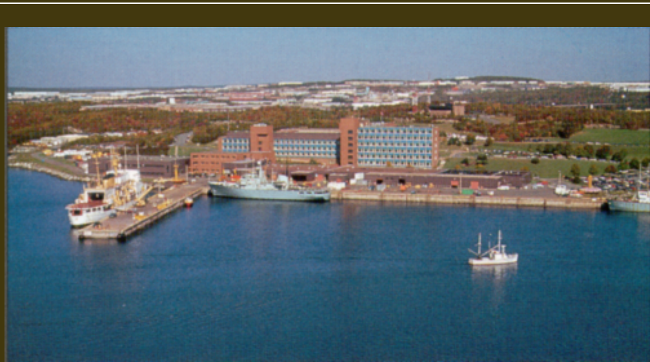
Science Review 1992 & '93

HOME



Bedford Institute of Oceanography

Halifax Fisheries Research Laboratory

St. Andrews Biological Station

Canada

(This Page Blank in the Original)

Science Review 1992 & ‘93

of the
Bedford Institute of Oceanography
Halifax Fisheries Research Laboratory
St. Andrews Biological Station

Published by:
Department of Fisheries and Oceans
Scotia-Fundy Region
1994

The Science *Review* of the Bedford Institute of Oceanography, the Halifax Fisheries Research Laboratory, and the St. Andrews Biological Station is published biennially by the Scotia-Fundy Region of the Department of Fisheries and Oceans.

Change of address notices, requests for copies, and other correspondence regarding this publication should be sent to:

Marine Assessment and Liaison Division
Department of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
Canada. B2Y 4A2

ISSN: 0846-9121 (English)
Aussi disponible en français.
ISSN: 1182-6541 (French)

Editor: Anna Fiander, Library, BIO
Electronic Artwork, Layout and Assembly: Francis Kelly, Technographics, BIO
Photographs: BIO Technographics and Authors
Printer: Atlantic Nova Print Co. Inc., Halifax

Science Review 1992 & '93 was produced using:
Power Macintosh 8100/80(R) computer
Aldus Freehand@
Aldus Pagemaker@
Adobe Photoshop@

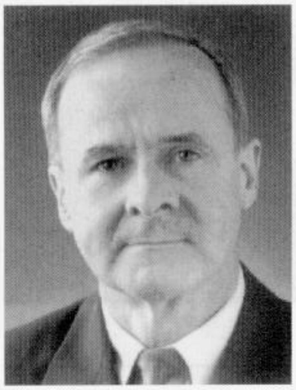
Contents

Research

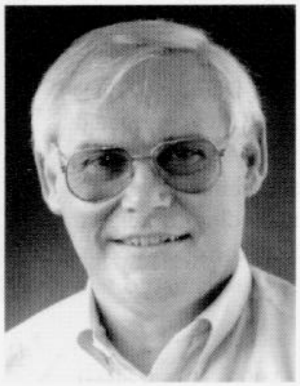
Research

1992 and '93 in Review

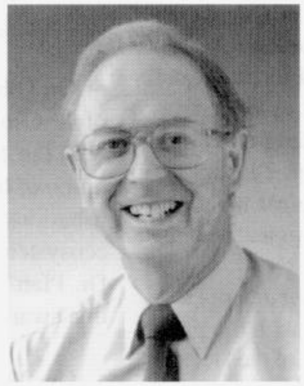
S. B. MacPhee, D. B. Prior, and H. B. Nicholls



S. B. MacPhee



D. B. Prior



H. B. Nicholls

The years 1992 and '93 continued the trend of financial restraint characteristic of the previous review period. Nevertheless, the years were interesting and fruitful ones for the research and survey programs carried out at the Bedford Institute of Oceanography (BIO), the Halifax Fisheries Research Laboratory (HFRL), and the St. Andrews Biological Station (SABS). The following paragraphs describe significant events that occurred during those years at the laboratories of the Department of Fisheries and Oceans (DFO), the Department of Natural Resources (NRCan) and Environment Canada.

Staff

A number of key staff changes occurred within the laboratories during the 1992-93 biennium. In April 1992 Dr. D.I. Ross, Director of the Atlantic Geoscience Centre (AGC), of the then Department of Energy, Mines and Resources (DEMR), resigned to take up an appointment in New Zealand as Chief Executive Officer at the Institute of Geological and Nuclear Sciences. He was succeeded as Director by Dr. D.B. Prior, Head of AGC's Environmental Marine Geology Subdivision. Also in 1992, Dr. R.H. Cook, Director, SABS transferred within DFO Scotia-Fundy Region to assume the position of Manager of the newly established Aquaculture Coordination Office. He was succeeded as Director, SABS by Dr. Wendy Watson-Wright of the Region's Inspection Services Branch. In late 1993, Dr. R.A. Pickrill was appointed as the new Head of AGC's Environmental Marine Geology Subdivision.

In Memorium

Dr. William L. Ford, who retired as Director-General of Ocean and Aquatic Sciences, Atlantic, at BIO in 1978, died January 15, 1992 in Halifax. He was appointed Director of the Institute in 1965 and remained there, through several major federal reorganizations, until his retirement. In his early years he worked as an oceanographer at the Woods Hole Oceanographic Institute in Massachusetts. He subsequently held several scientific positions with the Department of National Defence. Among the many highlights in his distinguished career were: his participation in Operation Crossroads-Bikini to study the oceanographic effects of the first peacetime atomic bomb test; leading the scientific investigation and cleanup of the Arrow oil spill in Chedabucto Bay; and chairing the Environmental Advisory Committee set up by the Royal Commission on the Ocean Ranger disaster. Perhaps more than anyone else, Bill Ford oversaw the development of the Institute to its present stature as a world class research organization.

Awards and Presentations

The following were among the awards and presentations involving staff of the laboratories:

- Dr. Lubomir Jansa of AGC's Basin Analysis Subdivision was presented with the 1992 Professor Purkyne Medal of the Czechoslovakia Geological Survey and Geological Societies at a ceremony in Prague on September 11, 1992. The award was made in recognition of Dr. Jansa's research into Mesozoic geology, including fundamental studies of sedimentary basin evolution, ocean basin evolution, and the application to hydrocarbon resources exploration.

- Dr. Charlotte Keen of AGC's Regional Reconnaissance Subdivision was awarded honorary membership of the Canadian Society of Exploration Geophysicists.

- Dr. Stu Smith of the Ocean Circulation Division of DFO was awarded the American Meteorological Society's Editor's Award for 1991 in recognition of his significant reviews of manuscripts submitted to the Journal of Atmospheric and Oceanic Technology and dealing with meteorological measurements from surface buoys, ships and islands.

- Dr. Arni Sutherlin, a former member of the SABS, was honoured through the presentation of the "Aquaculturist of the Decade Award" by the Aquaculture Association of Canada at its 1993 meeting. Dr. Sutherlin worked at the St. Andrews Biological Station in the 1970's and was a key participant in the development of the Bay of Fundy salmonid industry.

- Dr. Gus Vilks of AGC's Environmental Marine Geology Subdivision was awarded honourary membership of the North American Micropalaeontology Section of the Society of Exploration of Palaeontology and Mineralogy. This award, which came on the eve of his retirement in 1993, was in recognition of his outstanding contributions to Quaternary marine geology, paleoecology and paleoceanography.

Huntsman Award

The A.G. Huntsman Award for excellence in the marine sciences is administered by a private foundation based at BIO. It was first awarded in 1980, and up to the end of 1993, 16 persons had received the Huntsman Medal. The following awards were made during the period covered by this Review:

On February 24, 1993, Dr. Trevor Platt of the Canadian DFO at BIO was presented with the 1992 Huntsman Medal in recognition of his extensive and innovative contributions to the understanding of pelagic ecosystems, especially in the open ocean. Dr. Platt is the first DFO scientist to win this award.

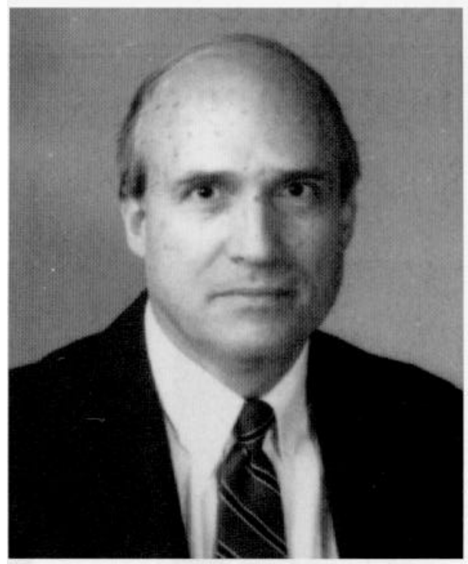
On November 5, 1993, Dr. Robert Berner of Yale University in New Haven, Connecticut was presented with the 1993 Huntsman Medal in recognition of his work on the mathematical modelling of kinetics in the field of sedimentary geochemistry.

Research and Survey Highlights

Some of the major events that occurred during the 1992-93 biennium are outlined below by broad geographic region.

Gulf of Maine, Georges Bank, Bay of Fundy

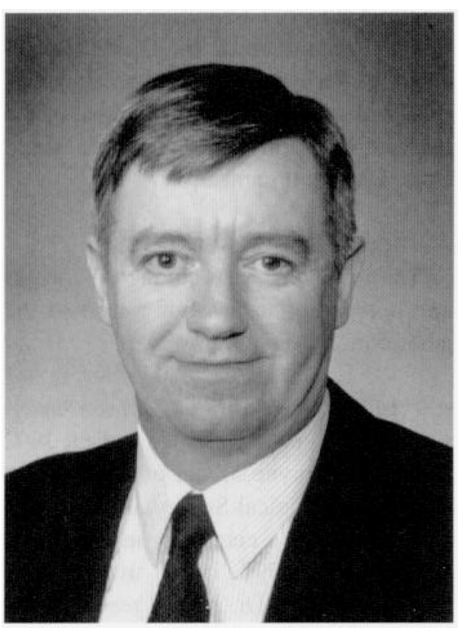
Since 1987, scientists at the SABS have been monitoring the recovery of the Georges Bank (5Z) herring stock through



Dr. R. Rerner

annual larval and adult surveys. The data are used to document the resurgence of one of the world's largest herring stocks, once thought lost to commercial fishing. Surveys were carried out in both 1992 and 1993. In 1992, for example, the work involved two vessels: *EE Prince* surveyed adults while CSS *Parizeau* conducted larval studies. The information obtained on distribution and abundance is used to provide an assessment of stock status in the likely event that a commercial herring fishery is re-established.

DFO research continued throughout the review period to address issues pertaining



Dr. T. Platt

St. Andrews Biological Station

Halibut acuaqulture

to possible offshore oil/gas development on the Canadian portion of Georges Bank. The research is coordinated via the Georges Bank Steering Committee, which is chaired by DFO and has members from a variety of groups including the federal government (Fisheries and Oceans, Environment Canada, Natural Resources Canada and the National Energy Board), provincial governments (New Brunswick and Nova Scotia), academia (Dalhousie University), industry (LASMO Nova Scotia and Texaco Canada), as well as agencies such as the Canada-Nova Scotia Offshore Petroleum Board and the Seafood Producers Association of Nova Scotia. The Committee reviews the progress of ongoing research projects that are undertaken by DFO at BIO and funded primarily through the Panel on Energy Research and Development (PERD). The results of this research will be a significant consideration in the federal/provincial environmental assessment of exploratory drilling on Georges Bank. This assessment is expected to get underway in 1996.

Aquaculture in the cold waters of Atlantic Canada has some unique limiting factors. "Winter kill" is the condition of freezing to death when water temperatures fall below -0.70C. The salmon aquaculture industry in the Bay of Fundy's Quoddy region has operated under the threat of winter kill since its inception in 1978. SABS researchers recently increased their monitoring of oceanographic conditions in this region. The work indicates that the water is coldest in localized inshore areas and in the northern part of Passamaquoddy Bay. and that it becomes progressively warmer farther offshore. The minimum water temperature observed during a period of record low air temperatures in February 1993 that resulted in sub-zero water temperatures was -0.930C near the head of the St. Croix River estuary; the warmest water at this time was in the offshore (1.100C). Temperatures were relatively uniform throughout the water column, indicating that attempts to avoid winter kill by bringing up deeper, warmer water would be futile in most areas.

An ongoing experiment is underway on Campobello Island in the Bay of Fundy to evaluate the feasibility of growing halibut in salmon cages. The SABS and Harbour DeLoutre Products Ltd. are working cooperatively on the project. Norwegian and Scottish attempts to grow halibut in salmon cages have been only partially successful. Problems include severe fin chafing and eye damage as a result of rubbing on the cage twine, and deteriorating water conditions from faeces and uneaten food in the tarpaulin-lined cage bottoms. The cage in the Campobello study is designed to overcome these problems. Wild-caught juvenile halibut were placed in the cage in 1990 and fed a combination of frozen herring and semi-moist salmon pellets. Results to date indicate that Atlantic halibut stocks may provide better genetic material for aquaculture than Icelandic or Faroese stocks.

AGC research in this geographic region includes the analysis of the hydrocarbon potential of Fundy Basin, one of a series of rift basins occurring along the eastern margin of North America that were formed during the early Mesozoic breakup of the super continent Pangaea. Industry seismic data as well as data from exploratory wells and outcrop sections are being utilized in this investigation. The seismic data show that Triassic and Jurassic strata occur in the west-central portion of the basin. Facies projections suggest the probability that thick lacustrine sequences, which could contain rich petroleum source rocks, will be widespread along the basin axis.

Scotian Shelf

During 1992, as part of its mandate to produce navigation charts, the Canadian Hydrographic Service (CHS) conducted surveys of Halifax Harbour and Approaches that have been of interest to the scientific community at large. The surveys employed state-of-the-art multibeam echosounders and acoustic sweep systems that produced complete images of the seafloor through image processing software developed by the AGC and the University of New Brunswick. For the first time, hydrographers and geologists could see the "big picture" of the seafloor in this area. The hydrographers detected previously uncharted features and potential hazards to navigation, including ship wrecks. The geologists were able to define the extent of various sea-floor features that will assist in the development of theories on post-glacial rebound, climate change and sea-level variations.

Until recently, it has not been possible to continuously monitor zooplankton population changes except from ships. DFO scientists have addressed this problem by developing a prototype moored instrument

Cohasset/Panuke offshore drilling platform

based on the BIO optical plankton counter. The instrument was deployed successfully for several extended periods during 1992 and 1993 to monitor zooplankton populations in Emerald Basin. Since the abundance of zooplankton (food) can affect survival of commercially important fish species, information on zooplankton population changes over many years is of potential use to stock assessment biologists.

AGC scientists involved in the analysis and interpretation of geochemical data from wells proximate to Sable Island have found wide variations in kerogen types in the Jurassic and Cretaceous formations. Differences in the activation energies of the kerogens have resulted in the generation and expulsion of considerable amounts of oil from some Cretaceous shales at a relatively low level of maturation. Based on oil-to-source rock correlations, some of the source rocks for the 22 Scotian Shelf oil and gas discoveries have been identified. Of significance is the fact that oils from many of the mature source rocks have not been identitied in discoveries to date, indicating possible sizeable undiscovered resources.

DFO freshwater scientists have initiated a long-term biomonitoring program to detect the effects of airborne loadings of acidic sulphur and nitrogen oxides on the freshwater ecology of Nova Scotia. Specifically targeted are the lakes and rivers along Nova Scotia's South shore, between Halifax and Yarmouth, since these are particularly sensitive to acidification as a result of the low neutralizing capacity of the soils and bedrock. Monitoring sites have been chosen to reflect areas that have historically supported salmon populations and are removed from local sources of acidic loading.

AGC's new capabilities for sidescan seafloor-mosaic construction and wide-diameter piston coring were utilized in a study of pockmarks on the Scotian Shelf conducted from CSS *Hudson.* These depression features imply seepages or venting of fluids from the seabed. As a result of this work, it has been concluded that the pockmarks result from seafloor subsidence due to subsurface reorganization of sediment particles and reduction in porosity, rather than expulsion and removal of the uppermost seafloor sediments.

DFO scientists from BIO are conducting a monitoring study of particulate drilling wastes at the Cohasset-Panuke offshore oil production site on Sable Island Bank. This project involves collaboration with the oil company, LASMO Nova Scotia, and AGC. The purpose is to investigate the dispersion, deposition, and ultimate fate of particulate drilling wastes (muds and cuttings) that the operator is permitted to discharge into this high energy, shallow water continental shelf environment. A major field program was completed in 1993 from CSS *Parizeau.* Data were obtained along transects west and north of the Cohasset site. Suspended matter, both naturally-occurring and drilling waste, was sampled, special attention being given to the benthic boundary layer (the half meter just above the seafloor) where drilling wastes are thought to temporarily accumulate during the dispersion process. The results of this research will be relevant to possible future oil developments on Georges Bank. Other research pertaining to the Cohasset-Panuke site included a joint AGC-LASMO study of extreme sediment transport and scour effects during winter storm conditions.

Grand Banks, Labrador Sea

The Canadian Atlantic Storms Program (CASP II) continued in 1992 with a scientific mission from CSS *Hudson.* Funded by the Panel on Energy Research and Development (PERD), CASP's ultimate goals include accurate ice movement and wave forecasting in support of offshore oil and gas development. This particular mission successfully recovered a moored current meter array on the northern Grand Bank near Hibernia, and surveyed currents and hydrographic properties in the area with a combination of a ship-mounted acoustic doppler current profiler (ADCP), surface drifters, a Batfish and a Conductivity Temperature Depth (CTD) profiler. In addition to conventional ship-based oceanographic measurements, a station was set up using a helicopter, on an ice floe in the interior of the pack ice.

CSS Hudson

A collaborative project involving BIO and the Northwest Atlantic Fisheries Research Centre in St. John's, Newfoundland successfully completed the first phase of a trawling impact experiment on the Grand Banks. The experiment, being conducted to provide quantitative information on the possible impacts of mobile fishing gear on the benthic habitat of fishing banks, is the first of its kind to be conducted in Canadian waters. The study site, located 40 nautical miles northeast of the Hibernia oil development, was selected because of its well-developed benthic fauna and relatively uniform sandy sediments. Additionally, sidescan sonar surveys had shown no evidence of recent trawling activity and the site is now offtcially closed to trawling. The experiment placed special demands upon the two ships involved: the *Wilfred Templeman* was required to repeatedly trawl along the same lines within the very narrow experimental corridors, while the CSS *Parizeau* was required to hold station within a few meters so that biological samples could be collected from precise locations within disturbed areas.

In July 1992 the AGC participated in a collaborative project with scientists from the French oceanographic institute IFREMER to acquire seismic data in the Newfoundland Basin. Using the CSS *Hudson* with a French seismic system, the data were acquired as part of a study to understand mechanisms of formation of conjugate passive margins. Similar studies are underway on the Iberian conjugate.

In June, 1993, scientists from BIO, the University of Goteborg, the Lamont Doherty Earth Observatory and the University of Washington took part in an annual survey of conditions in the Labrador Sea aboard CSS *Hudson*. The work was part of Canada's contribution to the World Ocean Circulation Experiment (WOCE) and focused on the changing properties of Labrador Sea water, which is renewed via convection in the winter. One of the more interesting observations from this year's work was that the temperature of the Labrador Sea water is continuing to decrease: it was down to 2.70C, whereas in the mid 1960's it was as high as 3.50C.

Arctic

In the fall of 1992, CSS *Hudson* worked in Hudson Bay and James Bay, collecting geological, sediment geodynamical, geochemical and biological information. This AGC-led research mission was undertaken in order to obtain some of the information required to evaluate the environmental impact assessment for Hydro-Quebec's proposed Grande Baleine hydroelectric power generation project and to provide recommendations on subsequent monitoring programs. This, and a follow-up mission in 1993, also investigated the deglacial evolution of Hudson Strait. The area is a key one for global change studies since discharge from the Laurentide ice sheet through the region triggered freshwater inputs to the ocean, resulting in major climatic changes around the North Atlantic Basin.

Chemists from DFO's Marine Chemistry Division at BIO participated in investigations of radioactivity in the Arctic marine environment during the review period. One scientist took part in a 1993 research mission of the Russian research ship, *Geolog Fercman* for a four week investigation of radioactive waste dump sites in the Barents and Kara Seas. Also in 1993, another scientist participated in an investigation aboard CCGS *Larsen* in the Arctic Ocean to obtain samples for the determination of various radionuclides in seawater and marine sediments. The latter mission was conducted in collaboration with DFO staff from the Institute of Ocean Sciences, Sidney, B.C.

In August, 1993, the AGC participated in "Arctic '93", a joint project with the U.S. Geological Survey. The project was conducted from the U.S. icebreaker *Polar Star*. Refraction data were collected in the Canada Basin, data which will eventually lead to an improved understanding of the Basin's crustal structure.

A 10-year program of repetitive seafloor mapping was completed in the Beaufort Sea in which over 5000 new sea-ice scour events were documented, providing information on their distribution, characteristics, and the processes involved. The results of this program have led to an improved understanding of sediment reworking and will provide key input to the engineering design of future hydrocarbon production facilities.

Also in the Beaufort Sea, a multi-year study of shoreline retreat, sedimentary dynamics, coastal geology, and geotechnics was completed. Its results have been applied to pipeline engineering, environmental protection, community planning, and climate change issues.

During September, 1993, scientists from AGC, together with colleagues from the United States and Europe, gathered geological and geophysical data between Iceland and eastern Greenland. The mission involved CSS *Hudson*. Among the topics investigated were: the role of turbidity currents and debris flows in fjord sediment transport within an environment where deltas are not present; the role of iceberg/sea ice shelves fronting larger tidewater glaciers and their effect in controlling sedimentary processes within fjords; the role of iceberg calving and rafting on sediment accumulation distal from the ice margins; and the role of subglacial sediment transport through a fjord and onto the continental slope during periods of ice sheet expansion.

Offshore and International

Biological Oceanography Division scientists at BIO undertook a trans-Atlantic mission in the fall of 1992 aboard CSS *Hudson* as part of the international Joint Global Ocean Flux Study (JGOFS) investigation of primary and secondary processes in the upper ocean and their role in the global oceans carbon cycle. This was a cooperative venture between DFO and Italian, German and Spanish scientists. The research program had two components. The first was a detailed transect of daily hydrographic and biological sampling, extending from Halifax to the coast of Morocco, and return. The second was a more localized study of upwelling. The following year, as part of the same international program, BIO scientists completed a study of the bio-optical properties of the upper ocean.

During October 1992, an AGC scientist participated in a scientific expedition to investigate gas hydrates in the Okhotsk and Japan Seas, off the east coast of Russia. He was a member of an international team operating from a Soviet research vessel. A total of ten seafloor gas vents were discovered during the expedition, in addition to one vent that had been previously documented. Methane discharge from the active vents was estimated to equal or exceed many other global methane sources, but most of the vented methane dissolves in the sea and is oxidized before reaching the atmosphere. Gas hydrate samples were recovered from seven cores taken in two areas. The hydrates appear to form when methane gas flows from subsurface petroleum deposits. The focus of AGC's interest is in determining if hydrates can release significant amounts of methane gas into the atmosphere, thereby enhancing the greenhouse effect.

The North Atlantic Tracer Release Experiment (NATRE) field program has recently been completed. NATRE is an international study of the rate of mixing and dispersion of ocean waters in the eastern North Atlantic being carried out by a group of scientists from the United States, the United Kingdom and Canada as a part of the World Ocean Circulation Experiment (WOCE). The final surveys of the NATRE study were carried out in April-May, 1993 in the Canary Basin in the eastern Atlantic Ocean, one from the CSS *Hudson* and the other from the United Kingdom's RRS *Darwin.*

Contaminant distributions in the northern part of the North Atlantic Ocean were studied in August, 1993 during an expedition on CSS *Hudson.* This was the second of a large-scale survey of contaminants in the Atlantic Ocean organized by the Intergovernmental Oceanographic Commission (IOC). The first mission to the eastern part of the South Atlantic was conducted in 1990 from the German research vessel R.V. *Meteor*. The main objective for the overall IOC open-ocean baseline survey for contaminants in the Atlantic Ocean is to determine the present day distributions of contaminants within the oceanic deep water masses. This will provide baseline concentrations against which to assess future changes and also establish reference levels for coastal zone monitoring. The results will provide the first comprehensive survey of contaminant concentrations in the Atlantic Ocean.

Non-Site Specific

During May 1992, CHS staff coordinated trials of the semi-submersible DOLPHIN vehicle from the CCGS *Sir Wilfred Grenfell.* The trials were conducted under the Canadian Ocean Mapping System (COMS) initiative by Brooke Ocean Technology, GeoResources Ltd. and CHS to check handling system modifications and test the procedure for recovering "dead" DOLPHINS. The vehicle performed flawlessly during the trials and a five kilometre square area was surveyed using the SIMRAD EM100 multibeam sounder and differential Global Positioning System (GPS).

For several years the Habitat Ecology Division of the Biological Sciences Branch at BIO has been developing models to assess the environmental impacts of aquaculture. One of the main objectives is to develop criteria for evaluating licence applications, based on the potential habitat damage. However, a major concern was that the complexity of the models and the amount of data required to run them rendered them impractical in the context of a realistic licensing scheme. Therefore a decision support system (DSS) for managers was developed that extracts the necessary data and runs the relevant models automatically. The DSS is based on three separate environmental impact models involving oxygen demand, benthic loading and eutrophication. It has received considerable attention in demonstrations before potential users and at international workshops. Current work involves development of a real database to include variables such as bathymetry, current speed and sediment type. A geographical information system (GIS) for storing the data in a form accessible by the DSS is being investigated.

In 1986, the Malouf Royal Commission on Seals and Sealing stated that seals have a significant impact on the fish resource and that control of the herds might have beneficial effects. As an alternative to supporting a cull, it suggested that work be done to investigate other methods to control both the seal and its parasite, the sealworm. As a result the Sealworm Intervention Program (SWIP) was initiated as a cooperative effort between DFO and Dalhousie University, Halifax. This long-term research project is investigating chemical and immunological methods to control seal production and sealworm infestation. One of the major thrusts is an examination of the feasibility of controlling the number of sealworm parasites by using deworming drugs. Such a response causes seals to eliminate worms. A second research thrust is a study of immunocontraception methods to control the fertility of female grey seals.

In 1992, an extensive geophysical and geological digital database was donated to AGC by Husky Oil and Petro-Canada. Covering offshore sedimentary basins from Georges Bank to the Arctic Ocean, the data base includes over 100,000 line kilometres of seismic data. The data transfer from Calgary to Dartmouth during March, 1993, required 8 semi-trailers! AGC has established a specialized computer work-station facility to provide access to the data for clients.

The Disease Research Unit of the HFRL has been working on developing a vaccine against the Gram-negative bacterium, Aeromonas salmonicida, the causative agent of furunculosis in salmonids. Although this is the most widely investigated pathogen of salmonids. there is no efficacious vaccine to prevent this disease. Furthermore, it is not yet clear which arm of the immune system (humeral or cellular) is responsible for the protection of fish against this disease. To answer this question, the laboratory has developed an assay to isolate and stimulate salmonid lymphocytes into mounting an immune response to the bacterium. For the first time this easy-to-use method allows the investigation of the role of humeral and cellular immunity in fish in relation to vurunculosis. This research will ultimately help determine the direction of future vaccine development.

Pursuant to the work of the CHS at BIO pertaining to the development of the electronic chart, two significant events occurred during 1993. An electronic chart facility was installed at the Marine Institute, St. John's, Newfoundland, to coincide with the 1993 Marine Simulation and Ship Manoeuvrability (MARSIM) Conference, while a second installation was placed on the Marine Atlantic ferry, MV *Princess of Acadia* operating between Saint John, N.B. and

Digby, N.S. Further installations of this new navigational technology are expected.

DFO scientists are involved in a number of projects under the Ocean Production Enhancement Network (OPEN) Centres of Excellence initiative. Working with university and industry colleagues, research is being undertaken by BIO scientists on two specific projects: cod physiology-heritability; and adult scallop trophic resources. The former project has established that cod stocks are quite different, and in particular that Atlantic cod occupy diverse habitats with discrete genetic stocks that manifest very different performance characteristics. In the second part, an improved understanding has been obtained of bivalve responses to short-term food fluctuations, lack of knowledge of which has hampered attempts to model food acquisition and subsequently to predict growth rates and site carrying capacity. In addition to providing information on scallop (and mussel) feeding and digestion rates, this work will enable an evaluation of how scallops cope with high concentrations of particulate material (important in assessing the effects of land-based erosion, bioturbation and anthropogenic activities).

Appointments

Staff were appointed to a variety of national and international memberships and positions during the review period, including the following:

- Allyn Clarke of DFO's Ocean Circulation Division, was invited to serve as a co-opted member on the Executive Committee of the Scientific Committee on Oceanic Research (SCOR). In this role he will provide advice on climate issues; he was also appointed a member of the Joint Scientific Committee (JSC) of the World Climate Research Programme.

- Susan Waddy of the SABS was named President-Elect of the World Aquaculture Society. Susan will be the Society's 24th President and the first woman to hold this office. She will assume the presidency in 1993-94 after serving as President-Elect for one year.

- Stephen MacPhee, Regional Science Director, DFO Scotia-Fundy Region, was appointed to the Board of Directors of the Centre for Cold Ocean Resources Engineering (C-CORE).

- Brian Nicholls of DFO's Marine Assessment & Liaison Division at BIO, was appointed Honorary Treasurer of the Engineering Committee on Oceanic Resources (ECOR). Brian is also the Secretary of the Canadian National Committee for ECOR.

- Don Gordon of DFO's Habitat Ecology Division was appointed a member of the Scientific Steering Committee of Land-Ocean Interactions in the Coastal Zone (LOICZ). LOICZ is a core program of the International Geosphere-Biosphere Programme (IGBP).

Conferences and Workshops

During the review period, the following conferences and workshops were among several held at, or sponsored in whole or in part by, the three regional facilities:

- ICES Working Group on Statistical Aspects of Trend Monitoring-This group met at the HFRL in April 1992 to discuss the statistical treatment of data on contaminant levels in marine materials, particularly fish tissues.

- US/Canada Joint Ice Working Group - The seventh annual meeting of this group was held at BIO in May 1993. The group coordinates operational ice observation and forecast activities between Canadian and US agencies.

- International Commission for the Conservation of Atlantic Tuna (ICCAT) -The SABS hosted a five-day international workshop of this body in July 1993. Participants examined the problem of using analytical techniques to convert catch-at-size to catch-at-age in large pelagic fishes.

- Ocean Observing System Development Panel (OOSDP) -This international panel held a 5-day meeting at BIO in November, 1993. The panel is providing the design and scientific rationale for the climate module of the Global Ocean Observing System (GOOS). Dr. G. T. Needler of BIO is a member.

Technology Transfer

Technology transfer events and highlights during the review period included the following:

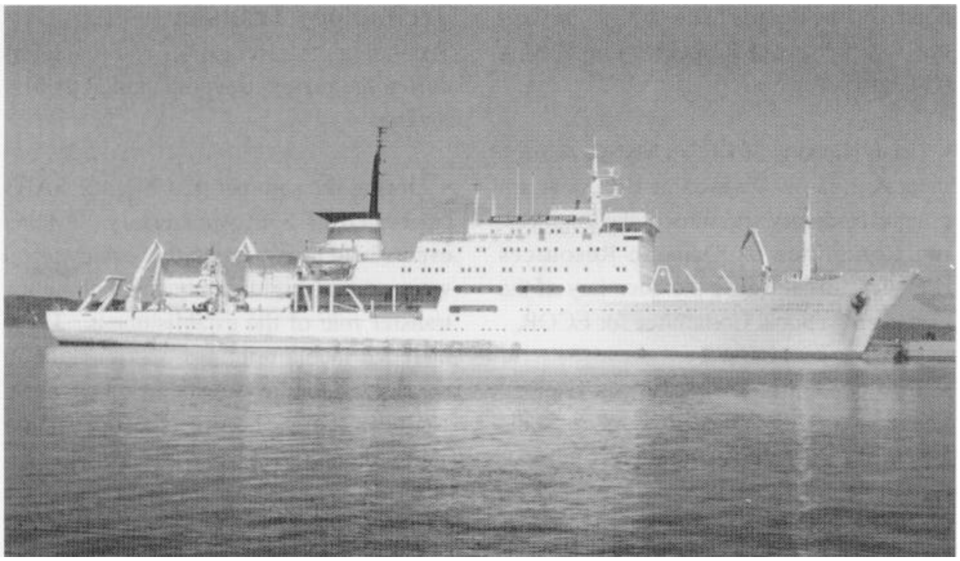
- During the summer of 1993, the SABS celebrated its 85th Anniversary. Among events held to recognize this achievement were several highlighting the technology transfer role of the establishment. These included media briefings, participation in the Sixth Atlantic Aquaculture Fair in St. Andrews, and the hosting of an open house at the Station.

- In March 1992 DFO signed a Canada-Oracle Collaboration Agreement for the Hydrographic Hyperspatial Code. This agreement, which stemmed from research on digital data management carried out by the CHS at BIO, will result in Oracle Canada investing several million dollars in the development of database management software.

- A tri-party collaboration was established among DFO, Guildline Instruments Ltd. and Focal Technologies Inc. for the further development and promotion of the BATFISH towed vehicle, which was originally developed at BIO in the 70's. The work includes sensors to be mounted on the vehicle such as Focal's optical plankton counter.

- In April 1993 Canada's Department of National Defence (DND) established a route survey office at BIO. Staffed by four members of DND, the purpose of this office is to build up navy ocean survey expertise and to share resources with other government departments in the mapping of Canada's littoral zone.

- On November 24, 1992, local ocean-industry companies participated in a day-long event at BIO that focused on ocean technology development and transfer. The central part of the event was an exhibition involving several of the companies, together with exhibits from universities, non-government agencies and federal departments (including NRCan groups at BIO and DFO units at BIO and the SABS). In total there were 54 such exhibits. Other features included short talks by industry and government experts, poster



Russian Vessel Keldysh

presentations and a large "Help-Yourself' table for trade literature, etc. Three hundred 'outside' persons attended the event, plus many DFO and NRCan staff from BIO. The overwhelming reaction of industry participants was that the event was beneficial and should be repeated.

- Throughout the two-year period, DFO's Physical and Chemical Sciences Branch at BIO continued to produce its monthly "State-of-the-Ocean" report for the Gulf of Maine to the Grand Banks region. The report, which includes maps showing surface thermal features, is available to industry, government and other agencies.

Visitors

As in previous years, the three regional establishments received many special visitors from Canada and abroad. Of particular interest were the visits to BIO by the following:

- the Minister of Agriculture & Fisheries and Commerce & Industry of the Sultanate of Oman;
- the French Ambassador to Canada;
- Her Royal Highness Princess Chulabhom of Thailand;
- Prof. Lauro Barcelles, Director of the Museum of Oceanography, Rio Grande, Brazil;
- The Netherlands Ambassador to Canada, His Excellency Baron de Vos van Stenwijk;
- Dr. Gunnar Kullenberg, Secretary, Intergovernmental Oceanographic Commission (UNESCO);
- Dr. John Savage, Premier, Province of Nova Scotia;
- Dr. Lucien Laubier, Director of International Relations and Cooperation, IFREMER.

In May 1993 the Russian research vessel RV *Akademic Mstislav Keldysh* visited BIO under the sponsorship of the Dartmouth-based International Marine Biodiversity Development Corporation. The vessel was alongside for several days during which time discussions on deep-ocean research topics took place between Canadian and Russian scientists.

Facilities and Support Services

Items of interest during the 1992-93 biennium included the following:

- The BIO scientific computing system underwent major changes, moving away from a mainframe dependence into an open system environment;
- CSS *Parizeau,* sister ship to CSS *Dawson* which was retired from active service in 1991, arrived at BIO in February 1992 after transit from DFO Pacific Region. *Parizeau* is now based permanently on the east coast.
- The AGC established an in-house, on-demand digital publishing operation to provide timely release of large-format colour maps and posters.

Publications

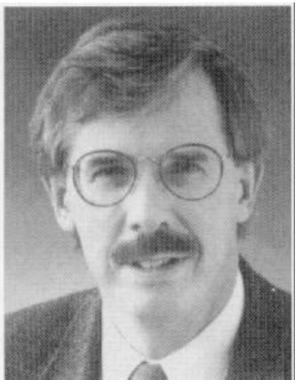
The establishments reach their respective clients and customers through a variety of means, including journal articles, reports and nautical charts. During 1992 and 93, the published output of the establishments continued at a high level. In particular, several books and atlases were produced. Full details are provided in the section of this Review entitled "Charts and Publications". Selected highlights pertaining to the publications of the three establishments are noted below:

- The Geological Survey of Canada's (GSC) map, "Circumpolar Map of Quaternary Deposits of the Arctic", which was compiled in part by scientists of the Atlantic Geoscience Centre, received top honours as an entrant in the International Map exhibition held at the 16th International Cartographic Conference in Germany in 1993. The map was "highly commended for its comprehensive content and outstanding design in the thematic map category".
- Although published in 1991, book reviews of Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans by K.H. Mann and J.R.N. Lazier of DFO did not appear until the following year. The book received favourable reviews in a variety of scientific journals including Limnology and Oceanography and Nature. A second edition is in the planning stage.

A New Understanding of the Ocean Floor Through Multibeam Mapping

R. C. Courtney and G. B. J. Fader

R. C. Courtney



G. B. J. Fader

Abstract

The advent of digital multibeam bathymetric systems has redefined seabed mapping, revealing a hitherto unexpected detail and complexity of the ocean floor's geomophology. Recent co-operative efforts by the Geological Survey of Canada, the Canadian Hydrographic Service and other partners of the National Advisory Committee for Ocean Mapping have significantly enhanced, and even changed, our knowledge of the sea floor and its associated dynamics in the inner part of Halifax Harbour and the nearby offshore Scotian Shelf. To illustrate these new data, this paper highlights interpretations of a bathymetric data set collected by the CSS F.C.G. Smith *in 1992, using a Navitronic sweep system. The seabed in the harbour is shown to be shaped by both natural and anthrophogenic ,forces. Images of Halifax Harbour's floor show a highly variable character, ranging from areas rough and irregular in the Narrows region, to a smoother more undulating bottom in the middle harbour Broad areas of sediment deposition, including obstacle induced sediment drifts and non-depositional moats, are clearly defined. The integrated use of multibeam systems, coupled with complete coverage sidescan mosaics and high density grids of seismic lines, must in future be used to understand the more complex problems of depositional and erosional processess and environmental quality that face a modern industrial society.*

Introduction

Traditional methods of mapping seafloor morphology (bathymetry) and sediment distribution have relied on the collection, interpretation, and correlation of echosounder profiles and seabed grab samples. King (1970) pioneered this method, mapping the distribution of seabed sediments on the central Scotian Shelf. These methods have yielded a regional understanding of the seabed, but are generally of low spatial resolution and have not adequately dealt with characterization of coarse-grained sediments.

On the eastern continental shelf of Canada, where the surficial geology is often dominated by glaciogenic sediments, echosounders cannot normally penetrate hard seabeds of glacial and relict beach materials. Advances in seabed mapping during the late 1970's and 1980's, using sidescan sonar systems combined with high-resolution seismic reflection profilers, have largely replaced the echosounder for sediment acoustic characterization. Their major benefits include an ability to discriminate between most sediment units and an ability to map backscatter images of seabed relief and texture. These newer systems are also carefully calibrated and can provide reflectivity metrics (a quantified assessment) of sediment acoustic properties. These measurements are routinely correlated with sample textural information to assist the marine geologist in establishing sediment formations for mapping. Additionally, advances in the accurate positioning of ships, tow fish sensor packages and sampling equipment, have further enhanced our mapping capability.

One of the major limiting factors in building a detailed and coherent understanding of the seabed and its subsurface geology has been a lack of continuity between survey tracks. The tracks are normally spaced at hundreds of metres to kilometres and correlation between tracks in complex areas has been difficult, if not impossible.

This paper features a new and exciting development in marine geologic seabed surveying called multibeam bathymetric mapping, technology capable of providing a complete areal coverage of the seabed's bathymetry. Conventional sidescan sonar and high-resolution seismic reflection data sets can be correlated with these bathymetric data sets to significantly enhance our knowledge of seabed processes and subsurface geology, providing a basis for new insights into geological interpretation. Highlighting a recent multibeam bathymetric map from inner Halifax Harbour (Courtney, 1993) we will demonstrate how it complements more conventional seismic and sidescan data sets, providing new knowledge on sediment distribution and associated geological processes which have affected the harbour bottom.

Multibeam Bathymetric Mapping

Multibeam bathymetric data were collected in Halifax Harbour during the summer of 1992, by members of the Canadian Hydrographic Service (under the direction of M. Lamplugh), from the CSS *F.C.G. Smith*. It is a twin hulled catamaran outfitted with a Navitronic sweep system comprising 33 separate sounders spaced 1.3

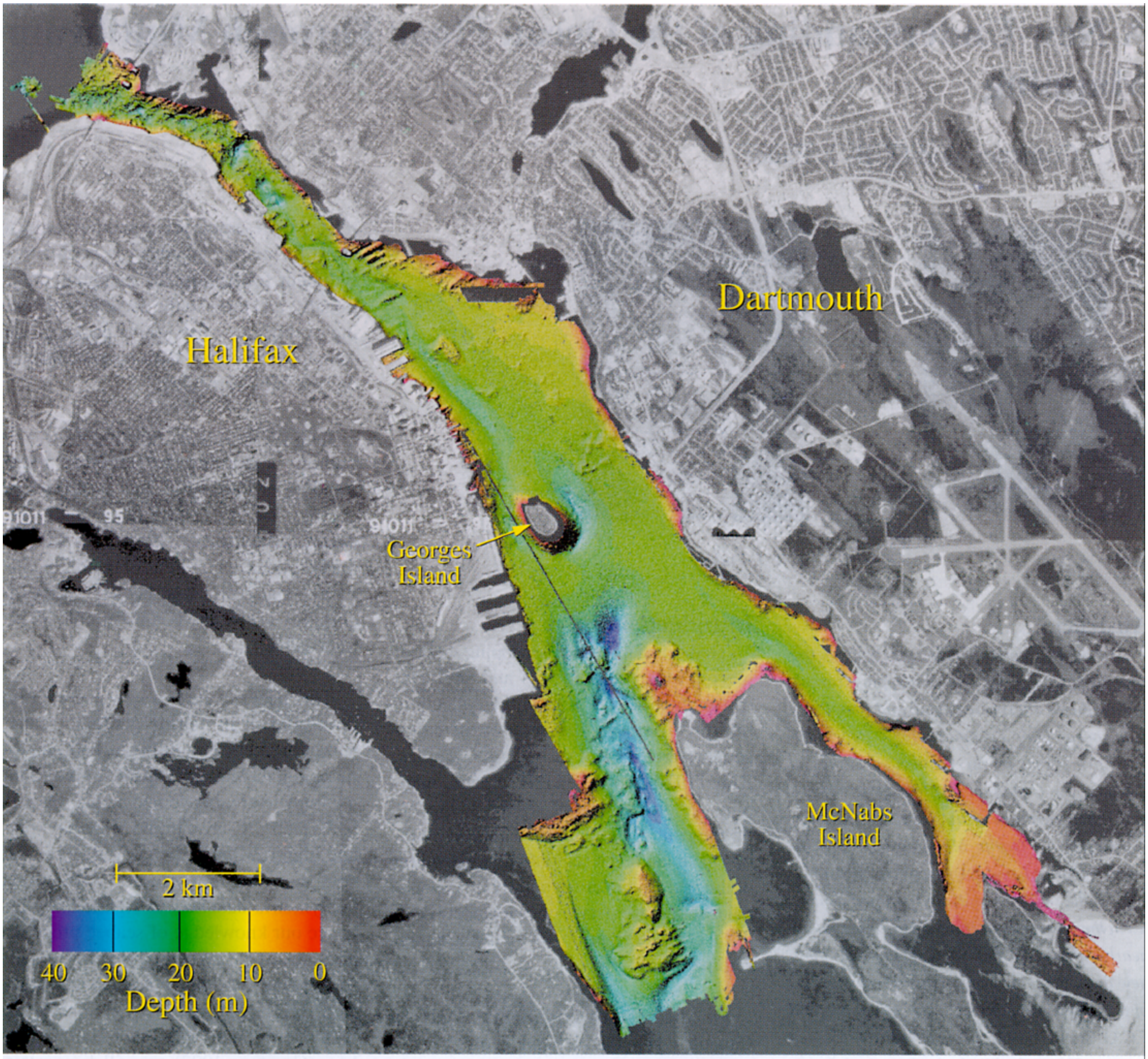


Figure 1: Colour depth coded shaded relief image of bathymetry in Halifax Harbour; integrated onshore with rectified aerial photographs. The bathymetry is artificially illuminated by a light source shining from the northwest at an altitude of 45° from the horizon.

m apart. The sounding transducers are fixed on outriggers mounted across the beam of the vessel, permitting a 32 metre wide swath coverage of the seabed on a single ship track. Unlike the side-looking Simrad systems mounted on other hydrographic vessels, this sweep system sounds depths vertically through the water column; thus the surveyed swath width does not vary with water depth Because of the geometry of the sweep systems, errors in measured water depths are less sensitive to variations in the water column velocity common in estuarine harbours, as refraction effects are avoided. Errors in measured depth vary depending on the sea state and bottom roughness, but are generally accurate to within 10 to 20 cm. The ship's position was measured with a Polarfix laser range and bearing system which locates the vessel to within 1 or 2 metres. The sweep soundings, ship's position, roll and pitch were recorded digitally on magnetic tape and later integrated on a workstation. Over 11 million separate depth soundings of depth were collected during this survey.

Hydrographic data cleaning is a time consuming and interpretive process where one must distinguish false returns arising from air bubbles in the water column, or fish, from real obstacles near the seabed which may be hazards to shipping. This effort is further exacerbated by the sheer number of soundings to be examined. Fortunately, advanced computer aided techniques are now being used to facilitate this process. The hydrographic data used in this article have been subjected only to a first order cleaning and do not yet meet international hydrographic standards. However, images of the seafloor constructed using these data are suitable for geologic interpretation. The soundings were geographically positioned using the ship's navigation which has been corrected for ship roll and pitch as well as transducer offset from the centre of the vessel. Water depths were corrected for tidal variations. These processed water depths were stored in the HIPS hydrographic data base format and made available to researchers at the Atlantic Geoscience Centre (AGC).

Researchers at AGC have developed a set of software tools to access the HIPS bathymetric data base and incorporate the depth data into a raster based geographic information system (GIS) for the production of seabed images and maps.

The first step in the process is gridding the point estimates of depth stored in the HIPS data base using a technique called "binning". In this step, a rectangular area covering the inner harbour region is divided into an array of small squares, or cells, measuring 2 metres on a side; the total number of squares in this study exceeded 30 million. Each of the point soundings of depth are projected, in turn, onto this gridded array and the depths falling within each cell are saved in the computer's memory. The depth value to be assigned to each cell is calculated from the point values falling within that cell; one can choose the average, minimum or maximum value as well as the standard deviation of the depths within this cell. The images displayed in this paper were generated using a choice of maximum depth. This gridded array of depth is saved in the native GIS GRASS format.

The gridded data contained numerous shallow values, artifacts that were most likely missed during the first pass of data cleaning. Various statistical methods can be used to automatically remove these values, sufficient for geologic purposes but potentially dangerous for navigational objectives. A nearest neighbour median filter was used to reject isolated peaks in the gridded data wherein grid cell values were rejected if the median of nearest neighbour grid cells differed from the central value by more than 1 metre of water depth. The rejected grid cell was replaced by the median value. This second step removed the majority of isolated peaks in the data set.

Images of the seafloor bathymetry were produced using a pseudo three-dimensional shading of the surface with illumination emanating from the northwest, at an altitude of 45° from the horizon. On these images, shadows are cast on the lower right hand side of structural high points. The bathymetry has been vertically exaggerated by a factor of ten to enhance surface features. A set of aerial photographs covering the harbour area was scanned and projected onto the coordinate system using common identifiable tie points located on the gridded bathymetric data set. A composite image was constructed using the registered aerial photographs where no bathymetric data was measured. Both colour depth coded (Figure 1) and grey scale (Figures 2, 3, and 5) images were produced in this manner. These images were first examined on the computer monitor and later printed on a large width electrostatic plotter (poster sized prints are available as a Geological Survey of Canada Open File - Courtney, 1993). It should be noted that up to this point the image, or map, production has used soley digital techniques with quantitative and nonsubjective treatment of the measured data.

True three-dimensional images of the seabed topography, generated on a specialized workstation, were used to interactively explore these data. These techniques allow the visualization of the information in ways not previously available. The viewpoint and illumination can be easily changed, often highlighting different aspects of the data sets not apparent on the pseudo 3-D prints. In addition, other types of data. such as sidescan imagery, can be projected onto bathymetry to further enhance interpretation.

Image of Inner Halifax Harbour

Multibeam bathymetric data presently exist for an area of Halifax Harbour between the Narrows and the Maugher Beach area of McNabs Island, a region we refer to as the inner harbour. On first assessment of the image (Figure 1). it is clear that the shape of the harbour floor is complex. The largest depression, an elongate feature trending north-south, occurs between the northwestern area of McNabs Island and the southern area of peninsular Halifax. Other smaller deeps are several isolated circular depressions in the Narrows, and a

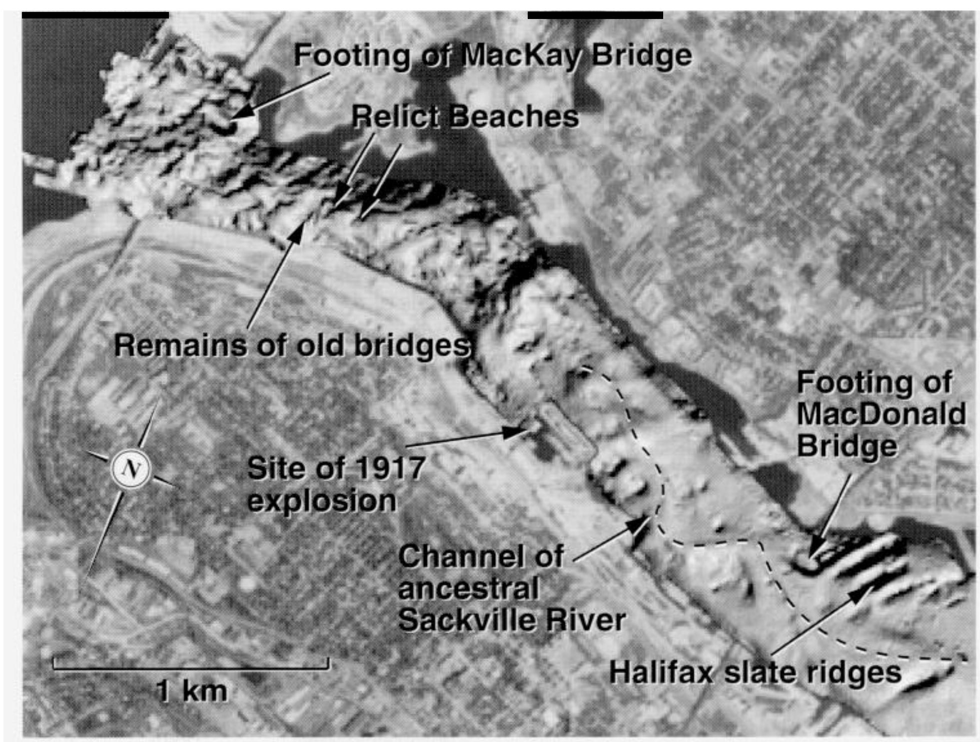


Figure 2: A grey scale shaded relief image of the Narrows region of Halifax Harbour, showing natural and anthropogenic features on the seabed.

curved moat-like depression southeast of Georges Island.

The seabed of the Narrows is rough and irregular with ridge-like features trending southwest-northeast. The broad area to the north and south of Georges Island is generally flat or gently sloping and appears featureless. However, upon closer examination, many small irregular-shaped topographic elements are evident. The southernmost part, east of McNabs Island, off the image is very complex, with areas of smooth, flat seabed and rough irregular seabed.

Such a cursory examination does not shed much light on the nature or origin of the relief elements on the image. Comprehensive geophysical studies of Halifax Harbour (Fader and Miller 1992, Fader et al. 1991, Miller and Fader 1989, Miller et al. 1990) based on sidescan sonar and seismic reflection surveys together with samples and photographs, help us to interpret the bathymetric image and to understand the origin of the morphological elements.

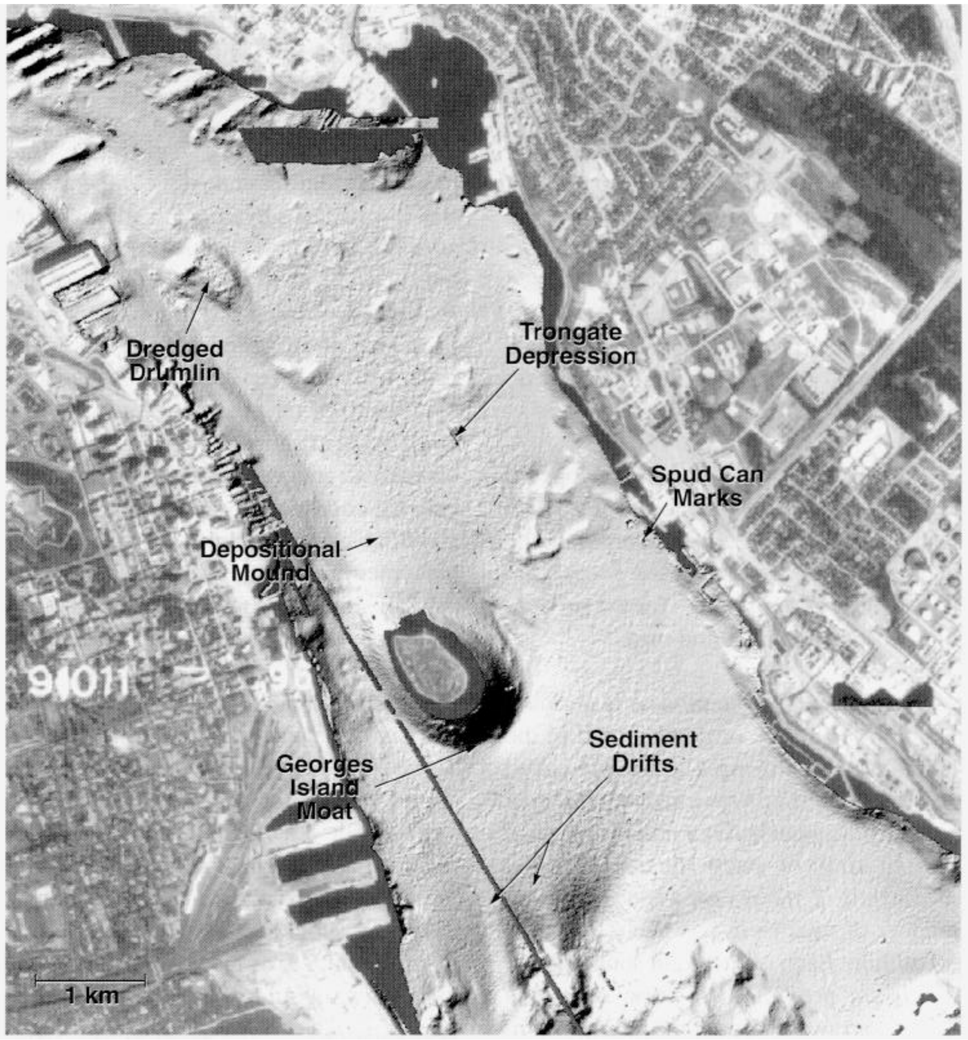


Figure 3: A grey scale shaded relief image of the central harbour.

Interpretation

There are many natural geological features on the seabed of Halifax Harbour but these are often obscured on sidescan sonogram images by an overwhelming anthropogenic imprint (Buckley and Winters 1992, Fader et al. 1991). Some examples include dredge spoils, anchor marks, borrow pits, shipwrecks, and unidentified debris. These features are also difficult to interpret, and historical documents, archival information and personal communication have provided a valuable source of information for a large part of the understanding of the anthropogenic imprint. The following is a brief interpretation of the major features of the bathymetric image, extending from the Narrows region (Figure 2) to McNab's Island (Figure 5).

The Narrows

The seabed of the Narrows (Figure 2) is very hard, largely composed of gravel with boulders and some outcropping bedrock with a thin vaneer of discontinuous mud (Fader et al 1991). East-west trending ridges are morphologic expressions of buried bedrock ridges in places covered by up to 16 m of till (Fader in press). The remains of the first two Narrows bridges, constructed in the late 1800's, occur 500 m south of the A. Murray Mackay Bridge, and appear on the multibeam image as a linear, faint shadow that transects the Narrows. Details of the bridge remains had been previously revealed through a sidescan sonar survey (Miller et al. 1990), showing a cribwork on the seabed, comprising boulders,

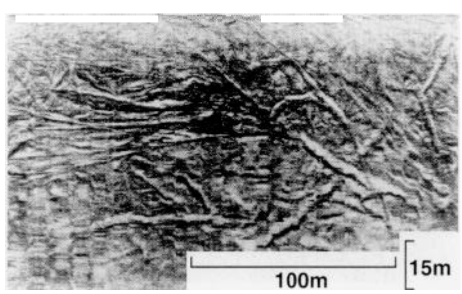


Figure 4: A sidescan sonar image of anchor marks on the floor of Halifax Harbour

rail track and wood pilings. Curvilinear features in the same area are interpreted as relict gravel beach ridges. formed during the marine transgression of the harbour (circa 6.000 y BP (Miller et al. 1982), as the sea flooded up the Narrows in post-glacial time. Also indicated on Figure 2 is the interpreted location of the explosion of 1917 where the *Mont Blanc's* cargo detonated into the world's largest explosion prior to the atomic bomb (Fader in press).

In the southern part of the Narrows, the relect incised channel of the ancestral Sackville River can be clearly identified (King 1970, Fader et al. 1991). Its sinuous course meanders between bedrock ridges that appear along the flanks of this part of the harbour. Sedimentation since the marine transgression of Halifax Harbour has been very low in the southern part of the Narrows. 0.2-0.4 cm/y (Buckley and Winters 1992),

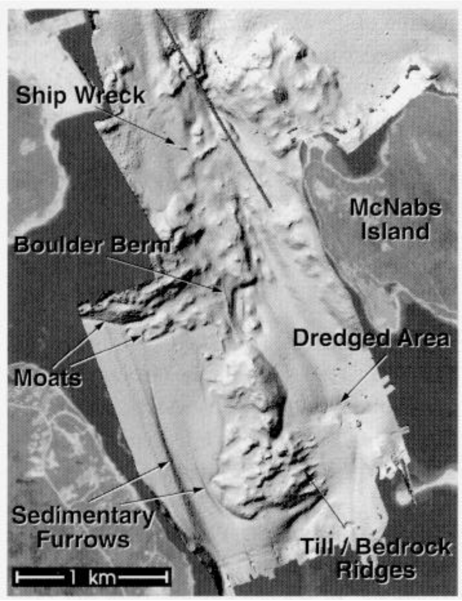


Figure 5: A grey scale shaded relief image of the seabed of Halifax Harbor from Point Pleasant Park to Sandwich Point McNabs Island.

preserving the seabed expression of the old river channel. Large ridges south of the eastern footing of the Angus L. Macdonald Bridge are Halifax Slate exposed at the seabed.

Central Harbour

Although the seabed image appears generally flat and featureless in the area surrounding Georges Island (Figure 3), sidescan sonograms indicate that it is criss-crossed with many generations of anchor marks (Figure 4). Through the process of mechanical turbation (anchorturbation), the deployment and dragging of anchors can produce linear depressions flanked by berms together with isolated pit marks. These vestigial marks can be as large as 2 km in length, 5 m in width, and up to 3 m in depth. Although they often dominate the character of sidescan sonograms in this area, only the largest ones can be seen in the multibeam bathymetric data.

Other features in this area result from the grounding of ships and oil rigs. Near the Dartmouth shoreline, large 15 m diameter, rimmed pits, are interpreted as spudcan footprints left from the testing of jack-up oilrigs on the Harbour bottom. One of the larger anthropogenic features is the impression of the hull of the ship *Trongate,* termed the "Trongate Depression" (Fader and Miller 1992), which was purposely scuttled in the harbour in 1942 north of Georges Island. The ship caught fire creating a risk that the large cargo of ammunition and explosives would explode. The remains of the vessel were finally salvaged in 1956, but a large linear depression, flanked by two asymmetrical mud berms, and the cargo of munition shells, boots, and rolls of newsprint are still on the harbour floor.

The multibeam image shows most clearly larger scale geomorphology that is produced by naturally occuring depositional and erosional processes. South of Georges Island are two linear depositional features resulting from northward flowing bottom currents that pass around bedrock mounds on the seabed. As the bottom current flow bifurcates around the obstacle, the current's speed increases, reducing the deposition of sediment around the sides of the bottom feature. In the lee of the obstacle, the current speed decreases, allowing sediment to fall to the bottom and accumulate at a high rate. This produces, over time, a linear mounded deposit of fine-grained sediment north of the feature. Since the bottom current flow is predominately northward (Fader and Petrie 1991), these features are maintained over time. These deposits are termed obstacle-induced sediment drifts.

Surrounding the south side of Georges Island is a moat-like feature which we term the "Georges Island Moat". It is produced by the same processes of bottom current deflections described above. Directly north of Georges Island is a positive feature, a large depositional mound of Holocene mud, over 6m in thickness (Fader et al. 1991). On first assessment, the moat appears as if it may have been eroded into the soft sediment. However, the internal structure of seismic reflection profiles indicates that it has been a characteristic of this part of the harbour since the deposition of fine-grained Holocene sediments, perhaps as early as 5 thousand years ago, suggesting that the harbour's current patterns have not significantly changed since that time.

Point Pleasant Park to Sandwich Point

This area of the Harbour (Figure 5) is very complex with areas of rugged relief and other flat areas with isolated features. Interpretation of the topographic elements is difficult. Several interesting erosional or non-depositional features occur in this area. Adjacent to Sandwich Point, and continuing to the north are a series of bifurcating, linear erosional scours, known as sedimentary furrows (Fader and Miller 1992). Their presence was suspected from conventional acoustic surveys but they were very difficult to interpret and delineate because of their muted registration on sidescan sonar data. They are probably formed in response to strong, helical, unidirectional bottom currents. Sedimentary furrows bifurcate in the direction of current flow, and as such are excellent sediment transport indicators. The direction of the northern bifurcation reafftrms that the currents that formed them flow from south to north, toward the inner harbour. Other bottom features are notable in this area. A long meandering and sinuous ridge-like feature, found at about 23 m water depth, is interpreted as a boulder berm, a relict coastline of an ancient lake which existed more than six thousand years ago when sea level was lower (Miller et al. 1982, Shaw et al. 1993). A similar feature was previously mapped (Fader et al. 1991) ringing Bedford Basin. The natural undulation of the seabed is disrupted in the east side of the area by recent dredging. This activity left a broad incised depression in the bottom which has since been muted and reshaped by subsequent current or wave action. Ship wrecks can also be identified on these images but little, if any, detail can be resolved concerning their structure. The shipwreck shown on Figure 5 has been examined by divers and is thought to be the *Havana,* sunk in a collision in 1906. Sidescan systems must be used to examine the details of similar features, allowing the mapper to distinguish between anthropogenic and natural objects.

Societal Impact

Of prime importance to the design of a wastewater management system for Halifax Harbour (Fournier 1990) was the need for an understanding of the fate of particles released from a marine outfall placed on the harbour seabed. The bathymetric image can be interpreted to address such an issue and has contributed to a much clearer picture of sedimentation in the harbour. The harbour bathymetry results from an integration of all the processes that have affected the seabed of Halifax Harbour since the glaciers receded over 12 thousand years ago (Shaw et al. 1993).

The sedimentary furrows, the sediment drifts, the moat surrounding southeastern Georges Island and the depositional mound north of Georges Island, all indicate net sediment transport to the north, up the harbour. There is also substantial corroborative information supporting long term transport to the north, including heavy metal distribution patterns, (Buckley and Winters 1992), sediment depocentres, (Fader et al. 1991) oceanographic measurements (Fader and Petrie 1991) and anecdotal information on the drifting of objects.

The sewage management system for Halifax Harbour was designed to enhance containment and deposition of effluent particles in the inner Harbour, (Fournier 1990, Halifax Harbour Cleanup Project 1993). Consequently, it was necessary to understand sediment transport pathways and depositional centres. Interpretation of the traditional geophysical data showed where the depositional centres were located, but the multibeam bathymetry maps produced a much clearer regional picture and revealed previously unknown features. The continuity and extension of the sedimentary furrows is more clearly defined on the multibeam images. The sediment drifts were not previously known. The clarity and continuity of the bathymetric images removed much of the ambiguity associated with the intrepretation and correlation of sidescan sonar and seismic reflection data sets. This more integrated perception helped the Environmental Assessment Panel to select the Georges Island Moat as the preferred location for the outfall diffuser from the wastewater treatment facility.

Relationship of Multibeam Bathymetric Data to Other Geophysical Information

The value of complete seabed coverage in the presentation of bathymetry cannot be understated. The ability to delineate structural trends aids planning of engineering projects that involve the seabed, such as cable or pipeline routing. Seabed habitat is characterized in a broad sense, but localized roughness (the presence or absence of boulders) remains undefined. Large obstructions to seabed fishing are clearly shown.

It is tempting to assume that bathymetric multibeam images are sufficient to characterize the nature and geology of the seabed, making more traditional surveying methods obsolete. We now know, however, that this view is overly optimistic. The multibeam systems excel in defining the regional major structural relationships in a geologic environment; but they do not have sufficient spatial resolution to define many benthic features of interest, such as boulders, small scale bedforms or smaller anthropogenic objects. Nor do the multibeam systems give us any information about the subsurface, a key to understanding the temporal and spatial history of an evolving environment. The integrated use of multibeam systems, however, coupled with complete coverage sidescan mosaics and high density grids of seismic lines, must in future be used to understand the more complex problems of depositional and erosional processes and environmental quality that face a modern industrial society.

Acknowledgements

The authors would like to especially thank members of the Canadian Hydrographic Service for their diligent time and effort spent collecting data used in this paper and making these new data sets readily available for our use. We also thank R.O. Miller, S.S. Pecore, and D. Buckley for collection of data, geological interpretation and discussion of Halifax Harbour geology.

References

BUCKLEY, D.E. and G.V. WINTERS, 1992. Geochemical characteristics of contaminated surficial sediments in Halifax Harbour: impact of waste discharge. Canadian Journal of Earth Sciences, vol. 29: 2617-2639.

COURTNEY, R.C. 1993. Halifax Harbour bathymetric morphology; Geological Survey of Canada Open File Report no. 2637, 1 colour map sheet.

FADER, G.B.J. (in press). The marine geological setting and seabed impacts of the 1917 explosion of the *Mont Blanc* in Halifax Harbour. In Proceedings of the 1917 Explosion Conference, Goresbrook Institute, 1992, St. Mary's University, Nova Scotia.

FADER, G.B.J and R.O. MILLER, 1992. Cruise report F.R.V. *Navicula* 1990-010, Geological Survey of Canada Open File Report no. 2445, 26 p.

FADER, G.B.J., R.O. MILLER, and S.S. PECORE, 1991. The Marine Geology of Halifax Harbour and Adjacent Areas, Geological Survey of Canada Open File Report no. 2384, vol. 1, 23 p. and vol. 2, 25 maps.

FADER, G.B.J. and B. PETRIE, 1991. Halifax Harbour - How the currents affect sediment distributions. *In* Science Review, 1988 and 1989. T.E. Smith [ed.], Bedford Institute of Oceanography, p. 31-35.

FOURNIER, R.O., 1990. Final report of the Halifax Harbour Task Force, submitted to Nova Scotia Minister of the Environment, 84 p.

HALIFAX HARBOUR CLEANUP PROJECT, 1993. Report of the Federal-Provincial Environmental Assessment Panel for the Halifax-Dartmouth Metropolitan Wastewater Management System. 79 p.

KING, L.H. 1970. Surficial geology of the Halifax-sable Island map area, Marine Sciences Branch paper no. 1, Department of Energy, Mines and Resources. 15 p.

MILLER, A.A.L., P.J. MUDIE, and D.B. SCOTT, 1982. Holocene history of Bedford Basin, Nova Scotia: foraminifera, dinoflagellate and pollen records, Canadian Journal of Earth Sciences, 19: 2342-2367.

MILLER, R.O. and G.B.J. FADER, 1989. Cruise Report 88-018(A) Phase 1, C.S.S. *Navicula*, Geological Survey of Canada Open File Report no. 2039, 22 p., 1 map.

MILLER, R.O., G.B.J. FADER, and D.E. BUCKLEY, 1990. Cruise Report 89-009 Phase A, C.S.S. *Navicula*, Geological Survey of Canada Open File Report no. 2242, 64 p.

SHAW, J., R.B. TAYLOR, and D.L. FORBES 1993. Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia, Geographie physique et Quaternaire, 47: 221-238.

Light Scattering by Marine Heterotrophic Bacteria

O. Ulloa

O. Ulloa

The modelling of light penetration in the ocean and the interpretation of optical measurements obtained by remote sensing and by *in* situ optical sensors require some knowledge of the optical properties of the different substances present in sea water. Considerable attention has been paid to the study of the absorption and scattering characteristics of phytoplankton. They are regarded (along with their derived products) to be the main contributors to the optical properties of sea water. This is the case not only in deep-ocean waters, but also in coastal waters that are not significantly affected by terrigenous inputs or by the resuspension of sediments. The focus of some of our recent work, on the other hand, has been the much-less-studied, non-pigmented particles, particularly the heterotrophic bacteria (Ulloa *et al.*, 1992).

Heterotrophic bacteria are micro-organisms present in all marine environments, in number concentrations 1-2 orders of magnitude higher than phytoplankton; however, their influence on the light field in the ocean has been little studied. They are small (typical diameter of ~ 0.5 µm), compared to the other organisms comprising the plankton; nevertheless they can make a significant contribution to the total planktonic biomass (in units of carbon), particularly in oligotrophic waters (Cho and Azam, 1990). Studies of some of their absorption and scattering characteristics have been carried out on cultures (Yentsch, 1962; Kopelevich et al., 1987; Morel and Ahn, 1990; Stramski and Kiefer, 1990). These studies suggest that heterotrophic bacteria could contribute significantly to the scattering of light in the field. However, no direct evaluations of their contribution to the optical properties of sea water have yet been made.

Approach

Lacking a direct approach for estimating bacterial scattering in natural waters, we used an alternative approach, which was to combine the theory of light scattering with data on bacterial size and abundance. The coccoid shape, random orientation, and simple cellular structure of most free-living marine bacteria suggested that, as a first approximation, bacteria could be assumed to be spherical and optically homogeneous particles. For such particles, Mie theory of scattering (Mie, 1908) gives exact solutions, provided that the refractive index of the particles and their size are known.

The size distribution of bacteria in nature can differ significantly from that of laboratory cultures, which represent a selected group, free of predators. On the other hand, information on bacterial size in the ocean is still limited. Although bacterial size can be measured in cultures using electronic particle sizers, bacterial sizes in natural samples are still most commonly determined using epifluorescence microscopy, a tedious and time-consuming method. With most particle counters it is not possible to distinguish between living and non-living particles, and in most cases the resolution of the instruments has been insufficient to yield reliable information on particles smaller than 1 µm and therefore on the size ranges comprising heterotrophic bacteria. Our work was based on detailed size measurements of bacterial natural samples, obtained with image-analised, epifluorescence microscopy. For the bacterial refractive index we used values published in the literature.

The scattering properties of natural bacterial assemblages in different marine environments were assessed by applying Mie theory to field data on bacterial size and abundance. Samples for bacterial counts and size measurements were collected on board the C.S.S. *Hudson* during August-September, 1988. We analysed data from two stations on Georges Bank, two stations in the Northeast Channel (Gulf of Maine), and one station in the Sargasso Sea. The samples came from waters that varied over almost 2 orders of magnitude in their pigment concentration. In the laboratory, cells were stained with DAPI and counted under an epifluorescence microscope. For the size determination, slides of randomly selected fields were taken. The images of the slide projection were captured with a video camera, and then digitized and processed with an Image Analyzer. The size distribution of all the bacteria measured is given in Fig. 1.

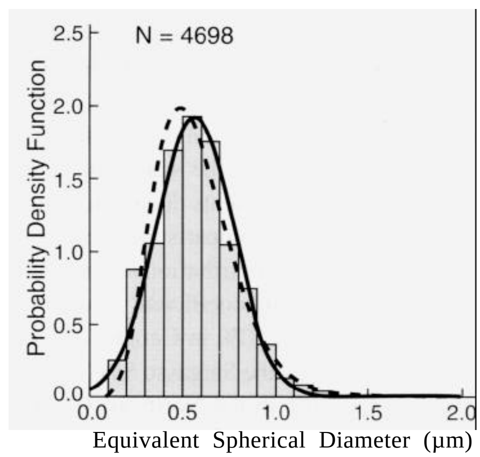


Figure 1: Bacterial size distribution for the Western North Atlantic. Combined data from Georges Bank, the Northeast Channel, and the Sargasso Sea. A normal (solid line) and a gamma (dashed line) distribution hove been fitted to the data.

Optical Characteristics of Bacteria

One way to characterize the scattering process in sea water is through the scattering coefficient b (with dimensions of $[L^{-1}]$), which specifies the fraction of the light per unit pathlength that is removed from a beam due to scattering. For many problems in optical oceanography (e.g., theory of ocean colour, remote sensing) the interest is also on the portion of the light that is scattered just in the backward direction, with respect to the incident light. Hence, it is also useful to have information on the backscattering coefficient b_b (same dimensions as b), which specifies the fraction of light per unit pathlength that is removed from a beam due to backscattering. Both the scattering coefficient and the backscattering coefficient are inherent optical properties, since their magnitudes depend only on the components present in sea water and are independent of the geometry of the incident light field. They correspond to the sums of contributions from pure sea water and substances in solution and suspension.

The bacterial scattering and backscattering coefficients were obtained by numerical computations applying the Mie equations to the measured size distributions. Results for the 550-nm wavelength are shown in Figs. 2 and 3. The total scattering and backscattering coefficients (obtained from the pigment data using empirical relationships) and the scattering and backscattering coefficients due to pure sea water are given for comparison. These results show that the contribution of bacteria to the total scattering coefficient would be on average around 10% in Georges Bank (range 7-17%) and the Sargasso Sea (range 3-16%), and 30% in the Northeast Channel (range 9-57%). With respect to the total backscattering coefficient, the bacterial contribution would be on average around 7% in Georges Bank (range 5-9%), 12% in the Northeast Channel (range 3-22%), and 3% in the Sargasso Sea (range l-4%). The apparent higher contribution to the scattering and backscattering coefficients by bacteria in the Northeast Channel, as compared with the other locations, can be explained by the observed higher bacterial abundance in the low-chlorophyll, summer-stratified, surface waters.

These results show that bacteria could contribute significantly to the total scattering coefficient in any of the three different environments studied. However, their contribution would depend not so much on the trophic status of the ecosystem (i.e., phytoplankton abundances as indexed by their pigment concentration) as on the local relative abundance (and optical properties) of each of the major components influencing the optical properties of the sea water. The stations that showed the highest contribution from bacteria to the total scattering were those in the Northeast Channel, which represent an intermediate case between the phytoplankton-rich waters of Georges Bank and the oligotrophic waters of the Sargasso Sea. With respect to backscattering, the bacterial contribution to the total backscattering coefficient seems to be somewhat lower than for the total scattering coefficient, but nevertheless significant.

Discussion

These results did not support previous theoretical predictions which indicated that bacterial scattering relative to total scattering would be more important in waters that have a higher concentration of bacteria (Kopelevich et al., 1987), that their relative contribution would be independent of the amount of pigments (Morel and Ahn, 1990), or that they would be more important contributors in the oligotrophic ocean (Stramski and Kiefer, 1990). Part of the problem with these earlier predictions was that a relationship was assumed between the concentration of heterotrophic bacteria and the phytoplankton pigment concentration. Recent results, including some from the same cruise that yielded the bacteria data for our study (Li *et al.*, 1992), show that this assumption is not valid, and that there is a high degree of scatter in the relation between bacteria and pigments. Consequently, the bacterial contribution to the scattering coefficients will have to be considered independently from that of phytoplankton.

These results have some significant implications for the interpretation of optical data. For example, it has been proposed that phytoplankton growth rates can be estimated from changes in the attenuation coefficient measured with transmissometers. Accurate estimates of their growth rates, however, require knowledge of the relative contribution of phytoplankton,

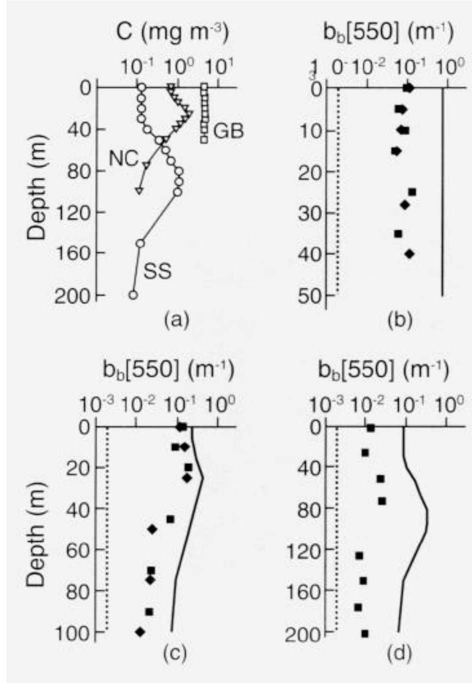


Figure 2: (a) Average vertical profiler of phytoplankton pigment concentration C (clorophyll-a + phaeopigments) in Georges Bank (GB), Northeast Channel (NC), and Sargasso Sea (SS), and comparison between the scattering coefficient at 550 nm nm to pure seawater (dotted line), heterotrophic bacteria (symbols: squares represent station 1 and diamonds station 2). and the total scattering coefficient at the same wavelength (solid line) derived from the pigment data in (b) Georges Bank, (c) Northeast Channel, and (d) Sargasso

microheterotrophs and detritus to the attenuation process. Since variations in the attenuation coefficient can be mainly controlled by scattering (as opposed to absorption) at the wavelengths used with the transmissometers, the contribution of bacteria cannot be neglected, or considered to be proportional to that of phytoplankton, and will have to be estimated independently.

For the modelling and interpretation of remotely-sensed data of ocean colour. it is necessary to consider the backscattering coefficient, since it is this optical property (in combination with the absorption coefficient) which is related to the irradiance reflectance, or ocean colour. Results of this work showed that heterotrophic bacteria could contribute up to - 20% to the total backscattering coefficient. but more typically their contribution would be <10%. Since the backscattering coefficient is directly proportional to the irradiance reflectance, neglecting the independent contribution of bacteria to the

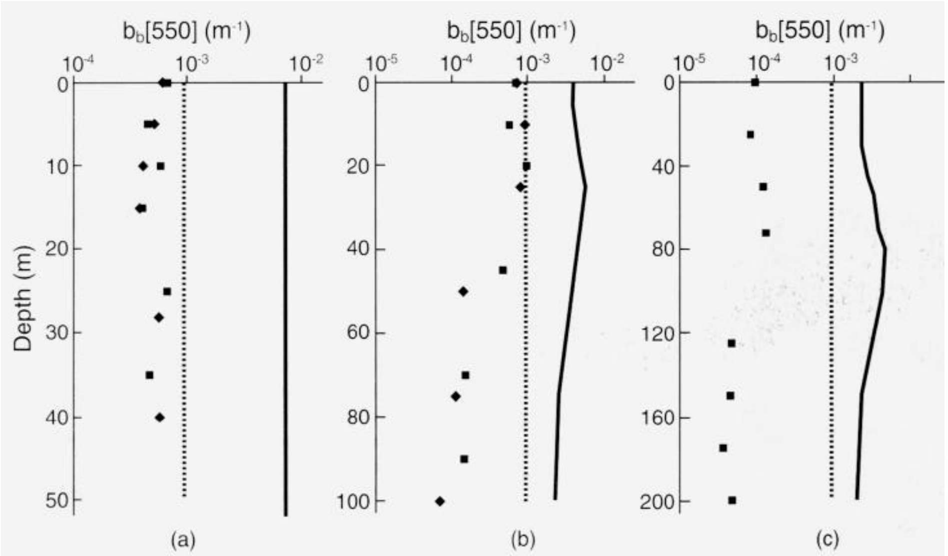


Figure 3: Vertical profiles of the backscattering coefficients at 550 nm in (a) Georges Bank, (b) Northeast Channel and (c) Sargasso Sea, derived from the pigment data in Fig. 2a. Symbols and line types as in Fig. 2 but for backscattering.

backscattering coefficient would introduce relative errors of the same magnitude.

More recently we have been looking at the effect of other sub-micrometer particles *(e.g.,* detrital particles) on light scattering in the ocean, and also at how changes in the size distribution of the total particle suspension can affect the optical properties of sea water. We expect to incorporate the results on bacteria and on other sub-micrometer particles into new models of light transmission in sea water, which can help us with a better interpretation of satellite images of ocean colour and the determination of primary production by remote sensing. This work has been carried out as part of the Canadian contribution to the Joint Global Ocean Flux Study (JGOFS).

References

CHO, B.C., and F. AZAM. 1990. Biogeochemical significance of bacterial biomass in the ocean's euphotic zone, Mar. Ecol. Prog. Ser. 63: 253-259.

KOPELEVICH, O.V., V.V. RODIONOV, and T.P. STUPAKOVA. 1987. Effect of bacteria on optical characteristics of ocean water. Oceanology, Engl. Trans. 27: 696-700.

LI, W. K. W., P.M. DICKIE. B.D. IRWIN, and A.M. WOOD. 1992. Biomass of bacteria, cyanobacteria, prochlorophytes and photosynthetic eukaryotes in the Sargasso Sea, Deep-Sea Res. 39: 501-519.

MIE, G. 1908. Beitrage zur Optik trüber Medien, Speziell kolloidalen Metallösungen, Ann. Phys. 25: 377-445.

MOREL, A., and Y.-H. AHN. 1990. Optical efficiency factors of free-living marine bacteria: Influence of bacterioplankton upon the optical properties and particulate organic carbon in oceanic waters. J. Mar. Res., 48: 145-175.

STRAMSKI, D., and D.A. KIEFER. 1990. Optical properties of marine bacteria. Proc. Soc. Photo. Opt. Instrum. Eng., Ocean Opt. X, 1302: 250-268.

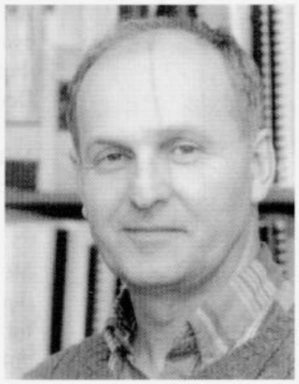
ULLOA, O.. S. SATHYENDRANATH, T. PLATT and R.A. QUINONES. 1992. Light scattering by marine heterotrophic bacteria. J. Geophys. Res. 97: 9619-9629.

YENTSCH, C. S. 1962. Measurements of visible light absorption by particulate matter in the ocean, Limnol. Oceanogr. 7: 207-217.

Technology Transfer From Marine Research

H. B. Nicholls and G. H. Seibert

H. B. Nicholls



G. H. Seibert

Introduction

Research and survey programs undertaken or supported by government agencies in pursuit of their mandates often produce results that industry can use. This is a frequent occurrence at the three federal laboratories, the Bedford Institute of Oceanography (BIO), the Halifax Research Laboratory and the St. Andrews Biological Station (the laboratories). These establishments undertake studies of the marine environment and its renewable and non-renewable resources along Canada's east coast. One category of produced results is technology (defined below). This paper analyses the transfer of technology from the laboratories to industry and other clients.

Technology Transfer - Description and Definition

Technology transfer is part of the overall innovation chain, which often takes place within a single company and involves five phases: idea generation; research and development; product development; production; and distribution (Doyle, 1990). The first two can take place in another organization, e.g., in a government laboratory, with the resulting concept being transferred to the commercial company. In this case, the following stages are involved (McKeown, 1993 pers. comm.):

- creation of concept by scientist or engineer
- communication of concept from scientist or engineer (the inventor) to commercial company
- production of commercial prototype by company
- production of end-product by company leading to its marketing and sale

This paper presents the number and type of technology concepts transferred from the laboratories to private industry and other clients during the six-year period 1987-92. The following definition of technology transfer has been used throughout (Nicholls, 1993 pers. comm.):

"the transfer of hardware, software, information or services that resulted, either directly or indirectly, in economic benefits to the recipient company ***through the marketing of a product or service that resulted in whole or in part from the technology transferred,*** *or had the potential for providing such benefits."*

It follows from the above definition that the provision of advice, data, etc. that does not result in economic benefits to the company through the marketing of a product is not considered to constitute a transfer of technology, and has therefore not been included in this review. However, the provision of such items, e.g., in connection with the assessment of the environmental impact of an industrial development, is a regular occurrence at the laboratories.

The following information was collected in respect of each transfer:

- name and location of company/client
- type of business of company/client
- specific technology transferred
- end result for company (product, service, etc.)
- source of technology transferred
- from joint collaboration between laboratory and company
- from work undertaken solely within the laboratory
- other
- technology development/transfer milestones and dates
- benefits to laboratory
- benefits to company, including general information on commercial applications
- any other supporting information

Because of space limitations, this paper does not address all of the above items. However, it is planned to provide a more comprehensive review in the form of a technical report at a later date.

Technology Transfers to Companies

Some 71 items of technology transferred to industry from the laboratories were identified for the six-year period, 1987-92, inclusive; these items involved 42 companies or other clients (refer to Table 1). In a breakdown of these items by type of technology some of the categories employed in the 1992 "SPARK" initiative of the Province of British Columbia, "The Oceans and British Columbia: A Strategic Framework for Ocean Industry, Science and Technology" (SPARK Oceans Committee, 1993) were used. The number of technology transfer items from the laboratories is shown against each category:

• Ocean observation systems (data collection technologies)	10
• Ocean information systems (processing, interpretation and display of data)	12
• Marine robotics and vehicles, including towed and semi-submersible vehicles	4
• Oceanographic instruments and electronics	24
• Marine navigation	1
• Marine applications of biotechnology aquaculture	14
• Scientific service (analytical chemistry, marine surveys, instrument maintenance)	6
• Other	0
TOTAL	71

A comparison was made with the results of an earlier survey for the years 1980 (approx.) - 1986, inclusive. This study (Fisheries and Oceans, 1988a and b) concluded, among other things, that the Department of Fisheries and Oceans (DFO) science activities result in many economic, technological, and industrial benefits to Canada. The coverage and level of detail of the two studies were not identical, which made comparison difficult. However, a review of the same categories, with the exception of aquaculture, and for DFO at BIO only, gives the following:

	1980-86	1987-92
• Ocean observation systems	0	10
• Ocean information systems	10	12
• Marine robotics and vehicles	1	4
• Oceanographic instruments and electronics	7	22
• Marine navigation	0	0
• Scientific services	6	6
• Other	3	0
TOTALS:	21	54

Results of Technology Transfers

Four examples are given below, outlining the events that occurred following the transfer of a specific technology concept.

Ocean Observation Systems - Lagrangian drifters

The company, Seimac Ltd. of Dartmouth, N.S., won a 1989 contract with the U.S. Government for 20 of these drifters to record currents and drift patterns in the Pacific Ocean. Seimac beat out two American bidders on technical merit and cost for the National Oceanic and Atmospheric Administration (NOAA) contract. The buoys, ordered by the NOAA's Seattle Washington, office, use a device similar to a sea anchor to stay with bodies of water of interest; the buoy's position is reported via the ARGOS satellite. In an article in the Business Section of the Halifax Mail-Star in September 1989, the company president noted that Bedford Institute of Oceanography staff provided support during Seimac's development of the buoy, adding local firms "are lucky to have a facility like BIO (in the area)." The NOAA contract has provided spinoff work to other local businesses for drogues, Kevlar line, sail hardware, aluminum battens, miscellaneous hardware, and fibreglass hulls for the transmitters.

Ocean Information Systems - structure/techniques for efficient storage, manipulation and queries on large (spatial, temporal) data sets

In addressing the Canadian Hydrographic Service's (CHS) data management problems, researchers at BIO invented a solution which was quickly seen to represent a significant breakthrough in the field. CHS teamed up with Oracle Corporation, the world's largest supplier of database software, to develop data management applications. The partnership, structured around a licensing agreement, required substantial transfer of technology from CHS to Oracle, involving the equivalent of one year's time of DFO's inventor. In return for the DFO contributions and technology, the Company agreed to deliver free software worth close to a million dollars. The long term impact of the partnership, however, would be the establishment of a world class research facility in Canada. In a speech made at the official inauguration of the Oracle research facility, the Hon. Benoit Bouchard, Minister Responsible for the Federal Office of Regional Development, Quebec, used the CHS-Oracle partnership as an example of how "The Government of Canada is committed to such joint efforts, to maximize our intellectual efforts and resources in achieving a better living and working environment for all Canadians."

Oceanographic Instruments and Electronics - optical plankton counter

The optical plankton counter (OPC) is a low maintenance instrument which permits rapid, continuous surveys of marine organisms over large regions at tow speeds of up to 12 knots. It can be mounted on undulating tow fish, vertical profilers, or net samplers. The technology was transferred under license to the company, Focal Technologies Inc. of Dartmouth, N.S., in 1990. In a November 1993 letter to BIO, the company noted its encouraging sales figures for the first three years as well as similar forecasts for the next few years. It was also noted that various new applications were being considered, including one with Ontario Hydro pertaining to the Zebra mussel issue. The letter closes with the statement: "Most certainly, the cooperation of the entire Metrology group (at BIO), from marketing support through to technical assistance, has contributed to this success. Thank you."

Marine Biotechnology, Aquaculture - expertise and knowledge (several items)

The transfer of technology from chiefly the St. Andrews Biological Station and the Halifax Fisheries Research Laboratory to the aquaculture industry on such aspects as egg and larval development, fish feed formulation and provision of seed stock is in direct support of DFO's Aquaculture Strategy. The latter aims to support, through joint partnerships between DFO and industry, advancement and innovation in aquaculture development, as well as cooperative management for a healthy and productive environment. DFO's statutory inspection and regulatory obligations under the Fish Health Protection Regulations and other frameworks must continue to be met, but, increasingly, as technology is being transferred, the private sector will conduct at least some of these activities, with DFO in a monitoring role. Longer term DFO research activities continue to be client-driven and are focused on initiatives that are leading to greater industrial diversification, e.g., introduction of halibut as a new aquaculture species. DFO will maintain essential services where the private sector has not yet developed the capability to respond to industry needs.

Closing Remarks

The transfer of technology from a laboratory to industry is generally regarded as an accomplishment and in some cases as a measure of the usefulness or value of the laboratory. Hoagland and Kite-Powell (1989) issue a word of caution, however. They note that the level of activity varies according to the subject field, e.g. oceanography generally ranks lower than such fields as biotechnology, microelectronics and special materials. They emphasize that the results of oceanographic research have application and value in areas other than for products or technologies of commercial use. This paper, which covers oceanography and related fields, demonstrates that it is possible to maintain a significant level of technology transfer over a period of several years. The Bedford Institute of Oceanography, for example, has developed, to meet its own requirements, novel instruments and systems not available on the commercial market. Because oceanographic instrument development is "slow and expensive - and increasingly painful" (Wunsch, 1989), this is often done in collaboration with industrial partners. Once transferred to industry, however, there are many hurdles to overcome before the technology is transformed into a marketable product. The St. Andrews Biological Station and the Halifax Fisheries Research

Laboratory are transferring technologies in support of the expanding aquaculture industry on the east coast of Canada. Here the emphasis is more on advice and expertise as opposed to instruments and systems.

References

DEPARTMENT OF FISHERIES AND OCEANS. 1988a. Fisheries and Oceans Research Centres: Economic and Technological Benefits. Department of Fisheries and Oceans, Ottawa, Ontario.

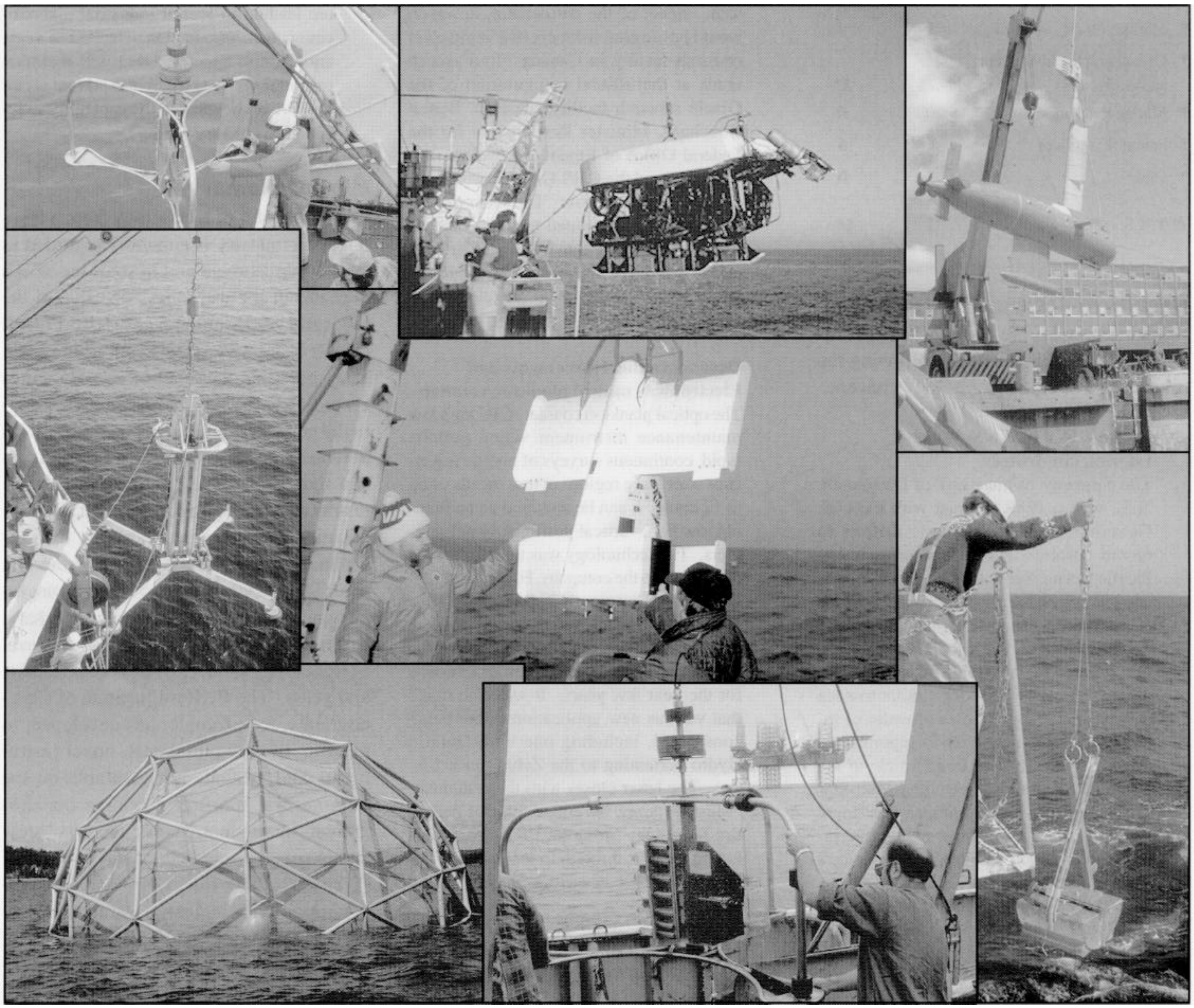
DEPARTMENT OF FISHERIES AND OCEANS. 1989b. Fisheries and Oceans Research Centres: Cases of Technology Transfer. Department of Fisheries and Oceans. Ottawa, Ontario.

