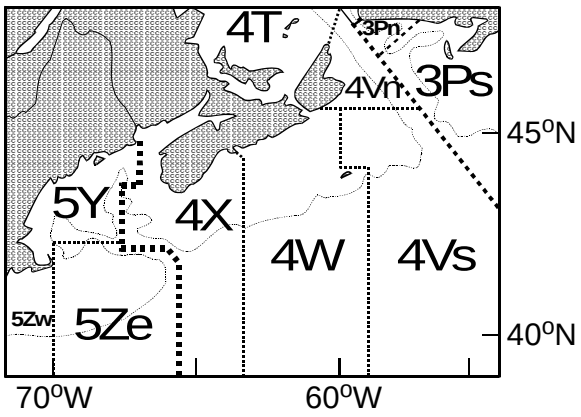
Fisheries and Oceans / Pêches et Océans
Maritimes Region

DFO Science
Stock Status Report G3-01(2000)

1999 State of the Ocean: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine



Summary

- Annual air temperatures in 1999 over the region were the highest in the historical records, some of which exceeded 100 years.
- There was little sea-ice on the Scotian Shelf during the winter with the 5th lowest areal coverage in the 38-year record.
- Sea surface temperatures were warmer-than-normal over most of the year (monthly anomalies of 2-6°C) with maximum values during the summer.
- For the first time since the mid-1980s significant proportion of the subsurface waters on the northeastern Scotian Shelf had temperatures that were above normal.
- The cold bottom waters that had flowed over the southwestern Scotian Shelf and into the Gulf of Maine in 1998 were replaced with warmer water in 1999 and returned to the near normal values.
- The source of these higher temperatures on the bottom was offshore Warm Slope Water that flowed onto the shelf through the deep channels and gullies.

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. 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.

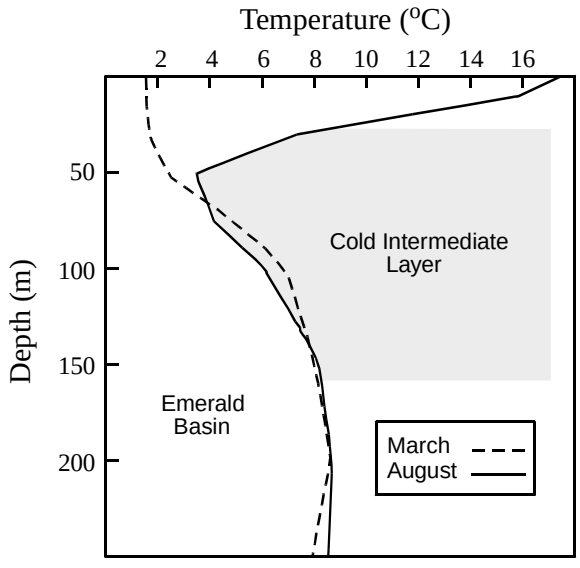
May 2000

Canada

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.

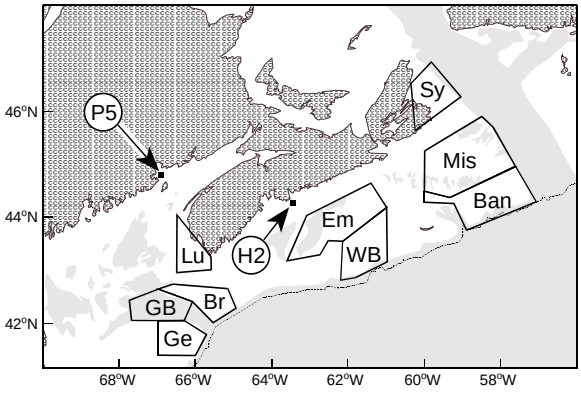
The upper layer is mixed by the winter winds and contains cold, low salinity water. The bottom layer has relatively warm and salty water. The latter originates from the offshore slope region and enters the Shelf through deep channels or gullies. In summer, seasonal heating forms a thin (30-40 m) warm 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 instituted 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.



