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Continuous Plankton Records: Massachusetts to Cape Sable, N.S., and New York to the Gulf Stream, 1990

by

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Abstract

Phytoplankton abundances were significantly above 1961-1987 averages during much of 1990 over Massachusetts Bay and Wilkinson Basin, and on the Scotian Shelf from June through August. High values over the central Gulf persisted to the end of the year. The Boston to Cape Sable transect averaged 200 percent above the base value for 1990 as a whole. Total Copepoda were significantly above average over nearly the entire transect after March, exhibiting increases in abundance levels not observed elsewhere during the base period. Copepods averaged more than 150 percent above the base value for the whole transect during 1990.

Phytoplankton blooms in the shelf waters of the Middle Atlantic Bight where less contiguous than normal. The spring bloom began early in two disconnected areas of the shelf, and terminated in late March, to be followed by a near-shore bloom in July that persisted till the end of October. On the outer shelf and slope spring and summer values were significantly below the 1971-1987 average, but by November an unusual bloom occurred from the shelf break to the end of the transect. For the transect as a whole in 1990 phytoplankton abundance averaged 13 percent below the base value. Abundance levels of total copepods were above average offshore during January to March, on the shelf during the spring and summer, and over the entire transect after October. Copepods averaged more than 200 percent above the base value for the whole transect during 1990.

Introduction

From 1961 through 1974 the Oceanographic Laboratory in Edinburgh Scotland conducted monthly monitoring of the zooplankton and larger phytoplankton between Cape Sable, Nova Scotia and the Boston, Massachusetts area using the Hardy Continuous Plankton Recorder (CPR) (Hardy, 1939; Glover, 1967). In 1972 the US National Marine Fisheries Service (NMFS) began a program of cooperation with the Oceanographic Laboratory (now a part of the Sir Allister Hardy Foundation for Ocean Science) for the extension of the long-term CPR survey into additional areas of the western North Atlantic. The two monthly sampling routes (Figure 1) reported on here are the results of that effort. These measurements are made to monitor changes in the state of the Northeast Shelf Ecosystem in relation to possible effects on the long-term sustainability of fishery yields of the system (Sherman et al, 1988). The year 1990 marks the 30th since sampling began on the Gulf of Maine, and the 20th on the Middle Atlantic Bight transects. Some 170 taxa are routinely identified and enumerated from these samples. Life stage is determined for most of the zooplankton. This report also presents (1) "total phytoplankton" obtained by visual comparison of sample color with a set of color standards using the index developed by Colebrook and Robinson, (1961), and (2) total copepod abundance.

Methods

Plankton and environmental sampling using merchant vessels and other ships of opportunity has been conducted along the transects shown in Figure 1 at a sampling frequency of approximately once per month.

Continuous records of net phytoplankton and zooplankton from a depth of 10 m were obtained by the sampler along the track of the ship. Towing speed was between 10 and 17 knots. Water passing through the CPR was filtered with bolting silk having mean aperture dimensions of 225 x 234 microns, when wet. The continuous record was cut into 18.5 km (10 n mi) sections (herein termed samples), and time, dates, and positions were calculated for the sample center points. Each sample contained plankton filtered from approximately 3 cubic meters of water. Alternate samples were always examined. Additional samples were examined in the event of unusual taxa, timing, or gradients.

Prior to taxa identification the green or green-brown color of each sample was compared to a set of four, easily distinguishable color standards (no color, very pale green, pale green, and green). Assignment of numerical values to these color categories was achieved by dilution of acetone extracts from samples in each category. The average chlorophyll concentrations for these categories (excluding no color) were in the ratios of 1.0 : 2.0 : 6.5 (Colebrook and Robinson, 1961). Thus, a crude, but useful measure of the relative distribution of phytoplankton in time and space was obtained. A beginning contour level of 0.5 color value has been used in this study to separate the time-space areas of "winter", and other low phytoplankton abundances from areas of blooms and higher abundances. In the process of determining average values at time-space grid points (see paragraph below on gridding techniques) a non-normal distribution was the rule, and no transformation could be found to bring the distribution to near normal. Thus, for the phytoplankton color values, grid medians were determined. An estimate of dispersion (the non-parametric equivalent of standard deviation) was determined by using the color values at percentile departures approximately equivalent to the one (15.87 and 84.1 pctl) and two (2.3 and 97.7 pctl) standard deviation levels as follows:

$$\text{Equiv. St. Dev.} = ((C_{84.1} - C_{15.7})/2 + (C_{97.7} - C_{2.3})/4)/2$$

Zooplankton organisms were counted and identified from aliquots ranging from 40-50. Abundances were log10 transformed and all subsequent calculations were performed on these transformed values. Values were back-transformed for portrayal purposes.

