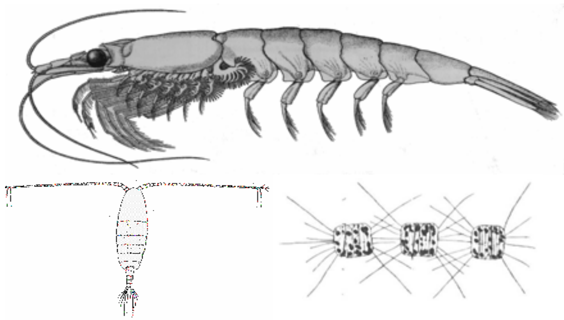

2004 State of the Ocean: Chemical and Biological Oceanographic Conditions in the Newfoundland and Labrador Region

Background

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.

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

Summary

- Nutrient inventories in the surface layer (top 50 m of the water column) at Station 27 showed an increase relative to the 2000-2003 average and near bottom nutrient inventories remain low relative to values observed in 2000.

- There was no evidence of a fall bloom at Station 27 although large scale satellite observations and the fall oceanographic survey indicate that a fall bloom occurs almost every year throughout much of the region.

- The onset and duration of the spring phytoplankton bloom were near the long term average, with the bloom starting in the last week of March and lasting until late May, but the overall magnitude of the spring bloom was lower than the 1999-2003 average.

- In 2004, the abundance of most phytoplankton groups was lower than in previous years, following a trend which started in 2000.

- Satellite observations revealed that over the Newfoundland shelf, the spring phytoplankton bloom occurred progressively later from 2000 to 2003, with a marked return to an April bloom in 2004.

- In 2004, the overall abundance of zooplankton at Station 27 was low relative to the long term average in 8 of the 12 dominant species groups.

- The abundance of *Calanus finmarchicus* at Station 27 was lower than in the previous three years, and much lower than in 1999 and 2000.

- In the Fall of 2004, the abundance of zooplankton over the Newfoundland Shelf was the highest since 1999.

- Starting in 2000, the summer abundance of main zooplankton species increased on the Newfoundland and Labrador shelves and decreased on the Grand Banks.

- The summer abundance of the three species of *Calanus* as well as for large calanoid nauplii was the lowest on record on the Flemish Cap transect while their abundance on the Seal Island transect was the highest since 2000.

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, with the largest species being 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.

Nutrient concentrations and phytoplankton biomass

During 2004, 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 onset and duration of the spring phytoplankton bloom were near the long term average, with the bloom starting in the last week of March and lasting until late May (Fig. 2). However, the overall magnitude of the spring bloom was approximately 30% lower relative to the average from 1999-2003. This may have been due to stronger mixing of the water column during winter and early spring relative to previous years. During the remainder of the year, the cycle and abundance of phytoplankton was also slightly lower than previously observed.

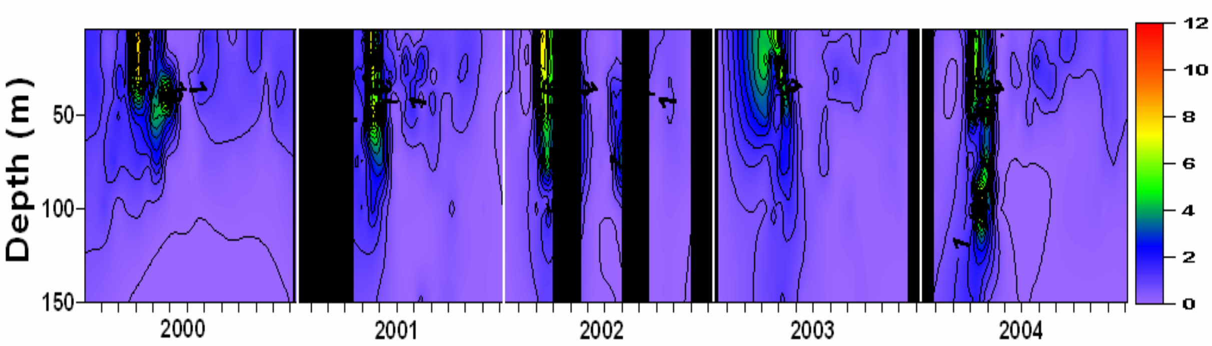

Figure 2: Seasonal vertical distribution of phytoplankton at Station 27 for 2000-2004. Black areas represent time periods when samples were unavailable.

