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Optical, chemical and biological oceanographic conditions in the Maritimes/Gulf regions in 2003.

Propriétés optiques, chimiques et biologiques de l'océan dans les régions des Maritimes et du Golfe en 2003.

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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 2003 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 2003 were, for the most part, comparable to conditions observed in previous years. Light attenuance, however, was lower (and euphotic depths deeper) at Shediac Valley than in the previous year, due in large measure to the lower (but more typical) chlorophyll levels observed there compared to the record high levels seen in 2002. Indices of stratification at the fixed stations followed patterns seen previously, however, winter-time mixed-layer depths were somewhat deeper at Halifax than seen in the previous year.

Nitrate levels below surface (>50 m) were somewhat lower at all the fixed stations in 2003 than seen in the previous year and considerably lower than the climatological mean (Halifax-2). Surface nitrate levels in winter, however, were higher at Halifax-2 and Prince-5 than in the previous year; levels at Halifax-2 were the highest seen in the 5-year AZMP data record for that station.

The most prominent feature of the phytoplankton in the Maritimes/Gulf regions in 2003 was the widespread and large spring bloom. Record high chlorophyll concentrations were seen at the Halifax-2 fixed station, during the spring seasonal sections survey and groundfish survey as well as being evident from Georges Bank to the Newfoundland coastal waters from satellite ocean colour data. At the Halifax-2 fixed station and adjacent waters, the bloom was not only of greater magnitude than seen before but also appeared to persist longer than normal. In contrast to most regions, chlorophyll levels were lower in 2003 in the Southern Gulf than seen in the previous year, however, in 2002 chlorophyll was unusually high in the Southern Gulf. The diatom-dominated phytoplankton community seen in the Southern Gulf in 2002 reverted in 2003 back to the more typical mix of diatoms and post-bloom flagellates. CPR data continue to show that contemporary phytoplankton levels are well above the long-term mean and that the seasonal growth cycle started earlier in the year than seen during the first decade of observations in the 1960s and 1970s.

Zooplankton levels, in general, increased at most sites in the Maritimes/Gulf regions in 2003. This was most evident at the Shediac Valley fixed station where the steady yearly increase in biomass and *C. finmarchicus* abundance reached record high levels in 2003. Higher *C. finmarchicus* abundance was also seen at Halifax-2, reversing the recent trend of declining numbers. In 2003, the timing of *C. finmarchicus* reproduction at Halifax-2 appeared to be later than in the previous year. At all fixed stations, but most prominent at Prince-5, the contribution of *C. finmarchicus* to the copepod community has steadily increase over the past few years; reaching highest fractions on record in 2003. Despite increases at the fixed stations, zooplankton biomass on Georges Bank in winter appears to be on the decline; lowest levels on record were observed in 2003. 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 now that during the decade of the 1960s and 1970s when observations began.

RÉSUMÉ

On passe en revue 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 2003, puis on les compare 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 (EPC), télédétection), on examine un certain nombre de données provenant de l'extérieur de ces régions 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 2003 étaient comparables aux conditions observées les années précédentes. L'atténuation de la lumière, toutefois, était moins marquée (et la couche euphotique plus profonde) dans la vallée de Shédiac que l'année précédente, en grande mesure à cause des teneurs en chlorophylle plus faibles (mais plus typiques) observées à cet endroit en comparaison des teneurs records atteintes en 2002. Les indices de stratification aux stations fixes suivaient les tendances observées par le passé; toutefois la couche de mélange en hiver était quelque peu plus profonde à Halifax que l'année précédente.

Les teneurs en nitrate sous la surface (>50 m) aux stations fixes étaient un peu plus faibles en 2003 que les teneurs observées l'année précédente et considérablement plus faibles que la moyenne climatologique (Halifax-2). Toutefois, les teneurs en nitrate en surface, au cours de l'hiver, étaient plus élevées à Halifax-2 et à Prince-5 en comparaison de l'année précédente; les teneurs observées à Halifax-2 correspondaient aux données les plus élevées du PMZA enregistrées depuis 5 ans à cette station.

L'étendue et l'ampleur de l'efflorescence printanière caractérisaient le phytoplancton dans les régions des Maritimes et du Golfe en 2003. Des teneurs records en chlorophylle ont été observées à la station fixe Halifax-2, pendant les transects printaniers et le relevé des poissons de fond, ce qui apparaissait évident dans les eaux côtières du banc Georges jusqu'à Terre-Neuve d'après les données satellitaires sur la couleur de l'océan. À la station fixe Halifax-2 et dans les eaux adjacentes, non seulement l'efflorescence était de plus grande ampleur que par le passé, mais encore elle semblait persister plus longtemps que la normale. Contrairement à la plupart des régions, les teneurs en chlorophylle étaient plus faibles en 2003 dans le sud du golfe qu'au cours de l'année précédente, quoique, en 2002 la teneur en chlorophylle ait été exceptionnellement élevée dans le sud du golfe. La communauté phytoplanctonique dominée par les diatomées, observée en 2002 dans le sud du golfe, est revenue en 2003 au mélange plus typique de diatomées et de flagellés après l'efflorescence. Les données EPC continuent à indiquer que les niveaux d'abondance récents du phytoplancton se situent bien au-dessus de la moyenne à long terme et que le cycle de croissance saisonnière a débuté plus tôt dans l'année que ce n'était le cas durant la première décennie d'observations des années 60 à 70.

