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Research Document 2007/030 | **Document de recherche 2007/030**

An assessment of the physical oceanographic environment on the Newfoundland and Labrador Shelf during 2006

Évaluation de l'environment océanographique physique sur la plate-forme continentale de Terre-Neuve et du Labrador en 2006

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ISSN 1499-3848 (Printed / Imprimé)

Canada

ABSTRACT

Oceanographic observations on the Newfoundland and Labrador Shelf during 2006 are presented in relation to their long-term (1971-2000) means. At Station 27 off St. John's, the depth-averaged annual water temperature increased over 2005 setting a new record high of nearly 1°C above normal. Annual surface temperatures at Station 27 were also the highest in 61-years at 1.7°C above normal. Bottom temperatures were also above normal by 0.8°C, the 3rd highest in the 61-year record. Annual surface temperatures on Hamilton Bank were 1°C above normal, the 10th highest on record, on the Flemish Cap they were 2.5°C above normal, the 3rd highest in 57 years. Upper-layer salinities at Station 27 were above normal for the 5th consecutive year. The area of the Cold-Intermediate-Layer (CIL) water mass on the eastern Newfoundland Shelf during 2006 was below normal for the 12th consecutive year and the 3rd lowest since 1948. The near-bottom thermal habitat on the Newfoundland and Labrador Shelf continued warmer than normal in 2006, with bottom temperatures remaining >2°C, about 0.5°C above normal on Hamilton Bank off southern Labrador during the fall. Bottom temperatures during the fall however decreased substantially from 2005, particularly in northern areas. The area of bottom habitat on the Grand Banks covered by sub-zero water has decreased from >50% during the first half of the 1990s to near 15% during the past 2 years, ranking the 3rd lowest in 2006. In general, except for late fall values, water temperatures on the Newfoundland and Labrador Shelf increased from 2005 values, continuing the warm trend experienced since the mid to late 1990s. Newfoundland and Labrador Shelf water salinities, which were lower than normal throughout most of the 1990s, increased to the highest observed in over a decade during 2002 and have remained above normal in most areas during 2006.

RÉSUMÉ

Les observations océanographiques effectuées en 2006 sur la plate-forme continentale de Terre-Neuve et du Labrador sont présentées en regard des moyennes à long terme (1971-2000). Par rapport à 2005, la température annuelle moyenne de la colonne d'eau s'est accrue à la station 27, au large de St. John's, établissant un nouveau record de près de 1 °C au-dessus de la normale. La température annuelle en surface à la station 27 était également la plus élevée depuis 61 ans, à 1,7 °C au-dessus de la normale. La température au fond était aussi supérieure à la normale de 0,8 °C, la 3e plus haute valeur enregistrée en 61 ans. La température annuelle en surface au banc Hamilton était 1 °C au-dessus de la normale, la 10e valeur historique la plus élevée, tandis qu'au Bonnet Flamant, elle était de 2,5 °C au-dessus de la normale, soit la 3e valeur la plus élevée en 57 ans. La salinité de la couche supérieure à la station 27 était au-dessus de la normale pour la 5e année consécutive. L'aire de la couche intermédiaire froide (CIF) dans la partie est de la plate-forme continentale de Terre-Neuve était inférieure à la normale pour la 12e année consécutive en 2006, affichant la 3e valeur la plus basse depuis 1948. L'habitat thermique situé près du fond sur la plate-forme continentale de Terre-Neuve et du Labrador a continué à être plus chaud que la normale pendant l'automne 2006, les températures de fond demeurant > 2 °C, soit environ 0,5 °C au-dessus de la normale sur le banc Hamilton, au large du sud du Labrador. En 2006, la température au fond pendant l'automne a toutefois diminué de façon substantielle par rapport à 2005, particulièrement dans les secteurs situés au nord. L'aire de l'habitat de fond des Grands Bancs couverte par de l'eau < 0 °C, qui a diminué de > 50 % pendant la première moitié des années 1990, a atteint près de 15 % au cours des deux dernières années, soit la 3e valeur la moins élevée. En général, à l'exception des valeurs enregistrées tard à l'automne, la température de l'eau sur la plate-forme continentale de Terre-Neuve et du Labrador s'est accrue par rapport aux valeurs de 2005, poursuivant la tendance vers un réchauffement observée du milieu jusqu'à la fin des années 1990. La salinité de l'eau sur la plate-forme continentale de Terre-Neuve et du Labrador, qui était inférieure à la normale pendant la majeure partie des années 1990, s'est accrue pour atteindre les niveaux les plus élevés depuis une décennie en 2002 et est demeurée au-dessus de la normale dans la plupart des secteurs en 2006.

INTRODUCTION

This manuscript presents an overview of the physical oceanographic environment in the Newfoundland and Labrador (NL) Region during 2006, in relation to long-term average conditions based on historical data. Where possible, the long-term averages were standardized to a 'normal' base period from 1971-2000 in accordance with the recommendations of the World Meteorological Organization. The information presented for 2006 is derived from three principal sources; (1) observations made at the fixed Atlantic Zonal Monitoring Program site (Station 27) throughout the year from all research and assessment surveys, (2) measurements made along standard Northwest Atlantic Fisheries Organization and AZMP cross-shelf sections from seasonal oceanographic surveys and (3) oceanographic observations made during spring and fall multi-species resource assessment surveys (Fig. 1). Data from other research surveys and ships of opportunity are also used to help define the long-term means and conditions during 2006. These data are available from archives at the Fisheries and Oceans Integrated Scientific Data Management (ISDM) Branch in Ottawa and maintained in regional databases at the Bedford Institute of Oceanography (BIO) in Dartmouth, Nova Scotia and at the Northwest Atlantic Fisheries Centre (NAFC) in St. John's Newfoundland.

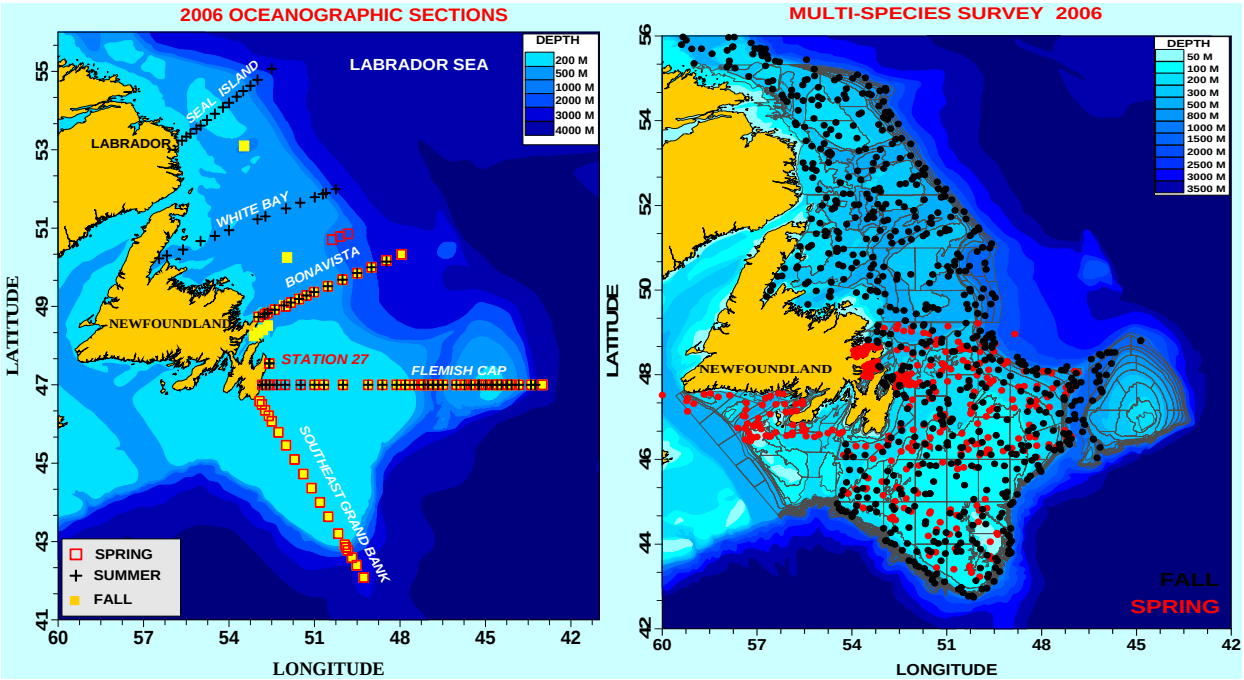

Figure 1. Maps showing sections sampled on the NL Shelf during 2006, the location of Station 27 and the positions of trawl-mounted CTD profiles obtained from the spring and fall multi-species assessment surveys during 2006.

Time series of temperature and salinity anomalies and other derived climate indices were constructed by removing the annual cycle computed over the standard base period. It is recognized that monthly and annual estimates of anomalies that are based on a varying number of observations may only approximate actual conditions; caution therefore should be used when interpreting short time scale features of many of these indices. Annual or seasonal anomalies were normalized by dividing the values by the standard deviation of the data time series over the indicated base periods, usually 1971–2000 if the data permit. A value of 2 for example indicates that the index was 2 standard deviations higher than its long-term average. As a general guide anomalies within ±0.5 standard deviations in most cases are probably not significantly different from the long-term mean. Water property time series and derived ocean climate indices from fixed locations and standard sections sampled in the Newfoundland and Labrador region during 2005 are presented as normalized anomalies in 0.5 standard deviation (SD) units

and summarized in tables. The anomalies are colour coded with blues representing cold-fresh environmental conditions and reds warm-salty conditions (Table 1). In some instances (NAO, ice and water mass areas or volumes for example) negative anomalies indicate warm conditions and hence are coloured red. More details on oceanographic monitoring programs, data analysis and long-term trends in the environment are presented in Colbourne et al. (2005).

