross-sectoral steering committee. For more information on this initiative, please contact Alain Vézina (alain.vezina@dfo-mpo.gc.ca), (902) 426-7706.



Map shows the seafloor terrain of the Gulf of Maine: the darker blues represent deeper areas, and lighter blues indicate shallower depths (image courtesy of the Gulf of Maine Council on the Marine Environment).

SCIENCE FOR INTEGRATED MANAGEMENT OF THE BRAS D'OR LAKES

In 1999, Cape Breton First Nations helped bring together DFO representatives and others for an Ecological Research and Monitoring Workshop which outlined stakeholder concerns for Cape Breton's Bras d'Or Lakes, the last nearly pristine saltwater inland sea on the east coast of North America. At this workshop, a Memorandum of Understanding (MOU) between DFO and the Unama'ki Institute of Natural Resources (UINR), a co-operative venture of the five Mi'kmaq bands of Cape Breton, was signed. DFO agreed to provide the 65-foot research vessel, the *Navicula*, to carry out research in the Bras d'Or Lakes over the next five years. DFO efforts gelled in 2000, under a program known as SIMBOL (Science for Integrated Management of the Bras d'Or Lakes), co-ordinated by Gary Bugden of DFO's Ocean Sciences Division at BIO. Once it was determined which of the stakeholder concerns required the acquisition of new information, a supplementary MOU was signed outlining cooperative research programs. Biologists, oceanographers, and hydrographers from DFO, as well as personnel from Natural Resources Canada, Environment Canada, and private companies, began working with First Nations members on a wide array of projects. Emphasis was placed on community involvement as well as prompt dissemination of research results.

Some highlights of the SIMBOL research program included an ecosystem study designed to permit a comparison between the Bras d'Or Lakes and nearby continental-shelf ecosystems; a mapping project to delineate sensitive habitats and help plan future sampling programs; and a mooring array to provide information on physical, chemical, and biological processes during the winter and early spring. The design of the research programs involved a detailed review of existing information about the Lakes. The compilation of this information resulted in the preparation of a monograph, designed for a general readership, describing the oceanog-

Aboriginal student Terrilyn Johnson conducting sampling as part of the DFO-UINR Scholarship Program

raphy of the Lakes. This monograph, published as a Nova Scotia Institute of Science Special Volume, included chapters on the ecology of the Lakes; invertebrates; demographics of the surrounding population; general physics, chemistry, and geology; and coastal morphology.

Another highlight was the Unama'ki-Fisheries and Oceans Canada Scholarship, awarded jointly by DFO and UINR to a Dalhousie University team for a graduate research project related to the Bras d'Or Lakes ecosystem. The terms of the scholarship required the researchers to mentor a high school student from one of the Cape Breton First Nations and to include this student in their research activities. Scholarships were awarded for topics including *Creating a Strategic Action Plan for the River Denys Watershed, Nova Scotia* and *Patterns in Colonization of the Alien Green Crabs in the Bras d'Or Lakes and Consequences for Native Decapods*.

The SIMBOL Project is now over and has filled many gaps in our knowledge of the Bras d'Or Lakes ecosystem. Future research needs for the Lakes will be met under the umbrella of a broader DFO nearshore research program. Steps in this direction have already been taken with the signing of an MOU with Cape Breton University and an MOU with UINR with more emphasis on coastal management issues.

Workshops and Special Meetings

SIX YEARS IN THE MUD – RESTORING MARITIME SALT MARSHES: LESSONS LEARNED AND MOVING FORWARD

E. Anita Hamilton

The workshop, *Six Years in the Mud*, was held at BIO February 1-2, 2007. It was sponsored by the Ecology Action Centre, Ducks Unlimited Canada, the Nova Scotia Department of Transportation and Public Works, DFO, and the Gulf of Maine Council on the Marine Environment through an Action Plan grant. Six years ago, a workshop was held in Halifax to discuss issues related to the health of salt marshes in the Maritime Provinces. Initiatives born from that workshop have contributed to a number of projects throughout the region to protect, conserve, and restore salt marsh habitats. The goal of the 2007 workshop was to bring together key people and agencies (government and non-government) to look at the successes and challenges facing salt marsh restoration in the Maritimes today. Researchers and regulators rubbed shoulders with industry, developers, environmental non-government organizations, and community representatives.

The two-day workshop was preceded on January 31 with a talk at Dalhousie University by the Nova Scotia naturalist, Harry Thurston. This award-winning writer renewed for attendees the wonder in nature, with his talk, *A Place between the Tides: a Naturalist's Reflection on the Salt Marsh*.

A major product of the workshop was a map to identify salt marsh restoration, monitoring, and research activities in the Maritimes. The generation of the map, undertaken by the 85 participants, revealed that the entire Bay of Fundy and Canadian Gulf of Maine except Yarmouth County has been inventoried for tidal barriers, that at least 260 hectares of salt marsh habitat have been restored, and that an additional nine projects are in the planning stages. It also revealed that there is renewed academic and scientific interest in coastal ecosystems and salt marshes, as evidenced in the more than 40 research and monitoring projects now underway. Public and research interest is complemented by a growing commitment by provincial and federal governments to protect and conserve coastal wetlands. In addition to ecological benefits, participants acknowledged that restoration projects have generated social and economic benefits such as eco-tourism, bird-watching, education, recreation, and the elimination of insect infestations.

Enduring issues and next steps include seeking funding for salt marsh restoration, improving education and awareness about the importance and value of salt marshes, developing capacity for communities to undertake restoration projects, preparing a selection process to prioritize candidate restoration sites for funders and decision-makers, and recognising that climate change impacts are expected to have dynamic effects on salt marshes in the Maritimes.

INTERNATIONAL HYDROGRAPHIC ORGANIZATION TIDAL COMMITTEE MEETING

The Canadian Hydrographic Service (CHS) Atlantic was the official host of the V111th Meeting of the International Hydrographic Organization Tidal Committee (IHO-TC), held October 23-25 at the Maritime Museum of the Atlantic in Halifax. The IHO is an intergovernmental consultative and technical organization whose mission is "to ensure the provision of adequate and timely hydrographic information for world-wide marine navigation and other purposes, through the endeavours of national hydrographic offices." A subsidiary mission is "the application of hydrographic data to support science, and to promote its use in geographic information systems." At present, 73 Member States comprise the organization, where much of the work is carried out by technical committees, among which is the IHO-TC.

The Tidal Committee meets approximately every 18 months; this is the first time the meeting has been held in North America. Charles O'Reilly of CHS Atlantic has just stepped down after several years as the official Canadian voting delegate. A new CHS representative will be named shortly to replace him. This was the best-ever attended meeting, with 11 countries represented by voting delegates, one IHO representative, one industry observer, and a representative from GLOSS, the Global Sea Level Observing System, as a measure to encourage co-operation between the organizations. As well, non-voting attendees included representatives from each of the CHS regions. Although all agenda items were of interest to the CHS, of particular interest were digital tide tables, secondary port calculations methods, global sea-level rise effects, and the evolution of digital navigational-quality tide table standards and specifications

Walton Marsh, Nova Scotia, the site of a salt marsh restoration project – photo courtesy of Jim Leadbetter

Some participants at the *Six Years in the Mud* workshop – photo courtesy of Ian Rowberry, Ecology Action Centre as a companion to the development of the electronic charts.

Harmonization of vertical datums is a leading priority with the IHO-TC. Several diverse reference systems exist around the world. The organization is striving to harmonize these nautical measurements of depths, heights, and clearances, from country to country. The issue was addressed at a half-day technical workshop held at BIO, with presentations from different countries on several vertical datum issues. One resolution of the meeting leaves the organization well favoured to recommend a unique naming convention for vertical hydrographic datums.

During their meeting at the Maritime Museum of the Atlantic, delegates at the IHO-TC (above) toured the museum and the retired hydrographic vessel, CCGS *Acadia*. Later, they enjoyed an official dinner at Salty's Restaurant, co-sponsored by the Canadian Hydrographic Association.

GEOSCIENCE FOR OCEANS MANAGEMENT SCIENCE WORKSHOP

Geoscientists from across the country were invited to attend the Geoscience for Oceans Management Science Workshop held at BIO, February 27-March 1. Over the three days, scientists working on the Geoscience for Oceans Management program presented their results. Eighteen scientific presentations were made in the mornings, followed by workshops in the afternoon. Poster presentations were also encouraged. Andrew Heap from Geoscience Australia and John Hughes-Clarke from the University of New Brunswick gave keynote addresses.

Afternoon workshops provided an opportunity to discuss common issues and share ideas in moving the program forward. Topics included:

- engineering development and equipment for the future
- future directions in habitat mapping
- the identification and interpretation of glacial features from multibeam and backscatter imagery and their differentiation from hydrodynamic bedforms
- database development and web access
- the future of collaborative seafloor mapping between the CHS and the GSC
- GIS and A-series map products
- digital data processing, seismic, and sonar tools.

The workshop was well attended by staff from the Geological Survey of Canada, the CHS, and DFO.

WORKSHOP ON LONG-RANGE, LOW-FREQUENCY ACOUSTIC FISH DETECTION

The Workshop on Long-Range, Low-Frequency Acoustic Fish Detection, held January 29–31, brought together 24 national and international invited participants to explore the use of long-range

Photo courtesy of Ruth Farre

Photo courtesy of Palle Bo Nielsen

On Saturday, the CHS Atlantic took the IHO-TC delegates on a field trip to the Minas Basin. These experts in tides who came from all around the world were excited to see the large tides of the Bay of Fundy.

active sonar to potentially address outstanding issues in the Maritimes Region pelagic assessment. The workshop, jointly convened by DFO's Norman Cochrane, Ocean Sciences Division, BIO, and Gary Melvin, Marine Fish Division, St Andrews Biological Station, was part of a broader initiative from the Regional Director, Science. After reviewing relevant assessment questions principally related to southwest Nova Scotia herring, the workshop participants examined promising implementations elsewhere, applicable theory, hardware specifics, and environmental considerations. Workshop Proceedings summarized presentations, drew general conclusions, and made recommendations for future action. For Proceedings, see (http://www.dfo-mpo.gc.ca/csas/Csas/Proceedings/2007/PRO2007_031_E.pdf).

SCIENCE ADVISORY PROCESS

In 2007, the Maritimes Regional Advisory Process (RAP) became the Science Advisory Process (SAP). The RAP Coordinator, Robert O'Boyle, retired in October. Additional changes include the renaming of the RAP Office to the Centre for Science Advice (CSA) – Maritimes Region and the creation of an independent CSA in the Gulf Region as of November 1, 2007. A national competition was held to establish CSA Coordinators across the country, and Tana Worcester has now been established as the Maritimes CSA Coordinator.

In 2007, 23 science peer-review meetings were held, one of which was a Recovery Potential Assessment (for cusk) and five of which were assessment framework meetings (for herring, Atlantic halibut, ocean quahogs, and Arctic surfclams). Recovery Potential Assessments (RPA) typically provide information on the current status of and threats to species being considered for listing under the *Species at Risk Act*, as well as advice on recovery targets and possible actions or alternatives to address these threats. Assessment frameworks provide an intensive review of the data and models used to conduct an assessment of a particular species or stock. Since RPAs and frameworks are very complex, involve international experts, and often require analysis of large amounts of information from a variety of sources, they are typically split into several different meetings to discuss data input, indices of abundance, and modeling. Several of the frameworks initiated in 2007 (e.g., herring and halibut) will continue into 2008/2009.

