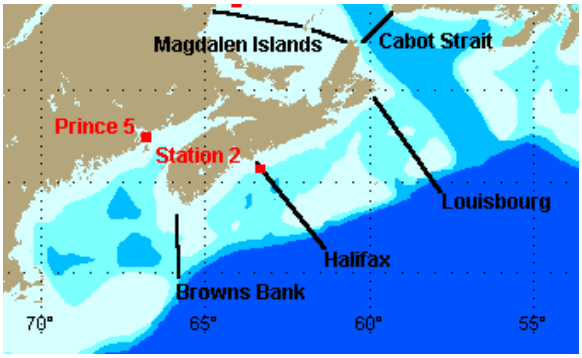
2002 State of the Ocean: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine



Background

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution catchability, availability) of marine organisms as well as the operations of the fishing industry. Changes in this environment may contribute directly to variations in resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass as well as influence the perception of the resource status and the efficiency and profitability of the industry.

Physical oceanographic conditions (mainly water temperature and salinity) are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the ***Atlantic Zonal Monitoring Program (AZMP)****. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, including standard monitoring stations, research studies, ships-of-opportunity, fishing vessels, and remote sensing (satellites).*

All of the hydrographic data are edited and archived in Canada's national Marine Environmental Data Service (MEDS) database. A working copy is maintained in a Northwest Atlantic database at the Bedford Institute of Oceanography.

Summary

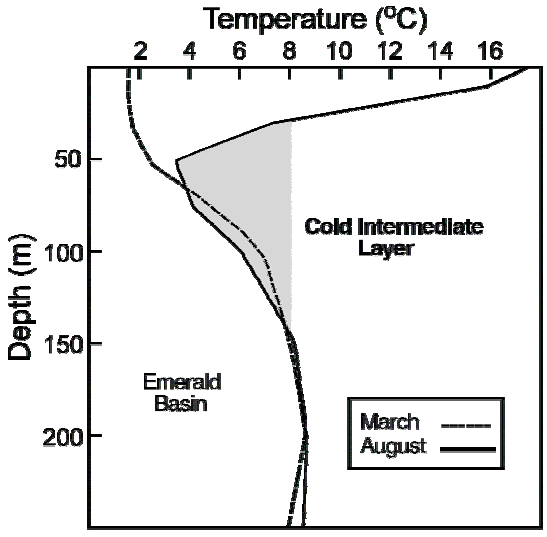
- Annual average air temperatures over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were warmer-than-normal.
- The amount of sea ice that was observed seaward of Cabot Strait remained low for the fifth consecutive year.
- Sea-surface temperatures were generally warmer-than-normal in the Gulf of Maine with Boothbay Harbor in Maine recording it warmest year since the 1950s and the third warmest in its 97-year record.
- Slightly warmer-than-normal bottom waters covered most of the Scotian Shelf and the Gulf of Maine in 2002, and a significant increase compared to 2001.
- Salinities tended to be saltier-than-average, especially at Prince 5 in the Bay of Fundy where they were at their highest level since 1980.
- Vertical stratification in the top 50 m over the Scotian Shelf was lower-than-average, and continued the decreasing trend of the past three years.

Average Conditions

Temperature and salinity conditions within the Scotian Shelf, Bay of Fundy and Gulf of Maine vary spatially due to complex bottom topography, transport from upstream sources such as the Gulf of St. Lawrence, melting of sea-ice in spring, and exchange with the adjacent, offshore slope waters. Water properties are also characterized by large seasonal cycles, depth differences and horizontal east-west and inshore-offshore gradients.

The seasonal temperature range of the waters over the Scotian Shelf decreases with depth. At the surface, the range is about 16°C but there is little or no seasonal change at depths greater than approximately 150 to 200 m. In the shallow regions of the Gulf of Maine, such as Lurcher Shoals, the Bay of Fundy and Georges Bank, the seasonal cycle shows much less change with depth due to vertical mixing by the strong tidal currents.

In the winter, the water column in deep regions of the Scotian Shelf consists of two layers separated by a transition zone, as can be seen in the plot of temperature as a function of depth in Emerald Basin.



