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Optical chemical and biological oceanographic conditions in the Maritimes/Gulf Regions in 2002.

Condition océanographiques optiques, chimiques et biologiques dans les régions du Golfe et des Maritimes en 2002.

G. Harrison[1], D. Sameoto[1], J. Spry[1], K. Pauley[1], H. Maass[1] and V. Soukhovtsev[2]

[1]Biological Oceanography Section and [2]Coastal Oceanography Section
Ocean Sciences Division
Bedford Institute of Oceanography
Box 1006
Dartmouth, NS
B2Y 4A2

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ABSTRACT

Optical, chemical, and biological oceanographic conditions in the Maritimes/Gulf Regions (Georges Bank, eastern Gulf of Maine, Bay of Fundy, Scotian Shelf and Southern Gulf of St. Lawrence) during 2002 are reviewed and related to conditions during the preceding year and over the longer-term where applicable. In addition to descriptions of AZMP core data collections (fixed stations, seasonal sections, groundfish surveys, CPR, remote-sensing), some data from outside the Maritimes/Gulf Regions are discussed also to provide the larger, zonal perspective.

Optical properties at the Maritimes/Gulf fixed stations in 2002 were, for the most part, comparable to conditions observed in previous years. Light attenuance, however, was higher (and euphotic depths shallower) at Shediac Valley, due in large measure to the higher than normal chlorophyll levels observed there throughout the year. Indices of stratification at the fixed stations followed patterns seen previously, however summer-time mixed-layer depths were shallower at Shediac Valley and deeper at Prince-5 in 2002 than in 2001. Winter-time mixed-layer depths in 2002 were also shallower at Halifax-2 than seen previously.

Surface nitrate levels at the Halifax-2 and Prince-5 fixed stations, along the seasonal sections and during groundfish surveys were generally comparable in 2002 to levels seen in 2001; levels were moderately elevated at the Shediac Valley station. Summer-time minimum nitrate levels at Prince-5 were elevated and winter-time maximum levels at Halifax-2 were low in 2002 compared with the previous year; nitrate levels at Halifax-2 overall were lower than the climatological mean. Deep-water (>50 m) nitrate levels at the fixed stations were higher in 2002 than in 2001 but below the climatological mean. A similar pattern was seen in the nitrate levels of the deep central basins of the Scotian Shelf. Oxygen levels (% saturation) in bottom waters were lower in 2002 than in 2001.

A prominent feature of the phytoplankton in the Maritimes/Gulf Regions in 2002 was the persistent and widespread high concentrations of chlorophyll in the Southern Gulf of St. Lawrence, particularly evident in the September groundfish survey data. A greater proportion of the phytoplankton community was represented by diatoms at Shediac Valley in 2002 than in previous years. Notable also were the early onset of the spring bloom at Halifax-2 and delayed start at Prince-5 in 2002 compared with the previous year. Satellite-based chlorophyll data suggest also that the magnitude of the spring boom has progressively decreased on the eastern Scotian Shelf over the past 5 years. CPR data continue to show that contemporary phytoplankton levels are well above the long-term mean and that the timing of the spring bloom is earlier than observed in the 30-40 years ago.

Zooplankton levels, in general, declined at the Maritimes/Gulf fixed stations in 2002. This was most evident at Halifax-2 where abundance of total zooplankton, total copepods and the dominant copepod species, *C. finmarchicus*, have shown a continuous decline since AZMP observations began in 1999. Zooplankton biomass observed during the groundfish surveys, however, indicated levels were about the same in 2002 as in 2001. CPR data continue to show that contemporary zooplankton levels are well below the long-term mean and that the peak seasonal abundance of important species such as *C. finmarchicus* is occurring earlier in the year than 30-40 years ago, similar to the seasonal shift observed in phytoplankton abundance.

RÉSUMÉ

Les propriétés optiques, chimiques et biologiques de l'océan dans les Régions des Maritimes et du Golfe (banc Georges, est du golfe du Maine, baie de Fundy, plateau néo-écossais et sud du golfe du Saint-Laurent) en 2002 sont passées en revue et comparées aux conditions durant l'année précédente et à long terme s'il y a lieu. En plus de descriptions des séries de données de base du PMZA (stations fixes, transects saisonniers, relevés du poisson de fond, enregistreurs de plancton en continu, télédétection), un certain nombre de données provenant de l'extérieur de ces régions sont examinées afin de donner une vue d'ensemble de la zone.

En général, les propriétés optiques aux stations fixes des Régions des Maritimes et du Golfe en 2002 étaient comparables aux conditions observées les années précédentes. L'atténuation de la lumière, toutefois, était plus marquée (et la couche euphotique moins profonde) dans la vallée de Shédiac, en grande mesure à cause des teneurs en chlorophylle plus élevées que la normale observées à cet endroit tout au long de l'année. Les indices de stratification aux stations fixes suivaient les tendances observées par le passé, toutefois la couche de mélange en été était moins profonde dans la vallée de Shédiac et plus profonde à Prince-5 en 2002 qu'en 2001. La couche de mélange en hiver en 2002 était aussi moins profonde à Halifax-2 que par le passé.

Les teneurs en nitrate en surface aux stations Halifax-2 et Prince-5, le long des transects saisonniers et durant les relevés du poisson de fond étaient généralement comparables en 2002 aux teneurs observées en 2001, alors qu'elles étaient modérément élevées à la station de la vallée de Shédiac. Les teneurs minimales en été à Prince-5 étaient élevées et les teneurs maximales en hiver à Halifax-2 étaient faibles en 2002 en comparaison de l'année précédente; les teneurs à Halifax-2 étaient en général plus faibles que la moyenne climatologique. Les teneurs en eau profonde (> 50 m) aux stations fixes étaient plus élevées en 2002 qu'en 2001, mais elles étaient inférieures à la moyenne climatologique. Une tendance semblable a été observée dans les teneurs en nitrate dans les bassins profonds du centre du plateau néo-écossais. Les teneurs en oxygène (pourcentage de saturation) dans les eaux de fond étaient moins élevées en 2002 qu'en 2001.

Les teneurs en chlorophylle continuellement élevées et largement répandues dans le sud du golfe du Saint-Laurent en 2002 caractérisaient le phytoplancton dans les Régions des Maritimes et du Golfe, ce qui était particulièrement évident dans les données du relevé du poisson de fond de septembre. Les diatomées constituaient une plus grande proportion de la communauté phytoplanctonique dans la vallée de Shédiac cette année-là que les années précédentes. La précocité de l'efflorescence printanière à Halifax-2 et le retard qu'elle a accusé à Prince-5 en 2002 en comparaison de l'année précédente était un autre fait particulier. Les données satellitaires sur le chlorophylle donnent également à penser que l'ampleur de l'efflorescence printanière a progressivement diminué dans le secteur est du plateau néo-écossais au cours des cinq dernières années. Les données CPR continuent à indiquer que les niveaux d'abondance récents du phytoplancton se situent bien au-dessus de la moyenne à long terme et que l'efflorescence printanière commence plus tôt que cela n'était le cas il y a de cela 30 à 40 ans.

En général, les niveaux d'abondance du zooplancton ont diminué aux stations fixes des Régions des Maritimes et du Golfe en 2002. Cela était davantage évident à Halifax-2, où le niveau d'abondance total du zooplancton et de copépodes, ainsi que le niveau d'abondance du copépode dominant, *C. finmarchicus*, ont diminué sans interruption depuis le début du PMZA en 1999. Toutefois, la biomasse zooplanctonique observée durant les relevés du poisson de fond indique que les niveaux d'abondance en 2002 se rapprochaient de ceux de 2001. Les données CPR continuent à indiquer que les niveaux d'abondance récents du zooplancton se situent bien au-dessous de la moyenne à long terme et que le pic de l'abondance saisonnière d'espèces importantes, comme *C. finmarchicus*, se manifeste plus tôt dans l'année que cela n'était le cas il y a de cela 30 à 40 ans, ce qui correspond au décalage saisonnier observé dans l'abondance du phytoplancton.

INTRODUCTION

The Atlantic Zonal Monitoring Program (AZMP) was implemented in 1998 (Therriault et al. 1998) with the aim of: (1) increasing DFO's capacity to understand, describe, and forecast the state of the marine ecosystem and (2) quantifying the changes in ocean physical, chemical and biological properties and the predator-prey relationships of marine resources. A critical element in the observational program of AZMP is an annual assessment of the distribution and variability of nutrients and the plankton they support.

A description of the distribution in time and space of nutrients dissolved in seawater (nitrate, silicate, phosphate, oxygen) provides important information on the water-mass 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 foodweb. An understanding of the production cycles of plankton is an essential part of an ecosystem approach to fisheries management.

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, groundfish surveys) in each region (Quebec, Maritimes/Gulf, Newfoundland) sampled at a frequency of bi-weekly to once annually. The sampling design provides for basic information on the natural variability in physical, chemical and biological properties of the Northwest Atlantic continental shelf. Groundfish surveys and cross-shelf sections provide detailed geographic information but are limited in their seasonal coverage. Critically placed fixed stations complement the geography-based sampling by providing more detailed information on temporal (seasonal) changes in ecosystem properties.

We review here the optical, chemical, and biological oceanographic conditions in the Maritimes/Gulf Regions, including the Georges Bank/Gulf of Maine/Bay of Fundy system, the Scotian Shelf and the Southern Gulf of St. Lawrence, during 2002. For some data (CPR, SeaWiFS ocean colour), descriptions will include observations outside the Maritimes/Gulf, i.e. the central and western North Atlantic. Conditions in 2002 will be compared with those observed during recent years and over the longer-term where historical information is available.

METHODS

To the extent possible, sample collection and processing conforms to established standard protocols (Mitchell, 2002). Non-standard measurements or derived variables are described.

Sample Collection

Maritimes/Gulf AZMP sea-going staff participated in 9 missions (seasonal section cruises and groundfish surveys) during the 2002 calendar year in addition to repeat trips to the 3 fixed stations; 744 sites were samples all together (Table 1).

Fixed Stations. The Maritimes/Gulf Regions' three fixed stations, Shediac Valley, Halifax-2 and Prince-5 (Fig. 1), are sampled on an approximately semi-monthly basis. Due largely to the availability of resources and difficulties with weather and ice, this sampling frequency is not always achieved. In 2002, Halifax-2 and Prince-5 were sampled on 25 and 20 occasions, respectively. Shediac was sampled only 17 times due to the ice-truncated open water season in that area; but this was still the most samplings made in any one year so far.

The standard sampling suite when occupying the fixed stations consists of:

- CTD (SBE25) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR (photosynthetically active radiation),
- Niskin water bottle samples at standard depths for nutrient, calibration salinity, calibration oxygen, and chlorophyll analyses,
- Niskin water bottle sample for phytoplankton enumeration,

- Vertical ring net tows for zooplankton biomass and enumeration,
- Secchi depth reading.

Seasonal Sections. Four primary transects (Browns Bank Line, Halifax Line, Louisbourg Line, Cabot Strait Line; Fig. 1) and a number of additional lines/stations (Fig. 2) are sampled seasonally in spring (April/May) and fall (October/November). An additional occupation of the Halifax Line is also made in June/July as part of the Labrador Sea program in the Maritimes Region. In 2002, the spring cruise was not possible since a platform was not available until after the spring critical period was over and conflicts with other programs became an issue. However, in view of our spring season problems, a special occupation of the Halifax section only was made in early May (4-5th).

The standard sampling suite when occupying section stations consisted of:
- CTD (SBE911 – Ship's Rosette) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR (photosynthetically active radiation),
- Niskin water bottle samples at standard depths for nutrient, calibration oxygen, and plant pigment analyses (chlorophyll, HPLC, absorbance),
- Niskin water bottle sample for phytoplankton enumeration,
- Vertical ring net tows for zooplankton biomass and enumeration.

Groundfish Surveys. There are four primary groundfish surveys that AZMP-Maritimes/Gulf participates in: the late winter (February) Georges Bank survey, the spring (March) eastern Scotian Shelf Survey, the summer (July) Scotian Shelf/eastern Gulf of Maine survey and the fall (September) Southern Gulf of St. Lawrence Survey (Fig. 3). In addition, a limited number of samples (mostly pigment and CTD's) have been collected from a grid on Western/Sable Banks during the fall (October) benthic habitat survey.

The standard sampling suite when occupying groundfish survey stations consisted of:
- CTD (SBE25) profile including electronic sensing of pressure, temperature, conductivity, dissolved oxygen, fluorescence, and PAR (photosynthetically active radiation),
- Niskin water bottle samples at surface (5 m) and near bottom depths for nutrient, calibration salinity, calibration oxygen, and chlorophyll analyses,
- Niskin water bottle samples for phytoplankton enumeration at fixed station sites,
- Vertical ring net tows for zooplankton biomass and enumeration at a subset of stations (see Fig. 3),
- Sea surface temperature.

Deployment

CTD. The CTD is attached to the end of a hydrographic wire and lowered at ~0.35 m/sec for the portable SBE25 (~0.83 m/sec for the higher resolution SBE911 ship's rosette) to within 2m of the bottom when possible.

Standard depths for water samples:
- Fixed-stations
  1. Halifax-2: 1, 5, 10, 20, 30, 40, 50, 75, 100, 140 m
  2. Shediac: 1, 5, 10, 20, 30, 40, 50, 60, 70, 80 m
  3. Prince-5: 1, 10, 25, 50, 95 m
- Seasonal sections - surface, 10, 20, 30, 40, 50, 60, 70, 80, 100, 250, 500, 1000, 1500, 2000 m (depth dependent)
- Groundfish surveys - 5m, near bottom

Net tows. Ring nets are towed vertically from near bottom to surface at ~1m/sec. In deep offshore waters, maximum tow depth is 1000 m. The net is hosed carefully and sample collected from the cod-end, then preserved in buffered formalin.

Secchi depth. The Secchi disc is lowered and the depth where it can no longer be visually detected is recorded.

Optical properties

Optical properties of the seawater (attenuation coefficient, photic depth) were derived from one or more of, (a) in-water light extinction measurements using a CTD-rosette mounted PAR (photosynthetically active radiation) meter, (b) Secchi depth and (c) chlorophyll biomass profile, according to the following procedures:

1. The downward vertical attenuation coefficient for PAR ($K_{d\text{-}PAR}$) was estimated from the linear regression of $\ln(E_d(z))$ versus depth z (where $E_d(z)$ is the value of downward irradiance at z m) in the depth interval from minimum depth to 50 m (minimum depth is usually around 2 m and is always less than 6 m).

2. The value of K_d from Secchi disc observations was found using:

$$K_{d\_secchi} = 1.44/Z_{sd}\ (m^{-1})$$

where Z_{sd} = depth in m at which the Secchi disc disappears from view. The estimate of euphotic depth was made using the following expression:

$$Z_{eu}\ (m) = 4.6 / K_d$$

Reference values were calculated from all estimates of $K_{d\text{-}PAR}$ and K_{d_secchi}.

3. The value of K_d from chlorophyll biomass profile observations was calculated as:

$$K_{d\_chla} = 0.027 + 0.015 + 0.04 {*} B_{exp}\ (m^{-1})$$ (Platt et al. 1988)

where B_{exp} is the observed values of chlorophyll a concentration B(z) (in mg m^{-3}) for depth interval from zero to z_e, the depth where the downwelling irradiance is 36.79% (e^{-1}) of the surface value. Chlorophyll observations were linearly interpolated each 0.25 m to calculate B_{exp}; K_{d_chla} was calculated over the interval 0 to z_e from:

$$E_d(0){*}\exp(-K_{d\_chla}{*}z_e) = (1/e){*}\ E_d(0), \text{ i.e.,}$$

$$K_{d\_chla}{*}z_e = \Sigma\ (0.027 + 0.015 + 0.04 {*} B(z_i)){*}dz_i = 1$$

Integrated chlorophyll for the depth intervals 0–50 m and 0–100 m (0–80 m for the Shediac fixed station) were calculated as the sum of products $Chl_i * dd_i$, where Chl_i is chlorophyll concentration measured for the depth z_i and dd_I is the depth interval around z_i: $dd_i = 0.5{*}(z_{i+1} - z_{i-1})$.

Mixed-layer and stratification Index

Two simple indices of the physical structure (vertical) of the water-column were computed for comparison with optical properties; mixed-layer and stratification.

1. The mixed layer depth was determined from the observations of the minimum depth where the density gradient (gradient_z(sigma-t)) was equal to or exceeded 0.01 (kg m^{-4}).

2. The stratification index ($Strat_{Ind}$) was calculated as:

$$Strat_{Ind} = (\text{sig-t}_{50} - \text{sig-t}_{zmin})/(50 - z_{min})$$

where sig-t_{50} and sig-t_{zmin} are interpolated values of sigma-t for the depths of 50 m and z_{min} (the minimum depth of reliable CTD data); usually z_{min} is around 5m and always less then 9 m.

Continuous Plankton Recorder (CPR)

The Continuous Plankton Recorder (CPR) is an instrument that collects phytoplankton and zooplankton at a depth of ~7 m on a long continuous ribbon of silk (~260 μm mesh) while towed from commercial ships (Fig. 4). The position on the silk corresponds to location of the different sampling stations. Historical CPR data are analysed to detect differences in the indices of phytoplankton (colour and relative numerical abundance) and zooplankton relative abundance for different years on in the northwest Atlantic. The indices are measures of biomass or numbers of plankton collected in CPR samples and represent relative changes in concentrations from year to year. The sampling methods from the first surveys in the northwest Atlantic (1961) to the present are exactly the same so that valid comparisons can be made between years. Data are available approximately one year after collection, i.e. 2001 data will be reported here.

Satellite remote-sensing of ocean colour

Phytoplankton biomass was also estimated from ocean colour data collected by the Sea-viewing Wide Field-of-view (SeaWiFS) satellite sensor launched by NASA in late summer 1997 (http://seawifs.gsfc.nasa.gov/SEAWIFS.html). Satellite data do not provide information on the vertical structure of phytoplankton in the water column but do provide highly resolved (~1.5 km) data on their geographical distribution in surface waters at the large scale. Bi-weekly composite images of surface chlorophyll for the entire NW Atlantic (39-62.5 N Lat., 42-71 W Lon.) are routinely produced from SeaWiFS data (http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/seawifs/seawifs_1.html). Basic statistics (mean, range, standard deviation, etc.) are extracted from the composites for selected sub-regions (Fig. 5), for the fixed stations (defined as a ~5x5 km box centered on the station location) and for the seasonal sections (defined by the inner and outer-most stations and ~5 km in width).

RESULTS

Fixed Stations

Optics and Mixing. Optical properties and mixing of the upper water column varied by season and location at the Maritimes/Gulf fixed stations (Figs. 6-8). Maximum vertical light attenuation at all stations coincided with the maximum in integrated chlorophyll in late spring and was minimum following the decline of the seasonal bloom. Generally, attenuance estimates derived from Secchi disc readings and direct downwelling irradiance (PAR) measurements were comparable and exceeded those derived empirically from chlorophyll concentrations (except during peak bloom conditions). The discrepancy was most notable at Prince-5 where water properties (dissolved and particulate substances) other than phytoplankton contributed significantly to the attenuation of light (Fig. 8). Depth of the euphotic zone in 2002, averaged over the year, ranged from 48 m at Halifax-2 to 20 m at Prince-5; Shediac Valley was intermediate at 35 m. In general, seasonal patterns and magnitudes of optical properties in 2002 at Halifax-2 and Prince-5 were similar to those observed in previous years. At the Shediac Valley station, however, light attenuance was higher and euphotic depths shallower in 2002 than in previous years, corresponding to the higher chlorophyll levels observed there in 2002.

Seasonal development of the mixed-layer and upper water-column stratification was most evident at the Shediac Valley station (Fig. 6); shallow mixed layers (<20 m) and maximum stratification (>0.1 kg m^{-4}) were evident throughout the summer and early fall months. Mixed-layer depths were slightly shallower in summer 2002 at this station compared with previous years. Stratification development at Halifax-2 also peaked in summer but was less intense (<0.1 kg m^{-4}) and summer mixed layers were somewhat deeper (>20 m) and more variable (Fig. 7). Maximum winter-time (2001/2002) mixed-layers were only ~ 60m at Halifax-2 compared with mixed-layer depths >100 m in during the previous winter. In marked contrast to the other fixed stations, stratification was extremely low (<0.01 kg m^{-4}) and mixed layers significantly deeper (>50 m) throughout the year at Prince-5 (Fig. 8). Mixed-layer depths at this station appear to have been increasing over the past few years, i.e. the shallowest mixed-layers seen in 2000 were <20 m whereas the shallowest seen in 2002 were ~40 m.

Nutrients. Distributions of the primary dissolved inorganic nutrients (nitrate, silicate, phosphate) included in the observational program of AZMP strongly co-vary in space and time (Petrie et al. 1999). For that reason and because the availability of nitrogen is most likely to limit phytoplankton growth in our coastal waters (DFO, 2000), emphasis in this report will be placed on variability in nitrate concentrations.

Rapid spring-time reduction in near surface nitrate concentrations was seen at all Maritimes/Gulf fixed stations in 2002 (Fig. 9). Low surface values persisted throughout the summer at Shediac Valley and Halifax-2; concentrations did not increase at the surface again until late fall. The zone of nitrate depletion (i.e. defined as depths where concentrations were $\leq$1 μM) in summer was greater at Halifax-2 (34 m) than at Shediac Valley (21 m). Nitrate depletion depths in 2002 at both stations were similar to depths seen in 2001. Nitrate concentrations at Prince-5 were never reduced to the 1 μM level. The seasonal evolution of the vertical nitrate structure 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. This is particularly evident in the nitrate anomaly plots for Halifax-2 (Fig. 9), showing a much lower negative anomaly (-2 to -4 μM) in the deeper waters in 2002 than in the previous three years (-8 to -10 μM).

