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Continuous Plankton Records: Massachusetts to Cape Sable, N.S., and New York to the Gulf Stream, 1989

by

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Abstract

In the Gulf of Maine during 1989 phytoplankton abundance showed major departures from average, mostly due to shifts in timing of up to one month from normal. For the Gulf, and 1989 as a whole, these departures nearly balanced out. Abundance of total Copepoda was above average along the transect for most of the year. One sample in Massachusetts Bay in October contained nearly 300,000 copepods/100 m^3 of water strained.

In the near-shore waters of the New York Bight during 1989 the phytoplankton were above average during their late summer seasonal peak. Abundances dropped off sharply at the end of October, nearly two months ahead of average. Abundance of total Copepoda over the inner 400 km of the transect was above average from March through December of 1989. Values reached 550,000/100m3 of water strained at the apex of the Bight in July. One area of below average abundance occurred offshore in March and April and coincided with the presence of warm core ring 88K.

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 part of the Institute for Marine Environmental Research (IMER) 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. The year 1989 marks the 29th and 19th year, respectively since sampling began on the Gulf of Maine and the New York Bight transects. Some 170 taxa are routinely identifed and enumerated from these samples. This report only presents "total phytoplankton" obtained by visual comparison of sample color with a set of color standards, and total Copepoda 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 desired 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. The continuous record was cut into 18.5 km (10 n mi) sections (herein termed samples), and times, dates, and positions were calculated for the sample center points.

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 is 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. Analysis of the distribution of color values about the long term, gridded means (see paragraph below on gridding techniques) indicates that departures from the means can be expressed in units of standard deviation, and that such z-scores are preferable to algebraic anomalies for these data.

Statistical analyses of zooplankton data were performed on log transformed values. However protrayals of abundance show antilogs.

Methods for generating standardized time-space matrices are described in Jossi and Smith (1989). Briefly, the method included 1) deleting any samples outside of the transect polygon (Figure 1); 2) calculating the sample's standardized distance along the transect- herein termed reference distance; 3) generating a uniform time-space grid (map) of interpolated values using the julian day and reference distance values from a single year of irregularly spaced samples; 4) using the data from the previous ten or more years of the survey to produce a long-term mean map; 5) calculating the yearly anomaly (single year map minus long-term mean map); 6) using the long-tern standard deviation to calculate Z-scores (yearly anomaly map divided by long-term standard deviation 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 New York Bight transects are presented as contoured time-space plots (Figures 2-5). Portrayed are the conditions during 1989, and the departures of these conditions from the 1961 through 1987, and the 1971 through 1987 means for the Gulf of Maine and the New York Bight, respectively. The departures are expressed in terms of algebraic anomalies (data units) and z-scores (standard deviation units).

Discussion

Massachusetts to Cape Sable, N.S.

"Total Phytoplankton": The spring bloom, as measured by phytoplankton color, was markedly discontinuous in 1989 (Figure 2A). A bloom confined to Massachusetts Bay began in early January peaked in early March, and remained high until early April. Another, fairly discrete bloom occurred over the central Gulf of Maine from early April through the beginning of June. Finally, a bloom on the eastern end of the transect began in early March and lasted into early May. Smaller fall blooms were seen over the shallower parts of the Gulf. When compared to the 1961 through 1987 means numerous large time-space areas of significantly anomalous conditions appear (Figures 2 B and C). The departures are caused by both differences of phytoplankton abundance and by differences in the timing of . The Massachusetts Bay spring bloom began almost one month early. The bloom in the central Gulf peaked about one month later than average but was significantly above normal. The Scotian Shelf spring bloom occurred at the usual time but was significantly above average. The shallow water fall blooms were one month earlier than average, however, their magnitude was slighly lower than average. These major shifts in timing resulted in the large areas of both positive and negative standardized anomalies seen in Figure 2C. Temperature and salinity conditions during 1989 (Jossi and Benway, MS 1990) show no clear-cut explanations for the above. Currently studies are underway to examine these departures in the context of other environmental data, such as wind speed and direction and water column stability.