The upper layer is mixed by the winter winds and contains cold, low salinity water. The bottom layer has relatively warm and salty water. The latter originates from the offshore slope region and enters the Shelf through deep channels or gullies. In summer, seasonal heating forms a thin (30-40 m) warm upper layer. The winter-cooled waters form a cold intermediate layer (CIL; 40-150 m) and the warm bottom layer remains unchanged. Variation in this vertical structure occurs over the shelf. The warm offshore waters do not penetrate onto the eastern Scotian Shelf and hence waters typical of the CIL (temperatures less than 5°C) extend to the bottom. Further, throughout the Scotian Shelf where depths are shallower than 150 m, there is no warm bottom layer. In areas of strong tidal currents, such as off southwest Nova Scotia, the waters even in summer are vertically well mixed.

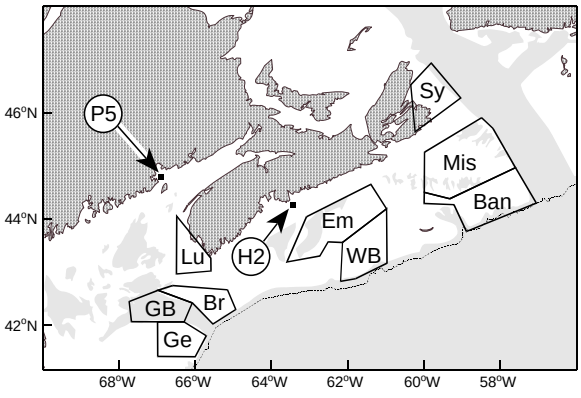
Temperatures and salinities generally increase from east to west and from inshore to offshore due to the influences of the warmer, more saline offshore waters and the outflow of the fresher water from the Gulf of St. Lawrence. For example, in the summer within the CIL, the 50 m temperatures typically range from 0-3°C over the eastern Scotian Shelf, 3-8°C over much of the central shelf and 6-9°C over the western Scotian Shelf, eastern Gulf of Maine and Bay of Fundy. The one exception to the general trend in horizontal distributions is the surface temperatures in summer, when they increase from west to east due to the warm surface outflow from the Gulf of St. Lawrence.

The near-bottom temperatures display similar ranges to those at 50 m, except over the central shelf where the range increases to 3-9°C, the slightly higher

range being caused by the intrusion of the offshore waters.

Long-Term Time Trends

Year-to-year, water temperatures on the Scotian Shelf and in the Gulf of Maine are among the most variable in the North Atlantic Ocean. Information on this variability is derived from several sources. Long-term coastal sea-surface temperatures are available at Halifax and St. Andrews. Hydrographic monitoring sites within the region include Prince 5 (P5), located at the mouth of the Bay of Fundy, and a new monitoring site established in 1998 at the location of standard station 2 on the Halifax Line (H2). Monthly temperature and salinity data have been collected at Prince 5 since the 1920s. The Atlantic Zonal Monitoring Program (AZMP) has also reinstituted the occupation of standard sections including the Halifax Line. In addition to these data from the monitoring sites and sections, temperature time series have been constructed for several areas from data collected during fisheries surveys and oceanographic studies.



Sy - Sydney Bight
Ban - Banquereau
WB - Western Bank
Lu - Lurcher Shoals
GB - Georges Basin
P5 - Prince 5
Mis - Misaine Bank
Em - Emerald Basin
H2 - Halifax Stn 2
Br - Browns Bank
Ge - Georges Bank

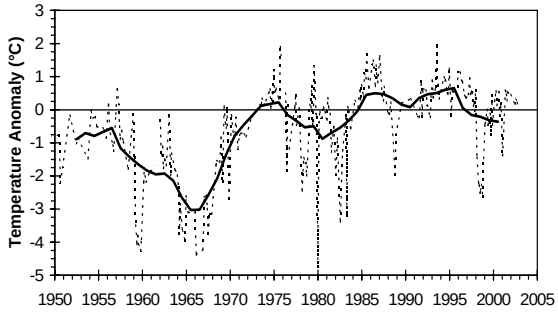
In order to detect time trends in temperature, the seasonal cycle is removed by calculating deviations (anomalies) of temperatures from the long-term (1971-2000) monthly averages for each area. Inter-annual variability is also expressed as anomalies. With the exception of the Prince 5 series, the data from most areas are sparse prior to 1950.

