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Middle Atlantic Outer Continental Shelf Environmental Studies. Volume IIA Chemical and Biological Benchmark Studies

Virginia Inst. of Marine Science
Gloucester Point

Prepared for

Bureau of Land Management
Washington, DC

Jul 79

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MIDDLE ATLANTIC OUTER CONTINENTAL SHELF ENVIRONMENTAL STUDIES

VOLUME IIA. CHEMICAL AND BIOLOGICAL BENCHMARK STUDIES

conducted by the
Virginia Institute of Marine Science
under Contract No. AA550-CT6-62

with the
Bureau of Land Management
United States Department of Interior

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16. Abstract (Limit: 200 words)

This volume includes an introductory chapter describing the purpose and scope of the study, a chapter on benchmark sampling describing station locations and their rationale, cruise tracks, and field sampling procedures, and two chapters of element reports. The physical oceanography chapter contains methods and equipment used, and a discussion of hydrographic conditions during each of the four seasons. The zooplankton chapter presents a faunal description for each station during each season and discusses community structure and seasonal succession.

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The use of trade names or identification of specific products or equipment by manufacturer does not constitute endorsement or recommendation for use.

PREFACE

The final report on contract AA550-CT6-62 between the Bureau of Land Management and the Virginia Institute of Marine Science consists of the following:

Volume I. Executive Summary.

This volume contains the Executive Summaries of the work conducted by VIMS under contract AA550-CT6-62 and the U. S. Geological Survey under Memorandum of Understanding AA550-MU7-31.

Volume IIA, IIB, IIC and IID. Chemical and Biological Benchmark Studies.

This volume contains the individual program element reports for the work completed by VIMS during the first year of the Chemical-Biological Benchmark Studies in the Middle Atlantic outer continental shelf region. Microfiche appendices containing field, laboratory, and data processing forms are included at the end of Volume IID.

Volume III. Geologic Studies.

This volume contains the individual program element reports for the work completed by USGS during the first year of the Geologic Studies in the Middle Atlantic outer continental shelf region. Microfiche appendices and a map supplement are included.

In addition to the printed and microfiched material, the final report also includes a complete, documented set of the environmental data generated by VIMS which has been deposited with the Environmental Data Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C. 20235. Data documentation has also been provided to BLM.

Copies of computer programs developed by VIMS during this study have been deposited with BLM as has a microfiched set of the raw data. Anyone desiring access to the computer programs, data documentation, or raw data can contact:

Environmental Studies Field Coordinator
Bureau of Land Management
Atlantic Outer Continental Shelf Office
6 World Trade Center, Suite 600D
New York, New York 10048

Eugene M. Burreson
Program Manager

ACKNOWLEDGEMENTS

This report is the result of the cooperative efforts of many people, especially the authors of the chapters of this volume who were also the principal investigators of the various program elements. Scientists, graduate assistants, and technicians throughout the Virginia Institute of Marine Science are also deserving of our acknowledgements.

Special appreciation goes to our patient clerical personnel, Cheryl Ripley, Ruth Edwards, Patti Alderman, and Annette Stubbs for typing, proofreading, and assistance in coordination of this volume.

We would also like to acknowledge all the personnel in the Drafting, Photography, Printing and Computer Services departments for their invaluable services.

E. M. Burreson
D. F. Boesch
B. L. Laird

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[1] Detailed Tables of Contents are provided with each volume.

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[1] Appendices are provided on microfiche at the end of Volume IID.
[2] Appendices are provided on microfiche at the end of Volume III.

VOLUME IIA
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[1] Appendices are provided on microfiche at the end of Volume IID.

CHAPTER 1

Introduction

E. M. Burreson

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Contract AA550-CT6-62
with the Bureau of Land Management

July 1979

CHAPTER 1

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CHAPTER 1

INTRODUCTION

E. M. Burreson

PURPOSE AND SCOPE OF THE STUDY

Increasing demand for petroleum and natural gas in the United States has led to a need for development of reliable new domestic sources. The Outer Continental Shelf of the United States holds great interest among the oil companies for possible exploration and development of oil and gas resources to meet these needs. This interest was demonstrated for the Middle Atlantic outer continental shelf in the oil company response to the lease sale conducted in August 1976. Of the 154 tracts comprising 876,750 acres selected in August 1975 for exploratory drilling in the Baltimore Canyon Trough (Figure 1-1), oil companies purchased drilling rights to 101 tracts comprising 575,011 acres. Because of the potential for environmental impact associated with drilling activities, it is necessary to provide as much protection as possible during development and production phases.

The primary purpose of the Bureau of Land Management (BLM) Environmental Studies Program is to provide environmental information for inclusion in decision making processes associated with exploration and development of oil and gas resources on the outer continental shelf (OCS). The ultimate goals of the study include providing data on the following parameters:

1. the uniqueness of biological assemblages, resources, or physical environments in the area proposed for development which, due to their location or sensitivity, are likely to be perturbed;
2. the biological, geological, chemical, and physical nature of the environment being considered for lease, and its sensitivity to prolonged exposure to contaminants derived from development activities;
3. proper methods for environmental monitoring to assure detection of significant changes as a result of OCS activities;
4. location of concentrations of economically important living resources in proposed lease areas:

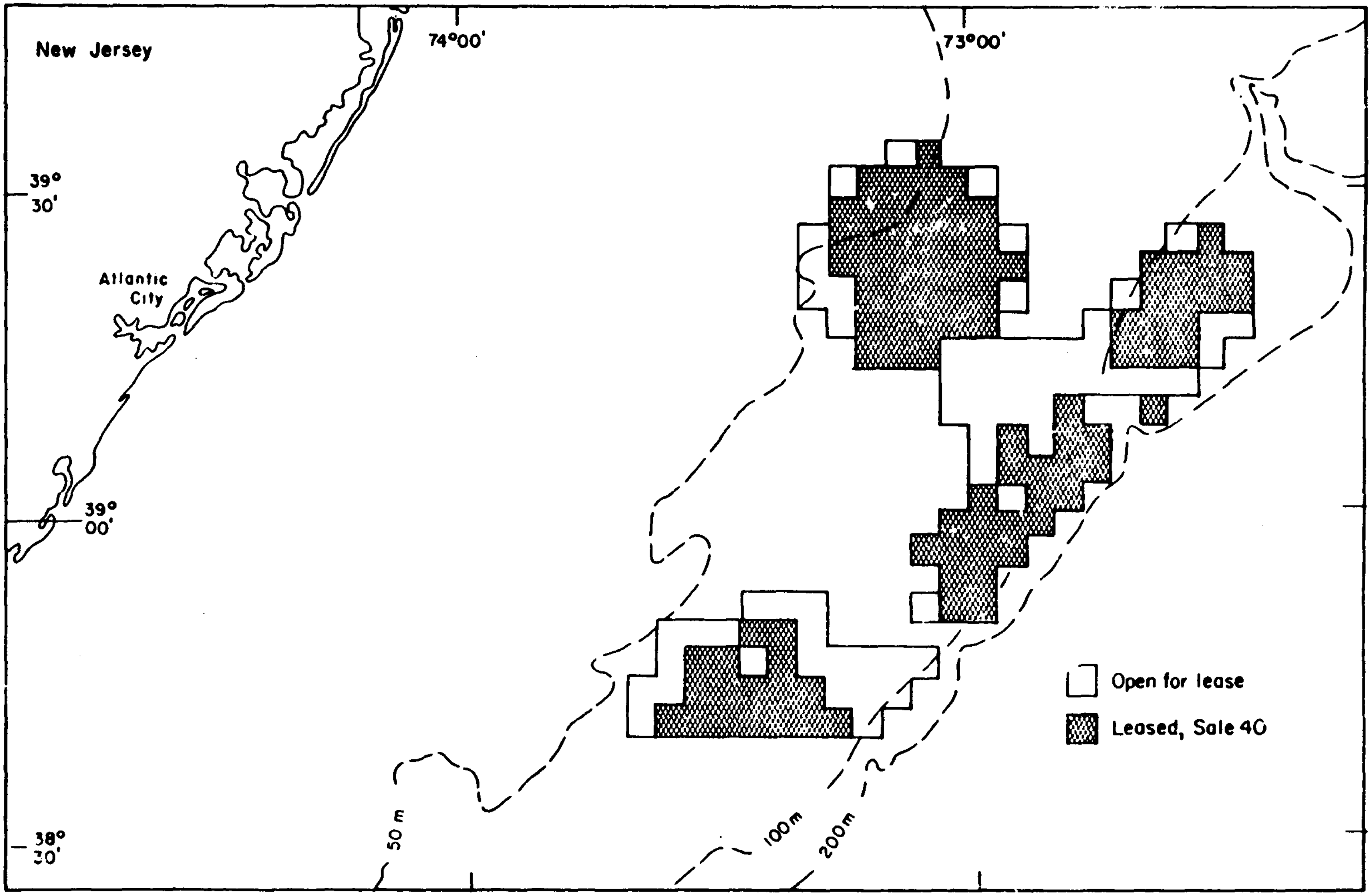

Figure 1-1. Middle Atlantic OCS lease tract area, Sale 40.

5. the pathways and rates of travel of contaminants introduced into the environment; and

6. the effect on various groups of organisms of long-term exposure to petroleum hydrocarbons and other materials associated with oil and gas developmental or production activities.

The Virginia Institute of Marine Science initiated Bureau of Land Management supported research on the Middle Atlantic outer continental shelf in October 1975. The principal objectives of these field studies were to provide chemical and biological data on conditions existing prior to oil and gas development, and on processes regulating biological community structure or levels of chemical constituents in the shelf environment. For environmental impact assessment it is insufficient to know only the organisms or chemical constituents present and their spatial and temporal distribution. An understanding of controlling mechanisms or processes is imperative before causality of change can be determined with any degree of certainty.

During the initial sampling year (October 1975 through September 1976, Contract No. 08550-CT5-42) specific goals of the Middle Atlantic chemical and biological benchmark studies were as follows:

1. summarization of shelf hydrographic and meteorological characteristiscs such as temperature, salinity, dissolved oxygen, and micronutrients during the four sampling seasons with particular emphasis on frontal systems and water mass identification;

2. characterization of the water column in terms of zooplankton, neuston, bacteria, particulate trace metals, and dissolved and particulate hydrocarbons as related to each other and temporal (seasonal and/or diurnal), spatial (geographic), and hydrographic variability as determined during the study;

3. characterization of the dominant infauna and epifauna in the macro- and mega-faunal ranges, foraminifera, and bacteria along with sediment characteristics such as grain size, organic carbon and nitrogen, sediment hydrocarbons, and sediment trace metals in relation to temporal, spatial, depth (bathymetric), and hydrographic variability as determined during the sample year;

4. description of the histopathology of selected epifaunal and infaunal species and discussion of histopathological conditions in relation to hydrocarbon and trace metal concentrations in the selected species and their environments;

5. characterization of the bottom sediments in terms of hydrocarbon and trace metal concentrations as related to temporal, spatial, depth, and hydrographic variation found during the sample year and to relate these characteristics with concentrations of hydrocarabons and trace metals in the water column;

6. discussion of temporal and spatial hydrocarbon degradation potential of microbial populations in surficial water and sediments and determination of the effect of hydrocarbon products on degradation potential and also on the mineralization of chitin and cellulose, the normal substrates for microbial populations;

7. extension of the Virginian Sea Wave Climate Model for the region from Cape Henlopen, Delaware to Cape Hatteras, North Carolina, and to Long Island, New York.

Preliminary findings based on the first year of study (1975-1976) were documented in an annual report (V.I.M.S. 1977) and can be summarized as follows:

1. The waters of the Middle Atlantic Bight were characterized by two vertical frontal zones subdividing three water mass types--the coastal boundary layer, shelf water, and slope water.

2. Water mass structure was generally reflected in the plankton community with distinct coastal, shelf, and slope assemblages.

3. Spring neuston tows were dominated by eggs and larvae of fishes and crustaceans.

4. Sediments on the Middle Atlantic shelf are characteristically medium to coarse sands grading to slightly muddy fine sands at the shelf break.

5. Trace metals and hydrocarbons tend to associate with fine sediment particles. Thus, the distribution of these chemical constituents closely reflected the distribution of fine sediments rather than potential sources of origin.

6. Density of heterotrophic bacteria in sediments appeared to be related to both proximity to shore and silt/clay content.

7. Macrobenthos, which demonstrated little seasonality, was most dense on the outer shelf and least dense on the continental slope. However, species diversity and richness increased offshore.

8. Probably the most significant finding from the first sampling year was documentation of the influence of local ridge and swale topography on the distribution of sediments, their constituents, and benthic biota. Ridges were characterized by coarse-skewed medium sands grading to fine sands in the swales. Concomitant with the shift in grain size was an increase in the silt and clay content. Trace metal, hydrocarbon, organic nitrogen, and organic carbon concentrations are closely related to silt and clay content of sediments and thus levels were higher in swales. Increases in density from ridge to swale were also characteristic for bacteria, foraminifera, and macrobenthos.

During the second sampling year (1976-1977), specific goals of the Middle Atlantic studies remained the same as during the first year. Thus, all sampling initiated during the first year was continued to provide comparative data with which to re-evaluate the preliminary findings discussed above. However, some sampling stations were added or deleted based on first year results (see Chapter 2). New studies were also initiated, primarily to expand the understanding of factors controlling benthic community composition. Included were programs to assess 1) relationship of macrobenthos to mesoscale (10^2 to 10^3 meters) sedimentary and topographic patterns; 2) response of benthos to catastrophic disturbance; 3) biotic interrelationships of macrobenthos and demersal fishes; and 4) community composition of meiobenthos. Other new studies included zooplankton biomass estimates, replication of zooplankton bongo sampling to provide an estimate of sampling variability, and an analysis of historical finfish catch data from the Middle Atlantic shelf.

The majority of the two-year Middle Atlantic environmental studies program was conducted with VIMS in-house personnel. Subcontracts were made with the Marine Science Consortium for carbon analysis to be conducted at American University, the University of Delaware for taxonomic assistance, the Virginia Associated Research Campus (VARC) of the College of William and Mary for some trace metal analysis, and the University of Virginia for foraminifera analysis. A listing of principal investigators and associate principal investigators is provided in Table 1-1.

Liaison was established between VIMS and the USGS and the Environmental Data and Information Service (EDIS) to coordinate other phases of the BLM OCS studies program related to the Middle Atlantic and to provide for data archiving with the National Oceanographic Data Center (NODC) of EDS.

Table 1-1. Program Elements and Responsible Principal Investigators, Contract 08550-CT5-42 (1975-1976) and AA550-CT6-62 (1976-1977).

Program Elements	Principal Investigator(s) Associate Principal Investigator(s)
I. Chief Scientist	D. Boesch
II. Principal Elements	
Benthic Studies	D. Boesch
	J. Kraeuter (megabenthos)
	K. Serafy (macrobenthos)
	D. Hartzband (meiobenthos)
	L. Watling (Univ. Delaware, taxonomic consultant)
	R. Ellison (Univ. Virginia, foraminifera)
Hydrocarbon Studies	C. Smith
	W. MacIntyre (December 1976 - May 1977)
	C. Su (laboratory analyses)
	R. Bieri (GC-MS)
	K. Cueman
Trace Metals	R. Harris
	R. Huggett
	R. Jolly (VARC, PIXE analysis)
	G. Grant (VARC, AA analysis)
Zooplankton-Neuston Studies	G. Grant
Bacteriological Studies	H. Kator
Histopathological Studies	C. Ruddell
Finfish Studies	J. Musick
	E. Foell
	G. Sedberry
III. Supporting Elements	
Physical Oceanography and Meteorology	E. Ruzecki
	C. Welch
	D. Baker

Table 1-1. (Concluded).

Program Elements	Principal Investigator(s) Associate Principal Investigator(s)
III. Supporting Elements (cont.)	
Carbon Analysis	M. Champ (American University)
Nitrogen Analysis	R. Wetzel
Sediment Grain Size	R. Byrne
Program Management	E. Burreson M. Lynch (October 1976 to May 1977) J. Jacobson (January 1976 to September 1976) B. Laird (reports) W. Athearn (logistics) (May 1977 to April 1978) J. Brokaw (logistics) (September 1975 to April 1977)
Data Management	G. Engel
Statistics	W. Roller
IV. Special Studies	
Baltimore Canyon Trough Wave Climate Model	V. Goldsmith
Degradation (Bacterial) Studies	H. Kator
Recolonization Studies	D. Boesch K. Serafy
Historical Finfish Analysis	J. Musick J. Colvocoresses

RELATIONSHIP OF STUDY TO OTHER STUDIES IN THE SAME AREA

Extensive geological studies of the Middle Atlantic OCS were conducted during this approximate time frame by the U. S. Geological Survey (USGS), Office of Marine Geology, Woods Hole, Massachusetts. The general objectives of these studies, funded under Memoranda of Understanding (08550-MU5-33 and AA550-MU7-31) between USGS and BLM were: to assess the potential geologic hazards to oil and gas development; to describe the sedimentary environments; to establish geochemical benchmark data; and to define rates of movements and pathways of pollutants.

Although many of the USGS and VIMS studies were conducted independently, there were several areas in which both institutions were involved. USGS supplied detailed bathymetry for use in the wave climate model early in the study. A preliminary sedimentary texture map (which was subsequently updated with VIMS sediment data) was provided for bio-lithofacies interpretation.

USGS personnel from the Atlantic-Gulf Coast Branch (hydrocarbon laboratory) participated in each VIMS benthic cruise. Sediment samples for hydrocarbons were analyzed by both USGS and VIMS personnel. USGS performed analyses on a blended sample taken at each benthic station each season while VIMS performed replicate analysis once at each station.

During the first sampling year, sediments collected on VIMS cruises were provided to USGS, Woods Hole, for analysis of total trace metal concentrations. Under the VIMS contract, sediments were analyzed for leachable metals and USGS total digestates were analyzed for barium and vanadium. During the second year VIMS analyzed sediments for both leachable and total metal concentrations.

VIMS collected suspended sediments for USGS analysis and, using a USGS instrument, provided USGS with records of nephelometer/ transmissometer traces.

VIMS biologists participated in USGS submersible cruises in the lease area during the first year to obtain quantitative and qualitative estimates of animal distributions.

National Oceanic and Atmospheric Administration (NOAA), U. S. Department of Commerce, conducted studies related to the Middle Atlantic Bight OCS area under Interagency Agreements Nos. AA550-IA6-3 and AA550-IA7-35 with BLM. The National Data Buoy Office maintained two meteorological data buoys in the region, one of which, in addition to standard meteorological wind-sea surface data, recorded wave data. This data, particularly the wave data, was used by VIMS in wave model studies. The Environmental Data and Information Service (EDIS) Center for Experiment Design and Data Analysis (CEDDA) of NOAA under

Interagency Agreement No. AA-550-IA6-12 analyzed historical oceanographic and meteorological data for long term and seasonal trends. VIMS physical oceanographers worked closely with CEDDA on this project and provided a complete set of all oceanographic data in the VIMS data base for offshore areas. A list of personnel responsible for liaison between BLM supported studies in the Middle Atlantic Region is provided in Table 1-2.

Other BLM funded studies in the region that did not directly relate to the benchmark study included two literature surveys. A literature survey of the 200 m - 2000 m slope area from the Gulf of Maine to Cape Hatteras, North Carolina, was conducted by The Research Institute of the Gulf of Maine (TRIGOM) under Contract No. 08550-CT5-47. An update of the TRIGOM 1974 socio-economic and environmental inventory which covered the northern portion of the Middle Atlantic Bight and a University of Rhode Island (URI 1973) coastal and offshore environmental inventory of the region from Cape Hatteras to Nantucket Shoals are underway by the Center for National Areas (CNA) under Contract No. AA-550-CT6-45. VIMS personnel have provided data and reports to CNA for their update.

Major non-BLM studies in the region include the ground fish surveys conducted annually by the National Marine Fisheries Service (NMFS), the Marine Ecosystems Analysis Program (MESA) New York Bight Studies, both of NOAA, and Environmental Protection Agency (EPA) funded dump site studies off Delaware Bay. A number of individual projects by scientists with the University of Delaware, The Johns Hopkins University, and other educational institutions provide information relevant to the region but are not primarily oriented towards BLM chemical-biological benchmark program needs.

VIMS' other major offshore study in the Middle Atlantic Bight is a National Science Foundation (NSF) funded study of the Norfolk Canyon ecosystem which focuses on shelf and canyon ichthyofauna, zooplankton, and epifauna. The investigators associated with the zooplankton and physical oceanographic and meteorological aspects of the Norfolk Canyon Study are program element principal investigators for comparable elements in the BLM benchmark study.

REPORT FORMAT

This report, which presents second year (1976-1977) results and discussions and conclusions based on both year's data, is divided into a number of individual chapters. Chapter 2 provides a summary of the overall sampling effort including a rationale for sample design strategy. Chapter 3 provides a summary of the physical oceanographic and meteorological observations including the distribution of dissolved oxygen and micronutrients. Chapter 5 summarizes the overall sedimentary framework of the region incorporating the grain size, and

Table 1-2. Liaison Responsibilities for the Middle Atlantic Bight BLM Supported Studies.

Agency (Project)	Agency Liaison	VIMS Liaison
USGS	D. Folger	M. Lynch (1975-1976)
	M. Ball	E. Burreson (1976-1977)
EDS	K. Hughes	G. Engel
Middle Atlantic Physical/ Meteorological Summary	G. Falk	E. Ruzecki
NOAA, N.E. Fisheries Center	R. Reid	E. Burreson
NODC Archiving	S. Marcus	G. Engel

organic carbon and nitrogen data. The remaining chapters discuss the major program elements Zooplankton-Neuston (Chapter 4), Benthos (Chapters 6, 7, and 8), Fish Community Analysis and Food Habits (Chapter 9), Historical Analysis of Finfish (Chapter 10), Bacteriology (Chapter 11), Histopathology (Chapter 12), Trace Metals (Chapter 13), Hydrocarbons (Chapter 14), and Wave Climatology (Chapter 15).

All processed environmental data developed during this study have been deposited with NODC. Data documentation information transmitted with the data tapes has been submitted to BLM. The field, laboratory and data processing forms used in this study are provided on microfiche at the end of Volume IIC. Computer programs developed for this contract have been submitted to BLM.

BLM PERSONNEL

Contract monitoring personnel within BLM responsible for these studies were Contracting Officers Authorized Representatives - Dr. J. Snyder, Dr. A. Horowitz, and Mr. P. Thomas; and Contracting Officers - Mssrs. W. Hamm, F. Galinsky, A. Guida, and P. Lubetkin. Liaison with the Branch of Environmental Studies, BLM, was the responsibility of Dr. R. Beauchamp and Mr. J. Cimato.

CHAPTER 2

Benchmark Sampling

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Contract AA550-CT6-62
with the Bureau of Land Management

July 1979

CHAPTER 2

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CHAPTER 2

BENCHMARK SAMPLING

Donald F. Boesch
William D. Athearn
John G. Brokaw

INTRODUCTION

The Benchmark Studies encompassed a wide variety of coordinated investigations on biota, water, and sediments, and their chemical constituents in the Middle Atlantic Bight. Emphasis on biota focused on macrobenthos, meiobenthos, demersal fishes, microbes, zooplankton, and neuston, while the emphasis in the chemistry investigations was on trace metals and hydrocarbons. These environmental components were selected in the development of a study plan by BLM because it was reasoned that they may be susceptible to alteration by oil and gas development and that resulting alterations could conceivably be detected. Other physical, chemical, geological, and biological data were also collected in support of these principal studies.

The Middle Atlantic benchmark study region covers a vast area of over 13,000 square nautical miles, or about 45,000 km^2, extending off New Jersey, Delaware, Maryland, and Virginia over the broad continental shelf and upper slope. Sampling not only had to be extensive enough to characterize this expansive environment, but it also had to be intensive enough to characterize the diversity of environments within regions of this topographically complex continental shelf. Although general requirements of the sampling scheme were set forth by BLM, VIMS was responsible for selection of the actual station locations.

The selection of stations and the general organization and procedures of sample collection are two extremely critical phases of the benchmark studies which affect the interpretation and usefulness of the resulting data. In this section the rationale of station selections will be detailed, station locations will be listed, and general field methodology outlined.

STATION LOCATIONS

1975-1976 Sampling Year

Sampling Design Criteria

The RFP and contract issued by the BLM prescribed a level of sampling effort and included some guidelines as to the location of sampling stations. It was the responsibility of VIMS, as the prime contractor, to choose the sampling locations in consultation with USGS and subject to the approval of BLM.

A total of 51 stations was stipulated for sampling of macrobenthos and sediments. Stations were to be located on transects extending outward across the continental shelf, one of which was to be located south of the then proposed leasing area. Three of the stations were to be located in depths greater than 200 m, in submarine canyons, or on the continental slope, and 24 were to be clustered in 6 groups of 4 each. These clustered stations were to be positioned so as to sample the range of topographic variability within regions of the shelf and were to be sampled quarterly. All other stations were to be sampled only twice during the year, in the "biological" summer and winter. Other factors to be considered in siting of stations included 1) distance from shore, 2) local topography, 3) areas of possible leasing, 4) sediment type, 5) latitude, and 6) existing sampling programs on the Middle Atlantic continental shelf.

Building on these criteria, it was decided to locate the quarterly sampled, clustered stations in a corridor bounded roughly by 38°30'N and 39°30'N and primarily concentrated in outer shelf areas then being considered for leasing, but also extending onto central and inner shelf zones. One cross-shelf transect of 7 stations was positioned near the northern border (40°N) of the larger area being considered for lease nominations and one of 6 stations near the southern border (38°N). A final transect of 6 stations crossed the shelf off Virginia between 37°00'N and 37°30'N. The remaining 8 stations were assigned to the continental slope and submarine canyons off the central clustered stations. It was felt this distribution of stations could provide broad geographic coverage of the central Middle Atlantic Bight such that bathymetric and latitudinal patterns could be described. More intense sampling in space and time in the central area of interest would, at the same time, allow a more refined assessment of the bathymetric, topographic, and sedimentologic environments within that area.

Nine stations were stipulated for dredge and trawl sampling of megabenthos, which, whenever possible, were to correspond to stations sampled for macrobenthos and sediments. Six stations on a cross-shelf transect were positioned in accord with the known hydrographic characteristics of the area and located, where possible, in the vicinity of benthic stations. Because of the small number of stations, these sites had to be restricted to the central study corridor occupied by the clustered benthic stations.

Unfortunately, information on what tracts would be offered for leasing under the first Middle Atlantic OCS scale (Sale 40) was not available at the time of station selection. Identification by the USGS of three areas of interest based on geophysical data provided some general guidance. Stations in the central study area sampled during the first year of benchmark studies are plotted in Figure 2-1 together with tracts actually leased in Sale 40. Comparison shows that coverage with regard to potential development sites was good, with the exception of water column studies in the northeastern and northwestern lease areas.

Rationale for Location of "Benthic" Stations

Cluster Stations. Quarterly sampling of the macrobenthos, foraminifera, bacteria, sediments, and hydrographic characteristics was accomplished at "cluster" stations (Figure 2-2). Four cluster stations each were located in 6 areas (Areas A-F), chosen as representative of bathymetric zones and/or reflective of high interest for oil and gas development. With each area, 4 permanent stations were fixed to cover the range of presumed biological and sedimentary habitats. In the 4 areas situated totally on the continental shelf (B-E), stations were chosen to represent at least ridge, flank, and swale environments of the first-order topographic system (McKinney et al. 1974). Existing geological information (see Chapter 5 for a general discussion of the sedimentary framework of the region) indicated that sediments and sedimentary processes varied considerably with respect to topography; however, comparable biological and chemical information was lacking, making this sampling design criterion hypothetical. The stations in areas A and B were located at depths lying beyond the presence of ridges and swales, thus the stations were established to cover the bathymetric ranges within these outer shelf-shelf break zones. The interpreted topographic location of each of the cluster stations is given in Table 5-4 (Chapter 5).

Three of the cluster areas are encompassed in regions in which the USGS conducted bathymetric surveys because of potential oil and gas development activities. VIMS Area A (included in USGS Area 1) covers a comparatively gently sloping portion of the outer shelf and shelf break south of Hudson Canyon (Figure 2-3). Low relief hummocks are found in the outer part of the area, and it is crossed by several sea level stillstand shore features (Milliman 1973; Cousins et al. 1977). Sediments in this region are generally muddier than elsewhere on the shelf to the south.

Area B (USGS Area 2) is crossed by the southwest-northeast trending Tiger Scarp, representing a portion of the Fortune Shore (Milliman 1973). Area B (Figure 2-4) includes a shallow terrace

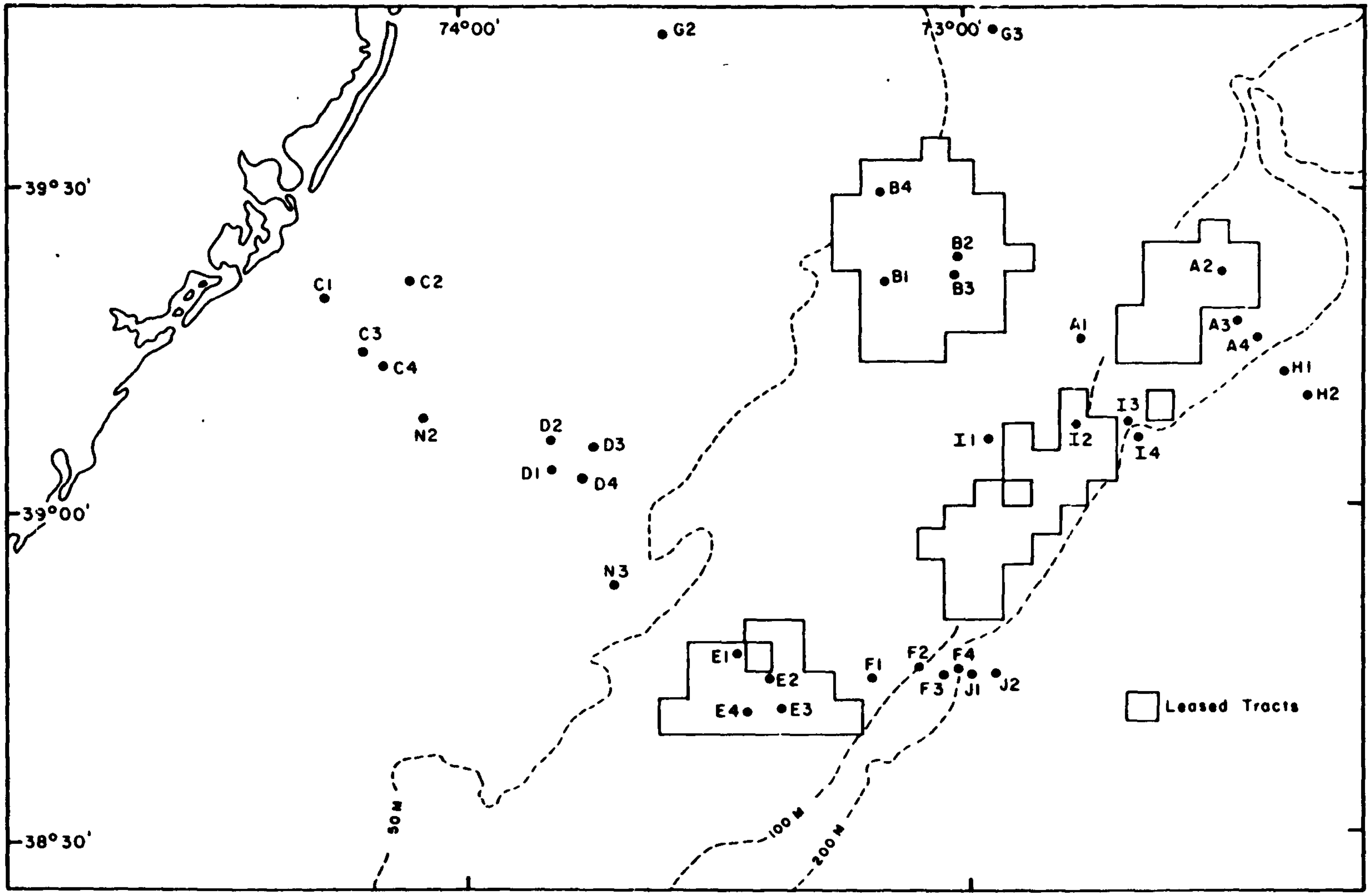

Figure 2-1. Stations in the central study area and tracts leased for oil and gas development in BLM Sale 40.

