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Northwest Atlantic Plankton Trends 1959 to 2000

Tendances du plancton dans l'Atlantique Nord-Ouest de 1959 à 2000

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Abstract

Continuous Plankton Recorder Survey data collected for years 1959 to 2000 between Iceland and New England showed that significant changes occurred in the abundance and seasonal timing of the blooms of both phytoplankton and zooplankton taxa, phytoplankton increased and zooplankton decreased. The changes occurred after 1991 in the region west of longitude 45° W rather than, east of 45° W these changes were not observed. It is suggested that the plankton changes were related to changes in the Labrador Current system.

Résumé

Les données d'enregistrement continu du plancton recueillies de 1959 à 2000 entre l'Islande et la Nouvelle-Angleterre révèlent que des changements importants se sont produits dans l'abondance et le moment des efflorescences de phytoplancton et de zooplancton, la quantité de phytoplancton ayant augmenté et celle de zooplancton ayant diminué. Ces changements, qui se sont produits après 1991 dans la région située à l'ouest de 45 de longitude ouest, n'ont pas été observés à l'est de cette longitude. On pense que ces changements sont liés à des changements dans le système du courant du Labrador.

Introduction

The longest time series of data describing phytoplankton and zooplankton species concentrations northwestern Atlantic on the Canadian eastern continental shelf is the Continuous Plankton Recorder Survey (CPR) collected for The Sir Alister Hardy Foundation of Plymouth, England. These data were collected between 1959 to the present, with a break of a number of years from 1976 to 1991, along two transect lines, the Z-line running between Iceland and Newfoundland and the E-line between Newfoundland and the east coast of the United States of America. The CPR is towed by commercial and weather ships at an average depth of approximately 6.7 m (Hays and Warner 1993) at speeds of up to 20 knots. The CPR has a mouth opening of 1.25 cm^2 and a filtering mechanism inside the vehicle that collects samples of phytoplankton and zooplankton on a slowly moving band of bolting silk with a mesh size of about 285 x 315 µm. The sample is then covered with a second silk and wound onto a spool in a tank of formalin and preserved. The CPR is towed at regular monthly intervals along generally fixed shipping routes. Myers et al. (1994) analyzed the 1959-1992 data for the Northwest Atlantic and presented seasonal cycles, and long-term trends for zooplankton and phytoplankton for different geographic sub-regions corresponding to the Northwest Atlantic Fisheries Organization divisions which included the Scotian Shelf and Gulf of Maine.

This study examines selected CPR data collected during two periods the years 1961 to 1974 and 1991 to 2000 (the section from Newfoundland to New England), and from 1959 to 1985 and 1991 to 2000 (the section between Iceland and Newfoundland). The emphasis was placed on detecting temporal and spatial differences in phytoplankton and zooplankton abundance in different regions between Iceland and the East Coast of North America.

Methods

The track of the CPR sampling route changed in 1991, when it no longer crossed the Gulf of Maine but sampled across Georges Bank (Fig. 1). Since the Gulf of Maine and Georges Bank are distinctly different regions, a comparison for the region west of longitude 66°W could not be made between year’s 1961 -1976 and 1991- 1998.

The data were subdivided at longitude 45°W with the aim of detecting the influence of the Labrador Current in these data west of 45° W.

Data from seven taxonomic groups, *Calanus finmarchicus* stages 1 – 4, *C. finmarchicus* stages 5 – 6, *Paracalanus/Pseudocalanus,* total euphausiids, the phytoplankton color index, total dinoflagellates and total diatoms were transformed to $\log_{10}(x+1)$ to normalize the variance before any statistical analyses were calculated. A least squares cubic spline smoother was calculated using the program S-plus 2000 (MathSoft 1999) to demonstrate trends in abundance with time. The smoother relies on the data to specify the form of the model and the curve is fit to data points locally so that any point on the curve depends only on observations at that point and a specified range of neighbouring points. The smoother gives a more realistic representation of the data than a polynomial regression.

The data were contoured using the Kriging method with the program Surfer 6 (Keckler, 1995). All of the samples in the data series were included in the contouring analysis. The contoured data demonstrate changes in consecutive monthly abundance with longitude during the years 1961 to 1976 and 1991 to 2000. The time resolution of the contours was one month and the longitudinal spatial resolution was 0.5 °. Data from both lines were divided into four monthly segments, January to March, April to June, July to September and October to December. Data from each of these months for each of these segments were contoured with longitude versus sequential month indicated as year.

Contour plots were calculated for the abundance of zooplankton taxa *C. finmarchicus* copepodite stages 1 – 4, the combined group of *Paracalanus spp*. and *Pseudocalanus spp*., total euphausiids, the phytoplankton color index, total dinoflagellates and total diatoms. Reid (1998) described the phytoplankton color index as, "A visual index of chlorophyll based on the intensity of the green coloration of the CPR filtering silk, which is assigned numerical values in four categories".

Results

Changes with longitude and time

The large increase in the phytoplankton color index after 1991 occurred primarily in the months January to March, with a lesser increase in the period October to December. The increase in the color index only occurred in the region to the west of longitude 45° W, over the Grand Banks, Scotian shelf and Gulf of Maine regions. During the months, April to September there was no obvious change in the pattern of the color index between the 1961 to 1975 period and the 1991 to 2000 period (Fig. 2).

The abundance contours of the diatoms were limited to the highest data values in an effort to detect changes in the timing of the bloom. By plotting these values against longitude and year we see that in regions west of longitude 45 °W the bloom primarily occurred in the January to March period in the years since 1991, reflecting the observations seen for the phytoplankton color index. These appeared to be little change in the timing of blooms for the other periods (Fig. 3). The same analysis for total dinoflagellates showed that a large bloom occurred on the region of the Grand Banks in the October to March period in years 1991 to 2000 that only occurred sporadically in the years 1961 to 1975 (Fig. 4).

The contours for *C. finmarchicus* stages 1 to 4 showed that in the July to September period after 1991 the concentrations of animals west of longitude ° W had a significant decrease that extended on to all the three regions, the Grand Banks, Scotian and Gulf of Maine/Georges Bank region. There were no obvious changes in the concentrations of *C. finmarchicus* stages 1 – 4 with year and longitude in the other three periods of the year (Fig. 5).

