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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2005/018

Research vessel CCGS Teleost

2004 State of the Ocean: Physical Oceanographic Conditions in the Newfoundland and Labrador Region

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 food source (plankton), resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass as well as influencing the perception of the resource status and the efficiency and profitability of the industry.

*Physical oceanographic conditions 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, 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 zonal database at the Northwest Atlantic Fisheries Centre in St. John's Newfoundland.*

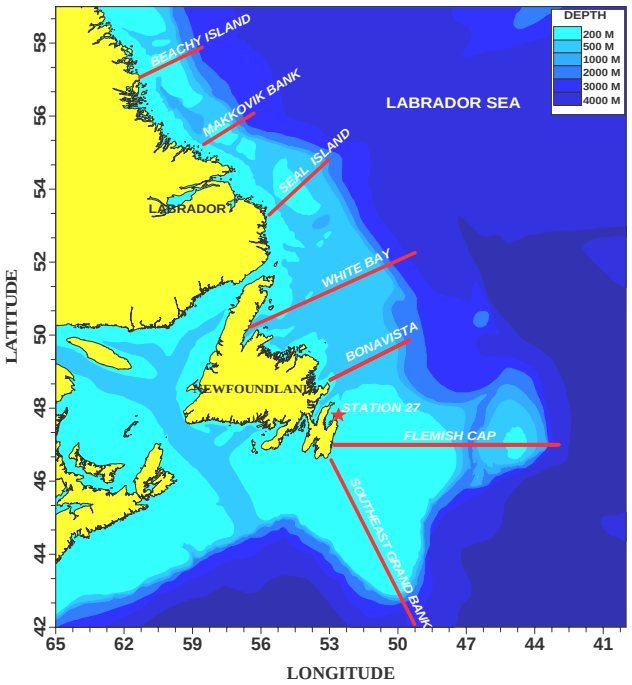

Figure 1: Location map showing the positions of standard sections and the fixed AZMP monitoring site (Station 27) in the Newfoundland and Labrador Region.

Summary

- Annual air temperatures were above normal in Newfoundland and Labrador during 2004 by 2°C at Cartwright and by 1°C at St. John's.
- Sea-ice extent on the Newfoundland and Labrador Shelf decreased compared to that of 2003, remaining below normal for the 10th consecutive year and the lowest since 1969.
- The Station 27 depth-averaged annual water temperature off St. John's increased over 2003 to the highest value on record.
- Annual surface temperatures off St. John's were 1°C above normal, the highest in the 59 year record; bottom temperatures were also above normal by 1°C, the highest since 1966.

- Near surface salinities off St. John's at Station 27 were above normal in the upper water column for the third consecutive year.

- The area of <0°C (Cold Intermediate Layer) water on the eastern Newfoundland Shelf during 2004 was below normal for the 10th consecutive year and the lowest since 1965.

- Bottom temperatures on the Newfoundland and Labrador Shelf during 2004 were above normal during both spring and fall.

Introduction

The ocean environment on the Newfoundland Shelf is influenced by several factors, including the Labrador Current, cross-shelf exchange with warmer continental slope water and bottom topography. Superimposed are large seasonal and inter-annual variations in solar heat input, ice cover and storm-forced mixing. The resulting water mass on the shelf is characterised by large annual cycles with strong horizontal and vertical temperature and salinity gradients. Water properties are monitored extensively by fisheries assessment and oceanographic research surveys throughout the year (Fig. 1). Some of these observations are expressed as differences from their average or anomalies. Where possible, the long-term averages are standardised to a base period from 1971-2000, sometimes referred to as the normal.

Conditions in 2004

Newfoundland and Labrador monthly air temperatures were either normal or above normal during all months of 2004 except in June at St. John's (Fig. 2a). Annually, air temperatures were above normal in both Newfoundland and Labrador during 2004 by 2°C at Cartwright and by near 1°C at St. John's. Since the 1960s, annual air temperature anomalies at Cartwright (Fig. 2b) show large variations, superimposed on a general downward trend through to the early 1990s. This was followed by a general rise in air temperatures through to the end of the 1990s and into the early 2000s.

