

Gulf of Maine NEWS

Regional Association for Research on the Gulf of Maine Summer 2000

Establishing a Framework for Effective Monitoring of the Gulf of Maine

Gerald Pesch, U. S. Environmental Protection Agency, RARGOM Chair

What is needed to achieve effective monitoring in the Gulf of Maine? RARGOM hosted workshops in November, 1997, and in April, 2000, to address this topic (RARGOM Report 98-1 and workshop summary, see p. 18). These meetings have in turn, helped to stimulate new ventures in the region. Discussions are occurring at both regional and federal levels because it is widely recognized that ocean science requires long-term measurements in order to address basic research questions as well as improve management practices.

Many programs presently exist that produce discontinuous data sets but cover broad spatial areas. This issue of the newsletter features selected initiatives in the region.

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A Century of Oceanographic Monitoring at the St. Andrews Biological Station

Fred H. Page, Blythe D. Chang, Jennifer L. Martin, Fisheries and Oceans Canada, St. Andrews Biological Station

Marine investigations have been carried out in eastern Canadian waters since the early 1800s. However, it was not until 1898, when the Canadian Marine Biological Station was founded, that the era of government funded marine science began in earnest in Canada. This was largely due to the efforts of Professor E. E. Prince, the Dominion Commissioner of Fisheries, who saw the need for a marine biological laboratory to conduct research on the fisheries and waters along Canada's Atlantic coast. The construction of the first marine biological station, a one story, 50 foot long wooden laboratory, was completed in 1899 and erected on the shores of Indian Point in St. Andrews, New Brunswick. Two years later, in 1901, the building was placed on a scow so it could be moved around Atlantic Canada as desired. For example, for various periods of time, it was moved to Canso (Nova Scotia), Malpeque (Prince Edward Island), and Gaspé (Quebec). Despite the merits of a mobile station, the advantages of a land-based station were soon recognized and in 1908 a permanent structure was erected in Brandy Cove, just north of Joe's Point at the mouth of the St. Croix estuary near St. Andrews. This is the site of the present Biological Station (Figure 1).

The location was chosen for many reasons (Penhallow 1912). It was in close proximity to a high diversity of habitat and marine life. The local fisheries were active and varied. Access to transportation and consequently supplies, was relatively good. Hence, scientific investigations of practical

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(Framework for Effective Monitoring continued)

In June, funding was approved for the establishment of a not-for-profit utility, the Gulf of Maine Ocean Observing System (GoMOOS). This organization will offer continuous data opportunities when the buoys become operational next year (see related article, p. 16). RARGOM has been asked by the GoMOOS Board to convene a workshop this winter to identify the data needs of researchers and managers in the Gulf of Maine region.

Protecting resources in the Gulf requires research to support ecosystem-based management, and monitoring to distinguish the effects of human activities from natural variability. Building sustained long-term support for regional research and monitoring requires local, state, national, and international commitment. RARGOM and the Gulf of Maine Council on the Marine Environment are the appropriate organizations to take the lead on bringing state-of-the-art science and management strategies to bear on existing and emerging environmental issues in the Gulf of Maine. RARGOM's mission is to foster quality scientific research on the Gulf of Maine through increased communication and collaboration among the region's institutions. RARGOM is an association of institutions, and includes government, academic and private organizations. The Gulf of Maine Council on the Marine Environment facilitates coordination of resource management of the Gulf and its Action Plan sets priorities and specifies measurable objectives for managing the Gulf of Maine and its resources. The Council reviews and updates its Action Plan on a five-year cycle. The current Action Plan expires next year, thus an evaluation and update is underway. This planning process is an opportunity for partnership between the Gulf of Maine Council and RARGOM. As a parallel activity to the Council Action Plan revision, RARGOM will revise the regional research plan, and in this context, address future management needs in the Gulf of Maine. The Council approved \$10K to support this collaborative activity in the upcoming year at their July meeting.

This is also an opportune time to hold a policy level discussion. RARGOM intends to convene a meeting of the directors of Gulf of Maine observing systems this October in order to develop a strategic plan and establish a process for governance and improved communication among the institutions conducting these monitoring programs. An additional goal of the directors meeting is to build support for integrated monitoring activity into agency budgets for the long term. It is important at this juncture to integrate these efforts, to plan for the management of all these data, and to make this information widely available. RARGOM seeks to conduct the necessary planning, and coordinate the exchange of ideas, leading to sustained funding for an integrated set of observing systems and monitoring programs in the region.

(Hydrography at St. Andrews continued)

importance could be undertaken at relatively little cost compared to the expense of working on distant offshore banks. These reasons were recognized by others, both before and after the establishment of the station. Interestingly, Spencer F. Baird's original choice, Eastport, Maine, for the establishment of the United States Fish Commission, now at Woods Hole, Massachusetts, was in the same area (Penhallow 1912).

