Fisheries and Oceans | Pêches et Océans

DFO Science
Stock Status Report G0-01(1998)

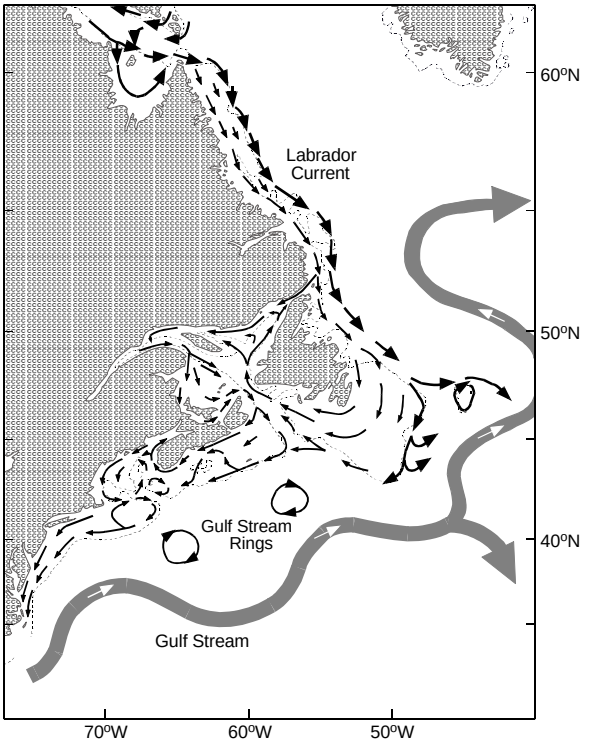
1997 State of the Ocean: Northwest Atlantic

Background

The abundance, growth, catchability and geographic distribution of many fish and shellfish stocks vary in response to environmental change. Therefore, to help understand the cause of observed fluctuations in fish and shellfish resources and eventually predict future changes, we seek to describe and understand the ocean climate and its variability.

Catches of most major fish and shellfish species off eastern Canada have centered on offshore banks but most of the continental shelf, including estuaries and embayments, from Hudson Strait to the Gulf of Maine are commercially exploited. In addition, the habitat of andromous (e.g. salmon) and catadramous species (e.g. eels) extend from the inland river systems to the deep open ocean at different times of the year. Climate summaries of the physical oceanographic conditions (mainly water temperature and salinity) within this broad geographic area are gathered from standard monitoring stations, regional resource surveys, research studies, ships-of-opportunity, fishing vessels, and satellite imagery. Additional data on hydrological, meteorological and sea ice conditions are collected or gathered from various government departments.

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



Mean Conditions

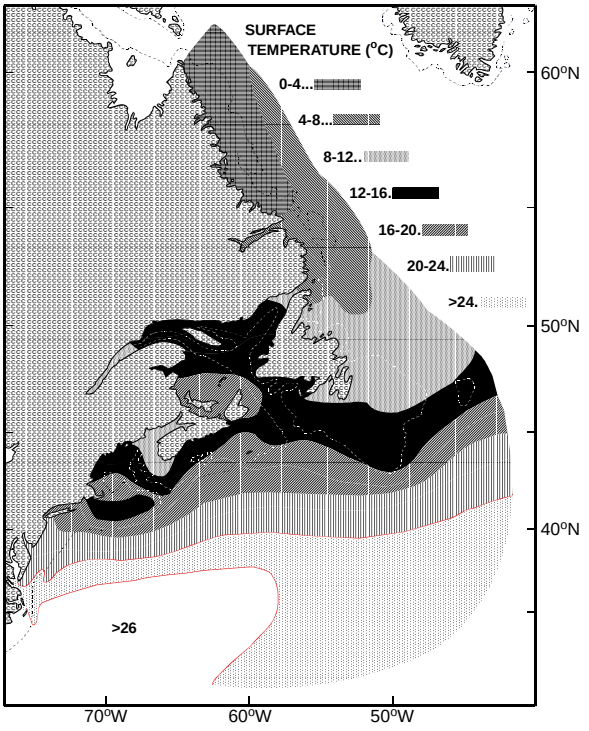
The circulation of the continental shelf waters off eastern Canadian is dominated by general southward flow. From Hudson Strait to the Grand Bank, the waters are transported south by the Labrador Current. Some of the surface flow continues into the Gulf of St. Lawrence, circulates anticlockwise within the Gulf and exits on the south side of Cabot Strait off the northern tip of Cape Breton Island. The water flows onto the Scotian Shelf and is transported south by the Nova Scotian Current. From there, it moves into and around the Gulf of Maine before continuing its southward journey on the Middle Atlantic Bight. In the deep