The Maritimes Centre for Science Advice also coordinates and publishes Science Special Responses or SSRs (previously referred to as Expert Opinions). These SSRs help to provide, in a timely manner, science information and advice on urgent and unforeseen issues that emerge throughout the year. In 2007, ten SSRs were produced.

FISHERIES OCEANOGRAPHY COMMITTEE

The Fisheries Oceanography Committee (FOC) of DFO met at BIO, April 3-5. The focus of the 2007 meeting was to evaluate different measures of the condition of diverse species (fish, invertebrates, mammals, and seabirds) with the aim of agreeing on some common indices that would subsequently be used in comparative analyses among groups. An additional issue was to consider a template for regional and zonal "Ecosystem Status" reporting in support of the "Ecosystem Approach". The Committee discussed the needs for indicators of oceanographic properties to interpret changes in ecological characteristics of species at higher levels of the food chain. It is the expectation that the Atlantic Zone Monitoring Program (AZMP) will provide this category of information. To accomplish the synthesis of zonal trends in ecosystem status for the northwest Atlantic, it was proposed that a joint meeting with AZMP would be desirable.

Seminars

Over the course of the year, BIO welcomed scientists from around the world to present seminars and to lecture at the Institute.

BIO SEMINAR SERIES

The BIO Seminar Series provides an Institute-wide forum for presentations covering topics of physical, chemical, biological, and fisheries oceanography; marine geophysics and geology; hydrography; marine ecology; and ocean engineering. During 2007, the Seminar Series featured the following talks:

The Media and the Message: The Care and Feeding of Science Journalists
Paul Kennedy, host, Ideas, CBC Radio One, Toronto, Ontario, Canada

The Ocean Tracking Network
Dr. Ron O'Dor, Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada

CENTRE FOR MARINE BIODIVERSITY SEMINARS

The Centre for Marine Biodiversity invites scientists whose research in fisheries, marine ecology, physical oceanography, and related sciences will enhance our knowledge towards the protection of marine biodiversity.

The Genetic Analysis of Continuous Plankton Recorder Sample
Dr. Richard Kirby, Royal Society University Research Fellow, Marine Biological Association, Plymouth, United Kingdom

Climate Effects in the Plankton Revealed by a Long-term Monitoring Program
Dr. Richard Kirby

Pacific Salmon Extinctions: Quantifying Losses of Biocomplexity at the Level of Populations, Major Ecologcial, Life History, and Genetic Components, and ESUs
Dr. Robin Waples, Associate Professor, Fisheries Science Centre, Seattle, Washington, United States

What is a Population? Some Empirical and Theoretical Considerations
Dr. Robin Waples

GSC MUD CLUB

Mud Club provides an informal opportunity to present findings in marine geoscience by showcasing GSC and DFO research. The following were speakers from outside BIO to Mud Club in 2007:

Fingerprinting Glacial Erosion and Till Production for Drift-Prospecting: Combining Cosmogenic Nuclides and Ice-sheet Modeling in the Central Arctic
Dr. John Gosse, Canada Research Chair and Associate Professor, Department of Earth Sciences, Dalhousie University

Rivers in the Rock Record
Martin Gibling, Professor, Department of Earth Sciences, Dalhousie University

Integration Orbital Tuning and Isotopes Geochronology
Felix Gradstein, Geology Museum, University of Oslo, Oslo, Norway

HARVEST FISHERIES SEMINAR SERIES

The Harvest Fisheries Seminar Series began in 2002. Hosted by the Population Ecology Division, the primary purpose is to provide an opportunity to exchange ideas and to hear about research both within BIO and at other institutions. Staff who will be speaking outside BIO are encouraged to also give their presentations at the Institute. As well, the program features visiting researchers and speakers from local universities.

The Science-Policy Interface in Fisheries Management
Douglas Wilson and **Clara Ulrich-Rescan**, Institute for Fisheries Management and Coastal Community Development, North Sea Centre, Hirtshals, Denmark

Impacts of Environmental Change and Direct and Indirect Harvesting Effects on the Dynamics of the Southern Gulf of St. Lawrence Marine Fish Community
Hugues Benoit, Gulf Fisheries Centre, DFO, Moncton, New Brunswick, Canada

Modeling Marine Food Webs for an Ecosystem Approach to Marine Resources in the Mediterranean Sea
Marta Coll, Department of Biology, Dalhousie University

A Camera on the Banks: Frederick William Wallace and the Fishermen of Nova Scotia (1911-1916)
Brook Taylor, Department of History, Mount Saint Vincent University, Halifax, Nova Scotia, Canada

The Integrated Multi-Trophic Aquaculture Project
Shawn Robinson, St. Andrews Biological Station, DFO, St. Andrews, New Brunswick, Canada

Can We Predict Behavioural Resilience to Disturbances?
David Lusseau, Department of Biology, Dalhousie University

The Management of the Tasmanian Scallop Fishery – Government and Industry Cooperation in Moving towards Rotational Management on a Micro Scale
Rod Pearn, Department of Primary Industries and Water, Tazmania, Australia

Biological Characteristics of Four Species of Northwest Atlantic Skate (Family Rajidae) on the Eastern Scotian Shelf: A Comparative Life History Study with Implications for Species Management
Romnie McPhie, Department of Biology, Dalhousie University

At-Sea Catch Analysis of the Lobster Fishery, Atlantic Coast, Nova Scotia
Nell den Heyer, Research Associate, Dalhousie University

Ambient Temperature Reconstruction during a Fishery Collapse
Brin Jones, Department of Biology, Dalhousie University

The Evolutionary Ecology of Atlantic Cod in Canadian Arctic Lakes
David Hardie, Department of Biology, Dalhousie University

OCEAN AND ECOSYSTEM SCIENCE SEMINAR SERIES

The Ocean and Ecosystem Science Seminar Series talks are given weekly and cover topics in physical, chemical, and biological oceanography. The series, run jointly by the Ocean Sciences and Ecosystem Research divisions, provided a forum for both local researchers and visiting scientists in 2007:

Interfacial Waves in a Laboratory Exchange Flow
Ted Tedford, Department of Civil Engineering, University of British Columbia, Vancouver, British Columbia, Canada

Coastal Flooding and Climate Change: Dynamics versus Statistics
Keith Thompson, Department of Oceanography, Dalhousie University

Wave-Field Evolution in a Coastal Bay
Ryan Mulligan, Department of Oceanography, Dalhousie University

Measurements and Interpretation of Chlorophyll Fluorescences in the Ocean
John Cullen, Department of Oceanography, Dalhousie University

Indian Ocean Tsunami Sources
Brian Atwater, United States Geological Survey and the University of Washington, Seattle, Washington, USA

Effects of UV-B and Ozone Depletion on Phytoplankton in the Ocean
Suzanne Roy, Research Professor, Institut des Sciences de la Mer de Rimouski
Université du Québec, Rimouski, Québec, Canada

Turbulence Measurements in the Coastal Ocean Using Particle Image Velocimetry
Lusko Luznik, Department of Mechanical Engineering, Johns Hopkins University, Baltimore, Maryland

Simulating the Three-Dimensional Circulation on the Scotian Shelf Using DalCoast3
Kyoko Ohashi, Department of Oceanography, Dalhousie University

Renewal of Operational Wind-Wave Prediction System at KMA Complying with High Resolution Coastal Wave
Sangwook Park, Korea Meteorological Administration, Soeul, Korea

Baroclinic Dynamics and Variability of Circulation and Heat/Salt Contents in Lunenburg Bay
Li Zhai, Department of Oceanography, Dalhousie University

The Mean Surface Topography of the North Atlantic: Oceanography and Geodesy Collide
Keith Thompson, Department of Oceanography, Dalhousie University

Arctic Oscillation: A Spatially Varied and Non-Seesaw-Like Oscillation
Professor Jinping Zhao, The Key Laboratory of Physical Oceanography, Ocean University of China, Qingdao, China

West Greenland Current Variability, 1949-2005
Paul Myers, Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada and President, Canadian Meteorological and Oceanographic Society

Measuring Pollution in the Troposphere: Two Billion Measurements Later
James Drummond, Canada Research Chair in Remote Sounding Atmospheres, Dalhousie University

Regional Modeling along the BC Shelf
Mike Foreman, Angelica Peña, Diane Masson, Institute of Ocean Sciences, Sidney, British Columbia, Canada

Dynamics of an Ocean Vortex: Planktonic and Biogeochemical Signatures
Dr. Anya Waite, School of Environmental Systems Engineering, University of Western Australia, Crawley, Australia

OCEANS AND HABITAT SEMINARS

Freshwater Aquatic Ecosystem Classification
Dr. Kristine Ciruna, The Nature Conservacy of Canada, Victoria, British Columbia
The talk was followed by a workshop, multi-disciplinary discussion, and information session about a freshwater aquatic ecosystem classification for the Maritimes.

ENGO Involvement in Oceans Governance: Australian and Canadian Experiences
Dr. Joanna Vince, School of Government, University of Tasmania, Australia

A.G. HUNTSMAN AWARD

The 2007 **A.G. Huntsman Award** was presented to **Dr. Thomas Kiørboe** of the Danish Institute of Fisheries Research, Charlottelund Castle, Denmark, for excellence in the marine sciences. Dr. Kiørboe holds a Ph.D and a Dr. Scient from the University of Copenhagen. He is a member of the Royal Danish Society of Science and Letters, the Danish Academy of Natural Sciences, and the European Union Network of Excellence in Climate and Marine Research. Dr. Kiørboe is listed by the Institute of Scientific Information as a Highly Cited Author and is on the editorial board of five international scientific journals.

Dr. Kiørboe, the thirty-first recipient of the Huntsman Award, is recognized world-wide for his original and provocative thinking that has led to pioneering contributions in many areas of marine ecology. He developed innovative approaches for field, laboratory, and modeling studies of how micro-scale physical processes interact with the responses of individual marine organisms to generate observed patterns in populations and food webs. He is a major intellectual force in the difficult but essential business of linking processes from the small to large scales. His work in other areas, such as larval fish metabolism and the impact of food quality on consumers, has had major and lasting impacts, in some cases helping to spur the development of new research areas. Overall, Thomas Kiørboe has played a major role in changing the way scientists view the field of plankton ecology.

The A.G. Huntsman Award recognizes international scientists for both research excellence and outstanding contributions and is presented annually in one of three categories: Marine Geosciences, Physical/Chemical Oceanography, and Biological/Fisheries Oceanography. The award was created in 1980 under the leadership of BIO scientists to honour the memory of Archibald G. Huntsman,

Dr. Thomas Kiørboe (right) is presented with the Huntsman Award by Dr. Andrew Miall.

a Canadian oceanographer and fishery biologist pioneer.

Dr. Andrew Miall, President of the Academy of Sciences of the Royal Society of Canada, presented the 2007 award at a special ceremony at BIO on November 21. The following evening at Dalhousie University, Dr. Kiørboe delivered a public lecture, *Sex and Death in the Ocean*, in which he linked evolutionary theory with the population dynamics of marine animals.

Special Events

A SPECIAL GATHERING

On January 31, approximately 400 BIO and Maritimes Region DFO staff, former staff, and guests gathered in the BIO auditorium for a screening and discussion of *An Inconvenient Truth*, the documentary film on climate change narrated by Al Gore, former Vice-President of the United States. The three-hour event was organized by Valerie Bradshaw of Fisheries and Aquaculture Management and Clive Mason of the BIO Oceans Association.

