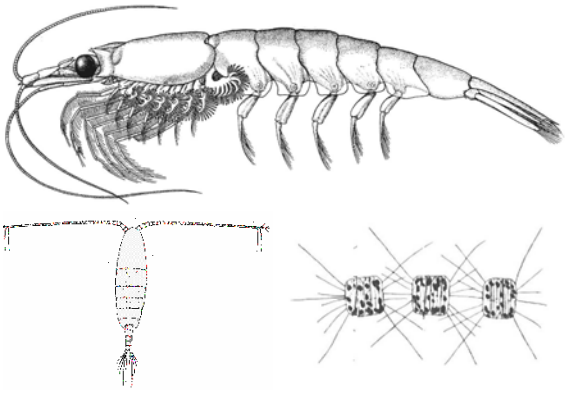


2002 State of the Ocean: Chemical and Biological Oceanographic Conditions in the Gulf of Maine - Bay of Fundy, Scotian Shelf and the Southern Gulf of St. Lawrence

Background

The Atlantic Zonal 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

- Surface nutrient concentrations in 2002 were generally higher in the Southern Gulf and lower on the Scotian Shelf than in 2001.
- Nutrient concentrations in the deep basins were higher in 2002 but lower than the long-term average.
- Oxygen concentrations in bottom waters were lower in 2002 than in 2001.
- Phytoplankton biomass in 2002 was higher in the Southern Gulf but lower on the Scotian Shelf than in 2001.
- The spring bloom occurred earlier on the Scotian Shelf and later in the Bay of Fundy than in 2001. The magnitude of the spring bloom continues to decrease on the eastern Scotian Shelf with lowest levels on record in 2002.
- Diatoms comprised a greater fraction of the phytoplankton community in 2002 in the Southern Gulf than in 2001.

- Dinoflagellates increased in importance on the Scotian Shelf in 2002 compared with previous years.

- Continuous Plankton Recorder (CPR) colour index and species counts showed that phytoplankton abundance on the Scotian Shelf continues to be well above levels observed in the 1960s and 1970s.

- Zooplankton biomass, overall, was lower in 2002 than levels observed in 2001.

- *Calanus finmarchicus* abundance was lower on the Scotian Shelf and in the Bay of Fundy in 2002 than in 2001 but higher in the Southern Gulf. Its seasonal reproductive cycle, however, was similar in 2001 and 2002.

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

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.

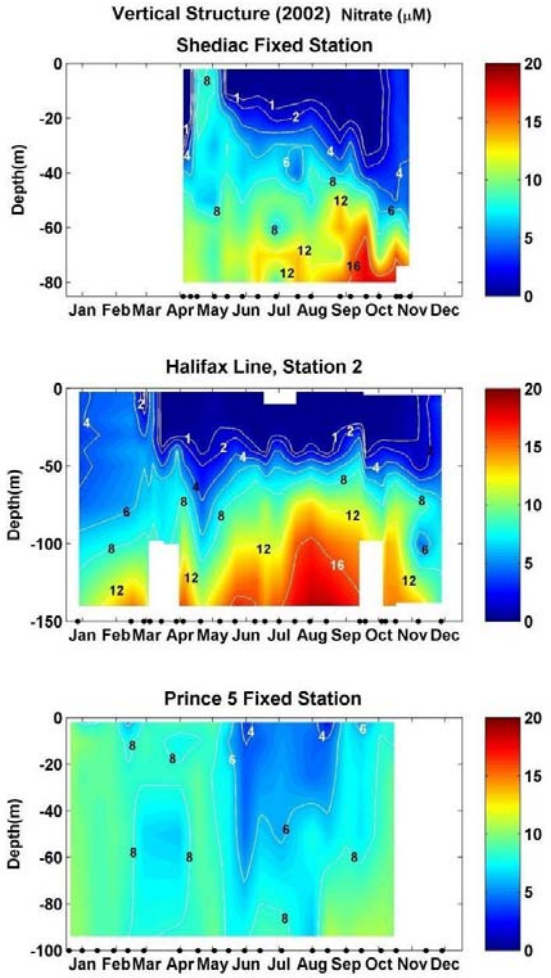
Phytoplankton constitute the base of the marine food-web and are the primary food source for the animal component of the plankton (zooplankton). Both phytoplankton and zooplankton, in turn, are food for larval fish and invertebrates and influence their survival rate. An understanding of plankton cycles 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 station in the Shediac Valley of the Southern Gulf of St. Lawrence, the Halifax-2 station on the Halifax section of 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.