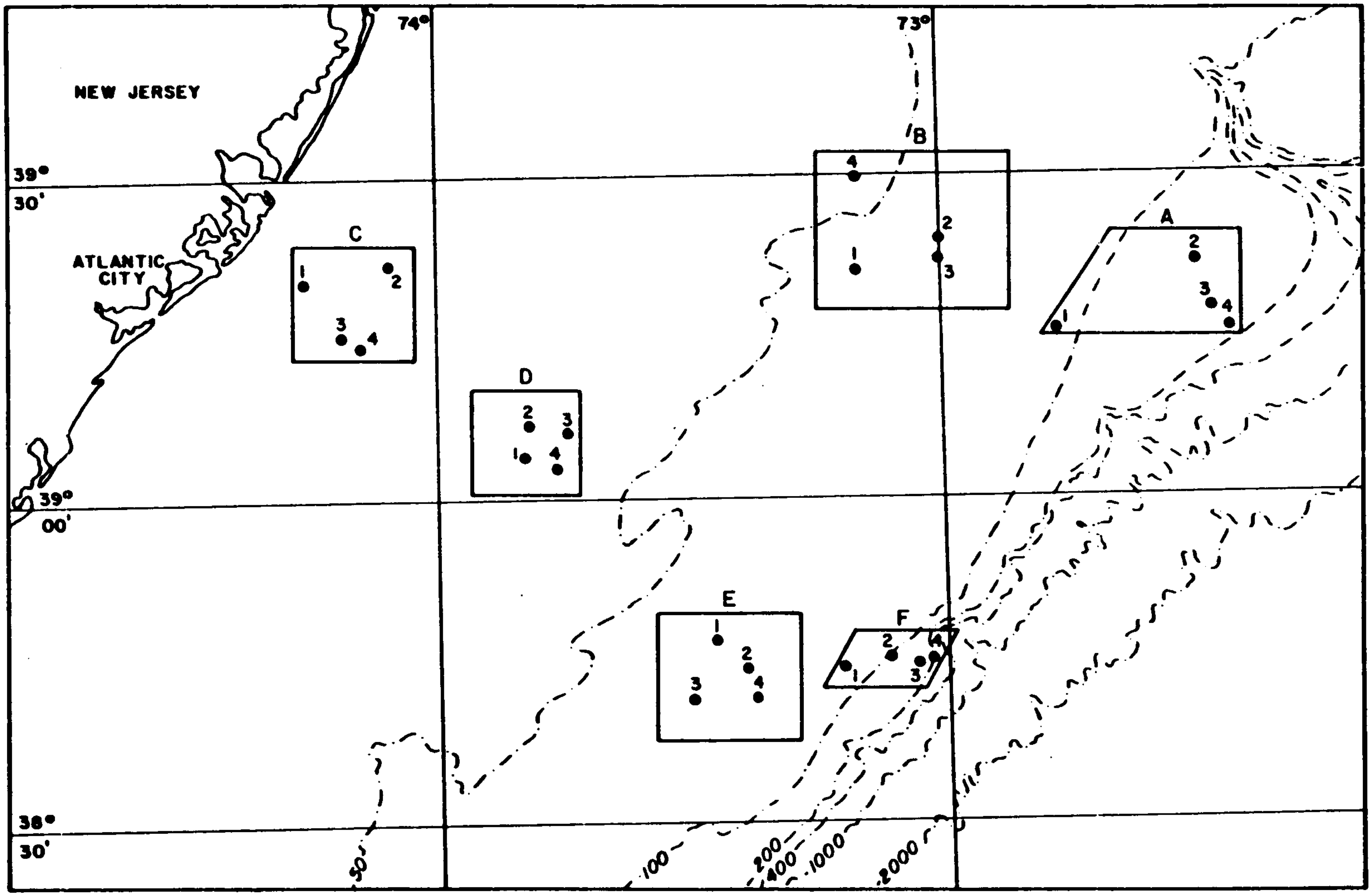

Figure 2-2. Cluster stations sampled quarterly for macrobenthos.

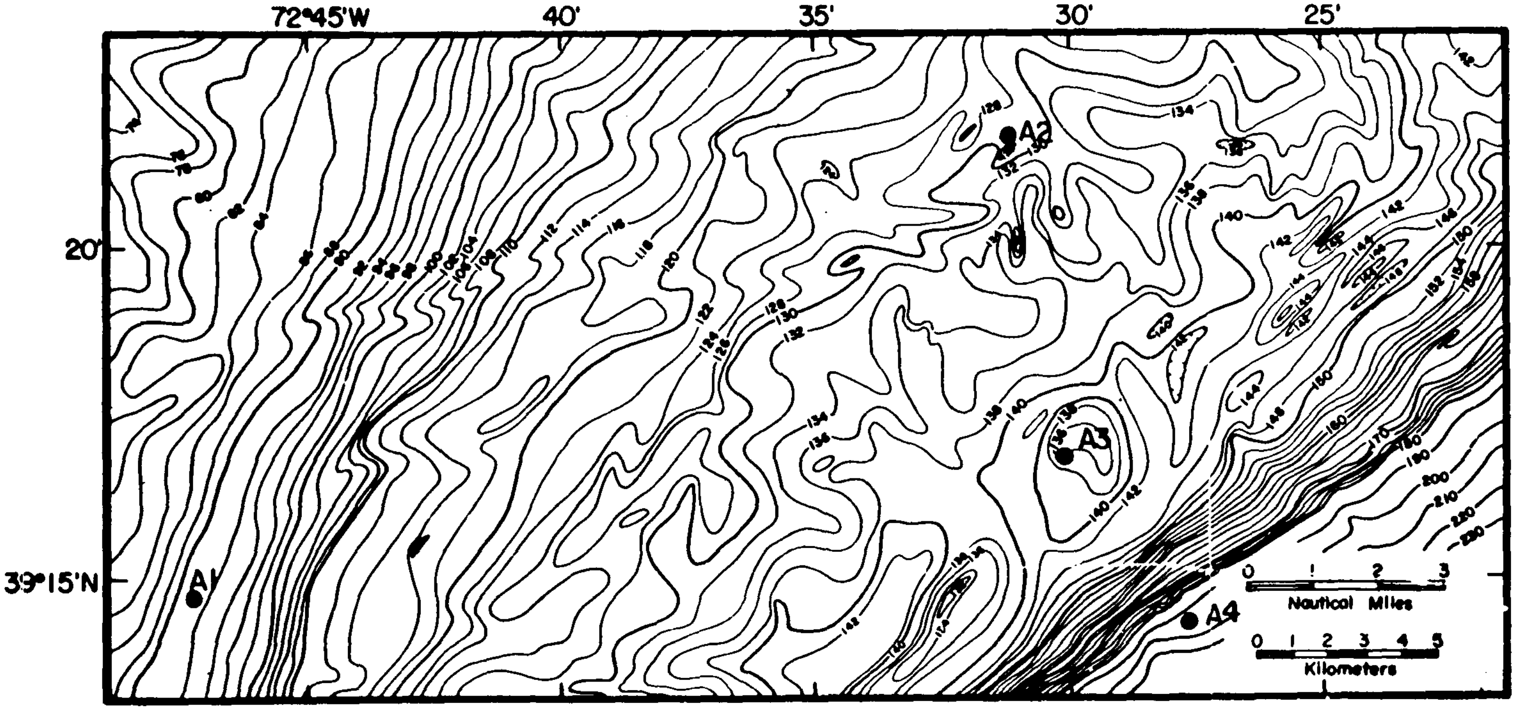

Figure 2-3. Cluster area A, bathymetry in meters. Source: U. S. Geological Survey.

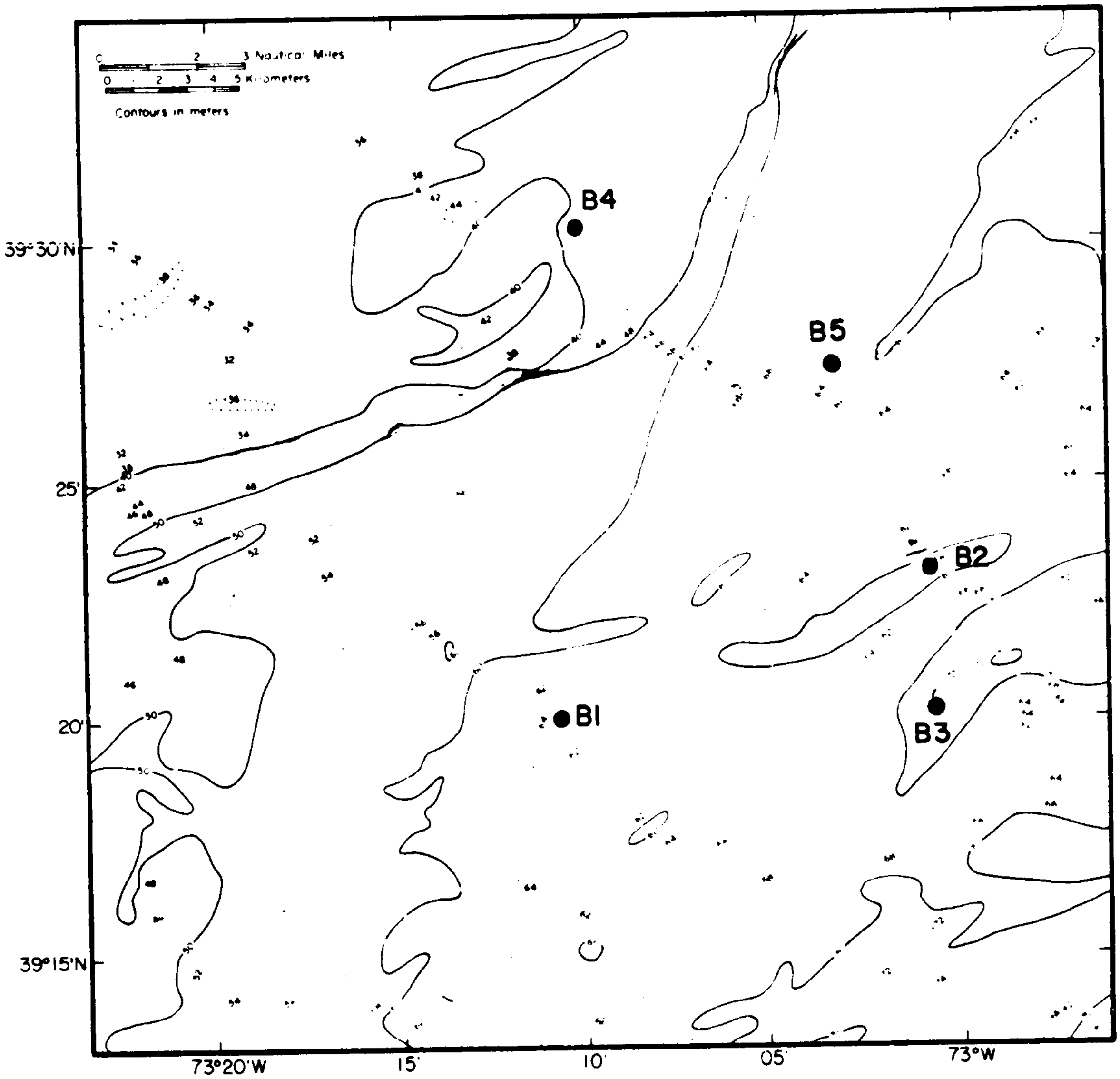

Figure 2-4. Cluster area B, bathymetry in meters. Source: U. S. Geological Survey.

(< 50 m deep), which contains cuesta-like features (Swift et al. 1972), and deeper ridge and swale topography (56-74 m). The distribution and variability of surface sediments (Knebel 1975) and the structure of the surficial sand sheet (Knebel and Spiker 1977) in this region have been studied by the USGS.

Area E falls within USGS Area 3 (Figure 2-5) and covers outer shelf ridge and swale topography (55-90 m) north of the head of Wilmington Canyon. Knebel and Spiker (1977) also studied the surficial sand in this area, and Knebel and Folger (1976) reported large sand waves in the southern part of this region.

Another area, Area F, to the east of Area E, was selected as an outer shelf-shelf break parallel of Area A. The depth gradient is much steeper, and the sediments are less muddy in this region than in Area A.

Two other cluster areas were selected to represent inner shelf and central shelf conditions. The central shelf area (Area D) is located on a segment of the shoal retreat massif of the Great Egg Valley (Swift et al. 1972; Swift 1975). This region is one of the most intensively studied shelf areas in terms of sedimentology, having been the subject of a number of investigations by the staff of the Atlantic Oceanographic and Meterological Laboratories (AMOL) of NOAA (McKinney et al. 1974; Stubblefield et al. 1975; Stubblefield and Swift 1976). Area D (Figure 2-6) is characterized by a well-developed system of NE-SW oriented ridges and swales (30-50 m depth range) superimposed by lesser order topographic features (McKinney et al. 1974).

Area C is located near the shoreward termination of the shoal retreat massif northeast of the ancestral Great Egg Valley (Swift et al. 1972) off Atlantic City, New Jersey. Well-developed ridges and swales characterize the area which ranges in depth from 15-35 m (Figure 2-7). The sediments in Area C include coarser sands than found in other cluster areas, but swales locally cut into underlying clay deposits.

Transect Stations. Semi-annual (winter and summer) sampling of macrobenthos, foraminifera, bacteria, sediments, and hydrographic characteristics was also conducted at 19 stations along three cross-shelf transects (Figure 2-8). Transect G extended from northern New Jersey, across the Hudson Shelf Valley to the upper continental slope north of Hudson Canyon. Transect K extended from the Maryland-Delaware region to the upper slope south of Baltimore Canyon. Transect L extended from off Virginia's Eastern Shore to the upper slope north of Norfolk Canyon. Along each transect, stations at approximately 25, 40, 55, 100, 165, and 350 m depths were sampled. On transect G a seventh station (G3) was located in the axis of the Hudson Shelf Valley at 73 m.

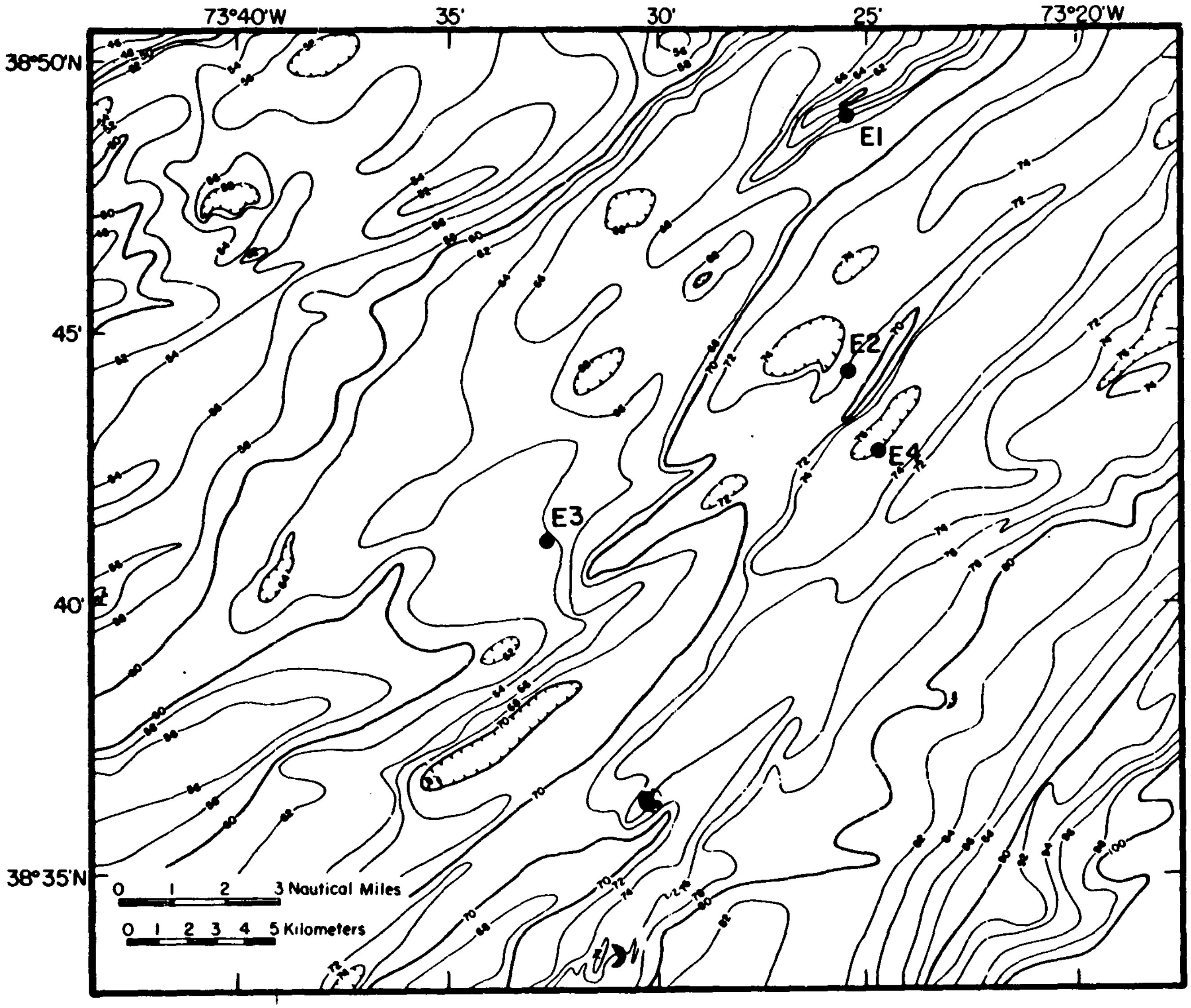

Figure 2-5. Cluster area E, bathymetry in meters. Source: U. S. Geological Survey.

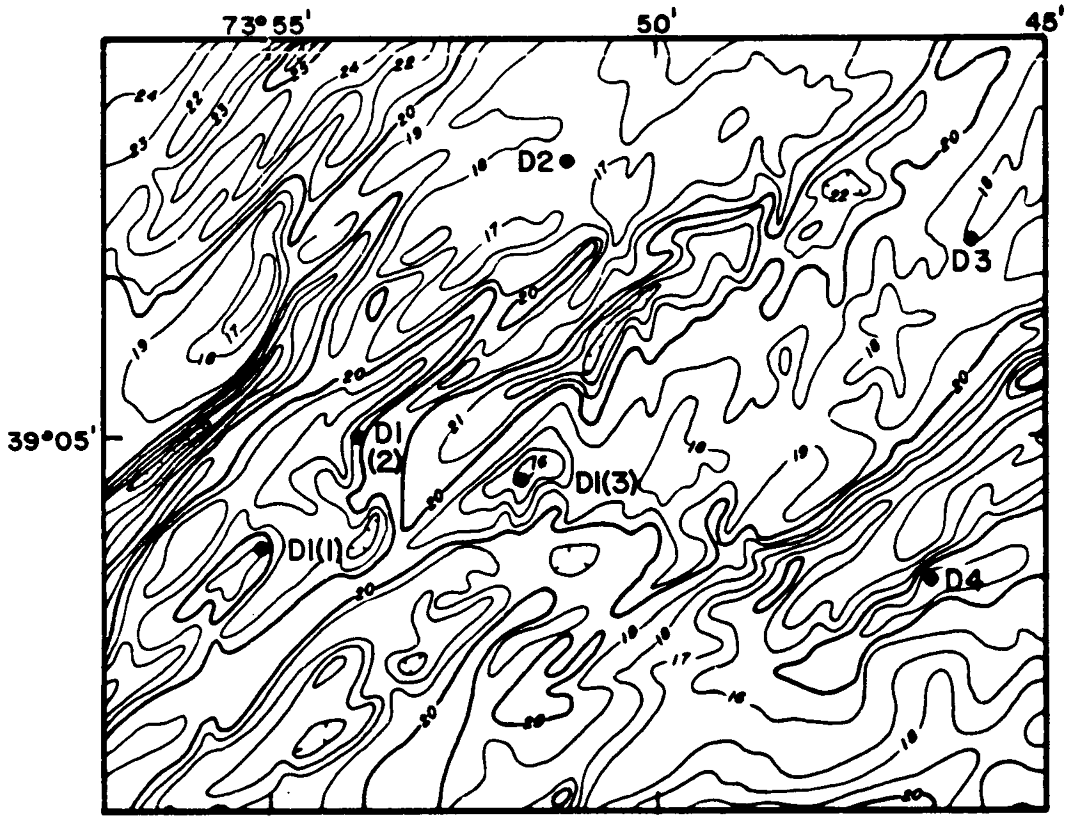

Figure 2-6. Cluster area D, bathymetry in fathoms. Source: U. S. Coast and Geodetic Survey and U. S. Bureau of Commercial Fisheries 1967.

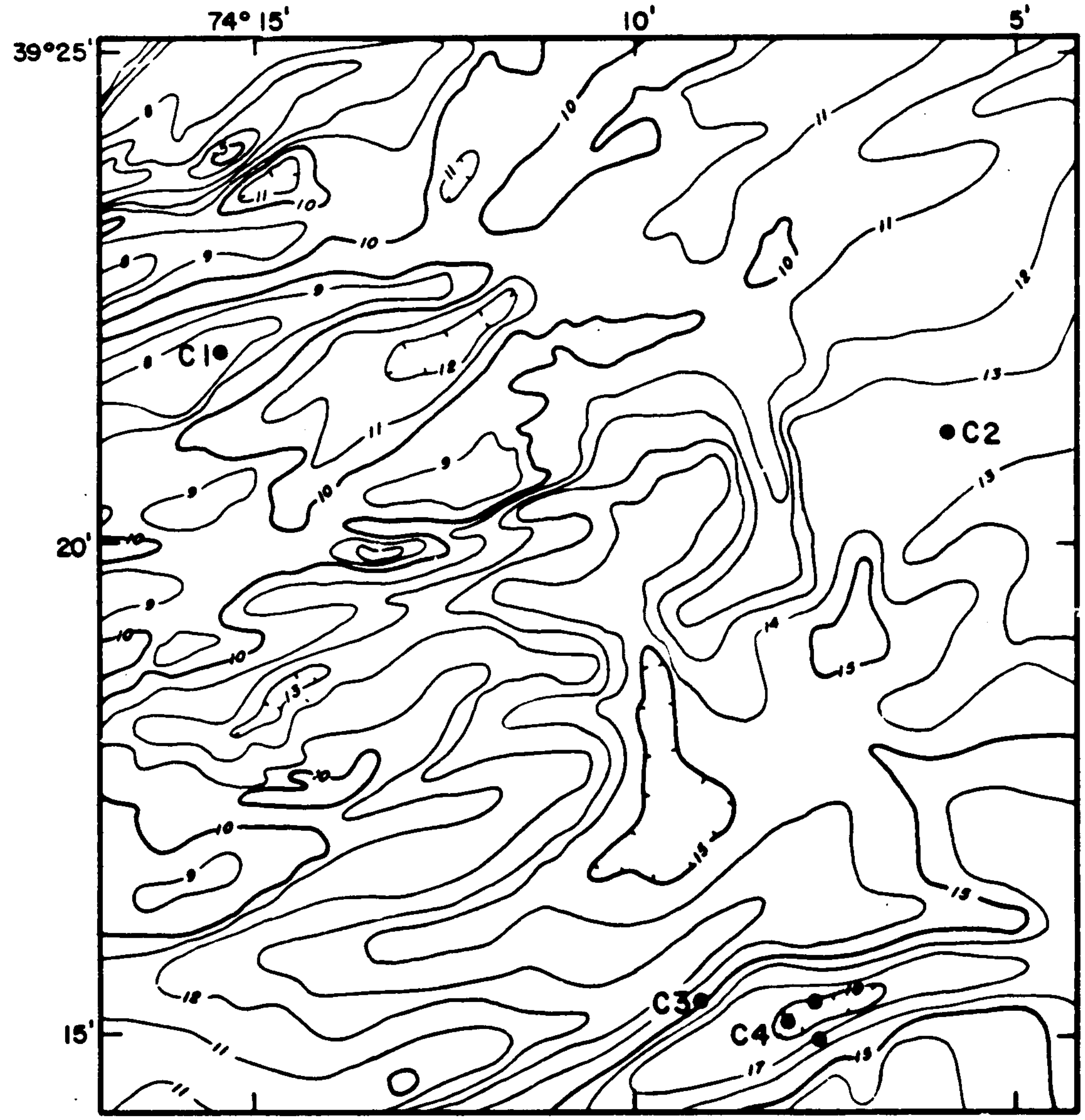

Figure 2-7. Cluster area C, bathymetry in fathoms. Source: U. S. Coast and Geodetic Survey and U. S. Bureau of Commercial Fisheries 1967.

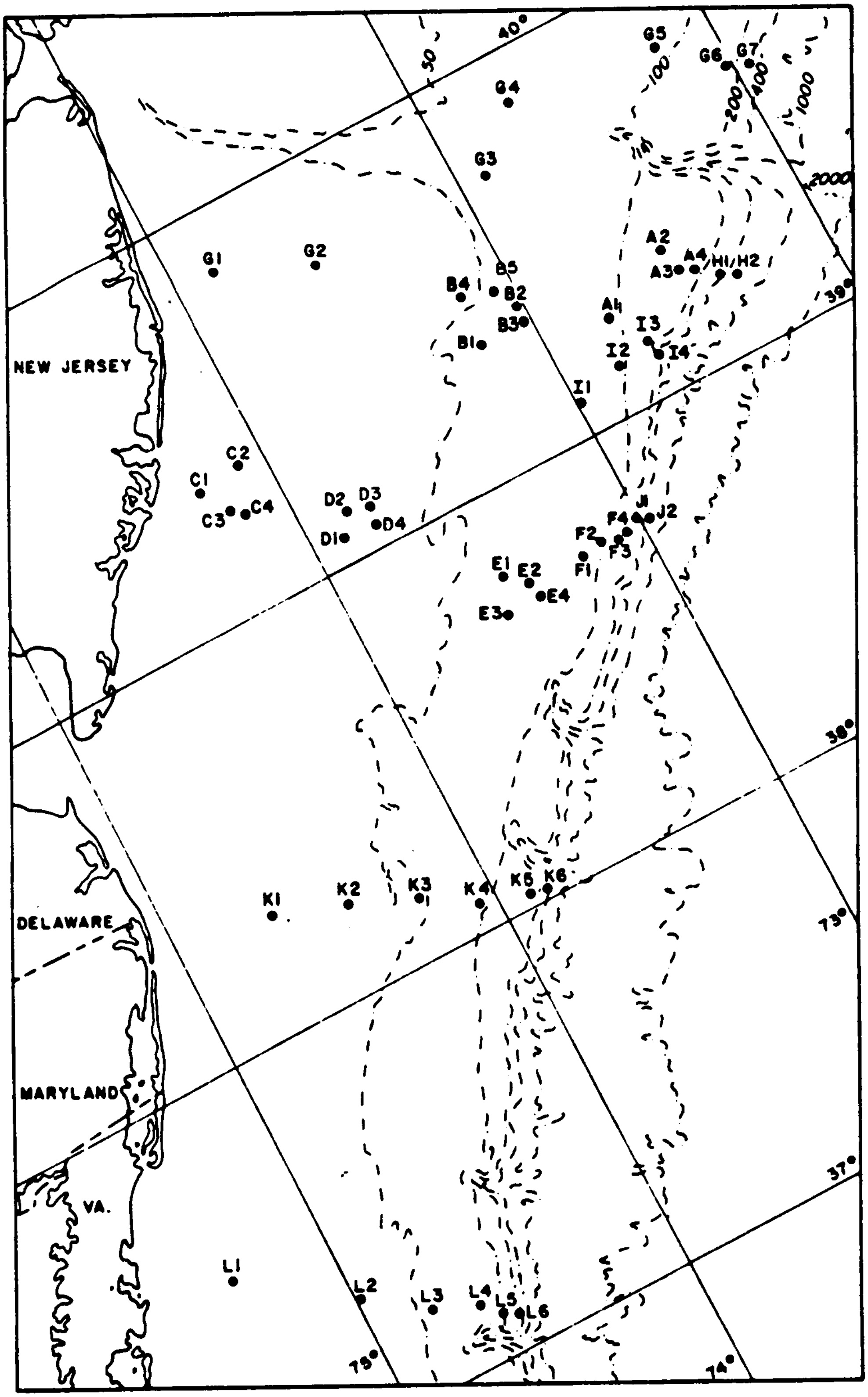

Figure 2-8. Stations sampled for macrobenthos.

Except for G3, stations on the continental shelf were positioned on flat or flank bottoms, while topographic highs and lows were avoided in order to minimize the effect of topographic variations on apparent cross-shelf patterns.

These transect stations are useful in describing the broad-scale biogeographic, sedimentologic, and hydrographic patterns in the Middle Atlantic Bight.

Continental Slope and Canyon Stations. Two stations each were positioned on the upper continental slope off Areas A and F (Figure 2-8). These stations are prefixed H and J respectively. The shallower pair of stations was located at 350-400 m and the deeper pair at 700-750 m. Many tracts leased under BLM-OCS Sale 40 are located at the shelf break, and many tracts located at slope depths have been nominated for leasing in a future sale. This underlines the importance of sampling the little-known slope environment.

Study plans initially stipulated at least one station in one of the submarine canyons incising the Middle Atlantic continental shelf. The canyon chosen for study was Toms Canyon which is smaller than the major canyons such as Hudson, Wilmington, and Baltimore, but is much closer to Sale 40 lease tracts than the larger canyons. Four stations were positioned along a transect (I1-I4) extending from the outer continental shelf (ca. 80 m) through the head and upper part of the axis of Toms Canyon (to 460 m).

Dredge and Trawl Stations. Nine "benthic" stations were sampled quarterly by dredge and trawl. The megabenthos captured was used for ecological studies, analyses of trace metals and hydrocarbons, and histological material. One station from each of the cluster areas plus 3 others, I1, J1, and N3 (located between cluster areas D and E), were selected (Figure 2-9). This sampling scheme gave broad coverage from the inner shelf to the upper slope over the central study area, but did not allow sampling of various topographic features within bathymetric zones or broad latitudinal sampling.