DOYLE, D.J. 1990. Making Technology Happen. Doyltech Corporation, Kanata, Ontario.

HOAGLAND, P. and H.L. KITE-POWELL. 1989. Technology Transfer and Intellectual Property Management in the Field of Oceanography: An Overview of Research Institution/ Industry Relations. Working Paper, Marine Policy Centre, Woods Hole Oceanographic Institution..

SPARK OCEANS COMMITTEE. 1993. The Oceans and British Columbia: A Strategic Framework for Ocean Industry, Science and Technology. Science Council of British Columbia, Victoria, B.C.

WUNSCH, C. 1989. Comments on Oceanographic Instrument Development. Oceanography. 2(2): 26-7, 64.



Exmnples of hardware technology transfers.

Table 1

Technology Transferred, 1987-92

Company/Agency	Technology
1 Applied Microelectronics Inst	analytical technology for nitrate determinations in seawater
2 Arctic Sciences Ltd	capability to measure sea ice parameters including associated data analysis methods
3 Atlantic Salmon Federation	perfomance data on previously mature salmon parr when reared in sea cages
4 ASA Consulting Ltd	coastal ocean water level information system (COWLIS)
5 ASA Consulting Ltd..	capability to use Synthetic Aperture Radar imagery in operational wave modelling *(joint transfer - see also #49)*
6 Atlantic Veterinary College	analytical technology and training in domoic acid measurement
7 Axiom Engineering Ltd	sensor concept and associated frame design for ice thickness measuring system utilizing helicopter deployment
8 Axiom Engineering Ltd	design for ice/snow monitoring system
9 Richard Branker Research Ltd	advice & data on temperature-conductivity logger design
10 Brooke Ocean Technology Ltd	design of oceanographic winch for free fall probes
11 Brooke Ocean Technology Ltd	ocean bottom magnetometer design
12 Brooke Ocean Technology Ltd	vibracorer design
13 Brooke Ocean Technology Ltd	system specifications, design advice and field experience pertaining to launch and recovery system for DOLPHIN semi-submersible vehicle
14 Brooke Ocean Technology Ltd	eneineerine information & user experience pertaining to BRUTIV towed vehicle *(joint transfer - sea also #35)*
15 Brooke Ocean Technology Ltd	conceptual design and advice for mid-ocean profiler
16 Brooke Ocean Technology Ltd	design of water sampling bottle for physical and chemical oceanogaphy *(joint transfer - see also #45)*
17 Brooke Ocean Technology Ltd	drawinns. fabrication details, sea trial experience for CTD block used in occanographic equipment handling systems
18 Brooke Ocean Technology Ltd	engine&ing drawings, fabrication details and sea trial experience for roller block used in oceanographic equipment handling systems *(joint transfer - see also #40.#44)*
19 Brooke Ocean Technology Ltd	design concepts and system details pertaining to moving vessel CTD
20 Connors Brothers	salmon egg and larval development data for aquaculture *(also transferred to other companies)*
21 Connors Brothers	aquaculture fish feed fomulation & processing requirements
22 Connors Brothers	optimal temperature to start feeding salmon fry in aquaculture operations *(also transferrd to other companies)*
21 Connors Brothers	use of water content of alevin to predict when to start feeding aquaculture salmon fry *(also transferred to other companies)*
24 Connors Brothers	use of overhead cover at first feeding of aquaculture salmon fry *(also transferred to other companies)*
25 Coretec Inc	computer model for forecasting sea-ice
26 Corey Feed Mills	aquaculture fish feed formulation and processing requirements
27 Correpro Atlantic Ltd.	underwater release mechanism without moving parts for moored oceanographic equipment
28 Correpro Atlantic Ltd.	system specification, design concepts and advice for underwater electromagnetic digital data link
29 Eastern Marine Marsh Ltd.	design concepts, drawings and user experience pertaining to trawl resistant package
30 Femto Electronics Ltd.	acoustic data processing techniques for acoustic estimation of fish abundance
31 Focal Technologies Inc.	system specification, field experience and test data pertaining to oceanographic slip rings
32 Focal Technologies Inc.	design, fabrication, testing and scientific use data pertaining to optical plankton counter
33 Focal Technologies Inc.	system specification, field experience and test data pertaining to fibre optic spectrometer
34 Focal Technologies Inc.	system specification, field experience and test data pertaining to fibre optic flurometer
35 Geoforce Consultants	maintenance and operation procedures pertaining to BRUTIV towed vehicle *(joint transfer - see also #14)*
36 Geonex Aerodat Inc.	on-ice validation of airborne instrumentation that measures snow plus ice thicknes
37 Geo-Resources Inc.	advice and expertise pertaining to ocean mapping system based on DOLPHIN semi-submersible vehicle
38 Geo-Resources Inc.	software package for automated navigation of DOLPHIN semi-submersible vehicle
39 Guildline Instrument? Ltd.	engineering design, system specifications and performance data for Batfish biological towed survey system
40 Guildline Instruments Ltd.	engineering drawings, fabrication detail? and sea trial experience for roller block used in oceanographic equipment handling systems *(joint transfer - see also #18, #44)*
41 Harbour DeLoutre Products	aquaculture expertise on husbandry of halibut
42 Harbour DeLoutre Products	aquaculture expertise on mass production of haddock juveniles
43 Harbour DeLoutre Products	aquaculture expertise on mass production of halibut juveniles
44 Hawbolt Industries (1989) Ltd.	engineering drawings, fabrication details and sea trial experience for roller block used in oceanographic equipment handling systems *(joint transfer- see also #18, #40)*
45 Intermarine	design of water sampling bottle for physical and chemical oceanography *(joint transfer - see also #16)*
46 I.S.F. Research Ltd	engineering and scientific evaluation of HYSUB 5000 ROV vehicle at sea
47 Jacques, Whitford & Assoc. Ltd.	strategies for designing a biological effects monitoring program around the Cohasset/Panuke offshore hydrocarbon development
48 MacLaren-Plansearch/SNC Lavalin	capability to use a standard wave radar for wave measurements
49 MacLaren-Plansearch/SNC Lavalin	capability to use Synthetic Aperture Radar imagery in operational wave modelling *(joint transfer - see also #5)*
50 Maritime Culture Systems	aquaculture methods for spawning and rearing striped bass, including provision of seedstock
51 MARTEC	wmd-driven current model code
52 New Brunswick Weir Fishermen's Assoc.	aquaculture expertise on husbandry of juvenile halibut in modified herring weir
53 Ocean Chem Group	analytical technology for polycyclic aromatic hydrocarbon measurement by HPLC
54 Ocean Chem Group	methodology for trace metal analysis of seawater
55 Oracle Corporation Canada Ltd	structure/techniques for efficient storage, manipulation & qucries on large (spatial/temporal) data sets
56 Satlantic Inc.	specifications, advice, application and test data pertaining to Continuous Ocean Data Acquisition (CODA) system
57 Seakem	expertise to produce sea surface temperature maps from satellite imagery
58 Seastar Instruments	multi-frequency sonar system design
59 Seastar Instruments	oceanographic capability for moored weather buoy
60 Seimac Ltd.	ocean turbulence probe design
61 Seimac Ltd.	system specification, advice and test data pertaining to Lagrangian drifters
62 Seimac Ltd	system specification, advice, test data and sensor design information pertaining to Arctic Ice Monitoring System (AIMS)
63 Seimac Ltd	system specification, advice and test data pertaining to MSAT (Mobile Satellite) demonstration project
64 Shur-gain Feeds	aquaculture fish feed formulation and processing requirements
65 SOCOMAR Inc.	integration of bubbler and optical encoder sensors in TMS1000 water-level recorder system
66 Software Kinetics	geo-referenced database technology, including visualization expertise
67 Sweeney Fisheries	aquaculture fish feed quality control criteria and silage technology
68 Tavel Ltd.	thermograph mooring gear and instruments for use in evaluating potential aquaculture sites
69 UMA Engineering	fecal coliform modelling protocols
70 Universal Systems Ltd.	software to process large volumes of digital seafloor mapping data
71 Xon Digital Communications Ltd.	PC based navigation logging and display-package *(first transferred to Coldwell Consulting who subsequently joined with this company)*

Engineering in Fisheries Sciences

H. Jansen

H. Jansen

Engineering staff play a key role in the activities of the Freshwater and Anadromous Division, Biological Sciences Branch. Major expansion and improvements at the five Atlantic salmon fish culture stations have resulted in improved fish quality, increased productivity and efficiency. Fish passage facilities constructed at natural and man-made barriers open up previously inaccessible fish habitat for anadromous fish species to develop self-sustaining populations. Fish trapping and handling installations permit biologists to undertake assessment of fish populations on many of the Scotia-Fundy rivers. Engineering staff direct the design and installation of fishery protective measures by water use developers as required by the ***Canada Fisheries Act.*** Old existing fish passage facilities are being upgraded to current standards to improve fish passage efficiency.

Fish Culture Engineering

Over the past eleven years major expansion and improvements to the Atlantic salmon fish culture stations have been undertaken to improve fish quality, productivity and efficiency. The fish culture operations are carried out at the Mersey, Coldbrook and Cobequid stations in Nova Scotia and at the Mactaquac and Saint John stations in New Brunswick. The production of Atlantic salmon smolts has been tripled to its current production of 900,000 annually. Parr production has been increased from 350,000 to 2,000,000 annually. The increased production has made it possible for the Department to provide smolts for the sea-cages of the developing Bay of Fundy aquaculture industry while maintaining the river stocking program for the recreational and native food fisheries.

All engineering design work and construction drawings, with the exception of electrical, are done in-house. In addition to the normal project management activities, the Engineering Services Section takes on the role of general contractor most of the time. For many projects the labour is obtained from the Department of Human Resources job creation projects through third party sponsors and even Corrections Canada. Engineering staff direct and control these projects.

One of the major projects was the design and construction of the Mactaquac Accelerated Rearing Facility (Farmer et al. 1989) at a cost of $1.9 M. This installation was constructed to utilize the waste warm water produced at the Mactaquac Hydroelectric Station in accelerating the development of eyed eggs and alevins. With the accelerated growth, the salmon begin feeding in April which is two months earlier than normal. This has resulted in the production of smolts in one year (rather than two years) and has doubled smolt production at Mactaquac Fish Culture Station (FCS). Basic infrastructure is in place to permit future doubling of production of accelerated parr.

All six generating units are connected to the hatchery water supply system. This improves reliability and enables the production of increased quantities of warm water as the water demand increases with fish growth. The river water used to cool the thrust bearings of the turbines and air around the stators of the generators is collected in two main pipelines which flow by gravity to a pump building. Cool river water is collected from two turbine penstocks and flows by gravity to the pump building. The water temperature is regulated with an automatic butterfly valve on the river water pipeline which is operated by a pneumatic temperature controller. The mixed, desired temperature water is pumped 200 m to a head tank building by a number of vertical turbine pumps. The water seeps through an automated self-cleaning sand filter before passing through

Mactaquac Fish Culture Station with Mactaquac Hydroelectric Station and Mactaquac Accelerated Rearing Facility in background.

30 packed column aerator-degasser units which are located over a concrete headtank. The filter decreases the concentration of suspended solids and the packed columns reduce the total gas pressure and associated problems with gas supersaturation. The warm treated water then flows by gravity to the incubation building or to four greenhouse-like structures (aquadomes). The water enters the incubation building through two ultraviolet sterilizers and proceeds to upwelling incubation boxes which contain eyed eggs and alevins in layers of perforated plastic poultry nesting. In early April the salmon are removed from the incubation boxes and transferred to 3 m by 3 m fibreglass rearing ponds which are housed in the aquadomes. The warm water (15°C) and automatic feeder system enables the production of two-gram parr by mid-June each year. The accelerated parr are then transferred to the outdoor concrete rearing ponds at the Mactaquac FCS.

Fish trapping facilities at upper end of the Liscomb River fishway

Salmon Enhancement Projects

Declines in salmon stocks have occurred due to loss of productive capacity of freshwater habitat, above average marine natural mortality, and overexploitation. Watt (1988) indicates that there has been a 50% reduction in productive capacity for Atlantic salmon in the Scotia-Fundy Region due to habitat loss. These losses are the result of acidification, water diversions, creation of impoundments, as well as agricultural, forestry and highway construction practices. The natural production of Atlantic salmon has not met the demands of the commercial, recreational and native food fisheries. As a result, the commercial fisheries have been closed and recently seasons and catches for the remaining salmon fisheries have been greatly restricted.

One of the major enhancement activities involves the release of hatchery-reared smolts to 30 rivers of the region. Another involves the construction of fish passage facilities at natural and man-made barriers to open up previously inaccessible fish habitat for anadromous fish species. Transplants of salmon adults and/or releases of hatchery-reared juveniles are generally used to seed the new habitat.

The Department owns and operates nine upstream and three downstream fish passage facilities which were designed and constructed by engineering staff. These facilities are on the East, Grand, LaHave, Liscomb, Medway and Sackville rivers in Nova Scotia and the Magaguadavic River in New Brunswick.

The Department also operates the trapping and initial fish sorting facility at the Mactaquac Hydroelectric Station on the Saint John River. This facility and the Mactaquac FCS were constructed to mitigate the effects of the Mactaquac hydro development. Alewives are trucked to a dumping station immediately above the dam. Salmon are transported to the sorting facility at Mactaquac FCS where they are separated for use as hatchery broodstock and for placement in upriver areas.

Functional fishway designs are also provided to owners of existing dams or other obstructions without fish passage facilities. A major trapping and trucking facility was recently constructed by a public salmon interest group (Atlantic Salmon for Northern Maine) and The Maine and New Brunswick Electric Power Company at the Tinker Hydroelectric Station on the Aroostook River. The Aroostook River has excellent Atlantic salmon rearing potential similar to the Tobique River which at present provides the main spawning and nursery area for the entire Saint John River above Mactaquac.

One of the Department owned downstream fish bypasses at East River, Sheet Harbour, was constructed originally as an experimental facility. It has a louver guidance system installed in the intake canal of the Ruth Falls Hydroelectric Station. It has proven to be about 95% effective in bypassing fish from the turbine intake when all the turbines are operating (Ducharme 1972). Similar systems are currently being incorporated into the design of several small hydro plants which are proposed in the Region.

The design for a major fishway at Grand Falls on the Saint John River is currently underway. The existing barrier to salmon migration consists of a 21.6 m falls and, just upstream, a 6.7 m high dam which is part of NB Power's hydroelectric development at the site. The project would allow Atlantic salmon to colonize large areas of habitat in Maine, Quebec and New Brunswick. The increase in returns to the Saint John River from this project is projected at 13,000 salmon and grilse annually, or double the return from the existing production upstream of Mactaquac Dam. The Canada - New Brunswick Cooperation Agreement on Recreational Fisheries has provided $1 M towards this project. Salen Inc., a public interest group, has accepted the challenge of raising the remaining $2.5 M required for the construction of the project plus additional funds for a trust fund for its long term operation.

Many Nova Scotia rivers have low productivity because of extreme low summer flows. Engineering investigations have shown that for relatively low cost it is possible to develop water storage potential that could be used to increase summer flows. A project with the Gold River Salmon Association and the Nova Scotia Salmon Association is currently in the planning stage.

Stock Assessment

The management of freshwater and anadromous fish populations is dependent on accurate information on the size of the annual migration of various fish species. With actual fish counts it is possible to make informed decisions on the need to adjust recreational and native food fisheries to permit spawning escapements. By knowing the actual size of the spawning escapement it is possible to make predictions on the size of the fish population in future years. Fish trapping facilities designed and constructed by engineering staff are currently installed at eighteen locations to enumerate fish populations. The trapping facilities also provide information on the success of hatchery stocking programs and provide broodstock for the hatcheries.

Fishways at dams or waterfalls are ideal locations to obtain total counts of upstream migrating fish because the fishway provides the only route for fish passage. Fish traps are operated in fishways on the Tusket, Liscomb, LaHave, East, Medway and Grand rivers in Nova Scotia and on the Petitcodiac, St. Croix, Tobique, Maguadavic, Aroostook and Saint John rivers in New Brunswick.

Traps are designed with features to make them effective in trapping and holding fish without mortalities and injuries. The traps must also be “poacher-proof’ and easy to operate by one person. The traps are constructed of steel or aluminum and usually operated with an electric hoist.

Fish counting fences must be installed to obtain information on fish populations if dams or waterfalls with fishways are not present. In 1993, fish counting fences were in operation on the LaHave, Sackville, Stewiacke and St. Mary’s rivers in Nova Scotia and the Meduxnekeag and Nashwaak rivers in New Brunswick.

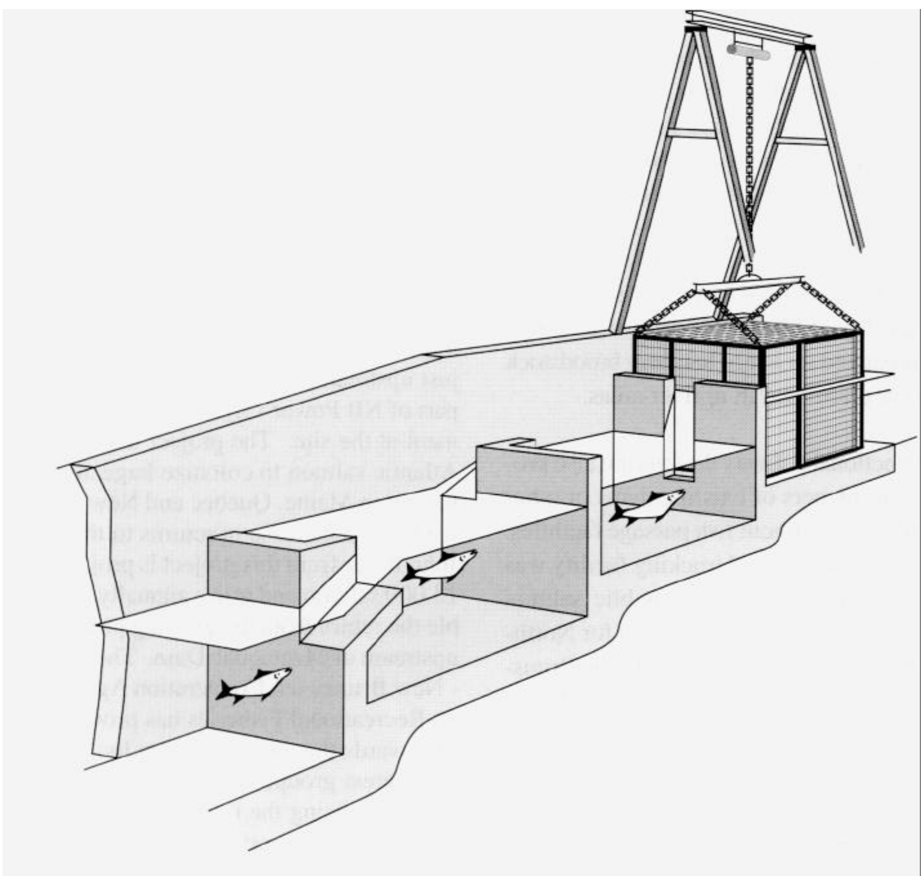
Fish counting fences are designed as pervious dams extending across the full width of the river. They are designed to pass water between bars which are spaced to create a barrier for the fish under consideration. The fence is laid out to lead fish to a trap. A walkway is provided across the top of the fence for servicing the trap and for cleaning debris from the fence.

The construction technique used on the counting fences varies considerably. The Naswaak fence has a rock filled timber crib set in the stream bottom and timber A-frame supports with aluminum barrier racks. The Stewiacke fence has a concrete base and steel A-frame supports with aluminum barrier racks. The LaHave and Meduxnekeg fences are portable types with steel tripods and steel channel drilled to accept steel electrical conduit to act as the fish barrier. The St. Mary’s fence utilizes nets suspended from a steel cable.

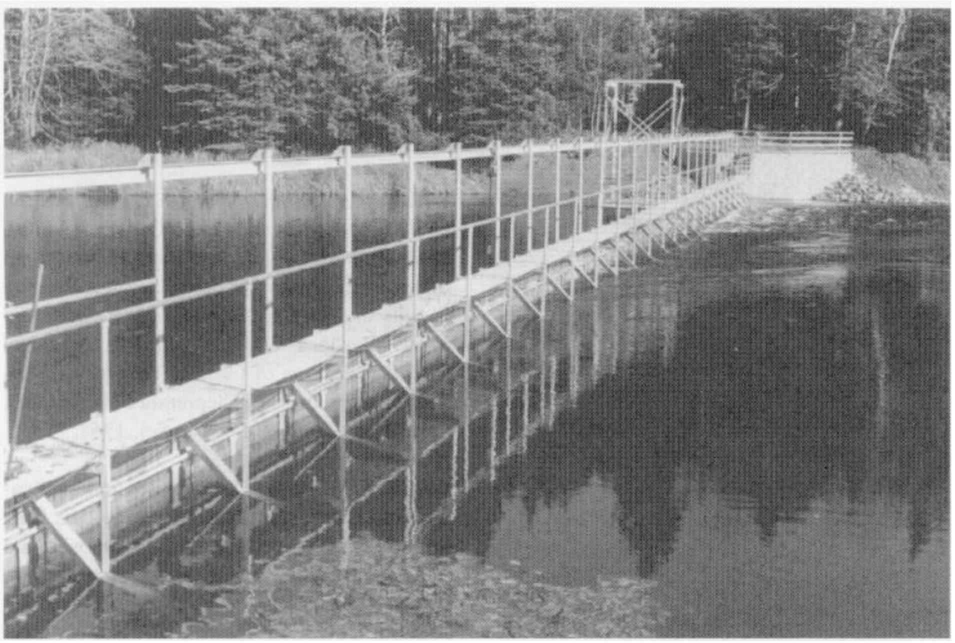
Funding for the operation of the Nashwaak, Meduxnekeag, and Stewiacke fences was provided by DFO through its Aboriginal Fisheries Strategy Program. These fences were installed by native crews working under the direction of engineering staff. The trapping operations are undertaken by native crews working under the direction of biological staff. The Stewiacke fence is a model venture in that it has involved natives, salmon anglers and DFO in a tripartite operation. The Cobequid Salmon Association and the Nova Scotia Salmon Association are contributing funding and participating in the steering of the Stewiacke fence program.

Fish Passage and Fisheries Protection

The Department participates in the provincial watercourse alteration permit system administered by the New Brunswick and Nova Scotia Departments of the Environment. Projects requiring engineering input are referred by the DFO Habitat Management Branch. Engineering staff direct the design and installation of fishery protective measures by the water - use developer as required by Sections 20, 21, 22, and 30 of the ***Canada Fisheries Act.*** These sections deal with upstream and downstream fish passage, fish stops, fish guards and provision of water for fishery protection.



Typical fish trap



Stewiacke River counting fence

Proponents' project proposals are reviewed and solutions for fishery protective measures are shown on functional drawings prepared by engineering staff. These drawings show the physical shape and size of the fishery protective measures incorporated into the proponent's project proposal. The proponent is responsible for preparation of the structural and detailed construction drawings which are submitted for review and Ministerial approval.

There are 222 fishways and 56 culverts with special provisions for fish passage in the Scotia-Fundy Region. Inspections by engineering staff, fishery officers and habitat coordinators are carried out to ensure that these facilities are operating efficiently. Engineering staff advise owners of maintenance requirements and operational changes to improve fish passage efficiency. Old existing fish passage facilities are being totally reconstructed or upgraded to current standards. Downstream fish passage facilities are being installed at hydroelectric stations where technically feasible, biologically justified and when the owner can be encouraged or directed to do so.

Phased upgrades of upstream fish passage facilities are currently being undertaken by NB Power at Tobique and Beechwood Hydroelectric stations on the Saint John River. The fish passage facilities at Tobique were constructed in 1953 and those at Beechwood in 1957. An assessment of these facilities showed major deficiencies in the amount of water released to attract fish. The location of the fish entrances were good; however, the entrances were not designed to provide attractive conditions over the full range of water levels expected during the fish migration.

In 1990 NB Power installed an automatic downward opening fish entrance gate at the Tobique fishway to provide improved entrance conditions for all water levels. Biological assessments have shown that further improvements would be desirable. A design is currently being developed to increase the attraction flow from 0.71 cubic metres/second (CMS) to 1.91 CMS with the installation of one low head submersible pump.

In 1992, NB Power upgraded the Beechwood fishway at a cost of $225,000. The improvements included doubling the fishway attraction flow to 2.4 CMS and the installation of two automatically controlled fish entrance gates. The results of the biological assessment of the Beechwood improvements in 1992 are encouraging. Prior to the improvements the fishway efficiency was approximately 40%. In 1992 the efficiency was 83%. The efficiency is based on the number of Atlantic salmon that passes through the Beechwood fishway compared with the total number released and available downstream.

Further evaluation of fish passage efficiency is underway at both sites. If found to be necessary, further improvements in fish attraction at both sites are possible.

Similar phased improvements are proposed for fishways operated by Georgia Pacific Corporation at Woodland and Grand Falls on the St. Croix River. Also of interest at both these locations are new downstream fish passage facilities. The installation of the downstream bypass at Woodland was completed in 1993 and the Grand Falls installation is planned for the future. The Woodland facility consists of a surface intake located at the face of one of the turbine trash racks. Approximately 1.9 CMS of water is withdrawn by gravity, over a downward opening gate, for attraction of downstream migrating salmon and alewives, i.e., spent adults and juveniles. The water passes into a chamber from which 1.2 CMS of the water is pumped back into the headpond for power generation. The fish and 0.7 CMS of the water travel 61 metres through a 600 mm pipeline to the tailrace of the power station. A significant reduction in fish mortality is expected by providing the fish a safe route away from the turbines.

The improper installation of highway culverts can cause major fish passage problems. The corrugated steel or concrete floors also result in loss of habitat which can be significant on four lane highways. Engineering staff are working closely with the Habitat Management Branch and the NB and NS Departments of Transportation in developing culvert designs that reduce these problems. Since major highway construction projects are planned for the next 10 years the proper installation of culverts is necessary to ensure fish passage and a minimum disruption to fish habitat. Where possible, bridges and arch culverts with concrete footings are installed so the natural stream bottoms can be retained. At high gradient locations and on small watersheds, oversized precast concrete sections with baffles are used. The baffle spacing varies with gradient and length of culverts. The culverts are filled with substrate material and boulders placed on top. The baffles ensure that the gravel does not wash out and that the water does not disappear through the gravel during low flow periods. Electroseining inside the gravel bottom culverts show that large numbers of juveniles are utilizing the habitat created.

Jim Leadbetter (left), Habitat Management Branch, and Vern Conrad, Biological Sciences Branch, electroseining in a natural bottom culvert.

Many corrugated steel culverts installed in the past are deteriorating, particularly along the bottom. Where the overlaying fill is deep, it is not feasible or it is costly to replace the culvert, so shot-creting about one half of their circumference at the bottom has been proposed to restore these culverts. Many of these culverts are already partial barriers to fish passage because of excessive drop at the downstream ends and steep gradient. Designs that include attaching baffles inside the culverts and weirs across the stream below the culverts have been developed and installed at several locations. As more of the failing culverts are located and their problems corrected, more fish habitat will be brought back into production of migrating fish.

References

DUCHARME, L.J. A. 1972. An Application of louver deflectors for guiding Atlantic salmon *(Salmo salar)* smolts from power turbines. J. Fish. Rec. Bd. Canada. 29: 1397-1404.

FARMER, G.J., P.D. HUBLEY, H. JANSEN, J.W. McASKILL, and G.B. ROBBINS, 1989. Production of juvenile Atlantic salmon *(Salmo salar)* at the Mactaquac Accelerated Rearing Facility and Fish Culture Station, New Brunswick, Canada, P. 107-118. *In:* R.L. Saunders [ed.] Proceedings of Canada - Norway finfish aquaculture workshop, September 11- 14, 1989. Can. Tech. Rep. Fish. Aquat. Sci. 1761.

WATT, W.D. 1988. Major causes and implications of Atlantic salmon habitat losses. In: R.H. Stroud [ed.] Proceedings of the symposium on present and future Atlantic salmon management, Portland, ME, October 27-29, 1987. Atlantic Salmon Federation, Ipswiik MA and National Coalition for Marine Conservation, Inc., Savannah, GA: 101-111.

CWS Seabird Colony Registry: A Computerized Data Management System for Access to Seabird Colony Data

D. N. Nettleship

D. N. Nettleship

Abstract

The Canadian Wildlife Service (CWS) computerized data management system - "CWS Seabird Colony Registy (SCR)" - was developed for the management of data from surveys and censuses of colonially-breeding seabirds in Canada. The aim is to provide superior data management and information dissemination services using new information technologies. This desktop information system comprises a relational data structure consisting of a master file containing census data for a single species, at one location and time, with details of the location, investigators, and citations of written reports separated into other database files. Data input is managed by a series of programs written in the dBase IV programming language that present input screens to the user; validate data, manage the subfiles in the relational design, and add the data to the database. Data can be retrieved, reported and statistically analysed using program routines within the SCR software or by using external software, such as word processors, spreadrheets, and/or GIS packages, that read dBase IIIfiles. The CWS-SCR 5.2 data management system will: (1) enhance project design and data collection by individual biologists, (2) ensure intra-regional data integration through a regional SCR, (3) provide inter-regional integration through a central (national) SCR, and (4) promote data assimilation and output from regional and central registries to governmental and non-governmental organizations. Overall, the seabird colony database will function as an essential tool for planning and managing coastal marine environments, for monitoring seabird populations in Canadian waters, and for environmental impact assessment studies.

Introduction

The Canadian Wildlife Service (CWS) Seabird Programme for the study of seabirds in Arctic and Eastern Canada was established in 1971 (Nettleship 1972a, 1973; also see below). One of the priorities identified at that time was the development of a computerized data management system for data from surveys and censuses of colonially-breeding seabirds. Preliminary specifications for a seabird colony database management system were prepared (Nettleship 1972b) and published (Nettleship 1976). But it was not until 1986 that a decision was taken by CWS-Atlantic to formalize and support a regional Seabird Colony Registry to begin in fiscal year 1987-88.

Following the guidelines of the 1986 initiative, the CWS Seabird Colony Registry (CWS-SCR) has four primary functions:

- to identify, collate and integrate existing information on breeding seabirds in Canada (colony locations, species composition, levels of abundance, population status and reproductive performance) from several files or databases which are at present not easily accessible;

- to develop specifications for a computerized seabird colony database retrieval system to minimize data redundancy and maximize efficiency of access to information on a local, regional, and national basis;

- to retrieve seabird data necessary for immediate and short-term applications to meet current regional and national needs such as

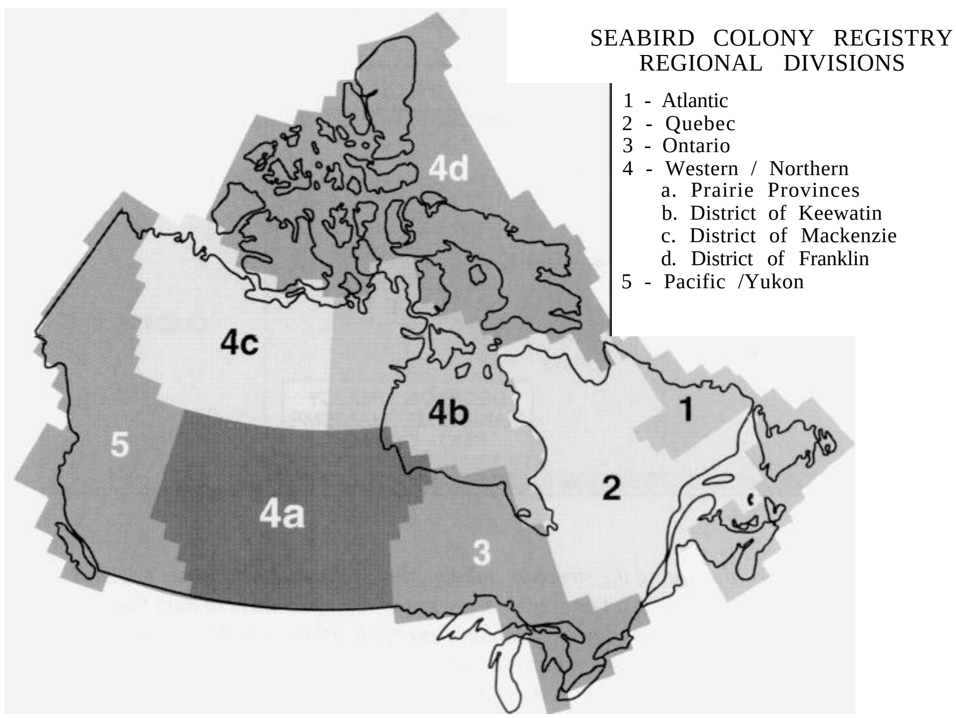


Figure 1: Seabird Colony Registry regional divisions showing areas under jurisdiction of each SCR regional coordinator: P&Y = Pacific & Yukon, W&N = Western & Northern, ONT = Ontario, HDQ = National Headquarters, QUE = Quebec, ATL = Atlantic.

oil spills or other environmental emergencies, and environmental impact assessments; and

- to allow the performance of long-term (strategic) planning to satisfy future regional and national needs including the development of marine conservation and protection initiatives, coastal management programs and action plans, as well as general applied studies on seabirds as monitors of changing marine environments and pollution.

The monitoring of the status of colonially-breeding seabirds in Canada and the publication of information on species distributions, abundance, and reproductive performance is essential to the conservation and protection of marine birds in Canadian waters (e.g., Nettleship 1977, Nettleship & Evans 1985, Evans & Nettleship 1985, Nettleship 1991, Nettleship 1993; Blokpoel & Scharf 1991; Rodway 1991; Duffy & Nettleship 1992). The mandate for this work is provided through various national and international acts and regulations, the most significant of which are the *Migratory Birds Convention Act* (1916: between Canada and the United States of America), the *Canada Wildlife Act* (1973), and Canada's commitment under the United Nations Convention on Biological Diversity (1992).

The SCR System: Scope and Design

The purpose of this review is to help direct our vision of the future for the provision of marine bird data services within and outside CWS in relation to original work objectives. The ultimate aim, of course, is to provide opportunities for superior data management and information dissemination services using new information technologies. This can be achieved by the development of an integrated seabird colony information services thrust in CWS. The present need is for ratification and implementation of the CWS-SCR system, a unified approach to data management that will link regions and enhance our abilities to conserve and protect marine avifauna and its habitats in all regions of Canada (see Figure 1 for SCR regional divisions and Figure 2 for details of SCR function and information flow).

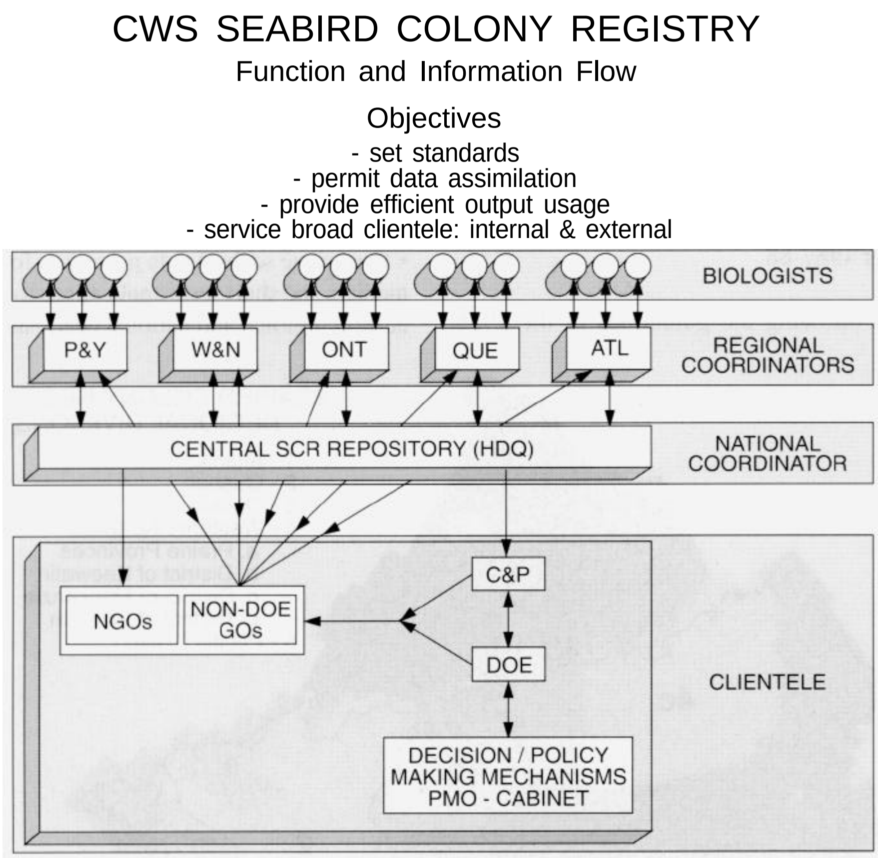


Figure 2: Flowchart illustrating the structure and function of the Seabird Colony Registry database management system. Solid lines with arrowheads show pathways of data flow to principal destinations for assimilation and management application, as well as enhanced information output to original point sources (see text for details). Symbols & codes: o = individual users/biologists within and outside CWS regions; CWS regions: P&Y = Pacific & Yukon, W&N = Western & Northern, ONT = Ontario, HDQ = National Headquarters, QUE = Quebec, ATL = Atlantic. Government departments & services: DOE = Environment Canada, C&P = Conservation & Protection (now the Environmental Conservation Service), PMO = Prime Minister's Office.

There are four main components of the SCR system (Figure 2), employing both computer programs and manual procedures on a regional and national basis. They are: (1) project design and data collection by individual biologists, (2) intra-regional data integration through a regional SCR, (3) inter-regional data integration through a central SCR repository, and (4) data assimilation and output from regional and central registries to governmental (GOs) and non-governmental (NGOs) organizations.

The SCR data management system was designed to set standards to seabird colony census data and permit information assimilation and output for application at both the biological and management levels. Data gathered by individual regional seabird biologists are made compatible and merged at the regional level to form an "information nucleus" to service internal and external regional needs. Information assimilation at the regional level ensures integration of individual projects and output, features beneficial to biologists and managers in attaining regional work objectives. It also permits an easy exchange and transfer of information between regions where inter-regional applications are required, as well as with other GOs and NGOs.

Data in regional registries are then entered in the central SCR repository to form a national seabird colony database. Consistency of the input data at the regional level ensures easy assimilation of inter-regional information for immediate application to problem solving at the national level

Database	Minimum number of input parameters required	Total number of input parameters available
Census information (master file)	8 -12	60
Location information	7	23
Personal information	0 - 1	14
Citation information	0 - 1	15
Totals	15 - 21	112

Table 1: The CWS Seabird Colony Registry database and input parameters showing minimum and maximum data entry requirements for each colony census and/or survey.

within CWS-C&P-DOE functions and responsibilities. Enhanced data availability and output efficiency will permit information usage at other decision points inside and outside government.

The rationale for using the SCR data management system is simple. It sets standards for data quality, permits data assimilation, provides efficient output usage to individual biologists and regions, and allows CWS-C&P (regionally and nationally) to service a broad clientele for decision making. Information flows from individuals to regions and a central repository where it is assimilated to form a knowledge base beneficial to all. Individual biologists receive access to much more data than they contribute, and managers are positioned to identify and evaluate management options much more easily than they could otherwise. Overall, the Seabird Colony Registry data management system is founded on the basis that high-quality information results from clear problem definition, proper project design, sound data collection, accurate analysis and efficient data output. Those characteristics can be achieved through the implementation of the SCR system for *"Access to Seabird Colony Data"*.

Specifications, Regional Agenda and Data Entry

The development of specifications for the SCR data management system (SCR Version 5.2) is complete. Its data input specifications, regional/national network structure and implementation schedule received approval from the CWS Executive Committee in late 1991. The overall structure of the relational database and its functions are described in *CWS Seabird Colony Registry: Input Specifications for a Seabird Colony Database* (Nettleship & Glenn 1992a), and how to use the system is outlined in *Using the Seabird Colony Registry - SCR Operation Instructions User's Guide* (Nettleship & Glenn 1992b). DBase IV has been used as the database management system allowing database design, input screen design, and full retrieval and report generation. The data within the database system includes detailed information on the location, seabird abundance (by species) and census methods used, survey biologists involved and technical reports available for all seabird colonies surveyed, information that can be retrieved by individual species, colony location or geographic region. Details associated with any single seabird colony survey can vary, ranging from information on 15-21 input parameters (required minimum) to a maximum of 112 items, a feature that provides considerable flexibility with census data entry limitations and routines (see Table 1 and Nettleship & Glenn 1992a for details).

The schedule for data collation and entry for seabird colonies in Arctic and Eastern Canada is outlined in Table 2. The aim is to complete data entry in a stepwise progression by geographic region with the publication of a regional gazetteer for each of the five regions (e.g., Nettleship & Glenn 1993), which will allow easy access to seabird colony data and certain demographic parameters of individual species populations: e.g., size and status. Once complete, these regional databases will result in the production of a major treatise on the marine ornithology of northeastern North America: *Seabirds in the Northwest Atlantic - Patterns of breeding and levels of abundance.*

The CWS-SCR is a desktop information system working on an IBM compatible PC using MS-DOS 6.2 and CWS-SCR 5.2 (available on either 3.5" 1.44MB or 5.25" 1.2MB floppy diskettes). The recommended workstation specifications for this colonial seabird application are an 80386DX33 microcomputer (or better) with 640K of installed RAM and 450K available at runtime, a hard drive with at least 10MB of free space plus room for an expanding data

Area / Region	CWS Regional Responsibility & Operations	Start Date	Projected Completion Date
Labrador	Atlantic	1992	1994
Eastern Arctic	Western & Northern Atlantic, and National HDQ	1994	1995
Central Arctic	Western & Northern, Atlantic	1994	1995
Newfoundland	Atlantic	1994	1996
Gulf of St. Lawrence	Atlantic and Quebec	1994	1996
Scotian Shelf Bay of Fundy Gulf of Maine	Atlantic	1995	1996
Great Lakes	Ontario	1991	1995
NE North America (summary overview and oceanographic synthesis)	Atlantic, National HDQ, Ontario and Quebec	1992	1998

Table 2: The CWS Seabird Colony Registry schedule of data entry for seabird colonies of Arctic and Eastern Canada.

set, a colour monitor, a 101-key AT keyboard, a backup system (a 44MB or 90MB removable cartridge-type external hard disk [i.e., a Bernoulli drive] and an uninterrupted power supply [UPS] are recommended) and an HP LaserJet III printer. Although the system does not require any additional software beyond the CWS-SCR 5.2 program for data entry or normal retrieval, it can generate ASCII text files and dBase III database files to facilitate the transfer of data to other software packages including spreadsheets (e.g., Excel) and word processors (e.g., Word).

The CWS-SCR data management system is expected to have wide-ranging appeal for seabird workers interested in performing spatial and temporal analyses of colonially-breeding seabirds in the North Atlantic and elsewhere. At the present time, considerable interest to adopt the SCR system has been expressed by several countries including: Australia, Denmark, Greenland, Iceland, Japan, New Zealand, Norway, and the United States (Atlantic & Pacific regions), as well as other countries associated with the 1991 Conservation of Arctic Flora and Fauna (CAFF) program of the International Arctic Environmental Protection Strategy.

Software Distribution and Program Implementation

Program copies of the CWS-SCR 5.0 data management system (data storage & retrieval) were distributed to all CWS regions in October 1992, with a workshop and training session held for regional coordinators at the University of Guelph in April 1993. The SCR 5.2 upgrade is available now for CWS regional coordinators. Plans are underway to initiate a limited distribution of the SCR 5.2 upgrade in 1994 to selected users in the scientific and resource management sectors including government, university and non-profit conservation organisations. The aim is to bring the CWS-SCR data management system into full operation as a national and regional marine bird data facility as soon as possible. For more information, contact: D.N. Nettleship, CWS, Bedford Institute of Oceanography, PO. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2 (phone and fax: 902-426-3274).

Acknowledgements

The Seabird Colony Registry data management system is a C&P-Atlantic Canadian Wildlife Service (CWS) project that involves participation and input from seabird biologists and managers from across the country within and outside CWS. Funding for the development of the conceptual design of the system and the ensuing programming that has culminated in the SCR version 5.2 software has come largely from CWS-Atlantic with supplemental support from other CWS regions and the Comprehensive Labrador Cooperation Agreement. My grateful thanks go to Gary N. Glenn who has executed the system's computer programming and endured my "never-ending" demands for the translation of my concepts *re* the management of seabird data into a software program (CWS-SCR 5.2) that works. This paper is associated with the program *"Studies on northern seabirds"*, Seabird Research Unit, Canadian Wildlife Service, Environment Canada (Report No. 266).

References

BLOKPOEL, H. &W.C. SCHARF. 1991. Status and conservation of seabirds nesting in the Great Lakes of North America. p. 17-41 *In* J.P. Croxall [ed.] Seabird **status** and conservation: a supplement. International Council for Bird Preservation Technical Publication No. 11, Cambridge.

DUFFY, D.C. & D.N. NETTLESHIP. 1992. Seabirds: management problems and research opportunities. p. 525-546 In D.R. McCullough & R.H. Barrett [ed.] Wildlife 2001: Populations. Elsevier Applied Science, London & New York.

EVANS, P.G.H. & D.N. NETTLESHIP. 1985. Conservation of the Atlantic Alcidae. p. 427-488 *In* D.N. Nettleship &T.R. Birkhead, [ed.], The Atlantic Alcidae, Academic Press, London & Orlando.

NETTLESHIP, D.N. 1972a. Inter-relationships of seabirds and the coastal zone: a summary report on seabird research. p. 131-136. In Proceedings Coastal Zone Seminar, BIO, Dartmouth, N.S., March 1972, Vol. 1. Environment Canada, Ottawa.

NETTLESHIP, D.N. 1972b. Seabird census techniques - preliminary draft. Canadian Wildlife Service "Studies on northern seabirds" Manuscript Report No. 4: 1-20.

NETTLESHIP, D.N. 1973. Canadian seabird research. Marine Pollution Bulletin 4: 62-64.

NETTLESHIP, D.N. 1976. Census techniques for seabirds of arctic and eastern Canada. CWS Occasional Paper No. 25: 1-33.

NETTLESHIP, D.N. 1977. Seabird resources of eastern Canada: status, problems and prospects. p. 96. 108 *In* T. Mosquin & C. Suchal, [ed.], Canada's Endangered Species and Habitats. Canadian Nature Federation Special Publication No. 6. Ottawa.

NETTLESHIP, D.N. 1991. Seabird management and future research. Colonial Waterbird\ 14: 77-84.

NETTLESHIP, D.N. 1993. Seabird Population Monitoring Program: National Issues & Program Priorities 1994-2004. Canadian Wildlife Service "Studies on northern seabirds" Report No. 265, Dartmouth, N.S. 77 p.

NETTLESHIP, D.N. & P.G.H. EVANS. 1985. Distribution and status of the Atlantic Alcidae. p. 53-154 *In* D.N. Nettleship & T.R. Birkhead. [ed.], The Atlantic Alcidae. Academic Press, London & Orlando.

NETTLESHIP, D.N. & G.N. GLENN. 1992a. CWS Seabird Colony Registry: Input specifications for a seabird colony database. Canadian Wildlife Service "Studies on northern seabirds" Report No. 255, Dartmouth, N.S. 77 p.

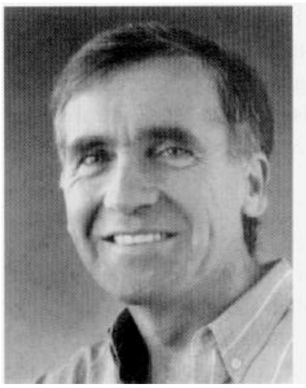
NETTLESHIP, D.N. & G.N. GLENN. 1992b. Using the Seabird Colony Registry - SCR operation instructions user's guide (short form). Canadian Wildlife Service "Studies on northern seabirds" Report No. 256, Dartmouth, N.S. 26 p.

NETTLESHIP, D.N. & G.N. GLENN. 1993. Seabird colonies in Labrador. Canadian Wildlife Service "Studies on northern seabirds" Report No. 254, Dartmouth, N.S. 85 p.

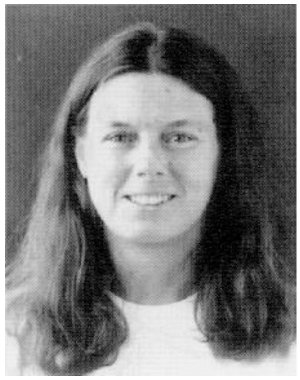
RODWAY, M. 1991. Status and conservation of breeding seabirds in British Columbia. p. 43. 102 *In* J.P. Croxall [ed.] Seabird status and conservation: a supplement. International Council for Bird Preservation Technical Publication No. 11, Cambridge.

Radioactivity Measurements in the Arctic Ocean

J. N. Smith and K. M. Ellis



J. N. Smith



K. M. Ellis

Introduction

Recent reports (Yablokov, 1993) of the dumping of radioactive wastes in the Russian Arctic Ocean have raised concerns about the levels of radioactive contaminants in the Arctic and the potential impacts on the environment and human health. The immediate threat stems from liquid radioactive wastes dumped in the Barents Sea and solid radioactive wastes, including fuelled nuclear reactors, dumped in the Kara Sea (Figure 1). However, longer term concerns have focused on the potential for continued releases of radioactive contaminants into the Arctic Ocean both from the large nuclear submarine and surface vessel fleets and from the numerous nuclear reactor and radioactivity storage sites on the Russian continental land mass. Since 1979, scientists in the Radioactivity Section of the Marine Chemistry Division have been involved in studies of radioactivity in the Arctic Ocean and, as a result, have been able to undertake an active role in international investigations of contamination of the Arctic Ocean from Russian sources. These recent activities and potential future impacts of radioactive contamination from Russia are reviewed in this article.

Sources of Radioactive Contamination

The first radioactive pollution of arctic ecosystems occurred between 1949 and 1951 when 100 PBq (equal to 3 x 10^6 Curies) of radioactive waste was released into the Techa River (Aarkrog, 1993) which drains into the Kara Sea through the Ob River system (Figure 1). Arctic regions were further contaminated between 1955 and 1962 when 87 atmospheric and 3 submarine test explosions were carried out at Novaya Zemlya (Figure 1). Approximately 300-900 PBq of Sr-90 and Cs-137 were released into the environment, some of which was deposited as regional fallout in the Arctic. A third, more localized source of radioactive contamination was created in 1968 when a US B-52 bomber crashed on the ice during its approach to a military airbase in Thule, Greenland resulting in the rupture of four nuclear weapons and the release of 1 TBq of Pu-239,240 into the proximal marine environment. A fourth major source of radioactivity transport into the arctic has been the Sellafield Reprocessing Plant in the UK. The transport of Sellafield-labelled water from the Irish Sea into the Norwegian Sea, maximized during the 1970s has contributed approximately 10-15 PBq to the present day inventory of Cs-137 in the Arctic Ocean. The most recent source of radioactive contamination of the Arctic Ocean was the 1986 Chernobyl accident which resulted in the direct atmospheric deposition of 1 PBq in the Arctic Ocean and the subsequent transport into this region via the Norwegian Coastal Current of an additional 5 PBq. In the Yablokov (1993) report it is further stated that the former USSR disposed of liquid radioactive wastes in a large area of the Barents Sea and solid radioactive wastes, including submarine nuclear reactors with spent fuel and spent nuclear fuel from the *Lenin* icebreaker, in inlets of Novaya Zemlya and in the Novaya Zemlya Trough. The total activity of dumped wastes has been reported as 85 PBq, although this entire inventory of radioactivity may not become an immediate source of marine contamination as the reactors have been filled with a furfurol barrier in attempts to delay interaction with seawater for several hundred years.

The mechanisms governing inputs of radionuclides from the Russian arctic into North American waters include the transport of dissolved radionuclides in surface water along the Siberian continental shelf, radionuclide transport with Atlantic water that flows through the Barents Sea and circulates through the Arctic Ocean at depths of 300-500 m and the possible ice rafting of radioactive particles from the shallow Russian marginal seas. Arctic regions are particularly sensitive to pollution owing to food chains which are relatively short and susceptible to rapid potential uptake of contaminants into higher trophic levels and where organisms are already under severe stress owing to the unfavourable living conditions associated with extreme low temperatures. The cold climate also influences the impact of pollutants on arctic ecosystems through diminished precipitation resulting in both longer atmospheric residence times for airborne contaminants and longer residence times for volatile organic compounds in soil and aquatic reservoirs. The human population of the Arctic is composed of approximately 1 million indigenous people who, from an environmental point of view, constitute an important component of the ecosystem because they live to a large extent on locally produced food such as reindeer, birds, fish, sea mammals and various arctic vegetation. The radiological exposure of humans in the arctic has been primarily through the terrestrial food chain by vectors such as the lichen-rein-

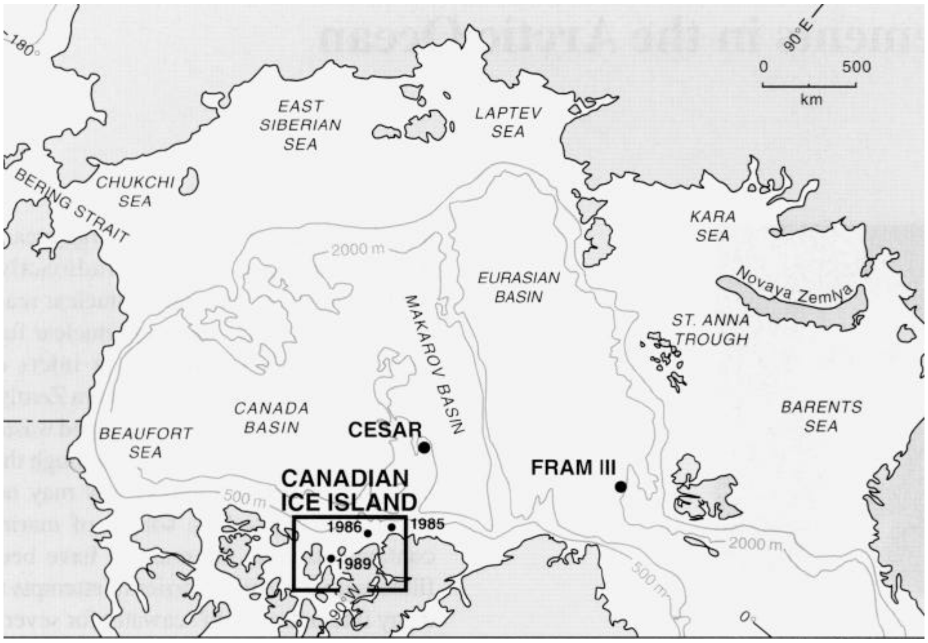


Figure 1: Locations of ice stations and Russian marginal seas in the Arctic Ocean.

deer-human pathway, because radioactivity concentrations in terrestrial flora and fauna are generally an order of magnitude greater than those found in large, diluting media such as marine and aquatic environments. However, the unique circumstances of events such as the Chernobyl accident and the seabed dumping of radioactive wastes in the Russian arctic require an assessment of their radiological threat to arctic inhabitants.

Department of Fisheries and Oceans (DFO) Radioactivity Studies in the Arctic Ocean

DFO interest in arctic radioactivity began in 1979 when measurements of Sellafield-derived, Cs-137 were conducted at the FRAM III Ice Station (Smith et al., 1990) located north of Fram Strait in the Arctic Ocean (Figure 1). Radioactivity measurements were subsequently carried out on water samples collected at the CESAR Ice Station in 1983 and the Canadian Ice Island in 1985, 1986, and 1989 (Figure 1) in order to determine radionuclide fluxes through the Arctic Ocean (Moore and Smith, 1986; Ellis et al. 1993; Smith and Ellis, 1994). The distribution of Cs-137 in the water column (Figure 2) at several of these locations illustrates the relative time scales which govern radionuclide transport through the Arctic Ocean. The elevated Cs-137 concentrations in sub-surface water at the FRAM III location (Figure 2) represent the transport of Atlantic water, contaminated with Cs-137 from Sellafield, as it enters the Arctic Ocean through Fram Strait. The absence of these high Cs-137 levels at the CESAR Ice Station (Figure 2) four years later, indicates that significant quantities of Sellafield-labelled water had not, by 1983, arrived in the Central Arctic Ocean. The Cs-137 inventories both at CESAR and at the Canadian Ice Island are mainly from nuclear weapons fallout from the atmosphere. The deeper penetration into the water column of Cs-137 at CESAR compared to the Ice Island indicates that the ventilation of the deep halocline at CESAR occurs on faster time scales than at the Ice Island. This observation implies that halocline water circulating through the Arctic Ocean at depths of 200 m tends to reach the Central Arctic before it arrives at the Canadian continental shelf.

The nuclear weapons accident at Thule is of particular importance to Canada and its northern inhabitants owing to the proximity of this event to Canadian territory and the radiological threat associated with the long-lived (t = 24,000 y), radioisotope, Pu-239. A joint Canadian/Danish study was conducted in coastal waters off Thule in 1984 and sediment samples were collected in a broad grid over the accident site to supplement previous work conducted in 1974 and 1979 (Aarkrog et al., 1987a; 1987b). Areal contours delineating the spatial distribution of Pu-239, 240 sediment inventories in 1974, 1979, and 1984 are shown in Figure 3. Only limited dispersion of Pu-239, 240 from the crash site has occurred since 1974 into the fine-grained sediments of the eastern basin and into the northern extension of the trough. The conclusion

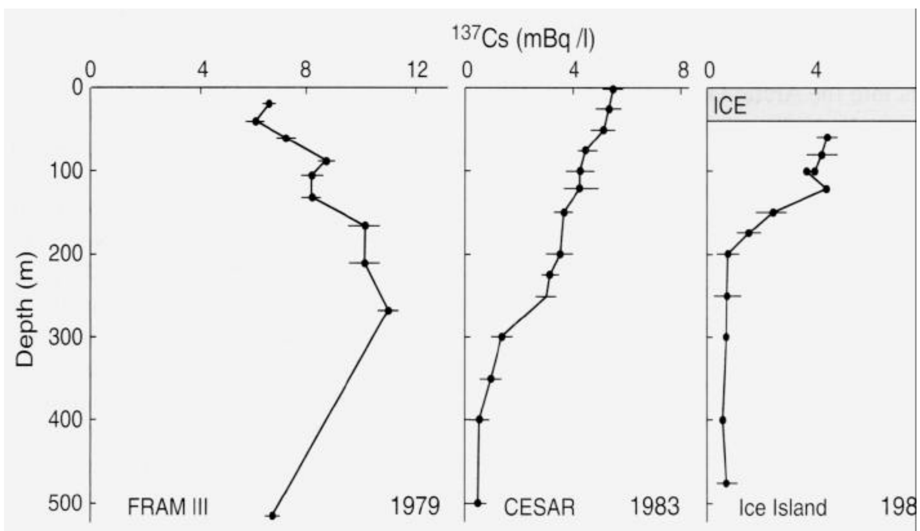


Figure 2: Cs-137 water column profiles at the FRAM III Ice Station in 1979, the CESAR Ice Station in 1983 and the Canadian Ice Island in 1989 illustrate the time distribution of Cs-137 at different arctic locations. The excess Cs-137 at FRAM III, was due to transport of Sellafield-derived Cs-137 into the Arctic Ocean with Atlantic water. Higher Cs-137 levels at 200 m at CESAR compared to the Canadian Ice Island are due to the longer time required for fallout Cs-137 to be transported through the halocline over the Canadian continental shelf compared to that of the Central Arctic.

drawn from these studies is that Pu-239, 240 released in particulate form into an arctic marine system undergoes only minimal dispersion from the release point and is rapidly buried by sedimentation and biological mixing in proximal sediment regimes (Smith et al., 1994).

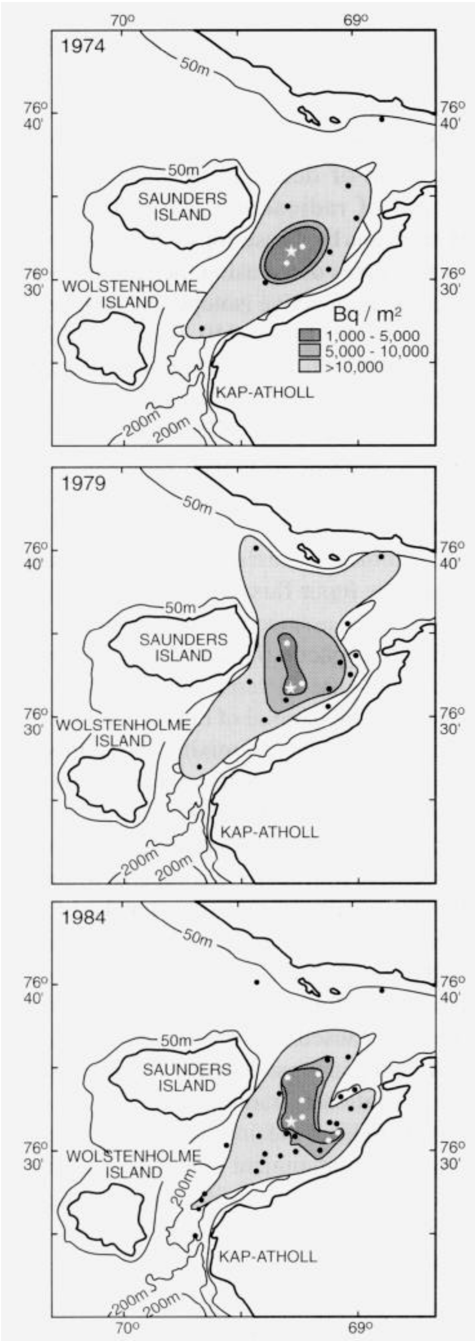


Figure 3: Sediment inventories of Pu-239, 240 were measured on cores collected (locations indicated by dots) around the accident site (indicated by star) during expeditions to Thule in 1974, 1979 and 1984. Only minimal resuspension and transport of contaminated sediments occurred out of the accident area by 1984, indicating that plutonium in other marine radioactive waste dumpsites may be relatively immobile.

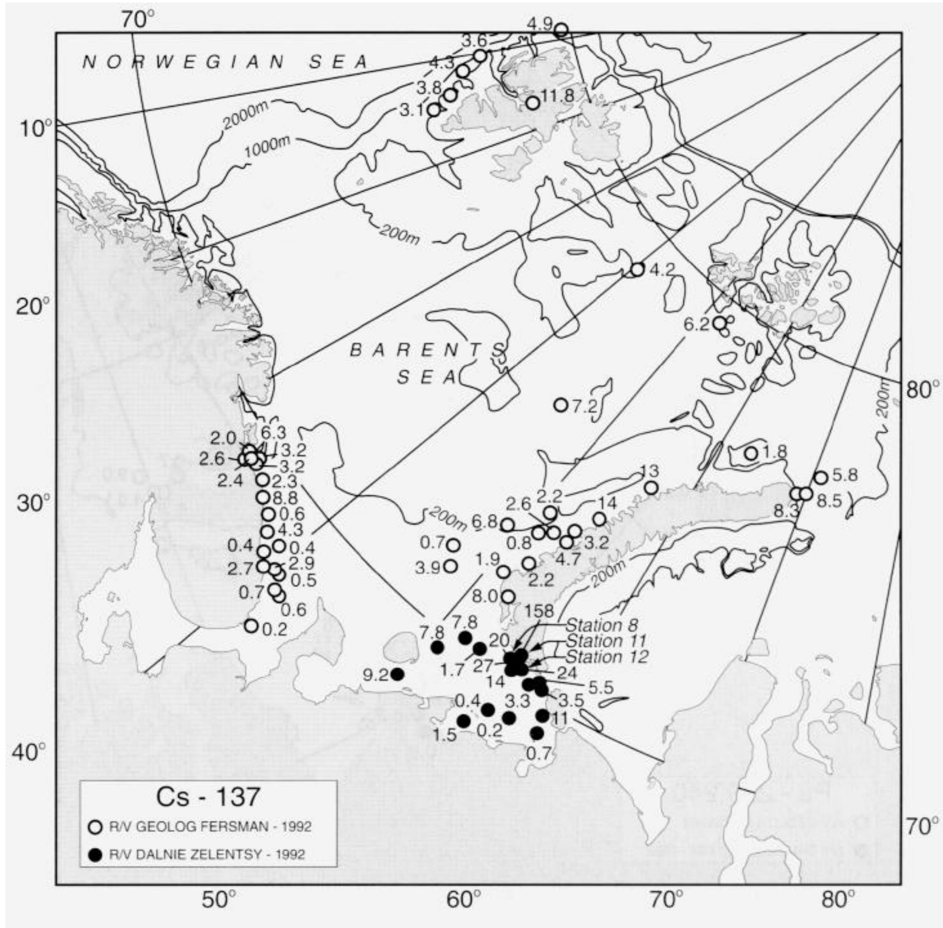


Figure 4. Cs-137 (Bq/kg) activities in surface sediments collected in the Barents Sea during two cruises in 1992 aboard the Russian ships: Geolog Fersman *(Okeangeologia, St. Petersburg) and* Dalnie Zelentsy *(Murmansk Marine Biological Institute, MMBI).*

The dispersal of plutonium at Thule since 1968 represents a useful case study for the dumping of radioactive wastes in the Barents and Kara Seas because: (1) the accident in Thule occurred in a similar shallow (150-300 water depth), near shore marine environment to the Novaya Zemlya Trough where much of the radioactive waste was dumped and at the same latitude (76°N) as the Russian and Norwegian marginal arctic seas, (2) the weapons plutonium was released in an insoluble oxide form, similar to matrices typical of radioactive wastes, and, (3) the spatially and temporally constrained Pu-239, 240 input function from the weapons accident provides a unique experimental framework to study Pu-239, 240 transport through the environment. This study suggests that the Russian radioactive waste dump sites are unlikely to become major sources for plutonium pollution of the Arctic Ocean.

Russian Arctic

Field Studies - 1992

Following reports of the dumping of radioactive wastes in the Russian Arctic, several studies were initiated in 1992 to identify dump site sources of radioactivity in the Barents Sea. These studies involved collaborations with Russian scientists at Okeanogeologia in St. Petersburg and the Murmansk Marine Biological Institute in Murmansk and with Norwegian scientists in Tromso and Grimstad, Norway. Surface sediments and sediment cores were collected at a wide range of stations in the Barents Sea aboard the Russian ships, the *Geolog Fersman* and the *Dalnie Zelentsy* during the summer of 1992. These samples were returned to Canada and analyzed for radionuclides at the Bedford Institute of Oceanography (BIO). The surface sediment distributions of Cs-137 and Pu-239, 240, illustrated in Figures 4 and 5, exhibit large variations in radionuclide concentrations

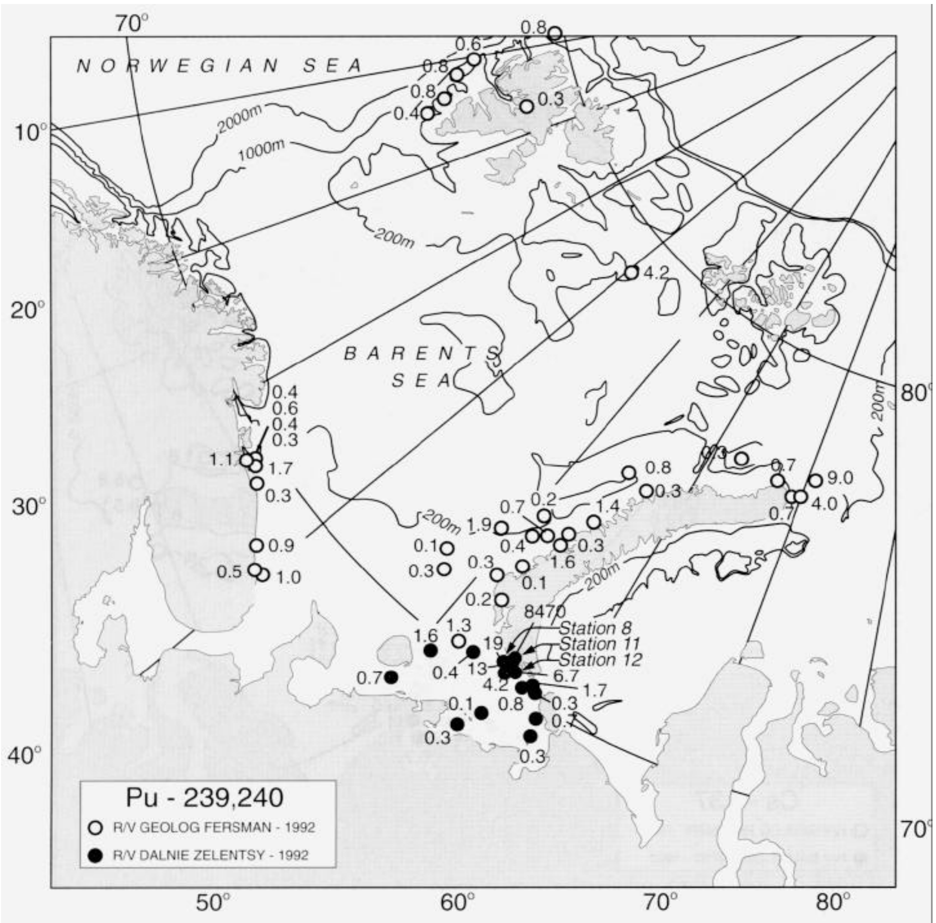


Figure 5: Pu-239, 240 (Bq/kg) in surface sediments collected in the Barents Sea.

throughout the Barents Sea, but these data mainly reflect the deposition of fallout radionuclides. Most of the variance in these distributions can be explained on the basis of particle size with the higher radionuclide concentrations associated with the finer-grained, organic rich sediment regimes.

The most remarkable feature of these data is the elevated levels of Cs-137 (158 Bq/kg) and, especially, Pu-239, 240 (8470 Bq/kg) measured in a surface sediment sample collected in the fjord of Chernaya Bay on the southwestern coast of Novaya Zemlya (Smith et al., 1994). Chernaya Bay is a long (10 km), narrow (1.6 km wide), fjord for which there are a number of potential sources of radioactive contamination. Since the early 1950s a series of underground and atmospheric nuclear weapons tests have been carried out at Chernaya Bay. In addition, approximately 11 TBq of low and medium activity solid radioactive wastes (SRW) were dumped in Chernaya Bay (Yablokov et al., 1993). However, the primary source of the sediment contamination was probably direct fallout from three underwater nuclear weapons tests carried out in Chernaya Bay in 1955, 1957 and 1961, all having yields of up to 20 kilotons. Underwater nuclear tests have introduced only an insignificant fraction (less than 1%) of the total fallout from fission detonations, but these events have the unique feature of being point source injections which can result in significant contamination of the local environment. The concentrations of Pu-239, 240 and Cs-137 in Chernaya Bay sediments are similar to those measured in surface sediments at Enewetak, a coral atoll in the Pacific Ocean which was the site of numerous US nuclear weapons tests conducted during the 1950s including several underwater nuclear explosions (Nelson and Noshkin, 1973).

The detection of the relatively short-lived activation product, Co-60 ($t_{1/2}$ = 5.26 y) in a gamma ray analysis of the sediment sample from Chernaya Guba also raised concerns about potential dump sites in this region. However, Co-60 is produced in nuclear tests by neutron activation of cobalt present in the weapons construction or support materials and its concentration in nuclear debris is highly dependent on this source term. The Co-60 activity of 92 Bq/kg measured at Chernaya Bay lies in the range of Co-60 values of 20-200 Bq/kg (decay corrected to 1992) measured in surface sediments and cores at Enewetak Atoll in 1972.

Sediment cores were collected with the intention of determining the historical record of radioactive pollution of the Barents Sea by measuring contaminant profiles in cores dated using the naturally-occurring, radioactive isotope, Pb-210. Sediment profiles for Pb-210, Cs-137 and Pu-239, 240 are illustrated in Figure 6 for a core collected in a basin 20 km seaward of the contaminated fjord of Chernaya Guba. Inputs of radioactivity into the sediments have been modelled using a two layer, biodiffusion model. The flux of Pb-210 to the sediments is assumed to be constant, while the input fluxes of Cs-137 and Pu-239, 240 are assumed to be proportional to their atmospheric fallout record. Curves a and b (Figure 6) represent end member cases in which burial of radioactive tracers is governed solely by mixing and sedimentation, respectively. Curves a and b are almost identical for Pb-210, but the Cs-137 and Pu-239, 240 distributions are in better agreement with curves a compared to curve b. This result indicates that uptake of radioactive and other types of contaminants in these sediments is almost entirely governed by sediment mixing, or bioturbation, which is caused by the activities of organisms living in the sediments. Unfortunately, the distortion of radionuclide profiles by mixing reduces the time-stratigraphic resolution of contaminant events and alternative methods must be utilized to reconstruct the historical record of pollution of this region.

Field Studies - 1993

DFO scientists from BIO participated in several cruises in 1993 designed to characterize source terms for the release of radioactivity from the Russian marginal seas. One cruise involved the collection of seawater and sediment samples from the Coast Guard icebreaker, the CSS *Henry Larsen* in the East Siberian Sea. These samples are presently being analyzed for radionuclides in an effort to measure the transport of radioactivity from Russian and

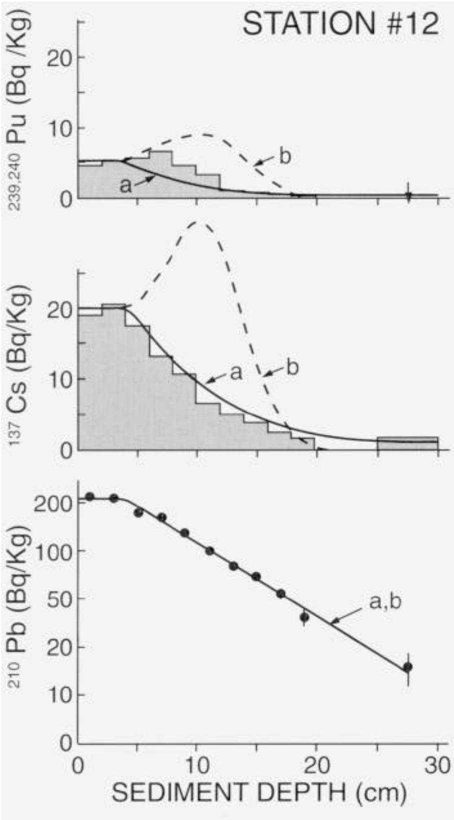


Figure 6: Pb-210, Cs-137 and Pu239, 240 profiles in core 12, collected off the island of Novaya Zemlya. Curve a represents the two-layer, biodiffusion model simulation solely for deep mixing while curve b represents model simulation for sedimentation in the absence of deep mixing. The good agreement between measured tracer profiles and curve a indicates that downward transport of radionuclides is governed mainly by sediment mixing or bioturbation.

European sources onto the Canadian continental shelf. A second cruise focused on the collection of samples from the estuaries of the Ob and Yenesy Rivers, which empty into the Kara Sea. Several large nuclear reprocessing plants in the interior of Russia, including the Chelyabinsk-40 and Tomsk-7 plants, release their wastes into these river systems. Finally, a scientist from BIO also joined a Russian research team on an expedition aboard the RV *Geolog Fersman* to the Barents and Kara Seas in 1993 (Figure 7). The goal of this cruise was to locate radioactive dump sites on the seabed in the Kara Sea and determine the extent of leakage of radioactivity from storage containers. On September 15, after a five day storm swept through the region, the research team located their primary target, a ship that had been scuttled in the Novaya Zemlya trough in 1980 and on which had been stored almost 10 TBq of Sr-90 as solid radioactive wastes. Sediment and seawater samples were collected in the vicinity of the ship whose position was precisely located using side scan sonar (Figure 7). Initial measurements of radioactivity, undertaken at BIO on sediments and seawater samples collected in the vicinity of the sunken vessel, have revealed relatively low levels of radioactivity and little evidence for significant leakage of radioactive contaminants from the seabed dump site.

Future Concerns

Priorities for future work include continued surveillance of radioactive dump sites in the Barents and Kara Seas and further investigations of fluxes of radionuclides entering the Arctic Ocean from Russian river systems. In 1994, scientists will participate in the Transarctic Cruise aboard the Coast Guard icebreaker, *CSS Louis St. Laurent* and sediment and seawater samples will be collected on the Canadian shelf and in the Central Arctic in order to determine fluxes of radionuclides being transported from European sources across the Arctic Ocean. The present consensus of scientists studying radioactivity in the arctic is that radioactive pollution of this region is significant on local scales, but that there is no convincing evidence yet for large scale contamination of the arctic marine environment from Russian sources.

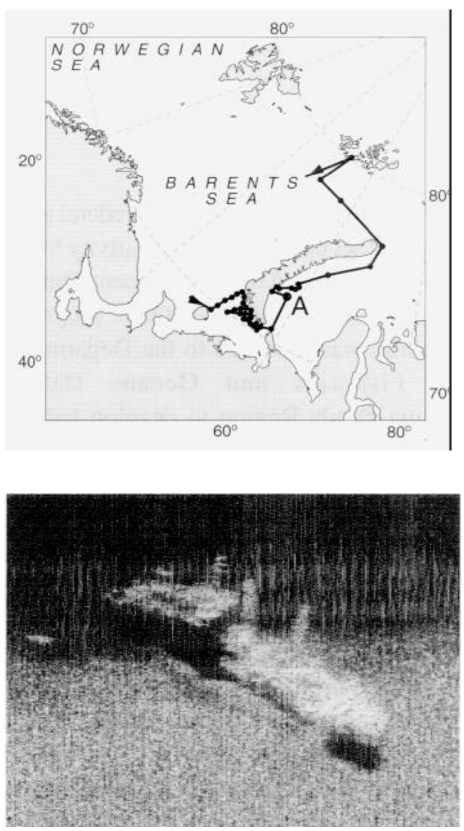


Figure 7: Upper panel: Cruise track of Geolog Fersman in 1993; Lower panel: sidescan sonar image of ship used for the storage of nearly 10 TBq of Sr-90 and then scuttled at site A in the Novaya Zemlya Trough.

References

AARKROG, A., S. BOELSKIFTE, H. DAHLGAARD, S. DUNIEC. E. HOLM and J.N. SMITH. 1987a. Studies of transuranics in an Arctic marine environment. J. Radioanaly. Nucl. Chem., 115: 39-50.

AARKROG, A., S. BOELSKIFTE, H. DAHLGAARD, S. DUNIEC, L. HALLSTADIUS, E. HOLM and J.N. SMITH. 1987b. Technetium-99 and cesiun-134 as long distance tracers in Arctic waters. Estuar. Coast. Shelf Sci.. 24: 637-647.

AARKROG, A. 1993. Radioactivity in Polar regions. International Conference on Environmental Radioactivity in the Arctic, Kirkenes. Norway, 23-27, August, 1993.

ELLIS, K.M.. J.N. SMITH and R.W. NELSON. 1993. Radionuclide measurements from the Canadian Ice Island. Proc. Int. Conf. Environ. Radioact. Arctic, Kirkenes, Norway, Aug 23-27, 1993.

MOORE, R.M. and J.N. SMITH. 1986. Disequilibria between Ra-226, Pb-210 and Po-210 in the Arctic Ocean and the implications for chemical modification of the Pacific water inflow. Earth and Planetary Science Letters, 77: 285-292.

NELSON, V. and V.E. NOSHKIN. 1973. Enewetak Survey Report. USAEC Nevada Operations Office, Las Vegas, Nevada, NVO- 140: 131-224.

SMITH, J.N., K.M. ELLIS and E.P. JONES. 1990. Cesium-137 transport into the Arctic Ocean through Fram Strait. Journal of Geophysical Research, 95 (C2): 1693-1701.

SMITH, J.N., K.M. ELLIS, D. MATISHOV, G. IVANOV, L. POLYAK, S. DAHLE and K. NAES. 1993. Levels of radioactivity in Barents Sea sediments off Novaya Zemlya. International Conference on Environmental Radioactivity in the Arctic and Antarctic, Kirkenes. Norway, August 23-27.

SMITH, J.N. and K.M. ELLIS. 1994. Ventilation rates for the Arctic Ocean halocline determined from Cs-137 tracer profiles at the CESAR Ice Station, Deep-Sea Research, submitted.

SMITH, J.N., K.M. ELLIS, A. AARKROG, H. DAHLGAARD and E. HOLM. 1994. Sediment mixing and burial of the Pu-239, 240 pulse from the 1968 Thule, Greenland nuclear weapons accident. J. Environ. Rad., submitted.

YABLOKOV, A.V., V.K. KARASEV, V.M. RUMYANTSEV, M. KOKEYEV, O.I. PETROV, V.N. LUSTOV, and A.F. YEMELYANENKOV. (1993). Russian Federation state report on sea burial of radioactive wastes. Administration of the President of the Russian Federation, Moscow, Russia, 108 p.

Habitat Sensitivity Mapping System: A Method of Linking Science With Managers

P. R. Boudreau

P. R. Boudreau

Introduction

The Public Review Panel on Tanker Safety and Marine Spills Response Capability (Brander-Smith 1990) identified a need for the development of tools that aid emergency response teams in their role in responding to marine environmental emergencies. One of the tools identified was habitat sensitivity maps based on electronic geo-referenced databases. In response to the Brander-Smith Report, the federal government set up a National Sensitivity Mapping Program led by Environment Canada (DOE). As part of this national program, funding was provided to the Department of Fisheries and Oceans (DFO) Scotia-Fundy Region to develop habitat sensitivity maps for use in oil spill response. The work was laid out in five main tasks: 1) convene a workshop of scientists and managers to review available data, to identify additional datasets required to fill gaps, and to select habitat variables on which to base measures of habitat sensitivity; 2) compile a list of existing habitat data, both digital and hard copy, that could be incorporated into sensitivity maps; 3) establish conversion protocols and begin accessing existing habitat data in a distributed data network fashion; 4) produce full documentation of electronic datasets and habitat sensitivity maps and 5) if time allows initiate modelling of habitat sensitivity measures for selected areas of coastlines.

Through these tasks the Scotia-Fundy project, entitled the Habitat Sensitivity Mapping System (HSMS), has as its main thrust the task of providing managers with access to existing scientific information. Since its inception the initiative has relied on cooperation between the Management and Science sectors within the Region. To formalize such cooperation a technical committee has been in place that includes representation from Science, Paul Boudreau from Biological Sciences Branch, Bob Rutherford, Habitat Management Branch and Gary Turner, Aquaculture Coordination Office. This committee, besides acting as the supervisors of the work contracted out to local private sector firms, provided direct support to the project by drawing on other sources of data within the Department. The technical committee also maintains good communication with the National Program, centred at DOE in Dartmouth, as well as the other Regional initiatives in Habitat Sensitivity Mapping and geomatics.

Task 1

The broad scope of resources to be protected in the event of an oil spill and the various responsibilities of DFO at such a time provides a major challenge to the delivery of habitat information. DFO has responsibilities for marine, coastal and freshwater environments. The diversity of responsibilities gives rise to many researchers and managers who are responsible for pertinent data and information. Besides the information directly managed by DFO, there is a variety of data required from, or shared with, other agencies such as the federal Department of the Environment (DOE) and several departments of provincial governments in Nova Scotia and New Brunswick. When preparing for, or responding to, an oil spill situation it is essential to have a system that can readily access this complex, yet extensive, community of data and information users.

The initial task of the HSMS project attempted to address this diversity by consulting with experts in both data and information management and the resource managers. A workshop held in February 1992 provided an opportunity for discussion and input into the direction of the project (see Anon., 1992). One of the early decisions required was to identify a focus area. The limited funding of the project required the selection of an area of high priority for much of the development. Based on proximity to oil tanker traffic, existence of sensitive coastline and availability of existing data, an area on the west coast of the Bay of Fundy between Saint John and Point Lepreau in the Province of New Brunswick was selected (see Figure 1). Although this area would form the core of the project, it was resolved that data from other areas would be included based on availability.

Much of the general discussion revolved around the actual makeup of the system to be developed. It was decided that the system should be based on PC technology, be highly portable, i.e. it should make use of electronic networks where possible but maintain much of the data on a portable stand alone PC. Past experience of DFO's Habitat Management Branch as part of the Regional Environmental Emergencies Team (REET) at the time of an oil spill suggested that the availability of data quality telephone lines necessary to access the network would not be guaranteed. A second significant point that came out of the meeting was the need to develop a distributed or federated database system that would provide access to data in a number of locations, rather than trying to bring all of the data into a central location. This requirement stems from the fact that the information required to properly define sensitive habitats is held by a number of agencies and that it is not possible to maintain such a diverse database in a single location.

It was also recognized that many other initiatives, both private and government, were dealing with the hardware and software necessary for data conversion, display and networking. As a result, it was decided that this initiative should take advantage of existing software developments and focus on the task of identifying existing data sources and document their location, format, responsible manager etc. By stressing the database management efforts, the system should be able to readily update the information at the time of the spill.

Task 2-4

The activities for Task 2, 3 and 4 of the project dealing with the listing and documentation of data began at the workshop and have proceeded concurrently over time. Data were found to be available in many formats: hardcopy, ASCII files, electronic maps and dBase files requiring some structuring. Because the aim was to develop the necessary links to established databases that were being regularly maintained, many of which were already in dBase format, this generic format was chosen to be the backbone of the new system. A low-end desktop geographic information system and information management system called Infocus/Quikmap was chosen because it readily handles dBase point and polygon data. It was recognized that this system would perform very well as the initial startup platform but may be replaced with new and more powerful software and hardware developments. The use of a generic dBase compilation of data allows for its access through a variety of software packages, taking advantage of existing translation applications.

The best example of an independently maintained database in dBase format that could be accessed by the system is the one designed for use by DFO's Aquaculture Coordination Office for tracking the licensing process of aquaculture sites. Although this database was set up originally to help managers follow licence applications through the review process by several federal and provincial departments, the database contains positional information on each site that is useful in displaying the sites geographically (see Figure 2). Fortunately, this important database contains information for the much larger area of the Scotia-Fundy Region

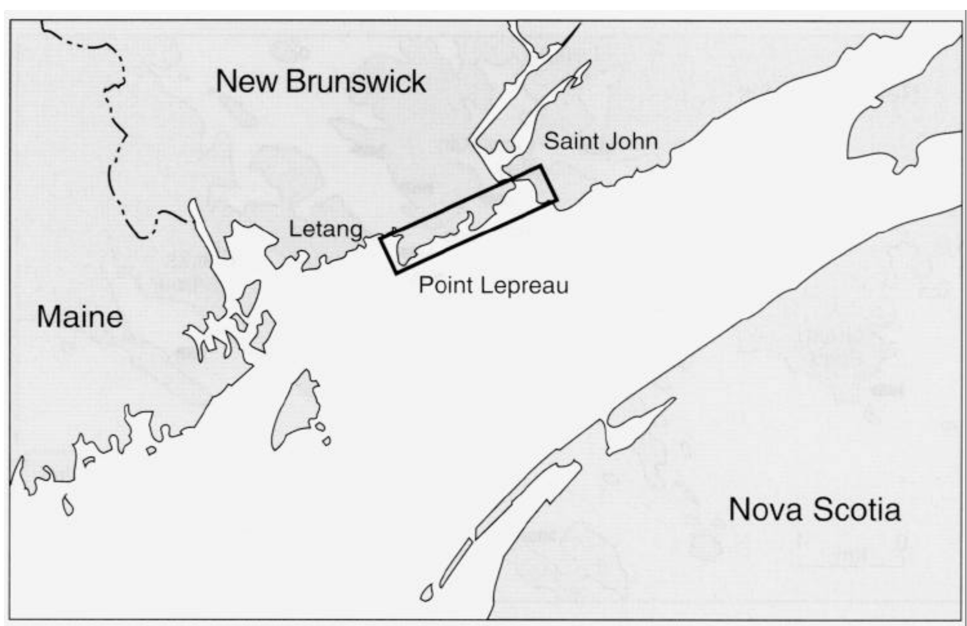


Figure 1: Saint John to Lepreau area of Neu Brunswick

This data base is typical of some of the better electronic databases required for the system. It already exists in a dBase format with accurate positioning information and considerable additional information regarding species, as well as telephone contacts for use in the case of an oil spill. The database is updated on a daily/weekly basis by the responsible manager and resides on the local Scotia-Fundy Region network. Even with this amount of structuring, the database originally required several hours of work to provide useful display of the data. This work included adding some missing fields and generating display codes for the records based on the state of the application, i.e., approved, rejected, withdrawn, etc. To facilitate this work software has recently been written that will automate this process with minimal operator input.

A second electronic database that can be accessed by the system is the topographic maps prepared by the Land Registration and Information Service of Nova Scotia (LRIS). Fortunately much of Atlantic Canada has excellent digital basemap information available in the form of 1: 10,000 basemaps. This source provides information products that include baseline information such as shoreline, roads, waterways etc. Comparable digital data are also available for some of the coastal and offshore areas from the Canadian Hydrographic Service (CHS) in the form of digital navigational charts. The digital charts, one of which is available of Saint John Harbour, provide all of the data usually found on a navigational chart in a more usable format. Both of the digital LRIS and CHS maps and charts are available in a form that required minimal effort to convert into the format used by this system. These two valuable sources of information provided the basemap material so that resource and habitat information could be usefully displayed and queried.

Although system development focused mainly on data already in electronic format, several hardcopy sources of information were identified as important enough to be digitized into the electronic Infocus/Quikmap format. One example of such high priority hardcopy source was data on shoreline geomorphology for the selected Saint John to Lepreau area available in a published hardcopy atlas (Hunter 1978). A consortium of local companies worked together to carry out this task. The resulting digital maps of geomorphology are highly accurate with the necessary detail to address most management questions, however, the cost of digitizing and lack of comparable data for other areas prohibits the development of a uniform coverage for the entire Scotia-Fundy Region.

Another hard copy data source of importance to the project was developed from fisheries officers. DFO employs fisheries officers throughout the region who fulfil many duties including enforcement, public relations and general communication with fishermen. In preparing the system it became evident that they represent an invaluable source of information. The fisheries officer in the Saint John area was able to provide information on biological resources such as lobster and scallop nursery areas and seal haul-out areas. As important, from the point of oil spill response, was the information on fisheries activities such as marine plant harvesting areas, fishing locations by species and type, fishing seasons and fish landing stations. All of these types of information required digitizing to bring into the electronic format.

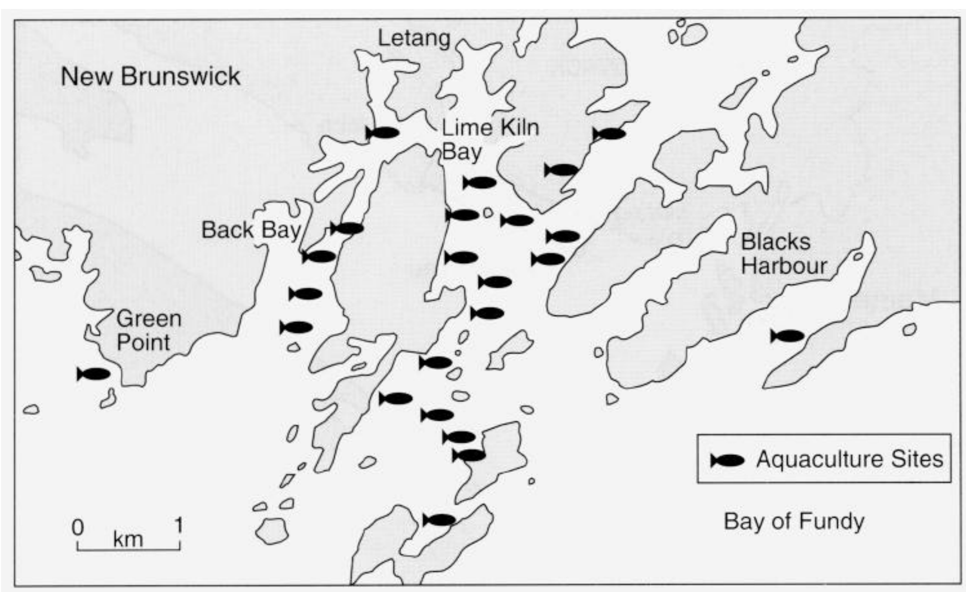


Figure 2: Detail for aquaculture siting information in the Letang area of Southern New Brunswick

Ongoing and Future Developments

Development thus far has generated a system that provides excellent coverage of a small, high priority area along with some more general information for the Atlantic Coast. With existing support the system presently provides access to about 60 data bases covering topics such as biology, geomorphology, commercial fisheries, oil response equipment etc. The system has been successfully used in an international oil spill response exercise, "CANUSLANT," held in the Bay of Fundy and Gulf of Maine area in the fall of 1992 to assess the risk to coastal resources.