Total Copepoda: Abundance began its spring increase in early April for most of the transect (Figure 3). Peak abundances were present in May and June over the western half of the Gulf, with the very important exception of Massachusetts Bay where abundances reached nearly 300,000/100m^3 in October. For the Gulf east of Wilkinson Basin various peaks of abundance, exceeding 25,000/100m^3 occurred from May through October. Departures from the 1961 through 1987 means (Figures 3B and 3C) show most of the time-space area above average. Only a small area of Massachusetts Bay in May, the Wilkinson Basin during October and November, and the eastern end of the transect in November and December had significantly low abundances.

<u>New York towards Bermuda</u>

"Total Phytoplankton": Two areas of phytoplankton in excess of the 0.5 color level appear over the inner shelf during January to March (Figure 4A). Otherwise the inner shelf had values below 0.5 until late June. This nearshore area peaked in August and returned to pre-bloom conditions after October. Over the outer shelf and slope the annual maxima occurred in May, followed with values above 0.5 from late June until mid-September. Offshore showed an area of high phytoplankton centered in early February, another from March through May, and one from July to August with its 300-350 km portion persisting until the end of November. Departures from the 1971 through 1987 means occurred in 1989 (Figures 4B and 4C). The values offshore in January were significantly above average. This bloom coincided with the presence of warm core ring 88K (Sano and Wood, MS 1990). This event was followed by below average conditions well offshore in March and April, and over much of the shelf from March - June where the bloom failed to reach the 0.5 color level in 1989. The positive anomalies offshore from July through November indicate a wider than average distribution of >0.5 color during the latter half of the year for this area. In August near-shore values were significantly above average, but this major area of phytoplankton abundance declined to <0.5 about 5 weeks earlier than average in 1989. This timing difference caused the below average conditions seen from mid-September to early December.

Total Copepoda: Abundance over the inner shelf remained well above 5,000/100m^3 during all but January (Figure 5A). The spring peak occurred over most of the transect in April amounting to over 100,000/100m^3 (404,000 at <50 km reference distance). Abundances of 400,000/100m^3 and 550,000/100m^3 occurred near shore in July and November, respectively. These conditions departed from the 1971 through 1987 means in a variety of ways (Figure 5B and 5C). Abundances over the shelf in January and the slope in January and February were significantly below average. Most of the transect to a reference distance of 400 km was above average for the rest of the year. The departures at the shelf break from January to June show no obvious relationships to the offshore shift of the shelf-slope front from average for these months (Jossi and Benway, MS 1990). Beyond 400 km two negative anomalies occupy fairly large areas. The first occurred during April and May while warm core ring 88L was present (Sano and Wood, MS 1990). The second was during September and October where small abundance anomalies in this usually low variance area produced significant departures.

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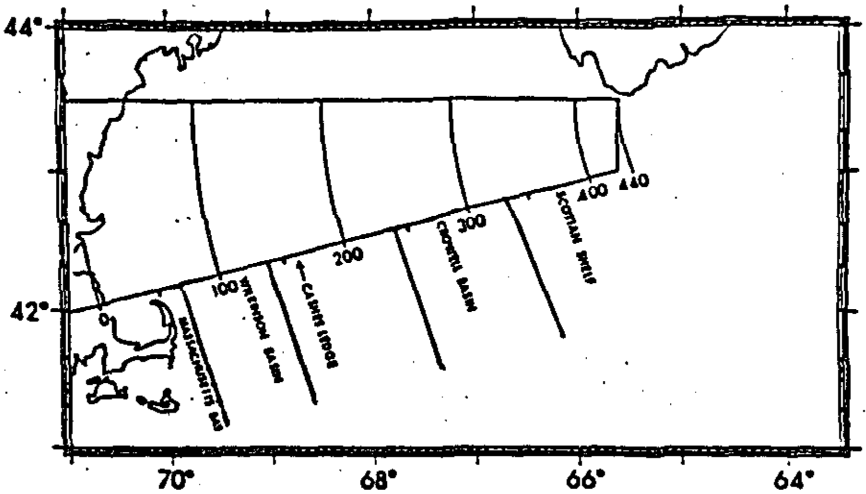
MARMAP ROUTE MC 1978 - 1989