Rationale for Location of "Water Column" Stations

In order to correspond with benthic stations, a cross-shelf transect extending through cluster areas C, D, E, and F was selected. One station from each of these areas, C1, D1, E3, and F2, was designated as a water column station together with N3, between areas D and E, and J1 on the continental slope off Area F. These stations constituted a section roughly perpendicular to the shoreline and slope break and extending from 9 km (15 m depth) to 145 km (400 m depth) offshore (Figure 2-10).

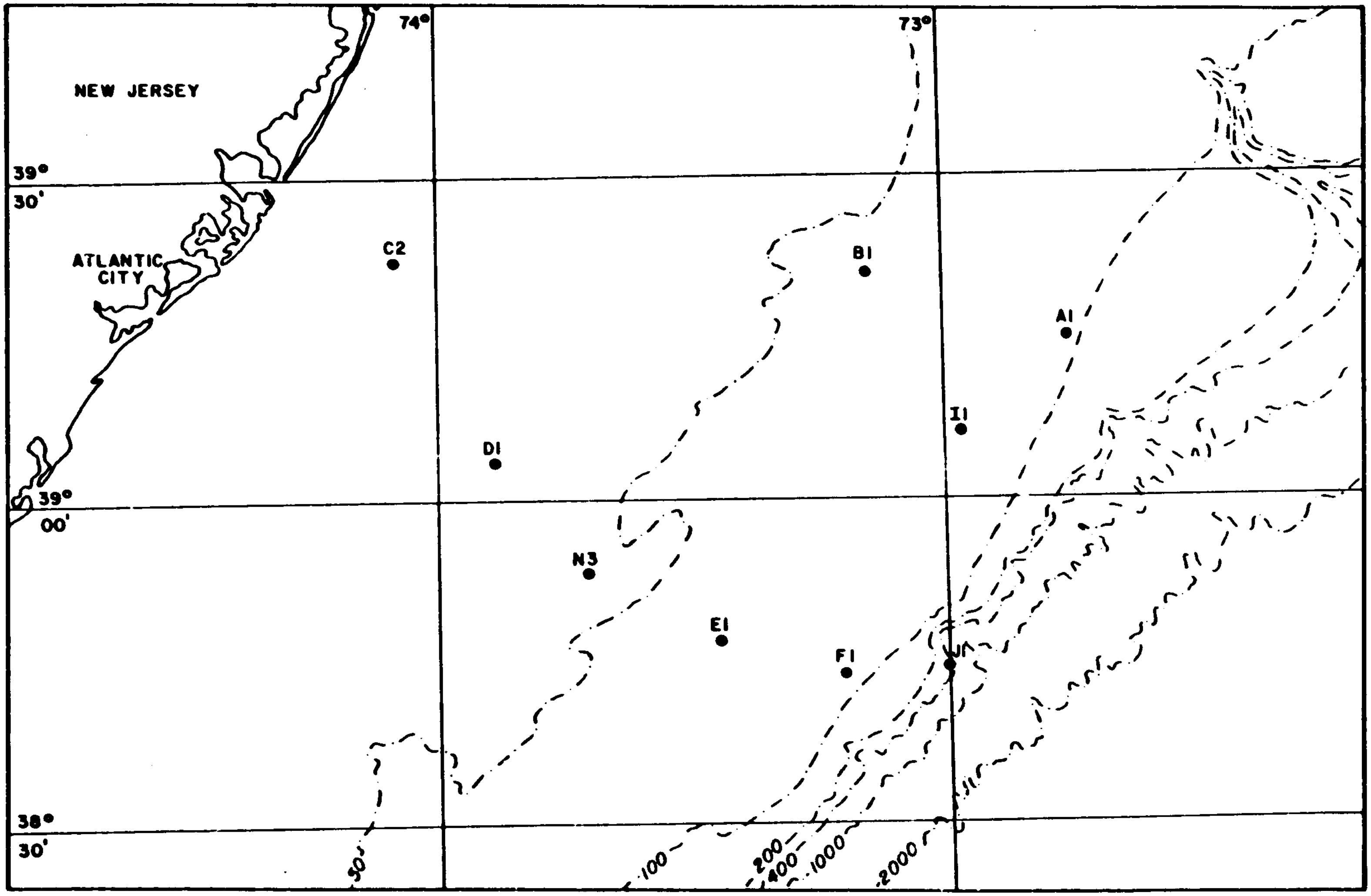

Figure 2-9. Stations sampled for megabenthos with dredge and trawl.

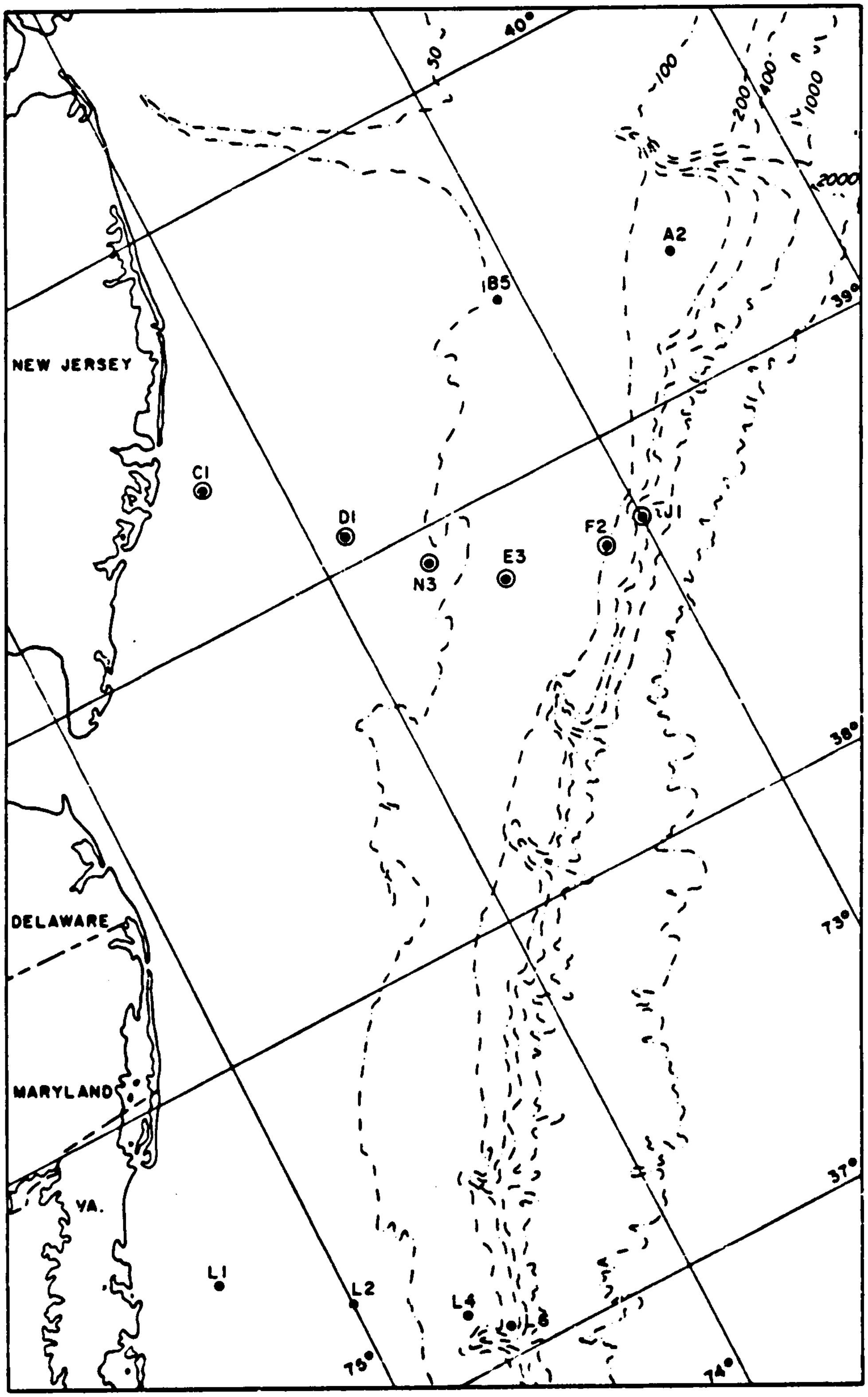

Figure 2-10. Water column stations. Open circles: 1975-1976; Solid dots: 1976-1977.

Navigation

Accurate navigation and positioning is essential for studies of the seabed in the Middle Atlantic continental shelf because of its considerable topographic and sedimentologic complexity. Unfortunately, truly high precision navigation systems are not available over most of the area. However, the Loran C system of radionavigation is available over the entire study area and was utilized in this study. It derives high accuracy from measured time differences of pulsed signals and the inherent stability of low frequency propagation. Signal and receiver errors account for normal position variations from 50 to 200 feet (15-61 m) in the study area (U. S. Coast Guard 1974).

Actually, because the sampling design relied on sampling topographic features, it proved more important to locate the feature to be sampled than to return to an electronically fixed position. The usual procedure for locating stations, particularly the cluster stations, was to cruise to the assigned position determined by Loran C and to then search for the feature with a precision depth measuring system. Too strict adherence to previous Loran fixes and Loran and echo sounder-recorder malfunctions caused some minor problems during earlier crusies, but most of these have been solved to the point that station relocation, evidenced by the sediments and biota, is now quite good.

Loran C readings were converted to latitude and longitude by use of a VIMS-revised, U. S. Naval Oceanographic Office computer program. Given a pair of Loran time differences and an approximation of geographic location to within three miles, it is possible to determine the geographic location within hundredths of a degree.

Station Positions

Tables 2-1 to 2-4 list the geodetic position, date occupied, and water depth for each station sampled during the four seasonal cruises, fall 1975 (BLM01), winter 1976 (BLM02), spring 1976 (BLM03), and summer 1976 (BLM04).

Cruise Tracks

The cruise tracks for each cruise conducted during the four seasonal sampling periods are given in Figures 2-11 to 2-23.

1976-1977 Sampling Year

Second year study objectives remained unchanged and thus, except for a few minor changes and the initiation of some new studies, the

(TEXT CONTINUES ON PAGE 2-36)

Table 2-1. BLM01 Sample Stations (Fall 1975)

Cruise	Ship	Station	Date	Depth (m)	Lat. (N)	Long. (W)
BLM01B	R/V Iselin	A1	3 XI/75	91	39°14.7'	72°47.3'
"	"	A2	"	128	39 21.6	72 31.0
"	"	A3	"	136	39 16.5	72 29.7
"	"	A4	"	196	39 14.3	72 26.7
"	"	B1	4 XI/75	63	39 19.3	73 10.2
"	"	B2	"	60	39 23.3	73 00.6
"	"	B3	"	72	39 19.7	73 00.4
"	"	B4	"	40	39 30.0	73 10.3
"	"	C1	5 XI/75	17	39 22.0	74 15.7
"	"	C2	"	21	39 21.0	74 05.3
"	"	C3	"	24	39 15.2	74 09.2
"	"	C4	"	34	39 15.2	74 07.9
"	"	D1	28 X/75	31	39 04.6	73 53.4
"	"	D2	29 X/75	33	39 07.4	73 50.1
"	"	D3	"	39	39 06.7	73 45.5
"	"	D4	"	49	39 02.9	73 47.1
"	"	E1	"	67	38 47.3	73 23.8
"	"	E2	30 X/75	64	38 44.2	73 25.8
"	"	E3	31 X/75	63	38 41.3	73 32.4
"	"	E4	"	77	38 42.8	73 24.3
"	"	F1	"	85	38 44.0	73 14.7
"	"	F2	1 XI/75	113	38 44.3	73 09.2
"	"	F3	"	152	38 43.8	73 04.4
"	"	F4	"	183	38 44.3	73 02.9
"	"	I1	3 XI/75	78	39 06.6	72 59.0
"	"	J1	2 XI/75	342	38 45.0	73 00.8
"	"	N2	5 XI/75	33	39 10.1	74 01.9
"	"	N3	4 XI/75	44	38 51.1	73 45.2
BLM01W	R/V Pierce	C1	23-24 X/75	17	39 22.0	74 15.3
"	"	D1	24-25 X/75	31	39 06.5	73 55.3
"	"	E3	26-27 X/75	63	38 42.4	73 32.7
"	"	F2	28-29 X/75	113	38 44.4	73 09.1
"	"	J1	29-30 X/75	342	38 40.8	73 04.3
"	"	N3	25-26 X/75	44	38 51.8	73 44.6

Table 2-2. BLM02 Sample Stations (Winter 1976)

Cruise	Ship	Station	Date	Depth (m)	Lat.(N)	Long.(W)
BLM02W	R/V Pierce	A1	15 II/76	90	39°14.6'	72°47.4'
"	"	B1	15 II/76	63	39 19.3	73 10.3
"	"	C1	5 II/76	15	39 22.0	74 15.7
"	"	C2	6 II/76	25	39 21.0	74 05.3
"	"	D1	9 II/76	40	39 04.5	73 53.4
"	"	E1	12 II/76	66	38 47.3	73 20.8
"	"	E3	11-12 II/76	64	38 41.4	73 32.5
"	"	F1	13 II/76	84	38 44.0	73 14.6
"	"	F2	12-13 II/76	110	38 44.3	73 09.2
"	"	I1	15 II/76	80	39 06.5	72 59.1
"	"	J1	13-14 II/76	375	38 44.0	73 00.7
"	"	N3	10 II/76	46	38 51.2	73 45.0
BLM02B	R/V Pierce	A1	4 III/76	90	39 14.7	72 47.4
"	"	A2	5 III/76	127	39 22.2	72 31.0
"	"	A3	15 III/76	136	39 16.6	72 30.0
"	"	A4	15 III/76	196	39 14.3	72 26.7
"	"	B1	4 III/76	63	39 19.3	73 10.1
"	"	B2	4 III/76	61	39 23.3	73 00.6
"	"	B3	4 III/76	72	39 19.7	73 00.3
"	"	B4	4 III/76	41	39 29.9	73 10.0
"	"	C1	20 II/76	15	39 21.8	74 15.8
"	"	C2	20-21 II/76	25	39 21.0	74 05.3
"	"	C3	21 II/76	24	39 15.2	74 09.3
"	"	C4	21 II/76	34	39 15.2	74 08.0
"	"	D1	21 II/76	39-40	39 04.6	73 53.5
"	"	D2	21 II/76	32	39 07.5	73 50.0
"	"	D3	21 II/76	35	39 06.7	73 45.5
"	"	D4	21 II/76	49	39 02.9	73 47.2
"	"	E1	3-4 III/76	66	38 49.1	73 25.6
"	"	E2	3 III/76	73	38 44.2	73 25.5
"	"	E3	2-3 III/76	64	38 41.3	73 32.3
"	"	E4	3 III/76	77	38 42.7	73 24.3
"	"	F1	18 III/76	84	38 44.1	73 14.7
"	"	F2	18 III/76	110	38 44.2	73 09.1
"	"	F3	18 III/76	150	38 43.8	73 04.3
"	"	F4	18-19 III/76	183	38 44.6	73 03.1
"	"	G1	8 III/76	27	39 51.4	73 53.1
"	"	G2	8 III/76	37	39 43.6	73 34.8
"	"	G3	8 III/76	73-74	39 43.7	72 54.7
"	"	G4	8 III/76	55	39 53.4	72 43.2
"	"	G5	9 III/76	90	39 48.9	72 12.3
"	"	G6	9 III/76	167	39 40.6	72 00.8
"	"	G7	9 III/76	350	39 39.2	71 57.4
"	"	H1	16 III/76	350-400	39 12.1	72 23.6
"	"	H2	19 III/76	720-750	39 11.2	72 18.0
"	"	I1	14 III/76	80	39 06.6	72 59.0
"	"	I2	14 III/76	94	39 07.5	72 49.1
"	"	I3	15 III/76	180	39 08.8	72 42.0
"	"	I4	15 III/76	460	39 06.1	72 40.5

Table 2-2. **BLM02 Sample Stations** (Winter 1976) (continued)

Cruise	Ship	Station	Date	Depth (m)	Lat.(N)	Long.(W)
BLM02B	R/V Pierce	J1	20 III/76	360-410	38°45.0	73°00.8'
"	"	J2	20 III/76	680-700	38 45.6	72 59.0
"	"	K1	2 III/76	29	38 17.5	74 41.0
"	"	K2	12 III/76	41	38 12.6	74 26.5
"	"	K3	12 III/76	53	38 08.0	74 13.0
"	"	K4	12 III/76	105	38 04.5	74 01.7
"	"	K5	12 III/76	151	38 01.6	73 53.8
"	"	K6	21 III/76	340-360	38 00.8	73 51.8
"	"	L1	22 III/76	26	37 31.2	75 18.6
"	"	L2	22 III/76	41	37 20.2	74 58.6
"	"	L3	22 III/76	58	37 13.6	74 46.6
"	"	L4	22 III/76	94	37 08.1	74 37.0
"	"	L5	22 III/76	180-200	37 06.1	74 33.4
"	"	L6	22 III/76	350	37 04.6	74 33.1
"	"	N2	21 II/76	33	39 10.3	74 02.1
"	"	N3	25 II/76	45	38 51.2	73 45.0

Table 2-3. BLM03 Sample Stations (Spring 1976)

Cruise	Ship	Station	Date	Depth (m)	Lat.(N)	Long.(W)
BLM03W	R/V Va Sea	C1	12-13 VI/76	17	39°21.8	74°15.8'
"	"	D1	13-14 VI/76	31	39 04.6	73 53.5
"	"	E3	15-16 VI/76	64	38 41.3	73 32.3
"	"	F2	9-10 VI/76	112	38 44.2	73 09.1
"	"	J1	8-9 VI/76	375	38 45.0	73 00.8
"	"	N3	14-15 VI/76	46	38 51.2	73 45.0
BLM03B	R/V Gilliss	A1	22 VI/76	92	39 14.7	72 47.2
"	"	A2	22 VI/76	132	39 21.6	72 31.0
"	"	A3	22 VI/76	139	39 16.5	72 29.9
"	"	A4	23 VI/76	196	39 14.3	72 26.8
"	"	B1	21 VI/76	65	39 19.4	73 10.3
"	"	B2	21 VI/76	61	39 23.4	73 00.6
"	"	B3	21 VI/76	74	39 19.8	73 00.4
"	"	B4	22 VI/76	42	39 30.0	73 10.0
"	"	C1	15 VI/76	17	39 22.1	74 15.7
"	"	C2	15 VI/76	26	39 21.0	74 05.2
"	"	C3	16 VI/76	25	39 15.2	74 09.1
"	"	C4	16 VI/76	36-37	39 15.6	74 07.6
"	"	D1	16 VI/76	31	39 04.6	73 51.2
"	"	D2	16 VI/76	33	39 07.5	73 50.1
"	"	D3	17 VI/76	36	39 06.6	73 45.9
"	"	D4	17 VI/76	51	39 02.9	73 47.1
"	"	E1	17 VI/76	66	38 47.1	73 27.4
"	"	E2	18 VI/76	73	38 44.1	73 25.0
"	"	E3	18 VI/76	56	38 41.4	73 32.4
"	"	E4	17 VI/76	80	38 42.8	73 24.3
"	"	F1	19 VI/76	86	38 44.3	73 14.6
"	"	F2	19 VI/76	112	38 44.2	73 09.3
"	"	F3	19 VI/76	157	38 43.6	73 04.7
"	"	F4	20 VI/76	184	38 44.3	73 03.1
"	"	I1	21 VI/76	80	39 06.3	72 59.2
"	"	J1	20 VI/76	315-400	38 44.2	73 00.9
"	"	N2	16 VI/76	38	39 10.2	74 01.7
"	"	N3	17 VI/76	45	38 51.1	73 45.1

Table 2-4. BLM04 Sample Stations (Summer 1976)

Cruise	Ship	Station	Date	Depth (m)	Lat.(N)	Long.(W)
BLM04B	R/V Pierce	A1	21 VIII/76	90	39°14.3'	72°46.8'
"	"	A2	22 VIII/76	127	39 21.6	72 30.7
"	"	A3	22 VIII/76	136	39 16.5	72 29.6
"	"	A4	22 VIII/76	198	39 14.1	72 26.4
"	"	B1	20 VIII/76	63	39 19.3	73 10.1
"	"	B2	21 VIII/76	60.5	39 23.3	73 00.5
"	"	B3	21 VIII/76	71.5	39 19.8	73 00.4
"	"	B4	21 VIII/76	41	39 29.9	73 10.1
"	"	C1	16 VIII/76	15.5	39 22.1	74 15.6
"	"	C2	16 VIII/76	25	39 20.9	74 05.2
"	"	C3	15 VIII/76	24	39 15.4	74 09.4
"	"	C4	15 VIII/76	34	39 14.9	74 07.5
"	"	D1	17 VIII/76	31	39 04.7	73 51.2
"	"	D2	17 VIII/76	32.5	39 07.1	73 49.6
"	"	D3	17 VIII/76	34	39 06.6	73 45.4
"	"	D4	17 VIII/76	48	39 02.9	73 47.1
"	"	E1	17 VIII/76	68	38 47.3	73 23.8
"	"	E2	18 VIII/76	70	38 44.2	73 25.6
"	"	E3	18 VIII/76	63	38 41.3	73 32.0
"	"	E4	18 VIII/76	75	38 42.6	73 24.3
"	"	F1	20 VIII/76	84	38 43.5	73 13.9
"	"	F2	20 VIII/76	113	38 43.7	73 08.5
"	"	F3	20 VIII/76	153	38 43.6	73 04.0
"	"	F4	20 VIII/76	183	38 44.2	73 02.8
"	"	G1	26 VIII/76	24	39 51.5	73 53.1
"	"	G2	26 VIII/76	36.5	39 43.7	73 34.9
"	"	G3	27 VIII/76	73	39 43.1	72 54.2
"	"	G4	27 VIII/76	55-56	39 53.4	72 43.1
"	"	G5	27 VIII/76	92	39 48.9	72 12.4
"	"	G6	27 VIII/76	167	39 40.7	72 00.7
"	"	G7	28 VIII/76	310	39 39.1	71 57.4
"	"	H1	28 VIII/76	390	39 12.1	72 23.6
"	"	H2	28 VIII/76	750	39 11.2	72 18.0
"	"	I1	23 VIII/76	77	39 06.6	72 59.0
"	"	I2	22 VIII/76	93	39 07.5	72 48.9
"	"	I3	22 VIII/76	176-181	39 08.8	72 41.8
"	"	I4	29 VIII/76	460	39 06.0	72 40.3
"	"	J1	29 VIII/76	350	38 45.2	73 01.0
"	"	J2	29 VIII/76	760	38 45.8	72 59.1
"	"	K1	23 VIII/76	29	38 17.5	74 41.0
"	"	K2	23 VIII/76	42	38 12.6	74 26.5
"	"	K3	23 VIII/76	53	38 08.0	74 12.9
"	"	K4	31 VIII/76	102	38 04.6	74 01.9
"	"	K5	31 VIII/76	140-150	38 04.6	73 53.9
"	"	K6	31 VIII/76	339-370	38 00.6	73 51.9

Table 2-4. BLM04 Sample Stations (Summer 1976) (continued)

Cruise	Ship	Station	Date	Depth (m)	Lat.(N)	Long.(W)
BLM04B	R/V Pierce	L1	1 IX/76	24	37°31.2'	75°18.6'
"	"	L2	1 IX/76	48	37 20.2	74 58.6
"	"	L3	1 IX/76	66	37 13.6	74 46.6
"	"	L4	1 IX/76	90-91	37 08.1	74 36.9
"	"	L5	1 IX/76	180-200	37 06.1	74 33.2
"	"	L6	1 IX/76	325-340	37 04.6	74 33.2
"	"	N2	26 VIII/76	33	39 10.1	74 01.9
"	"	N3	17 VIII/76	46	38 51.1	73 45.2
BLM04T	R/V C. Henlopen	A1	25 VIII/76	91	39 14.0	72 47.0
"	"	B1	25 VIII/76	63	39 19.0	73 10.0
"	"	C2	23 VIII/76	21	39 21.0	74 05.0
"	"	D1	24 VIII/76	31	39 05.0	73 51.0
"	"	E1	24 VIII/76	67	38 47.0	73 24.0
"	"	F1	24 VIII/76	85	38 43.0	73 14.0
"	"	I1	25 VIII/76	78	39 07.0	72 59.0
"	"	J1	25 VIII/76	400	38 45.0	73 01.0
"	"	N3	24 VIII/76	44	38 51.0	73 45.0
BLM04W	R/V Va Sea	C1	31 VIII-1 IX/76	15	39 22.0	74 15.3
"	"	D1	4-5 IX/76	31	39 04.5	73 53.4
"	"	E3	6-7 IX/76	63	38 41.4	73 32.5
"	"	F2	7-8 IX/76	113	38 44.4	73 09.1
"	"	J1	8-9 IX/76	350	38 44.0	73 00.7
"	"	N3	5-6 IX/76	46	38 51.2	73 45.0
BLM04G	R/V Smith	C2	14 IX/76	25	39 20.9	74 05.2
"	"	C3	14 IX/76	24	39 15.4	74 09.4
"	"	C4	14 IX/76	34	39 14.9	74 07.5
"	"	F2	14 IX/76	113	38 43.7	73 08.5
"	"	J1	14 IX/76	350	38 45.2	73 01.0
"	"	N2	14 IX/76	33	39 10.1	74 01.9

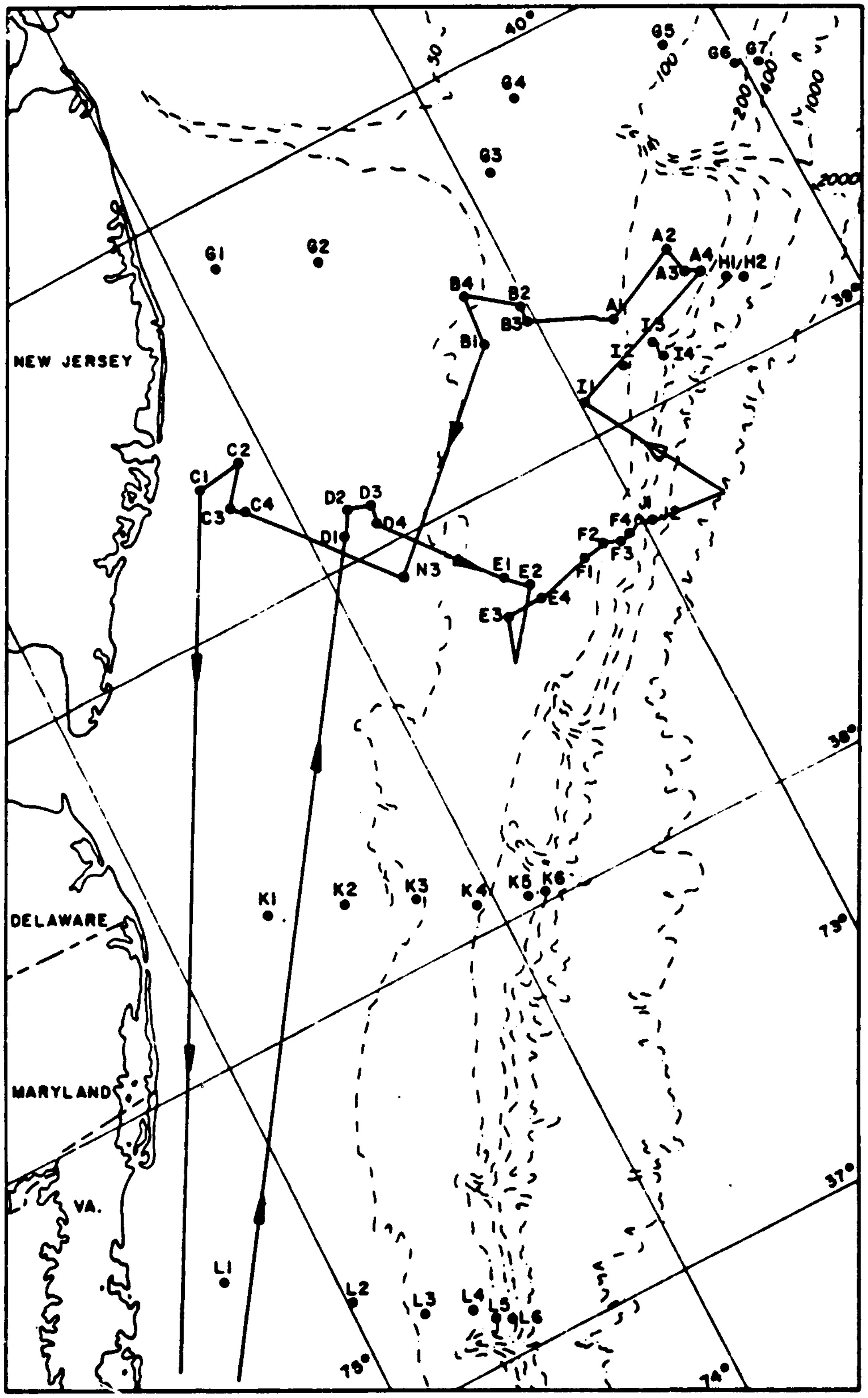

Figure 2-11. Cruise track, R/V Columbus Iselin, BLM01B, 27 October-6 November 1975.

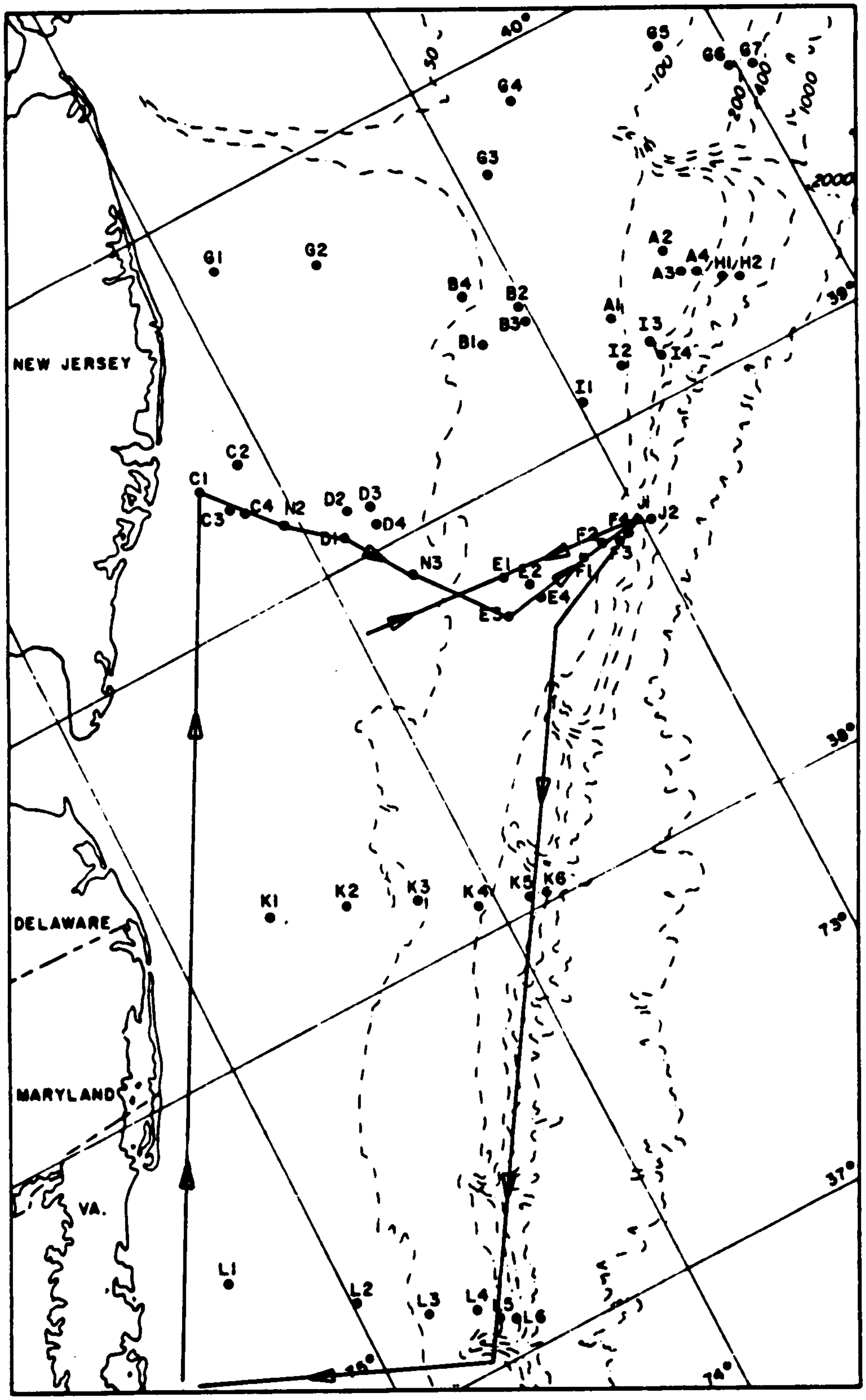

Figure 2-12. Cruise track, R/V G. W. Pierce, BLM01W, 22-31 October 1975.

