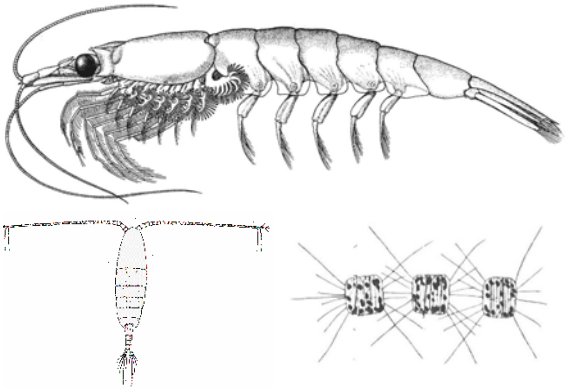


2003 State of the Ocean: Chemical and Biological Oceanographic Conditions in the Gulf of Maine - Bay of Fundy, Scotian Shelf and the Southern Gulf of St. Lawrence

Background

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.

Summary

- Near surface nutrient concentrations in 2003 were generally lower in the Southern Gulf and higher on the Scotian Shelf and in the Bay of Fundy than in 2002.
- Winter nutrient concentrations in 2003 off Halifax were the highest observed since 1999 but lower than historical levels.
- Bottom water nutrient concentrations and oxygen in the Southern Gulf and on the Scotian Shelf were comparable in 2003 to levels seen in previous years.
- Phytoplankton biomass was lower in the Southern Gulf but at record high levels during the spring bloom on the Scotian Shelf in 2003. The bloom appeared to persist longer than in previous years.
- Diatoms comprised a smaller yet still dominant fraction of the phytoplankton community in the Southern Gulf in 2003 than in 2002.
- Continuous Plankton Recorder (CPR) colour index and species counts in 2002

showed that phytoplankton abundance on the Scotian Shelf continues to be well above levels observed in the 1960s and 1970s.

- Zooplankton biomass on Georges Bank in 2003 continued a downward trend while levels continued to increase on the Eastern Scotian Shelf.

- Zooplankton biomass and *Calanus finmarchicus* abundance were at record high levels in the Southern Gulf in 2003.

- *Calanus finmarchicus* abundance increased on the Scotian Shelf in 2003, reversing a 3-year downward trend.

- CPR species counts in 2002 showed that zooplankton abundance continues to be well below levels observed in the 1960s and 1970s. Euphausiid numbers dropped dramatically in 2002.

Introduction

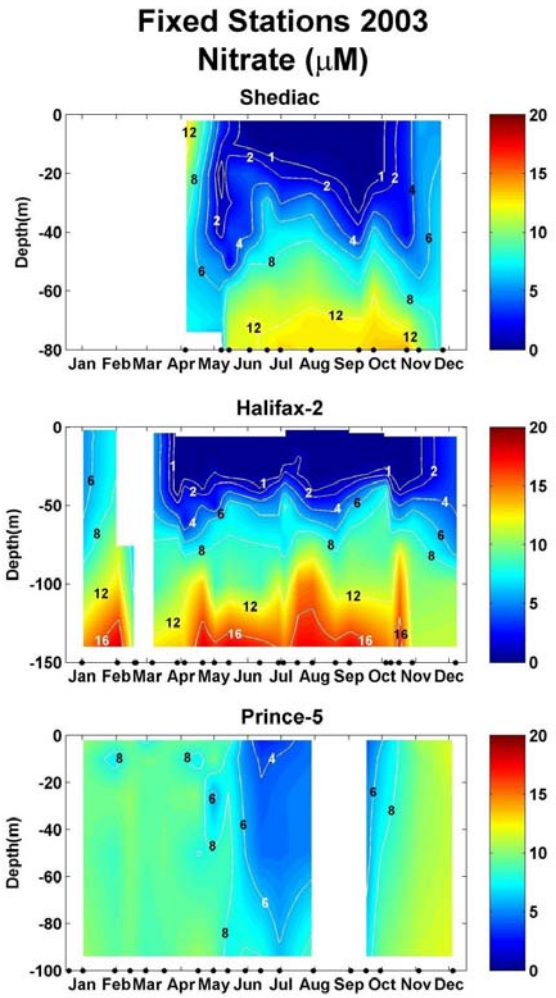
The production cycle of plankton is largely under the control of physical processes. Specifically, light and nutrients (e.g. nitrate, phosphate, silicate) are required for the growth of marine microscopic plants (phytoplankton). Of the major available nutrients, nitrogen is generally in shortest supply 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.

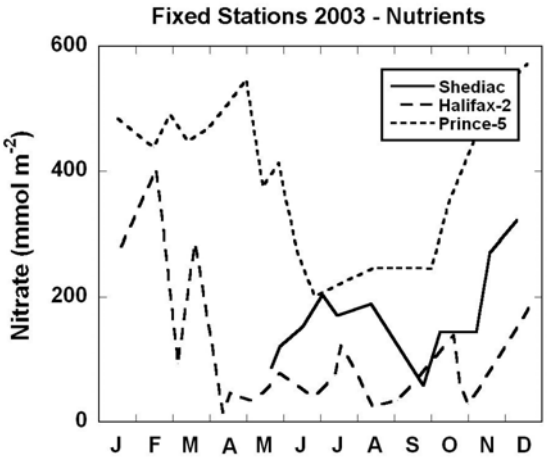
The AZMP provides basic information on the natural variability of physical, chemical and biological properties of the Northwest Atlantic continental shelf. Groundfish surveys and cross-shelf sections provide detailed regional geographic information but are limited in their seasonal coverage. Critically 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.

