Physical, Chemical and Biological Status of the Labrador Sea

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Sommaire

Il s'agit du deuxième rapport annuel sur les conditions physiques, chimiques, et biologiques dans la mer du Labrador produit par la direction des Sciences de la région des Maritimes, MPO, à l'Institut océanographique de Bedford. La majorité de l'information présentée provient des visites annuelles à la section AR7W, du banc Hamilton sur le plateau continental du Labrador à cap Désolation sur le plateau continental du Groenland. En 2007, le relevé s'est déroulé du 10 au 27 mai. L'information sur l'historique de la section AR7W peut être consultée dans le rapport d'état initial publié dans le bulletin du PMZA numéro 6. En général, les températures de l'air près de la surface et de l'eau dans la mer du Labrador sont demeurées plus chaudes que la normale en 2007 mais elles montraient un léger refroidissement par rapport aux valeurs record de la période 2002 à 2006. Les moyennes annuelles de la température de l'air près de la surface dans la partie ouest de la mer du Labrador et dans l'est de l'Arctique canadien étaient jusqu'à 2 °C plus froides que les niveaux record élevés de 2006. Les températures à la surface de la mer étaient jusqu'à 1 °C plus chaudes que la normale au centre-ouest de la mer du Labrador mais près ou sous la normale sur le plateau continental et la pente continentale supérieure du Labrador. Les couches supérieures de la mer du Labrador sont demeurées chaudes et salées. L'augmentation de la température et de la salinité des eaux qui n'ont pas été aérées récemment par la convection hivernale se poursuit, suggérant une augmentation de l'apport d'eaux de l'Atlantique en provenance du sud. Les tendances récentes de la température et de la salinité dans les 500 m supérieurs au centre de la mer du Labrador sont moins évidentes. Ces couches moins profondes sont demeurées exceptionnellement chaudes et salées au cours des 4 à 5 dernières années. Les concentrations totales de carbone inorganique dans les couches supérieures au centre de la mer du Labrador ont continué à augmenter, accompagnées d'une décroissance correspondante du pH. Les concentrations en oxygène dissous dans la même masse d'eau montrent une tendance à la baisse. L'état des sels nutritifs poursuit les tendances récentes, à la baisse pour les silicates et à la hausse pour les nitrates résultant en l'augmentation des ratios nitrate:silicate. La grande variabilité observée pour toutes les propriétés biologiques rend la détection de tendances multi annuelles incertaine. Les concentrations de chlorophylle et de bactéries dans la couche supérieure sont demeurées stables au cours de la dernière décennie, mais les tendances montrent une légère pente négative au centre de la mer du Labrador.

Introduction

DFO Maritimes Region Science Branch at the Bedford Institute of Oceanography monitors physical, chemical, and biological conditions in the Labrador Sea with annual occupations of the AR7W section from Hamilton Bank on the Labrador Shelf to Cape Desolation on the Greenland Shelf. This is the second annual Labrador Sea status report. Background material on the history of the AR7W section can be found in the initial status report published in AZMP Bulletin 6.

The AR7W Section

Figure 1 shows a map of the Labrador Sea and the locations of the standard hydrographic and selected meteorological stations discussed below. Ice conditions permitting, 28 stations are sampled annually between Hamilton Bank on the Labrador Shelf and Cape Desolation on the Greenland Shelf. The surveys measure temperature, salinity, and a comprehensive suite of chemical variables including dissolved oxygen, nutrients, and dissolved inorganic carbon. Since 1994, biological variables such as dissolved and particulate biogenic (organic) carbon, bacteria, phytoplankton, and zooplankton have been an integral part of the measurement program.

The 2007 survey took place from 10–27 May 2007. Most of the planned Labrador Sea AR7W work was completed but ice conditions prevented the occupation of the four most inshore stations on the Labrador Shelf and the most inshore station on the West Greenland Shelf.

