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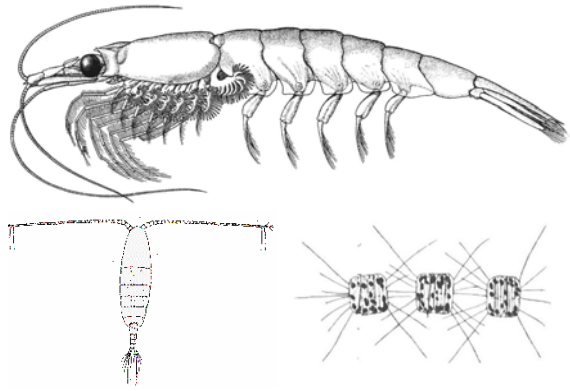
Maritimes/Gulf Regions

Canadian Science Advisory Secretariat
Science Advisory Report 2005/046

2004 STATE OF THE OCEAN: CHEMICAL AND BIOLOGICAL OCEANOGRAPHIC CONDITIONS IN THE GULF OF MAINE - BAY OF FUNDY, SCOTIAN SHELF AND THE SOUTHERN GULF OF ST. LAWRENCE



Context

The Atlantic Zone Monitoring Program (AZMP) was initiated in 1998 to: (1) increase DFO's capacity to understand, describe, and forecast the state of the marine ecosystem, and (2) quantify the changes in ocean physical, chemical and biological properties and predator-prey relationships of marine resources. A critical element of AZMP is an annual assessment of the distribution and variability of nutrients and the plankton that they support.

The AZMP uses data collected through a network of sampling locations (fixed point stations, cross-shelf sections, groundfish surveys, satellite remote-sensing) in Quebec, Maritimes, Southern Gulf, and Newfoundland sampled from bi-weekly to annually. Information on the relative abundance and community structure of plankton is also collected from Iceland to the coast of Newfoundland and Newfoundland to the Gulf of Maine through commercial ship traffic instrumented with a Continuous Plankton Recorder (CPR).

A description of the distribution in time and space of nutrients dissolved in seawater (nitrate, silicate, phosphate, oxygen) provides important information on the water movements and on the locations, timing and magnitude of biological production cycles. A description of the distribution of phytoplankton and zooplankton provides important information on the organisms forming the base of the marine food-web. An understanding of the production cycles of plankton is an essential part of an ecosystems approach to fisheries management.

Canada

SUMMARY

- Winter surface nutrient concentrations in 2004 off Halifax were among the highest observed and summer concentrations the lowest since regular observations began in 1999.
- The seasonal decline in surface nutrients in the Bay of Fundy started 2 months earlier in 2004 than observed previously.
- Bottom water nutrient concentrations off Halifax and the broader Scotian Shelf in summer were lower in 2004 than in 2003 while concentrations in the Southern Gulf in fall were higher.
- Strong spring blooms were observed in the Southern Gulf, on the Scotian Shelf and Georges Bank in 2004. Maximum phytoplankton biomass, however, was not as high as the record levels seen in 2003.
- Flagellates dominated the community composition of phytoplankton off Halifax in 2004.
- Continuous Plankton Recorder (CPR) colour index and species counts in 2003 showed that phytoplankton abundance on the Scotian Shelf continues to be well above levels observed in the 1960s/1970s.
- Zooplankton biomass and *Calanus finmarchicus* abundance in Shediac Valley in 2004 were lower than the record high levels observed in 2003. However, record high levels were observed in the broader Southern Gulf in fall.
- The contribution of *Calanus spp.* to the zooplankton community in Shediac Valley, off Halifax and in the Bay of Fundy has increased yearly since observations began in 1999.
- *Calanus finmarchicus* reproduction started earlier off Halifax in 2004 than in the previous 4 years.
- CPR counts in 2003 showed that the abundance of several important zooplankton species continues to be well below levels observed in the 1960s/1970s. Euphausiid numbers recovered in 2003 from the dramatic decline observed in 2002 while *Paracalanus* / *Pseudocalanus spp.* continued to exhibit record low counts.

INTRODUCTION

The production cycle of plankton is largely under the control of physical processes. Specifically, light and nutrients (e.g. nitrate, phosphate, silicate) are required for the growth of marine microscopic plants (phytoplankton). Of the major available nutrients, nitrogen is generally in shortest supply in coastal waters and is thought to limit the growth of phytoplankton, particularly in summer. A description of the cycle of nutrients on the continental shelf will aid in understanding and predicting the spatial and temporal variability in plankton populations.

Phytoplankton are the base of the marine food-web and the primary food source for the animal component of the plankton (zooplankton). Both phytoplankton and zooplankton, in turn, are food for larval fish and invertebrates and influence their survival rate. An understanding of plankton cycles will aid in assessing the state of the marine ecosystem and its capacity to sustain harvestable fisheries.

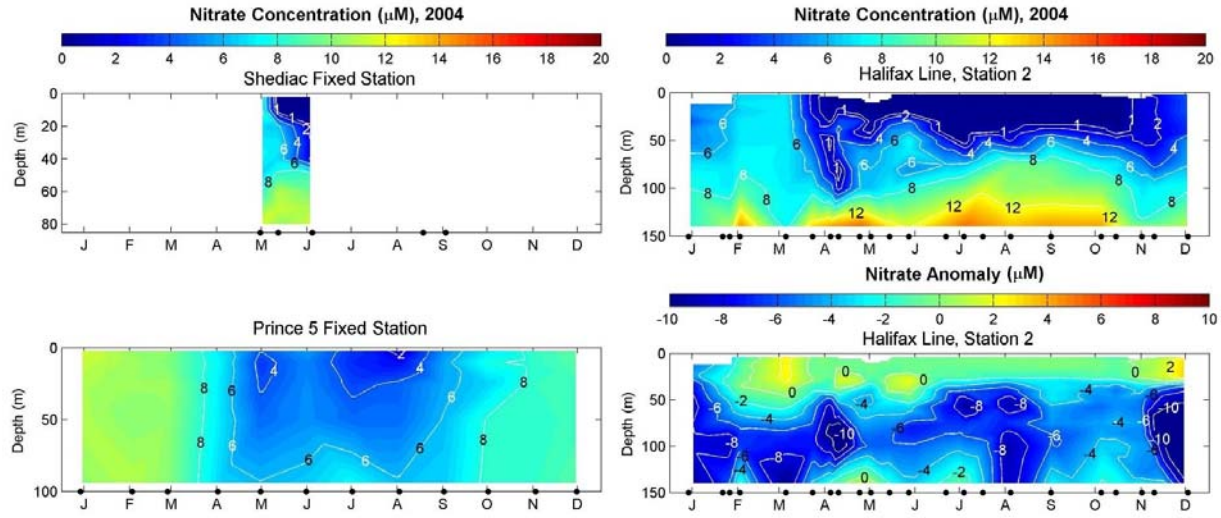
The AZMP provides basic information on the natural variability of physical, chemical and biological properties of the Northwest Atlantic continental shelf. Groundfish surveys and cross-shelf sections provide detailed regional geographic information but are limited in their seasonal coverage. Critically placed fixed stations (the Shediac Valley station in the Southern Gulf of St. Lawrence, Station 2 along the Halifax section on the Scotian Shelf and the Prince 5 station in the Bay of Fundy) complement the geography-based sampling by providing more detailed information on seasonal changes in ecosystem properties. Satellite remote-sensing of sea-surface phytoplankton biomass (chlorophyll) provides a large scale, zonal, perspective on

important environmental and ecosystem variability. The CPR sections provide information on large scale, inter-regional, and long-term (yearly to decadal) variability in plankton abundance and community structure.