Table 1. Standardized anomalies colour coding scale in units of 0.5 standard deviations.

			←	COLD/FRESH		WARM/SALTY		→			
<-2.5	-2.5 to -2.0	-2 to -1.5	-1.5 to -1.0	-1.0 to -0.5	-0.5 to 0.0	0.0 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2	2.0 to 2.5	>2.5

METEOROLOGICAL AND SEA-ICE CONDITIONS

The North Atlantic Oscillation (NAO) Index as defined by Rogers (1984) is the difference in winter (December, January and February) sea level atmospheric pressures between the Azores and Iceland and is a measure of the strength of the winter westerly and northwesterly winds over the Northwest Atlantic. A high NAO index corresponds to an intensification of the Icelandic Low and Azores High, which in most years creates strong northwest winds, cold air and sea temperatures and heavy ice conditions on the NL Shelf regions. During both 1999 and 2000 the NAO was well above normal, however, the colder-than-normal winter conditions usually associated with high NAO values did not extend into this region due to shifting anomalies in the sea level pressure (SLP) fields. The NAO index for 2001 to 2004 was below normal indicating a reduced Arctic outflow to the Northwest Atlantic during the winter months. In 2005, the index was slightly above normal whereas in 2006, it was slightly below normal and in both cases, the spatial patterns in the SLP fields during the winter months resulted in very weak northwesterly winds over the Newfoundland and Labrador area. The difference in SLP between Nuuk in West Greenland and Gander NL show similar patterns and correlation with local ocean conditions on the NL Shelf (Table 2).

Table 2. Atmospheric and ice anomalies from several locations in the Northwest Atlantic during 1990 to 2006. The anomalies are normalized with respect to their standard deviations over the indicated base period.

STANDARIZED PHYSICAL ENVIRONMENTAL ANOMALIES (METEOROLOGICAL AND SEA-ICE)																			
INDEX	LOCATION	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SEA-LEVEL PRESSURE	SLP (ICELAND-AZORES) NAO	1971-2000	1.05	0.33	0.23	0.87	0.38	1.27	-1.42	-0.64	-0.34	1.18	1.10	-0.96	-0.37	-0.39	-1.05	0.47	-0.39
	SLP (GREENLAND-GANDER)	1971-2000	0.49	1.45	0.79	0.98	0.04	-1.26	-0.83	0.57	-0.24	0.57	0.74	-1.90	-0.30	-1.07	-1.60	0.25	-1.35
AIR TEMPERATURES	NUUK (WINTER)	1971-2000	-0.45	-0.06	-0.72	-1.84	-0.28	-0.77	0.88	-0.05	0.12	-0.04	0.20	0.73	-0.04	1.11	0.86	1.40	1.15
	NUUK (ANNUAL)	1971-2000	-0.54	-0.11	-1.47	-1.68	-0.47	0.03	0.77	0.42	0.61	0.06	0.82	1.33	0.56	1.91	1.10	1.67	1.26
	IQALUIT (WINTER)	1971-2000	-0.60	-0.55	-0.80	-1.59	-0.12	0.14	0.62	0.13	-0.76	0.36	0.12	0.49	-0.65	0.25	0.37	0.84	1.45
	IQALUIT (ANNUAL)	1971-2000	-0.91	-0.15	-1.48	-1.54	0.01	1.02	1.00	0.72	0.58	0.53	0.91	1.05	0.29	1.31	0.54	1.40	1.98
	CARTWRIGHT (WINTER)	1971-2000	-1.38	-0.52	-0.59	-1.46	-1.00	-0.86	0.99	-0.40	0.97	1.61	0.70	0.55	-0.10	-0.20	1.59	0.50	1.46
	CARTWRIGHT (ANNUAL)	1971-2000	-0.94	-1.30	-1.05	-1.01	-0.17	0.20	1.12	0.12	1.23	1.82	1.13	1.22	0.18	1.01	1.79	1.59	2.56
	BONAVISTA (WINTER)	1971-2000	-1.51	-0.58	-0.84	-1.48	-1.46	-0.20	1.19	-0.62	0.84	2.12	1.41	0.50	0.29	-0.84	1.00	0.55	1.75
	BONAVISTA (ANNUAL)	1971-2000	-0.12	-1.42	-1.37	-1.37	-0.16	-0.25	1.21	-0.39	1.23	2.17	1.49	1.26	0.41	1.15	1.64	1.84	2.47
	ST. JOHN'S (WINTER)	1971-2000	-1.38	-0.63	-0.88	-0.97	-1.11	-0.22	0.87	-0.84	0.73	2.28	1.69	-0.11	-0.11	-0.81	0.48	0.39	1.26
	ST. JOHN'S (ANNUAL)	1971-2000	-0.07	-1.02	-1.39	-1.14	-0.03	-0.33	0.78	-0.69	1.13	2.51	1.55	0.78	0.07	0.88	1.11	1.26	2.19
SEA ICE COVERAGE	NL SEA-ICE EXTENT (Annual)	1971-2000	0.93	1.36	1.07	1.39	0.85	-0.29	-1.35	-0.58	-0.99	-1.21	-0.88	-1.41	-1.01	-0.61	-1.98	-1.40	-1.95
	NL SEA-ICE EXTENT (Winter)	1971-2000	0.86	0.87	1.02	1.52	1.02	-0.05	-1.08	-0.37	-1.33	-1.09	-0.77	-1.48	-1.13	-0.70	-2.45	-1.25	-1.95
	NL SEA-ICE EXTENT (Spring)	1971-2000	0.67	1.63	0.90	1.27	0.70	-0.45	-1.53	-0.70	-0.42	-1.23	-0.87	-1.13	-0.77	-0.30	-1.17	-1.50	-1.77
ICE BERG COUNT	GRAND BANKS	1971-2000	0.05	1.77	0.17	1.45	1.47	0.98	-0.22	0.37	0.91	-1.07	0.12	-0.98	0.17	0.25	-0.72	-1.09	-1.11

Air temperature anomalies at five sites in the Northwest Atlantic: Nuuk Greenland; Iqaluit on Baffin Island; Cartwright Labrador; Bonavista and St. John's, NL are also shown in Table 2. The predominance of warmer-than-normal annual air temperatures at all sites from the mid-1990s to 2006 is

evident, with 2006 annual and seasonal values ranging from 1 to 2 standard deviations (SD) above normal. Annual temperature at Cartwright on the mid-Labrador Coast broke a 73-year record at 2.56 SD above normal. Other recent extremes included 1999 which saw the second highest air temperatures at Cartwright (1.82 SD above normal) and a 126 year record at St. John's (2.51 SD above normal). The coldest overall air temperatures in the Northwest Atlantic since the 1990s occurred in 1993, when the annual anomalies were all at least 1 SD below normal.

The spatial extent and concentration of sea ice are available from the daily ice charts published by the Canadian Ice Services of Environment Canada. The time series of the areal extent (defined by 1/10 coverage) of sea ice on the NL Shelf (between 45°-55°N) show lower than normal amounts of ice during 2006 for the 12th consecutive year (Table 2). The spring of 2006 had the lowest extent of sea-ice on the NL Shelf since record keeping began in 1963. In general, during the past several years, the sea ice season was shorter than normal in most areas of the NL Shelf. Iceberg counts obtained from the International Ice Patrol of the US Coast Guard indicate that 11 icebergs drifted south of 48°N onto the Northern Grand Bank during 2005 and none in 2006, the lowest numbers since 1966 and well below the 106-year average of 477. In 2004, there were 262 icebergs observed on the Northern Grand Bank and in some years of the early 1990s, over 1500 icebergs were observed south of 48°N. Years with low iceberg numbers on the Grand Banks generally correspond to warmer than normal meteorological and oceanographic conditions on the NL Shelf.

A more extensive analysis of meteorological, sea ice and sea-surface temperature data in the Northwest Atlantic, including the Newfoundland and Labrador Shelf, are presented by Petrie et al. (2007).

TIME TRENDS IN TEMPERATURE AND SALINITY

Station 27, located in the Avalon Channel off Cape Spear NL (Fig. 1), was sampled 46 times (40 CTD profiles, 6 XBT profiles) during 2006. Depth versus time contours of the annual temperature cycle for 2006 are displayed in Fig. 2. The cold, near-isothermal water column during late January to early May has temperatures ranging from near 0° to –1°C. These temperatures persisted throughout the year below 120 m. Upper layer temperatures warmed to >1°C by late-April and to >15°C by August, after which the fall cooling commenced with values decreasing to 2°C by the end of December. The seasonally heated upper-layer penetrated to about 75 m depth by October and then began to cool down to 2°-3°C by December.