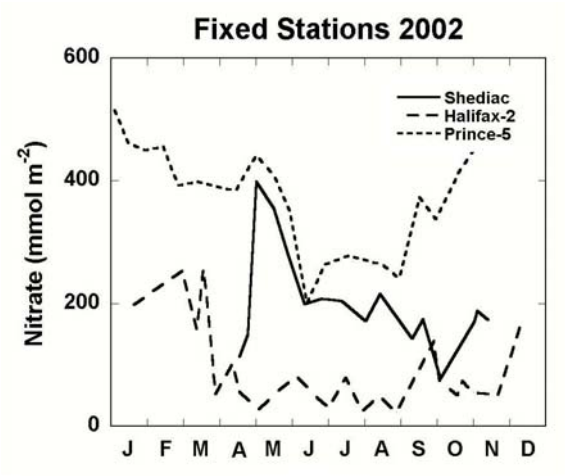
Nutrients

Fixed Stations. Rapid spring-time reduction in near-surface nutrient concentrations was seen at all Maritimes/Gulf fixed stations in 2002, as in previous years. Low surface values persisted throughout the summer at Shediac Valley and Halifax-2; concentrations did not increase at the surface again until late autumn. The depth of nutrient depletion in summer was greater at Halifax-2 than at Shediac Valley. Depletion depths in 2002 at both stations were similar to depths seen in 2001. Nutrient concentrations at Prince-5 were never reduced to depletion due to intense tidal mixing. The seasonal evolution of the vertical structure of nutrients at all fixed stations in 2002 was similar to that seen in previous years. However, concentrations below 50 m were higher in 2002 at all stations than previously observed. Despite the increase in nutrients at depth in 2002,

concentrations were still below the long-term average.



Seasonal variability in nutrients in the upper 50 m (nominal depth zone over which nutrient changes strongly influence biological processes) indicated that annual concentrations were higher in surface waters at Shediac Valley but lower at Halifax in 2002 than in 2001; nutrient levels at Halifax-2 were also significantly lower than the long-term average. Annual levels at Prince-5 were similar in 2002 to 2001, however, summer-time minimum values were higher than in previous years indicating that biological consumption may have decreased. The 4-year data record of AZMP shows a trend of increasing minimum summer-time nitrate concentrations at this station. Maximum winter-time nutrient concentrations were highest at Prince-5 and lowest at Halifax-2. Maximum winter nitrate concentrations at Halifax-2 in 2002 were lower than in 2001 but substantially lower than the long-term winter average.

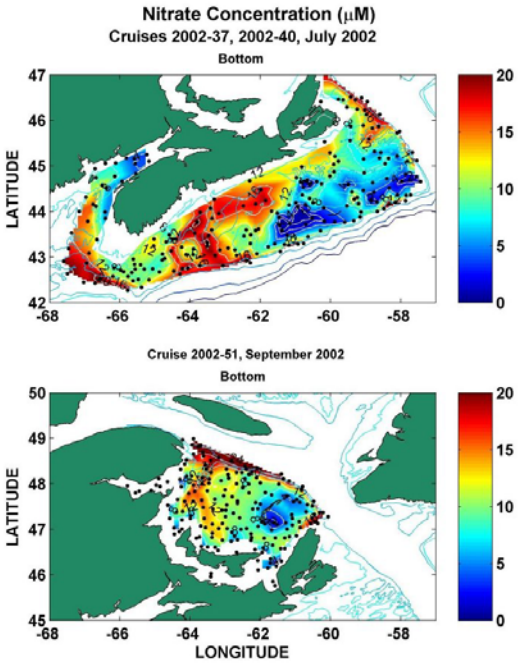


Seasonal Sections. Vertical distributions of nutrients in spring and summer were generally similar along the Halifax section in 2002, i.e. concentrations were low in near-surface waters (<50 m), as a result of biological consumption, and increased with depth. As seen in 2001, surface nutrient levels were already significantly depleted by early May. Deep-water concentrations were highest in the Emerald Basin and in slope waters off the edge of the shelf. Nutrient concentrations in May were slightly above the long-term average in surface waters but below the average in Emerald Basin and in deep slope waters. In June, the pattern reversed; nutrient levels in offshore surface waters were below the average while deep waters levels above.

Groundfish Surveys. Bottom water nutrient concentrations during the July groundfish survey on the Scotian Shelf were comparable overall to levels seen in 2001, except in the deep basins where concentrations were higher. Compared with the long-term average, however, concentrations were low in 2002, particularly on the eastern shelf. Bottom

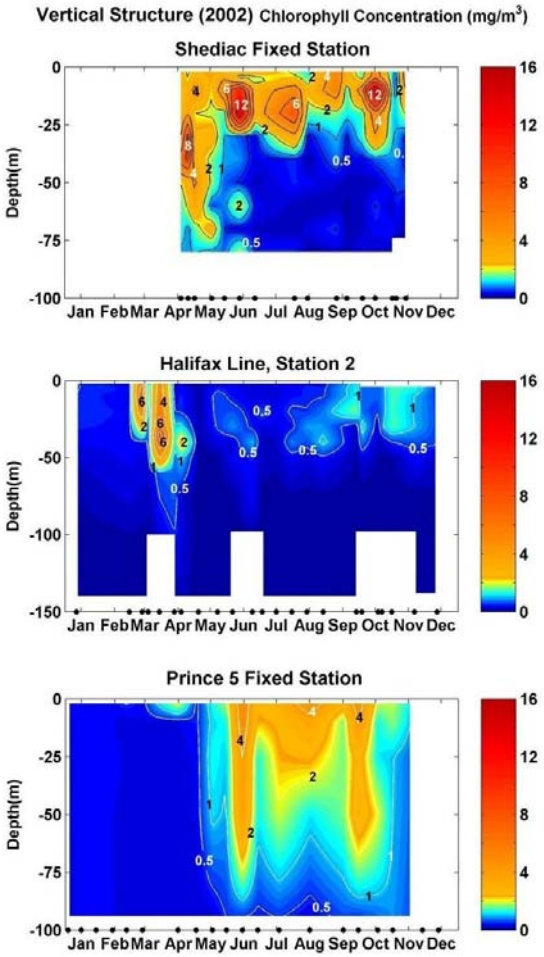
water oxygen saturation on the Scotian Shelf was also low in 2002 compared with 2001, and again this was most evident on the eastern shelf.