En général, les niveaux d'abondance du zooplancton ont augmenté à la plupart des sites dans les régions des Maritimes et du Golfe en 2003. Cela était davantage évident à la station fixe de la vallée de Shédiac où l'augmentation annuelle sans interruption de la biomasse et du niveau d'abondance de *C. finmarchicus* a atteint des niveaux records en 2003. On a également observé que *C. finmarchicus* était plus abondant à Halifax-2, signe d'un renversement de la tendance récente à la baisse. En 2003, il semble que le début de la reproduction de *C. finmarchicus* à Halifax-2 se soit produit plus tard que dans l'année précédente. À toutes les stations fixes, mais de façon plus marquée à Prince-5, la contribution de *C. finmarchicus* à la communauté des copépodes a augmenté de façon régulière au cours des quelques dernières années, atteignant les proportions les plus élevées enregistrées en 2003. En dépit des augmentations relevées aux stations fixes, la biomasse zooplanctonique au banc Georges, en hiver, semble décliner; les niveaux les plus bas jamais enregistrés ont été observés en 2003. Les données EPC continuent d'indiquer que les niveaux d'abondance récents du zooplancton se situent bien au-dessous de la moyenne à long terme et que le pic d'abondance saisonnier d'importantes espèces, comme *C. finmarchicus*, se manifeste maintenant plus tôt dans l'année que pendant la décennie des années 60 à 70, marquant le début des observations.

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 2003. 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 8 missions (seasonal section cruises and groundfish surveys) during the 2003 calendar year in addition to repeat trips to the 3 fixed stations; 596 station occupations were the total sampled 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 2003, Halifax-2 and Prince-5 were sampled on 21 and 17 occasions, respectively. Shediac was sampled only 11 times due to the ice-truncated open water season in that area. Fixed station occupations were reduced from our high in 2002. An extreme ice year, difficulty obtaining suitable platforms and the conscious decision to reduce effort at Prince-5 were the major factors resulting in the reduced sampling in 2003.

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) as the common suite.
- Niskin water bottle samples at standard depths for nutrient, calibration salinity, calibration oxygen, and chlorophyll analyses as the common suite of measurements.

- Niskin water bottle sample for phytoplankton enumeration.
- Vertical ring net tows for zooplankton biomass and enumeration,
- Secchi depth reading when possible.

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 2003, the spring cruise was much abbreviated and the Cabot Strait Line was not occupied at all since a platform was not available until well after our original promised date and conflicts with other programs became an issue. However, certain information was available from the Quebec region; who did manage to occupy the line on their spring mission.

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 salinity, calibration oxygen, POC 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).

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 (as a minimum) 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 – near-surface, 10, 20, 30, 40, 50, 60, 80, 100, 250, 500, 1000, 1500, 2000 m (depth dependent)
- Groundfish surveys - 5m, near bottom (minimum sample set)

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. 2002 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 dominated the attenuation of light (Fig. 8). At Shediac Valley also chlorophyll-derived attanuance coefficients were lower than Secchi and PAR estimates in many instances but not to the extent as at Prince-5 (Fig. 6). A similar discrepancy was noted at Shediac Valley in 1999 but in the intervening years, phytoplankton were the dominant contributors to light attenuation. At Halifax-2, in contrast, chlorophyll-derived attenuance was considerably greater than Secchi or PAR estimates during the peak of the spring bloom in 2003 (Fig. 7) but the rest of the year as seen at Shediac, phytoplankton were the dominant contributors to light attenuance. Depth of the euphotic zone in 2003 varied seasonally (deepest in winter, shallowest during spring) and ranged from 40-60 m at Halifax-2 and 20-40m at Shediac Valley. At Prince-5, euphotic depths showed no seasonal cycle and were remarkably constant at ~20m. In general, seasonal patterns and magnitudes of optical properties in 2003 at Halifax-2 and Prince-5 were similar to those observed in previous years. At Shediac Valley, however, light attenuance was lower and euphotic depths deeper in 2003 than in 2002 (when record high chlorophyll levels were seen) but similar to earlier years.