In general, Station 27 temperatures were below normal from 1990 to 1995, reaching minimum values in 1991 when they dipped to 2-3 SD below normal. Temperatures warmed during the mid-1990s and have remained, for the most part, above normal for the past 11 years (Table 3). The annual surface temperature at Station 27 has been increasing since 2002, reaching a 61-year high of 3.22 SD above their long-term means in 2006. Bottom temperatures were the 3rd highest at 2.7 SD, similar to 2004 and 2005 values. Vertically averaged values over various depths also set record highs >3 SD above normal (Table 3). At other locations, (Hamilton Bank, Flemish Cap and St. Pierre Bank) temperatures remained significantly above normal during both 2004 and 2005 with anomalies reaching a record 2.7 SD above normal on Hamilton Bank. During 2006, Hamilton Bank temperatures decreased compared to 2005 values while Flemish Cap values increased. Temperature data obtained from thermographs deployed at inshore sites showed considerable variability about the mean due to local wind driven upwelling. In general however, they show similar patterns, with mostly below normal anomalies during the first half of the 1990s and above normal during the latter half and up to 2006 (Table 3).

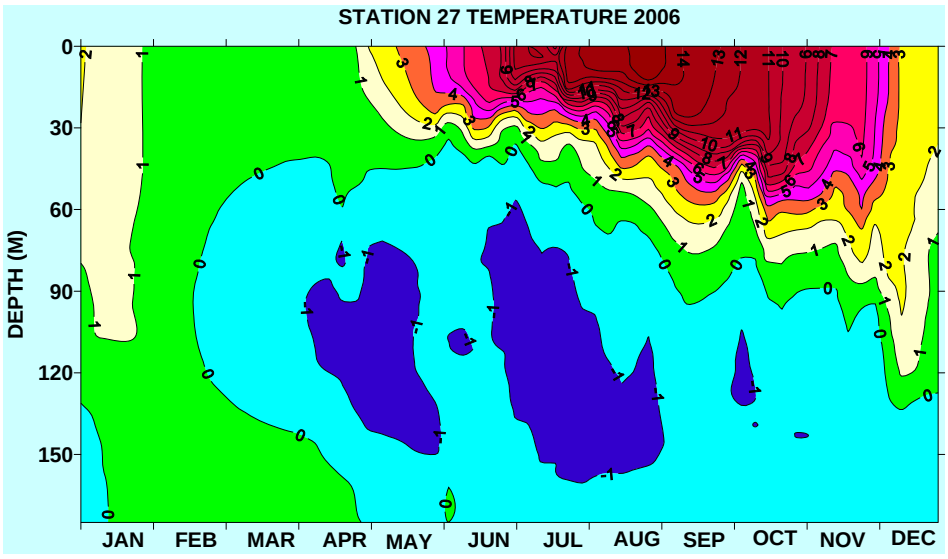

Figure 2. Contours of temperature observations (in °C) as a function of depth at Station 27 for 2006.

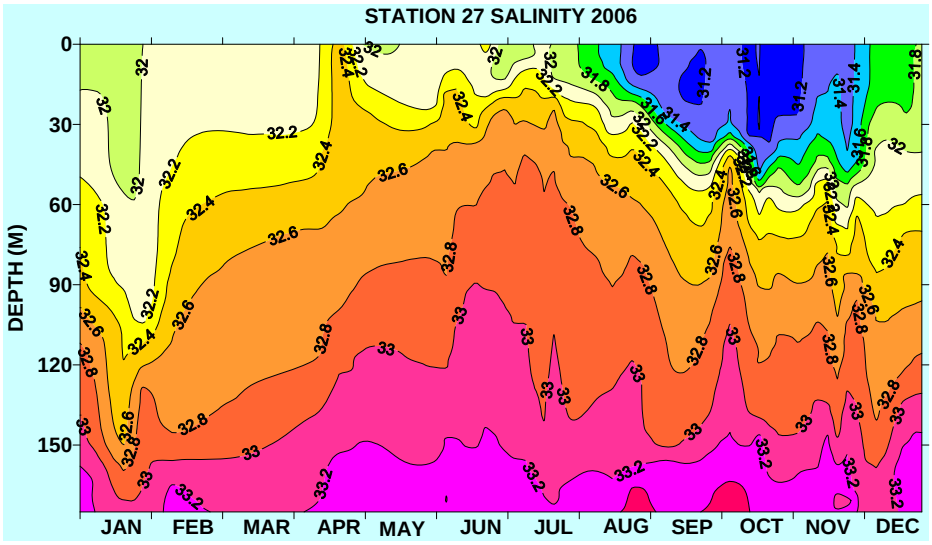

Figure 3. Contours of salinities observations as a function of depth at Station 27 for 2006.

Depth versus time contours of the annual salinity cycle for 2006 are displayed in Fig. 3. Surface salinities reached maximum values in early spring (>32) and decreased to minimum values by late summer and into the fall months (<31.2). In the depth range from 50 to 100-m, salinities ranged from 32.2 to 32.8 and near bottom they varied throughout the year between 33 and 33.4. The period of low salinity values at shallow depths occurred from late summer to late fall 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. Annual surface salinities at Station 27 increased from 2005 values and were above normal during 2006 by 0.65 SD. Depth averaged values also increased over 2005 values to 0.61-0.77 SD above normal. Upper-layer salinities during the past 5 years have ranged from near-normal to saltier than normal in contrast to the mainly fresher-than-normal values that dominated most of the 1990s (Table 3).

On the Flemish Cap, surface salinities were also higher than normal during 2006, while on Hamilton Bank they were about normal. Salinities on the Flemish Cap have been above normal from 2001 to 2006.

During the past several decades, cold ocean temperatures and fresher-than-normal waters were associated with strong positive NAO anomalies, colder-than-normal winter air temperatures, and heavy sea-ice conditions on the continental shelf (Colbourne et al. 1994; Drinkwater 1996). The magnitude of negative salinity anomalies (up to 1.8 SD) on the inner Newfoundland Shelf during most of the early 1990s is comparable to that experienced during the 'Great Salinity Anomaly' of the early 1970s (Dickson et al. 1988), however, the spatial extent of the fresh water was mainly restricted to the inner Newfoundland Shelf.

Table 3. Water property anomalies and ocean climate indices derived from temperature and salinity data collected on the Newfoundland and Labrador Shelf. The anomalies are normalized with respect to their standard deviations over the indicated base period. The grey shaded cells indicate no data.