C. finmarchicus stages 5 – 6 did not show as great a change in their abundance distributions in the four periods of the year as did stages 1 - 4. The one feature that stands out is the reduction in the abundance of stages 5 – 6 on the Grand Banks after 1991 during the April to September periods (Fig. 6).

Pseudocalanus/Paracalanus spp. concentrations after 1991 decreased markedly on the western Scotian and Gulf of Maine/Georges Bank regions, particularly in the July to December period. However, on the Grand Banks during January to March and October to December their concentrations increased over the values seen prior to 1991 (Fig. 7).

The total euphausiids taxon represents all stages of euphausiid species collected in the CPR samples. The highest concentrations of euphausiids occurred east of longitude 45° W and this was the case for all years. However, after 1991 the concentrations of euphausiids west of longitude 45° W decreased significantly on all three regions, particularly during the months July to September (Fig. 8).

Timing of the bloom

The bloom periods, defined as times of maximum abundance, for five taxa, phytoplankton color index, total diatoms, total dinoflagellates, *C. finmarchicus* stages 1 – 4 and *C. finmarchicus* stages 5 – 6 were compared by contouring high values of these data against month of the year and sequential months which were in turn identified as year. Only the high values were used in these analyses to better see any change in the timing of the maximum bloom. Three regions are compared, the Scotian, the western North Atlantic and the eastern North Atlantic. The bloom period for the phytoplankton color index after 1991 showed a trend towards occurring earlier in the year the Scotian and the western Atlantic, but no early trend was seen on the eastern Atlantic (Fig. 9). In the eastern Atlantic the bloom occurred during the same months after 1991 as it did before 1991.

The phytoplankton color index is the result of the numbers of diatom and dinoflagellates cells on the gauze of the CPR as well as the presence of other phytoplankton ; therefore we expect that the diatom and dinoflagellate blooms would show a similar pattern to the color index. This was the case on the Scotian Shelf where the total diatom bloom had a similar pattern to the color index, but the diatom bloom pattern on the western Atlantic, had less change in its timing after 1991. The dinoflagellate bloom on the Scotian Shelf showed less change to earlier months than did the diatoms, but on the western Atlantic section there was a pronounces increase in dinoflagellates in the earlier months of the year after 1991. Neither diatoms nor dinoflagellates showed any change in the timing of the bloom on the eastern Atlantic (Fig. 9).

The *C. finmarchicus* stages 1 – 4 bloom on the Scotian occurred earlier after 1991 than in the years from 1961 to 1975. But on the western Atlantic section their bloom tended to occur later in the year after 1991 (Fig. 9). On the eastern Atlantic section there was no change in the timing of the bloom for *C. finmarchicus* stage 1 – 4. No changes in the timing of the bloom of the *C. finmarchicus* stages 5 – 6 were found on any of the three sections (Fig. 9).

Yearly abundance of taxa

The yearly mean values and standard errors of the means for abundance of the phytoplankton color index, total diatoms, total dinoflagellates, *C. finmarchicus* stages 1 – 4, *C. finmarchicus* stages 5 –6, *Pseudocalanus/Paracalanus* spp., and total euphausiids were plotted for the Scotian Shelf, western Atlantic and eastern Atlantic regions (Fig. 10). The phytoplankton color index was significantly higher in the 1990s than in the earlier years in all three regions (Fig. 10). There was a sudden rise in values of the index in the early 1990s after which time the values remained at levels above the climatogical mean. Total diatoms showed a similar yearly change on the Scotian Shelf, with increasing mean values in the 1990s that were above the climatological mean. However, on the western and eastern Atlantic regions the yearly means of the diatoms were very close to the mean values with no sign of the large increase we see on the Scotian Shelf (Fig. 10). The total dinoflagellates on the Scotian Shelf and in the western Atlantic region both showed large increases in the yearly means in the 1990s. There was no increase in the dinoflagellate yearly means in the eastern Atlantic region (Fig. 10).

The yearly means of *C. finmarchicus* stages 1- 4 and stages 5 – 6 in the 1990s on the Scotian Shelf and in the western Atlantic were generally below the climatological means. However, on the eastern Atlantic region the yearly means in the 1990s were very similar to the climatological mean (Fig. 11). *Pseudocalanus/Paracalanus* spp. yearly means in the western Atlantic region were significantly above the climatological mean, but on the other two regions the values fluctuated around the mean (Fig. 11). The total euphausiid yearly means in all regions in the 1990s showed a downward trend. On the Scotian Shelf, the yearly means in the 1990s were all below the climatological mean. There was a minimum in 1997 after which there was an upward trend in the yearly means. In the western and eastern Atlantic regions the total euphausiids during the 1990s had a pronounced downward trend in their yearly mean values with no indication that the negative slope was reversing as was seen on the Scotian Shelf (Fig. 11).

Discussion

The 1990s appeared to be a unique period in the CPR time series in the region of the western North Atlantic between Iceland and North America. At no time in the data series do we see such large and persistent changes in abundance and timing of the blooms. The most striking changes occurred in the phytoplankton abundance, which is reflected in the phytoplankton color index. . The color index values in the 1990s increased significantly between October and March in the region west of longitude 45° W, but they did not change significantly from values seen in the earlier years east of longitude 45° W. The diatom and dinoflagellate abundance changes were independent of one another even though both showed increases in the 1990s. Diatoms increased during the months of January to March on all regions west of longitude 45 ° W. Dinoflagellates increased primarily on the Grand Banks and eastern Scotian regions during October to March, with the greatest increase happening on the Grand Banks. Similar increases in these two taxa did not occur in the eastern North Atlantic region.