waters off the continental shelf, the major circulation feature is the eastward flowing Gulf Stream and its northward extension, the North Atlantic Current. The waters that lay off the shelf over the continental slope and extend seaward out to the Gulf Stream are known as "slope waters". The slope water region normally contains one or more Gulf Stream rings or eddies. They form from Gulf Stream meanders which break off from the Stream and will last anywhere from a few days to over a year. These eddies tend to be about 1000 m deep which prevents them from moving onto the shallower continental shelf. As the eddies approach the shelf, they do promote cross-shelf exchange, drawing water off the continental shelf into the slope water region and pushing slope water onto the shelf.

Sea ice forms in winter off much of Canada's east coast. The Labrador Shelf, northern Newfoundland Shelf and the Gulf of St. Lawrence are typically ice covered during part of the year with the southern-most limit of ice extending onto the southern Grand Bank and the central Scotian Shelf in heavy ice years.

Large quantities of freshwater are discharged from Canadian rivers onto the continental shelves. Major contributors are the Churchill River on the Labrador coast, the numerous rivers flowing into the Gulf of St. Lawrence (of which the largest runoff comes from the St. Lawrence River), and the Saint John River which empties into the Gulf of Maine. The many rivers flowing into Hudson and Ungava bays provide freshwater to the Labrador Shelf through Hudson Strait. All of the rivers exhibit large seasonal variations with the maximum runoff in spring, when the snow melts, and a minimum in summer.

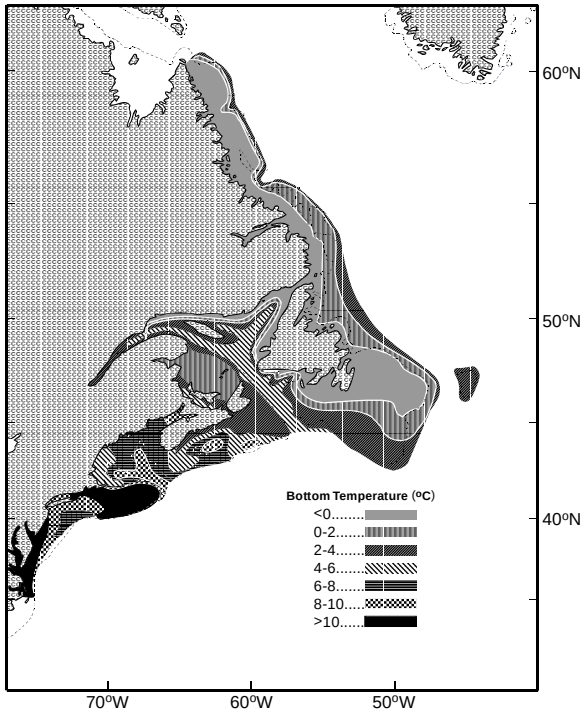
Temperature and salinity conditions of the waters within the Northwest Atlantic vary spatially due to these differences in river discharge and ice formation and melting as well as differences in atmospheric heating and cooling, vertical mixing and advection by ocean currents. The water properties are characterized by large seasonal cycles, depth differences, and horizontal gradients both north-south and inshore-offshore.