Nutrients

Fixed Stations. Rapid spring-time reduction in near-surface nutrient concentrations was observed at all Maritimes/Gulf fixed stations in 2003, as in previous years. Low surface values persisted throughout the summer at Shediac Valley and off Halifax; concentrations did not increase at the surface again until late autumn. The depth of nutrient depletion in summer was greater off Halifax than at Shediac Valley. Depletion depths in 2003 at both stations were similar to depths seen in 2002. Nutrient concentrations in the Bay of Fundy were never reduced to depletion due to intense tidal mixing of deep nutrient-rich waters. The seasonal evolution of the vertical structure of nutrients at all fixed stations in 2003 was similar to that seen in previous years. However, concentrations below 50 m were slightly lower in 2003 than seen in 2002 and below the long-term average off Halifax.

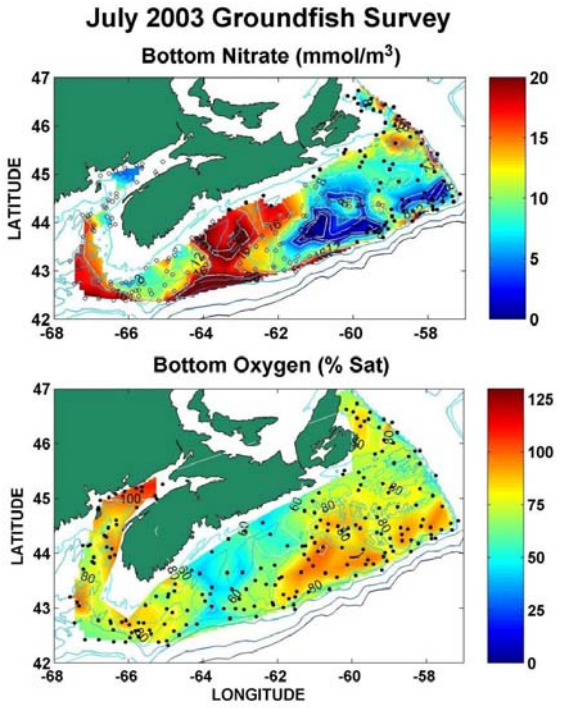


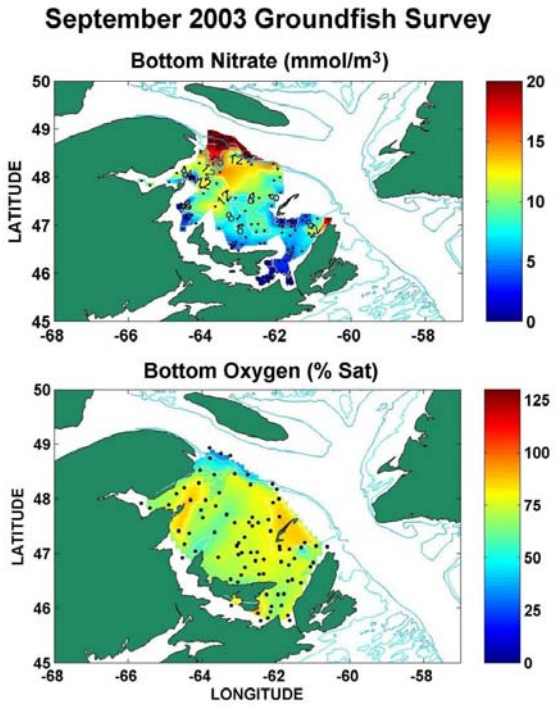
Nutrient inventories in the upper 50 m (nominal depth zone over which nutrient changes are strongly influenced by biological processes) varied seasonally at all the fixed stations. Nutrient levels in 2003, overall, were highest in the Bay of Fundy and lowest off Halifax, as seen in previous years. Overall, near-surface nutrient concentrations were lower in Shediac Valley and higher off Halifax and in the Bay of Fundy in 2003 than in the previous year. Winter nutrient levels off Halifax in 2003 were the highest seen since AZMP observations began in 1999 but still lower than historical levels. Winter nutrient levels in the Bay of Fundy were also higher in 2003 than in 2002 and continued an upward trend observed over the past 3 years. The trend of increasing summer-time minimum nutrient levels at this station, noted last year, appeared to stabilize in 2003, i.e. levels in 2003 were comparable to 2002.



Seasonal Sections. Vertical distributions of nutrients in spring and autumn were generally similar along the Scotian Shelf sections in 2003, i.e. concentrations were low in near-surface waters (<50 m), as a result of biological consumption, and increased with depth. Deep-water concentrations were highest in basins and in slope waters off the edge of the shelf. As seen in 2002, surface nutrient levels were already significantly depleted by the spring survey (April) and there was no evidence during the autumn survey (October) that seasonal mixing of nutrients into surface waters had occurred.

Groundfish Surveys. Bottom water nutrient concentrations during the July 2003 groundfish survey on the Scotian Shelf were comparable overall to levels seen in 2002. Oxygen saturation in bottom waters, likewise, was similar in 2003 to levels seen in 2002; saturation levels were lowest in deep basins and off the edge of the shelf where nutrients were highest.