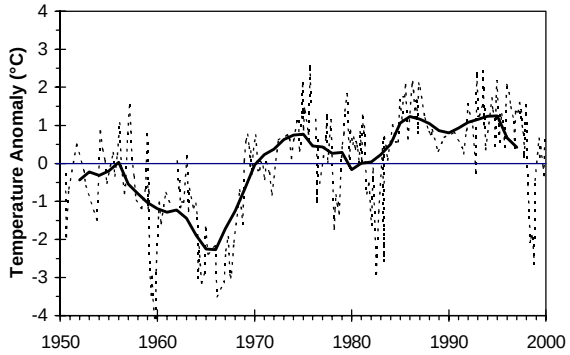
Sy -Sydney Bight
Mis-Misaine Bank
Ban-Banquereau
Em -Emerald Basin
WB-Western Bank
H2 - Halifax Stn 2
Lu - Lurcher Shoals
Br - Browns Bank
GB - Georges Basin
Ge - Georges Bank
P5 - Prince 5

In order to detect time trends in temperature, the seasonal cycle is removed by calculating deviations (anomalies) of temperatures from the long-term (1961-90) monthly means 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 in this section, the dashed lines indicate monthly means and the solid lines are the 5-year running means of the annual averages.

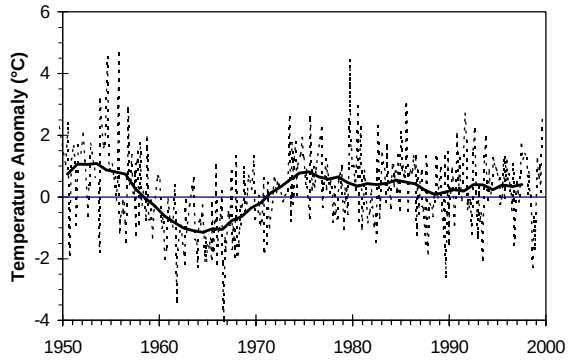
The temperature pattern in Emerald Basin is representative of the long-period trends in the deep waters throughout the central and western shelf and in the Gulf of Maine. Temperatures were near or above average in the 1950s and declined to below average in the 1960s. The extended period with the lowest 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 have subsequently disappeared to be replaced by conditions representative of the long-term mean. Temperature events in 1999 are discussed in more detail in the next section.

Emerald Basin – 250 m



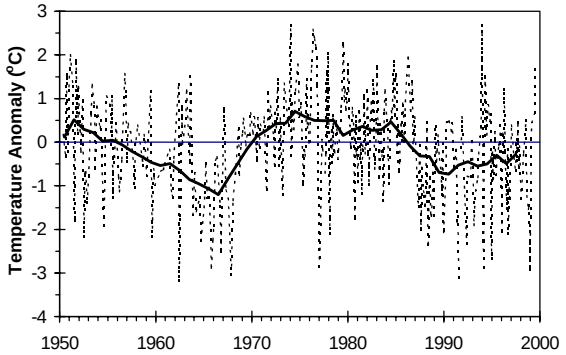
In shallower waters over the shelf, temperature trends were similar to those in the deep waters until the mid-1980s. Temperatures on eastern Georges Bank, which are representative of the offshore banks including Browns and Western, tended to be above average through most of the 1970s and 1980s but declined slightly in the late 1980s. Through the 1990s, temperatures have varied above and below the mean but their average (using 5-year running means) has generally remained above the long-term mean.

Eastern Georges Bank – 50 m



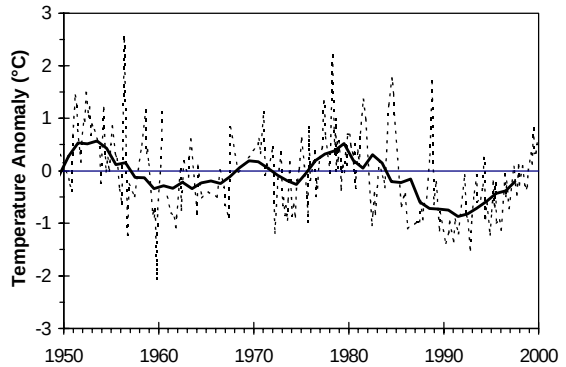
Temperatures in the shallow inshore areas of southwest Nova Scotia (Lurcher Shoals) show a clear decline from the mid-1980s to the early 1990s, reaching levels comparable to those in the cold period of the 1960s. Temperatures have generally remained below average since the mid-1980s. Very cold waters were observed in 1998, which have since warmed.

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 have generally remained colder-than-normal during the past decade although in recent years they have been rising. 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.