Seasonal development of the mixed-layer and upper water-column stratification was most evident at the Shediac Valley and Halifax-2 stations (Figs. 6, 7); shallow mixed layers (~10 m) and maximum stratification (~0.1 kg m^{-4}) were evident throughout the summer and early fall months (May-September). Stratification and mixed-layer depths at Halifax-2 were more variable than at Shediac (Fig. 7). Maximum winter-time mixed-layers at Halifax-2 in early 2003 were deeper (~80 m) than the previous winter (~60 m) but shallower than the >100 m mixed layers seen in 2001. In marked contrast to the other fixed stations, stratification was extremely low (<0.01 kg m^{-4}) at Prince-5 (Fig. 8). Mixed-layer depths are difficult to determine at this station due to the very small vertical density differences, although estimates ranged from ~40m in summer to full depth in winter in 2003.

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/early summer reduction in near surface nitrate concentrations was seen at all Maritimes/Gulf fixed stations in 2003 (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 mmol m^{-3}) in summer was greater at Halifax-2 (30-40 m) than at Shediac Valley (20-30 m). Nitrate depletion depths in 2002 at both stations were similar to depths seen in 2001. Nitrate concentrations at Prince-5 were never reduced below ~4 mmol m^{-3}. The seasonal evolution of the vertical nitrate structure at all fixed stations in 2003 was similar to that seen in previous years. Concentrations at depth (50-100 m) were slightly lower in 2003 than in 2002 at all stations. Nitrate anomaly plots for Halifax-2 (Fig. 9) showed that concentrations in 2003 (and 2002) were still below (-2 to –4 mmol m^{-3}) the climatological means in the deeper waters but less negative than during the three years previous (-8 to -10 mmol m^{-3}).

Seasonal variability in nitrate in the upper 50 m (depth zone over which nutrient dynamics are strongly influenced by biological processes) indicated that inventories were lower in surface waters at Shediac Valley and unchanged at Halifax-2 and Prince-5 in 2003 compared with 2002 (Fig. 10). Nitrate levels at Halifax-2 were also significantly lower than the climatological mean. Despite the low annual inventories, the highest winter-time nitrate concentrations (>400 mmol m^{-2}) in the 5 year data record were seen at Halifax-2 in 2003. Winter nitrate levels at Shediac are unknown because of station inaccessibility due to ice cover; levels are likely significantly reduced from biological consumption by the time sampling begins in late April/early May. Like Halifax-2, winter nitrate levels at Prince-5 were somewhat higher in 2003 than in 2002 and continued an upward trend observed over the past 3 years (from 430 to 490 mmol m^{-2}). Summer-time minimum concentrations at Prince-5, increasing over the past 4 years (from 170 to 250 mmol m^{-2}), appeared to stabilize in 2003. Overall, annual nitrate inventories continue to be greatest at Prince-5 and lowest at Halifax-2.

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 in the spring, only the latter phase of the spring bloom is normally caught in sampling at the Shediac Valley station; this was the case for 2003. Because of ice, the magnitude of the spring bloom at this station from field sampling cannot be determined. Chlorophyll concentrations at Shediac Valley in 2003 were lower, particularly during summer, than the 4-year record highs seen in 2002 but similar to level seen in previous years. Unique for 2003 was the appearance of a strong autumn bloom (max: ~4 mg m^{-3}), coincident with the passage in late September of the category-2 hurricane, "Juan". Chlorophyll inventories at Shediac in 2003 showed the fall bloom (>250 mg m^{-2}) to be a significant contributor on an annual basis (Fig. 10). Evolution of the phytoplankton community composition at Shediac Valley in 2003 also differed from the previous year, i.e. flagellates represented a more important fraction (up to 60%) of the community than seen in 2002 (generally 20% or less) but more typical of years previous (Fig. 12). An unusually strong spring bloom characterized the phytoplankton growth cycle at Halifax-2 in 2003; 5-year record high chlorophyll concentrations (>12 mg m^{-3} or almost 800 mg m^{-2}) were observed. Anomaly plots suggested that the 2003 spring bloom was also higher than historical levels and lasted longer (Fig. 11). Because of a sampling gap in early April, it was not possible to determine the time of bloom initiation at this station.

Interestingly, the magnitude of the spring bloom at this station has been increasing steadily since AZMP observations began in 1999. The phytoplankton community structure at Halifax-2 in 2003 was similar to that seen in previous years where diatoms dominated (>80%) during the spring and autumn blooms and flagellates became more prominent (50-80%) during inter-bloom periods in summer and late fall. In 2003, however, diatoms were somewhat more important late in the year at Halifax-2 than seen in previous years. The phytoplankton growth cycle at Prince-5 in 2003, in contrast to that at Shediac Valley and Halifax-2; was characterized by a sustained burst of growth beginning in early summer and lasting until fall; levels were generally comparable to 2002 levels. As has been noted previously, the phytoplankton community at Prince-5 are almost exclusively comprised of diatoms (>90%), year-round. In the past, Prince-5 sustained the largest phytoplankton inventories on an annual basis, however, the strong spring bloom at Halifax-2 in 2003 changed the ranking: Halifax-2>Prince-5>Shediac Valley.