Following the spring bloom, there were small amounts of phytoplankton below the surface which persisted throughout the summer and fall. This is in contrast with observations 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 2000-2004. Furthermore, we have not detected a 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), which provides a measure of the amount of material that will be available once the fall and winter mixing of the water column takes place, was similar to levels observed in 2001-2003 but about half the levels found in 1999-2000 at the fixed station near St. John's (Fig. 3). On the other hand, both silicate and nitrate inventories in the surface layer (0-50 m) at Station 27 appeared to continue to increase relative to levels observed at the start of 2000. The most notable relative change was in the concentration of nitrate, an essential element in the growth of all phytoplankton species. Although near bottom nutrient concentrations at Station 27 were still low relative to observations from 2000, this pattern did not appear to prevail across the Newfoundland Shelf where nutrient inventories were at comparable levels to the start of the program, with some instances showing a slight increase since the start of the century (Fig. 4).

Nutrient concentrations in the surface layer (top 50m) in 2004 along the sections were generally higher during the spring, summer and fall compared to those of 2000-2001 with the greatest changes occurring on the Grand Banks and off Bonavista, particularly nitrates.

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 the spring phytoplankton bloom is a time of the year when diatoms dominate, 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. This was also apparent during the regional oceanographic surveys. Although this did not appear to affect the overall biomass of phytoplankton available to zooplankton, the lower numbers may affect other elements of the pelagic ecosystem on the Newfoundland Shelf.

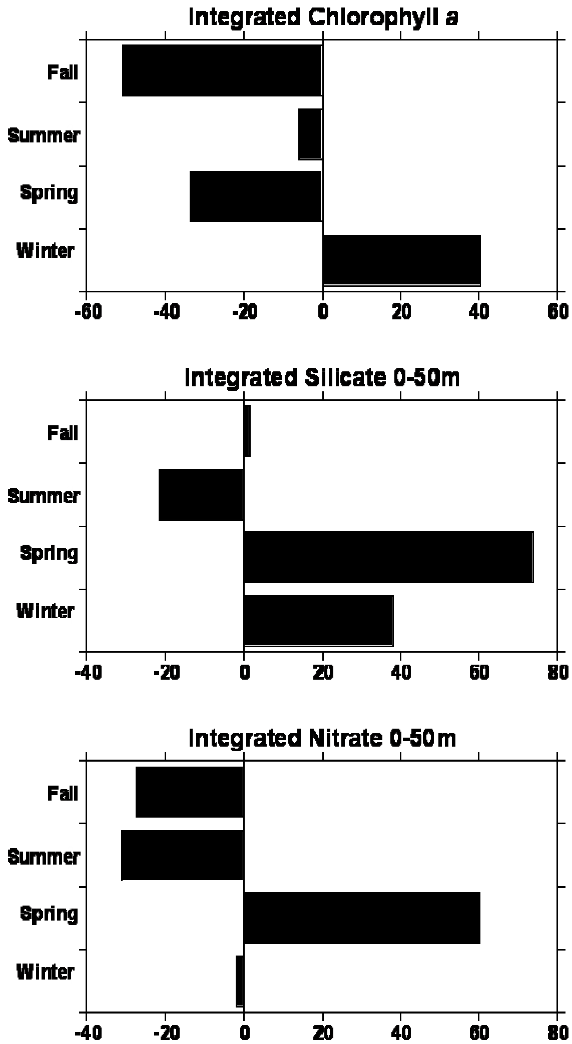

Figure 3: Relative seasonal change in surface (0-50 m) chlorophyll, silicate and nitrate at Station 27 during winter, spring, summer and fall of 2004 relative to 2000-2003 average.