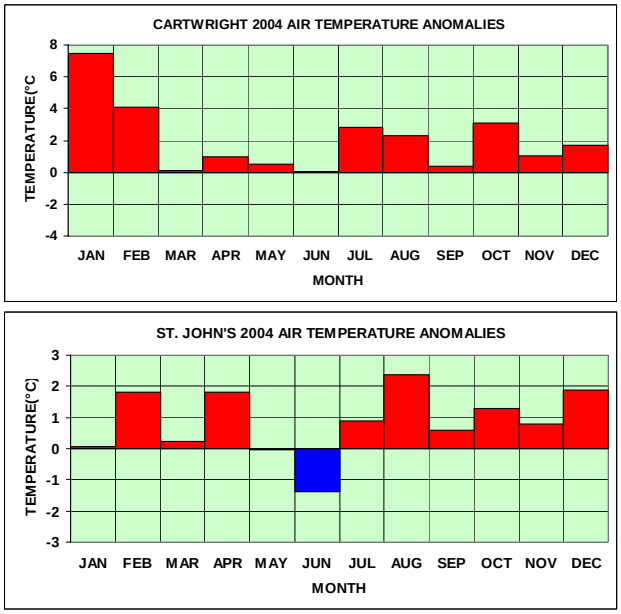

Figure 2a: Departures from normal monthly mean air temperatures at Cartwright and St. John's for 2004.

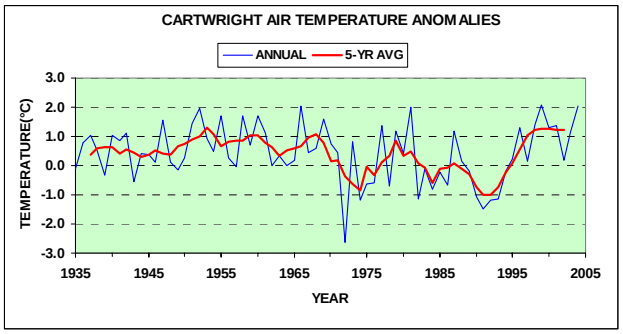

Figure 2b: Departures from normal annual mean air temperature (dashed line) and the 5 year means at Cartwright on the Labrador Coast.

During 1999 for example, temperature anomalies of 1.9°C above normal set historical highs at St. John's (126-year record) and Cartwright (65-year record). Air temperatures at Cartwright during 2004 increased over 2003 values and were close to the 65-year record set in 1999.

The peak extent of sea ice area during 2004 decreased compared to 2003 to the lowest in the 42-year record. Winter sea-ice extent on the

Newfoundland and Labrador Shelf decreased compared to that of 2003, remaining below normal for the 10th consecutive year and the lowest since 1969 (Fig. 3). Spring sea ice conditions were also below normal for the 10th consecutive year. The duration of the sea ice season was also shorter than normal on the Newfoundland and Labrador Shelf during 2004.

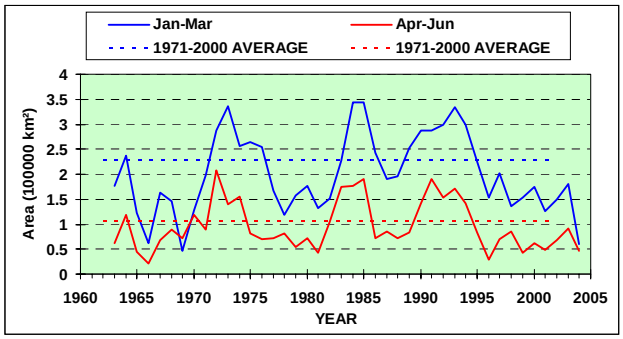

Figure 3: Time series of annual sea-ice areas off Newfoundland and southern Labrador for the winter (Jan.-Mar.) and spring (Apr.-June).

Station 27 Temperature and Salinity Variability

Temperature and salinity conditions have been measured at a standard hydrographic monitoring station (Station 27) off Cape Spear, about 7 km from St. John's Harbour, in a water depth of 176m since 1946. In 2004, upper layer temperatures at this site, which is located in the inshore branch of the Labrador Current (Fig. 1), were generally less than 0°C from mid-February to the end of March and from approximately 0°C to -0.5°C throughout the year near the bottom (176 m). By early-May upper layer temperatures had warmed to 2°C and to above 15°C by August, after which the fall cooling commenced. Temperatures were about 0.5°-1.5°C above normal during the winter months over most of the water column and throughout the year at the surface and near bottom. A colder than normal anomaly occurred at intermediate water depths during mid summer (Fig. 4). Annually, surface water temperatures off St. John's were 1.1°C above normal, the highest in the 59 year record and bottom temperatures were above normal by 0.9°C, the highest since 1966 (Fig. 5).