After the film, Michael Sinclair, DFO Regional Director, Science, introduced a panel discussion about the film and climate change in Canada. The panel, chaired by BIO physical oceanographer Peter Smith, comprised BIO emeritus scientists Dale Buckley (marine geologist) and Allyn Clarke (physical oceanographer and peer reviewer of scientific papers under consideration by the International Panel on Climate Change [IPCC]), James Calvesbert, (retired CCG Officer and Master Mariner), and Valerie Bradshaw.

During the question-and-answer session that followed, it was clear that there were nay-sayers as well as believers of Al Gore's warning. Regardless of causality or disagreements about the rate of global warming, Jim Calvesbert and Valerie Bradshaw both presented facts supporting the contention that we are already witnessing climate change effects in the Canadian Arctic and in Canada's marine fisheries. Two days after the BIO event, the IPCC released its latest findings, saying that global warming is occurring and that it is 90% likely that human activities are responsible for recent increases in the rates of warming and that we face catastrophic climate change impacts if we don't slow this pace significantly in the very near future—the "inconvenient truth" of the Al Gore movie.

Visitors

The **First Nations and Inuit Science Youth Camp** was initiated by Indian and Northern Affairs Canada (INAC) as a means to engage First Nations youth in science. Six participants from each of the First Nations and Inuit districts across Canada are selected yearly for the camp. The talented and highly motivated youth range in age from 12 to 16.

The 2007 group of about 60 students and their chaperone visited BIO on August 6, the day after arriving in Nova Scotia from various parts of Canada. The group assembled in the auditorium where, after the official welcome, volunteer science staff from NRCan and DFO presented illustrated overviews of the programs conducted at BIO. The students were very enquiring, particularly about climate change and work performed by BIO in the Arctic. These presentations were followed by a visit to the jetty where the group was introduced to the range of BIO working vessels, from Boston whalers to large research ships. At the Sea Pavilion, the young people viewed and touched several species of fish and invertebrates. Many questions were asked and pictures taken of individuals holding lobsters, sea urchins, snow crabs, and other creatures from the touch tank. Despite their jetlag and travel fatigue, the students were attentive and curious. The opportunity to see large vessels at close proximity and to make contact with live sea creatures, which many had seen before only in images, was a good way to conclude the visit.

Kenyan delegation visiting BIO, from left: Mr. Bernard Ayugu, Dr. Renison Ruwa, Mr. Cosmas Munyeki, and Mr. Michael Oloo

On November 14, a visiting **delegation from the Kenyan Ministry of Livestock and Fisheries** toured BIO. The delegation included Mr. Bernard Ayugu, Director of Fisheries; Dr. Renison Ruwa, Deputy Director of the Kenyan Marine and Fisheries Research Institute; Mr. Cosmas Munyeki, Ministry of Livestock and Fisheries; and Mr. Michael Oloo of the Kenya High Commission in Ottawa. In addition to the tour, the officials discussed several topics of mutual interest including coastal zone management, sustainable aquaculture, and fisheries stock assessments. The visit, hosted by Oceans and Habitat, was part of a larger visit to explore areas of collaboration between DFO and the Kenyan Government.

People at BIO

Awards and Honours

Four scientists at BIO were among those honoured for their contributions to the Fourth Assessment of the Intergovernmental Panel on Climate Change: **Dr. Donald Forbes** of NRCan's Geological Survey of Canada (GSC) (Atlantic) and **Dr. Allyn Clarke**, **Dr. Trevor Platt**, and **Dr. Igor Yashayaev** of DFO's Ocean Circulation Section. The Panel shared the **2007 Nobel Peace Prize** with former US Vice-President Al Gore for their efforts to build up and disseminate greater knowledge about climate change, and to lay the foundations for the measures that are needed to counteract such change.

Simon Prinsenberg, Head of DFO's Coastal Oceanography Section, is the recipient of the **2007 J.P. Tully Medal in Oceanography** from the Canadian Meteorological and Oceanographic Society. This prestigious award recognizes Simon`s contributions in Arctic Oceanography, in particular, his leadership in the development of new instrumentation for oceanographic and ice measurements in the harsh Arctic environment.

The Canadian Meteorological and Oceanographic Society conferred the title of **CMOS Fellow** on **Allyn Clarke**, Scientist Emeritus, at its Annual Congress in June. Dr. Clarke was recognized for his major contributions to the physical oceanography of the North Atlantic and to global climate studies through research, management, and leadership at both national and international levels.

Mike Lewis, Emeritus Scientist with the GSC Atlantic, NRCan, was awarded the **Michael J. Keen Medal**. This medal is awarded annually by the Marine Geoscience Division of the Geological Association of Canada to a scientist who has made a significant contribution to the field of marine or lacustrine science.

Simon Prinsenberg, recipient of the J.P. Tully Medal in Oceanography

Murray Scotney, Head, Field Support Group in the Ocean Sciences Division of DFO, received the 2007 **Beluga Award** in recognition of his contributions to the BIO community over his 38-year career. Murray was the first electronics technologist hired to maintain and deploy the growing inventory of electro-mechanical physical oceanographic instruments becoming available in the late 1960s. As technology changed significantly, Murray kept abreast of the needs of the scientific programs and the instruments required for these advances and also was a mentor and teacher for new technical support staff.

The display area outside the cafeteria provides a showcase for the work of BIO scientists. Displays are changed monthly, and at year's end a committee representing the participating groups judges the presentations on visual impact, communication value, science promotion value, and other factors. The winning team receives a small trophy, and both first- and second-place finishers receive gift certificates to a local restaurant. For 2007, the **BIO Display Awards** went to:

1st Place: Marie-Claude Williamson, Samantha F. Jones, Denis Lavoie, and **Peter Giles** of **NRCan**, for ***First Steps in the Production of a Geographic Information System (GIS) for Îles de la Madeleine, Québec***;

2nd Place: Shelley Armsworthy, Steve Campana, Tania Davignon-Burton, and **Jenna Denyes of the Population Ecology Division (DFO)**, for ***Ageing Atlantic Halibut***;

3rd Place: COOGER Staff, Ecosystem Research Division (DFO) for ***Centre for Offshore Oil and Gas Environmental Research***.

Natural Resources Canada Sector Merit Awards are awarded by the Earth Sciences Sector of Natural Resources Canada to recognize the behaviours, actions, or results of an individual or team whose level of impact and scope has enhanced the profile and contributed to the success of the Earth Sciences Sector. In 2007, **Steve Solomon** and **Don Forbes** of the Geological Survey of Canada (Atlantic) received Earth Sciences Sector Merit Awards.

2007

2006-2007 BIO Science Display Award Ceremony, from left, Jennifer Bates of the Science Display Committee, Samantha F. Jones, and Marie-Claude Williamson

DM's Prix d' Excellence award winners, Anna Fiander (left) and Lori Collins

The following **NRCan Long Service Awards** were given in 2007:

25 Years:	**Bruce Wile**
35 Years:	**Darrell Beaver**
	Paul Girouard
	Gary Grant
	Iris Hardy
	Bill MacMillan
	Bob Murphy

The **DFO Distinction Award** is granted to an employee for outstanding achievement and contributions that further the objectives of DFO and/or the Public Service of Canada. The award is based on excellence in service delivery; valuing and supporting people; and value, ethics, and excellence in policy and/or science. The most exemplary contributions to DFO are honoured with the **Deputy Minister's (DM's) Prix d'Excellence** or the **ADM's Award**.

DM's Prix d'Excellence, 2007:

Lori Collins and **Anna Fiander**, as members of the **Council of Fisheries and Oceans Librarians** (COFOL), contributed to WAVES, DFO's first online information database to be made available to the public. This innovative, state-of-the-art system is used by all 11 DFO libraries for circulation, serials control, reference, and cataloguing and makes available such ground-breaking services as e-journals and e-books, earning COFOL an international reputation as a model of good management and excellent service.

Theresa Dugas, Acting Executive Assistant to the Director of CHS Atlantic, is the sole support worker in the 60-person CHS Atlantic office. Pivotal to the functioning of the office, she brings efficiency, tact, dedication, and cheerfulness to her responsibilities which include budgets, human resources, reception, and organizing travel, meetings, and video conferences.

Sherry Niven and **Judy Simms** are members of the Maritimes **Regional Diversity Advisory Committee** to the DFO workplace, which provides a positive forum for attitudinal change through the identification of issues, goals, and strategies to ensure the fair treatment of employees. Noted achievements over the past few years include the Objective Eye Program for selection board members, an Aboriginal Employees Network and an Abilities Network that support employees and increase awareness of diversity, and the launch of a regional website.

DFO Distinction Awards, 2007:

For over 20 years in DFO's Habitat Management Program, **Ted Currie** has worked diligently to protect fish and habitat by establishing strong working relationships and clear communication with proponents. With his vast experience and understanding of the potential effects of development projects and appropriate mitigation techniques, colleagues and clients consider Ted the "go-to guy" for projects in southwestern New Brunswick.

Ted Potter was one of the three members of the **Small Craft Harbours (SCH) and Oceans and Habitat Compensation Team** whose creativity, commitment, and innovation established a marine habitat compensation bank, bringing certainty to the regulatory regime for SCH and providing immediate benefits to fish. Through compromise, the competing agendas of conservation groups and provincial partners were accommodated, and the methodology the team developed for dealing with habitat compensation is an excellent example of integrated program delivery between sectors, helping SCH meet construction commitments with harbour authorities while protecting fish habitat.

The **Marine Plants Team** of **Bob Semple** and **Glyn Sharp** has provided high-level expertise, problem solving, and advice on marine plant issues for decades, producing client satisfaction within DFO, and outside including federal and provincial interests and the marine plants and aquaculture industries. The team has been an innovator and leader in the application of the ecosystem-based approach to resource management.

The **Canadian Hydrographic Conference 2006 Team** of **Carrie MacIsaac, Mike Lamplugh,** and **Wendy Woodford** were honoured for their exemplary achievement in the delivery of the successful four-day international conference which attracted 440 delegates and 42 exhibitors from 16 countries. The team went beyond stated responsibilities and accountability in organizing, chairing, and executing all aspects of the diverse undertaking.