Since its initiation, the benefits of participating in a community of data and information users have become apparent. A review of the project, along with other complimentary initiatives in the region, showed significant areas where coordination of projects would benefit the HSMS (Anon. 1993a). Data compiled for this project is of use to a much broader community of users other than for oil spill response. Comparably the HSMS benefits from having access to data compiled by other agencies. One example of this is that as a result of the demands of the HSMS, the National Sensitivity Mapping Project and other federal Canada's Green Plan projects, local mapping agencies, CHS, LRIS and New Brunswick Geographic Information Corporation, are presently involved in coordinating the generation of a Coastal Database for Atlantic Canada. This project will provide access to "official" digital mapping databases on shoreline, bathymetry, surficial morphology, etc. This task requires the participation and cooperation of several agencies to compare their data and resolve differences in data collection and handling so as to allow consistent access to common baseline information. This initiative will benefit all agencies interested in activities in the coastal zone.

A significant result of the HSMS has been the successful initiation of a much larger project under the Green Plan. One portion of this National Program is called Inventory and Monitoring. In the summer of 1993, Scotia-Fundy Habitat Management Branch began what it called the Habitat Action Plan (HAP). Its purpose is to provide managers with access to information necessary for the rational evaluation of proposed modifications to aquatic habitats. The use of existing computer technology should allow managers to have more timely access to better data so that they can better address potential problems and provide better recommendations. Building on the experience of the HSMS, this new project has been able to begin work towards a consistent information base for the entire region including marine, coastal and freshwater habitats. The information compiled by the HAP project will be consistent with that already in the HSMS and so both projects will be working towards a single system that will provide access to as much relevant data and information as possible.

Thus far the Habitat Sensitivity Mapping System has been a win-win situation for all involved in the DFO Scotia-Fundy Region. Biological Sciences Branch has been able to provide some of its information to Habitat Management Branch as well as being able to take advantage of their larger data compilation project. Habitat Management Branch has been able to make use of the development work carried out by Biological Sciences Branch. The Aquaculture Coordination Office has been able to get some help in dealing with its information requirements at the same time as providing its information to the other Branches for use in their work. In addition, the Canadian Hydrographic Service has been able to get started on their plans to contribute to the Coastal Database that will serve many DFO purposes.

There is still much to do in terms of expanding the area of coverage beyond the initial high priority locations. One of the serious challenges is to make the large volumes of information available to a wider audience within DFO and to outside agencies. Although many of the necessary pieces exist to accomplish the task of putting the system on the individual desks of managers and scientists, work is still required to put the pieces together in a usable form. The available data, appropriate software and a workable electronic network must all be blended so as to be easy to use and maintain. It is envisaged that as the system expands to include additional participants, it will better serve the information needs of DFO for oil spill response and other management decisions.

Acknowledgements

I would like to thank all of the people who have participated and or contributed to the project thus far. They include both the data providers who have made their data available and the data users who have provided comments on the system and its functionality.

References

ANONYMOUS. 1992. Habitat Sensitivity Mapping Workshop: Review, Strategy and Recommendation. Can. Manuscr. Rep. Fish. Aquat. Sci.: 49 p.

ANONYMOUS. 1993a. Habitat Sensitivity Mapping (Brander-Smith/Green Plan) Project Review. Can. Manuscr. Rep. Fish. Aquat. Sci.: 13 p.

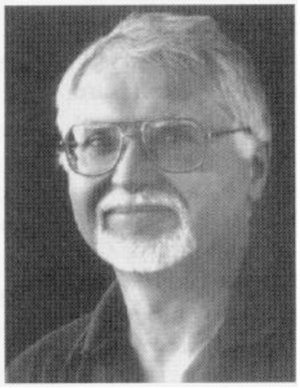
BRANDER-SMITH, D. 1990. Protecting our waters: final report: Public Review Panel on Tanker Safety and Marine Spills Response Capability. Ottawa: The Panel. 263 p.

HUNTER, G.T. 1978. Fundy Coastal Zone Study Map Atlas. Mineral Resources Branch, N.B. Dept. of Natural Resources. Fredericton, N.S.

Monitoring Euphausiid Concentrations in LaHave Basin Using Bottom-mounted Acoustics

N. Cochrane and D. D. Sameoto

N. Cochrane



D. D. Sameoto

Abstract

Observation of the water column by bottom-mounted sonars allows continuous monitoring of seasonal variations in zooplankton concentration supplementing traditional ship-based zooplankton surveys. Acoustic recordings are examined from a bottom-mounted sonar in LaHave Basin during the fall of 1990. Two biological scattering layers are distinguished by their distinct but differing daily vertical migration characteristics. One layer a strong near-surface to near-bottom daily migrator, is identified as the euphausiid Meganyctiphanes norvegica. *A second acoustic layer, a more limited range migrator, is identified as juvenile silver hake. A detailed picture of the euphausiid average daily migration is obtained. Innovative acoustic modelling yields a quantitative estimate of the water column euphausiid population. Bio-acoustic studies using fixed sonars enable a better understanding of the distributions and behaviours of various populations including their degree of natural variability. This will permit more confident interpretation of historical zooplankton databases, especially in regard to multi-year changes in euphausiid populations, which may have influenced fluctuations in fish stocks on the Scotian Shelf*

The past decade has seen significant advances in the application of acoustic echosounders to detect and monitor fish and zooplankton in the marine environment (Cochrane & Sameoto 1991). A fundamental problem facing biologists studying zooplankton populations is obtaining representative samples. Zooplankton are not evenly distributed in the ocean but tend to occur in patches or layers such that concentrations vary vertically and horizontally over distances of metres to 10's of kilometres. Many zooplankton also have a daily vertical migration cycle which can extend through hundreds of metres of the water column. Variability in the distribution of zooplankton in both location and time can strongly bias net samples taken at a fixed depth and even bias acoustic surveys extending through the entire depth of the ocean. Traditional ship-based surveys last 1 - 2 weeks, cover a variety of widely scattered sites, and are repeated at most once or twice a year. Such sparse, and very likely biased, sampling introduces considerable uncertainty when addressing the critical questions of seasonal, yearly, and longer term variability in populations. A self contained bottom mounted sonar capable of profiling the entire water column for zooplankton would have unique advantages. These include a continuous and long duration monitoring capability revealing systematic changes in zooplankton biomass and depth distribution over periods of months to years.

Doppler Current Profilers (ADCP's) are specialized sonars for remotely measuring ocean currents. Current profiles are obtained by measuring the small shifts in acoustic frequency (Doppler shifts) of sound echoed or "backscattered" from minute water column irregularities along the paths of four narrow acoustic beams oriented at oblique angles through the water column. The ADCP manufactured by RD Instruments also measures and records the signal strength of the backscattered signal along each acoustic beam (each beam inclined 20° to the vertical). At the acoustic frequency of 153 kHz most of the backscattered signal arises from zooplankton, making this instrument valuable for biological studies. An ADCP was bottom mounted in 192 m of water on the north side of LaHave Basin (Fig. 1). LaHave Basin is a major Scotian Shelf Basin which has been intensively studied for zooplankton throughout the 1980's. Ecologically the Shelf Basins are important because they contain a large biomass of euphausiids or krill (2-3 cm length crustaceans) which in turn support large stocks of silver hake and other species of fish.

Figure 2 shows a contoured plot of

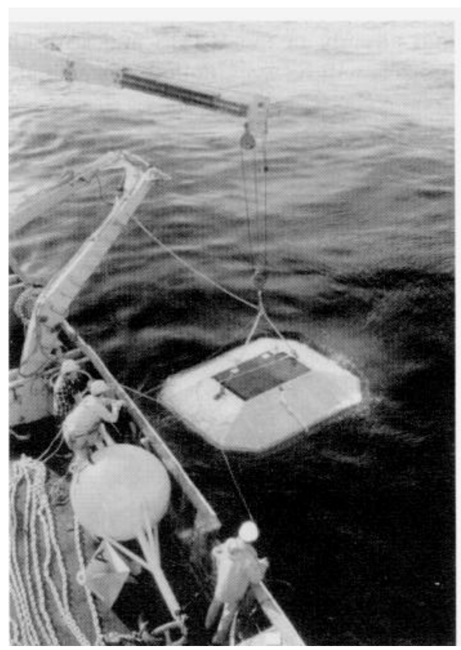


Figure 1: An acoustic Doppler current profiler being deployed from C.S.S. DAWSON. *The profiler is enclosed within a 4 x 3.3 x 0.5 m truncated pyramidal box with the largest face designed to sit on bottom. The shape forces fishing trawls to ride over the package with minimal disturbance.*

acoustic echo levels or "volume backscattering strength" (proportional to scatter abundance), vs water depth from surface (m) and elapsed recording time (hours). Data were sampled once per hour over a 49 day period starting on the 23rd October 1990. Individual zooplankton are not discerned; however high concentrations of animals appear as strongly scattering patches or layers in the water column. Two distinct scattering layers were seen. One layer was a strong and persistent daily migrator that moved from below 110 m in the daytime into the top 50 m at night. The second layer was confined to the top 50 m at all times and displayed only a small tendency to migrate vertically. This surface layer completely disappeared by Hour 500. We verified that the total water column biological scattering was roughly the same day and night by vertically summing the backscattering levels from top to bottom (the top 14 m of the water column cannot be reliably observed because of surface reverberation). These so called "column integrated" backscattering strengths are useful in discerning long term trends in biological populations since they are insensitive to how the scatterers are distributed with depth in the water column.

Comparison of the scattering layer behaviours with those observed on earlier ship-based sonar and net sampling studies (Cochrane et al. 1991) indicate the strong daily migrating horizon to be the euphausiid *Meganyctiphanes norvegica,* of 2.8 cm average length. Identification of the top 50 m scattering layer was more problematic. Ship-based multiple-frequency acoustic observations in adjacent Emerald Basin in November 1992 had revealed an upper water column scattering layer with a similar limited daily migration range. Net sampling showed this layer was composed of juvenile silver hake. Subsequent sonar cross sections across the entire Scotian Shelf using a 12 kHz shipboard echosounder and a 153 kHz shipboard ADCP profiler in October 1993 revealed extensive areas, especially over the Shelf Basins, populated by these juvenile fish. The bottom-mounted sonar provided the first direct measure of the seasonal decline and disappearance of the fish layer. The maturing fish probably migrate to deeper waters in the central portions of the Shelf Basins or near the Shelf edge when surface waters cool in the late fall.

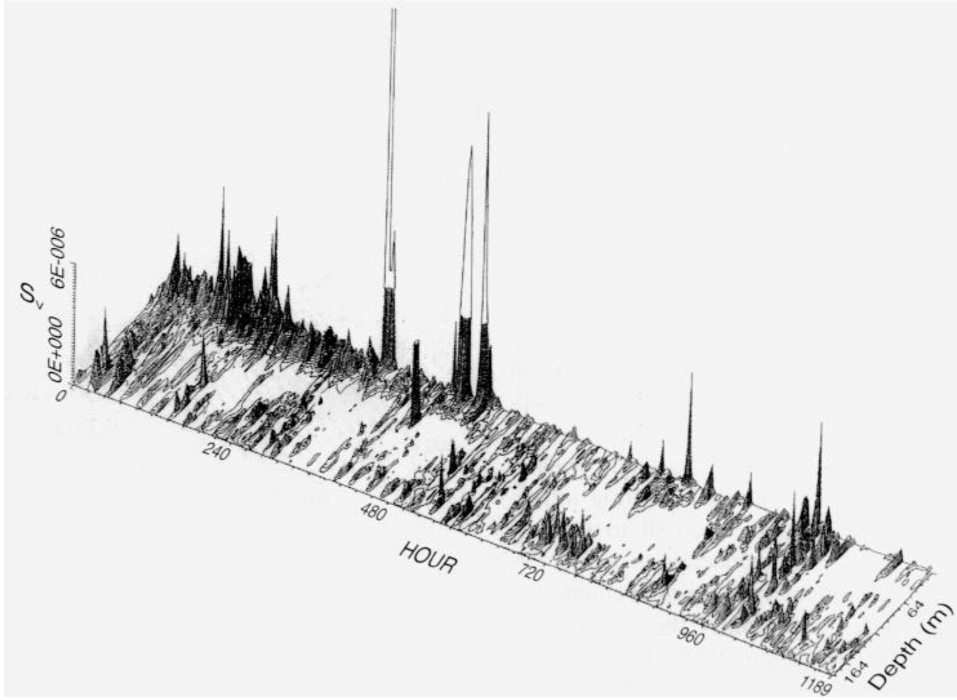


Figure 2: Three dimensional plot of acoustic volume hackscattering strength (s_v) vs elapsed recording time and water depth from surface (m)

Once the fish and euphausiid layers could be separately identified, the long duration sonar recording permitted detailed examination of the euphausiid daily migration. Figure 3 shows the hour-by-hour daily average of 14 consecutive days of recording starting at Hour 505 just after the disappearance of the near-surface fish layer. The euphausiid vertical migration was rapid, lasting scarcely longer than the 1 hour sampling interval. Migrations occurred near sunrise and sunset (average times marked, Fig. 3). The vertical distribution of scatterers appeared nearly symmetrical in time about local noon. When the euphausiid layer was deep its (average) scattering strength decreased to near zero about 10 m above bottom. This suggested euphausiids avoid the near-bottom zone, perhaps to escape bottom predators. Vertical summing of the average backscattering strengths revealed "column integrated" levels 26% lower at night than in the daytime. This nighttime reduction was consistent with a portion of the euphausiid population rising into the non-observable top 14 m excluded from the sum.

Euphausiids are "geometric" sound scatterers at 153 kHz. That is, a typical elongate euphausiid is sufficiently large compared to the acoustic wavelength (about 1 cm) that its backscatter is dependent on its orientation to the sonar beam. Backscatter is strongest when the organism is oriented broadside to the beam. Under natural conditions euphausiids tend to be oriented horizontally but with a degree of randomness in orientation from individual to individual that can be described statistically. An average horizontal orientation with a characteristic variability (Gaussian standard deviation) of about 30° is a good starting approximation. To predict an average acoustic scattering strength or "target strength" for an individual euphausiid we performed a statisticaly weighted average of the organism's backscattering over all possible organism orientations to the horizontal and all azimuthal orientations with respect to the observing sonar using a fluid cylinder representation developed by Stanton et al. (1993). This gave us a method for relating euphausiid size, abundance, orientation statistics, and physical properties, as well as the specific sonar beam geometry to observed scattering levels. Even though euphausiid orientation statistics are poorly known at present, modelling showed that for a large sample of euphausiids the combined backscattering is rather weakly dependent on the average orientation and its degree of statistical variability. Interestingly, the dependence is less for inclined beam ADCP type sonars than for traditional shipboard echosounder sonars with vertically oriented beams.

Vertical summing of scattering levels in Figure 3 showed that total column scattering levels drop not more than 1 dB (about 13 %) from their daytime values during the brief upward and downward euphausiid migrations. Intuitively one might expect an elongate organism to tilt its body upward when swimming upward. Our acoustic modelling showed the average orientation angle of a euphausiid during migration could scarcely exceed 30° to the horizontal to limit the reduction to 1 dB. Detailed hydrodynamic studies of euphausiid swimming, particularly the work of the German investigator U. Kils (1981), also convinced us that a 30° average orientation during upward migration would contradict neither basic physical principles or existing behavioural observations. Downward migration velocities and acoustic scattering levels are compatible with sinking in a near horizontal orientation. Using the best available estimates for euphausiid physical properties the integrated column backscattering implies average column densities of about 290 /m^2. The highest observed volume concentrations in the lower water column (ignoring the one data spike in Figure 3 which arose from a single isolated scattering event) are about 10 / m^3. These concentrations are in the range seen from shipboard studies but should be more representative of “average” conditions due to the extended period of observation.

Several observations arising from the above acoustic data set may assist critical evaluation of historical Shelf Basin euphausiid data. For example, acoustic surveys conducted in daytime may be more reliable than those at night. At night the euphausiids are near-surface and more likely to be mixed with a significant scattering population of juvenile fish. Total water column populations at a fixed location can deviate randomly from long term means by a factor of 50% over time scales of several days. Variations up to several hundred percent can characterize a single point sample at a given depth and time arising from random fluctuations in the strength

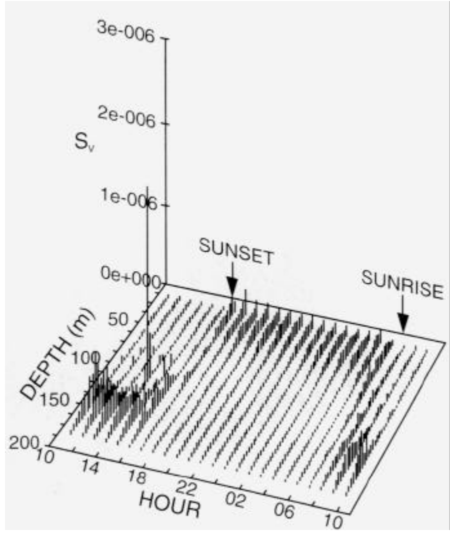


Figure 3: Three dimensional plot of average volume backscattering strength vs hour of day (Atlantic Standard Time) and water depth from surface. Data has been averaged over a 14 day period starting at Hour 505 in Fig. 2.

and timing of individual daily vertical migrations. This supports the common survey practice of collecting contiguous net samples over a wide range of water depths, when estimating a total column population.

A decade of ship survey zooplankton data now exists in the form of net, acoustic, and optical counter profiles. The collapse of the East Coast fishery has made it critical to determine if long term population changes in the underlying zooplankton ecosystem might be a contributing factor. Consequently, zooplankton data sets gathered before and during the decline of the fishery have taken on a new value. This again raises the question of what uncertainty characterizes any spot sample. Since much early zooplankton survey data was acquired in the Shelf Basins, and many samples include significant numbers of euphausiids, the above ADCP recordings will be especially valuable in addressing this question. ADCP’s, which are designed for a different primary task, are too expensive for long term biological monitoring. We intend to develop simpler and less expensive bottom mounted sonars to recover long duration recordings of multiple sites. These sonars will be precisely calibrated and will operate at two or more acoustic frequencies simultaneously to enable a rough discrimination of scatterer size. The use of multiple sonar frequencies coupled with judicious siting would allow the identification and continuous monitoring of distinct biomasses including major zooplankton and fish populations on the Scotian Shelf.

References

COCHRANE, N.A. and D. SAMEOTO. 1991. Research in hydroacoustics. hi: Thea E. Smith. [ed.] Science Review of the Bedford Institute of Oceanography, the Halifax Fisheries Research Laboratory, and the St. Andrews Biological Station (1988 & ‘89) Department of Fisheries and Oceans, Scotia-Fundy Region: 67-70.

COCHRANE, N.A., D. SAMEOTO, A.W. HERMAN, and J. NEILSON. 1991. Multiple-frequency acoustic backscattering and zooplankton aggregations in the inner Scotian Shelf basins. Can. J. Fish. Aquat. Sci. 48: 340-355.

KILS, U. 1981. The swimming behaviour, swimming performance and energy balance of Antarctic krill, *Euphausia superba*. BIOMASS Scientific Series No. 3: 122 p.

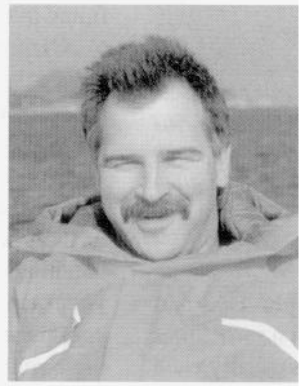
STANTON, T.K., C.S. CLAY, and D. CHU. 1993. Ray representation of sound scattering by weakly scattering deformed cylinders: simple physics and application to zooplankton. J. Acoust. Soc. Am. 94(6): 3454-3462.

Halibut Aquaculture Research at the St. Andrews Biological Station

K. G. Waiwood, K. G. Howes and J. Reid

K. G. Waiwood

K. G. Howes



J. Reid

Several factors have contributed to a growing interest in the culture of marine finfish in the Scotia-Fundy Region. The current success of Atlantic salmon farming has resulted in the establishment of a 100 million dollar a year industry, with this species accounting for the highest landed value of any finfish in the Region. To ensure its continued success and growth in a highly competitive market, the industry must diversify its production and market new species. The collapse of several wild fisheries has also focused our attention on alternate fish-based industries including the culture of marine species. In many parts of the world we see marine fish culture contributing more and more to local and national economies.

In 1988, a new program was established at the Biological Station in St. Andrews to evaluate and develop marine species for aquaculture in the Scotia-Fundy Region. The initial effort included upgrading and expanding facilities, collecting broodstock and experimental fish and learning new husbandry techniques. Originally the program focused on Atlantic halibut *(Hippoglossus hippoglossus)* but it has been expanded to include haddock *(Melanogrammus aeglefinus)*.

The activities of the group include: conducting basic research on the biology and culture of Atlantic halibut and haddock, adapting and improving culture technologies developed elsewhere, transferring technologies to industry and providing advice to the Department of Fisheries and Oceans (DFO) and other non-industry clients. Virtually all of the research and development is done collaboratively with industry partners.

Early Life History Research on Atlantic Halibut

Atlantic halibut is one of the most promising candidates for aquaculture in the Scotia-Fundy Region. The species has a high market value and yield, is very hardy and has been shown to grow 2 to 3 times faster in captivity than in nature. Unfortunately, this species has a relatively complicated early life history and the inability to mass produce juveniles reliably is the major impediment to commercial production.

Much of our early research activity has been focused on broodstock performance, egg production/quality, and techniques for the mass culture of yolk sac, startfeeding and metamorphosed larvae.

Most of the Atlantic halibut broodstock were collected with research vessels using longline gear, but some were obtained from commercial fishermen. The new broodstock building contains 6, 6-metre diameter tanks which hold about 36 large halibut. The collection of eggs from the females requires much hard work but the basic techniques have become routine after 4 years. Spawning occurs from the end of March to the beginning of June. During the spawning season, the water level in the tanks is lowered to about one metre. The mature females (30 to 8.5 kilograms) are individually herded up a ramp which is then raised with an electric winch. After the female calms down, her abdomen is stroked

Figure 1: Spawning a large female halibut. Eggs are collected by stripping

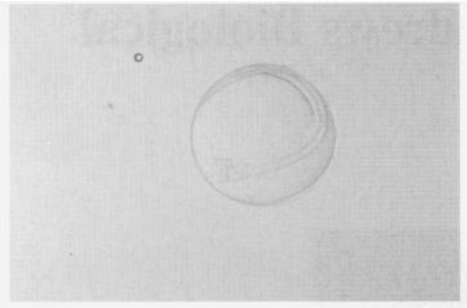


Figure 2: Halibut egg near hatching. Note the hatching ring in the head region. The egg shell will break along this line allowing the halibut to escape.

to induce the release of eggs (Fig. 1). Apart from first time spawners, which sometimes tighten their vents, the females usually yield their eggs without problem. Atlantic halibut are batch spawners, which, depending on size, spawn 3 to 12 times at 80 to 110 hour intervals. The timing of the stripping procedure is critical. Eggs must be collect within 2 to 3 hours of natural spawning. If early, the female will not yield the eggs and if late, the eggs will either be shed into the water or become over-ripe and poor in quality. The females are closely followed over the first few ovulation cycles and the timing of natural egg release is noted. With time the spawning times of each female can be predicted. However, spawning usually occurs at 0300 to 0800 hours and several attempts may have to be made during this period. Fortunately, the males, which are smaller, are more obliging. They yield milt at any time of the night or day. The eggs are fertilized in a large beaker and placed in the 250-litre egg incubators at 6°C for 13 - 15 days. During this time and for the next 30 days they will be in darkness.

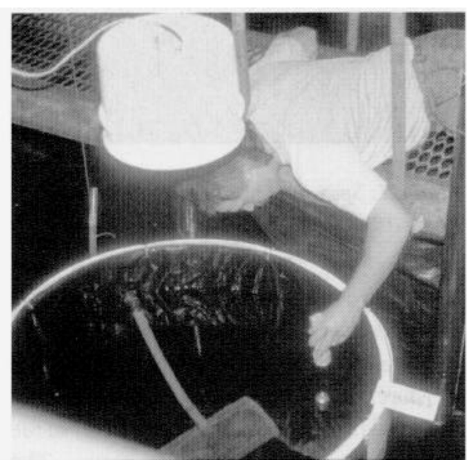


Figure 3: Floating bag used to hold yolk sac and early feeding larvae. The bag is suspended in a 4-metre deep tank which serves as a constant temperature water bath.

Many marine fish species have floating eggs, but Atlantic halibut eggs are bathypelagic. In nature they are usually found in the water column at depths of 100 to 200 metres (Haug et. al., 1986). The eggs have a special mechanism which allows them to increase their density when they are exposed to light (Mangor-Jensen and Waiwood, in press). This mechanism probably explains why the eggs are not found in the photic zone. About 2 days before hatching, the eggs are transferred to the yolk sac incubators. Prior to hatching, the eggs become more buoyant. During hatching a ring, high in hatching enzyme activity (Helvik, 1988), starts to form in the region of the head and the enclosed disk eventually separates allowing the larva to escape (Fig. 2).

During the lengthy yolksac stage (about 40 days at 7.5°C), the larvae change their density and, in nature, their position in the water column. Initially they are relatively light, but 3 - 7 days after hatching they commence drinking (Tytler and Blaxter, 1988), and become more dense. In the ocean they would usually be found just above the pycnocline where there is little light, relatively constant environmental conditions and few predators. One of the big challenges in culturing this stage is to duplicate, in about 4 metres of water, the conditions which in nature require 100 to 200 metres.

The initial approach, which was similar to the Norwegians, involved the use of 3-metre high conical-bottom silos (Rabben et. al., 1987). However, it was impossible to control temperature and the relatively low ambient salinity necessitated the use of high upwelling flow rates to keep the larvae in the water column. This approach did not work. At about 9 to 14 days after hatching the larvae became attracted to currents and used up their energy reserves swimming towards the bottom of the tank. The next approach was to use 3-metre by l-metre diameter floating bags in a large concrete tank. The tank acted as a large temperature-controlled water bath. Rather than increasing flow, it was decreased to 0.5 litres per minute and the salinity was increased from about 27 to 34 ppt. through the addition of sodium chloride. Fortunately the 5 tons of salt required to do this was relatively inexpensive. In 1993, several thousand healthy start feeding halibut larvae were produced in the experimental systems. Our best treatments had 70% survival through the yolk sac stage. The survival rate can be quite variable among apparently identical batches. This variability can not always be explained. In addition, there can be high rates of deformities of the jaw and yolk sac. More research will be required before the factors causing these various deformities are understood. A more detailed account of the biology and development of the yolk sac stage can be found in Lonning et. al. (1982), Pittman et. al. (1987), and Pittman (1990).

Early Feeding Biology

Probably the most challenging problem in halibut fry production is improving first feeding success. The period when the larvae change from endogenous (yolk) to exogenous (live prey) feeding is usually associated with high mortalities. After about 30 days post hatching, algae *(Isochrysis)* is added to the bags to produce "green water" (Fig.3). This has several benefits including the provision of food for copepods which are also added at this time.

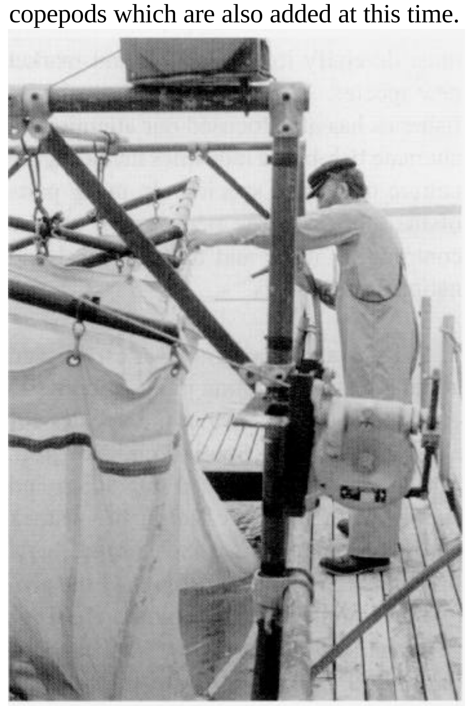


Figure 4: Hosing down a plankton net used to collect copepods for early feeding halibut. The large plankton nets are deployed into tidal-generated currents from a moored barge.

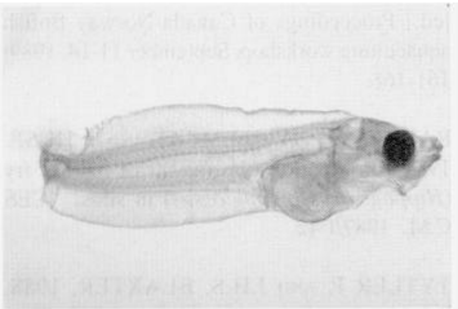


Figure 5: Early feeding halibut larva. Note the food in the gut.

This food is collected with large plankton nets suspended in tidal currents using a specially-built barge (Fig. 4). Artemia are fed but its exclusive feeding on artemia causes abnormal pigmentation of the larvae which manifests itself as irregular white blotches in the juvenile and market-sized fish. This significantly decreases their market value. The early feeding halibut (Fig. 5) are aggressive feeders and grow quickly. About 2 to 3 weeks before the larvae metamorphose (around 12 mm length), an inert micro-particulate diet is added to the water using automatic feeders. The Japanese-produced micro diet is specifically formulated for marine fish larvae. By the time the fish metamorphose, they are almost completely weaned onto the inert food

When the larvae start to metamorphose they are transferred from the bags to shallow troughs. Here it is easy to maintain high prey densities and remove uneaten food and faeces. The fish grow and complete metamorphosis (Fig. 6). At this time the left eye migrates over to the right side, the larvae spend most of the time on the bottom, and start to take on the appearance of miniature halibut. Feeding once more

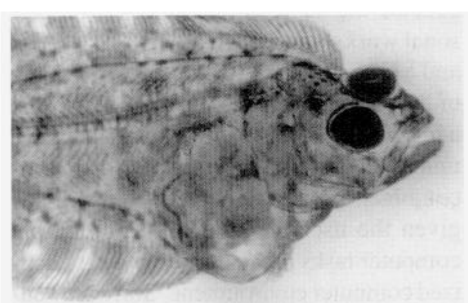


Figure 6: Metamorphosing larval halibut. The left eye has not vet migrated to the right side. This larva would be spending much of its time on the bottom of the tank.

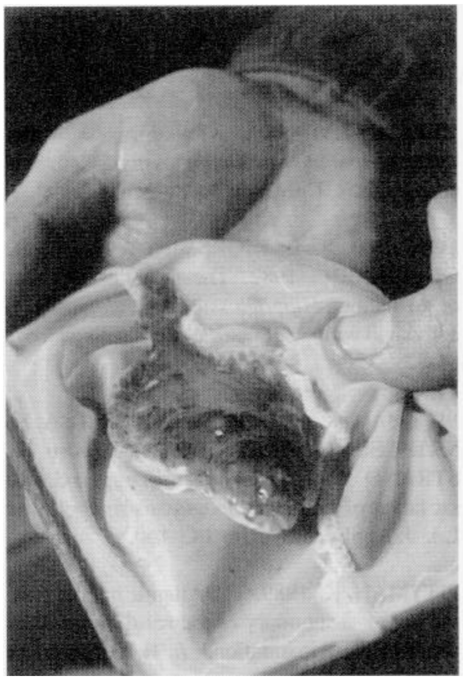


Figure 7: Juvenile Atlantic halibut approximately 9 months old.

becomes a problem. Because the fish are now in a benthic feeding mode, they seem to lose interest in the inert food and once more live copepods are used. However, by the time the juveniles are about 30 mm they accept dry pellets and do not require live food. At 9 months they attained a size of about 10 - 20 gm. In 1993, the first 48 juvenile halibut were produced (Fig. 7).

On-growing Studies

Research has also been conducted on the grow out stage using wild-caughtjuveniles. A special holding facility was designed and constructed for the Research Vessel *Lady Hammond,* and several hundred juvenile halibut were collected from the Sable Island Gully area. Growth and survival have been monitored in modified herring weirs, salmon cages and a bottom cage. The salmon cage study was conducted in collaboration with J. Malloch, a Campobello salmon grower. Unlike traditional salmon cages, the experimental cage was constructed with a solid flat bottom. About 45 juvenile halibut were placed in the cage in July, 1990. Growth and survival has been followed since that time (Fig 8).

Growth was much higher than in nature with the juvenile halibut quadrupling their weight over the 2 year period of the ex-

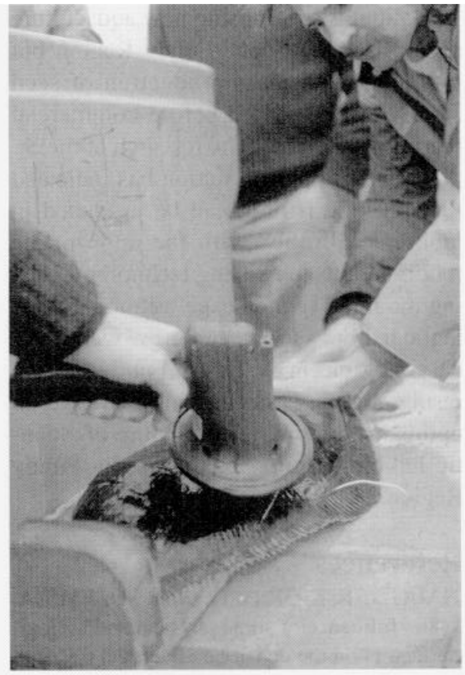


Figure 8: Identifying a caged halibut which has been tagged with an internal electronic tag. The fish will then be weighed and measured.

periment (Fig. 9). There was no difference in growth between males and females prior to maturation. However, when the male matured, at about 6 kg, their growth rates decreased significantly. Growth rates of females, which mature at a larger size (10 kg), showed little change even after maturation.

Conclusions

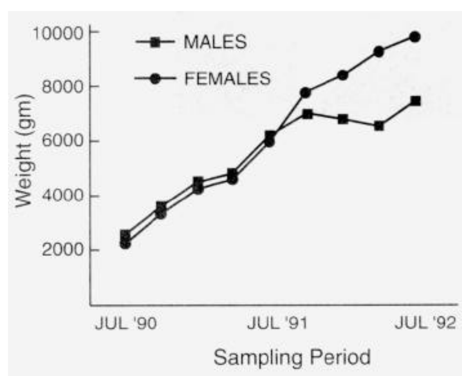


Figure 9: Growth of wild-caught Atlantic halibut held in a modified salmon cage. Note the change in growth patterns between the males and females after the males mature.

Halibut is a promising new aquaculture species for the Scotia-Fundy Region but problems with mass production of seed stock must be solved before commercial rearing is realized. The research at the St. Andrews Biological Station has indicated that juvenile halibut can be produced in ambient salinities with the appropriate modifications to existing technology. Using modified salmon cage technology, Atlantic halibut survive and grow well in local conditions in the Bay of Fundy. These results are very encouraging and give an optimistic outlook for the future of Atlantic halibut farming in the Scotia-Fundy Region.

References

HAUG, T., E. KJORSVIK AND P. SOLEMIDA. 1986. Influence of some physical and biological factors on the density and vertical distribution of Atlantic halibut *Hippoglossus hippoglossus* eggs. Mar. Ecol. Ser. 33: 207-216.

HELVIK, J.V. 1988. Klekkeprosessen hos kveite *(Hippoglossus hippoglossus)*. Can. Scientific thesis, University of Bergen, 87p.

LONNING, S., E. KJORSVIK, T. HAUG, B. GULLIKSEN. 1982. The early development of the halibut, *Hippoglossus hippoglossus* (L.), compared with other marine teleosts. Sarsia. 67: 85-92.

PITTMAN, K. O. BERGH, I. OPSTAD, A. B. SKIFTESVIK, L. SKJOLDDAL AND H. STRAND. 1990. Development of eggs and yolk sac larvae of halibut *(Hippoglossus hippoglossus* L.). J. Appl. Ichthyol. 6: 142-160.

PITTMAN, K. 1989. The Atlantic halibut yolk sac larva: a summary of the results from four years of experimentation. *In* R. L. Saunders [ed.] Proceedings of Canada-Norway finfish aquaculture workshop, September 11-14, 1989: 161-168.

RABBEN, H., A. JELMERT AND I. HUSE. 1987. Production experiment of halibut fry *(Hippoglossus hippoglossus)* in silos. ICES C.M. 1987/f:42

TYTLER P, AND J.H.S. BLAXTER. 1988. Drinking in yolk-sac stage larvae of the halibut, *Hippoglossus hippoglossus*. J. Fish Biol. 32: 493-494.

Directions in Scientific Computing

D. Swetnam

D. Swetnam

During the last few years the direction of scientific computing in the Scotia Fundy Region has taken a dramatic shift. This shift can be broken down into five areas:

- Increased computing power
- Ease of use or Graphical User Interface (GUI)
- Data visualization
- Computer connectivity
- Open systems

Scientific computing has moved from serial text based terminal connections with a mainframe and limited connectivity, to powerful personal computers that are connected to our own specialized equipment and to other research institutions all over the world. Scientists can now work on equipment with the appropriate power for the job, using open systems standards that will protect their software/hardware investment.

Increased Computing Power

In the past, most computing was done via a terminal connected to a centralized computer. This type of computing, although beneficial in some ways, had the drawbacks of being expensive, tedious, inflexible and, from the users point of view, subject to uncontrollable changes. The advent of personal computers with lots of inexpensive memory, Random Access Memory (RAM), large mass storage devices (such as hard disk drives, CD ROM drives, Digital Audio Tapes (DAT) and removable media), colour display and swift computational power has meant a shift in where the actual processing is done. Activities such as data acquisition, analysis and visualization to some extent, word processing and business graphics, have migrated to the desktop. Workers may now tailor their working environment to be comfortable and productive. Change to this personal environment can be controlled, remembering that the most important word in the phrase “personal computer” is “personal”. The scientists’ desktop has also become the home of a more powerful personal workstation, such as Next, VAX, HP, and SGI computers that outperform many of the old mainframe computers in use just a few years ago. The introduction of X terminals and X terminal emulation on micros combined with a high speed network has given the user the ability to do multiple computer tasks in the office via a personalized computer environment. Software vendors were quick to recognize this shift to local computing and many of the software packages previously exclusive to mainframe computers now have versions for desktop computers.

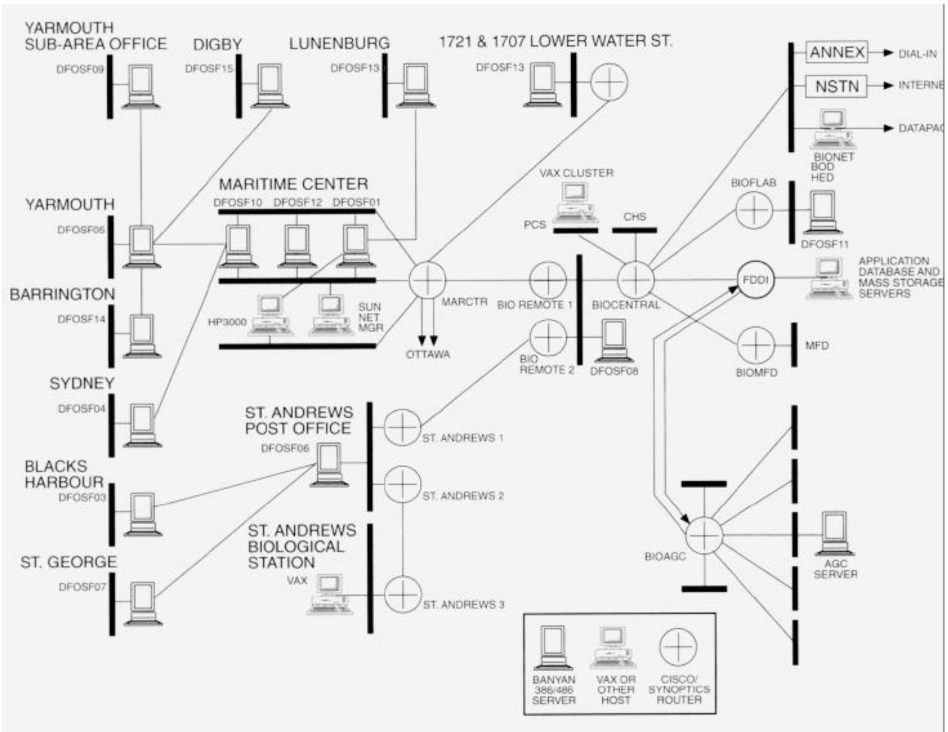


Figure 1. DFO Scotia-Fundy network

Ease of Use

Combined with the shift in power to the desktop has been an evolution in operating systems. The old method of scientific computing was programming in high level languages such as FORmula TRANslation (FORTRAN) linked with subroutine calls to speciality packages such as Display Integrated Software System and Plotting LAnguage (DISSPLA) for graphics or the International Mathematical Scientific Library (IMSL) for mathematical calculations. The interaction with the operating system was handled via complex job control language programs. This resulted in a time consuming learning curve that tended to discourage many researchers. Fortunately much of this has changed. With the extensive introduction of micro computers came the concomitant development of easy-to-use Graphical User Interfaces (GUI) to the operating system such as the Mac Operating System (OS) and the Windows environment for the Disk Operating System (DOS). The more powerful UNIX based systems also developed graphical interfaces such as Motif and SUN'S Open Windows environment. Much of the software on the market today and in use by staff in the Scotia Fundy Region conforms to certain GUI constraints or has a built-in GUI. Now software and computers are tools in scientific investigations rather than obstacles to the investigations.

Data Visualization

Combining the increase in computer power and the new graphic based user interfaces has enhanced the data visualization aspect of scientific computing. The largest project associated with data visualization is the Canadian Hydrographic Service (CHS) Electronic Chart program. This program has, as one of its goals, the production of charts for viewing on a computer screen or plotter directly from the most current digital data applicable to the region of interest. This digital data might be stored on disk, CD or downloaded from a satellite link. It is the ability to visualize the data in the form of a nautical chart that is key to the user. New techniques and applications are being developed in order to make sense of the data that we collect. In the Benthic Fisheries & Aquaculture Division of the Biological Sciences Branch (BSB), Jerry Black has developed software called A CONtouring package (ACON) to better visualize the distribution of invertebrate and fish stocks. This system has the capability of making QuickTime movies of the data so one may play the movie and see how distributions change and move over time. The Physical and Chemical Sciences Branch are making extensive use of commercial data visualization software such as PV/Wave and AVS. This software enables researchers to make three dimensional views of complex oceanographic systems and take slices out of this 3D cloud for further analysis. One special subset of data visualization is that of image analysis. An example of how this is being used is provided by Steve Campana's work in differentiating stocks of NW Atlantic cod by the use of otolith shape analyses.

The use of Geographic Information Systems (GIS) has always been appealing to DFO researchers but never fully utilized due to the temporal and spatial dimensional nature of the information with which we deal. Several groups including the Freshwater and Anadromous Division of the BSB are actively seeking to employ this technology in their work. Herman Varma of CHS is working to solve this problem in conjunction with Oracle Corp via use of the CHS developed Multi Dimensional (MD) code.

Data visualization is used every day to present information to our clients. Most workers now have access to business type graphical presentation tools in the form of software running on their desktop micro. This is used to present information in an understandable format in such diverse areas as journal articles and posters at Fisheries exhibitions.

Computer Connectivity

The computing communications environment used to be one of asynchronous terminal connections to a Private Automated Communications exchange (PACX) that allowed switching to the computer of choice. These connections were limited to 56,000 bits per second (bps) and one active session per user at a time. Many short haul modems and multiplexors were used to overcome both the RS232C distance limitation and to reduce wiring. File transfers were usually done by mail or courier and involved reels of magnetic tapes. In addition there was the problem of different tape densities and file formats. There was a proliferation of printers as the only ones accessible to all were central site printers served from the mainframe computers.

Fortunately all this has changed. The asynchronous connections gave way to a Regional Network consisting of IEE802.3 (Ethernet) wiring, a series of concentrators and routers all using the Transmission Control Protocol / Internet Protocol (TCP/IP) communications standard (see Figure 1). The multi protocol routers are also capable of handling protocols such as Decnet, Banyan/Vines StreetTalk and Appletalk so that original investments were not lost. The speeds now supported on the network range from 56,000 bps to speeds of 1Mbps. Users have the ease and speed of transferring files across the network without waiting for the mail or knowing the specific format of the data they need. The common file transfer protocol used is called File Transfer Protocol (FTP). This type of network also allows the use of such services as Network File Service (NFS) which has the ability to mount a segment of disk space on a remote computer so it looks like a disk drive on your local computer. This allows one to take advantage of machines with large arrays of disk space and eliminates many copies of the same data residing in different locations. Because of the speed of this service, on the backbone segment of the network, there is little difference in accessing your remote disk versus your local hard disk.

The sharing of printers is becoming a reality. A local printer can be set up so that it becomes available for use by any other computer on the network. This is very useful for sites that are not at the Bedford Institute of Oceanography (BIO) since before, these sites had to have all output sent to them. Now such sites can request printing on a local printer from the BIO remote host.

Electronic mail (E-mail) systems have now come into prominence. Whether it is Banyan/Vines E-mail or Al mail on a host or Post Office Protocol (POP) mail services to the desktop, it is now easy to communicate with other people on the network. The ability to easily transfer complicated documents, such as binary files and graphics, from one mail system to another is still involved, but standard text is quite straight forward. This feature is useful when collaborating with workers in other time zones in other parts of the world. It aids in the sharing of knowledge on a global basis. One of the greatest benefits of the new network was the decision to become part of the Nova Scotia Technology Network (NSTN). This has allowed us to become part of the Internet with access to millions of computers world-wide. The benefits include access to many library catalogues all over the globe, access to repositories of software developed by government and universities, companies and individuals and the opportunity to be part of a news group, or what is called a list or digest with people all over the world who are interested in common topics. These are tremendous ways to gain and share knowledge. This type of communication and sharing of expertise and software are extremely important and cost effective to a scientific organization. Tools such as Archie, Veronica. Gopher and Mosaic are being developed and improved every day to help in the search for information in this vast electronic sea of resources known as the Internet.

Another feature of our Regional network and attendant software is the ability to access specialized equipment. We now have access to virtually unlimited data storage capabilities via the network link to the Mass Storage Management system. There are expensive output devices such as the large Versatec colour plotter, the slide maker, and the dye sublimation printer that can be shared by any user on the network.

Open systems

In 1992 the Science sector of the Department of Fisheries and Oceans, Scotia-Fundy Region in concert with the Atlantic Geoscience Centre of the Geologic Survey of Canada, Department of Energy Mines and Resources, detailed the specifications for the procurement of a new open systems scalable computing environment. The definition of this open system was taken from the IEEE POSIX 1003.0 document and reads as follows: “a system that implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered applications software to be ported across a wide range of systems with minimal changes, to interoperate with other applications on local and remote systems, and to interact with users in a style which facilitates user portability”. What we were striving for was portable software applications and vendor independence. The object was to replace the Cyber mainframe, in place since 1972, with a network of high power UNIX workstations, each to replace one or several of the functions that the mainframe used to support. Concurrent with this was a network upgrade consisting of a Fiber Distributed Data Interconnect (FDDI) ring linking the new computers to a high speed multiprotocol router bridging up to 10

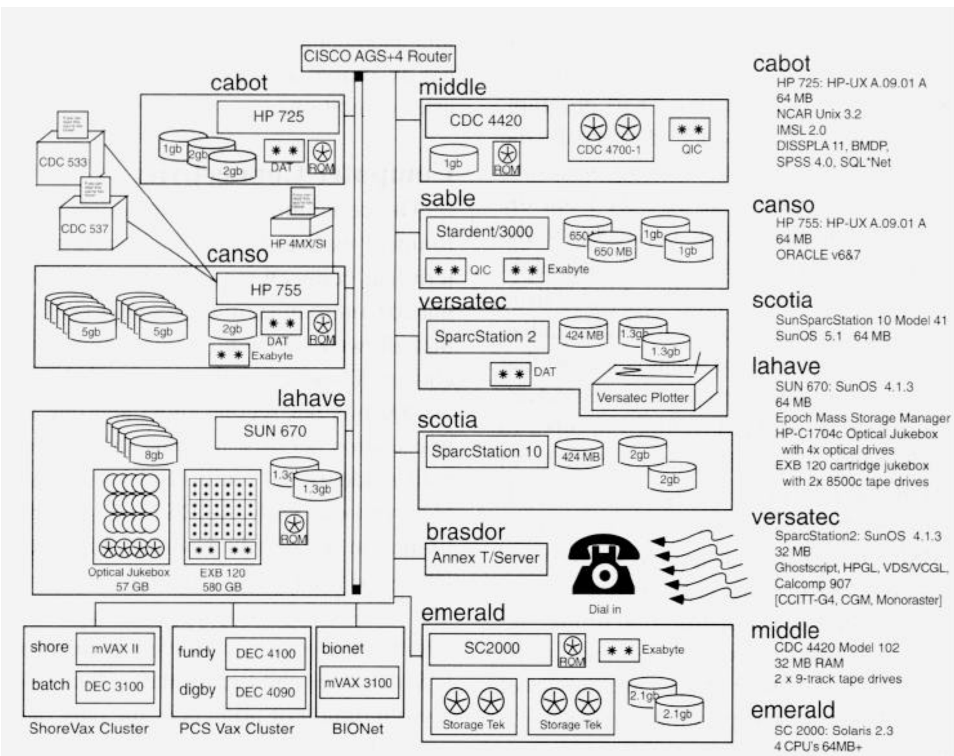


Figure 2. BIO computer network

Ethernet segments. The functional requirements defined were: input/output services and peripheral management, mass storage management, VAX/VMS services, database server, applications server. network services, conversion services (from the old Cyber files) and distributed management services. See Figure 2 for the current configuration at BIO as of August 1994. To a lesser scale these requirements were also necessary for the St. Andrews Biological Station. Tight specifications were written for a platform and/or software to serve each of the above functions. These were to be POSIX 1003.1 compliant and support UNIX SVR4.0, Berkeley 4.3 or equivalent. All systems were given performance targets and required the maximum user loads to be specified. These targets were evaluated by a performance measurement called an AIM rating that included such things as disk input/output performance and speed of computation.

Such a configuration allows work to be done on the appropriate system. For example: database work is done on a system tuned to deliver the maximum in database performance. Word processing is typically done on micros and work such as modeling is done on the more powerful computers such as the Stardent and SC2000. The strategy was to migrate to a modular computing environment which facilitates matching of separable computing functions to appropriately sized components. This strategy also facilitates the modification or replacement of individual components as requirements change.

There are many advantages to be gained from the selective use of standard pieces of software and hardware. There has always been some standardization within working labs or Divisions, partly because of the support that was resident in that lab or division for particular software or hardware. As we have become more exposed to the larger scientific community on an hourly basis by using the Internet, it has become obvious that there are many de facto standards. This type of standard has been arrived at by being the best solution to a particular problem based on the world wide use of many options. A de facto standard used on the Internet benefits from rigorous world wide testing. De facto software standards such as Telnet, Fetch, and Gopher have withstood the test of time.

Other standards such as the DFO data base standard Oracle are a double edged sword. On the one hand a common data base environment makes access to and the sharing of data very easy, while on the other hand the development cycle to create applications in Oracle can be described as tedious at best. But again the selective use of standards is the key. A project that is short term in nature would use one of the popular and easy to use data base systems such as Foxbase, Filemaker Pro or Dbase IV, while a long term multi user data base would be written in Oracle.

In many areas computing standards are hard to arrive at because of the intrinsic fast paced nature of the industry. One area where change is the rule is electronic mail. The industry itself has yet to develop a comprehensive set of standards to enable cross platform and mail package delivery. We would do well to follow these developments closely and adopt industry standards when they become mature. It is not by chance that the most common way of sending e-mail is still as ASCII text within the body of a message.

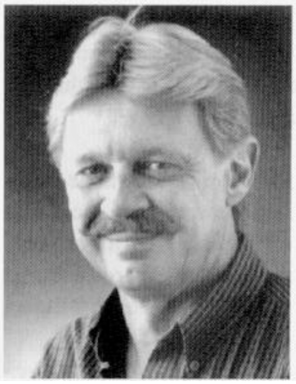
The future direction of scientific computing will be continued ease of use, more sophisticated software, increasingly more powerful and cost effective hardware and seamless interconnects to external resources.

Reference

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. 1988. IEEE Standard 1003.1-1988: Portable operating system interface for computer environments (POSIX). IEEE, New York, N.Y.

Development of a National Digital Geoscience Data Library and Client Facility: The Opportunity of a Lifetime

K. D. McAlpine and K. C. Coflin



K. D. McAlpine

K. C. Coflin

Figure 2: The Husky Oil tape storage facility in Calgary showing some of the 65,000 magnetic tapes before they were moved to Dartmouth.

In 1993 the Atlantic Geoscience Centre (AGC) was the proud recipient, on behalf of the Geological Survey of Canada (GSC) and the people of Canada, of more than $1000,000,000 worth of petroleum industry geophysical and geological **digital** data. The information covers most of Canada's offshore (and some onshore) sedimentary basins from eastern Canada to the Arctic, including Scotian Shelf, Gulf of St. Lawrence, Grand Banks, Labrador Shelf, Hudson Bay, Bafftn Bay, Arctic Islands and Ocean, Beaufort Sea and Yukon/NWT (Fig. 1).

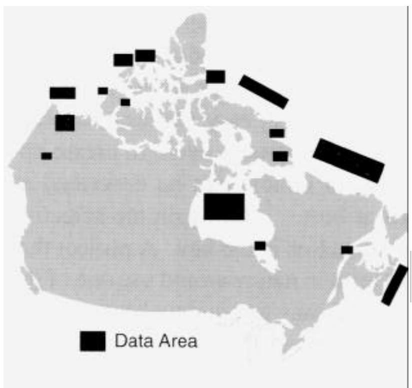


Figure 1: Map showing areas with data available in the National Digital Geoscience Data Library.

These data were donated by Husky Oil and Petro-Canada in recognition of an effective and continuing scientific collaboration that has evolved between the petroleum industry and the GSC and, particularly, in acknowledgement of the expert capability for seismic data interpretation and processing that has been developed at AGC. This gift of scientific data, unprecedented in magnitude and genre in Canada or elsewhere in the world, combined with state-of-the-art workstation technology, places the GSC at the forefront of marine seismic research and basin analysis capability.

Appropriate Curation of the data, and encouragement of its collaborative use for research purposes are specific terms of the donation agreements. The agreements allow access to the data not only by the Survey, but also by other research and academic organizations across Canada and world-wide. To assist clients within the petroleum industry, universities and the international geoscientific community, AGC has established a geoscience information facility to encourage research into the formation and evolution of sedimentary basins, including their oil and gas potential. The facility includes new, state-of-the-art Computer Aided Exploration (CAEX) workstations with seismic processing and 3-D interpretation capability.

The data are stored on over 65,000 half-inch, 9-track magnetic tapes (Fig. 2) and consist mainly of field and stack (processed) multi-channel seismic lines. There are over 100,000 line kilometres of seismic data comprising reconnaissance lines (over 100 km long), regional lines (1 -5 km spacing), detailed lines (prospect oriented) and 3-D surveys (25-50 m spacing). Also included are high resolution well-site surveys. side-scan data and refraction and potential field data. Transfer of this tremendous volume of tapes and associated material from Calgary to Dartmouth required the use of 8 specially equipped air-ride, temperature controlled semi-trailers! To store the information on behalf of the Survey, AGC has established a partnership with the National Archives of Canada. Storage required an upgrade to the existing Halifax Record Centre tape library that was funded jointly by Natural Resources Canada and Heritage Canada.

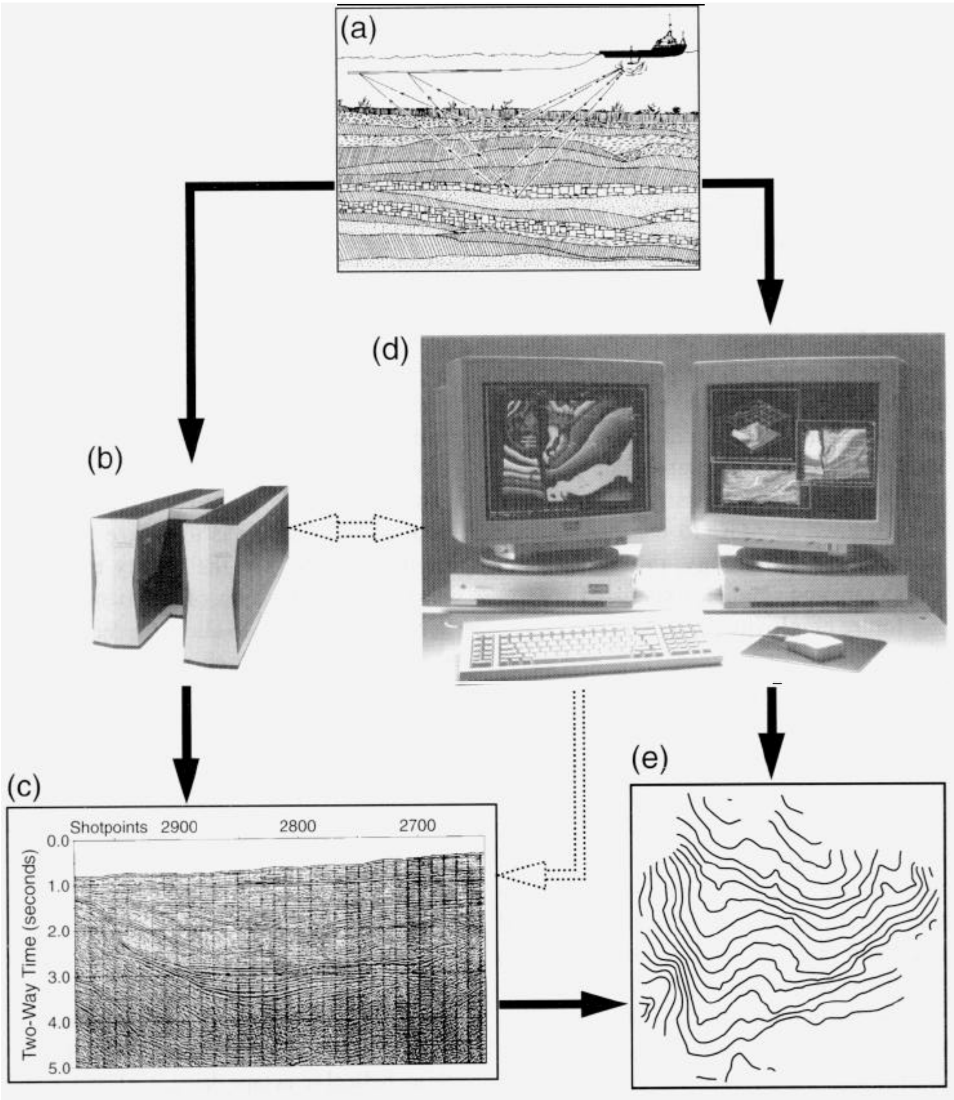


Figure 3: How multi-chnnnel reflection seismic data are acquired, processed and interpreted the old Way, a/b/c/e, and the new way a/d/e.

Multi-channel seismic data are used to interpret the stratigraphy and structure of rocks down to tens of kilometres beneath the earth's surface. In the offshore, specially designed seismic vessels equipped with an energy source (commonly an air gun), a cable or "streamer" (about 3000 m in length and containing many hydrophones) and recording instruments onboard the vessel, measure the 2-way travel time of acoustic energy reflected from sedimentary layers within a basin (Fig. 3a). The recorded data are processed ashore at sophisticated processing centres (Fig. 3b). For decades, black-and-white hardcopy paper sections were the only means of displaying and interpreting seismic data (Fig. 3c). The seismic events on these sections are hand-coloured, time values are laboriously posted on a map and contouring joins like values (Fig. 3e). The advent of geophysical workstations and associated software in the early 1980's was a technological breakthrough that revolutionized the way petroleum industry interpreters analyzed seismic data (Fig. 3d). These workstations permit digital data to be analyzed interactively and the resulting interpretation can be output to large format printers and plotters, eliminating the need for paper sections. Lately, more powerful workstations and new software enable the user to process directly the raw seismic data, eliminating in many cases the requirement for large processing facilities. In fact, AGC scientists were some of the first workers, outside the petroleum industry, to process multichannel seismic data at sea. This occurred in 1992 during an Ocean Drilling Program site survey east of Newfoundland in cooperation with the French research institute IFREMER.

Unfortunately for the research community, digital seismic data gathered by the petroleum industry have normally been closely guarded proprietary property. Sedimentary basin analysts in governments and academia (with very few exceptions) have had to rely on paper sections obtained through government petroleum regulatory agencies or loaned directly from industry operators. Now, armed with a digital seismic data base that covers all Canada's frontier sedimentary basins from the Scotian margin to the high Arctic (Fig. I), AGC is uniquely positioned to join the CAEX revolution. AGC has established a public domain seismic facility with state-of-the-art interpretation and processing capabilities, normally found only in large petroleum exploration companies.

History of the Data Donations

1970's/80's • AGC performs pioneering mapping and oil and gas resource appraisals of frontier sedimentary basins of eastern and northern Canada. This leads to collaboration and partnerships with the Canadian petroleum industry.

1991 • Husky Oil initiates discussions with AGC concerning their wish to donate Husky's frontier digital seismic data base to the GSC.

1992 March • Husky donation agreement is signed.

April • Petro-Canada initiates discussions with AGC.

July • AGC enters partnership with National Archives of Canada's (Heritage Canada) Halifax Record Centre to store the data tapes.

November • Petro-Canada donation agreement is signed.

1993 January • Specially designed racking is added to the climate controlled Halifax Records Centre to accommodate the 65,000 tapes.

March • 8 semi-trailers, featuring temperature control and air-ride suspensions, transfer the data from Calgary to Dartmouth.

May • A pilot project is undertaken for development of a Geographic Information System (GIS) data base for Curation and retrieval of the data tapes.
September • Another donation agreement is signed with Pembina Oil.

December • Client processing and interpretation facility is implemented at AGC.

Donation Agreements

Basic Elements:

• The GSC is recognized as the appropriate national custodian for the data. This is in keeping with the GSC's increasing emphasis as keeper and provider of the national geoscience information base.

• The GSC is free to use the data for research and concept/technology development.

• Collaborative scientific research is encouraged with non-profit organizations across Canada and world-wide.

• The donating companies reserve commercial rights to the data. The GSC and collaborating agencies (who are also bound by the agreements) may not use the data for resource exploration or to advise third parties. All scientific research/publication must acknowledge the donating companies as the owners.

• The GSC's liability for the data is limited to its preservation within federal/provincial regulations, and maintaining the data tapes to petroleum industry standards.

Benefits for Canada

• A Canadian heritage will be preserved. The library will prevent valuable data from being lost and will allow future data acquisitions to be planned more efficiently.

• The Canadian research community has gained access to a unique set of digital geophysical data, including data from very remote areas that may not be surveyed again in the foreseeable future. The digital format permits advanced analysis with workstation technology, including reprocessing and interpretation for enhanced basin analysis studies and oil and gas resource assessments.

• By putting Canadian researchers on a common technological foundation, collaboration and communication is facilitated among Canadian petroleum companies, governments, universities and research institutes.

• The Client Facility has become a valuable aid for university undergraduate teaching and for graduate and faculty research in basin analysis and will stimulate non-industry research in seismic data processing. So far, eight university students have been trained at AGC to use the seismic workstation technology, providing them with a rare and valuable expertise for gaining future employment.

Private Sector Advantages

• Generally, the Canadian oil industry is gaining enhanced competitiveness through new exploration concepts/technology gleaned and published by GSC and other non-industry researchers using the advanced technology. It is hoped that research that combines hitherto unavailable digital data with ongoing work in basin analysis will help reduce risk in oil exploration, reversing the economic effect of a diminishing resource base and low world prices. Additional highly innovative projects at home and abroad, leading to the development of new theories of sedimentary basin development and to new oil and gas plays, may be anticipated by combining these digital data with other data sets already available in governments and universities.

• Specifically, the donating companies are gaining national and international recognition for their leadership in fostering research. They have guaranteed access to value-added improvements to the data that will accrue from activities such as reprocessing, re-interpretation and re-formatting. They also enjoy close collaboration with research teams in the GSC while retaining all commercial rights to the data.

Seismic Interpretation and Processing Facility

To assist clients and collaborators within the petroleum industry, universities and the international geoscientific community, AGC has established a geoscience information facility (Client Facility) to encourage research into the formation and evolution of sedimentary basins, including their oil and gas potential. The system includes a new, state-of-the-art CAEX workstation with mapping, seismic processing and 3-D interpretation capabilities. This facility makes it possible to integrate the comprehensive data bases of geological information already available within the GSC with the newly acquired digital seismic data into one environment. At present, this type of fully integrated system is not available at any other division within the GSC and is rare outside of the petroleum industry. The goal of the Facility is to utilize fully the digital data held in the library to ensure maximum realization of the benefits described above, and to allow the technology that has been confined to large commercial organizations to be used by a much broader group of researchers and students. It is planned that geoscientists who cannot use the facility locally will be able to access some parts of it remotely through Internet.

Technical Features

The Client Facility consists of a Sun SPARC 10/51 workstation including two 19" monitors, approximately 9 gigabytes of disk storage, a CD-ROM reader, a high-density 8mm helical scan tape drive, a 22" black and white Versatec plotter and access to a 1/2 inch 9 track tape drive. The system is networked to a 44" colour Versatec plotter.

The system software comprises Landmark Graphics SeisWorks 2-D and 3-D interactive multi- and single channel reflection seismic interpretation software, Insight 1 version 5.1 (a full function 2-D seismic processing package) and Zycor Z-Map Plus mapping software. All of these packages are full feature commercial programs used widely throughout the hydrocarbon industry. The software is fully integrated around a single data base which enables nearly seamless exchange of information between individual modules and packages.

The seismic interpretation packages, SeisWorks 2-D and 3-D, give explor-ationists and researchers expanded interpretation capabilities by allowing a flexible and varied display environment that could not be achieved with traditional paper seismic

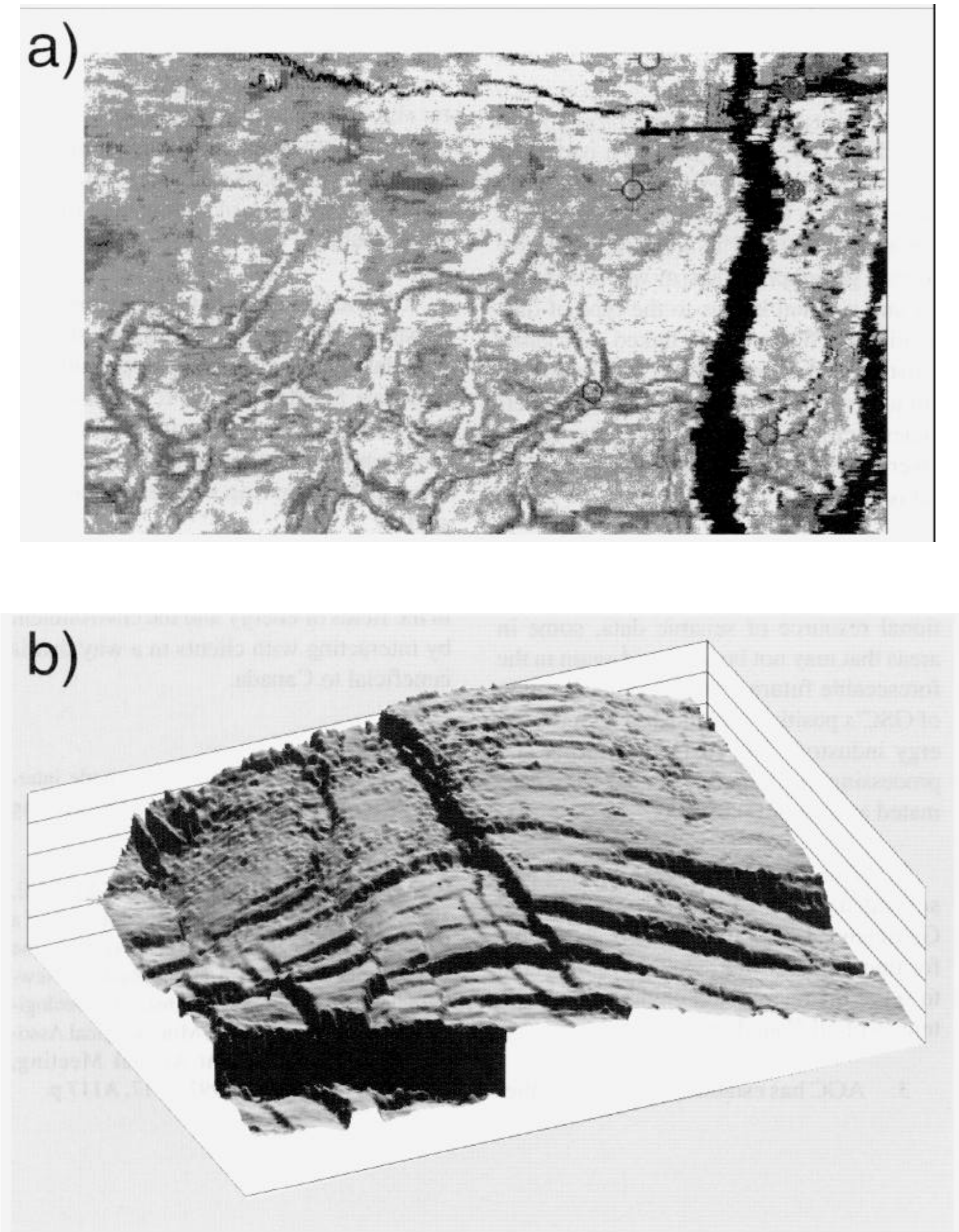


Figure 4: Two examples of interpretations using workstation technology, (a) seismic amplitude map (slice) of an unconformity and (b) 3-D perspective view of a faulted surface.

sections. In addition to the display advantages, interactive image processing and attribute analysis are possible, presenting new perspectives to users and the ability to extract geological information previously unavailable.

The procedure of taking multi-channel reflection seismic data from the raw field form to an interpretable seismic profile is a complex and computationally intensive task. The theory and practice of processing reflection seismic data were developed over the last 30 years within the petroleum industry. It is only within the last 5 years that this technology has been transported from mainframe and super computers onto desktop workstations, making it much easier to use and more affordable. The Insight 1 seismic processing package is one of the industry standards and is used also within academic (LITHOPROBE) and government (GSC in Ottawa and Sydney, BC) research communities. This package gives users of the Facility the ability to improve existing profiles with expanded imaging software or to fully re-process old data so that new profiles can be created taking advantage of modem processing approaches and algorithms.

Interpreted seismic data are converted into maps using the Z-Map Plus package, which makes the task of mapping geological features easier than using conventional techniques. Z-Map Plus has sophisticated mapping approaches and was specifically created for geological applications. It allows extensive user input and editing to ensure that the maps produced are not only technically correct but convey the user’s interpretation of the problem based on his or her unique geological knowledge.

Other capabilities that can be accessed through AGC’s local area network include a dedicated 2-D interpretation Sun SPARC 10/41 workstation with Landmark’s StratWorks geological interpretation software. This software is designed to manipulate petrophysical and geological information in an interactive environment, in the same way the seismic interpretation software works with seismic profiles. A major advantage of this system for offshore eastern Canada is that AGC has already digitized most of the geological and petrophysical information from exploratory wells and these data can be easily incorporated into the StratWorks data base. StratWorks is fully compatible with SeisWorks and Z-Map Plus, producing a seamless interpretation environment.

This fully integrated Facility encompasses capabilities to process, manipulate, interpret and map geological information from reflection seismic and geological data at a level seldom found outside of commercial organizations. Even though these software packages were designed by and for the petroleum industry, they can also be used for non-conventional applications such as processing and interpreting the high resolution seismic data frequently collected in environmental studies. This is providing AGC environmental marine geologists with a technology that has been previously unavailable to them.

Interpretation Examples

Figure 4 shows views of two buried surfaces at the Terra Nova oil field in the Jeanne d’Arc Basin, offshore Newfoundland. Neither one of these interpretations would have been possible before the advent, during the 1980’s, of 3-D marine seismic surveying and interactive workstation technology. For orientation, the fault at the left of Figure 4a and the fault in the centre of Figure 4b are the same feature; north is at the top in Figure 4a and at the bottom in Figure 4b.

Figure 4a is a horizon amplitude map (slice) of the Upper Jurassic, Kimmeridgian unconformity (Enachescu, 1993; Enachescu and McAlpine, 1992). Here can be seen a spectacular paleo-drainage system. This surface is about 155 million years old and now lies between 3000 and 3400 metres below the sea floor. Meanders, oxbow lakes and at least two generations of channels are clearly visible. This figure was constructed by mapping the amplitude variations along a time structure event picked in a 3-D seismic data volume.

Figure 4b is a 3-D perspective diagram with shaded relief created at the AGC Client Facility by John Shimeld as part of his Masters Thesis at Dalhousie University. This image is a detailed interpretation of a 3-D seismic data volume that clearly shows fault patterns on the 138 million year old “B” Marker, a Cretaceous limestone unit about 900 metres above the Kimmeridgian unconformity. Faults with vertical displacement of less than 10 milliseconds (about 30 metres at this depth) can be seen on this image. This research is focused on the role of faults in the migration of hydrocarbons within the Jeanne d’Arc Basin.

The Future

The large volume of data and varied data types in the National Digital Geoscience Data Library presents some problems in searching for specific data in a particular area of interest. To overcome this we are developing a GIS based interface for accessing the data. This interface will give users a geographic view of where data exist and a visual key as to the type of data available. When this is linked with other existing GIS information at AGC a powerful tool will exist to gather quickly and efficiently the information necessary to answer specific geological and environmental issues.

Conclusions

1. The GSC has been donated a national resource of seismic data, some in areas that may not be surveyed again in the foreseeable future. This is in recognition of GSC’s positive relationship with the energy industry. The cost of acquiring and processing the donated data has been estimated at over $1,000,000,000.

2. This national resource is being preserved as part of a National Digital Geoscience Data Library and is accessible for ongoing and future scientific research to serve the energy and environmental interests of all Canadians.

3. AGC has established a state-of-the-art Client Facility for processing and interpreting digital geophysical and geological data. This Facility is being made available for the academic and non-profit research community to encourage collaborative research into the formation and evolution of sedimentary basins, including their oil and gas potential.

4. The Facility is having a tremendous impact on the way AGC interprets subsurface data and the oil and gas potential of Canada’s frontier basins. It also has non-conventional applications such as in processing and interpreting high resolution seismic data deriving from environmental studies.

5. AGC continues to show leadership in the fields of energy and the environment by interacting with clients in a way that is beneficial to Canada.

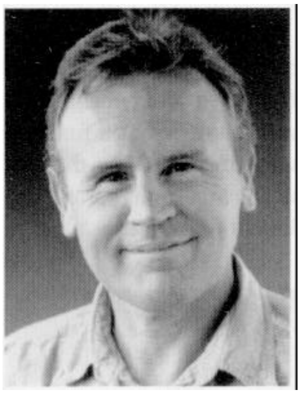
References

ENACHESCU, M.E. 1993. Amplitude interpretation of 3-D reflection data. The Leading Edge. Vol. 12, No. 6: 678-685.

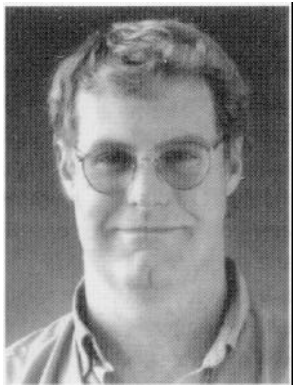
ENACHESCU, M.E. and K.D. MCALPINE, 1992. Three-dimensional seismic imaging of a Kimmeridgian paleo-drainage system in the south Jeanne d’Arc Basin, Grand Banks of Newfoundland, *In* Program with Abstracts, Geological Association of Canada/Mineralogical Association of Canada Joint Annual Meeting, Wolfville, May 25-27, 1992, v. 17, A117 p.

Instrumentation for *In Situ* Monitoring of Marine Sediment Geodynamics

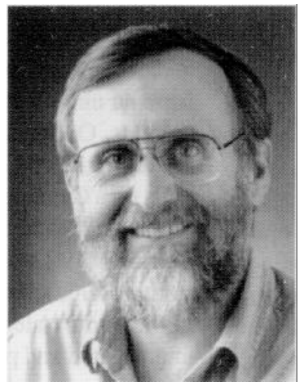
C. L. Amos, H. A. Christian, D. E. Heffler, and W. MacKinnon



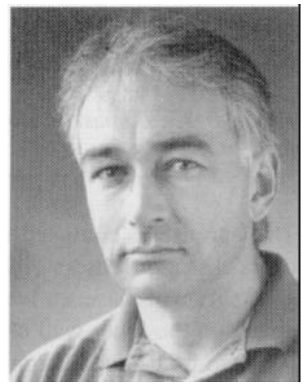
C. L. Amos



H. A. Christian



D. E. Heffler



W MacKinnon

General Introduction

Marine sediment geodynamics is the collective term used to describe the forces controlling the motion of seabed sediments within the marine environment and the consequent sediment response. This response embraces mass movements through slumping, sliding, and liquefaction at one extreme, and particle-by-particle transport as bed load or in suspension at the other extreme (Hodgins et al. 1986). A continuum of scales of sediment motion prevail between these extremes. Slumping is usually viewed as catastrophic, as it is triggered by unpredicted events such as earthquakes, rapid sedimentation or high gas content within the seabed. A well-known example of a massive slump is the 1929 Grand Banks event (Piper and Normark, 1982). It takes place rarely but may be very large in size. *In situ* information on sediment liquefaction susceptibility is essential in order to define the potential for slumping or the onset of liquefaction.

Particle-by-particle transport (also called sediment transport) is controlled by hydrodynamic and biological forces at the seabed (Middleton and Southard, 1984). These forces include: wave oscillatory motion under surface gravity waves or breaking internal waves; mean flows resulting from tidal currents; wind-driven currents; impinging oceanic gyres; or density-driven currents. Sediment transport produces a less obvious effect over the short-term, but is often long-lived. The impact of sediment transport may be viewed as chronic and the net effect may be greater than the effect of slumping. It takes place in almost all marine envionments from the tidal flats of the Bay of Fundy (Amos and Long, 1980) to the deep abyssal plains of the world's oceans (Hill et al. 1990). Sediment transport is important in geological reconstruction, in placer mineral exploration, in environmental impact assessment, and in engineering risk assessment.

Studies of sediment geodynamics are presently being undertaken in a wide variety of applied issues. These include: (1) the evaluation of the stability of the Fraser River delta foreslope which is of concern to southern British Columbia (Christian, 1993; Hart et al. 1992); (2) the determination of the stability of dredged material disposal sites in coastal waters (Fredette et al. 1992); (3) the evaluation of scouring potential of seabed installations (Philpott, 1986); and (4) the burial rates of power cables in the Straits of Georgia, B.C. For contaminated sites, it is desirable to determine the rate at which dissolved chemical compounds are transported by advecting porewaters back into the water column, as well as the conditions under which seabed instability might arise. Geophysical studies in areas of high gas concentration require better groundtruth in the evaluation of seabed geohazards restricting development.

The factors influencing sediment transport in the marine environment are extremely complex and poorly known. Consequently the Geological Survey of Canada has designed, developed and tested a series of instruments for the purposes of monitoring seabed instabilities and the forces causing the instabilities. These instruments include Sea Carousel, Submersible Observatory of Benthic Stability (SOBS), RALPH, LANCELOT and EXCALIBUR.

The Sea Carousel

Sea Carousel, named after the carousels of Postma (1967) and Hydraulic Research Limited (Burt, 1984) is a benthic annular flume designed for field use in intertidal and subtidal settings. The carousel is 1.0 m in radius with an annulus 0.15 m wide and 0.30 m high (Figure 1). It weighs approximately 150 kg in air and 40 kg in water and is made entirely of aluminium. Flow in the annulus is induced by rotating a movable lid that is driven by a 0.35 hp DC motor powered from the surface. Eight small paddles, spaced equidistantly beneath the lid, induce a flow of water in the annulus.

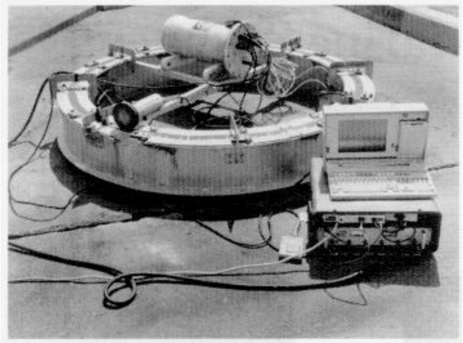


Figure 1: Sea Carousel - a benthic annular flume

The Carousel is equipped with three optical backscatter sensors (OBS's; Downing, 1983). Two of these are located non-intrusively on the inner wall of the annulus at heights of 0.03 and 0.18 m above the skirt (the skirt is a horizontal flange situated around the outer wall of the annulus 0.04 m above the base; it was designed to standardize penetration of the flume into the seabed). The third OBS detects ambient particle concentration outside the annulus, or it may be used to detect internal sediment concentration at a height between the other two. The OBS sensors give linear responses to particle concentration (of a constant size) for both mud and sand over a concentration range of 0.1 to 50 g/L (Downing and Beach, 1989). A sampling port, through which water samples may be drawn, is situated in the outer wall of the annulus at a height of 0.2 m above the skirt. It is used to calibrate the three sensors under well mixed conditions.

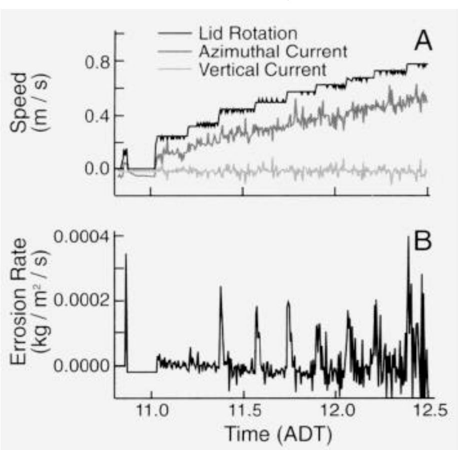


Figure 2: A time-series of results from Sea Carousel, deployed on the muddy tidal flats of Minas Basin, Bay of Fundy: (A) lid rotation, and azimuthal and vertical current speeds, and (B) sediment erosion rate (kg/m^2/s).

Flow within the carousel was determined from a relationship between azimuthal speed and lid rotation presented in Amos, Grant et al. (1992). Mean tangential lid rotational speeds are detected through a shaft end-coder resting on the lid. Tangential (U_y) and vertical (U_W) current speed is detected by a Marsh-McBirney EM flow meter (model 513) situated circa 0.16 m above the bed. Controller boards for each sensor and necessary power (12 VDC) are derived from an underwater pod located above the annulus. Output voltages from all sensors are digitized and transformed to scientific units on a Campbell Scientific(R) CR10 data logger and stored on a Campbell Scientific(R) SM192 storage module (storage capacity of 96,000 data values), also located in the underwater pod. The data logger is interrogated and programmed from the surface using a computer linked to the data logger through an RS232 interface. Maximum sampling rate of all channels is approximately 2 Hz, whereas U_Y and U_W may be logged at rates up to 10.66 Hz. All channels may be monitored and displayed on the surface computer allowing the operator to control the experiment interactively. Bed shear stress is varied in time by varying the power supplied to the underwater motor (0 to 350 watts) via a surface power supply. The data stored from each deployment may be downloaded remotely through the RS232 cable at the end of each experiment and the storage module re-initialized.

A window is located in the inner flume wall to observe and record the mechanics of bed failure. Visual observations are made using a Sony Handycam 8 mm video recorder model CCD-V11 held in an Amphibico, Amphibian V11 underwater housing. Light is provided by two 100-watt underwater lights powered from the surface. The housing has a lens that corrects for underwater geometric distortions and so is suitable for accurate image scaling. The camera images 60 frames/s. A co-axial cable connects the camera to a surface monitor for real-time detection and recording. Sequential video images are digitized to measure particle trajectories at varying heights above the bed. From these, velocity profiles are constructed. From such profiles, thicknesses of the logarithmic part of the benthic boundary layer are determined and friction velocities computed. These latter values may then be compared with laboratory measures.

Results of the Sea Carousel and subsequent interpretations are given in Amos, Daborn et al. (1992). An example is shown in Figure 2. It shows a time-series recorded on the muddy tidal flats of Minas Basin, Bay of Fundy. Figure 2A shows the incremental increases in lid rotation and current speed through the deployment, and Figure 2B shows the associated rates of bed erosion (kg/m^2/s). Note the high rates of erosion at the onset of each increase in current speed. Results from such deployments yield the bed resistence to erosion as a function of depth below the mudline, and the erosion rate. These are important parameters controlling sediment transport.

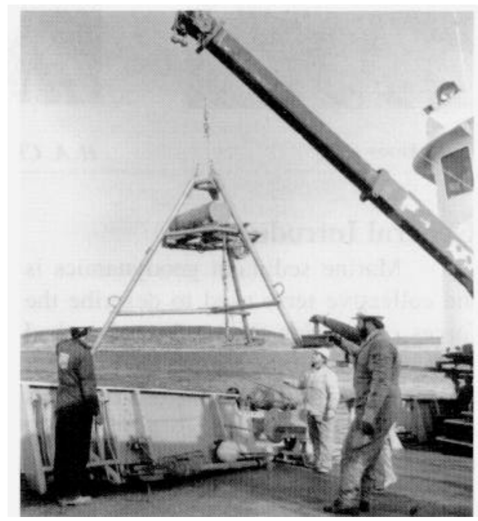


Figure 3: SOBS a benthic multiparameter tripod for detecting resuspension events.

The Submersible Observatory of Benthic Stability (SOBS)

The Submersible Observatory of Benthic Stability is a benthic tripod that is equipped with six Optical Backscatter Sensors (OBS's; Downing and Beach, 1989), a pressure transducer and a down-looking Hi8 Sony(R) video camera that records burst of imagery at pre-programmed intervals and durations (Figure 3). The lower OBS sensor is oriented in a down-looking mode at a height of 0.13 m above the base. The remaining 5 sensors are located from 0.16 to 1.8 m above the base in a logarithmic progression: 0.16 m; 0.27 m, 0.41 m; 0.95 m; and 1.80 m. The Sony Hi8 video camera is housed in an Amphibico(R) underwater housing. It is installed 0.43 m above the tripod base and is oriented approximately 45° from the horizontal to give a field of

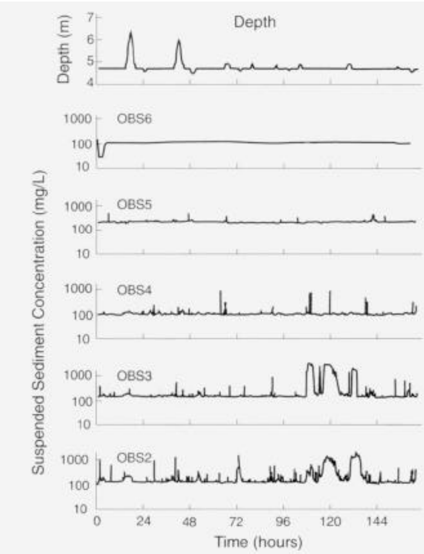


Figure 4: A time-series of results from SOBS, deployed in inner Miramichi Bay. The plot shows suspended sediment concentrations for OBS sensors 2-6 (OBS1 was buried), and water depth. Note the three near-bed resuspension events which were caused by strong wave activity.

view of *circa* 1 m^2. The seabed is illuminated by two Amphibico(R) 75-watt lights mounted normal to the field of view of the camera. Two AccuStar(R) clinometers, installed in the pressure case, give information on the attitude of the tripod from horizontal along two orthogonal axes. These sensors are sensitive to changes of .07°. A Data Instruments(R) pressure sensor records hydrostatic pressure to 200 psi (132 m), and is sensitive to 1 psi (0.7 m) changes. The system is powered by two 12-volt Sonnichsen(R) batteries capable of delivering 126 amp-hours of power. System control and data logging is controlled by a Tattletale(R) 6 data logger attached to a 20 Mbyte hard-drive. Data from each of the OBS sensors and the pressure sensor is logged at a rate of 1 Hz and is stored on the hard-drive. At this sampling rate, SOBS can operate for 7 days.

A 6.5 day (165 hours) time-series is shown in Figure 4. It shows SOBS measurements made in inner Miramichi Bay during July, 1993. The data shows 3 significant turbid events approaching the end of the deployment in the lowermost OBS's (2 and 3). These events have been correlated with periods of strong wind/wave activity in the bay and are caused by wave resuspension.

RALPH

RALPH is a free standing, instrumented tripod (Figure 5) described by Heffler (1984). The package consists of 2 Sea Tech transmissometers mounted at 37 cm and 68 cm above the seabed, 2 EG&G Smart Acoustic Current Meters (SACM's) mounted 50 cm and 100 cm above the seabed. A pressure transducer mounted 2 m above the bed is used to measure waves and tides with a resolution of a few centimetres. A downward looking super 8 mm movie camera (Minolta XL401) is synchronized with a 35 J flash for time lapse photography of bedforms. The nodal line of the camera is set 20° from the nadir, to produce a field of view of approximately 1.0 x 1.5 m. One roll of film has 3600 frames which may be viewed either as a movie or frame-by-frame. RALPH also has tilt and roll sensors as well as a fluxgate compass to define orientation.

RALPH is controlled by a microcomputer to store bursts of data at preset intervals. It is powered efficient and can be deployed for several months at a time. It is powered by two 12 v Sonnichsen batteries. Data are stored using a Tattletale 6 computer with a 20 Mbyte hard disk.

An example of a RALPH time-series is shown in Figure 6. The example, collected on Sable Island Bank, shows 2 groups of waves. Notice that sand is resuspended (see transmittance) under these waves, by the strong oscillatory motion near the seabed.

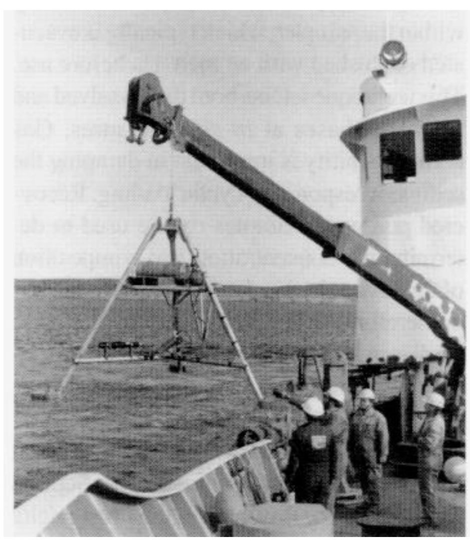


Figure 5: RALPH - a benthic multiparameter tripodfor detecting sediment transport events, and bedform stability.

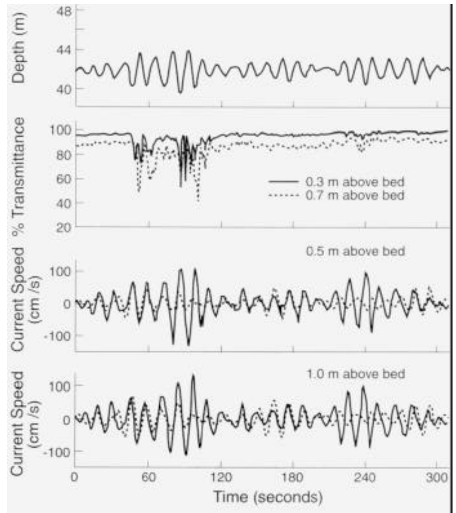


Figure 6: A time-series of a burst collected by RALPH on Sable Island Bank.

RALPH has been deployed in the nearshore zone as well as on the continental shelf. It has recorded useful data during 10 years of service. Upgrades to the sensor array and the control computer will give RALPH a continued usefulness

LANCELOT

LANCELOT is a remotely-deployed, autonomously operated seabed instrument that measures pore pressure at selected levels within the upper 6 m of sediment. It is used to determine the rate of consolidation and permeability of sediment, useful in analyzing the volume and migration rates of pore fluids within the sediment column. In *situ* testing in the deep-sea is undertaken by lowering it on a cable from a surface vessel. In shallow water, the instrument is deployed on a mooring as shown in Figure 7. The deep-sea system consists of a long stinger (3-6 m) and a telescoping electronic assembly (Christian et al. 1993). A porous filter stone located near the probe tip transmits the *in situ* pore pressure, which is sensed by an internal differential pressure transducer. It is logged relative to the hydrostatic water pressure (Figure 7b). Water depth, roll, pitch and vertical acceleration data are also stored in an onboard datalogger. Deployments typically last several hours. Additional memory can be installed to permit deployments lasting 28 days or more (Christian and Heffler, 1993).