Surface Temperatures in August

During winter, the water column over the deep regions of the shelf consists of two layers. The upper layer (top 50 to 150 m depending upon location) contains relatively cold, low salinity water and sits above a bottom layer of warm, salty water that originates offshore and penetrates the shelf through deep channels or gullies. In summer, there are usually three layers. Seasonal heating forms a thin (30-40 m) warm upper layer. The deeper winter-cooled waters form a cold intermediate layer (CIL) and the warm bottom layer remains unchanged. The coldest CIL waters (0°C) are found on the Labrador Shelf and off Newfoundland and the warmest (3°-6°C) in the western Gulf of Maine. The CIL extends to the

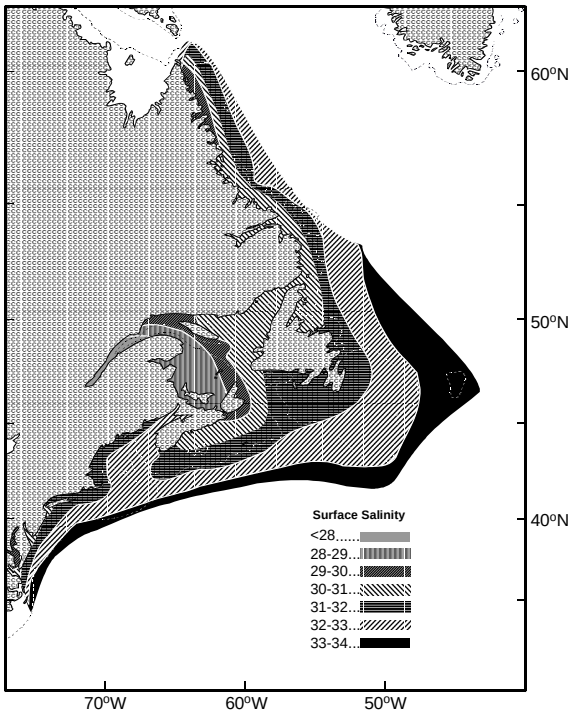
bottom in shallow areas (less than 150 m) or where the warm offshore waters cannot penetrate the shelf, as on the Grand Bank or the eastern Scotian Shelf. Also, where there are strong tidal currents, such as in the Gulf of Maine, and depths are less than approximately 100 m, tidal mixing results in the water being nearly homogeneous from top to bottom of the water column, even in summer. Such conditions occur on Georges Bank and off southwestern Nova Scotia, for example.



Bottom Temperatures in August

The seasonal range of the surface waters over much of the continental shelf from the Gulf of Maine to the southern Gulf of St. Lawrence (15°-20°C) is among the highest in the Atlantic Ocean. In winter, the minimum surface temperatures in these areas vary geographically from below -1°C to 5°C while in summer most of the region is covered with waters of 15° to greater than 20°C. The temperature and its seasonal range both decrease further north on the Grand Banks and Labrador Shelf with surface waters on the northern Labrador Shelf reaching only 4°C in summer and falling to almost -2°C in winter.

Near-bottom temperatures exhibit much less seasonal variability. Throughout most of the year, near-bottom temperatures from Labrador to the Grand Banks are typically less than 2°C. They are also relatively cold (less than 4°C) in the Gulf of St. Lawrence (except in the deep Laurentian Channel) and on the northeastern Scotian Shelf. Bottom temperatures increase over the southwestern Scotian Shelf and Gulf of Maine to 6°-12°C with the highest temperatures in the deep basins.



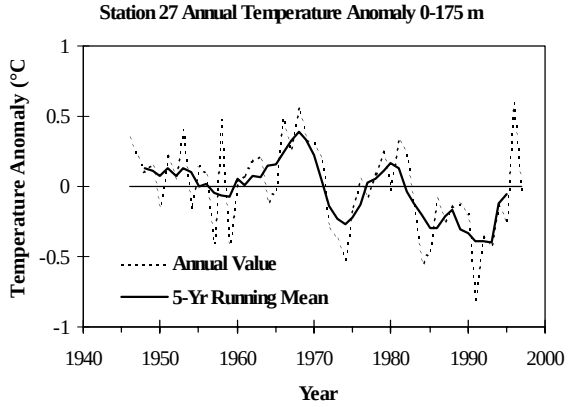
Surface salinities in August

Salinities show a strong inshore to offshore gradient due to the influences of the freshwater discharge along the coast and the warmer, more saline waters offshore. The lowest salinities are found in the St. Lawrence Estuary due to the influence of the St. Lawrence River system. The effects of the St. Lawrence runoff can be traced throughout the southern Gulf of St. Lawrence and onto the Scotian Shelf. Low