Methods for generating standardized time-space matrices are described in Jossi and Smith (1989). Briefly, the method involves 1) deleting any samples outside of the transect polygon (Figure 1); 2) calculating the sample's standardized distance along the transect, termed reference distance; (3) calculating a uniform time-space grid using the julian day and reference distance from all data in a single year to make a single year map; (4) generating a uniform time-space grid using all data over the base period to make a mean map, or median map in the case of phytoplankton color; (5) producing a standard deviation or asymptotic standard deviation map for the transect's base period; (6) calculating the residuals of raw data for a single year from the mean or median map and gridding these residuals to make an anomaly map; and (7) dividing the anomaly map by the standard deviation map to obtain a standardized anomaly map

Further details of the collection and processing methods may be found in Colebrook (1960, 1975).

Results

"Total Phytoplankton" as relative green color, and total Copepoda abundance for the Gulf of Maine and the Middle Atlantic Bight transects are presented as contoured time-space plots (Figures 2-5). Portrayed are the conditions during 1990, and the departures of these conditions from the 1961 through 1987, and the 1971 through 1987 averages for the Gulf of Maine and the Middle Atlantic Bight, respectively. The departures are expressed in terms of algebraic anomalies (data units) and standardized anomalies (standard deviation units).

Discussion

Massachusetts to Cape Sable, N.S.

"Total Phytoplankton": The spring bloom, as measured by phytoplankton color, began in Massachusetts Bay and western Wilkinson Basin in January, peaked in March, and persisted until the end of May (Figure 2 A). For the rest of the transect west of the Scotian Shelf the bloom began towards the end of February, peaking near the end of March and persisting into May. On the Scotian Shelf a weak bloom began in March, but was greatly overshadowed by a bloom from June through August. A fall bloom occurred on the western end of the transect between August and October. When comparing these events to the 1961 through 1987 base period the time-space patterns are close to average but the magnitudes depart significantly (Figure 2 B & C). The spring bloom occurred earlier than usual in the western Gulf, its peak was confined to the Massachusetts Bay waters, and it persisted about a month longer than average. The spring bloom on the Scotian Shelf was lower than that during the base period but the subsequent bloom in the late summer and fall was significantly above normal. Finally the fall bloom over Massachusetts Bay occupied a larger time-space area than average and was significantly higher than the 1961 through 1987 base period. The Boston to Cape Sable transect averaged 200 percent above the base value for 1990 as a whole.

Total Copepoda: During January and February abundances of from 5,000 to more than 10,000 copepods per 1000 m^3 were found over Massachusetts Bay (Figure 3 A). The annual increase over most of the transect began in late March reaching values in excess of 250,000 on the Scotian Shelf in May. Values remained above 100,000 west of Crowell Basin during most of June and July, and over Wilkinson Basin and Massachusetts Bay from September into October. Departures from the 1961 through 1987 base period were significant and covered an extensive area (Figure 3 B & C). With the exception of the February to March period east of Massachusetts Bay most of the area exhibited positive anomalies. The late-March annual increase (Figure 3 A) was nearly one month ahead of average; peak abundances were significantly above average for most of the transect during the spring, for the western Gulf during the summer, and again for the entire Gulf in the fall and early winter. Departures of this extent have not been seen elsewhere in the series. Copepods averaged more than 150 percent above the base value for the whole transect during 1990.

