NOAA Technical Memorandum NMFS-F/NEC-38

The Shelf/Slope Front South of Nantucket Shoals and Georges Bank as Delineated by Satellite Infrared Imagery and Shipboard Hydrographic and Plankton Observations

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts
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NOAA TECHNICAL MEMORANDUM NMFS-F/NEC

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ABSTRACT

Appreciable differences existed in water mass distributions along the edge of the continental shelf as interpreted from satellite infrared imagery and shipboard temperature, salinity, and dissolved oxygen observations. In general, shipboard indications of water mass distributions based on salinity and dissolved oxygen values were compatible, but the discontinuities observed were not as marked as those indicated by satellite imagery and evidenced a more southerly dispersion of shelf water. Chlorophyll concentrations and zooplankton volumes were appreciably greater over the continental shelf (<200 m). Nanoplankton/netplankton ratios were greatest in oceanic waters. The distributions of neritic and oceanic taxa of ichthyoplankton, zooplankton, and phytoplankton substantiated previous inferences as to their geographic range and optimum water type. Although the precise depth distribution of ichthyoplankton and zooplankton was not ascertained, oceanic species were restricted to areas of slope or Gulf Stream water or to areas in which these water types were readily accessible.

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INTRODUCTION

As part of an effort to determine the extent of seaward advection of shelf plankton assemblages in the vicinity of a semi-permanent frontal zone, a survey was conducted in autumn 1981 (Albatross IV Cruise 81-12; 12-23 October 1981). This report examines the changes in ichthyoplankton, zooplankton, and phytoplankton assemblages across the shelf/slope front in the area bounded by longitudes 70°00'W and 66°00'W.

MATERIALS AND METHODS

Shipboard sampling included standard double oblique 0.61 cm Bongo net tows (0.505 and 0.333 mm mesh) to a maximum depth of 200 m. Water samples for salinity, dissolved oxygen, phytoplankton species composition, and chlorophyll a were obtained at depths of 1, 10, 20, 30, 40, 50, 75 and 100 m. An XBT cast was made midway between stations. Hydrographic data (temperature, salinity, dissolved oxygen) were processed and summarized at the NMFS Woods Hole Laboratory, ichthyoplankton and zooplankton species composition and abundance were ascertained at the NMFS Narragansett Laboratory, chlorophyll determinations were made at the NMFS Sandy Hook Laboratory, and phytoplankton species composition and abundance were determined at Old Dominion University, Norfolk, VA.

RESULTS

Temperature, Salinity, and Dissolved Oxygen

The station locations and water mass distributions as interpreted from satellite infrared (IR) imagery on 12 and 21 October by the National Earth Satellite Service (NESS) are shown in Figure 1. Shipboard observed surface and 200 m temperatures and surface salinities are plotted in Figure 2. There is little conformance between the location of the shelf/slope boundary as interpreted from satellite imagery and from the distribution of shipboard observed surface temperature and salinity values, although the 14°C and 15°C isotherms and the 33.0‰ and 33.5‰ isohalines roughly encompass the infrared-inferred discontinuity. Both surface temperatures (>18°C) and salinities (>36‰) demark Gulf Stream water in the extreme southeast section of the sampling area. Subsurface temperatures (9°C and 15°C at 200 m) show that at this depth slope water bordered upon the 200 m isobath between 72°W and 66°W longitudes and that the Gulf Stream north wall was only manifest in the southeast extreme of the sampling area.

The poor agreement between the distribution of shelf and oceanic water masses (esp. the position of the shelf/slope front) as based on satellite IR imagery and shipboard hydrographic observations is consistent with previous observations made during late summer and early fall (Mooers, Flagg, and Boicort 1978; Chamberlin 1981; Joyce et al. 1984). It appears that the intensity of satellite coverage is such that thermal contrasts are detected that are not usually observable from widely spaced shipboard temperature observations. At this time of the year salinity and dissolved oxygen serve as better indices of shelf and oceanic water than does temperature. To further illustrate this point, we have plotted (Fig. 3) shipboard observed surface temperature, salinity, and dissolved oxygen values and satellite IR imagery during a detailed survey of Warm Core Ring 81-D made just prior to the cruise in question (Albatross IV Cruise 81-11, 23 Sept.-5 Oct. 1981). We have depicted shelf water (shaded) as having a salinity <34.5^{o}/oo (Wright 1976; Wright and Parker 1976) and a dissolved oxygen concentration >5.5 ml/l (McLellan 1957). The correspondence in the position, area, and form of Warm Core Ring 81-D based on satellite imagery and surface salinity and to a lesser extent dissolved oxygen was good. The distribution of surface temperature did not clearly delineate the warm core ring.

To more clearly define water mass distributions and boundaries prevailing at the time of Albatross IV Cruise 81-12, we have plotted in Figures 4-8 vertical profiles of salinity and dissolved oxygen for the 10 north-south sections shown in Figure 1 using the same criteria for differentiating shelf and slope water as in Figure 3. The agreement between these two criteria in separating shelf and slope water was fairly good.

In Section I (Fig. 4) salinity values show shelf water overlying slope water to a position just north of Station 7, while dissolved oxygen values reveal shelf water overlying slope water throughout the section. The Section II salinity values (Fig. 4) demonstrate a slight surface manifestation of slope water at Station 11, while dissolved oxygen values indicate that shelf water overlays the whole area. Both the Section III salinity and dissolved oxygen values (Fig. 5) evidence an upper layer of shelf water over the whole section, although dissolved oxygen values show subsurface slope water extending further onto the shelf. The Section IV salinity values (Fig. 5) show shelf water extending seaward to Station 26. The dissolved oxygen observations, although incomplete, indicate a similar distribution. There was no surface salinity or dissolved oxygen manifestation of the shelf/slope front in Sections V or VI (Fig. 6). The dissolved oxygen concentrations in Section VII (Fig. 7) indicate an isolated surface pool of low dissolved oxygen (slope?) water overlying the shelf break. This pool is not evidenced in the salinity values. In Section VIII (Fig. 7) there were two cells of low dissolved oxygen water, one at the bottom at 70 m depth and one at the surface (Sta. 61). The salinity values did not indicate any isolated pools of slope water in the shelf water layer. The salinity values in Section IX (Fig. 8) indicate that shelf water was present at inshore Stations 65-67 while dissolved oxygen values showed an additional isolated surface pool of shelf water at the two offshore stations (Sta. 69 and 70). The distribution of shelf water was essentially similar in Section X (Fig. 8) based on dissolved oxygen and salinity values, being confined to the area inshore of Station 74, the exception being an isolated patch of shelf water indicated by dissolved oxygen values at Station 73. Gulf Stream water, as indicated by salinity values >36^{o}/oo, was encountered at the two offshore stations (72 and 71).

With the exception of the extreme eastern region of the area of coverage (Sections IX and X), the surface salinity values indicated an appreciably greater offshore extension of shelf water than did the infrared temperature data. It was only in Sections I, IX, and X that slope water (>34.5^{o}/oo) was observed in the surface layer.

Ichthyoplankton

The distribution of two characteristic shelf and oceanic taxa of larval fishes are shown in Figure 9. Scophthalmus aquosus (windowpane) and Merluccius bilinearis (silver hake) were restricted for the most part to the continental shelf (<200 m), the one exception being the occurrence of silver hake larvae at Station 23 on Section III. At this station shelf water (salinity <34.5^{o}/oo) extended to a depth of 100 m. Seventeen taxa of Myctophidae were collected. Ceratoscopelus maderensis, Diogenichthys atlanticus, Benthosema glaciale, and Diaphus sp. made up the bulk (75%) of the catch. The myctophids were confined to areas deeper than 200 m and to areas characterized by surface or subsurface slope or Gulf Stream water. The myctophids are mesopelagic and most species inhabit considerable depth by day (200-600 m), but are often found at the surface at night. The night/day ratio in the catch of total myctophids was 5.7. Bothus ocellatus (eyed flounder), a warm water species which is commonly carried into northern areas via the Gulf Stream, was also confined to offshore waters deeper than 200 m, although its distribution was more limited than that of the Myctophidae. The distribution patterns of the four larval fish taxa in relation to water mass type is clearly reflected in the temperature-salinity-ichthyoplankton diagrams shown in Figure 10.

Zooplankton

Zooplankton displacement volumes tended to be highest over the continental shelf (Fig. 9), although relatively high values also occurred in offshore areas (e.g., Sections II, III, IX, and X). Copepods dominated the zooplankton collections with 60 species being identified (2 Harpacticoida, 3 Cyclopoida, and 55 Calanoida). Examples of the distributions of three neritic and three oceanic copepod species are shown in Figure 11. Temora longicornis, Centropages hamatus, and Calanus finmarchicus were confined almost wholly to continental shelf waters (<200 m) while

Rhincalanus cornutus, R. nasutus, and Pleuromamma borealis were restricted for the most part to waters south of the 200 m contour.