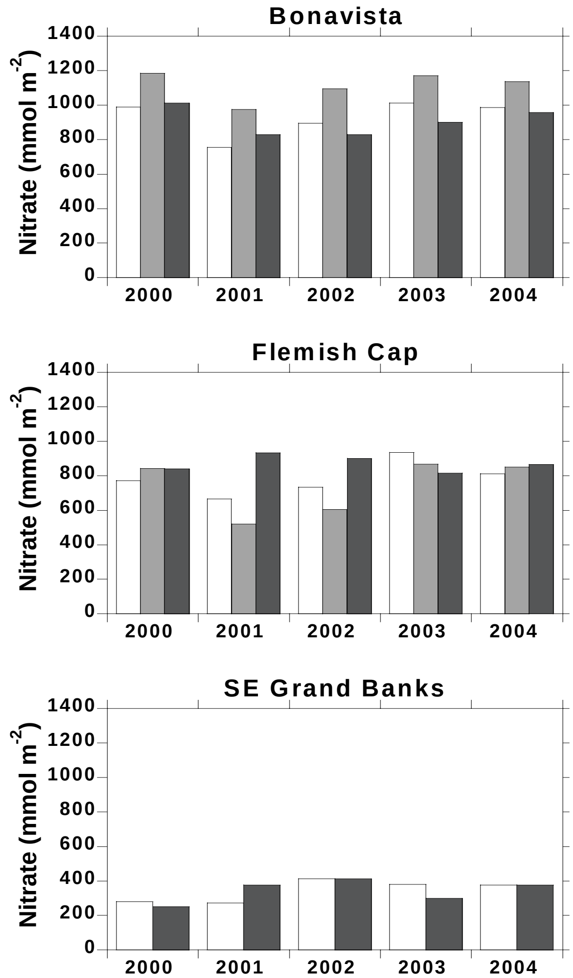

Figure 4: Annual deep water nitrate inventory (50-150 m) along the Bonavista Bay, Flemish Cap and Southeast Grand Banks transects. White, light grey and dark grey bars represent observations from the spring, summer and fall oceanographic surveys, respectively.

The pattern in phytoplankton biomass observed during the spring oceanographic survey showed an increase over 2003 but levels were similar to those observed in 2000-2002. The differences among years were largely due to 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 had occurred progressively later from 2000 to 2003, with a marked return to an April bloom in 2004.

Satellite-derived estimates of surface chlorophyll

Biological conditions derived from ocean colour data collected by satellite can be found at the Bedford Institute of Oceanography Ocean Sciences Division website (http://www.mar.dfo-mpo.gc.ca /science/ocean/ias/seawifs_1.html).

Although these data do not provide information on vertical structure of phytoplankton in the water column, they do provide highly resolved (~1.5km) data on their geographic distribution in surface waters. The data are provided as composite images over two week intervals for the northwest Atlantic.

The seasonal cycle of phytoplankton throughout most Newfoundland waters is characterized by two peaks, one in the spring (April-May) and another smaller peak in the late fall or early winter (October-January). The satellite information is generally consistent with observations from Station 27 and from transects across the Shelf. The timing of peak concentrations of surface chlorophyll concentrations in 2004 was substantially earlier than in 2003 in the region from the Flemish Cap line up to the St. Anthony basin. There was no evidence of a strong shift in the timing of the spring and fall phytoplankton blooms on the Southeast Shoal and on St. Pierre Bank, or off Labrador.

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) and blackberries (pelagic gastropods).

Species of small copepods (*Pseudocalanus* sp., *Oithona* sp., *Centropages* sp., *Acartia* sp.) 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 2004, the overall abundance of zooplankton at Station 27 was low relative to the long term average. In 8 of the 12 dominant taxa collected at Station 27, the overall seasonally average abundance was either the lowest since 1999, or the second lowest. Although the abundance was generally not significantly different from 2003, the abundance of *Metridia* spp. and *Pseudocalanus* spp. was statistically significantly lower than the overall average from the five previous years. The overall abundance of *C. finmarchicus* reached its lowest level since the start of the series in 1999 while the abundance of *C. glacialis* was near normal and that of *C. hyperboreus* reached it second highest seasonal average abundance. The abundance and occurrence of copepod species normally associated with cold (*Calanus glacialis, Calanus hyperboreus*, and *Microcalanus* sp.) and warm waters (*Temora longicornis*), which had shown a gradual shift toward cold water species since 1999 shifted back toward warm water species in 2003, a pattern which continued in 2004.

The overall abundance of *C. finmarchicus* at Station 27 was generally 20% lower than in the previous three years, and substantially lower than concentrations observed in 1999 and 2000 (Fig. 5). In contrast to previous years, there was no strong peak abundance in early summer, with abundance peaking on in September. Peak occurrence of CI stages occurred in late May/early June, as in 1999, 2000 and 2002. The overall pattern of abundance showed a much weaker seasonality than in previous years with the peak abundance being ~50% lower than in the previous two years. As in most years, early stage copepodites were present in the zooplankton community throughout the fall. However, there appeared to be a greater relative abundance of early stage copepodites well into the fall, when CIV and CV generally dominate (Fig. 5).

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 larger species being distributed further offshore.