In general, the temperature records are characterized by short period spikes, superimposed on long period (10-30 year) trends with amplitudes of 1-2°C. The spikes often represent “noise” due in large part to limited amounts of data and usually show little similarity from area to area. The long-period trends show strong similarity over much of the Scotian Shelf and the Gulf of Maine. In the time series plots, the dashed lines indicate monthly averages and the solid lines are the 5-year running averages of the annual averages.

The temperature pattern in Emerald Basin is representative of the long-period trends in the deep waters throughout the central and western shelf and in the Gulf of Maine. Temperatures were near or above average in the 1950s and declined to below average in the 1960s. The extended period with the lowest temperatures occurred during the mid-1960s. Temperatures rose rapidly in the late 1960s and from the 1970s to 1997 generally remained warmer-than-average. Indeed, the highest sustained temperature anomalies in the approximate 50-year record were observed in the 1990s. In 1998 there was a rapid decline to levels not seen since the early 1980s and the 1960s. These cold waters were in turn replaced with waters of temperatures near to their long-term average in 1999 and warmer in 2000 and 2001. Temperatures events in

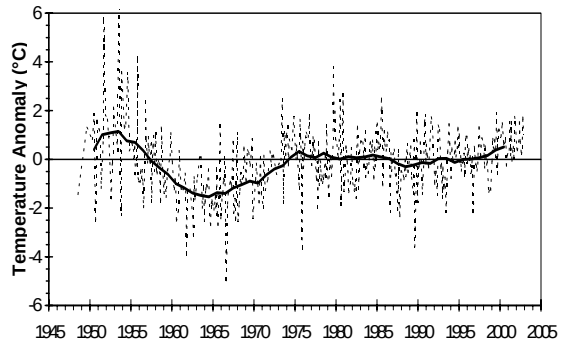
2002 are discussed in more detail in the next section.

Emerald Basin – 250 m



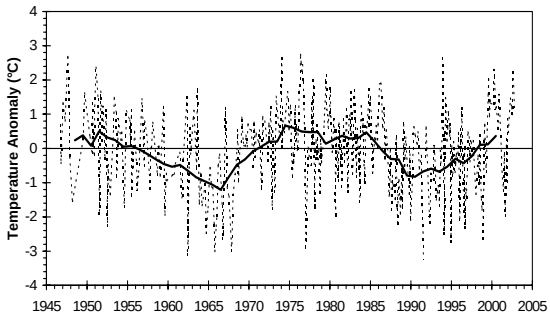
In shallower waters over the shelf, temperature trends were similar to those in the deep waters until the mid-1980s. Temperatures on eastern Georges Bank, which are representative of the offshore banks including Browns and Western, tended to be above average through most of the 1970s and 1980s but declined slightly in the late 1980s. Through the 1990s, temperature anomalies varied above and below zero but the 5-year running averages have generally remained above normal in recent years.

Eastern Georges Bank – 50 m



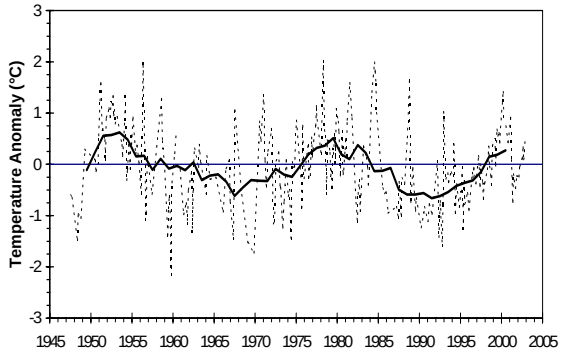
Temperatures in the shallow inshore areas of southwest Nova Scotia (Lurcher Shoals) show a clear decline from the mid-1980s to the early 1990s, reaching levels comparable to those in the cold period of the 1960s. Temperatures generally remained below average from the mid-1980s to the late 1990s. In 1999 and 2000 they rose to above normal but fell dramatically in 2001.