Bottom water nutrient concentrations during the September groundfish survey in Southern Gulf were higher overall in 2002 than in 2001 and highest levels were concentrated in the western basin. Bottom water oxygen saturation may also have been lower in the Southern Gulf in 2002 but data from 2001 are sparse.



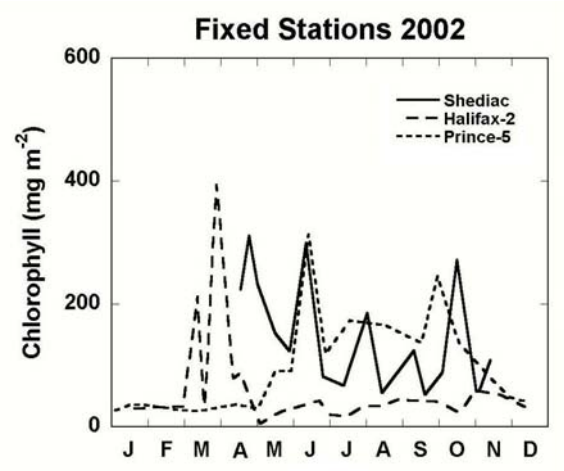
Phytoplankton

Fixed Stations. Distinctly different seasonal phytoplankton growth cycles were evident in 2002 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 sampled at Shediac Valley. Persistently high chlorophyll levels were seen at Shediac Valley throughout the sampling season. This is in marked contrast to low summer/autumn chlorophyll levels observed at this station in previous years.

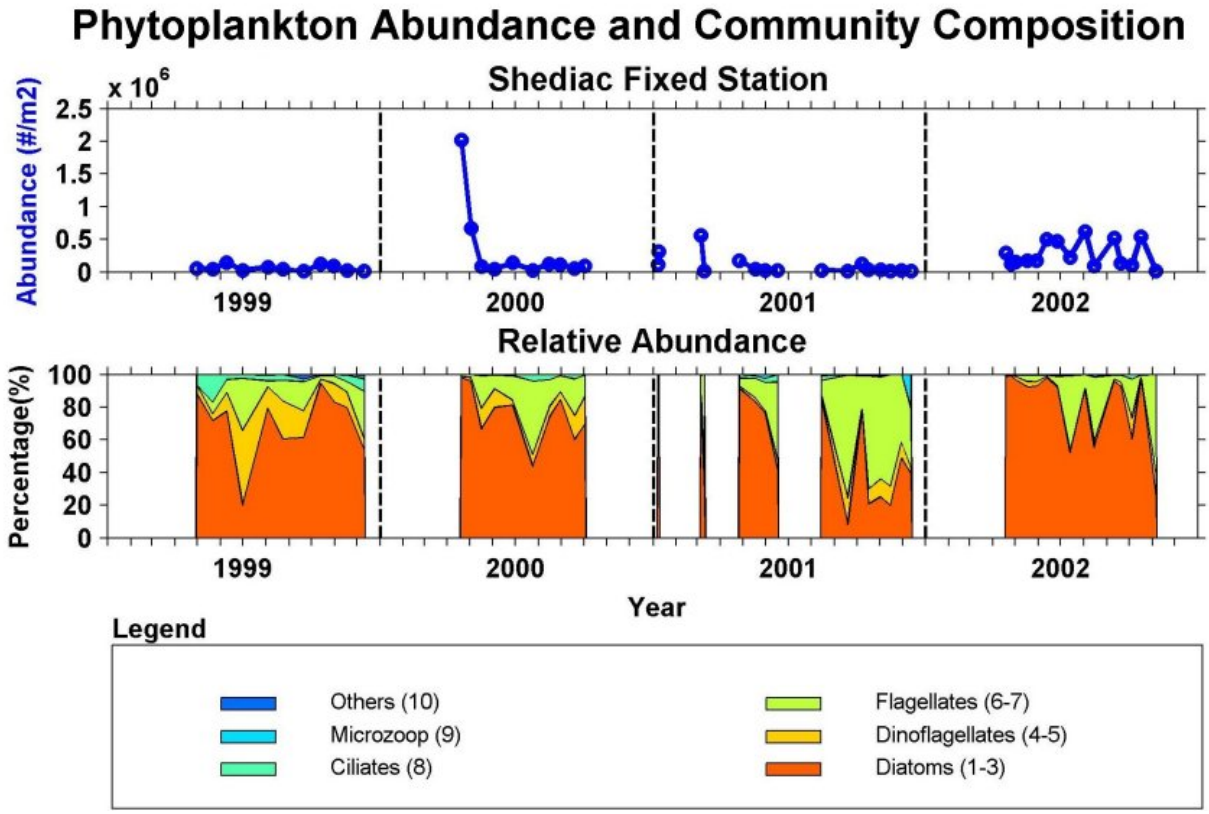


Annual chlorophyll concentrations in 2002 were twice levels in 2001 and 3-fold levels of previous years (1999-2000). Seasonal changes the phytoplankton community composition at Shediac Valley in 2002 also differed from previous years, i.e. diatoms represented a more important fraction of the community in summer/autumn than seen previously. The phytoplankton growth cycle in 2002 at Halifax-2 was similar to that observed in previous years, characterized by a short-lived spring bloom and moderate autumn bloom. In 2002, however, the spring bloom was earlier by 2 weeks than in 2001 and earlier than the long-term average timing of the bloom. Annual chlorophyll levels at Halifax-2 in 2002 were slightly lower than in previous years. The phytoplankton growth cycle at Prince-5, in contrast to that at Shediac Valley and

Halifax-2; is characterized by a single sustained burst of growth beginning in early summer and lasting until autumn. The initiation of phytoplankton growth at Prince-5 in 2002 was later by more than 6 weeks in 2002 compared with 2001. Annual chlorophyll levels at Prince-5 were somewhat higher in 2002 than in 2001.