Seasonal variability in nitrate in the upper 50 m (depth zone over which nutrient dynamics are strongly influenced by biological processes) indicated that annual inventories were higher in surface waters at Shediac Valley but lower at Halifax in 2002 than in 2001 (Fig. 10); ; nitrate levels at Halifax-2 were also significantly lower than the climatological mean. Annual levels at Prince-5 were similar in 2002 to 2001, however, summer-time minimum values were higher than in previous years. The 4-year record, in fact, shows a trend of increasing minimum summer-time nitrate concentrations at this station, ranging from a minimum of 77 mmol m^{-2} in 1999 to 201 mmol m^{-2} in 2002 (see also Fig. 9). Maximum winter-time nitrate concentrations were highest at Prince-5 (514 mmol m^{-2}) and lowest at Halifax-2 (253 mmol m^{-2}). Maximum winter nitrate concentrations at Halifax-2 in 2002 were slightly lower than in 2001 but substantially lower than the climatological winter mean.

Phytoplankton. Distinctly different seasonal phytoplankton growth cycles are evident at the three Maritimes/Gulf fixed stations (Fig. 11). Because of the presence of ice in the Southern Gulf of St. Lawrence in the spring, only the latter phase of the spring bloom is caught in sampling at the Shediac Valley station. Persistently high chlorophyll levels were seen at Shediac Valley throughout the sampling season. This is in marked contrast to summer/fall chlorophyll levels observed at this station in previous years. Annual chlorophyll inventories in 2002 (3×10^4 mg m^{-2}) were twice levels in 2001 and 3-fold levels of previous years (Fig. 10). Evolution of 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/fall 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 fall bloom. In 2002, however, the spring bloom at Halifax-2 was earlier (peak: 29 March) by a ~2 weeks than in 2001 (peak: 10 April) and earlier than historical timing of the bloom as evidenced from the chlorophyll anomaly plots (Fig. 11); peak chlorophyll concentration during the spring bloom was 393 mg m^{-2}. Annual chlorophyll levels at Halifax-2 in 2002 (1.8×10^4 mg m^{-2}) were slightly lower than in previous years (Fig. 10). 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 fall. The initiation of phytoplankton growth at Prince-5 in 2002 was later by more than more than 6 weeks in 2002 (peak: 14 June) compared with 2001 (peak: 2 May); peak chlorophyll concentration was 312 mg m^{-2}. Annual chlorophyll levels were somewhat higher in 2002 (3.5×10^4 mg m^{-2}) than in 2001 (3×10^4 mg m^{-2}) (Fig. 10).

Phytoplankton species counts indicated that total species abundance matched chlorophyll biomass distributions reasonably well at the fixed stations in 2002 (Fig. 12). Diatoms dominated during blooms at all stations. There was a general trend of decreasing importance of diatoms (numerically) and increasing importance of flagellates from spring to late fall at Shediac Valley and Halifax-2; in late summer and fall, flagellates comprised up to 90% of the phytoplankton community. In 2002, dinoflagellates comprised a larger fraction of the flagellate community at Halifax-2 in summer/fall than seen in previous years. In contrast, diatoms constituted a much larger fraction of the summer/fall phytoplankton community (60-

80%) at Shediac Valley in 2002 than seen in previous years (20-40%). Diatoms totally dominated (>90%) year-round at Prince-5. The patterns of seasonal evolution of phytoplankton community structure at all of the fixed stations were similar to the patterns observed for the previous three years.

Zooplankton. Zooplankton biomass (annual inventories) at all of the Maritimes/Gulf fixed stations was generally lower in 2002 ($6x10^3$ g m^{-2}) than in 2001 ($8x10^3$ g m^{-2}) (Fig. 13). Biomass at all of the fixed stations 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, due possibly to the timing of first sampling.

In contrast to zooplankton biomass, *Calanus finmarchicus* abundance (annual inventories) at Shediac Valley has increased over the 4-year observation period (from $3.4x10^6$ in 1999 to $6.3x10^6$ ind. m^{-2} in 2002) (Fig. 13). *C. finmarchicus* abundance at Halifax-2, on the other hand, progressively decreased over the same period (from $12.4x10^6$ in 1999 to $4.4x10^6$ ind. m^{-2} in 2002). *C. finmarchicus* abundance at Prince-5 was also lower in 2002 ($0.8x10^6$ ind. m^{-2}) than in 2001 ($4.9x10^6$ ind. m^{-2}) but levels at this station were highest on record in 2001 ($4.9x10^6$ ind. m^{-2}) and 2002 levels appeared to revert to levels seen in earlier years.

Hierarchical community analysis revealed that copepods continued to numerically dominated the zooplankton year-round at all of the Maritimes/Gulf fixed stations in 2002 (Fig. 14). Significant numbers of jellies and appendicularians (up to 40% of total count) were seen at Shediac Valley and Halifax-2 in early summer for the first time and a recurring pulse of echinoderm and barnacle larvae were observed again in 2002 at Prince-5 in spring. Total zooplankton abundance has progressively decreased at Halifax-2 over the 4-year observation period (from peak levels of ~$10x10^5$ in 1999 to <$2x10^5$ ind. m^{-2} in 2002); trends at the other two stations are not as apparent although zooplankton abundance at Prince-5 decreased from a record high in 2000 of almost $10x10^5$ ind. m^{-2}. The copepods were dominated (>50% much of the year) at all the fixed stations by small species (*Oithona*, *Pseudocalanus*, Paracalanus, *Clausocalanus*, *Centropoges* and *Temora* sp.) in 2002 (Fig. 15). The relative importance of the larger *Calanus sp.* decreased from Shediac Valley (~20%) to Halifax-2 (~15%) to Prince-5 (<10%). Total copepod abundance progressively decreased at Halifax-2 over the 4-year observation period (from peak levels of ~$5x10^5$ ind. m^{-2} in 1999 to ~$2x10^5$ ind. m^{-2} in 2002); 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 (Fig. 16). 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 (from peak levels of ~$12x10^4$ ind. m^{-2} in 1999 to ~ $2x10^4$ ind. m^{-2} per annum in 2002); trends at the other two stations are not as apparent although *C. finmarchicus* abundance at Prince-5 has decreased from the record high of ~$6x10^4$ ind. m^{-2} in 2001.

Seasonal Sections

Nutrients. Vertical distributions of nitrate in spring and summer were generally similar along the Halifax line in 2002, i.e. concentrations were low (<1 μM) in near surface waters (<50 m), as a result of phytoplankton consumption, and increased with depth (Fig. 17). As in the previous year (Harrison et al. 2002), nitrate levels in surface waters were already significantly depleted by May. Deep-water concentrations were highest in the Emerald Basin and in slope waters off the edge of the shelf; offshore deep water concentrations increased from May to June, i.e. from 12 μM at 200 m to >20 μM. Nitrate concentrations in May were slightly above the climatological mean (0 to 2 μM) in surface waters but below the mean (-2 to –6 μM) in Emerald Basin and in deep slope waters. In June, nitrate concentrations offshore surface waters were below the climatological mean (0 to –2 μM) and deep waters were above the mean (0-4 μM). Nutrient data for the fall survey are not yet available.

Phytoplankton. Chlorophyll concentrations were low (~1 mg m^{-3}) in surface waters along the Halifax line during the spring and summer surveys in 2002 (Fig. 17). Post (spring) bloom chlorophyll conditions were already apparent in early May; peak chlorophyll concentrations were further reduced in late June and well below the sea surface (25-40 m). During the fall survey, concentrations were high (>2 mg m^{-3}) at the inner stations of the Cabot Strait line but low along the other Scotian Shelf sections (Fig. 18).

Chlorophyll concentrations along the seasonal sections in spring (~50-500 mg m^{-2}) consistently exceed fall levels (~20-100 mg m^{-2}) and are generally higher on the eastern Scotian Shelf (Cabot Strait and Louisbourg lines) than on the western shelf (Fig. 19). In contrast, chlorophyll levels in fall are comparable along all lines. Chlorophyll concentrations in spring 2002 (~30 mg m^{-2}) along the Halifax line were low in comparison to earlier years, largely due to late sampling (i.e. May versus April in earlier years; Harrison et al. 2002). Fall chlorophyll concentrations in 2002 were similar in levels seen in previous years.

Zooplankton. Zooplankton biomass along the seasonal sections is generally highest on the east shelf (particularly the Cabot Strait line) and comparable between spring and fall (with exception of the late spring sampling in 2001 where biomass was significantly higher in spring than in fall) (Fig. 20). Biomass data were not available in spring, 2002. Fall biomass levels were slightly higher in 2002 (30-40 g m^{-2}) than 2001 (20-30 g m^{-2}) on the Louisbourg and Brown's Bank lines but lower on the Halifax line (20 g m^{-2} compared with 25 g m^{-2} in 2001).

Distributional patterns in *C. finmarchicus* abundance along the seasonal sections are in marked contrast to zooplankton biomass (Fig. 21). *C. finmarchicus* are much more abundant in spring (2-7x10^4 ind. m^{-2}) than in fall (<1-3x10^4 ind. m^{-2}) along the Scotian Shelf sections whereas abundance along the Cabot Strait line in fall is higher (3-4x10^4 ind. m^{-2}) than in spring (<1-2x10^4 ind. m^{-2}). *C. finmarchicus* abundance is also generally higher on the central/western Shelf than the eastern shelf in spring but this pattern reverses in fall. *C. finmarchicus* abundance was higher (~3x10^4 ind. m^{-2}) in 2002 along the Louisbourg line than in 2001(~1x10^4 ind. m^{-2}); 2002 levels were similar to 2001 levels along the Halifax and Brown's Bank lines (~0.5-1.5x10^4 ind. m^{-2}).

Groundfish Surveys

Nutrients. Bottom water nitrate concentrations on the Scotian Shelf in the July, 2002 (mean: 11.0 μM) were marginally lower than levels seen in 2001 (mean: 11.8 μM) (Table 2). Concentrations increase with water depth with highest concentrations observed in the deep basins on the shelf (e.g. Emerald Basin) and in slope waters off the shelf edge. Concentrations >15 μM were more widespread in 2002 than in 2001, particularly in the central basins (Fig. 22). Despite this, concentrations in the central basins (and on the eastern shelf) in 2002 were below (-2 to –6 μM) the climatological mean. Bottom water nitrate concentrations in the Southern Gulf of St. Lawrence in September were higher overall in 2002 (mean: 10.91 μM) than in 2001(mean: 8.93 μM); this was most evident in the western basin. Bottom water oxygen saturation on the Scotian Shelf in summer was somewhat lower in 2002 (mean: 73% sat) than in 2001 (mean: 82% sat), particularly on the eastern shelf (Fig. 23, Table 2). Low oxygen levels (<60% sat) in the central basins appeared also to be more widespread in 2002 than in 2001. Similarly, bottom water oxygen saturation in the Southern Gulf was lower in 2002 (mean: 68% sat) than in 2001 (mean: 98% sat) (Table 2); the latter may not be a reliable comparison, however, since very few stations were sampled in 2001 (8 versus 170 in 2002).

Phytoplankton. Near surface chlorophyll levels on the Scotian Shelf during the spring groundfish survey in 2002 were high (>2 mg m^{-3}), particularly on the outer shelf; a similar distribution pattern was seen in previous years (Fig. 24). During the 2002 summer survey, chlorophyll levels were uniformly low (<1 mg m^{-3}) over most of the shelf with elevated concentration (>2 mg m^{-3}) near the coast of central and SW Nova Scotia and approaches to the Bay of Fundy (Fig. 25). These areas are generally characterized by strong vertical mixing. High surface chlorophyll concentrations observed on the central shelf (Western Bank) during the summer survey of 2001 were not seen in 2002. Overall, summer surface chlorophyll concentrations on the Scotian Shelf (mean in 2002: 0.5 mg m^{-3}) were comparable to concentrations observed in previous years (Table 2) and comparable to the long-term mean. High near surface chlorophyll concentrations (>2 mg m^{-3}) were widespread during the fall groundfish survey in the Southern Gulf of St. Lawrence (Fig. 25) and considerably higher than seen in previous years, e.g. mean concentrations in 2002 were 2.4 mg m^{-3} versus 1 mg m^{-3} in 2001 (Table 2). Concentrations tended to be higher at the central and western stations in 2002. The high chlorophyll seen on the Cabot Strait line during the fall section surveys (Fig. 18) likely originated in the Southern Gulf.

Mesozooplankton. Zooplankton biomass distribution observed during the major winter/spring and summer/fall groundfish surveys can be characterized as highly variable in space and time (Fig. 26). During the spring eastern Scotian Shelf survey, biomass was highest on the outer shelf, similar to chlorophyll distribution (see Fig. 24). During the summer/fall surveys, highest biomass was observed on the western Scotian Shelf/eastern Gulf of Maine and deep-water stations of the Southern Gulf. Overall, zooplankton biomass on the Scotian Shelf in summer 2002 (mean: 37.4 g m^{-2}) was similar to levels observed in 2001 (mean: 36.8 g m^{-2}) (Table 2).

Remote-sensing of Ocean Colour

Satellite ocean colour (SeaWiFS) data provide an alternative means of assessing phytoplankton biomass (chlorophyll) at the AZMP fixed stations, along the seasonal sections, and at larger scales (Northwest Atlantic). SeaWiFS data for 2002 clearly show spring and summer surface blooms at the Shediac Valley and Halifax-2 fixed stations and multiple events at Prince-5 (Fig. 27). An inspection of the entire data record (1998-2002) shows no clear trends in inter-annual variability of chlorophyll at any of the AZMP fixed stations. It is noteworthy, however, that chlorophyll concentrations were higher at the Shediac Valley station in 2002 compared with 2001, consistent with the measured chlorophyll data (see Figs. 10, 11 and 25). The satellite data capture the major spring and fall blooms (and additional events) observed in the *in situ* data but tend to underestimate the magnitude of chlorophyll concentrations, the latter decreasing as the spatial scale increases (Fig. 28). Perhaps a more immediately useful application of the satellite-based chlorophyll fields is to characterise the larger spatial-temporal scales of variability in chlorophyll to aid in interpreting the more conventional time-space restricted field-sampling activities of AZMP. For example, spatially-synoptic images of surface chlorophyll give an indication of where the seasonal survey lines lie with respect to the larger scale surface chlorophyll distribution at the time of sampling (Fig. 2). They also provide confirmation of features seen in the other AZMP datasets; for example, the high off-shelf chlorophyll concentrations observed in the annual spring groundfish surveys (see Fig. 24) and the exceptionally high surface chlorophyll levels observed during the fall groundfish survey in the Southern Gulf in 2002 (see Fig. 25). The satellite-derived chlorophyll data can also be used to generate graphical representations of the seasonal chlorophyll dynamics along the seasonal sections. It is evident from the satellite-data, for example, that surface chlorophyll concentrations are generally higher on the eastern Scotian Shelf (Cabot Strait and Louisbourg lines) than on the central and western shelf (Fig. 29). The nature of the onset, duration and termination of the spring and fall blooms are also reveal in this graphical presentation and shows where across the shelf phytoplankton biomass accumulates in surface waters. Springs 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. The onset of the spring bloom along all the Scotian Shelf sections in 2002 appeared similar to the onset in 2001, however, the duration appeared longer at Cabot Strait and Louisbourg but shorter on the Halifax line in 2002. At the larger scale, the 5-year SeaWiFS time-series is beginning to reveal trends in seasonal chlorophyll dynamics (Fig. 30). It is apparent, for example, that the magnitude of the spring bloom in Cabot Strait and the eastern Scotian Shelf have steadily decreased since 1998 (>6 mg CHL m^{-3}) with the lowest values on record in 2002 (<3 mg CHL m^{-3}). Viewed on the largest scale (Hudson Strait to Georges Bank, see Fig. 5), mean (January-September) surface chlorophyll concentrations in 2002 were generally lower north of Cabot Strait and mixed (above and below the mean) south of Cabot compared with the 5-year mean (Fig. 31). Most differences, however, were small, equal or less than 1 SD (+/-14% of the time-series mean). A similar pattern was seen in chlorophyll changes at the fixed stations in 2002; chlorophyll levels were slightly lower at the Newfoundland and Laurentian stations and higher at the Maritimes/Gulf Shediac Valley and Halifax-2 stations than the 5-year mean, but again, were equal or less than 1 SD (+/-15% of the time-series mean).

Continuous Plankton Recorder (CPR)

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 colour index and adundance of large diatoms and dinoflagellates on the Scotian Shelf have been dramatically higher starting in the early 1990s and continuing into the 2000s when compared with levels seen in the 1960s and 1970s (Fig. 32). A similar pattern has been observed in the Northwest Atlantic; in this region, however, dinoflagellate increases have been more prominent than on the Scotian Shelf. On the shorter time scale, phytoplankton colour on the Scotian Shelf increased slightly in 2001 relative to 2000 (diatoms and dinoflagellates remained about the same) while colour, diatoms and dinoflagellates all increased in the Northwest Atlantic. In 2001, and the 1990s in general, there also appeared to be a shift toward earlier months for the seasonal (spring) peak in abundance compared to the 1960s and 1970s (Fig. 33).

While phytoplankton were increasing on the Scotian Shelf and the Northwest Atlantic in the 1990s, zooplankton were generally decreasing, particularly during the early to mid 1990s (Fig. 34). During the last 3-4 years, zooplankton numbers appeared to be recovering on the Scotian Shelf, however, numbers were down again in 2001. Most noteworthy were significant drops in *Paracalanus/Pseudocalanus sp.* and euphausiid numbers. In the Northwest Atlantic, zooplankton numbers were actually up slightly in 2001. A shift in peak abundance of *C. finmarchicus* and *Paracalanus/Pseudocalanus sp.* to earlier in the year in 2001 (and the 1990s in general) was apparent on the Scotian Shelf, similar to the seasonal shift seen in phytoplankton abundance (Fig. 35).

DISCUSSION

Sufficient data now exists from AZMP to begin to document recurring spatial and temporal patterns in optical, chemical and biological properties of the Maritimes/Gulf Regions and to describe changes (trends) in oceanographic properties. Although many of the oceanographic features in the Maritimes/Gulf Regions in 2002 were similar to observations from previous years a number of differences were noteworthy.

Optics and mixing. The seasonal development of the mixed-layer and stratification of the upper water-column are recurring features at the Maritimes/Gulf fixed stations, the annual reproducibility of these properties is particularly evident at the Shediac Valley station. Notable differences in mixed-layer cycles, however, were observed at all of the fixed stations in 2002. At the Shediac Valley station, summer-time mixed-layer depths were shallower in 2002 than in 2001 whereas winter-time mixed-layer depths were shallower at Halifax-2. At Prince-5, summer-time mixed-layers were considerably deeper than seen in previous years. These changes are likely driven by local meterological events but this link has yet to be explored and established.

Nutrients. Winter maxima in surface nutrients and summer-time reduction in concentrations is a common feature in the Maritimes/Gulf Regions. For the most part, the seasonal cycles of nutrients, vertical structure and regional variations were similar in 2002 to previous years; there were some differences, however. Deep-water (>50 m) nitrate concentrations at all of the fixed stations were higher in 2002 than in 2001 but still below the climatological mean, at least for Halifax-2 where long-term data exist. Bottom water nitrate concentrations observed during the annual groundfish surveys were generally similar or slightly greater than concentrations observed in 2001 but lower than the climatological mean in the deep basins. Oxygen conditions (% saturation) was lower on the Scotian Shelf and in the Southern Gulf and low levels were more widespread in 2002 than in 2001. This could result from water-mass changes or increased consumption from microbial activity. The former can be explored by analysis of hydrographic properties but data on the microbial community are not part of AZMP.

Annual nitrate inventories were somewhat higher at Shediac Valley in 2002 than in 2001 (but similar to levels seen in previous years) and although annual inventories were similar among years at Prince-5, residual summer-time levels were higher in 2002 than in previous years. Nitrate inventories were lower in 2002 at Halifax-2 and winter-time maximum concentrations were lowest on record. Mixed-layer development at these stations maybe be linked to nutrient conditions. Summer-time mixed-layers were shallower at Shediac Valley in 2002 and deeper at Prince-5 than in previous years. Shallow summer mixed-layer depths may translate to shallow nutriclines and thus higher surface nitrate inventories as seen at Shediac Valley. On the other hand, deep summer mixed-layers may mean less favorable light conditions for phytoplankton growth which may result in reduced nutrient consumption and higher residual summer-time nitrate concentrations as seen at Prince-5. Low winter-time (and annual) inventories of nitrate at Halifax-2 in 2002 can be at least partially explained by the less intense mixing during the winter of 2001/2002 as revealed by the shallow winter mixed-layers compared to winter mixed-layers in the previous year.