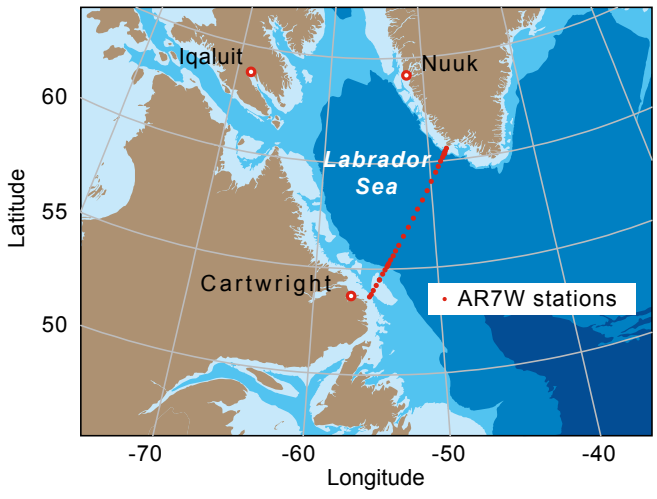

Fig. 1 Map of the Labrador Sea showing the AR7W section and selected meteorological stations.

Carte de la mer du Labrador montrant le transect AR7W ainsi que quelques stations météorologiques.

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Physical Environment

Air Temperature

Air temperatures in 2007 over the eastern Canadian Arctic and the Labrador Sea were 0.5 to 3.0°C warmer than normal (1971–2000 normal period) with maximum observed annual mean temperature anomalies in the northern sector near Davis Strait (Fig. 2). Surface air temperatures in 2007 in the Canadian Arctic and western Labrador Sea were slightly warmer than normal but up to 2°C cooler than the record high conditions observed in 2006. Surface air temperatures for 2007 at Iqaluit (Nunavut) were about 0.8°C warmer than normal based on January–September station data, compared with the record-high 2.3°C anomaly recorded in 2006.

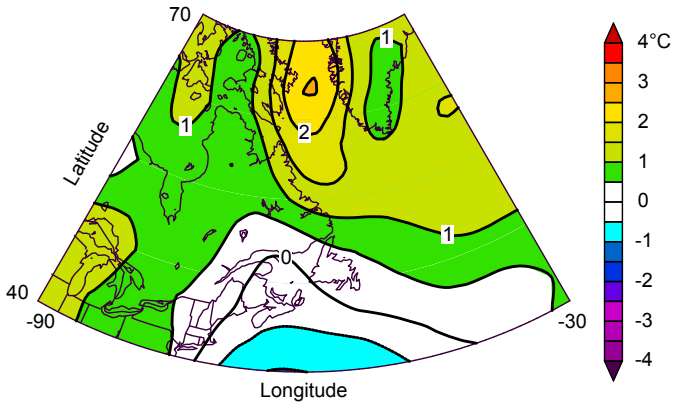

Fig. 2 Annual mean 1000 mb air temperature anomalies for 2007 relative to 1971–2000 from NCEP (National Centers for Environmental Prediction) Reanalysis data.

*Anomalies annuelles moyennes de la température de l'air à 1000 mb pour 2007 par rapport aux années 1971–2000 provenant des données de réanalyse des NCEP (*National Centers for Environmental Prediction*).*

Cartwright (Labrador) air temperatures in 2007 were about 0.9°C warmer than normal based on January–November station data, compared with a record-high 2.7°C anomaly in 2006. Annual average air temperatures over the eastern Labrador Sea continued to be warmer than normal but were nearly unchanged from 2006. Nuuk (Greenland) annual mean surface air temperatures based on station data were about 1.3°C warmer than normal in 2007, compared with a 1.6°C anomaly in 2006.