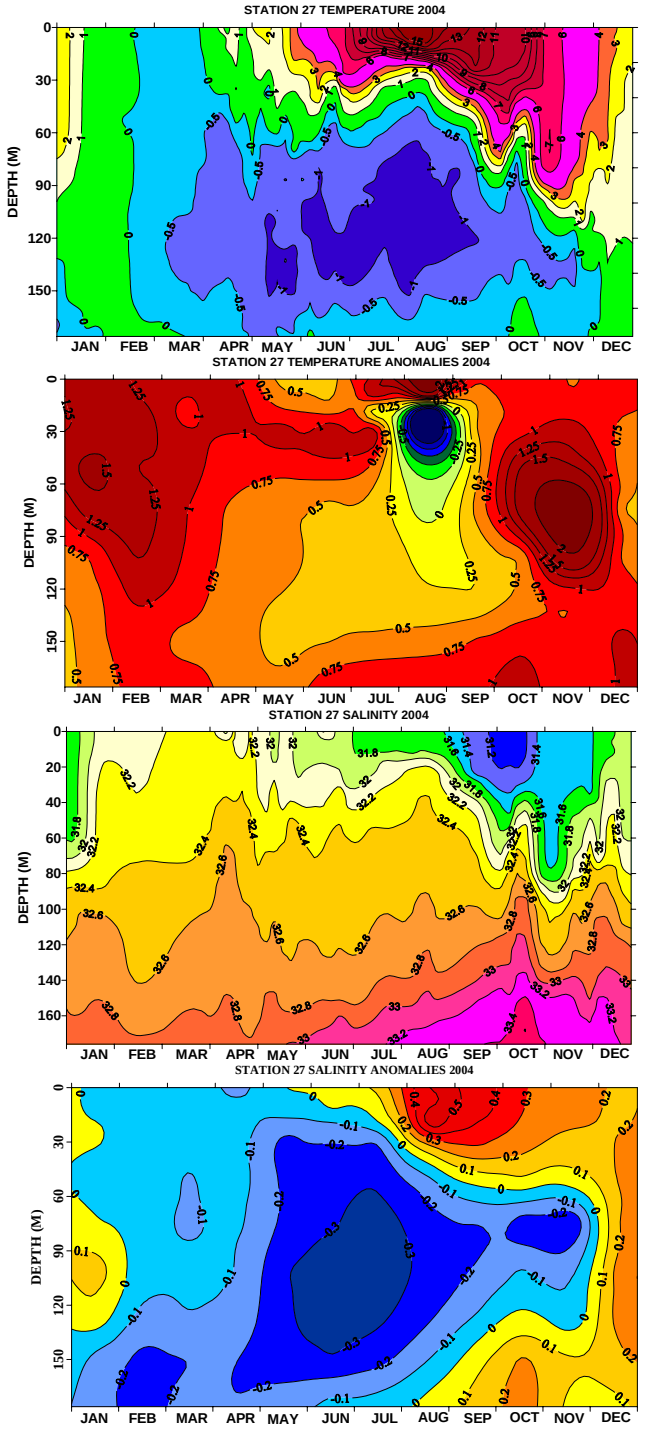

Figure 4: Contours of monthly temperature and salinity and their departures from normal (anomalies) at Station 27 as a function of depth for 2004.