Regional Diversity Advisory Committee
Sherry Niven
Judy Simms

35-Year Service Recognition:

Shayne McQuaid, Oceans and Habitat
Norwood Whynot, Communications
Brian Fleming, CCG Dartmouth Technical Workshop
Janice Gilbey, Finance

The BIO Oceans Association: Highlights of 2007

Betty Sutherland, President

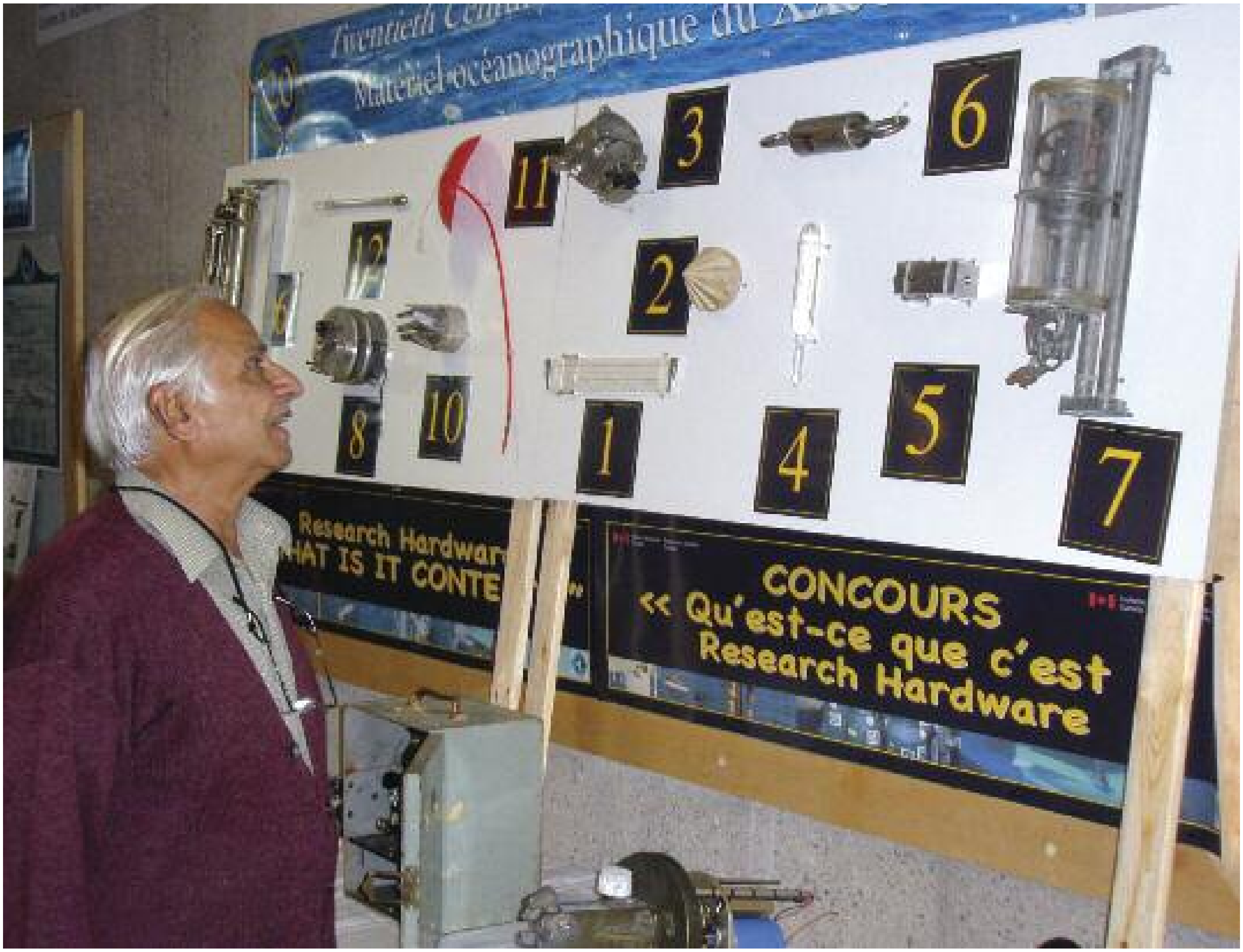
The Bedford Institute of Oceanography Oceans Association (BIO-OA) was established in 1998 by a group of former BIO staff to foster the continuing fellowship of members and maintain links to the Institute. The 191 members (in 2007) represent a broad spectrum of the scientific, hydrographic, technical, and administrative disciplines at BIO. Membership is not restricted to former employees but is open to all who share the Association's objectives: preserving oceanographic archival material, particularly relating to research carried out at BIO; increasing awareness and understanding of the oceans and ocean science; and providing opportunities for members to maintain relationships formed at BIO. The BIO-OA's quarterly newsletter keeps members informed of its activities and those of its members. For more information, visit the website (www.bedfordbasin.ca).

LIBRARY, EQUIPMENT, AND PHOTO ARCHIVES

Work continued through 2007 on preserving oceanographic archival material. The Library Archives' goal is to preserve all BIO records with research value that are not acquired by the National Archives of Canada, including cruise reports and contributions to national and international organizations. The Photo Archives has undertaken the task of identifying and cataloguing pre-1980 photographs. The Equipment Archives preserves oceanographic equipment developed at BIO and the knowledge around it. The impending major renovation of the van Steenburgh Building has resulted in the donation of a number of items.

OCEANS OUTREACH INITIATIVE

Work continued as well on the OA's Oceans Outreach Initiative (OOI). As noted in last year's report, this initiative features two key elements: a suite of 6 to 12 new dynamic displays intended to augment and modernize the present BIO public education display infrastructure, and new outreach activities aimed at engaging the general public, tourists, and career-minded young science students. The outreach activities would expand the existing summer program into a year-long program by incorporating a wider mix of educational offerings (e.g., summer science camps, speakers' bureau programs, workshops for students and the public on critical ocean issues, etc.). In April, a task force was set up that included people from organizations involved in the development of similar outreach activities (the Nova Scotia Museum of Natural History, Maritime Museum of the Atlantic, Joggins Fossil Interpretive Centre, and Halifax Discovery Centre), and representatives from the Nova Scotia Department of Education and the BIO-OA itself. Their task was to refine the OOI proposal and ensure that the funding and personnel requirements for its implementation were reasonable, given the acknowledgement by the OA Executive that this is not a project that can be managed by a volunteer group of retirees. Following several meetings over the summer, eight options were identified. These ranged from "doing nothing" to continuing to work on the full proposal which would require raising over $2 million. The Executive decided to "begin small" by developing one or two portable displays that could be taken into schools by BIO-OA volunteers. The OA can work within BIO's participation in the Scientists in the Schools program.



BIO Oceans Association member Shiri Srivastava visits the BIO-OA oceanographic equipment display at Open House 2007.

BELUGA AWARD

At the BIO-OA Annual General Meeting on May 30, Murray Scotney, head of the field support group in DFO's Ocean Sciences Division, was awarded the Association's annual Beluga Award in recognition of his dedication and professionalism over the years in support of BIO's research programs.

MEMBERSHIP ACTIVITIES

The OA held a wide range of social events in 2007. At the end of January, a number of members spent an evening with George Anderson at the Newfoundland Club, dancing and generally having a great time. Next, the Association co-sponsored a public lecture, *The Orphan Tsunami of 1700: A Trans-Pacific Detective Story*, by Dr. Brian Atwater of the US Geological Survey. On March 25, the Spring Celebration & Special Seminar featured Chris Mills's talk, *Nova Scotia Lighthouses: Guideposts of the Sea*. On a warm, sunny day at the end of June, a boat transported 37 members and guests to George's Island, and on a similar beautiful day in late August, a record crowd gathered at Shiri Srivastava's home for the annual Summer Barbeque. Highlights included Shiri's famous tandoori chicken and the music provided by George Anderson, Gordon Fader, and Al MacDonald. At our final get-together of the year, members attended and provided musical leadership at BIO's annual Christmas Party on December 24.

BIO OPEN HOUSE, OCTOBER 17-21

The Association was represented on the planning committee for the 2007 BIO Open House, and mounted two displays, staffed by members, which attracted considerable attention. The first featured a display of 21 vintage (pre-computer) oceanographic instruments. Each was numbered, and viewers were given the opportunity to try to identify six pieces of the equipment from clues provided in a handout. All who completed the quiz were eligible to win one of three BIO Open House shirts. The quiz proved amazingly popular with adults and children. The second display was a colourful poster about the Oceans Association, featuring a wonderful collage of photographs from various social events.

Charitable Activities at BIO

Theresa MacDonald, Maureen MacDonald, Mark McCracken, Sheila Shellnut, and Tara Rumley

In 2007, BIO staff continued their long tradition of giving back to their community.

The Government of Canada Workplace Charitable Campaign (GCWCC) is the oldest and largest workplace charitable campaign in Canada. Approximately 50 local agencies benefit from this campaign, which brings together two main recipient organizations—United Way and Healthpartners—in a co-ordinated fundraising effort. Alternatively, employees can give to a third option of the campaign, their Charity of Choice(s). In 2007, DFO employees at BIO donated $67,051 through the GCWCC gift forms. (This amount does not include the DFO BIO retiree donations since these are tracked nationally.) NRCan staff, who represent about one-fifth of the number of DFO staff, were equally generous, contributing $16,199 through gift forms. DFO and NRCan augmented their donations with fundraising through the BIO 17th annual Hockey Game and Christmas Party, a DFO raffle on a day trip to Sable Island, and the BIO library's 10th anniversary book sale, which took in $1,667—the largest amount ever. In all, staff at BIO contributed more than $87,000 to the GCWCC.

As in previous years, NRCan was instrumental in organizing BIO staff to pack and deliver Christmas dinners to shut-ins, for the Parker Street Food Bank. As part of that support, NRCan paid the rental fees for four large vehicles to deliver the dinners. As well, funds raised by NRCan at the BIO Christmas event were used to improve the Christmas of a local family who lost their house and belongings to a fire shortly before the holiday.

During what has become an annual event, as a show of compassion to those who ply the seas, the Canadian Hydrographic Service

In support of the Arthritis Society-Joints In Motion program, through individual donations and a BIO Movie Night, staff contributed to the participation of their colleague, Tara Rumley, in a half-marathon in Phoenix, Arizona, on January 14. Tara completed the 21.1 km trek in a time of 3:55:37, on the coldest day in Phoenix in 13 years (27°F). Tara is shown, centre, with team mates Angela Hatchette (left) and Adrienne Faulkner after completing the walk.

(CHS) Atlantic donated to the Mission to Seafarers by participating in the Halifax mission's Christmas Appeal. The Halifax Mission to Seafarers is renowned the world over for its Christmas services and hospitality. For the past nine years, the Mission has given thousands of Christmas Shoe Boxes of Gifts to the seafarers visiting the port over the holidays. In 2007, the CHS donated nine boxes, each one containing a hat, gloves, socks, scarf, soap, shampoo, toothbrush, toothpaste, candy, a memento from Halifax, and a holiday best wishes from our staff. As well, staff also donated warm clothing to the Mission. 2007 was a special year: a recent retiree, Nick Stuifbergen, asked that money collected for his retirement gift be used towards the Mission. Thanks to Nick, the CHS Atlantic was able to buy the Mission a new television.

The Ecosystem Research Division has been raising money to help people at Christmas since 2003. During 2007, fundraising events included an Easter Coffee Party, a Hallowe'en Coffee Party (complete with costumes and tickets on carved pumpkins), a Valentine's Day basket, and a Mother's Day basket. Many staff members are involved in organizing these events, but as with every such undertaking, there is a ring leader, Debbie Anderson. Funds raised bought gifts and groceries to brighten Christmas for 14 needy people.

In further charitable activity, the BIO Friends of Symphony Nova Scotia continued support of the symphony's Celebrity Concert Series through the Musical Chair of viola musician, Binnie Brennan; the Canadian Cancer Society's annual daffodil sale was well subscribed; and the SPCA was supported with funds and supplies. Other charities were helped on an occasional basis.