A significant decrease in abundance of *C. finmarchicus* stages 1 – 4 occurred after 1991 in all regions west of longitude 45° W. The abundance of *C. finmarchicus* stages 5 – 6 also decreased below the climatological mean in 1994 and remained low into 2000. The decrease in abundance that occurred in July to September in both groups suggested that the late summer and fall generation of *C. finmarchicus* either failed to reproduce or was greatly reduced. This reduction may have been the result of predation by the sandlance and/or herring, both of which have increased in abundance since the 1970s. There were no consistent decreases in abundance of these taxa on the eastern Atlantic region in the 1990s. *Pseudocalanus/Paracalanus* spp. increased on the Grand Banks and in the eastern Scotian Shelf regions during the months of January to March but deceased in abundance during July to September in the 1990s. Total euphausiids abundance decreased after 1991 in regions west of longitude 45° W. But there was no evidence that any significant change in the total euphausiids occurred east of longitude 45° W.

The bloom periods for diatoms and dinoflagellates occurred progressively earlier in the 1990s than they did in the years prior to the 1990s on the regions west of longitude 45° W. There was no shift in the timing of the bloom periods for these two taxa on the eastern Atlantic region in the 1990s. The *C. finmarchicus* stages 1 – 4 bloom on the Scotian occurred approximately a month earlier in the 1990s than in the earlier years. But the bloom occurred about a month later on the regions of the Grand Banks and western Atlantic. In the eastern Atlantic there was no change in the timing of the bloom in the 1990s compared to the earlier years. The bloom period of *C. finmarchicus* stages 5 – 6 did not change significantly in any of the regions during the time series. The yearly mean values of the phytoplankton color index showed a large increase in the 1990s on all the three regions west of longitude 45° W, with the greatest relative increase on the Scotian.

The CPR data provided evidence that significant changes in the abundance and the timing of blooms occurred during the 1990s in some of the major phytoplankton and zooplankton taxa. These changes occurred in the regions west of longitude 45° W that includes the Grand Banks, Scotian Shelf and Gulf of Maine/Georges Bank, all of which are influenced of the Labrador Current. . An increase in the greenness index after the mid-1980s was also reported in the central northeast Atlantic and central North Sea (Reid et al. 1998). The reasons for this increase greenness index are uncertain, but Reid suggested it maybe related to “a large export of fresh water from melted ice and permafrost in and around the Arctic Seas as a response to the high positive-temperature anomalies in northern Eurasia and Alaska”. Waters over the Newfoundland shelf were fresher and cooler in the 1990s than in the previous decades, suggesting a common mechanism maybe occurring in the North Sea and the western Atlantic.

Most of the changes in abundance appeared to start in the earlier 1990s and persisted until 2000. There was a change in the direction of the trend of the annual means of a number of taxa, *C. finmarchicus* stages 1 – 4, *C. finmarchicus* stages 5 –6, *Pseudocalanus/Paracalanus* spp. and total euphausiids on the Scotian. The trends of these taxa in 1997 switched direction from negative to positive and it remained positive until 2000, the last data year. The total euphausiids in the western and eastern Atlantic did not reverse the downward trend in the 1990s; both areas remained below the climatological mean. There was no indication that the pattern of high values seen during the 1990s for phytoplankton color index, total diatoms and total dinoflagellates was decreasing in 2000.

References

Hays, G. C. and A. J. Warner. 1993. Consistency of towing speed and sampling depth for the Continuous Plankton Recorder. J. Mar. Biol. Assoc. U.K. 73: 976-970.

MathSoft (1999). S-Plus 2000. Data Analysis Product Division, Seattle Wash.

Myers, R. A., N. J. Barrowman, G. Mertz, J. Gamble, and H. G. Hunt. 1994.

Analysis of continuous plankton recorder data in the northwest Atlantic 1959-1992. Can. Tech. Rept. Fish. and Aquat. Sci. 1966.

Keckler, D. 1995. Surfer for windows. Version 6 User's Guide.   Golden Software Inc. Golden Colorado.

Reid, P. C., M. Edwards, H. G. Hunt and A. J. Warner. 1998. Phytoplankton change in the North Atlantic. Nature 391: 546.

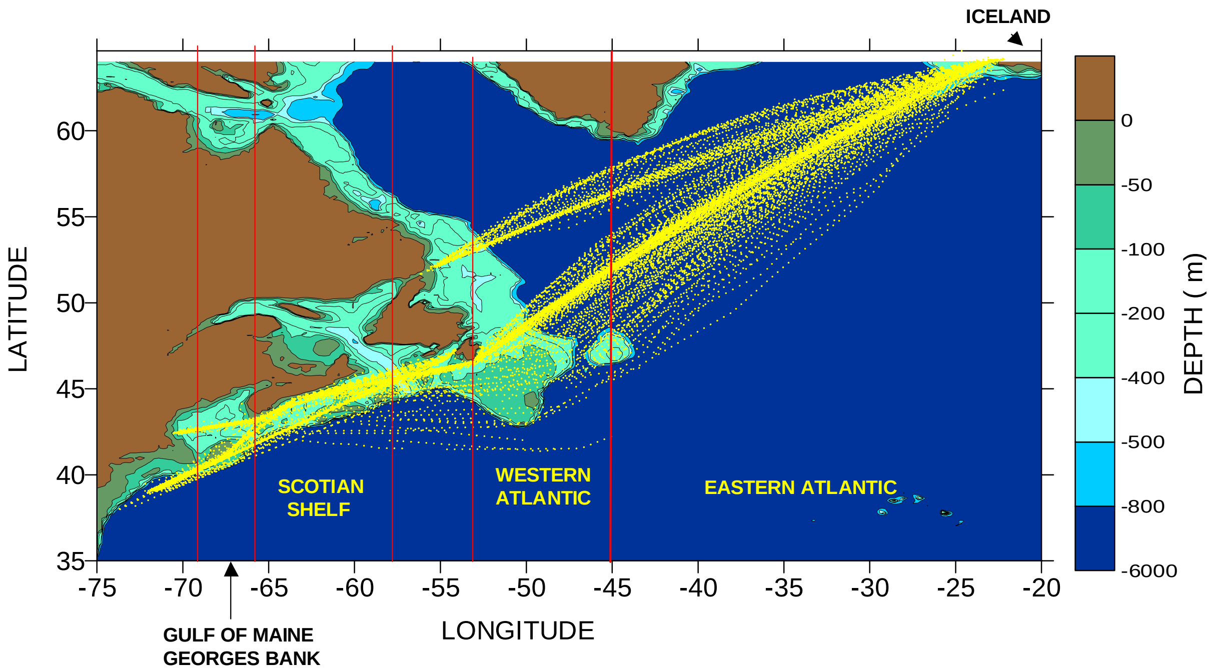

Fig. 1. Positions of CPR stations and locations of the four studied regions.