From the beginning, sampling of the biological and physical oceanographic aspects of the marine environment has been a component of the work conducted from the Biological Station. In the following overview, we give a brief, and necessarily incomplete, account of the oceanographic monitoring activities conducted from the Station, particularly those focused on phytoplankton and hydrography. In the early 1900s, the phytoplankton were studied at a range of locations by several investigators including L. W. Bailey, H. Gran, T. Braarud, and V. Davidson. However, a concerted plankton monitoring program was not established and maintained until 1987. The monitoring program was initiated to describe the background spatial and seasonal patterns in phytoplankton within the southwest New Brunswick area. Early motivating factors were the desire to be able to warn the salmon culture industry of pending blooms that might be harmful to cultured fish and the need to help identify the influence, if any, of aquaculture on phytoplankton (Martin and Wildish 1990, Martin et al. 1999). The program has been maintained largely because of its utility in monitoring toxic phytoplankton, especially those that influence harvesting strategies for local shellfish. At all stations (Figure 1), sampling has been conducted weekly from May through October, bi-weekly in April and November, and monthly during January through March and December. Surface samples were collected with buckets and subsurface samples with 1.8 L Niskin bottles. The details of preservation and sorting methodologies are given in Martin and Wildish (1990). Measurements of water temperature, salinity and nutrients are also collected at each station. The data are published every few years in technical reports (Wildish et al. 1988, 1990, Martin et al. 1995, 1999).

As with the plankton, hydrographic measurements have been an integral and valued component of the Biological Station activities from the beginning, both for their own merits and for their importance to understanding and developing the biological resources of the area, particularly the fisheries and aquaculture potential. In the early 1900s, hydrographic sampling was conducted by E. H. Craigie (University of Toronto) and W. H. Chase (Acadia University). Samples were taken in specific areas and times in relation to specific programs. For example, in 1910, the Canadian Department of Fisheries encouraged research that related to evaluating the suitability of the local habitat to aquaculture, in particular oyster culture (Copeland 1912). Hydrographic measurements were therefore taken at 54 stations distributed throughout the St. Croix Estuary, Passamaquoddy Bay. In 1913, a 50 foot



Figure 1: Map of southwestern New Brunswick, Canada and southeastern Maine, United States showing the location of the St. Andrews Biological Station and the Prince 5 monitoring station (marked by stars) in relation to some major physiographic features of the area.

motor launch was acquired and christened the “E. E. Prince”, after the Dominion Commissioner of Fisheries, Professor E. E. Prince (Annual Report of the Atlantic Biological Station 1913). In 1914, the E. E. Prince was “equipped with a hoisting engine, a Pettersen-Hansen water bottle, and a Richter reversing thermometer and a survey was made of bays along the southern coast of New Brunswick ” (Annual Report of the Atlantic Biological Station 1914). In August 1914, hydrographic transects were completed across the St. Croix estuary and Passamaquoddy Bay. A transect across the mouth of the Bay of Fundy included four stations (Annual Report of the Atlantic Biological Station 1915). In 1916, a series of oceanographic stations began to be routinely occupied and these became known as the Prince stations (Annual Report of the Atlantic Biological Station 1916, Vachon 1918). Some of the station locations had been occupied before, as in Copeland’s studies conducted in 1910 (Copeland 1912). One of the Bay of Fundy stations occupied in 1914 by Craigie (1916a, b) was in close proximity to Prince Station 5. In the early years, hydrographic stations were occupied only seasonally during the spring and summer when the Biological Station was open. Year round measurements began to be taken by about 1924 although it was not until 1928 that a full-time resident oceanographer, H. B. Hachey, was appointed and year-round oceanographic research began at the Station.

In 1946, the Atlantic Oceanographic Group, headed by H. B. Hachey, was formed and housed at the Biological Station. It was transferred to the Bedford Institute of Oceanography (Dartmouth, Nova Scotia) in the 1960s. In the early 1980s, oceanography was reinstated at the station to focus on fisheries issues and during the 1990s, the group expanded in number of staff and breadth of activity so that the focus is now on regional oceanography in relation to fisheries, aquaculture and climate change.

One of the early monitoring stations was the Prince 5 station, located between Campobello Island and the southern Wolves (Figure 1). Because of the close proximity of the sampling stations to the Biological Station and the commitment of several generations of Station staff, the Prince 5 sampling station has been almost continuously sampled since the early 1920s. The series is the longest continuously sampled Canadian hydrographic series in the Bay of Fundy, Gulf of Maine and Scotian Shelf area. Many publications have analyzed and used the Prince 5 data over the years. Without mentioning specifics, the temperature trends at Prince 5 have been shown to be indicative of low frequency trends throughout the Bay of Fundy and Gulf of Maine. The data have contributed substantially to what we know about ocean climate change in the Bay of Fundy, Gulf of Maine and Scotian Shelf areas. They have contributed to exploratory