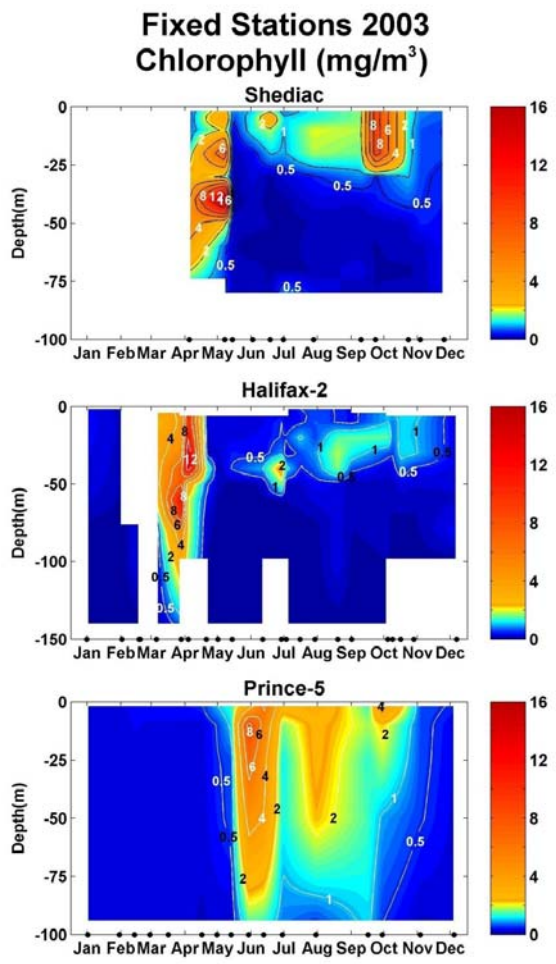


Bottom water nutrient concentrations during the September groundfish survey in Southern Gulf were lower overall in 2003 than in 2002 but comparable to levels seen in previous years; highest concentrations were observed in the western basin. Bottom water oxygen saturation in 2003 was comparable to 2002 levels with lowest saturation in the western basin where nutrients were highest. Station density during the 2003 Southern Gulf survey was reduced from previous years (i.e. by half), however, geographic coverage was comparable to previous years

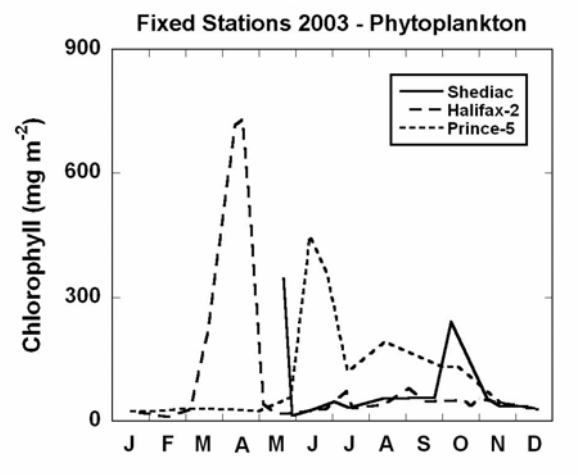
Phytoplankton

Fixed Stations. Distinctly different seasonal phytoplankton growth cycles were evident in 2003 at the three Maritimes/Gulf fixed stations. Because of the presence of ice in the Southern Gulf in early spring, only the latter phase of the spring bloom is normally captured in sampling at Shediac Valley. The tail of the spring bloom and a prominent autumn bloom were seen at Shediac Valley in 2003. This is in marked contrast to persistent high chlorophyll concentrations seen throughout the summer in 2002 at this station but more typical of the growth pattern seen in earlier years. A pronounced spring bloom was also seen off Halifax in 2003; chlorophyll levels highest in the 5-year record of AZMP were observed there and the bloom persisted longer than observed previously. The large spring bloom at this site might be linked to the high inventories of nutrients during the previous winter. Phytoplankton growth in the Bay of Fundy in 2003 began in late spring and chlorophyll persisting at relatively high levels throughout the summer. Extended phytoplankton growth at this site is typical and results from a continuous supply of

nutrients to surface waters from strong tidal mixing.