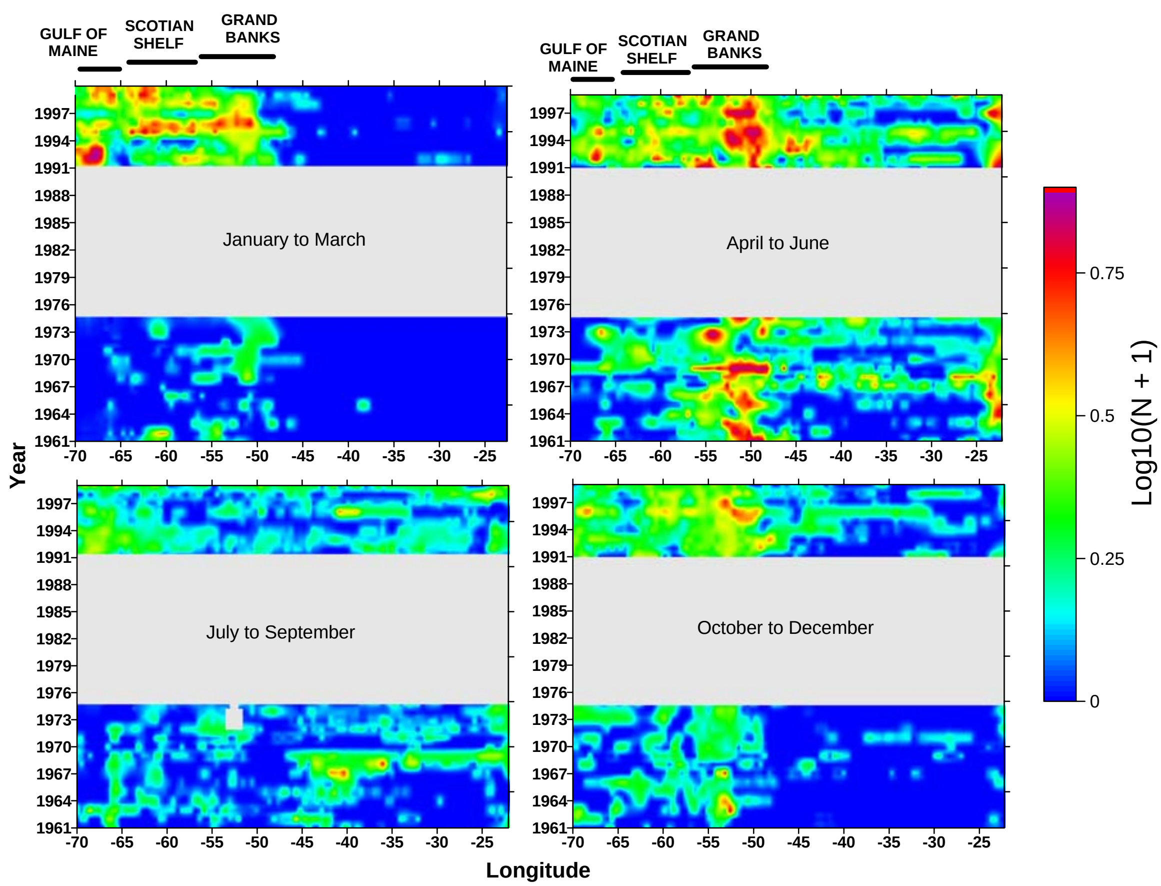

Fig. 2. Contours of phytoplankton color index levels for longitude versus time in years for four periods of the year.

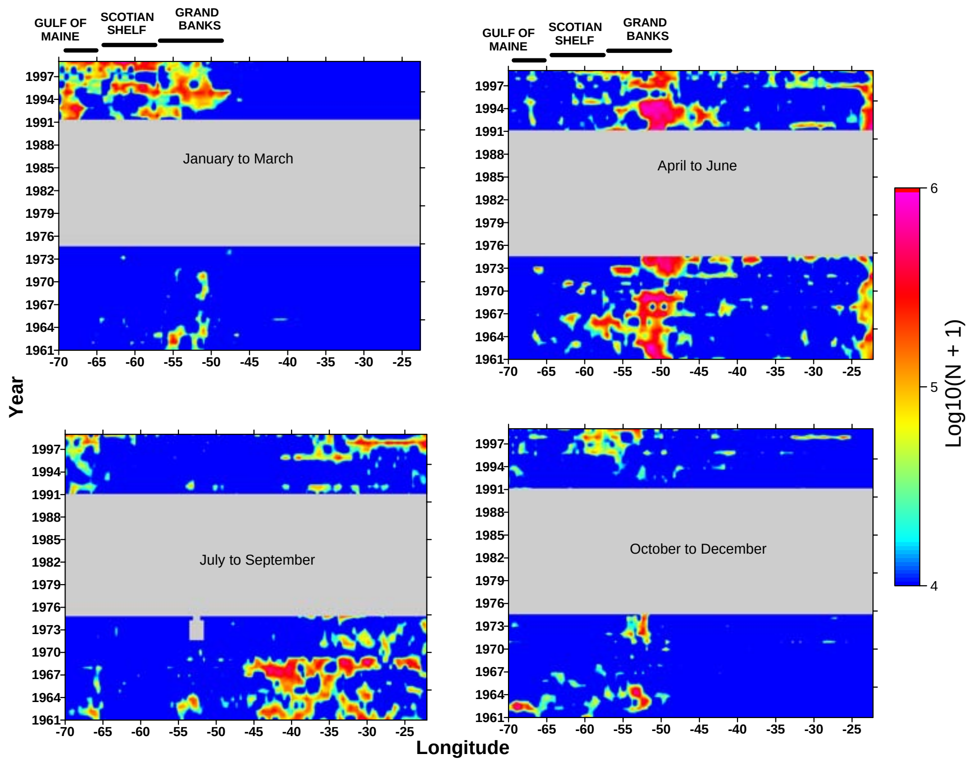

Fig. 3. Contours of total diatoms greater than 10^4 cells per sample for longitude versus time in years for four periods of the year.

