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Science Advisory Report 2008/017

2007 STATE OF THE OCEAN: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND AND LABRADOR REGION

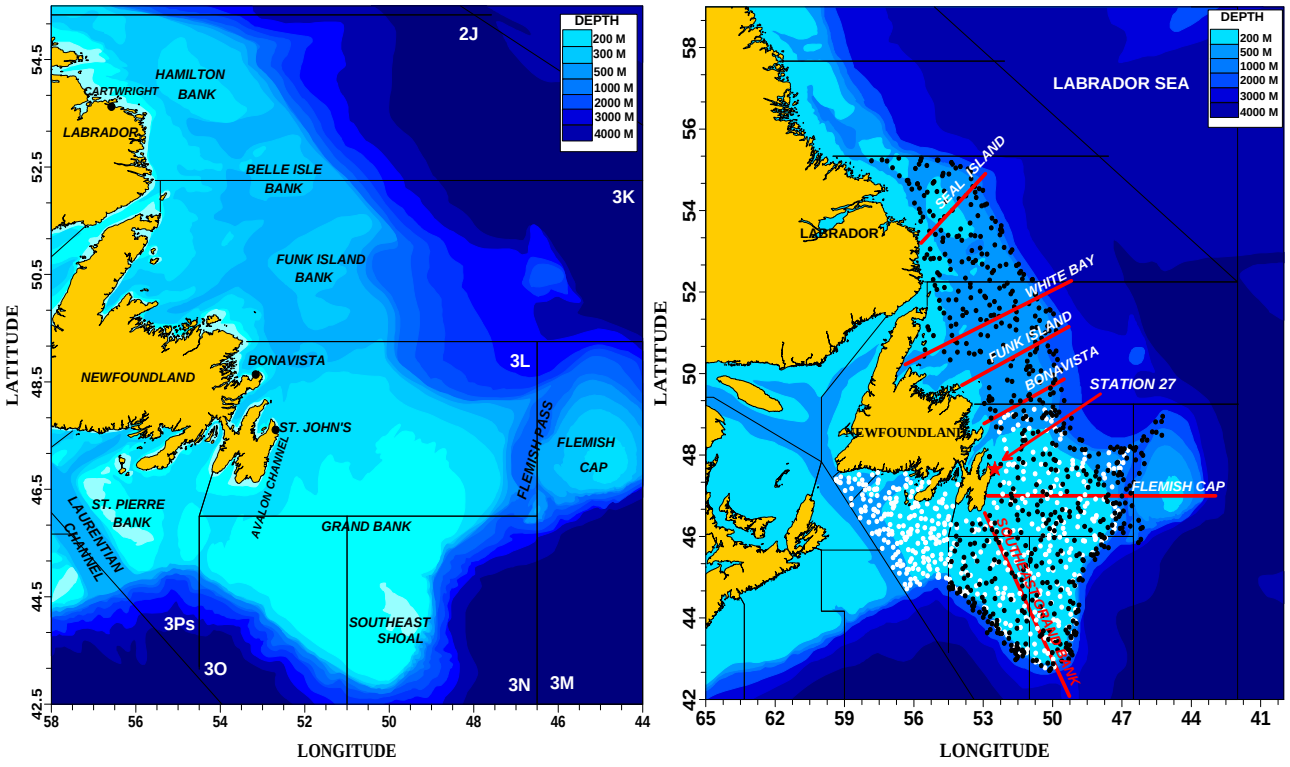

Fig. 1. Location Maps showing bathymetric features, NAFO Areas, the positions of standard sections (red lines), the fixed AZMP monitoring site (Station 27, red star) and the positions of oceanographic observations made during spring (white dots) and fall (black dots) fisheries assessment surveys in the Newfoundland and Labrador Region during 2007.

Context

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 a database at Canada's National Integrated Scientific Data Management (ISDM) branch in Ottawa. A working copy is maintained in a regional database at the Northwest Atlantic Fisheries Centre (NAFC), St. John's, Newfoundland and Labrador.*

SUMMARY

- Annual air temperatures were above normal in Newfoundland and Labrador by 0.7°C at Cartwright, 0.5°C at Bonavista and by 0.3°C at St. John's, significantly decreasing from the record highs of 2006.

- The annual sea ice extent on the NL Shelf remained below normal for the 13th consecutive year. The ice extent was the 7th lowest in the winter months of 2007 since 1963.

- 324 icebergs were detected south of 48°N on the Northern Grand Bank up from 0 in 2006 and 11 during 2005.

- The Station 27 depth-averaged annual water temperature decreased from the record high observed in 2006 to about normal.

- Annual surface temperatures at Station 27 also decreased from the record high of 2006 to 0.2°C above normal.

- Bottom temperatures at Station 27 have been above normal for the past 12 years. In 2006 they were 0.8°C above normal but decreased to 0.4°C above normal in 2007.

- Annual surface temperatures on Hamilton Bank and Flemish Cap were above normal by about 0.5°C.

- Near surface (0-50 m) summer salinities at Station 27 and along the Bonavista section were above normal for the 6th consecutive year.