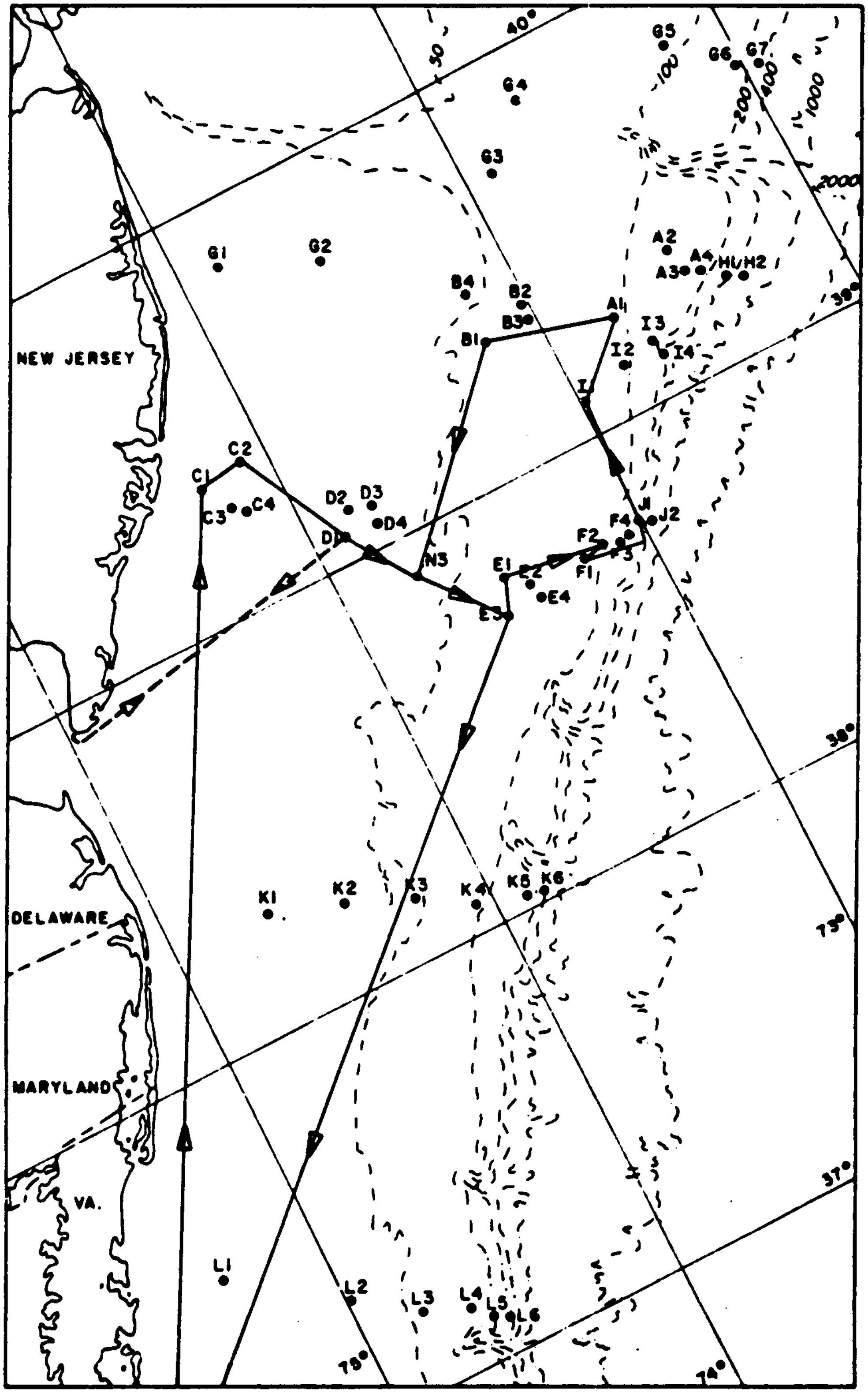

Figure 2-13. Cruise track, R/V G. W. Pierce, BLM02W, 4-17 February 1976.

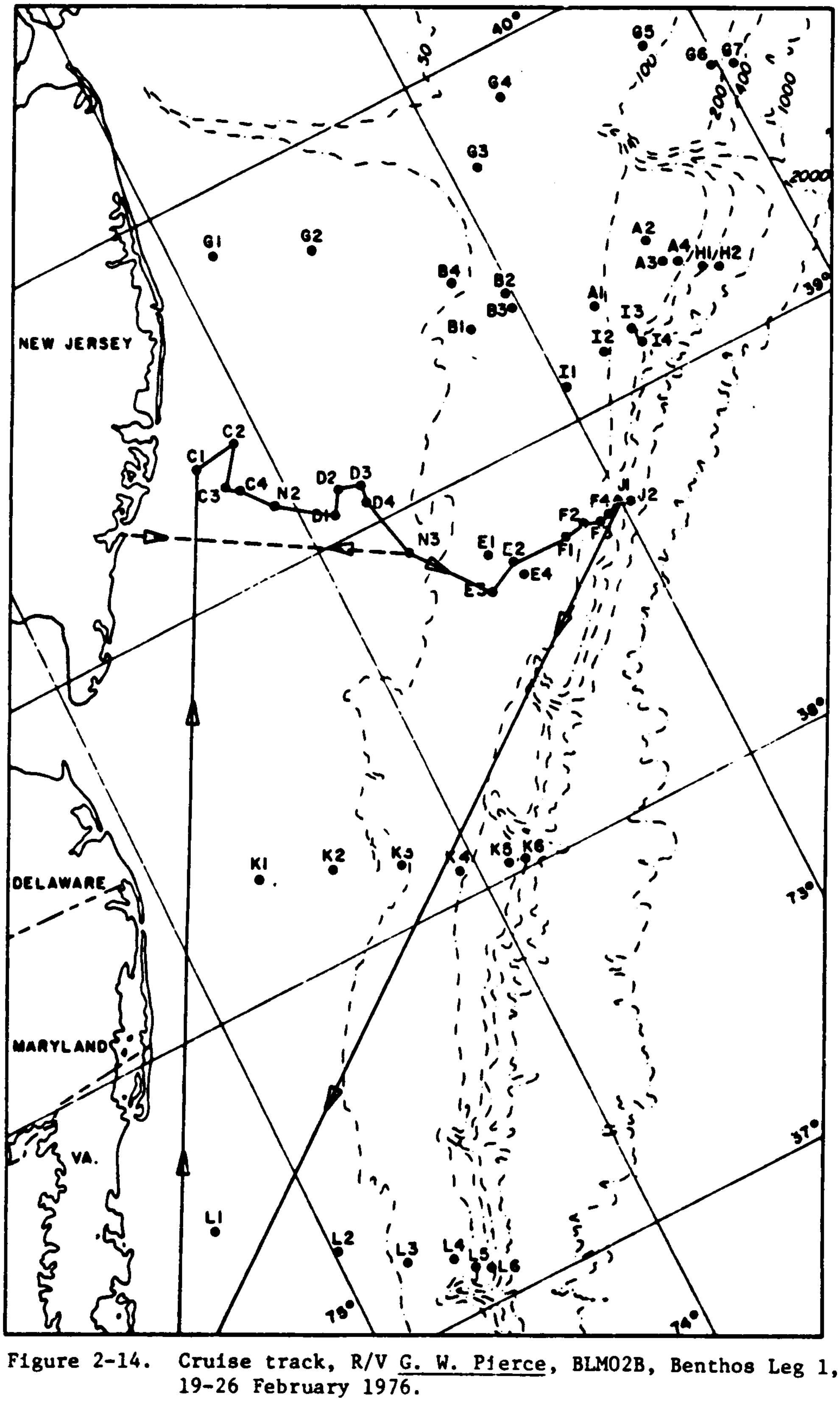

Figure 2-14. Cruise track, R/V G. W. Pierce, BLM02B, Benthos Leg 1, 19-26 February 1976.

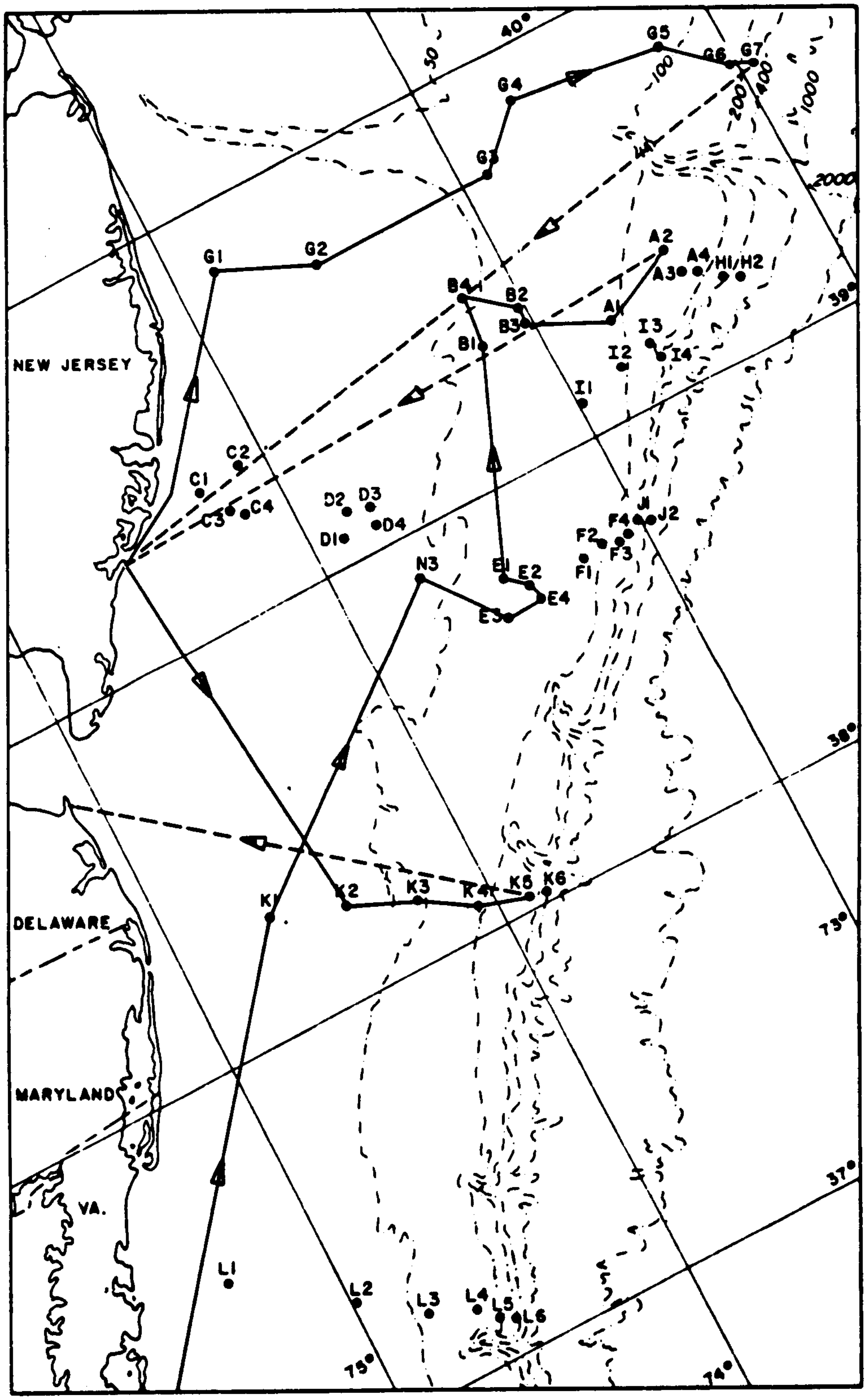

Figure 2-15. Cruise track, R/V G. W. Pierce, BLM02B, Benthos Leg 2, 1-13 March 1976.

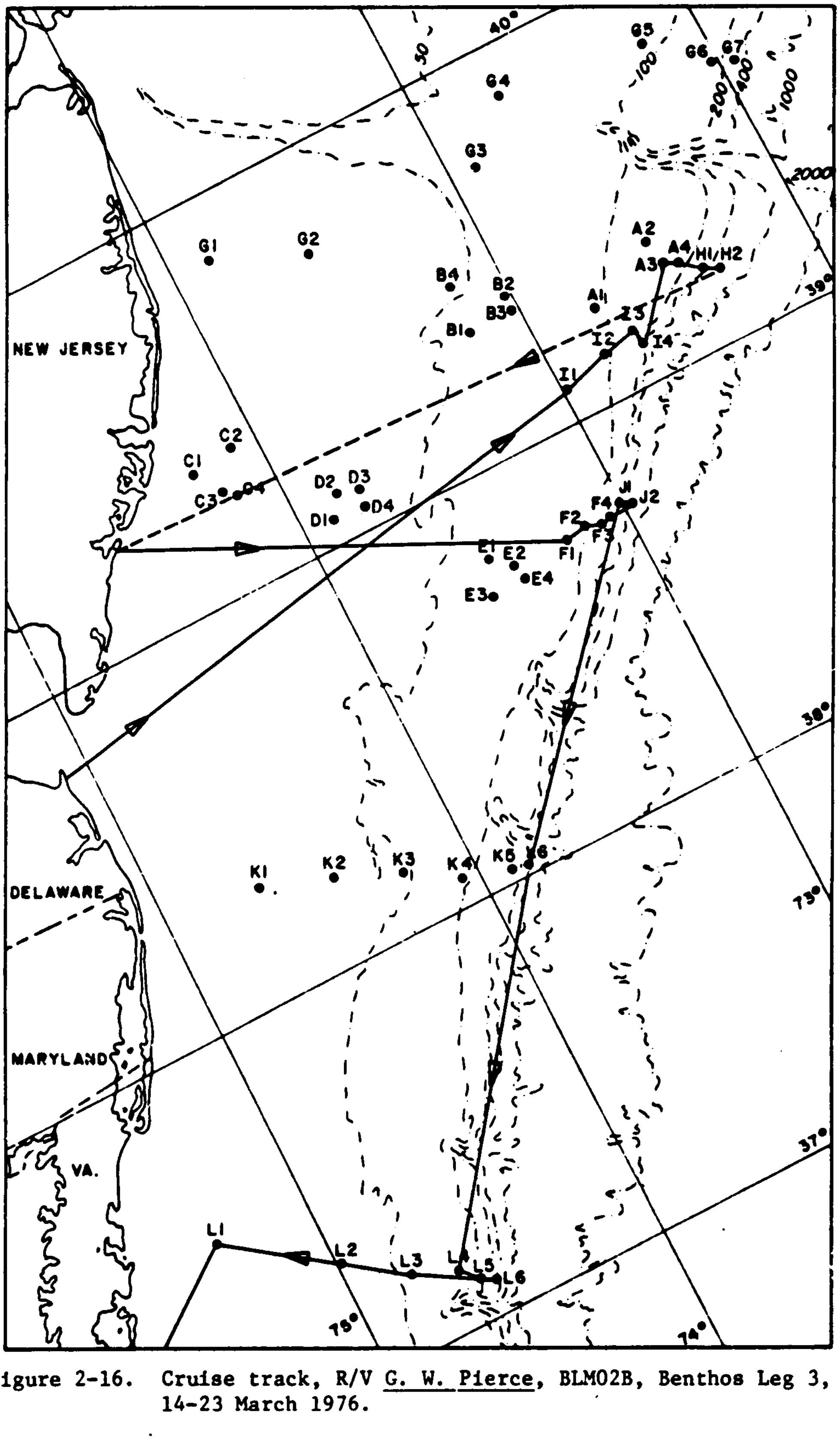

Figure 2-16. Cruise track, R/V G. W. Pierce, BLM02B, Benthos Leg 3, 14-23 March 1976.

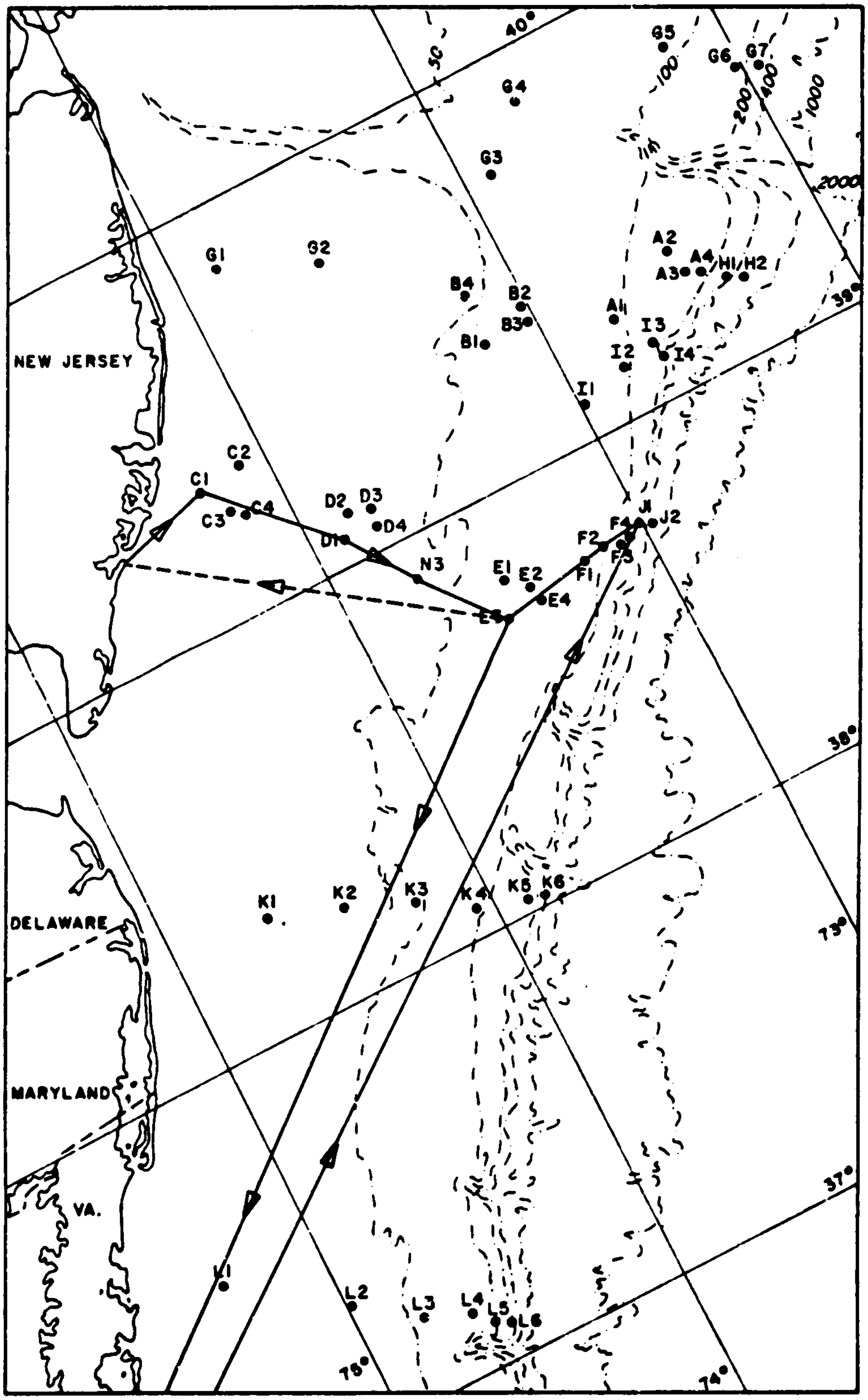

Figure 2-17. Cruise track, R/V Virginian Sea, BLM03W, 7-17 June 1976.

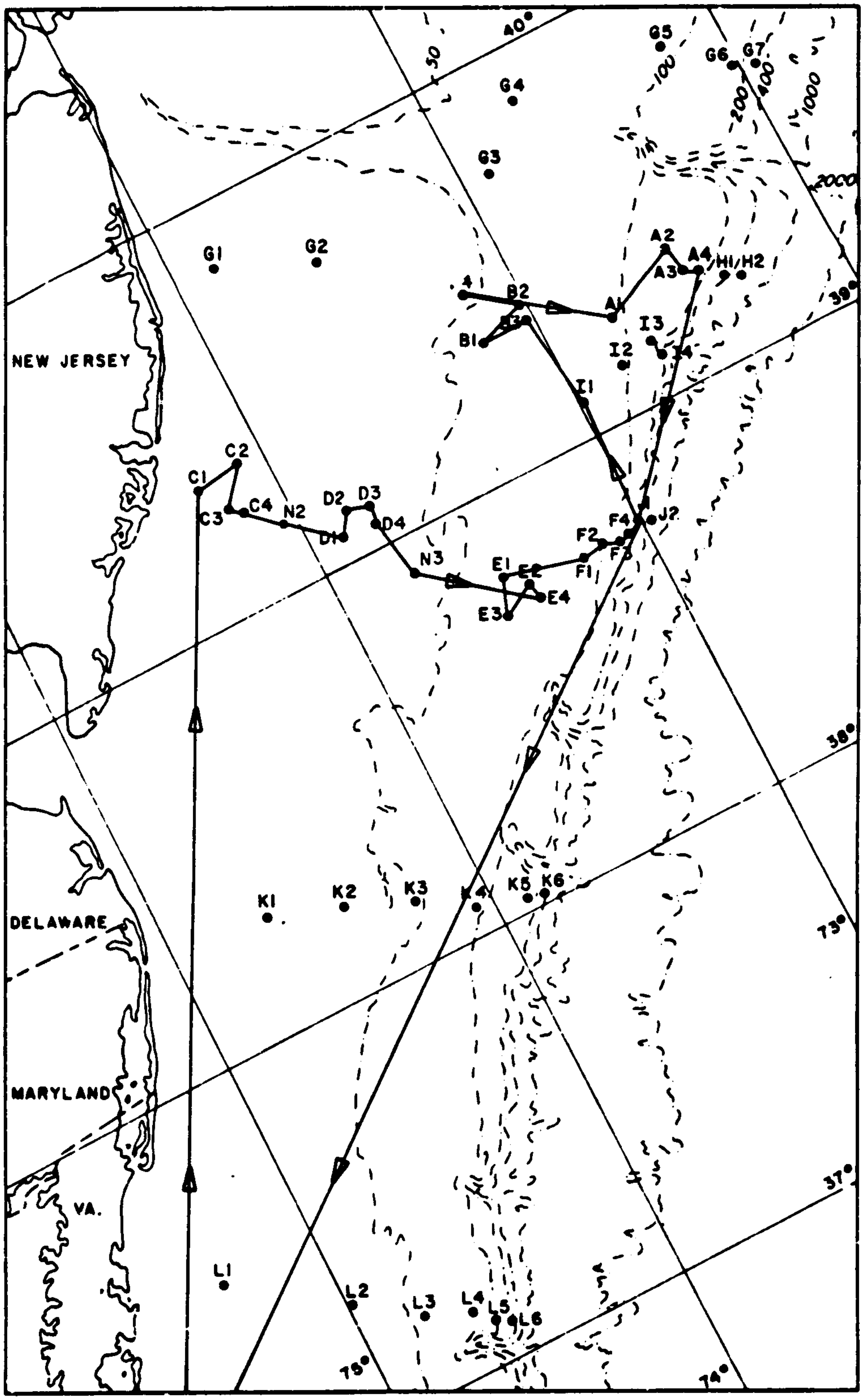

Figure 2-18. Cruise track, R/V J. M. Gilliss, BLM03B, 14-24 June 1976.

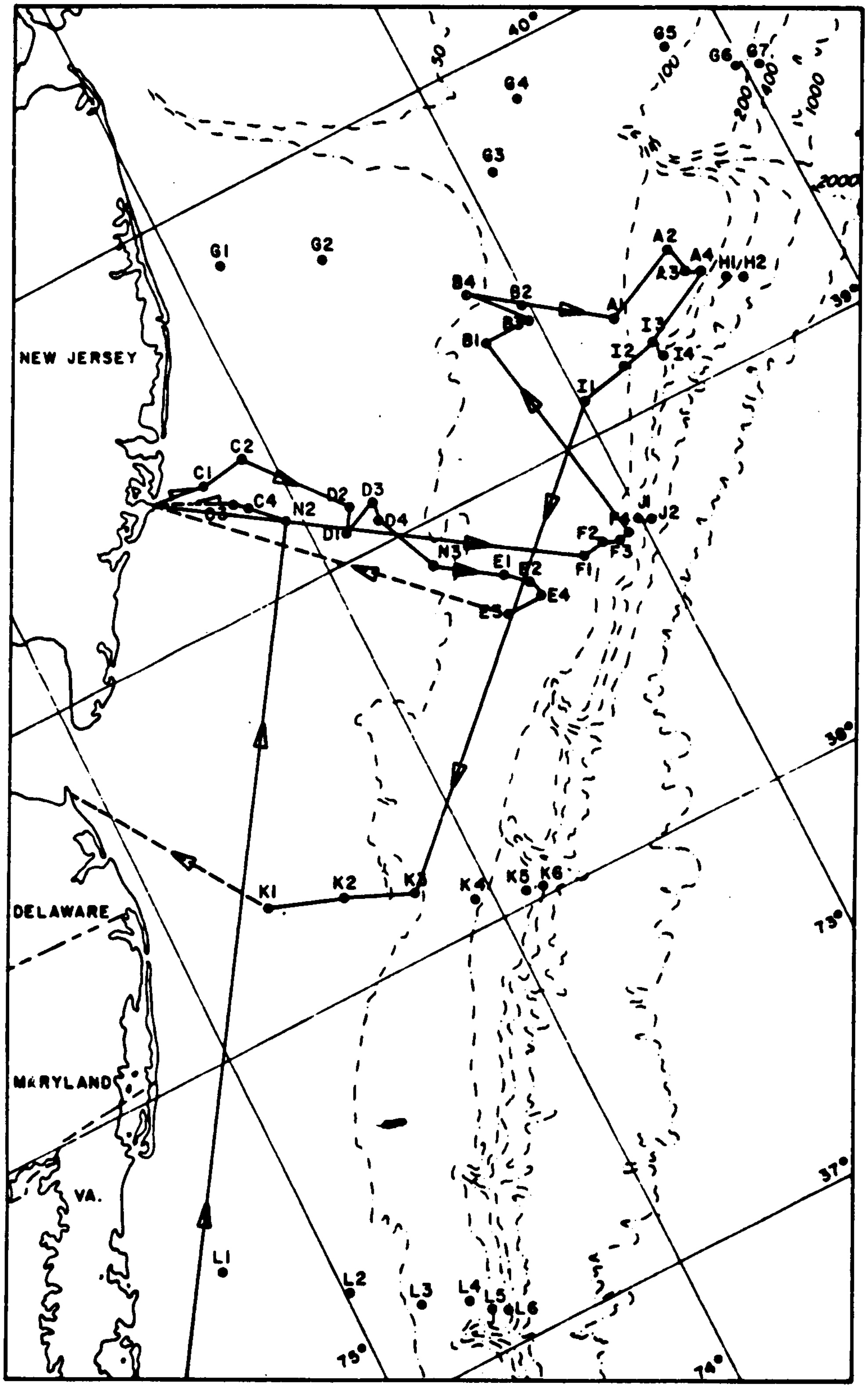

Figure 2-19. Cruise track, R/V G. W. Pierce, BLM04B, Leg 1, 14-24 August 1976.

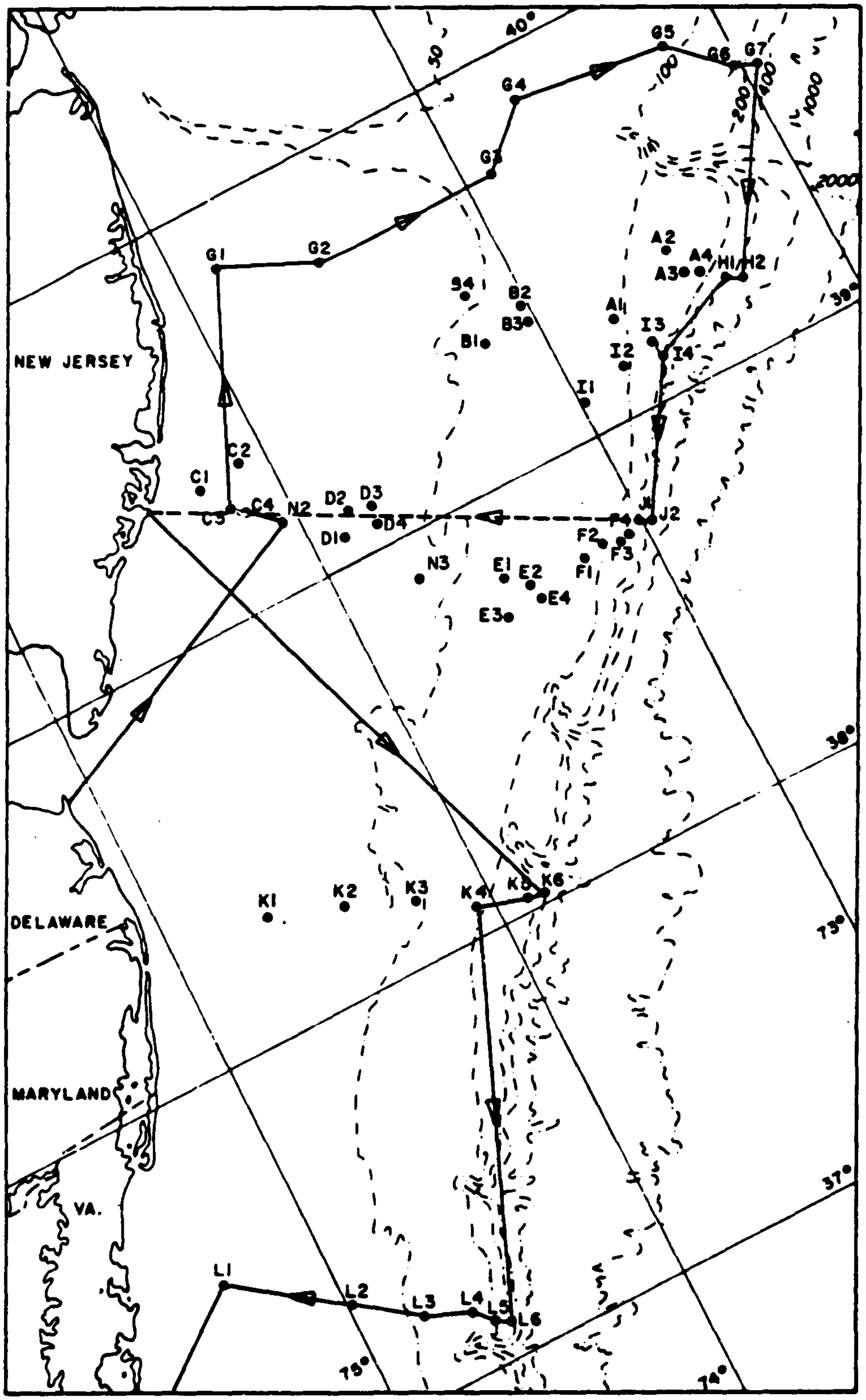

Figure 2-20. Cruise track, R/V G. W. Pierce, BLM04B, Leg 2, 26 August-2 September 1976.