Lurcher Shoals – 50 m



In intermediate and deep waters of the eastern shelf, as exemplified by Misaine Bank, the amplitude of the long-period temperature trend is smaller (order 1°C) than for the rest of the shelf. Also, the low temperature anomalies during the 1960s were not as cold as elsewhere on the Scotian Shelf such as in Emerald Basin or over Lurcher Shoals. From the late-1960s to the mid-1970s, temperatures at Misaine Bank oscillated near or above average. They rose above normal around 1980 but by the mid-1980s, temperatures fell sharply. Throughout most of the water column, temperatures were generally colder-than-normal until the late 1990s. The minimum temperature was recorded in the early 1990s, after which temperature anomalies rose. By 1999 and 2000 anomalies were above the long-term average but fell in 2001 to below average. The long-term temperature trends over the eastern inshore areas (e.g. Sydney Bight) and offshore banks (e.g. Banquereau) are similar to those in the Misaine area.

Misaine Bank – 100 m

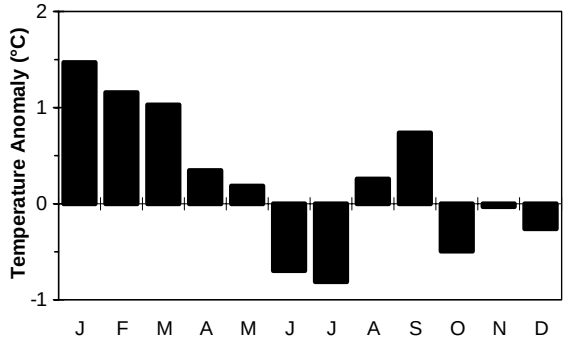


In the deep waters of Cabot Strait, temperatures were coldest during the 1960s but have been above or near average in recent years.

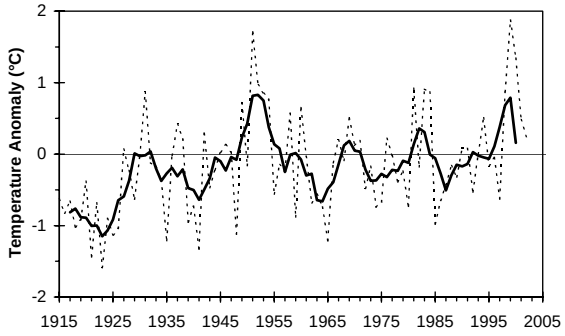
The general temperature trends described above are reflected in the time series of the summer research vessel stratified average near-bottom temperatures for the Bay of Fundy (NAFO Division 4X) as well as the western (4X), central (4W) and eastern (4Vs) Scotian Shelf.

Conditions in 2002

Sable Island Air Temperatures
2002 Monthly Anomalies



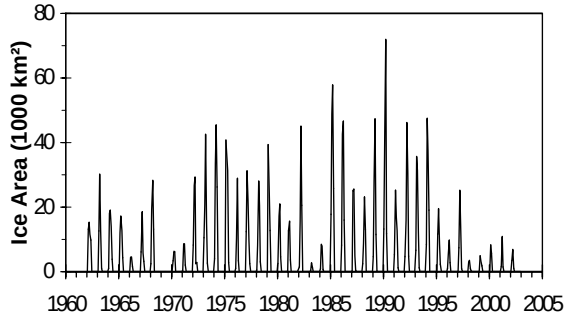
Annual Time Series



Annual air temperatures over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were warmer-than-normal in 2002. This was due mostly to warm conditions in the winter, early spring and late summer. The maximum monthly anomaly was in January (>1.5°C). Although 2001 was warmer-than-average, the annual temperature declined for the third consecutive year after the record setting high in 1999.

The amount of sea ice that was observed seaward of Cabot Strait in 2002 remained low for the fifth consecutive year. Most of this ice was located in the Sydney Bight region, with little ice reaching the Scotian Shelf proper. The total number of days with ice seaward of Cabot Strait in 2002 was the third lowest and the integrated ice coverage (the sum of the daily areas of ice) was the second lowest in the 41-year record.