- The area of <0°C (CIL) water mass on the eastern Newfoundland Shelf was below normal for the 13th consecutive year and the 14th lowest since 1948.

- Bottom temperatures during the spring of 2007 remained above normal on the Grand Banks but were below normal on St. Pierre Bank. During the fall they were significantly above normal in 2J3K and most of 3L, but were below normal in the shallow (<100 m) areas of 3NO.

- The area of bottom habitat on the Grand Banks covered by water with T<0°C decreased from >50% during the first half of the 1990s to near 15% during 2004-2006 but increased to near-normal at about 30% in 2007.

INTRODUCTION

The ocean environment on the Newfoundland and Labrador Shelf is influenced by several factors including the Labrador Current, cross-shelf exchange with warmer continental slope water and bottom topography. Superimposed on these oceanic processes 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 or anomalies from their long-term average values. Where possible, the long-term averages are standardized to a base period of 1971-2000, sometimes referred to as the normal.

2007 ASSESSMENT

Meteorological and Ice Conditions

Monthly air temperatures at Cartwright Labrador and St. John's were above normal for 7/12 months of 2007 (Fig. 2). Annual air temperatures were above normal in Newfoundland and Labrador by 0.7°C at Cartwright and 0.3°C at St. John's, a significant decrease over the record highs observed in 2006. Since the 1960s, annual air temperature anomalies at Cartwright (Fig. 2) showed large variations, superimposed on a general downward trend through to the early 1990s. This was followed by a general rise in air temperatures to the end of the 1990s and into the early 2000s. During 1999 for example, temperature anomalies of 1.9°C above normal set an all time high at St. John's (126-year record); and in 2006 the annual anomaly of 2.9°C at Cartwright was the highest in the 74-year record. Air temperatures at Cartwright have been above normal for the past 12 years and at St. John's for the past 9 years.

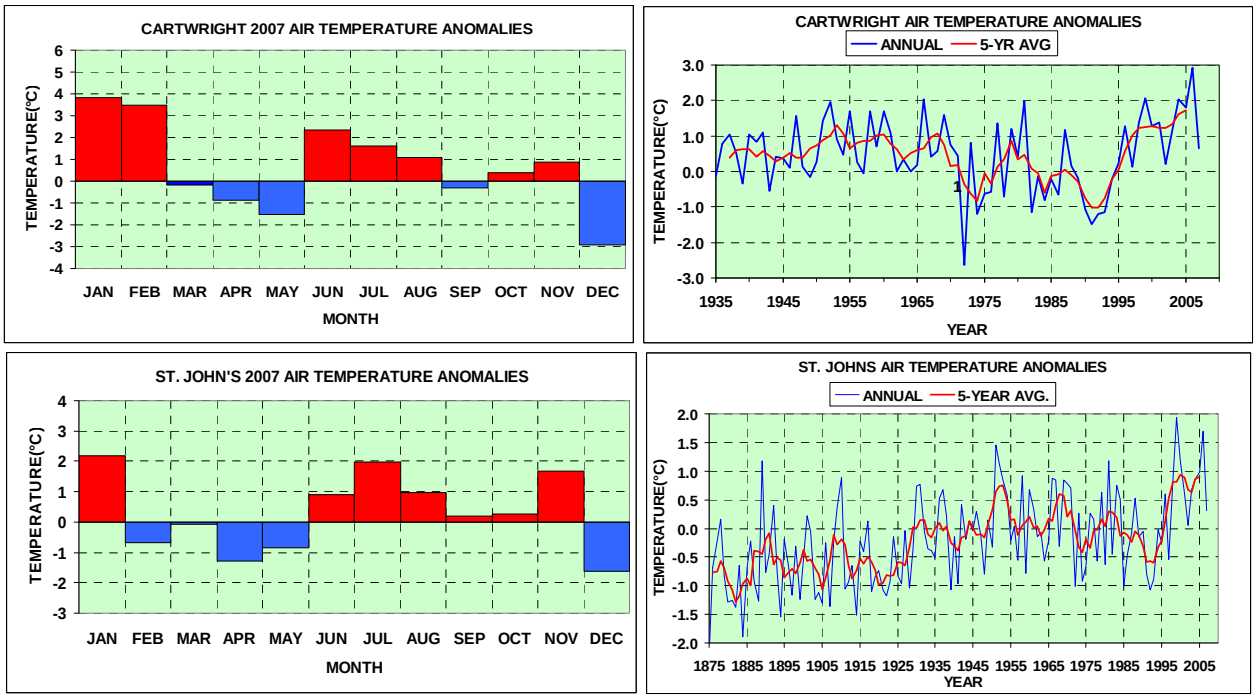

Fig 2. Departures from normal monthly mean air temperatures at Cartwright and St. John's for 2007 (left panels) and departures from normal annual means (blue line) and the 5 year means (red line) at Cartwright and St. John's (right panels).

Monthly sea-ice extent on the Newfoundland and southern Labrador Shelf south of 55°N latitude was well below normal during the winter months and about normal during May and June with the annual average below normal for the 13th consecutive year (Fig. 3). In general, during the past several years, the sea ice season was shorter than normal in most areas of the NL Shelf; however, it extended into June in the inshore areas in 2007. The extent of sea ice during the winter of 2007 was the 7th lowest in the 44-year record.