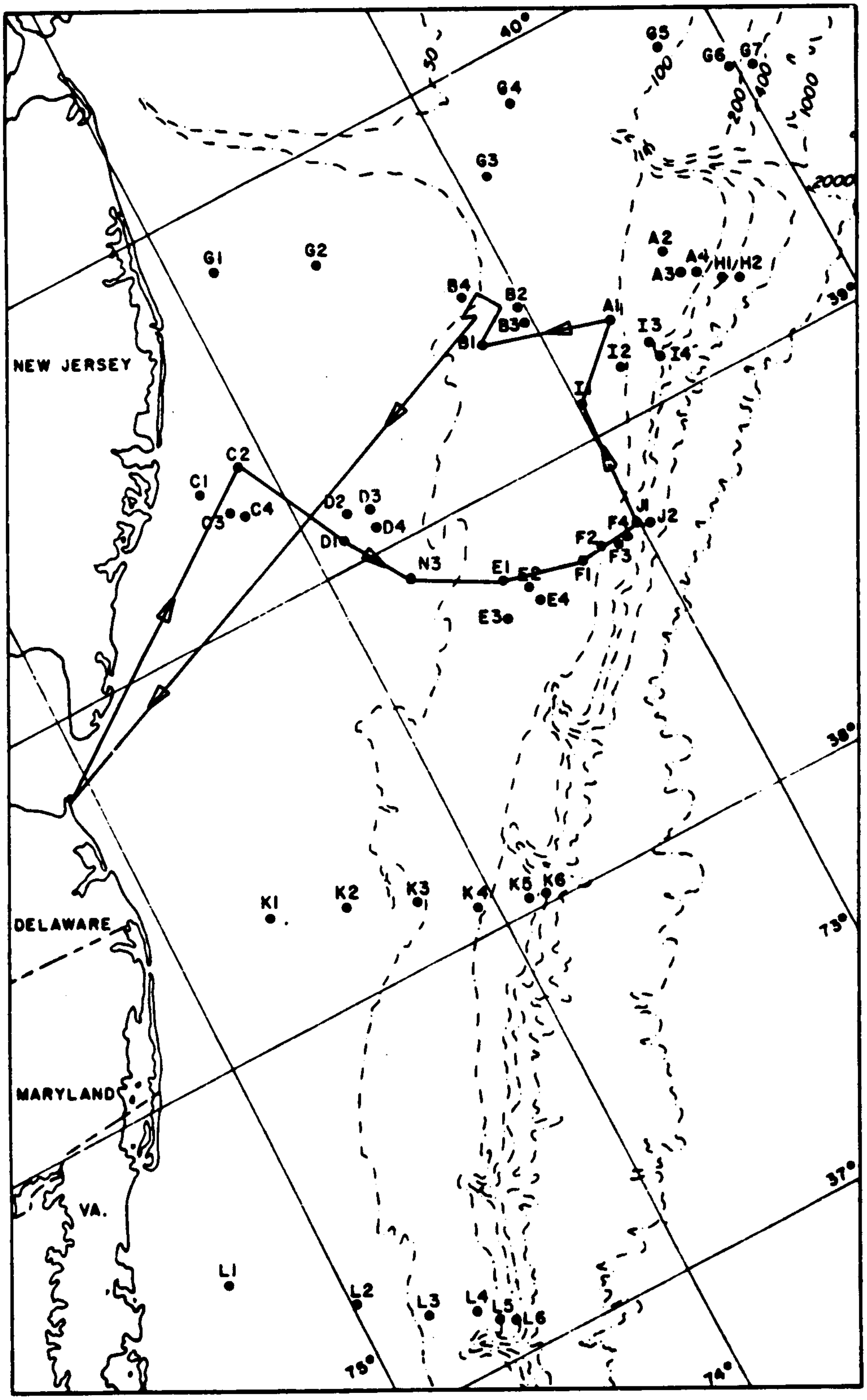

Figure 2-21. Cruise track, R/V Cape Henlopen, BLM04T, 23-27 August 1976.

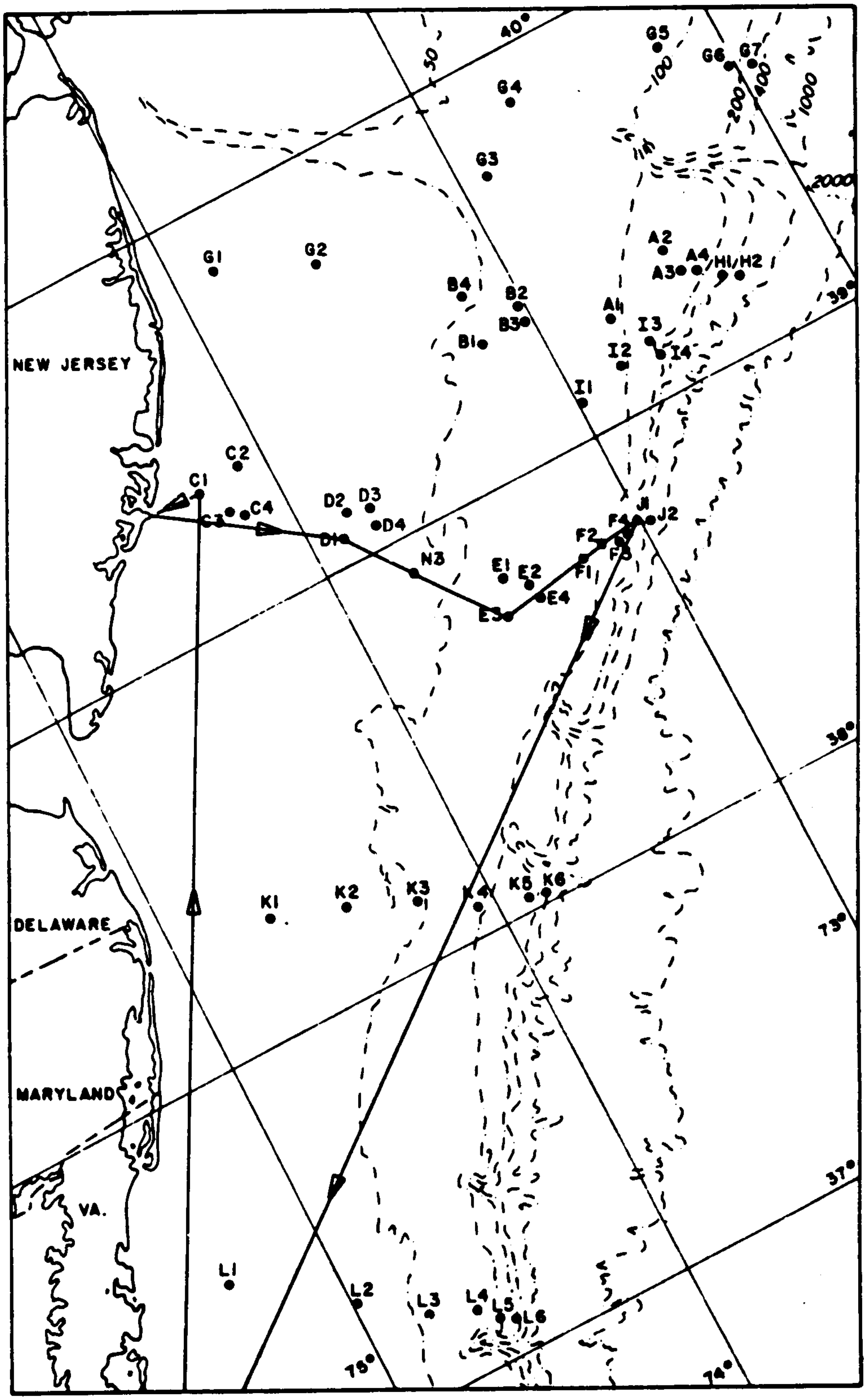

Figure 2-22. Cruise track, R/V Virginian Sea, BLM04W, 30 August-10 September 1976.

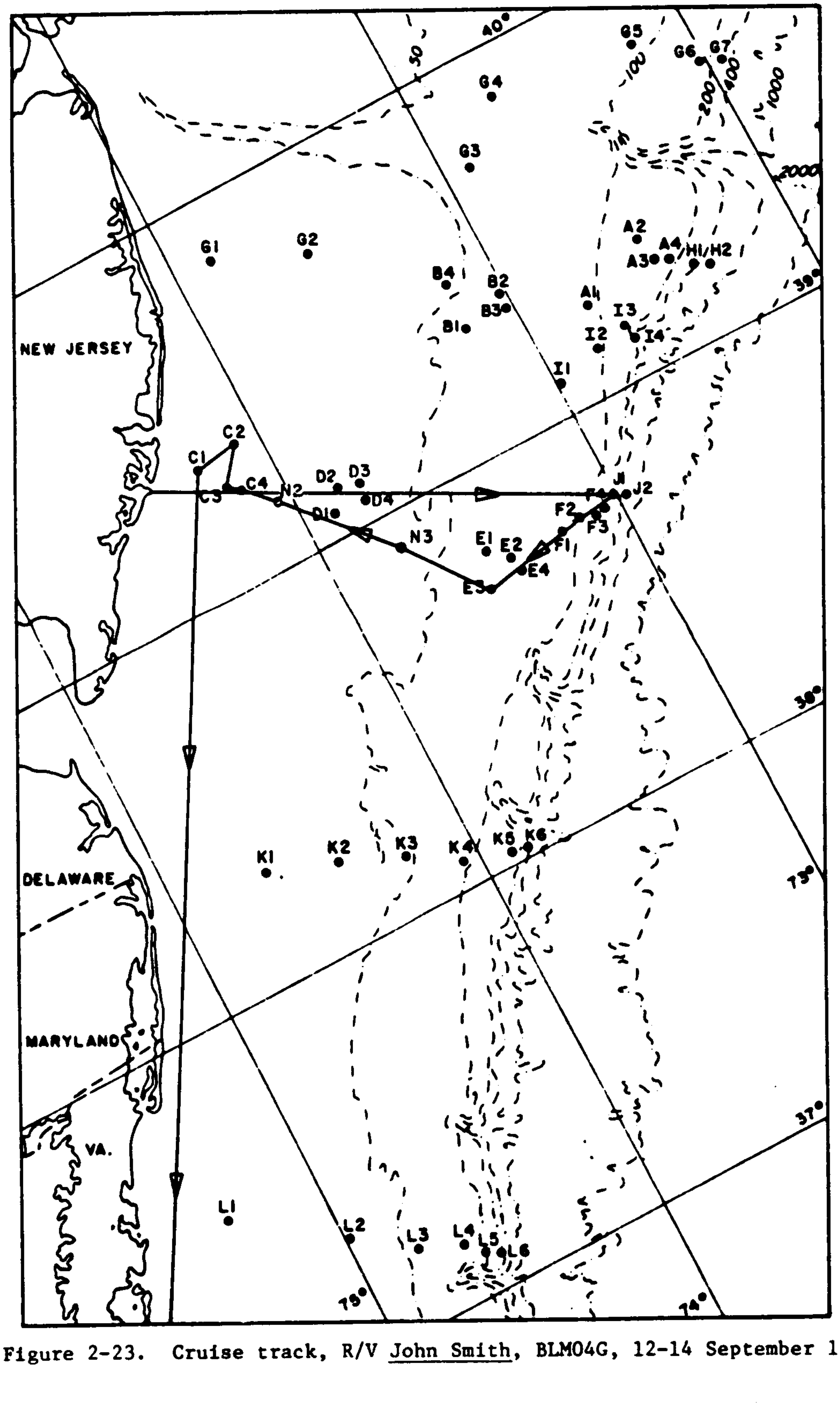

Figure 2-23. Cruise track, R/V John Smith, BLM04G, 12-14 September 1976.

sampling scheme for the 1976-1977 sampling year was similar to the first year. Only these changes or additions will be addressed.

Benthic Cluster Stations

Preliminary first year results suggested that some stations could be eliminated due to faunal similarity with other locations. Thus sampling was discontinued at the four cluster stations, C1, C3, D2, and D3 (Figure 2-2). These stations are a considerable distance inshore from the lease areas and were yielding little additional information. It was decided to retain only one ridge and one swale station in each of these two cluster areas.

Benthic Transect Stations

Sampling at seven transect stations, L1, L3, K1, K3, G1, G3, and G7 (Figure 2-8) was discontinued after the first sampling year. Stations L1, K1, and G1 were located far from the lease areas and any pollution event associated with oil development. Thus it was only necessary to document general community structure over a one year period. Stations L3, K3, and G3, although some distance seaward of L2, K2, and G2, were only about 10 m greater in depth than the latter stations and thus faunistically similar. Sampling at Station G7 was discontinued because it was faunistically similar to H1 and H2 and was peripherally out of the study area.

Water Column Stations

In order to more completely define seasonal neuston and subsurface zooplankton community structure in the present and future lease areas, a transect of 4 stations (L1, L2, L4, L6) from the coast of Virginia to the shelf-edge near Norfolk Canyon was added, as well as two stations (B5, A2) to the north of the original transect (Figure 2-10). Sampling protocol at these stations is outlined in Chapter 4.

Habitat Delineation Study

In order to determine if it was possible to extrapolate results from fixed stations located in topographically complex areas to other regions of the same features, or to similar features in other areas, and to document the relationship between benthic invertebrates and demersal fishes, a habitat delineation study was conducted. Cluster areas B and E (Figure 2-2) were chosen because many of the prime lease tracts are in these regions. Both regions were stratified based on existing bathymetry and sediment data and stations were determined by random selection of Loran C coordinates (Figures 2-24 through 2-27). Sampling was conducted during fall 1976 for megabenthos and

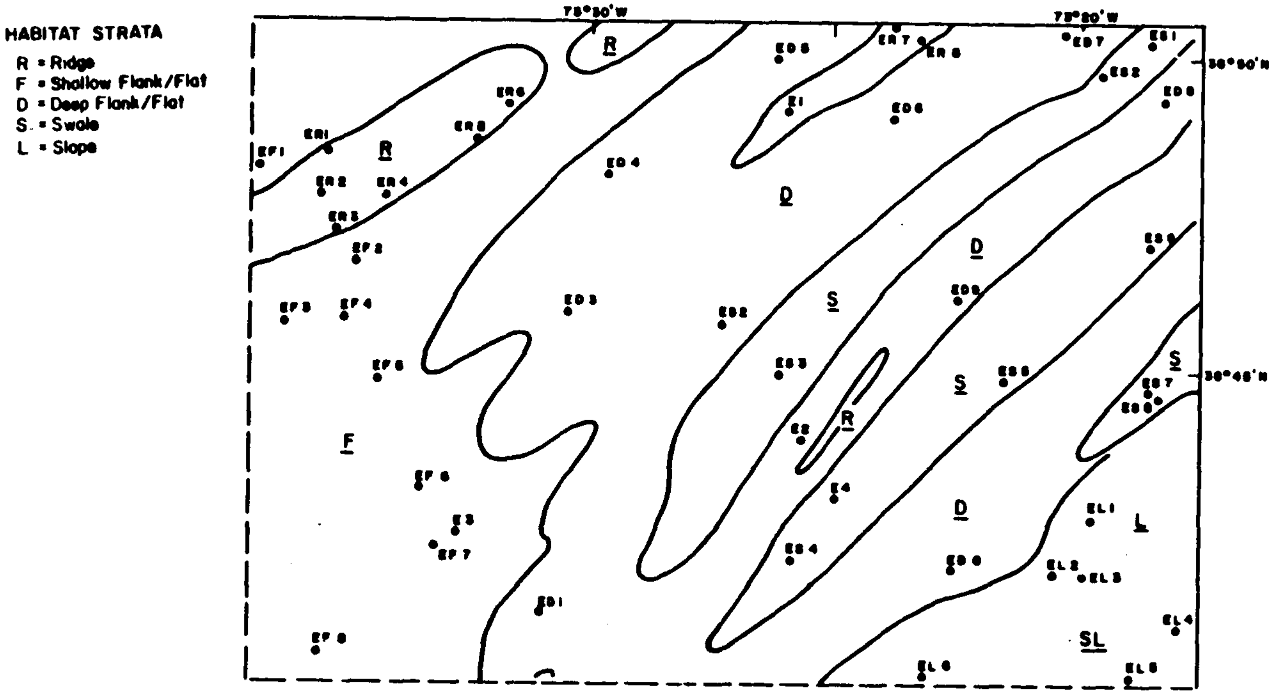

Figure 2-24. BLM05B, Benthic habitat delineation stations, Area E.

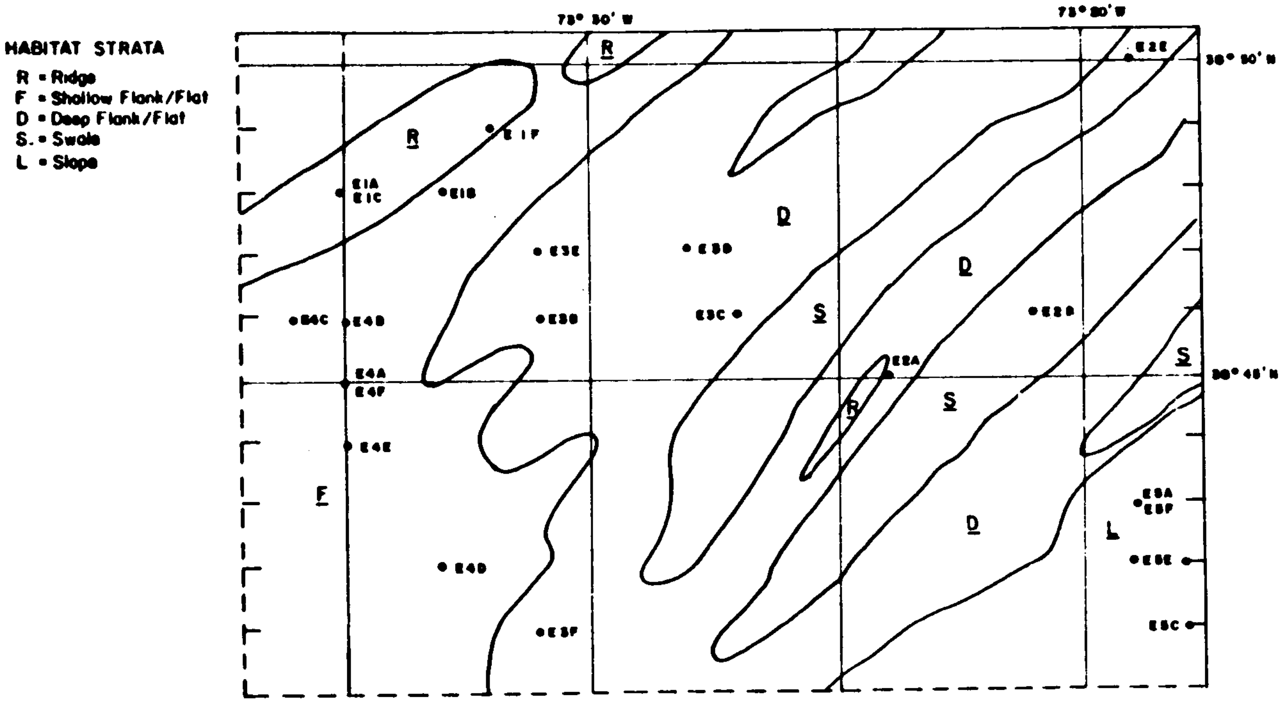

Figure 2-25. BLM05T, Megabenthic habitat delineation sites, Area E.

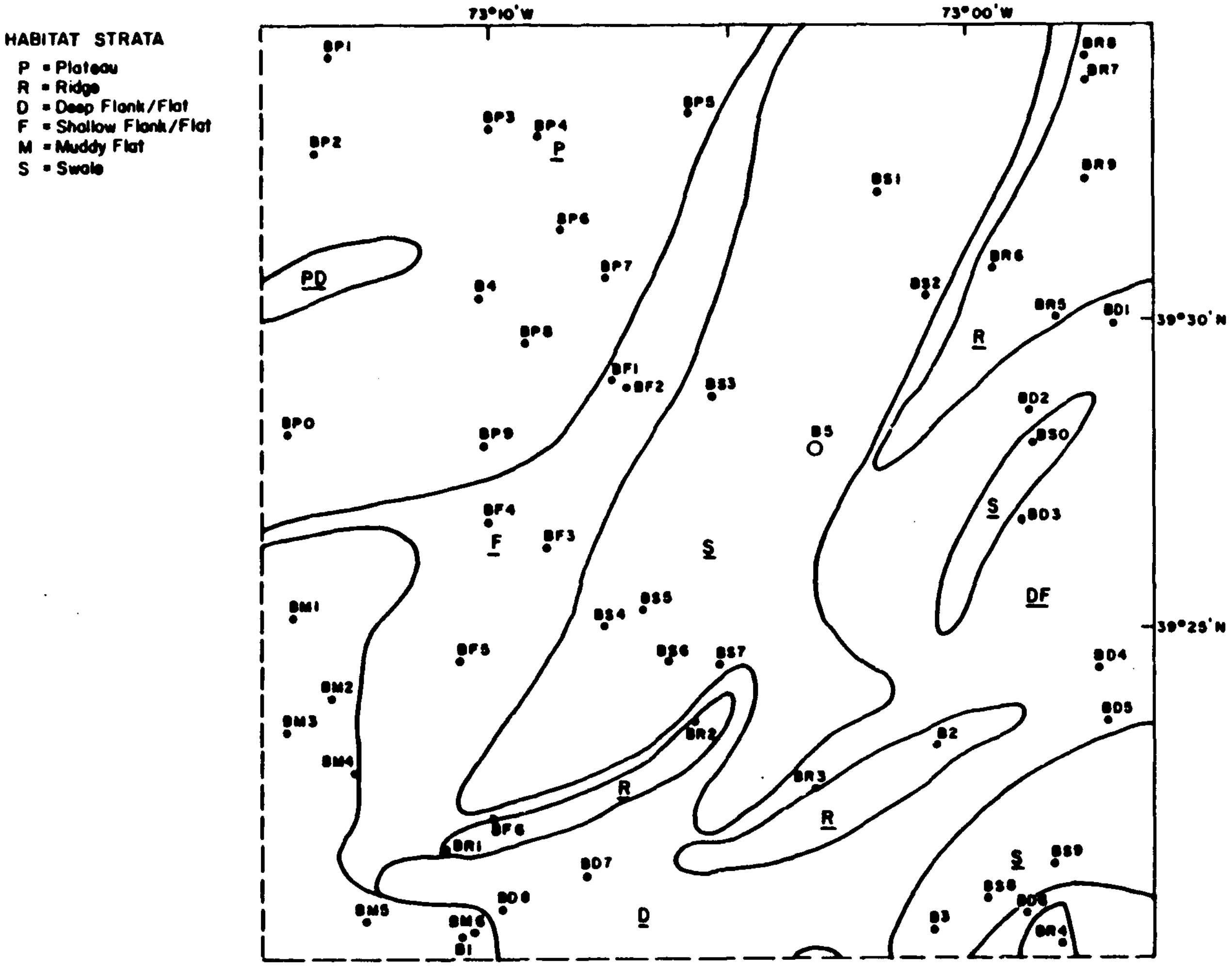

Figure 2-26. BLM05B, Benthic habitat delineation stations, Area B.

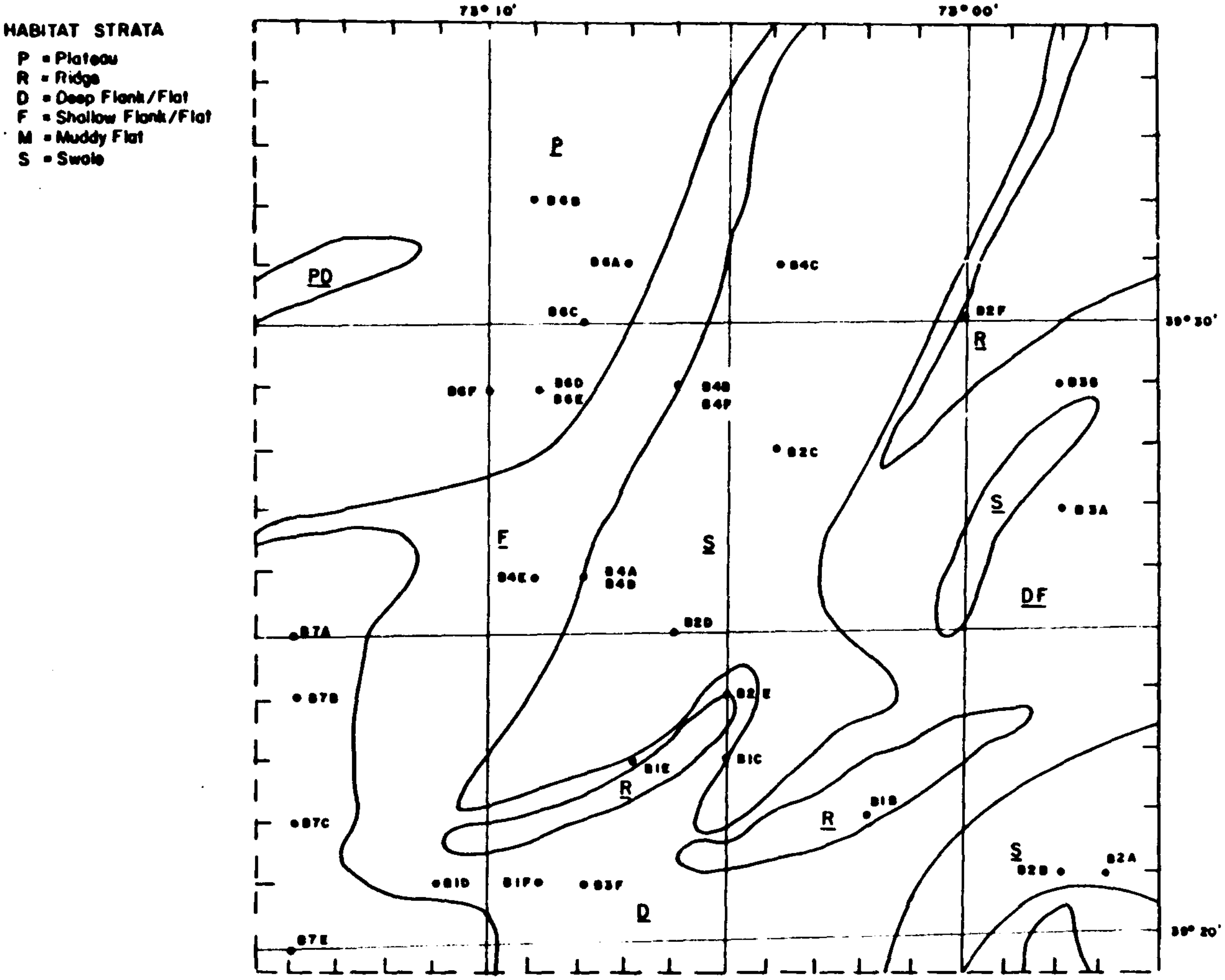

Figure 2-27. BLM05T, Megabenthic habitat delineation sites, Area B.

macrobenthos, but demersal fishes were sampled each season throughout the year. Additional information on sampling methodology can be found in Chapters 6 and 9.

Recolonization Study

This study, also initiated during the 1976-1977 sampling year, was designed to assess the effects of oiled sediment on recolonization of benthic invertebrates following catastrophic disturbance. The location chosen for this experiment (Station B5, Figure 2-4) is an area of fine sediment with relatively high silt and clay content which could retain oil.

Station Positions

Tables 2-5 to 2-9 list the geodetic position, date occupied, and water depth for each station sampled during 1976-1977. A key to sample type codes is presented in Table 2-10.

Cruise Tracks

The cruise tracks for each cruise conducted during 1976-1977 are shown in Figures 2-28 to 2-45.

SAMPLING PROCEDURES

Cruise Organization

The field sampling program throughout the first year consisted of separate cruises for water column and benthic studies. Each sampling season, one water column and at least one benthic cruise (two during winter and summer) occurred. During the summer season, a separate trawl cruise saved considerable time and expense. An additional bacteriological cruise (04G) was conducted one week after the summer water column cruise to resample bacteriological samples lost in a laboratory mishap.

During the second sampling year a three-cruise system was implemented with separate water column, benthic, and trawl cruises; deployment or recovery of recolonization boxes was also conducted on a separate cruise.

Participating in the majority of all cruises was a multidisciplinary scientific crew headed by a chief scientist. Composition of this party was dependent upon cruise; e.g. on benthic cruises there were representatives from physical oceanography, microbiology, benthic ecology, hydrocarbon chemistry, and trace metal

(TEXT CONTINUES ON PAGE 2-77)

Table 2-5. BLM05 Sample Stations (Fall 1976). Station types indicated in Table 2-10.