STANDARIZED PHYSICAL ENVIRONMENTAL ANOMALIES (FIXED SITES)																			
INDEX	LOCATION	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SURFACE TEMPERATURE	HAMILTON BANK	1971-2000	0.38	-0.87	-0.56	0.34	0.15	-0.19	-0.52	0.12	2.82	-0.01	1.75	0.05	-0.23	2.50	2.03	2.73	1.43
	FLEMISH CAP	1971-2000	-0.51	-1.30	-1.54	-1.66	-0.73	0.01	0.17	0.32	2.50	0.13	0.85	0.48	-0.66	0.20	0.53	1.97	2.29
	STATION 27	1971-2000	0.05	-2.49	-1.40	-1.37	0.32	-0.60	0.32	-0.39	0.86	1.81	1.15	0.92	-0.08	1.34	2.00	2.00	3.22
	ST. PIERRE BANK	1971-2000	-1.81	-0.01	-1.24	-0.40	-0.72	0.74	0.39	-0.41	1.13	1.21	1.51	-0.82	-0.08	-0.43	0.44	2.18	
SURFACE SALINITY	HAMILTON BANK	1971-2000	-0.40	0.07	-0.29	-1.06	-1.01	0.74	0.56	1.04	-0.21	-0.46	-0.06	0.13	-0.51	-0.35	-0.09	0.73	0.02
	FLEMISH CAP	1971-2000	0.75	0.47		0.00	-1.38	0.80	0.60	1.14	-0.06	0.82	-0.29	1.26	1.49	2.27	1.46	1.20	0.56
	STATION 27	1971-2000	1.48	-1.85	-0.96	-0.04	-0.33	-1.82	0.22	-0.26	-0.29	-0.37	-0.23	-0.56	1.06	1.01	0.58	0.44	0.65
BOTTOM TEMPERATURE	STATION 27	1971-2000	-0.76	-1.42	-0.95	-1.37	-1.16	-0.38	1.24	0.83	1.36	1.43	1.31	1.50	0.60	0.63	2.95	2.65	2.70
	FLEMISH CAP	1971-2000	-2.30	-1.02	-0.66	-0.41	-2.59	-0.51	-0.48	-0.11	0.82	1.78	0.36	-0.16	0.11	0.84	1.08	2.12	1.40
	HAMILTON BANK	1971-2000	-1.19	-0.45	-0.96	-1.29	-0.64	0.49	0.67	1.71	0.65	1.56	0.28	1.79	1.72	1.19	2.25	1.86	0.66
	ST. PIERRE BANK	1971-2000	-1.26	0.20	-0.47	-0.69	-1.78	-1.07	-0.21	-0.21	-0.61	0.67	0.70	-0.53	-0.62	-1.11	1.29	2.91	
VERTICALLY AVERAGED TEMPERATURE	STATION 27 (0-20 M)	1971-2000	0.26	-2.40	-1.10	-1.22	0.62	-0.31	0.67	-0.10	1.00	2.10	1.00	1.25	0.18	1.53	2.11	1.97	3.46
	STATION 27 (0-50 M)	1971-2000	-0.18	-3.04	-0.57	-0.54	0.63	-0.13	1.62	0.03	0.18	1.26	0.95	1.73	-0.11	1.48	1.96	1.94	3.91
	STATION 27 (0-100 M)	1971-2000	0.20	-2.71	-0.59	-0.89	0.59	-0.34	2.24	-0.33	-0.28	1.23	0.87	1.12	0.56	1.30	2.61	1.89	3.21
	STATION 27 (0-175 M)	1971-2000	-0.13	-2.46	-0.69	-1.04	0.16	-0.40	2.47	-0.05	-0.05	1.18	1.14	1.25	0.68	1.18	2.95	1.98	3.27
	ST. PIERRE BANK (0-75 M)	1971-2000	-2.46	0.45	-0.26	-0.87	-1.47	-1.27	-0.49	-1.01	-0.36	1.94	0.75	-0.65	-0.14	-0.59	0.31	0.84	
VERTICALLY AVERAGED SALINITY	STATION 27 (0-20 M)	1971-2000	1.57	-1.81	-0.95	0.02	-0.26	-1.77	0.17	-0.31	-0.24	-0.35	-0.19	-0.62	1.10	1.08	0.61	0.48	0.66
	STATION 27 (0-50 M)	1971-2000	1.90	-1.63	-1.46	-0.17	-0.31	-1.35	-0.17	-0.20	-0.03	-0.17	-0.44	-0.79	1.10	1.16	0.43	0.47	0.61
	STATION 27 (0-100 M)	1971-2000	1.91	-1.37	-1.57	-0.07	-0.63	-1.00	-0.74	0.16	0.08	-0.32	-0.71	-0.78	0.77	0.85	-0.31	0.01	0.77
	STATION 27 (0-175 M)	1971-2000	1.61	-1.41	-1.54	0.15	-0.63	-0.65	-1.07	0.08	0.16	-0.32	-0.50	-0.90	0.49	0.29	-0.49	-0.10	0.77
MIXED-LAYER	STATION 27 (WINTER)	1990-2004	-0.76	-1.11	-0.83	-0.92	1.39	-0.86	0.88	0.69	-0.78	-0.13	-0.90	0.72	0.94	-0.29	1.95	0.79	2.14
MIXED-LAYER	STATION 27 (ANNUAL)	1990-2004	-0.95	-1.34	0.11	-0.04	1.13	-1.60	0.60	-0.60	-0.27	-0.17	-0.50	0.45	1.18	-0.27	2.18	0.09	0.58
MIXED-LAYER	STATION 27 (SPRING)	1990-2004	-0.72	-0.79	-0.13	-0.13	0.38	-1.21	-0.45	-1.20	1.55	-1.11	-0.13	0.98	0.91	0.02	2.03	-0.64	-0.07
STRATIFICATION	STATION 27 (ANNUAL)	1971-2000	-0.92	0.07	-0.11	-0.79	-0.12	1.55	-1.09	0.56	1.22	1.44	0.68	1.44	-0.17	0.03	-0.35	0.27	1.36
STRATIFICATION	STATION 27 (SPRING)	1971-2000	-1.31	-0.63	-0.93	-0.22	-0.51	1.60	-0.75	0.05	0.92	0.73	-0.22	0.02	-0.91	-0.89	-0.28	0.21	0.57
STRAT ONSET	ONSET (25% OF MAX)	1993-2004				-0.46	0.77	-2.10	0.50	-1.01	-1.01	-0.46	0.63	0.22	0.91	0.91	1.09	0.36	0.04
STRAT PHASE	TIME OF MAX AMPLITUDE	1993-2004				0.48	0.23	-1.35	1.72	-0.43	-1.10	-1.35	0.56	-0.60	0.39	1.39	0.06	0.64	0.64
10 M TEMPERATURE	STOCK COVE BB	1971-2000	0.44	-1.73	-0.36	-1.76	0.98	0.09	0.53	-0.70	0.96	0.90	1.18	1.33	1.08	1.32	1.05	1.44	1.81
10 M TEMPERATURE	COMFORT COVE NDB	1982-2004	1.14	-1.98	-0.73	-1.75	0.11	-1.07	0.77	-0.62	-0.11	0.92	1.08		0.70	0.82		0.38	-0.02
10 M TEMPERATURE	ARNOLDS COVE PB	1981-2004	0.81	-1.86	-1.23	-1.42	0.56	-0.68	0.72	-0.26	0.56	2.33	1.03	0.52	0.59	1.10	-0.12	0.44	1.18
5 M TEMPERATURE	BRISTOL'S HOPE	1989-2004	-0.57	-2.81		-0.52	0.64	0.14	0.22	0.06	-0.54	1.15	0.83	0.78	0.18	1.03	0.37	0.98	1.07
9 M TEMPERATURE	HAMPDEN WB	1992-2004			-0.24	0.37	-1.32	-2.01	-0.20	-0.72	0.60	0.37	1.61	-0.73	0.75	0.50	1.02	1.11	1.63
10 M TEMPERATURE	OLD BONAVENTURE	1991-2004		-1.76	-1.11	-0.98	2.05	0.17	0.62	-0.01		-0.46	0.09	1.25	0.36	0.20	-0.41	0.63	1.20
10 M TEMPERATURE	UPPER GULLIES CB	1990-2004	-1.44	-1.57	1.13	-0.38	0.39	0.50	-1.03	0.00	-1.23	1.78	-0.15	0.22	0.50	1.26	0.02	1.85	1.93

The stratification of the water column (defined as the density difference between 0 and 50 m, i.e. $\partial\rho/\partial z$) was computed from temperature and salinity data collected at Station 27. The annual average stratification index was generally below normal in the early 1990s, increased to above normal from 1997-2001, varied about the mean from 2002-2005 and increased to 1.36 SD above normal in 2006. The spring values show similar patterns, however they were significantly below normal in 2002 and 2003. Before 1997 (except 1995) stratification was mostly below normal. The time of the spring onset of stratification and of maximum amplitude are highly variable; the initial onset was slightly later than normal from 2000 to 2006,

although were not significant during the past 2-years. The mixed layer depth (MLD), estimated as the depth of maximum density gradient, is also highly variable on the inner NL Shelf. During 2004 the MLD was significantly (>2 SD) deeper than normal but shoaled to near normal depths during 2005 and deepened again in 2006. Spring values were slightly shallower than normal in 2005 and 2006 (Table 3).

STANDARD SECTIONS

Beginning in the early 1950s several countries of the International Commission for the Northwest Atlantic Fisheries (ICNAF) carried out systematic monitoring along sections in Newfoundland and Labrador Waters. In 1976, ICNAF standardized a suite of oceanographic monitoring stations along sections in the Northwest Atlantic Ocean from Cape Cod (USA) to Egedesminde (West Greenland) (ICNAF 1978). Beginning in 1998 under the AZMP program, the Bonavista and Flemish Cap sections are occupied during the spring, summer and fall and a section crossing the Southeast Grand Bank was added to the spring and fall monitoring surveys. In 2006 the Southeast Grand Bank section was sampled during April and November, the Flemish Cap section during April, July and December, the Bonavista section during late April to early-May, July and December and the White Bay and Seal Island sections during early August (Fig. 1).

The water mass characteristics observed along the standard sections crossing the Newfoundland and Labrador Shelf (Fig. 1) are typical of sub-polar waters with a sub-surface temperature range on the shelf of -1º to 2ºC and salinities 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 3^{o} to 4^{o}C and salinities in the range of 34 to 34.75. Surface temperatures normally warm to 10^{o} to 12^{o}C during late summer, while bottom temperatures remain $<0^{o}$C over the Grand Banks but increase to 1^{o} to 3.5^{o}C near the shelf edge below 200 m and in the deep troughs between the banks. In the deeper (>1000 m) waters of the Flemish Pass and across the Flemish Cap, bottom temperatures generally range from 3^{o} to 4^{o}C. In general, the water mass characteristics encountered 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 which leads to intense vertical and horizontal gradients, particularly along the frontal boundaries separating the shelf and slope water masses.

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 (Fig. 4). This winter formed shelf water mass is commonly referred to as the cold intermediate layer or CIL (Petrie et al. 1988) and is area or volume bounded by the 0^{o}C isotherm is generally regarded as a robust index of ocean climate conditions off the eastern Canadian continental shelf. While the area of the CIL water mass undergoes significant annual variability, the changes are highly coherent from the Labrador Shelf to the Grand Banks. This shelf water mass remains present throughout most of the year as summer heating and salinity changes increases the stratification in the upper layers to a point where heat transfer to the lower layers is inhibited, although it continues to undergo a gradual decay during late summer reaching a minimum in late fall, due mainly to wind forced mixing. The seasonal extent of this winter-chilled water mass is evident in the contour plots of the temperature along the Bonavista section in 2006 (Fig. 4). The water mass extended to near the surface during spring, was the 3^{rd} smallest since 1948 in the summer and was still present at mid-depths by late November of 2006. Seasonal cross sections of salinity for 2006 show remarkable similarities from spring to fall with slightly fresher upper-layer shelf values occurring during the summer (Fig. 4).