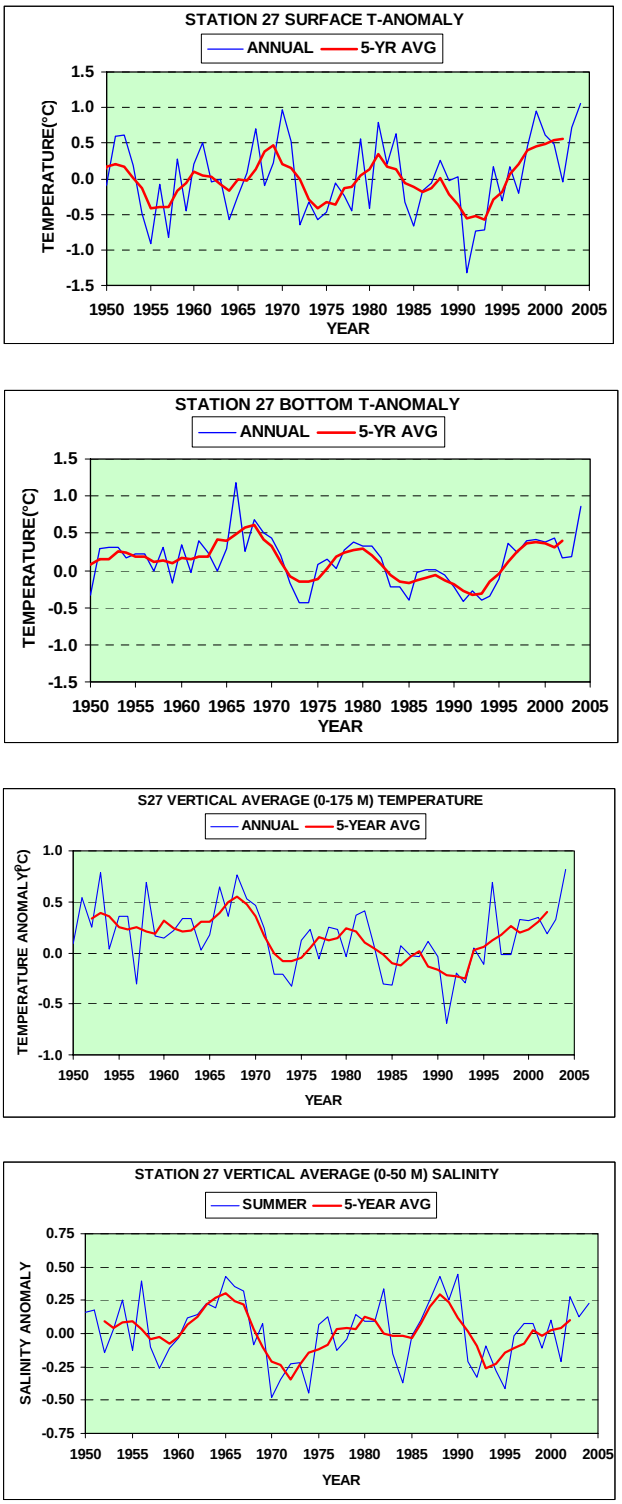

Figure 5: Departures from normal surface, bottom and depth averaged (0-176 m) Station 27 temperature (in °C) and upper layer depth averaged salinity. The red lines are the 5-year means.

Maximum surface salinities at Station 27 (Fig. 4) were >32.2 during March while minimum values of <31.2 occurred by late September. Upper layer values were near normal during the first half of the year and saltier than normal during the second half. Intermediate depth salinities were fresher than normal from April to November while near-bottom salinities were slightly below normal from January to June and above normal during the remainder of the year.

Station 27 depth-averaged annual temperature (which is proportional to the heat content of the water column) shows large fluctuations at near decadal time scales, with cold periods during the early 1970s, mid-1980s and early 1990s (Fig. 5). From 1950 to the late 1960s the heat content of the water column was generally above the long-term mean. Recently, the heat content of the water column varied from a record low in 1991, to a near record high during 1996 and was above the long-term mean from 1999 to 2004. The 2004 value increased over 2003 to the highest values in the 59 year record.

The depth-averaged summer salinity anomalies show similar patterns as the heat content with fresher-than-normal periods generally corresponding to the colder-than-normal conditions (Fig. 5). Since the fresh conditions of the early 1990s, salinities have fluctuated above and below normal. During 2002, summer salinities on the Newfoundland Shelf increased to the highest values in about 12 years. The 2003 and 2004 values remained above the long-term mean.

Temperature and Salinity Variability on the Newfoundland and Labrador Shelf

Summer monitoring of temperature and salinity along several standard sections across the Newfoundland and Labrador Shelf began in the late 1940s and early 1950s. In 1998, under the Atlantic Zone Monitoring Program (AZMP), sampling along the sections was expanded to include biological and chemical measurements and several sections are now sampled seasonally (Fig. 1).

The water mass characteristics observed along the standard sections are typical of sub-polar waters with sub-surface temperatures ranging from -1º to 2ºC and salinities in the range of 32 to 33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region, this water mass is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3º to 4ºC and salinities in the range of 34 to 34.75. Surface temperatures warm to 10º to 12ºC during summer, while bottom temperature over most of the shelf range from 1ºC to 4ºC. Throughout most of the year, the cold relatively fresh water overlying the shelf is separated from the warmer higher density water of the continental slope region by a strong temperature and density front. In general, water properties along the standard sections undergo seasonal modification due to the seasonal cycles of air-sea heat flux, wind forced mixing and ice formation and melt leading to intense vertical and horizontal changes or gradients (Fig. 6).

The most revealing feature of the temperature structure on the Newfoundland and Labrador Shelf, particularly during the summer, is the layer of cold <0°C water, commonly referred to as the Cold Intermediate Layer (CIL). This winter cooled water mass remains trapped during the summer and early fall months between the seasonally heated surface layer and warmer near bottom water originating from the continental slope region.