Phytoplankton. Despite the fact that phytoplankton variability (both temporal and spatial) is characteristically high in coastal waters, the development of a pronounced spring/summer (and less conspicuous fall) phytoplankton bloom is evident from observations at the Maritimes/Gulf fixed stations, seasonal sections, groundfish surveys, CPR and remote-sensing data. Recurring spatial patterns such as elevated chlorophyll concentrations off southwest Nova Scotia, the eastern Gulf of Maine/Bay of Fundy and the western Southern Gulf of St. Lawrence are also seen yearly. There were, however, some features of the phytoplankton growth cycle in the Maritimes/Gulf Regions distinctive for 2002. Most prominent were the persistent and widespread high concentrations of chlorophyll in the Southern Gulf seen in *in-situ* and satellite data; surface chlorophyll concentrations observed during the fall groundfish survey were highest on record. Field and satellite data also showed that the spring bloom on the Scotian Shelf (Halifax-2, Halifax line) was earlier and its duration shorter than in 2001 and that the late spring/summer phytoplankton bloom at Prince-5 was later in 2002 than in 2001. The high and persistent chlorophyll in the Southern Gulf could be linked to the shallow mixed-layers and higher nutrient levels in 2002. In a similar way, the increased summer mixed-layers at Prince-5 in 2002 could have been unfavorable for phytoplankton growth and could have contributed to the delay in onset of the spring/summer bloom there. The earlier spring bloom at Halifax-2 in 2002 could be linked to the reduced vertical mixing in the previous winter, setting the stage for favorable phytoplankton growth conditions earlier in the year. Satellite time-series data are also establishing trends in phytoplankton abundance in the Maritimes/Gulf Regions. For example, the magnitude of the spring bloom has been decreasing on the eastern Scotian Shelf and Cabot Strait since 1998 with lowest levels to date were recorded in 2002. A synoptic picture of phytoplankton conditions in the Northwest Atlantic in 2002 from satellite ocean colour indicated that overall levels decreased in some regions and increased in others but none of the changes were considered significant. Over the longer term, however, CPR data clearly show that contemporary phytoplankton abundance, region-wide, is much higher than it was decades ago and that the spring burst of growth is occurring earlier in the year now than in the 1960s and 1970s.

Zooplankton. Like phytoplankton, zooplankton in the Maritimes/Gulf Regions are characterized by high spatial and temporal variability. Despite that, recurring patterns in distribution and growth cycles are emerging from AZMP data. Both biomass and numerical abundance of zooplankton are generally highest in spring and higher on the western Scotian Shelf/eastern Gulf of Maine and Southern Gulf than on the eastern shelf. Lowest levels of zooplankton (and the important copepod, *C. finmarchicus*) have been observed at Prince-5 and highest at Halifax-2. Community composition, for the most part, has remained relatively unchanged at the Maritimes/Gulf fixed stations since AZMP observations began in 1999. Some features of the zooplankton community were notable for 2002, however. There has been a trend over the past few years of decreasing zooplankton biomass and abundance, copepod abundance and *C. finmarchicus* abundance at Halifax-2 with lowest levels on record in 2002. Zooplankton biomass was down in 2002 at all fixed stations, in fact. At Shediac Valley, however, *C. finmarchicus* was up in 2002 from the previous year. It is tempting to relate the latter observation to the high and persistent chlorophyll levels in the Southern Gulf in 2002. Jellies and appendicularians numbers were also elevated at Shediac Valley and Halifax-2 in 2002 compared with previous years. Zooplankton biomass observed during the 2002 annual groundfish surveys was similar to levels seen in 2001 while and biomass and *C. finmarchicus* abundance observed on the fall section survey on the Scotian Shelf was higher on the eastern Shelf in 2002 than in 2001. Over the long-term, CPR data show that contemporary zooplankton abundance, region-wide, is considerably lower than in the 1960s and 1970s and continues to fall well below the climatological mean.

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Table 1. AZMP Sampling Missions in the Maritimes/Gulf Regions, 2002.

Group	Location	Mission ID	Dates	# Hydro Stns	# Net Stns
Groundfish Surveys	Georges Bank	NED2002002	Feb 19 - Mar 01	48	13
	Eastern Shelf	NED2002003	Mar 05 – Mar 19	123	18
	Scotian Shelf	NED2002037	Jul 02 – Jul 16	120	14
	Scotian Shelf	NED2002040	Jul 20 – Jul 30	90	16
	SGSL	NED2002051	Sep 04 – Sep 28	179	15
	Western Bank	NED2002062	Oct 3 – Oct 9	55	---
Seasonal Sections	Scotian shelf	SWA2002013	May 04 – May 05	7	7
	Scotian Shelf	HUD2002032	Jun 23 – Jun 25	7	7
	Scotian Shelf	HUD2002064	Oct 18 – Oct 31	47	41
Fixed Stations	Shediac	BCD2002668	Apr 26 – Dec 12	17	17
	Halifax-2	BCD2002666 +	Jan 05 – Dec 08	25	24
	Prince-5	BCD2002669	Jan 02 – Nov 30	20	19
			Total:	**744**	**191**

Table 2. Chemical and biological properties of the 1999-2002 summer Scotian and fall Southern Gulf of St. Lawrence groundfish surveys. Statistics: mean, (range), #obs.

Survey	Year	Chlorophyll (mg m^{-3}) Surface (5 m)	Nitrate (mmol m^{-3}) Bottom	Oxygen (% Saturation) Bottom	Zoopl Biomass (gm wtwt m^{-2})	C. finmarchicus (# m^{-2})
Scotian Shelf						
	1999	**0.93** (0.10-7.07) 137	**13.22** (2.12-24.06) 163		**45.9** (0.2-228.2) 32	**20,872** (91-143,060) 33
	2000	**0.67** (0.11-6.17) 220	**12.87** (3.27-22.97) 178	**87** (43-121) 203	34.0 2.7-158.6 38	
	2001	**0.78** (0.03-4.08) 206	**11.75** (1.72-21.76) 155	**82** (40-107) 206	**34.4** (1.2-144.8) 38	
	2002	**0.51** (0.08-4.17) 303	**10.96** (0.32-22.66) 215	**74** (28-109) 215	**36.8** (8.0-120.1) 20	
Southern Gulf						
	1999	**1.65** (0.03-4.97) 185	**9.87** (0.35-22.92) 178	**84** (38-114) 180	**37.4** (5.1-112.0) 17	**18,101** (0-56,354) 17
	2000	**1.56** (0.16-6.35) 197	**11.45** (0.37-24.57) 192	**79** (33-117) 175	**44.9** 4.5-223.7 17	
	2001	**1.04** (0.04-3.60) 149	**8.93** (0.19-23.94) 155	**98** (68-118) 8	**30.6** (2.87-142.04) 18	
	2002	**2.36** (0.75-5.97) 176	**10.91** (0.37-24.94) 175	**68** (28-95) 175		

Figure 1. Primary sections and fixed stations sampled in the Maritimes/Gulf Regions.

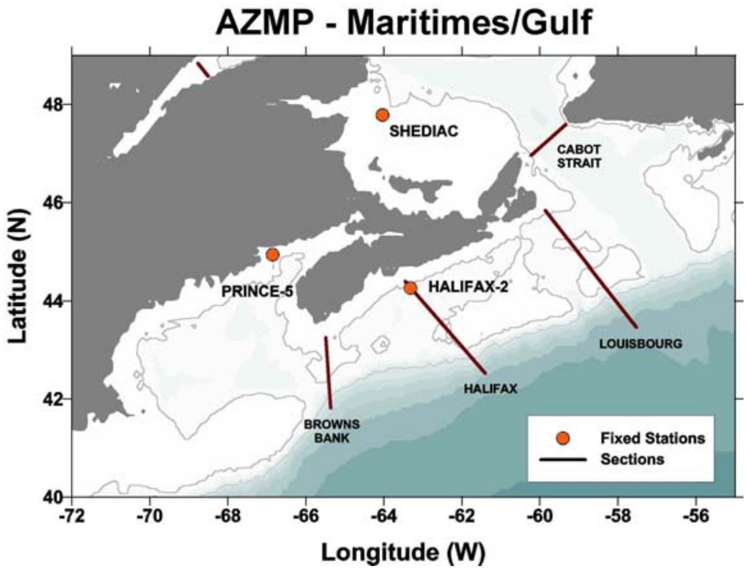

Figure 2. Stations sampled during the 2002 spring, summer and fall section surveys. Station locations superimposed on SeaWiFS bi-weekly colour composite images.

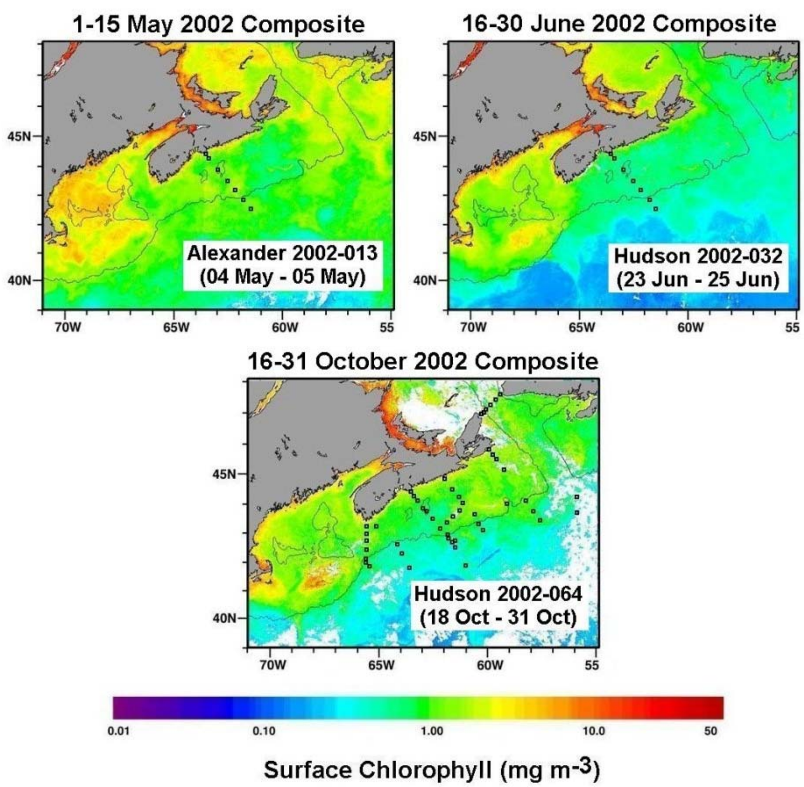

Figure 3. **Stations sampled during major groundfish surveys in 2002. Black symbols are hydrographic stations; red symbols are stations where vertical nets hauls were taken in addition to hydrographic measurements.**

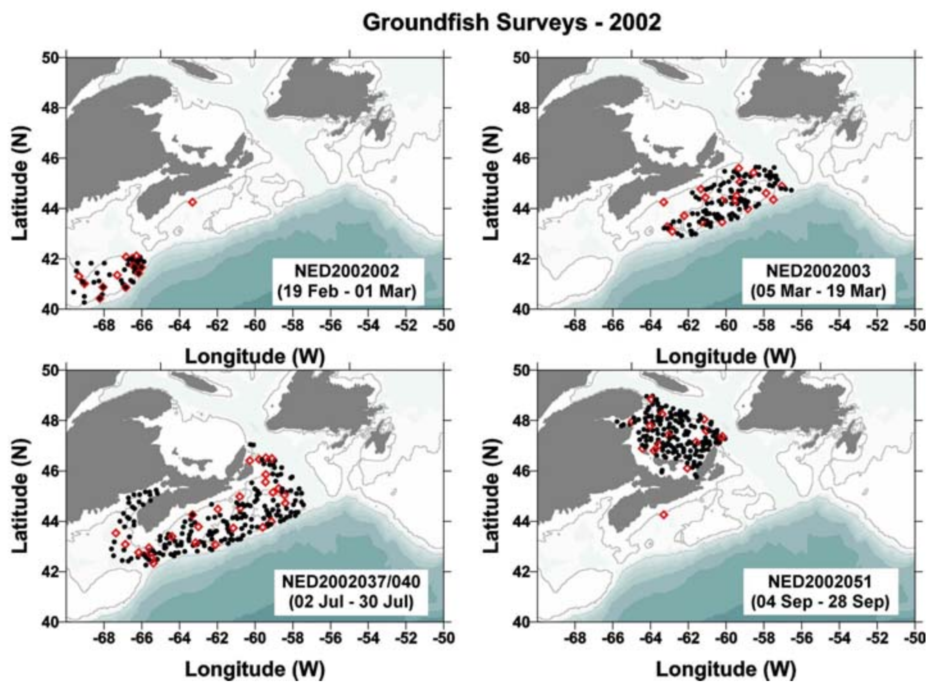

Figure 4. CPR lines and stations, 1961 to 2001 (2001 highlighted).

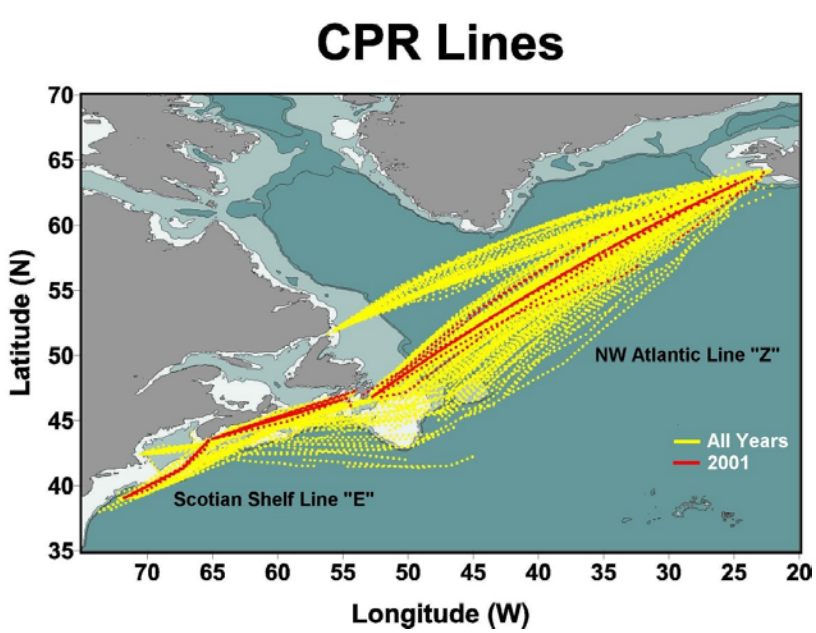

Figure 5. Statistical sub-regions in the Northwest Atlantic identified for spatial/temporal analysis of SeaWiFS ocean colour data.

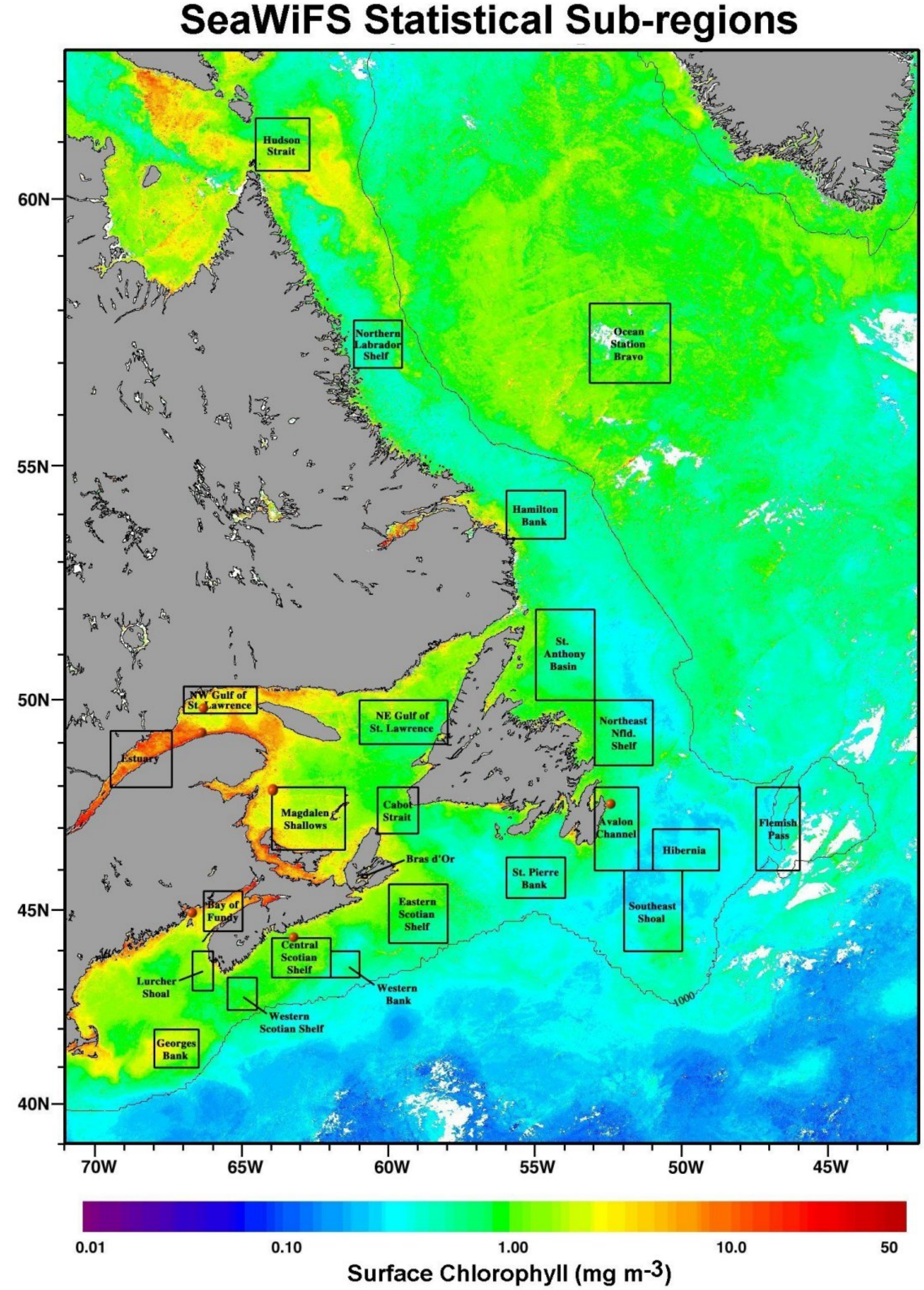

Figure 6. Time-series of optical properties (vertical attenuation coefficient, euphotic depth), mixed-layer depth and stratification at the Shediac Valley fixed station, 2000-2002.

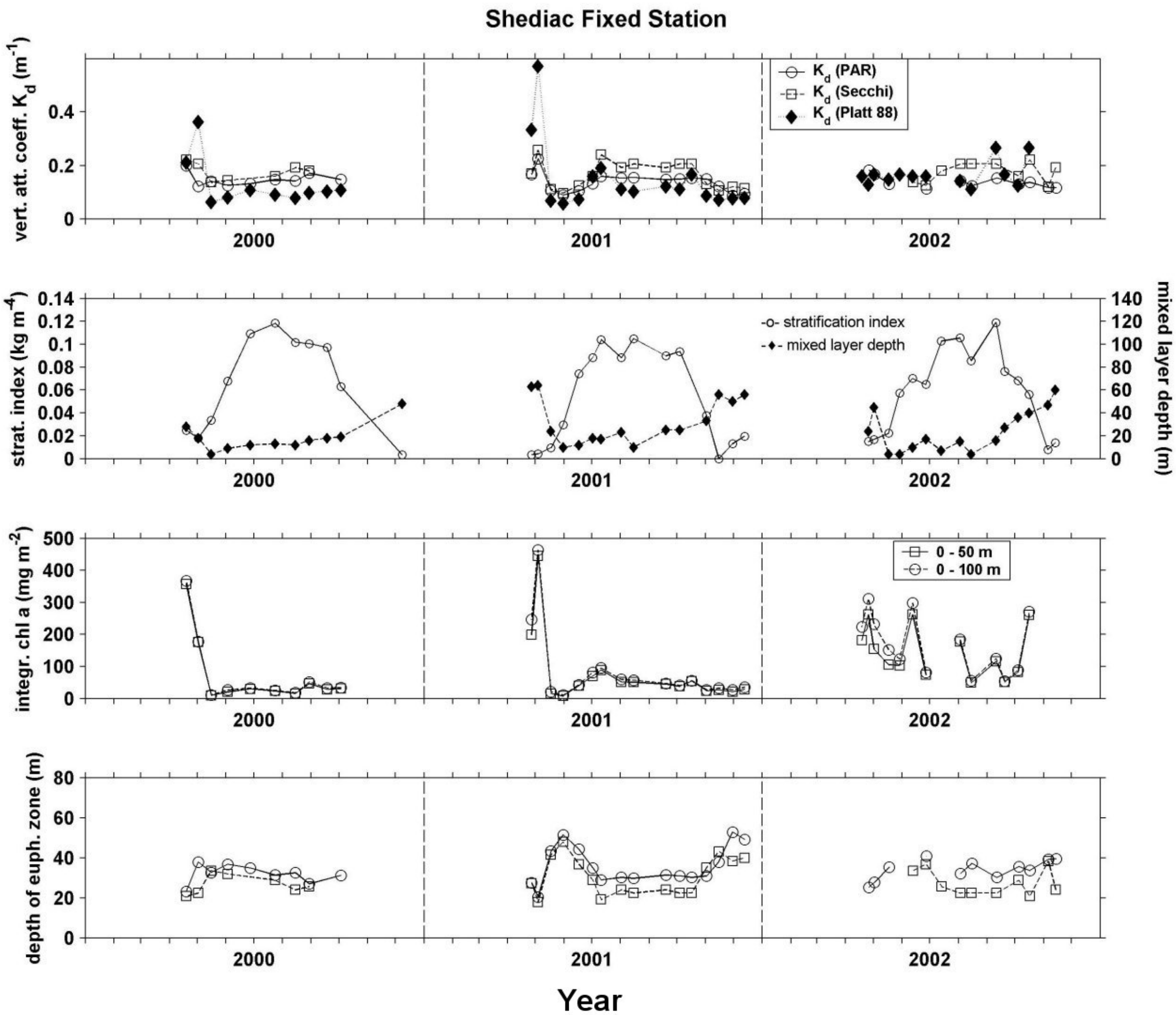

Figure 7. Time-series of optical properties (vertical attenuation coefficient, euphotic depth), mixed-layer depth and stratification at the Halifax-2 fixed station, 2000-2002.