Middle Atlantic Bight

"Total Phytoplankton": Three discontinuous blooms began along the transect in late February (Figure 4 A). The ones on the shelf and near the shelf break peaked near the beginning of March and had virtually disappeared by the first of April. The major bloom of 1990 began inshore in May, and at the shelf break by early June. It reached peak values very near shore in mid-July where it remained high until mid-October. Over the inner half of the shelf peak values were seen in October. Offshore values in excess of 0.5 color units occurred from April to May, during August, and from October to the end of the year. Positive departures from the 1971 through 1987 base period resulted from the slightly higher, but also earlier than normal values on the shelf in late February (Figure 4 B & C). Well offshore from May through early September the scattered blooms produced significant anomalies, and during November and December most of the shelf and all of the transect offshore of the shelf break exhibited significant positive departure from the base period. Negative areas of departure occurred offshore from February through April where either the bloom was below average or the spring bloom terminated earlier than normal. The area from 250 km to 350 km from April to September never reached the 0.5 color value in 1990 thus resulting in a large negative anomaly over that area. For the transect as a whole in 1990 phytoplankton abundance averaged 13 percent below the base value.

Total Copepoda: High values were present over the mid-shelf and offshore of the shelf break in January (Figure 5 A). The latter persisted till early May. The area of the shelf and shelf break again increased in March reaching values in excess of 250,000 copepods per 100 m^3 in early April, and over 500,000 near shore in late June, and near the shelf break in early August. Higher values spread across the entire transect in October and remained so through the end of the year. When compared to the 1971 through 1987 base period several features stand out (Figure 5 B & C). Positive departures occurred offshore of 200 km in January and February. Values of these magnitudes are not usually seen there until March. In April and May positive anomalies resulted from a slight shifting of the peak to nearer shore positions, and to the actual magnitude of the peak in April. Beyond mid-shelf the above inshore shift resulted in significantly lower than normal abundances for this time of year. At 100 km reference distance in September significantly high abundances were seen. They persisted to near the end of the year, and, after October were joined by positive anomalies over the entire transect. Copopods averaged more than 200 percent above the base value for the whole transect during 1990.

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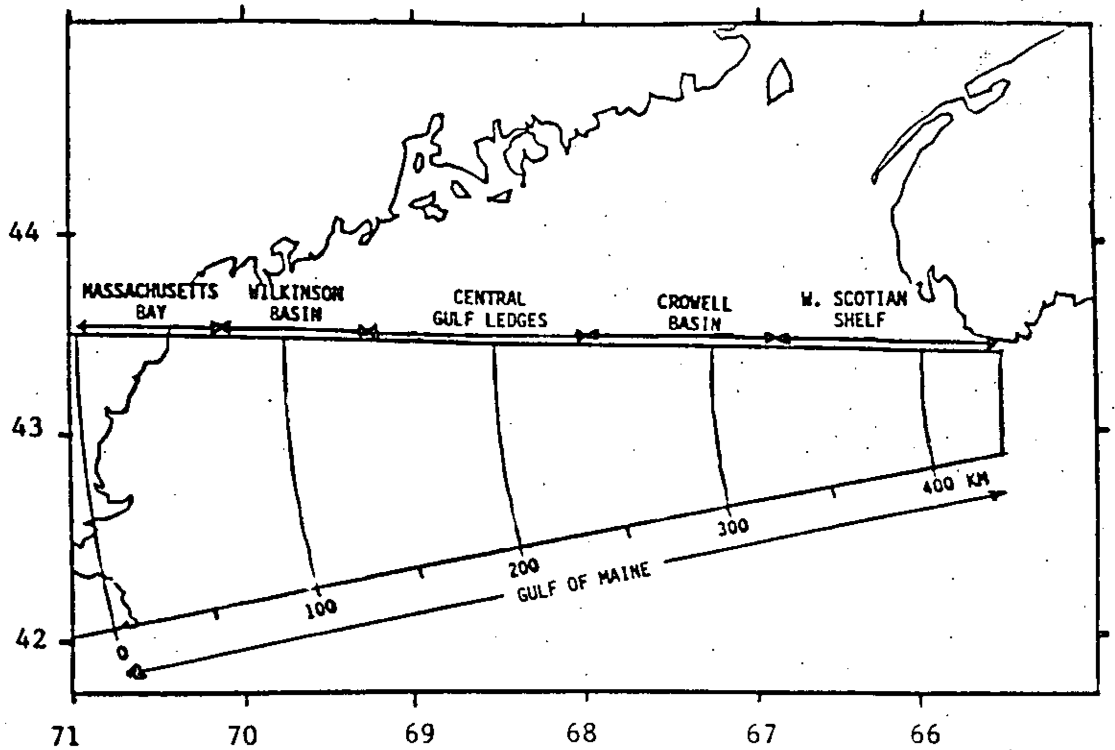
MARMAP ROUTE MC 1961 - 1990