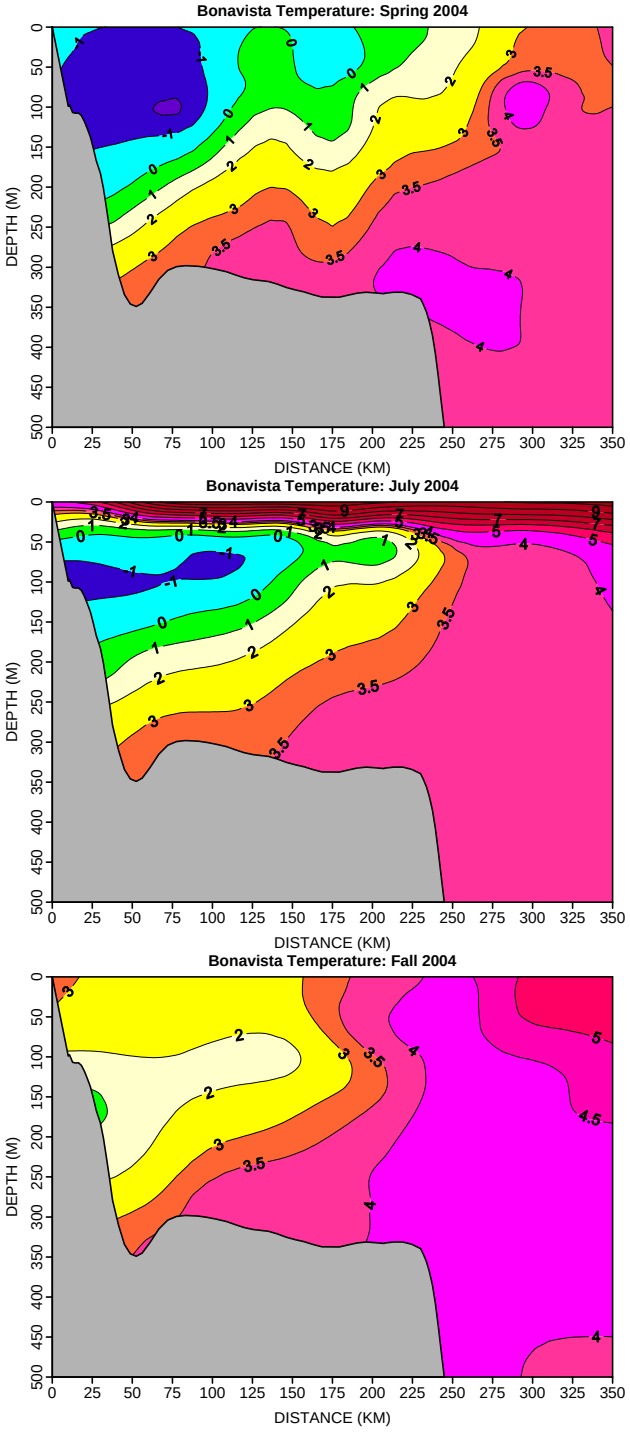

Figure 6: Cross sectional contour maps of the temperature structure on the Eastern Newfoundland Shelf off Cape Bonavista during the spring, summer and fall of 2004.

On average along the Bonavista section during the summer this cold layer extends offshore to over 200 km, with a maximum vertical extent of about 200 m. In 2004, this water mass extended to the surface during the winter, was the smallest since 1965 in the summer and was completely eroded by late autumn (Fig. 6). The time series of CIL area anomalies for the Seal Island, Bonavista and Flemish Cap sections (Fig. 1) are displayed in Fig. 7. In these plots, negative anomalies or below normal CIL areas correspond to warm oceanographic conditions. The CIL area during 2004 was below the long-term mean along all three sections from Labrador to southern Newfoundland. Along the Bonavista section the CIL was below normal during 2004 for the 10th consecutive year and the lowest since 1965. These values are in sharp contrast to the near record high values measured during the extremely cold years of the early 1990s on the Newfoundland Shelf. A time series of the average conditions along the Bonavista Section shows the increasing trend in both temperature and salinity since the early 1990s (Fig. 8).

Temperature Variability from Multi-Species Research Assessment Surveys

The collection of oceanographic data aboard fisheries resource assessment surveys was initiated in 1971 in the Newfoundland and Labrador Region. These data are routinely used by fisheries scientists and oceanographers to monitor changes in the near-bottom thermal habitat of many marine fish and invertebrate species. The data are also used to relate variations in the distribution and abundance of these species to changes in the ocean environment. Two standardized trawl surveys are conducted each year by Fisheries and Oceans in the Newfoundland and Labrador Region: one in the spring in NAFO areas 3PLNO and one in the fall in areas 2J3KLNO.

Spring Conditions

Bottom temperature maps for NAFO Divisions 3P and 3LNO during the spring of 2004 are displayed in Fig. 9. Bottom temperatures over most of St. Pierre Bank ranged from <0^{o} to 2^{o}C, which were above the long-term mean and a significant increase over 2003 values in this area. In general, the area of the bottom covered by water with temperatures <0^{o}C was the lowest since 1988. In the deeper regions (Laurentian and Hermitage Channels) of 3P temperatures were mostly below the long-term average but still generally >3^{o}C (Fig. 9).