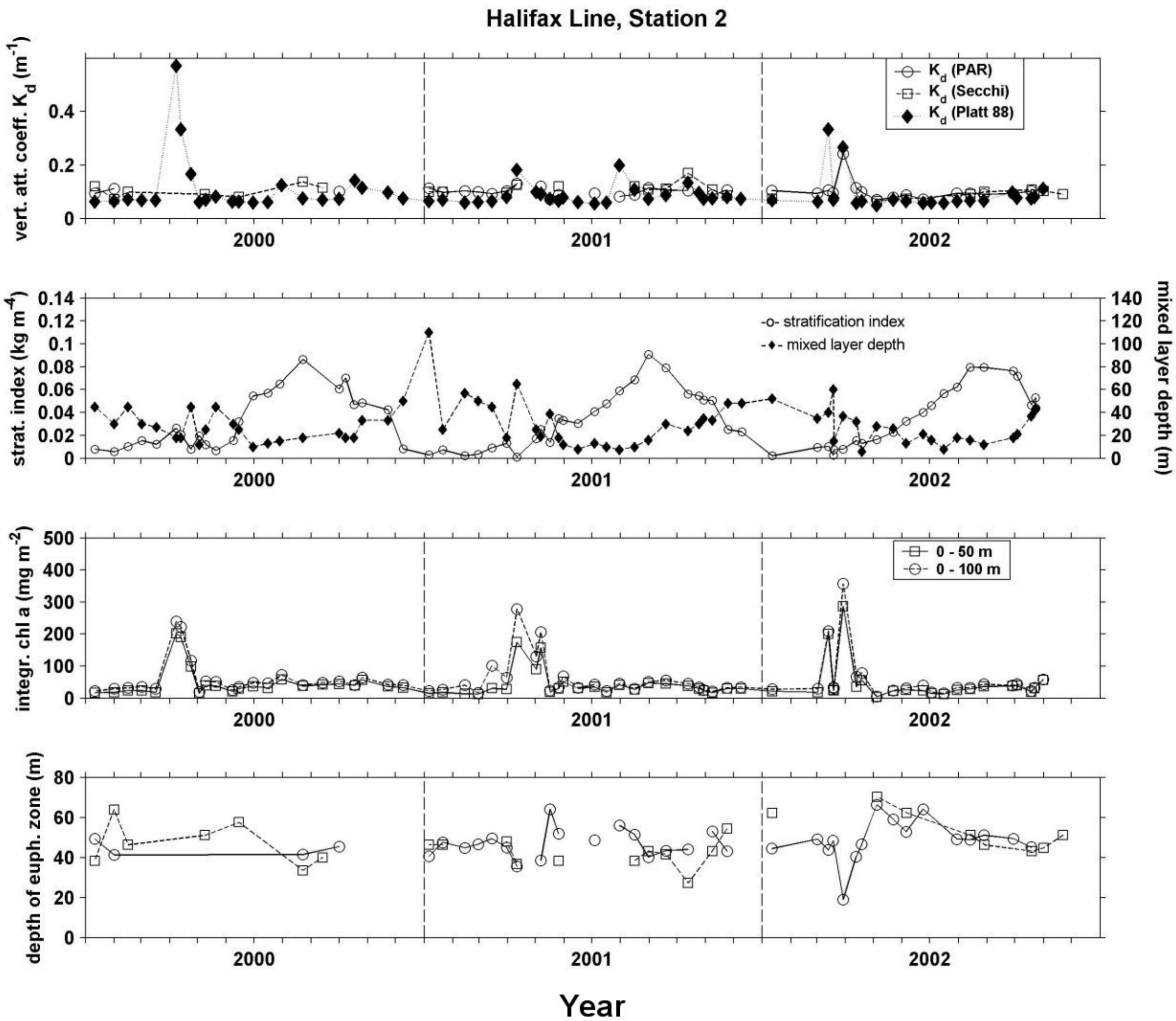

Figure 8. Time-series of optical properties (vertical attenuation coefficient, euphotic depth), mixed-layer depth and stratification at the Prince-5 fixed station, 2000-2002.

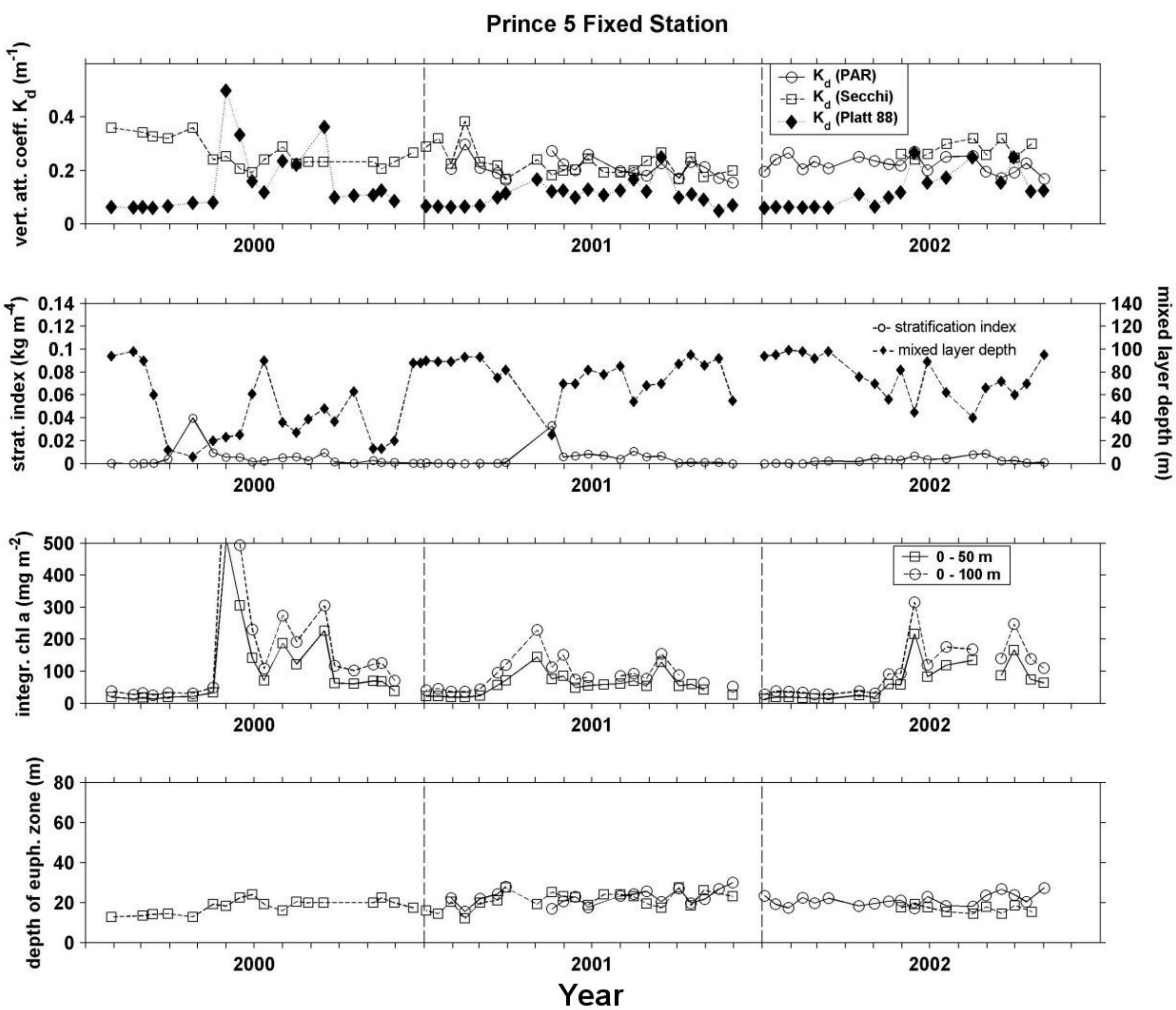

Figure 9. Time-series of vertical nitrate structure at the Maritimes/Gulf fixed stations, 1999-2002. Bottom panel: nitrate anomaly (yearly values minus long-term mean).

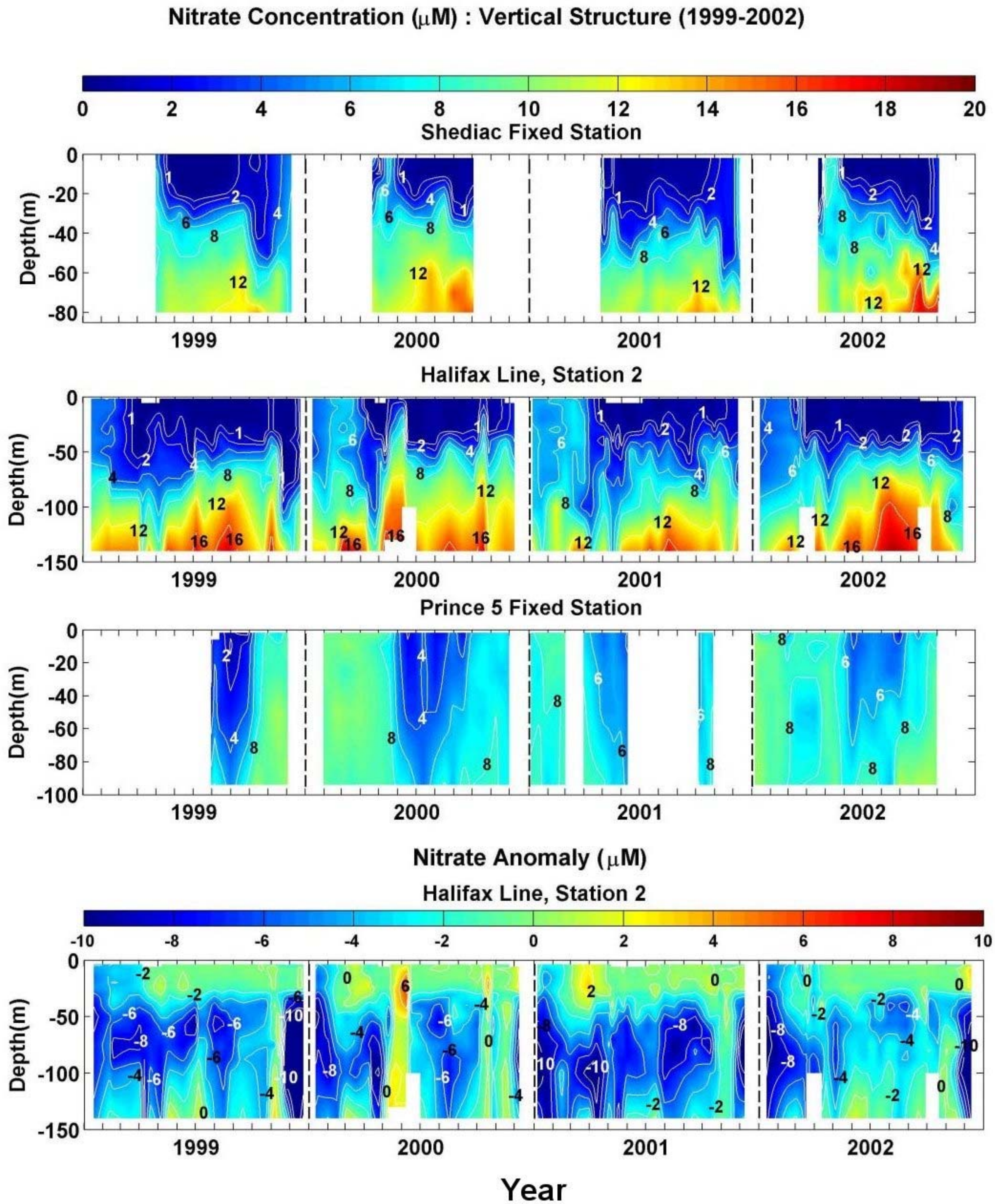

Figure 10. **Time-series of nitrate (surface-50 m integrals) and chlorophyll concentrations (surface-100 m integrals) at the Maritimes/Gulf fixed stations, 1999-2002. Numbers above each year are the annual inventories (Shediac Valley integrals do not begin until mid-April due to ice cover).**

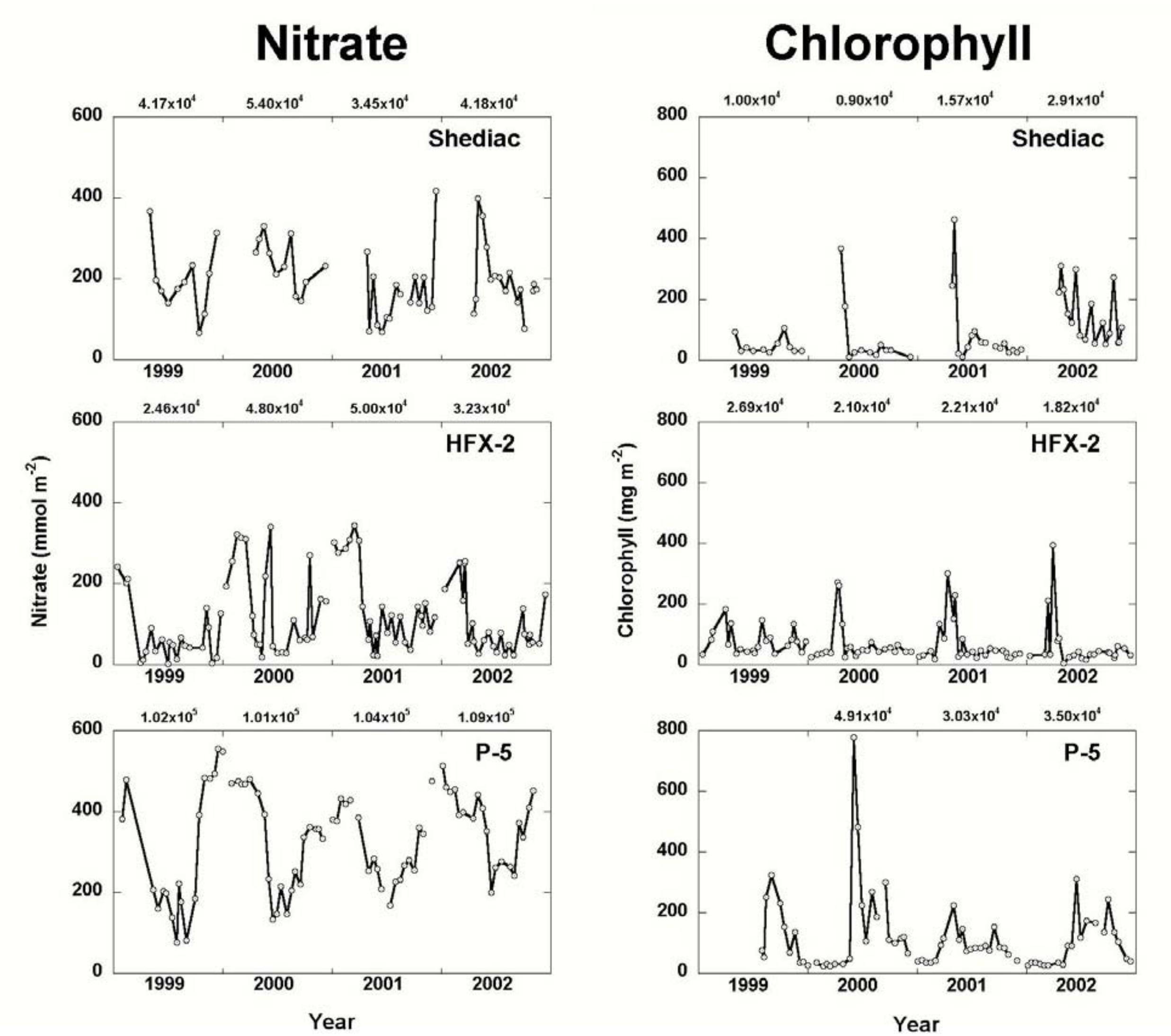

Figure 11. Time-series of vertical chlorophyll structure at the Maritimes/Gulf fixed stations, 1999-2002. Bottom panel: chlorophyll anomaly (yearly values minus long-term mean).

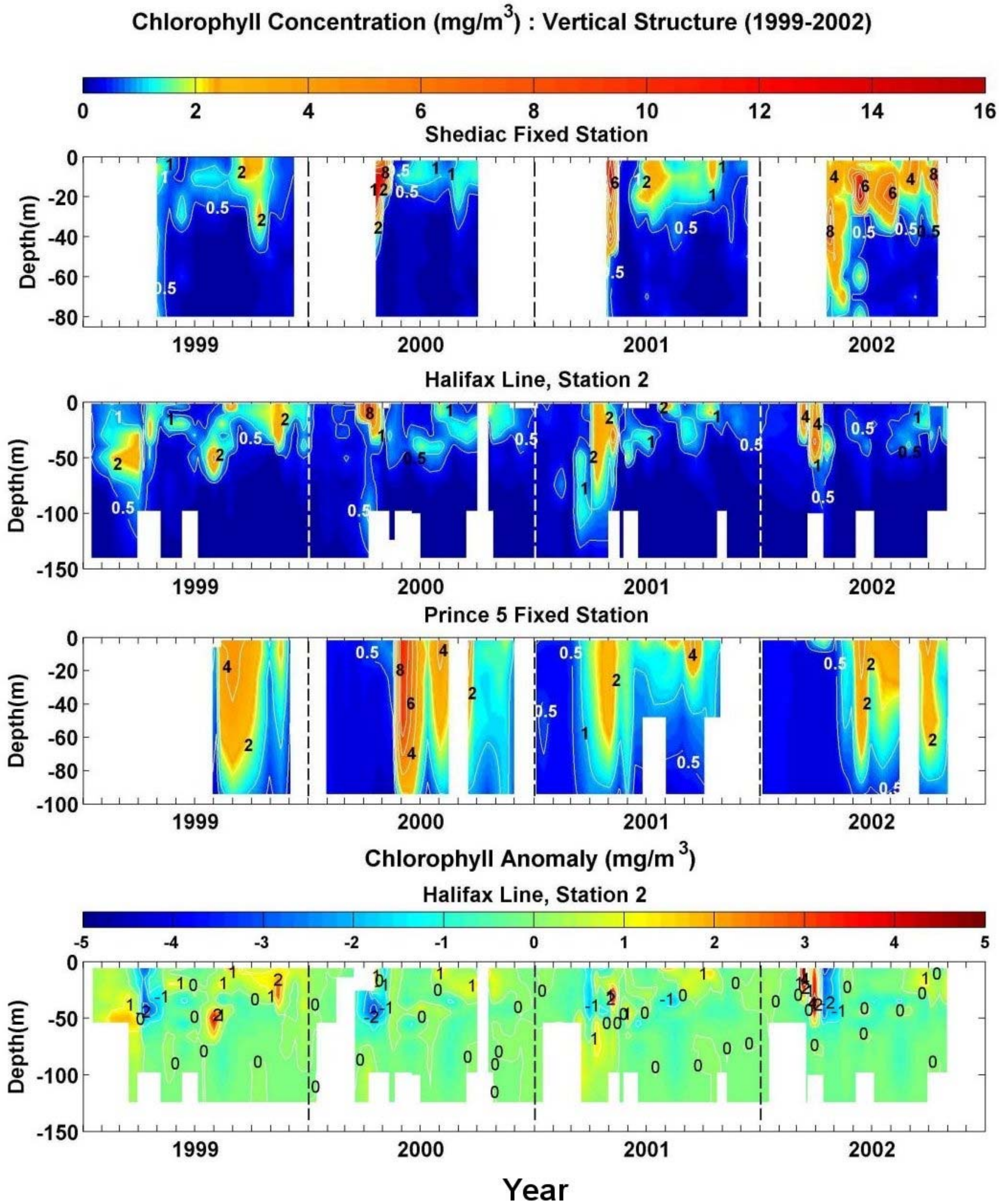

Figure 12. Time-series of phytoplankton abundance and community composition at the Maritimes/Gulf fixed stations, 1999-2002.