Phytoplankton

The distribution of integrated chlorophyll concentrations to a maximum depth of 75 m is shown in Figure 9. The highest integrated chlorophyll values (1.0-2.0 mg/m^3) occurred over the continental shelf (<200 m) in the northwest section of the sampling area and where shelf water extended to the bottom or close to the bottom. With few exceptions (Section VII) offshore (>2000 m) chlorophyll concentrations were <0.4 mg/m^3. The association of high chlorophyll values with shelf water is manifest in the chlorophyll vertical distribution plots shown in Figure 12.

For total stations the average ratio of nanoplankton (<20 μm) to netplankton (>20 μm) on a basis of chlorophyll a values was 4/1. As has been previously noted (cf. Malone 1971; Ryther 1969; Yentsch and Ryther 1959), percent nanoplankton values were appreciably higher in oceanic than in neritic waters (Fig. 13). Areas of high standing crop (chlorophyll a, Figs. 9 and 12) coincided with areas over the continental shelf having relatively high percent netplankton.

The samples contained 273 species of phytoplankton, in addition to a pico-nanoplankton component composed mainly of cyanobacteria (1.5-5.0μm). Higher surface cell concentrations of both total phytoplankton and diatoms were generally associated with the cooler and less saline shelf water (Fig. 14). The pico-nanoplankton fraction represented 71% of the total cell counts for all depths, averaging 34.9 x 10^4 cells/l. The diatoms were the next most abundant group at 16% of the total cells, averaging 8.0 x 10^4 cells/l for all stations and depths. Other groups represented included the Dinophyceae, Haptophyceae, Euglenophyceae, Cryptophyceae, Chrysophyceae, and cyanobacteria. The diatoms averaged 16 x 10^4 cells/l over the continental shelf compared to 2.6 x 10^4 cells/l at locations seaward. The highest diatom concentrations were in the northwest portion of the sampling area and correspond to sites of high mean chlorophyll values. These diatom populations included both small (<20 μm) and larger cell types. Using cell volume as the basis for determining phytoplankton biomass of the standing crop, the mean water column value for diatoms was 78% of the total, followed by the Dinophyceans (14%), with the pico-nanoplankton contributing less than 1%.

The most abundant diatoms over the shelf were colonial and chainforming species, e.g. Leptocylindrus danicus, Chaetoceros sociale, and Rhizosolenia delicatula. These are typically neritic species, with L. danicus and R. delicatula common dominants in estuaries along the coast. Regional patches of larger diatoms (Coscinodiscus spp. and Rhizosolenia spp.) also contributed to elevated biomass levels at several stations. In contrast, the pico-nanoplankton cyanobacteria were ubiquitous in both shelf and slope waters, with highest concentrations at the surface. There was also a tropical and sub-tropical phytoplankton component that was more evident in, but not limited to slope water. There were 25 of these species, representing 9% of the total phytoplankters, although none of these were numerically dominant.

There was generally a positive relationship between a more diverse and abundant phytoplankton assemblage and shelf waters. This phytoplankton community contained an abundant diatom flora that included as dominants *Leptocylindrus danicus*, *L. minimus*, *Thalassionema nitzschoides*, *Nitzschia pungens*, *Cylindrotheca closterium*, and *Rhizosolenia delicatula*. In contrast, the slope water was dominated by phytoflagellates and cyanobacteria, with most of the shelf water species either absent or in low concentrations.

DISCUSSION

The majority of ichthyoplankton, zooplankton, and phytoplankton taxa were confined to either a neritic or oceanic province, at least in a biogeographic sense. Species generally considered neritic were found in areas shoaler than 200 m and oceanic species occurred in regions deeper than 200 m. Hedgpeth (1957) and Colebrook et al. (1961) have commented on the fact that the edge of the continental shelf (200 m contour) frequently marked the boundary between oceanic and neritic plankton communities and that a feature of the distribution of many species of ichthyoplankton, phytoplankton, and zooplankton was the close correspondence between the contours of abundance and the edge of the continental shelf. Our information on the vertical distribution of the various taxa is inadequate, however, for us to ascertain if these spatial patterns of species distributions were controlled by environmental conditions (water mass properties). The fact that few neritic species were found south of the 200 m contour suggests that factors other than temperature and salinity are involved in determining distribution patterns. As has been noted previously (Colton and Byron 1977), a conspicuous aspect of the larval fish distribution in the area of concern is the almost total segregation of shelf (boreal) and oceanic (tropical and subtropical) species of larval fishes north and south of the shelf break (200 m contour). This division appears to be linked in part to water mass distribution, as the 200 m isobath coincided with the subsurface manifestation of the shelf/slope front (9°C at 200 m). Although surface shelf water extended a considerable distance south of the 200 m contour and in some sections to the southerly extreme of the sampling area, diel migrants such as the myctophids would have ready access to slope water at all locations south of the 200 m contour. Why shelf species such as windowpane and silver hake did not occur in the overlying shelf water south of the 200 m contour is not readily apparent. Possibly they, too, are diel migrants and find the underlying slope water intolerable.

In future studies of this nature it would be desirable to sample in the spring when the temperature contrast between shelf and slope waters is at a maximum and the surface temperature manifestation of the shelf/slope front is readily discernible from satellite IR imagery and shipboard observations. In addition, it would be expedient to employ a discrete depth plankton sampler such as the MOCNESS (Wiebe et al. 1976) so that the vertical distribution of larval fishes and associated zooplankton could be ascertained and more precise correlations of abundances with oceanographic features established.

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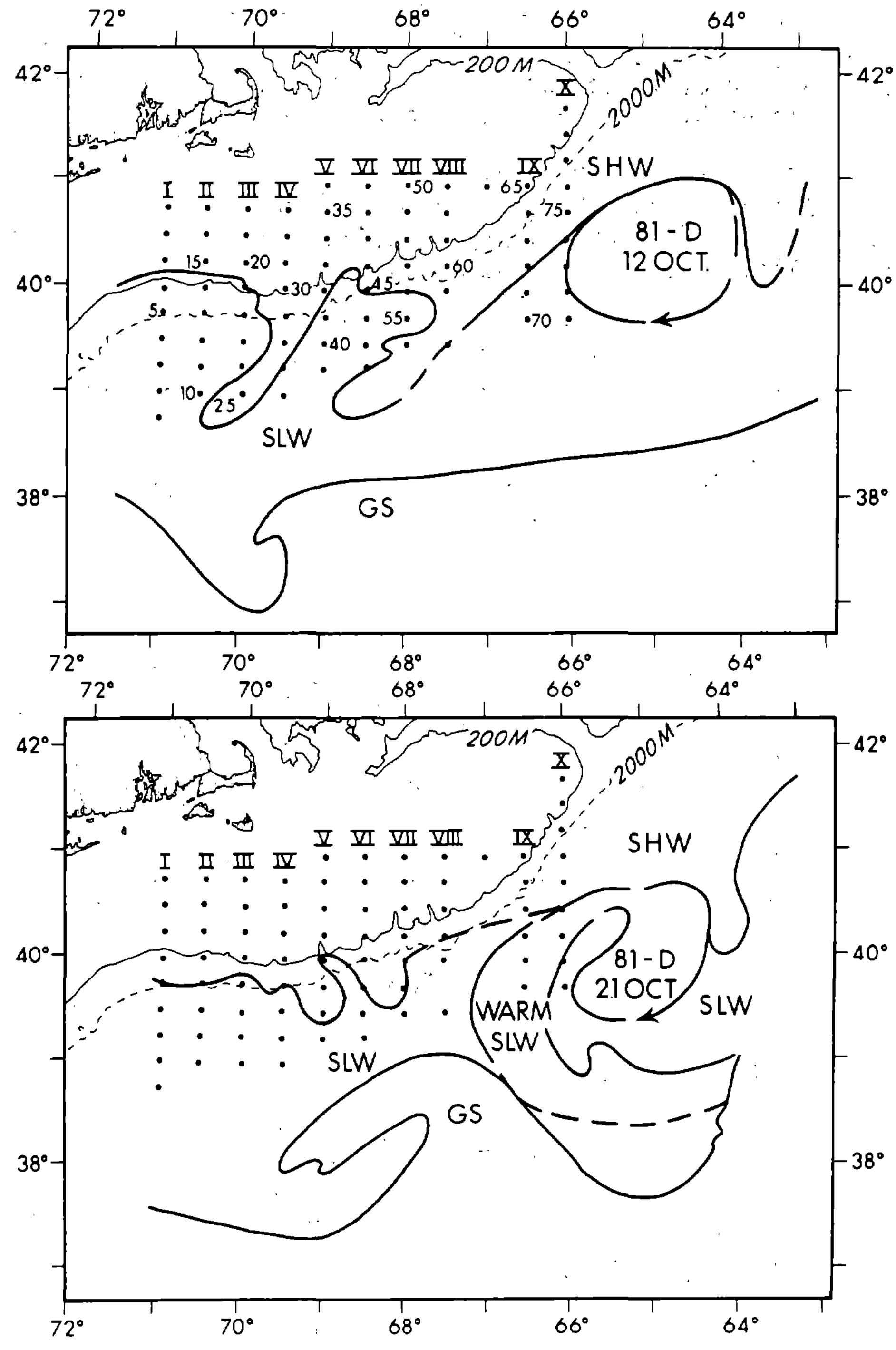

Figure 1. Albatross IV Cruise 81-12 station locations (12-23 October, 1981) and water mass distributions based on satellite infrared imagery on 12 October and 21 October 1981.