Zooplankton. Zooplankton biomass at all of the Maritimes/Gulf fixed stations was higher in 2003 than in 2002 (Fig. 13). Biomass at Shediac Valley was the highest of the 5-year AZMP record (max: >200 g ww m^{-2}) and averaged annually about 2-fold higher than seen in previous years. Biomass was also up at Halifax-2 in 2003 (~40 g ww m^{-2}) by about 2-fold from 2002 levels. Averaged over the year, zooplankton biomass at Prince-5 in 2003 was comparable to 2002 levels except that a sharp rise right at the end of the year was noted. Zooplankton biomass at Prince-5 is typically only a small fraction (10-20%) of the biomass at the other fixed stations.

As was the case for zooplankton biomass, *Calanus finmarchicus* abundance at all the fixed stations was up in 2003 from 2002 levels (Fig. 13). *C. finmarchicus* abundance at Shediac Valley was at 5-year record highs (max: >500,000 ind m^{-2}), exceeding numbers in previous years by at least 3-fold. *C. finmarchicus* numbers at this station, in fact, have been steadily increasing since AZMP sampling began in 1999. At Halifax-2 the increase in *C. finmarchicus* abundance in 2003 reversed a downward trend seen in the previous 3 years. *C. finmarchicus* abundance at Prince-5 , same as the case for zooplankton biomass, was relatively unchanged in 2003 from levels seen 2002 except for an end of the year peak. *C. finmarchicus* abundance at Prince-5 is typically only a small fraction of the counts of that species at the other fixed stations. During the first 3 years of AZMP observations, *C. finmarchicus* abundance was highest at Halifax-2 but over the past two years highest levels have been seen at Shediac Valley.

Hierarchical community analysis revealed that copepods continued to numerically dominated the zooplankton year-round at all of the Maritimes/Gulf fixed stations in 2003 (Fig. 14). Significant numbers of jellies and appendicularians seen at Shediac Valley and Halifax-2 in early summer in 2002 were absent at Shediac in 2003. A recurring pulse of echinoderm and barnacle larvae and euphausiids were observed again in 2003 at Prince-5 in spring. 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 2003 as in previous years (Fig. 15). In the first 3 years of AZMP, copepods were numerically dominant at Halifax-2 but that has appeared to shift to Shediac in the past 2 years. The relative importance of the larger *Calanus sp* appears to have been increasing at all fixed stations since AZMP sampling began in 1999. This is most evident at Prince-5 where *Calanus sp.* have steadily increased from <10% in 1999 to a record high of up to 40-80% in 2003. Also at Prince-5, "other" copepod species (e.g. *Acartia sp*., herpacticoids) comprised a significant fraction (>60% in 2002 and 2003) of the copepods in summer whereas they played a minor role (<10%) at Sheciac and Halifax-2. An exception was the post spring period at Shediac where "other" species comprised as much as 50% of the copepod count. 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 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 as in previous years. The timing of reproduction off Halifax may have been somewhat later in 2003 than in 2002 based on first appearance of young stages, i.e. late March in 2003 versus early/mid March in 2002. Moreoever, the disappearance of small stages later in the season suggested that reproduction in 2003 may have lasted somewhat longer in 2003 than in 2002.

Seasonal Sections

Nutrients. Vertical distributions of nitrate in spring and autumn were generally similar along the Scotian Shelf sections in 2003, i.e. concentrations were low (<1 mmol m^{-3}) in near surface waters (<50 m), as a result of phytoplankton consumption, and increased with depth (Figs. 17, 18). Deep-water concentrations were highest in basins (>12 mmol m^{-3}) and in slope waters off the edge of the shelf. As in the previous year (Harrison et al. 2003), nitrate levels in surface waters were already significantly depleted by the spring survey in April (1 mmol m^{-3} depth horizon: 20-40 m). Likewise, surface nitrate concentrations were still low during the autumn survey in October (1 mmol m^{-3} depth horizon: 20-50 m), showing no evidence of seasonal mixing of nutrients from depth into surface waters. Nitrate inventories in the upper 50 m in 2003 were comparable to or slightly lower than levels observed in previous years (Fig. 19).

Phytoplankton. Chlorophyll levels during the spring 2003 survey were at 5-year record high concentrations (>10 mg m^{-3} or 300-700 mg m^{-2}) along all sections except Cabot Strait (Figs. 20, 22). Concentrations during the fall survey, in contrast, were an order of magnitude lower (<1 mg m^{-3} or 30-50 mg m^{-2}) and more typical for that time of year (Figs. 21, 22). Generally, a pronounced subsurface chlorophyll maximum layer is seen at stations along the Scotian Shelf sections in autumn (Harrison et al. 2003), however, highest concentrations in 2003 survey appeared to be confined to surface waters.