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM05B	A1/A	15-16 XI 76	91	39°14.5'	72°47.5'
"	A2/A	16 XI 76	133	39 21.6	72 31.1
"	A3/A	16 XI 76	139	39 16.5	72 29.8
"	A4/A	16 XI 76	198	39 14.3	72 26.8
"	B1/A	13 XI 76	65	39 19.3	73 10.2
"	B2/A	13 XI 76	62	39 23.2	73 00.5
"	B3/A	14 XI 76	74	39 19.7	73 00.3
"	B4/A	13 XI 76	42	39 30.0	73 10.1
"	B5/A	13 XI 76	68	39 27.6	73 04.3
"	C1/A	6 XI 76	15	39 22.0	74 15.6
"	C2/A	7 XI 76	26	39 21.0	74 05.3
"	C4/A	5&7 XI 76	33	39 15.2	74 07.9
"	D1/A	7 XI 76	30	39 04.6	73 51.1
"	D4/A	7 XI 76	48	39 02.8	73 47.0
"	E1/A	9 XI 76	63	38 49.0	73 25.4
"	E2/A	11 XI 76	72	38 44.1	73 25.0
"	E3/A	7 XI 76	65	38 41.4	73 32.2
"	E4/A	11 XI 76	78	38 43.0	73 24.4
"	F1/A	12 XI 76	85	38 44.1	73 14.7
"	F2/A	12 XI 76	111	38 44.3	73 09.3
"	F3/A	12 XI 76	151	38 43.6	73 04.5
"	F4/A	12 XI 76	179	38 44.5	73 03.2
"	N3/A	7 XI 76	46	38 51.1	73 45.2
"	BD1/B	15 XI 76	62	39 29.9	72 56.8
"	BD2/B	15 XI 76	64	39 28.4	72 58.7
"	BD3/B	15 XI 76	66	38 26.9	72 59.3
"	BD4/B	15 XI 76	64	39 24.3	72 57.4
"	BD5/B	15 XI 76	65	39 23.4	72 57.2
"	BD6/B	15 XI 76	74	39 20.1	72 59.0
"	BD7/B	15 XI 76	64	39 20.9	73 08.1
"	BD8/B	15 XI 76	64	39 20.3	73 10.1
"	BF1/B	15 XI 76	52	39 29.0	73 06.8
"	BF2/B	15 XI 76	54	39 28.9	73 06.8
"	BF3/B	15 XI 76	58	39 26.1	73 08.4
"	BF4/B	15 XI 76	58	39 26.6	73 09.8
"	BF5/B	15 XI 76	59	39 24.3	73 10.4
"	BF6/B	15 XI 76	62	39 21.9	73 09.8
"	BM1/B	15 XI 76	56	39 25.0	73 13.8
"	BM2/B	15 XI 76	58	39 23.7	73 13.2
"	BM3/B	15 XI 76	56	39 23.1	73 14.1
"	BM4/B	15 XI 76	56	39 22.4	73 12.9
"	BM5/B	15 XI 76	63	39 20.1	73 12.7
"	BM6/B	15 XI 76	63	39 20.0	73 10.7
"	BP1/B	15 XI 76	42	39 34.3	73 12.6
"	BP2/B	15 XI 76	41	39 32.6	73 13.1
"	BP3/B	15 XI 76	42	39 32.9	73 09.5

Table 2-5. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long. (W)
BLM05B	BP4/B	15 XI 76	46	39°32.9'	73°08.5'
"	BP5/B	15 XI 76	48	39 33.5	73 05.5
"	BP6/B	15 XI 76	46	39 31.3	73 07.9
"	BP7/B	15 XI 76	47	39 30.7	73 07.2
"	BP8/B	15 XI 76	45	39 29.5	73 09.0
"	BP9/B	15 XI 76	42	39 27.9	73 09.7
"	BP0/B	15 XI 76	41	39 28.0	73 13.9
"	BR1/B	15 XI 76	62	39 21.4	73 11.0
"	BR2/B	14 XI 76	66	39 23.4	73 05.7
"	BR3/B	14 XI 76	66	39 22.3	73 03.5
"	BR4/B	15 XI 76	65	39 19.8	72 58.5
"	BR5/B	15 XI 76	63	39 30.0	72 57.9
"	BR6/B	15 XI 76	66	39 30.6	72 59.4
"	BR7/B	15 XI 76	64	39 34.0	72 57.5
"	BR8/B	15 XI 76	65	39 34.5	72 57.4
"	BR9/B	15 XI 76	62	39 32.3	72 57.5
"	BS1/B	15 XI 76	71	39 32.0	73 01.5
"	BS2/B	15 XI 76	69	39 30.4	73 00.7
"	BS3/B	15 XI 76	66	39 28.7	73 05.1
"	BS4/B	15 XI 76	64	39 24.9	73 07.5
"	BS5/B	15 XI 76	66	39 25.1	73 06.5
"	BS6/B	15 XI 76	66	39 24.2	73 06.2
"	BS7/B	14 XI 76	68	39 24.2	73 05.1
"	BS8/B	15 XI 76	75	39 20.4	73 00.0
"	BS9/B	15 XI 76	74	39 20.8	72 58.3
"	BS0/B	15 XI 76	66	39 27.9	72 58.5
"	ED1/B	9 XI 76	69	38 41.2	73 30.8
"	ED2/B	10 XI 76	70	38 46.0	73 26.9
"	ED3/B	10 XI 76	70	38 46.0	73 30.1
"	ED4/B	10 XI 76	70	38 48.3	73 29.0
"	ED5/B	11 XI 76	69	38 50.2	73 25.2
"	ED6/B	11 XI 76	71	38 49.4	73 23.0
"	ED7/B	11 XI 76	74	38 51.0	73 19.2
"	ED8/B	11 XI 76	76	38 49.8	73 17.3
"	ED9/B	11 XI 76	76	38 46.3	73 21.4
"	ED0/B	11 XI 76	77	38 42.0	73 21.9
"	EF1/B	10 XI 76	57	38 48.5	73 36.6
"	EF2/B	10 XI 76	58	38 46.8	73 34.3
"	EF3/B	10 XI 76	62	38 45.8	73 36.0
"	EF4/B	10 XI 76	62	38 46.1	73 34.8
"	EF5/B	10 XI 76	66	38 44.9	73 34.0
"	EF6/B	10 XI 76	68	38 43.2	73 33.5
"	EF7/B	10 XI 76	65	38 42.2	73 33.1
"	EF8/B	9 XI 76	61	38 40.5	73 35.0

Table 2-5. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM05B	EL1/B	11 XI 76	74	38°42.9'	73°19.2'
"	EL2/B	11 XI 76	78	38 42.1	73 19.8
"	EL3/B	11 XI 76	80	38 42.0	73 19.2
"	EL4/B	11 XI 76	89	38 41.1	73 17.1
"	EL5/B	11 XI 76	87	38 40.2	73 17.9
"	EL6/B	11 XI 76	79	38 40.2	73 23.0
"	ER1/B	10 XI 76	58	38 48.8	73 35.2
"	ER2/B	10 XI 76	56	38 48.0	73 35.3
"	ER3/B	10 XI 76	52	38 47.3	73 35.0
"	ER4/B	10 XI 76	54	38 48.0	73 33.8
"	ER5/B	10 XI 76	57	38 49.0	73 31.7
"	ER6/B	10 XI 76	57	38 49.6	73 31.1
"	ER7/B	11 XI 76	67	38 50.8	73 22.8
"	ER8/B	11 XI 76	66	38 50.4	73 22.0
"	ES1/B	11 XI 76	77	38 50.7	73 17.9
"	ES2/B	11 XI 76	77	38 50.2	73 18.4
"	ES3/B	11 XI 76	76	38 45.3	73 25.5
"	ES4/B	9 XI 76	73	38 42.5	73 25.6
"	ES5/B	11 XI 76	78	38 45.2	73 20.9
"	ES6/B	11 XI 76	77	38 47.3	73 17.9
"	ES7/B	11 XI 76	80	38 45.1	73 17.8
"	ES8/B	11 XI 76	79	38 44.8	73 17.4
BLM05R	B5/C	1 XII 76	68	39 27.5	73 03.6
BLM05T	A1/D	14 XI 76	90	39 14.0	72 46.0
"	B1/D	17 XI 76	65	39 19.0	73 11.0
"	C2/D	9 XI 76	25	39 21.0	74 05.0
"	D1/D	9 XI 76	30	39 04.0	73 52.0
"	E1/D	11 XI 76	65	38 46.0	73 25.0
"	F1/D	13 XI 76	85	38 45.0	73 15.0
"	I1/D	14 XI 76	75	39 06.0	73 01.0
"	J1/D	14 XI 76	375	38 44.0	73 00.0
"	N3/D	9 XI 76	45	38 50.0	73 45.0
"	B1A/E	15 XI 76	64	39 19.0	72 58.0
"	B1B/E	15 XI 76	55	39 22.0	73 02.0
"	B1C/E	15 XI 76	-	39 23.0	73 05.0
"	B1D/E	15 XI 76	-	39 21.0	73 11.0
"	B1E/E	15 XI 76	-	39 23.0	73 07.0
"	B1F/E	15 XI 76	-	39 21.0	73 09.0
"	B2A/E	15 XI 76	-	39 21.0	72 57.0
"	B2B/E	15 XI 76	-	39 21.0	72 58.0
"	B2C/E	15 XI 76	68	39 28.0	73 04.0
"	B2D/E	15 XI 76	-	39 25.0	73 06.0
"	B2E/E	15 XI 76	68	39 24.0	73 05.0
"	B2F/E	16 XI 76	-	39 30.0	73 00.0
"	B3A/E	16 XI 76	75	39 27.0	72 58.0
"	B3B/E	16 XI 76	-	39 29.0	72 58.0

Table 2-5. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long. (W)
BLM05T	B3C/E	16 XI 76	-		
"	B3D/E	16 XI 76	-	39°27.0'	72°55.0'
"	B3E/E	16 XI 76	-	39 26.0	72 55.0
"	B3F/E	17 XI 76	-	39 21.0	73 08.0
"	B4A/E	15 XI 76	58	39 26.0	73 08.0
"	B4B/E	15 XI 76	-	39 29.0	73 06.0
"	B4C/B	15 XI 76	-	39 31.0	73 04.0
"	B4D/E	15 XI 76	-	39 26.0	73 08.0
"	B4E/E	16 XI 76	58	39 26.0	73 09.0
"	B4F/E	16 XI 76	-	39 29.0	73 06.0
"	B6A/E	16 XI 76	44	39 31.0	73 07.0
"	B6B/E	16 XI 76	-	39 32.0	73 09.0
"	B6C/E	16 XI 76	-	39 30.0	73 08.0
"	B6D/E	16 XI 76	42	39 29.0	73 09.0
"	B6E/E	16 XI 76	39	39 29.0	73 09.0
"	B6F/E	16 XI 76	-	39 29.0	73 10.0
"	B7A/E	17 XI 76	55	39 25.0	73 14.0
"	B7B/E	17 XI 76	57	39 24.0	73 14.0
"	B7C/E	17 XI 76	57	39 22.0	73 14.0
"	B7D/E	17 XI 76	-		
"	B7E/E	17 XI 76	-	39 20.0	73 14.0
"	B7F/E	17 XI 76	-	39 19.0	73 15.0
"	E1A/E	12 XI 76	55	38 48.0	73 35.0
"	E1B/E	12 XI 76	55	38 48.0	73 33.0
"	E1C/E	12 XI 76	55	38 48.0	73 35.0
"	E1D/E	12 XI 76	68	38 51.0	73 23.0
"	E1E/E	12 XI 76	-	38 50.0	73 25.0
"	E1F/E	12 XI 76	55	38 49.0	73 32.0
"	E2A/E	12 XI 76	78	38 45.0	73 24.0
"	E2B/E	12 XI 76	76	38 46.0	73 21.0
"	E2C/E	12 XI 76	-	38 48.0	73 16.0
"	E2D/E	12 XI 76	77	38 51.0	73 17.0
"	E2E/E	12 XI 76	75	38 50.0	73 19.0
"	E2F/E	12 XI 76	75	38 47.0	73 16.0
"	E3A/E	11 XI 76	67		
"	E3B/E	11 XI 76	67	38 46.0	73 31.0
"	E3C/E	11 XI 76	68	38 46.0	73 27.0
"	E3D/E	13 XI 76	71	38 47.0	73 28.0
"	E3E/E	13 XI 76	68	38 47.0	73 31.0
"	E3F/E	14 XI 76	71	38 41.0	73 31.0
"	E4A/E	11 XI 76	65	38 45.0	73 35.0
"	E4B/E	12 XI 76	61	38 46.0	73 35.0
"	E4C/E	12 XI 76	-	38 46.0	73 36.0
"	E4D/E	14 XI 76	65	38 42.0	73 33.0
"	E4E/E	14 XI 76	65	38 44.0	73 35.0
"	E4F/E	14 XI 76	65	38 45.0	73 35.0

Table 2-5. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM05T	E5A/E	12 XI 76	76	38°43.0'	73°19.0'
"	E5B/E	13 XI 76	79	38 42.0	73 18.0
"	E5C/E	13 XI 76	87	38 41.0	73 18.0
"	E5D/E	13 XI 76	90	38 40.0	73 16.0
"	E5E/E	13 XI 76	82	38 42.0	73 19.0
"	E5F/E	13 XI 76	-	38 43.0	73 19.0
"	B1G/F	15 XI 76	64	39 18.0	72 55.8
"	B1H/F	15 XI 76	55	39 22.6	73 00.2
"	B1I/F	15 XI 76	60	39 22.2	73.06.4
"	B1J/F	15 XI 76	60	39 21.3	73 09.7
"	B1K/F	15 XI 76	59	39 21.6	73 07.2
"	B1L/F	15 XI 76	64	39 20.7	73 10.9
"	B1M/F	16 XI 76	63	39 29.3	73 00.2
"	B2G/F	15 XI 76	73	39 21.5	72 55.5
"	B2H/F	15 XI 76	71	39 21.5	72 58.3
"	B2I/F	15 XI 76	68	39 27.3	73 04.6
"	B2J/F	15 XI 76	68	39 23.8	73 07.0
"	B2K/F	15 XI 76	65	39 23.8	73 07.0
"	B2L/F	16 XI 76	65	39 26.6	73 02.6
"	B3G/F	16 XI 76	75	39 26.1	72 57.2
"	B3H/F	16 XI 76	64	39 29.2	72 56.4
"	B3I/F	16 XI 76	60	39 28.7	72 55.7
"	B3J/F	16 XI 76	61	39 25.9	72 55.3
"	B3K/F	16 XI 76	60	39 24.8	72 55.5
"	B3L/F	17 XI 76	58	39 20.5	73 08.0
"	B4G/F	15 XI 76	58	39 27.3	73 08.2
"	B4H/F	15 XI 76	56	39 30.1	73 05.3
"	B4I/F	15 XI 76	60	39 29.8	73 05.6
"	B4J/F	15 XI 76	58	39 26.4	73 07.4
"	B4K/F	16 XI 76	59	39 24.5	73 10.2
"	B4L/F	16 XI 76	60	39 29.9	73 05.3
"	B6G/F	16 XI 76	46	39 31.5	73 08.0
"	B6H/F	16 XI 76	44	39 30.8	73 08.4
"	B6I/F	16 XI 76	42	39 29.0	73 07.9
"	B6J/F	16 XI 76	38	39 27.9	73 09.7
"	B6K/F	16 XI 76	39	39 29.6	73 09.4
"	B6L/F	17 XI 76	39	39 29.4	73 10.4
"	B7G/F	17 XI 76	55	39 24.5	73 13.5
"	B7H/F	17 XI 76	57	39 24.7	73 14.4
"	B7I/F	17 XI 76	57	39 20.8	73 13.6
"	B7J/F	17 XI 76	61	39 18.8	73 12.4
"	B7K/F	17 XI 76	54	39 20.1	73 14.9
"	B7L/F	17 XI 76	56	39 19.2	73 13.0
"	E1G/F	12 XI 76	55	38 48.2	73 34.7
"	E1H/F	12 XI 76	55	38 48.8	73 33.0
"	E1I/F	12 XI 76	55	38 47.8	73 34.9
"	E1J/F	12 XI 76	64	38 49.9	73 23.6
"	E1K/F	12 XI 76	68	38 48.9	73 25.1
"	E1L/F	12 XI 76	55	38 48.6	73 32.3

Table 2-5. (Concluded)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM05T	E2G/F	12 XI 76	75	38°45.8'	73°22.7'
"	E2H/F	12 XI 76	77	38 46.4	73 19.1
"	E2I/F	12 XI 76	77	38 47.3	73 16.6
"	E2J/F	12 XI 76	80	38 49.5	73 16.8
"	E2K/F	12 XI 76	78	38 48.8	73 19.1
"	E2L/F	12 XI 76	77	38 47.1	73 17.3
"	E3G/F	11 XI 76	72	38 45.6	73 26.5
"	E3H/F	11 XI 76	69	38 45.4	73 29.9
"	E3I/F	11 XI 76	68	38 45.8	73 29.3
"	E3J/F	13 XI 76	73	38 45.4	73 26.3
"	E3K/F	13 XI 76	71	38 45.9	73 29.0
"	E3L/F	14 XI 76	70	38 40.9	73 29.9
"	E4G/F	11 XI 76	64	38 44.6	73 34.7
"	E4H/F	12 XI 76	63	38 45.0	73 34.2
"	E4I/F	12 XI 76	60	38 44.6	73 35.9
"	E4J/F	14 XI 76	67	38 43.3	73 33.9
"	E4K/F	14 XI 76	65	38 44.5	73 34.1
"	E4L/F	14 XI 76	65	38 44.3	73 33.5
"	E5G/F	13 XI 76	80	38 42.1	73 18.0
"	E5H/F	13 XI 76	92	38 40.6	73 16.8
"	E5I/F	13 XI 76	90	38 41.5	73 18.9
"	E5J/F	13 XI 76	86	38 41.1	73 17.8
"	E5K/F	13 XI 76	88	38 41.2	73 17.3
"	E5L/F	13 XI 76	80	38 42.9	73 18.0
"	E5M/F	13 XI 76	84	38 42.1	73 17.5
"	E5N/F	13 XI 76	90	38 41.6	73 17.4
"	E5O/F	13 XI 76	82	38 41.5	73 18.0
"	E5P/F	13 XI 76	83	38 41.6	73 17.9
BLM05W	L1/G	5 XI 76	25	37 31.5	75 16.2
"	L6/G	6 XI 76	350	37 04.6	74 33.1
"	D1/G	24 XI 76	40	39 04.6	73 53.4
"	L1/G	21-22 XI 76	25	37 30.8	75 17.4
"	L2/G	20-21 XI 76	43	37 20.1	74 58.8
"	L4/G	19-20 XI 76	94	37 07.7	74 36.1
"	L6/G	18-19 XI 76	375	37 01.5	74 32.5
"	N3/G	24-25 XI 76	46	38 51.2	73 45.0
"	A2/G	22,23,25 XI 76	127	39 22.4	72 42.4
"	B5/G	24-25 XI 76	62	39 27.3	73 03.7
"	C1/G	20-21 XI 76	14	39 23.7	74 11.4
"	D1/G	28 XI 76	40	39 04.7	73 53.1
"	E3/G	27-28 XI 76	56	38 41.4	73 32.2
"	F2/G	26-27 XI 76	102	38 44.3	73 09.3
"	J1/G	26-27 XI 76	273	38 45.2	73 01.0
"	L2/G	29 XI 76	42	37 20.2	74 58.7
"	L4/G	29 XI 76	98	37 08.2	74 37.0
"	L6/G	28-29 XI 76	403	37 04.6	74 33.1
"	N3/G	28 XI 76	46	38 51.2	74 45.0

Table 2-6. BLM06 Sample Stations (Winter 1977). Station types indicated in Table 2-10.

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long.(W)
BLM06B	A1/A	12 II 77	90	39°14.4'	72°47.3'
"	A2/A	12 II 77	128	39 21.6	72 31.0
"	A3/A	12 II 77	136	39 16.5	72 29.8
"	A4/A	12 II 77	203	39 14.1	72 26.8
"	B1/A	11 II 77	64	39 19.4	73 10.3
"	B2/A	11 II 77	58	39 23.3	73 00.5
"	B3/A	11-12 II 77	72	39 19.7	73 00.2
"	B4/A	11 II 77	41	39 30.0	73 10.0
"	B5/A	8 III 77	65	39 27.5	73 03.7
"	C1/H	14 II 77	17	39 22.2	74 15.4
"	C2/A	14 II 77	26	39 21.0	74 05.2
"	C4/A	14 II 77	36	39 15.3	74 08.0
"	D1/A	8 II 77	29	39 04.6	73 51.1
"	D4/A	8 II 77	49	39 03.0	73 47.2
"	E1/A	9 II 77	60	38 49.0	73 25.3
"	E2/A	9 II 77	74	38 44.3	73 25.5
"	E3/A	9 II 77	63	38 41.2	73 32.2
"	E4/A	9 II 77	77	38 42.8	73 24.4
"	F1/A	9 II 77	79	38 45.4	73 16.3
"	F2/A	10 II 77	103	38 44.3	73 08.9
"	F3/A	10 II 77	155	38 43.8	73 04.1
"	F4/A	10 II 77	206	38 44.2	73 02.6
"	G2/A	14 II 77	36	39 43.6	73 34.7
"	G3/A	8 III 77	71	39 43.0	72 54.1
"	G4/A	8 III 77	56	39 53.5	72 43.1
"	G5/A	8 III 77	85	39 48.9	72 12.1
"	G6/A	9 III 77	174	39 40.5	72 00.7
"	H1/A	9-10 III 77	400	39 12.2	72 23.5
"	H2/A	9 III 77	744	39 11.1	72 17.9
"	I1/A	13 II 77	77	39 06.6	72 59.0
"	I2/A	13 II 77	93	39 07.5	72 49.1
"	I3/A	13 II 77	174	39 09.0	72 42.1
"	I4/A	10 III 77	514	39 06.0	72 40.3
"	J1/A	10-11 II 77	362	38 45.2	73 00.8
"	J2/A	11 III 77	740	38 45.8	72 59.3
"	K2/A	16 II 77	40	38 12.5	74 26.6
"	K4/A	16 II 77	103	38 04.6	74 01.7
"	K5/A	16 II 77	152	38 01.5	73 53.8
"	K6/A	12 III 77	370	38 00.7	73 51.8
"	L2/A	17 II 77	43	37 20.2	74 58.6
"	L4/A	13 III 77	94	37 08.1	74 36.9
"	L5/A	16 II 77	190	37 06.2	74 33.4
"	L6/A	12-13 III 77	350	37 04.7	74 33.1
"	N3/I	9 II 77	47	38 51.0	73 45.2

Table 2-6. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long. (W)
BLM06T	A1/D	24 III 77	90	39°14.0'	72°48.0'
"	B1/D	24 III 77	65	39 19.0	73 10.0
"	C2/D	19 III 77	27	39 20.0	74 06.0
"	D1/D	19 III 77	41	39 04.0	73 52.0
"	E1/D	20 III 77	77	38 47.0	73 23.0
"	F1/D	21 III 77	84	38 44.0	73 15.0
"	I1/D	23 III 77	78	39 07.0	72 59.0
"	J1/D	22 III 77	490	38 43.0	73 01.0
"	N3/D	19-20 III 77	46	38 52.0	73 43.0
"	B1G/F	27 III 77	62	39 21.2	73 03.7
"	B1H/F	26 III 77	61	39 21.3	73 07.8
"	B1I/F	26 III 77	62	39 22.4	73 01.4
"	B1J/F	26 III 77	62	39 31.0	72 56.9
"	B1K/F	26 III 77	62	39 31.0	72 56.4
"	B1L/F	26 III 77	62	39 30.5	72 56.9
"	B2G/F	26 III 77	66	39 32.3	73 03.6
"	B2H/F	26 III 77	70	39 29.0	73 01.4
"	B2I/F	26 III 77	69	39 24.6	73 06.8
"	B2J/F	26 III 77	67	39 23.2	73 06.5
"	B2K/F	26 III 77	67	39 23.6	73 03.6
"	B2L/F	27 III 77	70	39 21.8	72 57.8
"	B3G/F	27 III 77	64	39 21.7	73 06.7
"	B3H/F	27 III 77	65	39 21.5	73 06.1
"	B3I/F	26 III 77	65	39 20.5	73 03.8
"	B3J/F	26 III 77	65	39 19.9	73 04.2
"	B3K/F	26 III 77	66	39 24.9	72 59.1
"	B3L/F	26 III 77	65	39 28.6	72 58.8
"	B4G/F	26 III 77	58	39 31.7	73 04.6
"	B4H/F	26 III 77	55	39 29.7	73 06.0
"	B4I/F	27 III 77	59	39 26.6	73 09.1
"	B4J/F	25 III 77	59	39 26.8	73 09.1
"	B4K/F	27 III 77	60	39 25.4	73 11.5
"	B4L/F	27 III 77	59	39 22.9	73 12.5
"	B6G/F	26 III 77	42	39 31.3	73 10.7
"	B6H/F	26 III 77	44	39 31.4	73 09.8
"	B6I/F	26 III 77	45	39 31.4	73 08.2
"	B6J/F	26 III 77	43	39 33.2	73 09.1
"	B6K/F	26 III 77	49	39 32.9	73 05.5
"	B6L/F	27 III 77	46	39 29.0	73 07.7
"	B7G/F	27 III 77	50	39 25.9	73 14.2
"	B7H/F	27 III 77	58	39 24.1	73 13.8
"	B7I/F	27 III 77	57	39 23.3	73 14.0
"	B7J/F	27 III 77	58	39 23.0	73 14.0
"	B7K/F	27 III 77	58	39 21.2	73 14.8
"	B7L/F	27 III 77	67	39 19.7	73 11.9
"	E1G/F	20 III 77	54	38 47.1	73 36.4
"	E1H/F	20 III 77	53	38 47.1	73 35.5
"	E1I/F	20 III 77	57	38 48.8	73 33.8

Table 2-6. (Concluded)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM06T	E1J/F	20 III 77	56	38°48.5'	73°33.7'
"	E1K/F	20 III 77	67	38 50.5	73 23.3
"	E1L/F	21 III 77	62	38 49.3	73 24.5
"	E2G/F	21 III 77	74	38 43.2	73 26.8
"	E2H/F	21 III 77	75	38 44.0	73 26.5
"	E2I/F	21 III 77	77	28 47.2	73 22.3
"	E2J/F	21 III 77	79	38 44.4	73 23.1
"	E2K/F	21 III 77	77	38 46.7	73 18.7
"	E2L/F	21 III 77	78	38 47.1	73 18.1
"	E3G/F	21 III 77	71	38 42.6	73 28.3
"	E3H/F	20 III 77	73	38 43.1	73 28.8
"	E3I/F	20 III 77	72	38 47.7	73 25.0
"	E3J/F	21 III 77	75	38 42.4	73 27.2
"	E3K/F	21 III 77	77	38 46.7	73 21.7
"	E3L/F	21 III 77	80	38 48.4	73 19.3
"	E4G/F	20 III 77	68	38 48.9	73 29.2
"	E4H/F	20 III 77	62	38 45.9	73 34.7
"	E4I/F	20 III 77	66	38 43.4	73 34.0
"	E4J/F	20 III 77	67	38 42.8	73 34.0
"	E4K/F	20 III 77	67	38 42.8	73 32.8
"	E4L/F	20 III 77	64	38 40.7	73 35.2
"	E5G/F	21 III 77	82	38 40.4	73 21.0
"	E5H/F	21 III 77	82	38 40.3	73 21.4
"	E5I/F	21 III 77	84	38 41.1	73 19.8
"	E5J/F	21 III 77	83	38 41.3	73 19.7
"	E5K/F	22 III 77	86	38 41.5	73 17.9
"	E5L/F	21-22 III 77	82	38 42.2	73 18.4
BLM06W	A2/G	3-4 III 77	128	39 22.0	72 31.0
"	B5/G	2-3 III 77	64	39 27.0	73 02.0
"	C1/G	5-6 III 77	15	39 22.0	74 16.0
"	D1/G	5 III 77	39	39 04.0	73 53.0
"	E3/G	28 II-1 III 77	63	38 41.0	73 32.0
"	F2/G	28 II 77	97	38 44.0	73 09.0
"	J1/G	26-27 II 77	351	38 45.0	73 01.0
"	L1/G	22-23 II 77	22	37 32.0	75 19.0
"	L2/G	23-24 II 77	41	37 20.0	74 59.0
"	L4/G	25-26 II 77	93	37 08.0	74 37.0
"	L6/G	20-22 II 77	362	37 05.0	74 33.0
"	N3/G	28 II 77	43	38 52.0	73 45.0

Table 2-7. BLM07 Sample Stations (Spring 1977). Station types indicated in Table 2-10.