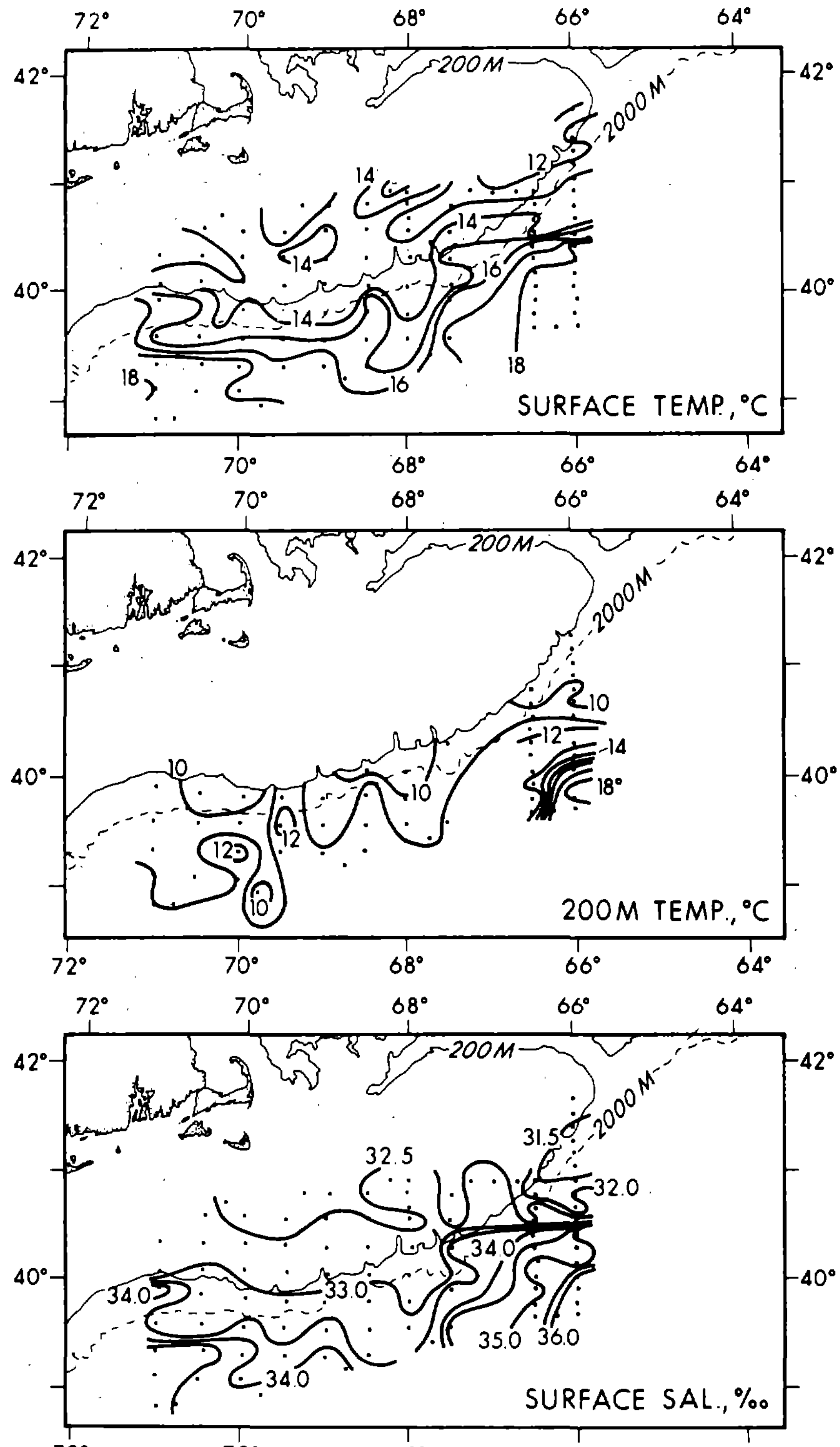

Figure 2. Shipboard observed surface and 200 m temperatures and surface salinities.

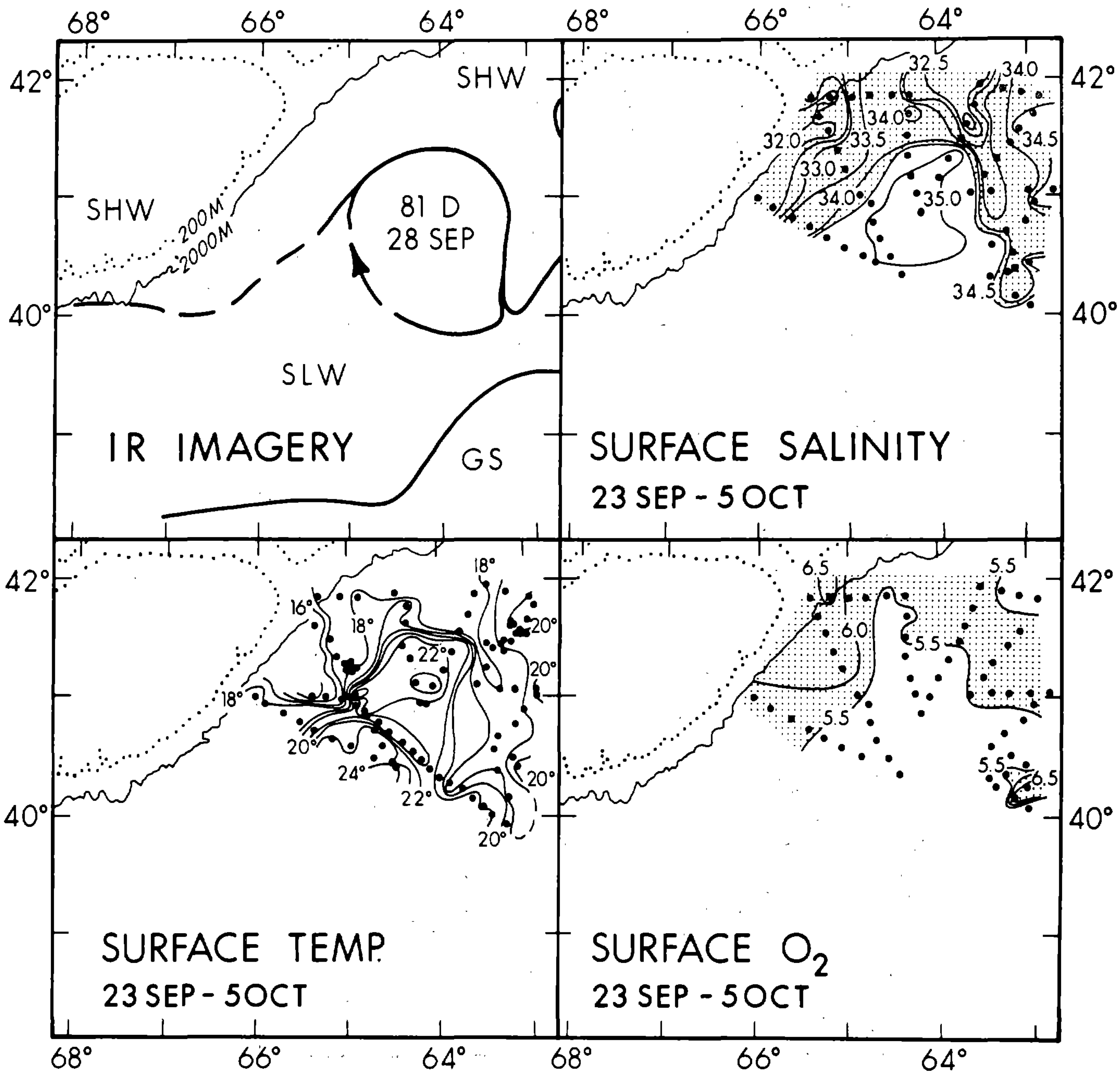

Figure 3. Shipboard observed surface temperature salinity, and dissolved oxygen during 23 September-5 October 1981 and position of Warm Core Ring 81-D and associated water masses as determined from satellite imagery on 28 Septemer 1981.