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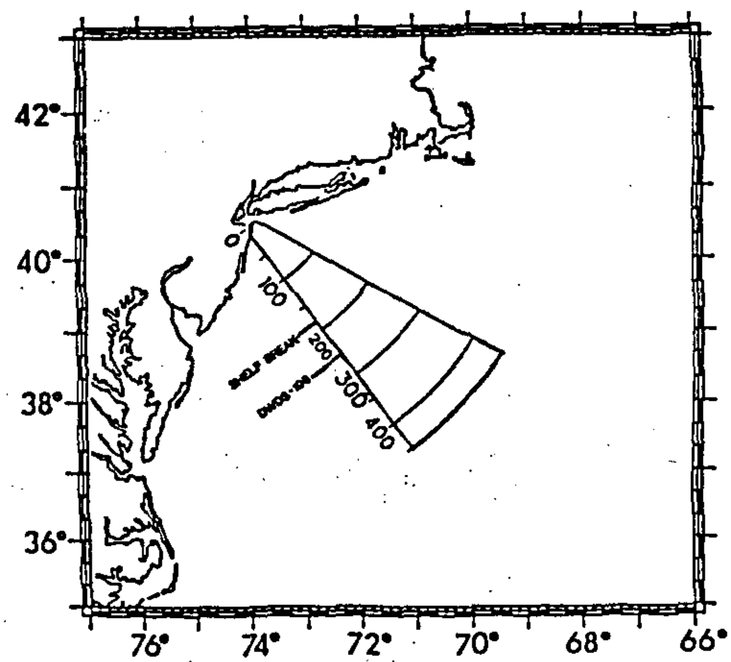
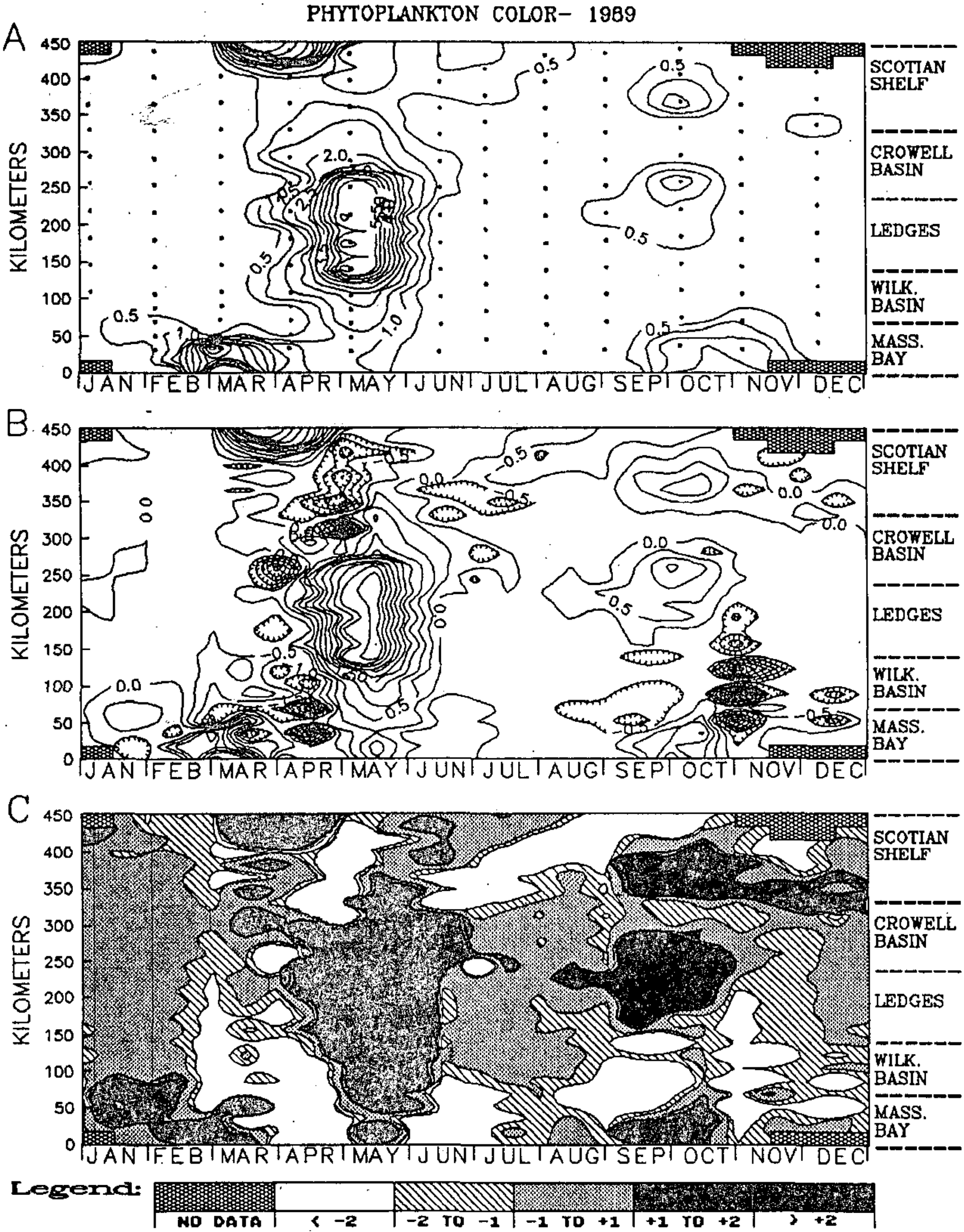