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM07B	A1/A	2 VI 77	90	39°14.7'	72°47.4'
"	A2/A	2 VI 77	130	39 21.8	72 31.2
"	A3/A	2 VI 77	139	39 16.5	72 29.7
"	A4/A	2 VI 77	195	39 16.9	72 30.4
"	B1/A	3 VI 77	63	39 19.4	73 10.2
"	B2/A	3 VI 77	61	39 23.3	73 00.6
"	B3/A	3 VI 77	73	39 19.7	73 00.4
"	B4/A	3 VI 77	40	39 29.9	73 10.1
"	B5/A	3 VI 77	66	39 27.5	73 03.6
"	C1/H	30 V 77	17	39 22.0	74 15.7
"	C2/A	30 V 77	26	39 21.0	74 05.2
"	C4/A	31 V 77	34	39 15.2	74 08.3
"	D1/A	31 V 77	32	39 04.7	73 51.4
"	D4/A	31 V 77	51	39 02.9	73 47.1
"	E1/A	31 V 77	67	38 49.0	73 25.8
"	E2/A	1 VI 77	74	38 44.2	73 25.0
"	E3/A	31 V 77	66	38 41.4	73 32.4
"	E4/A	1 VI 77	80	38 42.8	73 24.3
"	F1/A	1 VI 77	85	38 44.0	73 14.7
"	F2/A	1 VI 77	110	38 44.3	73 09.2
"	F3/A	1 VI 77	152	38 44.0	73 04.3
"	F4/A	1 VI 77	183	38 43.9	73 04.3
"	N3/I	31 V 77	47	38 51.1	73 45.2
BLM07R	B5/J	3 VI 77	66	39 27.5	73 03.6
BLM07T	A1/D	19 V 77	90	39 11.0	72 50.0
"	B1/D	21 V 77	64	39 19.0	73 10.0
"	C2/D	16 V 77	25	39 22.0	74 04.0
"	D1/D	16 V 77	37	39 05.0	73 53.0
"	E1/D	18 V 77	73	38 47.0	73 23.0
"	F1/D	18 V 77	75	38 46.0	73 14.0
"	I1/D	19 V 77	82	39 07.0	72 58.0
"	J1/D	18 V 77	410	38 44.0	73 01.0
"	N3/D	16-17 V 77	40	38 50.0	73 43.0
"	B1G/F	19 V 77	65	39 22.6	73 06.6
"	B1H/F	19 V 77	62	39 20.6	73 06.1
"	B1I/F	19 V 77	58	39 21.8	73 01.4
"	B1J/F	20 V 77	57	39 29.1	72 59.2
"	B1K/F	21 V 77	59	39 30.0	72 57.3
"	B1L/F	21 V 77	60	39 31.2	72 55.3
"	B2G/F	19 V 77	64	39 20.2	73 09.2
"	B2H/F	20 V 77	66	39 26.6	73 04.5
"	B2I/F	21 V 77	68	39 30.3	73 02.8
"	B2J/F	20 V 77	64	39 31.2	73 03.7
"	B2K/F	20 V 77	65	39 32.9	73 03.1
"	B2L/F	20 V 77	62	39 33.4	73 02.3

Table 2-7. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM07T	B3G/F	21 V 77	64	39°20.8'	73°09.6'
"	B3H/F	19 V 77	66	39 20.0	73 00.7
"	B3I/F	19 V 77	69	39 21.0	73 00.2
"	B3J/F	20 V 77	55	39 24.7	72 58.3
"	B3K/F	20 V 77	60	39 26.0	72 58.3
"	B3L/F	20-21 V 77	62	39 26.9	72 57.7
"	B4G/F	20 V 77	59	39 21.8	73 12.8
"	B4H/F	20 V 77	53	39 25.1	73 11.1
"	B4I/F	19-20 V 77	57	39 24.8	73 08.4
"	B4J/F	19 V 77	57	39 25.1	73 08.4
"	B4K/F	20 V 77	57	39 27.4	73 07.7
"	B4L/F	20 V 77	53	39 31.2	73 04.9
"	B6G/F	20 V 77	42	39 25.0	73 13.4
"	B6H/F	20 V 77	40	39 26.6	73 11.9
"	B6I/F	20 V 77	42	39 27.4	73 06.8
"	B6J/F	20 V 77	37	39 31.2	73 11.7
"	B6K/F	20 V 77	40	39 32.1	73 11.7
"	B6L/F	20 V 77	45	39 31.9	73 07.9
"	B7G/F	20 V 77	49	39 25.2	73 13.1
"	B7H/F	20 V 77	56	39 21.8	73 14.3
"	B7I/F	20 V 77	56	39 21.9	73 13.8
"	B7J/F	20 V 77	57	39 21.0	73 13.7
"	B7K/F	20 V 77	55	39 20.9	73 13.7
"	B7L/F	20 V 77	58	39 19.9	73 12.3
"	E1G/F	17 V 77	51	38 47.3	73 34.9
"	E1H/F	17 V 77	51	38 48.0	73 34.5
"	E1I/F	17 V 77	51	38 48.4	73 32.7
"	E1J/F	17 V 77	56	38 48.9	73 32.1
"	E1K/F	18 V 77	65	38 49.1	73 24.8
"	E1L/F	18 V 77	65	38 48.6	73 22.9
"	E2G/F	18 V 77	78	38 46.8	73 23.6
"	E2I/F	17 V 77	80	38 49.4	73 18.2
"	E2J/F	17 V 77	77	38 48.8	73 17.8
"	E2K/F	17 V 77	79	38 46.3	73 18.7
"	E2L/F	17 V 77	78	38 47.0	73 17.9
"	E2M/F	19 V 77	77	38 47.4	73 22.4
"	E3G/F	17 V 77	68	38 46.2	73 30.4
"	E3H/F	17 V 77	66	38 47.1	73 29.7
"	E3I/F	18 V 77	68	38 47.0	73 26.8
"	E3J/F	17-18 V 77	77	38 49.3	73 20.1
"	E3K/F	17 V 77	71	38 43.5	73 27.7
"	E3L/F	19 V 77	75	38 45.4	73 18.0
"	E4G/F	17 V 77	63	38 46.6	73 33.4
"	E4H/F	18 V 77	65	38 43.0	73 32.2
"	E4I/F	17 V 77	68	38 45.2	73 32.7
"	E4J/F	18 V 77	66	38 42.0	73 31.1
"	E4K/F	17 V 77	63	38 42.2	73 34.6
"	E4L/F	17 V 77	55	38 49.4	73 34.6

Table 2-7. (Concluded)

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long. (W)
BLM07T	E5G/F	17 V 77	77	38°40.9'	73°21.9'
"	E5H/F	17 V 77	75	38 41.3	73 20.8
"	E5I/F	17 V 77	87	38 41.2	73 17.5
"	E5J/F	19 V 77	84	38 39.7	73 18.4
"	E5K/F	19 V 77	77	38 42.4	73 18.0
"	E5L/F	19 V 77	77	38 42.4	73 19.0
"	MUD1-27/C	21 V 77	∿40	39 28.0	73 04.0
"	A2/G	25-26 V 77	131	39 22.0	72 31.0
"	B5/G	26-27 V 77	65	39 27.0	73 03.0
"	C1/G	27-28 V 77	17	39 22.0	74 15.0
"	D1/G	25 V 77	35	39 04.0	73 53.0
"	E3/G	23-24 V 77	65	38 41.0	73 33.0
"	F2/G	23 V 77	125	38 44.0	73 10.0
"	J1/G	22-23 V 77	370	38 44.0	73 01.0
"	L1/G	17-18 V 77	24	37 31.0	75 18.0
"	L2/G	18-19 V 77	42	37 20.0	74 59.0
"	L4/G	19-20 V 77	96	37 08.0	74 37.0
"	L6/G	20-21 V 77	350	37 04.0	74 33.0
"	N3/G	24 V 77	45	38 51.0	73 45.0

Table 2-8. BLM08 Sample Stations (Summer 1977). Station types indicated in Table 2-10.

Cruise	Station/Type	Date	Depth (m)	Lat. (N)	Long. (W)
BLM08B	A1/A	7 VIII 77	89	39°14.7'	72°42.4'
"	A2/A	7 VIII 77	129	39 21.6	72 31.3
"	A3/A	7 VIII 77	149	39 16.3	72 29.3
"	A4/A	7 VIII 77	188	39 14.2	72 26.6
"	B1/A	6 VIII 77	64	39 19.3	73 10.1
"	B2/A	6 VIII 77	62	39 23.2	73 00.5
"	B3/A	6,7 VIII 77	71	39 21.0	73 02.1
"	B4/A	6 VIII 77	41	39 30.1	73 09.9
"	B5/A	6 VIII 77	66	39 27.5	73 03.6
"	C1/H	12 VIII 77	14	39 21.9	74 15.5
"	C2/H	12 VIII 77	23	39 21.1	74 05.2
"	C4/H	12 VIII 77	33	39 15.0	74 07.6
"	D1/H	12 VIII 77	30	39 04.7	73 51.0
"	D4/H	12 VIII 77	49	39 03.0	73 47.2
"	E1/H	11 VIII 77	63	38 49.1	73 25.3
"	E2/H	11 VIII 77	76	38 45.2	73 25.2
"	E3/H	11 VIII 77	66	38 41.2	73 31.8
"	E4/H	11 VIII 77	80	38 42.7	73 24.9
"	F1/H	10 VIII 77	82	38 45.4	73 16.5
"	F2/H	11 VIII 77	116	38 44.2	73 09.1
"	F3/H	10 VIII 77	162	38 43.9	73 04.1
"	F4/H	10 VIII 77	180	38 44.5	73 03.0
"	G2/H	13 VIII 77	36	39 43.6	73 34.6
"	G3/H	14 VIII 77	74	39 43.1	72 54.2
"	G4/H	14 VIII 77	56	39 53.5	72 43.1
"	G5/H	14 VIII 77	90	39 49.0	72 12.1
"	G6/H	14 VIII 77	178	39 40.5	72 00.4
"	H1/H	8 VIII 77	390	39 12.3	72 23.9
"	H2/H	8 VIII 77	740	39 11.3	72 18.2
"	I1/H	9 VIII 77	77	39 06.7	72 59.1
"	I2/H	9 VIII 77	95	39 07.5	72 49.0
"	I3/H	9 VIII 77	170	39 08.9	72 41.9
"	I4/H	8 VIII 77	445	39 06.1	72 40.3
"	J1/A	9 VIII 77	355	38 45.3	73 01.0
"	J2/A	9 VIII 77	756	38 46.0	72 59.1
"	K2/A	16 VIII 77	42	38 13.4	74 27.9
"	K4/A	16 VIII 77	103	38 04.5	74 01.6
"	K5/A	15 VIII 77	150	38 01.5	73 53.9
"	K6/A	15 VIII 77	370	38 00.8	73 51.8
"	L2/A	4 VIII 77	43	37 20.2	74 58.6
"	L4/A	4 VIII 77	97	37 08.1	74 36.9
"	L5/A	5 VIII 77	140	37 06.5	74 33.6
"	L6/A	5 VIII 77	380	37 04.8	74 33.1
"	N3/I	12 VIII 77	46	38 51.2	73 45.3
BLM08R	B5/K	13,16 VIII 77	63	39 27.5	73 03.6

Table 2-8. (Continued)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM08T	A1/D	12 IX 77	91	39°14.0'	72°47.0'
"	B1/D	14 IX 77	64	39 19.0	73 10.0
"	C2/D	7 IX 77	24	39 21.0	74 06.0
"	D1/D	7 IX 77	37	39 04.0	73 55.0
"	E1/D	11 IX 77	68	38 47.0	73 24.0
"	F1/D	11 IX 77	85	38 44.0	73 14.0
"	I1/D	12 IX 77	77	39 06.0	72 59.0
"	J1/D	12 IX 77	400	38 50.0	72 55.0
"	N3/D	8 IX 77	44	38 51.0	73 46.0
"	B1G/F	12 IX 77	60	39 20.3	73 03.6
"	B1H/F	12 IX 77	60	39 21.2	73 03.3
"	B1I/F	12 IX 77	60	39 21.5	73 01.3
"	B1J/F	15 IX 77	60	39 30.5	72 56.9
"	B1K/F	15 IX 77	60	39 31.7	72 56.9
"	B1L/F	15 IX 77	62	39 33.4	72 56.0
"	B2G/F	12 IX 77	79	39 20.7	72 57.9
"	B2H/F	13 IX 77	66	39 25.3	73 04.1
"	B2I/F	14 IX 77	65	39 28.0	73 04.4
"	B2J/F	14 IX 77	68	39 32.0	73 02.8
"	B2K/F	14 IX 77	65	39 33.7	73 00.3
"	B2L/F	15 IX 77	69	39 30.6	73 00.8
"	B3G/F	13 IX 77	62	39 20.3	73 09.3
"	B3H/F	13 IX 77	62	39 20.8	73 09.1
"	B3I/F	14 IX 77	66	39 24.6	73 01.5
"	B3J/F	14 IX 77	64	39 25.5	73 02.5
"	B3K/F	14 IX 77	64	39 26.8	73 01.0
"	B3L/F	14 IX 77	65	39 28.2	72 58.7
"	B4G/F	13 IX 77	60	39 23.5	73 10.9
"	B4H/F	13 IX 77	60	34 24.2	73 10.2
"	B4I/F	13 IX 77	59	39 25.2	73 09.8
"	B4J/F	13 IX 77	57	39 25.2	73 08.2
"	B4K/F	14 IX 77	60	39 26.7	73 08.6
"	B4L/F	14 IX 77	53	39 28.3	73 07.1
"	B6G/F	13 IX 77	40	39 30.4	73 09.4
"	B6H/F	13 IX 77	42	39 30.3	73 08.0
"	B6I/F	13 IX 77	44	39 31.8	73 08.7
"	B6J/F	14 IX 77	48	39 32.4	73 06.0
"	B6K/F	13 IX 77	41	39 33.0	73 13.4
"	B6L/F	13 IX 77	38	39 34.4	73 10.2
"	B7G/F	13 IX 77	59	39 20.8	73 14.5
"	B7H/F	13 IX 77	58	39 21.3	73 14.4
"	B7I/F	13 IX 77	57	39 22.6	73 14.1
"	B7J/F	13 IX 77	60	39 24.1	73 12.8
"	B7K/F	13 IX 77	57	39 25.0	73 13.2
"	B7L/F	13 IX 77	57	39 25.7	73 13.2

Table 2-8. (Concluded)

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM08T	E1G/F	11 IX 77	64	38°49.8'	73°23.1'
"	E1H/F	8 IX 77	57	38 48.9	73 31.9
"	E1I/F	8 IX 77	54	38 48.7	73 33.3
"	E1J/F	8 IX 77	53	38 47.9	73 34.2
"	E1K/F	9 IX 77	55	38 47.5	73 34.8
"	E1L/F	9 IX 77	51	38 47.3	73 35.6
"	E2G/F	11 IX 77	75	38 43.8	73 21.0
"	E2H/F	12 IX 77	77	38 45.1	73 21.2
"	E2I/F	11 IX 77	74	38 47.3	73 18.0
"	E2J/F	11 IX 77	75	38 47.9	73 17.1
"	E2K/F	11 IX 77	75	38 47.5	73 17.1
"	E2L/F	8 IX 77	71	38 43.1	73 27.5
"	E3G/F	11 IX 77	74	38 42.8	73 20.2
"	E3H/F	8 IX 77	73	38 41.4	73 32.6
"	E3I/F	8 IX 77	69	38 41.6	73 30.0
"	E3J/F	11 IX 77	70	38 48.2	73 22.8
"	E3K/F	10,11 IX 77	65	38 49.4	73 26.9
"	E3L/F	9 IX 77	71	38 47.6	73 25.3
"	E4G/F	9 IX 77	69	38 42.2	73 32.7
"	E4H/F	8,9 IX 77	64	38 42.4	73 32.5
"	E4I/F	8 IX 77	64	38 40.1	73 35.3
"	E4J/F	8 IX 77	68	38 43.1	73 33.8
"	E4K/F	8 IX 77	68	38 42.7	73 35.7
"	E4L/F	8 IX 77	57	38 48.9	73 34.8
"	E5G/F	11 IX 77	84	38 40.5	73 17.4
"	E5H/F	11 IX 77	88	38 39.8	73 17.4
"	E5I/F	11 IX 77	84	38 40.2	73 18.0
"	E5J/F	8 IX 77	75	38 41.1	73 20.4
"	E5K/F	8 IX 77	77	38 40.5	73 22.4
"	E5L/F	8 IX 77	75	38 40.5	73 22.7
BLM08W	A2/G	25,26 VIII 77	132	39 22.0	72 31.0
"	B5/G	26,27 VIII 77	70	39 27.0	73 02.0
"	C1/G	27,28 VIII 77	16	39 22.0	74 15.0
"	D1/G	28 VIII 77	42	39 05.0	73 53.0
"	E3/G	29 VIII 77	66	38 41.0	73 33.0
"	F2/G	25 VIII 77	115	38 44.0	73 09.0
"	J1/G	24 VIII 77	367	38 44.0	73 01.0
"	L1/G	19,20 VIII 77	26	37 31.0	75 19.0
"	L2/G	20,21 VIII 77	45	37 20.0	74 59.0
"	L4/G	21,22 VIII 77	99	37 08.0	74 37.0
"	L6/G	22,23 VIII 77	354	37 05.0	74 33.0
"	N3/G	28 VIII 77	47	38 51.0	73 45.0

Table 2-9. BLM09 Sample Stations (Fall 1977).

Cruise	Station/Type	Date	Depth (m)	Lat.(N)	Long.(W)
BLM09R	B1/L	30 XI 77	63	39°19.5'	73°10.3'
"	B2/L	4 XII 77	60	39 23.3	73 00.6
"	B3/L	4 XII 77	72	39 19.8	73 00.3
"	B4/L	1 XII 77	40	39 30.0	73 10.1
"	B5/L	3 XII 77	65	39 27.6	73 03.8
"	C2/L	30 XI 77	25	39 21.0	73 05.4
"	C4/L	30 XI 77	34	39 15.1	74 08.0
"	B1/M	30 XI 77	68	39 19.0	73 10.0
"	C2/M	29 XI 77	29	39 21.0	74 05.0
"	N3/M	30 XI 77	44	38 51.0	73 46.0

Table 2-10. Sample type code explanations for second year sample station listings.

Code	Explanation
A	Regular benthic grab station, includes oceanographic and meteorological data collection.
B	Benthic habitat delineation study (grab samples), Cruise 05B only.
C	Recolonization study grab samples.
D	Regular megabenthic samples. Depths and positions are averages of individual samplings.
E	Megabenthic habitat delineation study (SBT). Cruise 05T only. Positions listed are midway points between set and haul of the trawl. Depths are averages.
F	Food habits and community analysis of fish study with otter trawl. Positions are midway points between set and haul. Depths are averages.
G	Planktology, physical oceanography, and chemical oceanography samples and data. Positions and depths are approximate means of all subsample stations occupied.
H	Bacteriology station only, surface transect and benthic sample.
I	Bacteriology station only, surface transect.
J	SBT Samples for echinoderms for recolonization enclosure experiments, Cruise 07T only.
K	Samples recovered from recolonization experiment boxes.
L	Special benthic grabs (grain size, foraminifera, nitrogen, carbon, photographs), Cruise 09R.
M	Special megabenthic SBT samples, Cruise 09R. Positions and depths are averages of individual samplings.

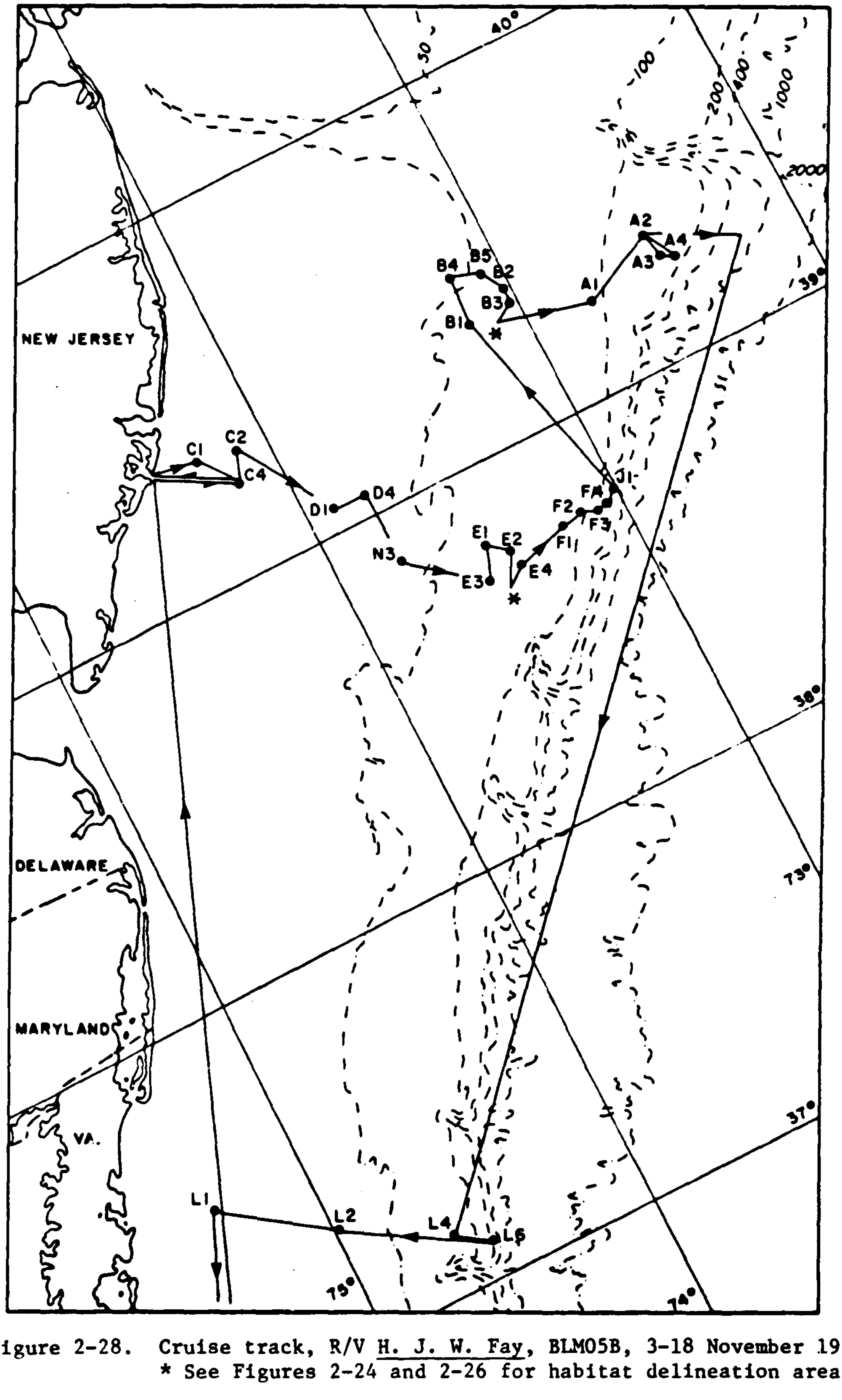

Figure 2-28. Cruise track, R/V H. J. W. Fay, BLM05B, 3-18 November 1976.
* See Figures 2-24 and 2-26 for habitat delineation areas.

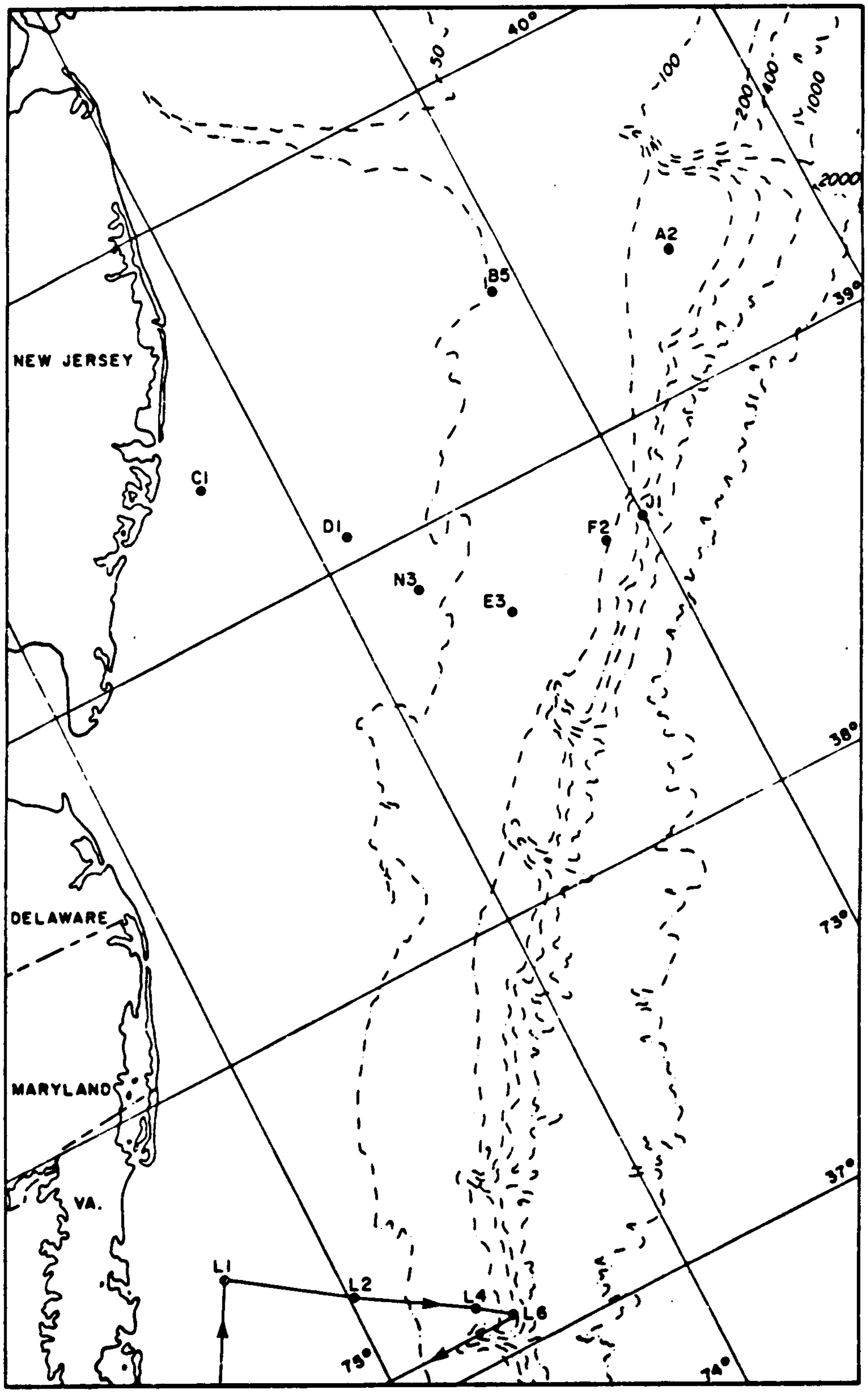

Figure 2-29. Cruise track, R/V Virginian Sea, BLM05W, Leg 1, 4-7 November 1976.

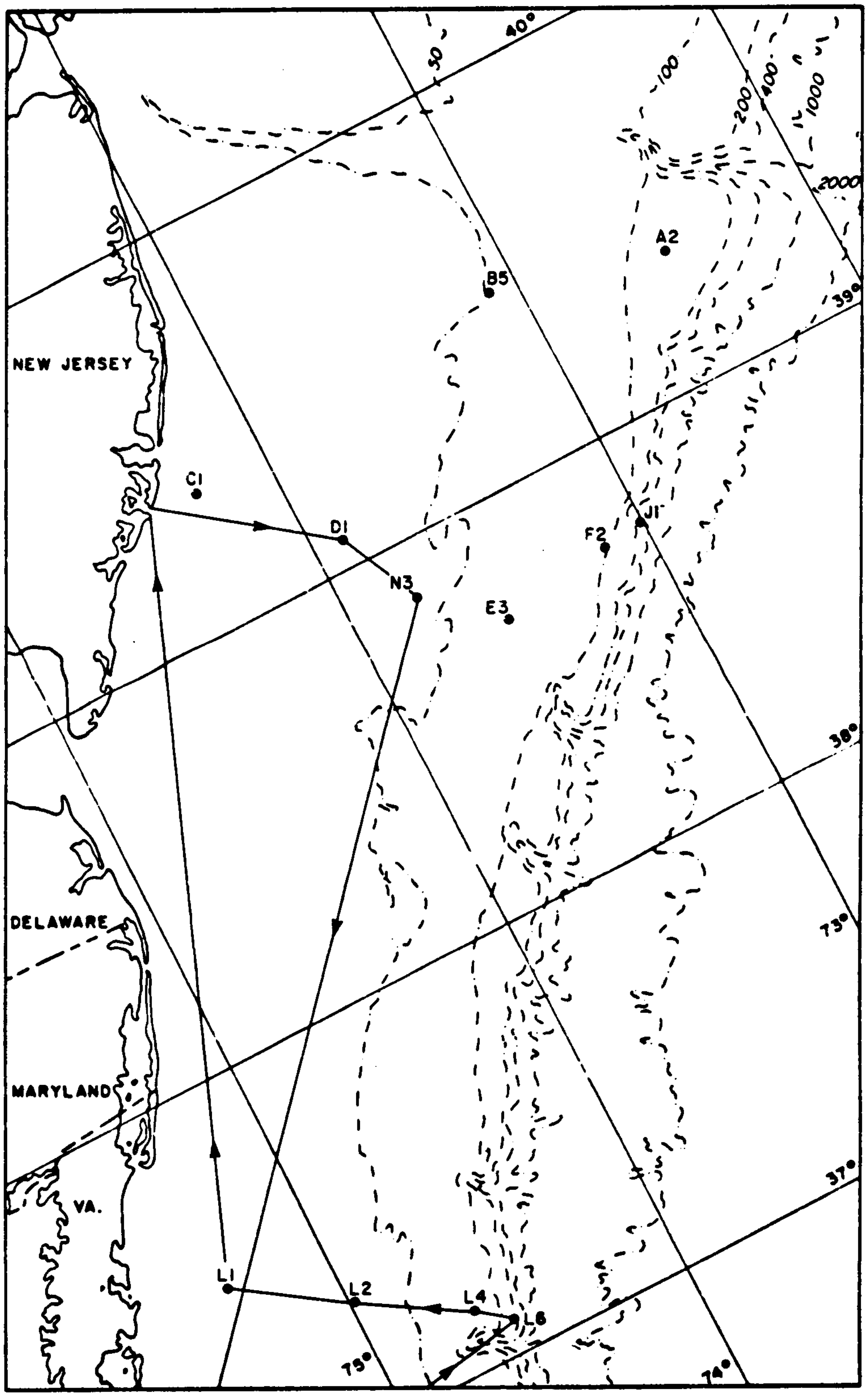

Figure 2-30. Cruise track, R/V Virginian Sea, BLM05W, Leg 2, 17-26 November 1976.

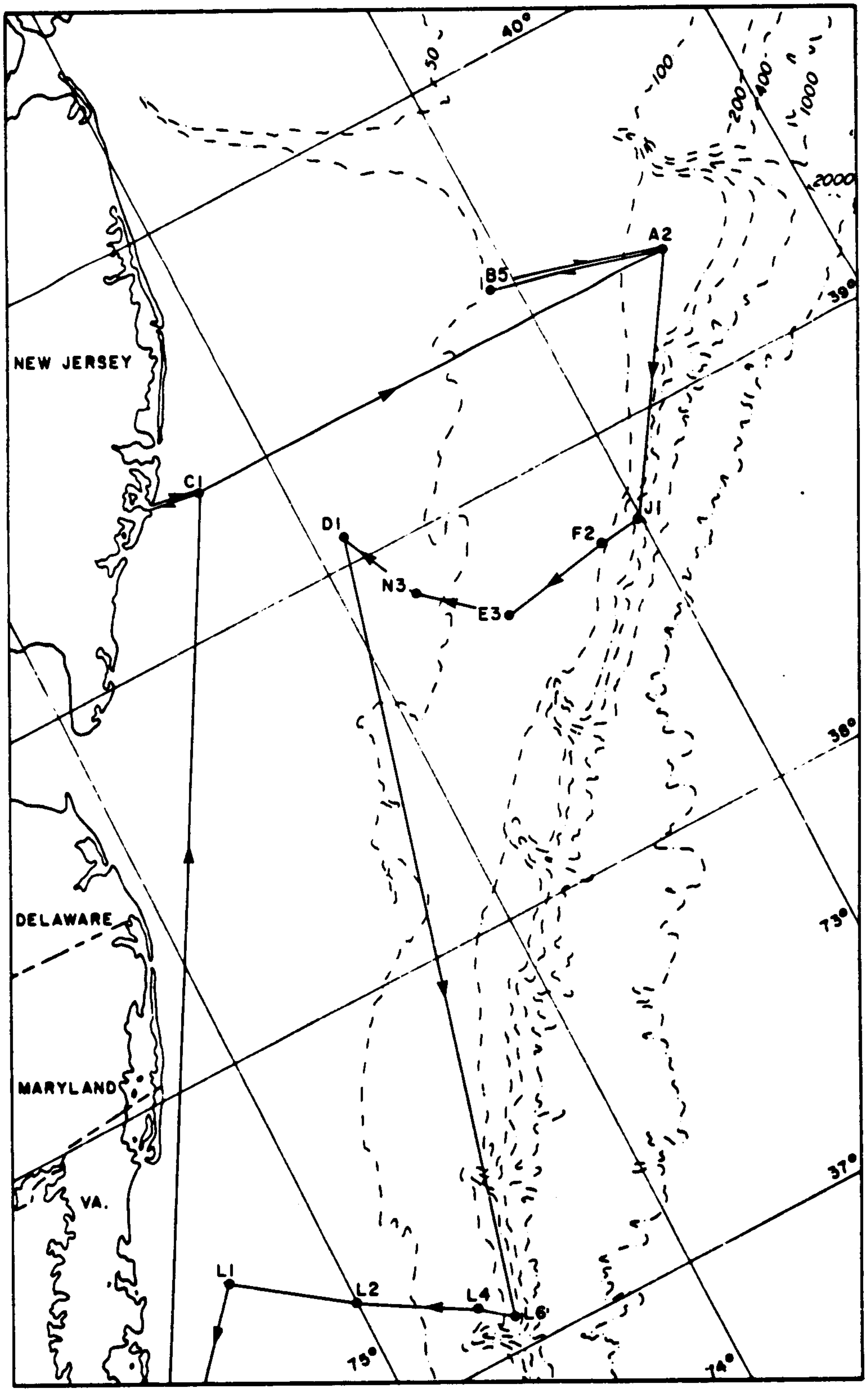

Figure 2-31. Cruise track, R/V H. J. W. Fay, BLM05W, Leg 3, 19-29 November 1976.