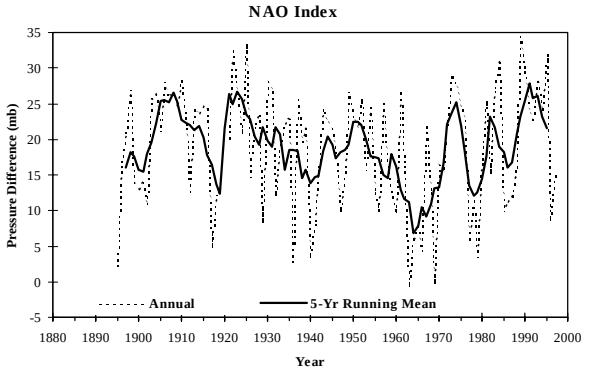
salinities south of Hudson Strait reflect the influence of the Hudson Bay river discharge that exits from Hudson Strait whereas those in the Gulf of Maine are due to the discharge from the Saint John River. Near surface salinity undergoes seasonal changes on account of the variability in the freshwater discharge and ice melt.

Time Trends

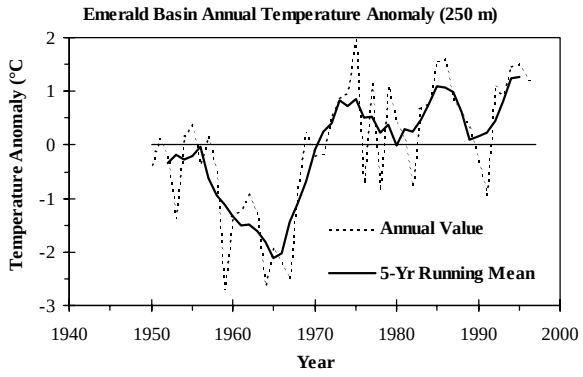
Long-term (1947-1997) hydrographic measurements representative of the Labrador and Newfoundland shelves are available from Station 27 located just off St. John's Harbour. The long period temperature trends show high similarity through the water column. The annual depth-averaged (0-175 m) temperature was near normal through the 1950s and rose to peak values in the 1960s, and declined through to the 1990s. Since the 1960s, temperatures have also fluctuated with a period of approximately 10 years resulting in minima in the 1970s, the mid-1980s and the early 1990s. In 1996, temperatures rose sharply resulting in conditions well above normal. Similar trends are observed in the air temperatures along the Labrador coast. (Events in 1997 are discussed in the next section.)



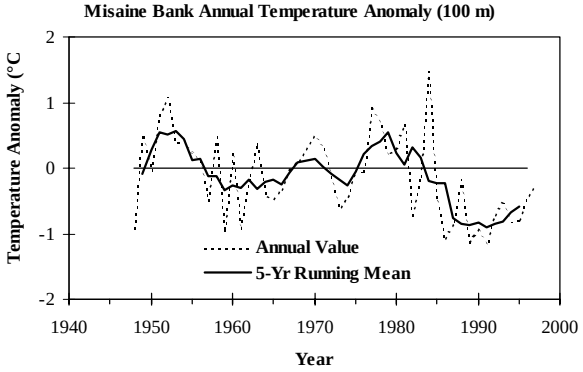
Accompanying the trend towards colder air and sea temperatures from the 1960s to the mid-1990s was an increase in the area of ocean covered by ice with peaks in the areal ice extent occurring during temperature minima. With the rise in temperature in 1996, ice coverage decreased. These conditions are related to the large-scale atmospheric circulation patterns, in particular the winter winds over the Labrador Sea. When the northwest winds increase, they push cold Arctic air farther south, leading to more ice formation and increased cooling of the shelf waters. One index of the strength of the large-scale atmospheric circulation is the north-south air pressure difference over the North Atlantic Ocean, known as the North Atlantic Oscillation (NAO) Index. When the index is high, the northwest winds over the Labrador Sea are strong, the air temperatures are cold, there is more ice and sea temperatures are cold. When the index is low, the northwest winds are weak, air temperatures are relatively warm, ice coverage is reduced and sea temperatures are warmer-than-usual. The decline of the NAO Index in 1996 was the single largest annual decrease in over 100 years of record. This decrease and its associated atmospheric response over the Labrador Sea (weaker northwest winds and warmer air temperatures) lead to the warmer sea temperatures and reduced ice cover over the Labrador and Newfoundland shelves.