In 2007 there were 324 icebergs detected south of 48°N on the Northern Grand Bank up from 0 in 2006 and 11 during 2005 compared to the 106 year average of 477 (Fig. 3). The highest number of icebergs normally occurs in May with just over 200. In some years of the early 1980s and 1990s, over 1500 icebergs drifted onto the northern Grand Bank with an all time record of 2202 in 1984.

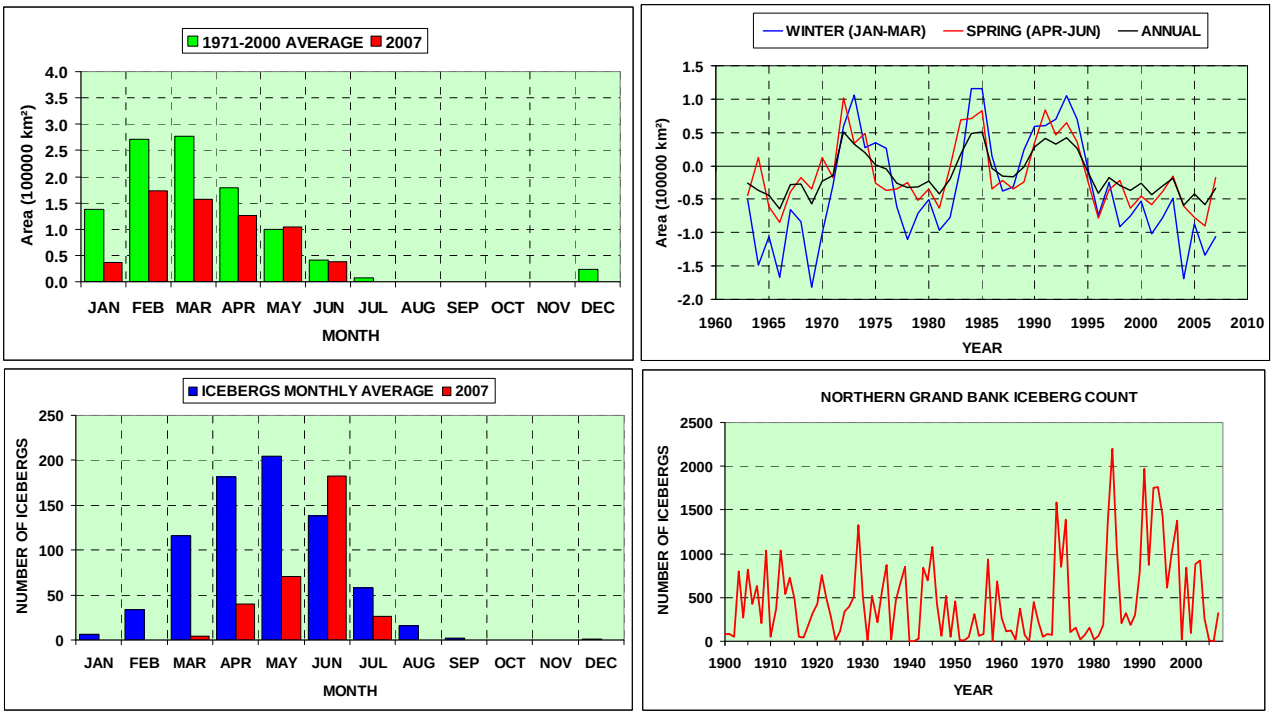

Fig. 3. Monthly and seasonal (winter, spring and annual) sea-ice extent anomalies off Newfoundland and southern Labrador (top panels) and monthly and annual iceberg counts for the northern Grand Banks (Bottom panels).

Temperature and Salinity Variability

AZMP Fixed Site (Station 27)

Temperature and salinity conditions have been measured at a standard hydrographic monitoring station (Station 27, bottom depth 176 m) off Cape Spear, about 7 km from St. John's Harbour, since 1946 (Fig. 1). In 2007 the cold, near-isothermal water column during late January to May had temperatures ranging from near 0^{o} to -1.5^{o}C. These temperatures persisted throughout the year below 100 m. Upper layer temperatures warmed to $>1^{o}$C by mid-May and to $>14^{o}$C by late August, after which the fall cooling commenced with temperatures decreasing to 2^{o}C by the end of December. The seasonally heated upper-layer was limited to only about 30 m by the end of the summer due to increased salinity stratification but increased to about 90 m during the fall months. This resulted in a significant sub-surface cold anomaly during the summer months with temperatures reaching as much as 4^{o}C below normal (Fig. 4).

Annual surface water temperatures decreased from the record high observed in 2006 to just 0.2°C above normal and bottom temperatures decreased from near 1°C to slightly less than 0.5°C above normal (Fig. 5). The Station 27 depth-averaged annual temperature (which is proportional to the total heat content) shows large annual and decadal fluctuations throughout the time series. From 1950 to the late 1960s, the total heat content was generally above the long-term mean. Recently, the heat content varied from a record low in 1991, to a record high during 2006 and near-normal in 2007.