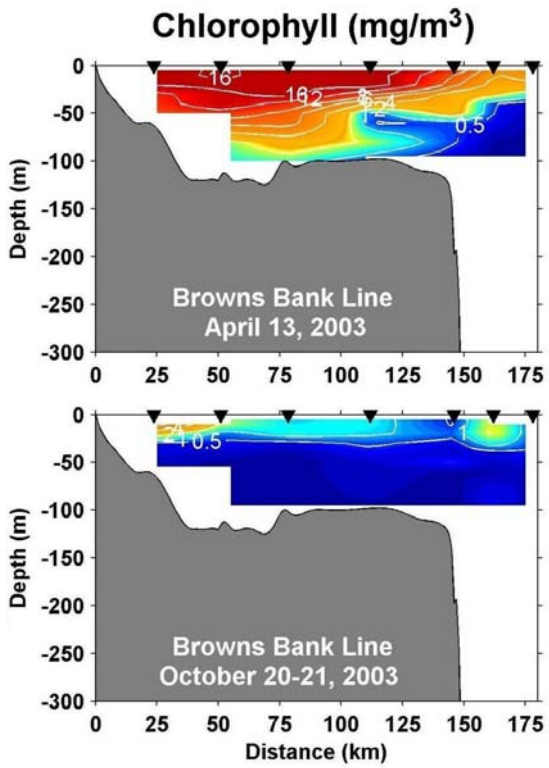


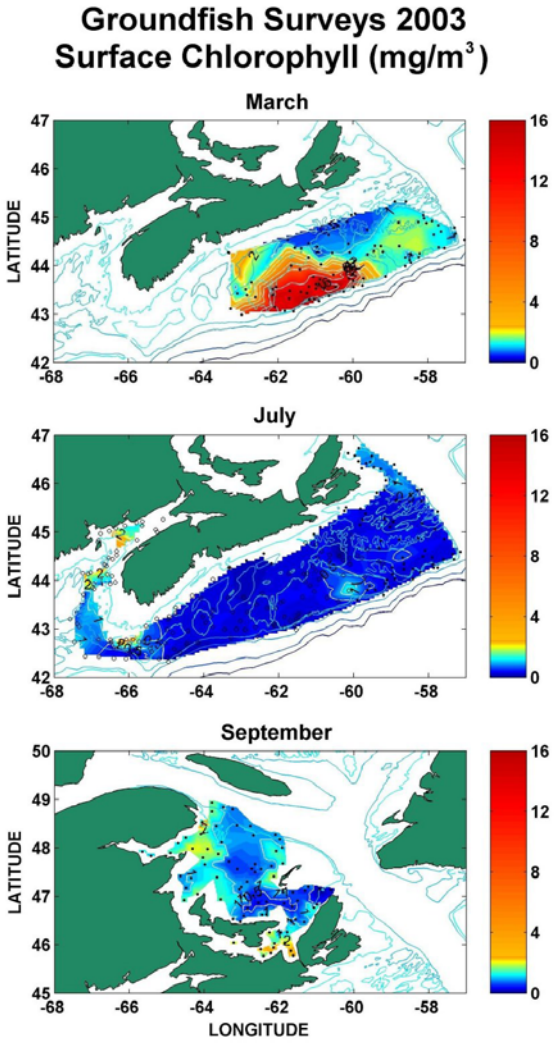
Chlorophyll inventories in 2003 were down at Shediac Valley compared to the record high levels seen in 2002. In contrast, spring chlorophyll levels off Halifax in 2003 were at 5-year record highs and have been increasing since AZMP observations began in 1999. In addition, annual chlorophyll inventories off Halifax in 2003 were well above historical levels for the region. Chlorophyll levels in the Bay of Fundy in 2003 peaked in early summer and were not noticeably different from levels seen in 2002 and years previous. Overall, annual chlorophyll inventories in 2003 were highest off Halifax and lowest at Shediac Valley; in previous years annual chlorophyll levels have been highest in the Bay of Fundy.



Phytoplankton species counts indicated that total species abundance matched chlorophyll biomass distributions reasonably well at the fixed stations in 2003. Diatoms dominated during blooms at all stations. Flagellates were an important component of the phytoplankton community after blooms of diatoms at Shediac Valley and off Halifax. The year-round prevalence of diatoms at Shediac Valley seen in 2002 was not observed in 2003; the mix of species and seasonal changes in community structure in 2003 were more typical of previous years. In 2003, diatoms continued to dominate the phytoplankton community year-round in the Bay of Fundy as has been seen since AZMP observations began in 1999.

Seasonal Sections. Five-year record-high surface chlorophyll concentrations were observed along all sections on the Scotian Shelf in spring 2003. Chlorophyll levels in autumn, in contrast, were low along all sections and showed no vertical structure as has been seen in previous years, i.e. no pronounced subsurface chlorophyll maxima were observed along any of the lines.