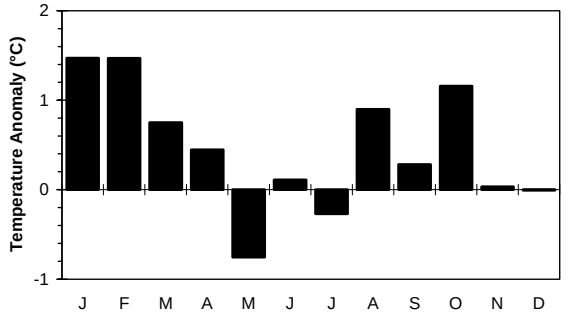
Monthly Average Area of Sea Ice
Seaward of Cabot Strait



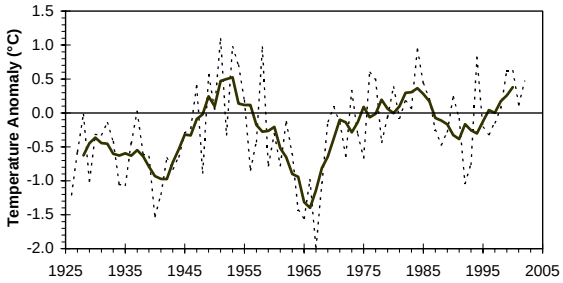
Monthly average coastal sea-surface temperatures in the Gulf of Maine during 2002 were warmer-than-normal continuing the trend of positive temperature anomalies that persisted through the 1990s. At Boothbay Harbor Maine, it was the warmest year since the 1950s and the third warmest in the 97-year record. St. Andrews, N.B., recorded its ninth warmest year in 81 years. In contrast, at Halifax, monthly average temperatures were generally colder-than-normal, similar to 2001 and below the warm conditions observed in 1999 and 2000.

At Prince 5, monthly average temperatures throughout the water column were dominated by warmer-than-average conditions. Annual average temperatures were above normal. At all depths temperatures increased relative to 2001 values. The annual salinity anomalies at Prince 5 were saltier-than-normal, rising dramatically from the 1999-2001 values, and well above the fresh conditions of the 1990s. The annual average salinity was the highest since 1980.

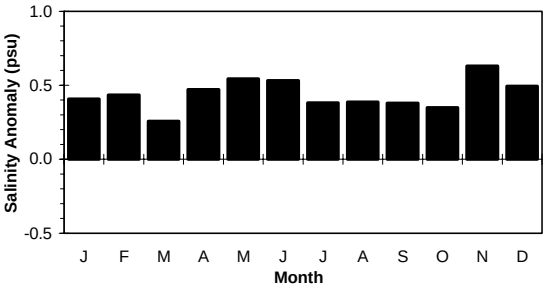
Prince 5 – 0 m
2002 Monthly Temperature Anomalies



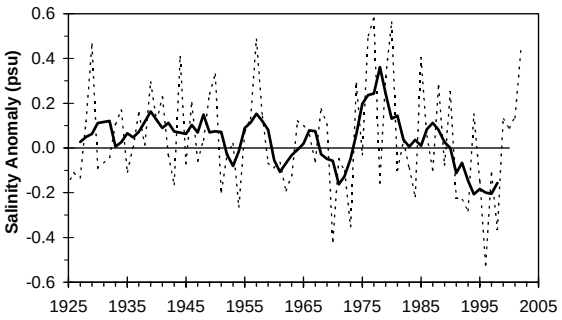
Annual Temperature Time Series



2002 Monthly Salinity Anomalies



Annual SalinityTime Series

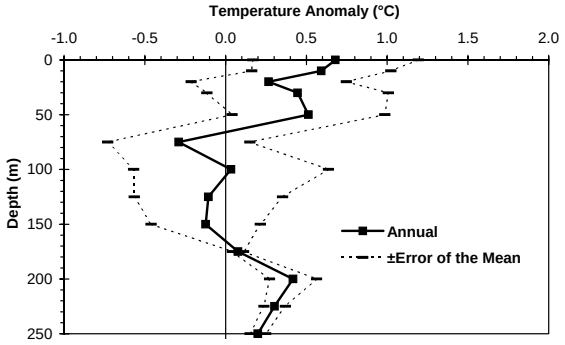


In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait were above normal in 2002, similar to 2000 and 2001. They are at levels not observed since the late 1970s.