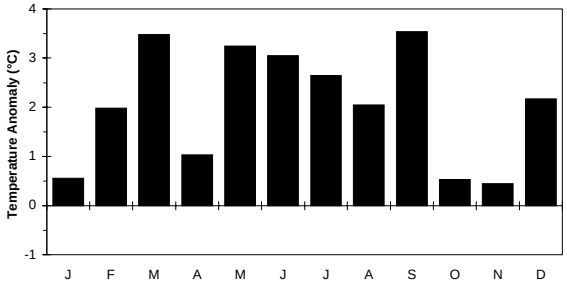
The general temperature trends described above are reflected in the time series of the summer research vessel stratified mean near-bottom temperatures for the Bay of Fundy (4X) as well as the western (4X), central (4W) and eastern (4Vs) Scotian Shelf.

Conditions in 1999

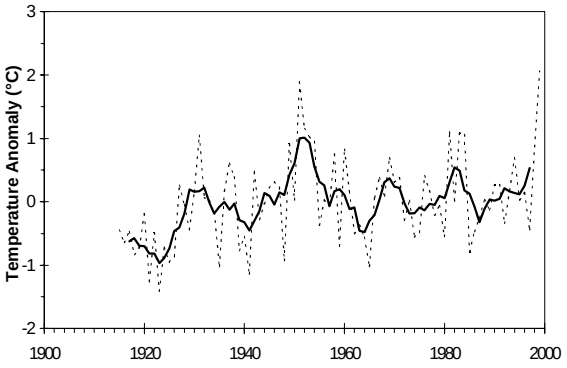
Annual mean air temperatures over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine set record highs during 1999 with anomalies approximately 2°C above normal. At some sites, the length of the dataset extends over 100 years. The highest temperature deviations from the long-term mean occurred during the spring and summer.

Sable Island Air Temperatures

1999 Monthly Anomalies

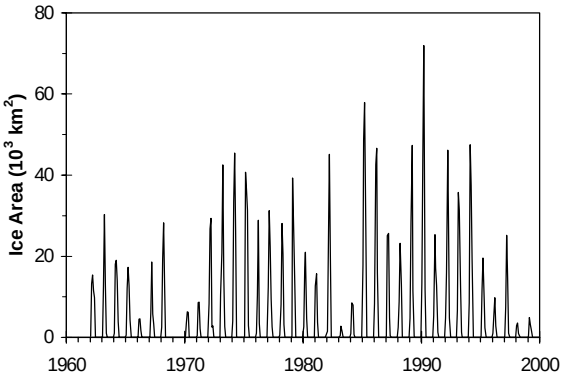


Annual Time Series



No significant amount of sea ice reached the Scotian Shelf in 1999, similar to the very low levels in 1998. The small amount of ice that did extend seaward of Cabot Strait was largely confined to the Sydney Bight region. The ice coverage in 1999 seaward of Cabot was the fifth lowest in the 38-year record.

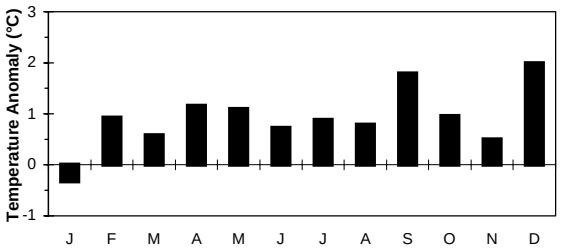
Monthly Mean Area of Sea Ice
Seaward of Cabot Strait



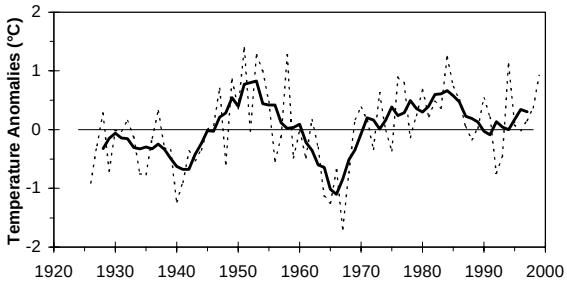
Ocean temperature conditions depend upon location and depth. Monthly mean coastal sea surface temperatures in the Gulf of Maine and the Bay of Fundy during 1999 were over 1°C warmer-than-normal. At Halifax, monthly mean temperatures deviated about their long-term averages resulting in a near normal annual mean. This was slightly cooler than in 1998.

