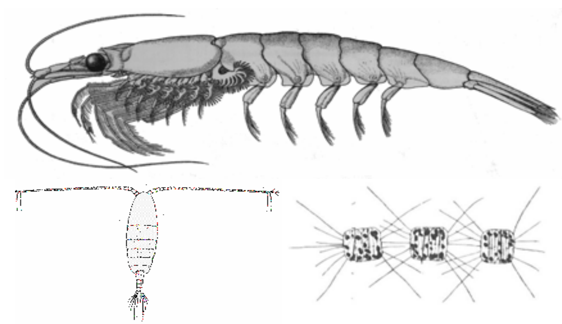
2007 STATE OF THE OCEAN: CHEMICAL AND BIOLOGICAL OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND AND LABRADOR REGION



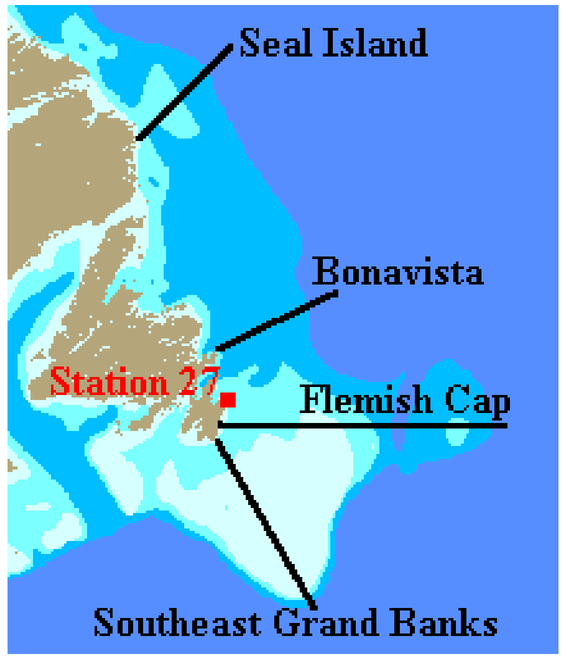


Figure 1: Map of survey region showing AZMP oceanographic transects (in black) and location of fixed station (in red).

Context

The Atlantic Zone Monitoring Program (AZMP) was implemented in 1998 with the aim of increasing DFO's capacity to understand, describe, and forecast the state of the marine ecosystem and to quantify the changes in the ocean's physical, chemical and biological properties. A critical element of the AZMP involves an observation program aimed at assessing the variability in nutrients, phytoplankton and zooplankton.

The AZMP derives its information on the state of the marine ecosystem from data collected at a network of sampling locations (fixed point stations, cross-shelf sections, and groundfish surveys) in each region (Quebec, Gulf, Maritimes, Newfoundland) sampled at a frequency of bi-weekly to once annually.

A description of the seasonal patterns in the distribution of phytoplankton (microscopic plants) and zooplankton (microscopic animals) provides important information about organisms that form the base of the marine foodweb. An understanding of the production cycles of plankton, and their interannual variability, is an essential part of an ecosystem approach to fisheries management.

SUMMARY

- The inventories of nitrate, the principal limiting nutrient, which had remained relatively stable or decreased throughout much of the last eight years, have increased throughout much of the region.

- The abundance of phytoplankton at Station 27 is near the long term average and similar to levels measured in 2006. However, the magnitude of the change from 1999–2007 is not statistically significant nor was the variation reflected along the oceanographic transects where the timing of the surveys can influence our estimates of abundance.

- In 2007, the overall abundance of zooplankton at Station 27 was above the long term average in 10 of the 16 dominant species groups, including *C. hyperboreus*, *Metridia* spp. and euphausiids. This resulted in the second highest biomass of zooplankton recorded since the start of monitoring activities.

- The abundance of most large copepods species was at or near the long term mean on the Newfoundland shelf, although two cold water species on the Grand Banks (*C. hyperboreus* and *C. glacialis*) have shown a decrease since 2002-2003.

- Many of the small copepods on the Grand Banks reached their highest abundance levels since the start of the monitoring program, a pattern that was not echoed further North on the Newfoundland and Labrador Shelves where abundance was near or below normal.

- Although the overall abundance of carnivorous and omnivorous zooplankton was generally slightly below the long term average, we noted a trend of decreasing abundance since 2004-2005 in many species throughout much of the region. A similar trend was observed in many of the non-copepod herbivores. In addition to a general decrease in recent years, most taxa in this category were below the average long term abundance levels.