Maximum surface salinities (>32.4) occurred at Station 27 during late winter and early spring while minimum values of <31 occurred during early August (Fig. 4). At mid depths, salinities ranged from 32.2 to 32.8 and near the bottom, from 33-33.4. The period of low salinity values at shallow depths occurred from early summer to late fall, somewhat earlier than usual. This prominent feature of the

salinity cycle on the Newfoundland Shelf is due largely to melting sea-ice off Labrador earlier in the year followed by advection southward onto the Grand Banks.

The 0-50 m 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 to 2007 values remained above the long-term mean for the 6th consecutive year.

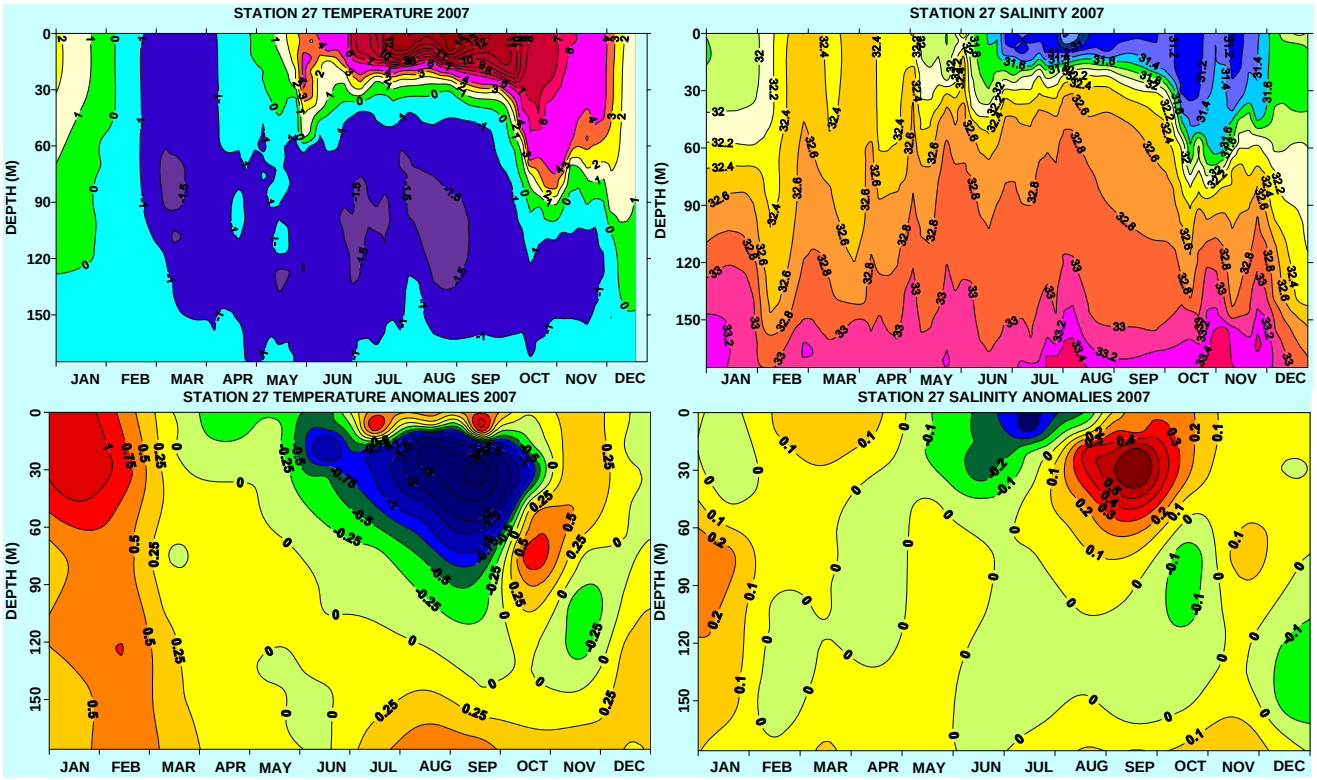

Fig. 4. Contours of temperature and salinity (top panels) and their anomalies (bottom panels) at Station 27 as a function of depth for 2007.

AZMP Standard Sections

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

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 from 32 to 33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region. This water mass is warmer and saltier than the sub-polar shelf waters with temperatures ranging from 3º to 4ºC and salinities from 34 to 34.75. Surface temperatures generally increase to 10º to 12ºC during summer, while bottom temperatures over most of the shelf range from 1º 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 sea-ice formation and melting, which lead to intense vertical and horizontal changes or gradients (Fig. 6).