CONDITIONS IN 2004

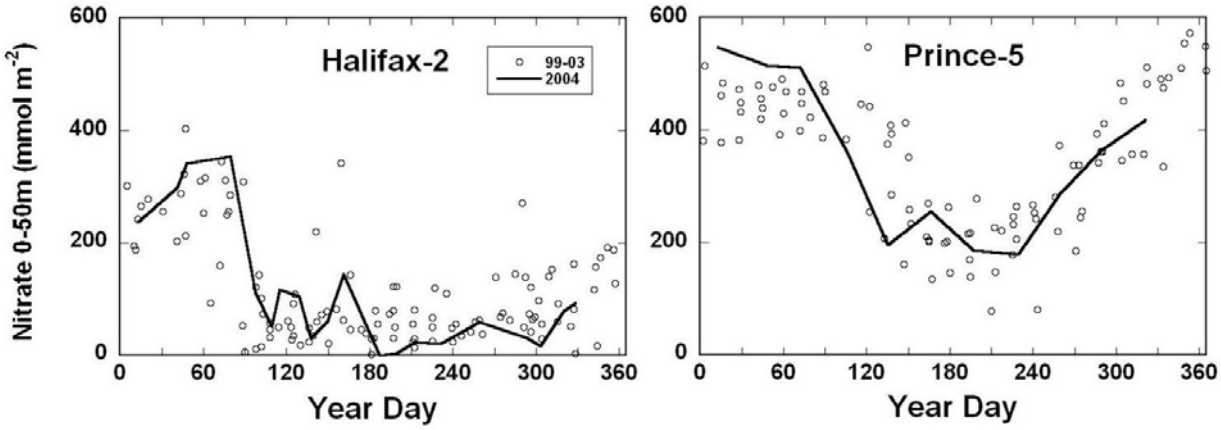
Nutrients

Fixed Stations. Rapid spring/early summer reduction in near surface nitrate concentrations was seen at all Maritimes/Gulf fixed stations in 2004. Low surface values persisted throughout the summer at Shediac Valley (evident despite limited sampling) and off Halifax and concentrations did not increase at the surface again until late fall. The depth of nitrate depletion in summer is generally greater off Halifax than at Shediac Valley. Summer nitrate depletion depths in 2004 off Halifax-were significantly greater than observed previously. Near surface nitrate concentrations in the Bay of Fundy were never exhausted. Limited sampling in 2004 precluded an evaluation of the seasonal nutrient cycle in Shediac Valley. The seasonal evolution of the vertical nitrate structure off Halifax in 2004 was similar to that observed in previous years except that concentrations at depth were notably lower in 2004. Surface concentrations in 2004 were comparable to the long-term average but concentrations at depth were substantially below the long-term average and comparable to concentrations observed in 1999 and 2001.



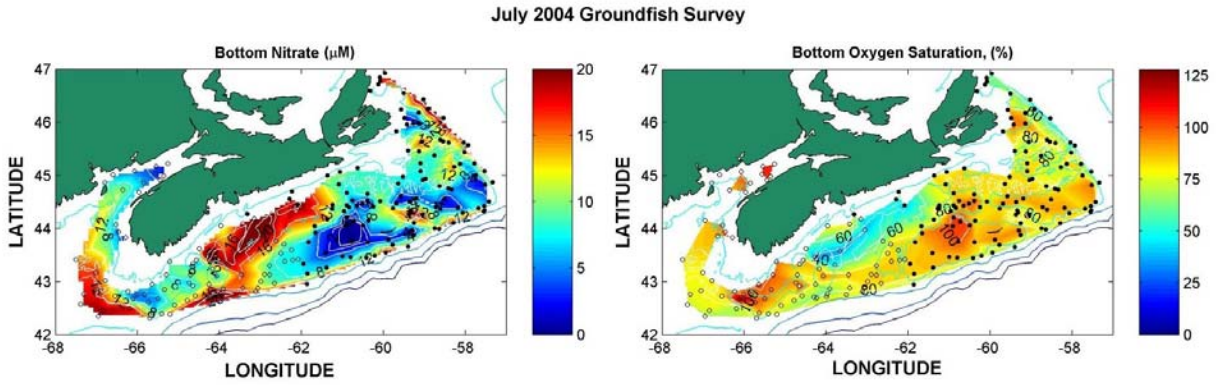
Strong seasonal variability in nitrate inventories of the upper 50 m (depth zone over which nutrient dynamics are strongly influenced by biological processes) was evident at all of the Maritimes/Gulf fixed stations. Nitrate levels at Shediac Valley in 2004 were comparable to levels observed previously, despite limited sampling. Although the seasonal pattern of variability in nitrate off Halifax in 2004 was similar to that observed in previous years, wintertime inventories in 2004 were among the highest observed since AZMP sampling started in 1999 and summer/fall inventories were among the lowest. Similarly, winter nitrate inventories in the Bay of Fundy were higher in 2004 than observed previously whereas summer/fall levels, never depleted, were comparable to levels observed over the past 6 years. In contrast to previous years, the spring/summer decline in nitrate (due to biological consumption) in the Bay of Fundy in 2004 started almost 2 months earlier (March versus May) than observed previously. A trend of increasing wintertime nitrate inventories at this

station has been evident for the past 4 years. Overall, annual nitrate inventories continue to be greatest in the Bay of Fundy and lowest off Halifax.



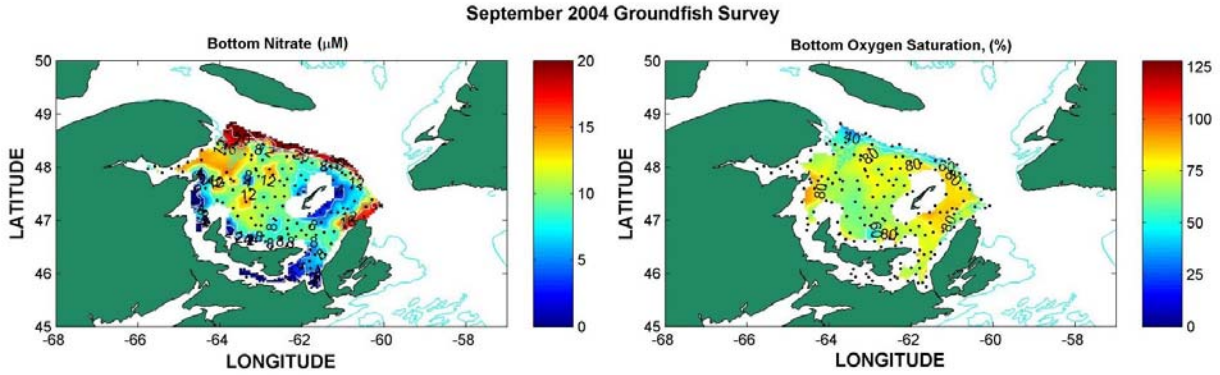
Shelf Sections. Vertical distributions of nitrate in spring and fall were generally similar along the Scotian Shelf sections in 2004, i.e. concentrations were low in near surface waters (<50 m), as a result of phytoplankton consumption, and increased with depth. Deep-water concentrations were highest in basins and in slope waters off the edge of the shelf. As in the previous year, nitrate levels in surface waters were already significantly depleted by the spring survey in April. Likewise, surface nitrate concentrations were still low during the fall survey in October, showing no evidence of seasonal mixing of nutrients from depth into surface waters. Near-surface nitrate inventories in 2004 were comparable to or slightly lower than levels observed in previous years.