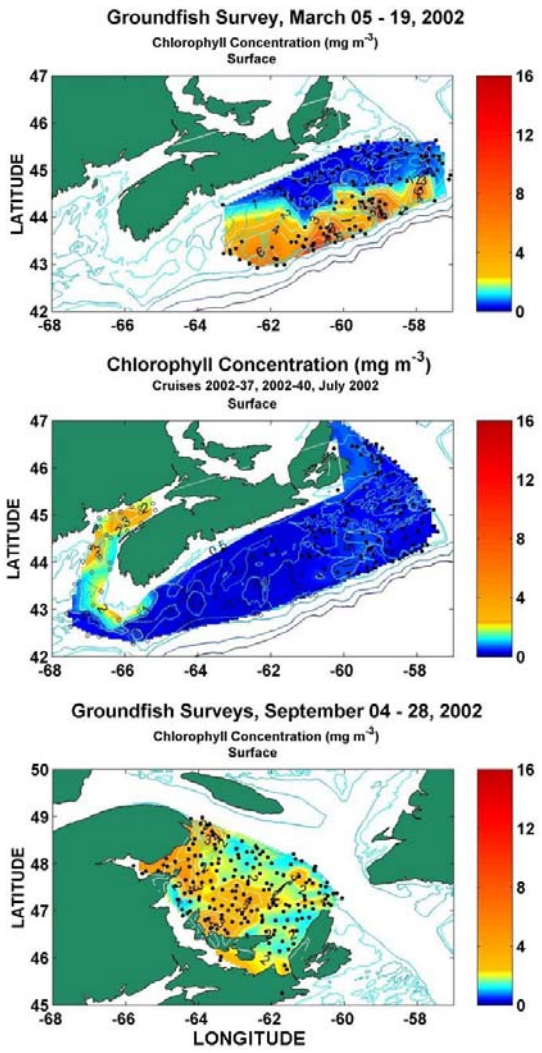
Phytoplankton species counts indicated that total species abundance matched chlorophyll biomass distributions reasonably well at the fixed stations in 2002. Diatoms dominated during blooms at all stations. There was a general trend of decreasing importance of the number of diatoms and increasing importance of flagellates from spring to late autumn at Shediac Valley and Halifax-2; in late summer and autumn, flagellates comprised most of the phytoplankton community. In 2002, dinoflagellates contributed a larger fraction of the flagellate community at Halifax-2 in summer/autumn than seen in previous years. In contrast, diatoms constituted a much larger fraction of the summer/autumn phytoplankton community at Shediac Valley in 2002 than seen previously. In 2002, diatoms continued to dominate the phytoplankton community year-round at Prince-5.



Seasonal Sections. Chlorophyll concentrations were low in surface waters along the Halifax section during the spring and summer shelf surveys in 2002, indicative of post-bloom conditions even in early May. Peak chlorophyll concentrations were at 25-40 m depth in June. During the autumn (October) survey, concentrations were high at the inner stations of the Cabot Strait section but low along the other Scotian Shelf sections. Similar patterns were observed in 2001.

Groundfish Surveys. Near-surface chlorophyll levels on the Eastern Scotian Shelf during the March, 2002 groundfish survey were high, particularly on the outer shelf; a similar distribution pattern was seen in previous years. During the 2002 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 2002 were comparable to concentrations observed in previous years and comparable to the long-term average.