INTRODUCTION

Phytoplankton are microscopic plants that form the base of the aquatic food web, occupying a position similar to that of plants on land. There is a wide variation in the size of phytoplankton. Some of the largest species are members of a group called diatoms while smaller species are members of a group called flagellates. They use light to produce organic matter from nutrients dissolved in marine waters. The growth rate at which new organic matter is produced depends on temperature and the abundance of light and nutrients. The phytoplankton constitute the primary food source of the animal component of the plankton, zooplankton. In most marine waters, phytoplankton undergo a spring-summer explosion in abundance called a bloom.

The dominant zooplankton in Newfoundland waters are copepods. They represent the critical link between phytoplankton and larger organisms. Young copepods (nauplii) are the principal prey of young fish while the older stages (copepodites) are eaten by larger fish, such as juvenile and adult capelin.

A description of the cycle of nutrients on the continental shelf aids in understanding and predicting the variability of plankton populations in space and time. An understanding of the plankton cycles will, in turn, aid in assessing the health of the marine ecosystem and its capacity to sustain fisheries. The data for this report are derived from approximately semi-monthly observations at Station 27, located 5 km from the mouth of St. John's Harbour, and from oceanographic surveys conducted along 3 to 4 cross-shelf transects in the spring, summer and fall. At each sampling site, physical (temperature, salinity, density), chemical (oxygen, nutrients), and biological (phytoplankton, zooplankton) variables are collected.

ANALYSIS

Nutrient concentrations and phytoplankton biomass

During 2007, the seasonal cycle of nitrate (a source of nitrogen) and silicate (a source of silica which is critical for some dominant species of phytoplankton) showed the typical pattern of depletion in surface waters following the spring phytoplankton bloom. The timing of the spring bloom at Station 27 was near normal but also of greater duration (nearly 60 days vs. an average of 45 days) (Figure 2). The average seasonally-adjusted biomass of phytoplankton at Station 27 in 2007 was only slightly below the long term average.

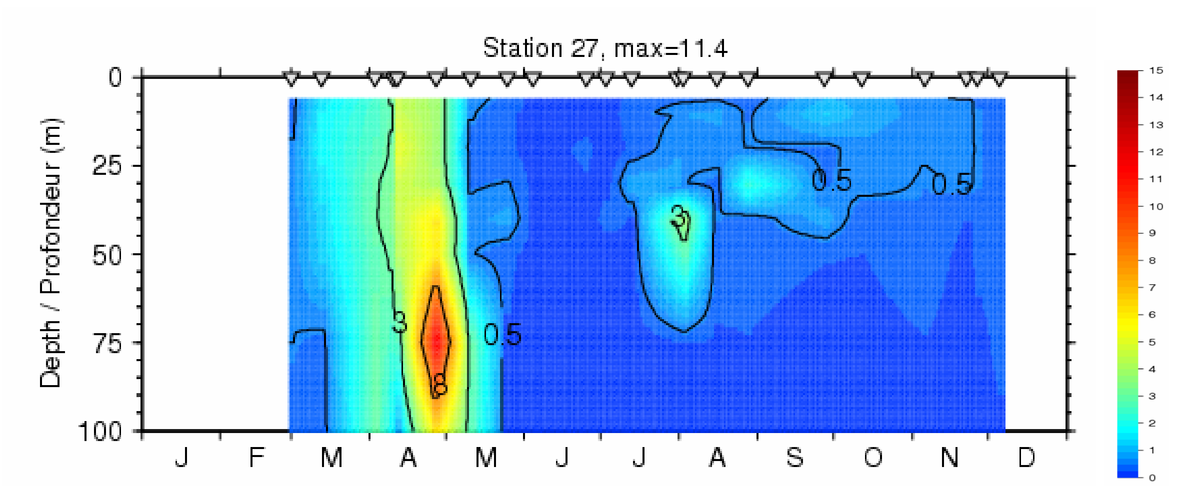


Figure 2: Seasonal vertical distribution of phytoplankton at Station 27 for 2007. White areas represent time periods when samples were unavailable. The color bar provides a measure of phytoplankton abundance.