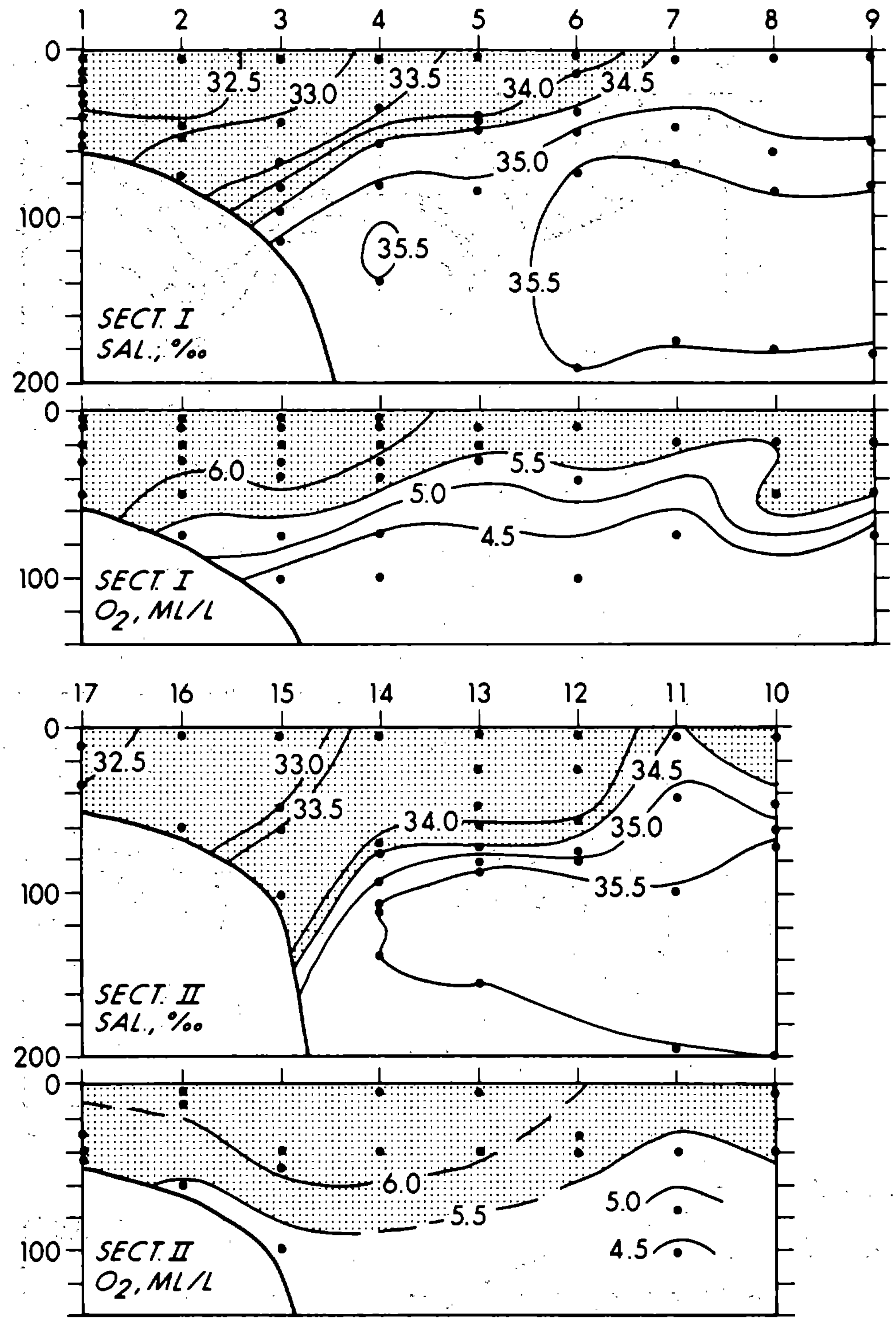

Figure 4. Vertical distribution of salinity and dissolved oxygen, Sections I and II. Shading indicates shelf water.

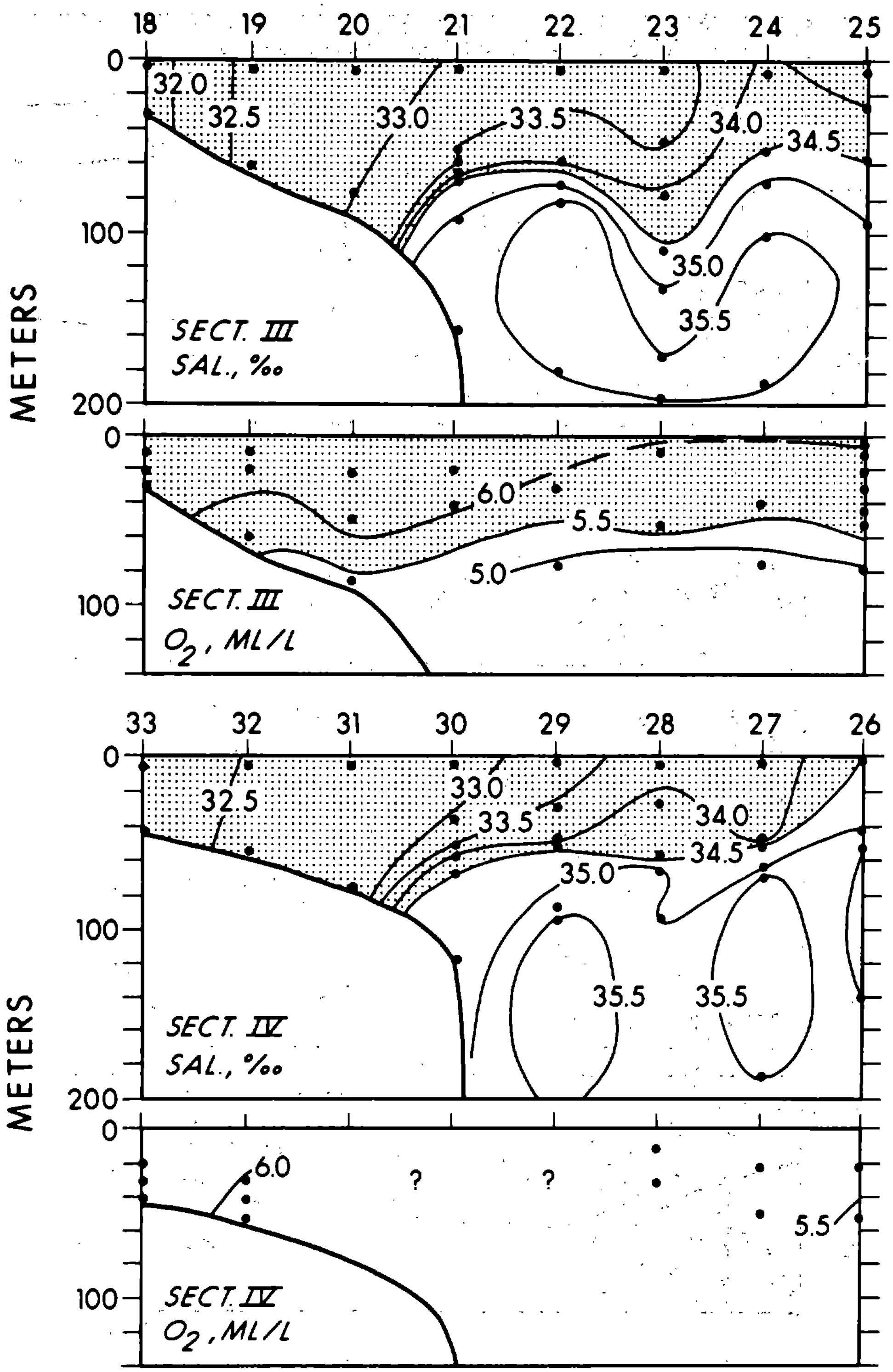

Figure 5. Vertical distribution of salinity and dissolved oxygen, Sections III and IV.