Excess porewater pressures beneath the seabed may arise through natural hydrodynamic processes or through anthropogenic

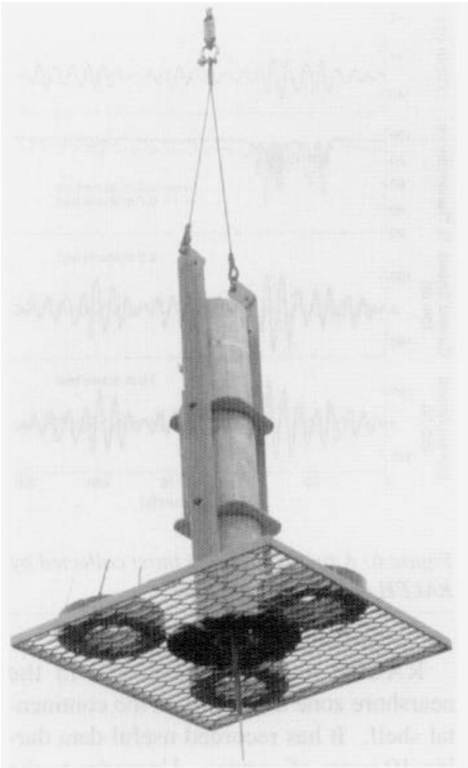


Figure 7: Deployment of EXCALIBUR during 1992 CSS Hudson *cruise 92028 to Grande Baleine, Hudson Buy. Note needle probe attached to hare of pressure case housing electronics and remote datalogger.*

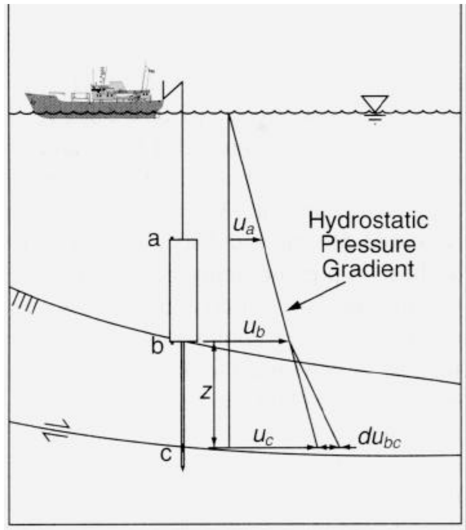


Figure 8: Schematic of pressure measurement points on LANCELOT and EXCALIBUR, for a deployment where the porous filter stone on tip is embedded within a seabed failure plane. Water column (hydrostatic) pressure reference (u_a) *monitored at port (a) throughout deployment; excess pore pressure (du,) measured between points b and c on stinger: With Excalibur, fluid sample enters at point c.*

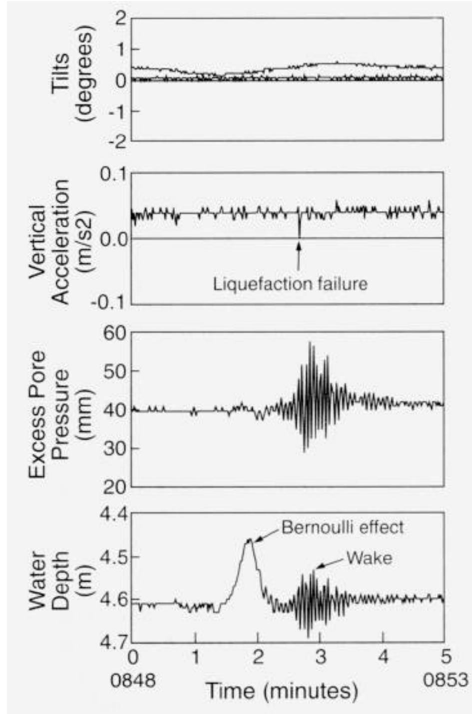


Figure 9: LANCELOT record from margin of dredged ship channel in Miramichi Inner Bay illustrating the surface wave disturbance caused by passage of fully-loaded tanker; as well as induced cyclic excess pore pressures for a point 50 cm below seabed. Note that the vessel wake triggered settling of the probe, through sediment liquefaction. Long-period wave trough along ship's hull had no effect on stability, as induced pore pressure changes were able to dissipate.

causes. Excess pore pressures du_{bc} within the seabed can develop under conditions where the expulsion of pore fluid is inhibited (Figure 8). The consequent reduction in sediment shear strength is the main cause of liquefaction failure and slumping.

LANCELOT was used in Miramichi Inner Bay, New Brunswick to investigate the stabilization of newly-dumped material. An example from this study is given in Figure 9. The example shows surface wave loading of the seabed caused by close passage of a fully-loaded bulk petroleum carrier. Note the extended pressure-reduction in the water column measurement brought about by the acceleration of flow along the ship's hull. This long-period wave did not result in a subseabed excess pore pressure response. High-frequency waves in the ship wake however led to a rapid cyclic pore pressure response, which triggered liquefaction failure (settlement). These observations suggest that the organic clayey silts of the site developed excess pore pressures only during rapid cyclic loading, due to their low permeability.

EXCALIBUR

EXCALIBUR is a re-development of Lancelot, built to provide the additional capability of recovering pressurized pore fluid samples. Such samples are used to study in situ gas concentrations and contaminant composition. The collection of a fluid sample under controlled conditions allows direct measurement of sediment permeability, through analysis of the pressure buildup within the sampler, which typically is evacuated or flushed with an inert gas before use. This technique retains both the dissolved and free-gas phases at in situ pressures. Gas compressibility is important in damping the sediment response to cyclic loading. Recovered porewater samples can be used to determine the concentration and composition of dissolved chemical compounds. Excalibur is therefore well-suited to contaminant/gas studies in soft seafloor sediments, since specific horizons can be targeted.

EXCALIBUR has been used with great success in field programs on the Scotian Shelf, in James Bay, and on the Fraser delta (Christian, 1993). Further development included the addition of an acoustic modem to allow real-time communication and control of the device through the water column. Figure 10 shows a complete deployment record from a field test conducted within a 100 m wide and 10 m deep pockmark in Emerald Basin, on the Scotian Shelf. The water column pressure response shows short calibration periods during deployment and retrieval as well as a rapid reduction in pressure upon the onset of sampling. Permeability k is determined from the pressure equalization curve. From this, an accurate determination of seepage velocities of migrating pore fluids can be made. New possibilities exist to obtain subseabed samples of contaminated fluids, as well as pressurized pore gases, through direct sampling of key horizons below the seabed, to water depths of 1000 m.

References

AMOS, C.L. 1990. Modem sedimentation processes, Chapter 11 *In* M.J. Keen and G.L. Williams [ed.] Geology of the Continental Margin of Eastern Canada. Geological Survey of Canada. Geology of Canda, no. 2: 609-673.

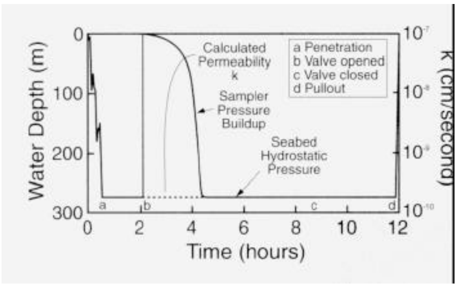


Figure 10: EXCALIBUR inflow permeability test result from its first deployment within a 100 m wide pockmark in Emerald Basin, on the Scotian Shelf. The probe penetrated to 60 cm. Legend indicates the onset of fluid sampling at point (b) *and closure of the internal valve at (c). Coefficient of permeability was calculated from the internal pressure buildup, from an initial vacuum within the sample container.*

AMOS, C.L. and B.F.N. LONG. 1980. The sedimentary character of the Minas Basin, Bay of Fundy. *In* S.B. McCann [ed.] The Coastline of Canada. Geological Survey of Canada. Paper 80-10: 153-180.

AMOS, C.L., J. GRANT, G.R. DABORN, and K. BLACK. 1992. Sea Carousel - A benthic annular flume. Estuarine, Coastal and Shelf Science 34: 551-577.

AMOS,C.L., G.R.DABORN, H.A. CHRISTIAN, A. ATKINSON, and A. ROBERTSON. 1992. *In situ* erosion measurements on fine-grained sediments from the Bay of Fundy. Marine Geology 108: 175-196.

BURT, T.N. 1984. The Carousel: commissioning of a circular flume for sediment transport research. Hydraulic Research Limited Report SR 33.

CHRISTIAN, H.A. 1993. *In situ* measurement of consolidation and permeability of soft marine sediments. Proceedings of the 4th Canadian Conference on Marine Geotechnical Engineering, St. John's, Newfoundland, 28-30 June, 2, p. 662-679.

CHRISTIAN, H.A. and D.E. HEFFLER. 1993. Lancelot -A seabed piezometer for geotechnical studies. Geo-Marine Letters, 13: 189-195.

CHRISTIAN, H.A., D.H. HEFFLER and E.E. DAVIS, 1993. Lancelot - an *in-situ* piezometer for soft marine sediments. Deep-Sea Research, 40(7): 1509-1520.

DOWNING, J.P. 1983. An optical instrument for monitoring suspended particulates in ocean and laboratory *In* Proceedings of Oceans '83: 199-202.

DOWNING, J.P. and R.A. BEACH. 1989. Laboratory apparatus for calibrating optical suspended solids sensors. Marine Geology 86: 243 -249.

FREDETTE, T.J., J.D. GERMANO, D.A. CAREY. P.M. MURRAY, P.G KULLBERG. 1992. Chemical stability of capped dredged material disposal mounds in Long Island Sound, USA. Chemistry and Ecology 7: 173-194.

HART, B.S., D.B. PRIOR, J.V. BARRIE, R.G CURRIE, and J.L. LUTERNAUER. 1992. A river mouth submarine channel and failure complex, Fraser Delta, Canada. Sedimentary Geology 81: 73-87.

HEFFLER, D.E. 1984. RALPH -An instrument to monitor seabed sediments. Current research Part B, Geological Survey of Canada Paper 84-1B, 47-52.

HILL, P.R., D.E. BUCKLEY, and D.J.W. PIPER. 1990. The continental slope, rise and deep sea. The classification of deep sea environments. *In* M.J. Keen and G.L. Williams [ed.] Geology of the Continental Margin of Eastern Canada, Geological Survey of Canada, Geology of Canada, no 2: 609-673.

HODGINS, D.O., D.A HUNTLEY, W.D. LIAM FINN, B. LONG, G. DRAPEAU, and A.J. BOWEN. 1986. Bottom sediment transport - Present knowledge and industry needs. Environmental Studies Revolving Funds Report 27, 394p.

HYDRAULICS RESEARCH LIMITED, 1987. Deposition of cohesive sediments in an annular flume. Unpublished Internal Report: 5p.

MIDDLETON, G.V. and J.B. SOUTHARD. 1984. Mechanics of Sediment Movement. Society of Economic Paleontologists and Mineralogists Short Course No. 3.

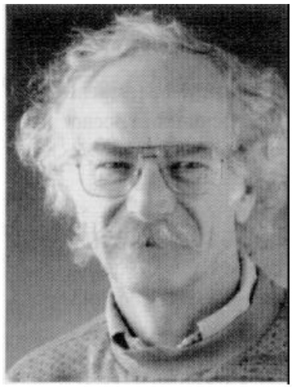
PHILPOTT, K. 1986. Scour around seafloor structures. Environmental Studies Revolving Funds Report 17, Ottawa. 249p.

PIPER, D.J.W. and W.R. NORMARK. 1982. Effects of the 1929 Grand Banks earthquake on the Continental Slope off Eastern Canada. Current Research, Part B. Geol. Survey of Can. Paper 82-1B: 147-151.

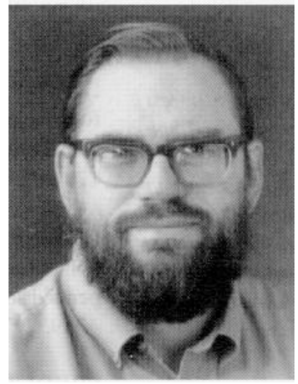
The Ocean's Role in the Climate System

D. G. Wright, J. R. N. Lazier and R. A. Clarke

D. G. Wright



J. R. N. Lazier



R. A. Clarke

Even the casual observer realizes that the oceans play an important role in determining the present climate, primarily as the major water reservoir for the planet. The devastating effects of an El Nino event provide striking evidence of the impact of "minor" redistributions of water around the globe. However, it may not be nearly so obvious that the oceans can cause major climate change. In fact, the oceans are far more than just a water reservoir, and in this essay we consider some effects which are intrinsically linked to ocean dynamics.

Heat Storage

The oceans are important to climate change because of their enormous capacity to store and transport heat. It takes four times as much heat to increase the temperature of a kilogram of water as it does to increase the temperature of a kilogram of air by the same amount. Since 10 metres of water have the same mass as the atmosphere above it, we see that just 2.5 metres of water have about the same heat capacity as the entire atmosphere above.

Because of their large heat capacities, the oceans serve as a temporary storage tank for heat. Heat is absorbed during warm periods (daytime, summer, etc.) and released during cooler periods (night-time, winter, etc.), reducing atmospheric temperature fluctuations. Of course, the amount of heat that can be stored depends on the depth of the ocean that can be accessed. Fortunately, as the timescale of interest increases, temperature anomalies penetrate to greater depths in the ocean so that more heat may be stored, and the ocean can affect atmospheric temperature fluctuations over a broad range of frequencies. For example, numerical models have shown that global warming associated with increased greenhouse gases could be delayed by more than a decade due to the ocean's ability to store and release heat.

Figure 1 illustrates a simplified analogue of the flow of heat through the atmosphere-ocean system which may help the reader to contemplate the importance of the ocean as a heat reservoir. The analogue is composed of two cylinders containing water and connected by an adjustable valve. The water represents our analogue for heat, and the water level represents temperature. The smaller cylinder represents the atmosphere, the larger cylinder represents the global ocean with its larger heat capacity, and the valve connecting the two cylinders represents all processes influencing the exchange of heat across the air-sea interface. The tap feeding into the "atmospheric" cylinder represents incoming short wave radiation, while the tap controlling flow out of this cylinder represents outgoing long wave radiation, which increases with the water level (temperature) of the "atmospheric" cylinder.

Many simple but informative experiments may be considered using this qualitative model of the climate system. For

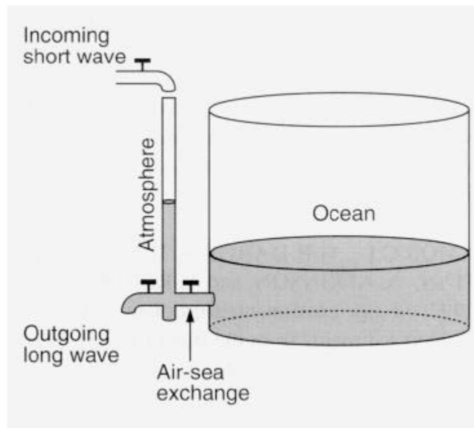


Figure 1: A simple annlogue of the earth's climate system.

example, the reader may visualize the response of surface air temperature to an increase in the incoming short wave radiation by further opening the tap feeding into the atmospheric cylinder, or the response to increased greenhouse gases by turning down the outgoing tap. By adjusting the valve connecting the "ocean" and "atmosphere", or adjusting the relative sizes of the "ocean" and "atmosphere" cylinders, you will easily visualize some of the effects that the ocean's ability to exchange heat with the atmosphere can have on climate variations.

Of course, this simple model is limited. Among other problems, it considers a single heat capacity for the global ocean when in reality different processes can involve more and more of the oceans' volume and hence greater and greater heat capacities. Conceptually, we could include a series of containers representing the different parts of the ocean, each connected to its neighbours by valves. Such a system is complicated by the fact that accurate representations of the processes involved in the exchanges are required: the determination of appropriate formulations is an area of active research.

Heat Transport

The ocean's role in the climate system goes further than serving as a storage tank for water and heat. Because of its large heat capacity, even relatively slow flows can move large amounts of heat around the globe. The best available estimates indicate that the north-south transport of heat across mid-latitudes by the oceans is comparable to the transport by the atmosphere. This heat transport is accomplished primarily by two effects. The first contribution is associated with the large horizontal gyres driven by the surface wind stress. These currents stir the upper kilometre or so of the oceans, mixing water around entire basins. Surface water receives heat at low latitudes and the wind driven gyres carry it through the high latitude regions where excess heat is released to the atmosphere. This heat transport mechanism could change with time due to changes in wind stress or ocean density structure, and such changes would affect the earth's climate. However, it is the second heat transport mechanism that has peaked the interest of many climate modellers.

The second major contributor to meridional heat transport involves a global scale overturning circulation. Deep water generally flows from regions of high density towards regions of low density, so high densities are an energy source which can drive an overturning circulation. The resulting vertical circulation occurring in the present-day ocean is illustrated schematically in Figure 2: it has come to be known as the global conveyor belt. Deep water is formed primarily in the North Atlantic with smaller amounts being added at other locations, principally around Antarctica. From these sources, the cold, deep water flows into each of the other basins, slowly upwelling into the surface layer as it goes. Heat is added to the ocean surface at low and mid latitudes. so that the water

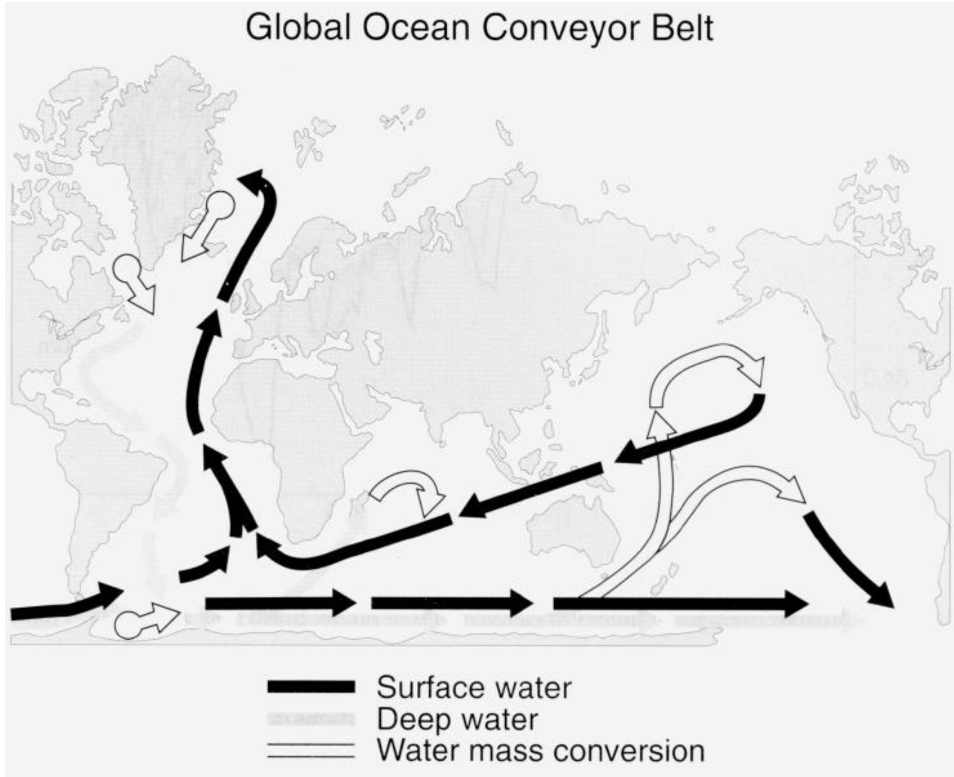


Figure 2: A schematic representation of the present-day global overturning circulation referred to as the conveyor belt. Note that there is generally net heat input to the oceans at low latitudes and that heat is releasedfrom the ocean to the atmosphere in regions of deep water formation. Present estimates indicate that on average, about 10^{15} Watts of heat are transported by the Atlantic overturning circulation across 20 degrees north. Three billion litres of water at room temperature (20°C) could be brought to the boiling point (100°C) each second by this amount of heat.

returning to the deep water production sites is relatively warm, and this heat is released to the high latitude atmosphere as part of the deep water formation process. It should be evident from Figure 2 that the North Atlantic region is a major beneficiary of ocean heat transport by the conveyor belt. Indeed, Manabe and Stouffer (1988) have used a coupled ocean-atmosphere climate model to show that surface air temperatures over the Norwegian-Greenland Sea could be reduced by as much as 10°C if the Atlantic overturning circulation were eliminated.

Potential for Change

The overturning circulation has attracted great interest because there are reasons to believe that it has changed dramatically in the past, and that it could do so again. This possibility is due to the different effects of atmospheric heat and fresh water transports on the density of sea water. Reduced radiative heating and the associated low temperatures at high latitudes cause a tendency for surface ocean density to increase towards the poles. However, the atmospheric transport of water vapour from warm low latitudes to cold high latitudes tends to decrease the salinity, and hence the density, of high latitude surface waters. If a water mass spends sufficient time at the surface in such a region of net precipitation, a stable surface layer could form and prevent convective overturning in the ocean. The influence of low surface temperatures on the waters below would be greatly reduced and the abyssal temperatures would increase due to heat input which enters the ocean through the surface at low latitudes.

The effect described above has far reaching consequences. The natural tendency is for convection to result in vertical penetration of cold, dense, high latitude water into the deep ocean, resulting in a much stronger driving force for the overturning circulation than if the density anomaly were restricted to the surface layer. However, since the high latitude regions of deep water formation are also regions of net pre-

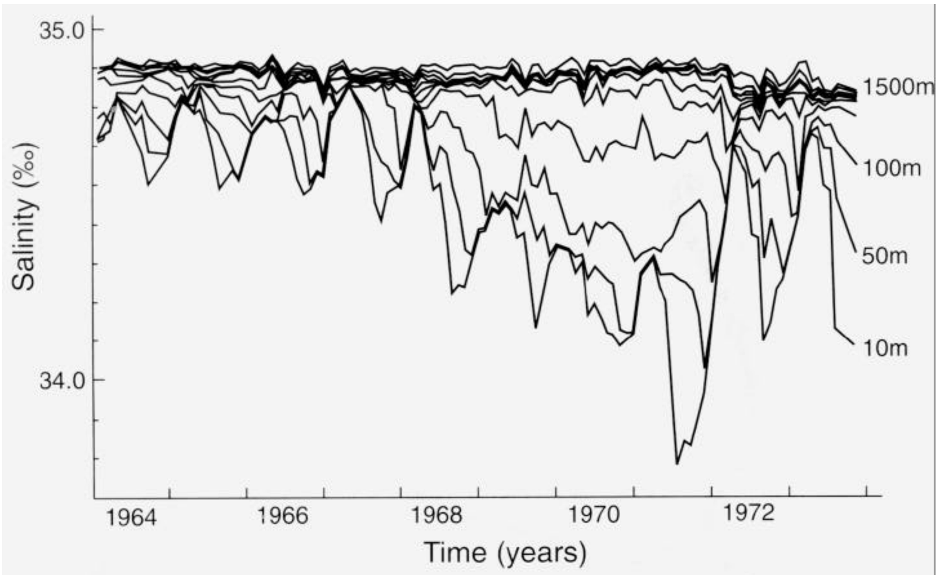


Figure 3: Monthly averages of salinity at eleven depths at station Bravo *from 1964 to 1973 (after Lazier, 1980).*

cipitation, there is always a tendency for a fresh water cap to develop which could prevent convection from occurring: the low temperatures required to fuel the circulation are still present, but freshening of the surface layer can reduce the surface density and effectively isolate the deep ocean from the low air temperatures. This possibility is enhanced by the fact that any temporary reduction in convection will increase the time that water spends near the surface. This allows more time for fresh water to accumulate which could further reduce convection. Because of this feedback, a relatively minor change in the atmospheric transport of fresh water could have a major impact on the overturning circulation, and hence on the earth's climate (Bryan, 1986).

If we think of low temperatures as the fuel for the overturning circulation, then there are three major high latitude fuelling stations: the Southern Ocean and the northern reaches of the Atlantic and Pacific basins. These locations compete for control of the global overturning circulation, and the winner benefits from a large ocean to atmosphere heat flux. The North Atlantic appears to have an advantage in this competition due to the combination of its further poleward extent and narrower width than the Pacific, and the absence of complete north-south boundaries around Antarctica. However, precipitation or runoff into the North Atlantic could overcome these advantages and result in either of the other locations dominating deep water production and hence controlling the global overturning circulation.

Why does the present state of the overturning circulation persist if there are viable competing alternatives, especially when there is net precipitation over the North Atlantic? One contributing factor is that if deep water is actively being formed in a region, then the reduced residence time of surface waters helps to prevent the development of a fresh water cap. Also, the heat released in areas of deep water formation increases the local surface air temperatures. This increases local evaporation and hence reduces the net fresh water input to the area, again helping to prevent the development of a fresh water cap. Finally, if deep water formation were reduced, then the heat loss from the ocean to the atmosphere would decrease and the resulting decrease in surface air temperatures would help to re-initiate convection.

The Need for New Data Sets

While these factors favour the persistence of the present state, the interplay between surface air temperature, atmospheric water transport and the ocean conveyor belt is not completely understood. In fact the competition between reinforcing and counteracting feedbacks in the development of a stable surface layer are so numerous, and parametrizations of unresolved motions in numerical models are so uncertain, that even with the most sophisticated models presently available, we cannot confidently predict the effect of perturbations in the climate system. Indeed, at present we do not know if the response to perturbations is predictable.

Part of the problem in developing confidence in model predictions is the scarcity of data which could help validate and refine models. One approach to alleviate this problem is the collection and analysis of standard observational data sets for currents and water mass properties. Through this approach, the present state of the ocean can be described and processes that determine this state can be studied. In addition, long term monitoring studies can gradually build up a data base to be used in studies of longer timescales.

Researchers at the Bedford Institute of Oceanography (BIO) have taken a particular interest in processes occurring in the climatically sensitive North Atlantic region. An example is the annual late spring expedition to obtain measurements of temperature, salinity, oxygen, nitrate, silicate, phosphate, chlorofluorocarbons (CFCs), carbon dioxide and tritium across the Labrador Sea (Lazier, 1988). This region is of special interest since it is known to be an area of active convective mixing. In severe winters, convection occurs over a large area and mixes the water down to 2000 metres or more (Clarke and Gascard, 1983). In the process, biologically important gases such as oxygen and carbon dioxide are transported from the surface where they are in contact with the atmosphere to great depths in the ocean. Some people say this is how the ocean breathes.

In the late 1960s and early 1970s. winter conditions in the Labrador Sea were abnormally mild and the salinity at the surface became abnormally low. The changes in salinity over this period are shown in Figure 3. Each line shows the salinity at one depth. The lowest values are near the surface and the highest are at 1500 metres. In the summer of each year freshwater from melting sea ice and runoff from land cause the salinity near the surface to decrease. In winter, cooling produces convection which mixes this lower salinity water with the deeper high salinity water. It seems that between 1968 and 1971, winter convection did not occur: for a period of about three years, the ocean stopped breathing. The purpose of the annual observations is to understand what processes control these variations and what role they play in the climate system. This remains an active area of research.

The process of collecting such data sets is time consuming, difficult and expensive, and additional data sources are constantly being investigated. Information on past climate events represents another possibility to help fill the data gap. The paleoclimatic archives contain qualitative and quantitative information about major climate events that have occurred in the past. These records indicate that the earth's climate has undergone quasi-periodic variations on timescales ranging from decades to millennia as well as abrupt step-like changes. They also indicate that the present-day conveyor belt circulation has been continuously present over the past 9000 years but there are strong suggestions that prior to this period, there were times when the North Atlantic overturning was either eliminated or greatly reduced. Such events offer an opportunity to test the ability of models to simulate major shifts in the climate system and to improve our understanding of processes affecting these shifts.

The Need for New Modelling Approaches

Attempts to validate or improve climate models through comparisons with paleo data face significant obstacles. The data themselves are incomplete and subject to interpretation: neither the forcing associated with atmospheric heat and water transports, nor the response are accurately determined. Thus a complete study generally requires examination of a range of possibilities. The situation is further complicated by the fact that general circulation models (GCMs) used in such studies are intrinsically complex, computationally expensive and time consuming to run and analyze. Combined with the very long timescales associated with paleoclimate simulations and an incomplete understanding of the nature of the system under consideration, it is clear that the task at hand is enormous, and novel approaches are required to optimize progress.

A hierarchy of lower order models which are less expensive, less time consuming and more easily interpreted have played an important role in mapping out the range of possible responses that can be expected, and in understanding the mechanisms determining these responses. Researchers at BIO are making significant contributions to this area of research. One recent effort has focused on the development and application of an efficient latitude-depth climate model. The geometry of the ocean component is illustrated in Figure 4. The model uses equations for the conservation of mass, heat and salt to determine the evolution of the zonally averaged water mass properties in each ocean basin. From this information, the density is determined and the overturning circulation is then diagnosed using a very efficient closure scheme (Wright & Stocker, 1991, 1992). The ocean model is coupled to a classical atmospheric energy balance model (Stocker et al., 1992b) which accounts for long and short wave energy exchange across the top of the atmosphere, energy absorption within the atmosphere, and heat and fresh water exchange with the ocean.

The resulting model is suitable for the study of timescales of many thousands of years, is relatively easy to interpret in comparison to GCM results, and yet exhibits response characteristics remarkably similar to those of a GCM: similar equilibrium states, stability properties and transient behaviour are found. It has been successfully applied to a variety of problems in climate research: interocean exchange of freshwater (Stocker & Wright, 1991 a,b), the effect of changing high latitude conditions (Stocker et al., 1992a), the uptake of CO, from the atmosphere (Stocker et al., 1993) and simulations of the Younger Dryas climate event (Wright & Stocker, 1993; Lehmann et al., 1993).

The Younger Dryas event provides an interesting example of a major climate change and the role of low order models in climate research. During the last Ice Age, northern Europe and North America were covered by huge ice sheets. About 14,000 years ago, the climate changed and these ice sheets began to retreat. Then between about 11,000 and 10,000 years ago, the ice sheets advanced again to near full glacial

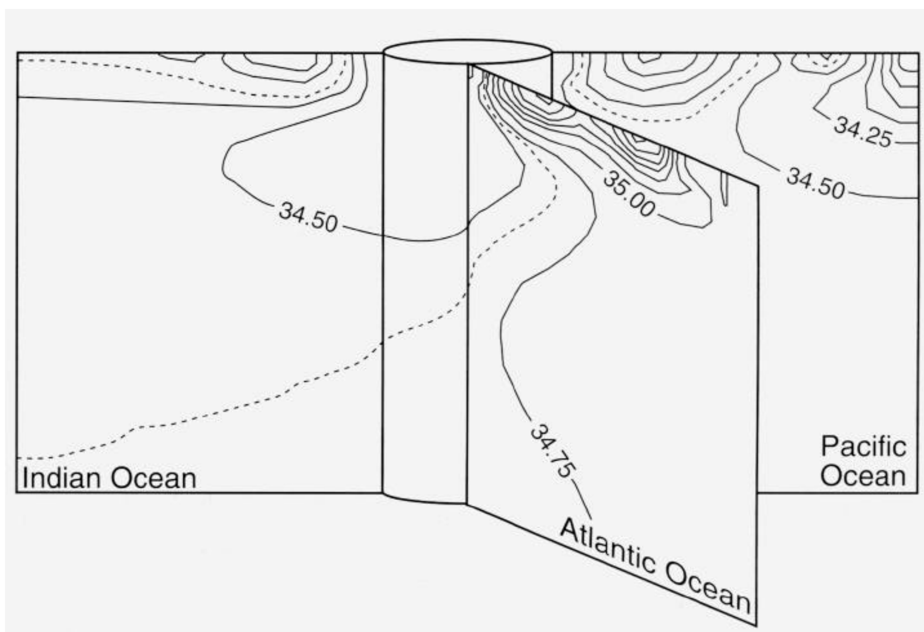


Figure 4: An illustration of the output from the latitude-depth model developed for the study of long term climate variations. The central cylinder represents the Southern Ocean and the three planar sections represent the Pacific, Atlantic and Indian Oceans. The model estimate of zonally averaged salinity under present-day surface conditions is shown. Comparison with the observed salinity field is good. A major advantage of using zonally averaged equations of motion is their computational efficiency. Even on the modest computer resources available to the Physical and Chemical Sciences Branch at BIO, a one thousand year simulation with the couple ocean atmosphere-model can be completed in under one hour.

conditions before continuing their retreat to the present state. The period of ice advance is known as the Younger Dryas event and is of special interest to climate modellers because it is a well-documented event which clearly demonstrates that major climate change can occur over a period of just a few decades. Further, it appears that this event was geographically centred over the North Atlantic where much of the deep water is formed in the present-day ocean, and this has emphasized the important role of the oceans in climate change.

Broecker et al. (1985) proposed that the Younger Dryas event was initiated when a major portion of the meltwater input to the North Atlantic was diverted from its Mississippi route to more northerly routes through the Hudson and St. Lawrence valleys. They suggested that the ocean's conveyor belt may have been shut off by the meltwater input and subsequent model studies by Maier-Reimer and Mikolajewicz (1989) and Stocker and Wright (1991b) have provided support for this basic idea. However, what caused the termination of the Younger Dryas event and why it occurred only once, remain questions of current interest. In our attempts to model this event, we found that the observed re-initiation of North Atlantic Deep Water formation did not occur unless the net precipitation in this area was reduced during the Younger Dryas. Observations presented by Alley et al. (1993) now suggest that this may have actually occurred. Our model results also suggested that glacial meltwater accumulated in the surface layers of the North Atlantic and was subsequently flushed through the deep ocean when the conveyor belt restarted. This result has suggested a re-interpretation of low $\delta^{18}O$ values seen in the sediment layer corresponding to the termination of the Younger Dryas (Lehman et al., 1993).

Significant progress has been made in the field of climate research over the past few decades, but a full understanding of what controls even the present state of the climate system, let alone the interannual, decadal, century and longer timescale variability is still beyond us. Many questions need to be addressed before we will even be able to properly quantify the reliability of predictions that have been made. The data for model validation is still very limited and we must continue to assemble new data sets both by monitoring the present system and by mining the data archives that nature has stored away for us. The continued use of a broad range of innovative approaches is required to optimize progress on this difficult and important problem.

References

ALLEY, R.B.. and 10 others. 1993. Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event. Nature. 362: 527-529.

BROECKER, W.S., D.M. PETEET and D. RIND. 1985. Does the ocean-atmosphere system have more than one stable mode of operation? Nature. 315: 21-26.

BRYAN, F., 1986. High-latitude salinity effects and interhemispheric thermohaline circulations, Nature. 323: 301-304.

CLARKE, R. A., and J. C. Gascard, 1983. The Formation of Labrador Sea Water, Part I - Large Scale Processes. J. Phys. Oceanogr. 13, 1764-1778.

LAZIER, J. R. N., 1980. Oceanographic conditions at Ocean Weather Ship Bravo, 1964-1974. Atmos.-Ocean. 18: 227-238.

LAZIER, J. R. N., 1988. Temperature and Salinity Changes in the Deep Labrador Sea, 1962-1986. Deep-Sea Research, Vol. 35: 1247-1253.

LEHMAN, S.J., D.G. WRIGHT, and T.F. STOCKER. 1993. Transport of Freshwater into the deep ocean by the conveyor. p. 187-209. *In* W.R. Peltier [ed.] NATO ASI Series, Vol 12, Ice in the Climate System. Springer-Verlag, Berlin, Heidelberg.

MAIER-REIMER, E., and U. MIKOLAJEWICZ. 1989. Experiments with an OGCM on the cause of the Younger Dryas. p. 87-100. In A. Ayala-Castanares, W. Wooster and A. Yanez-Arancibia [ed.] Oceanography, UNAM Press.

MANABE, S., and R.J. STOUFFER. 1988. Two stable equilibria of a coupled ocean-atmosphere model. J. Climate. 1: 841-866.

STOCKER, T.F., W.S. BROECKER and D.G. WRIGHT. 1994. Carbon uptake experiments with a zonally averaged global ocean circulation model. Tellus B. 46B: 103-122.

STOCKER, T.F., and D.G. WRIGHT. 1991 a. A zonally averaged ocean model for the thermohaline circulation. Part II: Interocean circulation in the Pacific-Atlantic basin system, J. Phys. Oceanogr. 21 : 1725-1739.

STOCKER, T.F., and D.G. WRIGHT. 1991b. Rapid transitions of the ocean's deep circulation induced by changes in surface water fluxes. Nature. 351 : 729-732.

STOCKER, T.F., D.G. WRIGHT and W.S. BROECKER. 1992. The influence of high-latitude surface forcing on the global thermohaline circulation. Paleoceanography. 7: 529-541.

STOCKER, T.F., D.G. WRIGHT, and L.A. MYSAK. 1992. A zonally averaged, coupled ocean-atmosphere model for paleoclimate studies. J. Clim. 5: 773-797.

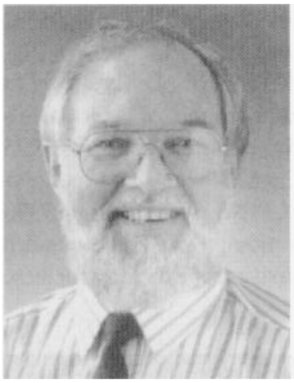
WRIGHT, D.G., and T.F. STOCKER. 1991. A zonally averaged ocean model for the thermohaline circulation. Part I: Model development and flow dynamics. J. Phys. Oceanogr. 21: 1713-1724.

WRIGHT, D.G., and T.F. STOCKER. 1992. Sensitivities of a zonally averaged global ocean circulation model. J. Geophys. Res. 97: 12707-12730.

WRIGHT, D.G., and T.F. STOCKER. 1993. Younger Dryas Experiments. p. 395-416. *In* W.R. Peltier [ed.] NATO AS1 Series, Vol 12, Ice in the Climate System. Springer-Verlag. Berlin. Heidelberg.

Electronic Chart Initiatives in the CHS

S. T. Grant



S. T. Grant

Abstract

In October of 1990 the Canadian Public Review Panel on Tanker Safety and Marine Spills Response Capability identified spill prevention as the highest priority for protecting the coastal and marine environment. Specifically it recommended that the Canadian Hydrographic Service (CHS) expedite development of electronic charting technology and the required infrastructure, and then introduce regulations requiring the use of electronic charts on all tankers in Canadian waters.

In response to this recommendation the CHS initiated a program in partnership with private industry to build the infrastructure to create and manage electronic chart data, to distribute it to ships in Canadian waters and to keep it up to date. The CHS is also contributing to the development of international and national standards for all aspects of Electronic Charts and is accumulating information that will contribute to the drafting ofappropriate legislation. The CHS is installing a number of Electronic Charts on ships and at Marine Institutes to test the infrastructure and standards and to demonstrate the technology to the marine community. This paper reports on the progress of the project to date and presents plans for the next year or two.

Introduction

On 24 March 1989 the oil tanker *Exxon Valdez* slammed onto Bligh Reef in Prince William Sound, Alaska, while avoiding ice in the main navigation channel. One of the factors that contributed to this disaster was the slow and tedious traditional navigation methods being used. These methods required the Officer-of-the-Watch to make observations and then manually plot them on the paper chart to find out where the ship was when the observations were taken - often 2 to 3 minutes earlier. An exciting new technology, generically known as the Electronic Chart, that continuously plots a ship's position on a high resolution video screen over a digitized nautical chart background, could have prevented this accident.

Following the grounding of the *Exxon Valdez,* the Canadian Public Review Panel on Tanker Safety and Marine Spills Response Capability (1990), chaired by Mr. D. Brander-Smith, identified spill prevention as the highest priority for protecting the coastal and marine environment. This panel recommended that:

"In order to reduce the risks of accidents the Canadian Hydrographic Service: Expedite development of the electronic charting technology and the required infrastructure, then introduce regulations requiring the use of electronic charts on all tankers in Canadian waters."

In June 1991, the Ministries of Transport, Environment, and Fisheries and Oceans announced a commitment of $l00M for a New Marine Environmental Emergencies Response Strategy that called for the development of a new electronic navigation chart capability that can alert ships to possible groundings or collisions.

The CHS Strategic Plan for the accomplishment of these goals divided the task into three distinct but interdependent subprograms:

- The Electronic Chart Demonstration Project
- The Electronic Chart Data Infrastructure Program
- National and International Standards Development

The Electronic Chart Demonstration Project

Electronic Charts (ECs) generally fall into two categories; those that will be recognized as being legally and functionally equivalent to the paper chart, known as Electronic Chart Display and Information Systems (ECDIS), and systems that complement but do not replace the paper chart on the ship's bridge known as Electronic Chart Systems (ECS). The expression 'will be recognized' in the previous sentence refers to the fact that regulations do not presently exist anywhere in the world certifying an ECDIS. However, an ECDIS Performance Standard, developed jointly by the International Maritime Organization (IMO) and the International Hydrographic Organization (IHO), was submitted to the IMO in September 1993 and could be approved in 1995. It will then be up to individual Nations to adopt and/or adapt those standards and implement procedures to cer-

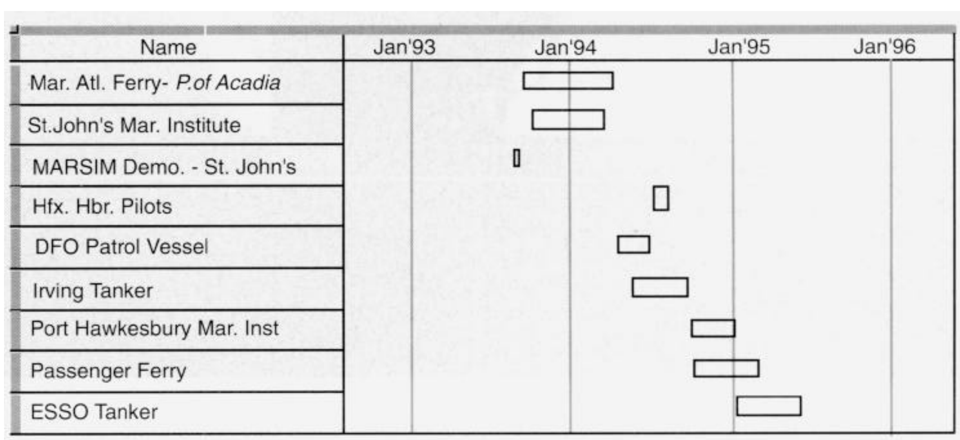


Figure 1: ECPINS Deployments in Atlantic Canada

tify that equipment complies with the standards. Two key elements for the efficient and effective use of ECDIS are accurate positioning, such as can be provided by the Differential Global Positioning System, and accurate up-to-date digital Hydrographic Office chart data described as the Electronic Navigational Chart (ENC).

Although the ECDIS Performance Standard is presently before IMO many of the details are still being developed, tested and evaluated by a number of countries. In Canada these tests are being done as part of the CHS Electronic Chart Demonstration Project. The following specific tasks are being addressed:

- work with the clients to develop specifications which will address their needs
- build the appropriate ENC files for the major tanker routes in Canada
- test and evaluate existing and proposed standards for systems and data
- work with Marine Institutes across Canada to develop ECDIS training programs to ensure users are aware of the strengths and limitations of the new technology.

To conduct these tests the CHS established a partnership with Offshore System,, North Vancouver, B.C., a leading world supplier of ECDIS-like equipment called ECPINS (Electronic Chart Precise Integrated Navigation System). Six systems were purchased and by end of 1993 a dozen different public demonstrations and/or installations on ferries, tankers and at marine institutes had taken place across Canada. The deployments in Atlantic Canada are summarized in Figure 1 and the ECPINS display is shown in Figure 2. A similar number of deployments are scheduled for 1994 and plans for 1995 are underway. Canada Steamship Lines purchased eleven ECPINS systems during 1993 so the demonstration project was expanded to include the provision of ENC data for these systems.

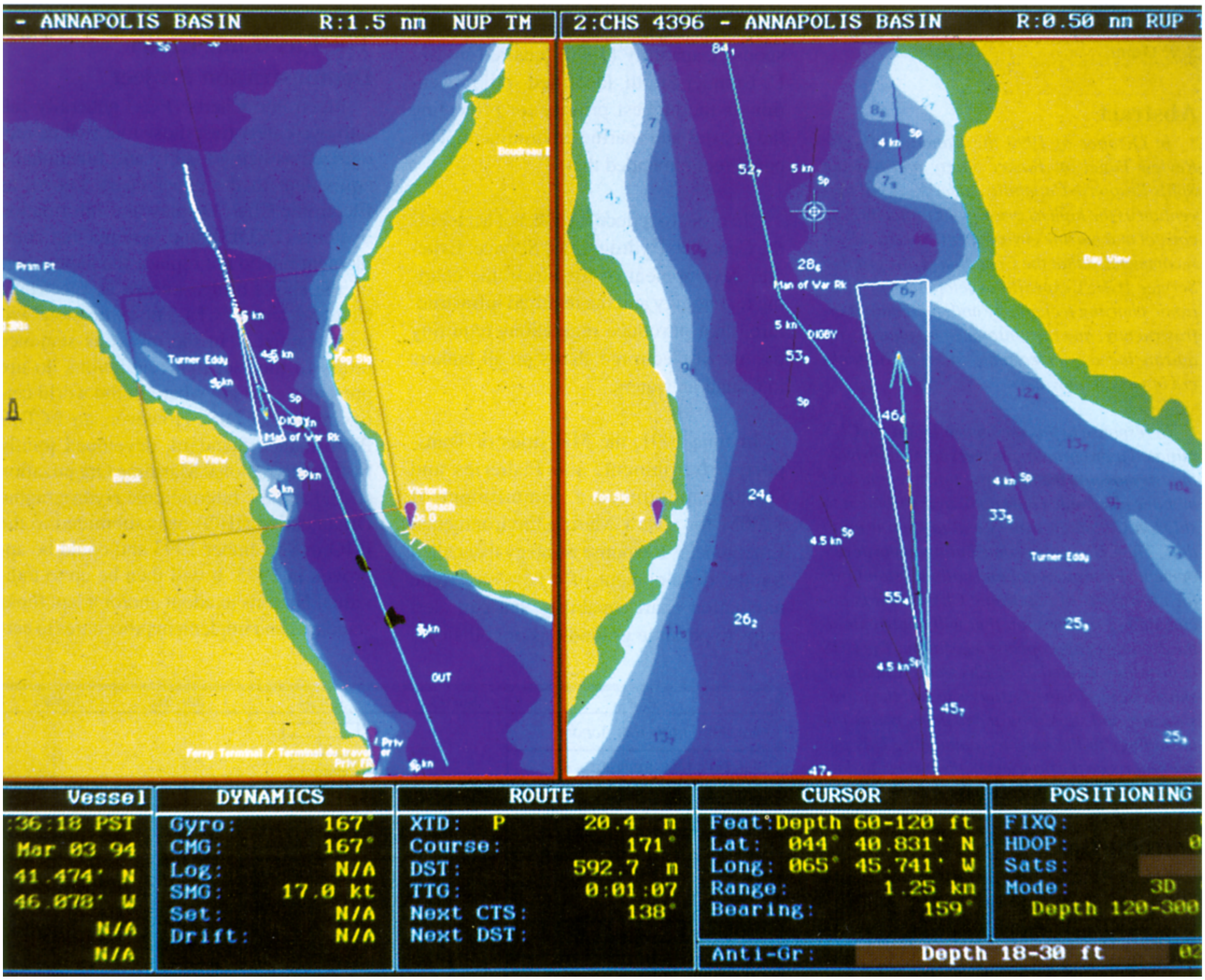


Figure 2: This figure shows the Canadian ECPINS Electronic Chart Display and Information System manufactured by Offshore Systems, N. Vancouver, B.C. Shown is the system in operation aboard the Marine Atlantic Ferry Princess of Acadia *entering Digby Gut in it's 'split screen' configuration; the screen on the right is 'ship's head up' while the screen on the left is 'north up'. The triangle ahead of the vessel is the operator set danger rector that the system automatically scans for dangers to navigation. The arrow is the vessel's Course / Speed Made Good vector:*

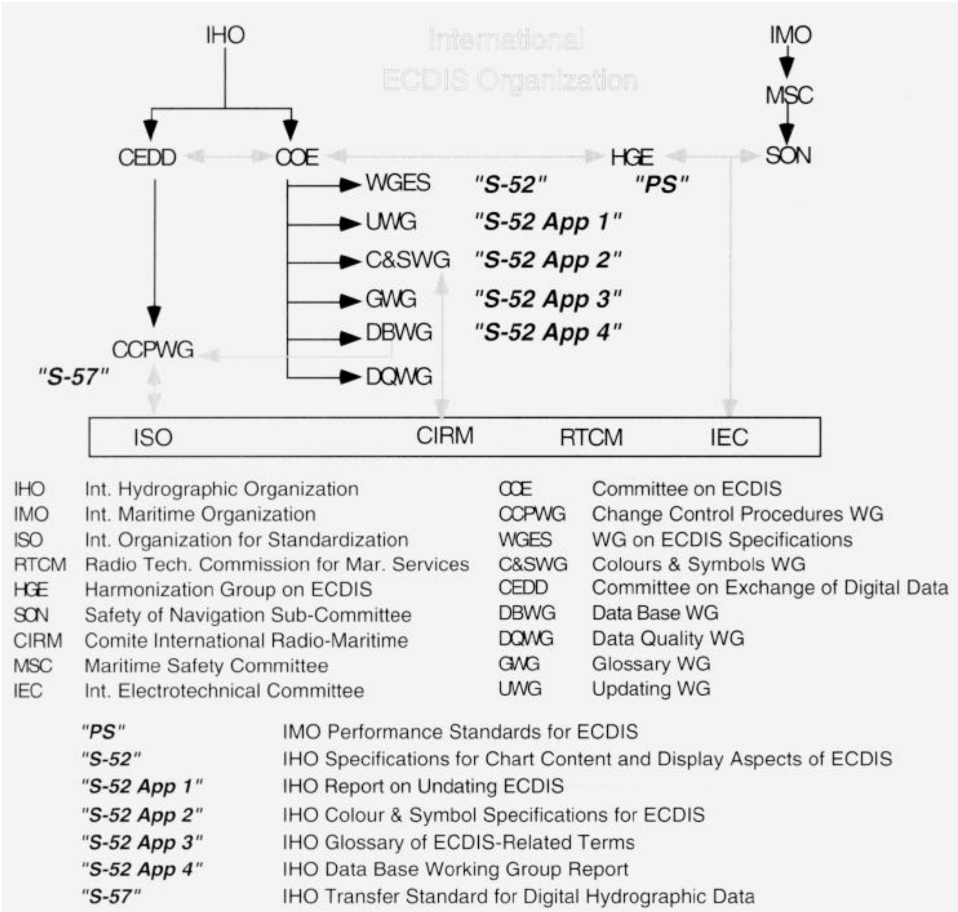


Figure 3: Internartiobal ECDIS Organization

The Electronic Chart Data Infrastructure Program

The objective of this program is to reorganize the CHS to meet the new demand for digital data and its support services. It involves the following tasks:

- build ENCs for charts covering Canadian waters

- implement an object-oriented spatial data model for ECDIS data and develop and demonstrate the use of area based objects for storing, processing and displaying navigation information

- develop the necessary data base infrastructure including a network system to link all of the CHS Regional and HQ offices

- develop, implement and load data bases that manage information about CHS data and product

- develop and implement a distribution network to service new client demands

- develop and implement an electronic updating service to ensure all users have up-to-date chart data

- provide whatever staff training is required to meet the new challenges

- develop a new organizational structure as required to perform the above tasks.

The digital data management infrastructure in the CHS is broadly described as the Hydrographic Information Network (HIN). Initially, emphasis was on creating and loading databases containing information about CHS product and source data (i.e. meta-data). The Source Directory System (SDS), which manages information about source data/documents has been in operation for about 3 years and now contains information about nearly all CHS source data/documents. In the long term the focus will be on source data management and, to this end, a partnership was established with ORACLE Canada Ltd. to develop a spatial/temporal data management capability in their relational database management system. This development originated as a research project in the CHS and is now at the beta stage of testing; the product is called ORACLE Multi Dimension.

The CHS recognized at an early stage that its limited resources would not enable it to meet the rapidly growing demand for ENCs and other digital chart products. Therefore, a partnership was established with Nautical Data International (NDI), St. John's, Nfld. to market CHS digital products. Revenue from the sale of these digital products will be used to digitize other charts. To ensure that these products have the same high standards as traditional CHS products the CHS and ND1 are actively investigating implementing an International Organization for Standardization Quality Management System (IS0 9000) for this activity.

National and International Standards Development

At the beginning of 1993 just over 100 of the approximately 400 charts for which the Atlantic Region of the CHS is responsible were digital, but none could be used as Electronic Navigational Charts. The problem was due to the fact that the digital chart files were created to support ONLY a paper chart product and some charts had been produced several years earlier, before the significance of correct digital feature identification codes was appreciated. At that time if the paper chart looked correct that was all that mattered. Electronic Charts rely on accurate digital data for proper reliable operation so these earlier digital chart files had to be updated. Furthermore Electronic Charts are designed to perform tests and checks on the chart data such as determining if the vessel is within certain areas (e.g. anchorages) or a specified distance away from a safety contour or other dangerous point or area feature. To be able to perform these checks the chart data or ENC must be much more rigorously structured than was possible or even known a year or so ago. By March 1994 about 25 Atlantic Region charts will be fully compliant with the current ENC standards.

Within the CHS major efforts are underway to develop digital chart file standards, data exchange standards, etc. and, in cooperation with a number of private sector partners, tools and procedures are being developed to create, manage and disseminate

ENCs, ENC updates and other digital hydrographic products. Much of this work is directly linked to similar work being carried out in international working groups under the auspices of the IHO, IMO and similar organizations. Figure 3 illustrates the relationships among these organizations and lists some of the reports that have been published.

Another objective of the CHS Electronic Chart program is to gather sufficient information to allow work on Legislative and Regulatory Amendments to the *Canada Shipping Act* such as including new regulations governing the carriage and use of ECDIS in the Charts and Publications Regulations. These amendments will have to be compatible with the pertinent regulatory conventions of the IMO and IHO as well as related Canadian Acts and Regulations such as the *Crown Liability Act* and the *Copyright Act.*

Conclusion

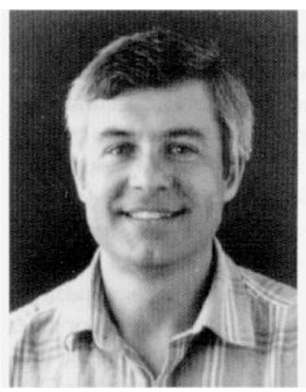
The Electronic Chart has been described as the most significant development in marine navigation since radar. And, tests and evaluations from around the world have clearly demonstrated that ECs improve navigation safety significantly. However, whereas radar is a stand-alone system, ECs depend on several factors for their effectiveness. They require accurate positioning (e.g. DGPS); official, accurate hydrographic chart data and updates; radar and other navigational inputs (e.g. log, gyro, depth sounder, etc.); and fast, reliable, easy to use ECDIS equipment. Performance Standards for ECDIS are presently being studied by IMO and could be approved by 1995, but a lot of work is still required. The CHS and its commercial partners are among the world leaders in ECDIS related activities.

Reference

Protecting our Waters, (1990), Final Report to the Public Review Pannel on Tanker Safety and Oil Spill Response Capability, Sept. 1990; available from Ministry of Supply and Services.

Sailing Directions - A New Approach

B. Pietrzak



B. Pietrzak

Sailing Directions are produced by the Canadian Hydrographic Service (CHS) and provide important additional information that cannot be graphically displayed on navigational charts. A new series of user friendly booklets has been launched. This essay describes the new venture and explains how user groups are reached through public relations efforts and the Chart Dealer Network.

History

Sailing Directions are publications by Hydrographic Organizations. These *Directions* provide supplementary information to their accompanying charts. Historically, they were a collection of notes often referred to as coastal pilot books. They contained general impressions that were gathered from mariners who had sailed into various ports and harbours around the world. At that time, no accurate charts existed for many of those ports of call. “The natives are friendly”, “Water can be obtained”, “A certain Mr. Zwicker, living on the island, can arrange for stevedores on short notice” are quotes typical of these collections. So anxious were the early mariners to obtain information, that the publishing of these general impressions became a small but competitive industry, with each publisher trying to outdo the other. In time the information published was so exaggerated that credibility suffered when reliable charts became available. Eventually, government hydrographic offices took over the “official” publication of these navigational background notes and they were named *Sailing Directions.*

Use And Application

Under the Charts and Publications Regulations of the Canada Shipping Act, *Sailing Directions, Nautical Charts, Tide Tables* and other items produced by the Canadian Hydrographic Service and the Canadian Coast Guard are required to be carried on board all vessels of a certain size. Provisions allow for use of equivalent charts and publications produced by other maritime nations. *Sailing Directions* produced by CHS are used as reference material by other hydrographic offices in their publications.

Sailing Directions are also used by recreational boaters, shipping agents, and in government offices. The text is often quoted by authors of cruising guides and in articles for the recreational boating market. As the official guide to navigation, *Sailing Directions* have gained respect in the marine community.

Information shown on charts and published in *Sailing Directions* is dated and subject to change. Navigational hazards are discovered; man-made channels are dredged; aids to navigation are established or rebuilt; shipping terminals and wharves are constructed or altered; new hydrographic surveys replace old information. Changes and corrections to CHS published documents are disseminated through *Notices to Mariners*. These are issued biweekly by the Canadian Coast Guard to inform the marine community of changes pertinent to safe navigation. When too many changes have been made to any document published by CHS, a new edition of the document is produced.

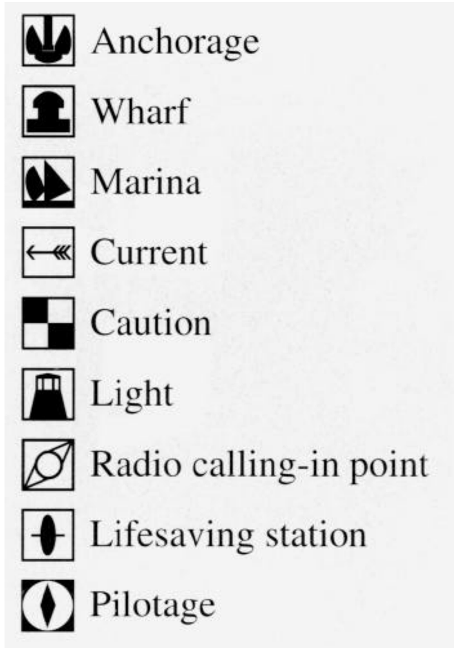
User Friendly *Sailing Directions*

- booklets about the coastline - user chooses information for specific waters of interest
- staple bound for cost efficiency (affordable to users)
- pictograph legend for easy reference
- small port charts

Hard cover *Sailing Directions* were printed on an infrequent basis prior to 1972. As the number of outstanding corrections to the text grew, supplements were published and distributed. It was common for the current edition held on board ship to have several "red ink" amendments from *Notices to Mariners* and a few paper bound supplements placed between the covers as inserts.

1972 - A New Look

A new look soft cover *Sailing Directions* appeared in 1972. With bright covers, these were produced using computerized typeset and offset photocopying. These *Sailing Directions* incorporated many full and partial sized photographs of ports, harbours, channels, and intricate passages. Though adequate, the books became hefty, with too



Pictograph legend for easy reference.

much detailed information. Included in these *Directions* was duplicate information taken from other publications which were also mandatory to have on board. Long, elaborately worded paragraphs described the history of the region, the livelihood of the population, and the responsibilities between the different levels of government. The books were written as if there was no other means of communicating conditions in Canada to the world of shipping.

The production of some of these *Directions*, in two official languages, was subsidized by the sale of other CHS products. Volumes covering waters with little navigation activity along remotely populated coastlines did not sell well. Many copies for those areas were distributed free of charge for the official use of other government agencies and fleets. The press run was small to avoid the buildup of outdated copies over time, so that the unit cost for each was high.

In the 1980's

New cost recovery programs were introduced in the 1980's that placed stringent rules on the pricing of government publications. *Sailing Directions* that typically sold for $8 in 1982 were priced as high as $55 in 1992, which for the non-compulsory user, became too costly. A new approach for *Sailing Directions* was initiated.

The Booklet Format

Through an extensive consultation process with user groups, a new series of *Sailing Directions* has been designed. These use a "booklet" format for covering smaller geographic areas. The advantages of the new format are many. Books are limited to 120 pages or fewer which allows for saddle-stitched binding (pages stapled), thus cutting costs. Users have the option of purchasing booklets for specific waters. Smaller booklets introduce flexibility in the frequency of printing updated editions, particularly for areas with a rapidly changing environment. In summary, the booklets allow for the delivery of a product that is affordable. After desktop publishing investments had been made, the first booklets for the St. Lawrence River were priced at $6.95.

Booklets are designed to be held in a standard three ringed binder along with associated publications such as *Chart I, Symbols and Abbreviations,* and *Tide Tables.* The user can thus collect all related materials in a single place.

Sailing Directions booklets incorporate diagrams of small harbours (small port chartlets) which show available berthing facilities and water depths. Many of these facilities are publicly owned and administered by agencies of the Department of Fisheries and Oceans, and Transport Canada. It is the first time that these smaller harbours have appeared in cartographic form. This detailed representation of the smaller harbours increases the marketability of *Sailing Directions* and promotes their use in safe navigation for all harbours.

Reaching Out To the Public

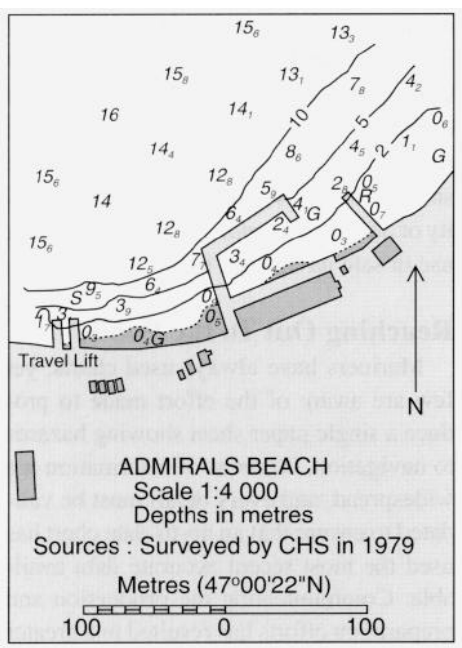
Mariners have always used charts, yet few are aware of the effort made to produce a single paper sheet showing hazards to navigation. Sources of information are widespread, and every detail must be validated to ensure that an up-to-date chart has used the most recent accurate data available. Communicating the production and preparation efforts has resulted in a greater appreciation for the quality of CHS products, and a better understanding of how these materials can be used.

Reaching the Public

- networking - finding groups of common interest
- "plugging" into other agendas to meet mutual interests
- using other groups' newsletters and magazines
- activities "we go to them" rather than "they come to us"
- seminars to target groups - explaining our work, our products

The most effective way of reaching customers is through retail agents who sell charts to the public. Agents are on the front line and are the first to listen to concerns about the quality of CHS products.

Retail agents are required to satisfy conditions of the Canadian Hydrographic Service Dealership Agreement. The most important of these conditions is the requirement to have on hand and sell only the latest printing of a CHS document. Cancelled charts have been replaced by new printings with updated information. Under this Agreement, cancelled charts cannot be sold. They must be destroyed.



Diagrams give a "portrait" of small harbours and ports.

Bob Corbett (MP for Fundy Royal) centre, and Neil Bellefontaine (DFO Regional Director-General) right, unveil the new chart 4116, at the Saint John Port Corporation National Transportation Week picnic, June 1993

Staff of CHS visit retail agents to review their stock on hand, and seek to understand, in person, how customers view CHS products. One notable result of such communication was the production and release of Chart 4116 which represents the western approach to Saint John Harbour, New Brunswick. This new chart became available in June, 1993. Bay of Fundy fishermen, yachtsmen and commercial shipping interests had been concerned about the lack of good chart coverage west of Point Lepreau. This coast had previously been shown only at a very small scale, and had been known locally as *The Gap* (i.e. as in " the gap" in adequate coverage of that particular shore). Chart agents, having voiced their concern to CHS, were instrumental in correcting this situation.

Sediment Core Processing at the Atlantic Geoscience Centre: State-of-the Art Geomechanical Applications to Marine Geological Research

K. Moran

K. Moran

Introduction

Marine geological research is a field of study which requires input from many disciplines. These disciplines include geophysics, paleontology, sedimentology, structural geology, paleomagnetics, and geochemistry. Most marine geological studies include, as a minimum, seismic reflection data, and use these data as the most basic and essential information. Variations in marine sediment properties (i.e. bulk density and acoustic velocity) cause varying levels of acoustic energy to be reflected from the seabed and subseabed. These variations in acoustic energy cause reflection events in the seismic data. Reflection events, when plotted with distance along a seismic track on the x-axis versus the time to the event on the y-axis, create a two-dimensional image of the subseabed (Fig. 1). These events are interpreted in terms of a geological framework and sites are selected along the seismic track for the collection of samples so that the seismic reflection events can be calibrated. Calibration of seismic data using core samples is normally called seismic groundtruth.

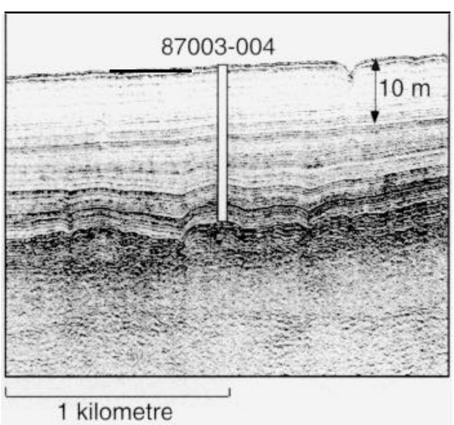


Figure 1: High resolution seismic reflection data from Emerald Basin, Scotian Shelf The dark lines which generally run along a sub-horizontal plane are reflection events. The position of a piston core sample, 87003-004 is shown (from Moran. 1993).

Requirements for groundtruth vary with each type of marine geological study. For example, for engineering site investigations, groundtruth is the strength and compressibility of sediment units defined by the seismic reflection events. In marine geological studies where the sediment column is analysed as a record of past climate change, groundtruth can be isotopic variations of sediment components which serve as proxy information for climate change. Glacial history and sedimentary basin studies require groundtruth which define the characteristics of seismic events that are interpreted as bedding, and in some places, as erosional surfaces. The groundtruth, in these cases, are sediment physical properties. In each of these examples, there is a requirement for the measurement of geomechanical properties.

In addition, physical property measurements on core samples are required so that core data and seismic data can be linked. There is an inherent problem in studies that require the use and integration of seismic reflection and core sample data: each of these data sets uses a different reference for depth below seafloor. Seismic reflection data are recorded as a function of the time it takes for the acoustic energy to travel from the source to the seabed where some of the energy is reflected back to the receiver. Core data are recorded as a function of the physical depth below seafloor. The most direct method for linking these two data sets is conversion of the core data to a time reference through the construction of a synthetic seismogram of the core sample. Synthetic seismograms are constructed using measurements of the sediment physical properties.

This paper presents the methods used in the Atlantic Geoscience Centre (AGC) laboratory for processing sediment cores for their physical properties, and examples of geomechanics applications to marine geological studies.

Methods

The most common tool used for recovering samples for marine geological studies is the piston core (Fig. 2). Piston coring technology is limited in its penetration depth. Cores have been recovered to depths of greater than 30 metres below seafloor (mbsf), but common recovery depths are 10 to 20 mbsf. Piston cores are also limited to soft, fine-grained sediments. When other sediment types are encountered, more complex sample recovery techniques must be used. For example, vibrocores are required to collect coarse-grained sediment and drilling technology must be mobilized when very stiff sediment is sampled.

Piston core collection is costly. This cost means that each piston core must be precisely positioned with respect to the reference seismic reflection data. Also, the analyses and measurements required to meet the objectives must be carefully planned for each core to optimize its scientific value.

Piston cores are collected using steel pipe that is lined with a clear plastic sleeve. When the core is recovered, the plastic liner

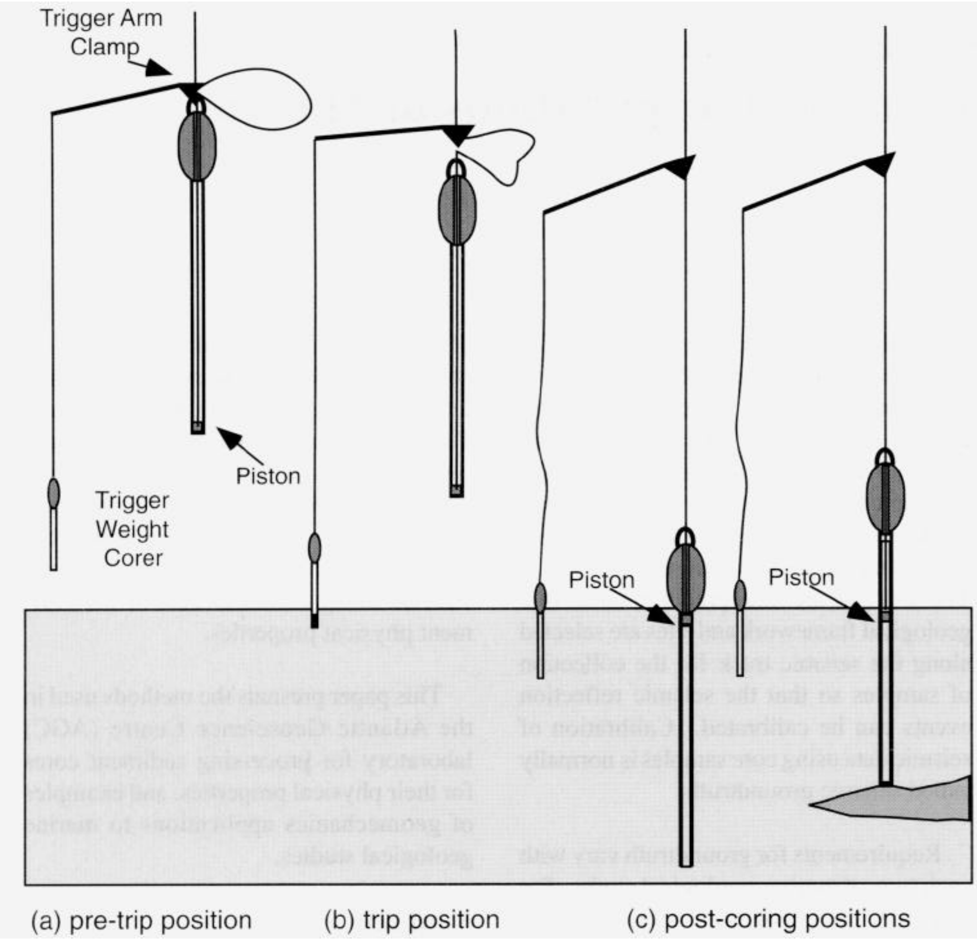


Figure 2: Cartoon diagram of a standard piston corer. The corer consists of a steel pipe which is driven into the seabed using the free fall mass of a large weight. A piston is inserted into the pipe to provide a small suction in the pipe for reduced core disturbance.

is removed from the steel pipe and the initial stages of core processing begin. Upon removal, each plastic liner is cut into 1.5 m lengths and capped. The cores are stored vertically in refrigerated space until further processing. If cores are not immediately processed, the caps are sealed with wax to prevent moisture loss.

Core processing is normally planned to meet the requirements of the specific study. However, core procedures at AGC have evolved so that basic standards are followed for each core and additional procedures are incorporated to meet specific science goals. At AGC, new and innovative techniques which enhance the information obtained from each core are included in standard core processing. Ten years ago, scientific objectives were more limited than now, and core processing consisted of splitting the core vertically into two half sections, sampling one half for biostratigraphy and grain size, and visually describing the other half for colour and sediment type. One of the disadvantages of this procedure is that once a core is opened by splitting, it begins to lose moisture, and oxidizes. Moisture loss results in destruction of the original sediment physical properties and oxidation destroys much of the original geochemistry. Consequently, if physical and mechanical measurements were not made when the core was opened, these data were lost and could only be recovered by collecting a new piston core from the same site.

Modern core processing includes the measurement of critical parameters that can degrade with time. At AGC, whole, sealed cores are initially X-rayed (Fig. 3), using X-ray fluoroscopy and recorded on high density video tape. The X-ray data are used for two purposes: (1) to interpret sedimentological or structural geological features; and (2) to select intervals for whole core geotechnical testing; e.g., compressibility and shear strength. The X-ray data also serve as an archive of the core prior to opening.

Next, whole cores are run through the new multi-sensor track (MST). The MST is a three component instrument built by GEOTEK™ that non-destructively measures sediment physical properties (Fig. 4). The three components include a pair of acoustic compressional wave velocity transducers (p-wave), a gamma ray attenuation device, and a magnetic susceptibility sensor. The p-wave sensor measures the acoustic velocity of the sediment. Gamma ray attenuation is a measure of bulk density. Changes in acoustic velocity and bulk density cause seismic reflection events. Measurement of these two physical properties at high depth resolution allow for the construction of a synthetic seismogram. Magnetic susceptibility is a measure of the density of magnetic minerals in the core samples. This parameter has been very successfully used as a correlation tool between core sites.

After non-destructuve testing is complete, whole core subsamples are cut from the core. For example, if the geomechanical properties of shear strength or compressibility tests are required for a specific study, subsamples from 10 to 1.5 cm in length are cut from the core. The depth intervals for subsampling are normally selected using the X-ray and MST data. These subsamples are capped, sealed in wax, and stored in refrigerated seawater until they are removed for testing.

Figure 3: Photograph of the AGC X-Ray system. Cores are placed vertically into a computer controlled track which remote!\ moves and rotates the whole core while the operator views the X-ray data on a video display monitor.

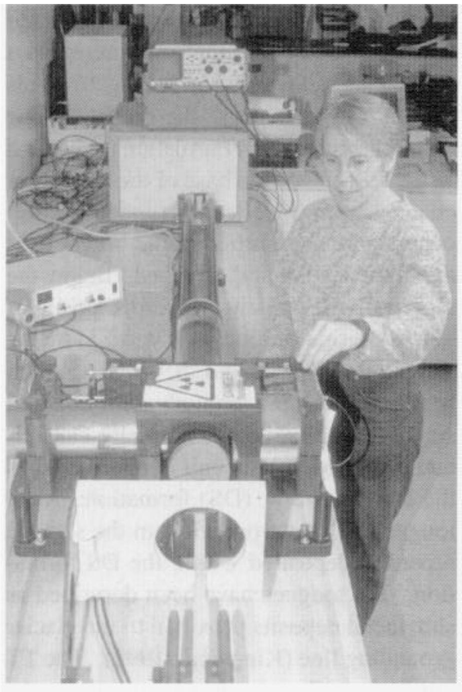


Figure 4: The multi-sensor track (MST) which consists of three sensors that measure, non-destructive!\: physical properties of whole core.

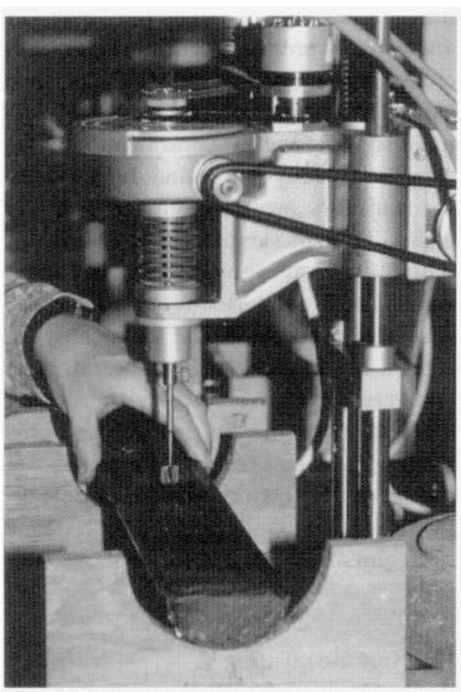


Figure 5: Miniature vane shear device shown here before insertion into the working half of a split core. This device measures the undrained shear strength of fine-grained sediment. AGC has modified this standard device so that data are collected digitally and automatically.

Once any whole core subsamples are removed, the cores are split longitudinally into two sections, the working half and the archive half. Each half is processed in a different manner. The archive half serves as both an archive and as a resource for future studies. The working half is utilized to meet scientific objectives already defined for the study. The archive half is immediately photographed and visually described. AGC has now replaced the subjective visual evaluation of core colour with the digital measure of colour reflectance. The working half is immediately measured for physical properties and geochemical parameters which degrade with time. For example, undrained shear strength (Fig. 5) electrical resistivity, and redox potential are measured soon after the core is split. Following these critical measurements, subsamples are taken for other analyses. Examples of other analyses include grain size analysis, micropaleontology, palynology, and paleomagnetics.

Cores are double sealed in plastic after processing is complete and stored in hard plastic d-shaped tubes in refrigerated core storage. Typically, cores are pulled from storage for additional subsampling and viewing of the archive once the initial data sets are compiled and interpreted.

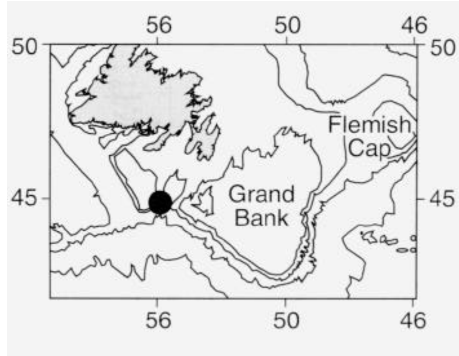


Figure 6: Map of the Grand Banks of Newfoundland. Borehole 87400-02 is located in Halibut Channel and its positron is shown on the map as a closed circle.

Geomechanics Applications:
Glacial History

The Grand Banks of Newfoundland consist of a series of banks including Green, Whale, St. Pierre, Burgeo, and the largest, Grand. Fader and King (198 1) describe two major surficial formations based on seismic reflection data on the Grand Banks: Grand Banks Sand and Gravel (GBS&G) and Adolphus Sand (AS). These formations are discontinuous across the bank tops and overlie glacial till, glacio-marine sediment, and bedrock of Cretaceous to Tertiary Age.

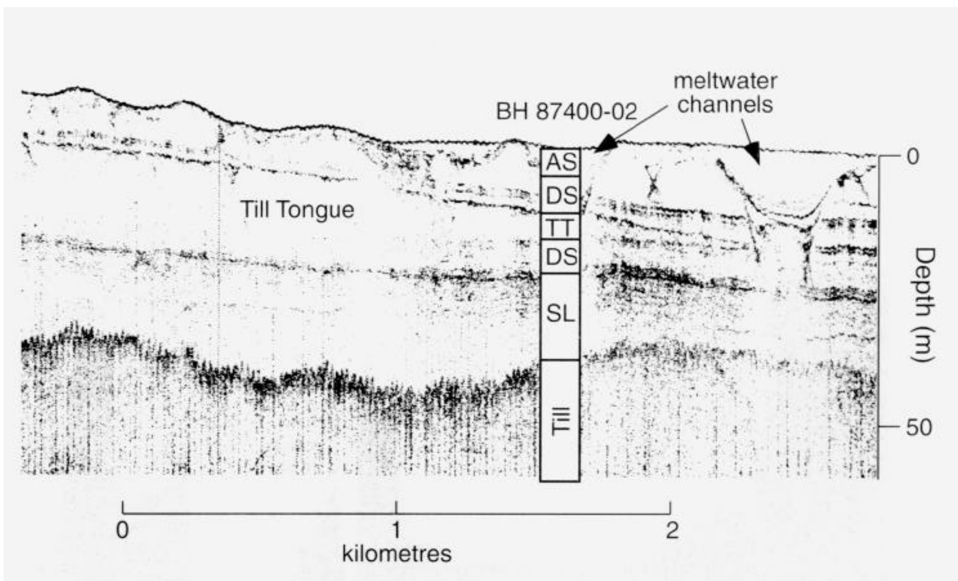


Figure 7: High resolution seismic reflection profile of sediment in Halibut Channel. The position of borehole 87400-02 is overlain on the record with lithogic units identified; AS is Adolphus Sand, DS is Downing Silt, TT represents the distal edge of a till tongue, and SL is red sediment from the Gulf of St. Lawrence.

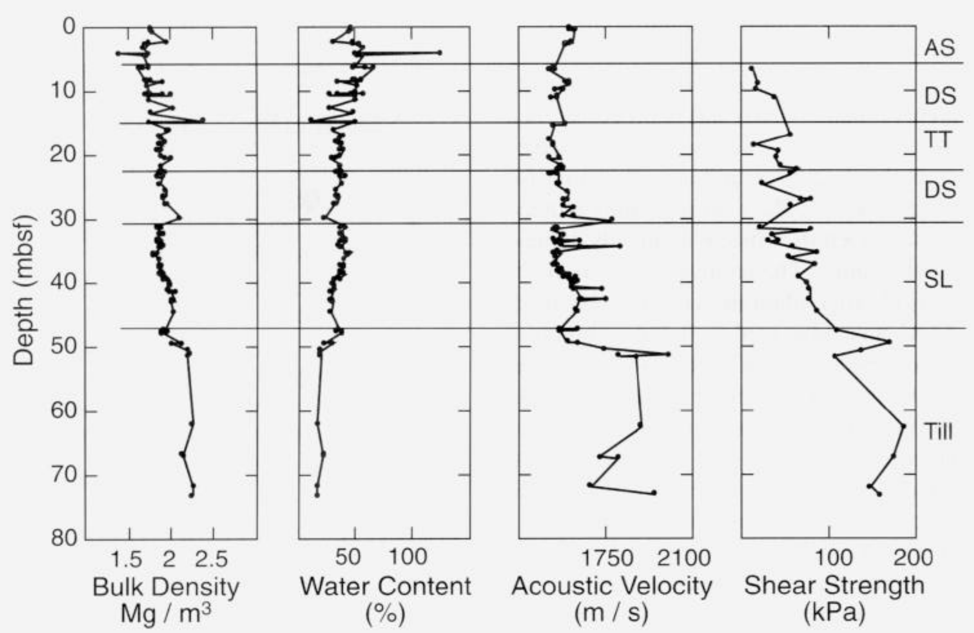


Figure 8: Physical and geotechnical properties of sediment from borehole 87400-02 in Halibut Channel. The lithologic unit boundaries are shown as horizontal lines and are labelled with abbreviations: AS is Adolphus Sand, DS is Downing Silt, TT represents the distal edge of a till tongue, and SL is red sediment from Gulf of St. Lawrence.

Three large channels separate Whale Bank, St. Pierre Bank and Burgeo Bank to the south of Newfoundland (Fig. 6). One of these channels, Halibut, was studied as groundtruth for the seismic data in terms of glacial history. In most regions of the Grand Banks, the sediment is too coarse-grained and/or too thick for recovery using standard piston coring techniques. Consequently, this site was sampled using drilling technology, rather than piston coring.

The interpreted high resolution seismic reflection data from Halibut Channel shows a series of glacial and glacio-marine deposits which have been affected by glacial outwash in the form of meltwater channels (Fig. 7). Three boreholes were drilled and sampled in the Channel to determine the depositional environments and stress history of these deposits (Moran, 1987).

Borehole 87400-02, the deepest drilled, intersected and sampled the major reflection events on the seismic reflection profile. In the upper 8 m of section, the borehole samples consisted of fine sand which infilled a channel interpreted as a subglacial meltwater feature (Fig. 8). This sand is interpreted as the recent marine Adolphus Sand (AS) Formation (Fader and King, 1981). At the base of the meltwater channel, a strong reflection (unconformity) occurs and is identified in the borehole as a 1 m thick shell and sand bed. Below the channel, the seismic interpretation of glacio-marine sediments is verified by the sample description and the shear strength profile. The shear strength and bulk density of this unit reflects a normally-consolidated silty clay. This unit is interpreted as the Downing Silt (DS) formation. A till tongue (TT), interpreted from the seismic record is deposited within the DS formation. Till tongues have been described as subglacial deposits proximal to the glacier grounding line (King et al. 1991). The TT unit has similar physical properties to the DS and is interpreted as a normally consolidated sequence which is likely deposited as a sediment flow rather than as a basal till, which would likely be overconsolidated. In the borehole, the DS bounds the top and bottom of the TT. A massive red clay underlies the lower DS and is likely sediment deposited from ice-eroded red beds of the Gulf of St. Lawrence (SL). The physical properties of the sediment suggest normal consolidation The acoustic velocity is low and the magnetic susceptibility profile is higher than any other sediment sampled in the borehole, which confirms the different sediment source for this unit. Below the red clay is a true basal till deposit. The sediment is described as a diamict with high shear strength and very large acoustic velocity. Using the shear strength data, an estimate of the ice thickness that rested at this site when the basal till was deposited can be estimated. At Halibut Channel, the estimate of minimum ice thickness is 430 metres.

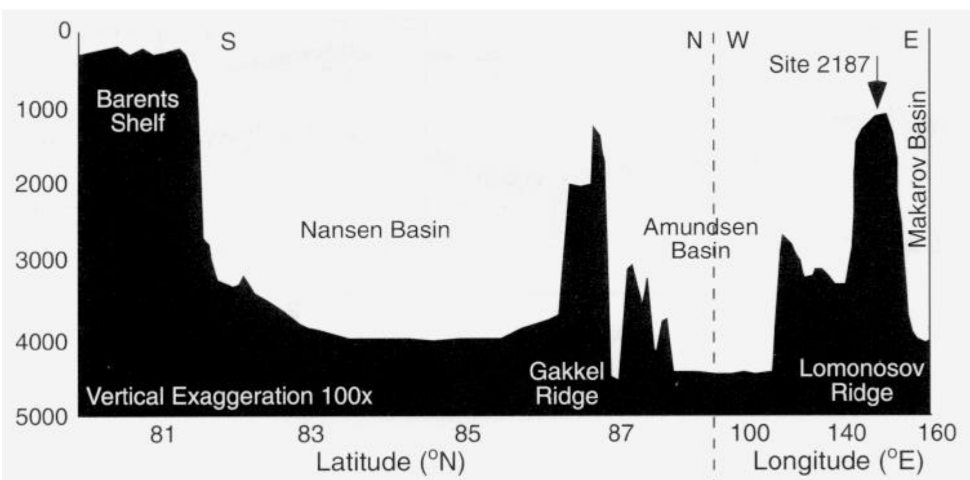


Figure 9: Schematic cross-section of the eastern to central Arctic Ocean basin. The position of site 2187 is located at the top of the Lomonosov where the sediment record is likely uninterupted and can be used for paleoceanographic studies (modified from Fütterer, et al., 1992).

Paleoceanography

Geomechanics has important applications to marine geology, particularly to paleoceanography. Paleoceanography is the study of the marine sediment record for understanding past ocean circulation, ocean "climate", the earth's climate and ocean/ice boundaries. Geotechnical methods and theories have been developed for many years and are proven for measure-

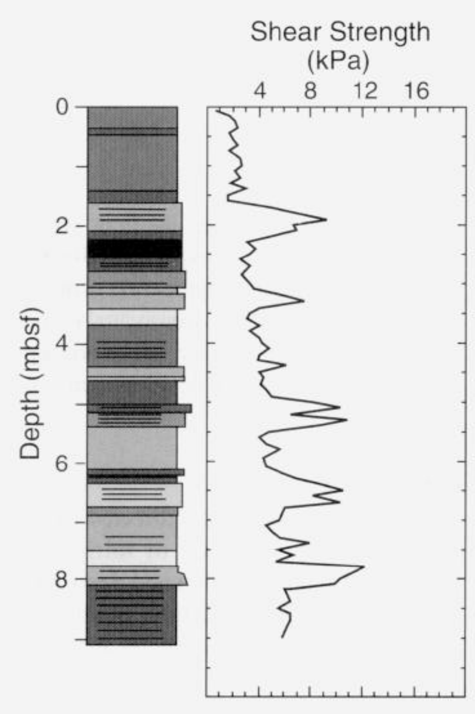


Figure 10: Downcore plot of shear strength and graphic lithology for a piston core from Site 2187 on the Lomonosov Ridge, central Arctic Ocean. The peaks in shear strength coincide with intervals of ice-rafted debris (modified from Fütterer, 1992).

ment of sediment index properties, strength and compressibility (Terzaghi, 1943). These measurements are used in paleoceanographic studies. For example, shear strength measurements from core samples collected in the Arctic Ocean may represent past climate events. Long cores collected on the Lomonosov Ridge in the central Arctic Ocean (Fig. 9) represent sediment sections uninterrupted by mass flow deposits and therefore may be a continuous record of climate.

In one core from the Lomonosov Ridge, shear strength data shows a background increase with depth below seafloor (Fig. 10). Superimposed on this background increase are high shear strength values. These high shear strength intervals occur because of an increase in ice rafted debris within the sediment. These intervals likely occur at the end of glacial cycles, representing large purge events from large northern hemisphere continental ice sheets. Determining the cyclicity of these intervals will be used to constrain ice sheet interactions with the global climate.

Summary

The core processing facilities at the Atlantic Geoscience Centre provide the most advanced capabilites for processing of marine sediment samples available today. The geomechanics capability is one part of the core processing at AGC. This research provides data for a wide range of marine geological studies. The range of studies varies from the applied (for example for engineering site investigations), to environmental research (for example paleoceanography) as described briefly in this paper. The laboratory facilities are a primary resource for scientists working at AGC in environmental marine geology as well as visiting scientists. In the past year, the facilities have been used by scientists from the United States, Russia, Sweden, Germany, and France. This laboratory resource is unique and is expected to receive increased demand as the need for environmental marine research increases.

Acknowledgements

Mike Lewis and Kevin Robertson reviewed this article for publication. Kate Jarrett assisted in the preparation of the photographs.

References

FADER. G. B. and L. H. KING 1981. A reconnaissance study of the surficial geology of the Grand Banks of Newfoundland. Current Research, Geological Survey of Canada 81- 1A: 45 56.

FÜTTERER, D. K. 1992. Reports on Polar Research: ARCTIC'91: The expedition ARK-VIII/ 3 of RV *Polarstem* in 1991. Alfred Wegener Institute for Polar and Marine Research, Federal Republic of Germany, 132 p.

KING. L. H., K. ROKOENGEN, G. B. FADER, and T. GUNLEIKSRUD 1991. Till tongue stratigraphy. Geological Society of America Bulletin, 103: 637-659.

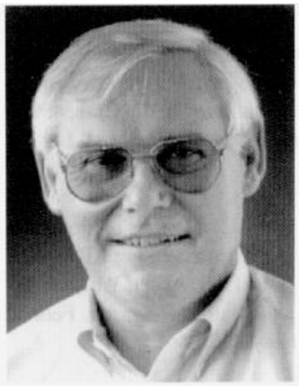
MORAN, K. 1987. Cruise Report 87400, M/V *Balder Challenger*, Atlantic Geoscience Centre, Bedford Institute of Oceanography, 32 p.

MORAN, K. 1993. Offshore site investigations on Canadian continental margins, p. 860-887 *In* Proceedings of the Fourth Canadian Marine Geotechnical Conference, St. John's, Newfoundland.

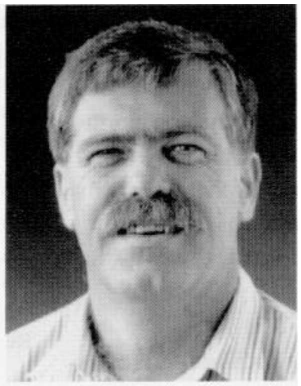
TERZAGHI, K., 1943. Theoretical Soil Mechanics, John Wiley & Sons, Inc., New York, 510 p.

Environmental Marine Geology

D. B. Prior and R. A Pickrill



D. B. Prior



R. A. Pickrill

The Geological Survey of Canada's Environmental Marine Geology program at the Bedford Institute of Oceanography (BIO) contributes to the sustainable development of Canada's coastal and offshore areas. The program seeks understanding of the natural geologic processes which affect coastal and offshore areas and the impacts of past, present and future development on environmental systems. A wide variety of projects provide baseline information towards the implementation of Canada's Marine Environmental Quality framework, and Coastal Zone Management strategies. Since marine environmental systems are complex, highly variable, and very dynamic, the full characterization of these systems, including coasts, estuaries, shelves and deep water regions, requires a holistic understanding of the interactions between biological, physical, chemical and geologic components. The Environmental Marine Geology Subdivision, of the Atlantic Geoscience Centre (AGC), develops and implements projects to deliver the needed geoscience component within this ecosystem framework. Principal research themes include coastal processes, seafloor stability and sediment transport, sediment geochemistry, marine engineering geology, and Quaternary paleoenvironmental reconstructions. The research activities are supported by a technology development program.

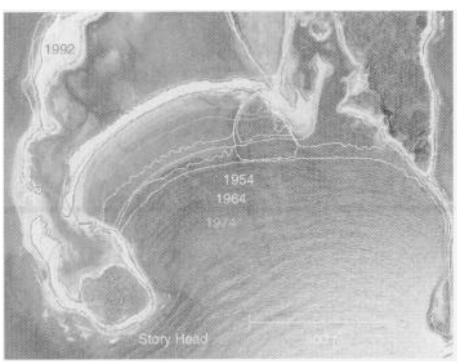


Figure 1: Coastal erosion from air photos. Coastal change is measured from digitally rectified aerial photographs using the Geographical Resource Analysis Support System (GRASS). Sequential shoreline changes since 1954 at Story Head, Nova Scotia are illustrated using the 1992 photograph as a hate. Barrier beach retreat was greatest in the late 1960s when movement of 8 to 12 m/a was recorded.