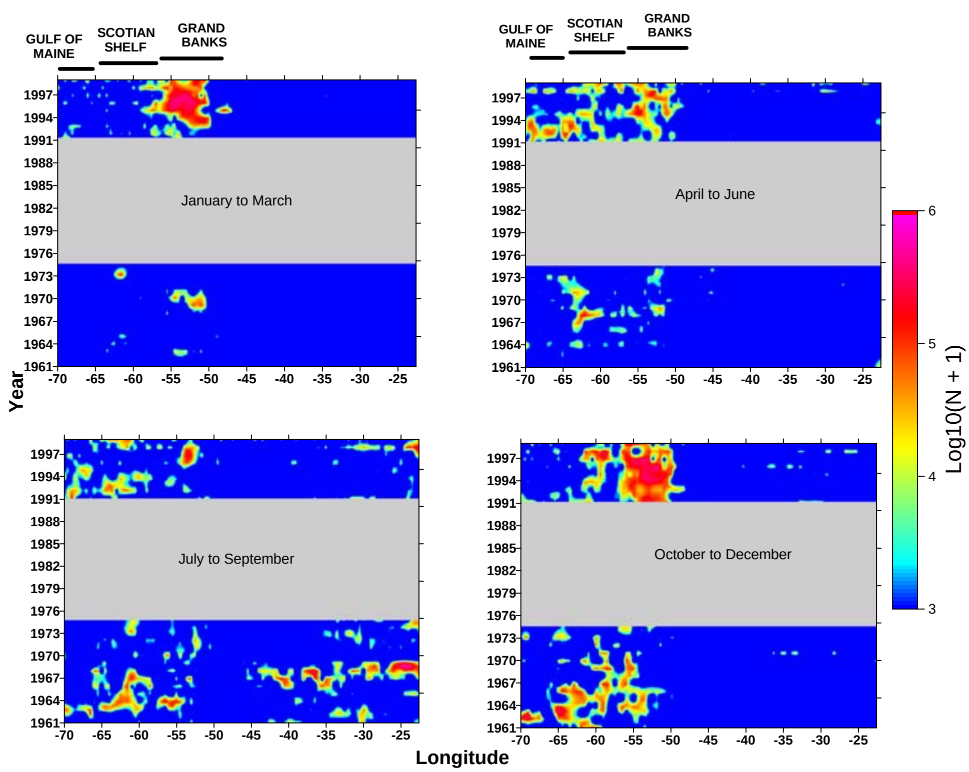

Fig. 4. Contours of total dinoflagellates greater than 10^3 cells per sample for longitude versus time in years for four periods of the year.

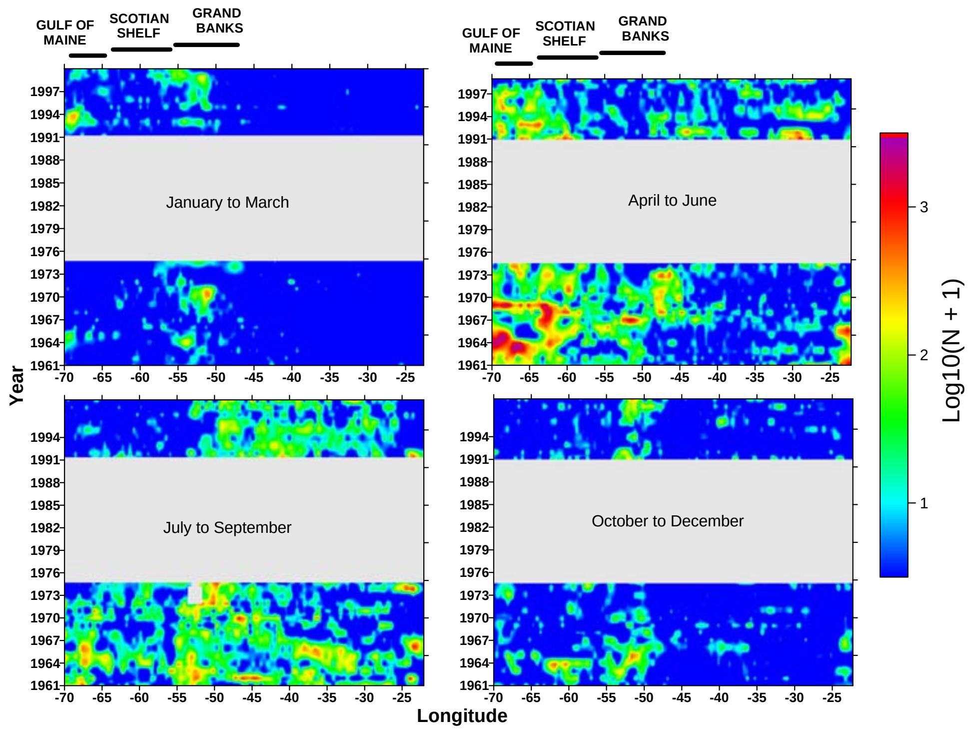

Fig. 5. Contours of *C. finmarchicus* stages 1 - 4 for longitude versus time in years for four periods of the year.