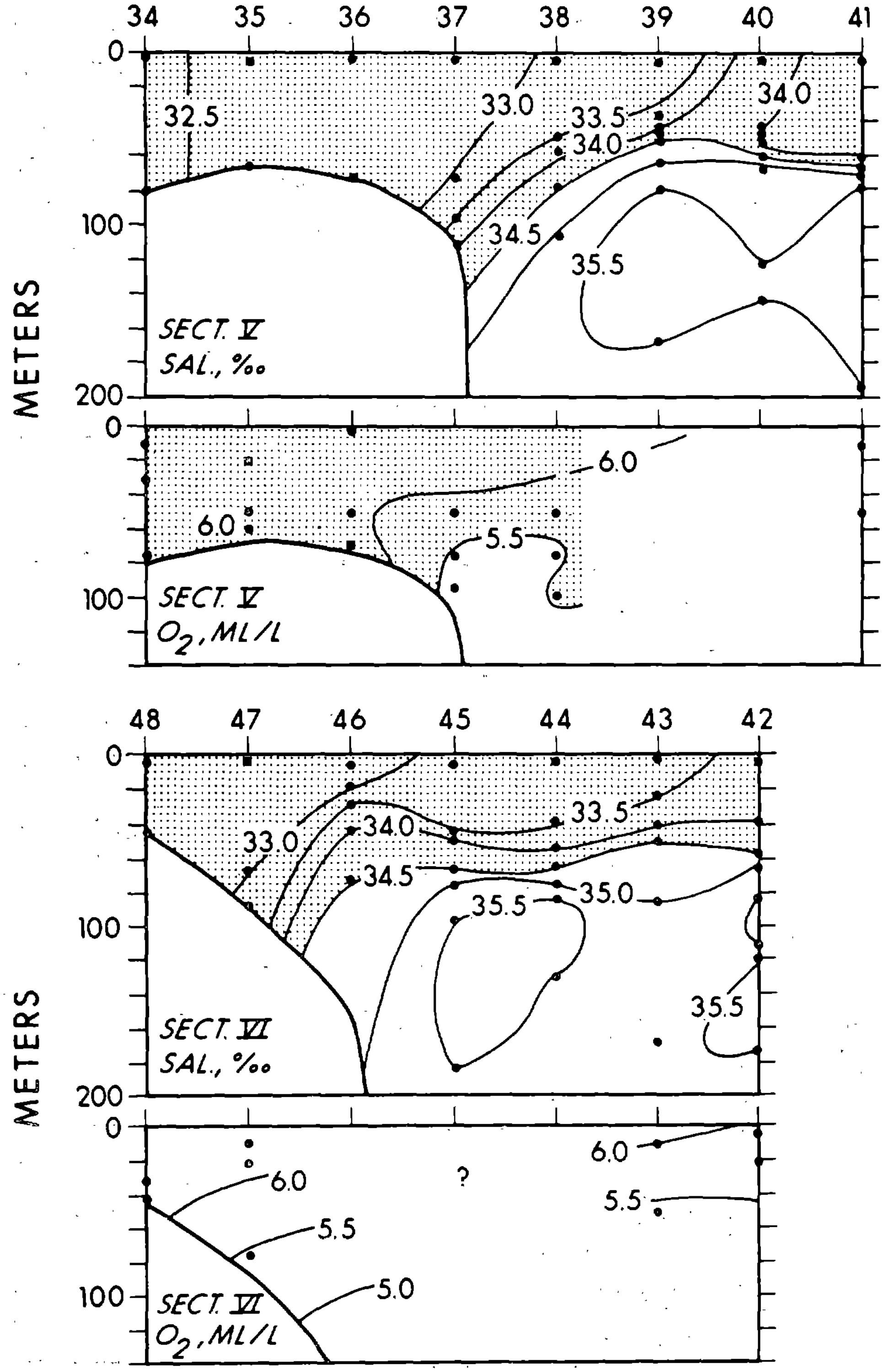

Figure 6. Vertical distribution of salinity and dissolved oxygen, Sections V and VI.

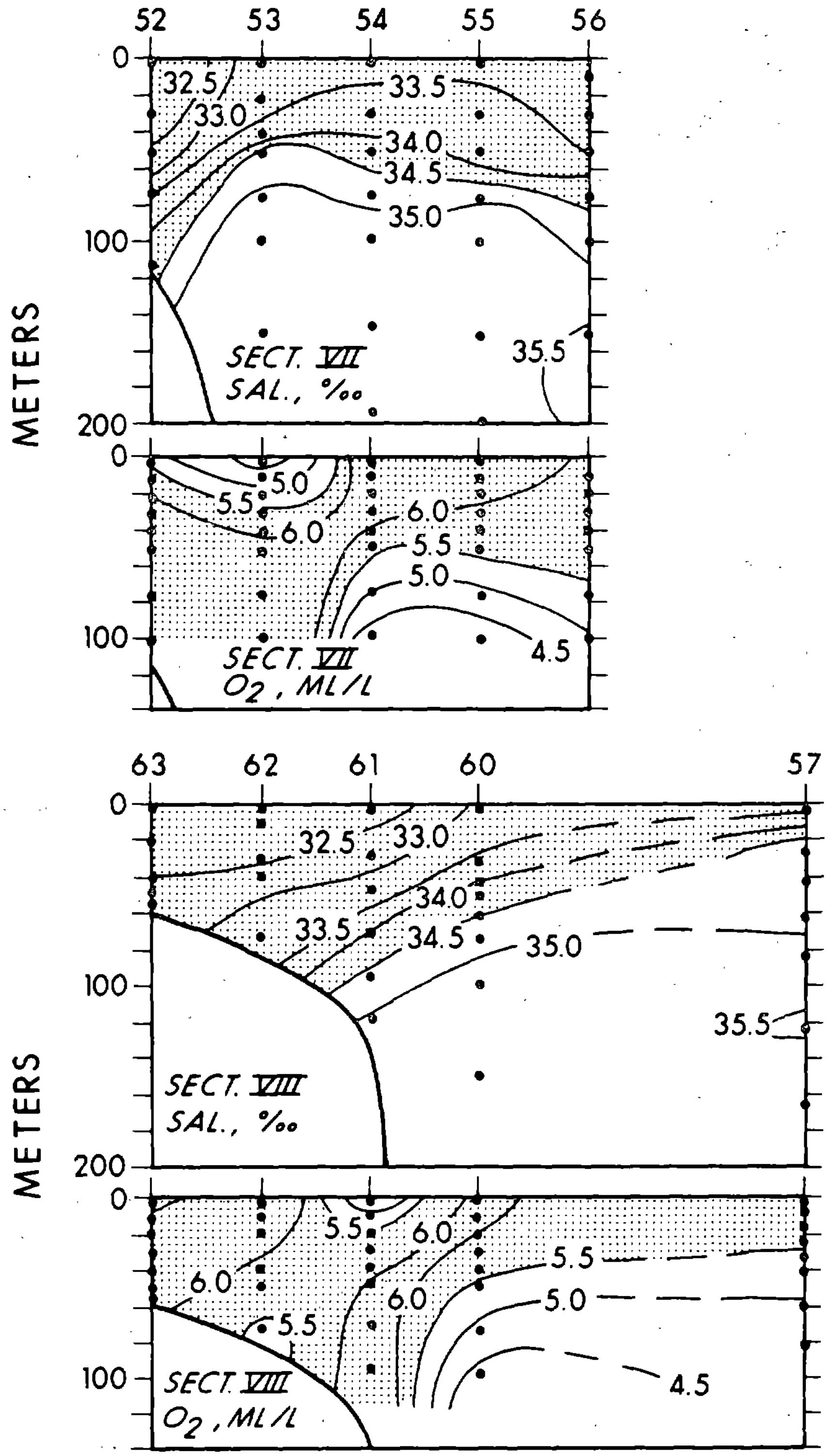

Figure 7. Vertical distribution of salinity and dissolved oxygen, Sections VII and VIII.