While temperature trends in the Gulf of St. Lawrence, on the Scotian Shelf, and in the Gulf of Maine have also been dominated by long-period fluctuations, their pattern differs from those off Labrador and Newfoundland. They show a gradual decline from warm or near normal temperatures in the early 1950s to very cold temperatures in the mid-1960s, a sharp rise in the late 1960s and above normal temperatures through the 1970s to the mid-1980s. This pattern was generally observed at all depths and throughout the entire region although the exact timing of the minima and maxima varied slightly. Since the mid-1980s, near-bottom temperatures in the deep basins (see Emerald Basin 250 m temperature time series) have remained relatively warm and in recent years have been at, or near, the warmest on record.



Temperature trends in the deep basins of the Scotian Shelf and Gulf of Maine originate within the offshore slope waters and are transported onto the shelf through cross-shelf exchange processes. In turn, changes in the slope water characteristics are dependent upon the amount of deep Labrador Current that flows southward into the slope water region. In years when this Labrador Current transport is large, the slope waters off the Scotian Shelf and the Gulf of Maine are colder. In most of the past 30 years, the Labrador component of Slope Water (temperatures <8°C) has been small and Warm Slope Water (8°-12°C) has occupied the region.



In contrast to the deep basins, the cold intermediate layer waters in the Gulf of St. Lawrence and on the Scotian Shelf have been cold since the mid-1980s. Temperatures in some areas, such as Misaine Bank on the northeastern Scotian Shelf, fell to levels as low as, or lower than, those observed during the mid-1960s. The cause of the low temperatures is believed to be due to enhanced winter cooling, most likely within the Gulf of St. Lawrence which are then advected onto the Scotian Shelf by the mean circulation. Local winter cooling and advection from off southern Newfoundland may also play a role in determining temperature trends on the Scotian Shelf.

Conditions in 1997

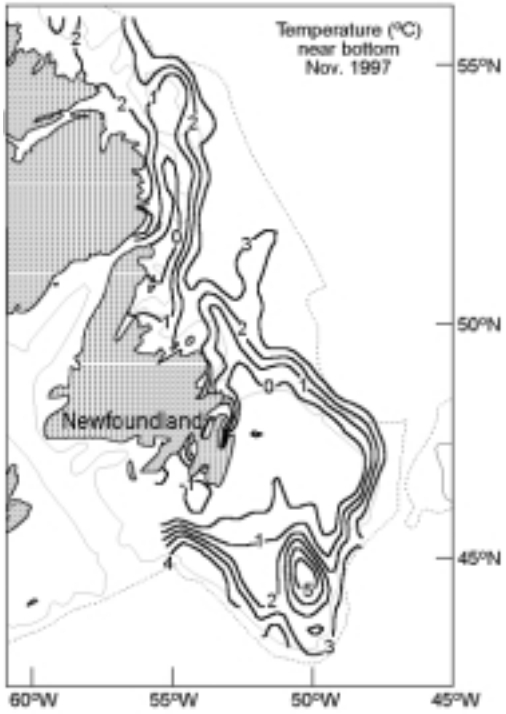
The mean annual air temperatures in 1997 throughout most of the northwest Atlantic were cooler than in 1996. Still, temperatures were above normal over much of the Labrador Sea and along the Labrador coast, but were below normal along the Atlantic coast from Newfoundland to the Middle Atlantic Bight. Of particular interest was a rather large drop in air temperature from well above normal in early winter to well below normal in late winter over