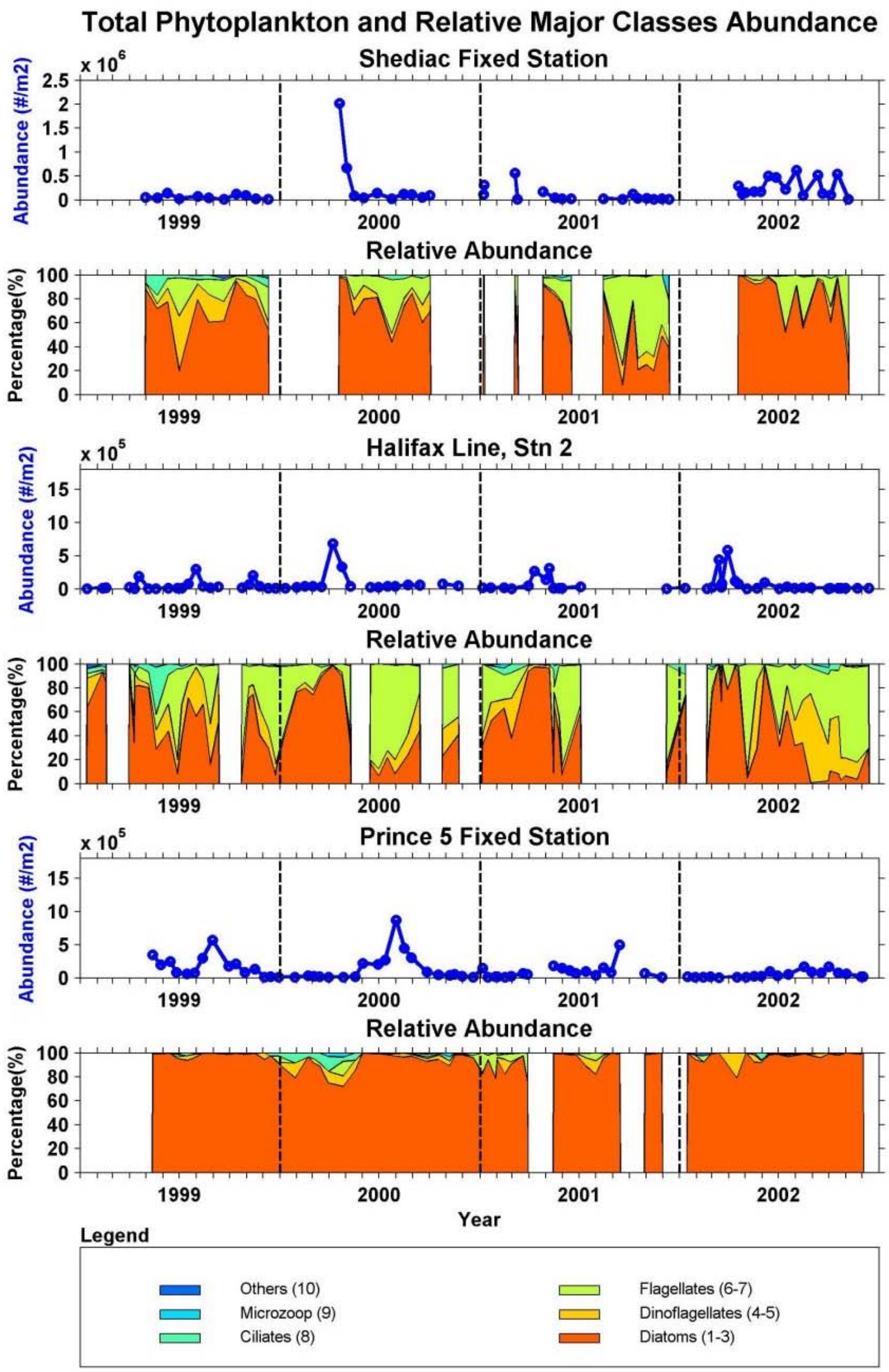

Figure 13. Time-series zooplankton biomass (surface-bottom) and *C. finmarchicus* abundance (surface-bottom) at the Maritimes/Gulf fixed stations, 1999-2002. Numbers above each year are the annual integrals (Shediac Valley integrals do not begin until mid-April due to ice cover).

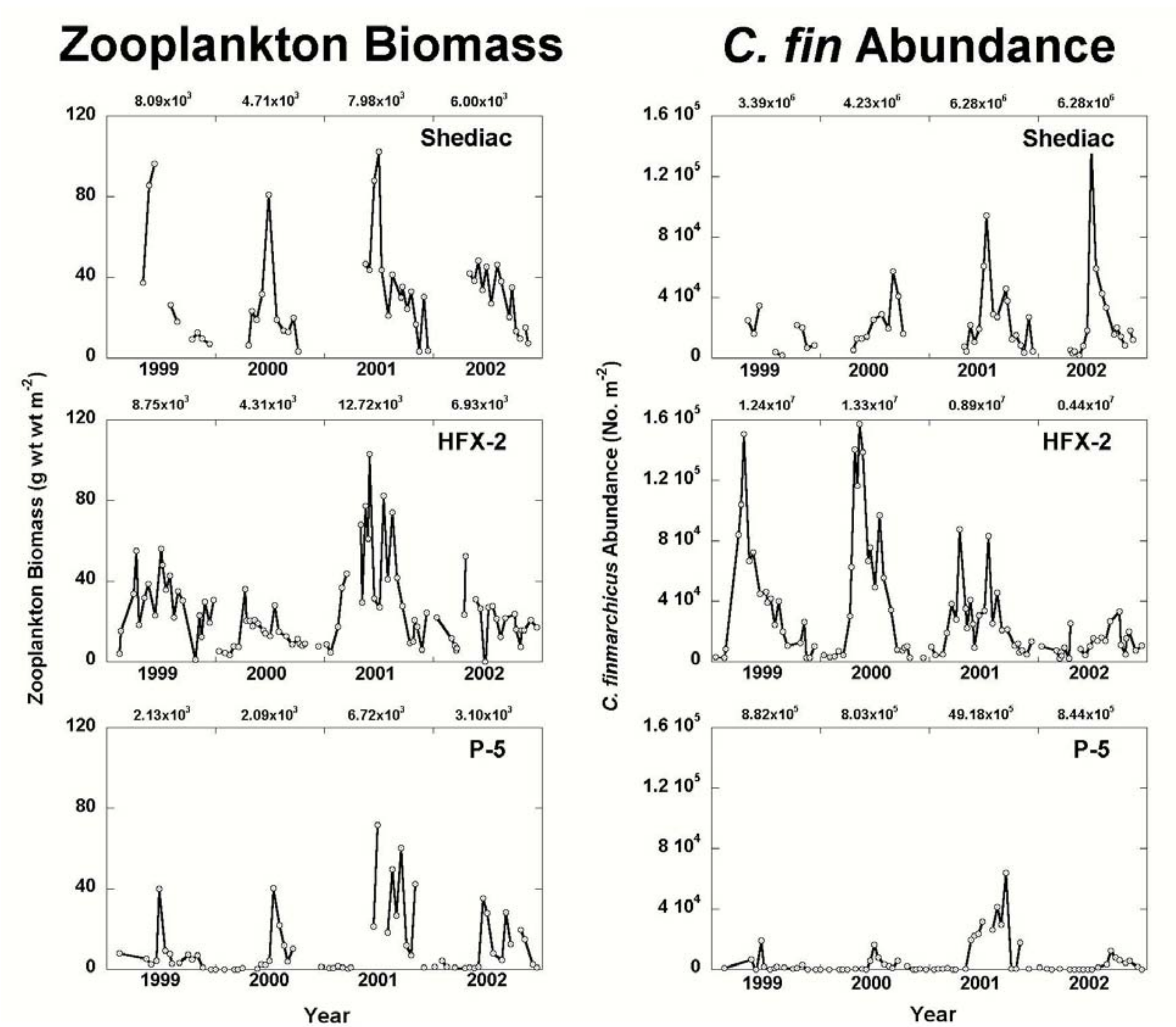

Figure 14. Time-series of zooplankton abundance and community composition at the Maritimes/Gulf fixed stations, 1999-2002.

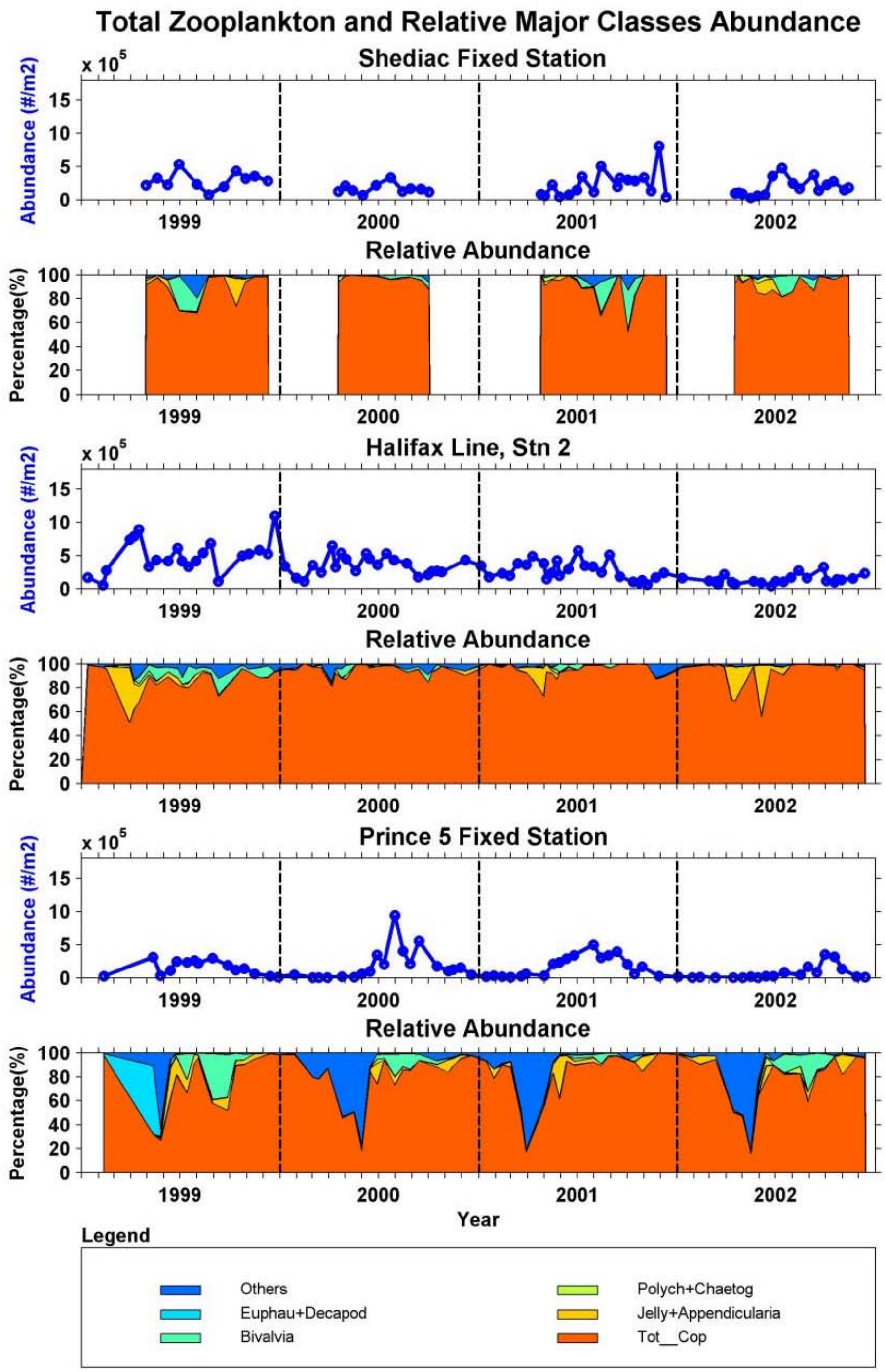

Figure 15. Time-series of copepod abundance and community composition at the Maritimes/Gulf fixed stations, 1999-2002.

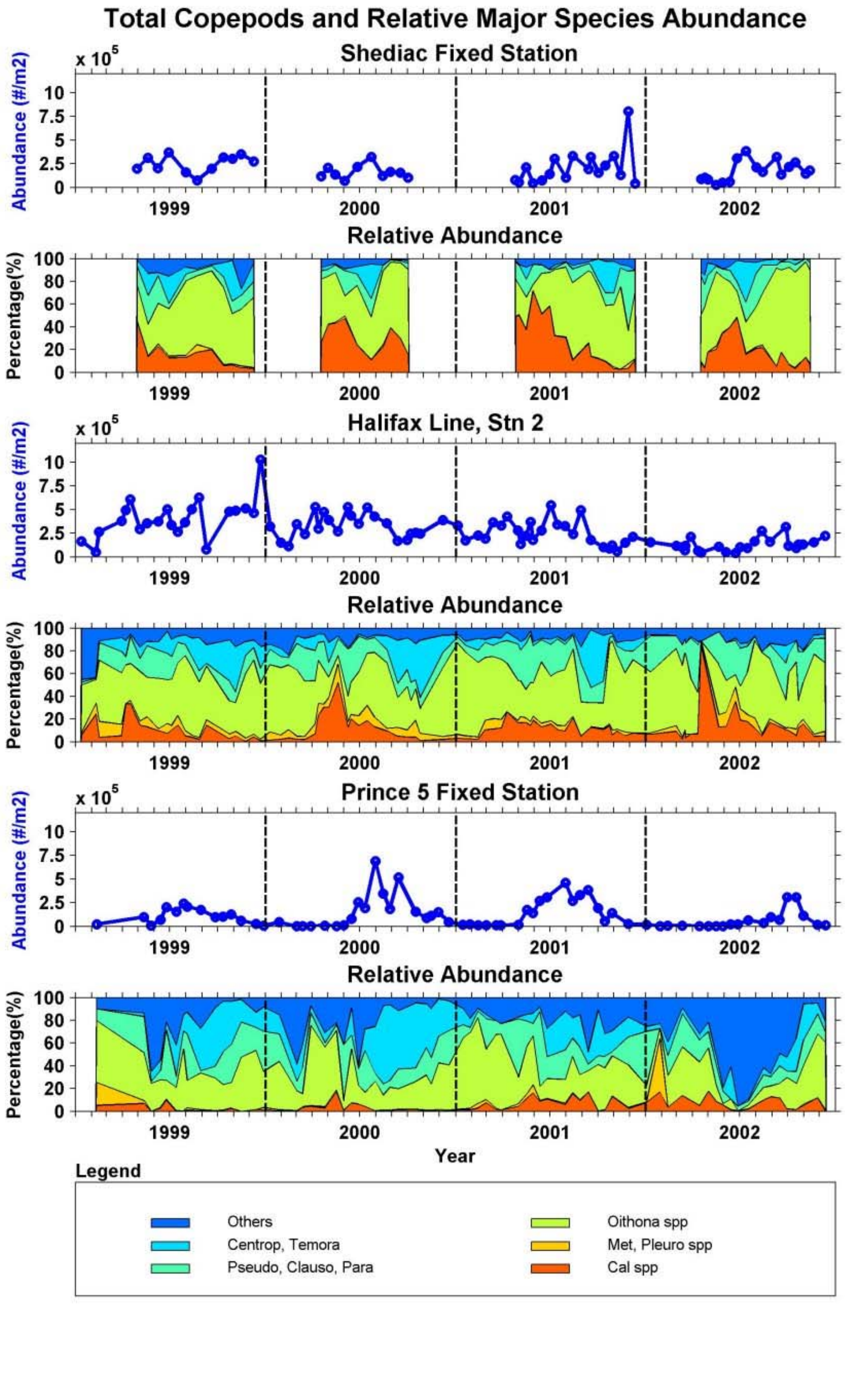

Figure 16. Time-series of *C. finmarchicus* abundance and developmental stages at the Maritimes/Gulf fixed stations, 1999-2002.

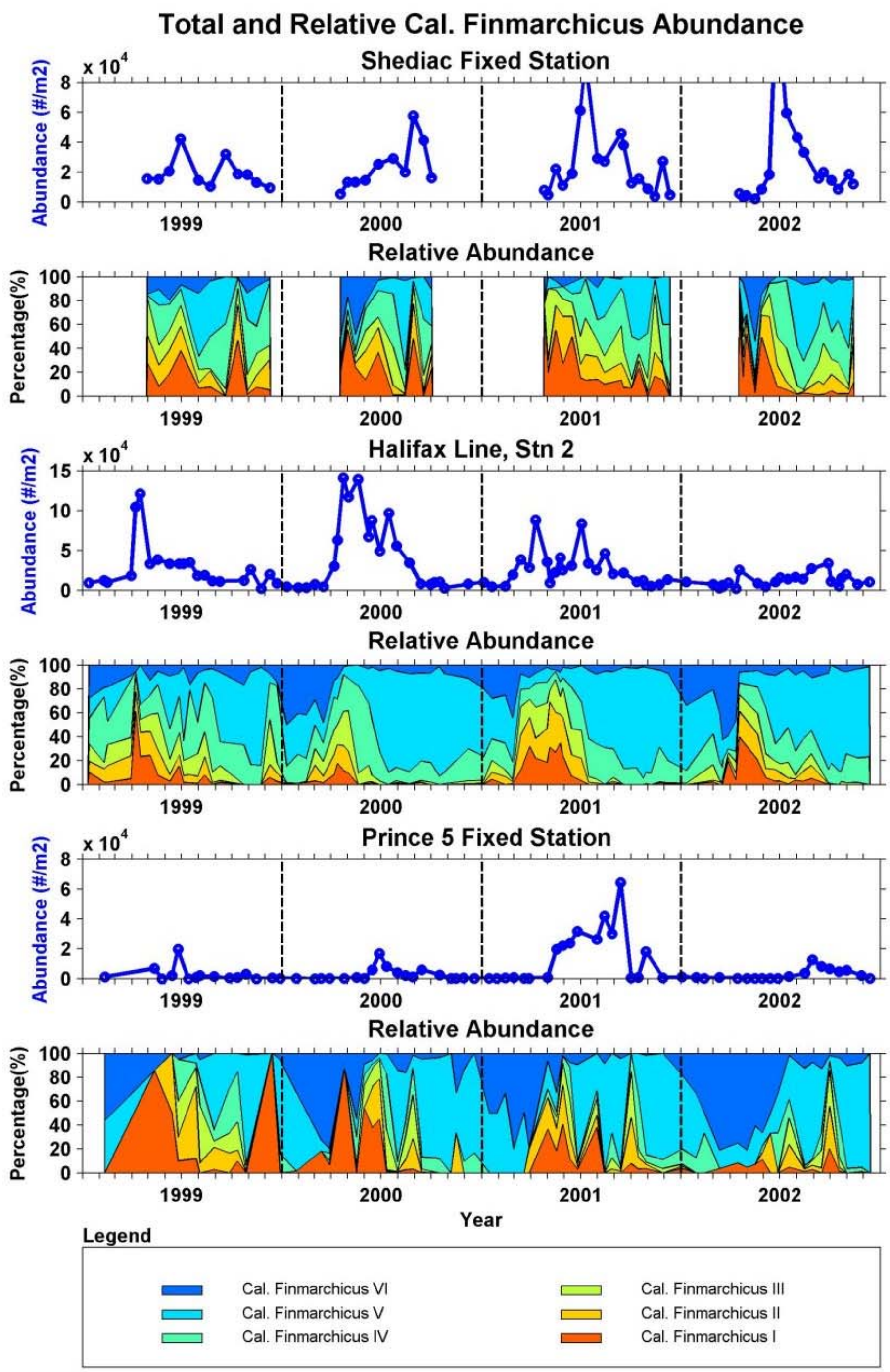

Figure 17. Vertical nitrate and chlorophyll structure along the Halifax section during the spring and summer surveys in 2002.

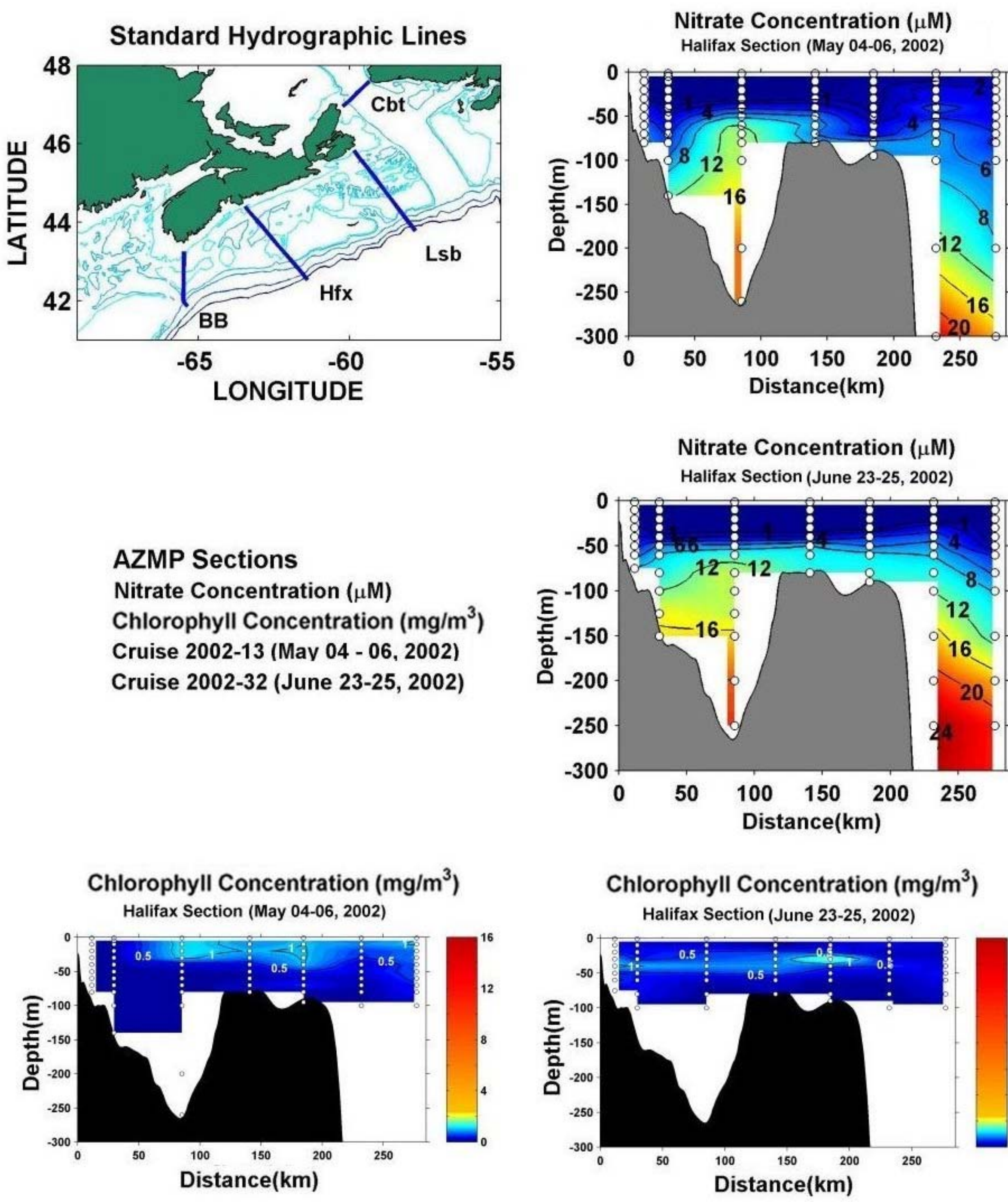

Figure 18. **Vertical chlorophyll structure along the Scotian Shelf sections during the fall survey in 2002.**