People at BIO in 2007

DEPARTMENT OF NATIONAL DEFENCE

LCdr Jim Bradford
Lt(N) Eric McDonald
Lt(N) Jennifer Miles
CPO2 Doug Brown
PO1 Drew Taveres
PO2 Emile Roussy
PO2 Jim McNeill
PO2 Ivan Lightwood
PO2 Krista Ryan
MS Karen Warren
MS Jessie Bouchard
MS Mike Comrie
MS Yann Beaulieu
LS William Brown
LS Gerard Arsenault

ENVIRONMENT CANADA

Christopher Craig
Patti Densmore
David MacArthur
Kayla Abbott, Student
Mark Coffin, Student
Ainsley Cormier, Student
Kenny MacAulay, Student
Rebecca Mouland, Student
Lauren Steeves, Student

FISHERIES AND OCEANS CANADA

Canadian Coast Guard - Technical Services

Marine Electronics
Jim Wilson, Supervisor
Terry Cormier
Gerry Dease
Jason Green
Julie LeClerc
David Levy
Robert MacGregor
Richard Malin
Morley Wright
Mike O'Rourke

Vessel Support
Andrew Muise, Supervisor
Richard LaPierre
Ensor MacNevin
Lawrence Morash (secondment)
Steve Myers
Lloyd Oickle
Harvey Ross
David Usher

Marine and Civil Infrastructure
Martin LaFitte
Leonard Mombourquette
Richard Myers
Raymond Smith

Dartmouth Technical Workshop
Paul McKiel, Supervisor
Lorne Anderson
Barry Baker
Bob Brown
Ray Clements
Chris Currie
Peter Ellis
Milo Ewing
Brian Fleming
Heather Kinrade
Susan Kolesar
Chad Maskine
Doug Murray
Derek Oakley
John Reid
Helmut Samland
Mike Szucs
Phil Veinot

Science Branch

Regional Director's Office
Michael Sinclair, Director
Karen Curlett
Bethany Johnson
Charlene Mathieu
Sharon Morgan
Sherry Niven
Bettyann Power

Canadian Hydrographic Service (Atlantic)
Richard MacDougall, Director UNCLOS
Steve Forbes, Director, Hydrography Atlantic
Bruce Anderson
Carol Beals
Dave Blaney*
Frank Burgess
Fred Carmichael
Mike Collins
Chris Coolen
Gerard Costello
Andy Craft
Elizabeth Crux
John Cunningham
Tammy Doyle
Theresa Dugas
Jon Griffin
Judy Hammond
James Hanway
Heather Joyce
Glen King
Mike Lamplugh
Christopher LeBlanc
Philip MacAulay
Bruce MacGowan
Carrie MacIsaac
Clare McCarthy
Dave McCarthy
Paul McCarthy
Mark McCracken
Larry Norton
Stephen Nunn
Charlie O'Reilly
Nick Palmer
Richard Palmer
Paul Parks
Stephen Parsons
Bob Pietrzak
Doug Regular
Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon
Mike Ruxton
Kelly Sabadash
Cathy Schipilow*
June Senay
Alan Smith

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2007.
* Retired in 2007

Andrew Smith
Christian Solomon
Nick Stuifbergen*
Michel Therrien
Herman Varma
Wendy Woodford
Craig Wright
Craig Zeller

Ecosystem Research Division
Thomas Sephton, Manager
Debbie Anderson
Sheila Shellnutt
Judy Simms

Centre for Offshore Oil and Gas Environmental Research (COOGER):
Kenneth Lee, Executive Director
Jennifer Beer, Student
Dan Belliveau, Student
Jay Bugden
Susan Cobanli
Jennifer Dixon
Paul Kepkay
Thomas King
Zhengkai Li
Brian Robinson
Peter Thamer

Habitat Ecology Section:
Timothy Milligan, Head
Brian Amirault
Robert Benjamin
Cynthia Bourbonnais
Chiu Chou
Pierre Clement
Andrew Cogswell
Peter Cranford
Claudio DiBacco
Ellen Kenchington
Gareth Harding*
Jocelyne Hellou
Brent Law
Barry MacDonald
Kevin MacIsaac
Paul MacPherson
Jean Marc Nicolas
Vanessa Page, Student
Lisa Paon
Shawn Roach
Dawn Sephton
Sean Steller
Herb Vandermeulen
Bénédikte Vercaemer
Jaime Vickers
Peter Walker, Student
Kees Zwanenburg

Ocean Research and Monitoring Section:
Glen Harrison, Head
Jeffrey Anning
Carol Anstey
Oliver Berreville, Student
Benoit Casault
Carla Caverhill
Emmanuel Devred, Research Associate
Grazyna Folwarczna
Cesar Fuentes-Yaco, Research Associate
Leslie Harris
Erica Head
Edward Horne
Catherine Johnson
Mary Kennedy
Marilyn Landry
William Li
Alan Longhurst, Visiting Scientist
Heidi Maass
Richard Nelson
Markus Pahlow, Research Associate
Ashley Parson, Student
Kevin Pauley
Tim Perry
Catherine Porter
John Smith
Jeffrey Spry
Alain Vézina
Phil Yeats

Centre for Marine Biodiversity:
Victoria Clayton

POGO Secretariat:
Shubha Sathyendranath, Executive Director
Marie-Hélène Forget
Tony Payzant

Ocean Sciences Division
Michel Mitchell, Manager
Gabriela Gruber
Coastal Ocean Science:
Simon Prinsenberg, Head
Dave Brickman
Gary Bugden
Sandy Burtch
Jason Chaffey
Joël Chassé
Brendan DeTracey
Adam Drozdowski
Jonathan Fisher, Postdoctoral Fellow
Ken Frank
Dave Greenberg
Charles Hannah
Ingrid Peterson
Brian Petrie
Liam Petrie
Roger Pettipas
Trevor Platt
Peter Smith
Seung-Hyun Son, Postdoctoral Fellow
Charles Tang
Chou Wang*
George White
Yongsheng Wu, Research Associate

Ocean Circulation:
John Loder, Head
Robert Anderson*
Karen Atkinson
Kumiko Azetsu-Scott
Paul Dunphy
Frederic Dupont, Research Associate
Yuri Geshelin
Blair Greenan
Doug Gregory*
Helen Hayden
Ross Hendry
Jeff Jackson
Peter Jones*
David Kellow
Zhenxia Long, Visiting Scientist
Youyu Lu
William Perrie
Tara Rumley
Hui Shen, Postdoctoral Fellow
Marion Smith
Jie Su, Visiting Scientist
Adhi Susilo, Student
Brenda Topliss
Bash Toulany

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2007.
* Retired in 2007

Zeliang Wang, Visiting Scientist
Dan Wright
Fumin Xu, Visiting Scientist
Zhigang Xu, Visiting Scientist
Yonghong Yao, Visiting Scientist
Igor Yashayaev
Lujun Zhang, Visiting Scientist
Weiqing Zhang, Visiting Scientist

Ocean Physics:
Jay Barthelotte
Brian Beanlands
Don Belliveau
Kelly Bentham
Rick Boyce
Derek Brittain
Zachariah Chiasson
Norman Cochrane
John Conrod
Mylene Di Penta
Helen Dussault
Richard Eisner
Bob Ellis
Jim Hamilton
Adam Hartling
Bruce Julien
Randy King
Mike LaPierre*
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Merle Pittman
Nelson Rice
Bob Ryan
Murray Scotney
Greg Siddall
George States
Leo Sutherby

Ocean Data and Information Services:
John O'Neill, Section Head
Lenore Bajona
Anthony Joyce
Flo Hum
Tobias Spears
Kohila Thana

Population Ecology Division
Ross Claytor, Manager
Margrit Acker
Doug Aitken*
Peter Amiro
Shelley Armsworthy
Jennifer Beanlands
Jerry Black
Shelley Bond
Don Bowen
Heather Bowlby
Rod Bradford
Josh Brading
Bob Branton
Dylan Buchanan
Alida Bundy
Steve Campana
Dollie Campbell
Henry Caracristi
Manon Cassista
Amy Chisholm
Jae Choi
Peter Comeau
Michele Covey
Tania Davignon-Burton
Louise de Mestral Bezanson
Jeremy Durling
Wanda Farrell
Mark Fowler
Cheryl Frail
Jamie Gibson
Sara Graham
Carolyn Harvie
Brad Hubley
Peter Hurley
Eric Jefferson
Ian Jonsen
Warren Joyce
Raouf Kilada
Peter Koeller
Mark Lundy
Bill MacEachern
Linda Marks
Larry Marshall*
Tara McIntyre
Kathi McKean-Sweet
Jim McMillan
Marta Mihoff
Bob Miller
Bob Mohn
Kathy Mombourquette
Rachelle Noel
Steve Nolan
Shane O'Neil
Patrick O'Reilly
Doug Pezzack
Alan Reeves
Jim Reid*
Dale Roddick
Sherrylynn Rowe
Karen Rutherford
Bob Semple
Glyn Sharp
Mark Showell
Angelica Silva
Jim Simon
Steve Smith
Debbie Stewart
Wayne Stobo*
John Tremblay
Kurtis Trzcinski
Megan Veinot
Cathy Wentzell*
Sophie Whoriskey
Daisy Williams
Scott Wilson
Linda Worth-Bezanson
Gerry Young
Ben Zisserson

Population Ecology Division Offsite Employees:
Mary Allen
Leroy Anderson
Krissy Atwin
Denzil Bernard
Christopher Carr
Corey Clarke
Adam Cook
Glori-Ann Cox
Bev Davison
Sean Dolan
Gilbert Donaldson
Jim Fennell
Claude Fitzherbert
Jason Flanagan
David Francis
Darrell Frotten
Trevor Goff
Michael Goguen
Randy Guitar
Ross Jones
Craig Keddy
Beth Lenentine
Judy Little
Philip Longue
Bill MacDonald
Danielle MacDonald
John Mallery
Andrew Paul
Robert Pelkey*
Greg Perley
Rod Price
Francis Solomon
Louise Solomon
Michael Thorburne
Malcolm Webb
John Whitelaw
Ricky Whynot
William Whynot

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* Retired in 2007

Gulf Fisheries Centre – Diadromous Fish Section
Paul LeBlanc

Centre for Science Advice, Maritimes Region and Gulf Region
Bob O'Boyle*, Coordinator
Kathryn Cook, Student
Joni Henderson
Valerie Myra
Lisa Savoie
Sarah Shiels, Student
Tana Worcester

Oceans and Habitat Branch

Regional Director's Office
Michael Murphy, Regional Director
Carol Ann Rose* A/Regional Director
Trudy Wilson, Assistant Regional Director
Janet Gilbey

Environmental Assessment and Major Projects Division
Ted Potter, Regional Manager
Ted Currie
Leslie Jenkins
Mark McLean

Habitat Protection and Sustainable Development Division
Paul Boudreau, Regional Manager
Joe Crocker
Rick Devine
Anna Dorey
Joy Dubé
Beverley Grant
Anita Hamilton
Janet Hartling
Tony Henderson
Darren Hiltz
Carol Jacobi
Brian Jollymore
Darria Langill
Jim Leadbetter
Dave Longard
Melanie MacLean
Kurt McAllister
Shayne McQuaid
Andrew Newbould
Stacey Nurse
Marci Penney-Ferguson
Joanne Perry
Peter Rodger
Tammy Rose-Quinn
Carol Sampson
Jennifer Voutier
Phil Zamora*

Oceans and Coastal Management Division
Heather Breeze
Scott Coffen-Smout
Penny Doherty
Dave Duggan
Derek Fenton
Jennifer Hackett
Glen Herbert
Tracy Horsman
Melanie Hurlburt
Stanley Johnston
Margie Lever
Paul Macnab
Denise McCullough
Melissa McDonald
David Millar
Jason Naug
Samson Nganga
Heidi Shaefer
Jaime Vickers
Maxine Westhead

Program Planning and Coordination Division
Tim Hall, Assistant Regional Director O&H
Jane Avery
Debi Campbell
Nancy Fisher
Carol Simmons

Aquaculture Management

Mark Cusack, Director
Darrell Harris
Cindy Webster
Sharon Young

Finance and Administration

Contract Services
Joan Hebert-Sellars*

Material Services (Stores)
Larry MacDonald, Co-Ordinator
Sean Byrne
Bob Page
Ray Rosse*

Real Property Safety and Security Branch

Brian Thompson, Senior Site Leader

Communications Branch

Francis Kelly
Carl Myers
Norwood Whynot

Corporate Services

Species at Risk Coordination Office
Diane Beanlands
Lynn Cullen
Arran McPherson
Kimberly Robichaud-LeBlanc
Dawn Sephton
Karen Spence