Groundfish Surveys. Bottom water nitrate concentrations on the Scotian Shelf in July, 2004 were lower than levels observed in 2003. Concentrations increased with water depth with highest levels observed in the deep basins on the shelf (e.g. Emerald Basin) and in slope waters off the shelf edge. Bottom water oxygen saturation on the Scotian Shelf in summer 2004 was somewhat higher than saturation levels observed in 2003; lowest saturation levels were found in deep basins and deep waters off the shelf edge where nutrients were highest.



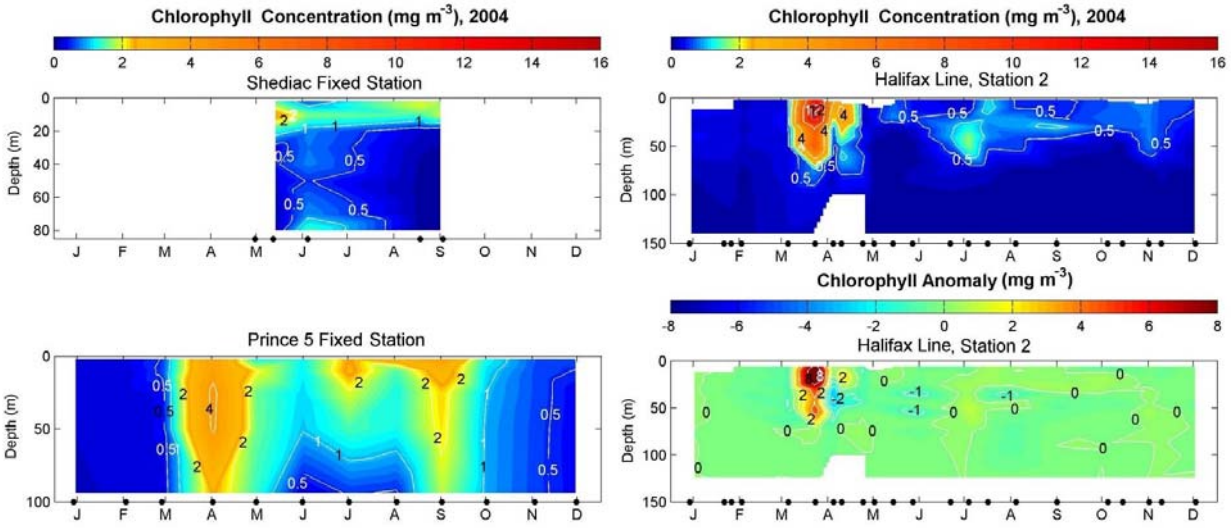
Bottom water nitrate concentrations in the Southern Gulf in September were higher overall in 2004 than in 2003. Highest concentrations were found in the western basin and in deep waters of the Laurentian Channel. Bottom water oxygen saturation in the Southern Gulf was

the same on average as levels observed in 2003. Saturation levels in the Southern Gulf were minimal in the western basin and deep waters of the Laurentian Channel, coincident with highest nutrient levels.



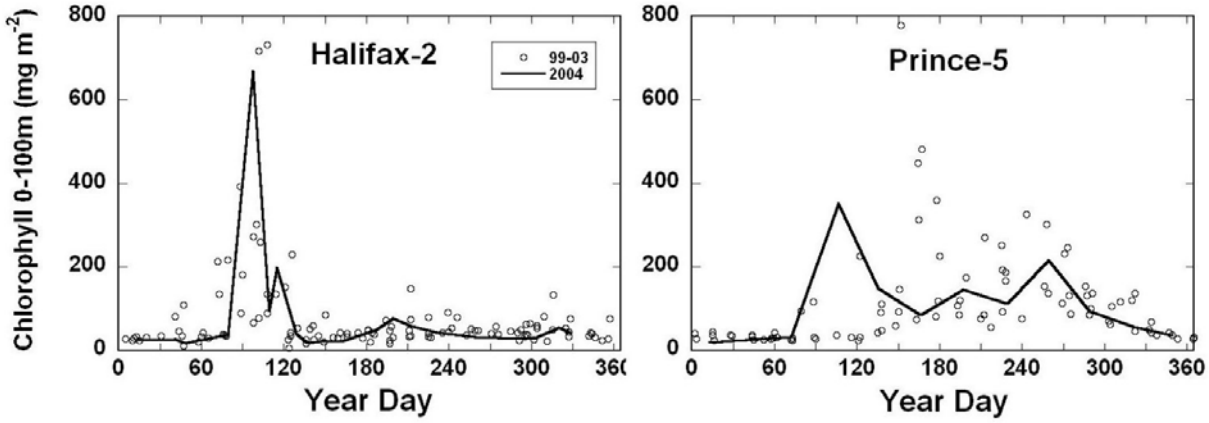
Phytoplankton

Fixed Stations. Distinctly different seasonal phytoplankton growth cycles are evident at the three Maritimes/Gulf fixed stations. Because of the presence of ice in the Southern Gulf in the spring, only the latter phase of the spring bloom is normally caught in sampling at Shediac Valley. This in addition to limited sampling during the ice-free period meant that little could be said about the magnitude and variability of phytoplankton biomass (chlorophyll), vertical distribution and community composition in 2004. The record high spring bloom observed off Halifax in 2003 was less pronounced in 2004 although still strong compared to previous years. The timing of the spring bloom off Halifax in 2004 was similar to observations made previously. The phytoplankton growth cycle in the Bay of Fundy in 2004, in contrast to Halifax, was characterized by a relatively sustained burst of growth beginning in early summer and lasting until fall and characterize by two peaks.