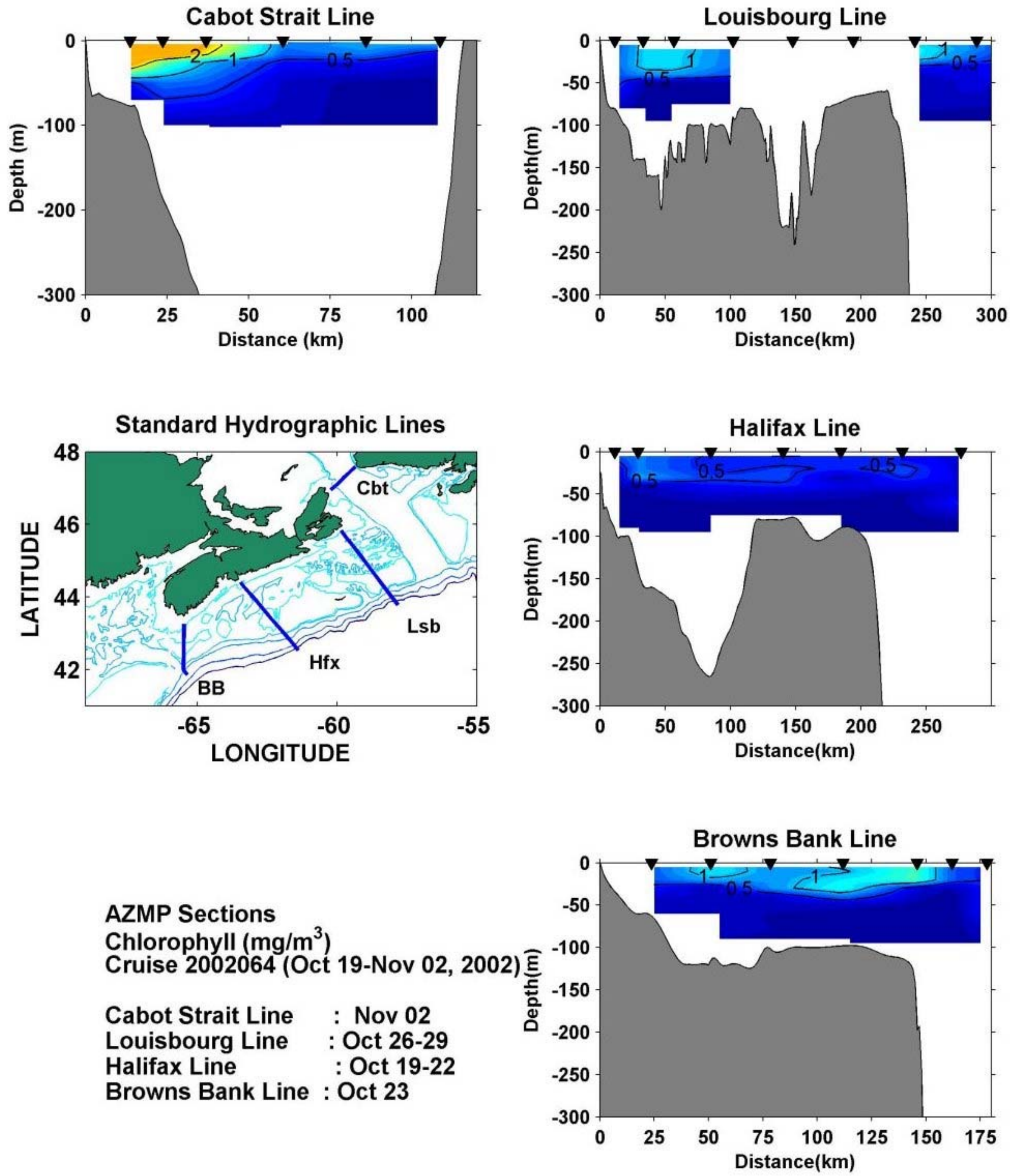

Figure 19. Mean chlorophyll concentrations (surface-100m integrals) along the section lines during the spring and fall surveys on the Scotian Shelf, 1999-2002. Numbers above the vertical bars are the number of stations sampled along the section.

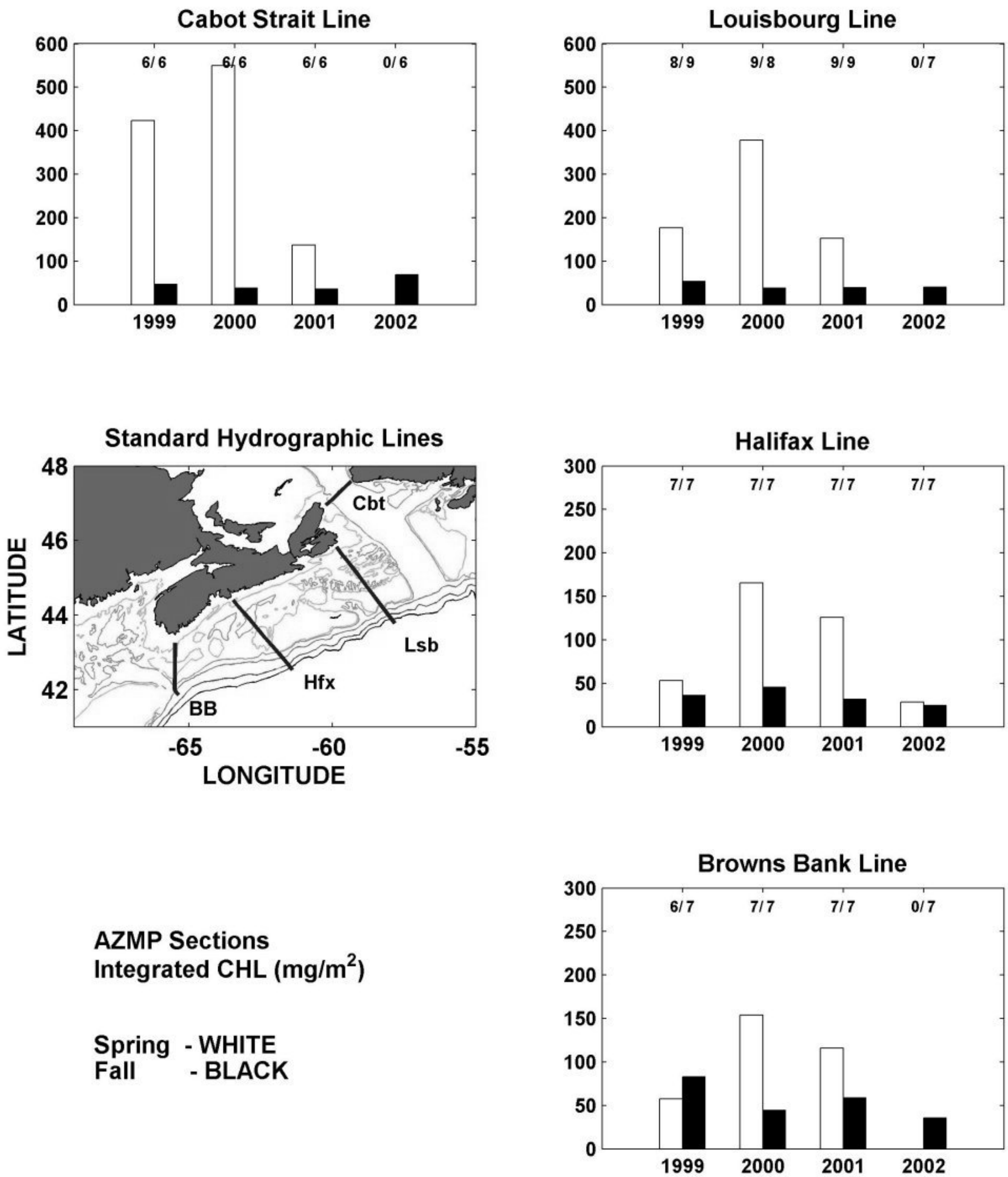

Figure 20. **Mean zooplankton biomass (surface-bottom) along the section lines during the spring and fall surveys on the Scotian Shelf, 1999-2002. Numbers above the vertical bars are the number of stations sampled along the section.**

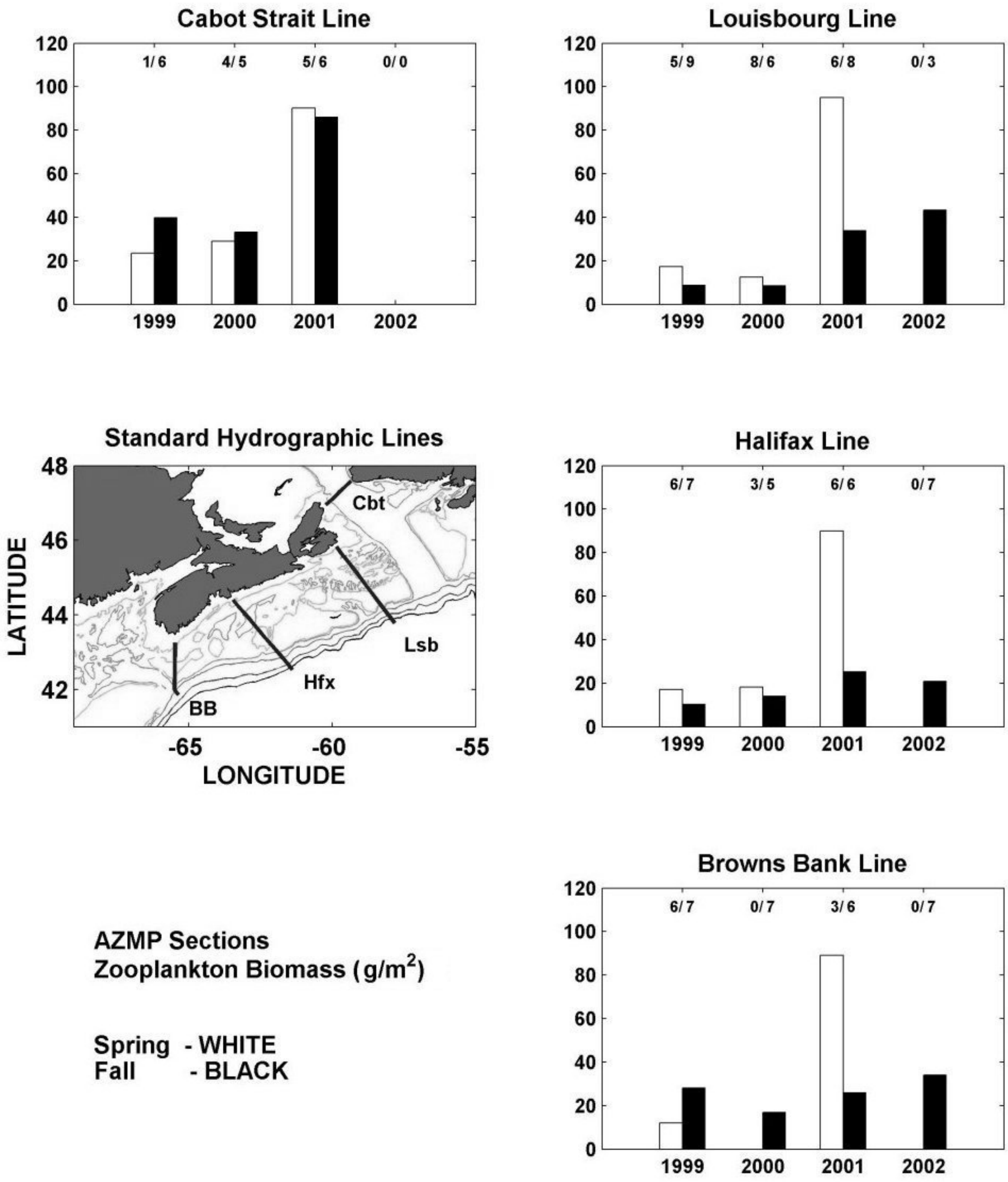

Figure 21. **Mean *C. finmarchicus* abundance (surface-bottom) along the section lines during the spring and fall surveys on the Scotian Shelf, 1999-2002. Numbers above the vertical bars are the number of stations sampled along the section.**

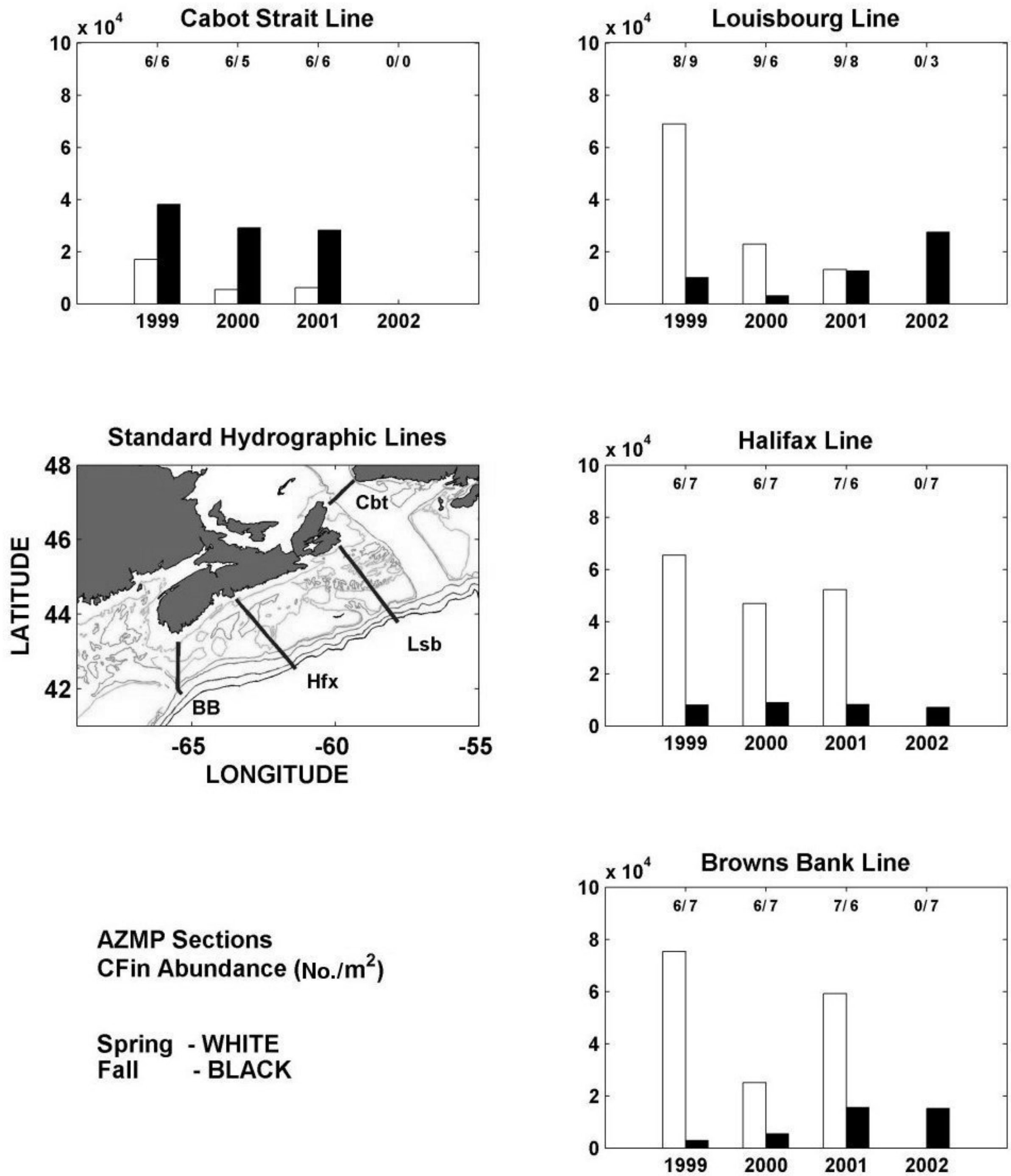

Figure 22. Bottom nitrate concentrations on the Scotian Shelf and in the Southern Gulf of St. Lawrence during the annual groundfish surveys, 1999-2002.

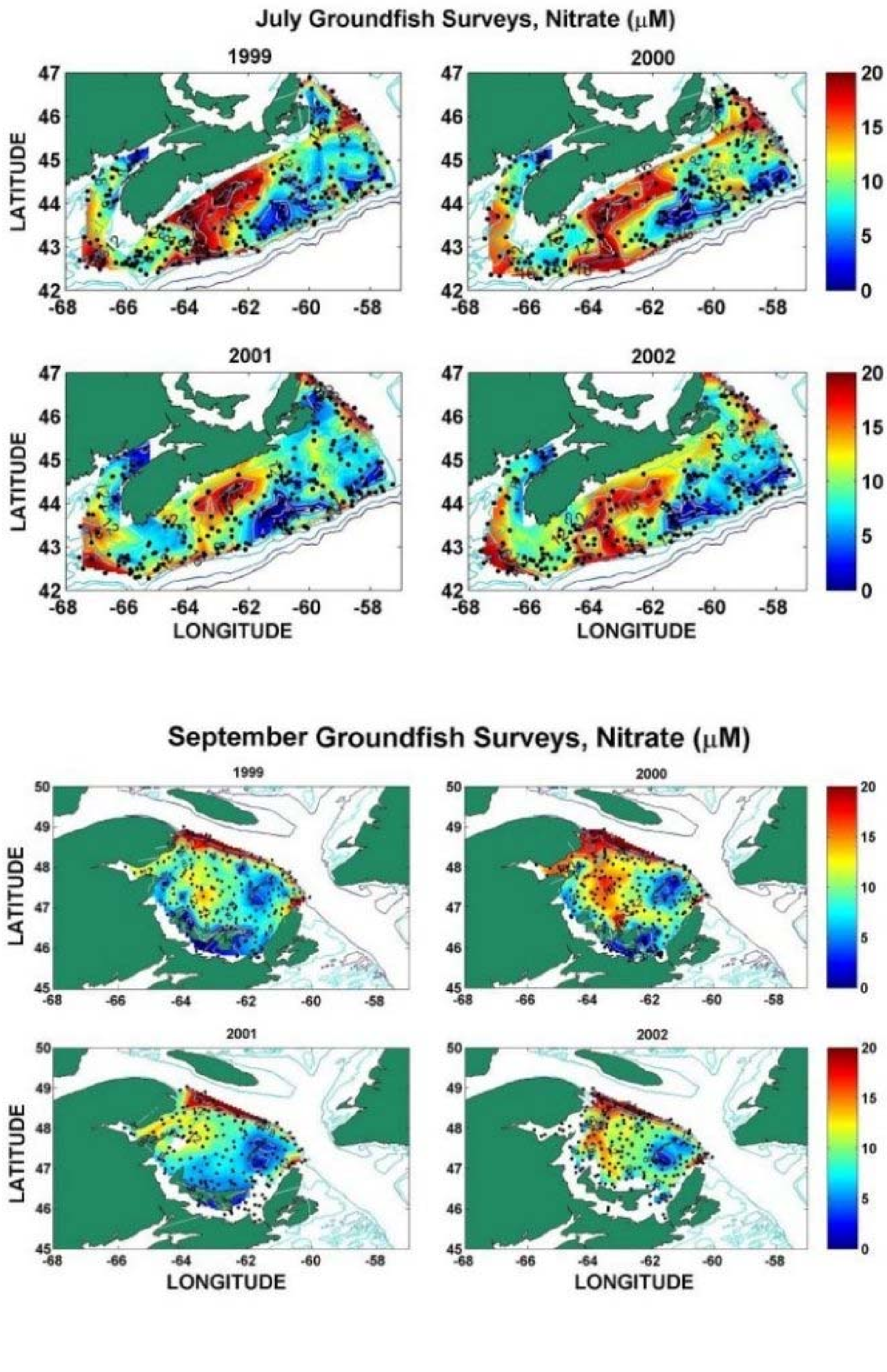

Figure 23. Bottom oxygen concentrations (% saturation) on the Scotian Shelf during the annual summer groundfish surveys, 1999-2002.