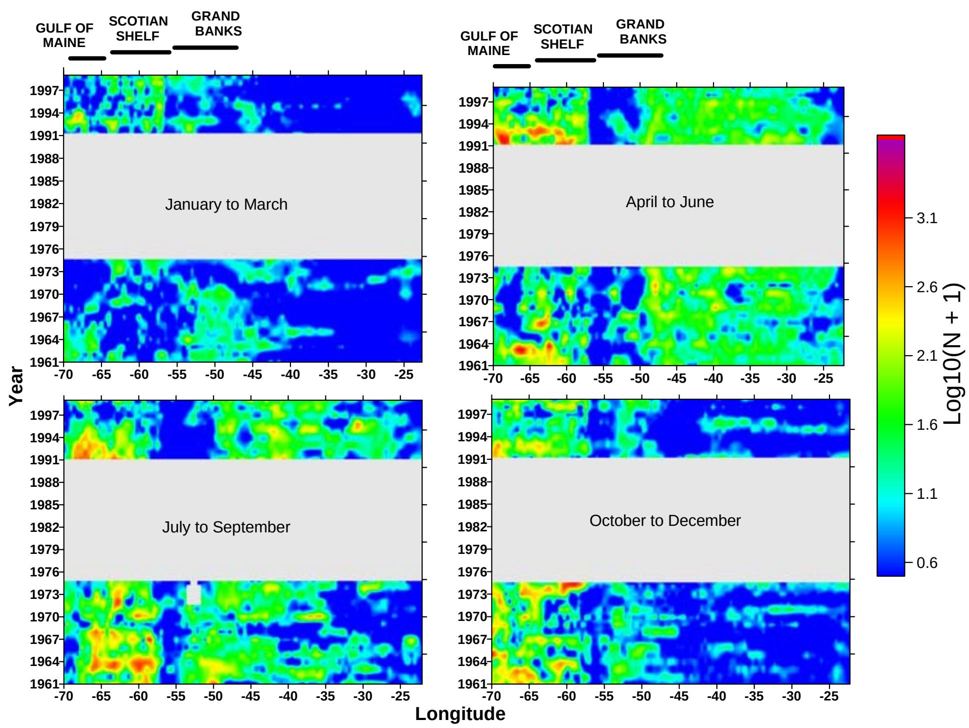

Fig. 6. Contours of *C. finmarchicus* stages 5 - 6 for longitude versus time for four monthly periods of the year.

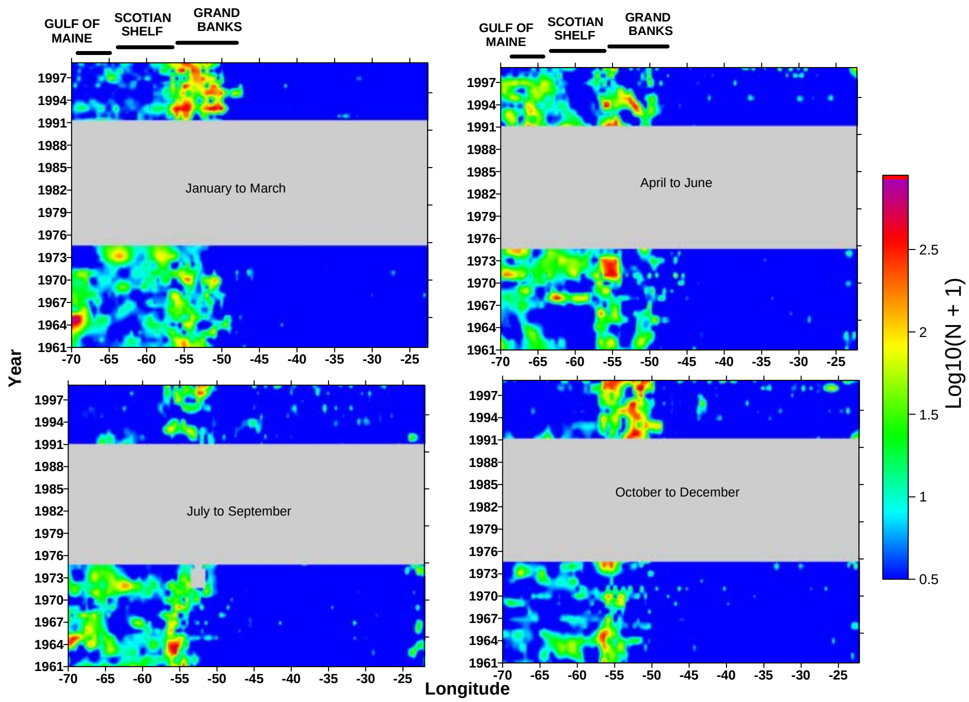

Fig. 7. Contours of *Pseudocalanus/Paracalanus* spp. for longitude versus time for four monthly periods of the year.

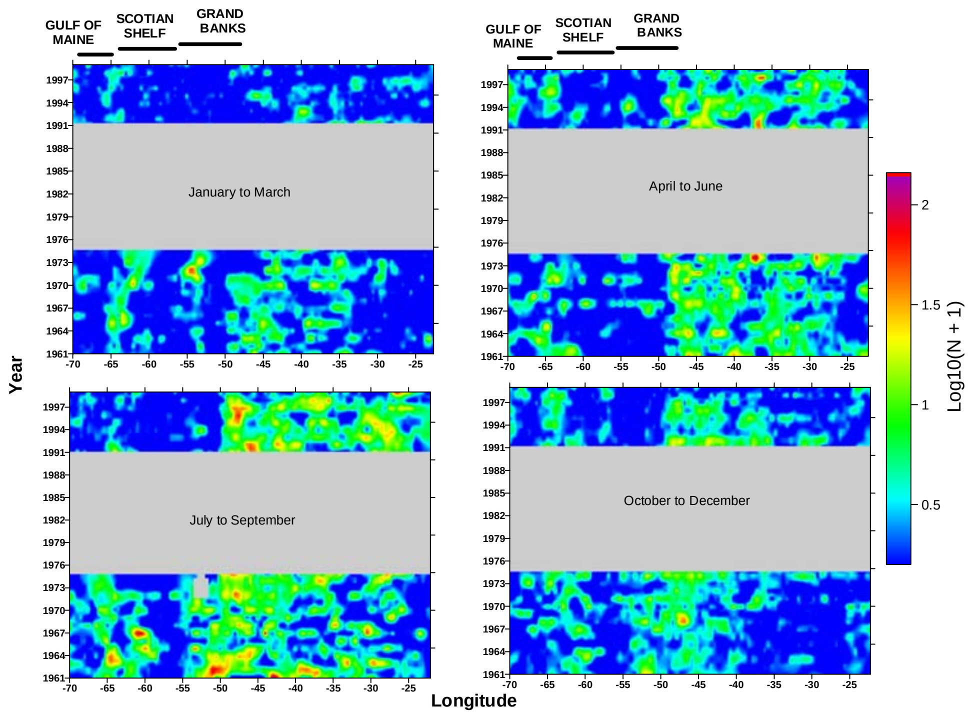

Fig. 8. Total euphausiid abundance contours for longitude versus time for four monthly periods of the year.