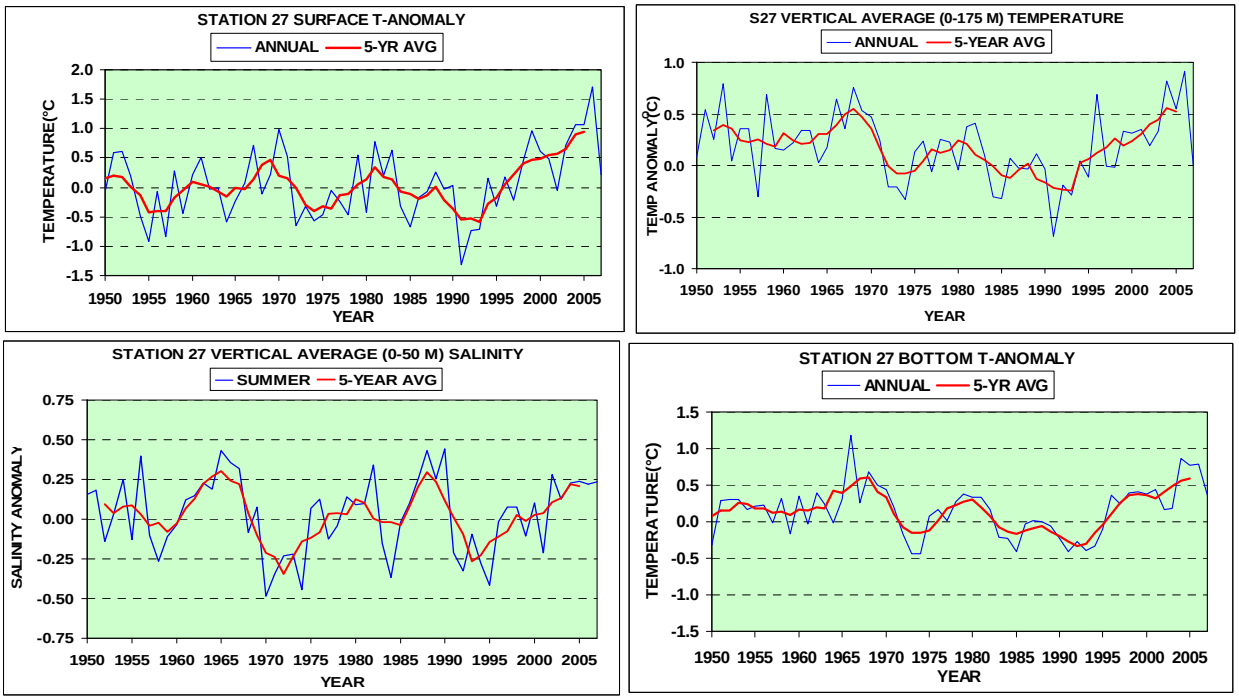

Fig. 5. Departures from normal surface, bottom and depth averaged (0-176 m) Station 27 temperature and upper layer depth averaged salinity.

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 isolated during the summer and early fall months between the seasonally heated surface layer and warmer near bottom water originating from the continental slope region. Along the Bonavista section during the summer the CIL normally extends offshore by approximately 200 km, with a maximum vertical extent of about 200 m. In 2007, the area of this water mass extended to the surface during spring, was below normal in the summer and was nearly completely eroded by late November. The seasonal cross sections of salinity show remarkable similarities from spring to fall with slightly fresher upper-layer inshore values occurring during the summer and fall (Fig. 6).

The time series of CIL area and mean temperature for eastern Newfoundland (Bonavista section) and southern Labrador (Seal Island) are displayed in Fig. 7. Low CIL areas correspond to warm oceanographic conditions. The summer CIL area during 2007 was below the long-term mean along all sections sampled from Labrador to the Grand Banks. Along the Bonavista section, the CIL was below normal for the 13th consecutive year ranking the 14th lowest in 59 years of observations. 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. The temperature time series for the eastern Newfoundland and southern Labrador sections decrease slightly from the previous three years (Fig. 7).