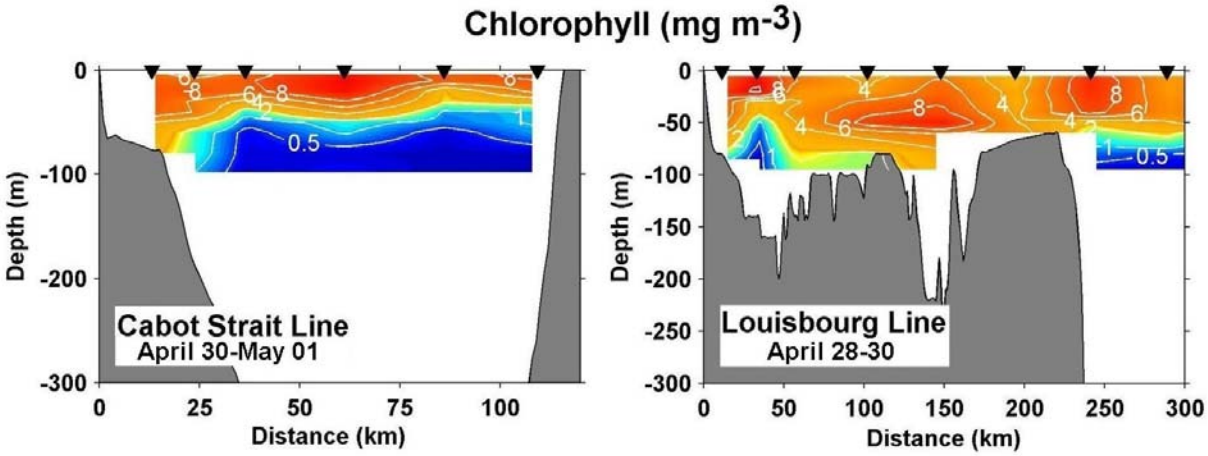
Chlorophyll inventories at Shediac during the limited sampling in 2004 were consistent with levels observed previously. Chlorophyll inventories off Halifax and in the Bay of Fundy were generally comparable to 2003 levels, however, the biomass maximum in the Bay of Fundy was observed almost 2 months earlier in 2004 (April versus June) than in previous years.

With the exception of 2003, the Bay of Fundy sustains the largest phytoplankton inventories, on an annual basis, of the 3 Maritimes/Gulf fixed stations.

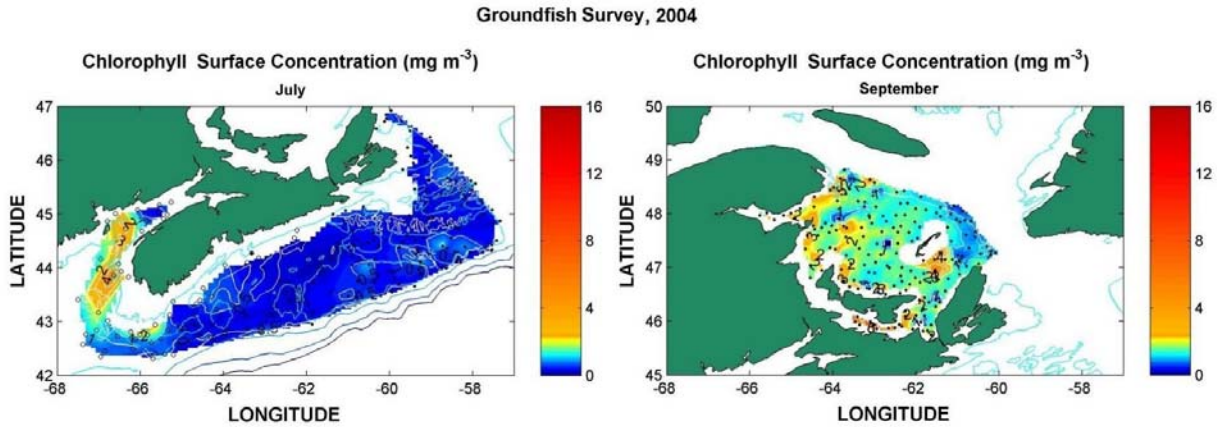


The evolution of the phytoplankton community composition at Shediac Valley in 2004 was consistent with observations from earlier years, i.e. a shift from diatom to flagellated dominated populations as the year progressed. Phytoplankton community composition off Halifax in 2004 differed from previous years in that flagellates dominated throughout the year except for the short period of the spring bloom where diatoms were dominant. Diatoms, in particular, generally dominate in the winter/spring months at this station. The phytoplankton community in the Bay of Fundy was almost exclusively comprised of diatoms year-round.

Shelf Sections. Chlorophyll levels during the spring 2004 survey were near the record high concentrations observed in 2003 along all sections except Halifax. As observed in previous years, chlorophyll inventories were generally higher on the eastern shelf than on the western shelf in spring. Concentrations during the fall 2004 survey, in contrast, were an order of magnitude lower and typical for that time of year. Generally, a pronounced subsurface chlorophyll maximum layer is observed at stations along the Scotian Shelf sections in fall, however, highest concentrations in the 2004 survey appeared to be confined to surface waters as observed in 2003. Chlorophyll inventories in fall 2004 were comparable along all sections and slightly lower than 2003 inventories.

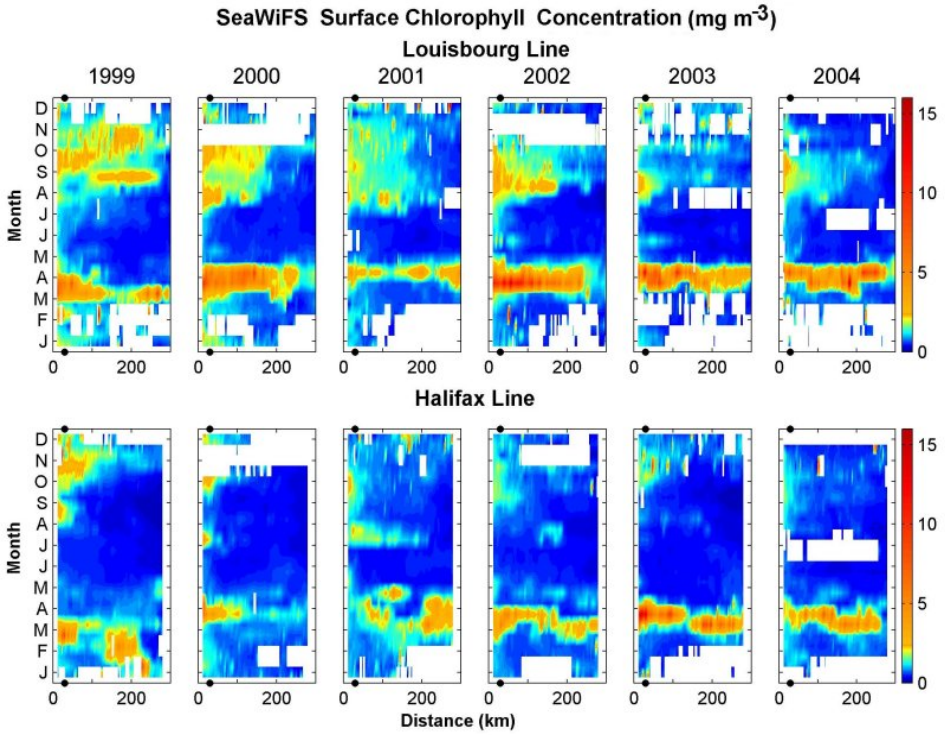


Groundfish Surveys. Surface chlorophyll levels during the 2004 summer Scotian Shelf survey were uniformly low over most of the central and eastern shelf. Elevated concentrations were observed near the coast off SW Nova Scotia and approaches to the Bay of Fundy, as observed in previous years. These areas are generally characterized by strong vertical mixing. Overall, summer surface chlorophyll concentrations on the Scotian Shelf in 2004 were lower than concentrations observed in 2003. Surface chlorophyll concentrations observed during the fall 2004 groundfish survey in the Southern Gulf were higher than values observed in 2003. Concentrations tended to be highest in the western basin as has been observed in previous years.