Sea-Surface Temperature

Annual mean sea-surface temperatures (SST) for 2007 from the UK Hadley Centre HadISST product were 0.8 to 1°C above normal over much of the interior of the Labrador Sea (Fig. 3), similar to conditions reported for 2006. Conditions on the Labrador Shelf in 2007 were near normal but notably cooler than seen in 2006. Waters to the south of Greenland including the southern part of the West Greenland Shelf saw annual mean surface temperature anomalies greater than 1°C, i.e., 0.5 to 1°C warmer than observed in 2006.

SST along the AR7W transect has generally increased since the cold period in the early 1990s and was exceptionally

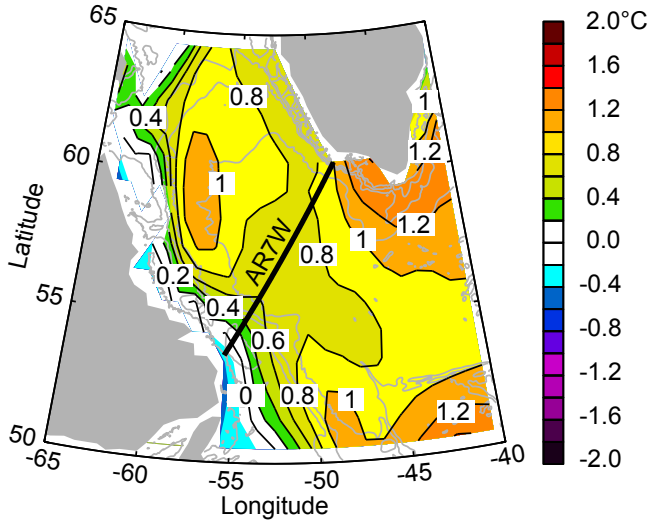

Fig. 3 Sea-surface temperature anomalies for 2007 relative to 1971–2000 (from the U.K. Hadley Centre HadISST climatology). The line marks the AR7W section.

Anomalies annuelles moyennes de la température de surface de la mer pour 2007 par rapport aux années 1971 – 2000 (provenant de la climatologie HadISST du Hadley Centre, Royaume-Uni). La ligne montre le transect AR7W.

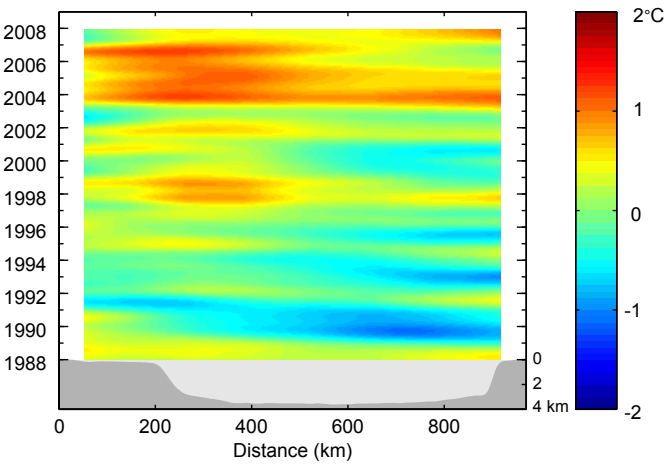

Fig. 4 Low-pass filtered 1988–2007 HadISST sea-surface temperature anomalies relative to 1971–2000 interpolated to the AR7W line. The bathymetry along the AR7W line is shown at the bottom of the figure.

Anomalies de la température de surface de la mer HadISST observées pour 1988 – 2007 par rapport aux années 1971 – 2000; ces données ont été filtrées par un filtre passe-bas et interpolées au transect AR7W. Le profil bathymétrique du transect est illustré au bas de la figure.

warm during the 2003–2006 period (Fig. 4). The annual mean section-averaged SST for each year from 2003–2006 was higher than any other time during the past 75 years of the HadISST record. The 2007 section-averaged SST was the tenth highest during this 75-year period, just lower than that observed in 1997. The SST data along the AR7W line show a recent cooling trend on the Labrador Shelf and a warming trend on the West Greenland Shelf, as was noted in the comparison of conditions in 2006 and 2007 above.