Zooplankton. Samples for zooplankton biomass and *C. finmarchicus* abundance were collected during both the spring and fall surveys, however, only the spring data are available at this time. Biomass (80-90 g ww m^{-2}) and *C. finmarchicus* abundance (20,000-60,000 ind m^{-2}) along all the Scotian Shelf sections in spring 2003 and comparable to levels seen in 2001 (no data were collected in spring 2002) (Fig. 23). *C. finmarchicus* abundance along the Louisbourg Line was significantly lower than along the Halifax and Browns Bank lines; a feature consistently seen in years previous (except 1999). Zooplankton biomass, on the other hand, was similar between the lines.

Groundfish Surveys

Nutrients. Bottom water nitrate concentrations on the Scotian Shelf in the July, 2003 (mean: 11.01 mmol m^{-3}) were essentially the same as levels seen in 2002 (mean: 10.96 mmol m^{-3}) (Table 2). Concentrations increased with water depth with highest levels observed in the deep basins on the shelf (e.g. Emerald Basin) and in slope waters off the shelf edge (Fig. 24). Bottom water nitrate concentrations in the Southern Gulf in September, on the other hand, were lower overall in 2003 (mean: 8.19 mmol m^{-3}) than in 2002 (mean: 10.91 mmol m^{-3}). Highest concentrations were found in the western basin and in deep waters of the Laurentian Channel. Similar to nitrate, bottom water oxygen saturation on the Scotian Shelf in summer 2003 (mean: 78% sat) was comparable to levels observed in 2002 (mean: 74% sat); lowest saturations were found in deep basins and deep waters off the shelf edge where nutrients are highest. Bottom water oxygen saturation in the Southern Gulf was marginally higher in 2003 (mean: 71% sat) than in 2002 (mean: 68% sat). Saturation levels in the Southern Gulf were minimum in the western basin and in the Laurentian Channel where nutrients were highest. Despite the fact that stations sampled during the 2003 Southern Gulf survey were reduced by half, geographic coverage was comparable to previous years and statistical comparisons (among years) should be valid.

Phytoplankton. Near-surface chlorophyll levels on the Eastern Scotian Shelf during the March 2003 groundfish survey were high (>10 mg m^{-3}), particularly on the outer central shelf (Fig. 25). A similar distribution pattern was seen in previous years although levels were highest on record in 2003. During the 2003 summer Scotian Shelf survey, chlorophyll levels were uniformly low (<1 mg m^{-3}) over most of the shelf with elevated concentrations (>2 mg m^{-3}) near the coast off SW Nova Scotia and approaches to the Bay of Fundy (Fig. 26). These areas are generally characterized by strong vertical mixing. Overall, summer surface chlorophyll concentrations on the Scotian Shelf in 2003 (mean: 0.72 mg m^{-3}) were somewhat higher than concentrations observed in 2002 (mean: 0.51 mg m^{-3}). The widespread, high surface chlorophyll concentrations seen during the fall 2002 groundfish survey in the Southern Gulf (mean: 2.36 mg m^{-3}) were absent in 2003; concentrations were significantly lower (mean: 1.13 mg m^{-3})

and more in line with concentrations observed prior to 2002 (Table 2). Concentrations tended to be highest the western basin as has been seen previously.

Zooplankton. 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. 27). Generally, however, biomass is highest in deep basins and deep waters off the edge of the shelf or in channels (e.g. Northeast Channel off Georges Bank, Laurentian Channel bounding the Southern Gulf). Additionally, during the summer surveys, biomass has consistently been higher on the western Scotian Shelf than on the eastern shelf. This is in contrast to the east-west comparability in biomass seen during the spring and fall surveys (Fig. 23). Over the past 4 years, zooplankton biomass in February on Georges Bank has steadily decreased (~39 g ww m^{-2} in 2000 to ~10 g ww m^{-2} in 2003). At the same time, biomass on the eastern Scotian Shelf in March has increased (~38 g ww m^{-2} in 2000 to ~84 g ww m^{-2} in 2003). Data collected during the summer/autumn surveys in 2003 are not yet available, however, there have been no trends in biomass on the Scotian Shelf in summer and in the Southern Gulf in autumn over the past 4 years; 36 +/- 8 g ww m^{-2} on the Scotian Shelf, 40 +/- 7 g ww m^{-2} in the Southern Gulf (Table 2). Zooplankton species data for the groundfish surveys are not yet available.