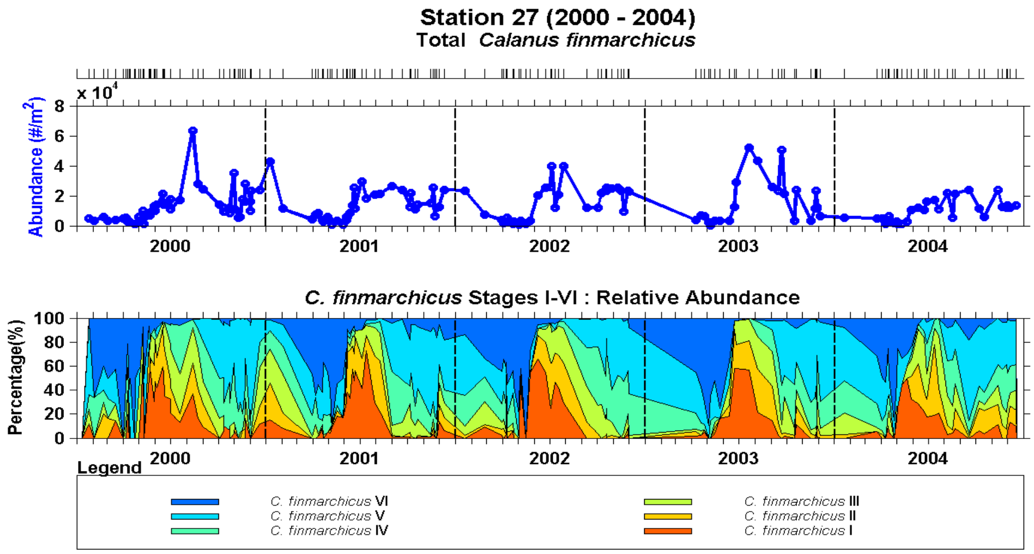

Figure 5: Seasonal abundance and relative stage distribution of copepodites of C. finmarchicus at Station 27 for 1999 to 2002. The youngest stages are indicated as CI and the oldest stages (CVI) represent the adults capable of reproduction.

In the Fall of 2003, the overall abundance of zooplankton was at the highest levels observed since 1999. This pattern of high abundance was consistent for a number of species, not just those that are numerical dominant, such as small copepods.

In the spring of 2004, overall copepod abundance appears to have been relatively uniform across the Shelf and the overall abundance also appears to have been at or near the highest levels since the start of the AZMP. The exception occurred on the Southeast Shoal where overall abundance of *C. finmarchicus, C. hyperboreus, C. Glacialis* and that of large calanoid nauplii were generally lower than previous years.

During summer months, most zooplankton species show a greater degree of spatial structure in their distributions and abundance. During the summer 2004 surveys, there appeared to be a split in the long term pattern of abundance when contrasting the Grand Banks, based on the Flemish Cap transect, with the Newfoundland and Labrador Shelf to the north. In general, the overall abundance of many zooplankton species along the Flemish Cap line was at the lowest levels since 2000. The pattern was strongest in the case of the three species of *Calanus* as well as for large calanoid naupli, where their abundance was the lowest on record on the Flemish Cap transect while their abundance levels on the Bonavista Bay and Seal Island transects were at their highest levels since 2000. *Calanus finmarchicus* generally makes up the bulk of the biomass across most of the Newfoundland Shelf, with the exception of the Flemish Pass and the inshore portions of the Bonavista Bay and Seal Island transects, where *C. hyperboreus* is the dominant component of the summer zooplankton biomass. The difference in abundance patterns between the Grand Banks and the Newfoundland and Labrador Shelf may explain why Station 27 appears to show a pattern different than many regions of the shelf. Variations in the cross-shelf transport of nutrients, phytoplankton and zooplankton likely play a significant role in determining the patterns of zooplankton abundance at that site.

Continuous Plankton Recorder

The Continuous Plankton Recorder (CPR) collections along the line from Iceland to St. John's, which crosses the northern edge of the Grand Banks, has been ongoing between the years 1959-1986 and 1991-present. The collections show that during the period after 1991, the abundance of all stages of *Calanus finmarchicus* had been lower than during the earlier period but that a gradual increase had occurred from 1991 to 2000. However since then, the overall abundance appears to have decreased, a pattern that is consistent with the observations from our oceanographic surveys of the Grand Banks. The abundance of small copepods (*Oithona* spp. and *Psudocalanus* spp.) had been higher in 1990 than in the period 1959-1986 but the trend has been toward a decreased overall abundance since that time, a trend that appears to be stronger than that suggested from our oceanographic surveys. Furthermore, the total abundance of euphausids, a shrimp-like animal, has been lower than during the earlier period, whereas the color index, a measure of phytoplankton abundance, has been substantially higher.

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