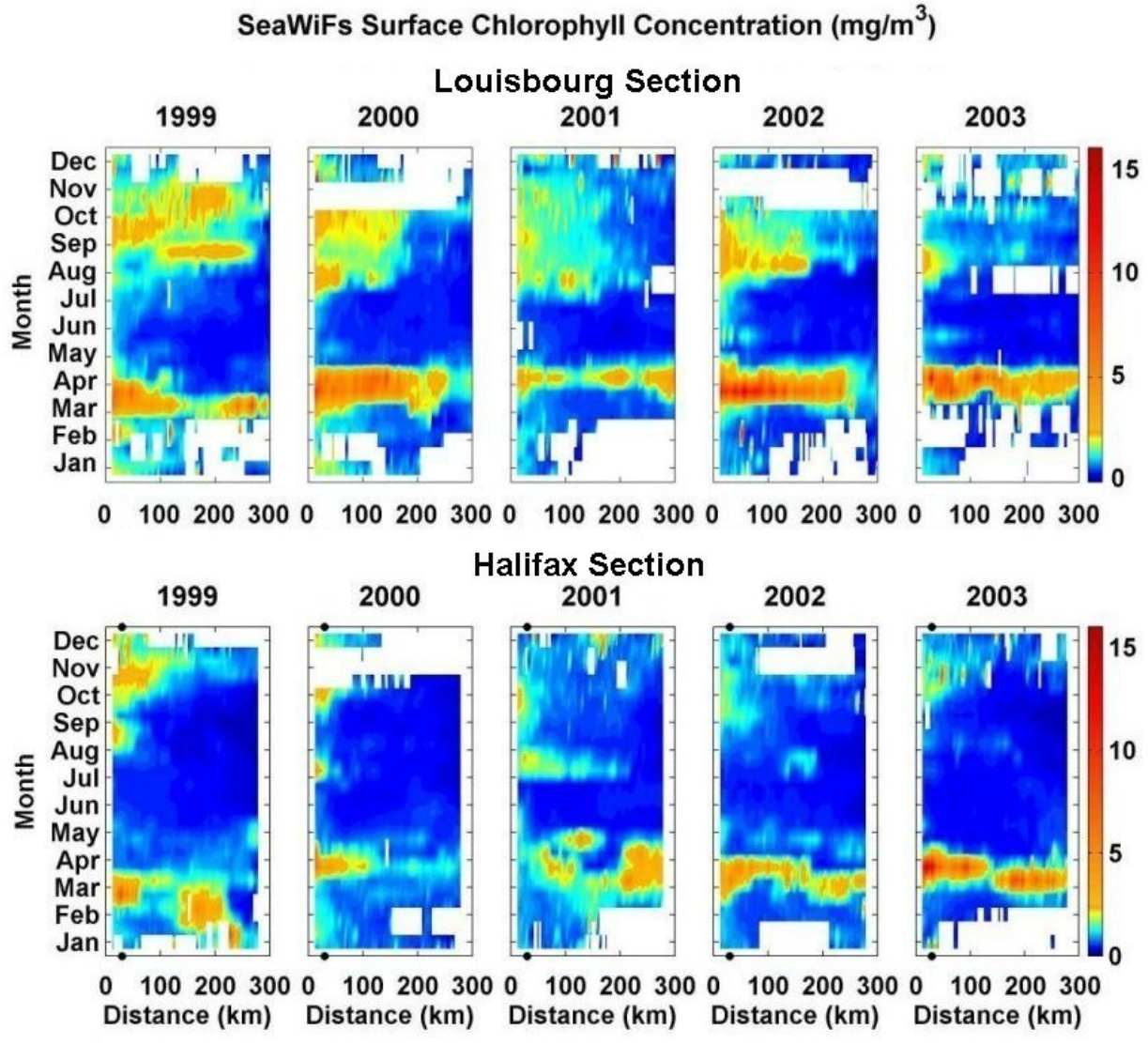


Groundfish Surveys. Near-surface chlorophyll levels on the Eastern Scotian Shelf during the March 2003 groundfish survey were high, particularly on the outer central shelf. A similar distribution pattern was seen in previous years although levels were highest in the 5-year record in 2003. During the 2003 July survey, chlorophyll levels were uniformly low over most of the Scotian Shelf with elevated concentration only near the coast of SW Nova Scotia and approaches to the Bay of Fundy. These areas are generally characterized by strong vertical mixing. Overall, summer surface chlorophyll concentrations on the Scotian Shelf in 2003 were comparable to concentrations observed in previous years and comparable to the long-term average.

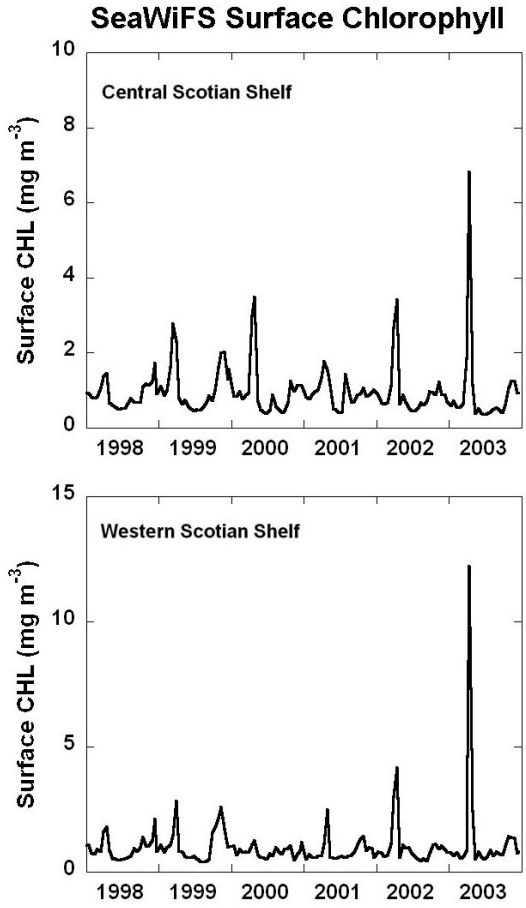
The record high surface chlorophyll concentrations observed during the September 2002 groundfish survey in the Southern Gulf were not seen in 2003; levels were lower and comparable to levels seen prior to 2002. Concentrations were highest in the western basin.

Satellite Remote-Sensing. Satellite ocean colour data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) provide an alternative means of assessing phytoplankton biomass (chlorophyll) at the AZMP fixed stations, along the seasonal sections, and at larger scales (Northwest Atlantic). Satellite data for 2003 clearly showed the surface bloom events at the Maritimes/Gulf fixed stations. Satellite data also provided confirmation of features seen in the other AZMP datasets, for example, the high off-shelf chlorophyll concentrations observed in the March 2003. The satellite-derived chlorophyll data can also be used to generate graphical representations of the seasonal chlorophyll changes along the cross-shelf sections. It is evident from the satellite-data, for example, that surface chlorophyll concentrations are generally