Figure 1. Gulf of Maine (MC) and New York Bight (MB) polygons within which sampling transects are conducted, with standard reference distances and major geographical features.



igure 2. "Total phytoplankton" along the Gulf of Maine transect during 1989. A. Relative reen color values in time and space. Dots indicate sampling locations. B. Color nomalies in time and space based on 1961 through 1987 means. C. Standardized color nomalies (standard deviations) in time and space based on 1961 through 1987 means nd variances. In panels A and B values decline on those sides of contour lines with achures.

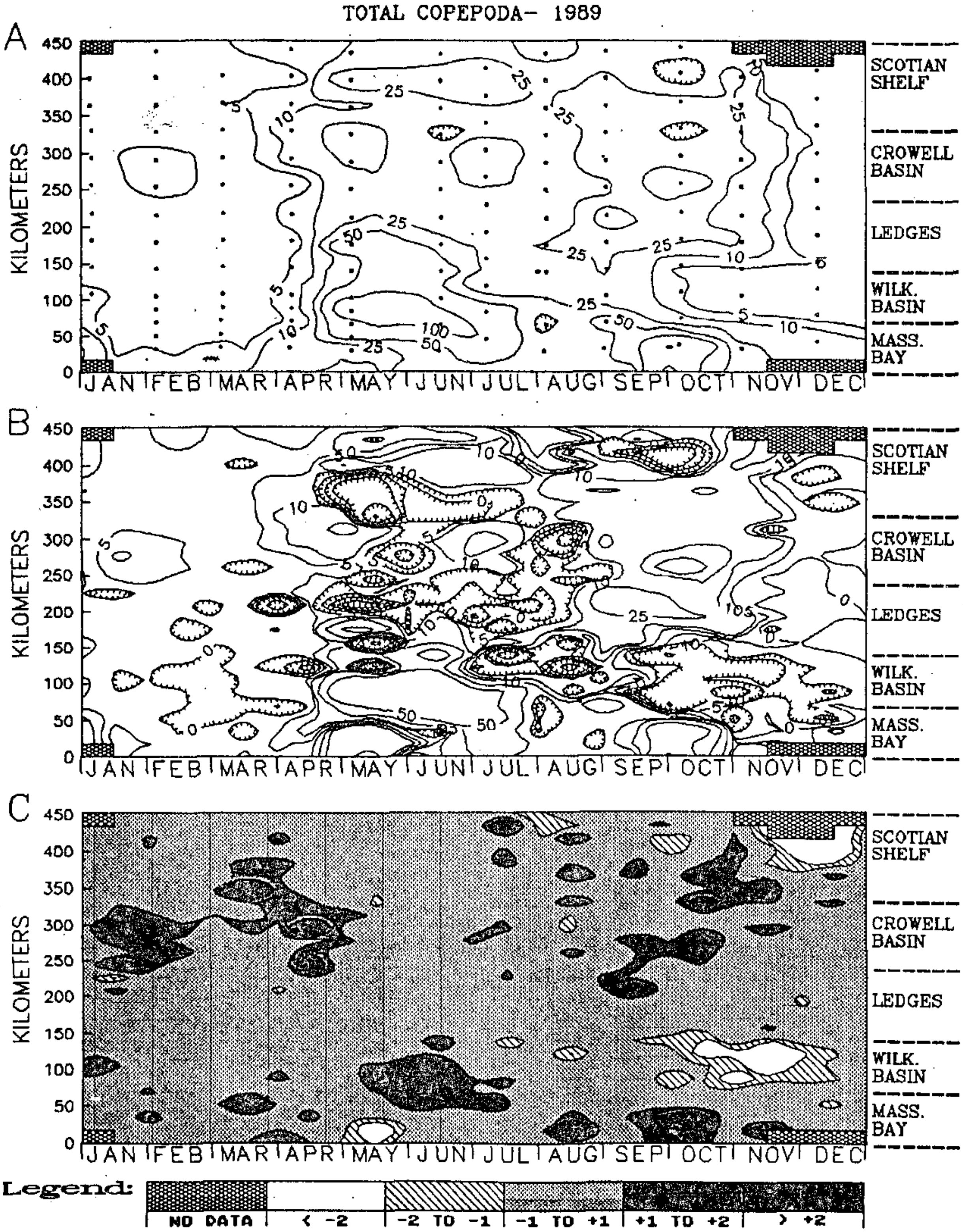


Figure 3. Total Copepoda abundance along the Gulf of Maine transect during 1989. A. Abundance values (thousands/100 m^3) in time and space. Dots indicate sampling locations. Panels A and B are contoured at 5, 10, 25, 50, 100, 250, and 500 levels. B. Abundance anomalies in time and space based on 1961 through 1987 means. C. Standardized abundance anomalies (standard deviations) in time and space based on 1961 through 1987 data. In panels A and B values decline on those sides of contour lines with hachures.