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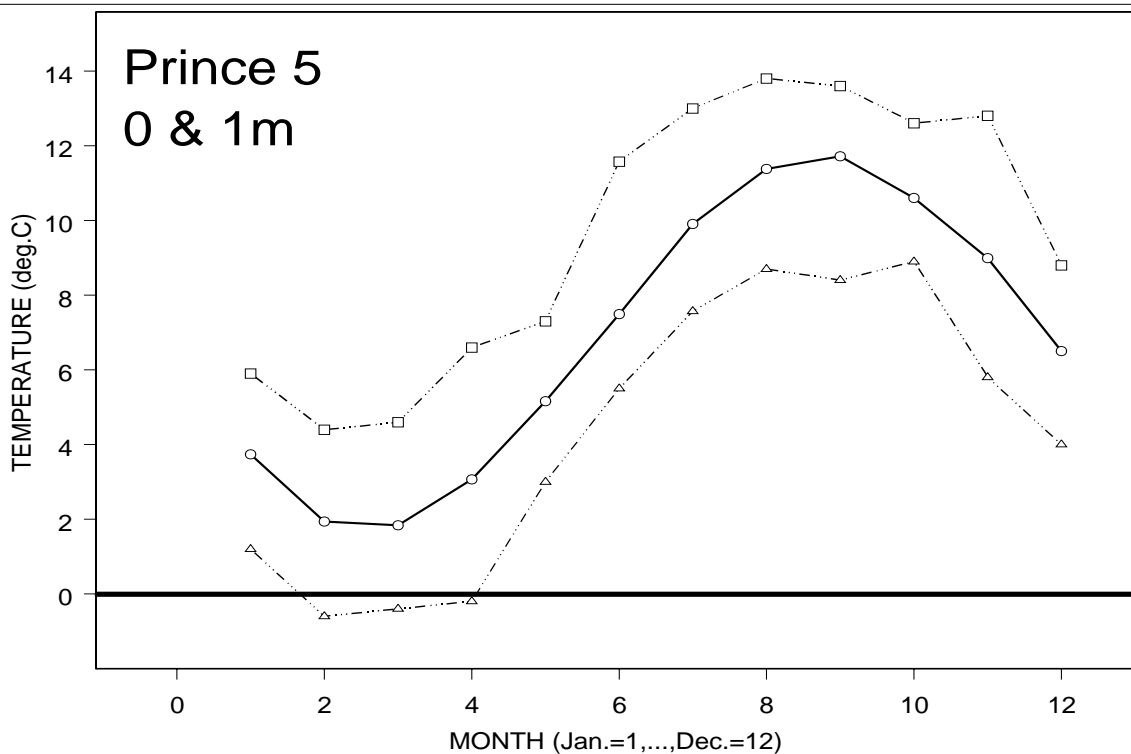


Figure 2. Annual cycle in monthly means and extremes (minima and maxima) of temperature at Prince Station 5 for the period 1924 through 1999.

analyses of the influence of temperature on the patterns of migration and recruitment in commercially important fish and invertebrates and for the assessment of the potential for temperatures lethal to cultured salmonid. The seasonal cycle in temperature and the deviations from the 1961-90 monthly means, referred to as anomalies are shown in Figures 2 and 3.

The sampling technology used at Prince 5 has changed throughout the years. Around 1916, data was collected using reversing thermometers and water bottles. Salinities were determined by chemical analyses of the salts in the water (Vachon 1918). Today, since 1989, a SeaBird Electronics conductivity, temperature and depth (CTD) profiler has been used to collect hydrographic data at Prince 5.

In addition to the Prince 5 station monitoring, daily measurements of sea surface temperature have been taken at the Biological Station wharf since the early 1900s. Vertical profiles of temperature and salinity have also been taken monthly at Prince 6 located in the middle of the St. Croix estuary near the Biological Station. Biological Station staff have also been actively involved in conducting annual hydrographic surveys throughout the Bay of Fundy, eastern Gulf of Maine and Scotian Shelf since 1970 (Losier et al. 1999). More recently, vertical profiles of temperature and salinity have been taken monthly with a CTD at a series of 21-25 stations more or less evenly distributed throughout the inshore region of southwestern New Brunswick (Robinson et al. 1996).

In recent years the recognition of the utility and hence the demand for oceanographic monitoring has increased. This has been due to a renewed interest in the influence of oceanographic conditions on fishery resources and a growing interest in climate change throughout Atlantic Canada. At a regional and local scale there is a desire to develop and sustain the salmon aquaculture industry and recognition that the knowledge of the environment is important in this regard. As a consequence, additional effort is being focused on compilation and analyses of historical data, particularly with respect to the spatial and temporal trends in phytoplankton and zooplankton abundance and community structure. The Prince 5 sampling effort became part of the Atlantic Zonal Monitoring program (described on p. 8 in this issue) in 1998-99 and the sampling effort has expanded to include water samples for nutrient and phytoplankton analyses, and vertical net hauls for identification and enumeration of phytoplankton and zooplankton. The intention is that the results will be reported annually in the Canadian Stock Assessment Secretariat Research Document Series along with other results from the Atlantic Zonal Monitoring Program. Preliminary results from 1998 and 1999 will be included in Page et al. (in prep. a, b).