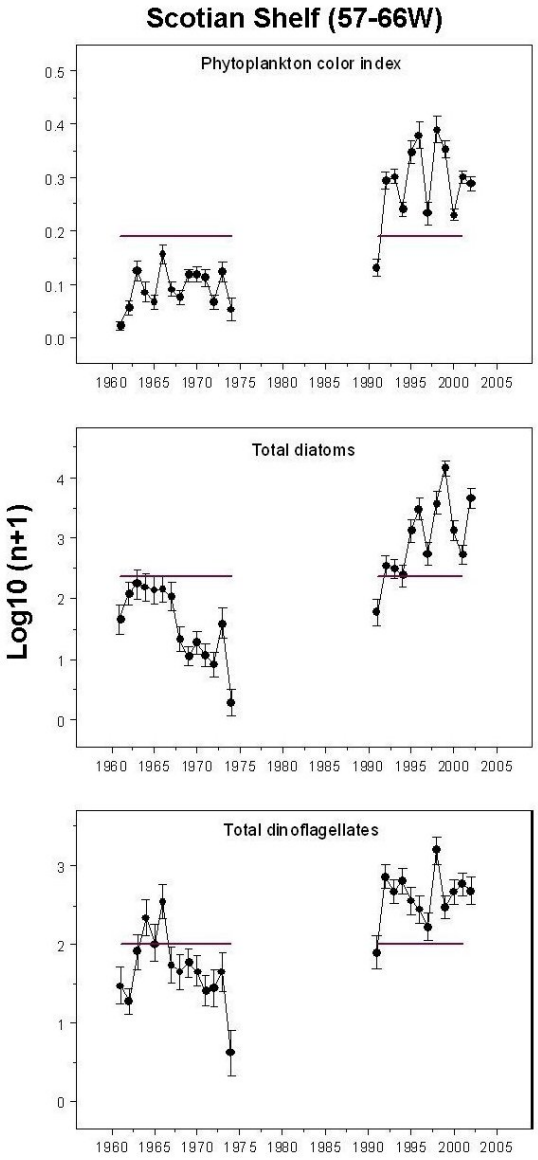
higher on the eastern Scotian Shelf (Louisbourg section) than on the central and western shelf (Halifax section). Also, the nature of the onset, duration and termination of the spring and autumn blooms is revealed and areas across the shelf are identifiable where phytoplankton biomass accumulates. Spring blooms on the Scotian Shelf can be viewed as discrete, short-lived events whereas the autumn blooms appear to be more diffuse and time-varying. The greater intensity of the spring bloom along the Halifax section in 2003 compared with previous years is evident from the satellite data. In addition, the bloom appeared to persist longer near shore in 2003 than on 2002.



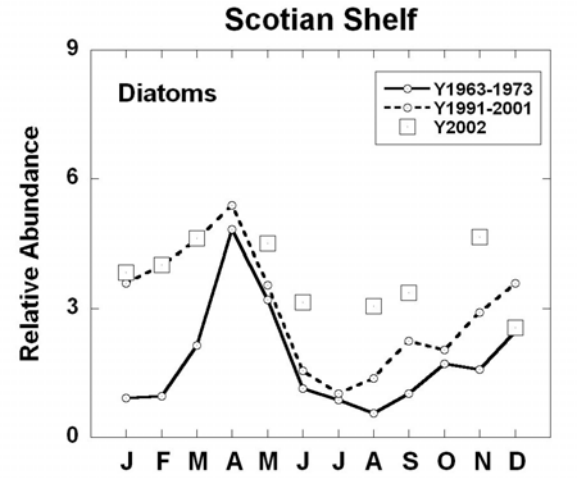
At the larger scale, the magnitude of the spring bloom on the central and western Scotian Shelf in 2003 was the highest observed since satellite data collection began in 1998.



Continuous Plankton Recorder. 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 2002 are currently available. Nonetheless, the phytoplankton color 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 compared with levels seen in the 1960s and 1970s. On the shorter time scale, the phytoplankton color index and dinoflagellate abundance on the Scotian Shelf did not change appreciably between 2002 and 2001. Diatoms, on the other hand, increased in 2002, reversing a downward trend seen over the previous 2 years.

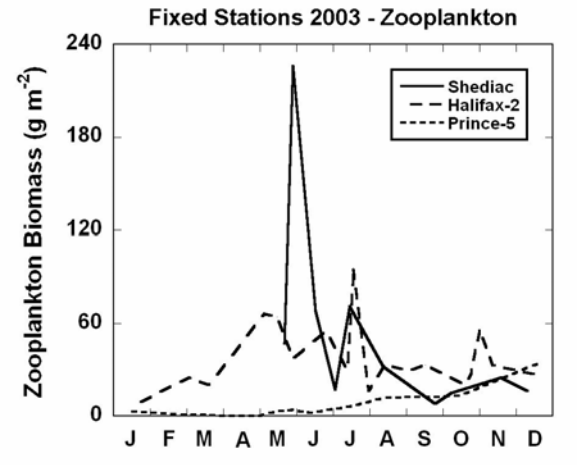


In 2002, and the 1990s in general, phytoplankton abundance was higher in all months but particularly so early in the year (January-March) compared to the 1960s and 1970s. In 2002, however, the increased abundance of diatoms on the Scotian Shelf was associated with elevated numbers during the later half of the year (June-November).

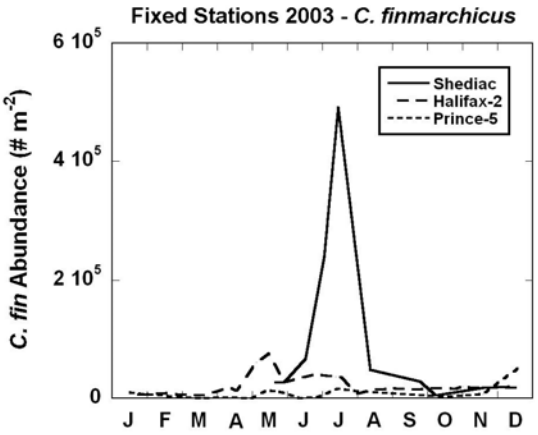


Zooplankton

Fixed Stations. Zooplankton biomass at Shediac Valley and off Halifax was higher in 2003 than in 2002 but somewhat lower in the Bay of Fundy in 2003. Biomass was at 5-year record high levels at Shediac Valley in 2003, almost twice the levels seen in previous years. Annual zooplankton inventories were highest in Shediac Valley and lowest in the Bay of Fundy in 2003 as observed in past years.