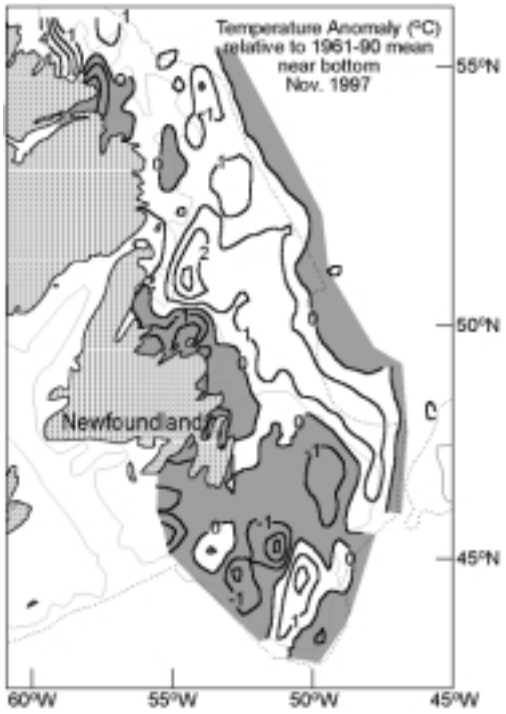
Labrador, Newfoundland and the Gulf of St. Lawrence.
The NAO Index in 1997 was below the long-term mean for the second consecutive year but higher than in 1996. Over the Labrador Sea, the associated weaker northwest winds during the winter contributed to warmer-than-normal air temperatures and a relatively light ice year. Ice appeared late and left early resulting in a shorter duration than usual, although the maximum areal extent recorded in 1997 exceeded that observed in 1996.

During the winter of 1997, ice covered the Gulf of St. Lawrence. Seasonally mild conditions during the early winter resulted in a later-than-normal arrival but the ice remained longer-than-usual. More ice reached the Scotian Shelf in 1997 than in 1996 but the amount of ice was still well below that recorded during the first half of the 1990s.

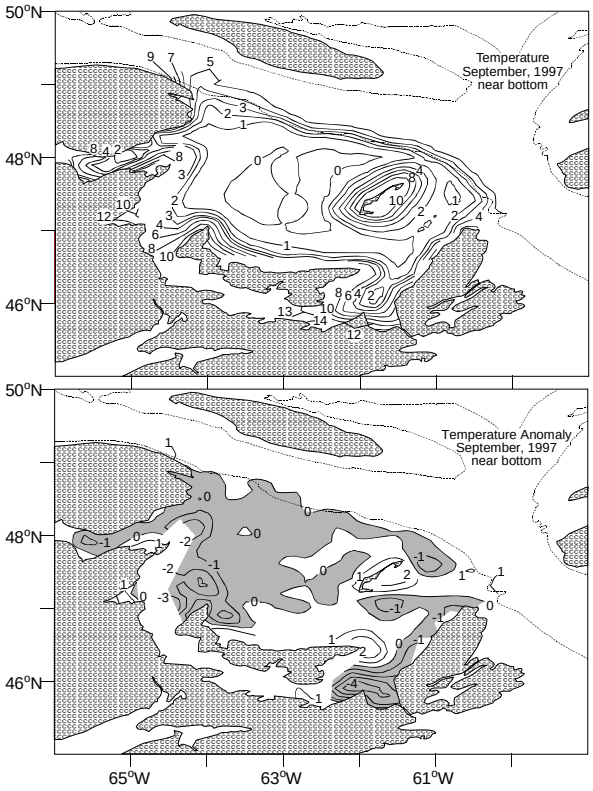
Ocean temperatures off Labrador and northern and eastern Newfoundland during 1997 continued to be relative warm after the cold conditions of the early 1990s. In 1996, temperatures in these areas had reached warmer-than-normal levels for the first time since the early 1980s. During the autumn of 1997, near-bottom temperatures over large sections of the southern Labrador Shelf, northern Newfoundland Shelf and the Southeast Shoals of the Grand Bank were above average. In contrast, waters over most of the Grand Bank and the nearshore regions off Newfoundland were colder-than-normal.

At Station 27, depth-averaged (0-175 m) temperatures were near normal in 1997 having fallen from the high values of 1996. They were, however, well above the very cold conditions of the early 1990s. In 1997, the volume of the cold intermediate water over the entire Newfoundland Shelf (defined by temperatures less than 0°C) was near its lowest value in the 17 year record. Consistent with this, the area of CIL water along the Bonavista Bay transect in summer was less-than-normal, and slightly less than in 1996. However, further south, the area of CIL was greater than usual, e.g. along the Flemish Cap section which crosses the Grand Bank, and larger than in 1996.