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 in the vicinity of the fixed stations, for example, confirmed the record high chlorophyll levels of the spring bloom at Halifax-2, i.e. >14 mg m^{-2} (Fig. 28). Moreover, SeaWiFS data suggested record high spring blooms in 2003 at Shediac (>20 mg m^{-2}) and Station 27 (>4 mg m^{-2}) off St. John’s, Newfoundland and strong blooms at Prince-5 and Anticoste. An equally informative 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, the high off-shelf chlorophyll concentrations observed during the annual spring groundfish surveys (Fig. 25) are also captured by the satellite data. 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 (Halifax and Browns Bank lines) (Fig. 29). The nature of the onset, duration and termination of the spring and fall blooms are also revealed in this type of graphical presentation and it shows where across the shelf phytoplankton biomass accumulates in surface waters. Spring blooms on the Scotian Shelf can be viewed as discrete, short-lived events whereas the fall blooms appear to be more diffuse and time-varying. This graphical representation also show, for example, that the spring blooms along the Halifax and Browns Bank lines were more intense in 2003 than during any of the previous years. It is also apparent that the onset of the blooms in 2003 was not noticeably different from previous years. It did appear, however, that the bloom along the inner Halifax line lasted somewhat longer in 2003 than in 2002, consistent with the field data from Halifax-2. At the larger scale (i.e. statistical sub-regions in the Maritimes/Gulf, see Fig. 5), record high spring blooms were seen in Cabot Strait (where a trend of decreasing spring bloom peaks was reversed), on the central and western Scotian Shelf and on Georges Bank (Fig. 30). Strong (although not the highest on record) blooms were also noted for the Magdalen Shallows and the eastern Scotian Shelf. Viewed on the largest scale (Northwest Atlantic: Hudson Strait to Georges Bank, see Fig. 5), and considering annual mean conditions, it was apparent that 2003 was a significant year for phytoplankton growth in only a few regions. Notably, increases were seen in the far northern and southern limits of the domain (Fig. 31). Curiously, the St. Pierre Bank region showed a significant decrease in annual chlorophyll levels in 2003 compared with the 1998-2002 mean.

Continuous Plankton Recorder (CPR)

The CPR is the longest data record available on plankton in the Northwest Atlantic (see Fig. 4). CPR data analysis lags AZMP reporting by one year; thus, only data up to 2002 are currently available. Nonetheless, the phytoplankton colour index and abundance of large diatoms and dinoflagellates on the

Scotian Shelf (57º-66ºW) have been dramatically higher starting in the early 1990s and continuing into the 2000s than levels seen in the 1960s and 1970s (Fig. 32). A similar pattern has been observed in the Northwest Atlantic (45º-53ºW); in that region, however, dinoflagellate increases have been more prominent than on the Scotian Shelf. 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. The colour index and diatoms in the Northwest Atlantic did not change appreciably between 2001 and 2002, however, dinoflagellates decreased in 2002. In 2002, and the 1990s in general, there appeared to be a shift in abundance toward earlier months; although peak abundance (April) did not change, much higher levels, particularly of diatoms, were seen in January-March on the Scotian Shelf compared to levels seen during the 1960s and 1970s (Fig. 33). In 2002, however, the increase in diatoms on the Scotian Shelf, appeared to be related to higher numbers during the later half of the year (June-November) rather than increases associated with the spring peak in abundance.

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 from a late 1990s low on the Scotian Shelf, however, numbers were steady or down in 2002. Most noteworthy were significant drops in *Paracalanus/Pseudocalanus sp.* and euphausiid numbers. In the former case, the downward trend was continued while in the latter case, a 4-year recovery (increase) in numbers was reversed. In the Northwest Atlantic, zooplankton numbers were largely unchanged in 2002. In marked contrast with the Scotian Shelf, *Paracalanus/Pseudocalanus sp* numbers in the Northwest Atlantic have been well above those seen in the 1960s and 1970s. A shift in peak abundance of *C. finmarchicus* and *Paracalanus/Pseudocalanus sp.* to earlier in the year in 2002 (and the 1990s in general) was apparent on the Scotian Shelf, similar to the seasonal shift seen in phytoplankton abundance (Fig. 35). The low numbers of *Paracalanus/Pseudocalanus sp.* and euphausiids seen on the Scotian Shelf in 2002 were evident in most months of the year.

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 2003 were similar to observations from previous years a number of differences were noteworthy.

Optics and mixing. The seasonal development of the mixed-layer, stratification and optical properties of the upper water-column are remarkably recurrent features at the Maritimes/Gulf fixed stations, the annual reproducibility of the hydrographic properties is particularly evident at the Shediac Valley station and the optical properties at Prince-5. The most notable difference in these physical properties in 2003 was evidence of a deeper winter mixed-layer at Halifax-2 than seen in 2002. This could have had a bearing on the record high winter-time nitrate inventories at the station and record high spring phytoplankton bloom the following spring. Other differences in 2003 included changes in optical properties at Sheciac Valley, i.e. attenuance coefficients were lower and euphotic depths deeper, due largely to the reduced summer chlorophyll levels in 2003 compared with the record high levels in 2002 that increased attenuance and reduced euphotic depths.