Following the spring bloom, there were small amounts of phytoplankton below the surface which persisted throughout the summer and fall. This pattern of seasonal variation is consistent with most others sampled since the onset of the monitoring program. The exception occurred in 1999 when the levels of phytoplankton below the surface showed substantial changes in abundance throughout the summer and fall, reaching concentrations that were approximately 2-3 times higher than what was observed in 2000-2007. Furthermore, we have not detected a prominent fall phytoplankton bloom at Station 27 since 2000, although satellite derived observations of surface concentrations of phytoplankton across a broader area of the Avalon Channel and other regions of the Shelf indicate an increase in phytoplankton abundance when mixing of the water column increases in the fall.

Nutrient concentrations near the bottom (50-150 m), a measure of the amount of material that will be available once the fall and winter mixing of the water column takes place, increased in 2007 reversing a trend observed in earlier years at the fixed station near St. John's (Figure 3).

Both silicate and nitrate inventories in the surface layer (0-50 m) at Station 27 which had shown a gradual reduction since the start of monitoring, recovered somewhat in 2007. The most notable change was in the concentration of nitrate, an essential element in the growth of all phytoplankton species. This pattern also appeared to be consistent with changes in surface nitrate concentrations across the Newfoundland Shelf.

Seasonal fluctuations in phytoplankton biomass in the Newfoundland region are dominated by changes in the abundance of diatoms. Information from 1999 to 2004 shows that diatoms are dominant during the spring phytoplankton bloom while in the fall it is primarily flagellates and dinoflagellates which dominate. In 2004 the numerical abundance of most phytoplankton groups was lower than in previous years, following a trend which started in 2000. Data were not available in 2007.

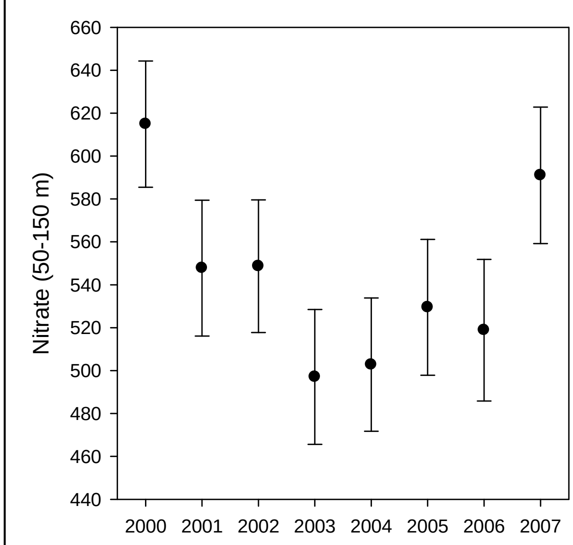


Figure 3. Seasonally-adjusted average deep-water nitrate inventory at Station 27.

The pattern in phytoplankton biomass observed during the 2007 spring oceanographic survey showed an increase over previous years. The differences among years can be the result of differences in the timing of the spring phytoplankton bloom relative to that of the survey. Satellite observations reveal that over much of the mid-shelf region off Newfoundland, the spring phytoplankton bloom occurred progressively earlier from 2003 to 2006, with a marked return to an April bloom in 2004. In 2007, the spring phytoplankton bloom on the continental shelf was generally dispersed throughout the water column, as in previous years, and the timing of the bloom was generally delayed by 10-15 days relative to the 2003 to 2006 average.

Zooplankton abundance

Zooplankton abundance shows a distinct seasonal cycle, with a gradual increase throughout the year until late fall when there is a substantial decrease following a reduction in phytoplankton production. This seasonal pattern reflects the increased production of copepod nauplii and copepodites, as well as larvaceans (the organisms associated with the occurrence of slub, jelly like material that often coats fishing nets) and blackberries (pelagic gastropods). Species of small copepods (*Pseudocalanus* spp., *Oithona* spp., *Centropages* spp., *Acartia* spp.) dominate in the spring and fall, whereas larger species of the genus *Calanus* (*C. finmarchicus*, *C. glacialis*, *C. hyperboreus*) reach similar levels of numerical abundance by early to mid-summer.

In 2007, the overall abundance of zooplankton at Station 27 was generally higher than in previous years, relative to the long term average, in 10 of the 16 dominant taxa collected at Station 27. These taxa included *C. hyperboreus*, *Metridia* spp. and euphausiids. In contrast, the abundance of *C. finmarchicus* at Station 27 decreased slightly following a substantial increase in the previous year. Most of these differences were not statistically significant.