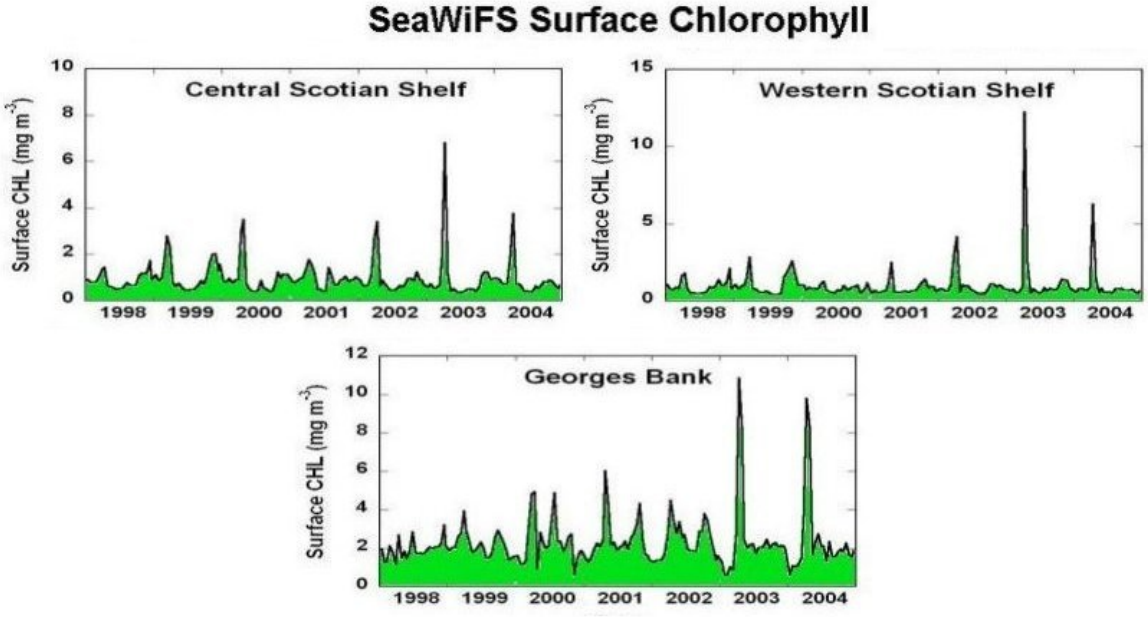


Satellite Remote-Sensing. Satellite ocean colour (SeaWiFS) data provide a valuable alternative means of assessing surface phytoplankton biomass (chlorophyll) at the AZMP fixed stations, along the shelf sections, and at larger scales (Northwest Atlantic). SeaWiFS data in the vicinity of the fixed stations, for example, showed high chlorophyll levels during the spring bloom at Shediac Valley immediately following ice-out and second only to the record high levels of 2003. This feature has been systematically missed due to the severely limited conventional sampling at this station, particularly in 2004. Interestingly, the satellite did not pick up the strong spring bloom off Halifax observed during conventional sampling in 2004. However, it did show that the timing of the blooms at Shediac Valley and and off Halifax were similar to the timing observed in previous years and it showed the earlier than usual bloom in the Bay of Fundy.

The satellite-derived chlorophyll data can also be used to generate graphical representations of the seasonal chlorophyll changes along the shelf sections. For example, that surface chlorophyll concentrations are generally higher on the eastern Scotian Shelf (Louisbourg section) than on the central and western shelf (Halifax section). Spring blooms on the Scotian Shelf can be viewed as discrete, short-lived events whereas the fall blooms appear to be more diffuse and time-varying. This graphical representation shows that the spring blooms along the Scotian Shelf sections were strong in 2004 but less intense than in 2003. It is also apparent that the onset and duration of the blooms in 2004 was not noticeably different from 2003.

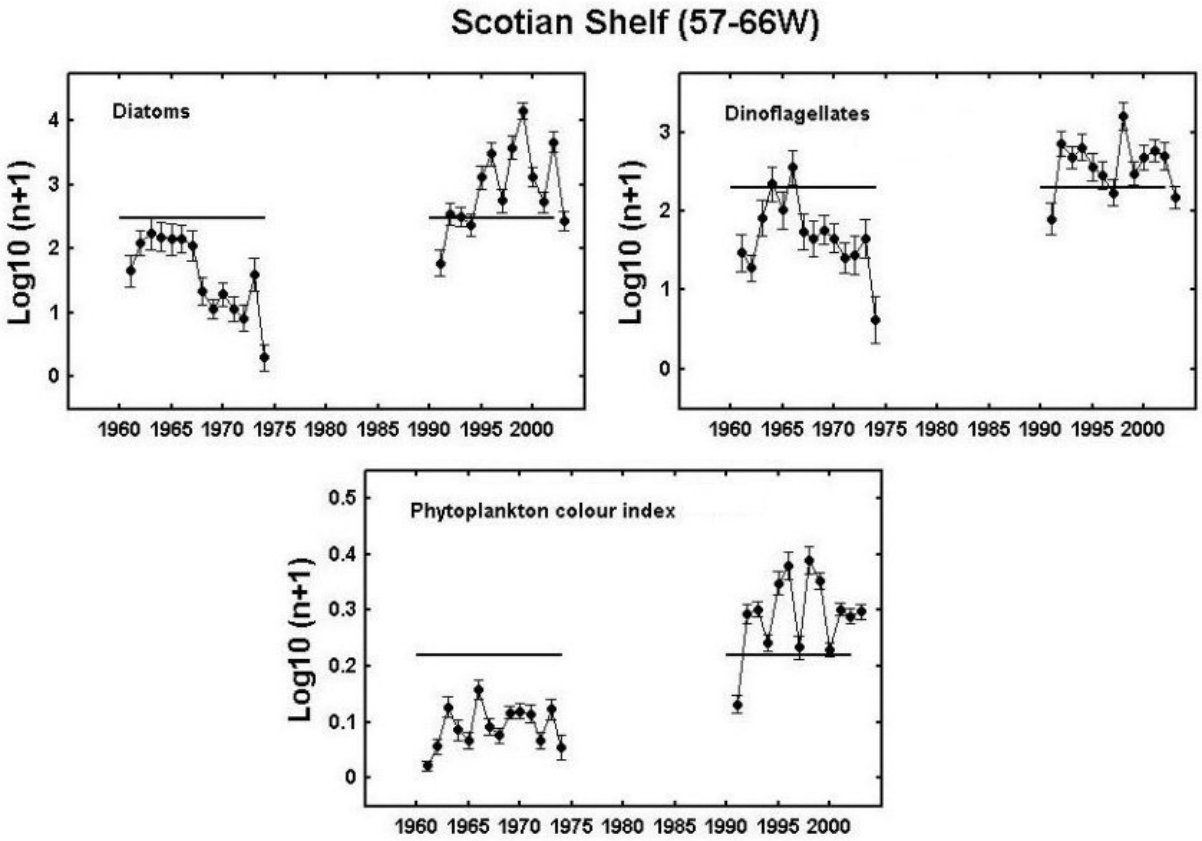


At the larger scale, strong blooms in 2004, although not the highest on record, were noted for the Southern Gulf of St Lawrence, the central and western Scotian Shelf and Georges Bank. When evaluated on an annual basis, it is apparent that 2004 was a significant year for phytoplankton production in the Southern Gulf and the Scotian Shelf/Gulf of Maine regions.