Figure 2: Sea Carousel, an AGC developed in situ *flume being deployed from CSS* Hudson *in Hudson Bay. The annular flume, equipped with optical backscatter sensor and a video recorder is used to simulate near-bed flows and initiation of sediment transport.*

Coastal Processes

Coastal research is directed to understanding, predicting, or mitigating coastal and seabed erosion and deposition problems and related hazards. Studies are undertaken at a number of scales and time-frames to understand both the detailed mechanics of sediment transport and erosion, and for development of conceptual models of medium- to long-term evolution of coasts and adjacent shelves. On the permafrost coasts of northern Canada, thermal erosion and frazil and anchor ice entrainment, processes not considered in more temperate latitudes, have been identified as major components in coastal erosion. A priority is being given to developing numerical models of coastal retreat (Figure 1). On the At-

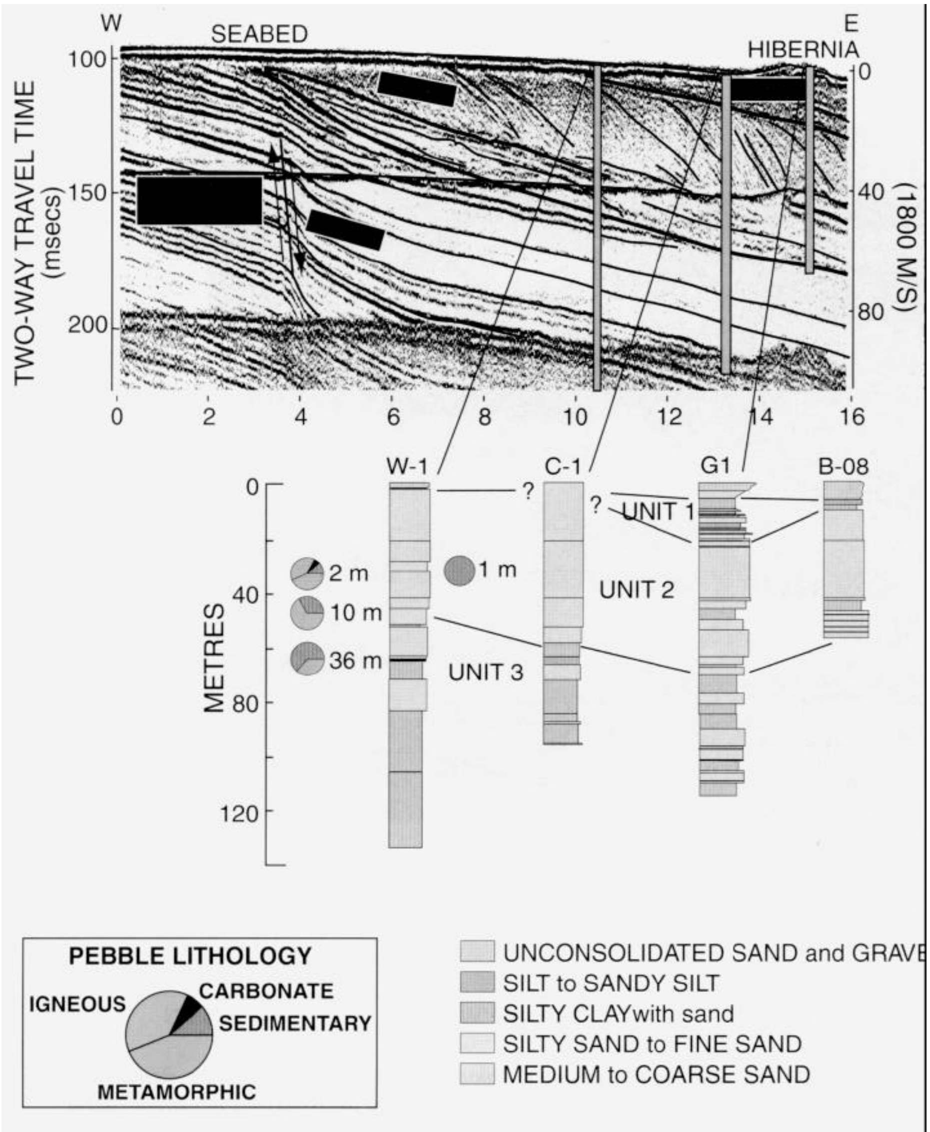


Figure 3: Engineering properties of seafloor and subsurface sediments can vary regionally and locally across the Grand Banks. Widespread variations are related to changes in the distribution and thickness of major stratigraphic units, each with their own distinct physical and sedimentary properties. Localized variations relate to small-scale sedimentary and structural variability within the major stratigraphic units. Both scales of variability are illustrated in this airgun seismic reflection profile through the Jeanne d'Arc basin. Three of four nearsurface seismostratigraphic units are identified; the very thin, reworked surficial sands and gravels at the seabed are not resolvable at this scale. Unit 1 consists of interbedded sandy silt and silty clay which occur as thin, discontinous acoustic reflections. Unit 2 comprises the progradational sequence, a sand-dominated unit with internal acoustic clinoform reflections. Unit 3 consists of stiff interbedded clay, silty clays and sands with low angle parallel reflections. Acoustic unconformity surfaces (thick lines) separate the units. The fault at 4 km is interpreted to be the nearsurface expression of the Murre Fault. Borehole logs indicate that sediments and physical properties vary significantly between the 3 major units. The logs also illustrate that there is considerable variation in the internal structure and sediments of the major units. The pebble lithologies indicate the source of some of the sediments; exotic pebbles from the mainland suggest glacial ice was the mechanism of transport and deposition for Unit 2.

lantic coast, understanding the stability of gravel barriers and sediment transport of mixed gravel sand beaches under high energy storm conditions and rapidly-rising sea levels are principal project objectives. Recent work has shown that the behaviour of coastal beaches is heavily influenced by the availability and transport of sediment in the nearshore zone. New digital acoustic techniques are being applied to nearshore mapping to develop quantitative sediment budgets and transfer functions. The expertise in coastal marine geoscience, developed along Canada's coasts, has application to problems of coastal development worldwide. A recent application has been to coastal stability in South Pacific developing island communities in cooperation with the South Pacific Applied Geoscience Commission (SOPAC).

Seafloor Stability and Sediment Transport

Our changing understanding of the marine environment has shown that sediment transport is active under waves, tides and currents down to considerable water depths. Principal objectives of this project are to understand transport processes at the seafloor and regional patterns of sediment transport. Our Program Support Subdivision has developed a suite of tools to monitor processes at the boundary layer. *In situ* monitoring is accomplished using state-of-the-art instrumentation, such as seafloor tripods capable of measuring particle motion initiation, suspended flux, and appropriate forcing factors such as wave tides and currents. A recent example of this work is the deployment of instrumentation packages during high-energy wave and storm conditions at the Lasmo Panuke-Cohasset production sites on the Scotian shelf. Spectacular video imagery of high magnitude transport events has been recorded from 30-day deployment periods. Other sediment transport projects include detailed studies of bay and estuarine systems where monitoring of natural conditions is augmented by artificial experimental initiation of sediment movement, using an AGC sea-floor flume -Sea Carousel (Figure 2). Particular applications of this technique and the resulting knowledge of seabed stability are used to study the behaviour of coastal dredge spoil disposal sites in Atlantic Canada. The data from local measurements are used to construct and calibrate numerical models relating regional sediment textural distributions to the long-term effects of various forcing functions such as currents and waves. Large-scale sediment transport models have been developed for the Scotian and Grand Banks Shelf regions and for local application to coastal stability and shoreline evolution in the Queen Charlotte Islands region of the Pacific coast.

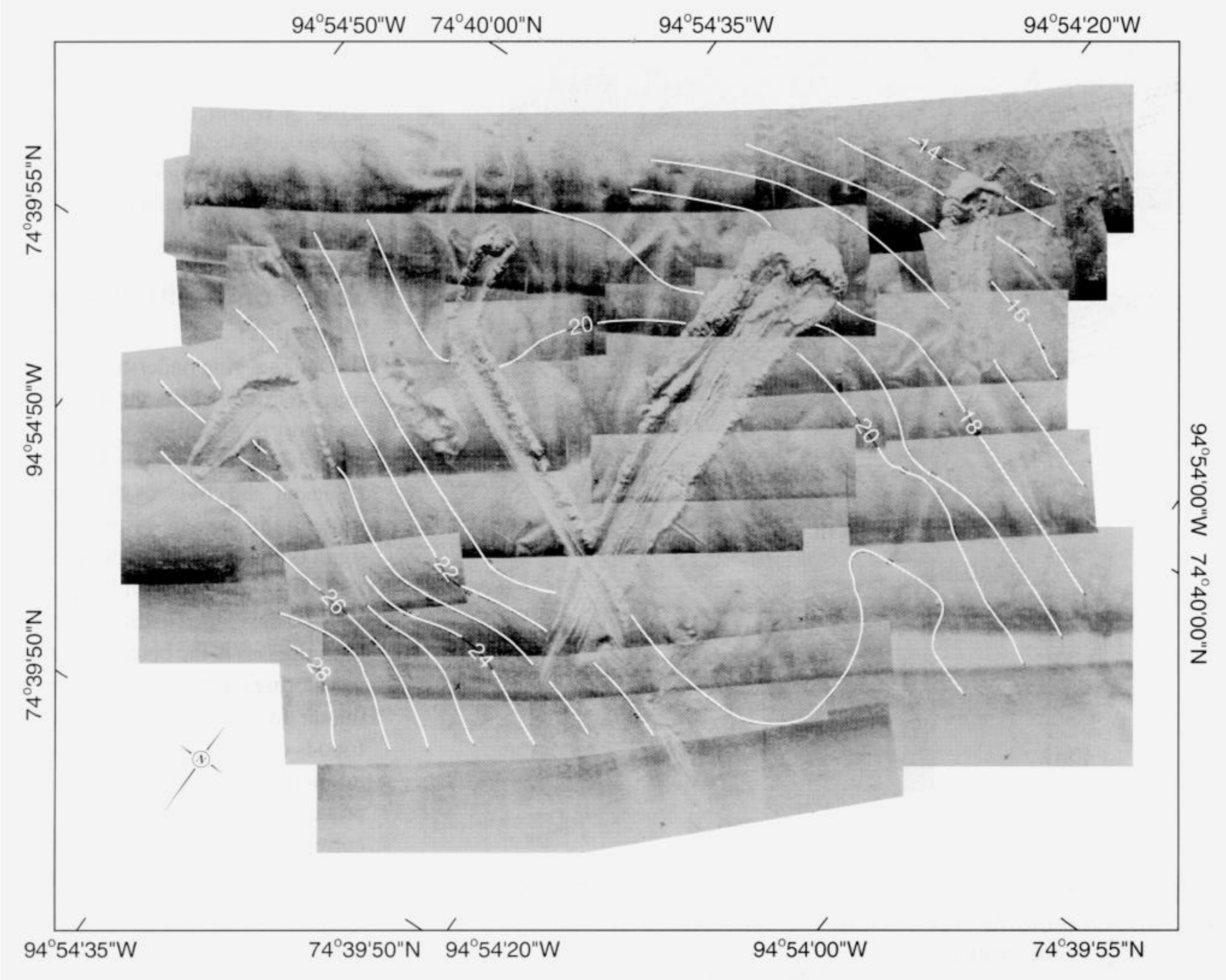


Figure 4: Sidescan sonar image, or acoustic "photograph", of the Arctic seafloor illustrating the morphology of recent ice scours. Remapping of this same sector of seafloor from year to year will allow AGC scientists to observe new scour events and predict the frequency of extreme scour events. These 'fresh" looking scours have cut as deep as 2.5 metres into the seafloor. The study of this ice-scouring process is a cooperative research project with the Canadian Museum of Nature and Canadian Seabed Research Ltd.

Marine Engineering Geology

Marine engineering geology is directed to providing a balance between baseline studies and applied research to address key scientific issues in support of safe, sustainable, environmentally low-risk, yet cost-effective, coastal and offshore development. Seabed sedimentary conditions provide design constraints for engineering structures and installations, and certain seabed processes are of sufficient magnitude and unpredictability to be designated hazards to offshore engineering. Definition of geotechnical properties of the sediment and assessments of seabed process magnitude and frequency are cost-effective contributions to engineering design and environmental protection. Marine engineering geology typically combines high-resolution geophysical mapping of sediment stratigraphy and structure and seabed process signatures with selected sediment sampling for ground truth and physical properties analyses in the laboratory.

The Program for Energy Research and Development (PERD) supports joint industry and government research in marine engineering geology specifically for oil and gas production, seafloor electrical transmission cables and hazards to coastal electricity-generating facilities. For example, AGC has conducted studies on the Scotian Shelf and Grand Banks areas in support of oil and gas development at Panuke-Cohasset and at Hibernia. Specific attention has focused on correlating sediment stratigraphy and properties from regional acoustic surveys and data on sediment properties measured from engineering boreholes for production platform design and pipeline routing (Figure 3). Attention is paid to the distribution of overconsolidated sediments due to erosion, the presence of relic buried channel systems with highly variable sediment properties, and underconsolidated sediments related to the presence of near surface gas. Process studies relevant to seafloor oil and gas engineering include hazard assessment of iceberg keel scour, faulting, and submarine slides. Development of petroleum resources in the Arctic presents a unique suite of engineering challenges. Geotechnical expertise is maintained to provide advice to industry and government on effects of subsea permafrost, gas, sea-ice scouring (Figure 4), and

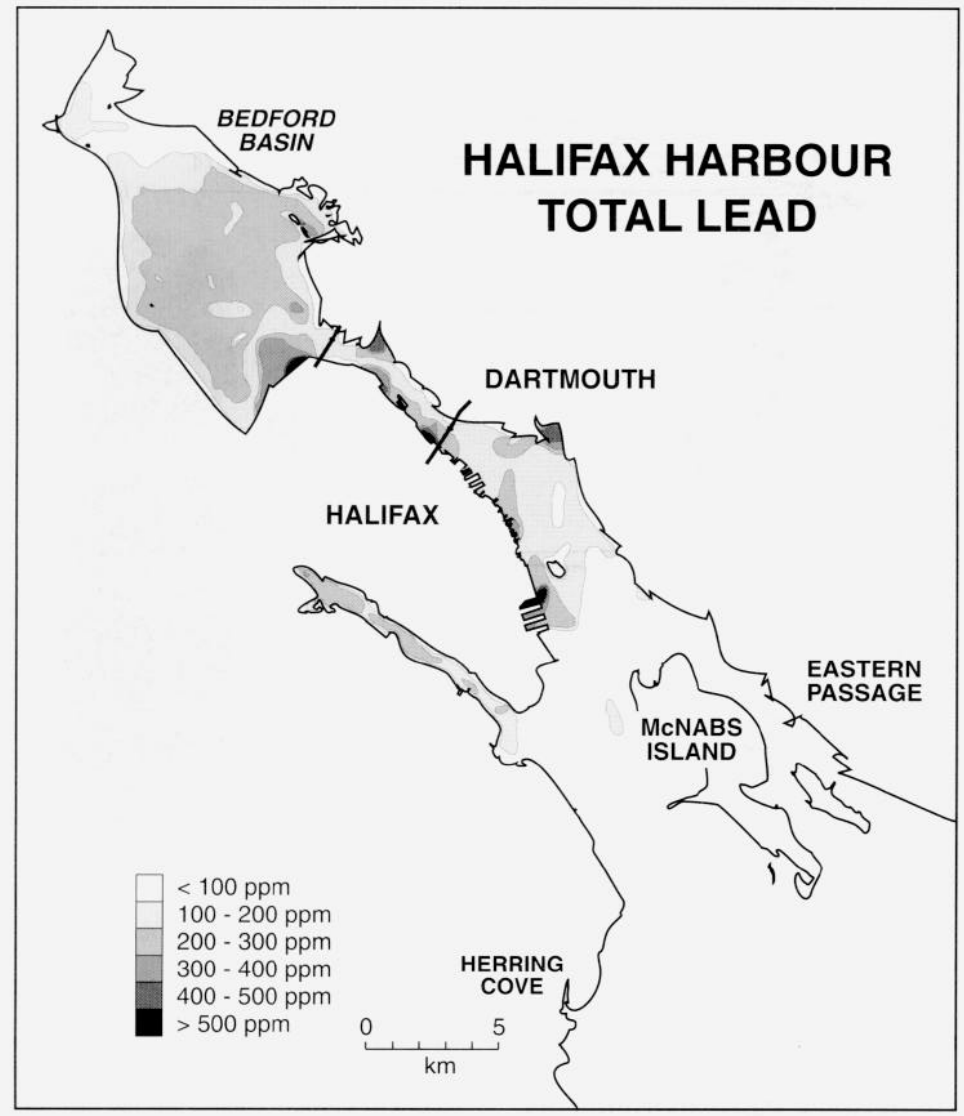


Figure 5: Concentration of total lead metal in surficial sediments of Halifax inlet. Highest concentrations are found adjacent to major sewer outfalls, military and industrial shipyards, and Seaview Point where the old city dump for Halifax was located.

engineering properties of soft seabed sediments relevant to foundation conditions. The regional distributions of the occurrence of these constraining conditions have been developed for large areas of the Beaufort Sea shelf and McKenzie Delta.

Marine engineering geology is also used to define hazards to seafloor cables in the Fraser Delta where maintenance of transmission capability to Vancouver Island depends on defining submarine slide distribution and frequency. Collaborative research with B.C. Hydro and the Pacific Geoscience Centre, funded by PERD, has led to new seafloor maps showing presently active slides in the Sand Heads area and former, possibly relic, slides along the southern flanks of the delta. These maps are used for assessment of cable route stability and engineering practice. AGC's particular focus on these problems is to define the processes and mechanisms of failure in areas prone to infrequent submarine slide risk.

A project has recently been initiated in Lake Ontario to examine the causes and effects of recent soft sediment deformation on the lake floor. One hypothesis for recently discovered lake floor features is that they are preserved signatures of regional bedrock structural deformation, with implications to the coastal and offshore engineering infrastructure, including power-generating plants and future cables. AGC is also exploring alternative hypotheses to explain lake-bed instabilities, such as syn-depositional consolidation deformation, perhaps related to fluid expulsion. This project combines high resolution mapping, supported by direct observations from manned submersibles, sediment sampling, geotechnical analysis, and deformational modelling.

A key component of AGC's marine engineering geology is the ability to conduct sophisticated geotechnical measurements of a wide range of sediment types, including heavily consolidated clays, very soft gas-rich sediment fluid mixtures, and liquefaction-prone sands. The Environmental Marine Geology Subdivision has a state-of-the-art sediment and core processing capability, including both static and cyclic stress tests. A wide range of geotechnical parameters can be correlated with detailed geological core descriptions and multi-sensor track procedures, including magnetic susceptibility. A particular strength of AGC's engineering geology capability is the correlation of measured laboratory properties with the results of high-resolution acoustic profile surveys. AGC's laboratories and core-processing facilities are available for collaborative research work with industry, the consulting community, and universities.

Marine Environmental Geochemistry

The sustainable development of Canada's coastal regions requires an understanding of man's impacts on natural environmental systems. Past development has led to chemical pollution of harbours and estuaries, especially in areas of high industrial and urban pressure. Coastal and offshore sediments contain a record of environmental degradation, storing contaminants, transporting and re-cycling to circulate them into the water to be dispersed by tidal currents. Cleanup of contaminated systems and mitigation of the effects of proposed new coastal developments requires detailed information on the nature and behaviour of the sedimentary systems and their organic and inorganic geochemical components.

Marine geochemical research has two principal thrusts: process studies and environmental quality assessment. Process studies are undertaken to understand how chemical elements are cycled through the marine environment with a goal to developing models to predict the fate of chemical contaminants. Application of these models to specific environments, such as Halifax Harbour, has been used to provide a basis for environmental quality assessment and for planning cleanup and future waste disposal. The environmental marine geology project, carried out in Halifax Harbour, is a showcase in Canada for marine environmental geochemistry, detailing the progressive accumulation of inorganic elements in the sediment layers since before European settlement (Figure 5). From results of high resolution analyses, the distribution of potentially toxic elements can be traced to different periods of urbanization and industrialization in the Halifax/ Dartmouth region. These data, combined with knowledge of sediment transport and water body circulation within the harbour, have been the basis for recommendations to the Environmental Assessment Review Panel that has been reviewing proposals from the Halifax Harbour Cleanup Corporation.

Similar multidisciplinary studies have been completed for other coastal areas, such as the Miramichi Estuary. AGC scientists have been leaders in an integrated systems approach, combining high-resolution seafloor mapping, high-resolution profiling of subsurface sediment geometries, detailed element analyses from cores and statistical modelling of system behaviour.

As a basis for the application of marine geochemistry to specific development problems, research is also conducted into fundamental geochemical processes associated with marine sediments. For example, ocean sediments are major repositories of carbon, a significant component of the global carbon cycle. Fundamental questions which remain to be answered in climatic modelling concern the controls on storage and release of carbon and carbon-rich gases from seafloor sediments. A fascinating enigma is the origin of seafloor pockmarks, due to leakage of biogenic methane or deep seated petrogenic gases by processes which can range from explosive to diffusive. The chemistry of sediments within pockmarks is a key to their formation and process frequency.

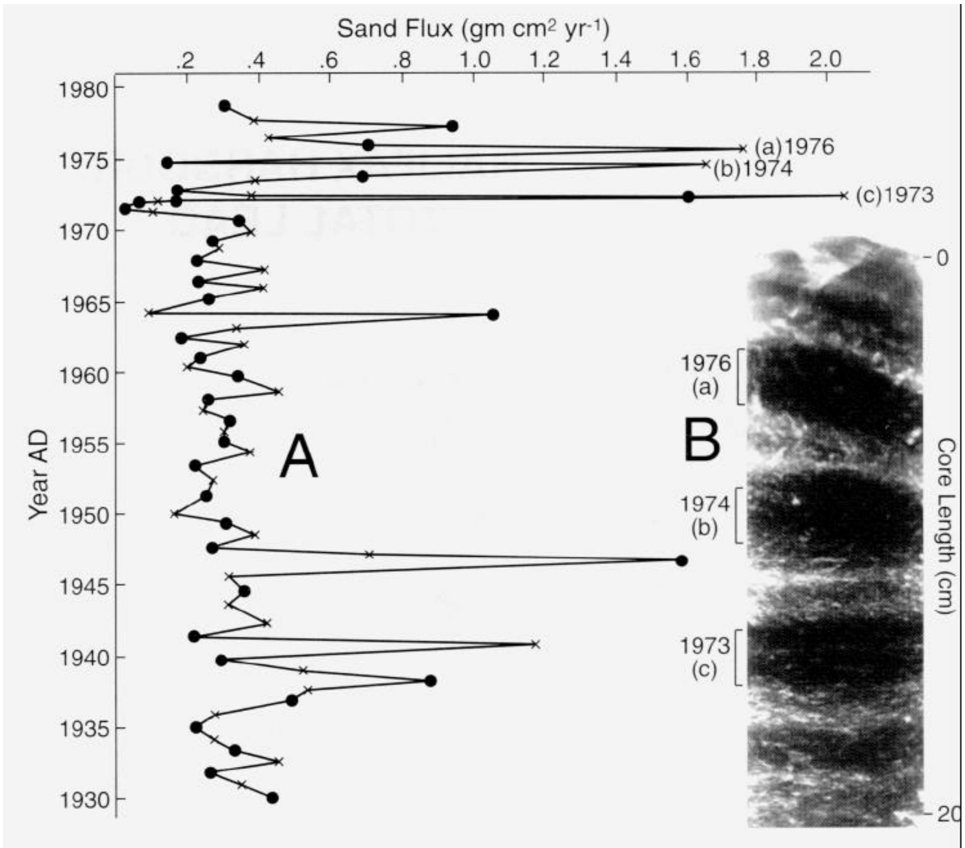


Figure 6: A. Sediment core record of sandparticle flux discharged into the Saguenay Fiord basin increases during relatively high spring river discharges.
B. Sediments accumulating near the head of the fiord show the effect of increased sand deposition (lighter layers) during the annual spring flood.

Quaternary Paleoenvironments

Coastal and offshore sedimentary sequences contain the record of past environmental events, particularly for the last one to two million years. High-resolution acoustic survey techniques are able to discriminate the most recent environmental changes, while deeper penetration medium-resolution profiles can detect glacial and inter-glacial cycles. A major effort in environmental marine geology is the mapping of Quaternary sediments around Canada's margins and reconstructions of the environmental history that they contain. Meltwater draining the Arctic, via Hudson Strait, is considered to play a key role in modifying the climate of the northern hemisphere. Cores from Hudson Strait and the Labrador Sea contain paleoenvironmental records which can be used to elucidate large scale forcings, feedbacks and changes in ocean circulation during glacial/interglacial cycles, particularly as they affect the northern hemisphere.

Environments with high-sedimentation rates often contain a very detailed proxy record of climate change for the last few thousand years. For example, in Saguenay Fjord and Halifax Harbour, correlations can be drawn between climatic conditions in the catchment and sediments deposited in basins (Figure 6). These data are used to improve our understanding of rapid and abrupt climatic change and to elucidate linkages between natural and anthropogenic sediment sources. Powerful computers have also enabled mathematical models to be developed, simulating climatic, hydrologic and catchment conditions during periods of colder and warmer climate. Simulated river flows and sediment discharge are then used as inputs to generate basin fill models which can be compared with natural systems recorded in seismic records and preserved in core samples (Figure 7).

The Future

The research program within Environmental Marine Geology powerfully inte-

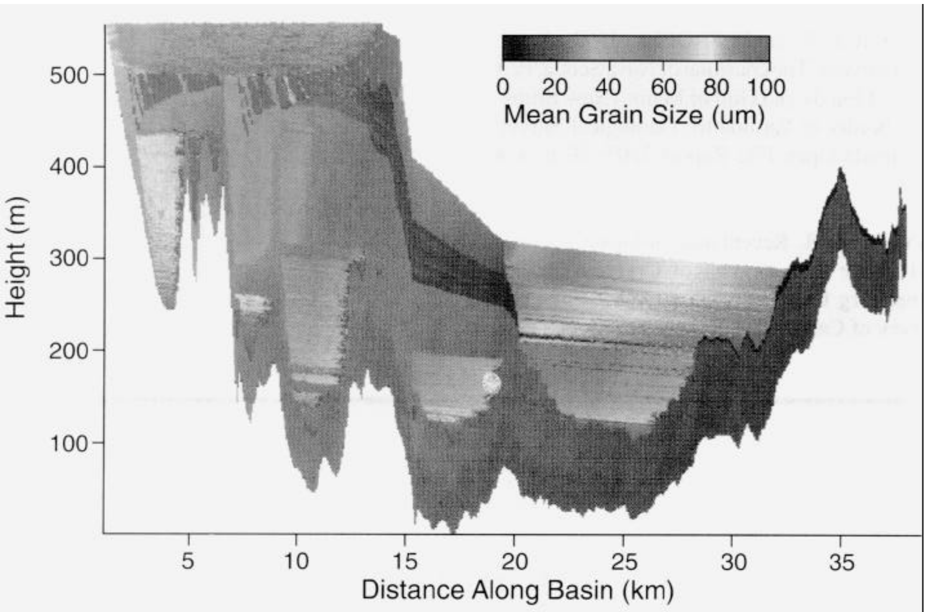


Figure 7: Numerical predictions of mean grain size generated by basin fill simulation. 5000 years of deposition for Itirbilung fjord are shown. Sediment pulses are varied while the system experiences a 30m exponential fall in sea level, followed by a linear sea level rise of 80m, followed by an exponential fall of 20m. Features of note include: coarse grained sloping foreset beds, interbedded turbidite and hemipelagic filled sub-basins, seaward grain size fining and backfilled basin created due to sea level rise. These predictions are bared on seasonal input of suspended load and bedload with knowledge of river hydrology and basin oceanography. The vertical data are averaged over 1m intervals to approximate airgun reflection seismic record resolution.

grates elements of pure and applied research. Advances in geoscience are made using data, technology and expertise gained from cooperating with clients and outside agencies in solving practical problems. Environmental investigations are focused on understanding natural processes and constraints affecting development, and on evaluating potential or previous impact on the environment by a development. Marine environmental issues are complex: geoscience knowledge provides the essential underpinning to solve marine environmental problems.

Public consciousness and public concern for the marine environment continues to grow. The Environmental Marine Geology Subdivision has a well-balanced and focused research program capable of meeting challenges to the marine environment and Canadian society into the 21st century. The impacts of offshore energy development on the environment, the relationships between fisheries and seafloor habitat, and coastal zone management with particular emphasis on the flux of sediments and toxins from land to the offshore, are just three issues of national importance that will continue to be addressed. The Environmental Marine Geology Subdivision will continue to develop new environmental technologies to meet these challenges, to find creative solutions to environmental problems, and to transfer this technology to the private sector.

References

AMOS, C.L. and J.T. JUDGE. 1991. Sediment dynamics of eastern Canadian Continental Shelf. Continental Shelf Research. 11: 1037-1068

AMOS, C.L., J. GRANT, G.R. DABORN and K. BLACK. 1992. Sea Carousel - a benthic, annular flume. Estuarine, Coast and Shelf Sciences, 34: 557-517.

BUCKLEY, D.E. and G.V. WINTERS. 1992. Geochemical characteristics of contaminated surficial sediments in Halifax Harbour: impact of waste discharge. Canadian Journal of Earth Sciences, 29: 2617-2639.

CHRISTIAN, H.A., T. MULDER, R.C. COURTNEY, D.C. MOSHER, J.V. BARRIE, R.G. CURRIE, H.W. OLYNK and P.A. MONAHAN. Slope instability on the Fraser River delta foreslope, Vancouver, British Columbia. *In:* 47th Canadian Geotechnical Conference, Halifax, September 21-23, 1994.

CRANSTON, R.E. and D.E. BUCKLEY. 1990. Redox reactions and carbonate preservation in deep-sea sediments. Marine Geology, 94: 1-8.

FORBES, D.L. and R.B. TAYLOR. 1994. Ice in the shore zone and the geomorphology of cold coasts; Progress in Physical Geography, 18 (1): 59-89.

MORAN, K. Offshore site investigations on Canadian continental margins. *In* Jack Clark, Lorne Boone, Michael Paulin, Richard McHenna and Keith Witney [ed.] 4th Canadian Conference on Marine Geotechnical Engineering, St. John’s, Newfoundland, June 1993, v. 3, 977 p.

ROGERS, B.T.. S.M. BLASCO and M.G. JEFFERIES. Pressure meter testing in Beaufort Shelf surficial sediments. *In* Jack Clark, Lorne Boone, Michael Paulin, Richard McHenna and Keith Witney [ed.] 4th Canadian Conference on Marine Geotechnical Engineering, St. John’s, Newfoundland, June 1993, v. 1, 209 p.

SCHAFER, C.T., J.N. SMITH and R. COTE. 1990. The Saguenay Fiord: A major tributary to the St. Lawrence Estuary *In* Elsabh and Silverberg, [ed.] Oceanography of a Large Scale Estuary: The St. Lawrence, Springer Verlag, New York, p. 421-428.

SHAW, J. and D.L. FORBES. 1992. Barriers, barrier platforms, and spillover deposits in St. George’s Bay, Newfoundland: paraglacial sedimentation on the flanks of a deep coastal basin; Marine Geology, 105: 119-140.

SHAW, J., R.B. TAYLOR and D.L. Forbes. 1993. Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia; Geographic physique et Quatemaire, 47 (2): 221-238.

SMITH, J.N. and C.T. SCHAFER. 1987. A 20th Century record of seasonally modulated sediment accumulation rates in a Canadian fjord based on Pb 210 measurements. Quaternary Research, 27: 232-247.

SOLOMON, S.M. and D.L. FORBES. 1993. Coastal circulation and sedimentation in an embayed thermokarst setting, Richards Island Region, Beaufort Sea. *In* Proceedings of the 1993 Canadian Coastal Conference, May 4-7, 1993, Vancouver, B.C., v. 2, 699-714.

SOLOMON, S.M., D.L. FORBES and B. KEIRSTEAD. 1993. Coastal impacts of climate change: Beaufort Sea erosion study; Geological Survey of Canada Open File Report 3558, 34 p., 30 figs. and 2 appendices.

SYVITSKI, J.P.M. and J.M. ALCOTT. 1993. GRAIN2: Predictions of particle size seaward of river mouths. Computers & Geoscience 19(3): 399-446.

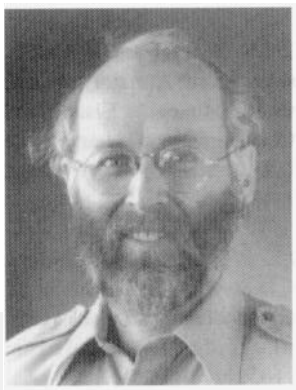
SYVITSKI, J.P.M. and J.M. ALCOTT. 1993. DELTA6: Numerical simulation of basin sedimentation affected by slope failure and debris flow runout. *In:* Proceedings of the Pierre Beghin International Workshop on Rapid Gravitational Mass Movements, Grenoble, France, Dec. 6-10, 1993, p.l80-195.

TAYLOR, R.B. and D. FROBEL. 1993. Aerial video surveys, The coastline of Nova Scotia, Part 1 Bay of Fundy and Gulf of Maine (New Brunswick border to Yarmouth); Geological Survey of Canada Open File Report 2705; 20 p. + 4 tapes.

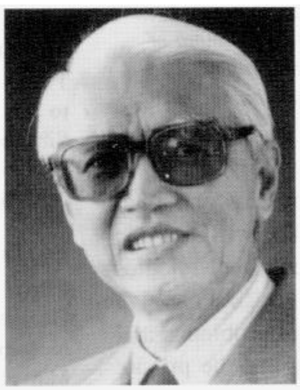
TAYLOR, R.B. Recent morphological changes and future management of Crescent Beach, Lunenburg County, Nova Scotia, Geological Survey of Canda Open File Report 2675, 20 p.

The Impact of Atmosphere-Ocean Coupling on the Wave Climate

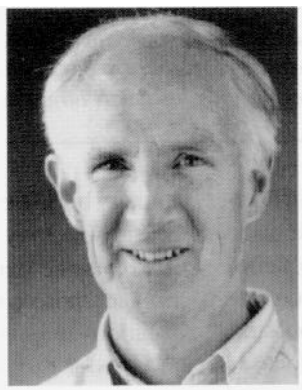
W. Perrie, L. Wang, F. Dobson and B. Toulany



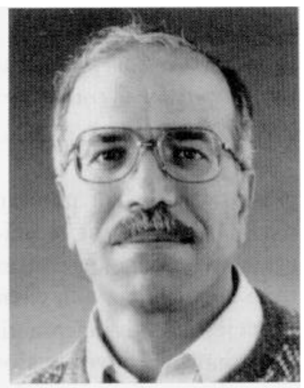
W Perrre



L. Wang



E. Dobson



B. Toulany

The last couple of years have seen the occurrence of 'episodic' wave fields that have been extraordinary in their extent and their intensity. They are mesoscale wave fields. In spatial extent they cover hundreds, not thousands of square km, and in temporal extent, they last for tens of hours. However in intensity they have been phenomenal. The 'Halloween storm' of October 31, 1991, produced waves that were measured by Scotian Shelf waveriders at a significant wave height (what sailors estimate: statistically, the average height of the highest third of the waves) of 17.3m, implying a maximum wave of about 30m. Had this occurred at Hibernia when the offshore oil platform was in place, operations would be seriously impacted and the facility might have to assume a survival mode, with the evacuation of all non-essential personnel. The peril to ships should also be evident. This includes supply and transport ships to Hibernia and Cohasset- Panuke as well as fishing boats. Figure 1 shows the storm track for the Halloween storm. The looped trajectory of the storm's path is notable for its level of complexity. Figure 2 shows the time series of the winds, waves and wave periods at waverider buoy 44137, during the storm. Furthermore, the Halloween storm is not alone. The recent 'storm-of-the-century', March 12-16, 1993 also saw significant wave heights (Hs) of almost 17m as measured by waverider buoys.

According to presently estimated extremes in the Scotian Shelf wave climate (shown in Figure 3) the 100-year significant wave, which is the estimated highest significant wave expected in 100 years, is about 12m. Therefore, the 17.3m significant wave height of the Halloween Storm is equivalent to a 1000-year wave. Figure 4 compares Gumbel versus Borgman distributions for a representative point, 46.88 N. 48.75 W for

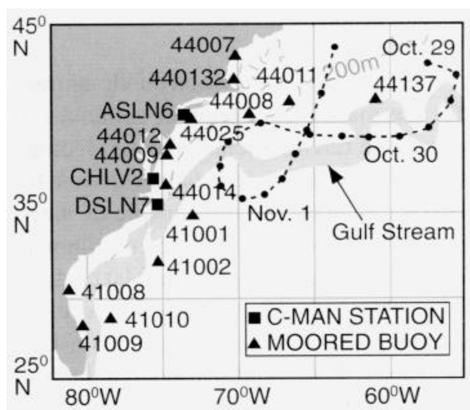


Figure 1: The October 1991 Halloween storm track, East Coast permanent buoys and the Gulf Stream.

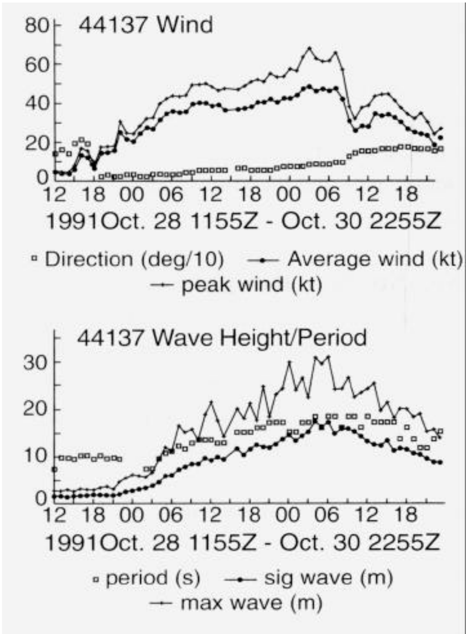


*Figure 2: Buoy wind and wave measurements for waverider buoy 44137. Average and peak wind speedy and wind directions are shown. The maximum wave is approximately 1.7 * Hs.*

the Grand Banks. The differences are slight, for the two distributions. Occurrence of a 17m wave, for example at the 100 year return period, may alter the fit of either distribution, and may make important differences in estimates for the 10- and 50-year estimated significant wave heights. The problem is that the return period for 17m significant wave heights is unclear, either for the Scotian Shelf or for the Grand Banks. Perhaps it is shorter than 100 years. More importantly, perhaps it is driven by variability in atmospheric forcing and may not be viewed merely as a stochastic process. In this case, distributions such as that of either Gumbel or Borgman are misleading.

It is evident that there is need for the ability to understand and model mesoscale (extremal) wave fields, in the sense of being able to predict them. Explanations for the occurrence of mesoscale storms in space and time, their evolution and their intensity are still sought (the first and second Canadian Atlantic Storms Programs have had this as a major goal). Atmosphere- ocean coupling may hold some of the factors important in modelling mesoscale extremal wave fields. This follows from the extreme sensitivity that wave estimates have to forcing wind fields. Atmosphere-ocean coupling will also lead to revised estimates for surface winds fields. Moreover, guidelines are needed for the asymptotic limits for wave parameters; the existing "Pierson- Moskowitz" limits have been proven inadequate in the sense that the two aforementioned storms appear to have exceeded them.

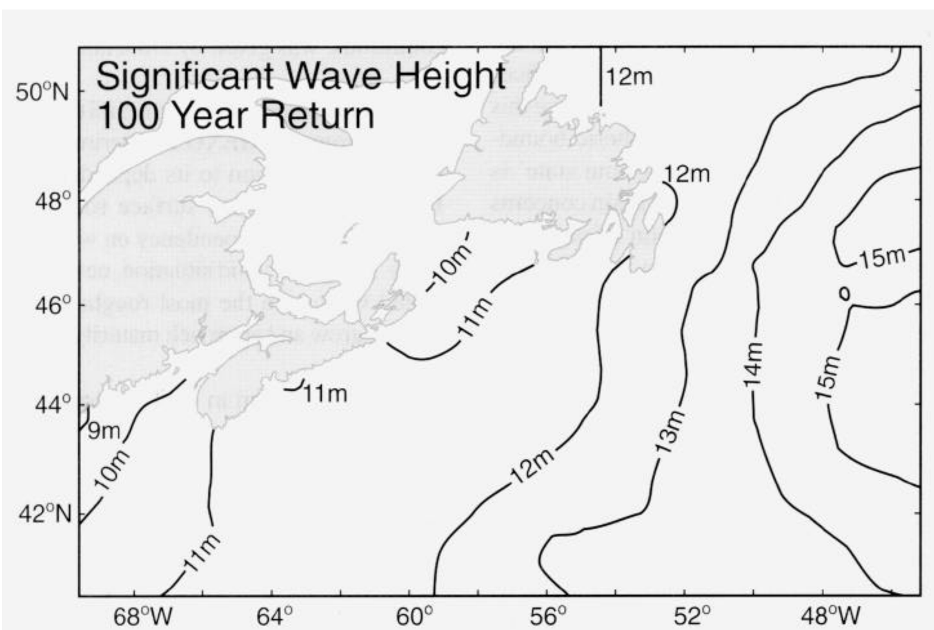


Figure 3: Contours for the 100-year significant wave heights for the northwest Atlantic off eastern Canada. These were generated by the Canadian Climate Centre by considering the 68 most severe storms recorded over the years 1959-88. Wind fields for these storms are constructed and wave heights are hindcasted, using the present operational Atmospheric Environment Service (A ES) wave model.

Atmosphere-wave coupling

We have considered the impact of coupling the atmospheric boundary layer (the lower 1000 m) to wave models of limited extent (less than one ocean) in Perrie and Wang (1994). In meteorology, the "geostrophic" wind is used to express the balance relationship between the gravitational potential field (over the ocean, the horizontal gradient of the air pressure) and the wind field on a two-dimensional surface. The "thermal" wind is used to express the balance relationship between the change of wind with height and the mean temperature field in three-dimensional space. A question of considerable interest in both atmospheric and oceanic dynamics, which is as yet unresolved, concerns the balance relationship between the vertical wind velocity profile in the boundary layer and the state of the sea surface. To answer this question, it is important to recognise that the key parameter at the air-sea interface in studies of oceanic and atmospheric dynamics is the sea surface roughness. But the roughness we speak of here is not the physical roughness of the sea surface itself: it is an equivalent length (or height) related to the sea surface drag, or wind stress. It is directly related only to those components of the surface waves which cause the drag, and are assumed to be the short, steep, slow-moving waves which darken the sea surface during wind gusts. Their characteristics are determined by the wind profile in the atmospheric boundary layer. The nonlinearity of the relationship makes it difficult to relate sea surface roughness to measurable wave parameters in a simple quantitative manner. Theoretical linear approaches have been developed by Chalikov and Belevich (1993) and Janssen (1989) but have not yet been applied two-dimensionally. Empirically motivated relations between sea surface roughness and sea state parameters such as wave age - the ratio of wave speed to wind speed - have been presented by Donelan (1990) and Smith et al. (1992). Because empirically motivated relations are much simpler than a more formal analysis, for example that of Chalikov and Belevich (1993), they allow a preliminary approach to atmosphere-wave coupling.

Presently, there is a growing interest in data assimilation in oceanic models, because the launch of a new generation of

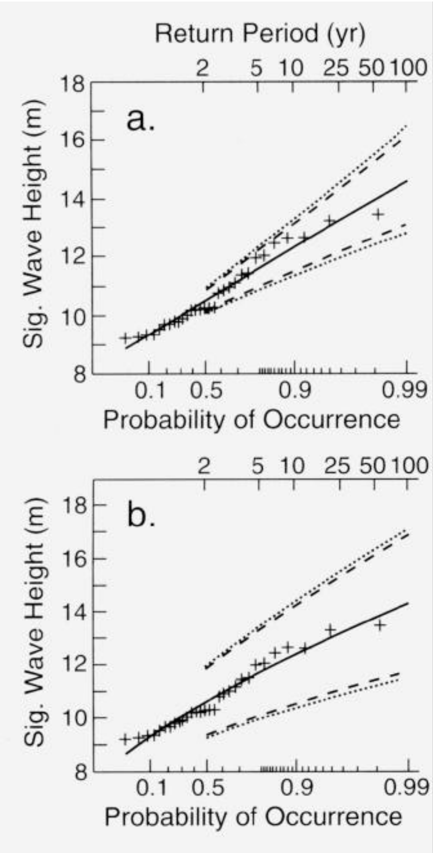


Figure 4: Peak significant wave heights in the top 30 storms for extrermal analysis using (a) Gumbel and (b) Borgman distributions for the Grand Banks (46.88 N, 48.75 W). In each case, the correlation is 0.98, with the 90% confidence limits denoted (---) and the 95% confidence limits, (...).

satellites makes a wealth of sea surface data available, both for the atmosphere and for the ocean. (Data assimilation is the technique of insertion of observations taken at differing places and times into dynamical models, such as weather forecasting models, or oceanic prediction models, by using the physics of the models and the known statistical variability of the observations to fit the data to the model predictions.) Since remotely sensed marine winds are derived - with the aid of empirical models - from the electromagnetic signature of wind-driven waves on the sea surface, a physics-based relationship between the sea surface winds and the waves they produce is required. The relationship of interest in this context is that between the wind stress - the area rate of transfer of wind momentum to the water below it, or the drag of the water on the wind in more common language - and the sea state - the ratio of the speed of the waves to the component of the wind in the wave direction. This allows us to understand, by using relationships between the short waves produced directly by the wind and sensed by the radars and the long-wavelength waves which dominate the open ocean, how to couple the wave prediction models with the meteorological models which predict the wind stress on the sea surface. Janssen (1989) and Del Las Heras and Janssen (1992) have demanded that the assimilated winds of the atmospheric model be consistent with the assimilated waves of the wave prediction model. However, although they adjusted the wind fields so that the winds are consistent with the waves, it was not in conjunction with a boundary layer model incorporating the sea-surface fluxes of momentum (the wind stress), heat and vapour. A coupled wind-wave model, utilizing a boundary layer model and a wave model, allows not only dynamic consistency between wind and wave models but also a consistent approach to data assimilation to correct both wind and wave fields.

Ultimately, the coupling of the atmospheric boundary layer with a wave model must result in a derivation of the equilibrium state between winds and waves. ‘Equilibrium’ is understood in terms of implicitly consistent estimates for sea surface roughness in both the boundary layer model and in the wave model. However, the present practice in weather forecast offices does not allow the wave model to have this consistency with the atmospheric boundary layer model: an ‘equilibrium state’ is not achieved. There are two main concerns involved in the specification of an ‘equilibrium state’. Firstly, given a wind speed at a given place and time, (specific space-time coordinates), the standard wave model implicitly involves sea surface roughness estimated via empirical formulae. This, in turn is related to estimates for the wave energy. However, the wind speed from a meteorological boundary layer model is related to the sea surface roughness and appropriate thermal conditions by a different formalism. The sea surface roughness in the atmospheric model differs from the sea surface roughness implicit in the wave model. Secondly, the reaction of sea states on the wind profile with height is not taken into account in modem wave models. This effect on the wind profile occurs because the interaction between the wind field and the wind- generated ocean waves is strong. A coupled wind-wave model must not only consider the interaction between winds and wind-generated waves, but must use the same sea surface roughness in modelling both waves and the atmospheric boundary layer.

Sea Surface Roughness

Dynamical coupling between the atmosphere and the ocean has been the subject of numerous research efforts in the last few years. Although the effects of some characteristic properties are becoming clearer, the extremely complex processes of air-sea interaction are still not fully understood. The best known relation for the roughness of the sea surface, proposed by Charnock (1953, states that the sea surface roughness depends only on the friction velocity: the friction velocity is understood as the wind speed multiplied by a friction factor, the square root of the ‘drag coefficient’. The Charnock relation is void of all characteristics of the wave field and therefore may be denoted as ‘uncoupled’. It follows that the Charnock relation is not capable of a good representation of specific dynamical processes, for example, young wind-generated waves or the response of waves to changing (turning) wind directions. A clear demonstration of the breakdown of the Charnock relation, in all but mature wave conditions, was given by Donelan (1982).

Recent observations of Smith et al. (1992) from the HEXOS experiment imply that, in addition to its dependency on friction velocity, sea surface roughness must also have a dependency on wave maturity. In a given wind situation, newly generated waves are the most rough: as they evolve, grow and approach maturity, the as-

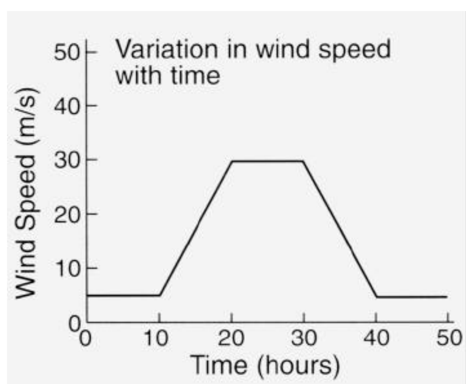


Figure 5a: Hypothetical variation in wind speed for a passing cyclonic system.

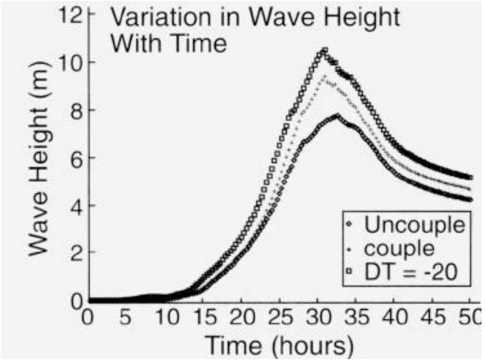


Figure 5b: Corresponding time series for Hs as modelled by 'uncoupled', 'coupled' and 'coupled unstable' models. The last of these assumes an air-sea temperature difference of -20. indicated by DT=-20.

sociated sea surface roughness decreases. Thus wave state is implicated in estimates for sea surface roughness. The HEXOS sea surface roughness may therefore be denoted as 'coupled' because it couples ocean wave parameters and atmospheric boundary layer parameters.

Coupled Wind-Sea Modelling

Perrie and Wang (1994) have made a preliminary approach to atmosphere- wave coupling, which may have application to

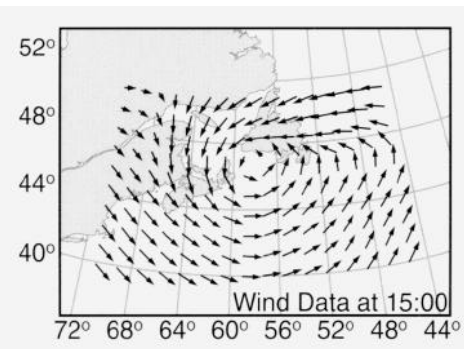


Figure 6: The wind velocity field at 0000 Z on November 15, 1991.

operational forecast situations. The roughness parameterizations described above as 'coupled' and 'uncoupled', the operational boundary layer model documented by Delage (1988) from Division de recherche en prevision numérique, Service de l'environnement atmosphérique, Dorval (RPN) and the WAM wave model of Hasselmann et al (1988) from the European Centre for Medium Range Weather Forecasting at Reading, UK (ECMWF) are connected together iteratively. The sea surface

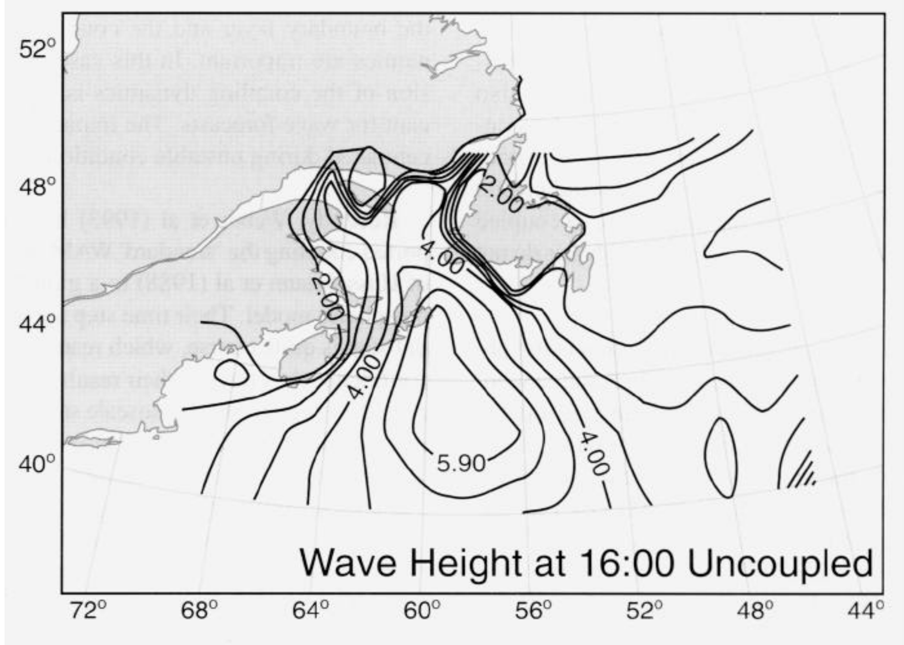


Figure 7a: Contours for Hs 0000 Z on November 16, 1991 as estimatedfrom the 'uncoupled' model.

roughness in the boundary layer model is consistent with that implicit to the wave model at each time step and for all the spatial gridpoints of the model simulation.

To demonstrate a comparison between the 'coupled' and 'uncoupled' models described above, we consider a time dependent wind field at a given point in space, associated with a passing cyclonic system, as in Figure 5a. Figure 5b presents corresponding time series for significant wave heights for 'uncoupled', 'coupled' and 'coupled unstable' model situations. The air-sea temperature difference is assumed -20°C in the unstable situation. During unstable conditions, the air temperature is colder than the sea surface temperature. The difference between the 'uncoupled' and 'coupled unstable' model results is about 25%. Moreover, although a given wind speed may be specified, it is implicit in

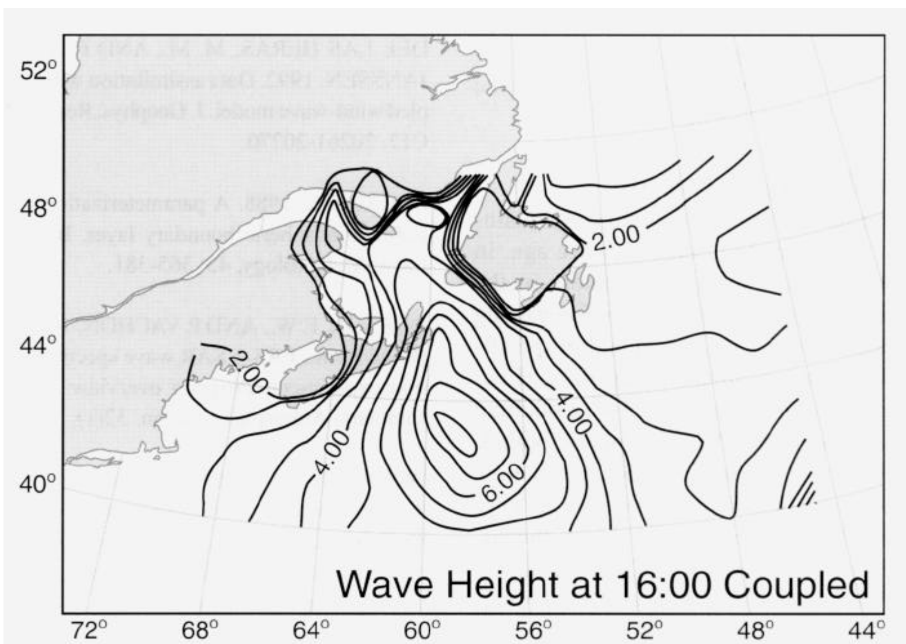


Figure 7b: Contours for Hs at 0000 Z on November 16, 1991 as estimated from the 'coupled' model.

these tests that as the roughness and friction velocity evolve, as the seastate matures, the vertical wind profile is also changed in time. This is evident in the 'coupled' model and is the subject of further work. Of course, the vertical wind profile with time is unchanged in the uncoupled model because changes of roughness do not occur.

To provide model verification using observed field data, the 'coupled' and 'uncoupled' models were implemented on the northwest Atlantic. Observations used to verify the model were collected during the Calibration/Validation (CAL/VAL) experiment of Dobson and Vachon (1993), from Nov. 8 to 25, 1991. Wind data was provided by RPN. During the CAL/VAL period a cyclone developed in the region between Nova Scotia and Newfoundland on November 1.5. The wind field for 0000 Z on November 1.5 is shown in Figure 6. Corresponding estimates for significant wave height Hs fields from the 'uncoupled' and the 'coupled' models are shown for 0000 Z on 16 November in Figures 7a-b, respectively. It is notable that the peak Hs reported by 'coupled' model is 7.0 m, whereas the 'uncoupled' model reported a peak Hs of only 5.9 m. The corresponding maximum Hs in the cyclone region, where the wind direction and wind speed are changing rapidly, and the wave age is very young, 7.1 m, which is good agreement with the 'coupled' model estimate. In other regions, because the wave age is older, estimates for Hs for the 'coupled' model are almost the same as for the 'uncoupled' model.

Concluding Discussion

Parameterization of wind-wave maturity, using variables such as wave age, in specifying sea surface roughness in the boundary layer is important in forecasting the significant wave height and in specification of wave climate parameters. However, the standard approach to modelling ocean waves and the atmospheric boundary layer assumes a Charnock-type relation, which presupposes that the waves are very old. If the wind speed is not strong, the difference between estimated Hs provided by the 'coupled' and the 'uncoupled' models is negligible, because the wind-waves quickly become mature. If the wind speed is strong (>20 m/s) or if the wave age is very young, the reaction of the seastate on the boundary layer and the coupling dynamics are important. In this case, inclusion of the coupling dynamics is significant for wave forecasts. The impact is accentuated during unstable conditions.

Recently, Weber et al (1993) have reported coupling the 'standard' WAM model of Hasselmann et al (1988) to a global atmospheric model. Their time step and spatial step is quite coarse, which restricts the confidence they have in their results. However, they suggest that mesoscale storm trajectories may be determined from the atmospheric-wave model coupling. We are pursuing a similar study with a more realistic modelling of both wave and atmosphere-wave coupling dynamics. A preliminary coupling of the wave model to the Regional Finite Element (RFE) model at RPN model is anticipated by winter 1995. A full coupling of the wave model to the RFE model including all aspects of operational modes, data assimilation and verification is planned by 1996-7.

References

CHALIKOV, D., AND M. YU. BELEVICH. 1993. One-dimensional theory of the wave boundary layer. Bound. Layer Meteor. 63: 65-96.

CHARNOCK, H. 1955. Wind stress on a water surface, Quart. J. Roy. Meteorol. Soc. 81: 639-640.

DEL LAS HERAS, M. M., AND P. A. E. M. JANSSEN. 1992. Data assimilation with a coupled wind-wave model. J. Geophys. Res. 97: No. C12, 20261-20270.

DELAGE, Y. 1988. A parameterization of the stable atmospheric boundary layer. Boundary Layer Meteorology, 43: 365-381.

DOBSON, F.W., AND P. VACHON. 1993. The Grand Banks ERS-1 SAR wave spectra validation experiment: Program overview and data summary. Atmosphere-Ocean. 32(1): 7-29.

DONELAN, M. A. 1982. The dependence of the aerodynamic drag coefftcient on wave parameters. p. 381-387. In Proc. First Int. Conf. on Meteorology and Air-Sea Interaction of the Coastal Zone. The Hague.

DONELAN, M. A. 1990. Air-Sea Interaction. p. 239-292 In B. LeMehaute and D. Hanes [ed.], The Sea: Ideas and observations on progress in the study of the seas. Vol.9. Wiley-Interscience, New York.

HASSELMANN, S., K. HASSELMANN, G. K. KOMEN, P. JANSSEN, J. A. EWING, AND V. CARDONE. 1988. The WAM model -A third generation ocean wave prediction model. J. Phys. Oceanogr. 18: 1775-1810.

JANSSEN, P. A. E. M. 1989. Wave induced stress and the drag of air flow over sea waves. J. Phys. Oceanogr. 19: 745-754.

PERRIE, W. AND L. WANG 1994. A coupling mechanism for wind and waves. Submitted to J. Phys. Oceanogr.

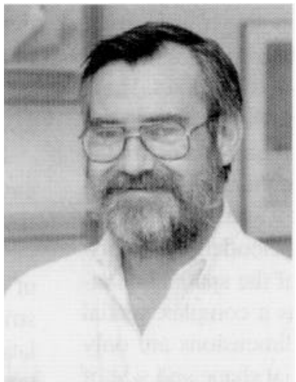
SMITH, S. D., R. J. ANDERSON., W. A. OOST., N. M. KRAAN., J. DECOSMO., K. B. KATSAROS., K. L. DAVIDSON., K. BUMKE.. L. HASSE., AND H. M. CHADWICK. 1992. Sea surface wind stress and drag coefficient: The HEXOS results. Boundary Layer Meteorology. 60: 109-142.

WEBER, S. L., H. VON STORCH, P. VITERBO, AND L. ZAMBRESKY. 1993. Coupling an ocean wave model to an atmospheric general circulation model. Climate Dynamics. 9: 63-69.

Topology and the Changing World of Chartmaking

H. Varma, and D. Frizzle

H. Varma



D. Frizzle

The past five years has seen a revolution in the process of position fixing. Global Positioning System (GPS) can now provide worldwide coverage with immense reliability. Navigating the electronic chart (ENC) can immediately inform the user of traversing danger zones or of collision potential. The implementation of these features requires the formal introduction of topology into these products.

What is Topology?

Topology has been defined as a study of relationships that exist between spatial objects. This has been taken to higher levels by research done at the Canadian Hydrographic Service (CHS), by the addition of new mechanisms where attribute topology is used to drive spatial topology. These new definitions allow the user to manipulate, search and analyse data in a database before final portrayal in a Geographic Information System (GIS). This paper outlines some of the solutions which the CHS and its partners have developed.

Conventionally, topological information is composed of lines called arcs whose end points meet to form precise nodes and which form non-overlapping polygons within each thematic layer. Nautical charting requires topology to define all color filled areas currently shown on the paper chart.

Topology and Chart Files

Chart files for the ENC require considerable information that was inferred by the paper chart mariner. For example, darker shades of blue indicating increasingly shoaler water must now be labeled, explicitly indicating water depth. ENC's and modern plotter systems require these completed topological files which make additional demands on the GIS and on the hydrographer. The solution viewed by the CHS is to include topological relationships within the relational database management system (RDBMS). This will allow the compiler to extract and manipulate these data in a resolved manner.

The digital chart is separated into three thematic layers: bathymetry, overlay areas and so-called non-topological information such as names, notes, roads, soundings, and symbols.

Coastline, contours, low water lines, danger lines, buildings and various limits are some features included in conventional plane sweep topology.

Topology and the Database

New Point Set Topological constructs using helical hyperspacial codes (HHcodes) incorporate the above conventional non-topological information into one consistent topological model which enhances GIS capabilities to perform queries such as "What is the relation between these two objects?', or "Get all objects that are in a specified relation to a given object". This is critical in trying to implement intelligence into the electronic chart to inform the user of imminent collisions or danger areas in traversing waypoints. In the ENC data base, spatial data such as islands, bathymetry (Figure 1), would be stored in topological quadrants called tiles. Tiles are constructs enabling storage of feature information and accuracy factors in an efficient binary manner hence the binary fractalization on shoreline occuring only where the line information exists.

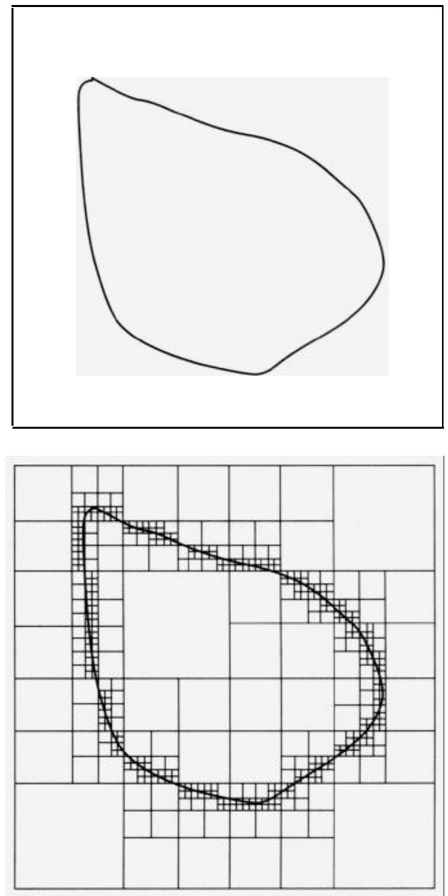


Figure 1

Topological Data Models

Topological data structures have become a well accepted method for modeling spatial objects among GISs. The currently known topological data models offer only a single degree of spatial relationship between objects. The problem has been the implementation of topology using intermediate data structures. Most topological structures are implemented from input polylines from which traditional topological components, such as closed polygons, spaghetti, rings, chains, and line segments are constructed using pointer lists. This intermediate structure is formed in a plane sweep process, in which line segments are connected with nodes. Nodes are connected in monotone polygonal subdivisions termed 'lobes', which always have a left side and right side. The line segments form two dimensional topological constructs of interior and boundary from which topological relationships can be formulated.

Point Set Topology

Egenhofer models topology on the point set topological notions of interior and boundary. This results in 16 binary topological relations. The relations are based on comparisons of empty and non-empty set intersections between boundary and interior of topological spaces.

The topological relations are described by the union of four intersections of the boundary and interior of two point sets. This forms the basis of interaction between two topological spaces A,B. Bits sequences of true and false are rendered from boundary interior intersections (i.e. 0 0 0 0 = r0, 0 0 0 1 = rl, 0 0 1 0 = r2 etc.)

Topological Functions and Definitions

r0 Disjoint	r8 Touch
rl Interior-in-body	r9 Contained-in-bdry
r2 Bdry-in-interior	r10 Contains-in-bdry
r3 Bdry-x-interior	r11 Most-in-bdry
r4 Interior-intersect	r12 Equal
r5 Contains	r-13 Covers
r6 Inside	r14 Covered by
r7 Indents	r15 Intersect

Point set topology allows the use of set operations involving spatial objects within the corporate relational model using spatial query language(SQL).

N Dimensional Topology

Complex topology can be depicted as a N dimensional topology. It consists of a union of boundary and interior of n dimensional interval constraints. A good example of a complex topology is a storm cloud. The storm cloud is said to consist of x, y, z, temperature, pressure, water content and electrical potential. Each is a dimension in its own right.

Specified intervals within each dimensional vector (i.e.: 2deg < temp < 5deg) determine the topological boundaries and interior of the storm cloud. If the range intervals of each dimension (other then the spatial dimensions) are moved to a new spatial location, the storm cloud topology must appear in this location. This is because these are the optimum conditions for a storm cloud. These attribute dimensions form the attribute topology of the storm cloud. If one or more of the dimensional elements of the attribute topology exceeds or is under it's respective interval constraint, the storm cloud topology disappears. The merging of the spatial and attribute topologies forms a complex spatial topology. The spatial dimensions are only consistent with the spatial shape and size of this complex topology. The attribute topology drives the spatial topology. Variable sized voxels are used to partition space to form the complex spatial topological structure.

Once data resides in this type of topological data structure, analysis can be performed between diverse data sets. This gives rise to a new spectrum of tools, such as correlative data analysis (data fusion). Such a generalized approach to data analysis is very valuable for correlative analysis of distinct, complex, multidimensional data sets in the earth and biological sciences.

Temporal Topology

Current databases describe only one state of the data. Historical states are essentially forgotten and the anticipated or forecast future cannot be treated. The obvious obstacle is that current databases cannot trace multiple versions of entities through time.

In reality, data in databases are temporally inconsistent because they become current at different and unknown points in time. In contrast, a temporal database models the dynamically changing world, tracking all points of change and retaining all data within the database.

The inclusion of the temporal element in HHcodes, conceptually speaking, creates space time cubes where depth is the time dimension. Temporal topologies can then be constructed over spatial areas by using time lines. This implies that objects have lifespans during which their attributes may change. Time lines provide the temporal boundary constraints and interior simplices of the time line, defined over a specified spatial area. It creates continuity, which intersecting temporal topologies require. Then 1-dimensional topological operations can be used to interrelate documents, data or products by their respective life spans, which is critical in maintaining or versioning data, documents or products.

Extended SQL Queries

Current commercial database query languages do not sufficiently support such queries. This is because these languages provide only tools to compare equality or order of simple data types, such as integers and strings. The incorporation of topological relationships over spatial domains into the syntax of a spatial query language is an essential extension beyond the power of traditional query languages. This topological query language is currently being introduced in the Oracle Multi-Dimension Product.

EXAMPLE:
HHcode represents the spatial contingent in the query.

QUERY: "Select all surveys that touch or are contained in Chart 4096."

METHOD:

```
    select chart.name
    from FS.Chart
where
        Chart.name=('4096')
 and
        touch(FS.hhcode.chart.hhcode)
 or
        cross(FS.hhcode.chart.hhcode)
```

This framework has an immediate impact on the design and implementation of geographic information systems. Topological spatial relations can be derived from a single consistent data model. Such concepts provide better interaction between diverse data sets based on time and area. This facilitates the idea of data fusion concerning how one set of data affects another set of data, and introduce the concept of the area paradigm.

Conclusion

By the inclusion of HH Codes, spatiotemporal topology, and query facilities on existing database engines, the CHS has produced a new database product with enhancements which will change the world of chartmaking.

Organization and Staff

The Bedford Institute of Oceanography (BIO), the Halifax Fisheries Research Laboratory (HFRL), and the St. Andrews Biological Station (SABS) are research establishments of the Government of Canada and are operated by the Department of Fisheries and Oceans (DFO), both on its own behalf and, in the case of BIO, for the other federal departments that maintain laboratories and groups at the Institute. There are two such departments: Natural Resources Canada (NRCan); and Environment Canada. The former maintains a major unit at BIO, the Atlantic Geoscience Centre of the Geological Survey of Canada. Environment Canada maintains two units at BIO: the Marine Wildlife Conservation Division of the Canadian Wildlife Service; and an Environmental Quality Laboratory. In leased accommodation at BIO are the following private companies, which do work related to the marine sciences: ASA Consulting Ltd. and Brooke Ocean Technology Ltd.

Note: The Department of Energy, Mines and Resources (EMR) became Natural Resources Canada (NRCan) on June 25, 1993.

Presented below are the major groups at BIO, and their managers as at December 1, 1993. In addition to the three research establishments, several staff are located in an office building in Halifax called the Maritime Center (MC). Telephone numbers are included. Note that all numbers at BIO, the Halifax Laboratory and the Maritime Center should be preceded by 902-426.

DEPARTMENT OF FISHERIES AND OCEANS

Scotia-Fundy Region

Regional Director-General
N.A. Bellefontaine MC/2581

Regional Science Director
S.B. MacPhee BIO/3492

Marine Assessment and Liaison Division
H.B. Nicholls, Head BIO/3246

Scientific Computing Services
D. Porteous, Head BIO/2452

Biological Sciences Branch
M. Sinclair, Director BIO/3130
R.E. Lavoie, Asst. Director BIO/2147

Marine Fish Division
R.N. O'Boyle, Chief BIO/4890

Benthic Fisheries and Aquaculture Division
J.D. Pringle, Chief HFRL/6138
(and Director, Halifax Fisheries Research Laboratory)

Biological Oceanography Division
T.C. Platt, Chief BIO/3793

Freshwater and Anadromous Division
J.A. Ritter, Chief MC/3573

Habitat Ecology Division
D.C. Gordon, Chief BIO/3278

St. Andrews Biological Station
W. Watson-Wright, Director
SABS (506) 529-5860

Physical and Chemical Sciences Branch
J.A. Elliott, Director BIO/8478

Marine Chemistry Division
J.M. Bewers, Head BIO/2371

Coastal Oceanography Division
C. S. Mason, Head BIO/3875

Metrology Division
D.L. McKeown, Head BIO/3489

Ocean Circulation Division
R.A. Clarke, Head BIO/2502

Hydrography Branch
Canadian Hydrographic Service (Atlantic)
P. Bellemare, Director BIO/3497

Hydrographic Surveys Division
R.C. Lewis, Manager BIO/2432

Nautical Publications
S.L. Weston, Manager BIO/7286

Hydrographic Development
R.G. Burke, Manager BIO/5411

Data Management
S.T. Grant, Manager BIO/5409

Aquaculture Coordination Office
R. H. Cook, Manager MC/9068

Management Services Branch
J. Wheelhouse, A/Director BIO/7433

Marine Services
W. Cottle, A/Chief BIO/7292

Engineering and Technical Services
D.F. Dinn. Chief BIO/2009

Facilities Management
A. Medynski, Chief BIO/7449

Materiel Management
B. Tsinman. Chief BIO/5226

Information Systems Services
T. Wagg, A/Chief MC/9315

Library Services
A. Fiander. Chief BIO/3675

Administrative Services
G. Browne, A/Chief BIO/7037

Comptroller Branch
G.C. Bowdridge, Director MC/6166

Accounting and Treasury Operations
S. Lucas, Chief MC/3552

Financial Planning and Analysis
L.Y.N. Seto. Chief MC/7060

Communications Branch
J. Gough, Director MC/3550

Science Communications
M. MacDonald BIO/6414

NATURAL RESOURCES CANADA

Geological Survey of Canada

Atlantic Geoscience Centre
D.B. Prior. Director BIO/3448

Basin Analysis
K.D. McAlpine, Head BIO/2730

Environmental Marine Geology
R.A. Pickrill, Head BIO/7730

Regional Reconnaissance
J. Verhoef. Head BIO/5687

Program Support
K.S. Manchester. Head BIO/3411

Administration
G. McCormack, Head BIO/2111

ENVIRONMENT CANADA

Atlantic Region

Marine Wildlife Conservation Division
(Canadian Wildlife Service)
E.H.J. Hiscock, Manager BIO/6314

Environmental Quality Laboratory
Dr. P.E. Belliveau, Manager
(506) 851-3837

K.G. Doe, Administrative Head,
Dartmouth (BIO) Laboratory
BIO/3284

Projects

Presented below is a list of the projects and individual investigations undertaken by the Department of Fisheries and Oceans' laboratories in the Scotia-Fundy Region, by the Atlantic Geoscience Centre of Natural Resources Canada, and by Environment Canada units at BIO, during the review period.
For more information on these projects, many of which are continuing, please write to: Regional Director of Science, Scotia-Fundy Region, Department of Fisheries and Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2.

DEPARTMENT OF FISHERIES AND OCEANS SCOTIA-FUNDY REGION

PHYSICAL AND CHEMICAL SCIENCES BRANCH

A. OCEAN CLIMATE SERVICES

1. Humidity Exchange Over the Sea (HEXOS) Programme *S.D. Smith, R. Anderson*
2. Microstructure Studies in the Ocean
N.S. Oakey
3. Investigations of Air-Sea Fluxes of Heat and Momentum on Large Space and Time Scales using Newly Calibrated Bulk Formulae
F. W. Dobson, S.D. Smith
4. The Spin-Down and Mixing of Mediterranean Salt Lenses
N.S. Oakey, B.R. Ruddick (Dal)
5. Modelling of the Labrador Sea
C. Quon
6. Moored Measurements of Gulf Stream Variability: A Statistical & Mapping Experiment
R.M. Hendry
7. Newfoundland Basin Experiment
R.A. Clarke, R.M. Hendry, E.P Jones
8. Problems in Geophysical Fluid Dynamics
C. Quon
9. Norwegian/Greenland Sea Experiment
R.A. Clarke, E.P Jones, J. Reid (Scripps) J. Swift (Scripps)
10. Studies of the North Atlantic Current and the Seaward Flow of Labrador Current Waters
J.R.N. Lazier
11. Ship of Opportunity Expendable Bathythermograph Programme for the Study of Heat Storage in the North Atlantic Ocean
F. Dobson
12. Data Management & Archival
D.N. Gregory
13. Eastern Arctic Physical Oceanography
C.K. Ross
14. Water Transport through and in the Northwest Passage
S.J. Prinsenberg
15. Seasonal and Interannual Variability in the Gulf of St. Lawrence
G.L. Bugden
16. Tidal and Residual Currents - 3-D Modelling Studies
K.-T Tee
17. Circulation and Air/Sea Fluxes of Hudson Bay and James Bay
S. Prinsenberg
18. CTD's and Associated Sensors
A.S. Bennett
19. Handling and Operational Techniques for Instrument/Cable Systems
J.-G. Dessureault, R.F Reiniger
20. Climate Variability Recorded in Marine Sediments
J. Smith
21. The Carbonate System & Nutrients in Arctic Regions
E.P Jones
22. Distribution of Sea Ice Meltwater in the Arctic
FC. Tan, P. Strain
23. Intergyre Exchange: Flow Across 50°W South of the Grand Banks
R. Hendry
24. World Ocean Circulation Experiment (WOCE) Hydrographic Programme Sections
R.A. Clarke, R.M. Hendry, E.P Jones, J.R.N. Lazier
25. CO, Exchange at the Air-Sea Interface
S.D. Smith, R. Anderson, F. Dobson, E.P Jones
26. CTD System for Ship-of-Opportunity Program
J.-G. Dessureault, R.A. Clarke, B. Beanlands, S. W. Young
27. Turbulent Mixing Studies during the North Atlantic Tracer Release Experiment
N.S. Oakey, B.R. Ruddick
28. Oxygen Isotopes and Mixing on the Scotian Shelf
P. Strain, F. Tan, P. Smith
29. Development of Efficient Models for the Study of Long-Term Climate Variations
D.G. Wright, T.S. Stocker
30. Radar Viewing Mechanisms for Ocean Feature Mapping
B.J. Topliss, T. H. Guymer
31. Temperature/Salinity Chain Development
G.A. Fowler: R.A. Clarke

B. MARINE DEVELOPMENTS AND TRANSPORTATION

1. Oil Trajectory Analysis
D.J. Lawrence, PC. Smith
2. Winter Processes in the Gulf of St. Lawrence
G. Bugden
3. Point Lepreau Environmental Monitoring Program
J.N. Smith
4. Marine Emergencies
E.M. Levy
5. A Novel Vibracorer for Surface, Subsurface Remote, or ROV Support Operation
G. Fowler

C. OFFSHORE ENERGY RESOURCES

1. Labrador Coast Ice
S. Prinsenberg, I. Peterson
2. Wind Sea Dynamics
W. Perrie
3. Current Measurements near the Ocean Surface
P.C. Smith, D.J. Lawrence, J.A. Elliott, D.L. McKeown
4. Modelling of Ice and Icebergs Flowing along the Labrador and Baffin Island Coasts
M. Ikeda
5. A Large-Scale Circulation in the Labrador Sea and Baffin Bay
M. Ikeda
6. Labrador Ice Margin Studies
C. Tang, M. Ikeda
7. Oceanography of the Newfoundland Continental Shelf
B.D. Petrie
8. Study of Current Variability and Mixed Layer Dynamics on the Northeastern Grand Banks
C.L. Tang, B.D. Petrie
9. Anemometers for Drifting Buoys
J.-G. Dessureault, D. Harvey
10. Development of a Lagrangian Surface Drifter
D.L. McKeown
11. Petroleum Hydrocarbon Stress to Juvenile Fish
J.H. Vandermeulen
12. Contaminant Cycling in Estuarine Waters
J.H. Vandermeulen
13. Horizontal and Vertical Exchange on Georges Bank
J. Loder; K. Drinkwater, E. Horne, N. Oakey
14. Oceanic CO,
E.P Jones
1.5. Wave-Wind Field Interactions
F. Dobson, S. Smith, W. Perrie
16. Oceanographic Data Management System
D. Gregory, G. Boudreau
17. Ocean Currents over Atlantic Canada Waters using Satellite Altimeters and Models
M. Ikeda
18. Development of an Ice-Resistant Mooring Assembly
G. Fowler, D. Belliveau, J. Hamilton
19. Development of Continuous Ocean Data Acquisition Systems
D. Belliveau, J. Hamilton, G. Fowler
20. Development of a Platform for Atmospheric Data in Real Time (PADIRT)
J. Hamilton, G. Fowler; D. Belliveau
21. Sea Ice Flux onto Nfld. Shelves
S. Prinsenberg, I. Peterson
22. Cross-Shelf Exchange and Ice Motion on the Northern Grand Banks: The Oceanographic Component of the Canadian Atlantic Storms Program (CASP II)
I? Smith, C. Tang, S. Prinsenberg, M. Ikeda
23. Development of Low-Cost Ice Beacon/Instrumentation
G. Fowler, S. Prinsenberg, J. Hamilton
24. Three-Dimensional Circulation Model for the Gulf of Maine Region
J. Loder; D.A. Greenberg
25. Sea Ice Thickness
S. Prinsenberg
26. Impact Monitoring System (MIMS)
D. Belliveau
27. Black Carbon Particles
R. Pocklington
28. Data Assimilation and Remote Sensing in Ocean Wind Models
W. Perrie
29. Sea Ice Ablation Study
C. Tang
30. Ice Pressure in Mobile Pack Ice off the Canadian East Coast
S. Prinsenberg
31. Verification to Satellite Ocean Surface Information
F. Dobson
32. A Critical Evaluation of "Greenhouse Warming" and the Part Played in it by Emissions from Fossil Fuel Combustion
R. Pocklington
33. Assimilation of Satellite Remote Sensing Data into Sea Ice and Ocean Simulation
M. Ikeda

D. LIVING RESOURCES

1. Circulation off Southwest Nova Scotia: The Cape Sable Experiment
PC. Smith, D. LeFaivre (Quebec), K. Tee, R. Trites
2. The Shelf Break Experiment: A Study of Low-Frequency Dynamics and Mixing at the Edge of the Scotian Shelf
PC. Smith
3. Long-Term Monitoring of the Labrador Current at Hamilton Bank
J. Lazier
4. Long-Term Temperature Monitoring
D. Gregory, B. Petrie, E. Verge
5. Development of a Remote Sensing Facility in Physical & Chemical Sciences Branch
C.S. Mason, B. Topliss, M. Stepanczak
6. Horizontal and Vertical Exchange on the Southeast Shoal of the Grand Bank
J.W. Loder; C.K. Ross
7. Optical Properties of Canadian Waters
B.J. Topliss
8. Biological Arctic Instrumentation
A. Herman, M. Mitchell
9. Multi-Frequency Acoustic Scanning of Water Column
N.A. Cochrane
10. Fish Aging from $^{210}Pb/^{226}Ra$ Measurements in Otoliths
J.N. Smith
11. Growth Rates of the Sea Scallop (Placopecten Magellanicus) using the Oxygen Isotope Record
F.C. Tan, M Frechette (MLI), D. Roddick (BSB), S. Robinson (St. Andrews)
12. Effects of Hudson Bay Outflow on the Labrador Shelf
K. Drinkwater
13. Larval Transport and Diffusion Studies
R. Trites, T.W. Rowell
14. Environmental Variability - Correlations, Patterns, and Response Scales
K. Drinkwater

15. Ocean Feature Identification via Multi-Spectral *In Situ* and Remote Sensing Techniques
B. Topliss
16. TLC (Temperature, Light, Current) Recorders
J.-G. Dessureault, B. Beanlands
17. Exchange between Offshore Waters and the Estuaries, Inlets, and Coastal Embayments of the Scotia-Fundy Region
G. Bugden
18. Physical Oceanography in Conjunction with the Phytoplankton Profiling Program
G. Bugden
19. Classification of Estuaries, Inlets, and Coastal Embayments
R.W? Trites, B.D. Petrie
20. Quoddy Region Oceanography
R. W. Trites
21. Halifax Harbour Studies
D.J. Lawrence, B. Petrie
22. Advanced Technology Multifrequency Sonar
N.A. Cochrane
23. Development of Finite Element Models for Coastal and Shelf Circulation
D. Greenberg
24. Laser Particle Counter
A.W Herman, E.F Phillips, M. Mitchell, S. Young
25. Optical Microzooplankton Detector
A.W Herman, E.F Phillips, M. Mitchell, S. Young
26. Diagnosis of Current Measurement Problems with Aanderaa Paddle-Wheel Current Meters in High Flows
J.M. Hamilton, G.A. Fowler
27. Three-Dimensional Lagrangian Drift Studies off Southwest Nova Scotia
K.-T Tee, P.C. Smith, F. Page, R. Stephenson (BSB)
28. The Temporal and Spatial Scales of Current Variability on Western Bank
K.F Drinkwater, J.W Loder, B. Sanderson (Memorial U), K.R. Thompson (Dalhousie)
29. Climate Variability in the Water Mass Characteristics of the Shelf Waters in the Scotia-Fundy Region
K.F Drinkwater, J.W Loder, B.D. Petrie, P.C. Smith, D. Lawrence, F. Page (BSB), S. Smith
30. Fibre Optic Fluorometer
M. Mitchell, A.W Herman
31. Benthic Survey System: The Platform
D.L. McKeown
32. Long-Term Monitoring of Zooplankton/A Moored Optical Plankton Counter
A. Herman, D.D. Sameoto, N. Cochrane

E. BIOGEOCHEMISTRY

1. Sediment Geochronology and Geochemistry in the Saguenay Fjord
J.N. Smith
2. Trace Metal Geochemistry in Estuarine Mixing Zones
P. Yeats, J. Dalziel
3. Trace Metal Geochemistry in the North Atlantic
P.A. Yeats, J. Dalziel
4. Natural Marine Organic Constituents
R. Pocklington
5. Radionuclide Measurements in the Arctic
J. Smith
6. Carbon Isotope Studies on Particulate and Organic Carbon in Deep Sea and Coastal Environments
F.C. Tan, P. Strain
7. Joint Canadian/FRG Caisson Experiments
D.H. Loring, F. Prosi
8. Trace Metal Transport into the Western North Atlantic
P. Yeats
9. Defining Depositional Conditions from the Grain-Size Spectra of Bottom Sediments
K. Kranck
10. The Role of Flocculation in the Flux of Particulate Matter in the Marine Environment
K. Kranck
11. Chemical Reactivity in the Surface Ocean
P. Strain
12. Composition and Reaction of Marine Colloidal Matter
S. Niven
13. Nutrient Dynamics in Ship Harbour, N.S.
P. Strain, P. Yeats, S. Durvasula

F. TOXICOLOGY, CONTAMINANTS, AND HABITAT

1. Canadian Marine Analytical Chemistry Standards Program
M. Bewers, J. Uthe, P. Yeats, D. Loring
2. International Activities
J.M. Bewers, R. Addison, D.H. Loring, R. Misra, J. Uthe, P.A. Yeats
3. Heavy Metal Contamination of Sediments and Suspended Matter on the Greenland Shelf
D.H. Loring, G. Asmund
4. Risk Assessment of Toxic Chemicals
J.F Uthe, R. Misra, C.L. Chou, N. Prouse
5. Habitat Assessment and Related Research - Acid Rain
J. Uthe, R. Misra, P. Yeats, G.B. Sangalang
6. Risk Assessment of Organic Chemicals to Fisheries
V. Zitko
7. Biochemical Indicators of Health of Aquatic Animals
K. Haya, B.A. Waiwood, L.E. Burridge
8. MFO Induction by PCBs and PCB Replacements
R.F. Addison
9. Organochlorines in Seals
R.F. Addison
10. Sub-lethal Contaminants: Long-Term Fate and Effects of Petroleum Hydrocarbon Pollution in Aquatic Systems
J.H. Vandermeulen
11. Aquatic Toxicology of Marine Phytotoxins
K. Haya
12. Investigations into Amino Acid Shellfish Toxins
R. Pocklington
13. Molluscan Toxins, Techniques, and Improvements
V. Zitko

14. Contaminants in Municipal Harbour Lobster Fisheries
J.E Uthe, R.K. Misra, C.L. Chou, N. Prouse
15. Regional Assessment - Inshore Areas of the Scotia-Fundy Region
J.M. Bewers, PA. Yeats, J.E Uthe, G. Seibert, D.H. Loring
16. Contaminants in Sports Fisheries
J.E Uthe, C.L. Chou, N. Prouse
17. Effects of Pesticides and Agricultural Chemicals on Fish Habitat
V. Zitko, A.T Bielak (Gulf Region)
18. Endocrinological Sublethal Tests
J. Uthe
19 Sources, Distribution and Fate of Metallic Contaminants in Atlantic Estuarine and Harbour Sediments
D.H. Loring, T. Milligan
20 Modelling of Distributions of Toxic Chemicals in Harbours and Estuaries
PA. Yeats, B. Petrie, J. Dalziel, P. Strain
21 Factors Affecting the Concentrations of Toxic Chemicals in Lobsters
C.L. Chou, R.K. Misra, J.E Uthe, N. Prouse
22. Identification of Synthetic Organic Chemicals in Commercial Species from Municipal and Industrial Harbours and Rivers
J.M. Bewers, J. Uthe
23. Historical Record of Contaminant Fluxes in Marine Sediments
J.N. Smith, K.M. Ellis
24. Contaminant Trends in Selected Commercial Fisheries: Gulf of St. Lawrence Cod Study
J.E Uthe, R.K. Misra, C.L. Chou, N. Prouse
25. Assessment of Input Functions for Toxic Chemicals in Scotia-Fundy Region
PA. Yeats, D.H. Loring, PM. Strain, EC. Tan
26. Application of Biochemical Sublethal Tests for Detecting Pollution-Induced Effects in Commercial Atlantic Fish
R. Addison, J.H. Vandermeulen, D.E. Willis, M.E. Zinck
27. Tissue Banking of Flatfish from Coastal Waters
J.H. Vandermeulen
28. Toxic Chemical Regional Data Management System
I? Strain
29. Provision of Advice on Toxic Chemical Issues
J.M. Bewers, C.L. Chou, K. Haya, E.P Jones, D.H. Laring, S. Niven, R. Pocklington, J.N. Smith, EC. Tan, J.F. Uthe, J.H. Vandermeulen, PA. Yeats, V. Zitko
30. Development of Public Relations Video on the Health of the Marine Environment
J.M. Bewers
31. Measurements of Radioactive Contaminants in the Arctic Ocean
J.N. Smith, K.M. Ellis, R. McDonald (IOS), A. Aarkrog (Denmark)

HYDROGRAPHY BRANCH

A. HYDROGRAPHY

1. Ocean Mapping, Approaches to Halifax (Ship Based) (Atlantic Provinces)
G. Costello
2. Coastal and Harbour Surveys: Bonavista Bay Survey (Shore Based)
D. Blaney

Notre Dame Bay Survey (Shore Based),
Cottles Island
Comfort Cove
Bridgeport
Dildo Run
J. Goodyear
3. Harbour Surveys (Ship Based): Halifax Harbour
M. Lamplugh

Notre Dame Bay
Sir Charltes Hamilton Sound
C. Stirling
4. Revisory Surveys (Shore Based): Fredericton, N.B.
North Shore, P.E.I.
E. Comeau
5. Field Training - Halifax Harbour (DD/EG Conversion)
G. Henderson

B. TIDES, CURRENTS AND WATER LEVELS

1. Ongoing Support to CHS Field Surveys and Chart Production
C. O'Reilly, C.P McGinn, G.B. Lutwick, F. Carmichael
2. Operation of the Permanent Tide and Water Level Gauging Network
C. O'Reilly, C.P McGinn, G.B. Lutwick, F. Carmichael
3. Review and Update of Tide Tables and Sailing Directions
C. O'Reilly
4. Scientific and Engineering Project Support: Calibration & Maintenance of Portable & Submersible Gauges

Tidal Analysis of Minas Basin (Five Islands) for Queens University Tidal Survey - Head of Tide Miramichi River

Development of Remote Arctic Tide Gauge (with ARGOS satellite link & underwater EM data communications)

Development of Coastal Ocean Water Level Information System (COWLIS)

Development of Tidal Databases Information System (Database/ Modelling)
C. O'Reilly, C.P McGinn, G.B. Lutwick, F. Carmichael

C. NAUTICAL PUBLICATION PRODUCTION

1. Production of Charts as follows:
14 New Charts
6 New Editions
36 Chart Correction Patches
150 Notices to Mariners
S. Weston, M. Chenier, A. Hantzis
2. *Sailing Directions*
Publication of Sailing Directions (Gulf of St. Lawrence and Saint John River)
S. Weston, R. Pietrzak

D. DATA MANAGEMENT AND PLANNING

1. Hydrographic Data Centre
   Updates and maintenance of the Source Directory Files Management System
   C. Day-Power; S. Nickerson
   Interaction with the Validation Unit
   C. Day-Power; S. Nickerson
2. Validation
   Validation of New Charts 5051 Nunaksuk I. to Calf, Cow and Bull I., Nfld.

   Validation of New Editions 4846 Motion Bay to Cape St. Francis
   4911 Entrance to Miramichi River
   4912 Miramichi
   8049 St. Michael Bay to Gray Islands

   Sailing Directions Diagrams
   Pointe Sapin, N.B.
   Val Comeau, N.B.
   Escuminac, N.B.