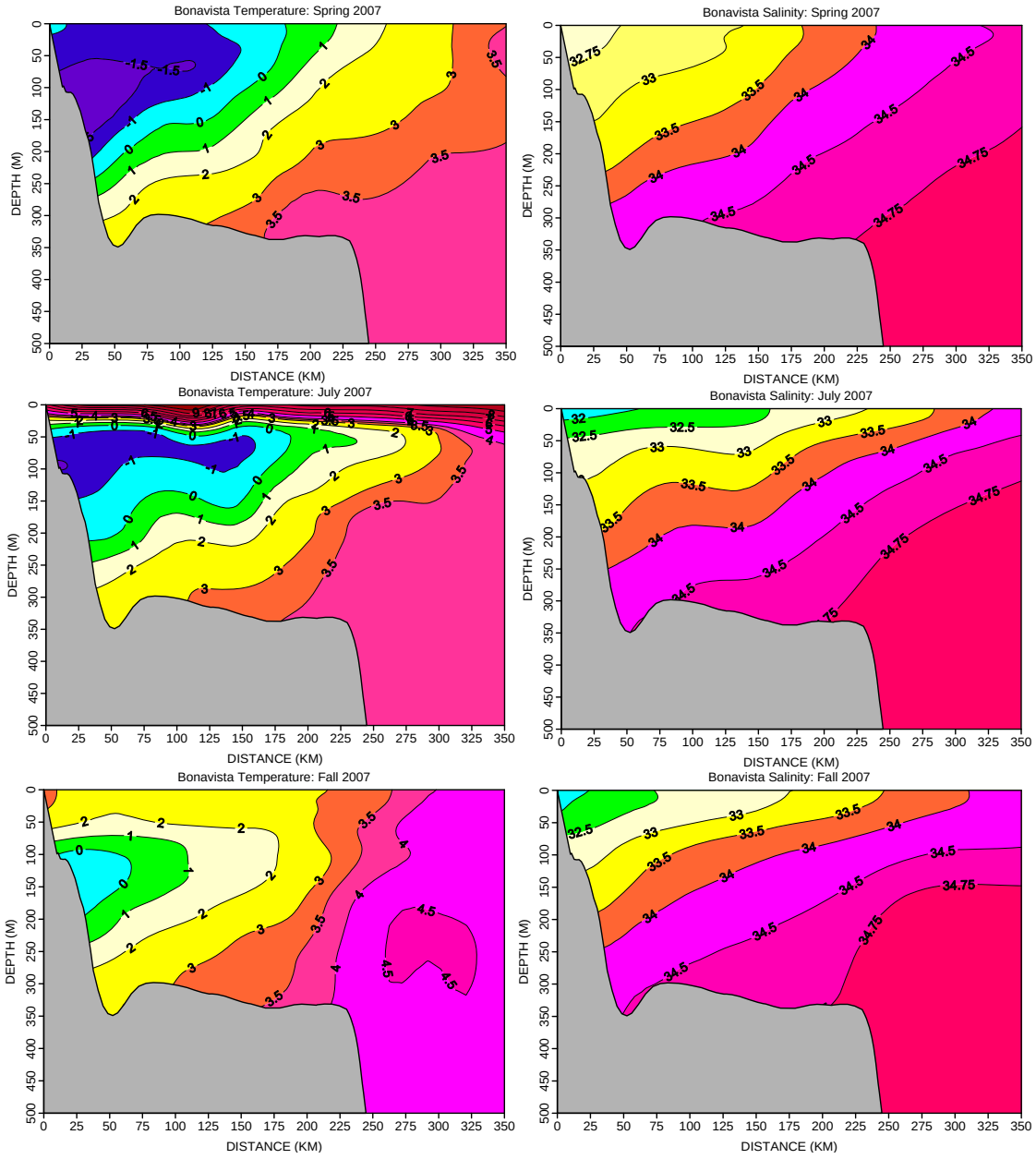

Fig. 6. Cross sectional contour maps of the temperature and salinity structure on the Eastern Newfoundland Shelf off Cape Bonavista during the spring, summer and fall of 2007.

Multi-Species Survey Results

The collection of oceanographic data aboard fisheries resource assessment surveys was initiated in 1971. 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 groundfish species to changes in the ocean environment. Two standardized trawl surveys are conducted each year, one in the spring in NAFO areas 3PLNO and one in the fall in areas 2J3KLNO (Fig. 1).

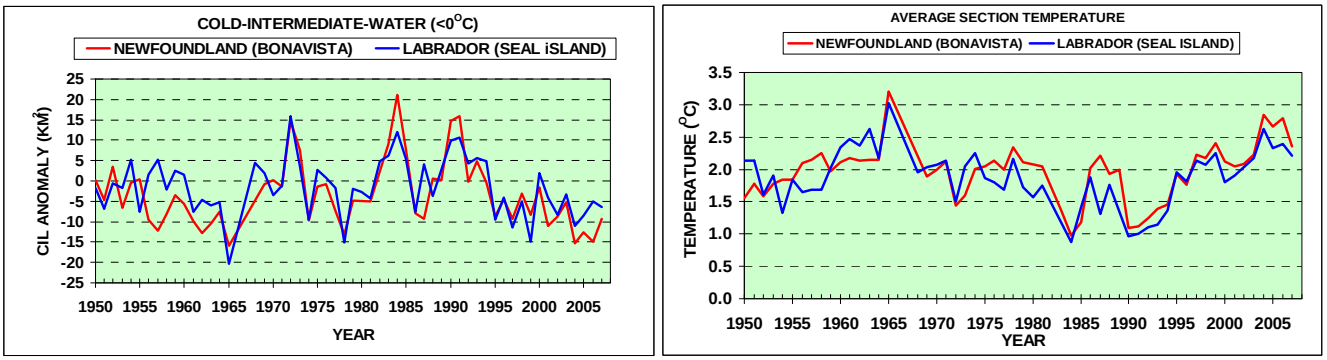

Fig. 7. Time series of the Cold-Intermediate Layer (CIL) areas and the average temperature along the Bonavista Section off eastern Newfoundland and the Seal Island Section of southern Labrador. See Fig. 1 for locations.