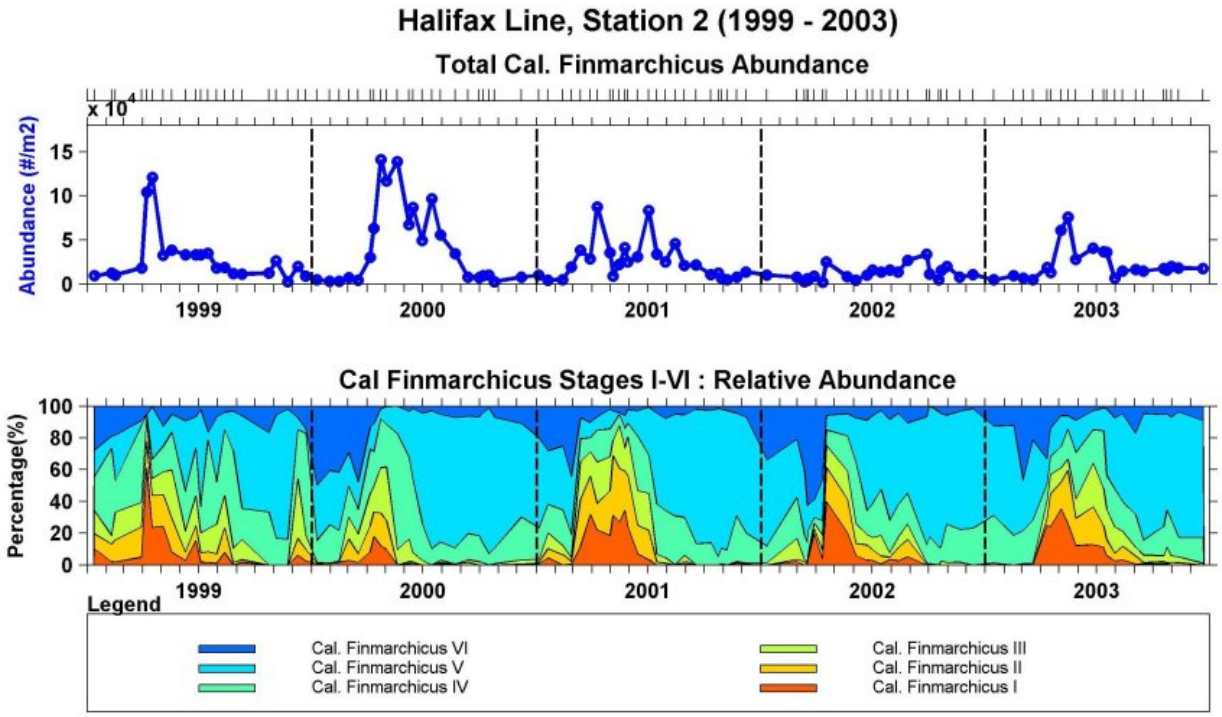


Calanus finmarchicus abundance at the fixed stations in 2003 followed the trends seen in zooplankton biomass. Five-year record high levels were seen at Shediac Valley where numbers exceeded those seen in previous years by 3-fold. *C. finmarchicus* abundance off Halifax was higher in 2003 than in 2002 and reversed the downward trend seen in the previous 3 years. In contrast to zooplankton biomass, *C. finmarchicus* abundance in the Bay of Fundy was somewhat higher in 2003 than in 2002 but levels at this station continue to be considerably lower than those seen at the other fixed stations.



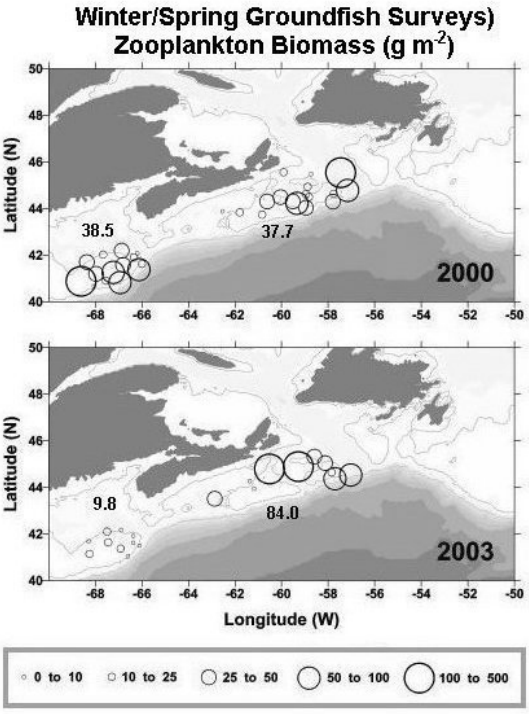
Copepods continued to dominate the zooplankton year-round at all of the Maritimes/Gulf fixed stations in 2003. Significant numbers of jelly fish and related plankton were seen off Halifax in early summer again in 2003 and a recurring spring pulse of echinoderm and barnacle larvae and euphausiids was observed in 2003 in the Bay of Fundy. The progressive decrease in zooplankton abundance seen off Halifax for the past 3 years was reversed in 2003; levels were up slightly. The copepods were dominated at all the fixed stations by small species in 2003. The relative importance of the larger *Calanus sp.* was greatest in the Southern Gulf and least important in the Bay of Fundy. As was the case for total zooplankton numbers, copepod abundance off Halifax was slightly higher in 2003 than in 2002, reversing the downward trend seen for the last 3 years. Stage distribution of *C. finmarchicus* in 2003 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 the Bay of Fundy, as seen in previous years. However, the major reproductive activity appeared to occur in

spring at all stations. The timing of reproduction off Halifax may have started somewhat later in 2003 (and persisted longer) than in 2002 based on appearance of young stages, i.e. late March in 2003 versus early/mid March in 2002. The dramatic decrease in *C. finmarchicus* abundance seen off Halifax over the past 3 years was reversed in 2003, similar to the trend seen in total copepods and zooplankton abundance. Five-year record high levels of *C. finmarchicus* were observed at Shediac Valley in 2003.