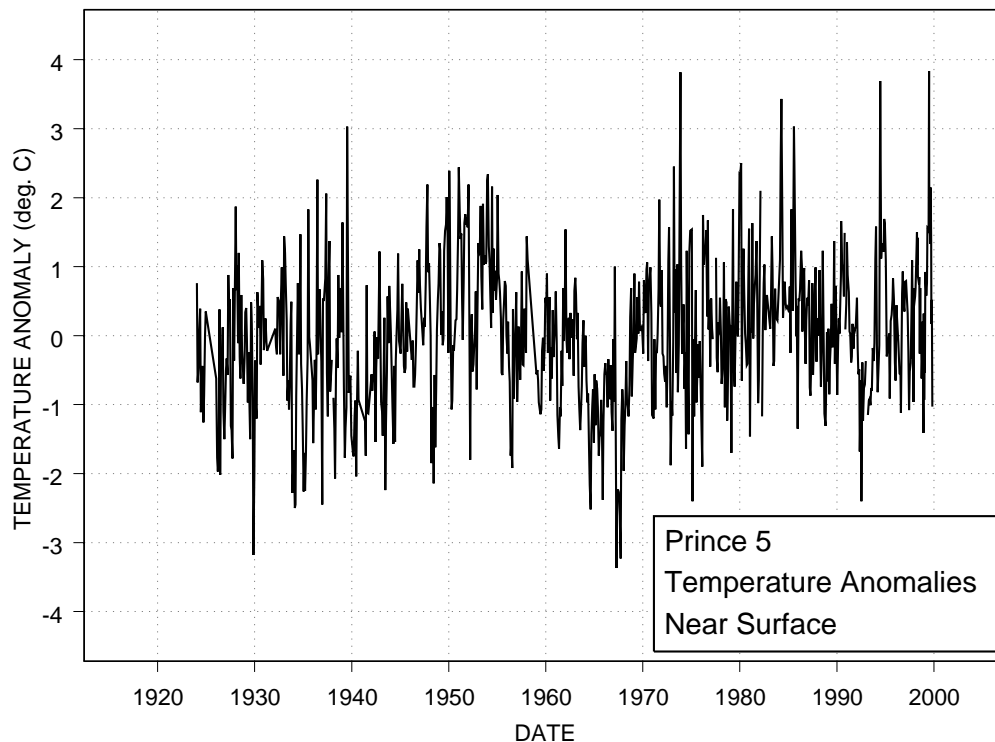


Figure 3. Time series of monthly sea surface temperature anomalies at Prince 5 from 1924 through 1999. The anomalies are deviations of individual recordings from the 1961-90 monthly means. Data from 1924 to October 1990 are from 0m and that since November 1990 is from 1m.

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The Northeast Fisheries Science Center Sampling Program

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The primary purpose of the NOAA Northeast Fisheries Science Center (NEFSC) sampling programs is to collect the data needed to assess the status of the managed fish stocks in the region. With these assessments, the NEFSC provides information and advice to the regional Fishery Management Councils to guide their management decisions. The second purpose of the sampling programs is to monitor variability in key components of the ecosystem that supports the commercially valuable stocks. These measurements contribute to an increased understanding of the ecosystem, which will allow for better, more informed, management of the living marine resources in the future. Sampling is conducted throughout the Gulf of Maine through ship surveys for finfish, shellfish, and other invertebrate species, for selected marine mammal populations, for key components of the plankton community and for the basic water properties. The major survey activities conducted by the NEFSC are briefly described here.

Bottom Trawl Surveys

Trawl surveys, which began in 1963, are conducted across all or part of the Gulf of Maine each winter, spring and fall, with about 400 locations sampled in the Gulf region each year. The surveys have a stratified random design and provide data that are collected independently from the fishing industry in order to assess the status of ground fish stocks. Abundance (catch per unit effort), length, and weight are determined for all species caught. Age by otolith (rings on the ear bone) analysis, sex, maturity stage and food habits data are collected for over 30 fish species. The sampling design and protocols are based on strict statistical considerations and have been supported by a number of internal and external reviews over the years, including a recent review by the National Research Council of the overall stock assessment process used by NEFSC.

Shellfish Surveys

A survey of the scallop population on the entire Georges Bank is conducted each summer. The surveys began in 1975 and sample approximately 175 sites each year, using a stratified random survey design similar to that used in the bottom trawl surveys.

Northern Shrimp Survey

Each summer, a survey of the Gulf of Maine northern shrimp stock is conducted by the NEFSC in cooperation with the states of Massachusetts, New Hampshire and Maine. Approximately 50-60 tows are made in the western Gulf of Maine during the two-week survey.

Pelagic Herring Surveys

A survey of the pelagic herring stocks on Georges Bank and selected areas of the Gulf of Maine is conducted each fall using hydroacoustic technology. Mid-water trawls are done during the survey to provide species verification and biological characteristics of the population. This work is part of a cooperative research effort involving researchers from the NEFSC, the state of Maine and Canada.

Sampling of the Fishery

Information on the fisheries is obtained by agents in the ports and by observers on fishing vessels. Data on the amount and size structure of the landings, the amount and size composition of discards at sea, the by-catch of protected species, as well as economic information about the landings are routinely collected. In addition, biological samples (scales and otoliths) are collected to determine the age structure of the landed catch.

Marine Mammals

Surveys to assess the harbor porpoise, pelagic dephinid and harbor seal populations are conducted annually on a three-year rotating basis. Each involves sampling substantial areas within the Gulf of Maine. In addition, surveys are conducted for right whales and small cetaceans. These latter surveys are done in conjunction with ongoing research on the populations and do not have an established, routine sampling pattern.