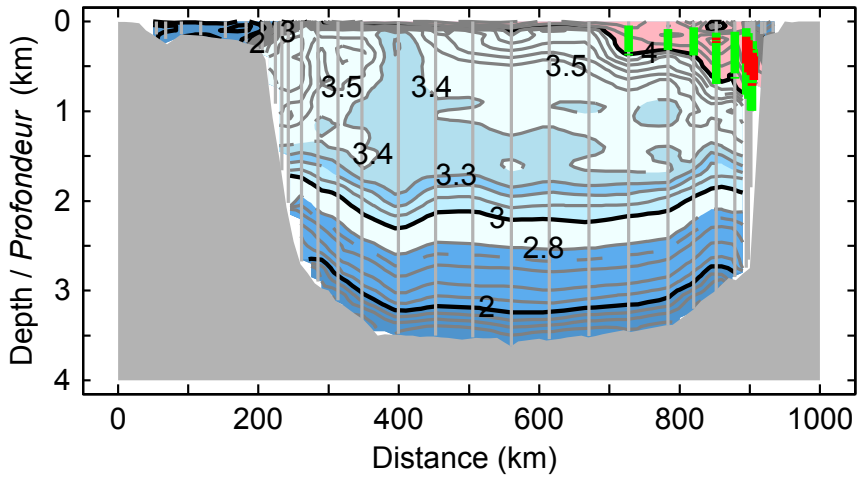

Fig. 5 Section plot of potential temperature from the 2007 occupation of AR7W. Station positions are marked by vertical lines. Waters with potential temperatures in the range 4–6°C are highlighted for salinities in the range 34.95–35.10 (red) or 34.85–34.95 (green).

Profils verticaux de la température potentielle au cours de la campagne AR7W 2007. Les lignes verticales montrent les positions des stations. Les régions colorées indiquent des eaux avec températures potentielles dans l'intervalle 4 – 6°C dont la salinité est dans l'intervalle 34,95 – 35,10 (en rouge) ou 34,85 – 34,95 (en vert).

AR7W Hydrography

The 2007 AR7W survey of the Labrador Sea took place from 12–18 May 2007, the earliest occupation of AR7W since annual observations began in the early 1990s. Heavier ice conditions than in recent years prevented the occupation of inshore stations on the Labrador Shelf. The survey also encountered an unusual band of sea ice on the outer West Greenland Shelf. Nevertheless, the 2007 survey found a continuation of the warm conditions at intermediate depths that have been observed in recent years (Fig. 5). Waters warmer than 4°C were abundant in the upper 500 m on the West Greenland side in 2007, as has been found in recent years. Figure 5 highlights the warm and saline Atlantic waters from the Irminger Current that enter the Labrador Sea as an offshore branch of the West Greenland Current and play an important role in the regional heat and salt balance.

During the early 1990s, deep winter convection in the Labrador Sea filled the upper 2 km with cold and fresh water. Milder conditions in later years have seen winter overturning to depths of 500 to 1000 m. There has been at least a partial annual renewal by winter convection in the upper 500 m, but the deeper layers have been more isolated from direct surface inputs of heat and fresh water. Steady increases in temperature and salinity of the 500–1500 m layer in the central Labrador Basin (Fig. 6) since the end of deep convection in 1994 indicate increasing proportions of Atlantic water from the south. The 100–500 m layer shows a more variable recent trend to warmer and saltier conditions. This layer is subject to the effects of surface heat and freshwater forcing and freshwater input from ice melt in addition to horizontal exchanges. In both layers, the past four years show the warmest and saltiest conditions of the AR7W record.

Chemical Environment

Deep mixed layers formed in the Labrador Sea during winter convection exchange oxygen, carbon dioxide (CO_2), and other gases with the overlying atmosphere. The Labrador Sea acts as a net sink of atmospheric CO_2 as the surface waters absorb it during winter overturning and rapidly transport it to depth.