MARMAP ROUTE MB 1971 - 1990

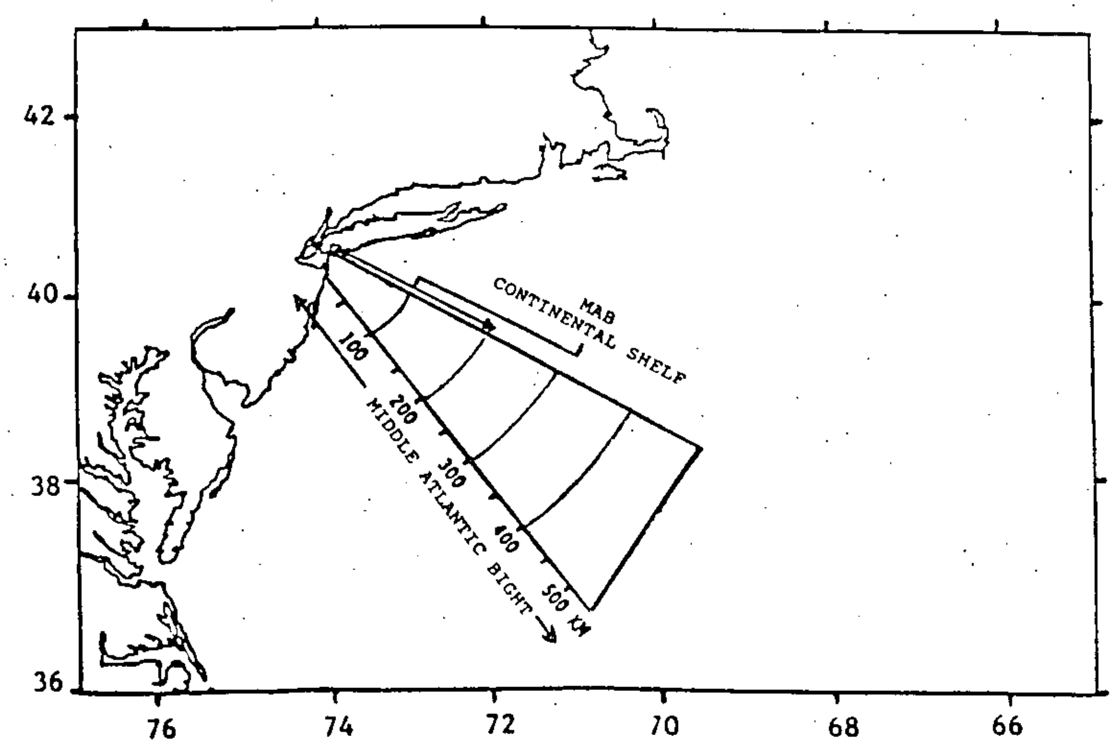


Figure 1. Gulf of Maine (MC) and Middle Atlantic Bight (MB) polygons within which monitoring transects occur, with years of plankton sampling, standard reference distances, and major subareas of the Northeast Continental Shelf ecosystem.