Zooplankton

Surveys of the zooplankton populations are conducted six times per year, with about 60 stations occupied in the Gulf of Maine region on each survey. The sampling is done by bongo net tows, using 333 micron (0.33 mm) mesh. The samples are sorted to identify species and life stage for over 50 zooplankton species. The objective is to document seasonal and interannual changes in the abundance and species composition of the zooplankton community in the region. The design of the survey is based on analysis of data from the ten year MARMAP program (1978-1987), to assure the time and space scales of the sampling are appropriate for the zooplankton objective. The gear and sorting protocols are the same as those used during MARMAP, resulting in a nearly continuous time series of the zooplankton community for over two decades. This sampling is often conducted during other survey activities in order to achieve greater efficiency and minimize personnel and vessel requirements.

Phytoplankton

Both of the large vessels used by the NEFSC (ALBATROSS IV and DELAWARE II) collect continuous, near surface temperature, salinity and fluorescence data while underway. Extracted chlorophyll samples are collected

Table 1.
NEFSC Survey Activities in the Gulf of Maine, 2000

Survey Activity	Surveys/year	~Stations/year
Bottom Trawl	3	400
Scallop	1	175
Shrimp	1	60
Herring	1	acoustic transects
Marine Mammals	1-3	trackline
Zooplankton	6	360
Hydrography (CTD)	all surveys	700
Ship-Of-Opportunity Program (CPR)	12	transect

routinely to compare with the fluorescence data. In addition, the ALBATROSS IV is equipped with a Fast Repetition Rate Fluorometer (FRRF) to obtain a continuous measure of the primary production potential. The intent of the underway sampling is to determine seasonal and interannual changes in the phytoplankton component of the ecosystem. However, the activity has been initiated only recently, and a few years of sampling will be needed before its effectiveness can be properly evaluated.

Hydrography

Temperature and salinity profiles are made by conductivity, temperature, depth (CDT) recorders at each sampling site on the trawl and plankton surveys, and selectively on other NEFSC survey and research cruises. Approximately 700 profiles are collected in the Gulf of Maine region each year. The temperature data are used in some stock assessment analyses. The larger objective of the sampling is to identify seasonal and interannual variability of basic water properties in the region.

Ship-Of-Opportunity Program

Each month, a commercial container vessel traveling between Boston, Massachusetts and Halifax, Nova Scotia makes observations along a transect across the southern Gulf of Maine. A continuous plankton recorder (CPR) is towed at a depth of 10m, providing samples of the zooplankton and phytoplankton populations. In addition, surface temperature, salinity measurements, and expendable bathythermograph (XBT) profiles (which give temperature vs. depth) are collected approximately every 25 km. This monthly Ship-Of-Opportunity transect cruise has been collecting data nearly continuously for 39 years.

Satellite Imagery

The NEFSC operates the NOAA northeast COASTWATCH node, which distributes a variety of satellite-derived oceanographic products to the regional scientific community via the website at <http://narwhal.gso.uri.edu/cwatch.html>.

Summary

Overall, Gulf-wide sampling from vessels is attained five to six times each year. While the majority of the sampling is conducted to support the needs of operational fishery management, all of the sampling contributes to identifying the status and changes in important components of the Gulf ecosystem. The accumulation of these observations over time has resulted in multi-decadal time-series of the fish and plankton populations and of the hydrographic conditions. Comparable data are available in only a few other regions of the world. These time-series have been the basis for considerable research and have generated an increasing understanding of the dynamics of the Gulf ecosystem. They provided important background and rationale for the U. S. GLOBEC Georges Bank Program. More recently, the collective data sets provided the basis for identifying the essential fish habitat for many of the managed species in the Gulf region, as required by the Sustainable Fisheries Act.

The long time-series and resulting knowledge of the Gulf system are important components for a future, integrated regional observing system. When new observations indicate a change within the Gulf, the historic data and existing knowledge provide a basis for determining the significance, in a statistical sense, and importance, in an ecological sense, of that change. The ability to determine the significance and importance of observed variability make new observations considerably more valuable.

Northwest Atlantic Zonal Monitoring Program of DFO Canada

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The Atlantic Zonal Monitoring Program (AZMP) was initiated to provide the data that would advance Canada's Department of Fisheries and Oceans' (DFO) capacity to understand and describe the variability and trends of the marine ecosystem. A working group was formed to implement the program for the Atlantic coast (including the Gulf of St. Lawrence and the Bay of Fundy). The program mandate is to: (1) track and predict changes in ocean and ecosystem state and productivity; (2) respond to immediate questions posed by clients; (3) alert clients to short- and long-term changes; and (4) provide an adequate database to meet future needs. The working group's proposal (Therriault *et al.*, 1998) became the foundation of DFO's Zonal Monitoring Program for the Northwest Atlantic implemented over the last two years. This article summarizes the program, featuring the details that relate to the Bay of Fundy and Gulf of Maine.

Zonal monitoring was defined as "the minimal, ongoing collection and analysis of ocean data required to obtain a quantitative description leading to an understanding of the variability of the biological, chemical, and physical characteristics" of the region and was planned to complement existing ongoing monitoring activities. This monitoring program seeks to "(1) collect and analyze biological, chemical, and physical data to characterize and understand the causes of oceanic variability at the seasonal, interannual, and decadal scales; and (2) to provide the multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables. An additional but no less important objective is to ensure the protection of the marine environment by providing adequate data to support the sound development of ocean activities".