Dissolved CO_2 reported as total inorganic carbon (TIC) has increased steadily in recent years in the upper layers (100–500 m) of the central Labrador Sea (Fig. 7). Increasing levels of dissolved CO_2 lead to ocean acidification through corresponding increases in the concentration of carbonic acid, which has potential impacts on marine ecosystems. The concentration of total inorganic carbon in this newly ventilated Labrador Sea water has increased by about 12 µmol kg^{-1} from 1996 to 2007, with a corresponding decrease of about 0.04 pH units (Fig. 7).

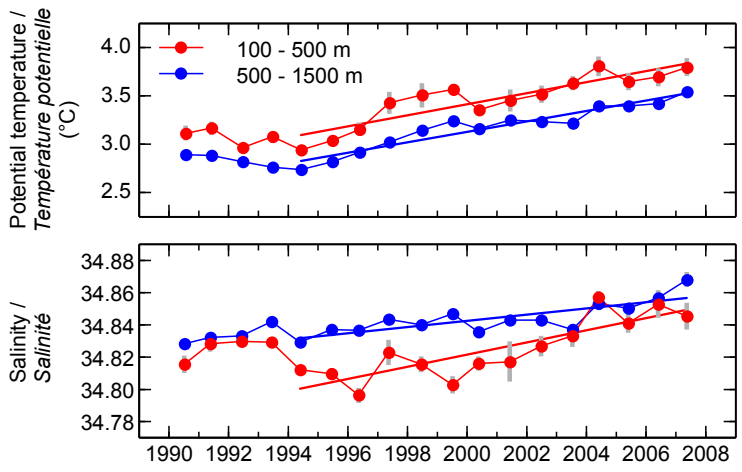

Fig. 6 Time series of potential temperature (top) and salinity (bottom) in the 100–500 m and 500–1500 m depth ranges for the period 1990–2007 and corresponding regression lines for the period 1994–2007 for stations in the central Labrador Basin.

Séries temporelles de la température potentielle (panneau du haut) et de la salinité (panneau du bas) pour les intervalles de profondeurs 100 – 500 m et 500 – 1500 m pour la période 1990 – 2007, et les lignes de régression correspondantes pour la période 1994 – 2007 pour les stations au centre du bassin du Labrador.

Dissolved oxygen shows a negative trend in this same central Labrador Sea water mass (Fig. 8). As much as half of this decrease could be due to decreases in oxygen solubility associated with warmer water temperatures. Decreased air–sea exchanges of oxygen and a reduction in the transport of oxygen to depth are expected in the milder conditions of the past decade. Under these conditions, biological oxygen consumption (respiration) will decrease oxygen concentration. Any decrease in dissolved oxygen associated with increased respiration will increase TIC. The observed increases

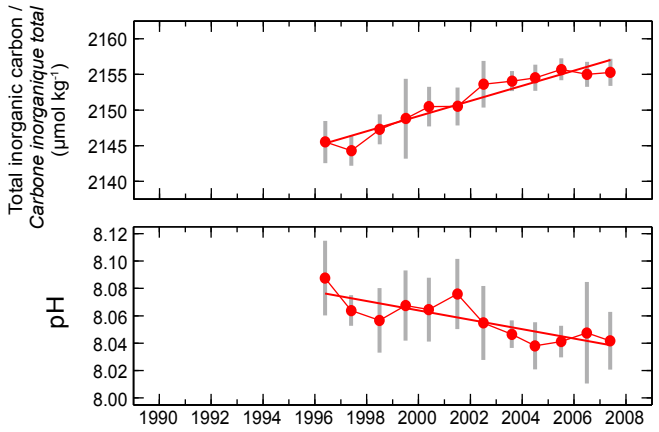

Fig. 7 Total inorganic carbon (top) and pH (bottom) in the 100–500 m depth range and corresponding regression lines for stations in the central part of the Labrador Basin for the period 1996–2007.