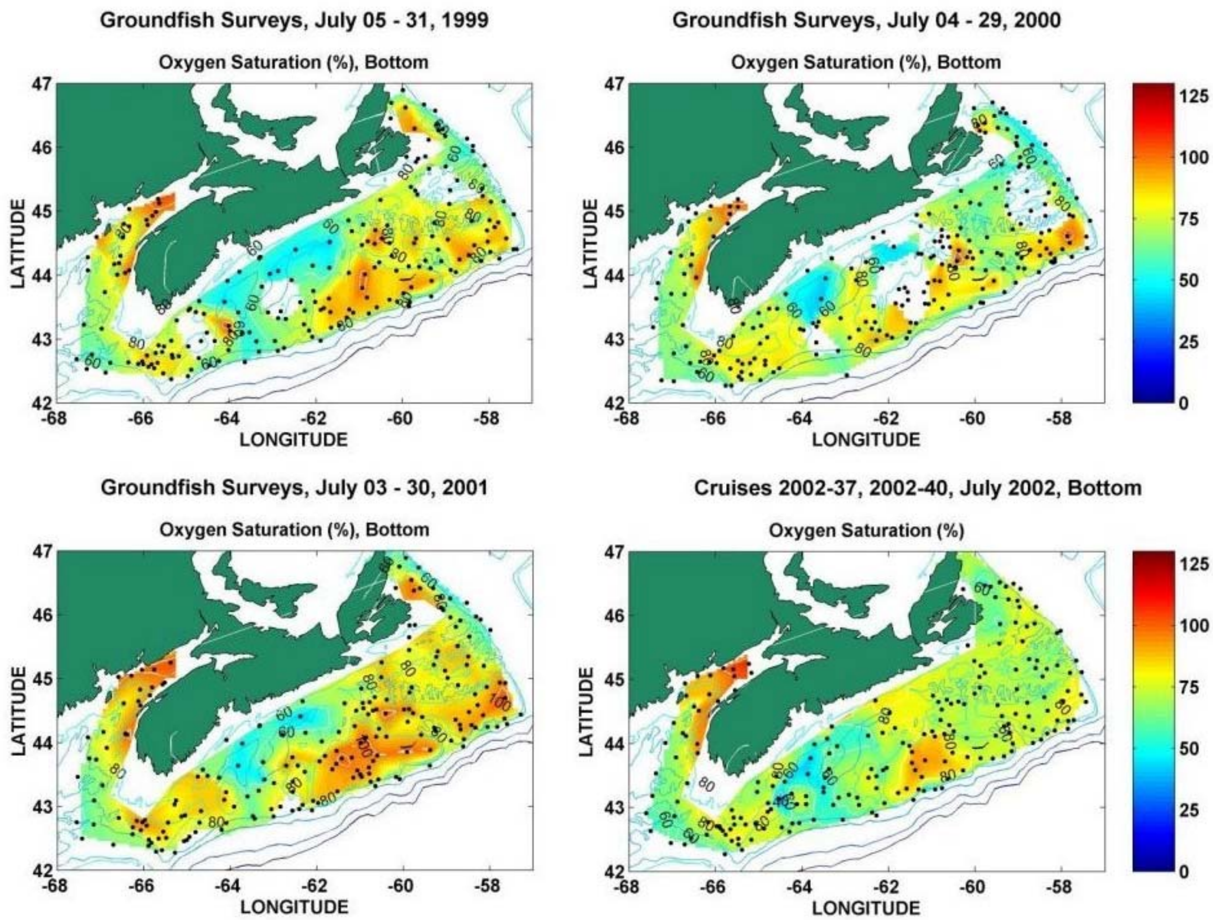

Figure 24. Surface chlorophyll concentrations on the eastern Scotian Shelf during the annual spring groundfish surveys, 2000-2002.

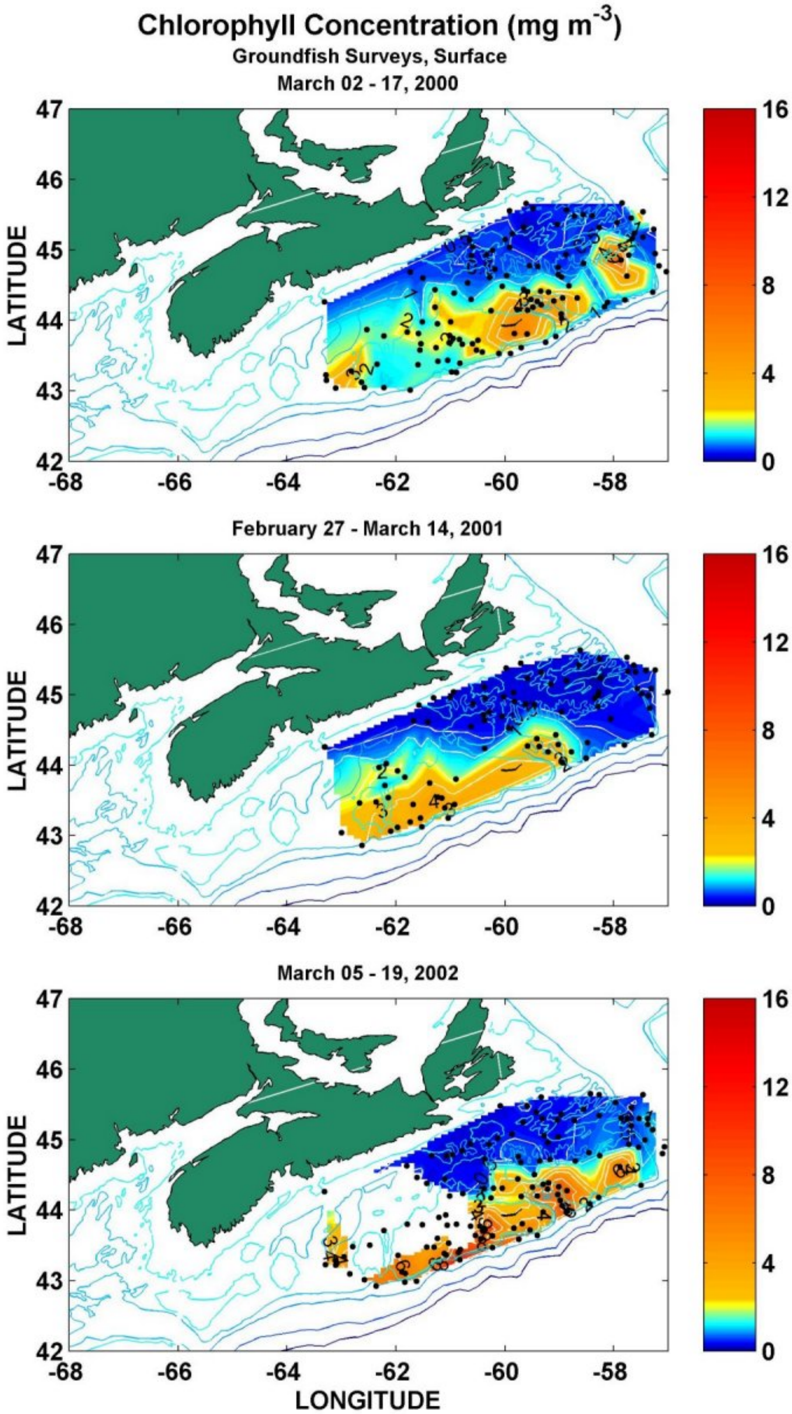

Figure 25. Surface chlorophyll concentrations on the Scotian Shelf and in the Southern Gulf of St. Lawrence during the annual groundfish surveys, 1999-2002.

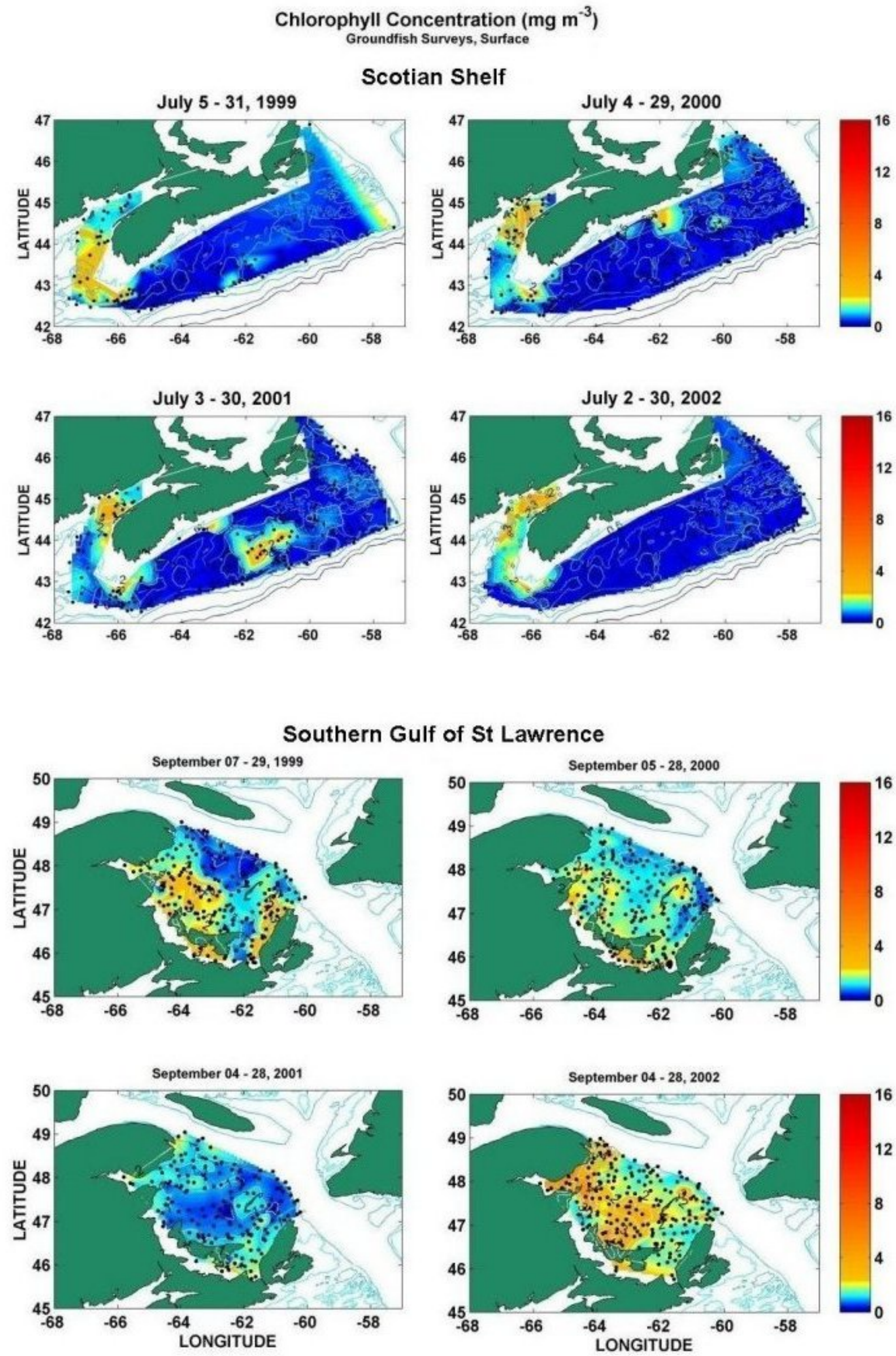

Figure 26. Zooplankton biomass on Georges Bank (February), the Scotian Shelf (March and July) and the southern Gulf of St. Lawrence (September) during the annual groundfish surveys, 2000-2002.

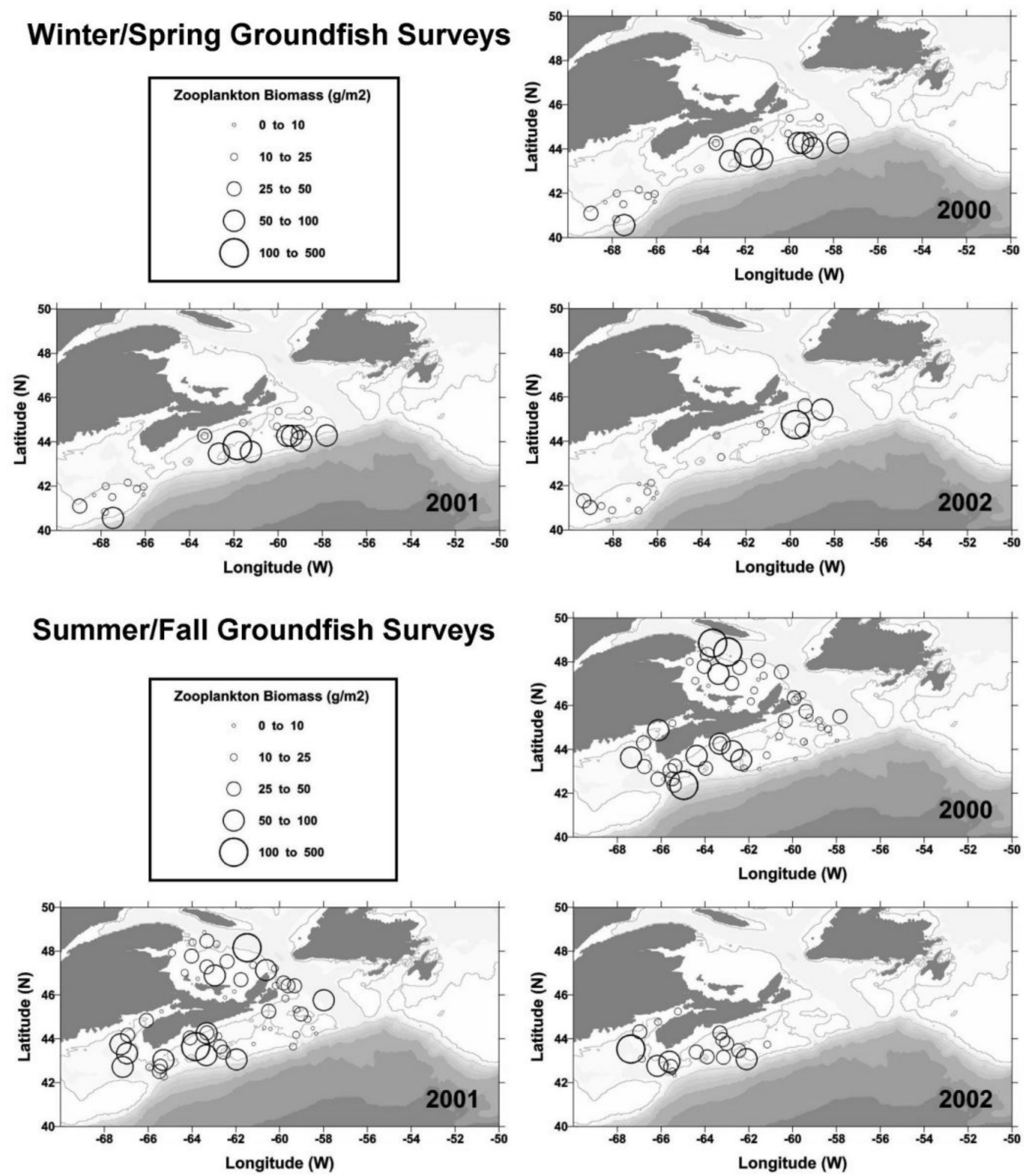

Figure 27. **Time-series of surface chlorophyll concentrations (from SeaWiFS bi-weekly ocean colour composites) at the six AZMP fixed stations, 1998-2002.**

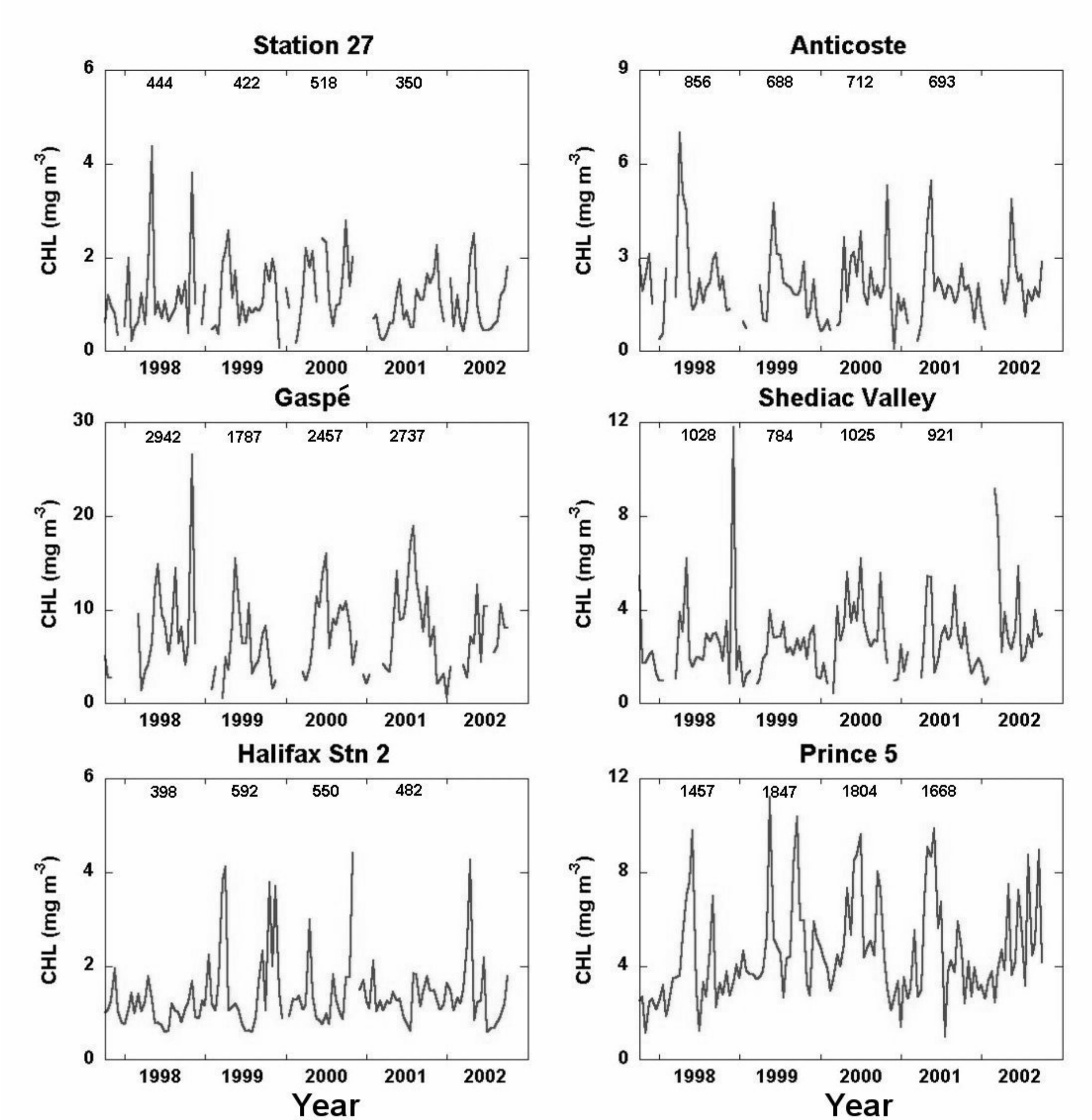

Figure 28. **Comparison of *in-situ* and SeaWiFS-derived surface chlorophyll concentrations for the Halifax-2 fixed station and the central Scotian Shelf sub-region (see Fig. 5).**

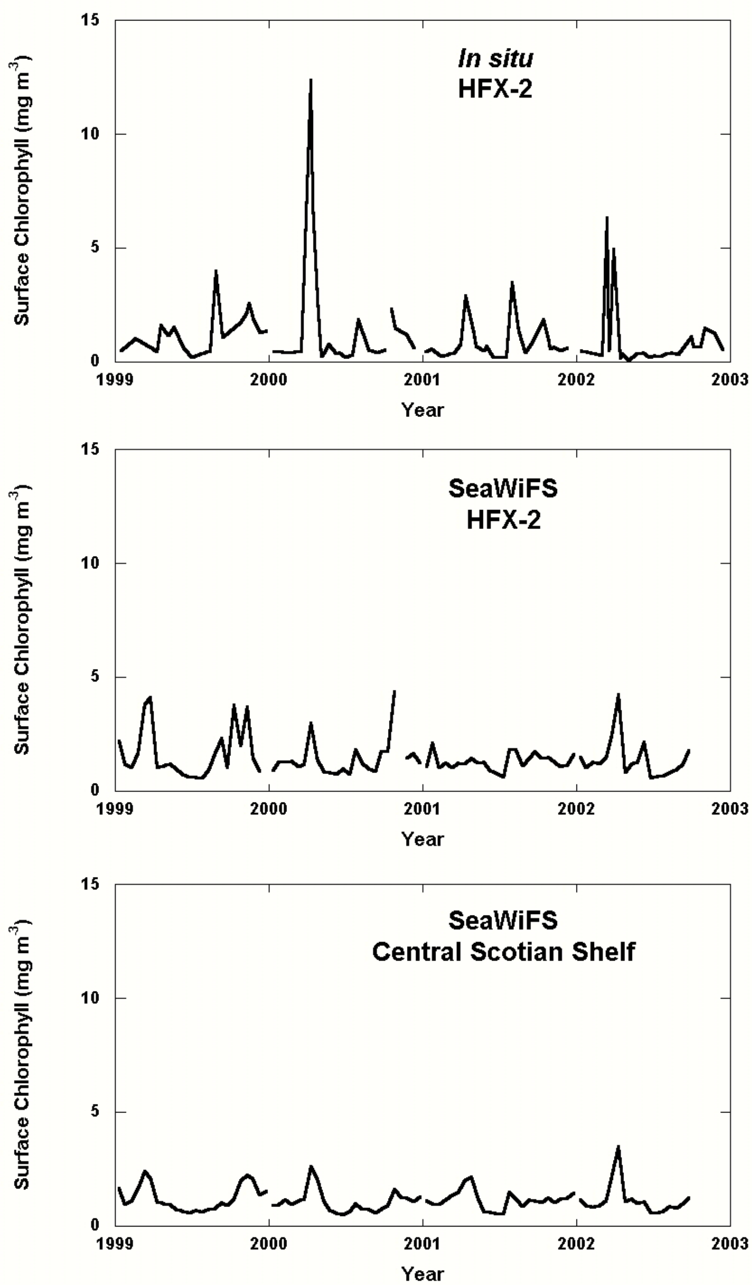

Figure 29. Time-series of surface chlorophyll concentrations (from SeaWiFS bi-weekly ocean colour composites) along the Maritimes/Gulf sections (see Fig. 1), 1998-2002. Vertical axis is distance from shore.