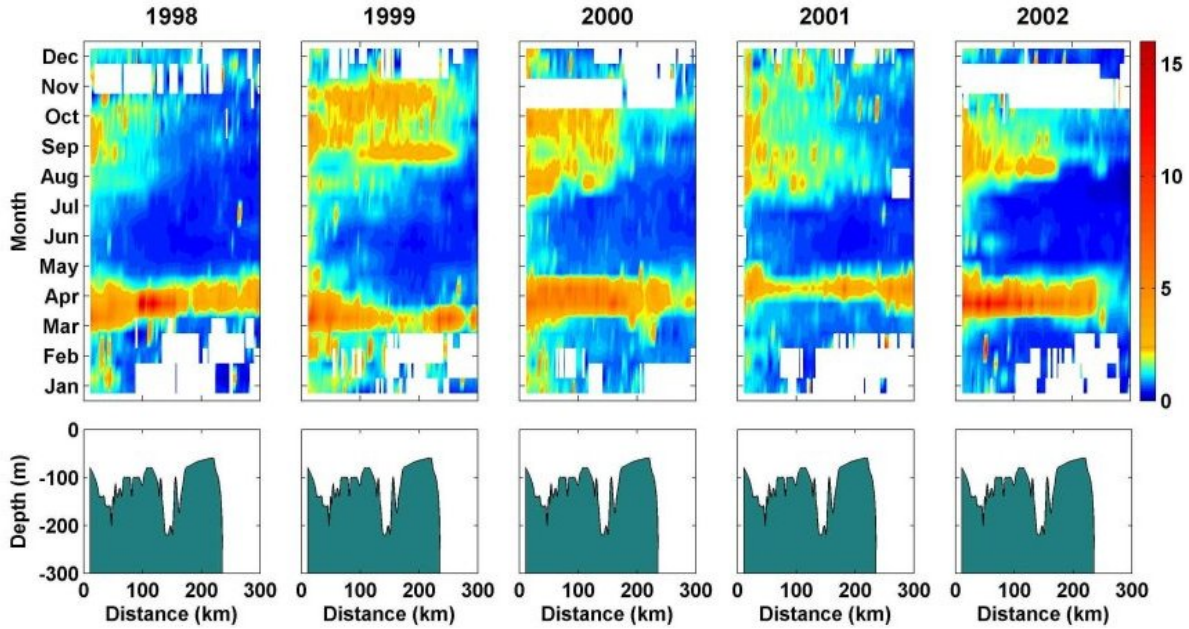
High near-surface chlorophyll concentrations were widespread during the September 2002 groundfish survey in the Southern Gulf and considerably higher than seen in previous years. Concentrations were highest in the central and western sectors.



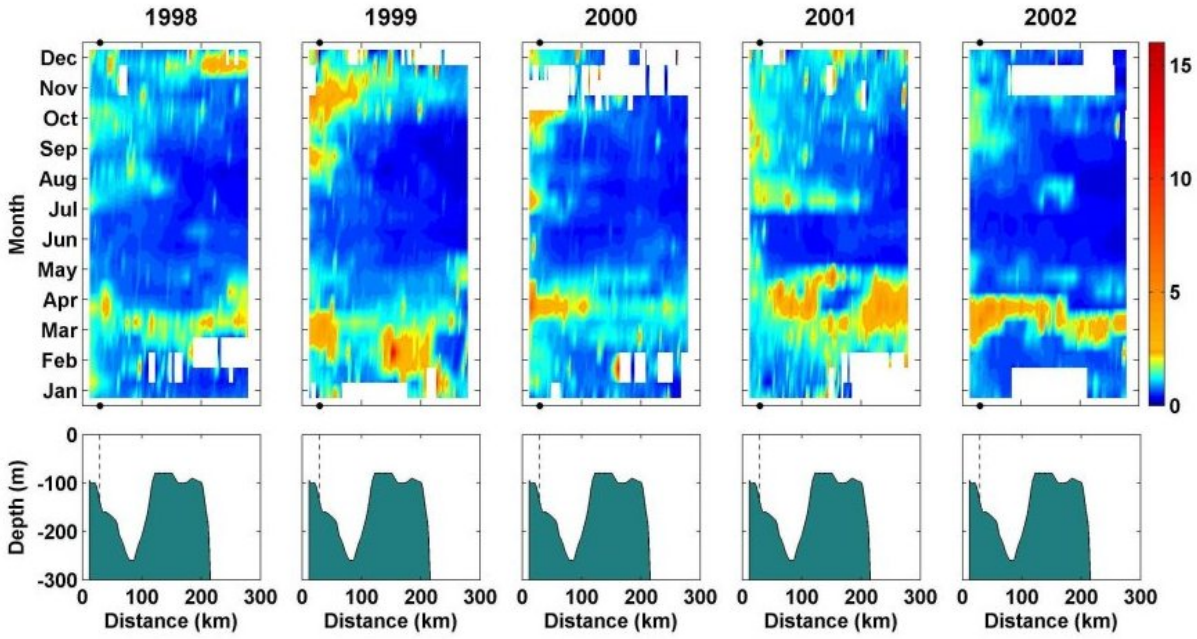
Satellite Remote-Sensing. Satellite ocean colour data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) provide an alternative means of assessing phytoplankton biomass (chlorophyll) at the AZMP fixed stations, along the seasonal sections, and at larger scales (Northwest Atlantic). Satellite data for 2002 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 2002 groundfish survey and the exceptionally high surface chlorophyll levels observed during the September survey in the Southern Gulf in 2002. The satellite-derived chlorophyll data can also be used to generate graphical