At Prince 5, temperatures throughout the water column were warmer-than-normal in 1999 during all months except January. This resulted in above-normal annual mean temperatures and an increase relative to 1998 values. The annual salinity anomalies at Prince 5 were saltier-than-normal and rose relative to 1998 values.

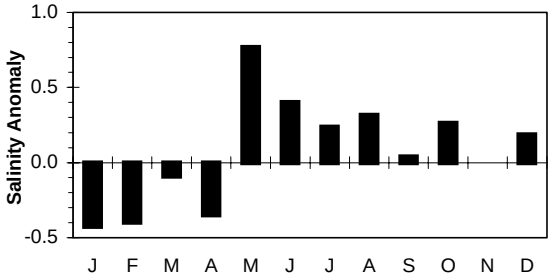
Prince 5 – 0 m
1999 Monthly Temperature Anomalies



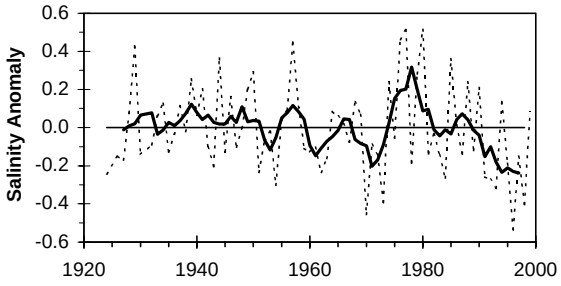
Annual Temperature Time Series



1999 Monthly Salinity Anomalies



Annual SalinityTime Series

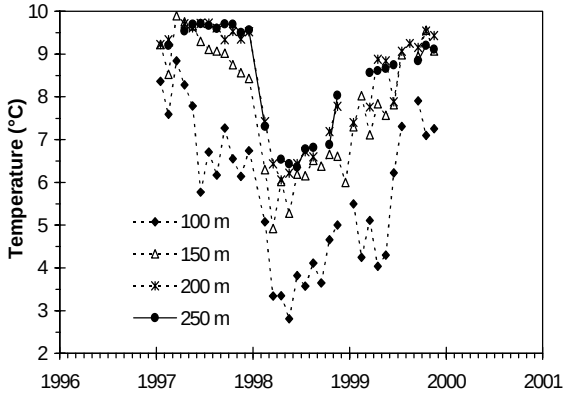


In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait also rose significantly over the near normal values observed in 1998. They reached levels not observed since the late 1970s.

Temperature of the bottom waters over most of the northeastern Scotian Shelf during the July groundfish survey was at or slightly above the long-term mean. This is the first time in approximately 15 years that most of the region has experienced above normal temperatures, although temperatures have been increasing during the past several years.

During the autumn of 1997, very cold waters of Labrador Current origin were observed along the continental slope of the Scotian Shelf at depths of 100 to 300 m as far south as Emerald Basin. They replaced Warm Slope Water that had occupied this region over most of the past 30 years. By December of that year, these cold waters began to penetrate into Emerald Basin and by February of 1998, they completely occupied the deep layers of the basin. Between December and April of 1998 temperatures in the basin fell by over 3°C while salinities declined by over 0.6. By the time the summer groundfish survey was conducted in July 1998, these cold waters had spread throughout much of the central and southwestern Scotian Shelf. Indeed, the 1998 temperatures in 4X and 4W from the groundfish survey were the coldest recorded since the survey began in 1970.