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 2003 to previous years; there were some differences, however. Deep-water (>50 m) nitrate concentrations at all of the fixed stations were somewhat lower in 2003 than highs observed in 2002 and well below the climatological mean (where long-term data exist). Bottom water nitrate concentrations observed during the autumn groundfish survey in the Southern Gulf were also lower than concentrations observed in 2002.

Annual nitrate inventories in the upper water column were somewhat lower at Shediac Valley in 2003 than in 2002. Winter inventories at Halifax-2 were the highest in the 5-year AZMP record in 2003 (lowest levels were seen in 2002). Winter nitrate levels were also up at Prince-5 in 2003. The high winter nitrate levels at Halifax-2 could be linked to the deeper winter mixing there in 2003 and larger spring bloom as discussed above. In contrast to Halifax-2, changes in vertical mixing at Prince-5 could not explain the increase in surface nitrate inventories observed in 2003; mixing to the bottom in winter is a common feature at Prince-5 (and nutrient levels are uniform surface to bottom). Advective processes would have to be at play to explain variations in winter nutrient levels.

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 2003, the most prominent of which was the widespread and large spring bloom. Record high levels of chlorophyll during the spring bloom were particularly evident at the Halifax-2 fixed station and on the central and western Scotian Shelf but also significant in the Cabot Strait and outside the Maritimes/Gulf Region (e.g. Station 27 off Newfoundland). Satellite ocean colour data suggested that the time of initiation of the 2003 bloom was not different from earlier years but there was some evidence that the bloom persisted longer in 2003 than in 2002 (i.e. from the Halifax-2 data and satellite chlorophyll changes along the Halifax line). Bloom timing (initiation) is regulated largely by the phytoplankton's light environment that is, in turn, determined by incident irradiance and mixed-layer properties. Bloom magnitude and duration is regulated largely by nutrient supply. Since, generally speaking, the timing of the 2003 spring bloom in the Maritimes/Gulf region was not an issue (based on evidence from satellite data) but the magnitude and duration were, one should be looking for changes (increases) in nutrient inventories (principally in the winter preceding) to explain the record bloom seen in 2003. Unfortunately, AZMP-Maritimes/Gulf monitors winter nutrient levels only at the Halifax-2 and Prince-5 fixed stations thus a broad-scale assessment of winter nutrient levels is not possible. Nonetheless, winter nitrate inventories at both these fixed stations were up in 2003 and at a 5-year high at Halifax-2. Still, the increase in winter nitrate at Halifax-2 did not appear large enough to account for the 2003 bloom that was some 2-fold larger than the 2002 bloom. Also, the steady increase in the magnitude of the spring bloom observed over the past 4 years at this station was not reflected in the winter nutrient inventories, i.e. they did not increase in a similar manner over that period. Moreover, climatological nitrate levels off Halifax are much higher than seen in 2003 but climatological chlorophyll levels are much lower than in 2003. Clearly, more must be involved in determining the magnitude of the spring bloom than winter nutrient levels. On the other hand, the link may be there but our convention AZMP sampling strategies may simply be inadequate to provide the appropriate data to test the hypothesis. Another factor that could determine bloom magnitude and duration would be on the loss side, i.e. "top-down" control from zooplankton grazing. Perhaps the apparent delay in *C. finmarchicus* reproduction at Halifax-2 in 2003 meant that grazing was reduced (or delayed) during the bloom period, allowing for greater phytoplankton biomass (chlorophyll) accumulation, resulting in a larger spring bloom than in previous years? Some progress in answering these important questions on bloom dynamics could be addressed through modelling (scenario-testing). On the longer term (CPR results), it appears that the spring phytoplankton bloom on the Scotian Shelf for the last decade has been much larger and started earlier in the year than blooms during the first decade of the CPR measurements beginning some 30 years ago.

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 Maritimes/Gulf data. Both biomass and numerical abundance of zooplankton are generally highest in spring and higher (summer and autumn) 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 Shediac Valley. Community composition, in a broad sense, has remained relatively unchanged within stations since AZMP observations began in 1999, e.g. the prevalence of copepods in the zooplankton community and importance of small copepod species (e.g. *Oithona*) at all stations year-round. The very regular and predictable seasonal emergence of barnacle/echinoderm larvae in the late spring at Prince-5 is another example. Some features of the zooplankton community were notable in 2003, however. The remarkable and steady increase in zooplankton biomass in general, and abundance of *C. finmarchicus* in particular, at Shediac Valley was most evident in 2003. Zooplankton biomass and *C. finmarchicus* abundance also increased at Halifax-2 and, with regard to the latter, reversing a multi-year trend of decline. The timing of *C. finmarchicus* reproduction at Halifax-2, in addition, appeared to be later than in the previous year, linked possibly to the colder water temperatures during the spring of 2003 and perhaps contributing, through reduced grazing, to the record high spring bloom. At all stations, the contribution of *C. finmarchicus* to the complement of copepod species has apparently been on the increase since AZMP sampling began in 1999, the increase in the proportion of *C. finmarchicus* at Prince-5 was most striking in 2003. The causes of these changes in species composition are unclear. Major changes in zooplankton biomass have also been occurring on Georges Bank in winter and the eastern Scotian Shelf in spring (i.e. the former declining by a factor of 4 in four years and the latter increasing by a factor of 2). Causes for these biomass changes are also unclear and whether this reflects true (annual) changes or seasonal shifts in abundance is unknown at this point. At the larger scale and over the long-term, CPR data record shows that contemporary zooplankton abundance, in general, has been considerably lower over the past decade than it was during the decade following the initiation of the CPR surveys in the 1960s. The explanation for the this fundamental shift (decrease) in zooplankton in recent years in the presence of an increasing food supply (phytoplankton) is still a major unknown.