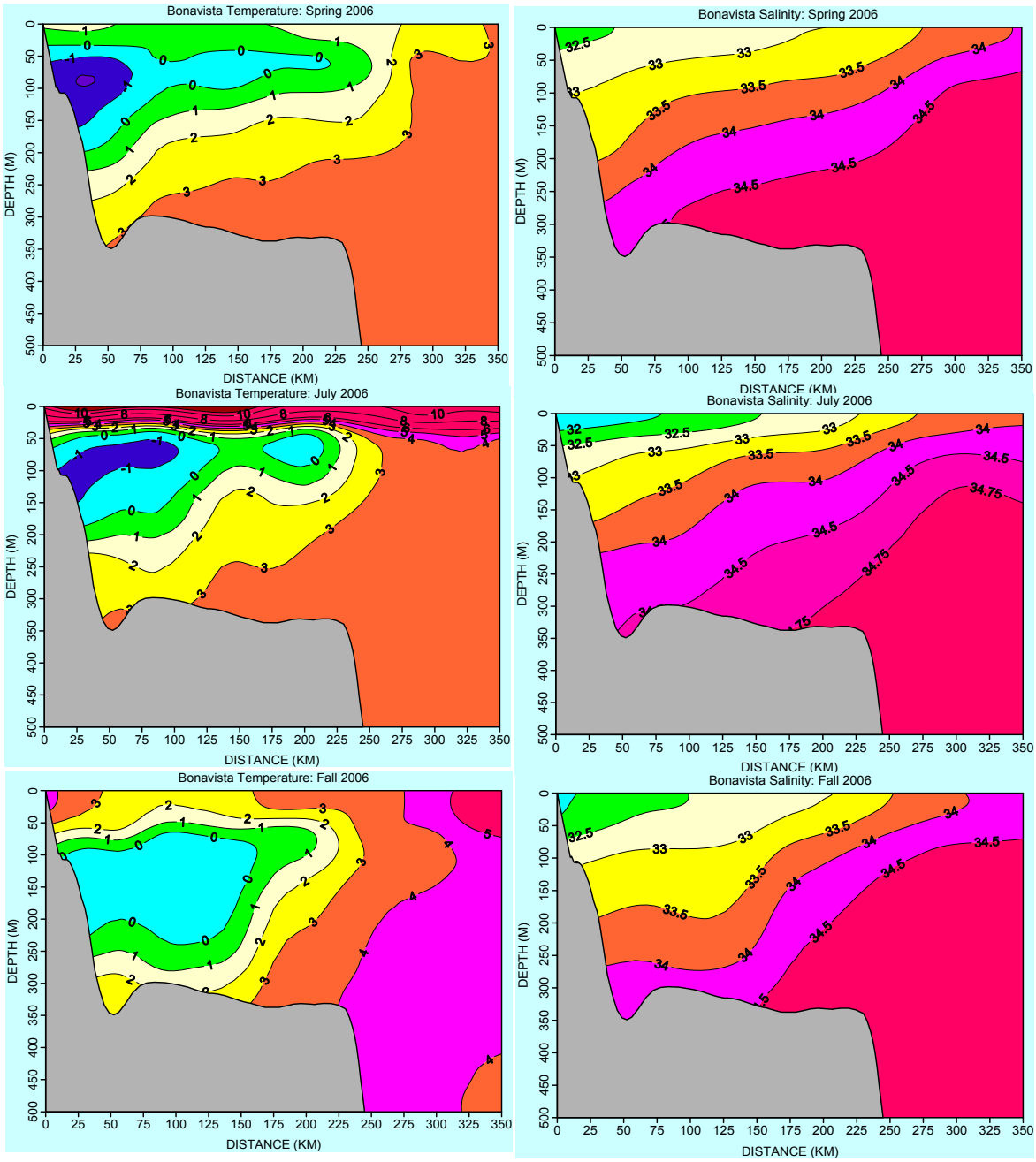

Figure 4. Contours of temperature (^{o}C) and salinity across the Newfoundland Shelf along the Bonavista Section (Fig. 1) during the spring, summer and fall of 2006.

Climate indices based on temperature and salinity data collected along sections from southern Labrador to southern Newfoundland are displayed in Table 4 for the years 1990-2006. On the southern Labrador Shelf south to eastern Newfoundland temperature and salinity have been increasing since the near-normal year of 2000, reaching near-record high values in 2004 and continuing warm and salty during 2005 and 2006. From 1990 to 1994 conditions were significantly below normal in these areas. Farther south on the Grand Bank and St. Pierre Bank, conditions have been more variable with near-record cold conditions during the spring of 2003. During 2004 to 2006 however, ocean conditions in this area have also become generally warmer and saltier than normal, although the magnitude of the anomalies are lower than

those observed farther north. Insufficient data were available for the spring of 2006 along the St. Pierre Bank section to construct T/S cross-sections.

Table 4. Temperature and salinity anomalies and ocean climate indices derived from data collected along standard sections from southern Labrador to southern Newfoundland. The anomalies are normalized with respect to their standard deviations over the indicated base period.