Emerald Basin

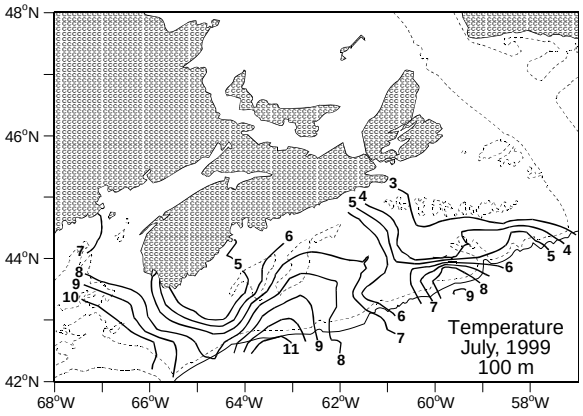


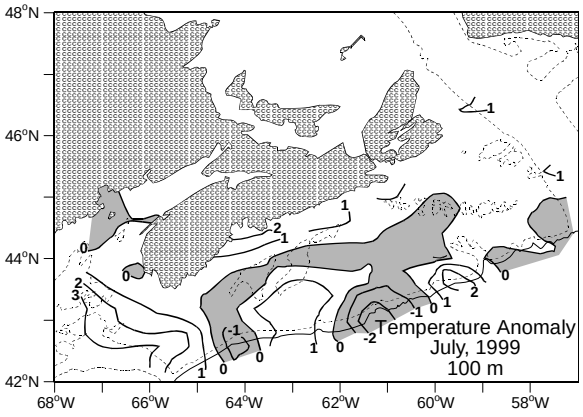
The cold Labrador Slope Water also pushed southward along the continental slope, extending the entire length of the Scotian

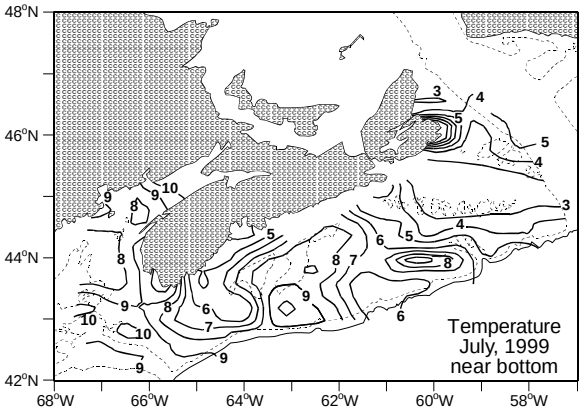
Shelf by January 1998. At this time, these waters began to enter the Gulf of Maine through the Northeast Channel. By February, they occupied the southern flank of Georges Bank and by March moved even further westward to lay at the offshore entrance to the Great South Channel. In the Gulf of Maine, the cold waters flushed Georges Basin by April 1998 but did not penetrate the inner basins of the Gulf until that summer. It appeared as if they had mixed with the warmer resident waters rather than replaced them, as had occurred in Emerald and Georges basins. The effects of this cold water were not limited to the deep basins but were also observed in some shallower areas as well, e.g. on Georges Bank.

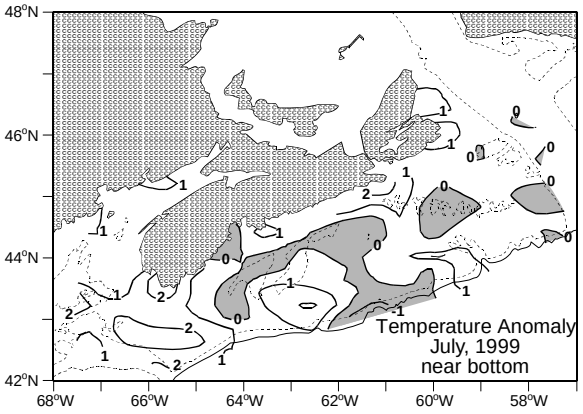
In 1999, the cold Labrador Slope Water that had penetrated southward along the shelf retracted northward so that its leading edge was restricted to approximately the area of the Laurentian Channel. As it retracted, the Warm Slope Water replaced it and throughout 1999 this warm water occupied the outer edge of the Gulf of Maine and the Scotian Shelf. It also gradually penetrated onto the Shelf in the deep layers, replacing the remnants of the Labrador Slope Water that had covered the region since early to mid-1998.

The temperatures at 100 m show a similar pattern to that observed near bottom, i.e. above normal temperatures throughout most of the Scotian Shelf.









In the ocean, lighter water lays over top of heavier, denser waters due to differences in the temperature and salinity characteristics. The difference in density with depth is referred to as density stratification. From the early 1990s to present, the vertical density stratification in the top 50 m over the Scotian Shelf has increased significantly. Since the mid-1990s, it has been at or near its maximum in the approximately 50-year record. No increase in density stratification has been observed in the Gulf of Maine, however. The primary cause of changes in the Scotian Shelf stratification has been a freshening of the near surface waters. As the stratification increases in the upper layers, vertical mixing is reduced, which in turn can decrease nutrient replenishment to the surface waters.

For more Information

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Internet address: http://www.dfo-mpo.gc.ca/csas
ISSN: 1480-4913

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Correct citation for this publication

DFO, 2000. 1999 State of the Ocean: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine. DFO Science Stock Status Report G3-01 (2000).