Concentrations de carbone inorganique total (panneau du haut) et pH (panneau du bas) dans l'intervalle de profondeur 100 – 500 m et les lignes de régression correspondantes pour des stations au centre du bassin du Labrador pour la période 1996 – 2007.

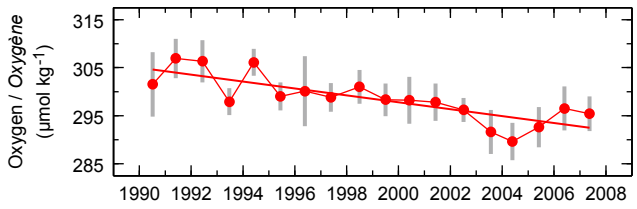

Fig. 8 Dissolved oxygen concentration in the 150–500 m depth range and corresponding regression lines for stations in the central part of the Labrador Basin for the period 1990–2007.

Concentration d'oxygène dissous dans l'intervalle de profondeur 150 – 500 m et la ligne de régression correspondante pour des stations au centre du bassin du Labrador pour la période 1990 – 2007.

in TIC (Fig. 7) are a reflection of increases in atmospheric CO_2 related to global change, but biology plays a role.

Changes have also been observed in the inventories of nutrients needed for primary production. Silicate is essential to most diatoms for shell construction and to silicoflagellates for skeletal structure. While other phytoplankton, many of which are smaller in size, do not need silicate, nitrate is used by virtually all phytoplankton species for protein synthesis. Nutrients in the 60–200 m depth range reflect the surface water concentrations after winter mixing and drive the annual plankton growth. Nutrient climatologies at 200 m (Fig. 9) suggest that exports from Baffin Bay provide the main source of upper-layer silicate in the Labrador Sea, leading to relatively high values on the Labrador Shelf and Slope, while North Atlantic waters provide the main source of upper-layer nitrate, leading to relatively high values in the interior of the Labrador Sea. For 2007, section averages for silicate and nitrate in the 60–200 m depth range indicate a continuation of the trends observed for the 1990 to 2006 period: a general increase in nitrate concentrations and decrease in silicate concentrations, consistent with a decrease in the relative importance of Arctic source waters compared to Atlantic source waters. These trends in nitrate and silicate concentrations generate increases in nitrate to silicate ratios across the entire AR7W section (Fig. 10). The largest changes in ratio are seen on the Greenland Shelf. Increases in the nitrate:silicate ratio have the potential to influence phytoplankton growth and community structure. Differential nutrient availability is a selective force that may influence species composition and thereby the size structure of phytoplankton communities in the Labrador Sea.

Biological Environment

Time series of 0–100 m mean chlorophyll concentration and bacterial abundance for station groups on the Labrador Shelf, the central Labrador Basin, and the Greenland Shelf show large scatter partly caused by sampling issues related to seasonal variability (Fig. 11). Although both biogenic carbon pools have remained relatively stable for the last decade,