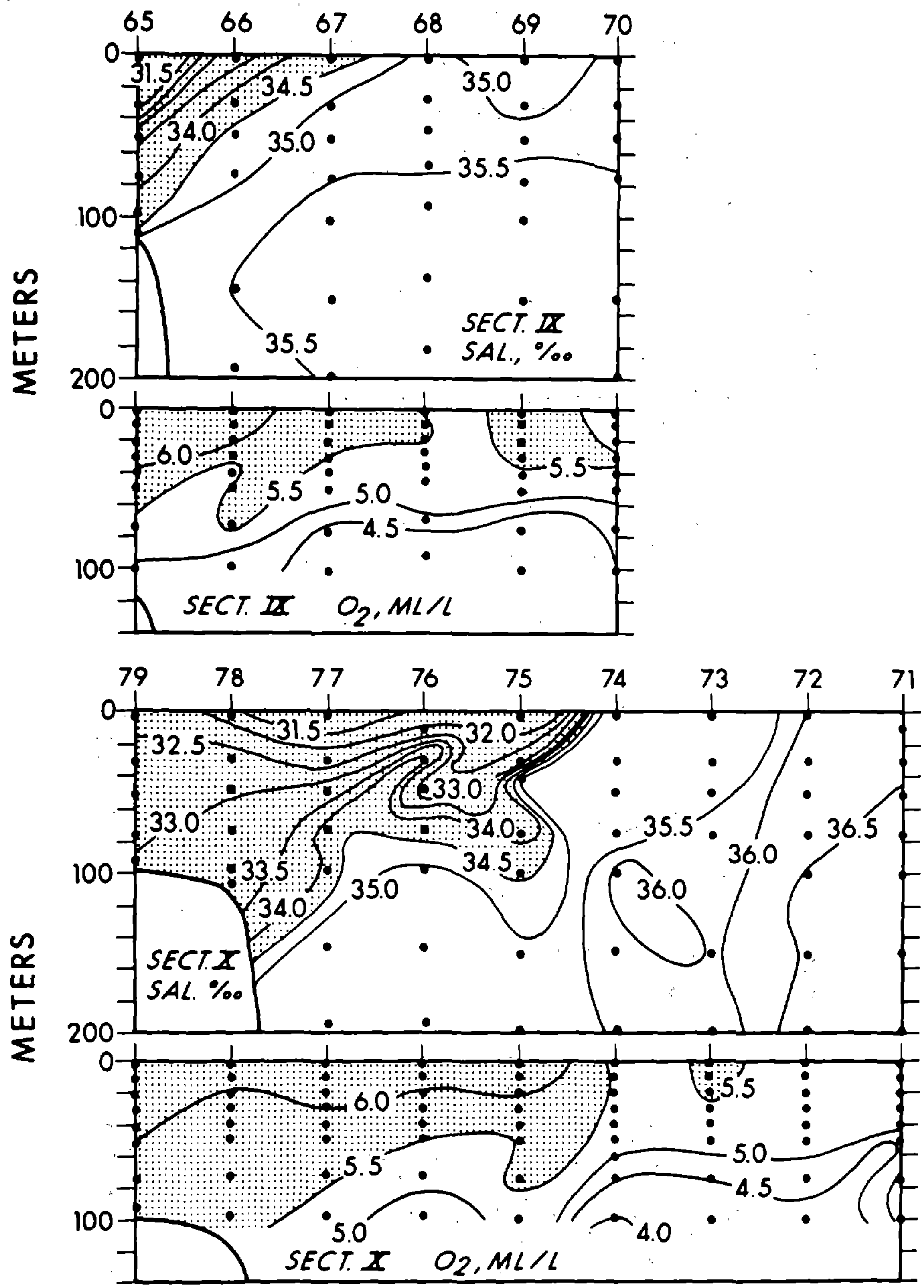

Figure 8. Vertical distribution of salinity and dissolved oxygen, Sections IX and X.

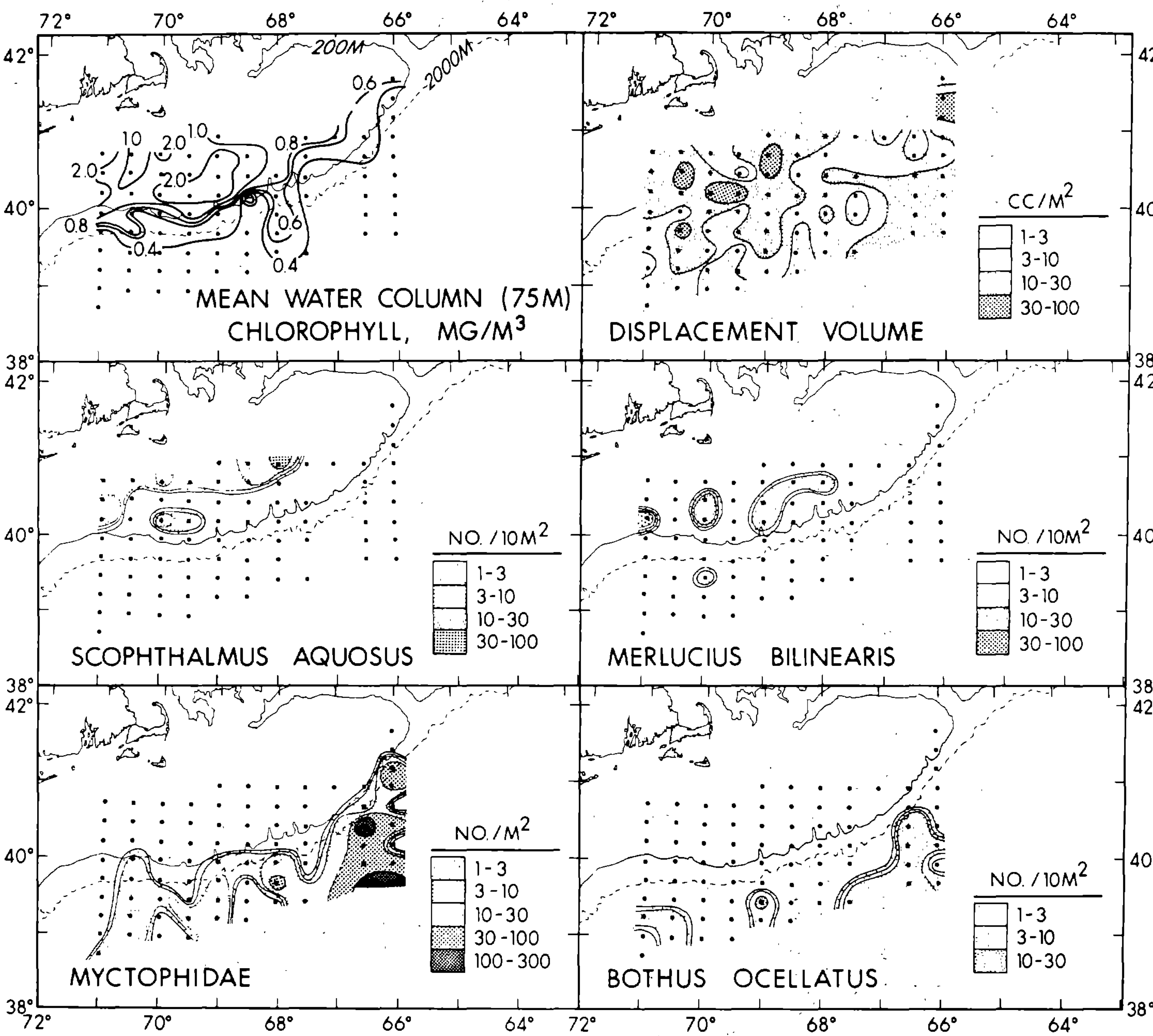

Figure 9. The distribution of mean water column chlorophyll, zooplankton displacement volume, and two shelf and oceanic taxa of larval fishes, 12-23 October 1981.