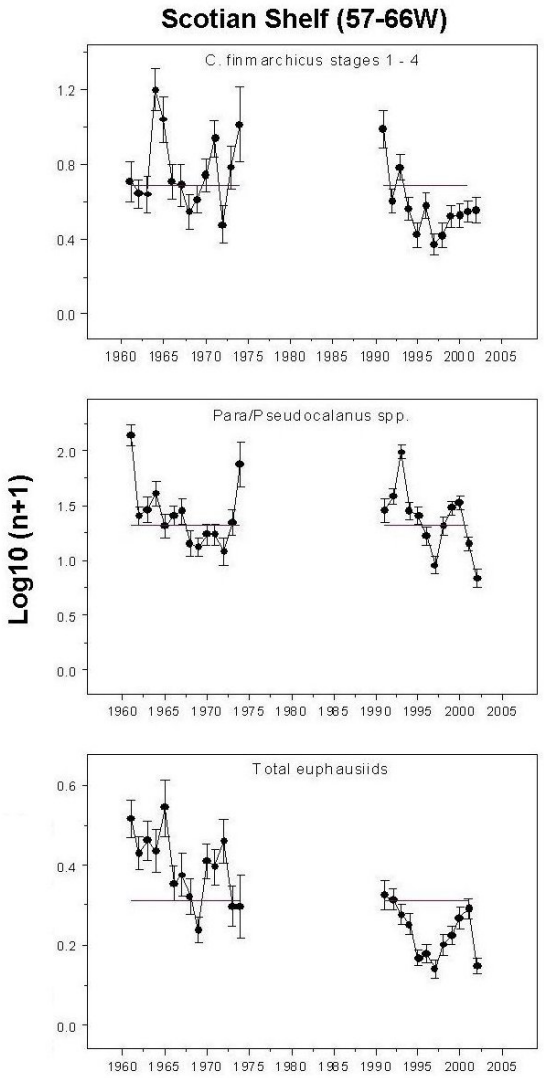


Seasonal Sections. Zooplankton biomass was collected during both the spring and fall surveys, however, only the spring data are available at this time. Biomass along all the Scotian Shelf sections was high in spring 2003 and comparable to the high levels seen in 2001 (no data were collected in spring 2002). *C. finmarchicus* abundance data for 2003 are not yet available.

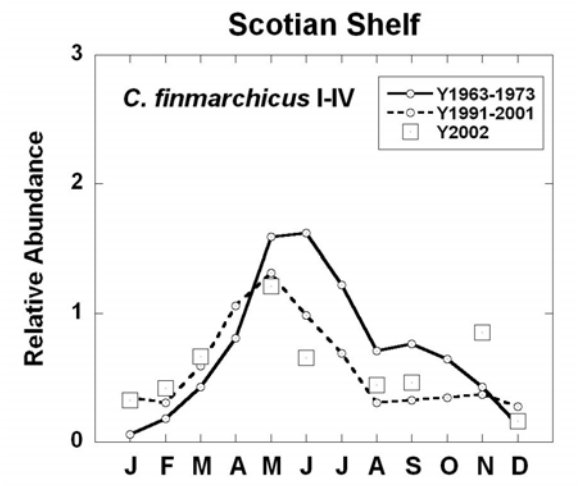
Groundfish Surveys. Zooplankton biomass was collected during the major winter/spring (Georges Bank/Eastern Scotian Shelf) and summer/autumn (Scotian Shelf/Southern Gulf of St. Lawrence) groundfish surveys in 2003. Biomass distribution can be characterized as highly variable in space and time. Generally, however, biomass was 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 to the north). This pattern of distribution recurred each year. Over the past 4 years, zooplankton biomass collected in February on Georges Bank has been decreasing (by almost a factor of 4 in 2003) while biomass on the Eastern Scotian Shelf collected in March has increased (by a factor of 2 in 2003). Data collected during the summer/autumn surveys in 2003 are not yet available, however, in previous years the highest biomass was observed on the western Scotian Shelf/eastern Gulf of Maine. Overall, zooplankton biomass on the Scotian Shelf in summer and in the Southern Gulf in autumn has been fairly constant for the past 4 years.



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, and levels were much lower than seen in the 1960s and 1970s. During the last 3-4 years, zooplankton numbers appeared to be recovering, however, numbers were steady or down in 2002. Most noteworthy were significant drops in *Paracalanus/Pseudocalanus sp.* and euphausiid numbers. In the latter case, a 4-year recovery (increase) in numbers was reversed.



Highest abundance of *C. finmarchicus* and *Paracalanus/Pseudocalanus sp.* occurred somewhat earlier in the season in 2002 than seen in the 1960s and 1970s; a pattern that has persisted for the decade of the 1990s. This seasonal shift in zooplankton abundance is similar to the shift in abundance (to earlier months) of diatoms seen in recent years.



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For more Information

Contact:

Dr. G. Harrison
Ocean Science Division
Biological Oceanography Section, BIO
Dartmouth, Nova Scotia

Tel: (902) 426-3879
Fax: (902) 426-9388
E-mail: harrisong@mar.dfo-mpo.gc.ca
Website: http://www.meds-sdmm.dfo-mpo.gc.ca/zmp/main_zmp_e.html

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Maritime Provinces
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Department of Fisheries and Oceans
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Dartmouth, Nova Scotia
Canada B2Y 4A2

Phone number: 902-426-7070
Fax number: 902-426-5435
e-mail address: myrav@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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