Information Management and Technology Services

Scott Graham, Regional Director, Informatics
Doug Earle, Chief, Planning
and Information Management Services
Gary Somerton, Chief, Technology Services
Chris Archibald
Keith Bennett
Paulette Bertrand
Patrice Boivin
Phil Comeau
Bruce Fillmore
Judy Fredericks
Pamela Gardner
Lori Gauthier
Marc Hemphill
Charles Mason
Sue Paterson
Andrea Segovia
Mike Stepanczak
Paul Thom
Charlene Williams
Paddy Wong

Client Services
Jonathan Fleming
Sandra Gallagher
Ron Girard
Carol Levac
Dave MacDonald
Francis MacLellan
Roeland Migchelsen
Juanita Pooley

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2007.
* Retired in 2007

Mike Van Wageningen
Bobbi Zahra
Library
Anna Fiander, Chief
Rebecca Arsenault
Rhonda Coll
Lori Collins
Lois Loewen
Maureen Martin
Lori O'Connor, student
Marilynn Rudi
Diane Stewart*

Records
Jim Martell, Supervisor
Myrtle Barkhouse
Carla Sears

NATURAL RESOURCES CANADA

Geological Survey Of Canada (Atlantic)

Director's Office
Jacob Verhoef, Director
Jennifer Bates
Pat Dennis
Carmelita Fisher
Judith Ryan

Marine Resources Geoscience
Mike Avery
Ross Boutilier
Bob Courtney
Bernie Crilley
Claudia Currie
Sonya Dehler
Kevin DesRoches
Rob Fensome
Peter Giles
Paul Girouard*
Gary Grant
Evelyn Inglis
Ruth Jackson
Chris Jauer
Nelly Koziel
Paul Lake
Bill MacMillan
Anne Mazerall
Phil Moir
Gordon Oakey
Phil O'Regan
Russell Parrott
Stephen Perry
Patrick Potter
Matt Salisbury
John Shimeld
Phil Spencer
Barbara Szlavko
Frank Thomas
Hans Wielens
Graham Williams
Marie-Claude Williamson
Mark Williamson

Marine Environmental Geoscience
Ken Asprey
Anthony Atkinson
Darrell Beaver
Robbie Bennett
Steve Blasco
Owen Brown
Gordon Cameron
Calvin Campbell
Borden Chapman
Mark Deptuck
Garret Duffy
Robert Fitzgerald
Donald Forbes
Paul Fraser
David Frobel
Michael Furlong
Iris Hardy*
Robert Harmes
Scott Hayward
Sheila Hynes
Kate Jarrett
Kimberley Jenner
Fred Jodrey*
Edward King
Vladimir Kostylev
Bill LeBlanc
Michael Li
Maureen MacDonald
Kevin MacKillop
Bill MacKinnon
Gavin Manson
Susan Merchant
Bob Miller
David Mosher
Bob Murphy
Michael Parsons
Eric Patton
Dick Pickrill
David Piper
Peter Pledge
Walta Rainey
Angus Robertson
John Shaw
Andy Sherin
Steve Solomon
Gary Sonnichsen
Bob Taylor
Brian Todd
Dustin Whalen
Bruce Wile

Shared Services Office
George McCormack, Manager
Cheryl Boyd
Terry Hayes
Cecilia Middleton
Julie Mills
Christine Myatt
Wayne Prime
Barb Vetese

PUBLIC WORKS AND GOVERNMENT SERVICES

Leo Lohnes, Property Manager
Tony Barkhouse
Tim Buckler
Bob Cameron
Geoff Gritten
Paul Fraser
Jim Frost
Garry MacNeill
John Miles
Craig Sanford
Arthurina Smardon
Phil Williams
Bill Wood

COMMISSIONAIRES

William Bewsher
Paul Bergeron
Dave Cyr
Marilyn Devost
Monique Doiron
Roger Doucet
John Dunlop
Donnie Hotte
Francis Noonan
Dave Smith
Don Smith
Daniel Wynn

CAFETERIA STAFF

Debbie Beaton
Kelly Bezanson
Lynn Doubleday
Mark Vickers

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* Retired in 2007

OTHERS ON THE BIO CAMPUS

International Ocean-Colour Coordinating Group (IOCCG)

Venetia Stuart, Executive Scientist

Fishermen and Scientists Research Society (FSRS)

Jeff Graves
Cornelia den Heyer
Carl MacDonald
Shannon Scott-Tibbetts

Geoforce Consultants Ltd.

Ryan Pike
Dwight Reimer
Graham Standen
Martin Uyesugi

Contractors

Derek Broughton, Population Ecology
Jason Burtch, Coastal Ocean Science
Melinda Cole, COOGER
Kate Collins, Coastal Ocean Science
Barbara Corbin, Records
Ewa Dunlap, Coastal Ocean Science
Michael Dunphy, Ocean Circulation
Susan Hannan, Ocean Circulation
Yongcun Hu, Ocean Circulation
Xiacwei Ma, COOGER
Alan McLean, CHS
John Newgard, Ocean Circulation
Jeff Potvin, Informatics
Daniel Ricard, Population Ecology
Ron Selinger, Records
David Slauenwhite, Ocean Circulation
Victor Soukhovtsev, Coastal Ocean Science
Jenny Take, CHS
Patrick Upson, Ocean Data and Information Services
Tineke van der Baaren, Coastal Ocean Science
Rob Walters, CHS
Alicia Williams, Population Ecology
Kari Workman, COOGER
Inna Yashayaeva, Ocean Circulation

Scientist Emeritus/Science Alumnus

Piero Ascoli
Allyn Clarke
Ray Cranston
Subba Rao Durvasula
Jim Elliott
George Fowler
Donald Gordon
Alan Grant
Ralph Halliday
Bert Hartling
Alex Herman
Lubomir Jansa
Brian Jessop
Charlotte Keen
Paul Keizer
Tim Lambert
René Lavoie
Mike Lewis
Doug Loring
David McKeown
Brian MacLean
Ken Mann
Clive Mason
Peta Mudie
Neil Oakey
Charlie Quon
Charlie Ross
Doug Sameoto
Hel Sandstrom
Charles Schafer
Shiri Srivastava
James Stewart
John Wade

Recognition

BIO staff wish to recognize the contribution and support provided by the Captains and crews of Canadian Coast Guard vessels tasked to assist scientific research at BIO.

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2007.
* Retired in 2007

Retirements 2007

Retirement notices are prepared usually by colleagues in the organizations where the retirees were employed.

Doug Aitken retired in June after 34 years of service to DFO. Doug played a key role in DFO's fish culture programs. He had a stint as a summer student at the Mactaquac Fish Culture Station, New Brunswick (NB) in 1969, and later was a technician at the Antigonish, Nova Scotia (NS) hatchery. From 1980, he was hatchery manager at the Yarmouth, NS and Saint John, NB (1989) facilities. At the Saint John Fish Culture Station he was instrumental in program changes resulting in the ability to rear juvenile Atlantic salmon to the smolt stage in just one year. The ever changing landscape in the program saw him overseeing closure of both the Yarmouth and Saint John stations and moving to NS to take on the role of coordinator of the fish culture aspects of the Live-Gene-Banking programs in 1997. Doug's legacy will be the improvements in fish culture and the mentoring of staff at the biodiversity facilities at Coldbrook and Mersey, in support of live gene banks for endangered Inner Bay of Fundy Atlantic salmon and Atlantic whitefish populations. His colleagues wish Doug the best with his sailing and trips to the back woods for adventures in Atlantic Canada's outdoors.

Robert Anderson retired from DFO's Ocean Sciences Division in August. Bob came to BIO in 1976 to join the Air-Sea Interaction Group to assist with air-sea-ice interaction studies in the Arctic. He remained with this group throughout his BIO career as it moved from the old Metrology Division through various administrative reorganizations to the Ocean Circulation Section. Bob provided scientific and technical support for numerous field experiments. He designed, built, and upgraded a series of data acquisition systems for wind stress and related fluxes which, together with his meticulous data analysis, enabled the Air-Sea Interaction Group to take quality measurements in difficult environments. Bob participated in a variety of international experiments in the Arctic and North Atlantic. His skill and dedication working in harsh environments were key factors in the development of BIO's world-class reputation in air-sea interaction research. Bob's retirement marks the end of an era of air-sea studies at BIO.

Dave Blaney retired from the Canadian Hydrographic Service (CHS) Atlantic in March. During his distinguished, 35-year career, Dave spent several years in the field, sailing on many hydrographic and charter ships. He was legendary as a knowledgeable, fair, and organized Hydrographer-in-Charge. In 1976, he was pulled out of the water after the charter vessel MV *Christmas Seal* caught fire and sank three hours outside of Halifax Harbour. Dave spent the last four years with the Tidal section of the CHS, traveling throughout all parts of the Atlantic Region installing and maintaining water level equipment. All CHS staff will miss Dave, his expertise, and work ethic, and we wish him a very happy retirement.

Art Cosgrove retired in June 2006 after 35 years of public service as an illustrator and the long-time head of the DFO Drafting and Illustrations Group. A Nova Scotia Community College graduate in technical design and drafting, Art briefly worked in local industry before joining BIO in November 1970 as a draftsman with the Marine Geology Division of the Atlantic Oceanographic Laboratory. In May 1971, he became an illustrator in the central drafting unit at BIO and in 1977, became Head of the unit, which, through departmental reorganizations, was now part of the newly created DFO. Along with the day-to-day routine of creating illustrations, presentations, and displays, he and his group met many challenges including work on Sciences Reviews, Open Houses, the Georges Bank Dispute, and numerous local, national, and international conferences. His dedication and effective teamwork in meeting the illustration needs of staff and managers were recognized by DFO with a Regional Citation for Excellence in 1995 and, by his peers in 2003 when he was awarded the Beluga Award from the BIO Oceans Association. Art will be remembered at BIO for his calm and professional approach to the needs of staff and the helpful and generous nature he exhibited in his personal dealings. In retirement, he and his wife, Iris, plan to visit England and more southerly destinations, and to complete renovations of their cottage for year-round living in Lunenburg, Nova Scotia.

Doug Gregory retired in March after many years as the group leader for data management in DFO's Ocean Sciences Division and its predecessor organizational units. Doug arrived at BIO in 1973 as a physical oceanographer in the Coastal Oceanography Section. He soon became head of the "Data Shop" group, coordinating the systematic processing, archiving, and disseminating of temperature, salinity, currents, and other datasets. During the 1990s, he led a joint initiative with computer scientists to develop web query systems to make these datasets and associated products readily available to the broader oceanographic community and public. Many of these data management innovations were pioneering activities for DFO Science nationally. Doug has been broadly recognized for his lead role in putting Maritimes Region at the forefront of oceanographic data dissemination in DFO and ensuring an important data legacy of oceanographic programs in the region.