   Validation of Incoming Documents from Outside Agencies
   35 NTM Recommended as a result of New Document Review Includes 2 patches, one an inset for Cape Saint Mary's (mini chart-digital) 800 documents (FC's)

   5000 Notices to Shipping and 260 Foreign Notices to Mariners Booklets reviewed

   791 Accessions Lists Documents Validated
   Approximately 1100 existing documents superseded, changed to redundent or cancelled as a result of all Validation Unit Work (Charts, Accessions, Patches, etc.)
   D. Nicholson, J. Ferguson, W. Burke, E. Crux, D. Frizzle, H. Joyce, B. McCorriston, S. Parsons, K. Paul, V. Randhawa, D. Roop, T. Rowsell
3. Navigation
   BIONAV Maintenance & User support
   H. Boudreau

   LORAN-C Chart Latticing
   N. Stuifbergen

   Navigation - User Support and Training
   H. Boudreau, N. Stuifbergen
4. Data Base Management Systems & Electronic Charts
   Green Plan DBMS and Electronic Chart Research
   S. Grant, D. Frizzle, G. MacLeod, C. Day-Power; H. Varma, M. Eaton, H. Boudreau, J. Davison, R. Pietrzak, M. MacDonald, C. Stirling

E. HYDROGRAPHIC DEVELOPMENT

1. Coordination of Research and Development within CHS
   R.G. Burke
2. Implementation of Hydrographic Data Processing System
   R.G. Burke, S. Forbes
3. *ISAH* and GPS Implementation
   S. Forbes
4. ORACLE
   MD-Multi-Dimensional Spatial Information Management System
   H. Varma
5. Ocean Mapping Initiative for Canada (OMIC)
   G. Costello
6. Enhancing Computer-Assisted Chart Production Techniques
   S. Forbes, K. White
7. Informatics Support and Coordination
   S. Forbes, L. Norton, K. White, M. Ruxton

BIOLOGICAL SCIENCES BRANCH

A. MARINE FISH AND MARINE MAMMAL STOCK ASSESSMENTS AND ASSOCIATED RESEARCH

1. Herring Assessment and Associated Research (Subarea 4)
   R. Stephenson
2. Herring Assessment and Associated Research (Subarea 5)
   G. Melvin
3. 4TVW Haddock Assessment and Associated Research
   K. Zwanenburg
4. 4X Haddock Assessments and Associated Research
   P. Hurley
5. 5Ze Haddock Assessments and Associated Research
   S. Gavaris
6. 4Vn Cod Assessments and Associated Research
   T. Lambert
7. 4VsW Cod Assessments and Associated Research
   R. Mohn
8. 4X Cod Assessment and Associated Research
   S. Campana (1992); S. Gavaris (1993)
9. 5Z Cod Assessments and Associated Research
   J. Hunt
10. Pollock Assessment and Associated Research
    C. Annand (1992); E. Trippel (I 993)
11. Silver Hake Assessment and Associated Research
    D. Waldron
12. Redfish Assessment and Associated Research
    R. O'Boyle
13. Flatfish Assessment and Associated Research
    C. Annand
14. Continental Shelf Margin Studies, Including Argentine Assessment
    R. Halliday
15. Winter Flounder and Associated Research
    F. Page
16. Seal Diet and Energetics
    W.D. Bowen
17. Population Ecology of Sealworm
    G. McClelland
18. Seal Population Monitoring
    W. Stobo
19. Population Ecology and Assessment of Seals
    W.D. Bowen
20. Seal Research Infrastructure
    W.D. Bowen

21. Grey Seal Research - Dalhousie University
R. O'Boyle
22. Groundfisheries Management Research
R. Halliday
23. National Sampling Program (Groundfish)
K. Zwanenburg
24. International Observer Program (IOP) Management Research
D. Waldron
25. Groundfish Trawl Surveys
J. Hunt, R. Mohn
26. Groundfish Age Determination
J. Hunt, C. Annand
27. Ichthyoplankton Studies
P. Hurley
28. Fisheries Recruitment Variability
K. Frank
29. Otolith Studies
S. Campana
30. Finfish Tagging Studies
W. Stobo
31. Oceanographic Data Handling
J. McRuer, F. Page
32. Large Pelagics Assessment and Associated Research
J. Porter
33. Pelagic Acoustics Surveys
U. Buerkle
34. Oceanography and Fish Distribution
F. Page
35. Pelagic Fisheries Management Studies
T. Iles
36. EDP Support
R. Branton
37. Survey Design and Biometrical Research
S. Smith
38. Cooperative Science-Industry Groundfish Research and Communication
P. Hurley
39. Dynamics of Recruitment Processes for Gulf of Maine Gadids
E. Trippel
40. Groundfish Ecosystems: Research Information - Survey Data
D. Clark
41. Stock Structure Studies
K. Zwanenburg

B. INVERTEBRATE AND MARINE PLANT STOCK ASSESSMENTS AND ASSOCIATED RESEARCH

1. Informatics
D. Swetnam
2. Larval Ecology and Lobster Assessment in LFA 33
R. Miller
3. Scallop Assessment and Research
G. Robert
4. Offshore Clam Assessment and Research
D.L. Roddick
5. Scallop Research
E. Kenchington
6. Cape Breton Crustacean Assessment and Research
J. Tremblay
7. Marine Plants Assessment and Research
G. Sharp
8. Lobster Stock Assessment and Research in LFAs 34 & 41
D. Pezzack
9. Lobster Habitat Research
R. Miller, J. Tremblay, P. Koeller
10. Lobster Resource Science and Assessment - LFAs 31 & 32
P. Koeller
11. Wild Mussel Resource Assessment and Research
G. Sharp
12. Resource Mapping and Special Projects
G. Black
13. Lobster Resource Science - Larval Biology
G. Harding, J. Pringle
14. Bay of Fundy Scallop Population Dynamics and Assessment
S. Robinson
15. Lobster Stock Assessment (LFAs 35, 36 & 38)
P. Lawton
16. Population Dynamics and Ecology of Bay of Fundy Lobsters
P. Lawton
17. Invertebrate Reproductive Biology
S. Waddy
18. Resource Potential of Underutilized Invertebrate Species
S. Robinson, P. Lawton
19. Lobster Biology
D. Aiken
20. Soft-Shell Clam Fishery Research
S. Robinson

C. ANADROMOUS SPECIES STOCK ASSESSMENTS, SALMON ENHANCEMENT, AND ASSOCIATED RESEARCH

1. Salmon Assessment Research
T.L. Marshall
2. Non-Salmonid Assessment Research
B. Jessop
3. Salmon Enhancement Research
R. Cutting
4. Enhancement and Fish Passage Engineering
H. Jansen
5. Fish Culture Engineering
H. Jansen
6. Finfish and Invertebrate Introductions and Transfers
R. Cutting
7. Hatchery Operations and Production
G. Farmer
8. Fish Culture Research
G. Farmer
9. Anadromous Species Statistical Data Collection and Analysis
S. O'Neil

D. AQUACULTURE RESEARCH

1. Salmon Genetics Research Program
W. Watson- Wright
2. Salmonid Growth, Smolting, and Reproduction
R.L. Saunders
3. Marine Finfish Aquaculture
K. Waiwood
4. Environmental Requirements for Early Fish Development
R. Peterson
5. Invertebrate Fisheries Research and Aquaculture
D. Aiken
6. Invertebrate Nutrition
J. Castell
7. Fish Nutrition
S. La11
8. Fish Disease Research
G. Olivier
9. Parasitology
C. Morrison

10. Molluscan Culture and Phytotoxin Research
D. Scarratt
11. Fish Health Services Unit
J. Cornick

E. BIOLOGICAL OCEANOGRAPHY

1. Bio-optical Properties of Pelagic Oceans
T. Platt
2. Nutrient Dynamics: Effects on Primary Production, Global Climate and Fisheries
W. Harrison
3. Physical Oceanography of Selected Features in Connection with Marine Ecological Studies
E. Horne
4. Productivity of Marine Microorganisms
W. Li
5. Carbon Dioxide and Climate: Biogeochemical Cycles in the Ocean
T. Platt
6. Analysis of Pelagic Ecosystem Structure
A. Longhurst
7. Carbon and Nitrogen Utilization by Zooplankton and Factors Controlling Secondary Production
R. Conover
8. Secondary Production and the Dynamic Distribution of Micronekton on the Scotian Shelf
D. Sameoto
9. Biological Stratification in the Ocean and Global Carbon Flux
A. Longhurst
10. The Role of Copepods in Vertical Fluxes of Carbon and Pigments in the Ocean
E. Head
11. Year Round Plankton Research in the Arctic
R. Conover
12. Shore-Based Studies of Under-Ice Epontic and Pelagic Plankton Communities
R. Conover
13. Summertime Shipboard Studies in the Eastern Canadian Arctic
E. Head
14. Dissolved Organic Carbon (DOC), Coagulation and Microbial Metabolism
P. Kepkay
15. Mathematical Models of Marine Pelagic Communities
G. White

F. HABITAT RESEARCH

1. Fish Habitat Assessment Advice
D. C. Gordon
2. Microbial Ecology
J.E. Stewart
3. Microbial-Marine Toxin Interactions
J.E. Stewart
4. Physiological Ecology of Toxic Algae
S.R.V Durvasula
5. Biological-Physical Interactions in Coastal Habitats
K.H. Mann
6. Benthic Habitat Studies
T.W. Rowell
7. Scallop Habitat Research
P. Cranford
8. Zooplankton Habitat Studies
G. C. Harding
9. Phytoplankton Monitoring
PD. Keizer
10. Environmental Interactions with Aquaculture
PD. Keizer
11. Bioenergetics of Marine Mammals
P.F. Brodie
12. Habitat Mapping
P.R. Boudreau
13. Size-Dependent and Bioenergetic Processes in Fish Production Habitats
S.R. Kerr
14. Evaluation of Estuarine and Continental Shelf Habitats
W. L. Silvert
15. Contaminant Fluxes in Marine Benthic Food Webs
B.T Hargrave
16. Organochlorines in the Arctic Ocean Marine Food Webs
B.T Hargrave
17. Instrumentation Support
W.P. Vass
18. Acid Rain Research (Nova Scotia)
W. Watt
19. Freshwater Fish Habitat Assessment and Related Research
W. Watt
20. Phytotoxin Research
D. Wildish
21. Effects of Acid Rain Control Programs on Salmonid Recovery
G.L. Lacroix
22. Aquaculture Ecology Research
D. Wildish

ENVIRONMENT CANADA ATLANTIC REGION

ENVIRONMENTAL QUALITY LABORATORY, BIO

1. Development of a Chronic Sublethal Sediment Toxicity Test using Estuarine/Marine Polychaetes.
P. Pocklington, K. Doe, S. Wade and A. Huybers.
2. Canadian Shellfish Growing Area Contaminants Monitoring.
J. Machell, P. Hennigar, H. Li, O. Vaidya and W. Horne.
3. Aquatic Toxicity and Environmental Impact of Sanitary Landfill Leachate Discharges.
L. Rutherford, K. Doe, W. Horne and S. Wade.
4. Gulf of Maine Mussel Watch Contaminants Project.
J. Machell, P. Hennigar and H. LI.
5. Environmental Assessment of Miramichi River Sediments.
G. Lindsay, K. Doe and R. Parker:
6. Environmental Spills: Oil Identification and Matching.
P. Hennigar.
7. Ocean Dumpsite Monitoring.
K. Tay, K. Doe, D. Vaughan and S. Wade.
8. Industrial Emissions Compliance Monitoring (Fisheries Act and CEPA).
O. Vaidya, P. Hennigar and K. Doe.
9. Toxicity Testing of Oilspill Treating Agents.
A. Huybers and K. Doe.

10. Chlorofluorocarbon Aerosol Products and PCB Paint Pigments Monitoring Surveys.
J. Bamwoya, P. Hennigar and B. MacDonald.
11. Interlaboratory Study on the Development of a Sea Urchin Fertilization Assay.
K. Doe, S. Wade and A. Huybers.
12. Acute and Chronic Toxicity of Thiophanate-methyl to Fish, Invertebrates, and Bacteria.
S. Wade and K. Doe.

MARINE WILDLIFE CONSERVATION DIVISION (CANADIAN WILDLIFE SERVICE)

A. DISTRIBUTION AND ECOLOGY OF SEABIRDS IN ATLANTIC CANADA AND THE EASTERN CANADIAN ARCTIC

1. Distribution and Population Trends of Coastal Seabirds in Atlantic Canada (Gulls and Terns)
A.R. Lock
2. Marine Pollution Impacts on Seabirds
A.R. Lock
3. Gazetteer of Marine Birds in Atlantic Canada: an atlas of sea bird vulnerability to oil pollution.
A.R. Lock, R.G.B. Brown and S. H. Gerriets
4. Seabird Population Monitoring Program: National Issues & Program Priorities 1994-2004.
D.N. Nettleship
5. Seabird Colony Registry - Computerized Database Management System for Colonially Breeding Seabirds in Eastern Canada
D.N. Nettleship, G.N. Glenn
6. Seabird Gazetteers of Northeast em North America: I. Seabird Colonies in Labrador
D.N. Nettleship, G.N. Glenn
7. Seabird Gazetteers of Northeastern North America: II. Seabird Colonies in Arctic Canada
D.N. Nettleship, A.J. Gaston, G. Chapdelaine
8. Seabird Gazetteers of Northeastern North America: III. Seabird Colonies in Newfoundland
D. N. Nettleship, W. Montevecchi, et al.
9. Distribution and Abundance of Breeding Seabirds in Northeastern North America
D.N. Nettleship
10. Development of Management Methods for Populations of Threatened Seabirds
D.N. Nettleship
11. Seabirds as Monitors of Changing Marine Environments and Commercial Fisheries Interactions
D.N. Nettleship
12. Thick-Billed Murres *Uria lomvia* in Arctic Canada, Greenland, Iceland, Spitsbergen: Status, Recent Changes, and Management.
D.N. Nettleship, G. Chapdelaine, A. Gaston, K. Kampp, E Mehlum, A. Petersen
13. Modelling the Effects of Hunting on Thick-Billed Murres *Uria lomvia* Breeding in Eastern Canada and West Greenland *D.N. Nettleship, J. W. Chardine*
14. Seabirds on Islands: Threats, Case Studies and Action Plans
D.N. Nettleship, J. Burger, M. Gochfeld
15. Monitoring Alcid Populations at Machias Seal Island, N.B.
D.N. Nettleship
16. Reintroduction of the Atlantic Puffin *Fratercula arctica* to Former Breeding Sites in Maine
D.N. Nettleship, S. Kress

B. STUDIES ON THE PRODUCTIVITY OF AQUATIC BIRD HABITATS

1. Kejimkujik National Park LRTAP Studies (Integrated Monitoring) Coordination
J. Kerekes
2. Monitoring of Piscivorous Birds in the Kejimkujik Watersheds
J. Kerekes
3. Development of a Volunteer Loon Population Survey in the Atlantic Provinces
J. Kerekes
4. Effects of Fertilization on Acidic Wetlands
J. Kerekes, M. Brylinsky
5. Habitat Use of Winter Populations of Aquatic Birds in Coastal Lagoons in Mexico.
J. Kerekes, F. Contreras, R. Acuna

NATURAL RESOURCES CANADA

ATLANTIC GEOSCIENCE CENTRE

A. COASTAL GEOLOGY PROGRAM

1. Beaufort Sea Coastal Zone Geotechnics
S. Solomon
2. Geological Mapping of the Coastal Zone
R. Taylor
3. Sediment Dynamics and Depositional Processes in the Coastal Zone
D. Forbes
4. Relative Sea-level Changes and Coastal Response
J. Shaw
5. Nearshore Sediments and Non-Fuel Minerals - Nova Scotia MDA 2
G. Fader
6. SEDFLUX: On transfer of Sediments from Landmass to Continental Shelf (J. Syvitski)
7. Fraser Delta Studies
H. Christian

B. GEOLOGY OF THE SOUTH-EASTERN CANADIAN MARGIN

1. Surficial and Shallow Bedrock Geology of Grand Banks and Scotian Shelf
G. Fader
2. Engineering Geology of the Atlantic Shelf

R. Parrott

3. Ice Scouring of Continental Shelves
   M. Lewis
4. Physical Property Studies of Canadian Eastern and Arctic Continental Shelves and Slopes
   K. Moran
5. Quaternary Geological Processes on Continental Slopes
   D. Piper
6. Stability and Transport of Sediments on Continental Shelves
   C. Amos

C. EASTERN ARCTIC AND SUB-ARCTIC GEOLOGY

1. Eastern Baffin Island Shelf and Hudson Strait: Bedrock and Surficial Geological Mapping Program
   B. MacLean
2. Quantitative Quaternary Paleoecology, Eastern Canada
   P. Mudie
3. Surficial Geology, Geomorphology and Glaciology of the Gulf of St. Lawrence, Labrador Shelf and Hudson Bay
   H. Josenhans

D. WESTERN ARCTIC GEOLOGY

1. Surficial Geology and Geomorphology, Beaufort Sea Continental Shelf
   S. Blasco

E. GEOCHEMISTRY

1. Diagenesis and Geochemical Cycling
   R. Cranston
2. Early Diagenesis in Quaternary Marine Sediments of Eastern and Arctic Canada
   D. Buckley
3. Environmental Marine Geology of Halifax Inlet and Approaches, Nova Scotia
   D. Buckley

F. REGIONAL GEOPHYSICAL SURVEYS

1. Interpretation of Potential Field Data
   J. Verhoef
2. Magnetic and Gravity Anomalies over Sedimentary Basins
   B. Loncarevic
3. Magnetic Data Compilations
   R. Macnab
4. Regional Geophysics of Mesozoic-Cenozoic of Newfoundland Margin
   K. Coflin
5. Evolution of Continental Margins
   G. Bassi

G. HYDROCARBON RESOURCE APPRAISAL

1. Hydrocarbon Inventory of Sedimentary Basins of Eastern Canada
   D. McAlpine
2. Maturation Studies
   D. McAlpine

H. BIOSTRATIGRAPHY

1. Biostratigraphic Zonation of the Mesozoic and Cenozoic Rocks of the Atlantic Shelf
   P. Ascoli
2. Quantitative Stratigraphy in Paleoceanography and Petroleum Basin Analysis
   F. Gradstein

I. QUANTITATIVE DATABASES

1. Sample and Data Curation
   I. Hardy

J. GEOLOGICAL TECHNOLOGY DEVELOPMENT

1. Large Diameter Piston Corer Development
   W. McKinnon
2. Development and Implementation of Remotely Operated Vehicle Technology
   K. Manchester
3. Systems Development
   D. Heffler

K. SPECIAL GEOLOGICAL PROJECTS

1. Basin Atlases - Offshore Eastern Canada
   D. McAlpine
2. Bedrock Geology of Hudson Bay and Gulf of St. Lawrence
   A. Grant
3. Appalachian Initiative
   P. Giles

L. INVESTIGATION OF DEEP GEOLOGICAL STRUCTURES

1. Evolution of Deep Ocean and Adjoining Sedimentary Basins off Eastern Canada and Western Greenland
   S. Srivastava
2. Crustal Properties
   M. Salisbury
3. Geophysical Study of the Gulf of St. Lawrence Region
   F. Marillier
4. Marine Deep Seismic Reflection Studies - Eastern Canada
   C. Keen
5. Seismic Refraction - Labrador Sea and Baffin Bay
   R. Jackson
6. Dynamic Modelling of Canadian Cratonic Basins - Western Canada and Hudson Basins
   R. Courtney

M. THEORETICAL GEOPHYSICAL MODELLING

1. Rift Processes and the Development of Passive Continental Margins
   C. Keen

N. BASIN ANALYSIS AND PETROLEUM GEOLOGY

1. Palynostratigraphic Atlases
   R. Fensome
2. Regional Geology of the Mesozoic and Cenozoic Rocks of the Atlantic Continental Margins
   J. Wade
3. Stratigraphy and Sedimentology of the Mesozoic and Tertiary Rocks of Atlantic Continental Margin
   L. Jansa
4. Sedimentary Basin Evolution of the Continental Margin of Newfoundland, Labrador and Baffin Bay
   D. McAlpine
5. Hydrocarbon Charge Modelling Offshore Eastern Canada
   M. Williamson

Voyages

This section describes the vessels that the federal Department of Fisheries and Oceans (DFO), Scotia-Fundy Region, operates for the purpose of scientific research and hydrographic surveys. It also lists the voyages that these vessels made during 1992 and 1993, and the nature of the research carried out. Voyages on vessels not operated by the Deparment, but which involved scientific personnel from DFO's Scotia-Fundy Region and Natural Resources Canada's Atlantic Geoscience Centre, are included as well.

In the following pages, these abbreviations are used:

ADCP	Acoustic Doppler Current Profiler
AGC	Atlantic Geoscience Centre
BSB	Biological Sciences Branch, Scotia-Fundy Region
CHS	Hydrography Branch, Canadian Hydrographic Service
CM	Anchored sub-surface current meter
CTD	Conductivity-Temperature-Pressure profiler
FHM	Fisheries and Habitat ManagementScotia-Fundy Region
GULF	Department of Fisheries and Oceans, Gulf Region
IOC	International Oceanographic Commission
JGOFS	Joint Global Ocean Flux Study
Mun	Memorial University of Newfoundland
NAFO	North Atlantic Fisheries Organization
NCSP	Northern Cod Science Program
Nfld	Department of Fisheries and Oceans, Newfoundland Region
PCS	Physical and Chemical Sciences Branch, Scotia-Fundy Region
Qué	Department of Fisheries and Oceans, Quebec Region
RAFOS	Ranging and fixing of Sound
SAR	Synthetic Aperture Radar
WOCE	World Ocean Circulation Experiment

C.S.S. *HUDSON*

is a diesel-electric powered ship designed and used for multi-disciplinary marine science research. The ship is owned by DFO and is operated by the Department's Scotia-Fundy Region. The Atlantic Geoscience Centre of Natural Resources Canada is a major user of this vessel.

Hull......Lloyds Ice Class I
Built 1962
Length . . . 90.4 m
Breadth . . 15.2 m
Draft . . . . 6.3 m
Freeboard to working deck . . 3.2 m
Displacement . . . . 4847 tonnes
Gross tonnage . . . . . . 3721 tonnes
Full speed . . . . 17 knots
Service Speed . . . . 13 knots
Endurance . . . . 80 days
Range at service speed 23,000 naut. mi.
Complement . . . . 31 scientific staff
Twin screws
Bow thruster for holding position
Computer system
Heliport and hangar
205 m^2 of laboratory space
Four survey launches

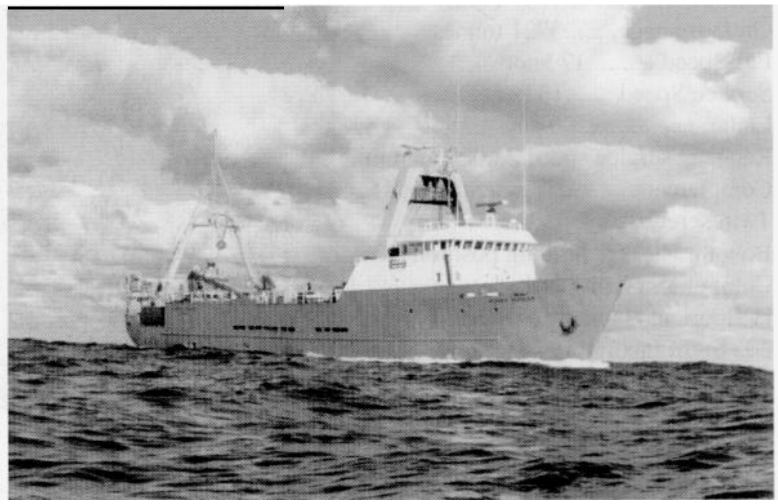
Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
91-61	24 Feb - 18 Mar	C. Tang (PCS)	Northeast Newfoundland Shelf	Ice Margin Study
92-01	6 Apr - 16 Apr	C. Amos (AGC)	Georges Bank	Geophysics
92-03	21 Apr - 1 May	D. Buckley (AGC)	Scotian Shelf	Geology-piston corer tests
92-10	8 May - 25 May	P. Smith, F. Dobson & G. Fowler (PCS)	Grand Banks Hibernia	Physics- CM moorings, CTD transects
92-14	27 May - 15 Jun	J. Lazier (PCS)	Labrador Sea	Physics
92-22	29 Jun - 31 Jul	S. Srivastava (AGC)	Flemish Cap	Geology
92-28	5 Aug - 12 Sept	C. Amos, B. MacLean(AGC)	Hudson Bay/ Great Whale River	Environmental Geology
92-37	16 Sept - 21 Oct	W. Harrison (BSB)	Moroccan Basin, Africa	JGOFS Biol. Oceanogr.
92-45	26 Oct - 20 Nov	R. Hesse (McGill), A. Aks (Mun)	Labrador slope and rise, Flemish Cap	Seismic reflection studies, coring
92-50	24 Nov - 4 Dec	G. Bugden (PCS)	Gulf St. Lawrence	Annual Ice Forecast Survey
92-51	6 Dec - 18 Dec	B. Klein (Que.)	Gulf St. Lawrence	JGOFS-plankton studies
1993				
92-53	24 Apr - 13 May	N. Oakey (PCS)	Canary Basin	WOCE Physics
93-02	18 May - 8 Jun	W.G. Harrison (BSB)	Northwest Africa	JGOFS-plankton biomass, productivity studies
93-16	10 Jun - 16 Jun	C. Amos (AGC)	Sable Island Bank	Seabed sediment stability
93-19	17 Jun - 29 Jun	J. Lazier (PCS)	Hamilton Bank, Labrador Sea	Physical Oceanography- ADCP moorings; CTD transects
93-25	16 Jul - 7 Aug	R. Hesse (McGill) D. Piper (AGC)	Labrador Sea	Geology
93-27	8 Aug - 2 Sept	P. Yeats (PCS)	Greenland Sea	Chemistry (IOC baseline survey)

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
93-30	3 Sept - 17 Sept	J. Syvitsky (AGC)	East Greenland/ Western Iceland Shelf	Geology and geophysical surveys
93-34	17 Oct - 8 Nov	B. MacLean B. Loncarevic (AGC)	Ungava Bay/Hudson Str.	Geology
93-39	15 Nov - 17 Dec	A. Clarke (PCS)	Labrador Current, Gulf Stream	WOCE Physics-RAFOS float deployment

C.S.S. *ALFRED NEEDLER*

is a diesel-powered stern trawler owned by DFO. It is operated by the Department's Scotia-Fundy Region and is used for fisheries research including acoustics, juvenile fish ecology, and recruitment studies.

Hull . . . . steel
Built 1982
Length . . . . 50.3 m
Breadth . . . . 11.0 m
Draft . . . . 4.8 m
Freeboard to working deck . . . . 2.5 m
Displacement . . . . 877 tonnes
Gross tonnage . . . . 925 tonnes
Full speed . . . . 13.5 knots
Service Speed . . . . 12 knots
Endurance . . . . 30 days
Range at service speed 3,000 naut. mi.
Complement . . . . . . 10 scientific staff



Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
91-163a	2 Jan - 5 Jan	D. Sameoto	Fundian Channel/Jordan Basin	Plankton Tows
91-163	6 Jan - 18 Jan	U. Buerkle (BSB)	Chedabucto Bay	Herring Acoustics
91-164	10 Feb - 15 Feb	M. Showell (BSB)	Scotian Shelf	Observer Training
91-165	18 Feb - 10 Mar	M.I. Buzeta (BSB)	Georges Bank, NAFO 5Z	Groundfish Survey, Cod and Haddock Fish tissue sampling
91-166	13 Mar - 23 Mar	W.J. MacEachern (BSB	Eastern Scotian Shelf 4Vs,4W	Cod and Haddock Survey
92-167a	29 Mar - 30 Mar	M.A. Showell (BSB)	Scotian Shelf	Observer training
92-167	10 Apr - 16 Apr	A.J. Hartling (PCS)	Grand Banks	Recover ADCP moorings, SAR Physics
92-168	23 Apr - 1 May	D. D'Amour (Qué.)	St.Georges Bay, Gulf of St. Lawrence (4RS)	Acoustic Cod/plankton tracking
92-169	2 May- 16 May	J. Gagne (Qué.)	Anticosti Island region Jacques Cartier Passage	Juvenile and adult Cod/herring Survey
92-170	19 May - 3 Jun	J. Morgan(Nfld)	Grand Banks, NAFO 3L	NCSP Impact of trawl on cod spawning
92-171	4 Jun - 9 Jun	G. McClelland (BSB)	Sable Island Bank	Larval Sealworm studies
92-172	10 Jun - 21 Jun	J.-F. St. Pierre (Qué.)	NAFO 4RS/Esquiman Channel	Redfish and Cod Larvae
92-173	22 Jun - 5 Jul	J. Hunt (BSB)	Scotian Shelf 4VWX,5Z	Groundfish trawl survey
92-174	6 Jul- 18 Jul	S. Smith (BSB)	Scotian Shelf 4VWX	Groundfish trawl survey
92-176	31 Jul - 9 Aug	G. Chouinard (Gulf)	Gulf of St. Lawrence	Cod fish survey comparisons
92-177	10 Aug - 4 Sept	B. Morin/ S. Hurtubise	(Qué) Northeast Gulf of St. Lawrence	Shrimp/redfish abundance Survey
92-178	5 Sept - 25 Sept	D. Swain (Gulf)	Southern Gulf of St. Lawrence	Groundfish Survey
92-179	27 Sept - 6 Oct	D. Marcogliese (Qué)	Gulf of St. Lawrence	Sealworm studies
92-180	8 Oct - 19 Oct	J. Gagne (Qué)	Anticosti/Strait of Belle Isle	Juvenile Cod/Herring survey

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
92-181	19 Nov - 6 Dec	E. Dalley (Nfld)	NAFO 3KL	Demersal juvenile northern cod survey
1993				
92-181	8 Feb - 26 Feb	J. Hunt (BSB)	Georges Bank	Groundfish survey
92-182	1 Mar - 15 Mar	R. Mohn (BSB)	Scotian Shelf 4VsW	Groundfish survey
92-183	17 Mar - 22 Mar	M. Showell (BSB)	Scotian Shelf (Western Gully)	Observer training
93-183	1 Apr - 8 Apr	M. Showell (BSB)	Scotian Shelf	Trawl trials
93-184	6 May	J. Dalziel (PCS)	Halifax Harbour and approaches	Chemistry
93-18.5	8 May - 16 May	K. Juniper (DAL)	Scotian Shelf (Emerald Basin)	JGOFS, Geology (box cores)
93-186	17 May - 29 May	D. Waldron (BSB)	Scotian Shelf	Silver hake survey, gear behaviour studies
93-187	29 May- 10 Jun	J. Morgan (Nfld)	East Newfoundland Shelf	NCSP Cod eggs trawl
93-188	28 Jun - 30 Jun	J. McRuer (BSB)	Scotian Shelf	Gear trials
93-189	5 Jul - 16 Jul	J. Hunt (BSB)	Western Scotian Shelf	Groundfish survey
93-190	19 Jul - 1 Aug	S.J. Smith (BSB)	Eastern Scotian Shelf	Groundfish survey
93-191	3 Aug - 12 Aug	G. McLelland (BSB)	Scotian Shelf (4X,4W) Cape Breton shelf	Seal worm studies
93-191a	16 Aug - 9 Sept	L. Savard/ B. Morin (Qué)	Northern Gulf of St. Lawrence	Shrimp and groundfish abundance survey
93-192	10 Sept - 29 Sept	D. Swain (Gulf)	Southern Gulf of St. Lawrence	Groundfish survey
93-193	30 Sept - 22 Oct	C. LeBlanc (Gulf)	Southern Gulf of St. Lawrence	Herring acoustic surveys
93-194	23 Oct- 10 Nov	M. Showell (BSB)	Scotian shelf, Brown’s Bank	USSR/Woods Hole?
93-195	12 Nov - 26 Nov	G. Melvin (BSB)	Georges Bank	Herring resurgence

C.S.S. *MATTHEW*

is a multi-disciplinary science vessel primarily used by the Canadian Hydrographic Service. The vessel is owned by DFO and is operated by the Department's Scotia-Fundy Region.

Hull . . . . steel
Built . . . 1990
Length . . . . 51.2 m
Breadth . . . . 10.5 m
Draft . . . . 3.2 m
Freeboard to working deck . . . 1.1 m
Displacement . . . . 745 tonnes
Gross tonnage . . . . . 857 tonnes
Full speed . . . . 12 knots
Service speed . . . . 10 knots
Endurance . . . . . . 20 days
Range at service speed . . . 4.000 naut. mi.
Complement . . 7 scientific staff
EM100
Autopilot
Various positioning systems

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-08	5 May - 15 May	G. Costello (CHS)	Halifax Harbour and approaches	Revisionary Survey
92-08	19 May - 29 May	G. Costello (CHS)	Halifax Harbour and approaches	Revisionary Survey
92-08	15 Jun - 26 Jun	G. Costello (CHS)	Halifax Harbour and approaches	Revisionary Survey
92-25	13 Jul - 25 Oct	J. Goodyear (CHS)	Notre Dame Bay	Newfoundland Hydrography 92-54
29	Oct - 5 Nov	J. Shaw (AGC)	Bay d'Espoir	Geology
92-54	12 Nov - 24 Nov	B. Loncarevic (AGC)	Halifax Harbour	Sidescan Sonar Survey and Equipment evaluation
1993				
93-07	10 May - 10 Jun	G. Henderson (CHS)	West and South coastal Newfoundland	Hydrographic measurements
93-53	28 Jun - 16 Jul	B. Loncarevic (AGC)	Southern Newfoundland Shelf	Evaluation of roll compensation on multi-beam echosounders
93-23	19 Jul - 23 Jul	C.H. Sterling (CHS)	Notre Dame Bay, Labrador Coast	Hydrography
93-23	26 Jul - 3 Sept	C.H. Sterling (CHS)	Nain, Labrador Coast	Charting
93-51	7 Sept - 29 Oct	CHS	Notre Dame and Bonavista Bay	Charting

C.S.S. *PARIZEAU*

is a diesel driven ship designed and used for multi-disciplinary oceanographic research, hydrographic surveying and handling of moorings in deep and shallow water. The ship is owned by DFO and is operated by the Department's Scotia Fundy Region.

Hull . . . . steel
Built 1967
Length . . . . 64.6 m
Breadth . . . . 12.2 m
Draft . . . . 4.6 m
Freeboard to working deck . . . 1.5 m
Displacement . . . . 2047.6 tonnes
Gross tonnage . . . . 1359.5 tonnes
Full speed . . . . 14 knots
Service speed . . . . 12 knots
Endurance . . . . 45 days
Range at service speed . . . 11,000 naut. mi.
Complement . . 13 scientific staff
Twin screws, variable pitch
Bow thruster for holding position
Computer suite
65 m^2 working space in two laboratories

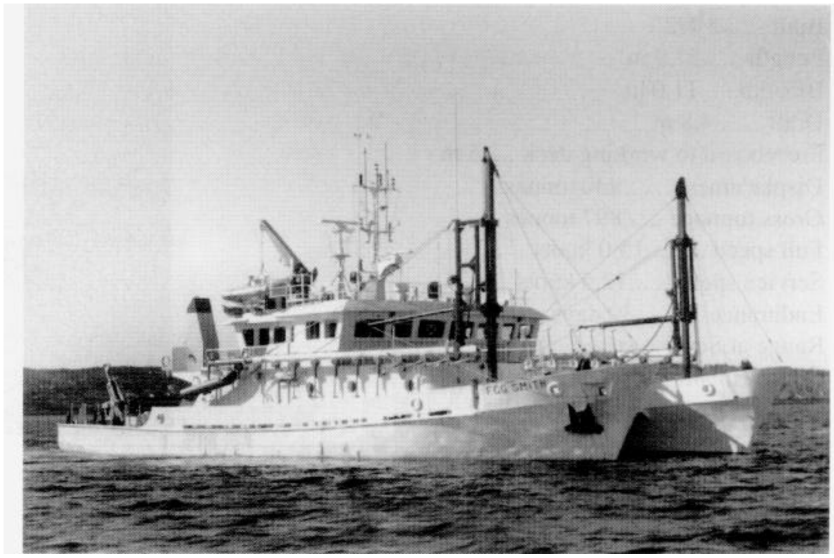
Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-04	23 Apr - 30 Apr	M. Mitchell (PCS)	Gulf of Maine/Scotian Shelf	Globec
92-06	2 May - 13 May	R. Parrott (AGC)	Laurentian and Avalon Channel	Geophysical Survey
92-13	24 May - 8 June	S. Narayanan (Nfld)	Labrador Sea/NE Nfld. Shelf	Physics-ADCP and CTD transects
92-11	9 Jun - 18 June	E. Colboume (Nfld)	Bonavista Bay	Cod/capelin oceanography
92-18	20 Jun - 24 Jun	N. Oakey (PCS)	Emerald Basin	Physics-test fine structure equip-ment
92-20	25 Jun - 3 Jul	R. Wrobleski (Mun)	Bonavista Bay	Cod tracking
92-23	6 Jul - 24 Jul	S. Narayanan (Nfld)	Labrador Sea	Physics-CM moorings, CTD transects
92-29	10 Aug - 17 Aug	J. Hamilton (PCS)	Georges Bank	Particle tracking and CM moorings
92-31	19 Aug - 29 Aug	D. McKeown (PCS)	Scotian Shelf	Gear Trials
92-34	1 Sept - 13 Sept	T. Rowell (BSB) P. Schwinghamer (Nfld	Grand Banks/Shelf	Trawl Impact studies
92-36	15 Sept - 22 Sep	E. Colbourne (Nfld)	Bonavista Bay	Cod/capelin Physics
92-39	23 Sept - 2 Oct	B. deYoung (Mun)	Northeast Newfoundland	Physics
92-42	3 Oct - 15 Oct	D. Forbes (AGC)	Bay d'Espoir, Northeast coast of Nfld	Geology; sedimentation of south and northeast coast of Nfld
92-43	16 Oct-l Nov	S. Narayanan (Nfld.)	Southern Labrador Sea/ NE Nfld.	Physics-CM morrings, ADCP and CTD transects
92-47	6 Nov - 20 Nov	A. Herman (PCS)/ D. Sameotos	Emerald Basin, Gulf of Maine	BIONESS tows, multi-freq. acoustic
92-49	23 Nov - 1 Dec	G. Melvin (BSB)	Georges Bank	Herring resurgence trawling/ plankton
92-55	2 Dec - 3 Dec	J. Hamilton (PCS)	Halifax Harbour Approaches	Halifax Gear Trials

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objective of Voyage
92-52	7 Dec - 17 Dec	D. Piper (AGC)	St. Pierre/Fogo Islands	Sea Mount/geophysics-seismic mapping
1993				
92-56	6 Jan - 11 Jan	D. Sameoto (BSB)	Scotian Shelf Basins	Zooplankton and acoustic survey
93-09	13 Apr - 25 Apr	D. Deibel (Mun)	Southeast Newfoundland, Whale Bank	JGOFS-flourescence studies
93-04	26 Apr - 6 May	E. Colbourne (Nfld)	Newfoundland Shelf	Physics-ADCP and CTD survey
93-10	10 May - 25 May	A. Herman/ J. Hamilton	(PCS) Gulf of Maine, Globec Emerald Basin	BATFISH tows
93-13	31 May - 12 Jun	E. Colboume (NFLD)	Newfoundland Shelf	Physics
93-18	16 Jun - 25 Jun	D. McKeown (PCS)	Scotian Shelf	Equipment trials
93-21	28 Jun - 16 Jul	T. Rowell/ Shwinghamer (BSB)	Newfoundland Grand Banks & Scotian Shelf	Tow impacts
93-26	3 Aug - 17 Aug	D. Piper (AGC)	Scotian Gulf	Geology-stratigraphy
93-29	4 Sept - 21 Sept	T. Rowell (BSB)	Sable Island Bank	Tow impact properties
93-31	23 Sept - 2 Oct	E. Colbourne (NFLD)	Northeast Newfoundland Shelf	Physics-CTD, Oxygen survey
93-32	5 Oct - 16 Oct	M. Mitchell/ J. Loder (PCS)	Gulf of Maine	Globec moorings
93-33	16 Oct - 25 Oct	J. Smith (PCS)	Scotian Shelf and Fundy Channel	Radionuclides
93-37	28 Oct - 9 Nov	S. Narayanan (Nfld)	Northeast Newfoundland Shelf	Physics
93-40	10 Nov - 20 Nov	R. Lively (PCS)	Gulf of St. Lawrence	Annual ice forecast
93-41	22 Nov - 4 Dec	B. Klein (Qué)	Gulf of St. Lawrence	JGOFS Physics
93-52	6 Dec - 11 Dec	B. Sundby (Rimouski)	Gulf of St. Lawrence	JGOFS Geology-sediment samples

C.S.S. F.C.G. *SMITH*

is owned by DFO and is operated by the Department's Scotia-Fundy Region. The vessel is used primarily by the Canadian Hydrographic Service as an acoustic sweep vessel in the near-shore coastal areas of the Maritime Provinces.

Hull . . . . . . steel
Built 1985
Length . . . . 34.8 m
Breadth . . . . 14 m
Breadth single hull . . 4 m
Draft . . . . 2.1 m
Freeboard to working deck 1.3 m
Displacement . . . . . . 370 tonnes
Gross tonnage . . . . . 438 tonnes
Full speed . . . . 12 knots
Service speed . . . . . 10 knots
Endurance . . . . 7 days
Complement . . . . . 4 scientific staff
Integrated sweep transducers
Auto-pilot Laser-ranging positioning system
Onboard data processingup to
500,000 depth measurements daily



Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-00	**4** May - 25 Sept	M. Lamplough	Halifax Harbour and Sidney	Hydrographic Sweep Surveys
1993				
93-12	25 May - 7 Jun	J.D. Ferguson (CHS)	Halifax Harbour and approaches	Hydrographic Sweep Surveys
93-12	8 Jun - 2 Aug	J.D. Ferguson (CHS)	Strait of Canso/ Sydney Harbour	Hydrographic Sweep Surveys
93-12	9 Sept - 21 Oct	J.D. Ferguson (CHS)	Sydney Harbour	Hydrographic Sweep Surveys

M.V. *LADY HAMMOND*

is a converted fishing trawler owned by Northlakes Shipping Limited and is chartered by DFO specifically for fisheries research. The ship is operated by the Department's Scotia-Fundy Region; its main user is the Biological Sciences Branch which has components at BIO, in Halifax, and in St. Andrews, New Brunswick.

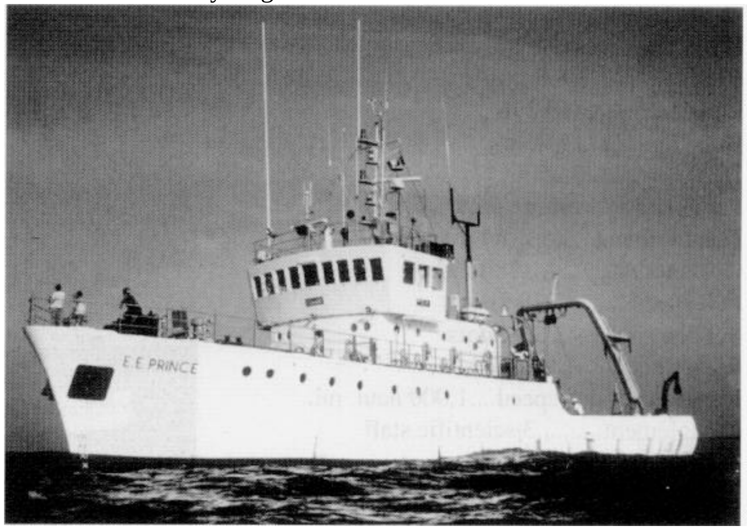
Hull . . . . Steel
Built 1972
Length . . . . . . 57.9 m
Breadth . . . . . . 11.0 m
Draft . . . . 4.8 m
Freeeboard to working deck . . 25 m
Displacement . . . . 930 tonnes
Gross tonnage . . . . . . 897 tonnes
Full speed . . . . 15.0 knots
Service speed . . . . . . 12.5 knots
Endurance . . . . 30 days
Range at Service speed . . 8,000 naut. mi.
Complement . . . . . scientific staff

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-237	23 Mar - 28 Mar	M. Showell (BSB)	Scotian Shelf	Observer training
92-237a	31 Mar - 10 Apr	D. Taylor (Nfld)	St. Mary's Bay	Crab Studies
92-237b	10 Apr - 16 Apr	E. Dawe (Nfld)	St. Mary's Bay	Crab Studies
92-238	19 Apr - 4 May	J. Anderson (Nfld)	NAFO 2J, 3K, L	NCSP Plankton surveys
92-239	6 May - 20 May	P. Pepin (Nfld)	NAFO 2J, 3K, L	NCSP Plankton surveys
92-240	23 May - 26 May	G. Rose (Nfld)	NAFO 3L	Acoustic Equipment trials
92-241	27 May - 12 Jun	J. Helbig (Nfld)	NAFO 2J, 3K, L	NCSP Plankton Survey
92-242	14 Jun - 26 Jun	E. Dalley (Nfld)	NAFO 2J, 3K, L	NCSP Plankton-cod eggs and larval distribution
92-243	28 Jun - 20 Jul	G. Rose (Nfld)	Newfoundland Shelf	NCSP Acoustics/oceanography
92-244	21 Jul - 29 Jul	E. Colbourne (Nfld)	Bonnavista Bay	NCSP Cod/capelin survey
92-245	31 Jul - 9 Aug	T. Hurlbut (Gulf)	Southern Gulf of St. Lawrence	Comparative fishing survey

C.S.S. *E.E. PRINCE*

is a stem trawler used for fisheries research including experimental and exploratory fishing and resource surveys. The ship is owned by DFO and is operated by the Department's Scotia-Fundy Region.

Hull . . . . steel
Built 1966
Length . . . . 39.6 m
Draft . . . . 3.65 m
Freeboard to working deck . . 0.7 m
Displacement . . . . 580 tonnes
Gross tonnage . . . . 406 tonnes
Full speed . . . . 10.5 knots
Service speed . . . . 10 knots
Endurance . . . . 14 days
Range at service speed . . . 3,000 naut. mi.
Complement . . . . 6 scientific staff



Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-426	21 Apr - 26 Apr	H. Dupuis (Gulf)	Chaleur Bay	Juvenile Herring abundance survey
92-427	6 May - 20 May	M. Butler (BSB)	Scotian Shelf	Annual Scallop Survey
92-428	25 May - 26 May	C. Cooper (FHM)	Scotian Shelf	Gear trials
92-429	2 Jun - 14 Jun	B. Chenard/ M. Measures	Matane, St. Lawrence Estuary	Live fish capture
92-430	15 Jun - 3 Jul	F. Gregoire (Qué)	Gulf St. Lawrence	Mackerel egg survey
92-431	6 Jul - 13 Jul	M. Hanson (Gulf)	Miramichi Bay	Juvenile cod survey
92-432	14 Jul - 17 Jul	D. Sameoto (BSB)	Gulf of Maine Basins	Zooplankton distribution
92-433	4 Aug - 9 Aug	J. Porter (BSB)	Hell Hole	Tuna tagging
92-434	11 Aug - 4 Sept	G. Robert (BSB)	Georges Bank	Scallop Survey
92-435	8 Sept - 23 Sept	C. Dickson (BSB)	Hell Hole	Tuna tagging
92-436	28 Sept - 23 Oct	C. LeBlanc (Gulf)	South Gulf of St. Lawrence	Herring-Acoustic comparisons
92-437	26 Oct - 13 Nov	J. Sochasky (BSB)	Bay of Fundy	Herring larvae
92-438	14 Nov - 27 Nov	M. Strong (BSB)	George's Bank	Herring resurgence trawling
92-439	30 Nov - 14 Dec	C. LeBlanc (Gulf)	Northumberland Strait, Chaleur Bay	Juvenille herring survey
1993				
92-440	4 Jan - 25 Jan	U. Buerkle (BSB)	Chedabucto Bay	Herring acoustics
93-441a	28 Apr - 30 Apr	C Amos (AGC)	Sable Island Bank	Geology
93-441	3 May - 21 May	M. Butler (BSB)	Scotian Shelf	Scallop survey
93-442	26 May - 2 June	D. Marcogliese (Qué)	Sable Island	Seal worm
93-443	3 June - 13 June	M. Peloquin (Qué)	Matane (Gulf of St. Lawrence)	Live Fish Survey
93-445	14 June - 30 June	F. Gregoire (Qué)	Southern Gulf of St. Lawrence	Mackerel Egg survey
93-446	2 July - 10 July	M. Hanson (Gulf)	Southern Gulf of St. Lawrence	Juvenile cod survey
93-448	9 Aug - 27 Aug	G. Robert (BSB)	Georges Bank	Scallop survey
93-451	22 Oct - 5 Nov	J. Sochasky (BSB)	Bay of Fundy	Herring Larvae survey
93-452	9 Nov - 28 Nov	L. Lefebre (Qué)	Gulf of St. Lawrence	Herring survey
93-453	29 Nov - 10 Dec	C. LeBlanc (Gulf)	Gulf of St. Lawrence	Juvenile Herring survey

C.S.S. *NAVICULA*

is a fishing vessel owned by DFO. It is operated by the Department's Scotia-Fundy Region and is used for biological oceanographic research in the near shore coastal ocean.

Hull . . . . wood
Built 1968
Length . . . . 19.8 m
Breadth . . . . 5.85 m
Draft . . . . 3.25 m
Freeboard to working deck . . 2.5 m
Displacement . . . . 104 tonnes
Gross tonnage . . . . 78 tonnes
Full speed . . . . 10 knots
Service speed . . . . 9 knots
Endurance . . . . 8-10 hours
Range at service speed . . . 1,000 naut. mi.
Complement . . . . 3 scientific staff

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-02	5 May - 12 May	S. Campana (BSB)	Scotian Shelf	Otoliths
92-12	21 May - 30 May	T. Lambert (BSB)	Sydney Bight	Eastern Scotian shelf plankton
92-15	1 Jun - 4 Jun	J. Vandermeulen (PCS)	Nova Scotian Coastal waters	Winter flounder distributions
92-16	5 Jun - 10 Jun	J. Smith (Gulf)	St. Georges Bay	Phytoplankton collection for PSP toxin studies
92-17	10 Jun - 20 Jun	T. Lambert (BSB)	Sidney Bight	Plankton pollution studies
92-19	21 Jun - 30 Jun	D. Willis (PCS)	St. Georges Bay	Flounder collection for MFO studies
92-24	3 Jul - 17 Jul	J. Shaw (AGC)	Chedabucto Bay	Geology-sediment cores
92-27b	19 Jul - 23 Jul	T. Hurlbut (Gulf)	Northern PEI	Silverhake survey
92-27	23 Jul - 24 Jul	S. Courtney (Gulf)	Gulf of St. Lawrence	Silverhake survey
92-26	24 Jul - 27 Jul	A. Locke (Gulf)	Miramichi Estuary	ichthyoplankton survey
92-33	9 Sept - 14 Sept	J. Vandermeulen (PCS)	Nova Scotian Coastal waters	Collection of winter flounder for hydrocarbon analysis
92-35	15 Sept - 28 Sept	R. Morin (Gulf)	Fisherman's Bank	Groundfish distribution survey
92-40	30 Sept - 2 Oct	T. Lambert (BSB)	Nova Scotian Coastal waters	Flounder survey
92-32	4 Oct - 9 Oct	J. Tremblay (BSB)	Scotian Shelf	Gear Trials
92-44	14 Oct - 17 Oct	T. Lambert (BSB)	Sydney Bight	Eastern Shelf Plankton survey
92-30	20 Oct - 24 Oct	J. Smith (Gulf)	PEI Coastal Waters	Toxic dinoflagellate bloom survey
92-41	25 Oct - 4 Nov	J. Vandermeulen (PCS)	Nova Scotian coastal waters	Collection of benthos, fish and water samples for hydrocarbon analysis
92-48	5 Nov - 13 Nov	P. Vass (BSB)	Halifax Harbour and approaches	Use of side scan to detect gill nets
92-46	16 Nov - 18 Nov	J. Vandermeulen (PCS)	Nova Scotia coastal waters	Flounder distribution survey
1993				
93-05	28 Apr - 5 May	G. Harding (BSB)	Bedford Basin	Organochlorine survey
93-06	5 May - 6 May	D. Mossman (PCS)	Halifax Harbour and approaches	Flounder studies

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
93-08	10 May - 21 May	T. Lambert (BSB)	Sydney Bight	Cod population characteristics survey
93-11	21 May - 28 May	G. Harding (BSB)	Cape Breton coastal waters	Organochlorine survey
93-14	28 May - 3 June	S. Courtney (Gulf)	Miramichi Estuary	Cod survey
93-15	5 June - 15 June	D. Mossman (PCS)	Cape Breton coastal waters	Obtain winter flounder samples, sediment grab samples
93-17	16 June - 18 June	G. Harding (BSB)	Coastal Cape Breton	Snow-crab survey
93-20	22 June - 29 June	J. Tremblay (BSB)	Cape Breton	Compare selectivity and catch rates of flounder trawls and crab traps
93-22	5 July - 16 July	T. Lambert (BSB)	Cape Breton	Cod survey
93-24	20 July - 23 July	G. Harding (BSB)	Cape Breton	Organochlorine survey
93-45	1 Sept - 9 Sept	D. Marcogliese (Qué)	Bras D'Or Lakes, St. Georges	Bay Parasite survey
93-44	9 Sept - 15 Sept	J. Vandermeulen (PCS)	Cape Breton coastal waters	Hydrocarbon pollution survey
93-46	16 Sept - 21 Sept	G. Harding (BSB)	Cape Breton coastal waters	Organochlorine distribution
93-47	23 Sept - 4 Oct	T. Lambert (BSB)	Cape Breton costal waters	Cod distribution studies
93-36	6 Oct - 13 Oct	G. Harding (BSB)	Cape Breton coastal waters	Organochlorine studies
93-48	19 Oct - 22 Oct	S. Courtney (Gulf)	Miramichi Estuary	Cod Larvae survey
93-38	29 Oct - 7 Nov	J. Vandermeulen (PCS)	Cape Breton coastal waters	Hydrocarbon pollution
93-49	9 Nov- 11 Nov	G. Harding (BSB)	Cape Breton coastal waters	Organochlorine survey
93-54	16 Nov	J. Vandermeulen (PCS)	Cape Breton coastal waters	Hydrocarbon pollution

C.S.S. J.L. HART

is a stern trawler used for fisheries research, including light trawling operations (bottom and midwater), ichthyoplankton surveys, oceanographic sampling, and scientific gear testing. The ship is owned by DFO and is operated by the department's Scotia-Fundy Region.

Hull .... steel
Built 1974
Length .... 19.8 m
Breadth .... 6.1 m
Draft .... 3.65 m
Freeboard to working deck . . 0.5 m
Displacement .... 109 tonnes
Gross tonnage .... 89.5 tonnes
Full speed .... 10 knots
Service speed .... 8.5 knots
Endurance .... 7.5 days
Range at service speed . . . 2.00 0 naut. mi.
Complement .... 3 scientific staff

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
1992				
92-106	3 June - 12 June	E. Kenchington (BSB)	Bay of Fundy	Scallop survey
92-107	22 June - 25 June	J. Martin (BSB)	Fundy	Toxins
92-108	6 July - 16 July	P. Hurley (BSB)	S W Nova	inshore trawl survey
92-109	20 July - 5 Aug	S. Robinson (BSB)	Passamaquody, Bay of Fundy	Scallops survey
92-110	10 Aug - 21 Aug	E. Kenchington (BSB)	Lurcher shoal	scallop survey
92-111	8 Sept - 11 Sept	P. Lawton (BSB)	Grand Manan	Lobster survey

Year & Number	Voyage Dates	Person-in-Charge	Area of Operation	Objectives of Voyage
92-112	14 Sept - 17 Sept	J. Martin (BSB)	Fundy	Toxins
92-113	21 Sept - 28 Sept	S. Robinson (BSB)	Grand Manan	Scallops survey
92-113	6 Oct - 7 Oct	S. Robinson (BSB)	Grand Manan	Scallops
92-116	2 Nov - 17 Nov	R. Jones (FHM)	South West Nova	Lobster surveillance
1993				
93-118	17 May - 21 May	U. Buerkle (BSB)	Grand Manan	Groundfish survey
93-119	26 May - 28 May	E. Trippel (BSB)	Grand Manan	Groundfish survey
93-120	31 May - 18 June	M. Lundy (BSB)	Digby area, Annapolis Basin	Scallop survey
93-121	21 June - 26 June	J. Martin (BSB)	Bay of Fundy	Toxin survey
93-122	5 July - 15 July	S. Robinson (BSB)	Passamaquody	Scallop survey
93-123	26 July - 6 Aug	P. Hurley (BSB)	SW Nova	Groundfish survey
93-124	9 Aug - 20 Aug	P. Lawton (BSB)	Bay of Fundy	Lobster survey
93-125	23 Aug - 3 Sept	E. Kenchington (BSB)	Briar Island Region	Scallop survey
93-128	13 Sept - 17 Sept	J. Martin (BSB)	Bay of Fundy	Toxins
93-129	4 Oct - 12 Oct	M. Lundy (BSB)	Digby	Scallop survey
93-130	18 Oct - 21 Oct	K. Waiwood (BSB)	Grand Manan	Broodstock

Participation In Other Research Cruises

Department of Fisheries and Oceans Scotia-Fundy Region

Brannetelle (Canada)
March 31, 1992, May 4, 1992, Sept. 21, 1992, Nov. 10, 1992, Jan. 7, 1993
Mark Lundy (BSB)
Gulf of Maine
Study of annual variation in scallop meat yield.

Sea Diver (USA)
July 19-26, 1993
Douglas Pezzack, Peter Lawton (BSB)
Georges Bank
Lobster Habitat/Population Structure using submersible.

Betty R (Canada)
Sept. 15-19, 1992
R. Miller and J. Tremblay (BSB)
Nova Scotia Coastal Waters
Survey to predict lobster abundance.

William R (Canada)
Sept. 16-20, 1993
R. Miller and J. Tremblay (BSB)
Nova Scotia Coastal Waters
Survey to predict lobster abundance.

D. A. Moore (Canada)
July 23-24, 1993
Wade Scott (BSB Contract)
Eastern Scotian Shelf 4VW
Shrimp Biomass Assessment.

April & Colette (Canada)
Aug. 17-19, 1993
Sept. 1-2, 1993
Wade Scott (BSB Contract)
Eastern Scotian Shelf 4VW
Shrimp Biomass Assessment.

R/V Heinke (Germany)
August 21, 1992
Kate Kranck, T.G. Milligan
Elbe Estuary
Suspended particulate material study.

CCGS *Henry Larsen* (Canada)
Sep 04 - Sep 25, 1993
R. Nelson, PCS
Beaufort Sea, Chukchi Sea and East Siberian Sea
Measurement of radioactivity in water and sediments as part of contaminant and circulation studies.

Geolog Fersman (Russia)
Aug 30 - Sep 29, 1993
K. Ellis, PCS
Barents Sea and Kara Sea
Investigation of radioactive contamination as a result of nuclear tests and dumping by Russians in the Barents Sea and Kara Sea.

Lance (Norway)
Dec 27, 1992 - Mar 22, 1993
F. Zemlyak, PCS
Weddell Sea
CO_2 sequestering and global climate change.

Petrel V (Canada)
Apr 28 - May 12, 1993
P.C. Smith, D. Lawrence, M. Scotney, PCS
Western Bank of Scotian Shelf
Study surface drift and dispersion on Western Bank.

Mary Hitchens (Canada)
Oct 25-28, Oct 30 - Nov 1, 1992
D. Lawrence, M. Scotney, PCS
Browns Bank to Sable I. Bank
Conduct drifter trials in conjunction with emergency response exercise.

R/V Oceanus (USA)
Oct. 26 - Nov. 19, 1992
N. Oakey, R. Ryan, A. Hartling, E. Verge, PCS
Canary Basin
North Atlantic tracer release experiment, NATRE; micro- structure studies.

R/V Ocemus (USA)
Jul 27 - Aug. 7, 1992
A. Clarke, M. Scotney, R. Boyce, J. Hamilton, PCS
South of Grand Banks
Deploy WOCE moorings.

Natural Resources Canada Atlantic Geoscience Centre

CSS *Tully* 92006 (Canada)
Nov. 14 - 25, 1992
Christian, MacKinnon
Fraser Delta
To study seabed instability features, collect seismic data for geohazard mapping and perform geotechnical tests with Lancelot, Excalibur and shear-wave equipment from the University College of North Wales.

GSC/BC Hydro Joint Geotechnical Site Investigation at Canoe Pass Submarine Cable Terminal
Dec. l-6, 1992
Christian
Fraser Delta
To conduct continuous drilling and sampling of Quaternary sediments, to allow an evaluation of seismic liquefaction potential and to constrain geologic model.

GSC Offshore Geotechnical Site Investigation Program at Crest of Delta Foreslope
Sept. 19-26, 1993
Christian
Fraser Delta
To carry out detailed in situ testing and borehole sampling program, to evaluate liquefaction potential of delta front deposits.

CSS *Tully* 93010 (Canada)
Nov. 2 - 13, 1993
Christian, Heffler, Parrott
Fraser Delta
To conduct geophysical surveys of delta foreslope, Excalibur geotechnical tests and shear-wave tests with the University College of North Wales group.

CCGS *Griffon* (Canada)
Aug. 17 - Sept. 9, 1992
Lewis, Atkinson, Jodrey, Sherin
Lake Ontario
A major survey of the surficial geology and upper most bedrock will be carried out to determine seismostratigraphy, features of discontinuity and disruption and the geotechnical and lithostratigraphic sedimentary profiles in areas of Lake Ontario.

CCGS *Griffon* (Canada)
June 21 - July 19, 1993
Lewis, Atkinson, Jodrey, Nielsen, Johnston
Lake Ontario
Geophysical surveying and sampling in Lake Ontario of the surficial geology and upper most bedrock will be carried out to determine a seismostratigraphy, features of discontinuity and the geotechnical and lithostratigraphic sedimentary profiles in the second year of a multi-year program.

MV *Lough Beltra* (Ireland)
June 11 - 22, 1993
Shaw, Wile, Beaver
Dingle Bay, Southwest Ireland
Collect geophysical and sample data offshore from a major spit-barrier complex in Dingle Bay, southwest Ireland. Surveys may also extend behind the barrier, with a view to examining the backbarrier estuarine deposits. This work is in collaboration with the University of Cork and a number of European partners (who will collect data onshore), and is part of a Commission of European Community project to examine the potential impact of rising sea level on the coast.

HMCS *Moresby* (Canada)
Sept. 27 - Oct. 8, 1993
Fader, Atkinson, Hughes, Johnston
Nova Scotia Shelf
Sidescan sonar survey of coastal area to map surficial geology.

Polar Star (USA)
Aug. 14 - Sept. 17, 1993
Jackson, Locke, Nielsen
Arctic Ocean, Canada Basin
Refraction seismic surveys to determine coastal structure in these areas.

Lough Beltra (Ireland)
June 10-22, 1993
Shaw, Forbes, Wile, Beaver
Dingle Bay, Ireland
To study the marine geology of Dingle Bay with a view to determining long-term coastal and barrier evolution under conditions of rising sea level.

Joides Resolution (USA)
May 20 - July 20, 1992
Jansa
northwestern Pacific Ocean
To investigate geologic history of some of the drowned guyots in northwestem Pacific Ocean, to establish if the drowning of the reefs and atolls is related to middle Cretaceous climate global change and crises, and use the guyots as measuring sticks to investigate time periods and magnitude of eustatic sea level changes to verify global applicability of the Mesozoic-Cenozoic cycle chart.

Tignish Sea (Canada)
June 16 - 25, 1993
Fader
Scotian Shelf
To survey and determine two routes for new fibre optic telecommunication cables across the Scotian Shelf and Slope. The survey was a joint project with Teleglobe Canada, McElhanney Surveys and the Geological Survey of Canada

HMCS *Moresbv* (Canada)
Sept. 27 - Oct. 8, 1993
Fader, Miller, Atkinson, Johnston, Hughes
Scotian Shelf
To map the geology of the seabed of the inner Scotian Shelf and provide ground truth for the new swath bathymetric data produced by the CSS Matthew. To undertake sediment studies in cooperation with the Department of National Defense and the Royal Canadian Mounted Police.

Miramichi Surveyor (Canada)
Oct. 13-17, 1992
Fader, Christian, Murphy
St. John Harbour
To assess the geological effects of dredging on the seabed and to understand sedimentation and transport pathways.

Joides Resolution (USA)
Jan. 21 - Mar. 10, 1993
Salisbury
Costa Rica Rift, Equatorial Pacific
Determine composition of oceanic Layer 3 and the nature of the Layer 21 3 transition through drilling.

Charts and Publications

Chart Production

The Scotia-Fundy Region of the Canadian Hydrographic Service (CHS) has responsibility for 400 nautical charts covering Canada's east coast from Georges Bank to Prince of Wales Strait in the Arctic.

The charts produced by CHS are divided into three types. A new chart is the first chart to show an area at that scale or to cover an area different from any existing chart. These charts are constructed to the metric contour style in bilingual form using new formats. A New Edition is a new issue of an existing chart showing new navigational information and including amendments previously issued in *Notices to Mariners*. A Reprint is a new print of a current edition that incorporates amendments previously issued in *Notices to Mariners*. Reprints for the Scotia-Fundy Region are produced by CHS headquarters in Ottawa.

In addition to the New Charts and New Editions listed below, about one hundred chart amendments and fifteen paste-on patches are issued through *Notices to Mariners* each year.

1992

New Charts

7575 Peel Sound and Prince Resent Inlet
4170 Glace Bay Harbour
4839 Head of Placentia Bay
4913 Caraquet Harbour, Baie de Shippegan and Miscou Harbour
4124 Harbours in the Bay of Fundy
7481 Foxe Channel
7482 Winter Island to Cape Jermain
7489 Navy Channel to Longstaff Bluff
4114 Campobello Island

New Editions

4391 LaHave River - Conquerall Bank to Bridgewater
7552 Bellot Strait and Approaches
4242 Cape Sable Island to Tusket Islands

1993

New Charts

4116 Approaches to Saint John
7134 Robinson Bay and Approaches
7136 Cape Mercy and Approaches
4847 Conception Bay

New Editions

4911 Entrance to Miramich River
4912 Miramichi
4846 Motion Bay to Cape St. Francis

Publications

We present below alphabetical listings by author of publications produced in 1992 and 1993 by staff at BIO from the Department of Fisheries and Oceans (DFO), Natural Resources Canada, and Environment Canada; publications of DFO science staff at the Halifax Fisheries Research Laboratory and the St. Andrews Biological Station are also incorporated. Articles published in scientific and hydrographic journals, books, conference proceedings, and various series of technical reports have also been included. The style and format of these references are as supplied by each unit. For further information on any publication listed here, contact: Marine Assessment and Liaison Division, Department of Fisheries and Oceans, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2; or call (902)426-3559.

DEPARTMENT OF FISHERIES AND OCEANS SCOTIA-FUNDY REGION

OFFICE OF THE REGIONAL DIRECTOR, SCIENCE

1992 AND 1993

Boudreau, P.R. 1993. Regional Data and Information System Requirements for the Gulf of Maine, p. 5. *In* E. Braasch [ed.] Proc. Gulf of Maine Data and Information Systems Workshop. Dartmouth College, Hannover, NH, Nov. 3-5, 1993.

MacPhee, S.B. 1993. The Bedford Institute of Oceanography: Current Program and Future Directions, p. 15-43. *In* Noniyuki Nasu and S. Honjo [ed.] Proc. of Symp. New Directions of Oceanographic Research and Development, Springer Verlag, Tokyo.

Nicholls, H.B. 1993. ECOR, An international organization active in the Coastal Zone, p. 3218-3225. *In* L.T. Tobin [ed.] Coastal Zone '93. Proc. 8th Symp. on Coastal and Ocean Management. Amer. Soc. Civ. Engineers, N.Y.

Nicholls, H.B. 1993. The Role of the Bedford Institute of Oceanography in Addressing Marine Coastal Zone Issues, p. 213-221. In L.P. Hildebrand and O.T. Magoon [ed.] Coastlines of Canada. Amer. Soc. Civ. Engineer, N.Y.

Peer, D., N. Prouse, and G. Seibert. 1992. Concerns addressed in the ocean dumping permit process, p. 84-86. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. Oceans, Dartmouth, NS.

BIOLOGICAL SCIENCES BRANCH

1992

Ackman, R.G., S. Sigurgisladottir, S.M. Polvi and S.P Lall. 1992. Fatty acid absorption and transformation in Atlantic salmon *(Salmo salar),* p. 23. Int. Symp. on Cultivation of Atlantic salmon. Bergen, Norway, August 17-20, 1992.

Ackman, R.G., S.M. Polvi, S. Sigurgisladottir, S.P La11 and R.L. Saunders. 1992. Absorption and deposition of n-3 fatty acids in Atlantic salmon *(Salmo salar). In* A. Sinclair and R. Gibson [ed.] Proc. 3rd Int'l Congress on Essential fatty acids and Eicosanoids. American Oil Chemists Society.

Addison, R.F. 1992. Detecting the effects of marine pollution, p. 9-12. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

Aiken, D.E. 1992. The perils of accountability in science. World Aquacult. 23(3): p. 3.

Aiken, D.E. [ed.] 1992. World Aquacult. 23(4): 72 p.

Aiken, D.E. [ed.] 1992. World Aquacult. 23(1): 80 p.

Aiken, D.E. [ed.] 1992. World Aquacult. 23(3): 72 p.

Aiken, D.E. [ed.] 1992. World Aquacult. 23(2): 72 p.

Aiken, D.E., and S.L. Waddy. 1992. The growth process in crayfish. Rev. Aquat. Sci. 63(3): 335-381.

Amadi, I., D.V. Subba Rao, and Y. Pan. 1992. A *Gonyaulax digitale* red water bloom in the Bedford Basin, Nova Scotia, Canada. Bot. Mar. 35: 451-455.

Amiro, P.G., R.E. Cutting, B.M. Jessop, T.L. Marshall, and S.E O'Neil. 1992. Status of Atlantic salmon stocks of Scotia-Fundy Region, 1991. CAFSAC Res. Doc. 92/21, 22 p.

Anderson, S.A., S.P La11 and D.M. Anderson. 1992. Apparent and true availabilities of amino acids from common feed ingredients for Atlantic salmon *(Salmo salar)* reared in sea water. Aquaculture 108: 111-124.

Annand, C. 1992. Review of management measures for 1991 Scotia-Fundy groundfish fishery. CAFSAC Res.Doc. 92/103.

Annand, C, and D. Beanlands. 1992. Assessment of pollock *(Pollachius virens)* in Divisions 4VWX and Subdivision 5Zc for 1991. CAFSAC Res. Doc. 92/44.

Anon. 1992. Report of the ICES Study Group on Ecosystem Effects of Fishing Activities (Copenhagen, Denmark, April 7-14, 1992). ICES C.M.l992/G:ll.

Barrie, L.A., D. Gregor, B.T. Hargrave, R. Lake, D. Muir, R. Shearer, B. Tracey, and T. Bidleman. 1992. Arctic contaminants: Sources, occurrence and pathways. Sci. Total Env. 122: 1-74.

Bird, C.J., E.L. Rice, C.A. Murphy, and M.A. Ragan. 1992. Phylogenetic relationships in the agarophyte family Gracilariaceae *(Rhodophyta, Gracilariales).* XIVth International Seaweed Symposium, August 16-21, Brittany, France. (Abstract)

Bird, C.J., C.A. Murphy, R.K. Singh, E.L. Rice, R.R. Gutell, and M.A. Ragan. 1992. Classical taxonomy and rRNA sequences in red algae: conflict and congruence. International Society for Evolutionary Protistology 9, July 3-7, Orsay, France.

Bird, C.J., C.A. Murphy, E.L. Rice, R.R. Gutell, and M.A. Ragan. 1992. Genetic relationships among red algae *(Rhodophyta)* as evidenced by sequences of 18S ribosomal RNA genes. XIVth International Seaweed Symposium, August 16-21, Brittany, France.(Abstract)

Bird, C.J., E.L. Rice, C.A. Murphy, R.R. Gutell, and M.A. Ragan. 1992. Towards an rRNA gene phylogeny of the red algae *(Rhodophyra).* Northeast Algal Symposium, April 25-26, Woods Hole, MA. (Abstract)

Bird, C.J., CA. Murphy, M.A. Ragan, E.L. Rice, and R.R. Gutell. 1992. Towards an rRNA gene phylogeny of the red algae *(Rhodophya).* Aquatech '92: Progress and profits from research. March 1-3, Halifax, N.S.

Bird,C.J., E.L. Rice, CA. Murphy, and M.A. Ragan. 1992. Phylogenetic relationships in the Gracilariales *(Rhodophpa)* as determined by 18S rDNA sequences. Phycologia 31: 510-522.

Bird, C.J.,C.A. Murphy, E.L. Rice, and M.A. Ragan. 1992. The 18S rRNA gene sequences of four commercially important seaweeds. J. of Appl. Phycol. 9: 1-6.

Bjerknes, V., J. Duston, D. Knox, and P.R. Harmon. 1992. Importance of body size for acclimation of underyearling Atlantic salmon parr *(Salmo salar* L.) to seawater. Aquacult. 104: 357-366.

Bose, R., C.L. Schnell, C. Pinsky, and

V. Zitko. 1992. Effects of excitotoxins on free radical indices in mouse brain. Toxicol. Letters 60: 211-219.

Bones, D.J., W.D. Bowen, S.J. Iverson, and O.T. Oftedal. 1992. Influence of storms and maternal size on mother-pup separations and fostering in the harbour seal. Can. J. Zool. 70: 1640-1644.

Boudreau, P.R. 1992. Data and Information Management Committee of the Gulf of Maine Council on the Marine Environment directory of data bases. DFO Internal Rep.

Boudreau, P.R. 1992. DFO user needs survey for the Gulf of Maine. DFO Internal Rep.: 54 p.

Boudreau, P.R. 1992. Habitat Sensitivity Mapping Workshop: Review, strategy, and recommendations. DFO Internal Rep.: 49 p.

Boudreau, P.R. 1992. DFO component of the Atlantic Coastal Zone Information Management Steering Committee directory of data bases. DFO Internal Rep.: 218 p.

Boudreau, P.R., and L.M. Dickie. 1992. Biomass spectra of aquatic ecosystems in relation to fisheries yield. Can. J. Fish. Aquat. Sci. 49: 1528-1538.

Bowen, W.D. 1992. Population energetics of seals on the Scotian Shelf, p. 13-17. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

Bowen, W.D., O.T. Oftedal, and D.J. Boness. 1992. Mass and energy transfer during lactation in a small phocid, the harbour seal. Physiol. Zool. 65: 844-866.

Bowen, W.D., W.T. Stobo, and S.J. Smith. 1992. Mass changes of grey seal *Halichoerus grypus* pups on Sable Island: Differential maternal investment reconsidered. J. Zool.(London) 227: 607-622.

Bradford, R.G., and T.D. Iles. 1992. Unique biological characteristics of spring-spawning herring *(Clupea harengus* L.) in Minas Basin, Nova Scotia, a tidally dynamic environment. Can. J. Zool. 70: 641-648.

Bradford, R.G., and R.L. Stephenson. 1992. Egg weight, fecundity, and gonad weight variability among northwest Atlantic herring *(Clupea harengus)* populations. Can. J. Fish. Aquat. Sci. 49: 2045-2054.

Brander, K., and P.C.F. Hurley. 1992. Distribution of early stage cod, haddock and witch eggs on the Scotian Shelf: A re-appraisal of evidence on the coupling of cod spawning and plankton production. Can. J. Fish. Aquat. Sci. 49: 238-251.

Branton, R. 1992. ZIF Verification Workshop Report #2.

Branton, R. 1992. BSB 1992 EDP Status Report.

Brodie, P.F. 1992. Whale mechanics and fisheries oceanography. Sou'wester, September 15, 1992.

Brodie, P.F. 1992. Status, energetics and incidental by-catch mortality of harbour porpoise in the Gulf of Maine/ Bay of Fundy. *In* NOAA/National Marine Fisheries Service. Harbour Porpoise in Eastern North America: Results of a Scientific Workshop (Woods Hole, Mass., April-May 1992). Northeast Fish. Sci. Center Ref. Doc. 92-06.

Buerkle, U. 1992. Results of the 1991-92 herring acoustic surveys in NAFO Div. 4WX. CASAC Res. Doc. 92173: 23 p.

Bugden, G., R. Forbes, D.C. Gordon, B. Huppertz, PD. Keizer, M. Levasseur, J.L. Martin, R. Penny, J. Smith, D.V. Subba Rao, D.J. Wildish, and P Yeats. 1992. Overview of Canadian phytoplankton monitoring program, p. 15-16. *In* J.-C. Theniault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)

Bugden, G.L., D.V. Subba Rao, and P.A. Yeats. 1992. The phytoplankton profiling project, p. 18-22. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

Bugden, G.L., P Butts, PD. Keizer, K. Kranck, T. Milligan, E.A. Orr; D.V. Subba Rao, and P.A. Yeats. 1992. The Scotia-Fundy phytoplankton monitoring program; the Nova Scotian component, p. 39. *In* J.-C. Therriault and M. Levasseur [ed.] Proceedings of the Third Canadian Workshop on Harmful Marine Algae. Maurice-Lamontagne Institute, Mont-Joli, Quebec, May 12- 14, 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)

Butler, M.A.E.and G. Robert. 1992. Update of the Scotian Shelf shrimp fishery - 1991. CAFSAC Res. Doc. 92/33, 17 p.

Buzeta, M.-I. 1992. Use of backcalculations on NAFO Subdivision 5Ze cod otoliths for the correct assignment of settling checks and first annuli. CAFSAC Res. Doc. 92/47: 15 p.

Buzeta, M.-I., J.J. Hunt, N. Munroe, and L. Van Eeckhaute. 1992. Report of the Georges Bank cod and haddock ageing workshop. CAFSAC Res. Doc. 92/119: 34 p.

Campana, S.E. 1992. Measurement and interpretation of the microstructure of fish otoliths, p. 59-71. *In* D.K. Stevenson and S.E. Campana [ed.] Otolith Microstructure Examination and Analysis. Can. Spec. Publ. Fish. Aquat. Sci. 117.

Campana, S., and J. Hamel. 1992. Status of the 1991 4X cod fishery. CAFSAC Res. Doc. 92/46.

Campana, S.E. 1992. Projecting fish stock levels. Guest editorial to the December 8 Chronicle Herald newspaper.

Campana, S.E. and C.M. Jones. 1992. Analysis of otolith microstructure data, p. 73-100. *In* D.K. Stevenson and S.E. Campana [ed.]. Otolith Microstructure Examination and Analysis. Can. Spec. Publ. Fish. Aquat. Sci. 117.

Campana, S.E., and J.M. Casselman. 1992. Discrimination of the 4Vs/4T cod stocks using otolith shape analysis. CAFSAC Res. Doc. 92/45.

Carver, C.S., S. Hancock, G.G. Sims, and W. Watson-Wright. 1992. Phytoplankton monitoring in Nova Scotia, p. 30-31. *In* J.-C. Therriault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)

Chang, B.D. and J.-P Thonney. 1992. Overview and environmental status of the New Brunswick salmon culture industry. Bull. Aquacult. Assoc. Can. 92-3: 61-63.

Chopin, T., J. Pringle and R. Semple.

1992. Impact of harvesting on frond density and biomass of Irish moss *Chondrus crispus* stackhouse beds in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 49: 349-357.

Clay, D. and J.M. Porter. 1992. National report of Canada, 1990-91. Int. Comm. Conserv. Atl. Tunas, Rep. for Biennial Period 1990-91, Part 2: 254-258.

Cower, R.J., J.M. Porter, and J.J. Hoey. 1992. Casting the Shepherd stock-production model in a statistical framework suitable for swordfish stock assessment and management advice. Int. Comm. Conserv. Atl. Tunas, Coil. Vol. Sci. Pap. (Madrid) 39: 593-599.

Cranford, P.J., D.K. Muschenheim, and D.C. Gordon, Jr. 1992. Studies on the possible impacts of petroleum developments on Georges Bank scallop stocks, p. 237-240. *In* J. Wiggins and C.N.K. Mooers [ed.] Proceedings of the Gulf of Maine Scientific Workshop, Woods Hole, Massachusetts, 8-10 Jan. 1991. Gulf of Maine Council on the Marine Environment. Urban Harbors Institute, University of Massachusetts, Boston.

Crawford, R.E., C. Hudon, and D.G. Parsons. 1992. A hydroacoustical study of shrimp *Pandalus montagui* distribution near Resolution Island (eastern Hudson Strait). Can. J. Fish. Aquat. Sci. 49 (5): 842-856.

DiBacco, C., and J.D. Pringle. 1992. Larval lobster *(Homarus americanus,* H. Milne Edwards, 1837) distribution in a protected Scotian Shelf Bay. J. Shellf. Res. 11: 81-84.

DiBacco, C. 1992. The reproductive cycle of the giant scallop *(Placopecten magellanicus Gmelin)* on eastern Georges Bank. Marine Benthic Ecology Meeting, 1992, Newport, R.I., U.S.A.(Abstract)

Duston, J., and J.D.E. Knox. 1992. Acclimation of Atlantic salmon *(Salmo salar)* parr to seawater in autumn: stimulatory effect of a long photoperiod. Aquaculture 103: 341-358.

Duston, J.,and R.L. Saunders. 1992. Effects of 6-, 12-, and 18-month photoperiod cycles on smolting and sexual maturation in juvenile Atlantic salmon *(Salmo salar).* Can. J. Fish. Aquat. Sci. 49: 2273-2280.

Elner, R.W., and PG. Beninger. 1992. The reproductive biology of Snow Crab, *Chionoecetes opilio:* a synthesis of recent contributions. Amer. Zool. 32: 524-533.

Farmer, G.J., D. Ashfield, and D.K. MacPhail. 1992. Chemical characteristics of selected rivers in Shelburne County, Nova Scotia, 1988-1991. Can. MS Rep. Fish. Aquat. Sci. No. 2155. 35 p.

Farmer, G.J. 1992. Some factors which influence the survival of hatchery Atlantic salmon *(Salmo salar)* smolts utilized for enhancement purposes. Can. Tech. Rep. Fish. Aquat. Sci. No. 1855. 19 p.

Frank,K.T., J.W. Loder, J.E. Carscadden, W.C. Leggett, and C.T. Taggart. 1992. Larval flatfish distributions and drift on the southern Grand Bank. Can. J. Fish. Aquat. Sci. 49: 467-483.

Frank, K.T. 1992. The demographic consequences of age-specific dispersal in marine fish populations. Can. J. Fish. Aquat. Sci. 49: 2222-2231.

Friars, G.W., J.K. Bailey, and F.M. O'Flynn. 1992. Merging conventional mating and selection practices with transgenic technology. Progress and Profits from Research. Aquactech '92. Dept. Fish. and Oceans, Aquacult. and Res. Devel. Branch, Halifax. p. 39-42.

Furuya, K. and W.K.W. Li. 1992. Evaluation of photosynthetic capacity of phytoplankton by flow cytometric analysis of DCMU-enhanced chlorophyll fluorescence. Mar. Ecol. Prog. Ser. 88: 279-287.

Gavaris, S. and L. Van Eeckhaute. 1992. Assessment of haddock on eastern Georges Bank. CAFSAC Res. Doc. 92129: 32 p.

Gordon, D.C., Jr. 1992. Current applications and future developments in the use of mathematical models in the implementation of monitoring programs and regional assessments. Discussion paper prepared for the ICES Working Group on Environmental Assessment and Monitoring Strategies. Annex 3. ICES C.M.1992/ Poll: 9(Sess. V): 18-28.

Gordon, D.C., Jr. 1992. Theoretical framework for using benthic organisms to assess environmental change. Discussion paper prepared for the ICES Benthos Ecology Working Group. Annex 12. ICES C.M. 1992/ L:11: 90-102.

Govind, C.K., A.T. Read, W.T. Claxton, and R.W. Elner. 1992. Neuromuscular analysis of the chela-closer muscle associated with precopulatory grasping in male snow crabs, *Chionoecetes opilio.* Can. J. Zool. 70: 2356-2360

Hagen, N.T., and K.H. Mann. 1992. Functional response of the predators American lobster *Homarus americanus* (Mime-Edwards) and Atlantic wolffish *Anarhichas lupus* (L.) to increasing numbers of the green sea urchin *Strongylocentrotus droebachiensis* (Müller). J. Exp. Mar. Biol. Ecol. 159: 89-112.

Halliday, R.G., and T.J. Kenchington. 1992. Profile of Scotia-Fundy groundfish longline fleet. DFO Scotia-Fundy Region, Halifax, N.S., Project Summary No. 35: 4 p.

Halliday, R.G., F.G. Peacock, and D.L. Burke. 1992. Development of management measures for the groundfish fishery in Atlantic Canada -A case study of the Nova Scotia inshore fleet. Marine Policy 16(6): 411-426.

Hammill, M.O., R.A. Myers, G. Stenson, and W.T. Stobo. 1992. Mark-recapture estimates of non-Sable Island grey seal *(Halichoerus grypus)* pup production. CAFSAC Res. Doc. 92/91: 15 p.

Harding, G.C. 1992. A review of the major marine environmental concerns off the Canadian East Coast in the 1980s. Can. Tech. Rep. Fish. Aquat. Sci. 1885: vi + 38 p.

Harding, G.C. 1992. American lobster *(Homarus americanus* Milne Edwards): A discussion paper on their environmental requirements and the known anthropogenic effects on their populations. Can. Tech. Rep. Fish. Aquat. Sci. 1887: vi + 16 p.

Hargrave, B.T., P.J. Cranford, B.A. MacDonald, and J.E. Ward. 1992. *In situ* feedings studies on adult sea

scallops. Presentation at the annual Ocean Production Enhancement Network meeting, Dalhousie University, Halifax, N.S. (Poster)
Hargrave, B.T., P. Germain, J.-C. Philippot, G. Hermon, and J.N. Smith. 1992. Stable elements and ^{210}Po in the deep-sea amphipod *Eurythenes gryllus.* Deep-Sea Res. 39: 37-44.
Hargrave, B.T., G.C. Harding, W.P. Vass, P.E. Erickson, B.R. Fowler, and V. Scott. 1992. Organochlorine pesticides and polychlorinated biphenyls in the Arctic Ocean food web. Arch. Environ. Contam. Toxicol. 22: 41-54.
Harrison, W.G. 1992. Regeneration of nutrients, p. 385-407. In P. Falkowski [ed.] Primary Productivity and Biogeochemical Cycles in the Sea. Brookhaven Symposium in Biology No. 37, Plenum Press, N.Y.
Harrison, W.G. and G.F. Cota. 1992. Primary production in polar waters: relation to nutrient availability, p. 87-104. *In* E. Sakshaug, C.E. Hopkins and N.A. Oritsland [ed.] Proceedings from the Pro Mare Symposium on Polar Marine Ecology, Trondheim. 12. 16 May 1990. Polar Res. 10.
Harrison, W.G., L.R. Harris, D.M. Karl, G.A. Knauer and D.G. Redalje. 1992. Nitrogen dynamics at the VERTEX time-series site. Deep-Sea Res. 39: 1535-1552.
Harrison, W.G. and E.J.H. Head. 1992. Particulate C, N, P and Si analysis at the Bedford Institute of Oceanography, Canada. *In* Hurd, D.C., Spencer, D.W. [ed.] The analysis and characterization of marine particles. Publ. AGU, Washington, DC.
Head, E.J.H. 1992. Gut pigment accumulation and destruction by arctic copepods *in vitro* and *in situ.* Mar. Biol. 112: 583-592
Head, E.J.H. 1992. Comparison of the chemical composition of particulate material and copepod faecal pellets at stations off the coast of Labrador and in the Gulf of St. Lawrence. Mar. Biol. 112: 593-600.
Head, E.J.H. and L.R. Harris. 1992. Chlorophyll and carotenoid transformation and destruction by *Calanus* spp. grazing on diatoms. Mar. Ecol. Prog. Ser. 86: 229-238.
Herbinger, C.M., and G.W. Friars. 1992. Effects of winter temperature and feeding regime on the rate of early maturation in Atlantic salmon *(Salmo salar)* male parr. Aquacult. 101: 147-162.
Hudon, C. 1992. Critical factors for the development of a collector for postlarval and juvenile lobster. *In* DeLafontaine, Y. [ed.]. Proceedings of the Workshop "Juvenile stages: the missing link in fisheries research", held at BIO, October 1-3, 1991. Can. Tech. Rept. Fish. Aquat. Sci. 1890.
Hudon, C. 1992. Nearshore habitats. p. 13. *In* Bunch, J.N. and R.R. Reeves [ed.] Proceedings of a workshop on the potential cumulative impacts of development in the region of Hudson and James Bays, 17-19 June 1992. Can. Tech. Rep. Fish. Aquat. Sci. **1874.**
Hudon, C., D.G. Parsons, and R.E. Crawford. 1992. Die1 pelagic foraging by a pandalid shrimp *(Pandalus montagui)* off Resolution Island eastern Hudson Strait. Can. J. Fish. Aquat. Sci. 49 (3): 565-576.
Hogans, W.E., and K.J. Sulak. 1992. *Diocus lycenchelus* new species (Copepoda: Chondracanthidae) parasitic on the eelpout *Lycenchelys verrillii* (Zoarcidae) from the Hatteras slope of the northwestern Atlantic Ocean. Bull. Mar. Sci. 51 : 301-308.
Hunt, J.J. 1992. Morphological characteristics of otoliths for selected fish in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 13: 63-75.
Hunt, J.J. and M. I. Buzeta. 1992. Status of the Atlantic cod stock on Georges Bank in unit areas 5Zj and 5Zm, 1978-91. CAFSAC Res. Doc. 92/48: 23 p.
Hunter, C. M. and M. J. Tremblay. 1992. A database for catch and length composition related to the Scotia-Fundy lobster fishery. Can. MS Rep. Fish. Aquat. Sci. 2149: 27 p.
Hurley, P.C.F., J. Simon, and K.T. Frank. 1992. Assessment of 4X haddock in 1991. CAFSAC Research Document 92/63: 40 p.
Jellett, J.F., L.J. Marks, J.E. Stewart, M.L. Dorey, W. Watson-Wright, and J.F. Lawrence. 1992. Paralytic shellfish poison (Saxitoxin family) bioassays: Automated endpoint determination and standardization of the *in vitro* tissue culture bioassay, and comparison with the standard mouse bioassay. Toxicon 30(10): 1143- 1156.
Jellett, J.F., L.M. Marks, J.E. Stewart, W. Watson-Wright, and M.L. Dorey. 1992. A comparison of the modified mouse neuroblastoma cell bioassay for paralytic shellfish poison *(saxitoxin)* with the standard AOAC mouse bioassay, p. 14. *In* J.-C. Therriault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)
Jellett, J.F., and J.E. Stewart. 1992. The role of bacteria in the growth and production of paralytic shellfish poisons by the toxic dinoflagellate *Alexundrium tumurense,* p. 15. *In* J.-C. Therriault and M. Levasseur [ed.] Proceedings of the Third Canadian Workshop on Harmful Marine Algae. Maurice-Lamontagne Institute, Mont-Joli, Quebec, May 12-14, 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1893.(Abstract)
Johnson, B.D. and P.E. Kepkay. 1992. Colloid transport and bacterial utilization of oceanic DOC. Deep-Sea Res. 39: 855-869.
Judson, G., R. Semple, and G. Sharp. 1992. Seaweed resources of Prince Edward Island. Canada. Abstracts and Programme, XIV International Seaweed Symposium.
Kenchington, E. and M.J. Lundy. 1992. 1992 Brier Island and Lurcher Shoal (Bay of Fundy) Scallop Stock Status. CAFSAC Invertebrate Committee Summary Sheet, November 1992.
Kenchington, E. and Lundy, M.J. 1992. 1991 Digby (Bay of Fundy) Scallop Stock Assessment. CAFSAC Res. Doc. 92/41, 27 p.
Kenchington, T.J., R.G. Halliday, and G.D. Harrison. 1992. Fishing grounds exploited in 1990 by longliners based in Canada's Scotia-Fundy Region. NAFO SCR Doc. 92/52, Serial No. N2104: 34 p.
Kenchington, E. and M.J. Lundy. 1992. 1992 Digby (Bay of Fundy) Scallop Stock Status. CAFSAC

Invertebrate Committee Summary Sheet, November 1992.
Kepkay, P.E. and M.L. Wells. 1992. Dissolved organic carbon in north Atlantic surface waters. Mar. Ecol. Prog. Ser. 80: 275-283.
Kerr, S.R., and R.A. Ryder. 1992. Effects of cultural eutrophication on coastal marine fisheries. Sci. Total Environ. (Suppl.): 599-614.
Komourdjian, M.K. and R.L. Saunders. 1992. Cells with affinity for periodic acid-Schiff are present in the pars intermedia of Atlantic salmon. Can. J. Zool. 69: 3105-3108.
Koshio, S., J.D. Castell, and R.K. O'Dor, 1992. The effect of different dietary energy levels in crab-protein-based diets on digestibility, oxygen consumption, and ammonia excretion of bilaterally eyestalk-ablated and intact juvenile lobsters, *Homarus americanus.* Aquaculture 108:285-297.
Kyewalyanga, M., T. Platt and S. Sathyendranath. 1992. Ocean primary production calculated by spectral and broad-band models. Mar. Ecol. Prog. Ser. 85: 171-185.
Lacroix, G.L. 1992. Mitigation of low stream pH and its effects on salmonids. Environmental Pollution 78: 157-164.
Lall, S.P. and O.J. Torrissen. 1992. Nutrition and feeding of marine cold water fish, p. 688-696. In M.K. Stopskopf [ed.] Fish Medicine. Saunders Press, N.Y.
Lall, S. P. 1992. Nutritional and chemical characteristics of Canadian fish meal and oil. Expert **Committee** on Animal Nutrition Meeting. Truro, N. S., May 31 -June 2, 1992.(Abstract)
Lall, S. P 1992. Report from the Canadian Working Group on Finfish Nutrition. Expert Committee on Animal Nutrition Meeting. Truro, N. S., May 31 -June 2, 1992. (Abstract)
Lall, S.P., and J.D. Castell. 1992. Fish and invertebrate nutrition, p. 42-46. In J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.
Lall, S. P, S. J. Kaushik, and R. A. Keith. 1992. Quantitative arginine requirement of Atlantic salmon *(Salmo salar)* reared in seawater, p 6. IV Int. Symp. Fish Nutrition and Feeding. Santiago, Chile, September 7-10, 1992. (Abstract)
Lambert, T.C. 1992. Subdivision 4Vn cod (May-December): Update of stock status for 1991. CAFSAC Res. Doc. 92/81.
Lavoie, R., D. Scarratt, K. Freeman, and B. Bradford. 1992. Shellfish culture in Nova Scotia, p. 47-52. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.
Lawson, J.W., G.D. Harrison, and W.D. Bowen. 1992. Factors affecting the accuracy of age determination in harp seals. Marine Mammal Sci. 8: 169-171.
Lawton, P. 1992. Identification of lobster areas in the vicinity of proposed, current and possible future aquaculture sites in southwestern New Brunswick. Interim Report to the New Brunswick Department of Fisheries and Aquaculture. 77 p.
Lawton, P., and D.A. Robichaud. 1992. Lobster habitat ecology research in the Bay of Fundy, p. 53-56. *In* J. Cook [ed.] Science Review 1990 & '91. Dept. Fish. and Oceans, Dartmouth, N.S.
Lawton, P., and D.A. Robichaud. 1992. Update on the fishing season extension issue in Lobster Fishing Area 36. CAFSAC Res. Doc. 92/20: 22 p.
Lawton, P, and R.K. Zimmer-Faust. 1992. Context-sensitivity in crab foraging studies. Amer. Zool. 32: 396-404.
Li, W.K.W., PM. Dickie, W.G. Harrison, and B.D. Irwin. 1992. Biomass and production of bacteria and phytoplankton during the spring bloom in the western North Atlantic Ocean. Deep-Sea Res. II, 40: 307-327.
Li, W.K.W., PM. Dickie, B.D. Irwin, and A.M. Wood. 1992. Biomass of bacteria, cyanobacteria, prochlorophytes and photosynthetic eukaryotes in the Sargasso Sea. Deep-Sea Res. 39: 501-519.
Li, W.K.W., M.R. Lewis, and A. Lister. 1992. Flow cytometric detection of prochlorophytes and cyanobacteria in the Gulf of Policastro, Italy. Archiv für Hydrobiol. 124: 309-316.
Loder, J.W., D. Brickman, and E.P.W. Home. 1992. Detailed structure of currents and hydrography on the northern side of Georges Bank. J. Geophys. Res., 97: 14331-14351.
Loder, J.W., R.I. Perry, K.F. Drinkwater, J. Grant, G.C. Harding, W.G. Harrison, E.P.W. Home, N.S. Oakey, C.T. Taggart, M.J. Trembley, D. Brinkman and M.M. Sinclair. 1992. Physics and biology of the Georges Bank frontal system, p. 57-61. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.
Longhurst, A.R. and R. Williams. 1992. Vertical carbon flux by seasonally migrating copepods is a small number. J. Plank. Res. 14 (11).
Longhurst, A.R., Koike, W.K.W. Li, J. Rodriguez, P. Dickie, P. Kepkay, F. Partensky, B. Bautista, J. Ruiz, M. Wells and D. Bird. 1992. Sub-micron particles in northwest Atlantic shelf water. Deep-Sea Res. 39: 1-7.
Lundy, M.J., and E. Kenchington. 1992. Brier Island Revisited: A 1991 Scallop Stock Status Report. CAFSAC Res. Doc. 92/42, 15 p.
MacPhail, D.K. 1992. Ages of the salmon broodstock collected in the Scotia-Fundy Region during 1991. Internal Document 92-04, 36 p.
Mann, K.H. 1992. Review of M.I. El-Sabh and N. Silverberg [ed.] Oceanography of a large-scale estuarine system: The St. Lawrence. Quart. Rev. Biol. 67: 220.
Mann, K.H. 1992. The extent and importance of rockweed as a habitat for finfish, shellfish, and other species. CAFSAC Res. Doc. 92/1 16: 8 p.
Mann, K.H. 1992. Physical influences on biological processes: How important are they? S. Afr. J. Mar. Sci. 12: 107-121.
Marcogliese, D.J., and G. McClelland. 1992. *Coyosoma vegeneri* (Acanthocephala: Polymorphida) and *Pseudoterranova decipiens* (Nematoda: Ascaridoidea) larvae in Scotian Shelf groundfish. Can. J. Fish. Aquat. Sci. 49: 2062-2069.
Marks, L.J., J.E. Stewart, and T. Hastein. 1992. Evaluation of an

indirect fluorescent antibody technique for detection of *Aerococcus viridans* (var.) *homari*, pathogen of homarid lobsters. Dis. Aquat. Org. 13: 133-138.