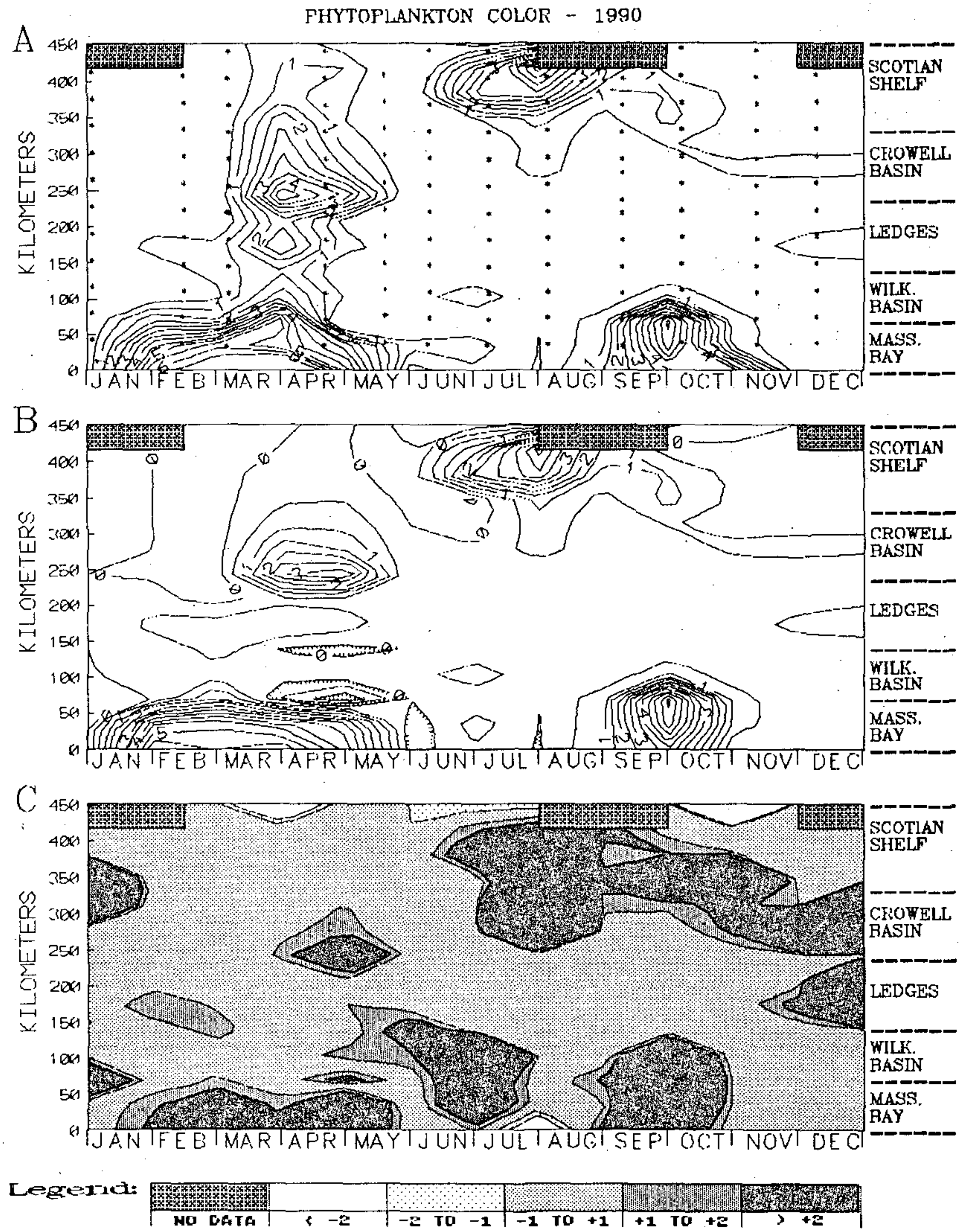


Figure 2. "Total Phytoplankton" along the Gulf of Maine transect during 1990. A. Relative green color values in time and space. Dots indicate sampling locations. B. Color anomalies in time and space based on 1961 through 1987 medians. C. Standardized color anomalies (asymptotic standard deviations) in time and space based on 1961 through 1987 medians and percentile departures. In panels A and B values decline on those sides of contour lines with hachures.