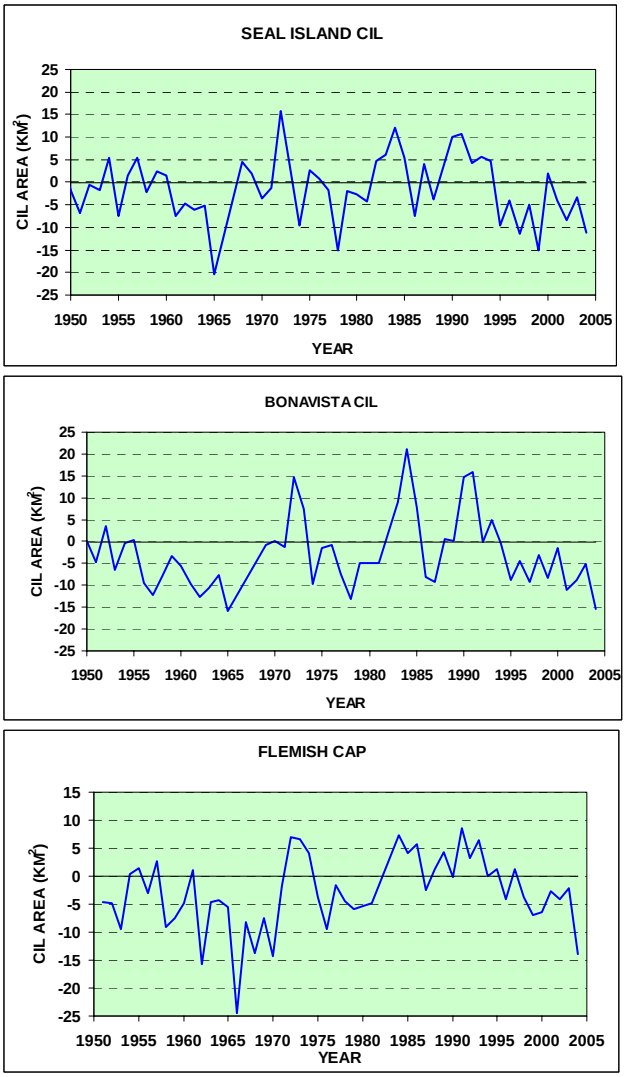

Figure 7: Time series of CIL area anomalies along the standard sections across the Newfoundland Shelf shown in Fig. 1.

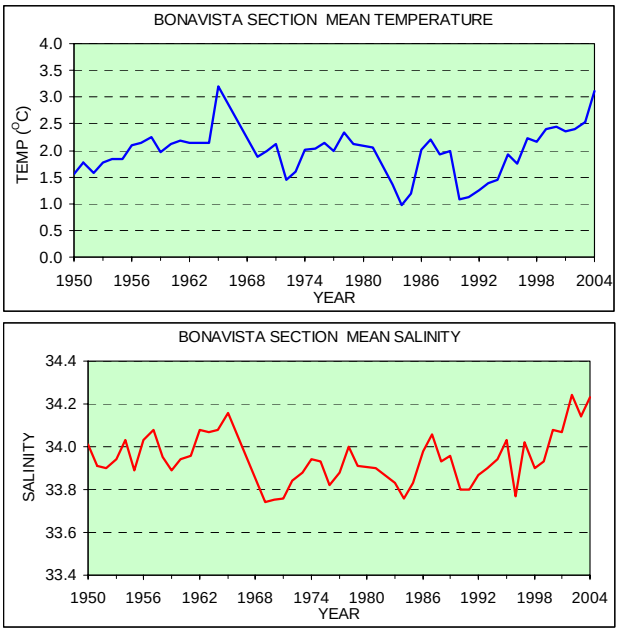

Figure 8: Time series of annual summer average temperature and salinity along the Bonavista Section across the Newfoundland Shelf shown in Fig. 1.