The overall abundance of *C. finmarchicus* at Station 27 was similar to its peak abundance in 2000 (Figure 4). There was a strong peak in abundance at the start of the summer, which is in contrast with the pattern in 2004/05, when peak abundance was less pronounced and only achieved in early fall. Peak occurrence of CI stages occurred in late May/early June, as in previous years. As in most years, early stage copepodites were present in the zooplankton community throughout the fall. The January emergence of *C. finrmarchicus* from winter dormancy appeared to be near normal in 2007 but there are indications of a delayed entry into dormancy in the fall.

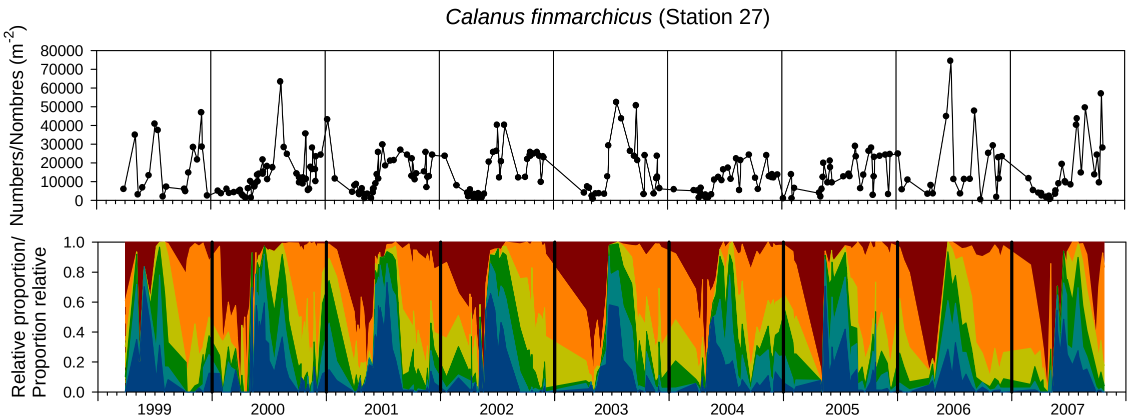


Figure 4: Seasonal abundance and relative stage distribution of copepodites of C. finmarchicus at Station 27 for 1999 to 2007. The youngest stages are indicated as CI (dark blue) and the oldest stages (C VI) represent the adults capable of reproduction (dark brown).

The general distribution of copepod species across the Newfoundland Shelf was generally consistent with previous observations, with most small species occurring closer to shore and on the southeast Shoal, and larger species distributed further offshore.

As a result of the data collected in previous years, we were able in 2007 to obtain quantitative estimates of abundance for a wider range of zooplankton taxa than was previously possible. To assist in the interpretation, we have grouped these into four broad categories: small copepods (e.g. *Oithona* spp., *Pseudocalanus* spp.), large copepods (e.g. all *Calanus* species), carnivores/omnivores (e.g. arrow worms, euphausiids, jellyfish), and non-copepod herbivores (e.g. larvaceans, larval stages of bottom dwelling invertebrates). Many of the small copepods on the Grand Banks reached their highest abundance levels since the start of the monitoring program, a pattern that was not echoed further North on the Newfoundland and Labrador Shelves. Two of the large cold water copepods (*C. glacialis, C. hyperboreus*) on the Grand Banks have been decreasing in abundance since 2002-2003 whereas their sister species (*C. finmarchicus*) and *Metridia* spp. have generally been increasing in abundance during that period. This is in contrast with conditions on the Newfoundland and Labrador Shelves where all species are generally at high levels of abundance. Although the overall abundance of carnivores/omnivores is generally slightly below average, we noted a trend of decreasing abundance since 2004-2005 in many species throughout much of the region. A similar trend was observed in many of the non-copepod herbivores. In addition to a general decrease in recent years, most taxa in this category were below the average long term abundance levels. In several cases, persistent patterns of increase or decrease may occur for three years in a row only to be followed by a sharp change in abundance, such as occurred for *C. hyperboreus* and *Pseudocalanus* spp. from 2002 to 2003. The lack of strong decadal trends in this area may indicate that the pelagic ecosystem is influenced by a number of factors (e.g. transport, local production, predation pressure), the balance of which may change abruptly.