TOTAL COPEPODA - 1990

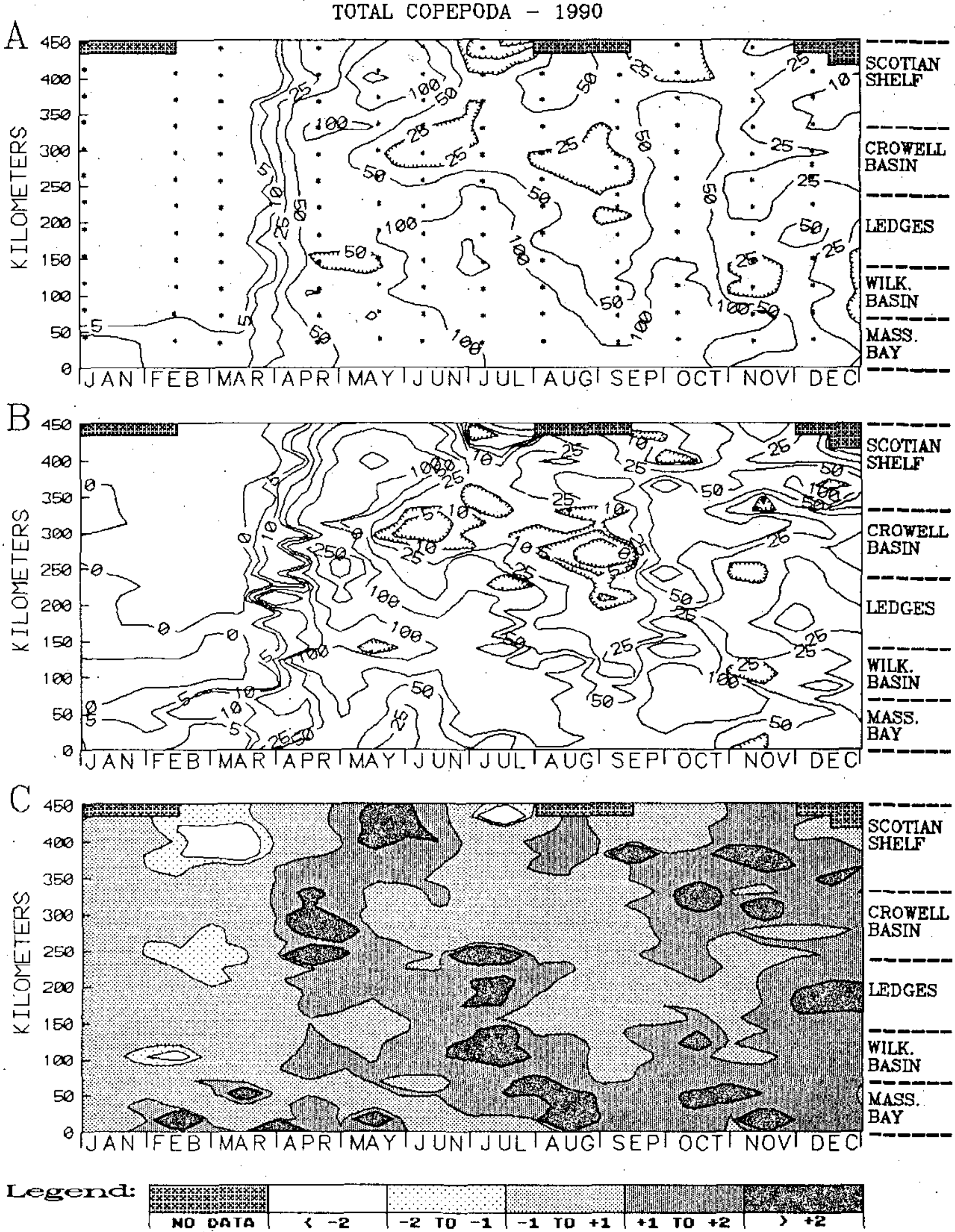


Figure 3. Total Copepoda abundance along the Gulf of Maine transect during 1990. A. Abundance values (thousands/100 m^3) in time and space. Dots indicate sampling locations. Panels A and B are contoured at 5, 10, 25, 50, 100, 250, and 500 levels. B. Abundance anomalies in time and space based on 1961 through 1987 means. C. Standardized abundance anomalies (standard deviations) in time and space based on 1961 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