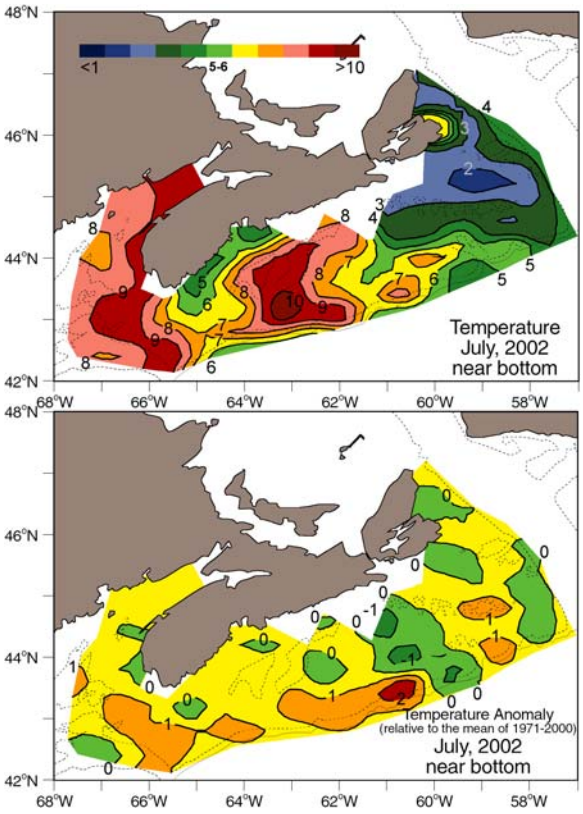
In 2002, the waters in Emerald Basin tended to be warmer-than-normal throughout the year in both the top 50 m and near bottom (200-250 m), resulting in positive annual temperature anomalies. At mid-depth (75 to 175 m), below normal annual temperatures were observed, but the latter were not considered significantly different than the long-term

averages based on the error of the means.

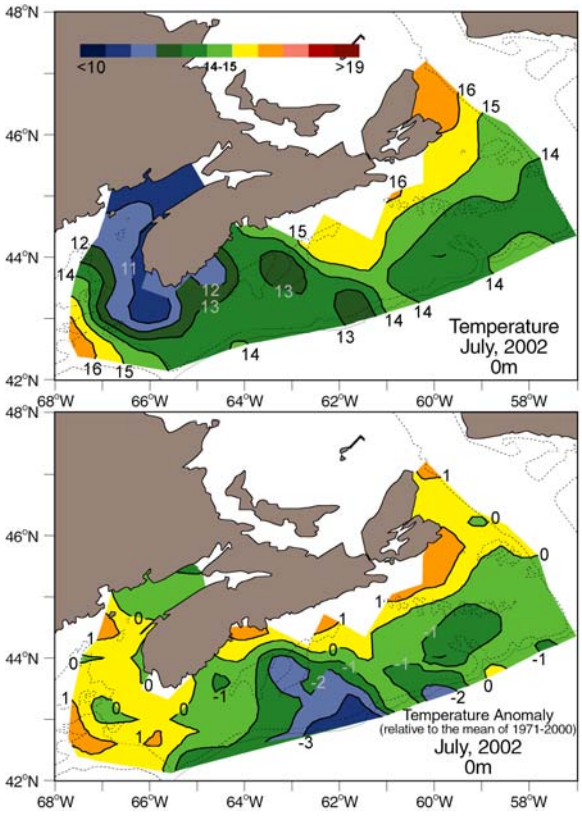
Emerald Basin
2002 Annual Temperature Anomaly Profile



Near-bottom temperatures over most of the Scotian Shelf during the July groundfish survey of 2002 were mostly above normal. The few areas of below normal bottom temperatures were mainly found in the northeast. In all regions of the Shelf and in the Bay of Fundy, these temperatures increased substantially over those in 2001. This resulted in a return to conditions observed during the late 1990s. Emerald and LaHave Basins in the central shelf were covered by near-bottom temperatures >9°C, indicative of the influence of Warm Slope Water from offshore. Temperature anomalies at 50 m and 100 m from the July survey were also dominated by positive anomalies but with larger areas of colder-than-normal temperatures than near bottom.