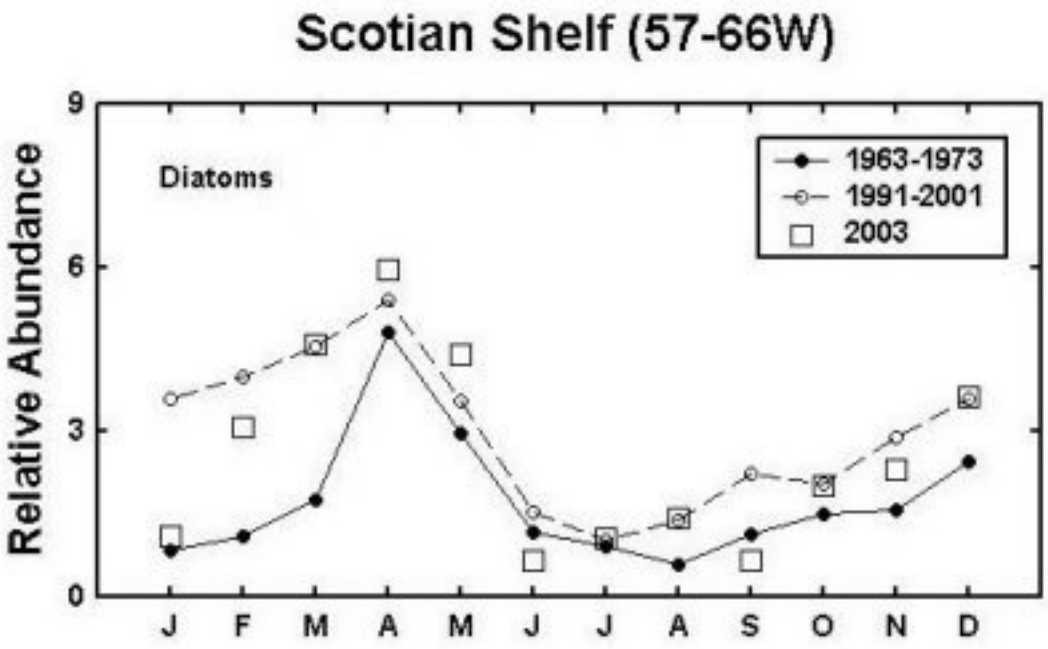


<u>Continuous Plankton Recorder.</u> The CPR is the longest data record available on plankton in the Northwest Atlantic. CPR data analysis lags AZMP reporting by one year; thus, only data up to 2003 are currently available. Nonetheless, the phytoplankton colour index and

abundance of large diatoms and dinoflagellates on the Scotian Shelf have been dramatically higher starting in the early 1990s and continuing into the 2000s than levels observed in the 1960s/1970s. On the shorter time scale, the phytoplankton color index on the Scotian Shelf has been relatively stable (and above the long-term average) over the past few years. Diatoms and dinoflagellate abundances, on the other hand, decreased in 2003 but remained above levels seen in the 1960s/1970s.

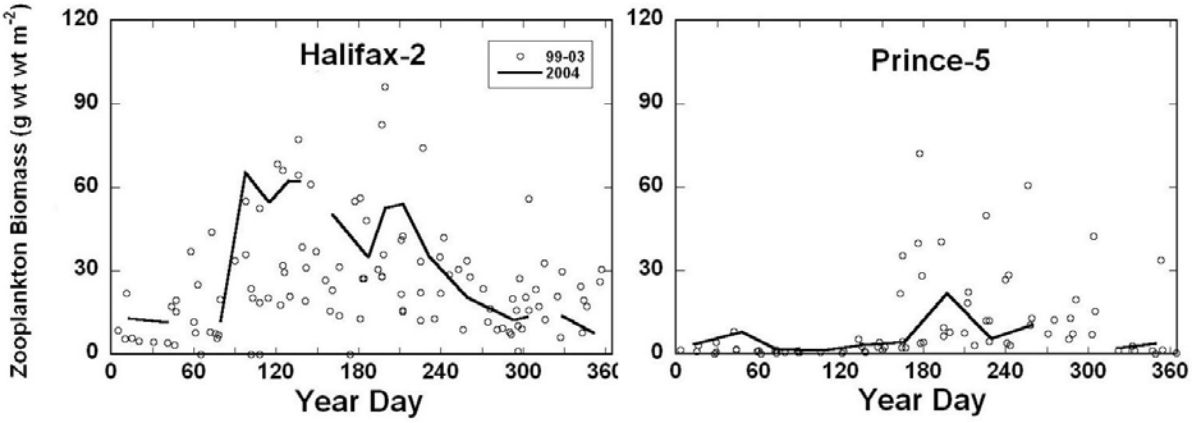


In 2003, the abundance and seasonal cycle of phytoplankton aligned more closely with the pattern observed in the 1990s than in the 1960s/1970s. There appeared to be a shift in phytoplankton abundance to earlier months in more recent years compared with the 1960s/1970s. Although timing of peak abundance (April) did not change, much higher levels, particularly of diatoms, were observed in February/March in 2003 compared to levels observed during the 1960s and 1970s.



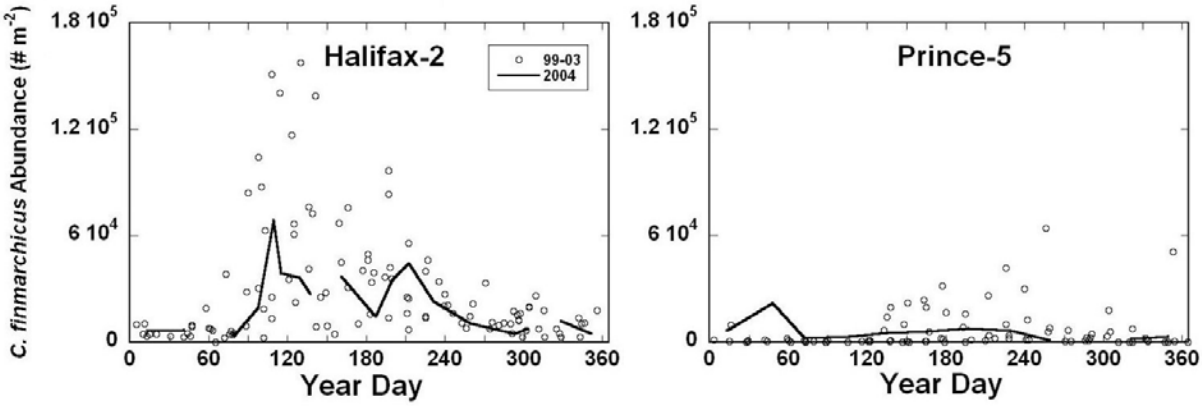
Zooplankton

Fixed Stations. Zooplankton biomass at all of the Maritimes/Gulf fixed stations was comparable to or lower in 2004 than levels observed in previous years. The record high biomass observed at Shediac Valley in 2003 was not observed in 2004, although sampling in 2004 was limited. Biomass off Halifax in 2004 was only slightly lower than 2003 levels, exhibiting a broad peak in summer. Zooplankton biomass in the Bay of Fundy in 2004 was comparable to 2003 levels. In the Bay of Fundy, zooplankton biomass is typically only a small fraction (10-20%) of the biomass at the other fixed stations and peaks later in the year.