Zonal summary

To provide a summary among variables for the entire Atlantic Zone, we summarize the data as differences (anomalies) relative to 1999-2006 average values; furthermore, because these series have different units, each anomaly time series is normalized by dividing by its standard deviation (SD), which is also calculated using data from 1999-2006 (Figure 6).

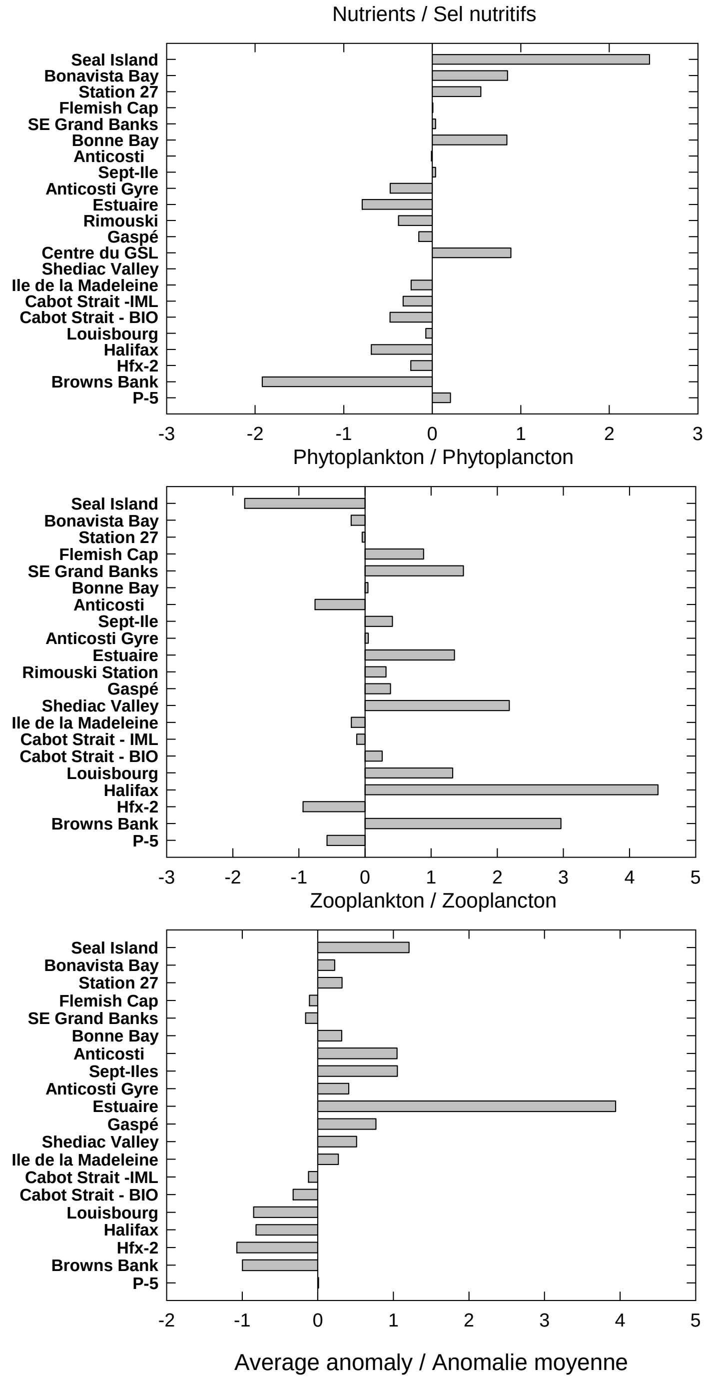


Figure 6. Zonal summary of the average anomaly of abundance indices for nutrients, phytoplankton and zooplankton for 2007.

Spring through fall nutrient inventories on the Newfoundland-Labrador and Grand Banks Shelf were above the 1999-2006 average, whereas nutrient inventories were generally below normal throughout much of the Gulf of St. Lawrence and the Scotian Shelf. However, winter maximum nutrients inventories (0-50 m) were above normal at all coastal fixed stations as well as in many areas of the Gulf of St. Lawrence (not shown). Phytoplankton demonstrated considerable spatial variability, with below average indices of abundance on the Newfoundland-Labrador Shelf and at coastal fixed sites off Halifax and in the Bay of Fundy, and above average indices of abundance throughout the western and southern Gulf of St. Lawrence as well as on the Scotian Shelf. Trends in average zooplankton abundance indices showed the greatest spatial coherence. Zooplankton abundance was well above average in the Gulf of St. Lawrence and to a lesser degree on the Newfoundland-Labrador Shelf whereas abundance was well below average from Cabot Strait, across the Scotian Shelf and into the Bay of Fundy, and only slightly below average on the Grand Banks.