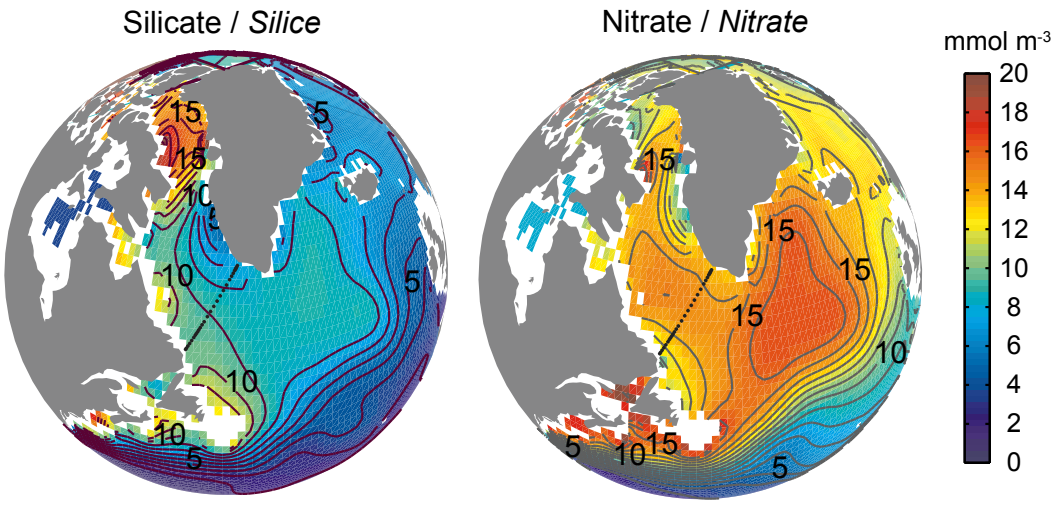

Fig. 9 Climatological distributions of silicate (left) and nitrate (right) at 200 m depth in the Northwest Atlantic from the World Ocean Atlas 2005. Dots mark the positions of the standard AR7W stations.

Concentration de la silice (à gauche) et de nitrate (à droite) à 200 m de profondeur dans l'Atlantique Nord-Ouest selon le World Ocean Atlas 2005. *Les positions des stations standards AR7W sont illustrées par les points noirs.*

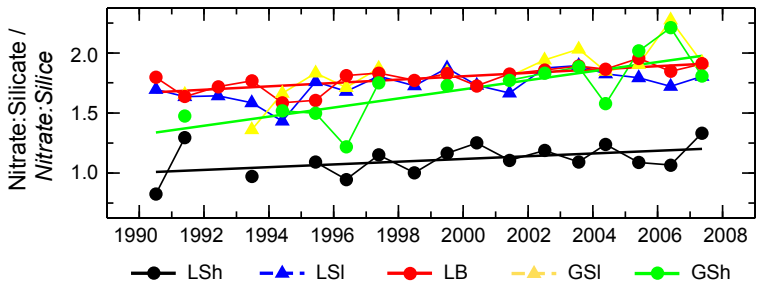

Fig. 10 Nitrate:silicate concentration ratios (60–200 m) and corresponding regression lines for groups of stations for the Labrador Shelf (LSh), the Labrador Slope (LSl), the central Labrador Basin (LB), the West Greenland Slope (GSl), and the West Greenland Shelf (GSh).

Les rapports des concentrations nitrate:silice (60 – 200 m) et les lignes de régression correspondantes pour des groupes de stations sur le plateau continental du Labrador (LSh), sur le talus continental du Labrador (LSl), dans le bassin du Labrador (LB), sur le talus continental de l'ouest du Groenland (GSl), et sur le plateau continental de l'ouest du Groenland (GSh).