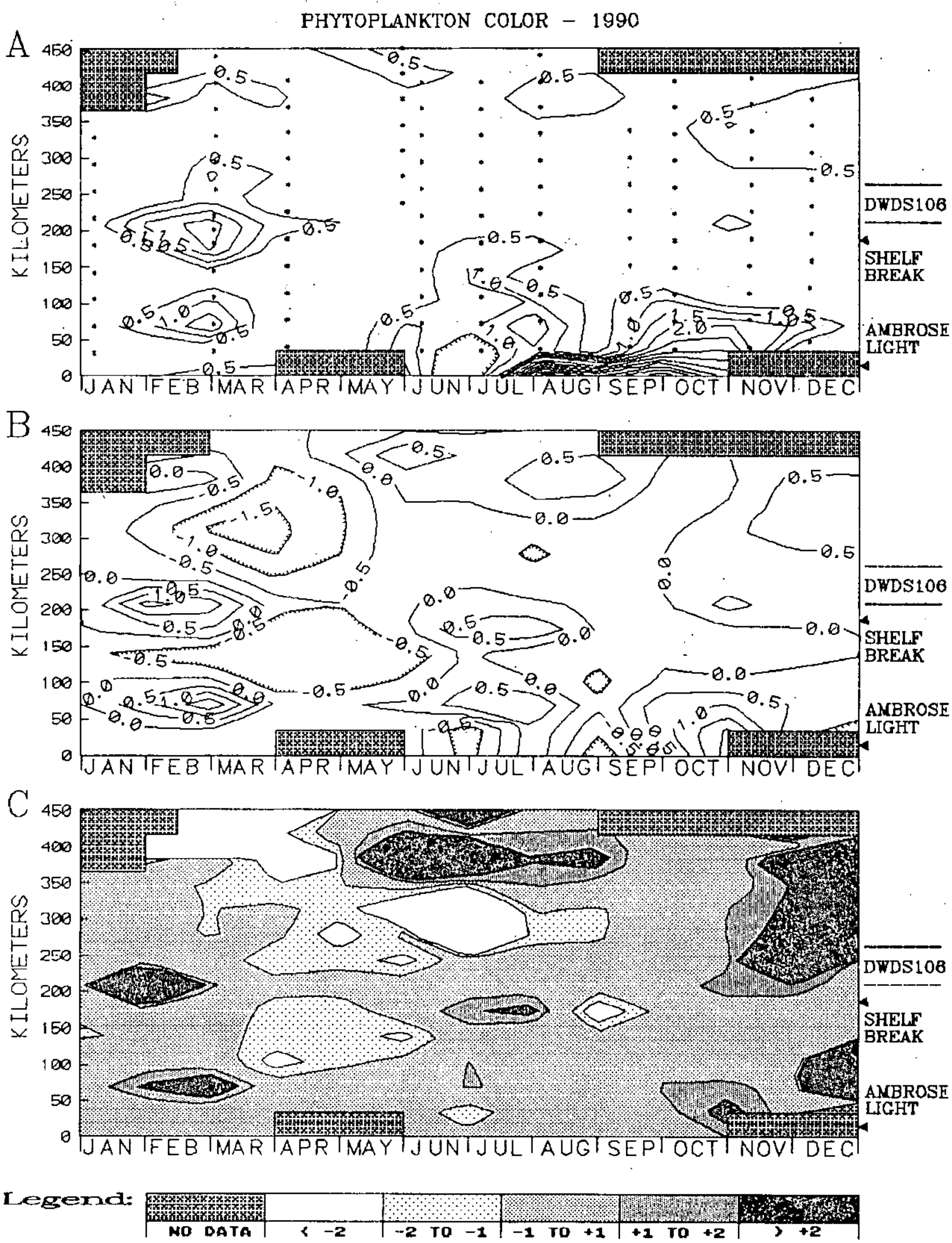


Figure 4. "Total Phytoplankton along the Middle Atlantic Bight transect during 1990. A. Relative green color values in time and space. Dots indicate sampling locations. B. Color anomalies in time and space based on 1971 through 1987 medians. C. Standardized color anomalies (asymptotic standard deviations) in time and space based on 1971 through 1987 medians and percentile departures. In panels A and B values decline on those sides of contour lines with hachures.