STANDARIZED PHYSICAL ENVIRONMENTAL ANOMALIES (AZMP STANDARD SECTIONS)																			
REGION/SECTION	INDEX	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SOUTHERN LABRADOR SEAL ISLAND SECTION (SUMMER)	COLD-INTERMEDIATE-LAYER AREA	1971-2000	1.26	1.36	0.55	0.71	0.61	-1.22	-0.51	-1.46	-0.63	-1.91	0.26	-0.52	-1.07	-0.43	-1.41	-1.09	-0.65
	MEAN CIL TEMPERATURE	1971-2000	-1.42	-0.87	-1.11	-1.30	-0.79	1.25	0.27	0.31	0.11	1.13	-0.48	0.62	0.54	-0.09	0.58	1.01	0.42
	MINIMUM CIL TEMPERATURE	1971-2000	-0.45	-0.71	-0.46	-0.82	-0.18	2.39	0.11	-0.16	0.06	1.48	-0.06	1.42	-0.13	1.08	2.68	1.42	1.53
	MEAN SECTION TEMPERATURE	1971-2000	-1.74	-1.64	-1.39	-1.32	-0.76	0.66	0.32	1.10	0.95	1.39	0.29	0.54	0.86	1.22	2.32	1.59	1.74
	MEAN SECTION SALINITY	1971-2000	-0.90	-1.03	1.12	-0.32	-0.58	0.86	-0.32	0.92	0.40	0.99	-0.58	0.40	1.31	0.21	1.51	0.86	0.66
	INSHORE SHELF SALINITY	1971-2000	0.07	-0.77	0.98	1.05	-0.54	0.71	-0.54	0.67	0.48	1.05	-1.11	0.29	0.67	0.18	0.22	1.21	0.33
	LABRADOR CURRENT TRANSPORT	1971-2000	0.64	0.84	1.32	-1.54	-0.52	0.43	0.84	0.50	1.18	-0.11	0.98	1.18	1.59	1.46	1.05	1.59	0.98
NORTHEAST NEWFOUNDLAND WHITE BAY SECTION (SUMMER)	COLD-INTERMEDIATE-LAYER AREA	1977-2000	1.69	0.95	1.02	0.83	0.96	-0.69	-0.10	-0.50	-1.03	-1.10	0.10	-0.64	-0.98	-0.54	-1.90	-1.29	-1.81
	MEAN CIL TEMPERATURE	1977-2000	-1.14	-0.54	-0.66	-1.08	-0.42	0.42	0.42	-0.24	0.42	1.55	-0.18	0.66	0.95	0.06	2.45	1.13	1.25
	MINIMUM CIL TEMPERATURE	1977-2000	-0.41	-0.68	-0.66	-0.94	-0.34	-0.16	0.80	-0.24	-0.20	1.20	0.29	0.15	0.22	0.37	4.65	0.75	2.25
	MEAN SECTION TEMPERATURE	1977-2000	-1.46	-0.84	-1.65	-1.29	-1.31	0.01	-0.11	1.00	1.22	1.50	0.55	0.53	0.60	1.00	1.92	2.00	2.11
	MEAN SECTION SALINITY	1977-2000	-1.07	-0.77	-0.66	-0.15	-0.77	0.57	-1.38	1.49	0.77	-0.25	-0.46	0.36	1.49	0.46	1.59	0.98	1.28
	MEAN SHELF SALINITY	1977-2000	0.17	-0.65	-1.21	0.98	-0.75	0.17	-0.90	1.59	0.07	-1.67	-0.60	0.07	1.19	-0.34	0.88	-0.09	0.93
EASTERN NEWFOUNDLAND BONAVISTA SECTION	CIL AREA (SPRING)	1977-2000	1.90	1.11	0.55	0.53	1.05	-0.74	-0.44	-0.44	0.14	-0.94	-0.14	-0.90	-0.34	-0.01	-1.02	-1.41	-1.44
	CIL AREA (SUMMER)	1971-2000	1.66	1.78	-0.01	0.55	-0.03	-0.99	-0.49	-1.03	-0.35	-0.93	-0.17	-1.24	-0.98	-0.58	-1.72	-1.41	-1.67
	CIL AREA (FALL)	1979-2000	1.46	0.45	0.84	1.33	0.92	-0.63	-0.45	-1.17	-0.76	-1.43	-0.19	-0.53	-0.93	-1.17	-1.43	-1.40	0.24
	MEAN CIL TEMPERATURE (SUMMER)	1971-2000	-0.95	-1.51	-0.40	-1.09	-0.47	0.71	1.41	-0.40	-1.02	-0.19	0.09	1.34	-0.26	-0.26	1.62	1.48	1.89
	MINIMUM CIL TEMPERATURE (SUMMER)	1971-2000	-0.41	-0.79	-0.25	-0.78	-0.48	0.19	0.88	-0.06	-0.09	0.62	0.34	1.22	0.54	0.28	2.78	1.73	3.02
	MEAN SECTION TEMPERATURE (SUMMER)	1971-2000	-1.68	-1.61	-1.30	-0.97	-0.83	0.30	-0.10	1.01	0.87	1.41	0.75	0.56	0.66	0.99	2.48	2.05	2.33
	MEAN SECTION SALINITY (SUMMER)	1971-2000	-1.18	-1.18	-0.32	0.04	0.53	1.63	-1.54	1.51	0.04	0.41	0.41	0.29	2.61	1.14	2.49	1.51	2.49
	INSHORE SHELF SALINITY (SUMMER)	1971-2000	0.74	-1.19	-1.10	0.30	0.56	-1.19	0.13	0.13	-0.31	-1.81	0.74	-0.40	2.32	0.04	1.00	1.09	1.80
	LABRADOR CURRENT TRANSPORT (SUMMER)	1971-2000	-0.16	1.49	1.49	0.39	-0.24	-0.24	0.47	0.08	-0.32	1.73	0.63	-1.02	0.39	0.70	-0.16	0.23	-0.95
GRAND BANK FLEMISH PASS FLEMISH CAP 47 °N SECTION	CIL AREA (SPRING)	1971-2000	0.95	0.90	0.77	1.02	0.87	0.42	-0.50	-0.10	-0.94	-2.17	-0.36	0.05	1.22	1.44	-1.57	-1.14	-1.77
	CIL AREA (SUMMER)	1971-2000	-0.03	1.68	0.62	1.26	-0.01	0.26	-0.80	0.26	-0.72	-1.37	-1.25	-0.54	-0.80	-0.41	-2.72	-1.06	-2.70
	CIL AREA (FALL)	1973-2000	0.47	0.66	0.02	0.09	0.76	-0.36	-0.28	-0.33	0.04	-1.37	0.01	-0.17	-0.62	-0.54	-1.50	-0.57	-0.69
	MEAN CIL TEMPERATURE (SUMMER)	1971-2000	-1.07	-1.83	-1.30	-1.70	-0.22	-0.85	0.86	0.27	0.59	1.39	0.99	0.90	0.14	-0.40	1.30	0.86	1.62
	MINIMUM CIL TEMPERATURE (SUMMER)	1971-2000	-0.11	-0.86	-0.25	-0.79	-0.55	-0.05	1.97	0.69	-0.08	1.06	0.93	2.34	-0.42	0.39	0.66	1.13	1.33
	MEAN SECTION TEMPERATURE (SUMMER)	1971-2000	-0.64	-1.31	-1.58	-2.47		-0.67	0.18	-0.12	0.82	1.59	0.45		-0.20	2.41	1.29	1.19	2.60
	MEAN SECTION SALINITY (SUMMER)	1971-2000		-0.15	0.05	0.15		0.54	0.34	1.12	0.73	0.83	-0.05		1.32	2.29	1.12	-0.44	1.61
	INSHORE SHELF SALINITY (SUMMER)	1971-2000		-0.54	-0.83	-0.42	-0.18	-0.42	-0.71	0.12	0.18	-0.06	-0.83	-0.83	0.47	0.06	-0.12	-0.30	0.95
	LABRADOR CURRENT TRANSPORT (SUMMER)	1971-2000		0.18	1.45	0.81		1.13	0.07	0.39	1.24	-0.14	1.13	1.24	1.45	2.51	1.13	1.13	0.18
SOUTHEAST GRAND BANK SECTION	CIL AREA (SPRING)	1972-2000	1.54	1.78	0.40	-0.21	-0.36	-0.83	-0.81	-0.19	-0.55	-0.87	-0.73	-0.21	0.79	2.08	-0.85	-0.94	-1.40
	MEAN CIL TEMPERATURE (SPRING)	1972-2000	-0.08	-0.38	-0.38	-1.81	-0.94	-1.50	0.40	0.09	0.65	-0.60	0.70	1.39	0.74	0.09	2.38	0.78	2.90
	MEAN TEMPERATURE (SPRING)	1972-2000	-1.77	-1.40	-0.89	-0.48	-0.29	-0.47	0.03	-0.17	0.29	1.46	0.20	-1.21	-1.61	-2.34	-0.07	-0.26	-0.07
	CIL AREA (FALL)	1990-2004	-0.51	1.47	-0.41	0.68	2.18	1.21	-0.54	-0.50	-0.38	-0.59	-0.38	-0.45	-0.57	-0.50	-0.70	-0.44	-0.44
	MEAN CIL TEMPERATURE (FALL)	1990-2004	-1.28	0.79	-0.77	0.42	-0.17	1.98	0.64	-1.14	-0.99	0.57	0.20	0.05	-1.06	-1.28	2.05	1.38	1.38
	MEAN SECTION TEMPERATURE (FALL)	1990-2004	-0.95	-0.46	-1.27	-0.43	-0.67	0.92	-0.64	-0.10	1.44	1.52	0.99	0.35	-0.44	-0.48	0.22	-0.39	0.93
ST. PIERRE BANK SECTION (SPRING)	CIL AREA	1993-2004				1.16	0.95	0.40	-1.03	1.09	-0.84	-1.16	-1.16	0.55	-0.09	1.20	-1.09	-1.16	
	MEAN TEMPERATURE (< 100 M)	1993-2004				-1.00	-0.82	-0.22	0.29	-0.96	0.80	1.81	1.45	-0.43	-0.16	-1.31	0.55	1.16	
	MEAN SECTION TEMPERATURE	1993-2004				-0.81	-1.45	0.47	0.16	-0.74	0.54	1.88	1.42	-0.81	0.10	-0.96	0.19	1.36	
	MEAN SALINITY < 100 M	1993-2004				0.99	-1.64	0.48	-0.68	-0.42	1.12	0.60	-1.64	1.12	-0.74	0.48	0.35	-0.55	
	MEAN SECTION SALINITY	1993-2004				1.60	-2.00	0.97	-0.92	-0.47	0.43	1.15	-0.47	-0.11	-0.65	-0.02	0.52	0.07	

In 2006 the CIL areas along most sections during spring, summer and fall were below normal, implying warmer-than-normal water temperatures on the continental shelf. Along the Bonavista section, the summer CIL area was below normal for the 12th consecutive year ranking the 3rd warmest year in the 58 year time series. This represents only a slight cooling from 2004 when it was the 2nd lowest on record. The overall average temperature along the Bonavista section was the 3rd highest on record in 2006, surpassed only by 2004 and 1965.

On the Grand Bank along the 47°N section, the summer CIL area was below normal for the 9th consecutive year and along the southeast Grand Bank section it was below normal for the 6th consecutive year with the spring of 2006 the lowest and 2003 the highest since 1972. On St. Pierre Bank the CIL area decreased sharply from the record high value during the cold spring of 2003. In this area, 1999 appears to be the warmest year in the time series. Again no data were available for 2006. Salinities continued above normal along all sections sampled in 2006. The baroclinic transport in the offshore branch of the Labrador Current was above normal during 2006 off southern Labrador and off the Grand Bank through the Flemish Pass, continuing a 7-year trend. Along the Bonavista Section however, where a significant component of the flow is in the offshore direction, there are no apparent patterns in the estimates of transport in recent years with 2006 showing a below normal estimate.

MULTI-SPECIES SURVEY RESULTS

Canada has been conducting stratified random bottom trawl surveys in NAFO Sub-areas 2 and 3 on the NL Shelf since 1971. Areas within each division, with a selected depth range, were divided into strata and the number of fishing stations in an individual stratum was based on an area-weighted proportional allocation (Doubleday 1981). Temperature profiles are available for fishing sets in each stratum and since 1989 trawl-mounted CTDs have provided profiles of salinity. These surveys provide 2 large spatial-scale oceanographic data sets on an annual basis for the Newfoundland Shelf, one during the spring from 3Pn in the west to 3LNO on the Grand Bank and one during the fall from 2J in the north, to 3NO in the south. The hydrographic data collected on the surveys are now routinely used to provide an assessment of the spatial and temporal variability in the thermal habitat of several fish and invertebrate species. A number of data products based on these data is used to characterize the oceanographic habitat. Among these are contoured maps of the bottom temperatures and their anomalies, a thermal habitat areal index, spatial variability in the volume of the cold intermediate layer and water-column stratification and mixed-layer depth spatial maps. In this section an analysis of the near-bottom temperature fields and their anomalies based on these data sets are presented for the spring and fall surveys.

SPRING CONDITIONS

Maps of bottom temperatures and their anomalies for NAFO Div. 3LNO during the spring of 2006 are displayed in Fig. 5. Spring bottom temperatures in Div. 3L ranged from <0°C 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°C to 3°C. The spring of 2006 had the 3rd lowest area of <0°C near-bottom water in Div. 3L since the surveys began in the early 1970s (Fig. 5). Bottom temperature anomalies ranged from 0.75° to 1°C above normal over most of the 3L region and in southern areas of 3NO they were more variable, but again, mostly above normal. The apparent negative anomalies along the slopes of 3O are most likely due to gridding extrapolations into areas of no data.

Climate indices based on the temperature data collected on the spring and fall multi-species surveys for the years 1990-2006 are displayed in Table 5 as normalized anomalies. In both 3Ps and 3LNO bottom temperatures were generally lower than normal from 1990-1995 with anomalies often exceeding 1 SD below the mean. By 1996 conditions had moderated to near-normal values but decreased again in the spring of 1997 to colder than normal in both 3Ps and 3LNO. In 3LNO from 1998 to 2006 with the exception of 2003 temperatures were above normal with 1999 and 2004 among the warmest years on record. The spring of 2004 had the lowest area of <0°C water in Div. 3L since the surveys began in the early 1970s at 2.13 SD below normal and in 2006 this area increased slightly to 1.81 SD below normal (Table 5).