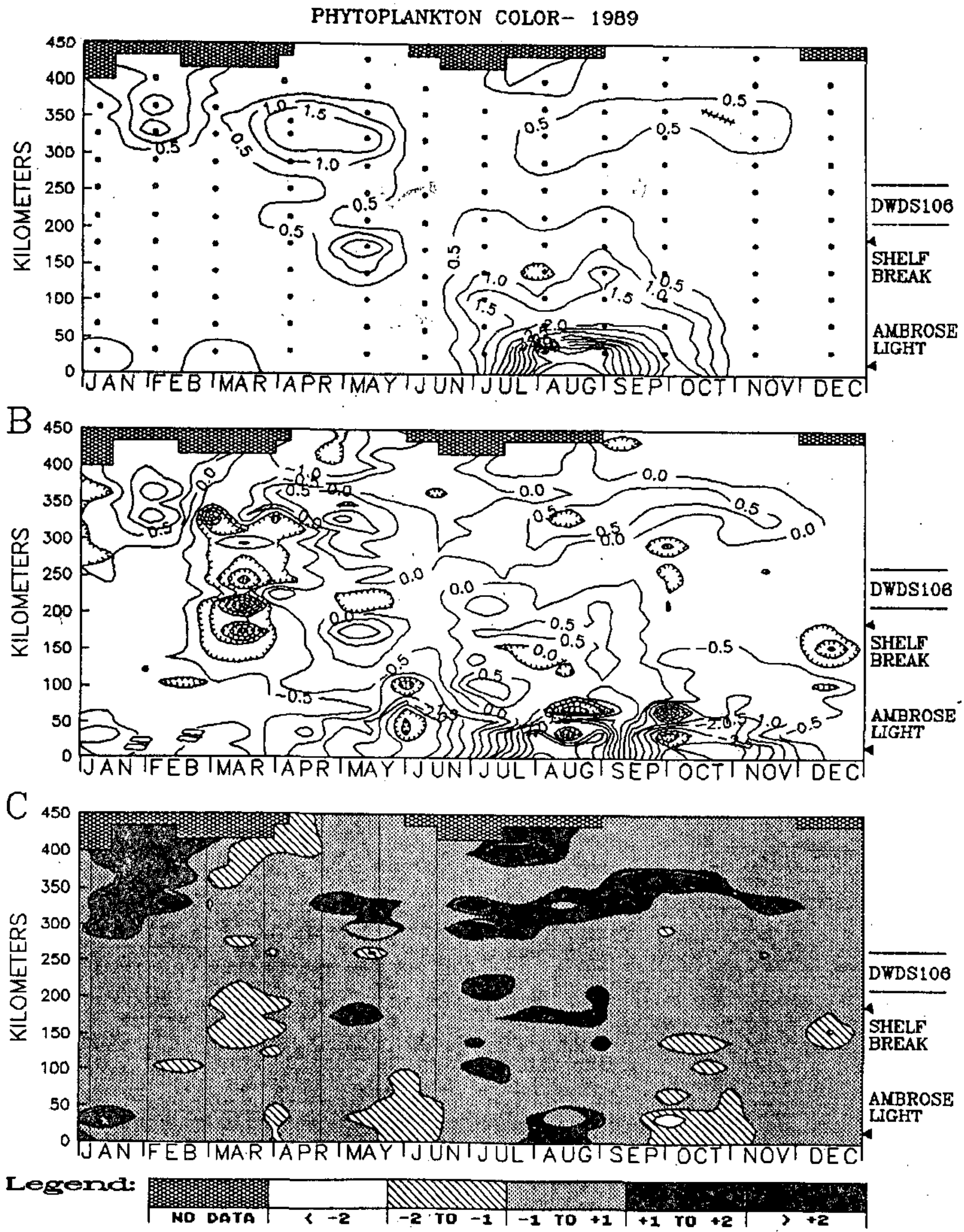


Figure 4. "Total phytoplankton" along with the New York Bight transect during 1989.
A. Relative green color values in time and space. Dots indicate sampling locations.
B. Color anomalies in time and space based on 1971 through 1987 means.
C. Standardized color anomalies (standard deviations) in time 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.