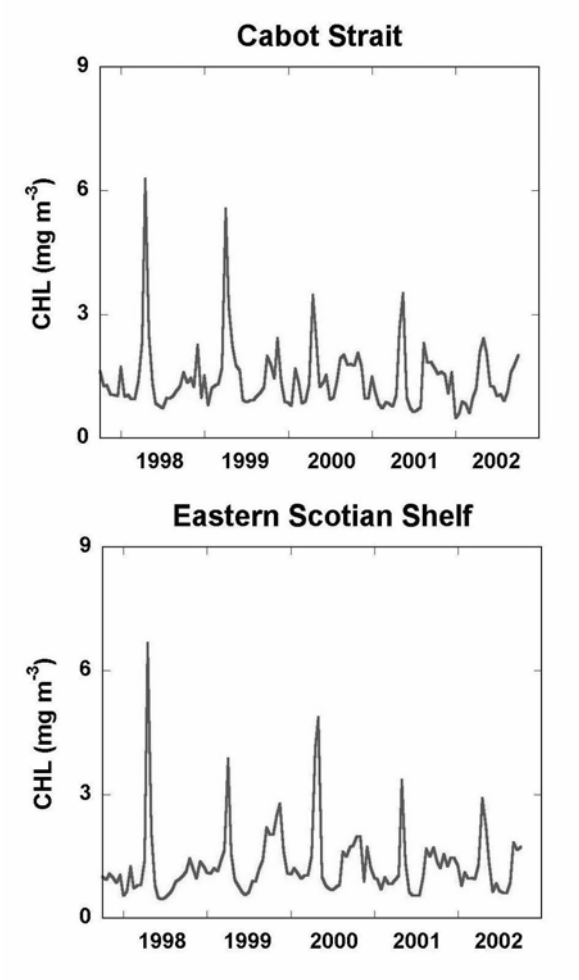
representations of the seasonal chlorophyll changes along the cross-shelf sections. It is evident from the satellite-data, for example, that surface chlorophyll concentrations are generally higher on the eastern Scotian Shelf (Louisbourg section) than on the central and western shelf (Halifax Section). 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. Springs 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 onset of the spring bloom along all the Scotian Shelf sections in 2002 appeared similar to the onset in 2001, but the duration appeared longer on the eastern shelf and shorter on the central shelf in 2002. At the larger scale, it is apparent, for example, that the magnitude of the spring bloom on the Eastern Shelf (Cabot Strait and Eastern Scotian Shelf) has steadily decreased since 1998 with the lowest values on record in 2002.

Louisbourg Section : SeaWiFs Surface Chlorophyll Concentration (mg/m^3)

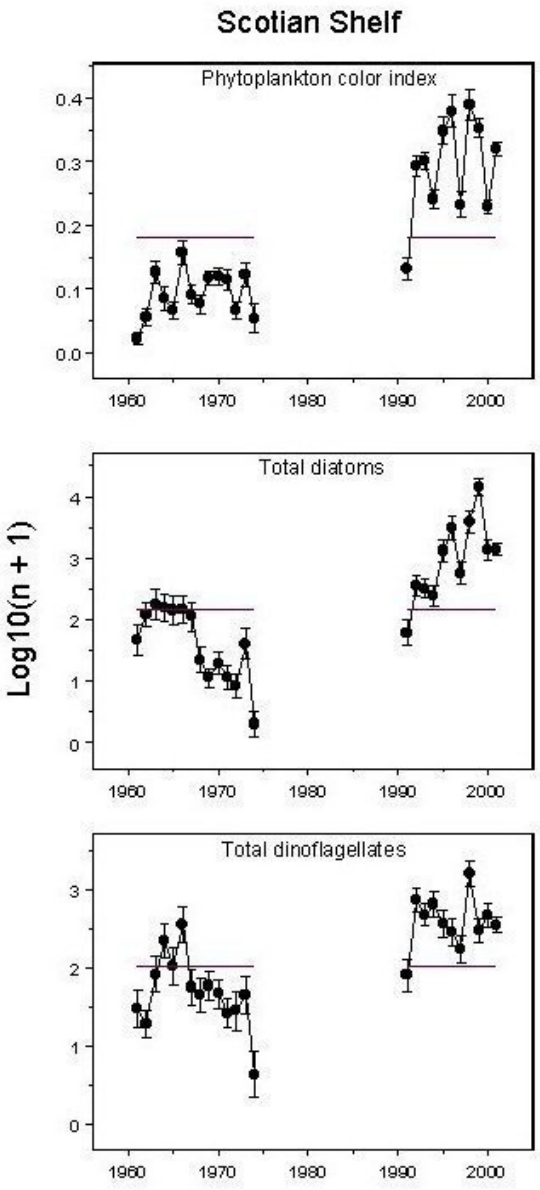


Halifax Section : SeaWiFs Surface Chlorophyll Concentration (mg/m^3)

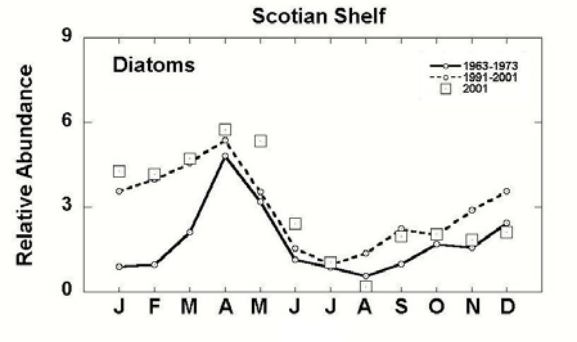




Continuous Plankton Recorder. The CPR is the longest data record available on plankton in the Northwest Atlantic. CPR data analysis lags AZMP reporting by one year; thus, only data up to 2001 are currently available. Nonetheless, the phytoplankton color index and abundance of large diatoms and dinoflagellates 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, phytoplankton color on the Scotian Shelf increased slightly in 2001 relative to 2000 (diatoms and dinoflagellates remained about the same).