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REFERENCES

DFO, 2000. Chemical and biological oceanographic conditions 1998 and 1999 – Maritimes region. DFO Science Stock Status Report G3-03 (2000).

DFO. 2002. Chemical and biological oceanographic conditions in 2001 – Gulf of Maine, Bay of Fundy, Scotian Shelf and Southern Gulf of St. Lawrence. DFO Science Stock Status Report G3-03 (2002).

Harrison, G., D. Sameoto, J. Spry, K. Pauley, H. Maass and V. Soukhovtsev. 2003. Optical, chemical and biological oceanographic conditions on the Scotian Shelf, in the Gulf of Maine/Bay of Fundy and Southern Gulf of St. Lawrence in 2002. Can. Sci. Adv. Sec. Res. Doc. 2003/072, 50 pp.

Mitchell, M. (ed). 2002. Atlantic Zonal Monitoring Program: Sampling Protocol. Can. Tech. Rep. Hydrogr. Ocean Sci. 223, 23 pp.

Petrie, B., P. Yeats and P. Strain. 1999. Nitrate, silicate and phosphate atlas for the Scotian Shelf and the Gulf of Maine. Can. Tech. Rep. Hydrogr. Ocean Sci. 203, 96 pp.

Platt, T., S. Sathyendranath, C.M. Caverhill, and M.R. Lewis. 1988. Ocean primary production and available light: further algorithms for remote sensing. Deep-Sea Res. *35(6):* 855-879.

Sameoto, D.D. and A.W. Herman. 1992. Effect of the outflow from the Gulf of St. Lawrence on Nova Scotia shelf zooplankton. Can. J. Fish. Aq. Sci. 49: 857-869.

Therriault, J.C., et al. (11 co-authors). 1998. Proposal for a Northwest Atlantic Zonal Monitoring Program. Can. Tech. Rep. Hydrogr. Ocean Sci. 194, 57 pp.

Table 1. AZMP Sampling Missions in the Maritimes/Gulf regions, 2003.

Group	Location	Mission ID	Dates	# Hydro Stns	# Net Stns
Groundfish Surveys	Georges Bank	NED2003002	Feb 16 - 27	36	12
	Eastern Shelf	NED2003003	Mar 04 – 20	113	18
	Scotian Shelf	NED2003036	Jul 02 – 16	151	21
	Scotian Shelf	NED2003042	Jul 21 – 30	76	15
	SGSL	TEM2003052	Sep 16 – 28	90	5
Seasonal Sections	Scotian Shelf	HUD2003005	Apr. 12 – 19	26	25
	Scotian Shelf	HUD2003038	Jul 13 – 15	7	7
	Scotian Shelf	HUD2003067	Oct 19 – 31	46	30
Fixed Stations	Shediac	BCD2003668 +	Apr 20* – Dec 10	12	11
	Halifax-2	BCD2003666 +	Jan 15 – Dec 22	21	21
	Prince-5	BCD2003669	Jan 03 – Dec 19	18	15
			Total:	**596**	**180**

Table 2. Chemical and biological properties of the 1999-2003 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 ($gm\ ww\ m^{-2}$)	C. finmarchicus ($Ind\ m^{-2}$)
Scotian Shelf						
	1999	**0.93** (0.10-7.07) 137	**13.22** (2.12-24.06) 163	**76.7** (41.9-106.7) 197	**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	**27.0** (1.0-120.1) 38	
	2003	**0.72** (0.03-6.65) 214	**11.01** (0.14-23.27) 213	**78** (34-109) 217		
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** (2.9-142.0) 18	
	2002	**2.36** (0.75-5.97) 176	**10.91** (0.37-24.94) 175	**68** (28-95) 175	**42.5** (4.5-153.0) 18	
	2003	**1.13** (0.07-2.78) 83	**8.19** (0.23-24.53) 79	**71** (27-90) 79		