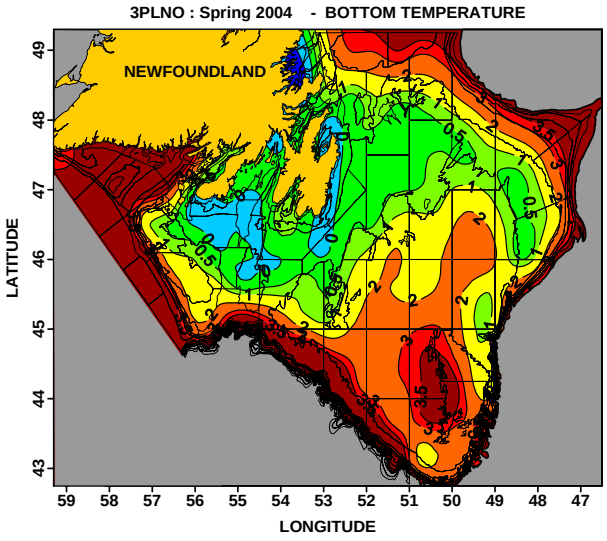

Figure 9: Bottom temperature map (in °C) for the spring of 2004 for NAFO Divisions 3P and 3LNO.

The averaged bottom temperature (Fig. 10) of the surveyed area in Division 3P ranged between 2° to 4°C from 1970 to 1984 but decreased to between 2° to 2.5°C from 1985 to 1997. During 1999 and 2000 the average bottom temperature increased to over 3°C but decreased to near 2.5°C in 2001 and 2002. During the spring of 2003, the mean bottom temperature decreased by 0.5°C over 2002 but rebounded by over 0.5°C in 2004.

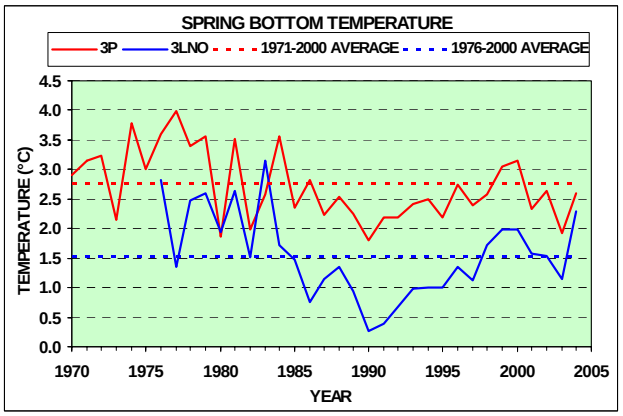

Figure 10: Average bottom temperatures during the spring for NAFO Divisions 3P and 3LNO.

Spring bottom temperatures in Division 3L ranged from <0°C in the inshore regions of the Avalon Channel, from 0.5°C to 1°C over most of the shallow northern Grand Bank to >3°C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1°C to 3.5°C and generally >3.5°C along the southwest slopes of the Grand Bank in Division 3O. The spring of 2004 had the lowest area of <0°C water in Division 3L since the surveys began in the early 1970s (Fig. 9). In general, temperatures were above normal in all areas of the Grand Banks by 1°C to 1.5°C. From 1998 to 2000 the 3LNO averaged bottom temperature increased significantly over the lows of the early 1990s. The mean bottom temperature during the spring of 1999 and 2000 reached to 2°C but decreased to just over 1°C from the spring of 2001 to 2003. In 2004 it increased by 1°C to near 2.5°C, the highest since 1983 (Fig. 10).

Fall Conditions

Bottom temperature maps for the fall of 2004 in NAFO Divisions 2J, 3K and 3LNO are displayed in Fig. 11. Bottom temperatures during the fall of 2004 in Division 2J ranged from <2°C inshore to >3.5°C offshore at the shelf break. Over Hamilton Bank they ranged from 2°C to 3°C, about 1.5° to 2°C above the long-term average.

Bottom temperatures during the fall in Division 2J generally average about 2°C, but during the latter half of the 1990s they increased to about 2.5°C. During the fall of 2003, mean bottom temperatures increased over 2002 values to near 3.0°C and to >3°C during 2004, the highest in the record (Fig. 12).