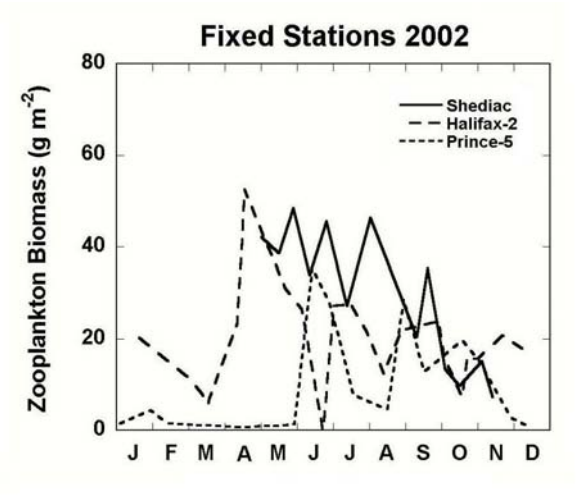


In 2001, and the 1990s in general, there also appeared to be a shift toward an earlier seasonal peak in abundance compared to the 1960s and 1970s.

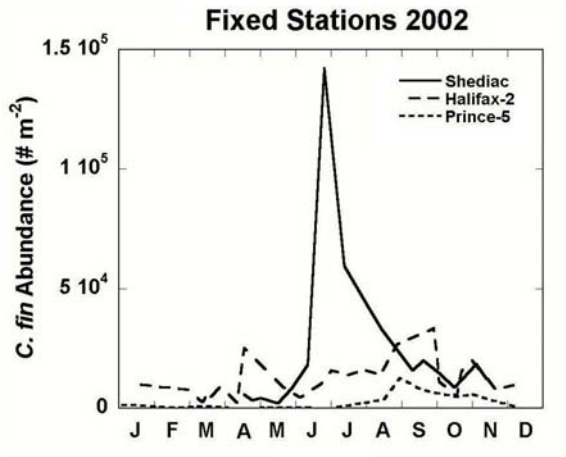


Zooplankton

Fixed Stations. Zooplankton biomass at all of the Maritimes/Gulf fixed stations was generally lower in 2002 than in 2001. Biomass was the highest on record in 2001 and levels in 2002 appear to have reverted back to levels seen in earlier years. At Shediac Valley, the spring biomass peak seen in previous years was absent in 2002.

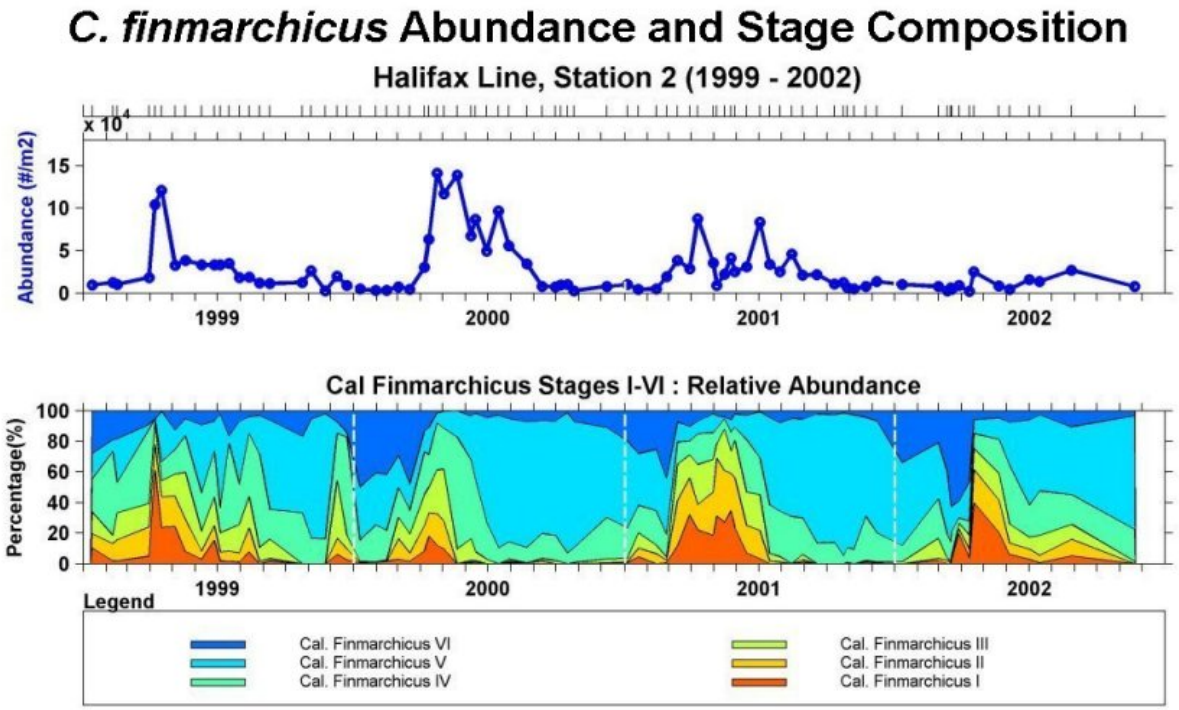


In contrast to zooplankton biomass, *Calanus finmarchicus* abundance at Shediac Valley has increased over the 4-year observation period while at Halifax-2, it progressively decreased over the same period. *C. finmarchicus* abundance at Prince-5 was also lower in 2002 than in 2001 but levels at this station were highest on record in 2001; 2002 levels appeared to revert to levels seen in earlier years.