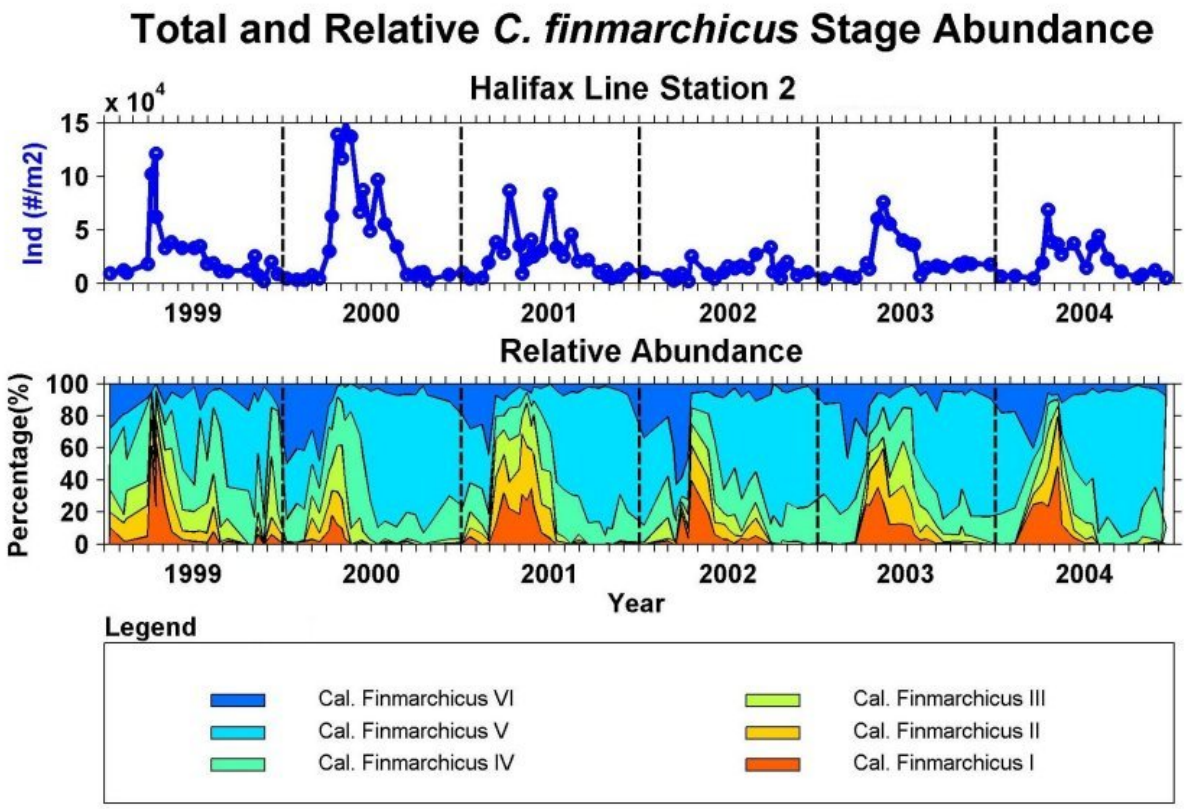


The abundance of the important copepod, *Calanus finmarchicus*, at all the fixed stations in 2004 was comparable to or lower than 2003 levels, similar to zooplankton biomass. *C. finmarchicus* abundance at Shediac Valley in 2004 reverted from the record peak abundance observed in 2003 to levels more typical of the region. Off Halifax, *C.*

finmarchicus abundance in 2004 was stable at 2003 levels and the downward trend observed in the previous 3 years had apparently stopped. *C. finmarchicus* abundance in the Bay of Fundy was relatively unchanged in 2004 from levels observed in 2003. Similar to zooplankton biomass, *C. finmarchicus* abundance in the Bay of Fundy is only a small fraction of the counts of that species at the other fixed stations.



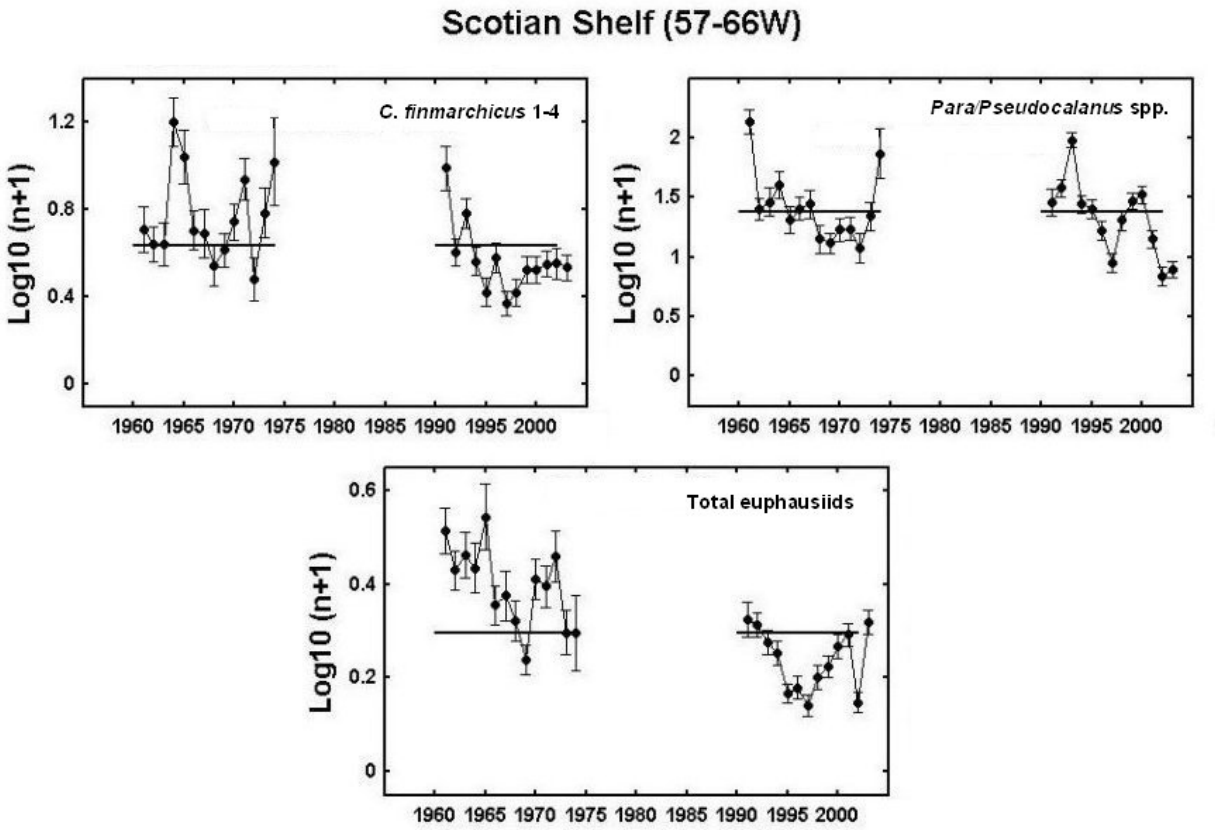
Hierarchical community analysis revealed that copepods continued to numerically dominate the zooplankton year-round at all of the Maritimes/Gulf fixed stations in 2004. The recurring pulse of echinoderm and barnacle larvae and euphausiids observed during the spring and summer in the Bay of Fundy was observed again in 2004. In addition, a pulse of jellies and appendicularia were also observed in summer at this station for the first time. The copepods were dominated at all the fixed stations by small species (*Oithona*, *Pseudocalanus*, *Paracalanus*, *Clausocalanus*, *Centropoges* and *Temora* sp.) in 2004 as in previous years. The relative importance of the larger *Calanus sp* appears to have been increasing at all fixed stations since AZMP sampling began in 1999. This is most evident in the Bay of Fundy where *Calanus spp.* have steadily increased from <10% in 1999 to a record high of up to ~80% in late 2003/early 2004. Also in the Bay of Fundy, "other" copepod species (e.g. *Acartia sp*., herpacticoids) comprise a significant fraction (>60%) of the copepods in summer whereas they play a minor role (<10%) at Shediac Valley and off Halifax. Stage distribution of *C. finmarchicus* in 2004 revealed that reproduction (indicated by presence of early developmental stages, I-III) was generally confined to the spring/early summer period off Halifax but was spread more broadly over the year at Shediac Valley and in the Bay of Fundy. However, the major reproductive activity appeared to occur in spring at all stations as in previous years. The timing of reproduction off Halifax appeared to start earlier in 2004 than in 2003 based on first appearance of young stages, i.e. late February versus late March, although the peak abundance of small stages occurred at about the same time in both years (May).