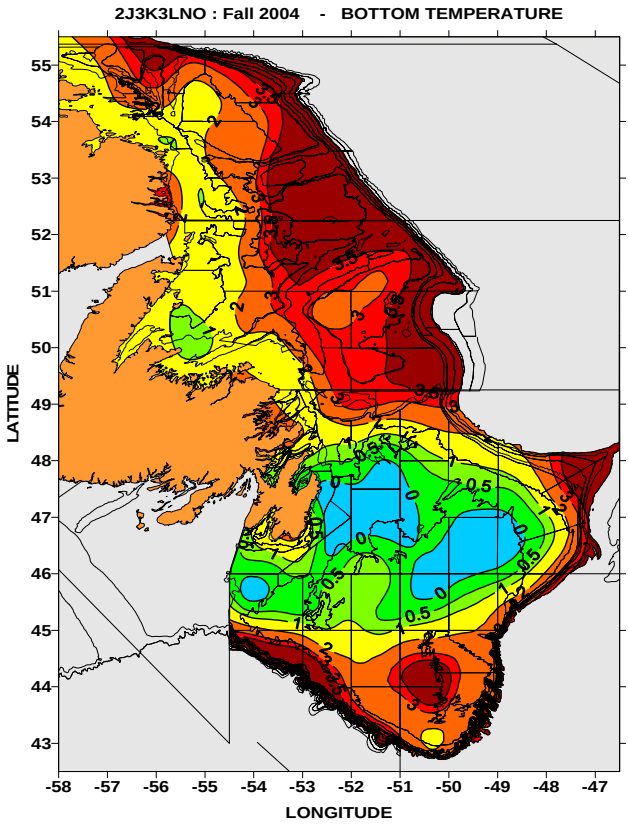

Figure 11: Bottom temperature map (in °C) for the fall of 2004 in NAFO Divisions 2J, 3K and 3LNO.

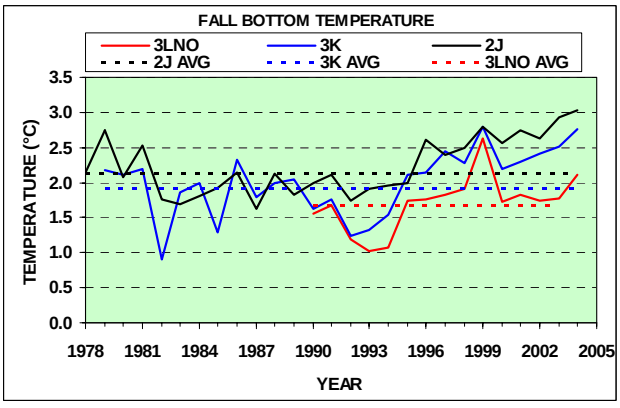

Figure 12: Average bottom temperatures during the fall for NAFO Divisions 2J, 3K and 3LNO.

Most of the 3K region is deeper than 200-m, as a result relatively warm slope water floods through the deep troughs between the northern Grand Bank and southern Funk Island Bank and between northern Funk Island Bank and southern Belle Isle Bank. Bottom temperatures on these banks during the fall of 2004 ranged between 2° to 3.5°C, which were about 0.5° to 1.5°C above their long-term means. Near the edge of the continental shelf in water depths below 500 m temperatures were generally near normal around 3.5°C. The time series of the average bottom temperature in Division 3K (Fig. 12) during the fall ranged from 1°C in 1982 to 2.3°C in 1986 with an overall average of about 2°C. From 1995 to 1999 they increased to above-average values reaching a maximum of 2.7°C during 1999. After decreasing by about 0.5°C in 2000 bottom temperatures have again increased to near-record highs in 2004.

Fall bottom temperatures in Division 3LNO generally ranged from <0°C on the northern Grand Bank and in the Avalon Channel to 3°C along the shelf edge. Over the central and southern areas, bottom temperatures ranged from 1° to 3.5°C during 2004 and to >3°C along the edge of the Grand Bank. During 2004, bottom temperatures were predominately above normal except for isolated areas over the central Grand Bank. The average bottom temperature in Division 3LNO during the fall decreased from approximately 1.5°C during 1990 to 1°C during 1993 and 1994 then increased to approximately 1.8°C during 1995. These remained relatively constant up to 1998 but then increased beyond 2.5°C during 1999, the highest in the 10 year record. During the fall of 2000 to 2003 the mean bottom temperature decreased by nearly 1°C over the 1999 value, but was still above the cold condition of the early 1990s. In 2004 temperatures again increased by about 0.5°C (Fig. 12).

Outlook

Oceanographic conditions in the Newfoundland and Labrador region of the Northwest Atlantic are to a large degree determined by the strength of the winter atmospheric circulation over the Northwest Atlantic. A circulation

pattern that promotes the flow of cold Arctic air southward results in extensive sea-ice along the coast and generally cold and fresh ocean conditions during spring and summer. On the other hand, when the circulation is weak the reverse it generally true leading to warm-saline ocean conditions. Early indications during the winter of 2004/2005 show a significant decrease in air temperatures over Labrador from 7.5°C above normal in January of 2004 to 4.2°C below normal in January of 2005. This has led to increased ice formation on the Newfoundland and Labrador Shelf compared to the winter of 2004. By February of 2005 however, the cold Arctic outflow had subsided and air temperatures rebounded to above normal from Baffin Island (+4°C) to Newfoundland and Labrador (+1°C - 3°C). The initial cold conditions over northern areas will likely cause spring water temperatures on the Newfoundland Shelf to be cooler than those of 2004. However, the late winter warming will limit the amount of cooling and ocean temperatures in the region will likely remained warmer than normal in 2005.

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