Gareth Harding retired from DFO in December. Gareth first worked for the Fisheries Research Board, Arctic Unit in 1962 and 1963 as a summer student in the western Arctic, collecting baseline fisheries observations from Aklavik to Cape Perry, NWT, aboard the MV *Salvelinus*. After obtaining his PhD from Dalhousie University, in 1972, with a background in the ecology of deep-sea plankton, he joined the Fisheries Research Board at BIO. His initial work of laboratory-oriented contaminant research with organochlorines ultimately led to field studies on the biomagnification of organochlorine compounds in the food chain of the southern Gulf of St. Lawrence. Over the next several years, his research included a St. Georges Bay ecosystem study to understand larval fish recruitment, ecosystem studies on the Labrador shelf to understand production processes and climatic influences, and vertical migration behaviour of planktonic organisms to understand vertical flux of primary production. Gareth worked intermittently for decades on understanding the ecology, genetics, and recruitment process in American lobsters in relation to inshore and offshore stocks and the causes of lobster population oscillations. Since 1992, he has participated in the joint US-Canada mussel watch contaminant programme in the Gulf of Maine. Most recently, he was involved in investigations on biomagnification of methylmercury in the marine ecosystem and the effect of increasing atmospheric mercury concentrations from fossil fuel use. He will continue his work in several of the above areas as a Scientist Emeritus. In retirement, following a six-month sojourn in Oxford, UK, Gareth plans to enjoy his many interests which include home renovation, canoeing, and bird watching and gardening at his seaside summer home.

Joan Hebert-Sellars retired in July after 32 years of dedicated service supporting DFO science. Joan began her DFO career in 1976 as a receptionist with the Fisheries Research Board in Halifax. In 1978, she progressed to the position of Resource Utilization Clerk for the Fish Lab. The next year, Joan entered the world of finance in Contracts Services, an area where she flourished. She worked as a Purchasing Clerk (1979-1987) at the Hollis Building in Halifax and then as the Science Contracts Officer (1988-2007) at BIO. Her work involved complex service contracts and Joint Project Agreements. Joan's never failing professionalism and her willingness to help made her a valued element in business activities related to DFO science. Her intelligence and cooperative approach were true assets that made her work greatly appreciated by colleagues and industry and her clients in Oceans and Habitat Branch nominated her for the DFO Distinction Award in 2004. If quality is an indication of success, then Joan's career was truly an achievement.

Peter Jones retired from DFO's Ocean Sciences Division in January. Peter came to BIO in 1973, first as a member of the Marine Chemistry Section and later moving to the Ocean Circulation Section. His research at BIO focused on measuring ocean carbon (natural and anthropogenic) concentrations and transport, and using various chemical "tracers" such as nutrients and chlorofluorocarbons to infer ocean circulation. His studies covered many areas of the Arctic and North Atlantic oceans, in many cases as part of international collaborations and/or programs. Peter's particular interest was in the circulation of the Arctic, an area in which he made a number of pioneering observations and publications. The significance of his Arctic research was recognized in 1994 when he was awarded a Doctor Honoris Causa from the University of Gothenburg (Sweden). During his career, he spent over two years at sea and published more than 70 papers in peer-reviewed journals. Peter is continuing his scientific productivity as an Emeritus Scientist in the Ocean Circulation Section.

Michael Robert LaPierre retired from the DFO's Ocean Sciences Division after 35 years of public service. In 1969, Michael joined the Mechanical Development Laboratory at BIO as a machinist apprentice and, upon completion of his apprenticeship, joined the heavy-duty machine shop here. As a machinist, and later as a mechanical design technician, Michael had close contact with a wide range of individuals involved in oceanography, all of whom enjoyed working with him. His group, Engineering Technical Support, was transferred to the Canadian Coast Guard in 1996 but returned to DFO Science in 2004 where Michael spent the balance of his career. His dedication and workmanship were always of the highest quality and were appreciated by all. Michael is looking forward to spending time with his family and persuing his many hobbies including furniture-making, metalworking, fishing, and hunting.

Dr. Larry Marshall retired in June after nearly 34 years of service with DFO, Maritimes Region. He had previously served as a fisheries biologist and limnologist to the Saskatchewan Department of Natural Resources and as a research assistant to the Colorado Division of Fish and Game. Larry began his Canadian federal public service in DFO's Freshwater and Anadromous Division, Resource Development Branch, in Halifax, as a salmon assessment biologist for the Saint John River, NB, and following that, for rivers of Cape Breton and the Eastern Shore of NS. He became responsible for salmon assessments in Cape Breton and southwest NB and in 2000, assumed the position of Manager of the Diadromous Fish Division, Science Branch. He enjoyed working with and promoting the skills of staff; the challenges, camaraderie, and travel associated with the Canadian Atlantic Fisheries Scientific Advisory Committee; and his nearly 20 years as a member and later Chair of the International Council for the Exploration of the Sea Working Group on North Atlantic Salmon. Larry completed his career with DFO by co-ordinating the inter-regional drafting of a conservation policy and a conservation status report for wild Atlantic salmon in Canada.

Paul McCarthy retired from the CHS in July after a dedicated career of 35 years. Paul came to the CHS in 1972, a recruit from the College of Trades and Technology in St. John's, Newfoundland. Primarily a field hydrographer, Paul sailed on ships such as the CNAV *Kapuskasing*, CSS *Baffin*, CSS *Maxwell*, and CCGS *Matthew*. He also served on numerous shore parties and spent considerable time surveying in Canada's Arctic. Later, Paul transferred his experience into numerous data validation and chart production tasks within the CHS. He will be remembered for his quiet, but methodical and meticulous approach to all aspects of hydrography.

Robert O'Boyle retired in October after 30 years with DFO at BIO. Bob grew up in Montréal, received his undergraduate degree from McGill University, and his MSc in biochemistry from the University of Guelph. After a short time in Calgary during the oil boom in the mid–1970s, constructing computer models of oil and gas well production, Bob moved east to BIO. From 1977 to 1997, Bob was a "sparkplug" within the Marine Fish Division: as an assessment biologist (1977 to 1981), a Section Head (1982 to 1988), and as Division Manager (1988 to 1997). During these two decades, he was a key participant and leader of the full range of activities (research, monitoring, data management, and advisory). Bob, with his exceptional energy, led the Scotian Shelf

Ichthyoplankton Program, and instructed many recruits in stock assessment methodology. Late nights in the computer room as assessment deadlines approached were always a delight with his good humour and generosity with tutoring. Bob made exceptional contributions to the technical arguments in Canada's documentation presented to the International Court of Justice in The Hague during the Gulf of Maine case (1982 to 1984). As Division Manager, he provided excellent leadership, taking the Division through the drama and introspection of the groundfish collapse on the eastern Scotian Shelf in the early 1990s.

From 1997 until his retirement, Bob was influential in establishing and leading the science advisory process for Maritimes Region, and had a major influence on the development of this process at the national (now termed the Canadian Science Advisory Secretariat) and international levels. He established new products, such as Expert Opinions (which evolved into the national Science Response series) and multi-year advice, as well as new standards for the review process and associated documentation. He was influential in establishing the USA-Canada transboundary assessment process for Georges Bank, which he co-chaired from its inception. As Associate Director of Science, Maritimes Region, during his last five years at BIO, he led strategic planning exercises, reconstituted the Species-at-Risk office, expanded the outreach program, and provided intellectual leadership for the implementation of the Ecosystem Approach to Management. He remained scientifically productive throughout his career, with many primary publications, book chapters, proceedings and technical documents, and other reports covering a wide range of research and advisory issues. Over the years, he has made contributions to the social life of BIO, including writing and directing a series of comical directors' skits for Christmas parties. Bob made an enormous contribution to BIO and Canada during his three decades at the Institute due to his gifts of energy, good humour, generosity of spirit, and intellectual curiosity.

Robert Pelkey, Senior Hatchery Technician, retired from the Population Ecology Division's Mactaquac Biodiversity Facility after 34 years of service. Bob began with DFO in 1973 as a seasonal employee at the Mactaquac Fish Culture Station (now, Biodiversity Facility). For the 20 years or so before retirement, he served as a Hatchery Technician. In the late 1990s, after program changes, Bob accepted the challenge of becoming one of the two Hatchery Technical Supervisors who managed the complex technical responsibility formerly held by several staff. He played a major role in the many technical and operational changes that have converted the former Fish Culture Station into a multi-species Biodiversity Facility supporting a Living Gene Bank for endangered inner Bay of Fundy Atlantic salmon, a wild juvenile-to-adult rearing program, juvenile salmon culture, and assessment and research for salmon, gaspereau, and striped bass. During his tenure, Bob was quick to apply his skills, under his own initiative, to solve infrastructure and fish-rearing problems. His cost-effective solutions contributed to the success of DFO programs. The department and his colleagues will greatly miss his leadership and technical abilities.

Jim Reid retired in November after 31 years with DFO. Jim began his career in marine science in 1976, first as a port technician and shortly after, as one of the first offshore fisheries observers. As senior observer, he trained new observers and tested the efficiencies of new fishing gears with foreign fishers. In late 1977, he joined the Marine Fish Division at BIO as a technician providing support to the Scotian Shelf Ichthyoplankton Program. Jim's extensive experience during that five-year program in the areas of cruise support and planning, training, leading survey missions, and the development of instrumentation used in plankton research led to his being chief scientist on several Fisheries Ecology Program missions in the mid 1980s, where his dedication to the work and attention to detail were key to the success of these programs. Jim later became involved with support of Ocean Data Handling within the existing Groundfish Bottom Trawl Survey Program, increasing the level and scope of hydrographic sampling on divisional and zonal missions. In 2004, he participated in the Comparative Fishing Experiment and the Zonal Surveys Trawl Working Group, where he embraced the concept that the Western IIA groundfish sampling tool required strict standards. With the Marine Institute at Memorial University, he produced a survey trawl manual that provides all details necessary to construct trawls to consistent, reproducible standards; this is his legacy to the Groundfish (now Ecosystem) Bottom Trawl Survey Program.

Jim was always involved in the community spirit of his division and BIO. In 1999, he created the *Beat The Winter Blues* concert which featured musical talent from within and outside the Institute and continued annually until 2006. He was also instrumental in introducing music to BIO All-Staff meetings. In retirement, as well renovating the family home, Jim will pursue his interests in writing folk music, camping, and ocean kayaking.

Carol Ann Rose retired in June, after 17 years with DFO. One of the Maritimes Region's most respected managers, Carol Ann came to DFO from the RCMP in 1990 as Regional Director, Conservation and Protection, for the Gulf Region, a position she held until 1996 when she became Area Director in Southwest New Brunswick. Carol Ann quickly became known as a personable and professional colleague, gaining the respect and trust of her co-workers, as well as industry representatives. In 2002, Carol Ann took over the role of Acting Regional Director, Oceans and Habitat (O&H). This was followed by a year as Regional Director, Policy and Economics. She had an immediate and positive impact on both of these branches. From 2005 until her retirement, Carol Ann continued as Acting Regional Director, O&H, where she led the development and implementation of several highly successful initiatives. We can be assured that in retirement Carol Ann will be pursuing her other passions - hunting, fishing, and traveling the country with her friends.

Raymond Rosse retired on January 19 after 37 years at BIO. Ray joined the crew of the CSS *Hudson* in July, 1969. His first trip was to Bermuda, after which he was selected to be part of the crew on the Hudson-70 Expedition, the 11-month, multidisciplinary oceanographic cruise which was the first circumnavigation of the Americas. He continued to serve on the *Hudson* for four more years before coming ashore to work with DFO's Vessel Support section. Later, he moved to the Material Services section, where he concluded his career working in Stores/Shipping and Receiving. Ray enjoyed his BIO experiences and has many memories to share with his friends. Clients of Stores will miss his cheerful help.

Cathy Schipilow retired from DFO on December 28, after 35 years with the CHS. After graduating from Algonquin College in 1972 with a Cartographic Technician diploma, Cathy joined the New Charting Section of the CHS Headquarters in Ottawa. After five years of working on the production of new charts, she relocated to BIO as a result of the decentralization of the charting and maintenance program. Cathy has the distinction of being the first CHS Atlantic cartographer to work with computer-assisted mapping technology (in 1980). Over the years, she brought dedication and exemplary leadership to a variety of CHS activities relating to tides, chart production, updating, quality control, and human resources. Cathy will be missed by her many friends and colleagues at BIO.