Marshall, T.L. 1992. Assessment of Atlantic salmon of the Saint John River, N. B., above Mactaquac, 1991. CAFSAC Res. Doc. 92/74, 22 + v p.

Marshall, T.L., PG. Amiro, J.A. Ritter, B.M. Jessop, R.E. Cutting, and S.E O'Neil. 1992. Perfunctory estimates of allowable harvests of Atlantic salmon in 18 rivers of Scotia-Fundy Region. CAFSAC Res. Doc. 92/16, 28 p.

Martell, D.J., and G. McClelland. 1992. Prey spectra of pleuronectids *(Hippoglossoides platessoides, Pleuronectes ferrugineus, Pleuronectes americanus)* from Sable Island Bank. Can. Tech. Rep. Fish. Aquat. Sci. 1895: vi + 20 p.

Martin, J.L. and D.J. Wildish. 1992. Integrated water column versus Niskin bottle sampling in the southwest Bay of Fundy, p. 18-19. *In* J.-C. Therriault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)

McLean, E.J. 1992. Quality evaluation of hatchery-reared 1+ Atlantic salmon smolts. Internal Document 92-03, 129 p.

McLean, E.J. 1992. Quality evaluation of hatchery-reared 2+ Atlantic salmon smolts. Internal Document 92-04, 36 p.

Melvin, G.D., M.J. Dadswell, and J.A. McKenzie. 1992. The usefulness of meristic and morphometric characters in discriminating populations of American shad *(Alosa supidissima)*, inhabiting a marine environment. Can. J. Fish. Aquat. Sci. 49: 266-280.

Melvin, G.D. and F.J. Fife. 1992. Comparison of Canadian and United States larval herring surveys on Georges Bank: 1987-91. CAFSAC Res. Doc. 92/67: 27 p.

Melvin, G.D., J.B. Sochasky, M.J. Power, F.J. Fife, and W.H. Dougherty. 1992. Georges Bank (5Z) herring - 1992 update. CAFSAC Res. Doc. 92/68: 22 p.

Miller, R. 1992. Strengths of lobster fishery management in Scotia-Fundy. CAFSAC - The Year of the Lobster. (Abstract)

Miller, R.J., A. Campbell, G.J. Sharp, and C. Hudon. 1992. Are juvenile lobsters habitat limited? p.33-42. *In Y.* de LaFontaine, G. Lilly, T. Lambert, and R. Miller [ed.] Proceedings of the Workshop "Juvenile stages: the missing link in fisheries research", held at BIO October 1-3, 1991. Can. Tech. Rep. Fish and Aquat. Sci. 1890.

Mohn, R. 1992. Length-based Virtual Population Analysis: A review and swordfish example. ICCAT Collected Volume of Scientific Papers. XXXIX(2): 503-514.

Mohn, R. 1992. Introduction to Sequential Population Analysis. Workbook written for NAFO Special Session of Fish Stock Assessment: A Tutorial/Workshop in Calibration Methods and Their Practical Use. Dartmouth, N.S., September 9-11, 1992: 44 p.

Mohn, R., and W.J. MacEachern. 1992. Assessment of 4VsW cod in 1991. CAFSAC Research Document 92/54: 37 p.

Mohn, R., D. Parsons, and L. Savard. 1992. Report of CAFSAC Special Meeting Invertebrate and Marine Plant Subcommittee: Shrimp management alternatives. December 5-8, 1989. Ottawa, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1884: 30 p.

Morin, B., C. Hudon, and F. Whoriskey. 1992. Environmental influences on seasonal distribution of coastal and estuarine fish assemblages at Wemindji, eastern James Bay. Environ. Biol. Fish. 35: 219-229.

Morrison, C.M. 1992. The digestive tract of the cod eleutheroembryo ("yolk-sac larva") and larva. Bulletin of the Canadian Society of Zoologists. 23:92. (Abstract)

Morrison, C.M., and G. McClelland. 1992. (Book review) Grabda, J. 1991. "Marine Fish Parasitology: An Outline". Polish Scientific Publications, Warsaw. *In* Europ. J. Protistol. 28: 249-250.

Morrison, C.M., and R.E. Zurbrigg. 1992. Cold-water commercial marine fish anatomy and physiology, p. 672-684. *In* M.K. Stopskoff [ed.] Fish Medicine, W.B. Saunders Co., Toronto, Montreal.

Muir, D.C.G., R. Wagemann, B.T. Hargrave, D.J. Thomas, D.B. Peakall, and R.J. Norstrom. 1992. Arctic marine ecosystem contamination. Sci. Total Environ. 122: 75- 134.

Muschenheim, D.K., and C.R. Newell. 1992. Utilization of seston flux over a mussel bed. Mar. Ecol. Prog. Ser. 85: 131-136.

Nolan, S. and R. Miller. LFA 33 lobster fishery statistics. CAFSAC summary sheet.

Nolan, S. and R. Miller (Abs.). Lobster assessment methodology. CAFSAC-The Year of the Lobster.

Novelli, A., J. Kispert, M.T. Femandez-Sanches, A. Torreblanca, and V. Zitko. 1992. Domoic acid-containing toxic mussels produce neurotoxicity in neuronal cultures through a synergism between excitatory amino acids. Brain Res. 577: 41-48.

Novelli, A., M.T. Femandez-Sanches, J. Kispert, A. Torreblanca, S. Gascon, and V. Zitko. 1992. The amnesic shellfish poison domoic acid enhances neurotoxicity by excitatory amino acids in cultured neurons. Amino Acids 2: 233-244.

O'Boyle, R., K. Drinkwater, B. Petrie, T.W. Rowell, and W.P Vass. 1992. The Atlantic Fisheries Adjustment Program, p.68-74. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

O'Flynn, F.M., R.L. Saunders, J.D. Martin, G.W. Friars, J.K. Bailey, and J.M. Terhune. 1992. The effect of extended daylength on early sexual maturation and growth in Atlantic salmon *(Salmo salar)* reared in sea cages. Salmon Genetics Res. Prog. Tech. Rep. Ser. 151: 14 p.

Olivier, G., S.G. Griffiths, J. Fildes and W.H. Lynch. 1992. The use of Western blot and electroimmunotransfer blot assays to monitor bacterial kidney disease in experimentally challenged Atlantic salmon, *Salmo salar* L. J. Fish Dis. 15; 229-241.

Olivier, G. 1992. Furunculosis in the Atlantic provinces: an overview. Bull. Aquacul. Assoc. Canada 92-1: 4-10.

Olivier, G, and J. Daly. 1992. Research progress in fish disease detection, diagnosis and control. Aquatech 92 "Progress and profits from research" Halifax, Nova Scotia, March 2-3, 1992. **(Abstract)**

Olivier, G., A. R. Moore, and J. Fildes. 1992. Toxicity of *Aeromonas salmonicida* cells to Atlantic salmon, *Salmo salar*, peritoneal macrophages. Dev. Comp. Immunol. 16: 49-61.

Ouellet, P., C.T. Taggart, and K.T. Frank. 1992. Lipid condition and survival in shrimp *(Pandalus borealis)* larvae. Can. J. Fish. Aquat. Sci. 49: 368-378.

Page, F.H., and R. Losier. 1992. Near-bottom temperature conditions during Canadian groundfish bottom-trawl surveys conducted within the Scotia-Fundy Region, NAFO areas 4VWX and 5Z, between 1970 and 1992. CAFSAC Working Paper 92/156.

Page, F.H., and R. Losier. 1992. Summer hydrographic conditions on the eastern Scotian Shelf in 1992. CAFSAC Working Paper 92/184.

Page, F., and S. Robinson. 1992. Salmon farming in the Bay of Fundy: a chilling reminder. World Aquacult. 23(4): 31-34.

Paine, M.D., W.C. Leggett, J.K. McRuer, and K.T. Frank. 1992. Effects of Hibernia crude oil on capelin *(Mallotus villosus)* embryos and larvae. Mar. Environ. Res. 33: 159-187.

Parsons, G.J., S.M.C. Robinson, R.A. Chandler, L.A. Davidson, M. Lanteigne, and M.J. Dadswell. 1992. Intra-annual and long-term patterns in the reproductive cycle of giant scallops *Placpecten magellanicus* (Bivalvia: Pectinidae) from Passamaquoddy Bay, New Brunswick, Canada. Mar. Ecol. Prog. Ser. 80: 203-214.

Parsons, G.J., C.R. Warren-Perry, and M.J. Dadswell. 1992. Movements of juvenile scallops *Placopecten magellanicus* (Gemlin, 1791) in Passamaquoddy Bay, New Brunswick. J. Shellf. Res. 11: 295-298.

Payne,A.I.L., K.H. Brink, K.H. Mann, and R. Hillborn [ed.] 1992. Benguela trophic functioning. Proceedings of a symposium. S. Afr. J. Mar. Sci. 12: 1-884.

Peer, D., N. Prouse, and G. Seibert. 1992. Concerns addressed in the ocean dumping permit process, p. 84-86. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

Pena, M. Angelica, W.G. Harrison and M.R. Lewis. 1992. New production in the central Equatorial Pacific. Mar. Ecol. Prog. Ser., 80: 265-274.

Perry, I.A., G.C. Harding, J.W. Loder, M.J. Tremblay, M. Sinclair, and K.F. Drinkwater. 1992. Zooplankton distributions at the Georges Bank frontal system: retention or dispersion? Cont. Shelf Res. 13(4): 357-383.

Peterson, R.H. and A. Sreedharan. 1992. Water content of Atlantic salmon fry at first feeding in southern New Brunswick hatcheries. Prog. Fish. Cult. 54: 181-183.

Peterson, R.H. and L. Van Eeckhaute. 1992. Distributions of Ephemeroptera, Plecoptera, and Trichoptera of three maritime catchments differing in pH. Freshwater Biology 27: 65-78.

Pezzack, D.S. 1992. A review of lobster *(Homarus americanus)* landing trends in the northwest Atlantic. J. Northw. Atl. Fish. Sci., Vol. 14: 115-127.

Pezzack, D.S. 1992. Overview Scotia Fundy, and LFA 34. 1992 CAFSAC Lobster Summary Sheets.

Pezzack, D.S. 1992. Book Review: Lobsters: Florida, Bahamas, the Caribbean. Lobster Newsletter 5(1).

Pezzack, D.S. and D. R. Duggan. 1992. LFA 41. 1991 Lobster Summary Sheet.

Pezzack, D.S. and D. R. Duggan. 1992. LFA 41. 1992 CAFSAC Lobster Summary Sheet.

Pezzack, D. S., M.J. Tremblay, C. Hudon, and R. J. Miller. 1992. The inshore-offshore lobster issue in southwestern Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 2165: 23 p.

Phillips, G.A., and B.T. Hargrave. 1992. Intercalibration of organochlorine residues in biota. Can. Data Rep. Fish. Aquat. Sci. 879: iv + 65 p.

Platt, T., S. Sathyendranath, O. Ulloa, W.G. Harrison, N. Hoepffner, and J. Goes. 1992. Nutrient control of phytoplankton photosynthesis in the western North Atlantic. Nature 356: 229-231.

Platt, T., P Jauhari, and S. Sathyendranath. 1992. The importance and measurement of new production, p.273-284. *In* P.G. Falkowski and A.D. Woodhead [ed.] Primary Productivity and Biogeochemical Cycles in the Sea. Plenum Press.

Pohle, G. 1992. First Canadian record of *Paralomis bouvieri* Hansen, 1908 (Decapoda: Anomura: Lithodidae), infected by the rhizocephalan *Briarosaccus callosus* (Cirrepedia: Peltogastridae) and carrying a hyperparasitic cryptoniscinid isopod (Epicardea). Can. J. Zool. 70: 1625-1629.

Pohle, G., T.J. Kenchington, and R.G. Halliday. 1992. Potentially exploitable deepwater resources off Atlantic Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1843: v + 79 p.

Porter, J.M. 1992. Swordfish research and assessment, p. 87-90. *In* J. Cook [ed.] Science Review 1990 & 91. Dep. Fish. and Oceans, Dartmouth, N.S.

Porter, J.M., and W.E. Hogans. 1992. A mark-recapture experiment on bluefin tuna *(Thunnus thynnus*, Linn.) from the Browns-Georges Banks region of the Canadian Atlantic. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap. (Madrid) 39: 689-691.

Renaud, C.B., and C.M. Morrison. 1992. Histological evidence from nuptial tubercles for the respective monophyly of the genera *Gadus* and *Boreogadus* (Gadidae). Copeia. 4: 1088-1094.

Ritter, J.A., and R.E. Cutting. 1992. Science and Salmon Management in the 1990s p.96-99. *In* J. Cook [ed.] Science Review 1990 & '91. Dep. Fish. and Oceans, Dartmouth, N.S.

Ritter, J.A., and T.L. Marshall. 1992. Management of the Atlantic salmon *(Salmo salar)* resource of Saint John River, New Brunswick, p. 205-218. *In* R.H. Stroud [ed.] Fisheries management: Dealing with development in the watershed. Amer. Fish. Symposium 13.

Robert, G., and M.A.E. Butler. 1992. Scallop fishing grounds on the Scotian Shelf - 1991. CAFSAC Res. Doc. 92/34: 27 p.

Robinson, S.M.C. 1992. Periwinkle fishery is growing. Atlantic Fish Farming 5(7): 8.

Robinson, S.M.C. [ed.] 1992. The Canadian Connection in the National Shellfish Association Newsletter.

Robinson, S.M.C. 1992. Enhancement of natural spat settlement in the soft-shell clam, *Mya arenaria.* J. Shellfish Res. 11: 206 (Abstract)

Robinson, S.M.C., and R.A. Chandler. 1992. An effective and safe method for sorting small molluscs from sediment. Limno. & Ocean. 38(5): 1088-1091.

Robinson, S.M.C., J.D. Martin, and R.A. Chandler. 1992. Grand Manan and Cape Spencer scallop stock update: 1990-1991. CAFSAC Res. Doc. 92/79: 23 p.

Robinson, S.M.C., J.D. Martin, and R.A. Chandler. 1992. Assessment of a large mortality of scallops in the Bay of Fundy. CAFSAC Res. Doc. 92/80: 13 p.

Robinson, S.M.C., J.D. Martin, R.A. Chandler, G.J. Parsons, and C.Y. Couturier. 1992. Larval settlement patterns of the giant scallop *(Placopecten magellanicus)* in Passamaquoddy Bay, New Brunswick. CAFSAC Res. Doc. 92/115: 26 p.

Roddick, D.L. 1992. Banquereau Bank Arctic surfclam *Mactromeris polynyma,* 1992. CAFSAC Invertebrate Committee Summary Sheet, November 1992.

Roddick, D.L., and D. Lemon. 1992. Exploratory Survey for Small Arctic Surfclams on the Eastern Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 215: 33 p.

Roddick, D.L., and R.J. Miller. 1992. The spatial and temporal overlap of the American lobster and giant scallop as related to the impact of inshore scallop dragging. Can. J. Fish. Aquat. Sci. 7: 1486-1492.

Ross, P.S., I.K.G. Visser, M.W.G. van de Bildt, W.D. Bowen, and A.D.M.E. Osterhaus. 1992. Phocine distemper virus enzootic in Canadian seals: Implications for the European outbreak of 1988. The Veterinary Record 130: 514-516.

Rowell, T.W. 1992. Destruction of a clam population *(Mya arenaria* Linné) through the synergistic effects of habitat change and predation by a nemertean *(Cerebratulus lacteus* Verril). Proc. 25th Europ. Mar. Biol. Symp.: 263-269.

Salmon Genetics Research Program. 1992. Newsletter on Salmon Genetics Research Program, January 1992.

Salmon Genetics Research Program. 1992. Newsletter on Salmon Genetics Research Program, August 1992.

Salmon Genetics Research Program. 1992. Salmon Genetics Research Program Annual Report 1991/92. Atlantic Salmon Federation, St. Andrews.

Sameoto, D. D. and A. Herman. 1992. Effects of the outflow from the Gulf of St. Lawrence on Nova Scotia shelf zooplankton. Can. J. Fish. Aquat. Sci. 49: 857-869.

Saunders, R.L. 1992. Enhancing smelt production. World Aquacult. 23(3): 37-39.

Saunders, R.L., A.P. Farrell, and D.E. Knox. 1992. Progression of coronary arterial lesions in Atlantic salmon *(Salmo salar)* as a function of growth rate. Can. J. Fish. Aquat. Sci. 49: 878-884.

Saunders, R.L. and F.M. O'Flynn. 1992. Physiological indications of smolt development in fibreglass and concrete tanks. Ann. Rep. Salmon Genetics Res. Prog. 1991/1992: 18-19.

Schneider, F.I., and K.H. Mann. 1991. Rapid recovery of fauna following simulated ice rafting in a Nova Scotia seagrass bed. Mar. Ecol. Prog. Ser. 78: 57-70.

Siferd, T.D. and R.J. Conover. 1992. An opening-closing plankton net for horizontal sampling through polar sea-ice. Sarsia 76: 273-277.

Siferd, T.D. and R.J. Conover. 1992. Natural history of ctenophores in the Resolute Passage area of the Canadian high arctic with special reference to Mertensia ovum. Mar. Ecol. Prog. Ser. 86: 133-144.

Sigurgisladottir, S.M., S.P. Lall, C.C. Parrrish, and R.G. Ackman. 1992. Cholestane as a digestibility marker in the absorption of polyunsaturated fatty acid ethyl esters in Atlantic salmon. Lipids. 27: 418-424.

Silverstone, M. 1992. Chamcook salmon saga. Salar 11(4): 8-9.

Silvert, W.L. 1992. BSIM Cookbook Supplement for Unit and VAX-VMS Systems. BSIM-Central. DFO Internal Rep.: 7 p. (Manual)

Silvert, W.L. 1992. BSIM Cookbook Supplement for MS-DOS. BSIM-Central. DFO Internal Rep.: 8 p. (Manual)

Silvert, W.L. 1992. Introduction to BSIM. BSIM-Central. DFO Internal Rep.: 5 p. (Manual)

Silvert, W.L. 1992. Many risks, many models: Addressing the variety of problems that pollution can cause. ICES 1992 Mini-Symposium on Ecosystem Modelling as a Tool to Predict Pollution Associated Risks for the Marine Environment. Proceedings of the International Council for the Exploration of the Sea Statutory Meeting. ICES C.M. 1992/Mini: 4: 4 p.

Silvert, W.L. 1992. Assessing environmental impacts of finfish aquaculture in marine waters. Aquacult. 107: 67-71.

Silvert, W.L., and D.V. Subba Rao. 1992. Dynamic model of the flux of domoic acid, a neurotoxin, through the *Mytilus edulis* population of Cardigan Bay, P.E.I. Can. J. Fish. Aquat. Sci. 49(2): 400-405.

Sinclair, M., S. Wilson, and D.V Subba Rao. 1992. Overview of the biological oceanography of the Gulf of Maine, p. 91 - 111. In J. Wiggins and C.N.K. Mooers [ed.] Proceedings of the Gulf of Maine Scientific Workshop, Woods Hole, Massachusetts, 8-10 Jan. 1991. Gulf of Maine Council on the Marine Environment. Urban Harbors Institute, University of Massachusetts, Boston.

Smith, S.J., and G. Robert. 1992. Scallops, sampling and the law. American Statistical Association, 1991. Proceedings of the Section on Statistics and the Environment: 102-

109.
Smith, T.E., and S.R. Kerr. 1992. Introductions of species transported in ships' ballast waters: The risk to Canada's marine resources. Can. Tech. Rep. Fish. Aquat. Sci. 1867: vi + 16p.
Smith, W.O., Jr. and W.G. Harrison. 1992. New production in polar regions: the role of environmental controls. Deep-Sea Res., 38: 1463-1479.
Stefansson, S.O., A.E. Berg, T. Hansen, and R.L. Saunders. 1992. The potential for development of salinity tolerance in underyearling Atlantic salmon (Salmo salar). World Aquacult. 23(2): 52-55.
Stephenson, R.L. 1992. An overview of herring assessments in the northeast and northwest Atlantic. ICES C.M. 1992/H: 26: 7 p.
Stephenson, R.L., M.J. Power, J.B. Sochasky, W.H. Dougherty, F.J. Fife, G.D. Melvin, and D.E. Lane. 1992. 1991 4WX herring assessment. CAFSAC Res. Doc. 92/69: 51 p.
Stevenson, D.K. and S.E. Campana [ed.] 1992. Otolith microstructure examination and analysis. Can. Spec. Publ. Fish. Aquat. Sci. 117: 130 p.
Stewart, J.E. 1992. Invertebrates, p. 53-56. *In* J. Wong [ed.]. Proceedings of the Canadian Council on Animal Care Workshop on Animal Care Committees: Role and Responsibilities. Can. Counc. Anim. Care, Ottawa.
Stewart, J.E., and R.H. Cook. 1992. Final progress report of the Study Group on the Potential for Culture of Species. ICES C.M. 1992/F3 (Maricult. Comm.): 24 + Append.
Stobo, W.T., G.M. Fowler, and A.F. Sinclair. 1992. Short-term tagging mortality of laboratory held juvenile Atlantic herring *(Clupea h. harengus).* J. Northw. Atl. Fish. Sci. 12: 27-33.
Storey, A.E., R.E. Anderson, J.M. Porter, and A. McCharles. 1992. Absence of parent-young recognition in kittiwakes: a re-examination. Behaviour 120: 302-323.
Strong, M.B. 1992. Variability of trawl performance on Scotia-Fundy groundfish surveys. CAFSAC Res. Doc. 92158: 24 p.
Subba Rao, D.V, F. Partensky, G.D. Wohlgeschaffen, and W.K.W. Li. 1992. Gametogenesis in *Nitzschia pungens* f. *multiseries.* J. Phycol. 28: 574-576.
Subba Rao, D.V., and Y. Pan. 1992. Physiological ecology of *Dinophysis norvegica,* a redwater bloom species, in Bedford Basin, Nova Scotia, p. 43. *In* J.-C. Therriault and M. Levasseur [ed.] Proceedings of the Third Canadian Workshop on Harmful Marine Algae. Maurice Lamontagne Institute, Mont-Joli, Quebec, May 12-14, 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)
Subba Rao, D.V., J. Sita Devi, and J.S.S. Lakshminarayana. 1992. Harmful marine phytoplankton of Canadian Atlantic waters, p. 43. *In* J.-C. Therriault and M. Levasseur [ed.] Proceedings of the Third Canadian Workshop on Harmful Marine Algae. Maurice Lamontagne Institute, Mont-Joli, Quebec, May 12-14, 1992. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)
Sulak, K.J. 1992. Guide to adult flatishes (poissons plats) of the Canadian Atlantic. Atlantic Reference Centre Species ID Leaflet No. 91-01 F: 22 p.
Suthers, I.M., A. Fraser, and K.T. Frank. 1992. Comparison of lipid, otolith and morphometric condition indices of pelagic juvenile cod *(Gadus morhua)* from the Canadian Atlantic. Mar. Ecol. Prog. Ser. 84: 31-40.
Taylor, S. 1992. Halibut ho! Northern Aquacult. 8(1): 23-24, 32.
Thiebaux, M.L., P.R. Boudreau, and L.M. Dickie. 1991. An analytical model of acoustic fish reflection for estimation of maximum dorsal aspect target strength. Can. J. Fish. Aquat. Sci. 48: 1772-1782.
Thiebaux, M.L., and L.M. Dickie. 1992. Models of aquatic biomass size spectra and the common structure of their solutions. J. Theor. Biol. 159: 147-161.
Thouzeau, G. 1992. Biological interactions between sea scallops *(Placopecten magellanicus)* and other benthic megainvertebrates on Georges Bank, Northwest Atlantic. Marine Benthic Ecology Meeting, 1992, Newport, R.I., U.S.A. (Abstract)
Tremblay, M. J., M. Eagles, and R. W. Elner. 1992. Trial use of a claw gauge as an alternate measure of minimum legal size in the snow crab fishery of eastern Cape Breton (Area 23). CAFSAC Res. Doc. 92/24. 11 p.
Tremblay, M.J., R.S. Rodger, and D.S. Pezzack. 1992. Evaluating trends in catch rate from voluntary fishing logs in the Nova Scotia lobster fishery. CAFSAC Res. Doc. 92/121: 21 p.
Tremblay, M.J., and M. Sinclair. 1992. Planktonic sea scallop larvae *(Placopecten magellanicus)* in the Georges Bank region: broadscale distribution in relation to physical oceanography. Can. J. Fish. Aquat. Sci. 49: 1597-1615.
Trippel, E.A., and J.D. Neilson. 1992. Fertility and sperm quality of virgin and repeat-spawning Atlantic cod (Gadus *morhua)* and associated hatching success. Can. J. Fish. Aquat. Sci. 49: 2118-2127.
Tsukimura, B., S. Waddy, J.M. Vogel, and D.W. Borst. 1992. The regulation of vitelogenesis in the lobster, *Homarus americanus.* Amer. Zool. 32: 28A (Abs.)
Ugarte, R.A., J. Pringle, and R. Duggan. 1992. A field study of embryo development and ovigerous female *Homarus americanus* behaviour in relation to temperature. First European Crustacean Conference, Paris, August 1992. (Abstract)
Ulloa, O., S. Sathyendranath, T. Platt and R.A. Quifiones. 1992. Light scattering by marine heterotrophic bacteria. J. Geophys. Res. - Oceans 97(C6): 9619-9629.
Volterra, L., and S.R. Kerr. 1992. Summary of discussions of Workshop 2: Impact of Marine Eutrophication on Humans and Economic Activities. Sci. Total Environ. (Suppl.): xix-xx.
Waddy, S.L. [ed.] 1992. Bull. Aquacult. Assoc. Can. 92-1: 72 p.
Waddy, S.L. [ed.] 1992. Bull. Aquacult. Assoc. Can. 92-2: 24 p.
Waddy, S.L. [ed.] 1992. Bull. Aquacult. Assoc. Can. 92-3: 88 p.
Waddy, S.L. [ed.] 1992. Bull. Aquacult. Assoc. Can. 92-4: 36 p.
Waddy, S.L., and D.E. Aiken. 1992. Seasonal variation in spawning response of preovigerous lobster

(Homarus americanus) to manipulation of photoperiod and temperature. Can. J. Fish. Aquat. Sci. 49: 1114-1117.
Waddy, S.L., and D.E. Aiken. 1992. Environmental intervention in the reproductive process of the American lobster, *Homarus americanus.* Invert. Reprod. Develop. 22: 245-252.
Waiwood, K.G. 1992. Continuing studies on Atlantic halibut. The Water Column (Winter 1992)
Waiwood, B.A., K. Haya, and L. Van Eeckhaute. 1992. Energy metabolism of hatchery-reared juvenile salmon *(Salmo salar)* exposed to low pH. Comp. Biochem. Physiol. 101C: 49-56.
Waldron, D.E. 1992. Diet of silver hake *(Merluccius bilinearis)* on the Scotian Shelf. J. Northw. Atl. Fish. Sci., Vol. 14: 87-101.
Waldron, D.E., M.A. Showell, and M.C. Bourbonnais. 1992. Status of the Scotian Shelf silver hake (whiting) population in 1991 with projections to 1993. NAFO SCR Doc. 92/50.
Watson-Wright, W.M., M.M. Maher, G.G. Sims, and J.F. Lawrence. 1992. Cooking-induced changes in toxicity and profile of paralytic shellfish poisons in lobster hepatopancreas, p.99. VIII Int. IUPAC Symp. on Mycotoxins and Phycotoxins, Mexico City, November 1992. (Abstract)
Watson-Wright, W.M., G. Sims, C. Smyth, M. Gillis, M. Maher, D.E. Sinclair, and M. Gilgan. 1992. Identification of tetramine as toxin causing food poisoning in Atlantic Canada following ingestion of whelks *(Neptuna decemcostata).* Proc. 10th World Congress on Animal, Plant and Microbial Toxins 2: 634-641.
Watson-Wright, W.M., C. Smyth, G. Sims, J. Marr; J. Lawrence, D. Sinclair, and M. Gilgan. 1992. Recent food safety incidents involving marine biotoxins in Atlantic Canada, p. 69-79. *In* K. Mise and J.L. Richard [ed.] Proc. 7th UJNR Int. Symp. on Emerging Food Safety Problems Resulting from Microbial Contamination, Tokyo, Japan.
Watt, W.D. and W.J. White. 1992. Creating a de-acidified Atlantic salmon refuge in the East River, Nova Scotia. Atlantic Region LRTAP Monitoring and Effects Report for 1991, p. 108-147. Environment Canada, Dartmouth, NS.
Welch, H.E., M.A. Bergmann, T.D. Siferd, K.A. Martin, M.F. Curtis, R.E. Crawford, R.J. Conover and H. Hop. 1992. Energy flow through the marine ecosystem of the Lancaster Sound region. Arctic 45(4): 343-357.
Werner, F.E., F.H. Page, D.R. Lynch, J.W. Loder, R.G. Lough, R.I. Perry, D.A. Greenberg, and M.M. Sinclair. 1992. Influences of mean advection and simple behaviour on the distribution of cod *(Gadus morhua)* and haddock *(Melanogrammus aeglefinus)* on Georges Bank, p. 319. EOS 73(43).(Abstract)
Wildish, D.J. 1992. The effect of flow on the suspension feeding of molluscs, p. 108-110. *In* J. Cook [ed.] Science Review 1990 & ‘91. Dep. Fish. and Oceans, Dartmouth, N.S.
Wildish, D.J., D.D. Kristmanson, and A.M. Saulnier. 1992. Interactive effect of velocity and seston concentration on giant scallop feeding inhibition. J. Exp. Mar. Biol. Ecol. 155: 161-168.
Wildish, D.J., J.L. Martin, and M. Ringuette. 1992. Methods to assess potentially harmful microalgae in the Bay of Fundy salmonid culture industry, p.23. *In* J.-C. Therriault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract)
Wildish, D.J., and A.M. Saulnier. 1992. The effect of velocity and flow direction on the growth of juvenile and adult giant scallops. J. Exp. Mar. Biol. Ecol. 155: 133-143.
Wildish, D.J., A.J. Wilson, and B. Frost. 1992. Benthic boundary layer macrofauna of Browns Bank, northwest Atlantic as potential prey of juvenile benthic fish. Can. J. Fish. Aquat. Sci. 49: 91-98.
Williamson, A. 1992. Historical lobster landings for Atlantic Canada, 1892-1989. Can. MS Rep. Fish. Aquat. Sci. 2164: 110 p.
Wohlgeschaffen, G.D., K.H. Mann, D.V. Subba Rao, and R. Pocklington. 1992. Dynamics of the phycotoxin domoic acid: Accumulation and excretion in two commercially important bivalves. J. Appl. Phycol. 4: 297-310.
Wohlgeschaffen, G.D., D.V. Subba Rao, and K.H. Mann. 1992. Vat incubator with immersion core illumination - a new inexpensive set-up for mass phytoplankton culture. J. Appl. Phycol. 4: 25-29.
Wormuth, J.H., R.K. O’Dor, N. Balch, M.C. Dunning, E.C. Forch, R.F. Harman, and T.W. Rowell. 1992. Ommastrephidae, p. 105-119. *In* M.J. Sweeney,C.F.E. Roper, K.M. Mangold, M.R. Clarke, and S.V. Boletzky [ed.] Larval and Juvenile Chephalopods: A Manual for Their Identification. Smithson. Contrib. Zool.
Zitko, V. 1992. Assessment of the significance of chemicals in sediments. J. Environ. Sci. Health A27: 273-281.
Zitko, V. 1992. Patterns of 2,3,7.8-substituted chlorinated dibenzodioxins and dibenzofurans in aquatic fauna. Sci. Total Environ. 111: 95- 108.
Zouros, E., K. R. Freeman, A. O. Ball, and G.R. Pogson. 1992. Direct evidence for extensive paternal mitochondrial DNA inheritance in the marine mussel *Mytilus.* Nature. 359(6394): 412-414.
Zwanenburg, K. 1992. An assessment of eastern Scotian Shelf haddock for 1992. CAFSAC Research Document 92/39.
Zwanenburg, K.C.T., P. Bentzen, and J.M. Wright. 1992. Mitochondrial DNA differentiation in western North Atlantic populations of haddock *(Melanogrammus aeglefinus).* Can. J. Fish. Aquat. Sci. 49: 2527-2537.

1993

Addison, R.F., and W.T. Stobo. 1993. Organochlorine residue concentrations and burdens in grey seal *(Halichoerus grypus)* blubber during the first year of life. J. Zool. 230: 443-450.
Aiken, D. E. [ed.] 1993. World Aquaculture 24(1): 80 p.
Aiken, D. E. [ed.] 1993. World Aquaculture 24(2): 112 p.
Aiken, D. E. 1993. Aquaculture in Atlantic Canada. Can. Bull. Fish.

Aquat. Sci. 226: 411-466.
Amiro, P.G. 1993. Habitat measurement and population estimation of juvenile Atlantic salmon (Salmo salar), p. 81-97. *In* R.J. Gibson and R.E. Cutting [ed.]. Production of juvenile Atlantic salmon, *Salmo salar*, in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118.
Amiro, P.G., R.E. Cutting, B.M. Jessop, T.L. Marshall, and S.E O'Neil. 1993. Status of Atlantic salmon stocks of Scotia-Fundy Region, 1992. DFO Atl. Fish. Res. Doc. 93/13: ix + 16 p.
Anderson, S. A., S. P. Lall, D. M. Anderson and M. A. McNiven. 1993. Evaluation of protein quality in fish meals by chemical and biological assays. Aquaculture, 115: 305-325.
Anderson, S. A., S. P. Lall, D. M. Anderson and M. A. McNiven. 1993. Lysine requirement for Atlantic salmon *(Salmo salar)* fingerlings. p. 867-872 *In* S. J. Kaushik and P. Luquet [ed.] Fish Nutrition in Practice. INRA, Paris.
Anderson, S. A., S. P. Lall, D. M. Anderson and M. A. McNiven. 1993. Quantitative lysine requirement of Atlantic salmon *(Salmo salar)*. Can J. Fish Aquat. Sci. 50: 316-322.
Ang, P., G.J. Sharp and R. Semple. 1993. Changes in the population structure of *Ascophyllum nodosum* Le Jolis due to mechanical harvesting. Hydrobiologica 260/261: 321-326.
Anon. 1993. Briefing on measures to minimize bycatches in the silver hake fishery. Presented to Harris Panel on Foreign Fishing, 13 August 1993. 21 p.
Anon. 1993. Briefing on biological aspects of silver hake fishery management. Presented to FRCC 6 August 1993. 18 p.
Anon. 1993. Salmon Genetics Research Program Annual Report 1992/93.
Anon. 1993. Salmon Genetics Research Program Newsletter. April **1993.**
Baily, J. K, G. Olivier and G. W. Friars. 1993. Inheritance of furunculosis resistance in Atlantic salmon, p. 6. Aquaculture Canada '93, Charlottetown, PEI, Aug 24-27. (Abstract)
Benz, G. W. and W. E. Hogans, 1993. Pennella filosa (L., 1758) (Copepoda: Siphonostomatoida) from the escolar *Lepidocybium flavobrunneum* (Smith, 1849) in the north-west Atlantic. Systematic Parasit. 26: 127- 131.
Black, G.A.P., R.K. Mohn, G. Robert, and M.J. Tremblay. 1993. Atlas of the biology and distribution of the sea scallop *Placopecten magellanicus* and Iceland scallop *Chlamys islandica* in the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1915: 40 p.
Black, G.AP., and R. Mohn. 1993. Interactive data visualization of fisheries management systems. ICES CM 1993/D: 6: 17 p.
Boness, D.J., W.D. Bowen, and J. Francis. 1993. Implications of DNA fingerprinting for understanding pinniped mating systems and reproductive strategies. Symp. Zool. Soc. Long. 66: 61-93.
Boudreau, P.R. 1993. Regional data and information system requirements for the Gulf of Maine, p.15-18. *In* E. Braasch [ed.] Gulf of Maine Data and Information Systems - Workshop Proceedings. Dartmouth College, Hanover, N.H.
Bowen, D., R. Brown, W. Kimmins, M. Mezei, J. Parsons, B. Pohojdak, and W. Sobo. 1993. Birth Control for seals. Symposium on contraception in wildlife management. Denver, Colorado. October, 1993. (Poster)
Brock, J., S. Sathyendranath, and T. Platt. 1993. Modeling the seasonality of subsurface light and primary production in the Arabian Sea. Mar. Ecol. Prog. Ser. 101: 209-221.
Brodie, P.F. 1993. A note on some aspects of the physiology and biomechanical research conducted on rorquals from Iceland. Int. Whaling Comm. Rep. Comm. 43: 501-504.
Brodie, P.F. 1993. Noise generated by the jaw actions of feeding fin whales. Can. J. Zool. 71.
Butler, M.A.E. and G. Robert. 1993. Update of the Scotian Shelf shrimp fishery - 1992. CAFSAC Res. Doc. 92/108, 20 p.
Campana, S.E., and J.M. Casselman. 1993. Stock identification using otolith shape analysis. Can. J. Fish. Aquat. Sci. 50: 1062-1083.
Campana, S.E., H.A. Oxenford, and J.N. Smith. 1993. Radiochemical determination of longevity in flyingfish *(Hirundichthys affinis)* using Th-228/Ra-228. Mar. Ecol. Prog. Ser. 100: 211-219.
Christie, W.J., S.R. Kerr, J. Eaton, C.J. Edwards, E.L. Mills, J.H. Leach, M.L. Jones, W.W. Taylor, C.P Schneider, J.F. Koonce, J. Elrod, R.A. Ryder, U. Borgmann, and O.E. Johannson. 1993. Lake Ontario: An ecosystem in transition. Report of the Lake Ontario Pelagic Community Health Indicator Committee, Ref. No. 1-635-160: 65 p.
Clark, D. S. 1993. The influence of depth and bottom type on area swept by groundtrawl, and consequences for survey indices and population estimates. DFO Atl. Fish. Res. Doc. 93/40 15 p.
Conover, R.J., and T.D. Siferd. 1993. Dark-season survival strategies of coastal-zone zooplankton in the Canadian arctic. Arctic 46(4): 303-311.
Cranford, P.J., B.T. Hargrave, B.A. MacDonald, and J.E. Ward. 1993. *In situ* feeding studies of adult sea scallops. Presentation at the 9th International Pectinid Workshop, Nanaimo, B.C. (Poster)
Cross, T., Bailey J., Friars, G. and O'Flynn, F. 1993. Maintenance of genetic variability in reared Atlantic salmon (Salmo salar) stocks, p.356-366. *In* Salmon in the Sea. Sponsored by the Atlantic Salmon Trust, Atlantic Salmon Federation, Dept. of Fisheries and Oceans.
Daly, J. G., A. K. Kew, A. R. Moore and G. Olivier. 1993. Responses of the salmonid immune system after vaccination with live, avirulent *Aeromonas salmonicida,* p.75. Aquaculture Canada '93, Charlottetown, PEI, Aug 24-27. (Abstract)
Duston, J. 1993. Effects of dietary betaine and sodium chloride on seawater adaptation in Atlantic salmon parr *(Salmo salar* L.). Comp. Biochem. Physiol. 105A: 673-677
Frank, K.T., J.E. Carscadden, and W.C. Leggett. 1993. Causes of spatio-temporal variation in the

patchiness of larval fish distribution: Differential mortality or behaviour? Fish. Oceanogr. 2: 3/4, 114-123.
Friars, G.W., 1993. Breeding Atlantic Salmon: A Primer. Atlantic Salmon Federation, St. Andrews, 33 p.
Gavaris, S. 1993. Assessment of the southwest Scotian Shelf and Bay of Fundy cod. DFO Atl. Fish. Res. Doc. 93/32: 25.
Gavaris, S. 1993. Analytical estimates of reliability for the projected yield from commercial fisheries, p. 185-191. *In* S. J. Smith, J. J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.
Gavaris, S., and L. Van Eeckhaute. 1993. Application of length at age distributions to derive age compositions of Georges Bank haddock from length frequencies. ICCAT SCRS/93/55.
Gavaris, S., and L. Van Eeckhaute. 1993. Assessment of the eastern Georges Bank haddock. DFO Atl. Fish. Res. Doc. 93/36: 33 p.
Gibson, R.J., and R.E. Cutting [ed.] 1993. Production of juvenile Atlantic salmon, *Salmo salar,* in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118: 262 p.
Gordon, D.C., Jr., P.J. Cranford, D.K. Muschenheim, J.W. Loder, PD. Keizer, and K. Krank. 1993. Predicting the environmental impacts of drilling wastes on Georges Bank scallop populations, p. 139-147. *In* PM. Ryan [ed.] Managing the Environmental Impact of Offshore Oil Production. Proceedings of the 32nd annual meeting of the Canadian Society of Environmental Biologists, St.John’s, Newfoundland, Canada, April 1-4, 1992.
Haist, V., and J. M. Porter. 1993. Evaluation of alternative methods to estimate age compositions from length frequency data with specific reference to Atlantic swordfish, *Xiphias gladius.* Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 40: 331-343.
Halliday, R.G. 1993. An analysis of scientific advice and TAC levels for the Scotian Shelf (Divisions 4VWX) silver hake stock. NAFO SCR Doc. 93/108, Ser. No. N2301: 8 p.
Halliday, R.G., and T. Kenchington. 1993. Size selection of groundfish longline gear. DFO Scotia-Fundy Region, Halifax, N.S., Project Summary No. 40, April, 1993, 4 p + insert.
Hanke, A. R. 1993. Commercial fishery based estimate of pollock abundance on the Scotian Shelf. DFO Atl. Fish. Res. Doc. 93/43: 6 p.
Hanke, A. R. 1993. Commercial fishery based estimate of cod abundance in NAFO Division 4X. DFO Atl. Fish. Res. Doc. 93/44: 7 p.
Hanke, A.R. 1993. Commercial fishery based estimate of cod and haddock abundance on Georges Bank. DFO Atl. Fish. Res. Doc. 93/45: 8 p.
Hanke, A.R., 1993. The effects of hatch time and family competition on the growth of grilse and a two-seawinter stock of Atlantic salmon parr *(Salmo salar* L.). Ph.D. Thesis, University of New Brunswick, Fredericton.
Harding, G.C. 1993. Larval lobster ecology and recruitment, p. 2-4. *In* Can. Atl. Fish. Sci. Adv. Comm. Invertebrates and Marine Plants Subcommittee Report 92/15. Addendum: The Year of the Lobster.
Harding, G., E. Kenchington, and Z. Zheng, 1993. Morphometrics of lobster larvae, *Homarus americanus* Milne Edwards, in relation to stock determinations in the Maritimes, Canada. Can. J. Fish. Aquat. Sci. 50(1): 43-52.
Hargrave, B.T. 1993. Seasonal variability in particle sedimentation. Cont. Shelf Res. 14(2/3): 279-293.
Hargrave, B.T., B. von Bodungen, P. Stoffyn-Egli, and P.J. Mudie. 1993. Seasonal variability in particle sedimentation under permanent ice cover in the Arctic Ocean. Cont. Shelf Res. 14: 279-293.
Hargrave, B.T., L.I. Doucette, and T.G. Milligan. 1993. Geochemical characteristics and benthic macrofauna biomass in intertidal and subtidal sediments of Annapolis Basin, Nova Scotia, 1993. Can. Data Rep. Fish. Aquat. Sci. 915: iv + 88 p.
Hargrave, B.T., D.E. Duplisea, E. Pfeiffer, and D.J. Wildish. 1993. Seasonal changes in benthic fluxes of dissolved oxygen and ammonium associated with marine cultured Atlantic salmon. Mar. Ecol. Prog. Ser. 96: 249-257.
Hargrave, B.T., D.C.G. Muir, and T.F. Bidleman. 1993. Toxaphene in amphipods and zooplankton from the Arctic Ocean. Chemosphere 27: 1949-1963.
Harrison, W.G. 1993. Nutrient recycling in production experiments, p.149-158. *In* W.K.W. Li and S.Y. Maestrini [ed.] Measurement of Primary Production from the Molecular to the Global Scale. ICES Marine Science Symposium 197.
Harrison, W.G., E.J.H. Head, E.P.W. Home, B. Irwin, W.K.W. Li, A.R. Longhurst, M.A. Paranjape, and T. Platt. 1993. The western North Atlantic Bloom Experiment. Deep-Sea Res. II 40: 279-305.
Head, E.J.H., and E.P.W. Home. 1993. Pigment transformation and vertical flux in an area of convergence in the North Atlantic. Deep-Sea Research IT 40: 329-346.
Heras, H., J. Kean-Howie, and R.G. Ackman, 1993 Use of lipid microspheres as nutritional supplements in aquaculture, p.48. Aquaculture Canada ‘93, Charlottetown, PEI, Aug 24-27. (Abstract)
Herman, A.W., N.A. Cochrane, and D.D. Sameoto. 1993. Detection and abundance estimation of euphausiids using an optical plankton counter. Mar. Ecol. Prog. Ser. 94: 165- 173.
Hoey, J. J., J. Mejuto, J. Porter, and Y. Uozumi. 1993. A standardized biomass index of abundance for North Atlantic swordfish. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid 40: 344-352.
Hogans, W.E., M.J. Dadswell, L.S. Uhazy, and R.G. Appy, 1993. Parasites of American shad, *Alosa sapidissima* (Osteichyes: Clupeidae), from rivers of the North American Atlantic coast and the Bay of Fundy, Canada. Can. J. Zool. 71: 941-946.
Hunt, J. J., and M.-I. Buzeta. 1993. Biological update Georges Bank cod in unit areas 5Zj,m for 1978-92. DFO Atl. Fish. Res. Doc. 93/39: 20 p.
Iverson, S.J., W.D. Bowen, D.J.

Boness, and O.T. Oftedal. 1993. The interrelationship of maternal size and milk energy output, and its effect on pup growth in grey seals. Physiol. Zool. 66: 61-88.

Johnson, C.R., and K.H. Mann. 1993. Rapid succession in subtidal understory seaweeds during recovery from overgrazing by sea urchins in eastern Canada. Bot. Mar. 36: 63-77.

Kang, S. J, S. P. Lall, and R. G. Ackman. 1993. Utilization of dogfish liver oil by Atlantic Salmon *(Salmo salar)*, p.49. Aquaculture Canada '93, Charlottetown, August 24-27, 1993. (Abstract)

Keizer, P.D., D.C. Gordon, Jr., T.W. Rowell, R. McCurdy, D. Borgal, T.A. Clair, D. Taylor, J.G.Ogden, III, and G.E.M. Hall. 1993. Synoptic water quality survey of Halifax/Dartmouth Metro Area lakes on April 16, 1991. Can. Data Rep. Fish. Aquat. Sci. 9 14: vii + 76 p.

Kenchington, E. 1993. The use of RNA/DNA in Monitoring Scallops Stock Health. Digby Scallop Days, Digby, N.S. (Poster)

Kenchington, E., and Lundy, M. J. 1993. Towards a minimum meat weight regulation for the inshore sea scallop *(Placopecten magellanicus)* fishery. DFO Atl. Fish. Res. Doc. 93/16, 5p.

Kenchington, E. and M.J. Lundy. 1993. Fishing Logbooks: The Value of Logbooks in Scallop Management. Digby Scallop Days, Digby, N.S., Science and Technology Awareness Week, Halifax, N.S. (Poster)

Kenchington, E. and M.J. Lundy. 1993. Scallop Abundance in the Bay of Fundy. Digby Scallop Days, Digby, N.S., Science and Technology Awareness Week, Halifax, N.S.(Poster)

Kenchington, E., M.J. Lundy, and V. Hazelton, 1993. Seasonal changes in somatic and reproductive tissue weights in wild populations of *Placopecten magellanicus* from the Bay of Fundy, Canada, 9th International Pectinid Workshop, Nanaimo, B.C. (Abstract)

Kenchington, E., K.S. Naidu, D.L. Roddick, D. Cook, and E. Zouros, 1993. The Use of biochemical genetic markers to discriminate between adductor muscles of the sea scallop *(Placopecten magellanicus)* and the iceland scallop *(Chlamys islandica).* Can. J. Fish. Aquat. Sci. 50: 1222-1228.

Kenchington, E. and D.L. Roddick, 1993. Molecular evolution within the phylum Mollusca with emphasis on the class Bivalvia, 9th International Pectinid Workshop, Nanaimo, B.C. (Abstract)

Kenchington, T. and E.L.R. Kenchington, 1993. An eighteenth-century commercial length-frequency sample of Atlantic cod, *Gadus morhua,* based on archaeological data. Fish. Res. 18: 335-347.

Kepkay, P.E. 1993. Surface coagulation of DOC and bacterial respiration - The biology of carbon dioxide flux across the air-sea interface. Abstracts of the American Society for Limnology and Oceanography: S33-1 (invited paper).

Kepkay, P.E., S.E.H. Niven, and T.G. Milligan. 1993. Low molecular weight and colloidal DOC production during a phytoplankton bloom. Mar. Ecol. Prog. Ser. 100: 233-244.

Lall, S. P., J. S. Anderson, D. M. Anderson and R.A. Keith. 1993. Digestibility and availability of amino acids from fishery by-products for Atlantic salmon, p.38. Fifth Int'1 Fish Nutrition and Feeding Symp. Hobart, Tasmania, October 4-7, 1993. (Abstract)

Lall, S. P. and G. Olivier. 1993. Role of micronutrients in immune response and disease resistance in fish. p. 101-118. *In* S. J. Kaushik and P. Luquet [ed.] Fish Nutrition in Practice. INRA, Paris.

Lall, S. P., and G. Olivier. 1993. Effects of vitamins, iron and commercial immunostimulants on immune response and disease resistance in Atlantic salmon, p.6. Fifth Int'1 Fish Nutrition and Feeding Symp. Hobart, Tasmania, October 4-7, 1993. (Abstract)

Lall, S. P. and G. Olivier 1993. The effect of ascorbic acid on the immune response and disease resistance of Atlantic salmon *(Salmo salar)* smolts reared in sea water. Progress report presented to Hoffmann-La Roche.

Lall, S. P. 1993. Fish Digestibility Measurements in Feedstuffs for Atlantic Salmon, p.92. Aquaculture Canada '93, Charlottetown, August 24-27, 1993. (Abstract)

Lane, D. E., and R. L. Stephenson. 1993. A decision making framework for providing catch advice in fisheries. Presented at Third Canadian Conference on Environmental and Natural Resources Economics, Univ. of Ottawa, Oct. 1-3, 1993. PRISM Working Paper 93-62 (Univ. of Ottawa, Faculty of Admin.).

Lawton, P. 1993. Salmon Aquaculture and the Traditional Invertebrate Fisheries of the Fundy Isles Region: Habitat Mapping and Impact Definition. Report to the New Brunswick Department of Fisheries and Aquaculture. 84 p.

Lawton, P, and D. A. Robichaud. 1993. Progress Report on the 1992 LFA 36 Lobster Tagging Study. Manuscript prepared for LFA 35, 36, and 38 Advisory Committees, February, 1993. 10 p.

Lawton, P., and D. A. Robichaud. 1993. Second Progress Report on the 1992 LFA 36 Lobster Tagging Study. Manuscript prepared for LFA 35, 36, and 38 Advisory Committees, August, 1993. 7 p.

Li, W.K.W. 1993. Estimation of primary production by flow cytometry, p.79-91. In W.K.W. Li and S.Y. Meastrini [ed.] Measurement of Primary Production from the Molecular to the Global Scale, ICES Marine Science Symposium 197.

Li, W.K.W., B.D. Irwin, and PM. Dickie. 1993. Dark fixation of ^{14}C: Variations related to biomass and productivity of phytoplankton and bacteria. Limno. Ocean. 38: 483-494.

Li, W.K.W., PM. Dickie, W.G. Harrison, and B.D. Irwin. 1993. Biomass and production of bacteria and phytoplankton during the spring bloom in the western North Atlantic Ocean. Deep-Sea Res. II 40: 307-327.

Li, W.K.W., and S.Y. Maestrini [ed.] 1993. Measurement of Primary Production from the Molecular to the Global Scale. ICES Marine Science Symposium 197: 1-287.

Li, W.K.W., T. Zohary, Y.Z. Yacobi,

and A.M. Wood. 1993. Ultraphytoplankton in the eastern Mediterranean Sea: towards deriving phytoplankton biomass from flow cytometric measurements of abundance, fluorescence and light scatter. Mar. Ecol. Prog. Ser. 102: 79-87.

Loder, J.W., K.F. Drinkwater, N.S. Oakey, and E.P.W. Home. 1993. Circulation, hydrographic structure and mixing at tidal fronts: the view from Georges Bank. Phil. Trans. Roy. Soc.(London) A 343: 447-460.

Longhurst, A.R. 1993. Seasonal cooling and blooming in the tropical ocean. Deep-Sea Res. 40(12): 1- 16.

Lundy, M.J. and E. Kenchington, 1993. The Scallop Life Cycle. Digby Scallop Days, Digby, N.S., Science and Technology Awareness Week, Halifax, N.S. (Poster)

Macdonald, J. S., and B. D. Chang. 1993. Seasonal use by fish of nearshore areas in an urbanized coastal inlet in southwestern British Columbia. Northw. Sci. 67: 63-77.

Mangor-Jensen, A., K. G. Waiwood, and R. H. Peterson. 1993. Water balance in eggs of striped bass *(Morone saxatilis).* J. Fish Biol. 43: **345-353.**

Mann, K.H. 1993. Physical oceanography, food chains and fish stocks: A review. Int. Count. Explor. Sea, J. Mar. Sci. 50: 105-109.

Marmorek, D. R., I. Parnell, J. Korman, and D. Meisner. 1993. Atlantic salmon regional acidification model. Results of hydrochemical work in FY92-93. Contract Report, ESSA Environmental and Social Systems Analysis Ltd., Vancouver.

Marshall, T.L. 1993. New estimates of commercial harvest and by-catch of Saint John River Atlantic salmon, 1981-1983. DFO Atl. Fish. Res. Doc. 93/46, 10 p.

Marshall, T.L., J.A. Ritter and D.G. Reddin. 1993. Forecasting multi-sea-winter salmon returns to the Saint John River, N.B., Canada. ICES C.M. 1993/M: 29, Ref C+H, 10 p.

Martin, J. L. 1993. In the Bay of Fundy, eastern Canada, p.7. In T. Wyatt and A. Cembella [ed.] Harmful algal news, No.6. International Oceanographic Commission of UNESCO, Paris.

Martin, J. L., K. Haya, and D. J. Wildish. 1993. Distribution and domoic acid content of *Nitzschia pseudodelicatissima* in the Bay of Fundy, p.613-618. *In* T. J. Smayda and Y. Shimizu [ed.] Toxic phytoplankton blooms in the sea. Elsevier, Amsterdam.

McClelland, G. 1993. *Eimeria phocae* (Apicomplexa: Eimeriidae) in harbour seals *Phoca vitulina* from Sable Island, Canada. Dis. Aquat. Org. 17: 1-8.

McCurdy, P. 1993. Fish population survey, Fifteen Mile Brook, Nova Scotia. Contract Report, Statcom Consultants Ltd.

McGladdery, S.E., B.C. Bradford, and D.J. Scarratt, 1993. Investigations into the transmission of parasites of the bay scallop, *Argopecten irradians* (Lamarck, 1819), during quarantine introduction to Canadian waters. J. Shellf. Res. 12(1): 49-58.

Messieh, S.N. 1993. Disposal of fish wastes in Atlantic Canada, p. 29-33. *In* Marine Pollution from Land-Based Sources. United Nations Environment Program. Industry and Environment, January-June 1992, 15(1-2).

Miller, R.J. 1993. More about habitat for juvenile *Homarus americanus.* Lobster Newsletter 6: 8-9.

Miller, R.J. 1993. Spatial correlations of American lobster in three life history stages. 4th International Workshop on Lobster Biology and Management, Samriku, Japan. (Abstract)

Miller, R.J. and R.W. Elner. 1993. A good time licensing strategy for limited entry fisheries. N. Am. J. Fish. Man. 13(2): 387-390.

Miller, R.J. and R.K. Mohn. 1993. Critique of the Leslie method for estimating sizes of crab and lobster populations. N. Am. J. Fish. Man. 13(4): 800-810.

Mohn, R. 1993. A comparison of three methods to convert catch at length data into catch at age. ICCAT SCRS/93/56.

Mohn, R.K. 1993. Bootstrap estimates of ADAPT parameters, their projection in risk analysis and their retrospective patterns, p. 173-184. *In* S.J. Smith, J.J. Hunt, and D. Rivard [ed.] Risk Evaluation and Biological Reference Points for Fisheries Management. Can. Spec. Publ. Fish. Aquat. Sci. 120.

Mohn, R., and R. Cook. 1993. Introduction to Sequential Population Analysis. NAFO Sci. Count. Studies. No. 17: 110 p..

Mohn, R., and W.J. MacEachern. 1993. Assessment of 4VsW cod in 1992. DFO Atl. Fish. Res Doc. 93/22: 40 p.

Moore, A. R., J. G. Daly, and G. Olivier. 1993. The S-layer on virulent strains of *Aeromonas salmonicida* protects bacteria against the bactericidal activity of salmonid peritoneal macrophages, p.59. Aquaculture Canada '93, Charlottetown, PEI, Aug 24-27, 1993. (Abstract)

Morrison, C. M. 1993. The digestive tract of the cod eleutheroembryo ("Yolk-sac larva") and larva. NAFO Sci. Coun. Studies. 18: 23-24.

Morrison, C. M. 1993. Histology (Gmelin): a summary atlas. Amer. Malac. Bull. 10: 1-24.

Morrison, C. M. 1993. Histology and cell ultrastructure of the mantle and mantle lobes of the Eastern oyster, *Crassostrea virginica* (Gmelin): a summary atlas. Amer. Malac. Bull. 10: 1-24.

Morrison, C. M. 1993. The reproductive stages of cod *(Gadus morhua):* gross anatomy and histology. NAFO Sci. Coun. Studies. 18: 11.

Morrison, C. M. 1993. The histology and ultrastructure of the adductor muscle of the eastern oyster *Crassostrea virginica* (Gmelin). Amer. Malac. Bull. 10: 25-38.

Morrison, C. M. 1993. Histology of the Atlantic cod, *Gadus morhua:* an atlas. Part Four. Eleutheroembryo and larva. Can. Spec. Pub. Fish. Aquat. Sci. No. 119: 504p.

Morrison, C. M. 1993. Histology of the mantle and mantle lobes of the eastern oyster, *Crassostrea virginica* (Gmelin). Aquaculture Canada '93, Charlottetown. PEI. Aug. 24-27, 1993. (Abstract)

Morrison, C. M., J.C. Harshbarger, and S. E. McGladdery. 1993. Schwannomas in rainbow smelt. J.

Aq. An. Health. 5: 317-323.
Morrison, C. M., J.P. Leger, and C. A. Morrison. 1993. Light microscopic and ultrastructural study of sporulation of *Goussia gadi* (Apicomplexa: Coccidia) in the swimbladder wall of haddock *Melanogrammus aeglefinus.* Dis. Aquat. Org. 17: 181-189.
Morrison, C. M., J.P. Leger, and C. A. Morrison. 1993. Gametogenesis of *Goussia gadi* (Apicomplexa: Coccidia) in the swim bladder wall of haddock *Melanogrammus aeglefinus.* Dis. Aquat. Org. 17: 127-135.
Morrison, C. M., J.P Leger, and C. A. Morrison. 1993. Light and electron microscopic study of the pathology and merogony of *Goussia gadi* (Apicomplexa: Coccidia) in the swim bladder wall of haddock *Melanogrammus aeglefinus.* Dis. Aquat. Org. 17: 113-125.
Morrison, C. M. and CA. MacDonald. 1993. The use of light and electron microscopy in studying the protozoan parasites of cod and other gadoids. Aquaculture Canada '93, Charlottetown. PEI, Aug. 24-27, 1993. (Abstract)
Morrison, C. M., and C.A. Morrison. 1993. Life-cycle and ultrastructure of *Goussia gadi* (apicomplexa: coccidia) in the swimbladder wall of the haddock. Aquaculture Canada '93, Charlottetown, PEI, Aug. 24-27, 1993. (Abstract)
Morrison, C. M., A.R. Moore, V.M. Marryatt, and D. J. Scarratt. 1993. Disseminated sarcomas of soft-shell clams, *Mya arenaria* Linnaeus 1758, from sites in Nova Scotia and New Brunswick. J. Shellf. Res. 12: 65-69.
Morrison, C. M., and C.A. Morrison. 1993. A study of the pathology and life-cycle of *Goussia gadi* apicomplexa, coccidia, in the swimbladder wall of the haddock. Proceedings of the 32nd Annual Meeting of the Canadian Society of Zoologists.
Muelbert, M.M.C., and W.D. Bowen. 1993. Duration of lactation and postweaning changes in mass and body composition of harbour seal pups. Can. J. Zool. 71: 1405-1414.
O'Flynn, F. M., J. K. Bailey, G. W. Friars, and R. L. Saunders. 1993. Biotechnology strain (85XC). Ann. Rep. Salmon Gen. Res. Prog. 1992/93: 10-11.
Oftedal, O.T., W.D. Bowen, and D.J. Boness. 1993. Energy transfer by lactating hooded seals, and nutrient deposition in their pups, during the four days from birth to weaning. Physiol. Zool. 66: 366-390.
Ojolick, E.J., R. Cusack, T.J. Benfey, and S.R. Kerr. 1993. Survival and growth of triploid rainbow trout *(Oncorhyncus mykiss)* at chronic high temperatures. Cooperation Agreement on Fisheries Development. Contract Rep.: 44 p.
Olivier, G., A. R. Moore, and J. G. Daly. 1993. The A-layer on virulent strains of *Aeromonas salmonicida* protects bacteria against the bactericidal activity of salmonid peritoneal macrophages, p.51. Sixth International Conference of the European Association of Fish Pathologists, Brest, France Sept. 5-10. (Abstract)
O'Neil, S. 1993. The Atlantic salmon sport fishery. N.S. Conservation, Vol 17(2) p.10-11.
O'Neil, S.E, and C.J. Harvie. 1993. Evaluation of the precision of catch data in the Nova Scotia Atlantic salmon catch-effort card system and feasibility of a New Brunswick application. DFO Atl. Fish. Res. Doc. 93/31, 34 p.
Page, F. H. 1993. Overview of Environmental Trends in the Scotia-Fundy Region Working/Discussion Document, Workshop on Scotia-Fundy Groundfish Management, BIO, Dec 7- 8, 1993.
Page, F., and S. Robinson. 1993. 1992 Salmon farming in the Bay of Fundy: a chilling reminder. World Aquacult. 23(4): 31-34
Pan, Y., D.V. Subba Rao, K.H. Mann, W.K.W. Li, and R.E. Warnock. 1993. Temperature dependence of growth and carbon assimilation in *Nitzschia pungens* f. *multiseries* Hasle, the causative diatom of domoic acid poisoning, p. 619-624. *In* T.J. Smayda and Y. Shimizu [ed.] Toxic Phytoplankton Blooms in the Sea. Elsevier Science Publishers, Amsterdam.
Parsons, J.L., R.G. Brown, W.C. Kimmins, M. Mezei, B. Pohajdak, D. Bowen, and W. Stobo. 1993. Immunocontraception of seals. Tenth biennial conference on the Biology of Marine Mammals. Galveston, Texas. November, 1993. (Poster)
Parsons, G. J., S. M. C. Robinson, J. C. Roff, and M. J. Dadswell. 1993. Daily growth rates as indicated by valve ridges in postlarval giant scallops *Placopecten magellanicus* (Bivalvia: Pectinidae). Can. J. Fish. Aquat. Sci. 50(3): 456-464.
Partensky, F., N. Hoepffner, W.K.W. Li, O. Ulloa, and D. Vaulot. 1993. Photoacclimation of *Prochlorococcus* sp. (Prochlorophyta) strains isolated from the north Atlantic and the Mediterranean Sea. Plant Physiology 101: 285-296.
Perry, R.I., G.C. Harding, J.W. Loder. M.J. Tremblay, M.M. Sinclair, and K.F. Drinkwater. 1993. Zooplankton distributions at the Georges Bank frontal system: Retention or dispersion? Cont. Shelf Res. 13(4): 357-383.
Peterson, R. H., and R. G. Camey. 1993. First feeding of salmon fry. Ann. Rep. Salmon Gen. Res. Prog. 1992/93, p. 12.
Peterson, R. H., and D. J. Martin-Robichaud. 1993. Rates of ionic diffusion across the egg chorion of Atlantic salmon *(Salmo salar).* Physiol. Zool. 66: 289-306.
Peterson, R. H., and P. McCurdy. 1993. Distribution of fish in 3 coastal watersheds of New Brunswick and Nova Scotia, Canada, p. 257. *In* R. J. Gibson and R. E. Cutting [ed.] Production of juvenile Atlantic salmon, *Salmo salar,* in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118. (Abstract).
Pezzack, D. S. 1993. Overview Scotia Fundy, LFA 41 and LFA 34. 1992 Lobster Summary Sheets.
Pezzack, D. S. 1993. (ed.) Scotia-Fundy Lobster Summary Sheets. 18 p.
Platt, T., and S. Sathyendranath. 1993. Commentary on "The remote sensing of ocean primary productivity: Use of a new data compilation to test satellite algorithms" by William Balch et al. J. Geophys. Res. 98(C9): 16583-16584.

Platt, T., and S. Sathyendranath. 1993. Estimators of primary production for interpretation of remotely sensed data on ocean color. J. Geophys. Res. 98(C8): 14561-14576.
Platt, T., and S. Sathyendranath. 1993. Fundamental issues in measurement of primary production, p.3-8. *In* W.K.W. Li and S.Y. Maestrini [ed.] Measurement of Primary Production from the Molecular to the Global Scale. ICES Marine Science Symposium 197.
Platt, T., S. Sathyendranath, I. Joint, and M.J.R. Fasham. 1993. Photosynthesis characteristics of the phytoplankton in the Celtic Sea during late spring. Fish. Ocean. 2: 191-201.
Porter, J. M. 1993. National Report of Canada, 1991-92. Int. Comm. Conserv. Atl. Tunas, Rep. for Biennial Period 1992-93, Part 1: 341-349.
Porter, J. M., M. J. W. Stokesbury, C. A. Dickson, and W. E. Hogans. 1993. A mark-recapture experiment on bluefin tuna *(Thunnus thynnus* L.) from the Browns-Georges banks region of the Canadian Atlantic: 1992 update. Int. Comm. Conserv. Atl. Tunas Coll. Vol. Sci. Pap., Madrid (SCRS/92/29).
Pringle, J.D. and D.L. Burke. 1993. The Canadian lobster fishery and its management, with emphasis on the Scotia Shelf and the Gulf of Maine, p. 91-122. *In* L.S. Parsons and W.H. Lear [ed.] Perspectives on Canadian marine fisheries management. Can. Bull. Fish. Aquat. Sci. 226.
Pringle, J., R. Ugarte, R. Duggan, and I? Koeller, 1993. Review of request for an extension to the lobster fishing season in LFA 31A. DFO At. Fish. Res. Doc. 93/67: 20p.
Ragan, M.A., C.J. Bird, E.L. Rice, and R.K. Singh, 1993. The nuclear 18S ribosomal RNA gene of the red alga *Hildenbrandia rubra* contains a group I intron. Nucleic Acids Research 21: 3898.
Rice, E. L., D. L. Roddick, and R. K. Singh, 1993. A comparison of molluscan (Bivalvia) phylogenies based upon palaeontological and molecular data. Molec. Mar. Bio. Biotech. 2: 137- 146.
Ritter, J.A. 1993. Changes in Atlantic salmon *(Salmo salar)* harvests and stock status in the North Atlantic, p. 3-25. *In* D. Mills [ed.] Salmon in the sea and new enhancement strategies. Fishing News Books, Cornwall, U.K.
Robert, G., G.A.P. Black, and M.A.E. Butler. 1993. Georges Bank scallop stock assessment - 1992. DFO Atl. Fish. Res. Doc. 93/15: 33 p.
Robert, G. and M.A.E. Butler. 1993. Scallop fishing grounds on the Scotian Shelf - 1992. DFO Atl. Fish. Res. Doc. 93/18: 32 p.
Robinson, S. M. C. 1993. A review of the biological information associated with enhancing scallop production. World Aquacult. 24(2): 61-67.
Robinson, S.M.C. 1993. The soft-shell clam fishery in the Canadian Maritimes: an industry in change, p. 145. J. Shellf. Res. 12(1). (Abstract)
Ross, P.S., B. Pohajdak, W.D. Bowen, and R.F. Addison. 1993. Immune function in free-ranging harbour seal mothers and their pups during lactation. J. Wildl. Diseases 29: 21-29.
Rowell, T.W., and G.B. Fader. 1993. Summary of a proposal to assess the offshore aggregate resources of the Scotian Shelf. Report presented to the ICES Benthos Ecology Working Group (Kiel, Germany, May 3-8, 1993) 3 p.
Sameoto, D.D., N. Cochrane, and A. Herman. 1993. Convergence of acoustic, optical and net-catch estimations of euphausiid abundance: use of artificial light to reduce net avoidance. Can. J. Fish. Aquat. Sci. 50: 334-346.
Sathyendranath, S., and T. Platt. 1993. Remote sensing of water-column primary production, p. 236-243. *In* W.K. Li and M. Maestrini [ed.] Measurement of Primary Production from the Molecular to the Global Scale, ICES Marine Science Symposium 197.
Sathyendranath, S., and T. Platt. 1993. Underwater light field and primary production: Application to remote sensing, p.79-93. *In* V. Barale and P.M. Schlittenhardt [ed.] Ocean Colour: Theory and Applications in a Decade of CZCS Experience, Kluwer Academic Publ., Brussels.
Saunders, R. L., R. S. Ferguson, and F. M. O'Flynn. 1993. Feed deprivation during winter-spring to reduce maturity as grilse - an update. Ann. Rep. Salmon Gen. Res. Prog. 1992193: 14.
Sevigny, J. M., and R. L. Saunders. 1993. Canadian studies on gene technology, biochemical markers, production of transgenics and means of reducing genetic interaction between cultured and wild salmon. Working Paper incorporated in Report of the Working Group on Genetics 1993, ICES C.M. 1993/F:7: 11- 18.
Sharp, G. J., C. Tetu, R. Semple and D. Jones. 1993. Recent changes in the seaweed community of Western P.E.I: implications for the seaweed industry. Hydrobiologia 260/26 1: 291-296.
Showell, M.A. 1993. Biology of silver hake, p.5-8. In Summary of the Silver Hake Workshop, Halifax, Nova Scotia, 23-24 November 1993.
Showell, M.A. 1993. Temporal/spatial restrictions for reduction of bycatch, 26-27 p. *In* Summary of the Silver Hake Workshop, Halifax, Nova Scotia, 23-24 November 1993.
Showell, M.A. 1993. Changes in mesh size for the 4Vn winter (Jan-Apr) cod fishery - 1979 to 1993. CAFSAC WP 93/118.
Showell, M.A. 1993. Effect of mesh size/type on size distribution and catch rates for 1991 Scotian Shelf groundfish fisheries. NAFO SCR Doc. 93/120, Ser. No. N2314: 10 p.
Showell, M.A., R. Branton, M.C. Bourbonnais, and R.G. Halliday. 1993. Status of the Scotian shelf silver hake population in 1992 with projections to 1994. NAFO SCR Doc. 93/102, Ser. No. N2295: 36 p.
Silvert, W.L. 1993. Size-structured models of continental shelf food webs, p.40-43. In V. Christensen and D. Pauly [ed.] Trophic Models of Aquatic Ecosystems. ICLARM Conf. Proc. 26.
Silvert, W.L. 1993. The distributed derivative: An aid to modular modelling. Ecol. Modell. 68: 293-302.
Silvert, W.L. 1993. Object-oriented ecosystem modelling. Ecol. Modell. 68: 91-118.
Silvert, W.L. 1993. Top-down modelling in ecology, p. 605. *In* P.C.

Young [ed.] Concise Encyclopedia of Environmental Systems. Pergamon Press.
Sinclair, A., K. Zwanenburg, and P. Hurley. 1993. Can we estimate F from length frequency data? DFO Atlantic Fish. Res. Doc. 93/
Smith, S.J. 1993. Conference Reports: Workshop on Risk Evaluation and Biological Reference Points for Fisheries Management. Reviews in Fish Biology and Fisheries. 3: 366-367.
Smith, S.J. and S. Gavaris. 1993. Improving the precision of abundance estimates of eastern Scotian Shelf Atlantic cod from bottom trawl surveys. N. Am. J. Fish. Man. 13: 35-**47.**
Smith, S. J., and S. Gavaris. 1993. Evaluating the accuracy of projected catch estimates from sequential population analysis and trawl survey abundance estimates. p. 163- 172. In S. J. Smith, J. J. Hunt and D. Rivard [ed.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120.
Smith, S. J., J. J. Hunt, and D. Rivard [ed.] 1993. Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120: 442 p.
Steeves, G., G. Siddall, G. Awalt, and B.T. Hargrave. 1993. “SMARTRAP”, p.I- 138-I- 143. *In* IEEE Oceans ‘93 Proceedings.
Stephenson, R. L. 1993. Herring larvae and hydrography: studies and observations from the Bay of Fundy and Gulf of Maine. ICES C.M. 1993/H:31: 6 p.
Stephenson, R. L., and D. E. Lane. 1993. Avoiding the risk of ignoring risk: toward a framework for use of risk in decision making. ICES C.M. 1993/H:32: 9 p.
Stewart, J.E. 1993. Infectious diseases of marine crustaceans, p. 319-341. *In* J.A. Couch and J. Fournie [ed.] Pathobiology of Marine and Estuarine Organisms, Chapter 12. CRC Press, Boca Raton, Florida.
Stewart, J.E. 1993. Studies involving fish and aquatic invertebrates, p. 15 18. *In* J. Wong [ed.]. Proceedings of the Canadian Council on Animal Care Maritime Regional Workshop on Animal Care Committees. Can. Counc. Anim. Care, Ottawa: 40 p.
Stewart, J.E. 1993. Review of: Lee, D.O.‘C, and J.F. Wickins. 1992. Crustacean Farming, Blackwell Scientific Publ., London. Aquaculture 116: 370-372.
Subba Rao, D.V. 1993. Improving ocean science in developing countries. Mar. Sci. Technol. Soc. J. 27: 42-54.
Subba Rao, D.V, and Y. Pan. 1993. Photosynthetic characteristics of *Dinophsis norvegica* Claparde & Lachmann, a red-tide dinoflagellate. J. Plank. Res. 15: 965-976.
Subba Rao, D.V, Y. Pan, V. Zitko, G. Bugden, and K. Mackeigan. 1993. Diarrhetic shellfish poisoning (DSP) associated with a subsurface bloom of *Dinophysis norvegica* in Bedford Basin, eastern Canada. Mar. Ecol. Prog. Ser. 97: 117-126.
Taylor, S. 1993. Striped bass move into sea cages. Northern Aquaculture 9(l): 11-12.
Todd, E. C. D., T. Kuiper-Goodman, W. M. Watson-Wright, M. Gilgan, S. Stephen, J. Marr; S. Pleasance, M.A. Qu Luu, and C. F. B. Holmes. 1993. Recent illnesses from seafood toxins in Canada: paralytic, amnesic and diarrhetic shellfish poisoning. p.335-340. *In* T. J. Smayda and Y. Shimizu [ed.] Toxic phytoplankton blooms in the sea: proceedings fifth Int. Conference on Toxic Marine Phytoplankton, 28 October- 1 November 1991, Newport, Rhode Island. Elsevier, Amsterdam.
Tremblay, M. J., J. W. Loder, F. E. Werner, C. E. Naime, D. R. Lynch, F. H. Page, and M. M. Sinclair. 1993. Drift of sea scallop larvae on Georges Bank: A model study of the roles of mean advection, larval behavior and larval origin, p. 44. Larval Ecology Meetings, Aug. 20-23, 1993, Port Jefferson, N.Y. (Abstract)
Trippel, E. A. 1993. Relations of fecundity, maturation, and body size of lake trout, and implications for management in northwestern Ontario lakes. N. Am. J. Fish. Man. 13: 64-72.
Trippel, E.A., and F. W. H. Beamish. 1993. Multiple trophic level structuring in *Salvelinus-Coregonus* assemblages in boreal forest lakes. Can. J. Fish. Aquat. Sci. 50: 1442-1455.
Trippel, E. A., and L. Brown. 1993. Assessment of pollock *(Pollachius virens)* in Divisions 4VWX and Subdivision 5Zc for 1992. DFO Atl. Fish. Res. Doc. 93/60: 44 p.
Tsukimura, B., S. Waddy, C. W. Burow, and D. W. Borst. 1993. The characterization and regulation of lobster vitellogenin. Amer. Zool. 33: 122A (Abstract).
Van Guelpen, L. 1993. Substantial northward range extension for *Gephyroberyx darwini* (Berycoidei, Trachichtyidae) in the western North Atlantic, possibly explained by habitat preference. J. Fish Biol. 42: 807-810.
Waddy, S. L. 1993. Affiliation and association; The real story. World Aquacult. 24(2): 88-89.
Waddy, S. L. [ed.] 1993. Proceedings of the Arctic Charr Conference. Bull. Aquacult. Assoc. Can. 93-2: 40 p.
Waddy, S. L. [ed.] 1993. Arctic Char Culture. Bull. Aquacult. Assoc. Can. 93-1: 40 p.
Waldron, D.E., M.A. Showell, and M.C. Bourbonnais. 1993. Scotian Shelf silver hake (whiting) population size in 1992. NAFO WP 93/6.
Walker, B.G., and W.D. Bowen. 1993. Behavioural differences among adult male harbour seals during the breeding season may provide evidence of reproductive strategies. Can. J. Zool. 71: 1585-1591.
Walker, B.G., and W.D. Bowen. 1993. Mass changes and feeding behaviour in male harbour seals, *Phoca vitulina,* in relation to female reproductive status and male age. J. Zool. (Lond.) 231: 423-436.
Walsh, S. J., P. A. Koeller. and W.D. McKone. 1993. Proceedings of the international workshop on survey trawl measuration, Northwest Atlantic Fisheries Centre, St. John’s, Newfoundland, March 18-19. Can. Tech. Rep. Fish. Aquat. Sci. 1911: iv + 114 p.
Watson-Wright, W. M., M. Dorey, and J. Jellett. 1993. Working together... World Aquacult. 24(4): 51-53.
Werner, F. E., F. H. Page, D. R.

Lynch, J. W. Loder, R. G. Lough, R. I. Perry, D. A. Greenberg and M.M. Sinclair. 1993. Influences of mean advection and simple behaviour on the distribution of cod and haddock early life stages on Georges Bank. Fish. Oceanog. 2(2): 43-64.
Wildish, D. J. 1993. Book review: Marine biology, its accomplishment and future prospect [J. Mauchline and T. Nemoto, ed.]. World Aquacult. 24(1): 70.
Wildish, D.J., P.D. Keizer, A.J. Wilson, and J.L. Martin. 1993. Seasonal changes of dissolved oxygen and plant nutrients in seawater near salmonid pens in the macrotidal Bay of Fundy. Can. J. Fish. Aquat. Sci. 50: 303-311.
Wildish, D. J., and D. D. Kristmanson. 1993. Hydrodynamic control of bivalve filter feeders: a conceptual view. p.299-324. *In* R. F. Dome [ed.] Bivalve filter feeders in estuarine and coastal ecosystem processes. NATO ASI Series Vol. 633. Springer Verlag, Berlin.
Xueliang Xu, W. Ji, J. D. Castell and R. O'Dor. 1993. The Nutritional value of Dietary n-3 and n-6 Fatty Acids for Chinese Prawn *(Penaeus chinensis).* Aquacult. 118: 277-285.
Zohary, T., Y.Z. Yacobi, N. Kress, S. Brenner, D. Engel, A. Neori, and W.K.W. Li. 1993. Microbial populations in a warm-core eddy in the Eastern Mediterranean: effects of deep mixing. Israel Ocean. & Limno. Res. Rep., ES-22-93.

PHYSICAL & CHEMICAL SCIENCES BRANCH

1992

Addison, R.F. 1992. Biochemical Indices of Marine Pollution: A Review of Recent Field Studies. ICES C.M. **1992/E:** 15.
Addison, R.F., and W.T. Stobo. 1992. Organochlorine residue concentrations and burdens in grey seal *(Halichoerus grypus)* blubber during the first year of life. J. Zool. (London) 230: 443-450.
Anderson, L.G., and E.P Jones. 1992. Tracing Upper Waters of the Nansen Basin in the Arctic Ocean. Deep-Sea Res. 39, Suppl. 2: 5425-5433.
Anonymous. 1992. Proc. Ocean Model Workshop held at BIO, January 15-17, 1992. Can. Tech. Rep. Hydrogr. Oc. Sci. 140: xiv + 395 p.
Bewers, J.M., J.O. Blanton, A.M. Davies, PA. Gurbutt, E.E. Hofmann, B.M.Jamart (Dec.), D.C.L. Lam, M. Takahashi, and G.K. Verboom. 1992. A Conceptual Model of Contaminant Transport in Coastal Marine Systems. AMBIO 21(2): 166-169.
Bewers, J.M. 1992. Global Strategies for Marine Environmental Protection. Can There be a Common Framework for Managing Radioactive and Non-radioactive Substances to Protect the Marine Environment? Rep. Stud. GESAMP 45, (Add.1): 13 p.
Bidleman, R.F., W.E. Cotham, R.F. Addison, and M.E. Zinck. 1992. Organic Contaminants in the North-west Atlantic Atmosphere at Sable Island, Nova Scotia, 1988-89. Chemosphere 24: 1389-1412.
Bose, R., C.L. Schnell, C. Pinsky, and V. Zitko. 1992. Effects of Excitotoxins on Free Radical Indices in Mouse Brain. Toxicol. Lett. 60: 211-219.
Brickman, D. and J.W. Loder. 1992. The Energetics of the Internal Tide on Northern Georges Bank. J. Phys. Ocean. 23(3): 409-424.
Bugden, G., R. Forbes, D.C. Gordon, B. Huppertz, P.D. Keizer, M. Levasseur, J.L. Martin, R. Penny, J. Smith, D.V. Subba Rao, D.J. Wildish, and P. Yeats. 1992. Overview of Canadian Phytoplankton Monitoring Program, p. 15- 16. *In* J.-C. Therriault and M. Levasseur [ed.] Proc. Third. Can. Workshop on Harmful Marine Algae. Can. Tech. Rep. Fish. Aquat. Sci. 1893. (Abstract).
Cahill, M.L., and K. Drinkwater. 1992. Warm-core Eddies and Cross-Shelf Exchange, p.87. Proc. and Abstracts of AGU 1992 Ocean Sciences Meeting, Jan. 27-31, 1992. New Orleans, Louisiana: (Abstract)
Cahill, M.L., and K. Drinkwater. 1992. Warm-core Eddies and Cross-Shelf Exchange, p.67. Proc. 26th Annual CMOS Congress, Laval Univ., Quebec, June 8-12, 1992.(Abstract)
Cai, D.L., F.C. Tan, and J.M. Edmond. 1992. Sources and Transport of Organic Carbon in the Changjiang Estuary. Geochemica 3: 305-312. (In Chinese).
Carr, M.-E., N.S. Oakey, B. Jones. M.R. Lewis. 1992. Hydrographic Patterns and Vertical Mixing in the Equatorial Pacific Along 150°W. J. Geophys. Res. 97: 611-626.
Clarke, R. A. 1992. Global Warming, Ocean Cooling. Nature 360: 17.
Dalrymple, R.W., E.M. LeGresley, G.B. Holocene, J. Fader, and B.D. Petrie. 1992. The Western Grand Banks of Newfoundland. Marine Geology, Waves and Currents 105: 95-118.
DeCosmo, J., K.B. Katsaros, S.D. Smith, R.J. Anderson, W. Oost. K. Bumke and A.L.M. Grant. 1992. Air-Sea Water Vapor and Sensible Heat Fluxes in High Winds - Observations and Model Predictions. EOS: 73(43) (Abstract).
Dobson, F.W., M. Khandekar, R. Lalbehany, and P.W. Vachon. 1992. The ERS- 1 Cal-Val Experiment: and Overview. Proc. 26th Annual CMOS Congress, Lava1 Univ., Quebec, June 8-12, 1992. (Abstract)
Dobson, F. 1992. *Hudson 91-055:* Cruise Report. 1992. BIO Internal Note, DFO, Dartmouth, N.S. April 1992: 75.
Dobson, F.W., M. Khandekar, R. Lalbehany, and P.W. Vachon. 1992. The ERS-1 Cal-Val Experiment. CMOS Newsletter 20, April 1992: 11-13.
Drinkwater, K.F., M.J. Graça, and J.W. Loder. 1992. Lagrangian Current Measurements from the Georges Bank Frontal Study, 1988-89, Part I: Drift Buoy Trajectories. Can. Data Rep. Hydrogr. Ocean Sci. No. 116: iv + 105 p.
Drinkwater, K., B. Petrie, and S. Narayanan. 1992. Overview of Environmental Conditions in the Northwest Atlantic in 1992. NAFO SCR Doc. 92/73: 36 p.
Drinkwater, K.F., PC. Smith, and R. Pettipas. 1992. Spatial and Temporal Scales of Temperature Variability in the Bay of Fundy. NAFO SCR Doc. 92/71: 17 p.
Drinkwater, K.F. 1992. Overview of Environmental Conditions on Eastern

Canadian Continental Shelves. CAFSAC Working Paper 921102: 24 p.

Drinkwater, K.F. 1992. AFAP Climate Studies in the Scotia-Fundy Region. NAFO SCR Doc. 92/72: 8 p.

Drinkwater, K.F. 1992. AFAP Climate Studies in the Scotia-Fundy Region. CAFSAC Working Paper 92/ 102: 10p.

Drinkwater, K.F., B. Petrie, and S. Narayanan. 1992. Environmental Conditions in the Newfoundland Region in 1991. NAFO Working Paper 92/18. Presented at the Special Meeting of the NAFO Scientific Council, June 1-2, 1992: 12 p.

Ellis, K.M., R.W.P. Nelson, and J.N. Smith. 1992. Environmental monitoring report for the Point Lepreau, N.B. Nuclear Generating Station - 1989, 1990. Can. Tech. Rep. Hydrogr. Ocean. Sci. 142: iv + 57 p.

Frank, K.T., J.W. Loder, J.E. Carscadden, W.C. Leggett, and C.T. Taggart. 1992. Larval Flatfish Distributions and Drift on the Southern Grand Bank. Can. J. Fish. Aquat. Sci. 49(3): 467-483.

Gershey, R.M., E.P Jones, and D.W.R. Wallace. 1992. Halocarbon distributions in the North Atlantic Ocean and Labrador Sea determined by purge and trap capillary GC, Proc. 1992 Ocean. Sci. Meeting. EOS 72: 62. (Abstract)

Greenberg, D.A., J.W. Loder, Y. Shen, D.R. Lynch, and F.E. Werner. 1992. A Finite Element Model for the Study of Georges Bank Circulation, p.84. Proc. 26th Annual CMOS Congress, Lava1 Univ., Quebec, June 8- 12, 1992.(Abstract).

Greenberg, D.A. and D.R. Lynch. 1992. Gulf of Maine Circulation Modelling, p. 127-143. *In* Wiggen, J. and C.N.K. Mooers [ed.] Proc. Gulf of Maine Scientific Workshop, Woods Hole, 8- 10 Jan. 1991. Gulf of Maine Council on the Marine Environment, Boston. Urban Harbors Institute, Univ. Mass.

Hargrave, B.T., P. Germain, J.-C. Philippot, G. Hemon, and J.N. Smith. 1992. Stable Elements and Po-210 in the Deep-Sea Amphipod Eurythenes gryllus. Deep-Sea Res. 39: 37-44.

Hendry, R.M. 1992. CSS *Hudson* 91-007/91-015 Cruise Report. Unpub. MS: 45 p.

Herman, A.W., N.A. Cochrane, and D.D. Sameoto. 1992. Detection and Abundance Estimation of Euphausiids Using an Optical Plankton Counter. Mar. Ecol. Prog. Ser. 94: 165-173.

Herman, A.W. 1992. Design and Calibration of a New Optical Plankton Counter Capable of Sizing Small Zooplankton. Deep-Sea Res. 39: 395-415.

Holladay, J.S., J. Lee, I. St. John, J. Rossiter, L. Lalumiere, and S.Prinsenberg. 1992. Real-time Airborne Electromagnetic Measurement of Sea Ice. Soc. Explor. Geophys., New Orleans, Nov. 1992: 5 p.

Ikeda, M. 1992. Numerical Simulation of Mesoscale Features in the North Atlantic Current Observed by Geosat Altimeter Data. Proc. 26th Annual CMOS Congress, Lava1 Univ. Quebec. June 8-12, 1992. (Abstract).

Ikeda, M. 1992. Recent Development of Coupled Sea Ice-ocean Modelling over the Continental Shelf. Trends in Oceanography 1: 153-162.

Ikeda, M. and C.L. Tang. 1992. Detection of the Labrador Current using Ice Floe Movement in Synthetic Aperture Radar Imagery and Ice Beacon Trajectories. Atmos.-Ocean 30: 223-245.

Ikeda, M. and Li Q. Zhang. 1992. Mesoscale Stability of an Ocean Current over the Continental Slope in the Bryan-Cox Primitive Equation Model. J. Mar. Res. 3: 519-527.

Jones, E.P 1992. Oden 91 Expedition to the Arctic Ocean. Cmos Newsletter/ Nouvelles SCM0 20(1): 7.

Jones, E.P, F. Zemylak, and P. Stewart. 1992. Operating Manual for the Bedford Institute of Oceanography Automated Dissolved Oxygen Titration System. Can. Tech. Rep. Hydrogr. Ocean Sci. 138: iv + 51 p.

Jones, E.P 1992. Chlorofluorocarbon Measurements in the Arctic Ocean: Ventilation and Circulation of Water Masses in the Eurasian Basin. EOS 73: 145. (Abstract)

Jones, E.P, and L.G. Anderson. 1992. Tracing Circulation in the Arctic Ocean with Chlorofluorocarbons. Annal. Geophys. 10 (Supplement): C197. (Abstract).

Jones, E.P 1992. Ocean Climate Questions and the CO_2 Problem: Transport of CO_2 from the Atmosphere to the Deep Ocean. Cmos Newsletter/Nouvelles SCM0 20(3): 6 p.

King, T.L., J.F. Uthe, and C.J. Musial. 1992. Polycyclic Aromatic Hydrocarbons in the Digestive Glands of the American Lobster, *Homarus americanus* captured in the proximity of a coal-coking plant. Bull. Envir. Contam. and Toxicol. 50: 907-914.

Kranck, K., and T.G. Milligan. 1992. Characteristics of suspended Particles at an 11 Hour Anchor Station in San Francisco Bay, California. J. of Geophys. Res. 97: 11-11, 382.

Kranck, K., E. Petticrew, T.G. Milligan, and I.G. Droppo. 1992. In Situ Particle Size Distributions Resulting from Flocculation of High Concentration Suspended Sediment, p.60-75. *In* Ashish J. Mehta [ed] Nearshore and Estuarine Cohesive Sediment Transport, Coastal and Estuarine Studies Series 42.

Lalumiere, L.A. 1992. Analysis of Snow Thickness Data Collected by Impulse Radar Over the Beaufort Sea Shelf in 1991, 1992. Can. Contr. Rep. Hydrogr. Oc. Sci. 43: viii + 73 p.

Lee, K. and E.M. Levy. 1992. Microbial Degradation of Petroleum in an Intertidal Beach Environment: *In situ* Sediment Enclosure Studies", p. 140-156. *In* C.S. Wong and P.J. Harrison [ed.] Marine Ecocystem Enclosed Experiments: Proceedings of a symposium held in Beijing, People's Repub. China, May 9 to 14, 1987, Int'1 Dev. Res. Ctr. (IDRC) Ottawa.

Levy, E.M. 1992. Persistent Marine Debris: Petroleum Residues and Plastics in the World's Oceans. The Science of Global Change, ACS Symposium Series 224-239.

Loder, J.W., R.I. Perry, K.F. Drinkwater, J. Grant, G.C. Harding. W.G. Harrison, E.P.W. Home, N.S. Oakey, C.T. Taggart, M.J. Tremblay, D. Brickman, and M.M. Sinclair. 1992. Physics and Biology of the Georges Bank Frontal System, p.57-

61. *In* J. Cook [ed.] Science Review 1990 & '91, Dept. Fish. Oceans, Dartmouth, N.S.

Loder, J.W., and C.K. Ross. 1992. Current and Hydrographic Variability on the Southeast Shoal of the Grand Bank. Proc. 26th Annual CMOS Congress, Lava1 Univ., Quebec, June 8-12, 1992. (Abstract).

Loder, J.W. (Chairman) and others. 1992. Circulation and Hydrography (Working Group Report), p. 159-168. *In* Report of the 1991 Gulf of Maine Scientific Workshop, Woods Hole, Mass.

Loder, J.W., D. Brickman, and E.P.W. Home. 1992. Detailed Structure of Currents and Hydrography on the Northern Side of Georges Bank. J. Geophys. Res. 97(C9): 14,331-14,351.

Loring, D., and R.T.T. Rantala. 1992. Manual for the Geochemical Analyses of Marine Sediments and Suspended Particulate Matter. Earth-Science Rev. 32: 235-283.

Lynch, D.R., F.E. Werner, D.A. Greenberg, and J.W. Loder. 1992. Diagnostic Model for Baroclinic Wind-Driven and Tidal Circulation in Shallow Seas. Cont. Shelf Res. 12(1): 37-64.

Mertz, G., and D.G. Wright. 1992. Interpretations of the JEBAR Term. J. Phys Ocean. 22: 301-305.

Misra, Raj K., J.F. Uthe, and C.J. Musial. 1992. Multivariate Analysis of a Round-Robin Study on the Measurement of Chloropiphenyls in Fish Oil. The Analyst 117: 1085-1091.