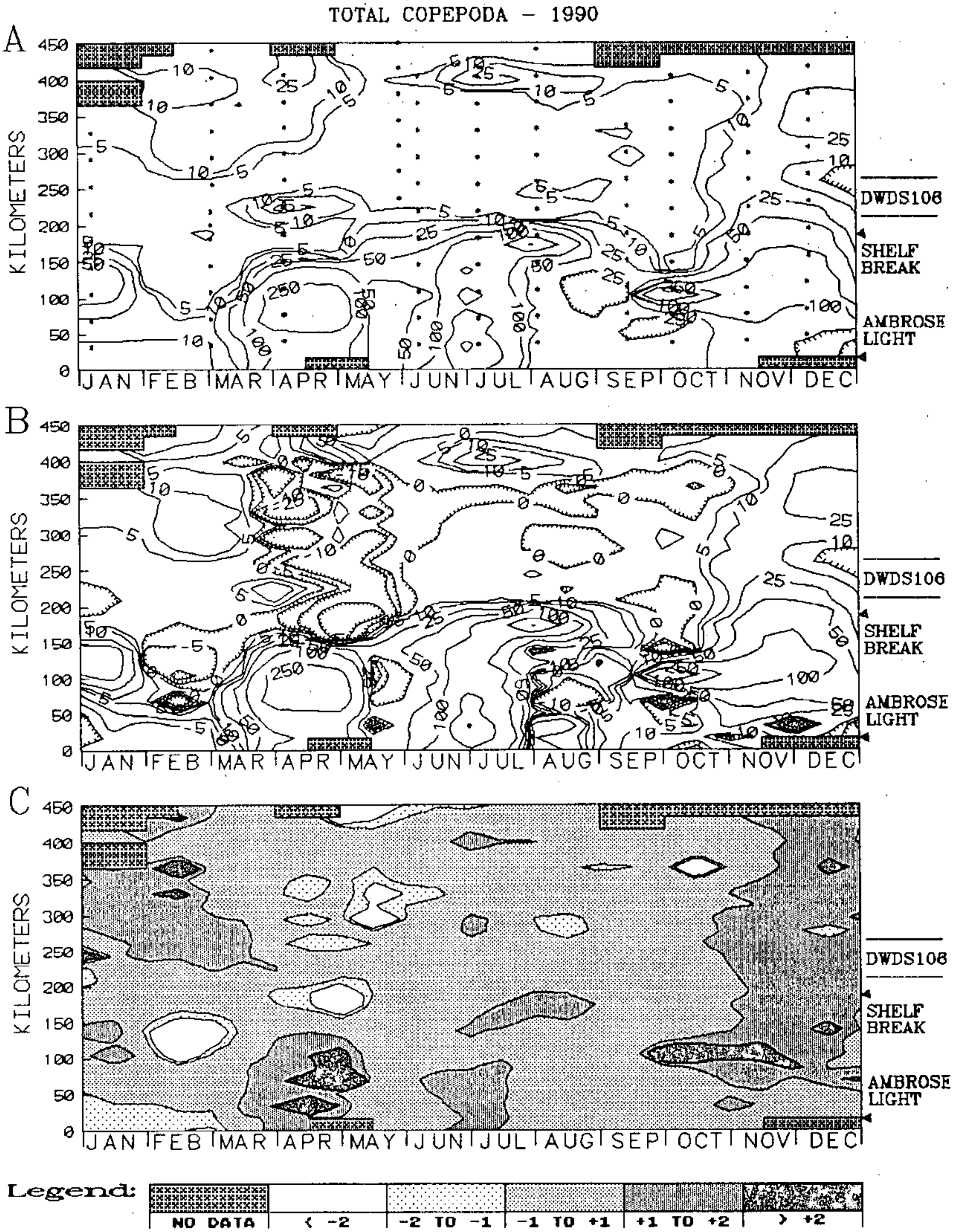


Figure 5. Total Copepoda abundance along the Middle Atlantic Bight transect during 1990. A. Abundance values (thousands/100 m^3) in time and space. Dots indicate sampling locations. Panels A and B are contoured at 5, 10, 25, 50, 100, 250, and 500 levels. B. Abundance anomalies in time and space based on 1971 through 1987 means. C. Standardized abundance anomalies (standard deviations) in time and space based on 1971 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.