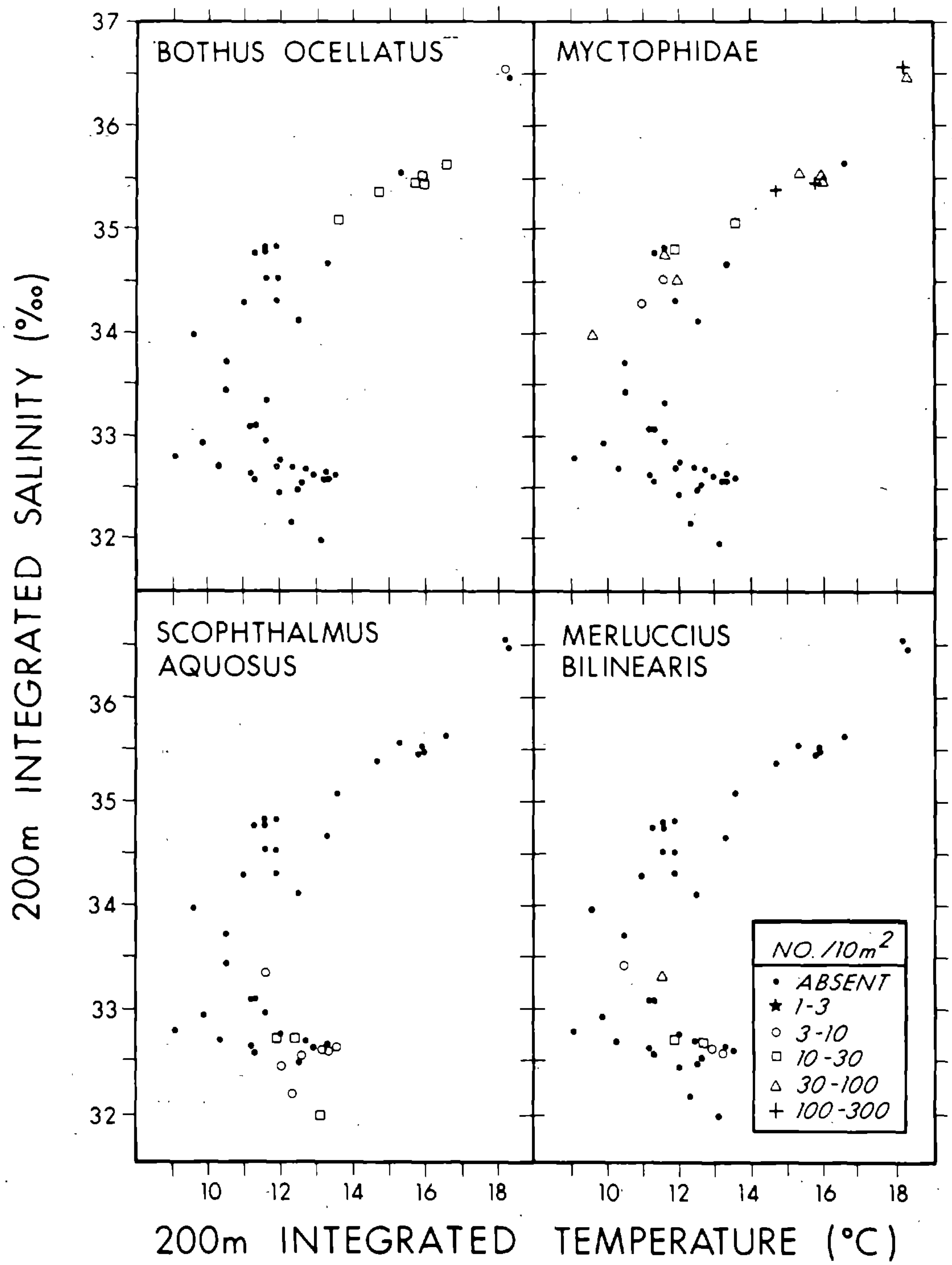

Figure 10. Ichchtyoplankton abundance in relation to temperature and salinity.

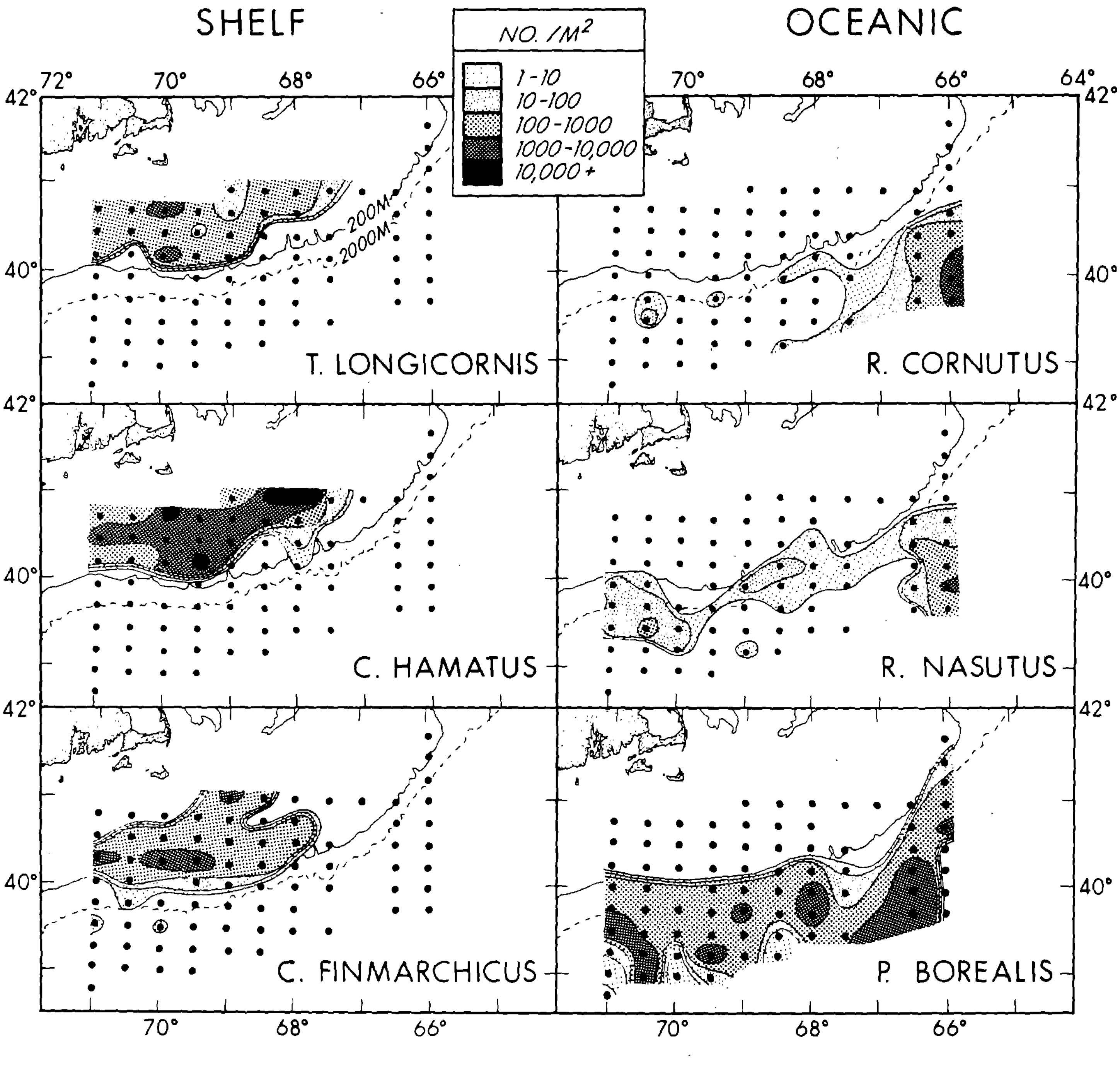

Figure 11. Distribution of neritic and oceanic copepod species.

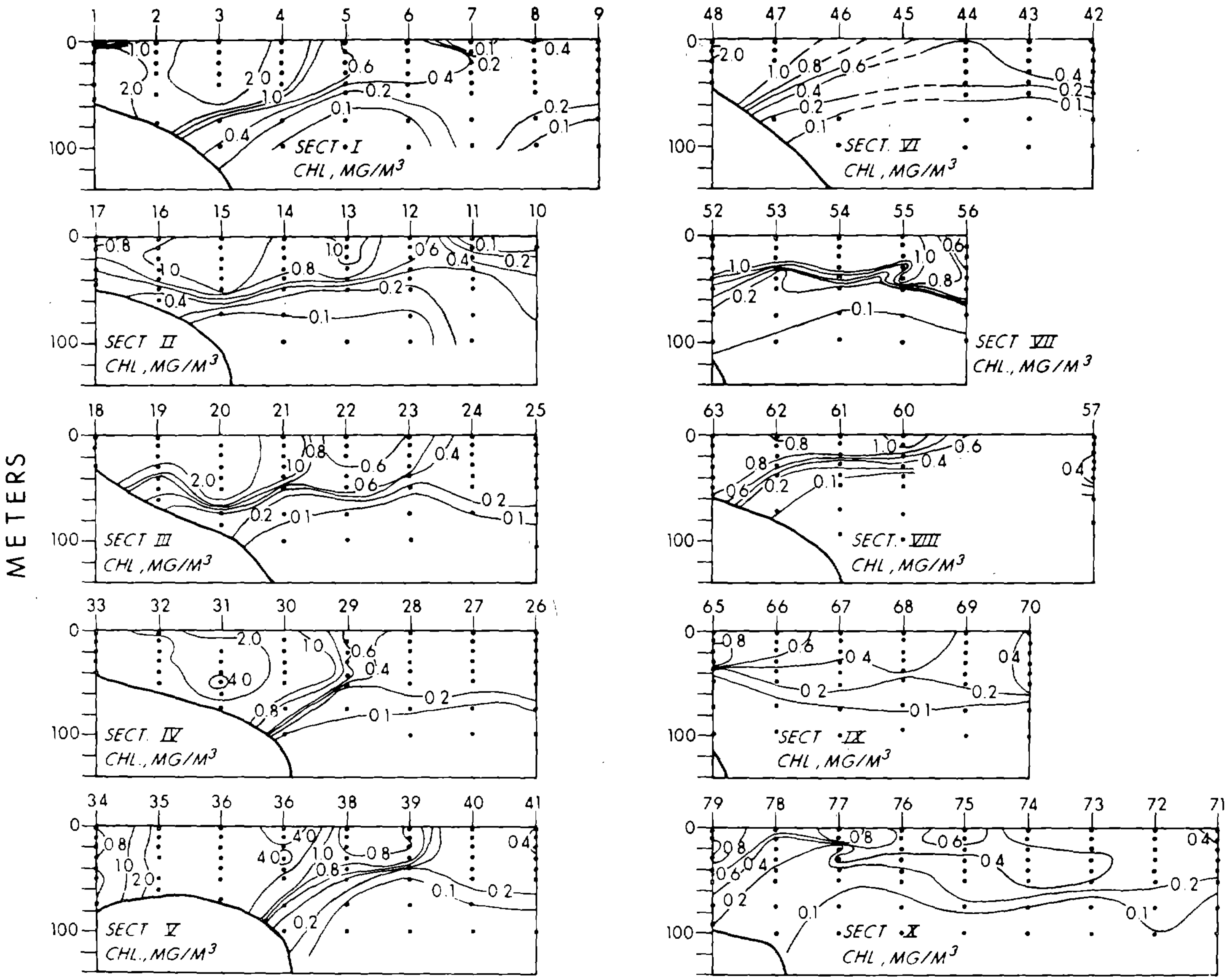

Figure 12. Vertical distribution of chlorophyll, Sections I-X.