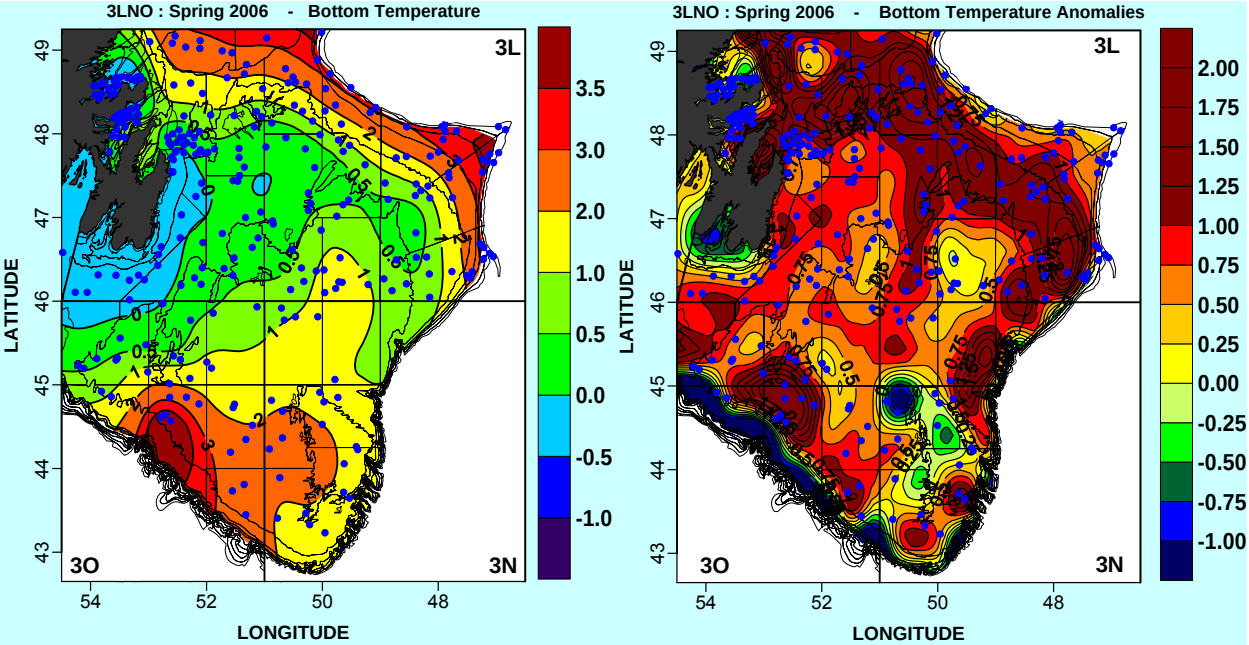

Figure 5. Contour maps of bottom temperature and their anomalies (in °C), during the spring of 2006 in NAFO Divisions 3PLNO. The blue dots indicate sampling positions.

In 3P bottom temperatures were below normal from 1990-1995, moderated in 1996, decreased again in 1997 but increased to above normal values by 1999 and 2000. Beginning in 2001 temperatures again decreased, reaching near-record cold conditions in 2003 with bottom temperatures on St. Pierre Bank (depths <100 m) reaching 1.57 SD below normal, the coldest since 1990. During 2004 and 2005 temperatures have again increased to above normal values with 2005 the highest on St. Pierre Bank since 2000, ranking the 6th highest in the 36 year time series (Table 5).

FALL CONDITIONS

Bottom temperature and temperature anomaly maps for the fall of 2006 in NAFO Div. 2J, 3K and 3LNO are displayed in Fig. 6. Bottom temperatures during the fall of 2006 in Div. 2J ranged from <0^{o}C inshore, to >3.5^{o}C offshore at the shelf break. Over Hamilton Bank they ranged from 0^{o}C to 2^{o}C which represent a significant cooling over 2005 values. 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 2006 ranged between 2^{o} to 3^{o}C. In the near-shore areas, temperatures were generally below 1^{o}C. Near the edge of the continental shelf in water depths >500 m, temperatures were near normal around 3.5^{o}C. Fall bottom temperatures in Div. 3LNO generally ranged from <0^{o}C on the northern Grand Bank and in the Avalon Channel to 3.5^{o}C along the shelf edge. Over the southern areas, bottom temperatures ranged from 1^{o} to 3.5^{o}C during 2006 and to >3.5^{o}C along the edge of the Grand Bank. During 2006, bottom temperatures were predominately above normal on the northern Grand Bank but varied about the mean in southern areas with an area of below normal values in the shallow waters of the southeast shoal of the Grand Bank (Fig. 6). The isolated areas of below normal values near the coast and within some bays are likely due to extrapolation by the gridding algorithm into areas of no data coverage and hence are not reliable. Overall bottom temperatures decreased from 2005 values however, the area of <0^{o}C bottom water on the Grand Banks during the fall of 2006 spring was the 3rd lowest on record with 2004 the lowest.

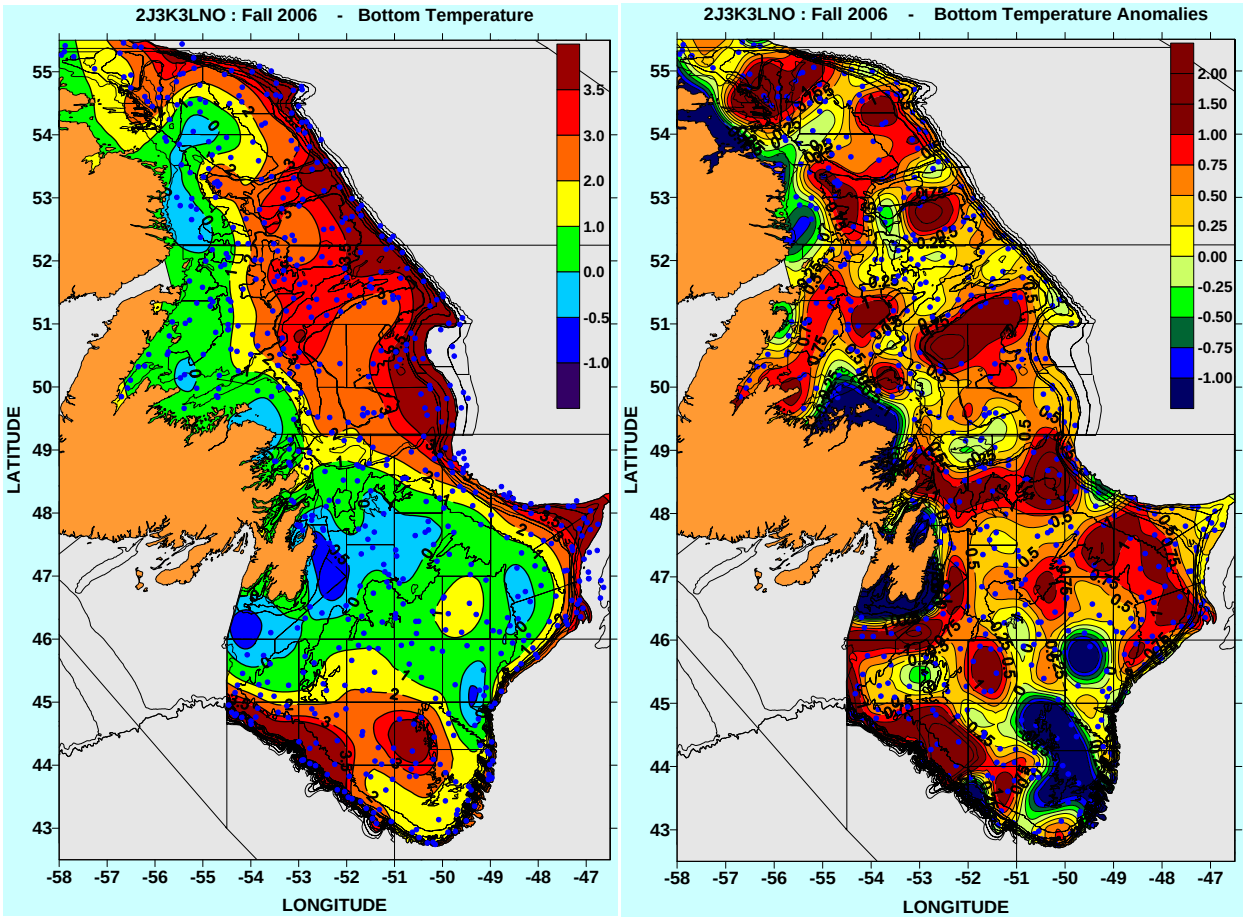

Figure 6. Contour maps of bottom temperature and temperature anomalies (in °C) during the fall of 2006 in NAFO Divisions 2J, 3KLNO. The blue dots indicate sampling locations.

The normalized temperature anomalies and derived indices based on data collected on the fall multi-species surveys for the years 1990 to 2006 are displayed in Table 5. In 2J, bottom temperatures were generally colder than normal from 1990 to 1995, with the coldest anomalies observed in 1992 when they reached >1.7 SD below normal on Hamilton Bank (<200 m depth). From 1996 to 2006 bottom temperatures were above normal reaching record high values in 2004 and 2005 (2.5 SD above normal). From 1998 to 2005 near-bottom water with temperatures <0°C disappeared from the Hamilton Bank during the fall with a corresponding increase in the area covered by water >2°C. During the fall of 2006 however, a small area of <0°C water was present on Hamilton Bank. In 3K, conditions were very similar with the 3 warmest years on record occurring in 1999, 2004 and 2005. In 3LNO during the fall bottom temperatures were somewhat cooler than those farther north in 2J and 3K with record high values in 1999, near normal values in 2000-2003 and above normal temperatures during 2004 to 2006, with 2005 being the 2nd highest in the time series. The total volume of CIL water remaining on the shelf during the fall was the lowest in the 26-year record during 1999 (1.81 SD), followed by 2004 and 2005. The 2006 value was at 0.5 SD below the long-term mean (Table 5).