Sources of Uncertainty

The general patterns in the spatial distribution of physical, chemical and biological oceanographic variables in the Northwest Atlantic zone monitored by AZMP have remained relatively constant during the period 1999-2006. Although there are seasonal variations in the distribution of water masses, plants and animals, these variations show generally predictable patterns. However, there is considerable uncertainty in estimates of overall abundance of phytoplankton and zooplankton. This uncertainty is caused in part by the life cycle of the animals, their patchy distribution in space, and by the limited coverage of the region by the monitoring program.

Physical (temperature, salinity) and chemical (nutrients) oceanographic variables are effectively sampled because they exhibit fairly conservative properties that are unlikely to show precipitous changes from year-to-year. Also, measurements of these variables are made with a good degree of precision. The only exception occurs in surface waters where rapid changes in the abundance of phytoplankton, particularly during the spring bloom, can cause rapid depletion of nutrients. In an attempt to be conservative in our description of the long-term changes in chemical variables, we restrict our conclusions to deep water inventories of nutrients.

The greatest source of uncertainty comes in our estimates of phytoplankton abundance because of the difficulties in describing the inter-annual variations in the timing, magnitude and duration of the spring phytoplankton bloom. Phytoplankton may undergo rapid changes in abundance, on time scales of days to weeks. Because our sampling is limited in time, and occasionally suffers from gaps in temporal coverage due to vessel unavailability or weather, which often occurs in the sampling at our fixed stations during the winter months, we may not sample the spring phytoplankton and other important variables adequately. Also, variations in the timing of the spring phytoplankton bloom across the region and in relation to our spring oceanographic surveys may limit our ability to determine inter-annual variations in maximum phytoplankton abundance. In contrast, we are better capable of describing inter-annual variations in the abundance of dominant zooplankton species because their seasonal cycle occurs at time scales of weeks to months because of their longer generation times. However, zooplankton show greater variability in their spatial distribution. Although inter-annual variations in the abundance of dominant groups, such as copepods, can be adequately assessed, variations in the abundance of rare, patchily distributed or ephemeral species cannot be reliably estimated at this time.

In the Newfoundland region, occupation of Station 27 during the winter and early spring are particularly limited, causing us to sometimes miss the onset of the spring phytoplankton bloom. Also, reductions in vessel scheduling within the region are also reducing the number of full observations at this fixed site. Loss of time during the spring oceanographic survey severely limited the number of stations sampled in offshore areas, leading to a loss of information. The losses were most acute for the zooplankton, which are most abundant in offshore areas.

CONCLUSIONS

There are consistent trends in some chemical and biological oceanographic conditions at Station 27. Deep water nutrient inventories have increased since 2003 reversing a downward trend at the start of the monitoring program. Nitrate inventories in the upper layer have recovered somewhat from the decline that had been observed since 2000. The cause of variations in shallow inventories of nitrate remains unknown, but may be linked to changes in productivity, water column structure, and influence of volume transport of the inshore branch of the Labrador Current. The decreasing trend in the average integrated biomass of phytoplankton since 2002 appears to have been reversed in 2006-2007 as has the general decrease in the abundance of some large calanoid copepods (*C. finmarchicus*, *Metridia* spp.) and the euphausiids. Although we have observed annual changes in nutrient inventories and biological variables since 2000, most are not statistically significant. The trends are likely indicative of changes taking place in coastal areas, from Bonavista to the southern Avalon, because the patterns do not always match the trends observed further offshore.

Other oceanographic variables showed fluctuations from year to year, but we have not been able to detect consistent decadal trends in these variables in either region. This pattern is in contrast with the general trends in the abundance of the dominant copepod species on the Labrador and Newfoundland shelves. Nearly all of the dominant species are at above average abundance levels, and most inter-annual variations are statistically significant. Although the abundance of most copepods is generally high on the northern Grand Banks, many species do not show clear long-term trends.

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