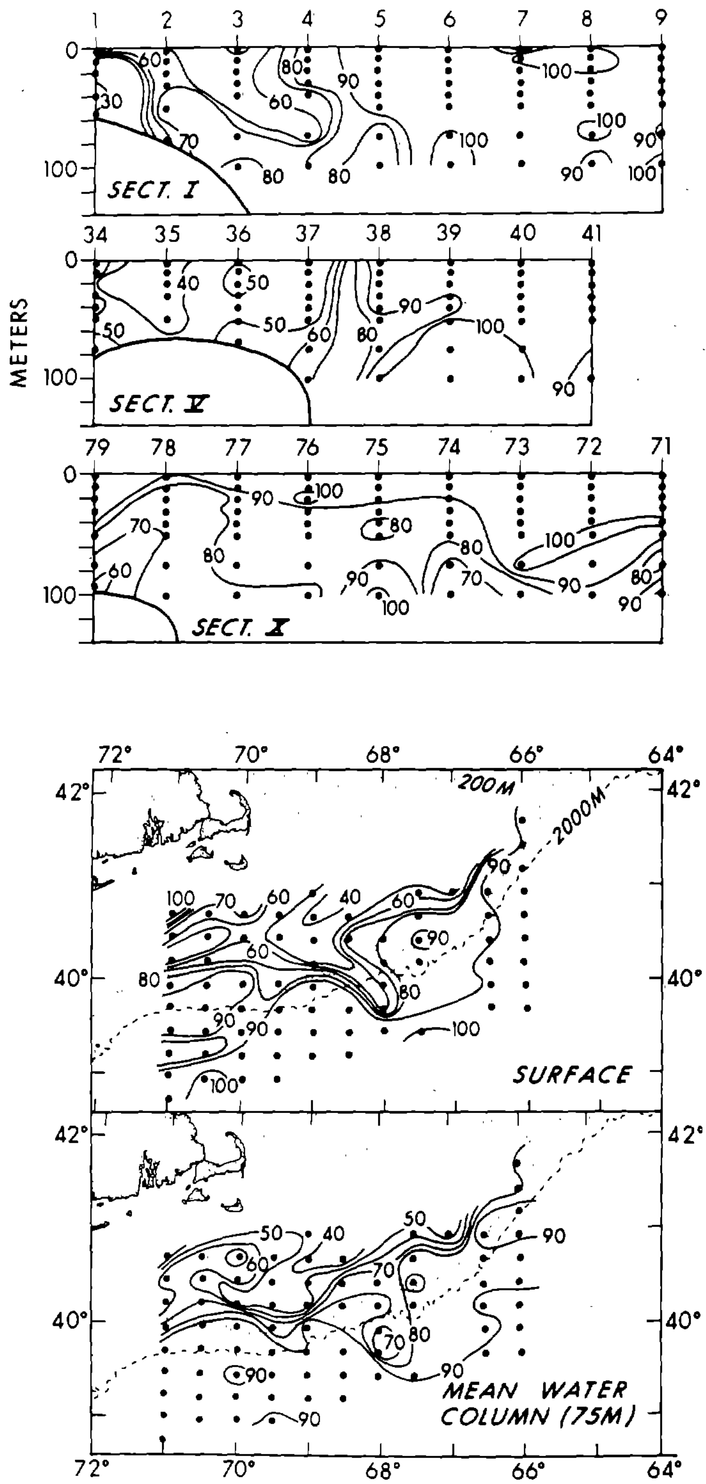

Figure 13. Percent nanoplankton.

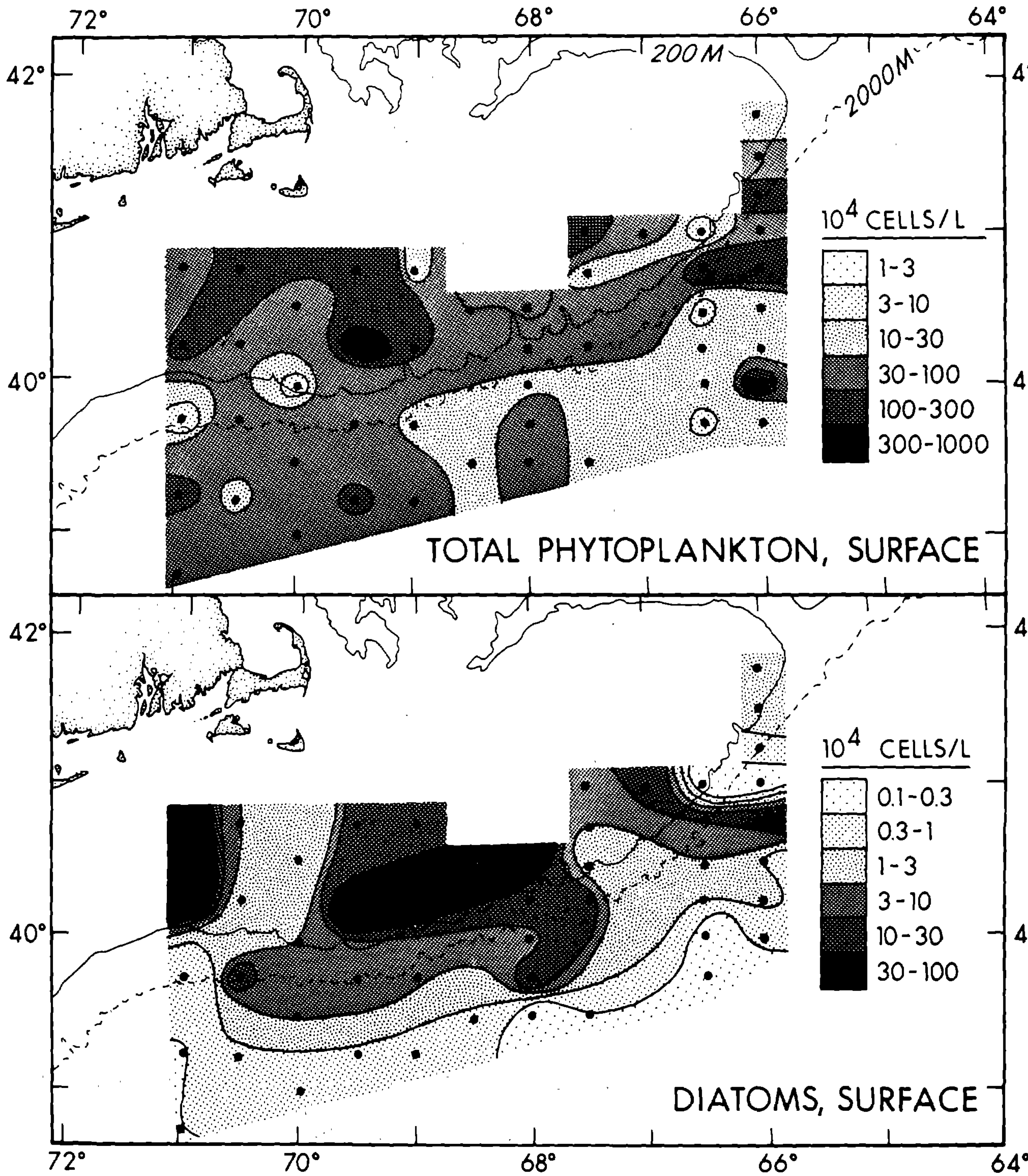

Figure 14. Total phytoplankton and diatom distributions.

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