Table 5. Temperature anomalies and derived indices from data collected during spring and fall multi-species surveys on the Newfoundland and Labrador Shelf. The anomalies are normalized with respect to their standard deviations over the indicated base period.

STANDARIZED PHYSICAL ENVIRONMENTAL ANOMALIES (MULTI-SPECIES SURVEYS)																		
REGION	INDEX	REFERENCE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NAFO DIV. 2J FALL	BOTTOM TEMPERATURES	1978-2000	-0.40	-0.04	-1.11	-0.61	-0.47	-0.39	1.38	0.74	1.05	1.91	1.25	1.74	1.43	2.28	2.56	2.51	1.54
	BOTTOM TEMPERATURES < 200 M	1978-2000	0.08	-0.32	-1.68	-1.71	-0.71	-0.45	1.01	0.39	0.32	1.36	0.47	1.78	0.81	1.44	2.28	2.35	1.09
	THERMAL HABITAT AREA >2°C	1978-2000	-0.76	-0.37	-0.96	-0.50	-0.28	0.45	0.92	1.01	0.73	1.28	0.54	1.53	1.14	1.57	2.17	2.70	0.65
	THERMAL HABITAT AREA <0°C	1978-2000	0.05	-0.32	1.15	0.80	-0.14	0.59		-0.58									-0.51
NAFO DIV. 3K FALL	BOTTOM TEMPERATURES	1979-2000	-0.67	-0.34	-1.51	-1.32	-0.83	0.43	0.52	1.17	0.80	1.96	0.64	0.86	1.11	1.35	1.91	1.82	0.86
	BOTTOM TEMPERATURES < 300 M	1979-2000	-0.69	-0.38	-1.27	-1.80	-1.39	0.42	0.46	1.04	1.17	1.47	0.32	0.51	0.94	1.31	1.74	1.60	0.37
	THERMAL HABITAT >2°C	1979-2000	-1.19	-0.23	-1.34	-1.26	-0.79	0.37	0.53	1.17	1.10	1.87	0.79	0.62	1.21	1.29	1.32	1.67	0.74
	THERMAL HABITAT AREA <0°C	1979-2000	0.33	0.70	1.28	0.93	0.56	-1.11	-1.07		-0.38		-0.78	-0.99		-1.04			-1.09
NAFO DIV. 3LNO FALL	BOTTOM TEMPERATURES	1990-2004	-0.38	-0.08	-1.26	-1.69	-1.58	0.08	0.12	0.30	0.51	2.32	0.06	0.29	0.11	0.19	1.01	1.98	0.19
	BOTTOM TEMPERATURES <100 M	1990-2004	0.02	-0.96	-0.87	-1.28	-1.46	0.37	0.71	0.49	0.71	2.56	0.09	-0.31	-0.50	-0.08	0.50	1.54	-0.24
	THERMAL HABITAT AREA >2°C	1990-2004	-1.09	-0.40	-0.88	-1.73	-0.83	-0.08	0.32	0.24	0.78	2.77	0.15	0.22	-0.38	-0.05	0.51	0.49	-0.07
	THERMAL HABITAT AREA <0°C	1990-2004	0.21	1.15	1.21	1.55	1.46	-0.90	-0.32	0.14	-0.69	-1.47	0.35	-0.27	-0.74	-0.17	-1.51	-1.25	-1.44
NAFO DIV 2J3KL	CIL VOLUME (SUMMER)	1980-1999	1.90	1.16		0.74	0.32	-1.23	-0.61	-0.81	-0.70	-1.28							
	CIL VOLUME (FALL)	1980-2004	0.94	1.05	1.46	1.55	0.74	-0.34	-0.85	-0.85	-0.58	-1.81	-0.45	-0.76	-0.57	-0.78	-1.47	-0.86	-0.50
NAFO DIV. 3LNO SPRING	BOTTOM TEMPERATURES	1976-2000	-1.66	-1.49	-1.11	-0.72	-0.71	-0.70	-0.24	-0.53	0.23	0.60	0.58	0.05	0.00	-0.50	0.99	0.43	
	BOTTOM TEMPERATURES <100 M	1976-2000	-1.17	-1.54	-1.22	-0.42	-0.99	-0.26	0.12	-0.81	0.98	1.82	0.57	-0.14	0.20	-0.98	1.25	0.75	0.58
	THERMAL HABITAT AREA >2°C	1976-2000	-1.54	-1.39	-1.13	-0.44	-0.46	-0.27	0.06	-0.17	0.82	2.00	0.90	-0.08	0.04	-0.10	2.05	1.18	
	THERMAL HABITAT AREA <0°C	1976-2000	1.02	1.46	1.01	1.11	0.76	0.44	-0.44	0.58	-1.10	-1.65	-0.80	-0.66	-0.41	0.43	-2.13	-1.38	-1.81
NAFO DIV. 3PS SPRING	BOTTOM TEMPERATURES	1971-2000	-1.56	-0.93	-0.94	-0.56	-0.42	-0.93	-0.03	-0.58	-0.30	0.46	0.65	-0.69	-0.19	-1.34	-0.25	0.38	
	BOTTOM TEMPERATURES <100 M	1971-2000	-1.65	-0.94	-1.07	-1.01	-0.73	-0.60	0.40	-0.46	0.45	1.29	1.58	-0.53	-0.30	-1.57	0.40	1.14	
	THERMAL HABITAT AREA >2°C	1971-2000	-1.49	-1.02	-0.72	-0.79	-0.96	-0.86	-0.21	-0.61	-0.06	0.77	1.15	-0.62	-0.50	-0.85	-0.48	0.17	
	THERMAL HABITAT AREA <0°C	1971-2000	1.66	0.95	1.20	1.27	0.77	1.02	-0.38	0.75	-0.03	-0.52	-0.88	0.67	0.47	1.48	-0.98	-0.88	

SUMMARY

The North Atlantic Oscillation winter index for 2006 was slightly below normal at 0.4 SD, while the sea-level pressure difference between Greenland and Newfoundland was significantly below normal. As a result, arctic outflow to the Northwest Atlantic was weaker-than-normal resulting in record high annual air temperatures in some locations and above normal values throughout the Northwest Atlantic from West Greenland to Baffin Island to Labrador and Newfoundland. Sea-ice extent and duration on the Newfoundland and Labrador Shelf remained below average for the 12th consecutive year. Consequently, water temperatures on the Newfoundland and Labrador Shelf remained well above normal in 2006, continuing the warm trend experienced since the mid-to-late 1990s. The annual values for 2006 increased over 2005 values even surpassing the record highs of 2004. However, data from late fall surveys show a decrease in sub-surface temperatures as slightly colder 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 in over a decade during 2002 and have remained above normal during the past 4 years.

HIGHLIGHTS FOR 2006

- Annual air temperatures were above normal in Newfoundland and Labrador by 2.9°C (record high) at Cartwright, 2°C (record high) at Bonavista and by nearly 1°C at St. John's.

- Annually, sea ice extent remained below normal for the 12th consecutive year on the Newfoundland and Labrador Shelf. The ice extent was the 4th lowest in winter and the lowest during spring since 1963.

- No icebergs were detected south of 48^{o}N on the Northern Grand Bank and only 11 during 2005, the lowest numbers since 1966, well below the 106-year average of 477.

- The Station 27 depth-averaged annual water temperature increased to 0.9°C above normal, the highest on record.

- Annual surface temperatures at Station 27 reached 1.7°C above normal, also the highest in 61 years.

- Bottom temperatures at Station 27 have been above normal for the past 11 years. In both 2005 and 2006 they were 0.8°C (2.65 SD) above normal, the 3rd highest in the 61-year record.

- Annual surface temperatures on Hamilton Bank were 1°C above normal, the 10th highest on record. On the Flemish Cap they were 2.5°C above normal, the 3rd highest in 57 years.

- Near surface salinities at Station 27 were above normal for the 5th consecutive year. The average salinity along the Bonavista section has remained above normal since 2002.

- The area of <0°C (CIL) water mass on the eastern Newfoundland Shelf was below normal for the 12th consecutive year and the 3rd lowest since 1948.

- The density driven component of the shelf-slope Labrador Current volume transport shows an increasing trend off southern Labrador and through the Flemish Pass from 2000 to 2006.

- Bottom temperatures during the fall of 2006 on the Newfoundland and Labrador Shelf were above normal in most all areas but decreased substantially from 2005, particularly off Southern Labrador.

- The area of bottom habitat on the Grand Banks covered by sub-zero water has decreased from >50% during the first half of the 1990s to near 15% during the past 3 years, ranking the 3rd lowest in 2006.

ACKNOWLEDGMENTS

We thank the many scientists and technicians at the Northwest Atlantic Fisheries Centre for collecting and providing much of the data contained in this analysis and to the Marine Environmental Data Service in Ottawa for providing most of the historical data and Environment Canada for meteorological data. We thank Ingrid Peterson at the Bedford Institute of Oceanography for providing the NL Shelf monthly sea ice areal extents. We also thank the captains and crews of the CCGS Teleost, Templeman and Hudson for three successful oceanographic surveys during 2006.

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