Clients of the program include members of federal and provincial science programs (such as Fisheries Management, Canadian Hydrographic Service, Canadian Coast Guard, and Inspection), fishers' associations, Canadian, U.S. and international scientific communities, environmental groups, and the private sector (for example, transportation and petroleum industries, engineering and environmental consultant groups).

In each of the three DFO administrative regions of the Atlantic zone, there are three small groups of field personnel, remote sensing specialists, and data analysts who are responsible for

collecting and processing the data, generating the required products and preparing the yearly reports. A data analysis working group advises on the products that are delivered and identifies new products required to answer the needs of the clients. A management and coordination committee ensures the program meets the needs of client by interacting with the clients and providing feedback to the AZMP scientists. The compilation and analysis of the datasets come to a conclusion in February of each year as results are presented at the annual meeting of the Fisheries Oceanography Committee (FOC) who is responsible to review the environmental conditions of the Northwest Atlantic.

Variables and Sampling

The geographical area of interest to DFO's monitoring program is large (Figure 1), encompasses a number of distinct marine ecosystems and is characterized by complex circulation patterns. To sample the biological, chemical and physical variables over this large area, the ZMP integrates observations from its dedicated sampling program, from other existing programs, as well as from opportunistic cruises.

The biological variables are grouped under three themes: primary production, secondary production, and fish and invertebrate species composition, distribution and abundance. The primary production variables are chlorophyll-*a* concentrations, phytoplankton-dominant species composition, Secchi depth and water transparency. Conventional field sampling is complemented with the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) that is carried by the SeaStar spacecraft ocean color imagery. Secondary production variables are

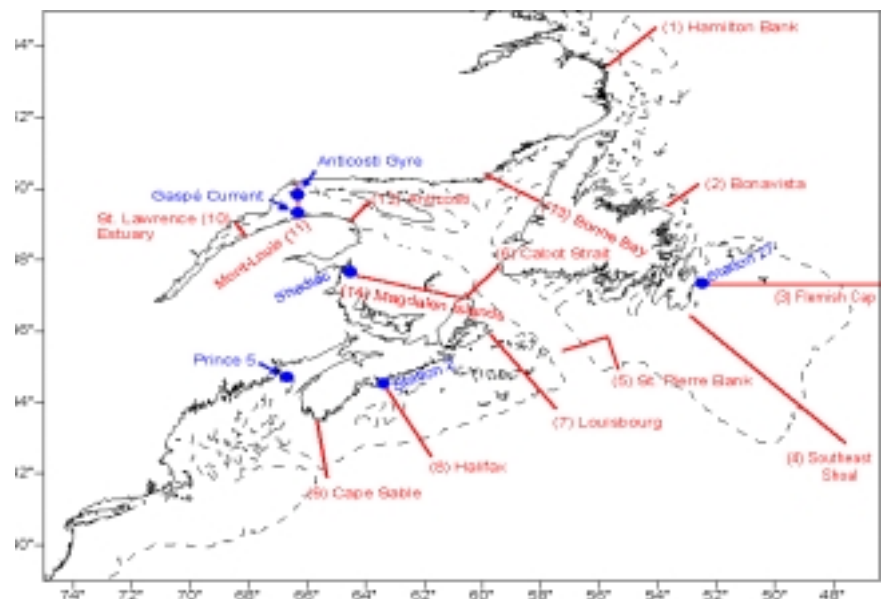


Figure 1. Location of the Sections (—) and Fixed Stations (●)

zooplankton biomass and zooplankton-dominant species composition, abundance and size structure. Trawl surveys provide data on the abundance and distribution of the fish and large invertebrates.

Chemical variables include nutrient concentrations (phosphate, nitrate, and silicate) and dissolved oxygen. These measurements add to an extensive data archive maintained at the Bedford Institute of Oceanography. Analysis of the archived and new observations has shown significant seasonal and interannual variability of nutrients and dissolved oxygen that is linked to water mass changes.

Physical variables include temperature, salinity, sea level, ice cover, freshwater runoff, and associated meteorological variables that influence currents, stratification and water properties. These are complemented by remotely sampled sea surface temperature from satellites.

The variables are measured at selected sites and sections, supplemented with data collected on regular fish surveys as well as other ship-of-opportunity cruises where key variables are measured. The selection of the sampling locations (Figure 1) and frequency was based mainly on estimates of the spatial and temporal scales of variability calculated using statistical analysis of existing physical data from the Scotian Shelf. A similar analysis is underway with the biological data sets to quantify the scales of variability for phytoplankton, zooplankton and chlorophyll (e.g., continuous plankton recorder (CPR) alongshelf transects, cross-shelf Batfish zooplankton counts (a towed undulating body), SeaWiFS, and Coastal Zone Color Scanner (CZCS) the predecessor of SeaWIFS).