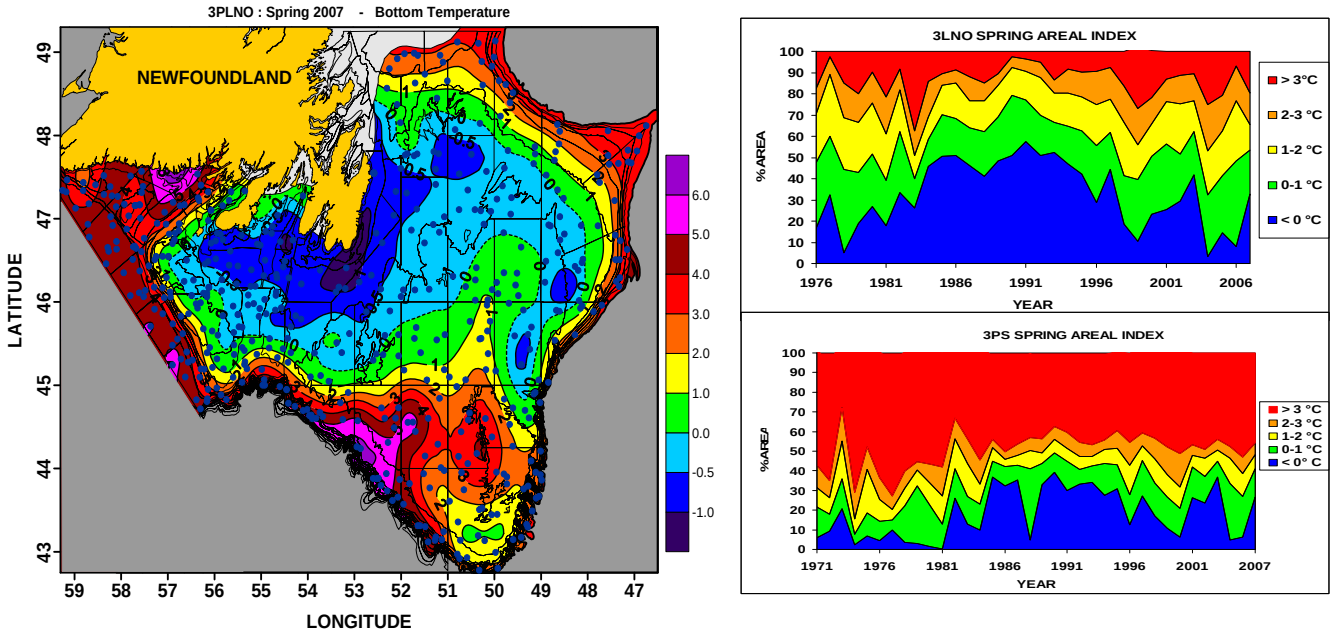

Fig. 8. Bottom temperature map (°C) for the spring of 2007 for NAFO Divisions 3PLNO and the percentage area of the bottom covered by water in different temperature ranges.

A bottom temperature map for NAFO Divisions 3PLNO based on the spring 2007 trawl surveys is displayed in Fig. 8 along with the percentage area of the bottom habitat covered with water in different temperature ranges. Spring bottom temperatures in Div. 3L ranged from <0° to 1°C in the inshore regions of the Avalon Channel and parts of the Grand Bank and from 1° to >3°C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1° to 5°C. There was a significant increase in the area of St. Pierre Bank (3Ps) and the Grand Banks (3LNO) covered by water with temperatures <0°C during the spring of 2007 compared to the previous three years (Fig. 8, right panels). In general bottom temperature anomalies were highly variable with values ranging from 0.8° to 2°C above normal over most of the 3L region and in southern areas of 3NO. In western areas of Div. 3Ps negative anomalies dominated, particularly in the deeper areas of the Laurentian Channel.

A bottom temperature map for the fall of 2007 in NAFO Divisions 2J, 3K and 3LNO along with time series of spatially averaged bottom temperatures is displayed in Fig. 9. Bottom temperatures in Div. 2J ranged from <2°C inshore, from 2° to 3°C over Hamilton Bank and >3.5°C offshore at the shelf break. Most of the 3K region is deeper than 200 m, as a result relatively warm slope water floods through the

deep troughs between the banks. Bottom temperatures in these areas during the fall of 2007 ranged between 2° to 3.5°C, a significant increase over 2006 values.

Fall bottom temperatures in Divs. 3LNO were generally above normal ranging from <0°C on the northern Grand Bank and in the Avalon Channel to 3.5°C along the shelf edge. Over the southern areas, bottom temperatures were mainly below normal ranging from 1° to 3.5°C during 2007. The spatially averaged bottom temperature in 2J and 3K increased compared to 2006 values to about 3°C, whereas in 3LNO the average bottom temperature remained identical to 2006 at about 1.8°C.