Misra, R.K., and J.F. Uthe. 1992. A Proposal for Judging Laboratory Performance in Trend Studies. Report of the Working Group on Statistical Aspects of Trend Monitoring. ICES C.M. 1992/Poll 1. Annex 5: 6 p.

Misra, R.K. 1992. A Multivariate Procedure for Linear Comparisons of Mean Vectors When Residual Covariance and Regression Coefficient Matrices are Unequal. Biometrical Journal 34(7): 771-779.

Myers, R.A., K. Drinkwater, and S. Brown. 1992. The Influence of Salinity on 2J3KL Cod Recruitment. NAFO SCR Doc. 92/74: 12 p.

Myers, R.A., K.F. Drinkwater, N. Barrowman, and J. Baird. 1992. The Influence of Salinity on Cod Recruitment in the Newfoundland Region. CAFSAC Res. Doc. 92198: 22 p.

Narayanan, S., S.J. Prinsenberg, and E. Colbourne. 1992. Overview of Environmental Conditions in 2J3KL NAFO Subareas in 1991: NAFO SCR. Doc 92/6: 27 p.

Needler, G. T. 1992. The World Ocean Circulation Experiment. Oceanus 35: 74-78.

Novelli, A., M.T. Femandez-Sanches, J. Kispert, A. Torreblanca, S. Gascon and V. Zitko. 1992. The Amnesic Shellfish Poison Domoic Acid Enhances Neurotoxicity by Excitatory Amino Acids in Cultured Neurons. Amino Acids 2: 233-244.

Novelli, A., J. Kispert, M.T. Fernandz-Sanches, A. Torreblanca and V. Zitko. 1992. Domoic Acid-containing Toxic Mussels Produce Neurotoxicity in Neuronal Cultures Through a Synergism Between Excitatory Amino Acids. Brain Res. 577: 41-48.

O'Boyle, R., T. Rowell, K. Drinkwater, and B. Petrie. 1992. Atlantic Fisheries Adjustment Program, p. 68-74. *In* J. Cook [ed.] Science Review 1990 & '91. Dept. Fish. Oceans, Dartmouth, N.S.

O'Neill, J.T., and J.L. Bodner (ed.) .1992. Oceans - An Oceanographic Analysis System; User Reference, ver. 1.52 (May 1, 1992).

Oakey, N.S. 1992. Tidal Mixing Studies on Georges Bank. AGU Spring Meeting, Paper 032E-2. (Abstract).

Oakey, N.S., and R.G. Pettipas. 1992. Vertical Mixing Rates on Georges Bank during June-July and October, 1988. Can. Data Rep. Hydrogr. Ocean Sci. 110: iv + 226 p.

Perrie, W., and L. Wang. 1992. Coupling Wind and Wave Models. In Proc. AES Marine Workshop Program. Oct. 26-30, 1992. Halifax, N.S.: 7 p.

Perrie, W., and D. Resio. 1992. Properties of evolving and fully developed wind-generated Waves, p. 115- 125. *In* Proc. Third Int. Waves Workshop, Montreal, May 20-22, 1992.

Perrie, W., and B. Toulany. 1992. Enhanced Wave Predictions from Assimilation of Wind Speeds and Wave heights from GEOSAT During LEWEX, p. 194-201 *In* Proc. Third Int. Waves Workshop, Montreal, May 20-22, 1992.

Perrie, W., and W. Liangming. 1992. The Impact of Coupling the Boundary Layer to Ocean Waves, p. l50- 158. *In* Proc. Third Int. Waves Workshop, Montreal, May 20-22, 1992.

Perrie, W., B. Toulany, and Z. Zhu. 1992. Wind Estimates from Observed Directional Wave Spectra. *In* Proc. Third Int. Waves Workshop. Montreal, May 20-22, 1992.

Petrie, B., K. Drinkwater, and R. Pettipas. 1992. Long-term Temperature and Salinity Variability on the Scotian Shelf and in the Gulf of Maine, p.91 - 117. *In* The Climate of Nova Scotia, Symposium, November 19, 1991, AES, Environment Canada.

Petrie, B. 1992. Ocean Climate Variability on the Newfoundland and Labrador Shelves. CAFSAC Working Paper 92/110: 14 p.

Petrie, B., and J. Elliott. 1992. Summary-Current Modelling Session p. 112- 113. *In* Proc. Ocean Model Workshop held at BIO, January 15-17, 1992. Can. Tech. Rep. Hydrogr. Ocean Sci. 140.

Petrie, B., K. Drinkwater, and R. Pettipas. 1992. Longterm Temperature and Salinity Variability on the Scotian Shelf and in the Gulf of Maine, p. 114. Proc. 26th Annual CMOS Congress Laval Univ., Quebec. June 8- 12, 1992. (Abstract).

Petrie, B., J.W. Loder, S. Akenhead, and J. Lazier. 1992. Temperature and Salinity Variability on the Eastern Newfoundland Shelf: The Residual Field. Atmos.-Ocean 30(1): 120-139.

Petrie, L. 1992. Oceanographic and Biological Data Relating to Short-Finned Squid *(Illex illecebrousus)* Southern Florida, January 1986. Can. Data Rep. Hydrogr. Ocean Sci. 111: vii + 47 p.

Pocklington, R. 1992. On the absence of evidence for a causal relationship between anthropogenic emissions of CO_2, increasing atmospheric CO_2 concentration, and global warming, p.78-90. *In* The Climate of Nova Scotia, AES, Environment

Canada, Ottawa.
Pocklington, R. 1992. On the Absence of Evidence for a Causal Connection between Anthropogenic Emissions of CO_2, Increasing Atmospheric CO_2 Concentration, and Global Warming. Delta 3: 6-7.
Prinsenberg, S.J., and I.K. Peterson. 1992. Newfoundland Shelf Sea Ice program, 1991. Can. Tech. Rep. Hydrogr. Ocean Sci. 141: vii+99 p.
Prinsenberg, S.J., J.S. Holladay, J.R. Rossiter, and L.A. Lalumiere. 1992. 1991 Beaufort Sea EM/Radar Ice and Snow Sounding Project. Can. Tech. Rep. Hydrogr. Ocean. Sci. 139: vi + 61 p.
Prinsenberg, S.J. 1992. Effect of the Snow Cover on Ice Growth Rates at Land-fast Ice Stations in the Canadian Arctic. IAHR 92, Proc. of 11th Int. Symp. on Ice, 2: 633-644.
Prinsenberg, S.J. 1992. Ice Cover Effects On the Ocean in the Marginal Ice Zone. In: The Effects of Sea Ice on the Atmosphere, Ocean and Structures in the Marginal Ice Zone, p. 1- 13. Inst. for Space and Terrestrial Science Rep. ISTS-EOL-PR92-005.
Prinsenberg, S.J., and I.K. Peterson. 1992. Sea-Ice Properties off Labrador and Newfoundland During LIMEX ‘89. Atmos-Ocean. 30(2): 207-222.
Prinsenberg, S. 1992. Research and Development in Sea Ice Modelling, p. 18-25. *In* Proc. Ocean Model Workshop., Can. Tech. Rep. Hydrogr. Ocean Sci. 140.
Prosi, F., D.H. Loring, and H. Back. 1992. Biochemical Pathways of Cadmium through an artificially contaminated Intertidal Mudflat system - A medium scale enclosure experiment. Oecologia 91: 396-403.
Quon, C. and M. Ghil. 1992. Multiple Equilibria in Thermosolutal Convection due to Salt-flux Boundary Conditions. J. Fluid Mech. 245: 449-483.
Rahman, M., M.G. Satish, W. Perrie, and J. Zhu. 1992. Drift Forces on a Pair of Vertical Cylinders. Int. J. Num. Meth. Fluids 15: 817-838.
Resio, D., W. Perrie, S. Thurston and J. Hubertz. 1992. A Generic Third-Generation Wave Model: AL, p. 102-114. In Proc. 3rd Int. Workshop on Wave Modelling, Montreal, May 20-22, 1992.
Rossiter, J.R., J.S. Holladay, and L.A. Lalumiere. 1992. Validation of airborne sea ice thickness measurement using Electromagnetic Induction during LIMEX ‘89 (UP-C8-028). Can. Contr. Rep. of Hydrogr. Ocean Sci. 41: x+86p.
Sandstrom, H., V. Tverberg, and N. Oakey. 1992. On Multi-layer and Continuous Flow over Topography - Hydrostatic Solution. AGU Fall Meeting, Paper A21E-11. (Abstract).
Sangalang, G., and J.F. Uthe. 1992. Development of a Biochemical General Stress Test for Juvenile Atlantic Salmon, p.168-170. *In* B.L. Beattie [ed.] Atlantic Region LRTAP Monitoring and Effects Workshop. AES, Environment Canada, Bedford, N.S. February 1992.
Smith, S.D. 1992. Air-Sea-Ice Exchange Processes, p.53-59. In W.A. Nierenberg [ed.] Encyclopedia of Earth Systems Science, Vol. 1, Academic Press, San Diego.
Smith, S.D. 1992. [ed.] 1992. HEXOS Newsletter 14, October 1992. Bedford Inst. of Oceanography: 29 p.
Smith, S.D., R.J.Anderson, W.A. Oost, C. Kraan, N. Maat, J. DeCosmo, K. B. Katsaros, K. L. Davidson, K. Bumke, L. Hasse, and H.M. Chadwick. 1992. Sea Surface Wind Stress and Drag Coefficients: The Hexos Results. Boundary-Layer Meteorology 60: 109-142.
Smith, S.D. 1992. Air-Sea-Ice Interaction and the Marginal Ice Zone, p.14-21. *In* M.M. Manore and D.G. Barber [ed.] Proc. 1991 CIWG Workshop on the Marginal Ice Zone. Rep. ISTS-EOL-TR92-005, Earth Observations Laboratory, Inst. for Space and Terrestrial Science and Dept. of Geography, Univ. of Waterloo.
Stocker, T.F., D.G. Wright and W.S. Broecker. 1992. The Influence of High-Latitude Surface Forcing on the Global Thermohaline Circulation. Paleoceanography 7: 529-541.
Stocker, T.F., D.G. Wright and W.S. Broecker. 1992. The Influence of High-Latitude Surface Forcing on the Global Thermnocline Circulation. *In* Ice in the Climate System: A NATO advanced research workshop. Aussois, France. (Abstract).
Stocker, T.F., D.G. Wright and L.A. Mysak. 1992. A Zonally Averaged Coupled Ocean-Atmosphere Model for Paleoclimate Studies. J. of Climate 5: 773-797.
Strain, PM. and F.C. Tan. 1992. Seasonal Evolution of Oxygen Isotope - Salinity Relationships in High Latitude Surface Waters. American Geophysical Union Annual Meeting, San Francisco, December 7-11, 1992. (Abstract).
Tan, F.C. and J.M. Edmond. 1992. Sources and Transport of Organic Carbon in the Orinoco Basin. 29th International Geological Congress, Kyoto, Japan, August 24 to September 3, 1992. (Abstract).
Tang, C.L. and M. Manore. 1992. Preface of LIMEX Special Issue. Atmos.-Ocean 2: 147-150.
Tang, C.L. 1992. Oceanographic Features in the Newfoundland Marginal Ice Zone. Atmos.-Ocean 30(2): 151-172.
Tang, C.L., and T. Yao. 1992. A Simulation of Sea-Ice Motion and Distribution off Newfoundland during LIMEX, March 1987. Atmos.-Ocean 30(2): 270-296.
Tang, C.L., A. Cavanie, M. El-Tahan, F. Gohin, and R.F. McKenna. 1992. Oceanic and Ice Processes in the Newfoundland Marginal Ice Zone. AGU Western Pacific Geophysics Meeting. August 17-21, 1992, Hong Kong. (Abstract)
Tang, C.L., and Q.Y. Gui. 1992. Atlas of Oceanographic and Ice Conditions in the Newfoundland Shelf and Northern Grand Bank, March-April 1990. Can. Data Rep. Hydrogr. Ocean Sci. 105: viii + 189 p.
Tee, K.T. 1992. Modelling of Low-frequency Salinity Variations in the St. Lawrence Estuary. Coastal and Estuarine Studies 40: 209-230.
Trites, R.W., and L. Petrie. 1992. Temperature and Salinity Measurements at the Salmonid Demonstration and Development Farm, L'Etang Inlet, N.B. during the Period 1986-1991. Can. Data Rept. Hydrogr. Ocean Sci. 115: iii + 24p.

Uthe, J. F. and R.K. Misra. 1992. Monitoring Chemical Contaminants in Fish: The Experience of the International Council for the Exploration of the Sea. 1. Problems in the Design and Execution of Monitoring Studies. 2. Problems in the Statistical Analysis of Data from the Monitoring Studies. Presented (by invitation) at the Workshop on Designing Field Studies Concerning Environmental Contaminants, held at the Institute of Ocean Sciences, Sidney, B.C., May 11 and May 13, 1992; 15 p. (Extended abstract).

Uthe, J.F. (Chair). 1992. Report of the Working Group on Statistical Aspects of Trend Monitoring. ICES C.M. 1992/poll. 1: 48 p.

Vachon, P.W., F.W. Dobson, S.D. Smith, R.J. Anderson, J.R. Buckley, M. Allingham, D. Vandemark, E.J. Walsh, M. Khandekar, R. Lalbeharry, and E. Gill. 1992. The Grand Banks ERS- 1 SAR Wave Spectra Validation Experiment. Proc. ERS-1 Symposium, Cannes, France, Nov. 1992. European Space Agency: 6 p.

Vachon, P., F. W. Dobson, and M. Khandekar 1992. High Sea State Validation of the ERS- 1 SAR. Proc. IGARSS 1992, Austin, TX, April 1992.

Waiwood, B.A., K. Haya, and L. Van Eeckhaute. 1992. Energy Metabolism of Hatchery-reared Juvenile Salmon *(Salmo salar)* Exposed to Low pH. Comp. Biochem. Physiol. 101C: 49-56.

Wells, P.G., and J.M. Bewers. 1992. Progress and Trends in Marine Environmental Protection: An Introduction and Tribute to Michael Waldichuk. 1992. Mar. Poll. Bull.: 2(1-4): 3-5.

Wells, PG. and J.M. Bewers [ed.] 1992. Progress and Trends in Marine Environmental Protection. Mar. Poll. Bull. 25: 119 p.

Wells, P.G. and J.M. Bewers. 1992. Challenges for Improved Marine Environmental Protection: Summary. 1992. Mar. Poll. Bull. 25: 1-4, 112-117.

Werner, F.E., F.H. Page, D.R. Lynch, J.W. Loder, R.G. Lough, R.I. Perry, D.A.Greenberg, and M.M. Sinclair. 1992. Influences of Mean Advection and Simple Behaviour on the Distribution of Cod *(Gadus morhua)* and Haddock *(Melanogrammus aeglefinus)* on Georges Bank, p.319. EOS 73(43). (Abstract).

Wohlgeschaffen, G. D., K. H. Mann, D.V. Subba Rao, and R. Pocklington. 1992. Dynamics of the Phycotoxin Domoic Acid: Accumulation and Execretion in Two Commercially Bivalves. J. Applied Phycology 4: 297-310.

Wright, D.G., and T.F. Stocker. 1992. Ice and the Younger Dryas. *In* Ice in the Climate System: A NATO advanced research workshop, Aussois, France. (Abstract).

Wright, D.G. and T.F. Stocker. 1992. Deep water mass properties in a 25D model of the global ocean, p. 140. *In* Proc. 26th Annual CMOS Congress, Laval Univ., Quebec, June 8-12, 1992. (Abstract).

Wright, D.G. and T.F. Stocker. 1992. Sensitivities of a Zonally Averaged Global Ocean Circulation Model. J. Geophys. Res. 97(C8): 12,707- 12,730.

Wright, D.G. 1992. Finite-Difference Approximations to the Advection-Diffusion Equation. Tellus 44A: 261-**269.**

Wright, D.G., and A.J. Willmott. 1992. On the Buoyancy-Driven Abyssal Circulation of the Southern Ocean. J. Phys. Oceanogr. 22: 139-154.

Yeats, PA., J.A. Dalziel, and S.B. Moran. 1992. A Comparison of Dissolved and Particulate Mn and Al Distributions in the Western North Atlantic. Oceanologica Acta 15: 609-**619.**

Yeats, PA. 1992. The Distribution of Dissolved Vanadium in Eastern Canadian Coastal Waters. Est., Coast. and Shelf Sci. 34: 85-93.

Yoshida, J., and N. Oakey. 1992. Mixing Studies at a Front on Georges Bank. *In* AGU Spring Meeting, Paper 032E-3 (Abstract).

Zitko, V. 1992. Patterns of 2,3,7,8-substituted Chlorinated Dibenzodioxins and Dibenzofurans in Aquatic Fauna. Sci. of Tot. Environ. 111: 95-108.

Zitko, V. 1992. Assessment of the Significance of Chemicals in Sediments. J. Env. Sci. Health A27: 273-281.

1993

Anderson, L.G., D. Dyrssen, and E.P. Jones. 1993. On Determining the Oceanic Uptake of Anthropogenic CO_2. Proc. 4th Int. CO_2 Conf., Carqueiranne, France, Sept. 13- 17, **1993.**

Anderson, R.J. 1993. A Study of Wind Stress and Heat Flux Over the Open Ocean by the Inertial-Dissipation Method. J. Phys. Oceanogr. 23(10), 2153-2161.

Anderson, R.J., S.D. Smith, and F.W. Dobson. 1993. Wind Stress Measurements during the ERS-1 CAL-VAL Experiment. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract)

Bewers, J.M., and J. Karau. 1993. Sediment Quality Guideline Development in Canada. ICES paper C.M. 1993/E.17.

Bonardelli, J.C., K. Drinkwater, and J.H. Himmelman. 1993. Current Variability and Upwelling Along the North Shore of Baie des Chaleurs. Atmos.-Ocean 31: 541-565.

Brickman, D., and J.W. Loder. 1993. The Energetics of the Internal Tide on Northern Georges Bank. J. Phys. Oceanogr. 23(3): 409-424.

But-ridge, L.E., and K. Haya. 1993. The Lethality of Ivermectin, a Potential Agent for Treatment of Salmonids Against Sea Lice, to the Shrimp Crangon Septemspinosa. Aquacult. 117: 9-14.

Chou, C.L., and B.A. MacLeod. 1993. Cadmium in American Lobster *(Homarus americanus)* from the area of Belledune Harbour, New Brunswick, Canada - 1992 results. Rep. to National Health & Welfare Canada, 9 p.

Chou, C.L., and J.F. Uthe. 1993. Cadmium in American Lobster *(Homarus americanus)* from the Area of Belledune Harbour, New Brunswick, Canada: 1980-1992 Results. Can. Tech. Rep. Fish. Aquat. Sci. 1916: vi + 25 p.

Chou, C.L., J.F. Uthe, and R.D. Guy. 1993. The Determination of Free and

Bound Metal Ions in Lobster *(Homarus americanus)* Digestive Gland Extracts by Gel Chromatography followed by Atomic Absorption Spectrophotometry and Polarography. J. Assoc. Official Analytical Chemists Intl. 76: 794-798.

Clarke, R. Allyn. 1993. The North Atlantic Current in the Northwest Atlantic, p.89-92. *In* P. Malonette-Rizolli and T. Rossby [ed.] The North Atlantic Current System: A Scientific Report. MIT Press, Cambridge, MA.

Clarke, R.A. 1993. The World Ocean Circulation Experiment (WOCE). Bull. WMO: 42(1): 28-33.

Dalziel, J.A., PA. Yeats, and D.H. Loring. 1993. Water Chemistry and Sediment Core Data from Pictou Harbour and the East River Estuary. Can. Tech. Rep. Fish. Aquat. Sci. 1917: iv + 78 p.

Dobson, F.W., S.D. Smith, R.J. Anderson, P.W. Vachon, D. Vandemark, J.R.Buckley, M. Allingham, M. Khandekar, R. Lalbehany, and E. Gill. 1993. The Grand Banks ERS-1 SAR Wave Equipment. EOS 74(4): 41 & 44-45.

Dobson, F.W., S.D. Smith, and P.W. Vachon. 1993. Recent Results from the Grand Banks ERS-1 SAR Experiment. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract)

Donelan, M.A., F.W. Dobson, S.D. Smith, and R.J. Anderson. 1993. On the Dependence of Sea Surface Roughness on Wave Development. Amer. Met. Soc. 23: 2143-2149.

Fernandez, M.T., V. Zitko, S. Gascon. A. Torreblanca, A. Novelli. 1993. Neurotoxic Effect of Okadaic Acid, a Seafood-related Toxin, on Cultured Cerebellar Neurons. Annals N.Y. Acad. Sci. 679: 260-269.

Gammelsrfld, T., L.G. Anderson, E. Fogelqvist, A. Foldvik, E.P. Jones, O.A. Nest, K. Olsson, O. Skagseth, T. Tanhua, and S. Osterhus. 1993. Distribution of water masses over the continental shelf in the southern Weddell Sea. Nansen Centennial Symposium, Solstrand, Norway, June 21-25.

Gershey, R.M. and E.P Jones. 1993. Distribution of inorganic carbon and halocarbons in the Labrador Sea. Third Scientific Meeting of the Oceanographic Society, Seattle, WA, April 13-16.

Gershey, R.M. and E.P Jones. 1993. Assessing recent ventilation of the Labrador Sea: Measurement of halocarbons and total dissolved inorganic carbon. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract)

Gordon, D.C., Jr., P.J. Cranford, D.K. Muschenheim, J.W. Loder, PD. Keizer, and K. Kranck. 1993. Predicting the Environmental Impacts of Drilling Wastes on Georges Bank Scallop Populations, p. 139- 147. *In* Proc. Can. Soc. Env. Biologists, Conf. on Managing Env. Impact of Offshore Oil Prod., St. John's, Nfld., April 1992.

Greenberg, D.A., T.S. Murly, and A. Ruffman. 1993. A Numerical Model for the Halifax Harbour Tsunami Due to the 1917 Explosion. Mar. Geod. 16(2): 153-167.

Greenberg, D.A., T.S. Murty, and A. Ruffman. 1993. The Tsunami from the 1917 Explosion in Halifax Harbour. Proc. 27th Annual CMOS Congress, Fredericton, N.B. June 8-11, 1993. (Abstract).

Greenberg, D.A., J.A. Loder, and Y. Shen. 1993. The Influence of Wind and Scotian Shelf Inflow on the Circulation Around Georges Bank, p.53. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993.(Abstract).

Gregory, D., B. Petrie, F. Jordan, and P. Langille. 1993. Oceanographic, Geographic and Hydrological Parameters of Scotia-Fundy and Southern Gulf of St. Lawrence Inlets. Can. Tech. Rep. Hydrogr. Ocean Sci. 143: viii + 248 p.

Gregory, D., E. Verge, and P. Langille. 1993. Long-term Temperature Monitoring Program 1991/1992 Scotia-Fundy and the Gulf of St. Lawrence. Can. Data Rep. Hydrogr. Ocean Sci. 120: vi + 309 p.

Gurbutt, PA., B. Petrie, and F. Jordan. 1993. The Physical Oceanography of the Bras D'Or Lakes: Data Analysis and Modelling. Can. Tech. Rep. Hydrogr. Ocean Sci. 147: vii + 61 p.

Hamilton, J.M., N.S. Oakey, and D.E. Kelley. 1993. Salt Finger Signatures in Microstructure Measurements. J. Geophys. Res. 98(2): 2453-2460.

Han, G., M. Ikeda, and PC. Smith. 1993. Annual Variation of Sea-Surface Slopes over the Scotian Shelf and Grand Banks from Geosat Altimetry. Atmos.-Ocean 31(4): 591-615.

Haya, K., J.L. Martin, B.A. Waiwood, and L.E. Burridge. 1993. Uptake and Depuration of Paralytic Shellfish Toxins by Mussels Cultured in the Southwest Bay of Fundy, Eastern Canada, p. 94. *In* Proc. 6th Int. Conf. Toxic Mar. Phytoplank., Nantes, France, Oct. 18-22, 1993. (Abstract).

Haya, K., B.A. Waiwood and J.L. Martin. 1993. Depuration of Paralytic Shellfish Toxins by Giant Scallops Captured from the Bay of Fundy, Canada, p. 95. Proc. 6th Int. Conf. Toxic Mar. Phytoplank., Nantes, France, Oct. 18-22, 1993. (Abstract).

Hendry, R.M. 1993. Bedford Institute of Oceanography CTD Trials. Can. Tech. Rep. Hydrog. Ocean Sci. 148: iv + 97 p.

Hendry, R.M. 1993. Currents South of the Grand Banks at 50: Estimates of Mass Transport. In, The North Atlantic Current System: A Scientific Report, p. 111-112. *In* P. Malanotte-Rizzoli and T. Rossby [ed.]. MIT, Boston, MA. (Extended Abstract).

Hendry, R.M. 1993. Seasonal Variations of Slope Water Currents South of the Grand Banks from GEOSAT and in situ Measurements. Annales Geophysicae, European Geophysical Society, Vol. 11 (supp), Part 1: C 101 (Abstract).

Herman, A.W., N.A. Cochrane, and D.D. Sameoto. 1993. Detection and Abundance Estimation of Euphausiids Using an Optical Plankton Counter. Mar. Ecol. Prog. Ser. 94: 165-173.

Herman, A. W. 1993. Instruments for Measuring Subice Algal Profiles and Productivity *in situ.* Can. J. Fish. Aquat. Sci. 50(2): 359-369.

Herman, A.W., D.F. Knox, J. Conrad, and M.R. Mitchell. 1993. Instruments for Measuring Subice Algal Profiles and Productivity *in situ.* Can. J. Fish. Aquat. Sci. 50(2): 359-369.

Ikeda, M. 1993. Mesoscale Variabilities and Gulf Stream Bifurcation in the Newfoundland Basin Observed by the Geosat Altimeter Data. Atmos.-Ocean 31(4): 567-589.

Ikeda, M. and R.A. Wood. 1993. Mesoscale Stability of an Ocean Current in the Bryan-Cox Model. J. Geophys. Res. 98: 12,527-12,536.

Jones, E.P., L.G. Anderson, and B. Rudels. 1993. The deep water of the Canadian Basin. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract).

Jones, E.P., L.G. Anderson, and B. Rudels. 1993. A model for the formation and circulation of the deep water of the Arctic Ocean. Nansen Centennial Symposium, Solstrand, Norway, June 21-25.

Kepkay, P.E., S.E.H. Niven, and T.G. Milligan. 1993. Low Molecular Weight and Colloidal DOC Production During a Phytoplankton Bloom. Mar. Ecol. Prog. Ser. 100: 233-244.

Khandekar, M.L., and F. Dobson. 1993. On the Relationships between the Wind Stress Coefficient, Fetch, Wave Age and the Wave Momentum Flux. Proc. Symp. on the Air-Sea Interface, Marseilles, France.

Lazier, J.R.N., and D.G. Wright. 1993. Annual Velocity Variations in the Labrador Current. J. Phys. Oceanogr. 23(4): 659-678.

Loder, J.W., K.F. Drinkwater, N.S. Oakey, and E.P.W. Home. 1993. Circulation, Hydrographic Structure and Mixing at Tidal Fronts: The View from Georges Bank. Phil. Trans. Royal Soc. of London (A) 343: 447-460.

Martin, J.L., K. Haya, and D.J. Wildish. 1993. Distribution and Domoic Acid Content of *Nitzschia psuedodelicatissima* in the Bay of Fundy, p. 613-618. *In* T.J. Smayda, and Y. Shimizu [ed.] Toxic Phytoplankton Blooms in the Sea, Elsevier Science Publishers B.V

Misra, R.K., J.F. Uthe, C.L. Chou, D.P. Scott, and C.J. Musial. 1993. Trend Analysis Using a Multivariate Procedure for Data with Unequal Residual Covariance and Regression Coefficient Matrices: Application to Canadian Atlantic Cod Data. Mar. Poll. Bull. 26(2): 73-77.

Moran,S.B., K.O. Buessler, S.E.H. Niven, M.P Bacon, J.K. Cochran, H.D. Livingston and A.F. Michaels. 1993. Regional Variability in Size-Fractionated C/^{234}Th Ratios in the Upper Ocean: Importance of Biological Recycling. Third Scientific Meeting of Oceanogr. Soc., Seattle, Washington, Apr. 13-16, 1993. (Abstract #2-PCP-312.).

Morgan, M.R., R. Pocklington and K. Drinkwater. 1993. Temperature Trends at Coastal Stations on the Periphery of the North Atlantic Ocean. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract).

Myers, R.A., K.F. Drinkwater, and N. Barrowman. 1993. Cold Water and Recruitment in 2J3KL Cod. CAFSAC Res. Doc. 92/97: 13 p.

Niven, S.E.H. and R.M. Moore. 1993. Thorium Sorption in Seawater Suspensions of Aluminum Oxide Particles. Geochimica et Cosmochimica Acta 57: 2169-2179.

O'Neill, John T. and J.L. Bodner [ed.] 1993. Oceans - An Oceanographic Analysis System; User Reference, ver. 1.53 (Feb. 1, 1993); ver. 1.54 (Dec. 1, 1993).

Perrie, W., and B. Toulany. 1993. An Accurate Efficient Nonlinear Code for Wave Modelling. Can. Tech. Rep. Hydrogr. Ocean Sci. 146: iv + 54 p.

Perry, R.I., G.C. Harding, J.W. Loder, M.J. Tremblay, M.M. Sinclair, and K.F. Drinkwater. 1993. Zooplankton Distributions at the Georges Bank Frontal System: retention or dispersion? Cont. Shelf Res. 13(4): 357-**383.**

Peterson, I.K., and S.J. Prinsenberg. 1993. Ice Drift off Newfoundland, Derived from AVHRR Imagery and Ice Beacons. Proc. 16th Canadian Symp. on Remote Sensing. Sherbrooke, Quebec.

Petrie, B., and F. Jordan. 1993. Nearshore, Shallow-water Temperature Atlas for Nova Scotia. Can. Tech. Rep. Hydrogr. Ocean Sci. 145: v + 84 p.

Petrie, B. 1993. Storm-Forced Currents on the Grand Banks from a Two-Dimensional Barotropic Model. Can. Tech. Rep. Hydrogr. Ocean Sci. 152: vi + 145 p.

Prinsenberg, S.J., J.S. Holladay, and L.A. Lalumiere. 1993. Electromagnetic/Radar Ice and Snow Sounding Project over the Newfoundland Shelf in 1992. Can. Tech. Rep. Hydrogr. Ocean Sci. 144: vii + 59 p.

Quon, C., and M. Ghil. 1993. Multiple Equilibria and Oscillations in Two-Dimensional Thermohaline Convection with One Without Rotation, p. 49-52. *In* J. Marshall [ed.] Proc. of 9th Conf. on Atmos. and Ocean. Waves and Stability, San Antonio, Texas. Amer. Met. Soc.

Quon, C., and M. Ghil. 1993. Ocean Climate and Multiple Equilibria in Thermohaline Convection due to Salt-Flux Boundary Conditions, p. 410-419. Proc. of Climate, Environment and Geophysical Fluid Dynamics, Beijing, China. China Meteorological Press.

Ross, C.K. 1993. Currents, Temperature and Salinity Data from Eastern Baffin Bay, August 1986 to September 1987. Can. Data Rep. Hydrogr. Ocean Sci. 118: vii + 193 p.

Rudels, B., E.P. Jones, and L. Anderson. 1993. Atlantic water in the Arctic Ocean. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8- 11, 1993. (Abstract)

Rudels, B., E.P Jones, and L.G. Anderson. 1993. Sources and circulation of intermediate depth waters of the Arctic Ocean. Nansen Centennial Symposium, Solstrand, Norway, June 21-25.

Sameoto, D., N. Cochrane, and A. Herman. 1993. Convergence of Acoustic, Optical, and Net-catch Estimates of Euphausiid Abundance: Use of Artificial Light to Reduce Net Avoidance. Can. J. Fish. Aquat. Sci. 50(2): 334-346.

Sandstrom, H., and C. Quon. 1993. On Time-dependent, Two-layer Flow over Topography. I. Hydrostatic Approximation. Fluid Dynamics Res. 11: 119-137.

Smith, S.D. 1993. Hindcasting iceberg drift using current profiles and winds. Cold Region Sci. and Tech. 22: 33-45.

Smith, S.D., F.W. Dobson, and R.J. Anderson. 1993. The Wind Stress -Sea State Relationship with Mixed Sea and Swell. Proc. Symposium on the Air-

Sea Interface, Marseilles, France.
Smith, J.N. and J.M. Bewers. 1993. Radionuclides in the Marine Environment -Uses and Concerns. Can. Chem. News: 23 - 25.
Strain, PM., and F.C. Tan. 1993. Seasonal Evolution of Oxygen Isotope-Salinity Relationships in High-latitude Surface Waters. J. Geophys. Res. 98(C8): 14,589-14,598.
Subba Rao, D.V., Y. Pan, V. Zitko, G. Bugden, K. MacKeigan. 1993. Diarrhetic Shellfish Poisoning (DSP) Associated with a Subsurface Bloom of Dinophysis Norvegica in Bedford Basin, Eastern Canada. Mar. Ecol. Prog. Ser. 97: 117- 126.
Tan, F.C., and P.M. Strain. 1993. Sea Ice and Oxygen Isotopes in Hudson Bay and Hudson Strait, Canada. Proc. 3rd Int. Symposium, The Arctic Estuaries and Adjacent Seas: Biogeochemical Processes and Interaction with Global Change, Svetlogorsk, Russia, April 19-25, 1993. (Abstract).
Tan, F.C., and J.M. Edmond. 1993. Carbon Isotope Geochemistry of the Orinoco Basin. Est., Coast. Shelf Sci. 36: 541-547.
Tang, C.L. 1993. Newfoundland Marginal Ice Zone. Proc. Int. Symp. on Sea-ice, Beijing, Oct. 19-22, 1993. (Abstract).
Tang, C.L. 1993. Effects of Winter Storms on Sea-Ice Over the Newfoundland Shelf. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract).
Tang, C.L. [ed.] 1993. Workshop on Remote Sensing of Sea-ice. Dartmouth, July 19-20, 1993.
Tee, K.T., PC. Smith, and D. LeFaivre. 1993. Topographic Upwelling off Southwest Nova Scotia. J. Phys. Oceanog. 23(8): 1703-1726.
Tee, K.T. 1993. Multiple Equilibrium State of the North Atlantic Ocean, p.325. EoS Trans. AGU 74(43).
Tilley, D.G., J.R. Buckley, F.W. Dobson, and R. Lalbeharry. 1993. Progress in SAR Ocean Wave Spectral Simulation and Inversion Using ERS-1 and Almaz Satellite Imagery and *in situ* Data from the Grand Banks Experiment. Proc. IGARSS 1933. Tokyo, Japan.
Topliss, B.J., P. Challenor, R. Tokamkian, and H. Snaith. 1993. A Review of GEOSAT Data over Canadian East Coast Waters. Can. J. Rem. Sens. 19(2): 117-130.
Tremblay, J.J., J.W. Loder, F.E. Werner, C.E. Naimie, D.R. Lynch, F.H. Page, and M.M. Sinclair. 1993. Modelling the Dispersal of Sea Scallop Larvae on Georges Bank in Autumn: the Effects of Mean Advection, Larval Behaviour and Larval Origin, p. 85. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract).
Trites, R.W., and L. Petrie. 1993. Moored Current Meter Data from L'Etang Inlet, New Brunswick, 1988-1990. Can. Data Rep. Hydrogr. Ocean Sci. 121: iii + 121 p.
Uthe, J.F. (Chair). 1993. Report of the Work. Group on Statistical Aspects of Trend Monitoring. ICES C.M. 1993/ Poll: 48 p.
Wang, L., and W. Perrie. 1993. Coupled Wind-sea Models and Their Impact on Fluxes of Momentum, Sensible Heat and Latent Heat. Can. Tech. Rep. Hydrogr. Ocean Sci. 149: viii + 131 p.
Werner, F.E., F.H. Page, D.R. Lynch, J.W. Loder, R.G. Lough, R.I. Perry, D.A. Greenberg, and M.M. Sinclair. 1993. Influences of Mean Advection and Simple Behaviour on the Distribution of Cod and Haddock Early Life Stages on Georges Bank, p.88. Proc. 27th Annual CMOS Congress, Fredericton, N.B., June 8-11, 1993. (Abstract).
Werner, F.E., F.H. Page, D.R. Lynch, J.W. Loder, R.G. Lough, R.I. Perry, D.A. Greenberg and M.M. MacKay. 1993. Influences of Mean Advection and Simple Behavior on the Distribution of Cod and Haddock Early Life Stages on Georges Bank. Fish. Oceanogr. 2(2): 43-64.
Wright, D.G., T.F. Stocker, and S. Lehman. 1993. Ocean Circulation Changes During Younger Dryas: Evidence from Modelling and Data, p. 130. Proc. 27th Annual CMOS Congress, Fredericton, N.B. June 8-11, 1993. (Abstract).
Yeats, PA. 1993. Input of Metals to the North Atlantic from Two Large Canadian Estuaries. Marine Chemistry 43: 201-209.
Zitko, V. 1993. Expanded Polystyrene as a Source of Contaminants. Mar. Poll. Bull. 26: 584-585.

ENVIRONMENT CANADA ATLANTIC REGION

ENVIRONMENTAL QUALITY LABORATORY, BIO

1992

Bamwoya, J.J., L.A. Rutherford, PA. Hennigar, W.H. Home. 1992. Soil and Sediment Contamination at Four Wood Preservation Facilities in New Brunswick and Nova Scotia in 1989. Environment Canada, Environmental Protection Atlantic Region. Surveillance Report EPS-5-AR-92-4.
McLeay, D.J., S.G. Yee, K.G. Doe. and L.M. Porebski. 1992. Development of 10-day Marine/Estuarine Amphipod Assay in Support of the Canadian Ocean Dumping Program (CEPA, Part VI). p. 222-234. ***In*** A.J. Niimi and M.C. Taylor [ed.] Proc. of the Eighteenth Annual Aquatic Toxicity Workshop: September 30 - October 3, 1991, Ottawa, Ontario. Can. Tech. Rep. Fish. Ocean Sci. 1863.
Rutherford, L.A., PA. Hennigar, K.G. Doe, M.L. Nicol, M.M.E. Holmes, B.C. MacDonald, and W.H. Home. 1992. Chemical Characterization, Aquatic Toxicity and Environmental Impact of Untreated Effluent Discharges from Three Textile Mills in the Atlantic Region. Environment Canada, Environmental Protection, Atlantic Region. Surveillance Report EPS-5-AR-93-1. 144 p.
Sowles, J., R. Crawford, J. Machell, G. Atkinson, P. Hennigar, S. Jones, J. Patersen, and K. Coombs. 1992. Evaluation of Gulf Watch 1991 Pilot Project of the Gulf of Maine Environmental Monitoring Plan. The Gulf of Maine Council on the Marine Environment, October 1992.
Tay, K.-L., K.G. Doe, S.J. Wade, J.D.A. Vaughan, R.E. Berrigan and M.J. Moore. 1992. Sediment

Bioassessment in Halifax Harbour. Env. Toxicol. Chem. 11: 1567-1581.

1993

Rutherford,L.A., W.R. Ernst, K.G. Doe, and P.A. Hennigar. 1993. Chemical Characterization, Aquatic Toxicity and Environmental Impact of Untreated Effluent Discharges from Three Textile Mills in the Atlantic Region. p. 293-299. *In* E.G. Baddaloo, S. Ramamoorthy, and J.W. Moore [ed.] Proceedings of the Nineteenth Annual Aquatic Toxicity Workshop: October 4-7, 1992, Edmonton, Alberta. Can. Tech. Rep. Fish. Aquat. Sci. 1942.

MARINE WILDLIFE CONSERVATION DIVISION (CANADIAN WILDLIFE SERVICE)

1992 and 1993

Contreras, F., and J. Kerekes. 1993. Total phosphorus-chlorophyll relationships in tropical coastal lagoons in Mexico. Verh. Internat. Verein. Limnol. 25: 1-4.

Kerekes, J. 1992. The Common Loon. Nova Scotia Conservation. **16(2&3): 1-4.**

NATURAL RESOURCES CANADA

ATLANTIC GEOSCIENCE CENTRE

1992

Aksu, A.E., A. Ulug, D.J.W. Piper, Y.T. Konuk, and S. Turgut. 1992. Quaternary sedimentary history of Adana, Cilicia and Iskenderun Basins: northeast Mediterranean Sea. Marine Geology 104(1/4): 55-71.

Aksu, A.E., T.J. Calon, D.J.W. Piper, S. Turgut, and E. Izdar. 1992. Architecture of late Orogenic Quaternary basins in northeastern Mediterranean Sea. Tectonophysics 210: 191-213.

Amos, C.L., A.J. Gibson, and M. Brylinsky. 1992. Sediment settling rate analyses for a sediment stability study of the inner Miramichi Bay, New Brunswick. Geological Survey of Canada, Open File 02606, 40 p.

Amos, C.L., and H.A. Christian. 1992. The Miramichi dump site B seabed stability survey - November 1991. Geological Survey of Canada, Open File 02605, 74 p.

Amos, C.L., B. Ardiles, K. Bentham, C. Davis, I. Hardy, W. Leblanc, L. Johnson, L. Lockhart, B. MacLean, Y. Michaud, R. Murphy, A. Robertson, M.H. Ruz, R. Sparkes, T. Sutherland, and J. Zevenhuizen. 1992. C.S.S. Hudson and MV Septentrion cruises - Grande-Baleine region, Hudson Bay: a multi-disciplinary survey of the coastal and nearshore regions. Geological Survey of Canada, Open File 02603, 208 p.

Anderson, T.W. and C.F.M. Lewis. 1992. Evidence for ice margin retreat and proglacial lake [Agassiz?] drainage by about 11 ka, Clearwater River Spillway Area, Saskatchewan. Current Research, Part B, Interior Plains and Arctic Canada. Geological Survey of Canada, Paper No. 92-01B: 7-11.

Avery, M.P 1992a. Vitrinite reflectance [Ro] of dispersed organics from Shell PCI et al. Panuke B-90. Geological Survey of Canada, Open File 02622, 13 p.

Avery, M.P 1992b. Vitrinite reflectance [Ro] of dispersed organics from Shell Demascota G-32. Geological Survey of Canada, Open File 02623, 15 p.

Bates, J.L. and Grant, G.M. 1992. Electronic publishing is an on-going learning experience. Poster presented at the Joint Meeting of the Canadian Cartographic Association and Carto-Quebec, McGill University, Montreal, Quebec, June 2-6, 1992.

Bergersen,D., Larsen, R.L. and shipboard scientific crew of ODP Leg 144 1992. Seismic stratigraphy of Guyots drilled during ODP Leg 144: Preliminary Results. AGU, Fall Meeting, 1992.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 879, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 877. Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 874, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 876, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 800, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 875, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 872, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 801, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 873, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P., Jansa, L.F., Lincoln, J.M. and Quinn, T.M. 1992. Site 800, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Bogdanov, Y., Camoin, G., Enos, P, Jansa, L.F., Lincoln, J.M. and Quinn,

T.M. 1992. Site 871, Lithostratigraphy. Preliminary Summary of Drilling Results, Ocean Drilling Program Leg 144.

Buckley, D.E. 1992. Hudson 92-003 cruise report. Geological Survey of Canada, Open File 02602, 67 p.

Cameron, G. and G.V. Sonnichsen. 1992. ROV and Submersible Video Interpretation of Iceberg Scour Features and Glory Holes on the Northern Grand Banks of Newfoundland. Geological Survey of Canada, Open File 2569, 49 p.

Christian, H.A. 1992. Geotechnical Behaviour of Annapolis Basin Intertidal Sediments, Geological Survey of Canada, Open File 2496, 11 p.

Christian, H.A. 1992. Results of Geotechnical Field Investigations in Cumberland Basin During a Four-Day Period in September 1989; Data and Interpretation, Geological Survey of Canada, Open File 2497, 31 p.

Clowes, R.M., EA. Cook,A.G. Green, C.E. Keen, J.N. Ludden, J.A. Percival, G.M. Quinlan, and G.F. West. 1992. Lithoprobe: new perspectives on crustal evolution. Canadian Journal of Earth Sciences 29(9): 1813- 1864.

Coflin, K.C., Keen, C.E. and Marillier, F. 1992. Crustal cross sections of the Appalachian orogen from the North American craton to oceanic crust. Abstract, 5th International Symposium on Seismic Reflection Probing of Continents and Their Margins, Banff, Alberta.

Coflin, K.C., Stephenson, R.A., Lane, L.S. and Dietrich, J.R. 1992. Crustal struture and development of the Canadian margin of the Beaufort Sea. GAC/MAC Wolfville, Nova Scotia (Poster).

Conetec Investigations Ltd. 1992. Guidelines for Interpretation of CPTU Test Data for Determination of Consolidation and Permeability Parameters of Soils, Geological Survey of Canada, Open File 2519, 69 p.

Courtney, R.C. and Piper, D.J.W. 1992. The Gravity Signature Induced by the Loading of an Old Atlantic Type Margin by a Quaternary Submarine Fan: Evidence for a Thick Mechanical Lithosphere. Geological Survey of Canada, Open File 2566, 1 sheet.

Coyner, K., Katsube, T.J., Williamson, M. and Best, M.E. 1992. Gas and water permeability of tight shales from the Venture Gas field, offshore Nova Scotia. Geological Survey of Canada, Paper 92-1D, p. 129-136.

Cranston, R.E. 1992. Gas hydrate investigations in the Okhotsk / Japan Seas. Geological Survey of Canada, Open File 02446, 104 p.

Cranston, R. E. 1992. Geochemical and Sedimentological Results from Sediment Cores Collected in the Okhotsk/Japan Seas, Geological Survey of Canada, Open File 2520, 67 p.

Dalrymple, R.W., E.M. Legresley, G.B.J. Fader, and B.D. Petrie. 1992. The western Grand Banks of Newfoundland: transgressive Holocene sedimentation under the combined influence of waves and currents. Marine Geology 105: 95-118.

Davies, E.H. and McAlpine, K.D. 1992. Integrated multidisciplinary study of the Hibernia oil field, offshore eastern Canada. In: Program with Abstracts, Geological Survey of Canada Oil and Gas Forum, Calgary, January 20-22, 1992, p. 6.

Davies, E.H. and McAlpine, K.D. 1992. Integrated multidisciplinary study of the Hibernia oil field, offshore eastern Canada. In: Program with Abstracts, American Association of Petroleum Geologists Annual Convention, Calgary, June 21-24, 1992, p. 27.

Edwardson, K.A., J. Shaw, B. Wile, and W. Prime. 1992. Cruise report 91-031: C.S.S. Navicula operations in northeastern Newfoundland coastal waters: Ming's Bight, White Bay, Moreton's Harbour, Bay of Exploits and Twillingate Harbour. Geological Survey of Canada, Open File 02492, 54 p.

Emory-More, M. and L. Davis. 1992. Detrital Gold Occurrences, Northern Newfoundland Shelf, Geological Survey of Canada, Open File 2591, 94 p.

Enachescu, M.E. and McAlpine, K.D. 1992. Three-dimensional seismic imaging of a Kimmeridgian paleodrainage system in the south Jeanne d'Arc Basin, Grand Banks of Newfoundland. In: Program with Abstracts, Geological Association of Canada/ Mineralogical Association of Canada Joint Annual Meeting, Wolfville, May 25-27, 1992, v. 17, p. A117.

Erik Banke Consulting. 1992. Listing of Possible Groundings by Icebergs on the Grand Banks of Newfoundland Between 1983 and 1989, Geological Survey of Canada, Open File 2530, 79 p.

Erik Banke Consulting. 1992. Recent Iceberg Groundings and Scours on the Grand Banks of Newfoundland, Geological Survey of Canada, Open File 2528, 218 p.

Erik Banke Consulting. 1992. Case Histories of the Groundings of Icebergs 001 and 004 During March, 1989 on the Grand Banks of Newfoundland, Geological Survey of Canada, Open File 2527, 69 p.

Erik Banke Consulting. 1992. Compilation of Historical Accounts of Iceberg Groundings on the Canada Continental Shelf, Geological Survey of Canada, Open File 2529, 79 p.

Fensome, R.A. and Williams, G.L. 1992. Neogene dinoflagellates and Scotian Shelf stratigraphy. Abstracts, Geological Survey of Canada, Oil and Gas Forum, Calgary, March 1992.

Fensome, R.A. and Williams, G.L.. 1992. Neogene dinoflagellates and Scotian Shelf stratigraphy. Poster Session, Canadian Paleontology Conference 11, Ottawa, September 1991.

Fensome, R.A. and Williams, G.L. 1992. Neogene dinoflagellates and Scotian Shelf stratigraphy. Geological Survey of Canada, Oil and Gas Forum, Calgary, February 1992.

Fensome, R.A. and Williams, G.L.. 1992. Neogene dinoflagellates and Scotian Shelf stratigraphy. Canadian Paleontology Conference, Program with Abstracts, no. 2, Ottawa, September 1992, p. 13.

Fowler, M.G., McAlpine, K.D. and Williamson, M.A. 1992. Generation and migration of oils in the Jeanne d'Arc Basin, offshore eastern Canada. In: Program with Abstracts, Geological Survey of Canada Oil and Gas Forum, Calgary, January 20-22, 1992, p. 5.

Fowler, M.G., McAlpine, K.D. and Williamson, M.A. 1992. Generation and migration of oils in the Jeanne d'Arc Basin, offshore eastern Canada. In: Program with Abstracts, American Association of Petroleum Geologists Annual Convention, Calgary, June 21-24, 1992, p. 42.

Fowler, M.G., McAlpine, K.D. and Williamson, M.A. 1992. Generation and Migration of hydrocarbons in the Jeanne d'Arc basin. AAPG Convention, Calgary 1992.

Fowler, M.G., McAlpine, K.D. and Williamson, M.A. 1992. Generation and migration of hydrocarbons in the Jeanne d'Arc basin. Calgary Oil and Gas Forum, March 1992 and AAPG Convention, Calgary, June 1992.

Gee, J.S., Nakanishi,M. and scientific party of ODP Leg 144 1992. Paleomagnetic studies of the Northwestern Pacific Guyots. Geomagnetism, Earth and Planetary Sciences Society, Japan.

Global Geoenergy Research Ltd. 1993. Analyses and Interpretation of Geochemical and Source Rocks Data from Scotian Shelf Wells. Geological Survey of Canada, Open File 2804, 232 p.

Gradstein, F.M. and Von Rad, U. 1992. Stratigraphic evolution of Mesozoic continental margin and oceanic sequences, NW Australia and N. Himalayas. Marine Geology.

Gradstein, F.M., U. Von Rad, M.R. Gibling, L.F. Jansa, M.A. Kaminski, I.L. Kristiansen, J.G. Ogg, U. Rohl, M. Sarti, J.W. Thurow, G.E.G. Westerman, and J. Wiedman (Analytic authors). 1992. Stratigraphy and depositional history of the Mesozoic continental margin of central Nepal, 141 p.

Grant, A.C. and P.N. Moir. 1992. Observations on coalbed methane potential, Prince Edward Island. Current Research, Part E. Geological Survey of Canada, Paper No. 92-0lE: 269-278.

Grant, A.C. 1992. Seismic character of coal measures in the Gulf of St. Lawrence region. In: Program and Abstracts, Geological Survey of Canada Oil and Gas Forum, Calgary, March 2-3, 1992, p. 35.

Grant, A.C. 1992. Intracratonic tectonism: key to the mechanism of diastrophism. In: S. Chatterjee and N. Hotton (eds.), New Concepts in Global Tectonics. Texas Tech University Press, p. 65-73.

Grant, A.C. 1992. Aspects of seismic character of Permo-Carboniferous sediments, Maritimes Basin and Sydney Basin. In: Programs with Abstracts, GAC/MAC Joint Annual Meeting, Wolfville, p. A42.

Grant, A.C. 1992. Seismic character of coal measures in the Gulf of St. Lawrence region. In: Program with Abstracts, Geological Survey of Canada Current Activities Forum, Ottawa, January 21-22, 1992, p. 12.

Grant, A.C. 1992. Seismic character of coal measures in the Gulf of St. Lawrence region. In: Proceedings, The Canadian Coal and Coalbed Muthane Geoscience Forum, Parksville, February 2-5, 1992, p. 33.

Grant, A.C. and Moir, P.N. 1992. Observations on coalbed methane potential, Prince Edward Island. Geological Survey of Canada, Current Research, Paper 92-1E, p. 269-278.

Hein, F.J. and J.P.M. Syvitski. 1992. Sedimentary environments and facies in an arctic basin, Itirbilung Fiord, Baffin Island, Canada. Sedimentary Geology 81: 17-45.

Hillaire-Marcel, C. and A. Rochon. 1992. Cruise report and on-board studies, C.S.S. Hudson 90-13, May 29 -June 22, 1990, Leg 1: the Labrador Sea. Geological Survey of Canada, Open File 02531, 126 p.

Huang, Z. and Williamson, M.A. 1992. Estimation of in-situ thermal conductivity in the Jeanne d'Arc basin. AAPG Convention, Calgary 1992.

Huang, Z. and Williamson, M.A. 1992. Thermal structure of the Jeanne d'Arc basin. Calgary Oil and Gas Forum, March 1992 and AAPG Convention, Calgary, June 1992.

Jansa, L.F. 1993. Cometary impacts into ocean, their recognition and the threshold for biological extinctions. Palaeo3, v. 104, p. 271-286.

Jansa, L.F., Loncarevic, B.D. and Pe-Piper, G. 1992. Cretaceous diabase dykes in the Proterozoic basement offshore Cape Breton, Nova Scotia and the offshore extension of the Meguma Group. GAC/MAC Annual Meeting, Wolfville 1992, Abstract.

Jackson, H.R., B.D. Loncarevic, and W. Blake Jr. 1992. Shallow seismic and magnetic data from northernmost Baffin Bay: Insights into geology. Current Research, Part B, Interior Plains and Arctic Canada. Geological Survey of Canada, Paper No. 92-01B: 23-29.

Jansa, L.F., Pe-Piper, G. and Loncarevic, B.D. 1992. Cretaceous diabase dykes in the basement offshore Cape Breton, Nova Scotia and the offshore extension of the Meguma Group. Atlantic Geoscience Society Annual Meeting, Fredericton, January 1992.

Jenner, K.A. and J. Shaw. 1992. Inner shelf Quaternary sediments off northeast Newfoundland. Current Research, Part D, Eastern Canada and National and General Programs. Geological Survey of Canada, Paper No. 92-01D: 189-198.

Johnston, B.L., K.W. Asprey, J.P.M. Syvitski, C.T. Schafer, M. Uyesugi, C.B. Chapman, S. Merchant, W.A. Boyce, R.J. Murphy, K.W. Leblanc, S. Hinds, P. Hamblin, and J. Locat. 1992. Hudson 91-033 cruise report. Geological Survey of Canada, Open File 02468, 109 p.

Josehans, H.W., K. Conway, M. Packard, W. Hill, G. Standen, and T. Vandall. 1992. Cruise report, Endeavour cruise, 92-004, Queen Charlotte Sound. Geological Survey of Canada, Open File 02584, 130 p.

Katsube, T.J., Williamson, M.A., Murphy, T.B. and Best, M.E. 1992. Relationship between pore structure and diagenetic processes of tight shales from the Scotian Shelf. AAPG Convention, Calgary, June 1992.

Katsube, T.J., Williamson, M.A. and Best, M.E. 1992. Shale pore structure evolution and its effect on permeability. In: Symposium Volume III of the 33rd Annual Meeting of the Society of Professional Well log analysts. Paper SCA-9214, p. 1-22.

Katsube, T.J., Williamson, M.A., Issler, D.R. and Best, M.E. 1992. Petrophysical properties of shales and significance for sedimentary basin modelling. AAPG Convention, Calgary 1992.

Katsube, T.J., Williamson, M.A., Issler, D.R. and Best, M.E. 1992. Petrophysical properties of shales and significance for sedimentary basin modelling. Calgary Oil and Gas Forum, March 1992.

Katsube, T.J., Scromeda, N. and Williamson, M.A. 1992. Effective porosity and irreducible water saturation of tight shales from the Venture Gas field. Geological Survey of Canada, Paper 92- 1D, p.111-119.

Katsube, T.J., Issler, D.R., Williamson, M.A. and Best, M.E. 1992. Evolution of shale petrophysical properties with compaction in the overpressured zone of the Beaufort-Mackenzie basin. AAPG Convention, Calgary, June 1992.

Katsube, T.J., N. Scromeda, and M. Williamson. 1992. Effective porosity of tight shales from the Venture gas field, offshore Nova Scotia. Current Research, Part D, Eastern Canada and National and General Programs. Geological Survey of Canada, Paper No.92-01D: 111-119.

Lake, P. 1992. Wellsys: A Database on Wells of Offshore Eastern Canada, Geological Survey of Canada, Open File 2501, 118 p.

Lewis, C.F.M., A.G. Sherin, A.S. Atkinson, R.H. Harmes, F.D. Jodrey, J.A. Nielsen, D.R. Parrott, B.J. Todd. 1993. Cruise Report C.C.G.S. Griffon - Western Lake Ontario. August 7 to September 9, 1992. Cruise Number 92-800. Geological Survey of Canada, Open File 2678, 76 p., 4 maps, 1 diskette.

Loncarevic, B.D. and D.J.W. Piper. 1992. Application of high-quality bathymetry to geological interpretation on the Scotian Shelf. Geoscience Canada 19(1): 5-13.

MacLean, B. C. 1992. Scotian Shelf Mesozoic Mapping Project, Geological Survey of Canada, Open File 2506, 5 p., 4 diskettes.

MacLean, B.C. and J.A. Wade. 1992. Petroleum geology of the continental margin south of the islands of St. Pierre and Miquelon, offshore eastern Canada. Bulletin of Canadian Petroleum Geology 40(3): 222-253.

MacLean, B.C. and Wade, J.A. 1992. Petroleum geology of the St. Pierre and Miquelon moratorium block, eastern margin of Canada. In: Abstracts of Geological Association of Canada/Mineralogical Association of Canada Annual Meeting, v. 17, Wolfville.

MacLean, B.C. and Wade, J.A. 1992. A first look at the petroleum geology of the Canada-France boundary dispute region south of St. Pierre and Miquelon. In: Abstracts of GSC Oil and Gas Forum, Calgary. Also in: Abstracts of American Association of Petroleum Geologists/ Canadian Society of Petroleum Geologists Annual Meeting, Calgary.

McAlpine, K.D, Coflin, K.C., Keen, C.E. and Verhoef, J. 1992. An intergrated geological and geophysical synthesis of deep crustal structure and the evolution of rift basins in the Grand Banks of Newfoundland. AAPG Annual Convention Calgary, Alberta (Poster).

Macnab, R., J. Verhoef, and S. Srivastava. 1992. A new database of magnetic observations from the Arctic and North Atlantic Oceans. Current Research, Part D, Eastern Canada and National and General Programs. Geological Survey of Canada, Paper No. 92-01D: 173-178.

Michel, H.K., K.E. Louden, F. Marillier, and I. Reid. 1992. The seismic velocity structure of northern Appalachian crust around western Newfoundland. Canadian Journal of Earth Sciences 29(3): 462-478.

Milliman, J.D. and J.P.M. Syvitski. 1992. Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. Journal of Geology 100(5): 525-544.

Moir, P.N. and Grant, G.M. 1992. The development of marine geoscience atlas products at the Atlantic Geoscience Centre. Poster presentation at Current Activities Forum, Geological Survey of Canada, Ottawa, January 2 1-22, **1992.**

Mosher, D.C. and G. Sonnichsen. 1992. Stratigraphy and sedimentology of sediments on the northeastem Grand Banks of Newfoundland from borehole investigation. Geological Survey of Canada, Open File 02409, 110 p.

Murphy, J.B., G. Pe-Piper, J.D. Keppie, and D.J.W. Piper. 1992. Correlation of Neoproterozoic III sequences in the Avalon composite terrane of mainland Nova Scotia: tectonic implications. Atlantic Geology 28: 143-151.

Nelson, J.B., D.A. Forsyth, D. Teskey, A.V. Okulitch, D.L. Marcotte, C.D. Hardwick, M.E. Bower, and R. MacNab. 1992. The 1991 Polar Margin aeromagnetic survey in the Lincoln Sea, northern Ellesmere Island and northern Greenland. Current Research, Part B, Interior Plains and Arctic Canada. Geological Survey of Canada, Paper No. 92-01B: 31-36.

Pe-Piper, G. and D.J.W. Piper. 1992. Geochemical variations with time in the Cenozoic high-K volcanic rocks of the Island of Lesbos, Greece: significance for Shoshonite petrogenesis. Journal of Volcanology and Geothermal Research 53(l/4): 371-387.

Perissoratis, C. and D.J.W. Piper. 1992. Age, regional variation, and shallowest occurrence of S1 Sapropel in the Northern Aegean Sea. Geomarine Letters 12: 49-53.

Piper, D.J.W., P. Cochonat, G. Ollier, E. Le Drezen, M. Morrison, and A. Baltzer. 1992. Evolution progressive d'un glissement rotationnel en un courant de turbidite: cas du seisme de 1929 des Grands Bancs [Terre - Neuve] (non-catastrophic evolution of a turbidity current from a slump: evidence from the 1929 “Grand

Banks” earthquake). Comptes Rendus de 1’Academie des Sciences, Serie II, Mechanique, Physique, Chimie, Sciences de l’Univers, Sciences de la Terre 314: 1057- 1064.

Piper, D.J.W. and C.P.G. Pereira. 1992. Late Quaternary sedimentation in central Flemish Pass. Canadian Journal of Earth Sciences 29(3): 535-550.

Piper, D.J.W. and A.E.Aksu. 1992. Architecture of stacked Quaternary deltas correlated with global oxygen isotopic curve. Geology 20(5): 415-418.

Piper, D.J.W. and Sparkes, R. 1992. Pliocene-Quaternary Sediment Isopachs in Central Flemish Pass, Geological Survey of Canada, Open File 2553, 5 p., 6 maps.

Potter, P., Courtney, R.C. and McCloskey, T. 1992. Digital Data Compilation: Scotian Shelf and Labrador Sea Basin Atlas Series, Geological Survey of Canada, Open File 2493, 85 p.

Praeg, D., B. D’Anglejan, and J.P.M. Syvitski. 1992. Seismostratigraphy of the middle St. Lawrence Estuary: a late Quaternary glacial marine to Estuarine depositional/erosional record. Geographie Physique et Quaternaire 46(2): 133-150.

Quinlan, G.M., J. Hall, H. Williams, and J.A. Wright. 1992. Lithoprobe onshore seismic reflection transects across the Newfoundland Appalachians. Canadian Journal of Earth Sciences (S.P. Colman-Sadd, S.J. O’Brien, G.S. Stockmal, and F. Marillier [ed.]) 29(9): 1865- 1877.

Shaw, J. 1992. Surficial Sediments of Baie Verte, Newfoundland, Geological Survey of Canada, Open File 2457, 39 p., 5 maps.

Shaw, J. and D.L. Forbes. 1992. Barriers, barrier platforms, and spillover deposits in St. George’s Bay, Newfoundland: paraglacial sedimentation on the flanks of a deep coastal basin. Marine Geology 105: 119-140.

Shaw, J., H. Russell, A. Sherin, and T. Atkinson. 1992. Cruise report 91-026: C.S.S. Dawson operations in Newfoundland coastal waters: La Poile Bay to Bay D’espoir, Notre Dame Bay, and Bay of Exploits. Geological Survey of Canada, Open File 02482, 55 p.

Shaw, J. and D. Frobel. 1992. Aerial video survey of the south coast of Newfoundland, Port aux Basques to Terrenceville. Geological Survey of Canada, Open File 02565, 56 p.

Sinclair, I.K., K.D. McAlpine, D.F. Sherwin, N.J. McMillan, G.C. Taylor, M.E. Best, G.R. Campbell, J.P. Hea, D. Henao, and R.M. Procter. 1992. Petroleum resources of the Jeanne d’art Basin and environs: Grand Banks, Newfoundland. Geological Survey of Canada, Paper No. 92-08, 100 p.

Solomon, S.M., D.L. Forbes, and P.J. Mudie. 1992. Report of the 1991 NOGAP coastal surveys in the Beaufort Sea. Geological Survey of Canada, Open File 02579, 114 p.

Stea, R.R., D.L. Forbes, and R.J. Mott. 1992. Quaternary geology and coastal evolution of Nova Scotia. Geological Association of Canada, Field Trip Guidebook, No. A6, 131 p.

Stea, R.R., G.B.J. Fader, and R. Boyd. 1992. Quaternary seismic stratigraphy of the inner shelf region, Eastern Shore, Nova Scotia. Current Research, Part D, Eastern Canada and National and General Programs. Geological Survey of Canada, Paper No. 92-01D: 179-188.

Stoffyn-Egli, P., G.V. Sonnichsen, and A. Zawadski. 1992. Clay-size minerals and near-surface stratigraphy on the northeastern Grand Banks of Newfoundland. Current Research, Part E. Geological Survey of Canada, Paper No. 92-01E: 323-331.

Syvitski, J.P.M. 1992. Marine geology of Baie des Chaleurs. Geographie Physique et Quatemaire 46(3): 331-348.

Syvitski, J.P.M. and A.G. Lewis. 1992. The seasonal distribution of suspended particles and their iron and manganese loading in a glacial runoff fiord. Geoscience Canada 19(l): 13-20.

Syvitski, J.P.M. and S. Daughney. 1992. Delta2: Delta progradation and basin filling. Computers and Geosciences 18(7): 839-897.

Syvitski, J.P., S.J. Hinds, and H. Josenhans. 1992. Quaternary marine geology of the N.W. Gulf of St. Lawrence. Geological Survey of Canada, Open File 02485.

Taylor, R. B. 1992. Coastal Stability and Flooding at Grand Etang, Fortress of Louisbourg, Nova Scotia. Geological Survey of Canada, Open File 2548, 25 p.

Taylor, R.B. and D. Frobel. 1992. Aerial video surveys, the coastline of Prince Edward Island. Geological Survey of Canada, Open File 02580, 16 p.

Wade, J.A. and MacLean, B.C. 1992. Petroleum resource estimates of St, Pierre Bank and adjacent arreas of Atlantic Canada. In: Abstracts of Geological Association of Canada/Mineralogical Association of Canada Annual Meeting, v. 17, Wolfville.

White, D.J., B. Milkereit, M.H. Salisbury, and J.A. Percival. 1992. Crystalline lithology across the Kapuskasing uplift determined using in situ Poisson’s ratio from seismic topography. Journal of Geophysical Research 97(B13): 19993-20006.

Williamson, M.A., Huang, Z., McAlpine, K.D., Thomas, F.C., Fensome, R.A., Katsube, T.J. and Avery, M.P. 1993. Hydrocarbon charge history of east coast offshore basins: modelling geologic uncertainty. In: Current Research, Part E, Geological Survey of Canada, Paper 93-1E, p. 299-306.

Williamson, M.A. and McAlpine, K.D. 1992. Hydrocarbon charge histories of Canada’s east coast basins: a research strategy. In: Program with Abstracts, Geological Association of Canada/ Mineralogical Association of Canada Joint Annual Meeting, Wolfville, May 25-27, 1992, v. 17, p. A117.

Williamson, M.A. and McAlpine, K.D. 1992. Understanding oil and gas distribution in offshore sedimentary basins: a research strategy for the 1990’s. In: Bedford Institute of Oceanography Science Review 1990 and 1991, p. 111-118.

Williamson, M.A. and Desroches, K.

1992. Source rock maturity modelling, Sable and Jeanne d'Arc Basins offshore eastern Canada. Calgary Oil and Gas Forum, March 1992 and AAPG Convention, Calgary, June **1992.**

Williamson, M.A. and Smyth, C. 1992. Timing of gas and overpressure generation in the Sable subbasin offshore Nova Scotia. AAPG Convention, Calgary, June 1992 (poster).

Williamson, M.A. and McAlpine, K.D. 1993. Understanding oil and gas distribution in offshore sedimentary basins: a research strategy for the 1990's. BIO Annual Review.

Williamson, M.A. and McAlpine, K.D. 1992. Hydrocarbon habitat studies of east coast frontier basins: past, present and future. In: Program with Abstracts, Geological Survey of Canada Oil and Gas Forum, Calgary, January 20-22, 1992, p. 2.

Williamson, M.A. and Smyth, C. 1992. Basin offshore Nova Scotia: implications for gas migration dynamics. Bulletin Canadian Petroleum Geology, v. 40, no. 2, p. 151-**159.**

Williamson, M.A. and C. Smyth. 1992. Timing of gas and overpressure generation in the Sable Basin offshore Nova Scotia: implications for gas migration dynamics. Bulletin of Canadian Petroleum Geology 40(2): 151-169.

Williamson, M.A., Coflin, K.C., McAlpine, K.D., Huang, Z., White, J. and Fowler, M.G. 1993. Heavy oil occurrence in the Jeanne d'Arc Basin: general data compilation. Proprietary report prepared for participants in the Heavy Oil IPP Project.

Williamson, M.A. 1992. The subsidence, compaction, thermal and maturation history of the Egret Member source rock, Jeanne d'Arc Basin, offshore Newfoundland. Bulletin of Canadian Petroleum Geology 40(2): 136- 150.

Williamson, M.A. 1992. Subsidence, compaction thermal and maturation history of the Egret Member source rock, Jeanne d'Arc Basin. offshore Newfoundland. Bulletin Canadian Petroleum Geology, v. 50, no. 4, p. 136-150.

Williamson, M.A. 1992. Hydrocarbon resource studies of east coast frontier basins: past, present and future. Ottawa Forum, January 1992, Calgary Oil and Gas Forum, March 1992 and AAPG Convention, Calgary 1992.

Winters, G.V. and J.P.M. Syvitski. 1992. Suspended sediment character and distribution in Mcbeth Fiord, Baffin Island. Arctic 45(1): 25-35. Avery, M.P. 1992. Vitrinite Reflectance (RO) of Dispersed Organics from Conventional Cores from Seven Scotian Shelf Wells, Geological Survey of Canada, Open File 2455, 13 p.

Winters, G.V. and D.E. Buckley. 1992. Factor analyses as a method of evaluating sediment environmental quality in Halifax Harbour, Nova Scotia. Current Research, Part D, Eastern Canada and National and General Programs. Geological Survey of Canada, Paper No. 92-01D: 165-171.

1993

Amos, C.L., J.T. Judge, and J.V. Barrie. 1993. Storm-enhanced tidal sand transport - Hecate Strait, British Columbia, Canada. Geological Survey of Canada, Open File 02604, 1 map sheet, scale 1:1,000,000.

Amos, C.L., K.L. Tay, M. Hughes, A. Robertson, and B. Wile. 1993. Seabed stability monitoring at dump site B of Saint John Harbour, New Brunswick, using Sea Carousel. Geological Survey of Canada, Open File 02764, 40 p.

Amos, C.L., T. Sutherland, and J. Zevenhuizen. 1993. Sea Carousel measurements of seabed stability in Manitounuk Sound, Grande Baleine, Hudson Bay. Geological Survey of Canada, Open File 02765, 155 p.

Ascoli, P. and Grigelis, A. 1993. Middle Jurassic-Lower Cretaceous foraminiferal zonation of eastern Canada and eastern Europe (in Russian). Journal Russian Academy of Sciences, section "Stratigraphy and Geological Correlation", v. 1, no.4, p. 47-55.

Atlantic Coastal Zone Information Steering Committee. 1993. Atlantic Coastal Zone Database Directory. Geological Survey of Canada, Open File 2614, 912 p.

Austin, J.A., Sibuet, J-C., Srivastava, S.P., Coflin, K.C. and Tucholke, B.E. 1993. Understanding the ocean-continent transition along conjugate passive continental margins: deep drilling in the northern Newfoundland Basin. 1993 AGU Fall Meeting, Balitimore, Maryland (Abstract).

Avery, M.P. 1993a. Vitrinite reflectance (RO) of dispersed organics from Mobil et al Bluenose 26-47. Geological Survey of Canada, Open File 02707, 19 p.

Avery, M.P. 1993c. Vitrinite reflectance (Ro) of dispersed organics from Shell PC1 et al South Debarres O-76. Geological Survey of Canada, Open File 02706, 17 p.

Avery, M.P 1993b. Vitrinite reflectance (Ro) of dispersed organics from Mobil et al. Hebron I-13. Geological Survey of Canada, Open File 02671, 16 p.

Bates, J.L. 1993. Digital on-demand publishing. Poster presented at the 16th International Cartographic Conference, Cologne, Germany, May 1993.

Batson, P.A., MacDonald, J., Wade, J.A. and Williams, G.L. 1993. Offshore Oil and Natural Gas: video guide. Atlantic Geoscience Society, Special Publication No. 12, 89 p.

Berry, J.A. and D.J.W. Piper. 1993. Seismic stratigraphy of the central Scotian Rise: a record of continental margin glaciation. Geomarine Letters 13: 197-206.

Buckley, D.E., G.V. Winters, R.A. Fitzgerald, S. Penney, and K.W.G. Leblanc. 1993. Inorganic geochemical data for marine sediments from Hudson Bay and James Bay: delta of Grande Baleine River, Manitounuk Sound, and delta of La Grande River. Geological Survey of Canada, Open File 02720, 126 p.

Coflin, K.C. 1993. Flying Foam Structure, Jeanne d'Arc Basin, Grand Banks of Newfoundland. 1993 Annual Meeting of the Geological

Society of America, Boston, Massachusetts (Poster and Abstract).
Coflin, K.C. and McAlpine, K.D. 1993. National Seismic Digital Library: Husky Frontier Geophysical Data Library. AGS Annual Meeting, Halifax, Nova Scotia.
Coflin, K.C., McAlpine, K.D., Enachescu, M.E. and Hogg, J.R. 1993. National Seismic Digital Library: Husky Frontier Geophysical Data Library. GSC Forum, Ottawa Ontario.
Coflin, K.C., Keen, C.E. and Marillier, F. 1993. Crustal cross section of the Applalachian orogen from the North American craton to oceanic crust. Tectonophysics. Submitted.
Coflin, K.C., McAlpine, K.D., Enachescu, M.E. and Hogg, J.R. 1993. National Seismic Digital Library. In: Program with Abstracts, Geological Survey of Canada Current Activities Forum, Ottawa, January 19-20, 1993, p. 34.
Coflin, K.C. and McAlpine, K.D. 1993. National seismic digital library: Husky geophysical data library. In: Program with Abstracts, Atlantic Geoscience Society Annual Colloquium and Symposia, Halifax, February 12-13, 1993, p. 1.
Courtney, R. 1993. Halifax Harbour bathymetric morphology. Geological Survey of Canada, Open File 02637, 1 map sheet, scale 1: 16,000.
Courtney, R.C. (compiler). 1993. Inner Scotian Shelf off Halifax (11D), Nova Scotia: EM100 Swath Bathymetry. Geological Survey of Canada, Open File 2803, 1 sheet.
Courtney, R., G. Sonnichsen, and R. Parrott. 1993. Hibernia swath bathymetry. Geological Survey of Canada, Open File 02712, 1 map sheet, scale 1: 10,000.
Damassa, S.P. and Williams, G.L. 1993. Provincialism and current events: North Atlantic Eocene-Oligocene dinoflagellates. Geological Society of America, Abstracts with Program, p. A386.
Dehler, S.A. and C.E. Keen. 1993. Effects of rifting and subsidence on thermal evolution of sediments in Canada's east coast basins. Canadian Journal of Earth Sciences 30(9): 1782-1798.
Edwardson, K.A., D.L. Forbes, J. Shaw, L. Johnston, D. Froebel, and D. Locke. 1993. Cruise report 92-301 : nearshore and beach surveys along the northeast Newfoundland coast: Dog Bay, Gander Bay, Green Bay and Baie Verte. Geological Survey of Canada, Open File 02619, 66 p.
Edwardson, K.A, D.L. Forbes, and J. Shaw. 1993. Gold assay results: northeast Newfoundland coastal and inner-shelf seabed samples. Geological Survey of Canada, Open File 02772, 35 p.
Fader, G.B.J., R.O. Miller, R.R. Stea, and S.S. Pecore. 1993. Cruise report, C.S.S. Dawson 91-018, inner Scotian Shelf, June 4-21, 1991. Geological Survey of Canada, Open File 02633, 30 p.
Fensome, R.A., MacRae, A. and Williams, G.L. 1993. Dinoflagellate diversities, extinctions, sea-level curves and other such things. G.S.C. Forum, Abstracts, Ottawa, January **1993.**
Fensome, R.A., MacRae, A. and Williams, G.L. 1993. Dinoflagellate diversities, extinctions, sea-level curves and other such things. Poster Session, Geological Survey of Canada, Forum, 18-20 January 1993.
Fensome, R.A., Henry, A.S., MacRae, R.A. and Williams, G.L. 1993. Dinoflagellates: a new look at old bugs. Poster Session, Atlantic Geoscience Society, Annual Meeting and Colloquium, Halifax, Nova Scotia.
Fensome, R.A., Gocht, H., Stover, L.E. and Williams, G.L. 1993. The Eisenack Catalog of Fossil Dinoflagellates. New Series, v. 2, 550 p.
Fensome, R.A., MacRae, A. and Williams, G.L. 1993. Dinoflagellate diversities, extinctions and sea-level curves. Fifth International Conference on Modem and Fossil Dinoflagellates, Program and Abstracts, p. 40.
Fensome, R.A., Taylor, F.J.R., Norris, G., Sarjeant, W.A.S., Wharton, D.I. and Williams, G.L. 1993. A classification of living and fossil dinoflagellates. Fifth International Conference on Modern and Fossil Dinoflagellates, Program and Abstracts, p. 39.
Fensome, R.A., Taylor, F.J.R., Norris, G., Sarjeant, W.A.S., Wharton, D.I. and Williams, G.L. 1993. A classification of fossil and living dinoflagellates. Micropaleontology Press Special Paper, no. 7.
Fensome, R.A., Taylor, F.J.R. and Williams, G.L. 1993. Dinoflagellate phylogeny and its basis in systematics: an evolving science. Fifth International Conference on Modem and Fossil Dinoflagellates, Program and Abstracts, p. 38.
Forbes, D.L., J. Shaw, and B.G. Eddy. 1993. Late Quaternary sedimentation and the postglacial sea-level minimum in Port au Port Bay and vicinity, west Newfoundland. Atlantic Geology 29(1): 1-26.
Global Geoenergy Research Ltd. 1993. Analyses and Interpretation of Geochemical and Source Rocks Data from Scotian Shelf Wells. Geological Survey of Canada, Open File 2804, 232 p.
Grant, A.C. 1993. Evaluation of coalbed methane "resource", Gulf of St. Lawrence region. Program with Abstracts, GSC Forum 1993, Ottawa, p. 7.
Grant, A.C. and Sanford, B.V. 1993. Hudson Platform: crustal geophysics. Chapter 8. In: Sedimentary Cover of the Craton in Canada, D.F. Scott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, no. 5, p. 655-658.
Grant, A.C. 1993. Book review, "Interior Cratonic Basins", M.W. Leighton et al. (eds.). American Association of Petroleum Geologists, Memoir 51, 819 p. In: Bulletin of Canadian Petroleum Geology, v. 41, p. 473-474.
Grant, A.C. 1993. Hudson Bay: Industry Seismic Reflection Data. In: Proceedings of the Hudson Bay Lithosphere Study Workshop, Ottawa, November 3-4, 1993, p. 13.
Hardy, I.A. and J. Zevenhuizen. 1993. Seabed surficial sediment

sampling in the Grande Rivière de la Baleine region, southeastern Hudson Bay. Geological Survey of Canada, Open File 02729, 362 p.

Hein, F.J., J.P.M. Syvitski, L.A. Dredge, and B.F. Long. 1993. Quaternary sedimentation and marine placers along the north shore, Gulf of St. Lawrence. Canadian Journal of Earth Sciences 30(3): 553-574.

Huang, Z., P.J. Mudie, and A.E. Aksu. 1993. Evaluation of paleoclimatic proxies by the resealed range method: results from Labrador Sea, ODP Site 646. Canadian Journal of Earth Sciences 30(7): 1385-1389.

Jansa, L.F., Pe-Piper, G. and Loncarevic, B.D. 1993. Appalachian basement and its intrusion by Cretaceous dykes, offshore southeast Nova Scotia, Canada. Canadian Journal of Earth Sciences, v. 30, p.

Jansa, L.F. 1993. Cometary impacts into ocean, their recognition and the threshold for biological extinctions. Palaeo3, v. 104, p. 271-286.

Jansa, L.F. 1993. Sea levels, land levels and tide gauges, by K.O. Ornery and D.C. Aubrey. Book Review, Elsevier.

Jansa, L.F. 1993. Break-up of Pangea: the North Atlantic perspective. Program and Abstracts, Annual Convention of the Canadian Society of Petroleum Geologists, August 15-19, 1993, Calgary, p. 151.

Jansa, L.F. 1993. Paleogeography and stratigraphic record of global change in the Mesozoic. Program with Abstracts, SEPM Meeting, Pennsylvania State University, August 8-12, 1993, State College, p. 65.

Jansa, L.F. 1993. Early Cretaceous carbonate platforms of the northeastem American margin with comments on processes leading to their demise and drowning. American Association of Stratigraphic Palynologists, Special Publication, p. 111-126.

Jansa, L.F. 1993. Cometary impacts into ocean: their recognition and the threshold constraint for biological extinctions. Palaeogeography, Palaeoclimatology, Palaeoecology 104: 271-286.

Jansa, L.F., G. Pe-Peper, and Z. Palacz. 1993. Geochemistry and regional significance of the early Cretaceous basalt-felsic igneous rock associations on the Grand Banks, eastern Canada. Geological Survey of Canada, Open File 02704, 1 map sheet, scale 1:4,000,000.

Jansa, L.F. 1993. Early Cretaceous carbonate platforms of the northeastem North American margin. American Association of Petroleum Geologists, Memoir 56: 111-126.

Jansa, L.F., G. Pe-Piper, and B.D. Loncarevic. 1993. Appalachian basement and its intrusion by Cretaceous dykes, offshore southeast Nova Scotia, Canada. Canadian Journal of Earth Sciences 30(12): 2495-2509.

Josenhans, H. and J. Zevenhuizen, 1993. Quaternary sediment maps of the Gulf of St. Lawrence. Geological Survey of Canada, Open File 02700, 463 p. and map sheets, scales 1: 1,000 and 1: 1,000,000.

Katsube, T.J. and Williamson, M.A. 1993. Shale petrophysics and basin charge modelling. Geological Survey of Canada, Paper 94-D, p. 179-188.

Lentin, J.K. and Williams, G.L. 1993. Fossil dinoflagellates: index to genera and species 1993 edition. American Association of Stratigraphic Palynologists, Contributions Series, no. 28, 856 p.

Li, M.Z. and C.L. Amos. 1993. Sedtrans 92: Re-evaluation and Upgrade of the A.G.C. Sediment Transport Model. Geological Survey of Canada, Open File 2769, 135 p.

Loncarevic, B.D. and the Shipboard Scientific Party. 1993. Cruise Report: CSS Matthew; Cruise 93054: Matthew Motion Sensor Trials (MMST-93). Geological Survey of Canada, Open File 2730, 88 p.

MacLean, B.C. and Wade, J.A. 1993. East coast basin atlas series: seismic markers and stratigraphic picks in Scotian Basin wells. Atlantic Geoscience Centre, Geological Survey of Canada, 276 p.

MacLean, B, B.D. Loncarevic, I. Hardy, R.G.B. Brown, R.A. Daigneault, M. Day, M.W. Kerwin, W.F. Manley. 1993. Cruise Report: CSS Hudson Cruise 93034 in Hudson Strait, Ungava Bay, Eastern Canadian Arctic. October 16 - November 8, 1993. Geological Survey of Canada, Open File 28 18, 135 p.

MacLean, B.C. and Wade, J.A. 1993. Petroleum geology of the continental margin south of the islands of St. Pierre and Miquelon. offshore eastern Canada. Bulletin of Canadian Petroleum Geology, v. 40, p. 222-253.

MacNab, R., W. Roest, and L.C. Kovacs. 1993. Visits to geoscience organizations in St. Petersburg and Moscow, Russia, June 29 to July 7, 1993. Geological Survey of Canada, Open File 02717, 61 p.

MacRae, R.A., Fensome, R.A. and Williams, G.L. 1993. Dinoflagellate diversities, extinctions and sea-level curves. Geological and Mineralogical Associations of Canada, Annual Meeting, Edmonton, Program and Abstracts, p. A65.

MacRae, R.A., Fensome, R.A. and Williams, G.L. 1993. Fossil dinoflagellate diversities: a specific approach. Geological Society of America, Abstracts and Program, p. A57. Poster also presented at the American Association of Stratigraphic Palynologists, Program and Abstracts, p. 56.

Miller, R.O. and G.B.J. Fader. 1993. Cruise report, C.S.S. Navicula 90-038. Cape St. Marys to Country Island, Nova Scotia. October 9-25, 1990. Geological Survey of Canada, Open File 2805, 18 p., 1 sheet.

Miller, A.A.L. 1993. Quaternary foraminiferal biostratigraphy of three shallow geotechnical boreholes, Balmoral, Cohasset and Panuke wellsites, western Sable Island Bank. Geological Survey of Canada, Open File 02710, 88 p.

Moir, P.N. 1993. Jeanne d'Arc Basin structure maps. In: Hydrocarbon Charge Modelling Project, IRAS Newsletter, v. 5, p. 18.

Moir, P.N. 1993. Industry standard petroleum data models: implementation at AGC. In: Hydrocarbon

Charge Modelling Project, IRAS Newsletter, v. 5, p. 19.
Mukhopadhyay, P.K. 1993. Characterization and Maturation of Selected Cretaceous and Jurassic Source Rocks and Crude Oil, Scotian Shelf. Geological Survey of Canada, Open File 2621, 99 p.
Mukhopadhyay, P.K. 1993. Characterization and Maturation of Selected Oil and Condensate Samples and Correlation with Source Beds, Scotian Shelf. Geological Survey of Canada, Open File 2620, 94 p.
Pe-Piper, G. and D.J.W. Piper. 1993. Revised stratigraphy of the Miocene volcanic rocks of Lesbos, Greece. Neues Jahrbuch Fur Geologie Und Palaeontologie, Monatschefte 2: 97- 110.
Piper, D.J.W. and B. Savoye. 1993. Processes of late Quaternary turbidity current flow and deposition on the Var deep-sea fan, north-west Mediterranean Sea. Sedimentology 40(3): 557-582.
Pogrebitsky, Y.E., V.N. Shimaraev, V.V. Verba, J. Verhoef, R. Macnab, J. Kisabeth, G. Jorgensen. 1993. Magnetic Anomaly Map of Russia and Adjacent Land and Marine Areas. Geological Survey of Canada, Open File 2639, 1 map
Ruffman, W.A. 1993. History of Canadian Geological and Geophysical Surveys in the Area of St. Pierre Bank 42 degrees to 48 degrees N; 52 degrees to 61 degrees. Geological Survey of Canada, Open File 2631, 114p.
Salem, H.S. 1993c. Detailed results of petrophysical, electric, anisotropic, and elastic parameters at one meter depth increments for eight Terra Nova wells. Geological Survey of Canada, Open File 02723, 258 p.
Salem, H.S. 1993a. A preliminary study of the physical properties of the Terra Nova and Hibernia oil fields in the Jeanne d'Arc Basin, offshore Newfoundland, Canada. Geological Survey of Canada, Open File 02686, 79 p.
Salem, H.S. 1993b. Detailed quantitative analyses of physical properties (measured and deduced) at one meter depth increments for the interval 355-5141 m (4786 m) of the Glenelg J-48 well in the Sable Island area, offshore Nova Scotia. Geological Survey of Canada, Open File 02724, 342 p.
Salem, H.S. 1993d. Detailed results of petrophysical, electric, anisotropic, and elastic parameters at one meter depth increments for six Hibernia wells. Geological Survey of Canada, Open File 02722, 222 p.
Sanford, B.V. and Grant, A.C. 1993. Hudson Platform - Recent Advances in the Geology of the Hudson Platform. Chapter 8. In; Sedimentary Cover of the Craton in Canada, D.F Scott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada no. 5, p. 687-689.
Savoye, B., D.J.W. Piper, and L. Droz. 1993. Plio-Pleistocene evolution of the Van deep-sea fan off the French Rivera. Marine and Petroleum Geology 10: 550-571.
Savoye, B. and D.J.W. Piper. 1993. Quaternary sea-level change and sedimentation on the continental shelf and slope of Antibes, French Riviera. Geomarine Letters 13: 2-8.
Shaw, J., R.B. Taylor, and D.I. Forbes. 1993. Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia. Geographie Physique et Quatemaire 47(2): 221-238.
Shaw, J. 1992. Surficial Sediments of Baie Verte, Newfoundland, Geological Survey of Canada, Open File 2457, 39 p., 5 maps.
Srivastava, S.P., Coflin, K.C. and Sibuet, J.-C. 1993. Multichannel seismic survey in the Newfoundland Basin: a Canadian-French collaboration. Abstract, GAC-MAC Annual Meeting, Edmonton, Alberta.
Srivastava, S.P., Coflin, K.C. and Sibuet, J.-C. 1993. Multichannel seismic survey in the Newfoundland Basin: a Canadian-French collaboration. Abstract, GSC Forum, Ottawa, Ontario.
Syvitski, J.P.M. 1993. Glaciomarine environments in Canada: an overview. Canadian Journal of Earth Sciences 30(2): 354-371.
Syvitski, J.P.M. and J.M. Alcott. 1993. Grain2: predictions of particle size seaward of river mouths. Computers and Geosciences 19(3): 399-446.
Syvitski, J.P.M., S.J. Hinds, and J.A. Bums. 1993. Marine Geology of Lake Melville (Labrador). Geological Survey of Canada, Open File 2759, 34 maps.
Syvitski, J.P.M., S.J. Hinds, and J.A. Bums. 1993. Marine Geology of Goose Bay (Labrador). Geological Survey of Canada, Open File 2760, 17 maps.
Taylor, R.B. 1993. Recent morphological changes and future management of Crescent Beach, Lunenburg County, Nova Scotia. Geological Survey of Canada, Open File 02675, 20 p.
Taylor, R.B. and D. Frobel. 1993. The coastline of Nova Scotia, Part 1, Bay of Fundy and Gulf of Maine (New Brunswick border to Yarmouth). Geological Survey of Canada, Open File 02705, 51 p.
Thomas, F. C. 1993. Preliminary Cenozoic Micropalaeontological Biostratigraphy of 16 Wells, Jeanne D'Arc Basin, Grand Banks of Newfoundland. Geological Survey of Canada, Open File 2799, 55 p.
Thomas, F.C. 1993. Cenozoic foraminiferal assemblages of the Hibernia area, Grand Banks of Newfoundland and paleoecological implications. In: Current Research, Part D, Geological Survey of Canada, Paper 1994-D, p. 1 - 12.
Verhoef, J. and W.R. Roest. 1993. Reading the stripes: offshore discoveries in plate tectonics with examples from eastern Canada. Canadian Journal of Earth Sciences 30(2): 261-277.
Williams, G.L., Stover, L.E. and Kidson, E.J. 1993. Morphology and stratigraphic ranges of selected Mesozoic-Cenozoic dinoflagellate taxa in the northern hemisphere. Geological Survey of Canada, Paper 92-10, 137 p.
Williams, G.L., L.E. Stover, and E.J. Kidson. 1993. Morphology and stratigraphic ranges of selected Mesozoic-Cenozoic dinoflagellate taxa in the northern hemisphere. Geological Survey of Canada, Paper No. 92-10, 140 p.
Williamson, M.A., Desroches, K. and King, S. 1993. Overpressure

and hydrocarbon migration in the Hibernia-Nautilus area of the Jeanne d'Arc Basin, offshore eastern Canada. Bulletin of Canadian Petroleum Geology, v. 41, no. 4, p. 389-406.

Williamson, M.A., Desroches, K. and King, S. 1993. Overpressure and hydrocarbon migration in the Hibernia-Nautilus area of the Jeanne d'Arc Basin, offshore eastern Canada. Extended abstract in Geofluids '93 volume, p. 69-72.

Williamson, M.A., Katsube, T.J., Huang, Z., Fowler, M.G., McAlpine, K.D., Thomas, F.C., Fensome, R.A. and Avery, M.P. 1993. Hydrocarbon charge history of east coast offshore basins: modelling geological uncertainty. In: Current Research, Part E, Geological Survey of Canada, Paper 93-1E, p. 299-306.

Williamson, M.A., Huang, Z., McAlpine, K.D., Thomas, F.C., Fensome, R.A., Katsube, T.J. and Avery, M.P. 1993. Hydrocarbon charge history of east coast offshore basins: modelling geologic uncertainty. In: Current Research, Part E, Geological Survey of Canada, Paper 93-1E, p. 299-306.

Williamson, M.A. and McAlpine, K.D. 1993. Understanding oil and gas distribution in offshore sedimentary basins: a research strategy for the 1990's. BIO Annual Review.

Williamson, M.A., T.J. Katsube, Z. Huang, M. Fowler, K.D. McAlpine, F.C. Thomas, R. Fensome, and M. Avery. 1993. Hydrocarbon charge history of east coast offshore basins: modelling geological uncertainty. Current Research, Part E. Geological Survey of Canada, Paper No. 93-1E: 299-306.

Williamson, M.A., Coflin, K.C., McAlpine, K.D., Huang, Z., White, J. and Fowler, M.G. 1993. Heavy oil occurrence in the Jeanne d'Arc Basin: general data compilation. Proprietary report prepared for participants in the Heavy Oil IPP Project.

Williamson, M.A. and K. Desroches. 1993. A maturation framework for Jurassic sediments in the Sable Subbasin, offshore Nova Scotia, Bulletin of Canadian Petroleum Geology 41(2): 244-257.

Williamson, M.A. 1993. Hydrocarbon Charge Modelling of Canada's East Coast Offshore Basins. Extended abstract and poster in Geofluids '93, p. 255-258.

Zevenhuizen, J. 1993. Surficial marine geology, southeastern Hudson Bay. Geological Survey of Canada, Open File 02770, 57 p. Amos, C.L. 1993. The Fox Island River Chromite Placer Survey - November 1991. Geological Survey of Canada, Open File 2607, 41 p.

(This Page Blank in the Original)

(This Page Blank in the Original)

Government of Canada

Fisheries and Oceans

Natural Resources

Environment

Gouvernement du Canada

Pêches et Océans

Ressources naturelles

Environnement