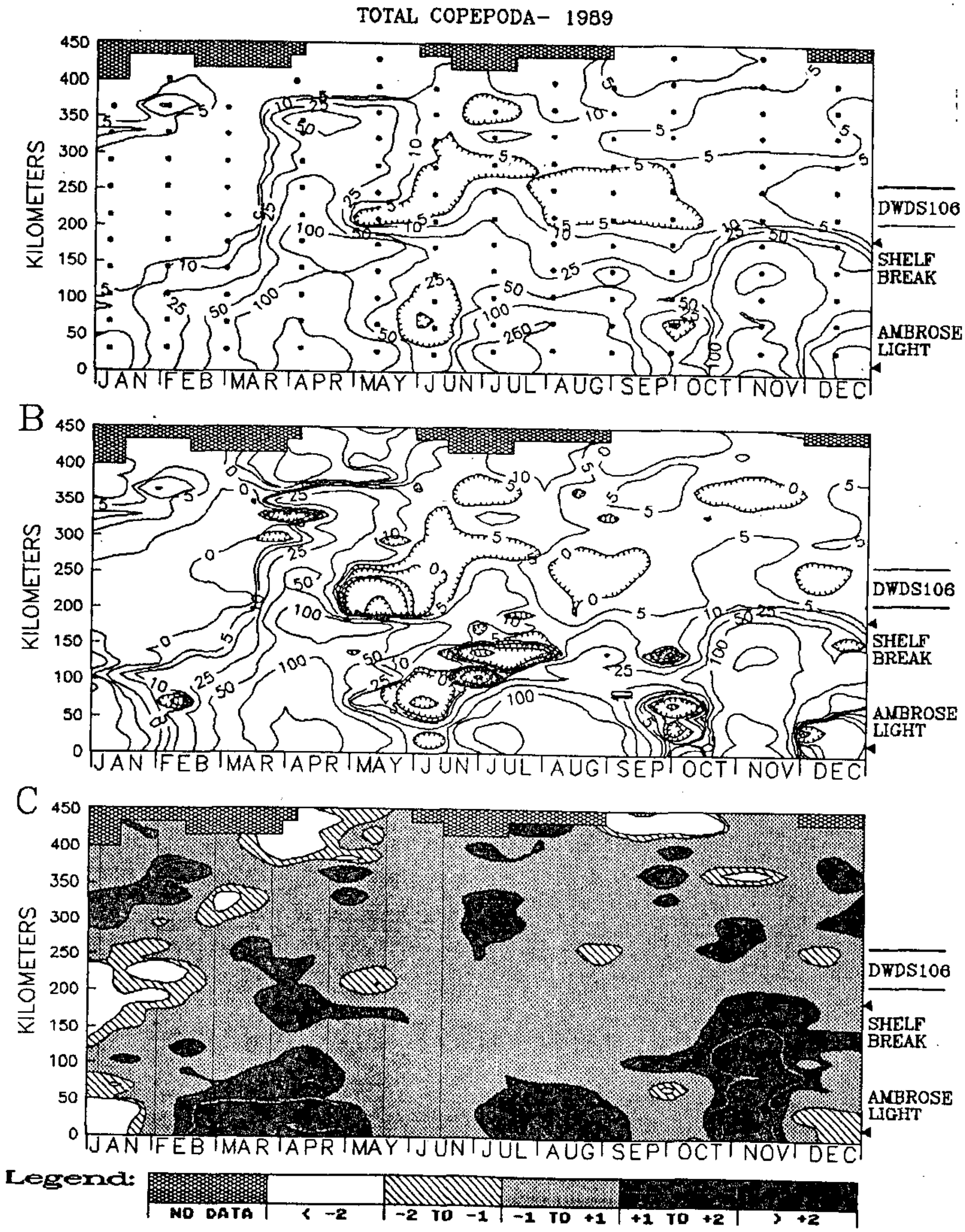


Figure 5. Total Copepoda abundance along the New York Bight transect during 1989. A. Abundance values (thousands/100 m^3) in time and space. Dots indicate sampling locations. Panels A and B are contoured at 5, 10, 25, 50, 100, 250, and 500 levels. B. Abundance anomalies in time and space based on 1971 through 1987 means. C. Standardized abundance anomalies (standard deviations) in time and space based on 1971 through 1987 data. In panels A and B values decline on those sides of contour lines with hachures.