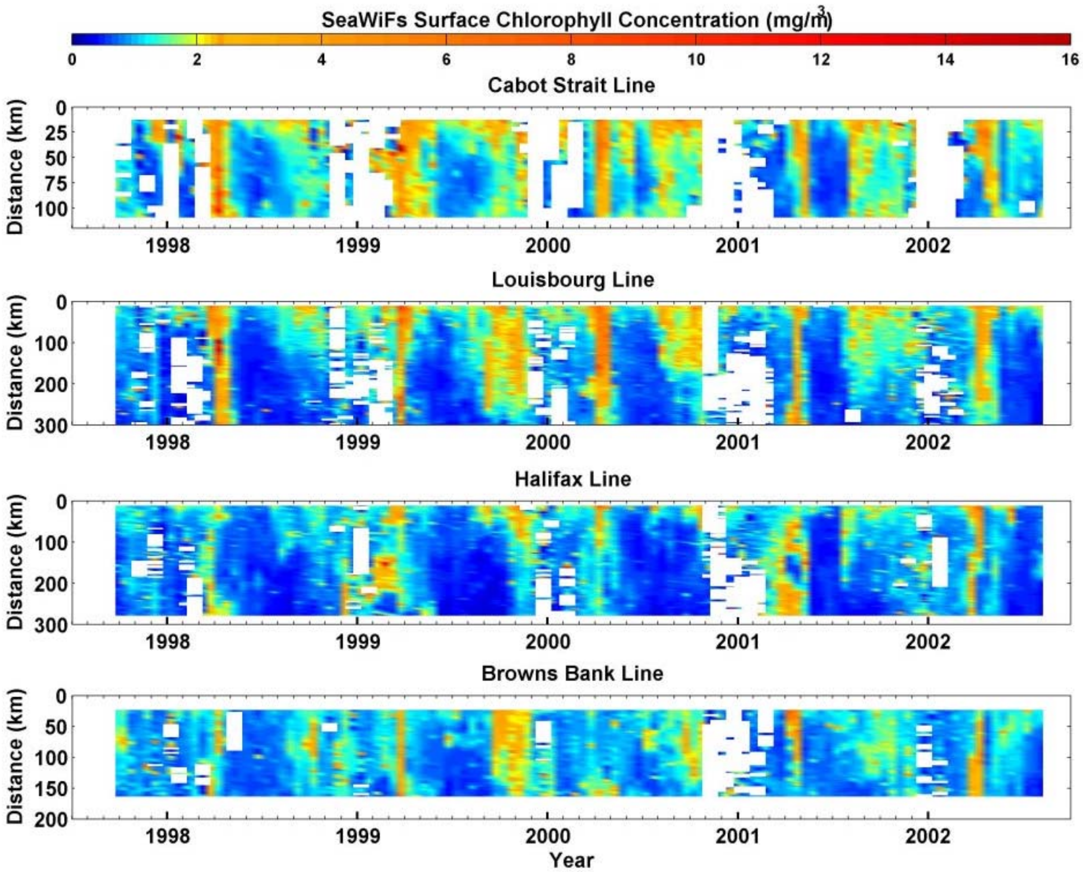

Figure 30. **Time-series of surface chlorophyll concentrations (from SeaWiFS bi-weekly ocean colour composites) for statistical sub-regions of the Maritimes/Gulf Regions (see Fig. 5),1998-2002.**

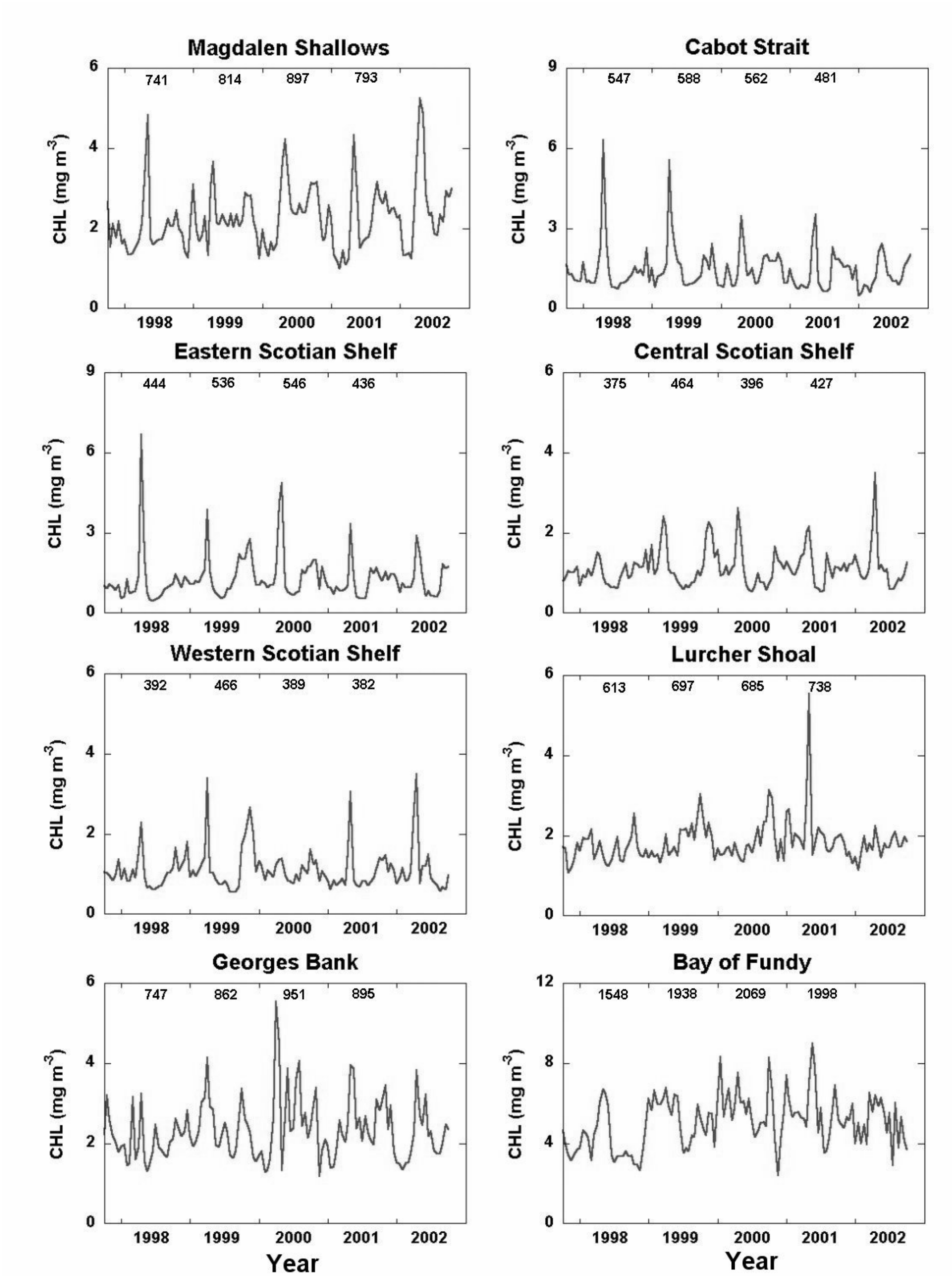

Figure 31. Surface chlorophyll conditions in the northwest Atlantic in 2002 from SeaWiFS composite images. Mean concentrations (January – September) in 2002 for the 24 statistical sub-regions (see Fig. 5) were compared with means concentrations for the total data record (1998-2002) and expressed as percent change. Dashed lines are +/- one standard deviation (expressed as % of mean) of the 1998-2002 data record.

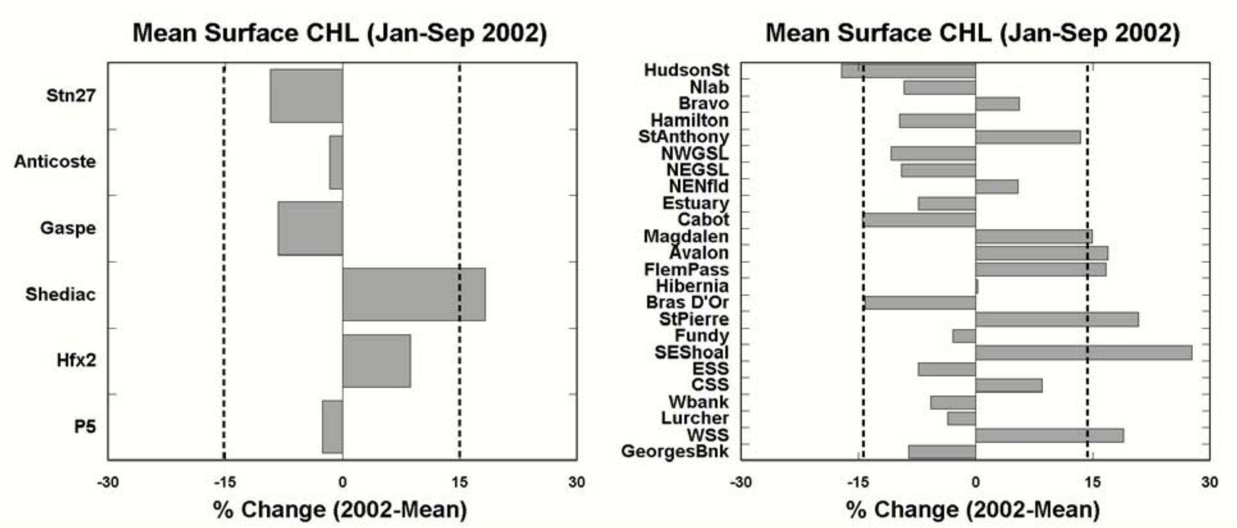

Figure 32. **Time-series of phytoplankton biomass (colour index), diatom and dinoflagellate relative abundances (annual means) on the Scotian Shelf and the Northwest Atlantic from CPR surveys, 1961-2001 (see Fig. 4 for area coverage). Vertical bars are standard errors.**

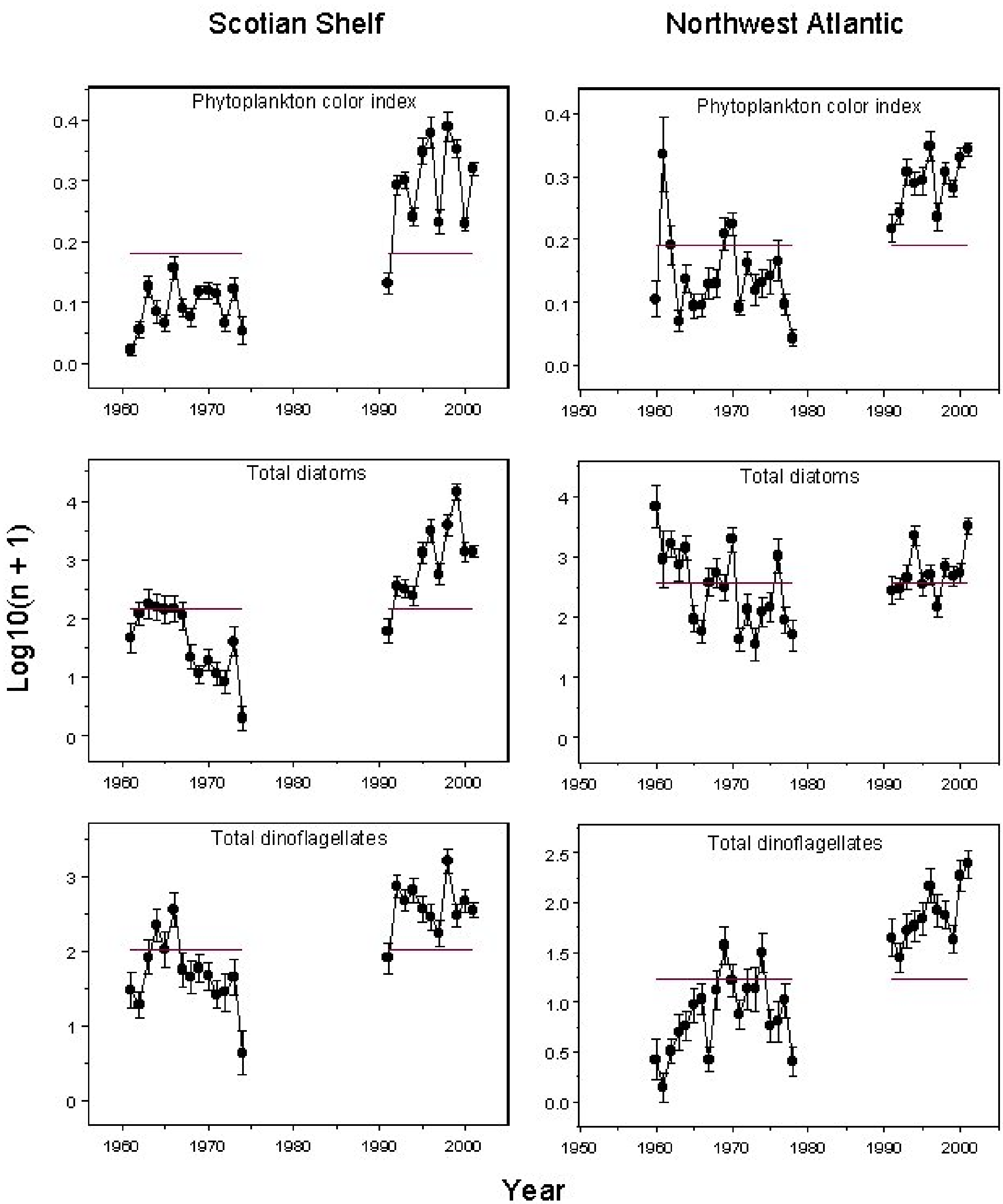

Figure 33. Monthly means of phytoplankton adundance on the Scotian Shelf in 2001 from CPR surveys. Means for the decades of the 1960s and 1990s shown for comparison.

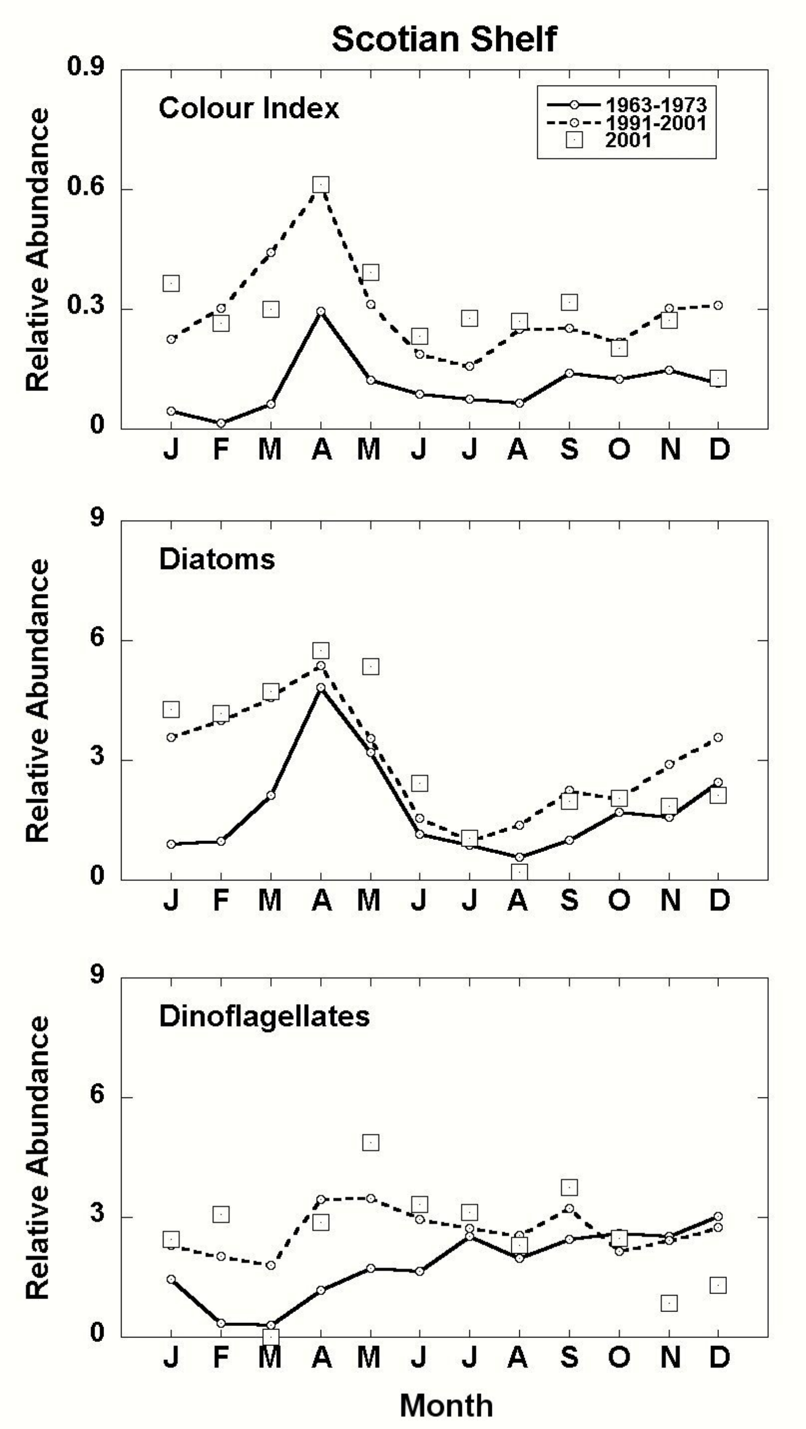

Figure 34. **Time-series of relative abundances of selected zooplankton species (annual means) on the Scotian Shelf and the Northwest Atlantic from CPR surveys, 1961-2001 (see Fig. 4 for area coverage). Vertical bars are standard errors.**

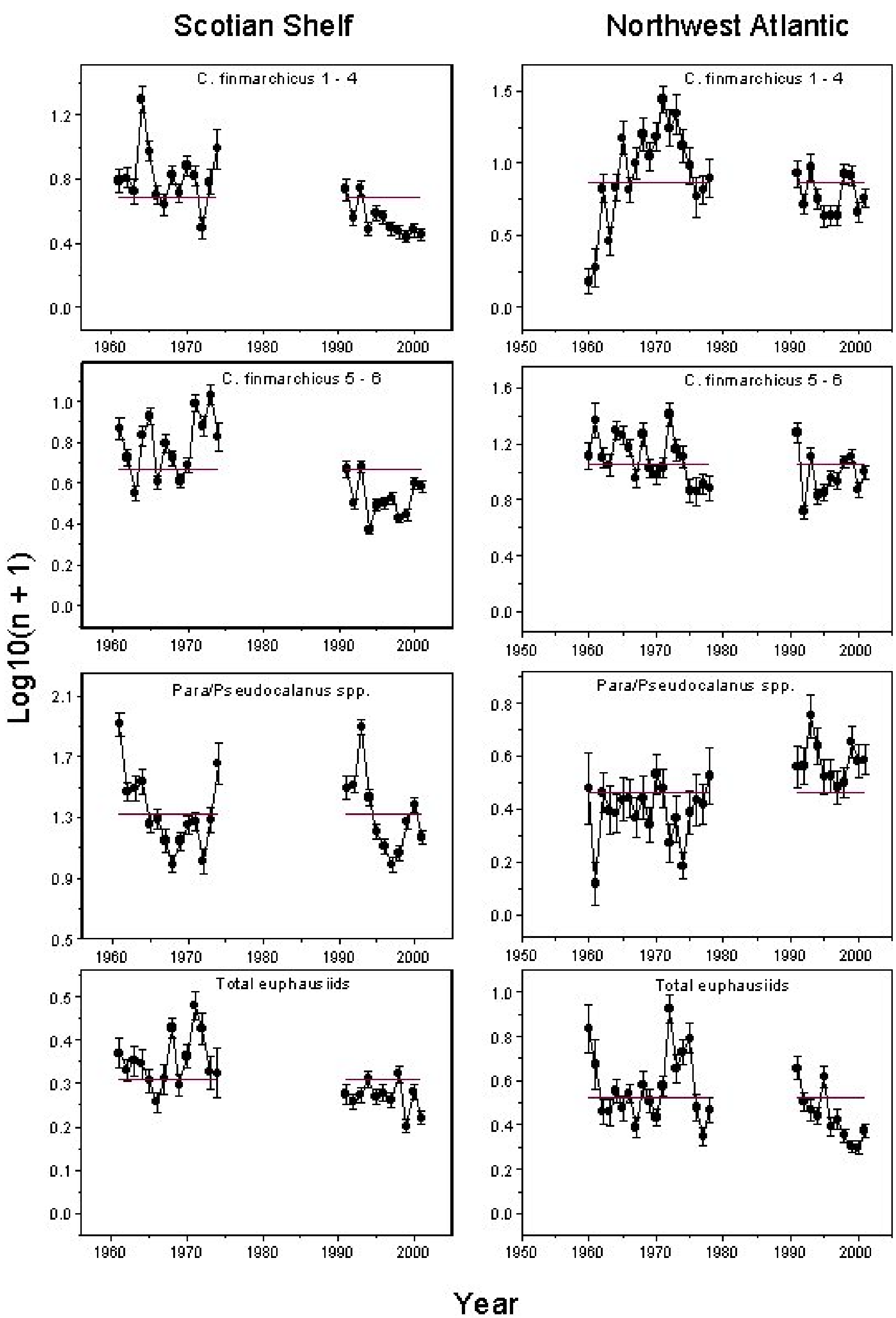

Figure 35. **Monthly means of zooplankton abundance on the Scotian Shelf in 2001 from CPR surveys. Means for the decades of the 1960s and 1990s shown for comparison.**