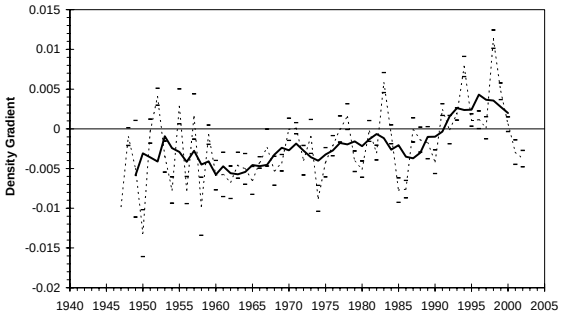


The temperatures at the surface ranged from over 16°C in the northeast to <11°C in the Bay of Fundy during the July groundfish survey in 2002. Over the outer two-thirds of the shelf, temperature anomalies indicated colder-than-normal temperatures, upwards of -2°C over parts of Emerald and LaHave Basins. Above normal surface temperatures were observed in the Gulf of Maine off southern Nova Scotia and inshore on the Scotian Shelf from the Laurentian Channel to an area south of Lunenburg Bay.



In the ocean, lighter water lies over top of denser waters. The density differences are due to differences in the temperature and salinity characteristics with depth. The difference in density with depth is referred to as density stratification. Through the 1990s, the density difference over the top 50 m averaged throughout the Scotian Shelf increased significantly. From the mid- to late 1990s, this stratification index was at or near its maximum in the approximately 50-year record. No increase in density stratification was observed in the Gulf of Maine, however. The primary cause of changes in the Scotian Shelf stratification was a freshening of the near-surface waters through advection of low salinity waters from off the Grand Bank. As the stratification increases in the upper layers, vertical mixing is reduced, which in turn can decrease nutrient replenishment to the surface waters. In 2002, stratification was lower-than-average and continued the decreasing trend of the past three years.

Density Stratification in Upper 50 m Over the Scotian Shelf



In 2002, the annual average position of the thermal boundaries between the shelf waters and the slope waters (the Shelf/Slope front) as well as between the slope waters and Gulf Stream (the north wall of the Gulf Stream) remained essentially unchanged relative to 2001. For the Shelf/Slope front, it was seaward of its long-term average position whereas the Gulf Stream front was shoreward of its long-term average.

For more Information

Contact:

Ken Drinkwater
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

Tel: (902) 426-2650
Fax: (902) 426-7827
Email: drinkwaterk@mar.dfo-mpo.gc.ca

References

Drinkwater, K.F., B. Petrie, R.G. Pettipas, and W.M. Petrie. 2003. Overview of meteorological, sea ice and sea-surface temperature conditions off

eastern Canada in 2002. DFO Can. Sci. Advisory Sec. Res. Doc. 2003/024, 37 p.

Drinkwater, K., B. Petrie, R. Pettipas, L. Petrie, and V. Soukhovtsev 2003. Physical oceanographic conditions on the Scotian Shelf and in the Gulf of Maine during 2002. DFO Can. Sci. Advisory Sec. Res. Doc. 2003/026, 54 p.

This report is available from the:

Maritime Provinces
Regional Advisory Process
Fisheries and Oceans Canada
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Phone number: 902-426-7070
Fax Number: 902-326-5435
e-mail address: myrav@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1480-4913 (printed)

La version française est disponible à l'adresse ci-dessus.

Correct citation for this publication:

DFO, 2003. 2002 State of the Ocean: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine. DFO Science Ecosystem Status Report 2003/005.