The basic sampling is biweekly at six fixed sites, along with periodic sampling (1-3 times per year) of sections on the continental shelf and in the Gulf of St. Lawrence. Temperature, salinity, nutrient, dissolved oxygen, fluorescence, phytoplankton, and zooplankton tow data from these are available to the public on the AZMP Internet WEB site listed below. This basic program is supplemented by fish surveys and other ship-of-opportunity seasonal sampling in these areas as well as in the Gulf of Maine and in the Bay of Fundy. The fish surveys provide extensive hydrographic, nutrient and oxygen data, as well as zooplankton and phytoplankton sampled at a subset of the stations surveyed.

There is one fixed station in the Bay of Fundy. Prince 5, located near Passamoquoddy Bay, is sampled biweekly (see related article on p. 1). This fixed station builds on a temperature and salinity database that began in 1924. Some yearly fish surveys are also directly relevant to the Gulf of Maine: a February groundfish survey of Georges Bank, a July groundfish survey of the Scotian Shelf and Gulf of Maine, and a November Herring survey of the Bay of Fundy and Gulf of Maine. Finally, the Cape Sable section (Figure 1) measures the physical, chemical and biological character-

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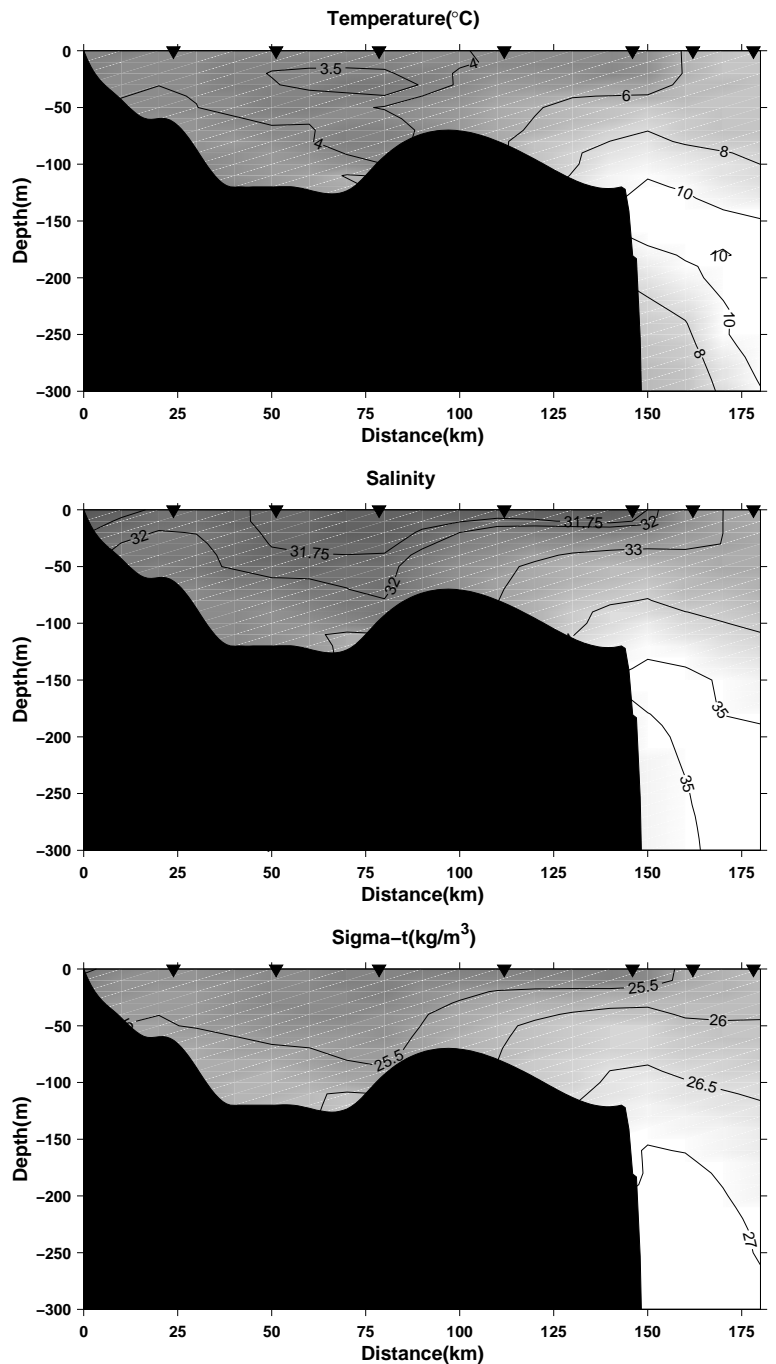


Figure 2. Compared to the long-term mean, the temperature in April 2000 was generally warmer by 2°C over the entire Shelf section. Salinity was also higher than the mean in the near-shore region but normal over Brown's Bank and over the slope. The density field was not significantly different, within 0.2 kg/m^3 , from the long-term mean.

(DFO continued)

istics of waters that flow into the Gulf of Maine and Bay of Fundy region. Figure 2 (see prior page) shows the April 2000 temperature, salinity, and density along the Cape Sable section.