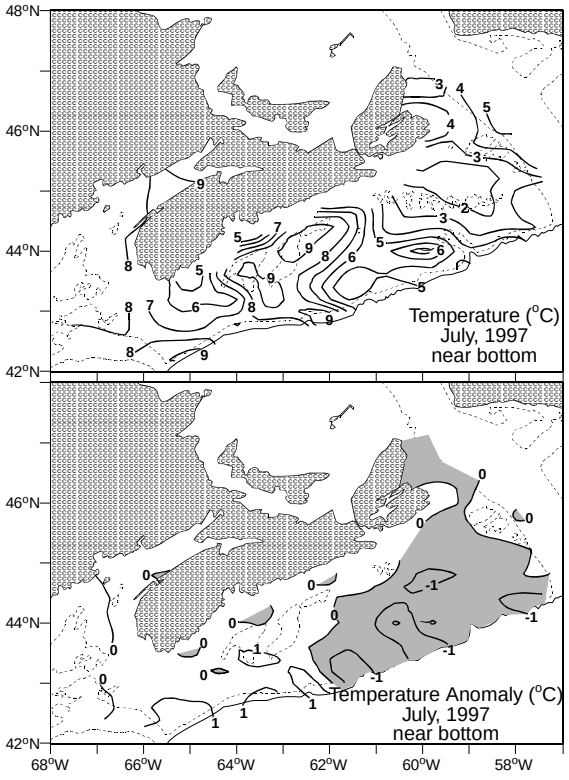


Over St. Pierre Bank, south of Newfoundland, bottom temperatures remained below normal continuing the temperature trend established in the mid-1980s.



In the Gulf of St. Lawrence, subsurface ocean temperatures generally remained cold. Core temperatures in the CIL waters have been below normal since 1985 but did increase slightly in 1997 for the third consecutive year from the extreme lows observed in the early 1990s. During the September groundfish survey, most of the Magdalen Shallows was covered by bottom waters with below normal temperatures. The exceptions were shallow regions, for example around the Magdalen Islands. The area of the Magdalen Shallows covered by bottom waters with temperatures less than 0°C decreased slightly compared to 1996, but remained above the long-term mean.

Deep (200-300 m) waters of Cabot Strait were near their long-term mean value, and similar to last year. These were below the maxima recorded in 1993 of 1°C above normal.



Ocean temperature trends over the Scotian Shelf and in the Gulf of Maine varied spatially in 1997 in a pattern similar to that observed during 1996. Colder-than-normal temperatures persisted in subsurface waters over the northeastern Scotian Shelf and off southwestern Nova Scotia continuing the pattern established in the mid-1980s. In contrast, the waters in the central Scotian Shelf over Emerald Basin and vicinity were warmer-than-normal but had cooled slightly relative to 1996. Similar conditions were observed in the deep waters of the central Gulf of Maine. The temperatures in the deep basins are related to the presence of warm slope water offshore which intrudes onto the shelf by intermittently cross-shelf exchange processes. It is noted, however, that by the autumn of 1997 the warm slope water adjacent to the northeastern Scotian Shelf had been replaced by colder Labrador-type slope water.

In summary, the waters over large areas of northern and eastern Newfoundland and Labrador in 1997 were warmer-than-normal for the second consecutive year and well above the temperatures of the early 1990s. The waters in the CIL within the Gulf of St. Lawrence and the bottom waters off southern Newfoundland and on the northeastern Scotian Shelf remained colder-than-average continuing a trend established in the mid-1980s. There are signs that these waters are slowly warming, however. In the deep basins of the Scotian Shelf and the Gulf of Maine, water temperatures continued to be warmer-than-normal, although they are cooler than in 1996.

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

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Canadian Stock Assessment Secretariat
Department of Fisheries and Oceans
200 Kent Street, Station 12032
Ottawa, Ontario
Canada K1A 0E6

Phone number: (613) 993-0029
Fax: (613) 954-0807
e-mail address: csas@dfo-mpo.gc.ca

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