Copepods continued to dominate the zooplankton year-round at all of the Maritimes/Gulf fixed stations in 2002. Significant numbers of jellies and related plankton were seen at Shediac Valley and Halifax-2 in early summer for the first time and a recurring pulse of echinoderm and barnacle larvae was observed again in 2002 at Prince-5 in spring. Total zooplankton abundance has progressively decreased at Halifax-2 over the 4-year observation period; trends at the other two stations are not as apparent, although zooplankton abundance at Prince-5 decreased from a record high in 2000. The copepods were dominated at all the fixed stations by small species in 2002. The relative importance of the larger *Calanus sp.* was greatest in the Southern Gulf and least important in the Bay of Fundy. Total copepod abundance progressively decreased at Halifax-2 over the 4-year observation period; trends at the other two stations are not as apparent although copepod abundance at Prince-5 has decreased from the record high in 2001. Stage distribution of *C. finmarchicus* in 2002 revealed that reproduction (indicated by presence of early developmental stages, I-III) was generally confined to the spring/early summer period at Halifax-2 but was spread more broadly over the year at Shediac Valley and Prince-5. However, the major reproductive activity appeared to occur in spring at all stations. Total *C.*

finmarchicus abundance dramatically decreased at Halifax-2 over the 4-year observation period; trends at the other two stations are not as apparent although *C. finmarchicus* abundance at Prince-5 has decreased from the record high in 2001.

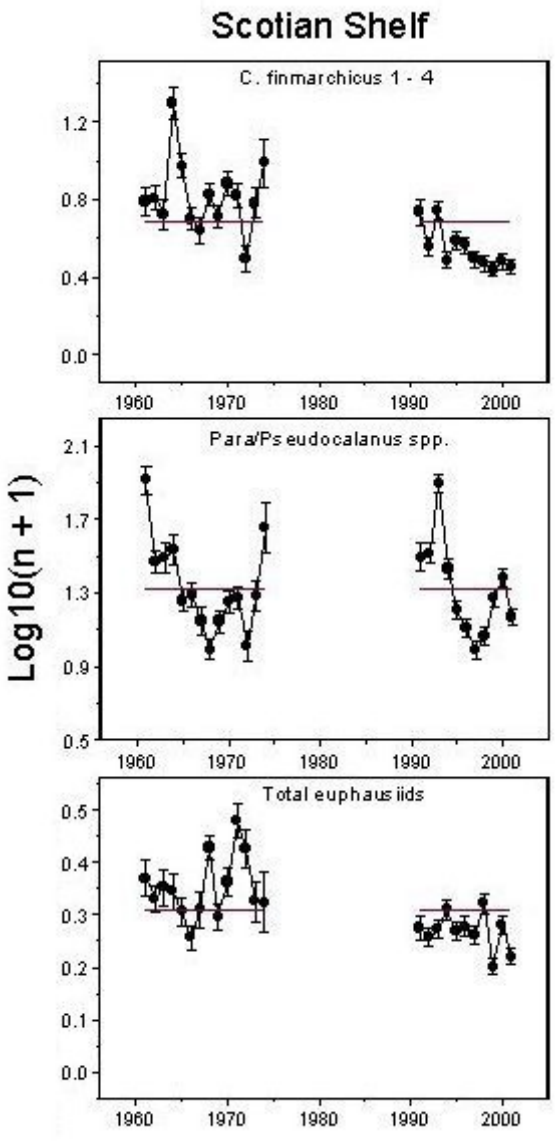


Seasonal Sections. Zooplankton biomass along the seasonal sections was not available in spring 2002, as in previous years. Autumn biomass levels were slightly higher in 2002 than 2001 on the Louisbourg and Browns Bank sections but lower on the Halifax section.

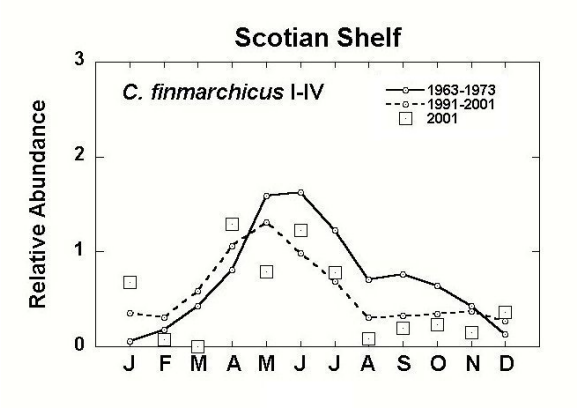
C. finmarchicus abundance was higher along the Louisbourg section in autumn, 2002 than in 2001; 2002 levels were similar to 2001 levels along the Halifax and Browns Bank sections.

Groundfish Surveys. Zooplankton biomass distribution observed during the major winter/spring and summer/autumn groundfish surveys can be characterized as highly variable in space and time. During the spring Eastern Scotian Shelf survey, biomass was highest in deep waters off the shelf, similar to chlorophyll distribution. During the summer/autumn surveys, the highest biomass was observed on the western Scotian Shelf/eastern Gulf of Maine and deep waters of the Southern Gulf. Overall, zooplankton biomass on the Scotian Shelf in summer 2002 was similar to levels observed in 2001.

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 down again in 2001. Most noteworthy were significant drops in *Paracalanus/ Pseudocalanus sp.* and euphausiid numbers.



Peak abundance of *C. finmarchicus* and *Paracalanus/ Pseudocalanus sp.* occurred earlier in the season in 2001 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 seen also in phytoplankton abundance in recent years.



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