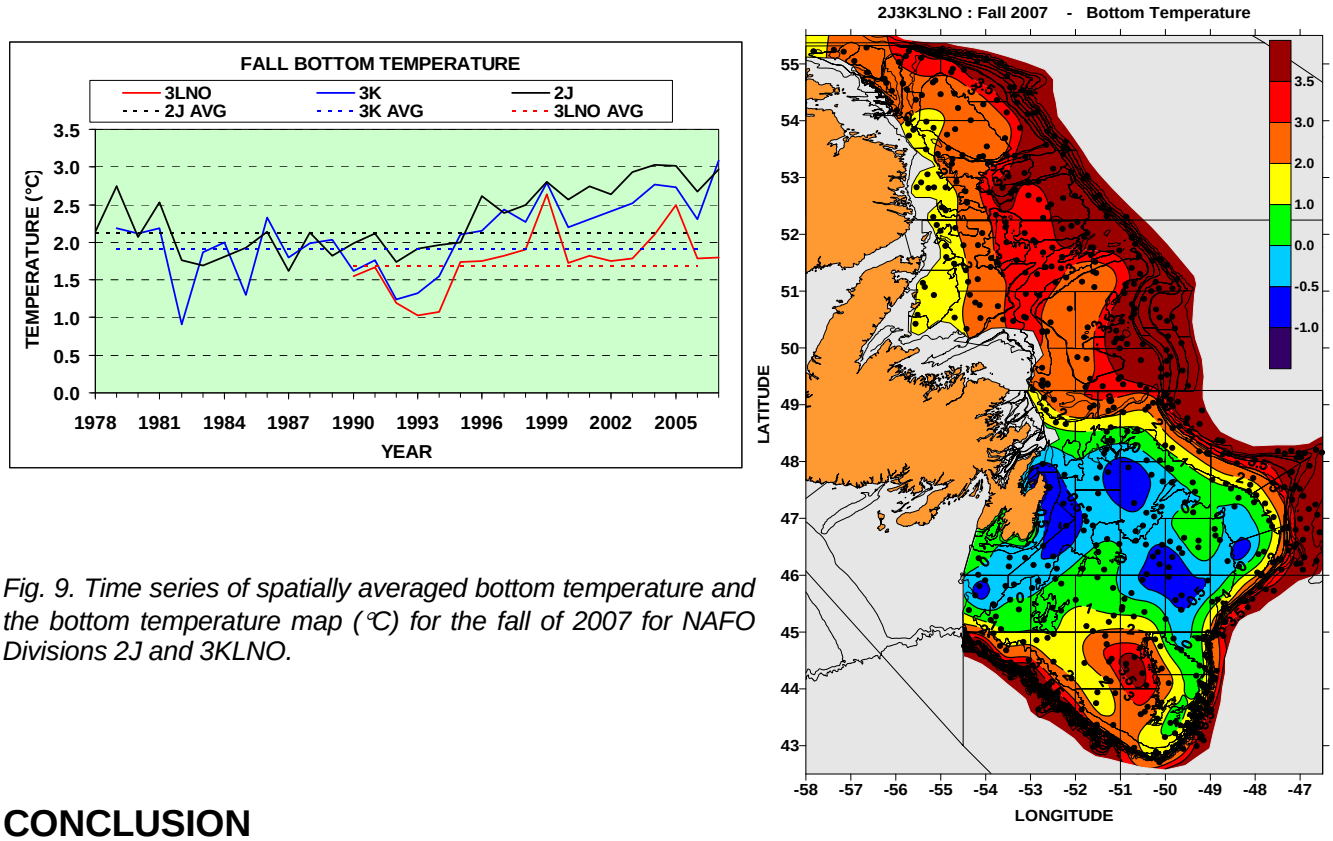

Fig. 9. Time series of spatially averaged bottom temperature and the bottom temperature map (°C) for the fall of 2007 for NAFO Divisions 2J and 3KLNO.

CONCLUSION

The North Atlantic Oscillation (NAO) index for 2007 was slightly above normal; as a consequence, arctic air mass outflow to the Northwest Atlantic was stronger than in 2006 resulting in a broad-scale cooling of air temperatures throughout the Northwest Atlantic from West Greenland to Baffin Island to Labrador and Newfoundland. Monthly sea-ice extent on the Newfoundland and southern Labrador Shelf south of 55°N latitude was below normal during the winter months and near normal during May and June with the annual average below normal for the 13th consecutive year. In general, during the past several years, the sea ice season was shorter than normal in most areas of the NL Shelf, although it extended into June in the inshore areas during the spring of 2007. In general water temperatures on the Newfoundland and Labrador Shelf also cooled from the record highs of 2006 but remained above normal in most areas, continuing the warm conditions experienced since the mid-to-late 1990s. The main exception appeared in data collected during late fall in NAFO Divs. 2J and 3K, which showed an increase in near-bottom temperatures as warmer slope water moved southward over the area. Salinities on the NL Shelf, which were lower than normal throughout most of the 1990s, increased to the highest observed since the early 1990s during 2002 and have remained mostly above normal during the past 6 years.

Outlook for 2008

Oceanographic conditions in the Newfoundland and Labrador region of the Northwest Atlantic are largely determined by the strength of the winter atmospheric circulation over the Northwest Atlantic and local air temperatures. 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 is generally true leading to warm-saline ocean conditions. A large area of lower than normal sea level pressure (SLP) over the northwest Atlantic during December caused enhance arctic air mass outflow to the region which resulted in significant negative anomalies in air temperatures, -3^{o}C in December at Cartwright and -1.6^{o}C at St. John's. This led to early and more extensive sea-ice formation on the Newfoundland and Labrador Shelf in January. The SLP in January however was above normal causing air temperatures to warm to about 0.5^{o}C below normal at Cartwright and to 1.2^{o}C above normal at St. John's. Temperature measurements at Station 27 in mid-February of 2008 indicate above normal water temperatures. Therefore, the outlook for 2008 indicates a continuation of near-normal to above normal ocean temperatures throughout the Newfoundland and Labrador Region. These conditions which may be similar to 2007 represent a significant cooling from the exceptionally warm period of 2004-2006.

SOURCES OF INFORMATION

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