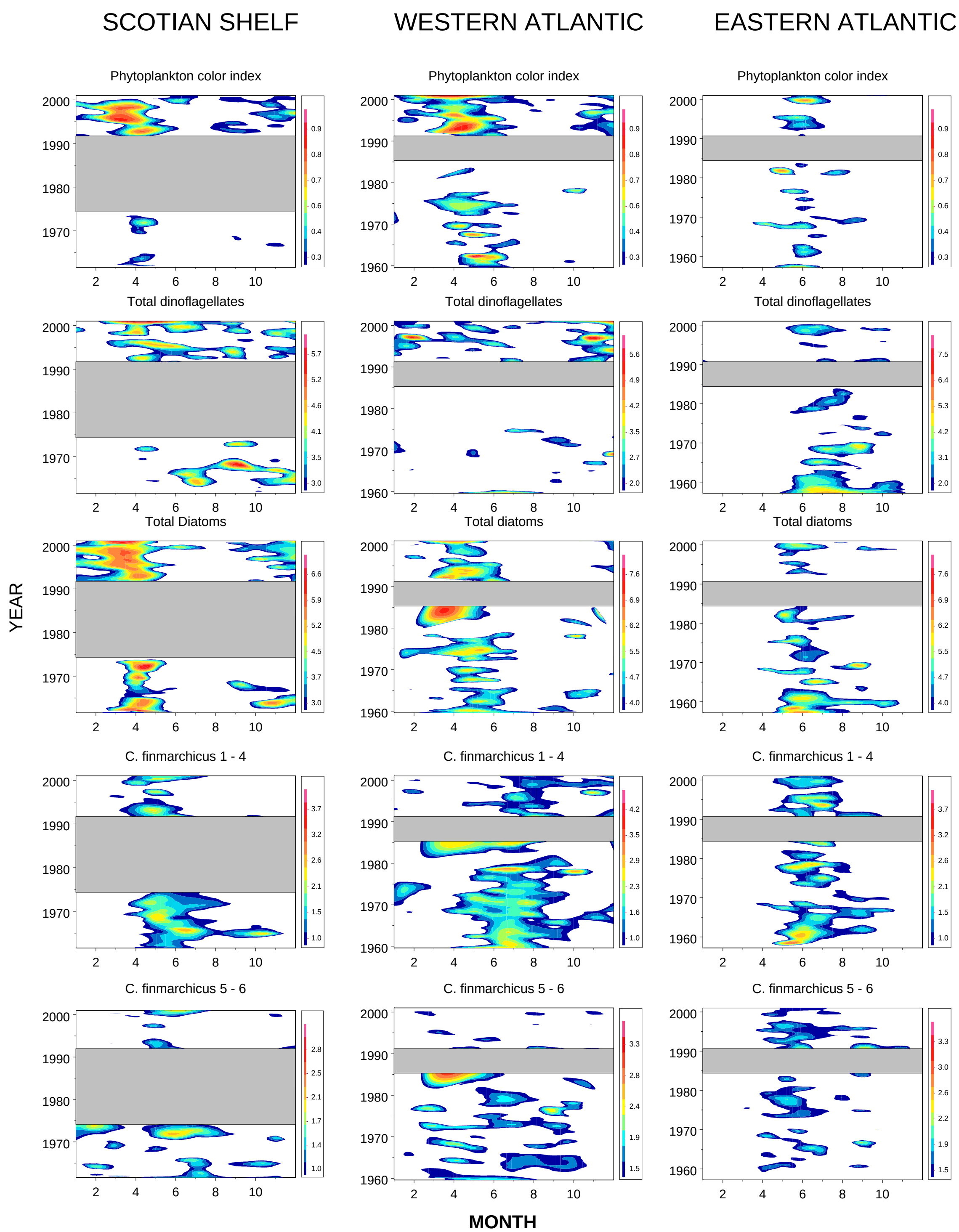

Fig. 9. Maximum bloom periods of phytoplankton color index, total diatom, total dinoflagellates *C. finmarchicus* stages 1 - 4 and *C. finmarchicus* stages 5 - 6 for the Scotian shelf, western North Atlantic and eastern North Atlantic. Grey areas represent periods of no data.