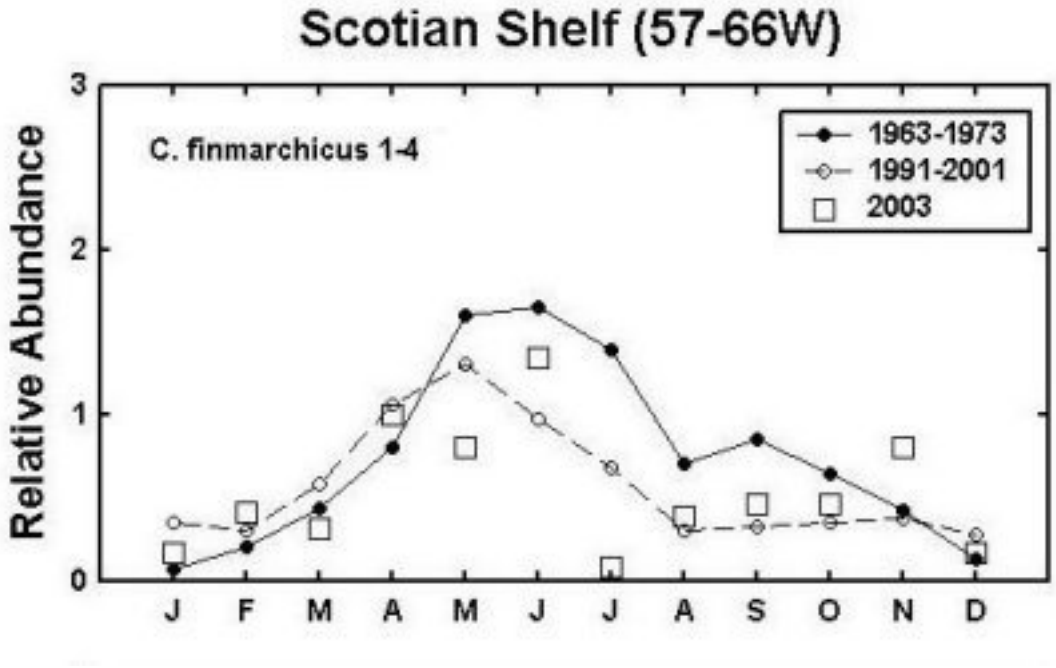
Shelf Sections. Zooplankton biomass and *C. finmarchicus* abundance were generally higher on the Scotian Shelf in spring 2004 than in fall, as observed in previous years. Although biomass levels are similar along the shelf, *C. finmarchicus* are generally more abundant on the western shelf in spring than on the eastern shelf. *C. finmarchicus* abundance along the Halifax and Brown's Bank sections in spring 2004 were lower than levels observed in 2003. In contrast, biomass levels along the Cabot and Halifax sections were significantly higher in fall 2004 than levels observed in 2003. *C. finmarchicus* abundance was also higher in fall 2004 along the Louisbourg section than observed in 2003.

Groundfish Surveys. Zooplankton biomass distribution observed during the major winter/spring and summer/fall groundfish surveys can be characterized as highly variable in space and time. Generally however, biomass is highest in deep basins and deep waters off the edge of the shelf or in channels (e.g. Northeast Channel off Georges Bank, Laurentian Channel bounding the Southern Gulf). Additionally, during the summer surveys, biomass has consistently been higher on the western Scotian Shelf than on the eastern shelf. This is in contrast to the east-west uniformity in biomass observed during the spring and fall surveys. In 2004, average zooplankton biomass in February on Georges Bank was significantly higher than biomass in 2003 and reversed the declining trend observed over the previous 4 years. No trends were observed in average biomass levels observed during the summer surveys over the past 5 years. Similarly, average biomass during the fall Southern Gulf surveys were relatively stable from 1999-2003, however, 2004 levels were significantly higher than observed previously. Zooplankton species data for most of the groundfish surveys are not yet available.

Continuous Plankton Recorder. While phytoplankton were increasing on the Scotian Shelf in the 1990s, zooplankton were generally decreasing, particularly during the early to mid-1990s. During the last several years, zooplankton numbers have recovered from the mid-1990s lows for some species on the Scotian Shelf, however, counts for other species are still down. Most noteworthy with regard to the latter was the near record low abundances of *Paracalanus/ Pseudocalanus spp.* in 2003*,* as observed in 2002; well below the long-term average. Euphausiid numbers, on the other hand, were up dramatically in 2003 from the 2002 lows and near the long-term average abundance levels. *C. finmarchicus* numbers in 2003 were steady, close to the long-term average.



The seasonal abundance cycles for zooplankton species in 2003 could not be as easily aligned with the patterns of the 1960s/1970s and 1990s as was the case for phytoplankton. The seasonal cycle of *C. finmarchicus* and *Paracalanus/ Pseudocalanus spp.* in 2003 appeared similar to the pattern observed for the 1990s, (although abundances for the latter species were well below the 1990s levels). The 2003 euphausiid cycle was more similar to the pattern observed in the 1960/1970s.



SOURCES OF INFORMATION

DFO SeaWiFS website: http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/remotesensing.html

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