Diane Stewart retired from the BIO Library in November after 29 years of service with DFO. Diane began in 1978 as a secretary at the Halifax Fisheries Research Board (FRB) Laboratory. Later she worked as a clerk in the library, before moving to the BIO library in 1985. She returned to the FRB in 1991 as an information officer, responsible for interlibrary loans, managing incoming journals, and most important to the users, answering reference questions. Diane knew and could put her hands on just about everything in the library. When the Halifax Laboratory closed, she moved back to BIO. Relocating the library collection to BIO happened much faster than planned when mould was discovered in the ageing FRB building. Diane spent weeks dressing up each day in a hazard suit, complete with mask and booties, while she examined every single publication for signs of mould. At BIO, her time was divided between working on the reference desk and cataloguing materials. Library users and staff will remember Diane's phenomenal memory and ability to find anything in the library.

Wayne Stobo retired from DFO Science in April, after 35 years conducting research on fish, seals, and birds, and managing the research programs of the Marine Fish Division of BIO. Wayne joined DFO at the St. Andrews Biological Station in 1972, initially concentrating on the biology and commercial stock assessment of Atlantic herring. Studies of herring migratory behaviour launched Wayne into the field of mark:recapture studies, involving many species of fish and marine mammals. Wayne initiated several large-scale tagging programs that laid the foundation for many of the fishery stock definitions used today for the assessment and management of these crucial resources. These investigations continued to be a central part of Wayne's research activities throughout his career, resulting in many contributions to the primary research literature. In 1977 Wayne was one of a small group of Science staff that were transferred from the St. Andrews Biological Station to BIO to form the core of the new Marine Fish Division. In 1999, Wayne became Manager of the Marine Fish Division, by this time an established unit of over 40 staff. He guided this group through the turbulent years that followed the declines of many fisheries in Atlantic Canada, directing research and assessment endeavours to sustain existing resources and recover those that had been lost. This demanding job remained his role for most of the period since 1999, but still he maintained his own research focus. Although now retired from DFO, Wayne continues his research into the movements, population relationships, and distributions of marine fish.

He is currently chairman of the Halifax Watershed Advisory Board, a member of the Shubenacadie Watershed Environmental Protection Society, a director of Scotian WindField Inc. (a conglomerate of community-owned renewable energy companies), and president of Chebucto Wind Field Inc.

Nick Stuifbergen retired in May after 46 years of service with the CHS. Nick started in Central Region in 1961, where he participated in many surveys. In the late 1960s, he was seconded to the Polar Continental Shelf Project, to carry out hydrography in the Arctic Archipelago. Nick moved to Atlantic Region in 1972. He is well known for his work in Loran-C latticing and datum shifts. In recent years, he has been responsible for the modernization of old and inadequate nautical charts, extending their usefulness and avoiding the need for costly re-surveying. Immediately following his retirement, Nick will continue his research with the CHS as appointed Science Alumnus at BIO.

Chou Wang retired in January, after 11 years working as a data technician for DFO's Coastal Ocean Science section. Her work at first consisted of processing large-scale, remotely sensed sea-ice imagery for identification of sea-ice property signatures. Later, she analyzed large oceanographic data files and created seasonal and monthly climatologies for inputs to the COSS ice-ocean forecast model. Her colleagues wish her improved health and much happiness as she pursues the next chapter of her life.

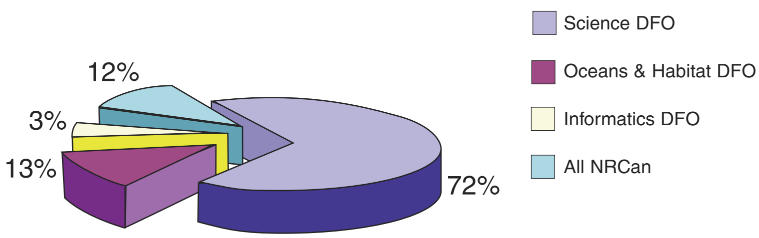
Cathy Wentzell put the finishing touches to her administrative work for the Population Ecology Division and retired from DFO in September, thus ending a distinguished career which began in 1970. Cathy applied herself methodically to everything she undertook, ensuring that the job was done well. When required, she put in the "extra miles"; this was especially appreciated after Program Review and implementation of the new administrative and financial protocols that dictated the manner in which industry partnerships were to be conducted with DFO. Cathy's love of life and appetite for new challenges carried her into diverse tasks over the years and she brought exemplary determination to several special assignments. In her regular work and as a volunteer for good causes, Cathy served Canada well and her colleagues wish her the best in retirement.

Phil Zamora retired in April after a 37-year career with DFO. Phil started in the Freshwater and Anadromous Division, working with Atlantic salmon in rivers throughout the region while developing his knowledge and respect for freshwater resources. He worked on various research initiatives examining impacts on fish and their habitats until moving in 1997 to the Habitat Management Division where he was able to apply the knowledge he gained. Phil realized that although fish and fish habitat are important, so are people and stakeholders, and he was successful in finding a common ground to uphold policy while accommodating the needs of others. Always eager to help problem-solve, lend a helping hand, and mentor newcomers to the Habitat Management Division, Phil instilled respect and knowledge in fellow employees. He was a true team player who made the work environment brighter for all around him and whose dedication and hardworking professionalism contributed to the success of our programs. In retirement, Phil will enjoy spending more time with his family.

Financial and Human Resources

Where BIO obtains funding and how it is spent

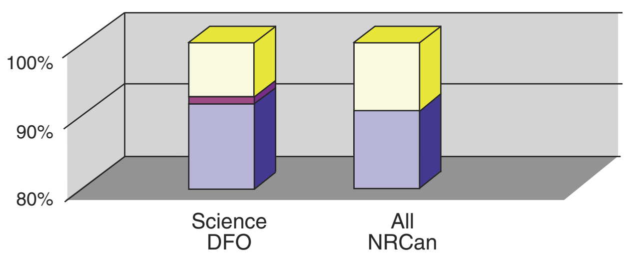
Annual appropriation from government



DEPARTMENT	SECTOR	AMOUNT ($000)
DFO	Science	22,849
DFO	Oceans & Habitat	4,312
DFO	Informatics	917
NRCan	All	3,985

Environment Canada and DND have staff working at BIO. The resources used by those staff members are not captured in this report.

Other sources of funding

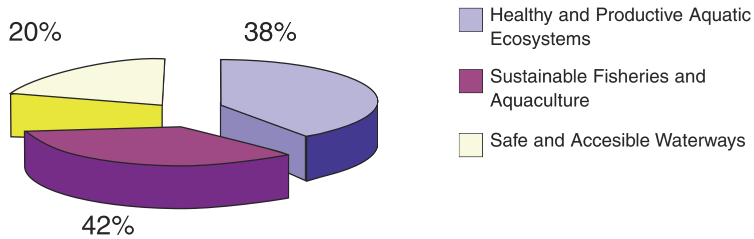


DEPARTMENT	SECTOR	GOVERNMENT ($000)	INSTITUTIONS ($000)	INDUSTRY ($000)
DFO	Science	14,059	220.3	1.017
NRCan	GSC & UNCLOS	13,700		1,372

Industry Institutions Government

Program spending

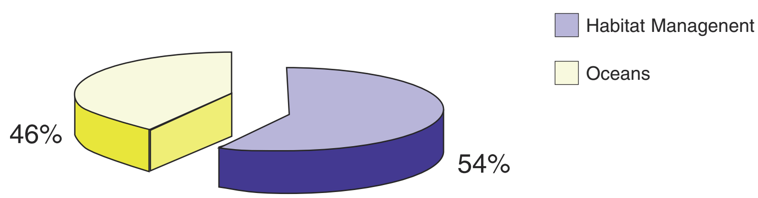
DFO Science



SECTOR	AMOUNT ($000)
Healthy and Productive Aquatic Ecosytems	14,596
Sustainable Fisheries and Aquaculture	15,901
Safe and Accessible Waterways	7,648

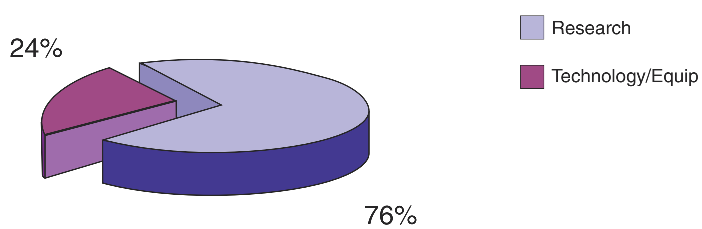
Program spending cont.

DFO Oceans and Habitat



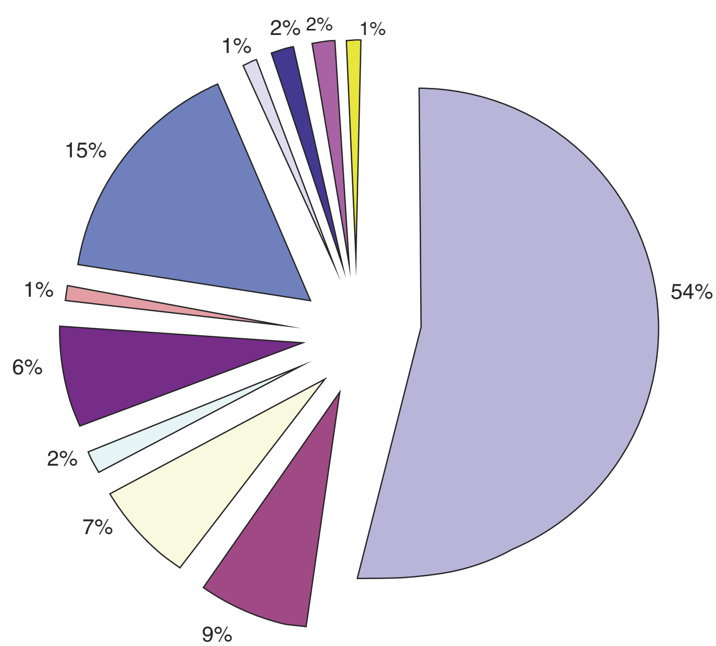
SECTOR	AMOUNT ($000)
Habitat Management	2,319
Oceans	1,993

NRCan



	AMOUNT ($000)
Research	14,395
Technology/Equipment	4,662

BIO staff by Division/Department



DFO - Science	344
DFO - Oceans & Habitat	60
DFO - Informatics	41
DFO - Other	15
DFO - Coast Guard Tech Services	40
DFO - Aquaculture Coordination	4
NRCan - GSC Atlantic	96
EC - Operational Laboratories	3
DND - Survey Office	15
PWGSC - Site Operations	13
Research Coordination Units	9
Total	640

Numbers are taken from the staff lists and do not include contractors, students, or emeritus scientists.

Publications and Products

Publications 2007

BEDFORD INSTITUTE OF OCEANOGRAPHY

SCIENTIFIC JOURNALS

DFO: Oceans and Habitat Branch

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While running a sounding line in a southerly direction one sunny day off Seven Islands Beach, Labrador, the Matthew *had a close call. The sun's glare on the water prevented the crew from seeing this family of polar bears until they were virtually under the bow. This provided a good picture opportunity but did not endear the crew to the mother! Photo © courtesy of Michael Lamplugh, Canadian Hydrographic Service Atlantic, BIO*

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