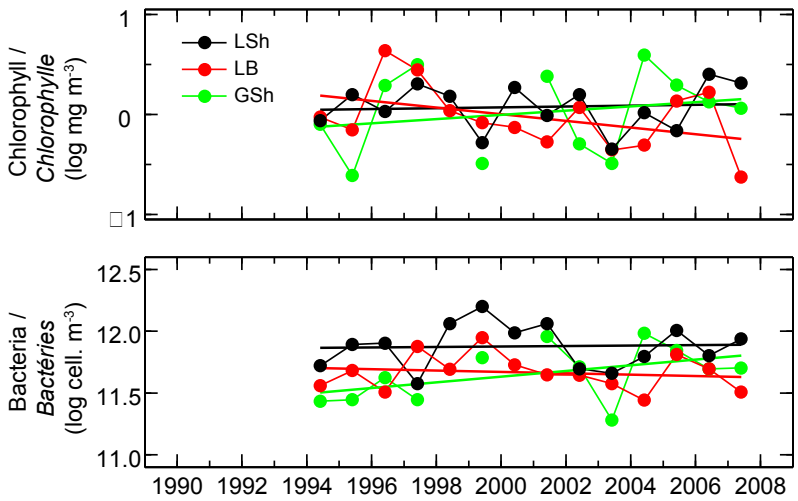

Fig. 11 Chlorophyll concentration (top) and bacterial abundance (bottom) in the 0–100 m depth range and corresponding regression lines for groups of stations for the Labrador Shelf (LSh), the central Labrador Basin (LB), and the Greenland Shelf (GSh).

Concentration de la chlorophylle (panneau du haut) et l'abondance des bactéries (panneau du bas) dans l'intervalle de profondeur 0–100 m et les lignes de régression correspondantes pour des groupes de stations sur le plateau continental du Labrador (LSh), dans le bassin du Labrador (LB), et sur le plateau continental de l'ouest du Groenland (GSh).

they both show slight negative trends in the central Labrador Basin. Increasing temperatures and shifts in nutrient levels might be expected to affect biological processes. These signals could be propagated through plankton food webs from the bottom up, starting at the level of phytoplankton, which are the primary producers. The issue of changes in species composition is under active investigation and is something to look for in future AR7W surveys.

The copepod *Calanus finmarchicus* makes up a large proportion of the total mesozooplankton biomass sampled on AR7W surveys. The 2007 survey took place from 12–18 May 2007, the earliest occupation of AR7W since annual observations began in the early 1990s. The spring bloom had not yet begun on the Labrador Shelf and Slope, and reproductive success was correspondingly low in the western Labrador Sea. In West Greenland waters, the spring bloom was well underway and there was a corresponding increase in reproductive success. More detailed analyses of the zooplankton measurements on the 2007 AR7W survey will follow when all of the samples have been processed.

Highlights 2007

Overall, Labrador Sea surface air and sea temperatures remained warmer than normal in 2007 but showed a slight cooling relative to record-high values during 2002–2006. Annual mean surface air temperatures over the western Labrador Sea and eastern Canadian Arctic were up to 2°C cooler than record-high conditions observed in 2006. Sea-surface temperatures were up to 1°C warmer than normal in the west-central Labrador Sea but near or below normal on the Labrador Shelf and inner Labrador Slope.

The upper layers of the Labrador Sea remained warm and saline. Waters that have not recently been ventilated by winter convection continue to become warmer and saltier, indicating an increasing fraction of Atlantic waters from the south. Recent temperature and salinity trends in the upper 500 m of the central Labrador Sea are less obvious. These shallower levels have remained exceptionally warm and saline during the past 4–5 years.

Total inorganic carbon concentrations in the upper levels of the central Labrador Sea continued to increase with a corresponding decrease in pH. Dissolved oxygen concentrations in the same water mass show a downward trend. Nutrient conditions followed recent trends—downward in silicate and upward in nitrate—resulting in increasing nitrate:silicate ratios.

High variability in all biological properties makes multi-year trends uncertain. Upper-layer chlorophyll and bacteria concentrations have remained relatively stable for the last decade, but both show slight negative trends in the central Labrador Sea.

Acknowledgements

Figure 2 was provided by the NOAA/ESRL Physical Sciences Division from their Web site at http://www.cdc.noaa.gov. The HadISST 1.1 global sea-surface temperature data were provided by the Hadley Centre for Climate Prediction and Research (http://www.metoffice.com). Climatological hydrographic and nutrient data from the World Ocean Atlas 2005 were provided by the U.S. National Oceanographic Data Center (http://www.nodc.noaa.gov/). Many staff and associates of Ocean Sciences Division and Ecosystem Research Division at BIO have contributed to the Labrador Sea program. The efforts of the officers and crew of CCGS *Hudson* in support of this work in recent years are gratefully acknowledged.