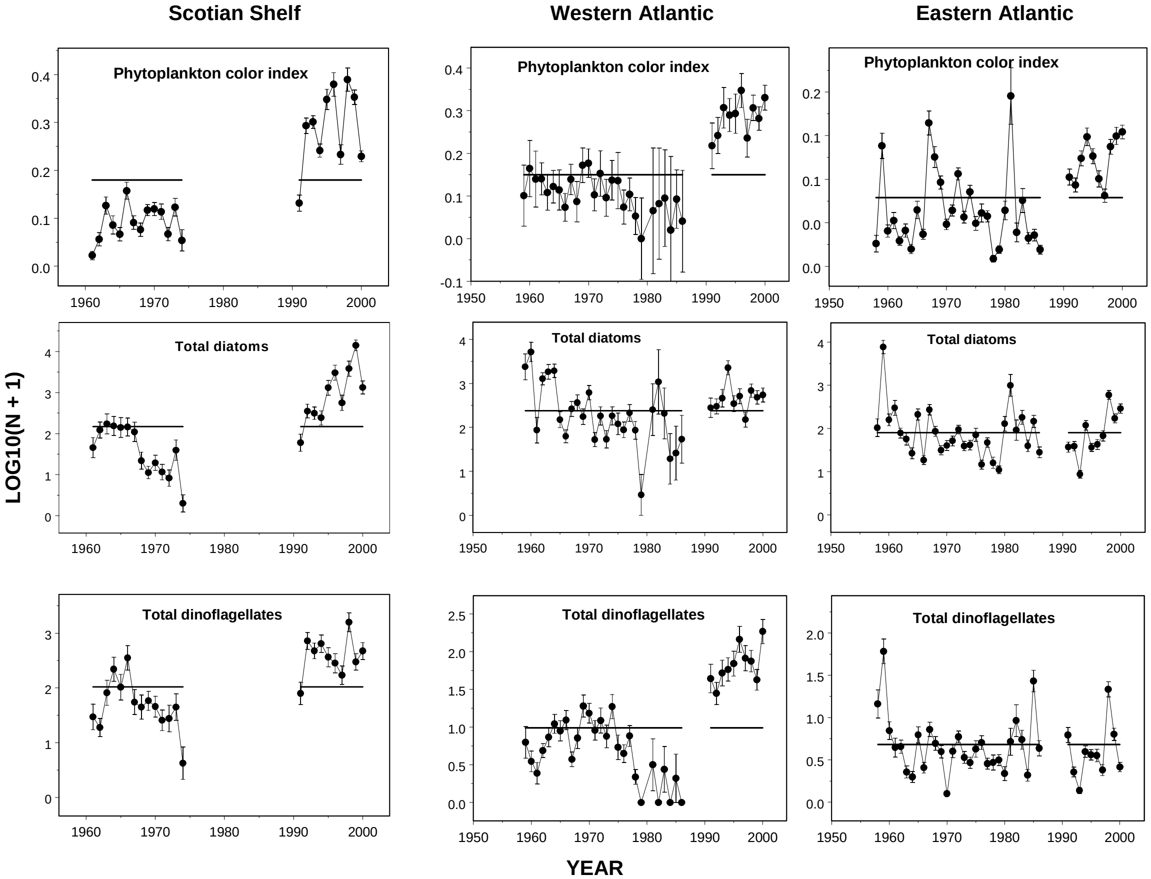

Fig. 10. Yearly means ± standard error of the means for phytoplankton color index, total diatoms and total dinoflagellates for the Scotian , western Atlantic and eastern Atlantic. The horizontal lines represent the climatological means calculated from data for all years.

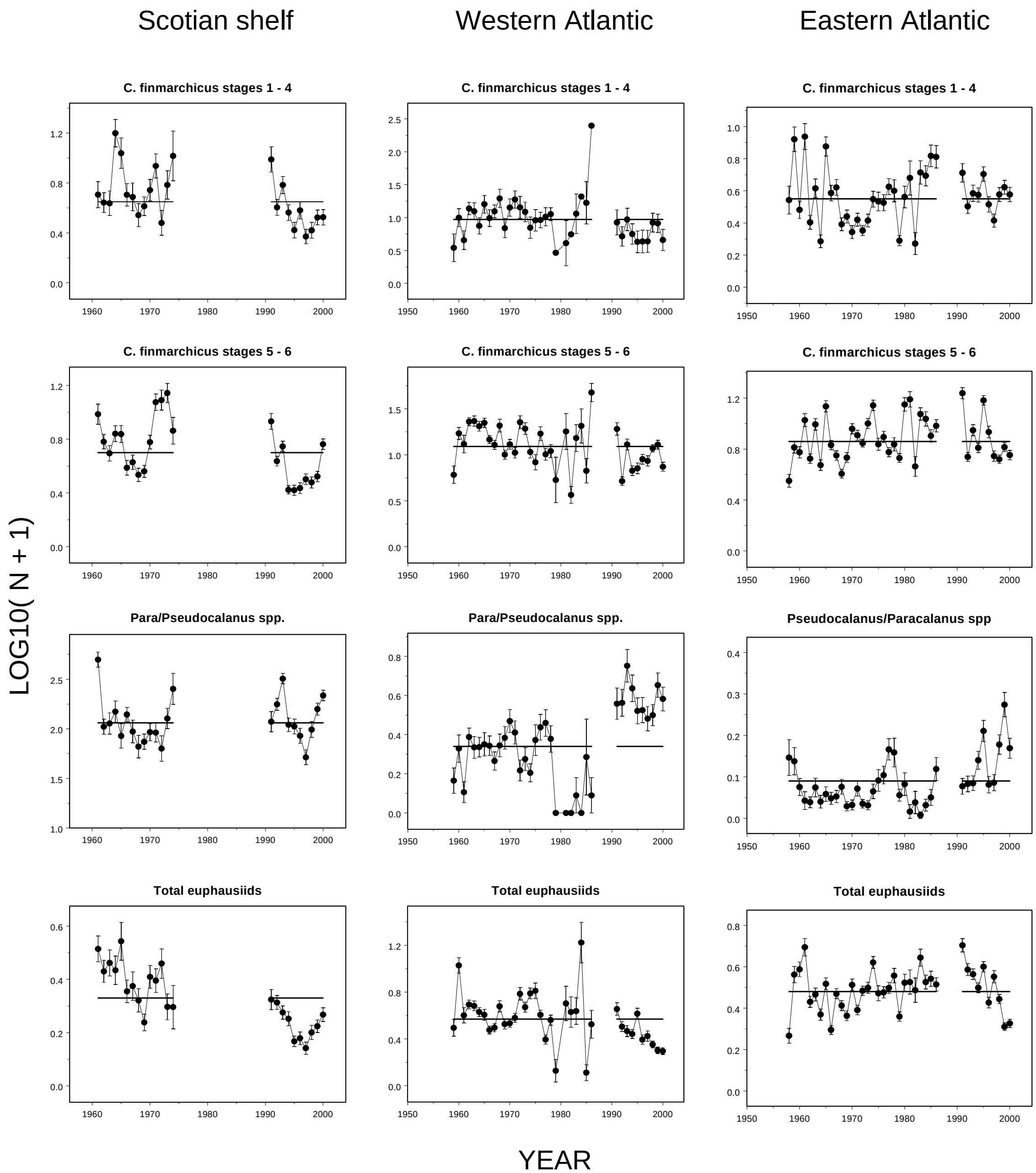

Fig. 11. Yearly means ± standard error of the means for *C. finmarchicus* stages 1 – 4 and stages 5 - 6, *Pseudocalanus/Paracalanus* spp. and total euphausiids for the Scotian , western Atlantic and eastern Atlantic. The horizontal lines represent the climatological means calculated from data for all years.