Remote sensing (sea surface temperature, ocean colour estimates of phytoplankton concentration) is also a major program component providing a view of the entire zone and help with the interpretation of the above mentioned data. Public access to the SeaWiFS imagery is available on the Internet at http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs_1.html. Public access to the sea surface temperature database as well as to various analyzed products from these datasets are available at http://www.mar.dfo-mpo.gc.ca/science/ocean/database/data_query.html.

Although the AZMP is not directly involved in the development of new technologies, it strongly supports such developments as a means of ensuring the increased efficiency and quality of the sampling program. A moving vessel profiler (MVP), developed by DFO to sample to a depth of 200 m at 12-15 knots, and the Seahorse, a moored profiler which uses surface wave energy to profile the water column with a conductivity temperature depth (CTD) and associated sensors are potential tools that the AZMP could use. Both are available commercially. The MVP-200 measures temperature, salinity, pressure, and chlorophyll fluorescence; efforts are now focussed on incorporating a zooplankton counter.

Data Management and Analysis

There is a strong need to ensure that the data collected are made available in a timely fashion to all program participants. Archiving data and providing access are high priorities. It has also been recognized that there are historical data, particularly biological observations, which have not yet been archived. Another important goal is therefore to assemble and properly archive existing biological data sets.

An archive of physical oceanography data with access and analysis tools already exists and is available to the public (http://www.mar.dfo-mpo.gc.ca/science/ocean/database/data_query.html). The majority of users of this database are from outside of DFO. A chemical database that covers the Northwest Atlantic has also been assembled. Although it is not available on a web site, the data can be obtained through AZMP contacts. Public use of this database is also increasing. Biological data (e.g., zooplankton species composition) have varied formats and typically have not been stored in standard databases for easy access. A major focus over the last two years has been the development of a proper database format to accommodate the various AZMP biological variables while still facilitating the analysis. Chemical data as well as some basic physical data will be included in this biological database.

It has been recognized that for a monitoring program to be useful, the delivery of products to clients must be timely. This

is a serious consideration for each element of the program. Also, to ensure the effectiveness of the program the data analysis working group will further develop climatological indices and other specific products that will be used to answer client requests for the detection of changes in the environment. The program is still in the startup stage of data retro-analysis, data collection and analysis. Already we have deemed it necessary to modify our sampling protocol (e.g., time of year sampling for nutrients and phytoplankton, procedure for processing of zooplankton samples) and we see the need for the development of models to synthesize the data.

Some interesting results that have come to light as a result of the monitoring activities are described in recent reports. Data from the fixed stations and sections on the Scotian Shelf revealed important hydrographic changes from the fall of 1997 and throughout 1998 (DFO, 2000). The evidence points to a significant intrusion of Labrador Slope Water onto the Scotian Shelf, replacing warm slope water that had occupied the region for many years. Consistent with this intrusion, the nutrient concentrations in the bottom waters of the Shelf were lower and the dissolved oxygen concentrations higher in 1998 and 1999 than the long term mean. The same report also presents ocean color data from SeaWiFS satellite which show that both the spring and fall phytoplankton blooms on the Scotian Shelf occurred earlier in 1999 than they did in 1998.

The AZMP data, various data products, as well as the complete proposal document (Therriault et al., 1998) are available to the public via the AZMP Internet web site (http://www.meds-sdmm.dfo-mpo.gc.ca/zmp/main_zmp.html).

Conclusion

The Atlantic Zonal Monitoring Program has been designed and implemented by DFO as part of the department's long term commitment to better understand the variability and trends in the marine ecosystem. The biological, chemical, and physical data collected from dedicated AZMP field programs and from opportunity cruises provide a growing database. Through continued analysis of these data, the AZMP will contribute toward our better understanding of oceanic variability and of the links between the biological, chemical and physical variability.

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Monitoring Effluent Discharge Effects in Massachusetts Bay: The Massachusetts Water Resources Authority Tests Value-Based Hypotheses

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Public goals for Massachusetts Bay and Boston Harbor are: to ensure that harbor beaches are safe for swimming, fish and shellfish are safe to eat, the marine ecosystem is healthy, and that the beauty of the environment is protected. The Massachusetts Water Resources Authority (MWRA, <http://www.mwra.com>), the public water and sewer utility serving greater Boston, is charged with the safe and sanitary treatment and disposal of sewage for 2.5 million people. MWRA has upgraded sewage treatment and is moving its effluent discharge from a near-shore location in Boston Harbor to an offshore location in the deeper waters of Massachusetts Bay.

To ensure that the discharge into Massachusetts Bay does not adversely impact the marine environment and that public health is protected, MWRA began implementing a comprehensive monitoring program in 1992. The monitoring program includes both harbor and bay, with measurements before and after the new offshore outfall is in use. The program tests specific hypotheses that were derived from public goals, in order to measure whether the goals are met. The hypotheses and the monitoring program were developed by an “Outfall Monitoring Task Force”, comprised of environmental advocacy groups, citizens, regulatory agencies, and scientists.

In the MWRA program, extensive monitoring of effluent, water column, sea floor, and fish and shellfish (see Table 1, next page), are linked to a contingency plan. The contingency plan, unique among wastewater dischargers, is designed to connect corrective actions to environmental monitoring results if an unexpected discharge-related impact may be occurring. The contingency plan is built around a number of testable

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