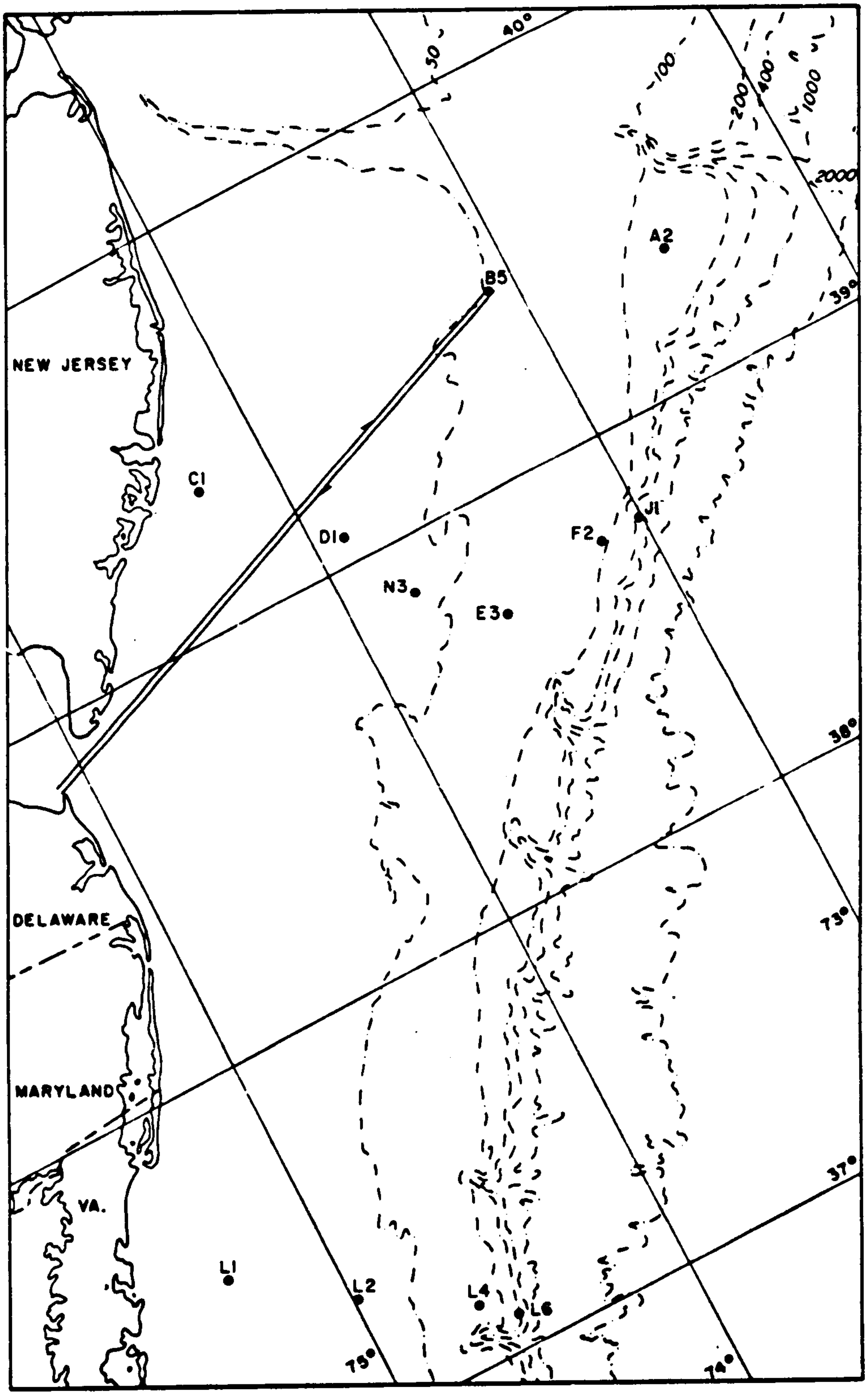

Figure 2-32. Cruise track, R/V Cape Henlopen, BLM05R, 19 November-3 December 1976.

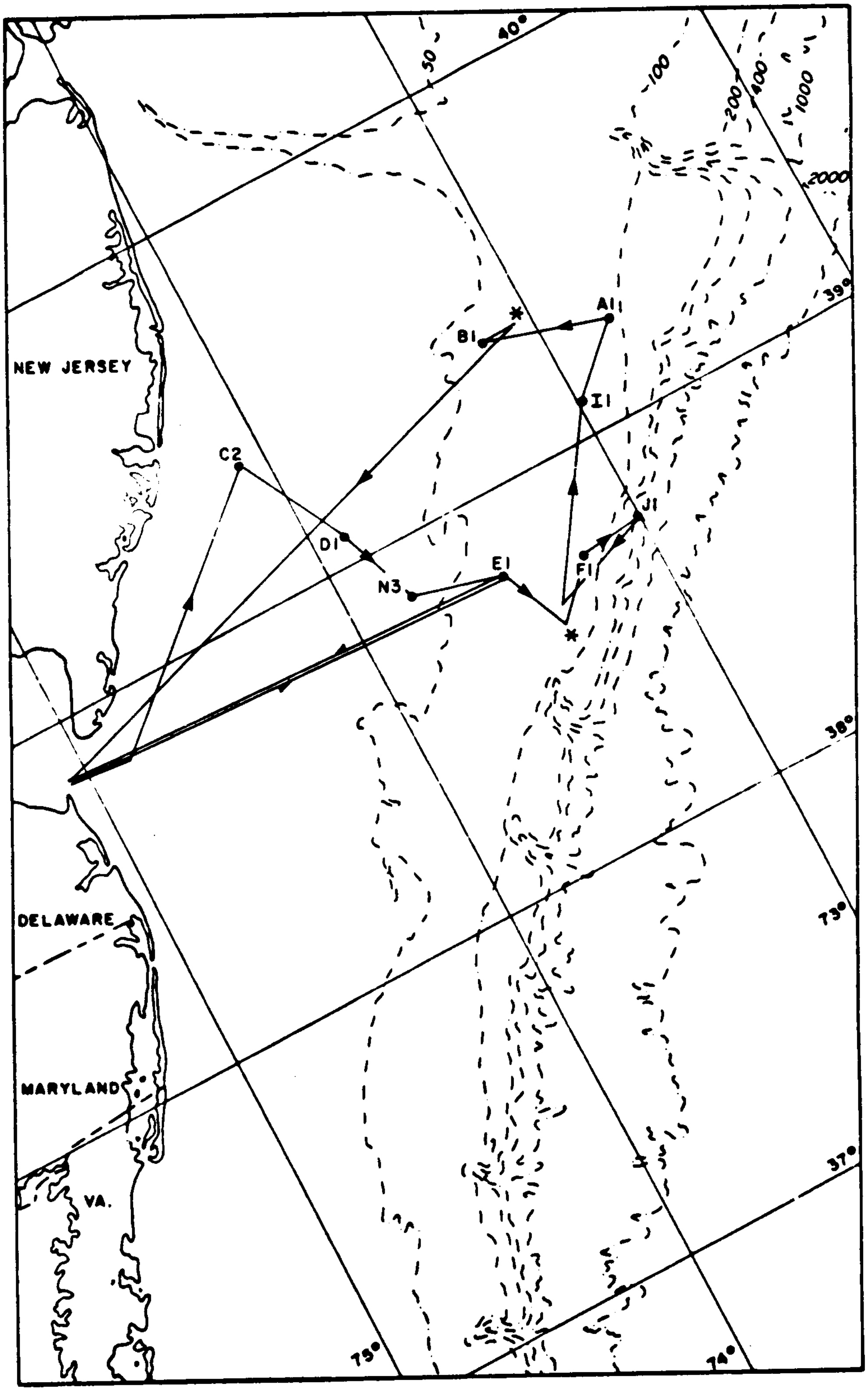

Figure 2-33. Cruise track, R/V Cape Henlopen, BLM05T, 8-18 November 1976. *See Figures 2-25 and 2-27 for megabenthic habitat delineation sites.

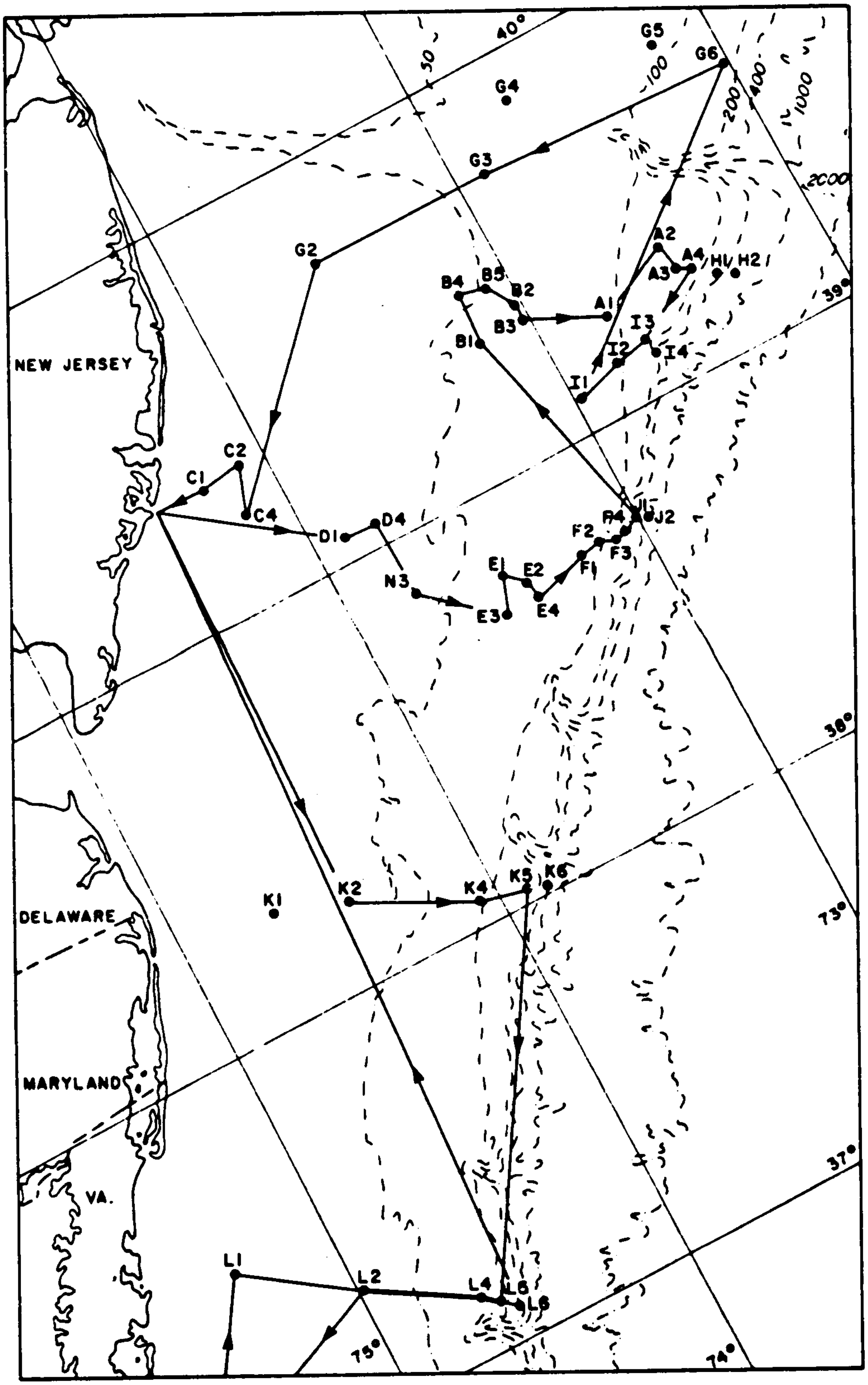

Figure 2-34. Cruise track, R/V <u>H. J. W. Fay</u>, BLM06B, Leg 1, 4-17 February 1977.

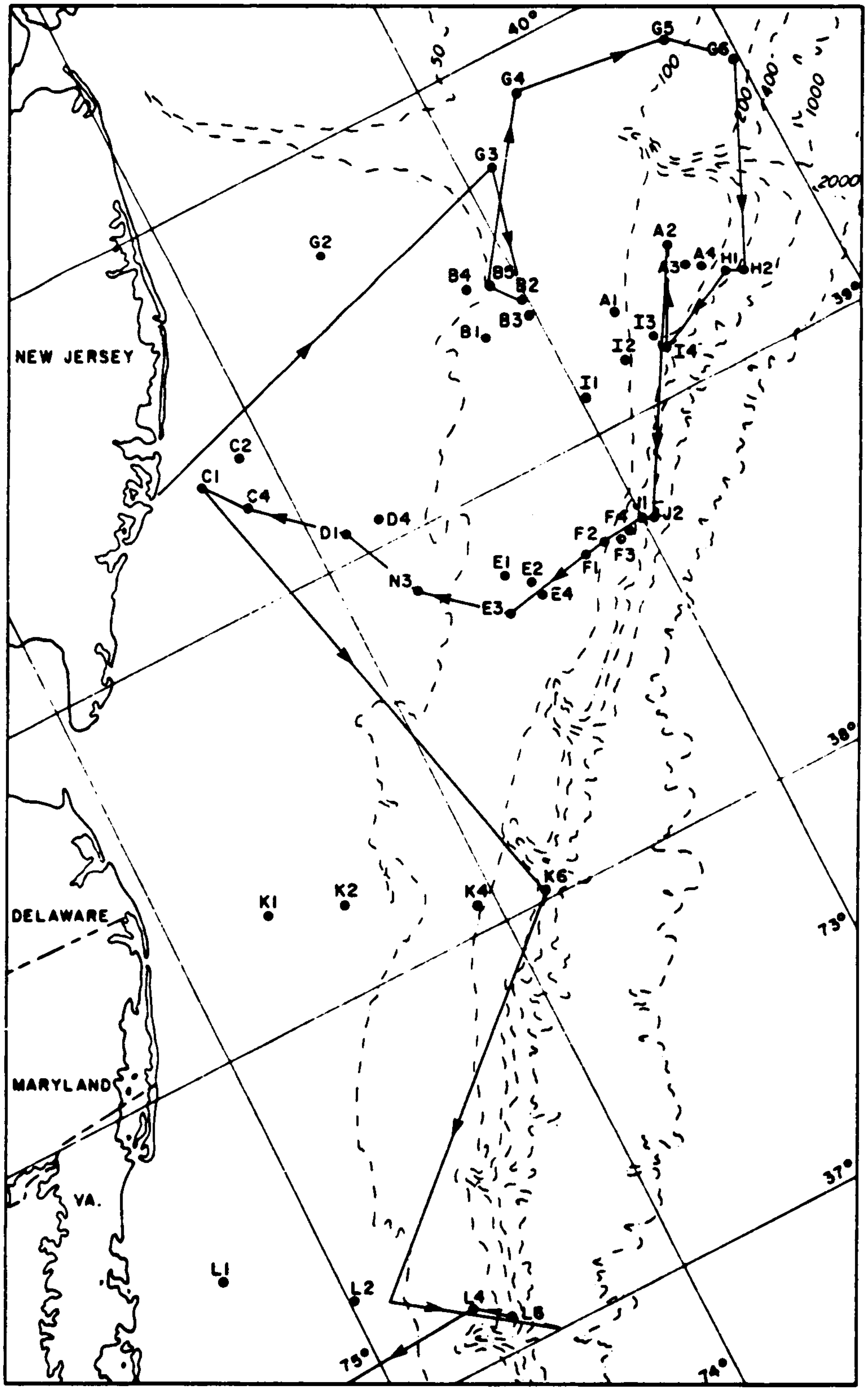

Figure 2-35. Cruise track, R/V H. J. W. Fay, BLM06B, Leg 2, 7-13 March 1977.

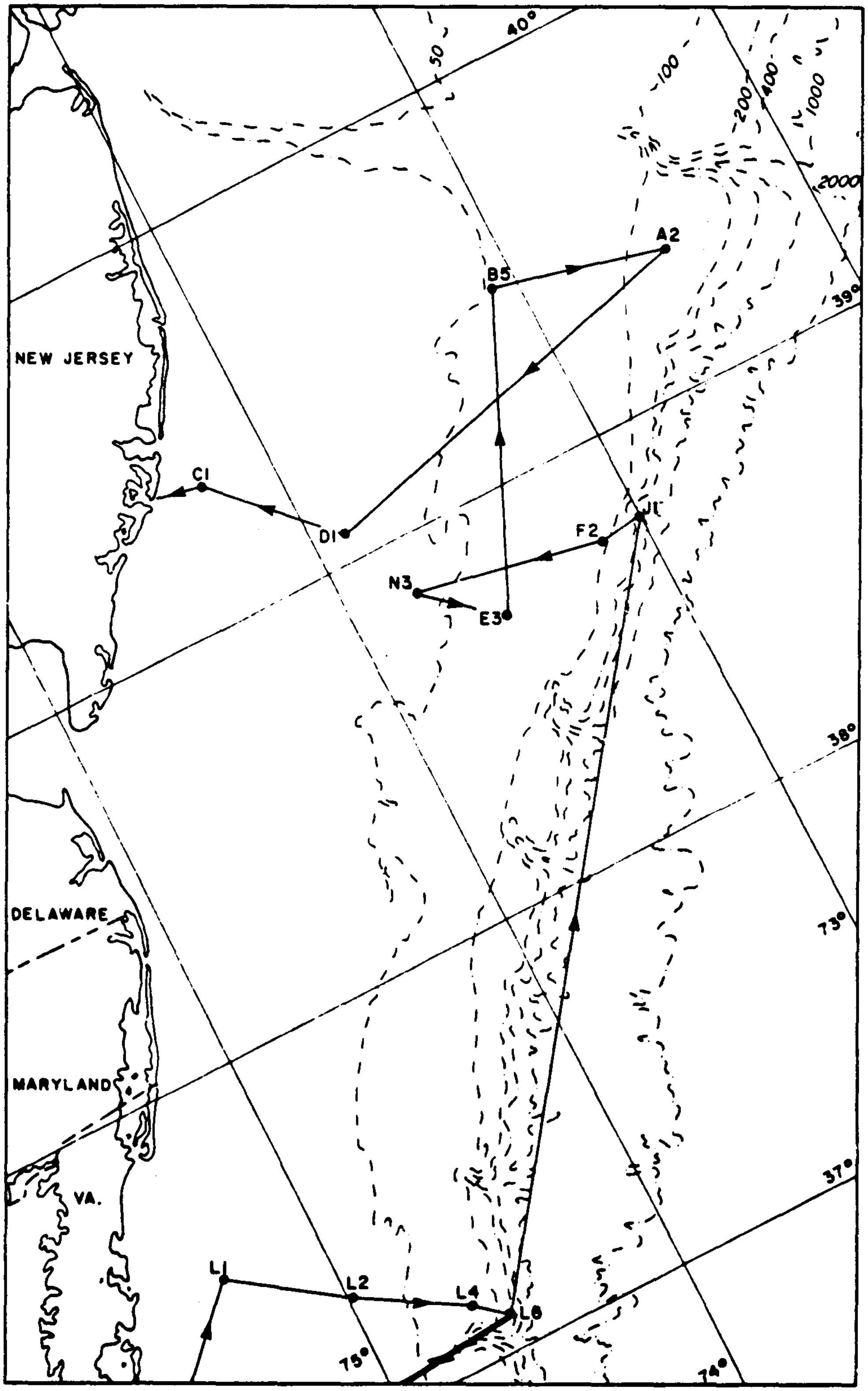

Figure 2-36. Cruise track, R/V H. J. W. Fay, BLM06W, 19 February-6 March 1977.

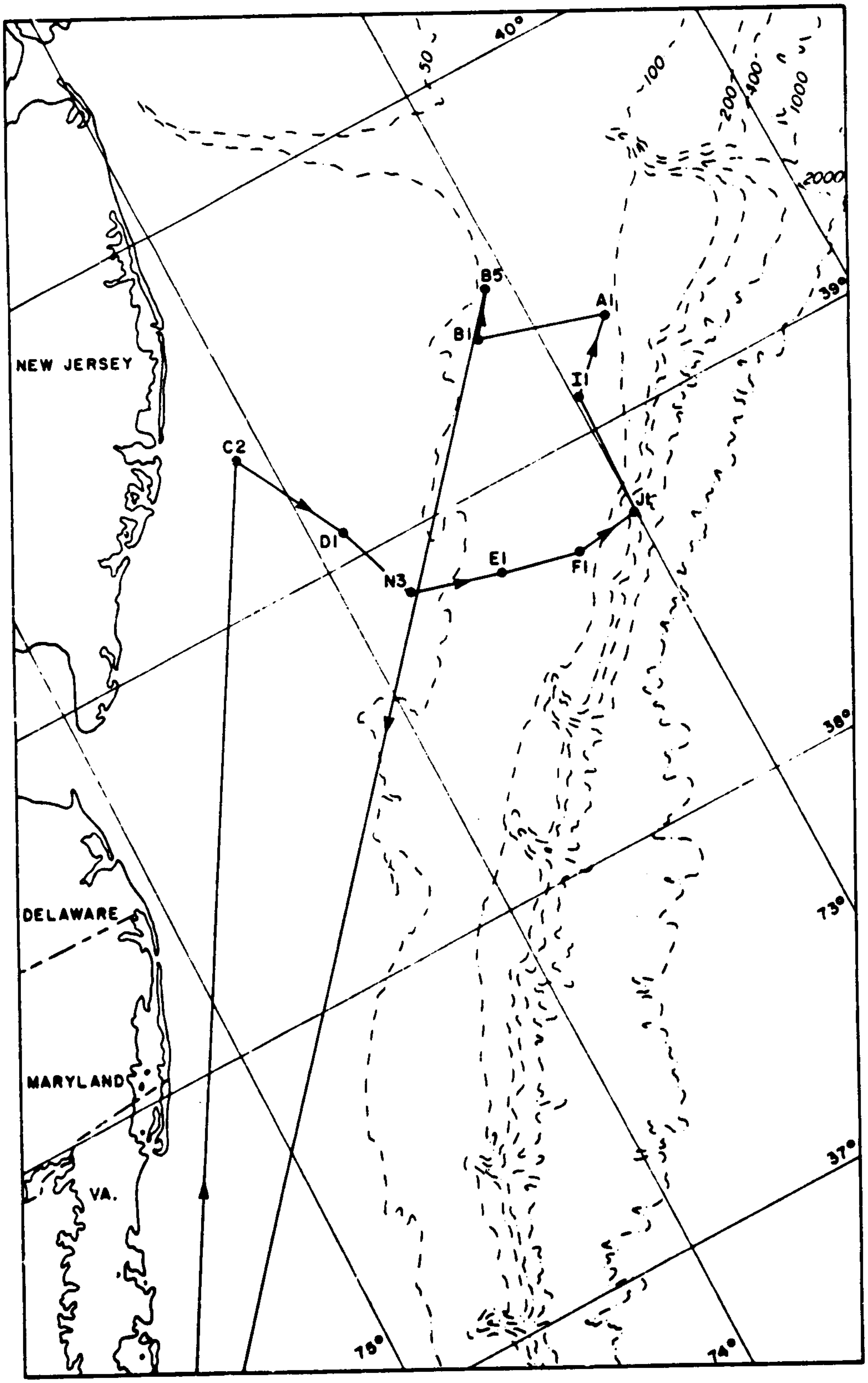

Figure 2-37. Cruise track, R/V J. M. Gilliss, BLM06T, 18-28 March 1977.

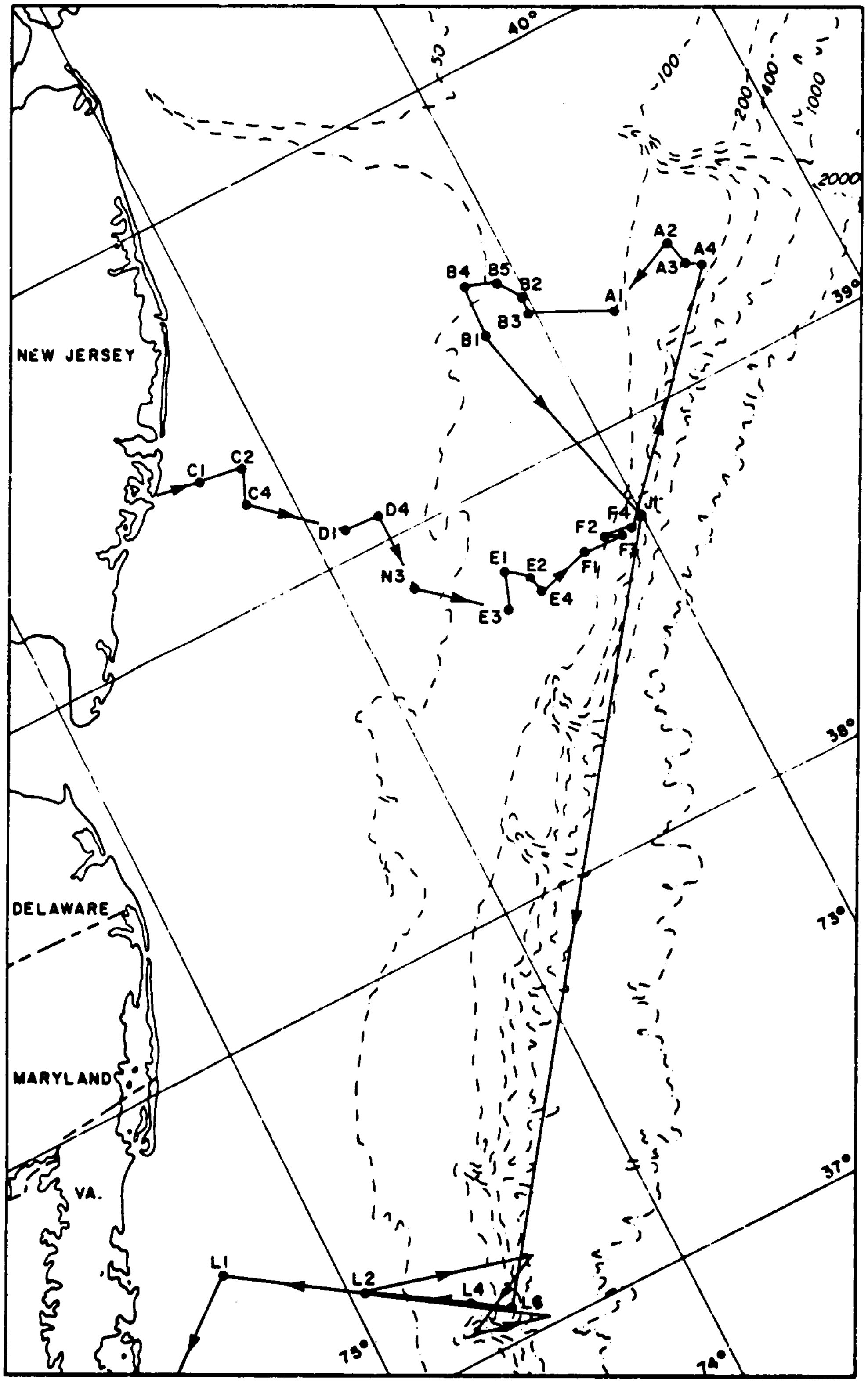

Figure 2-38. Cruise track, R/V H. J. W. Fay, BLM07B, 30 May-5 June 1977.

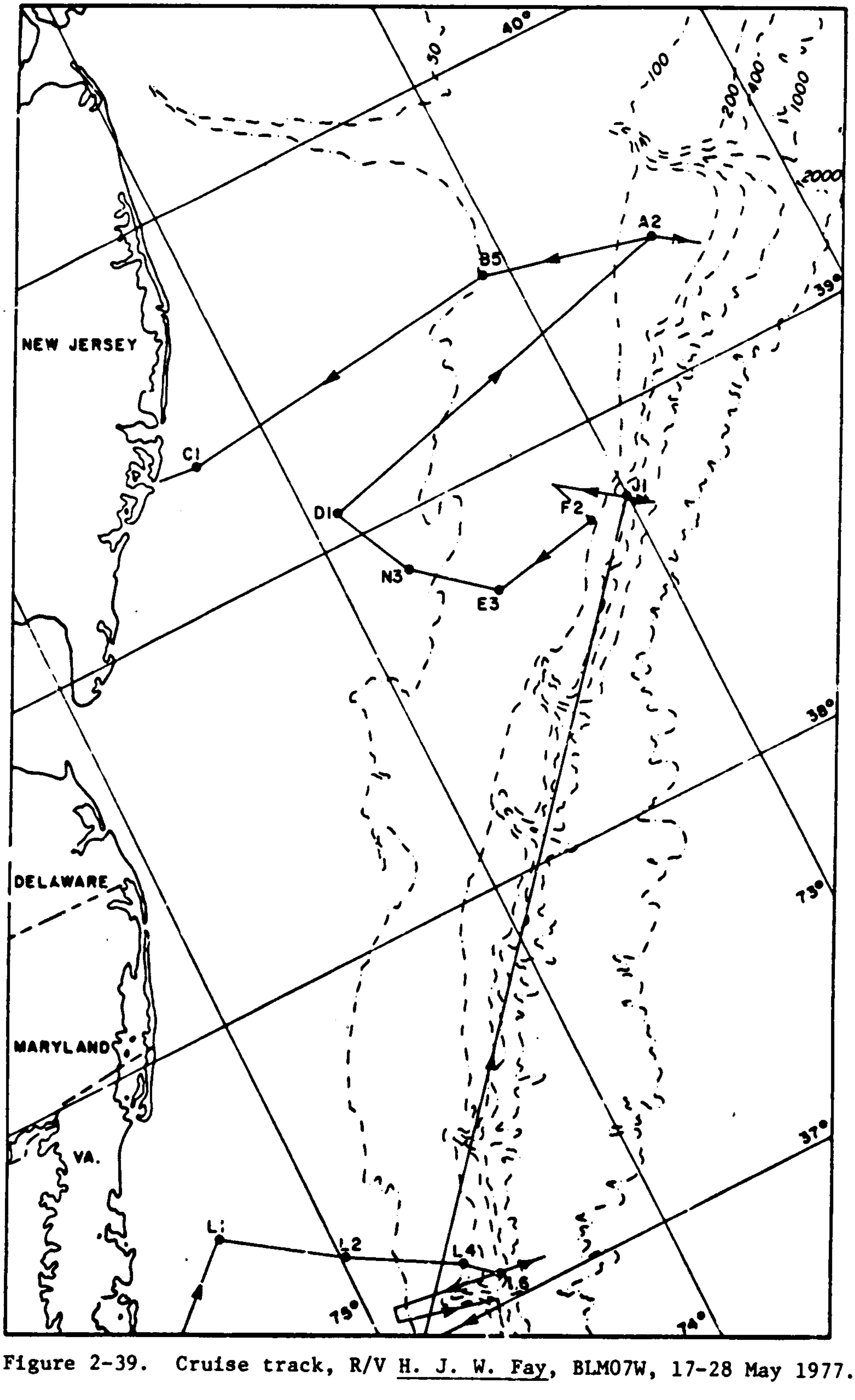

Figure 2-39. Cruise track, R/V H. J. W. Fay, BLM07W, 17-28 May 1977.

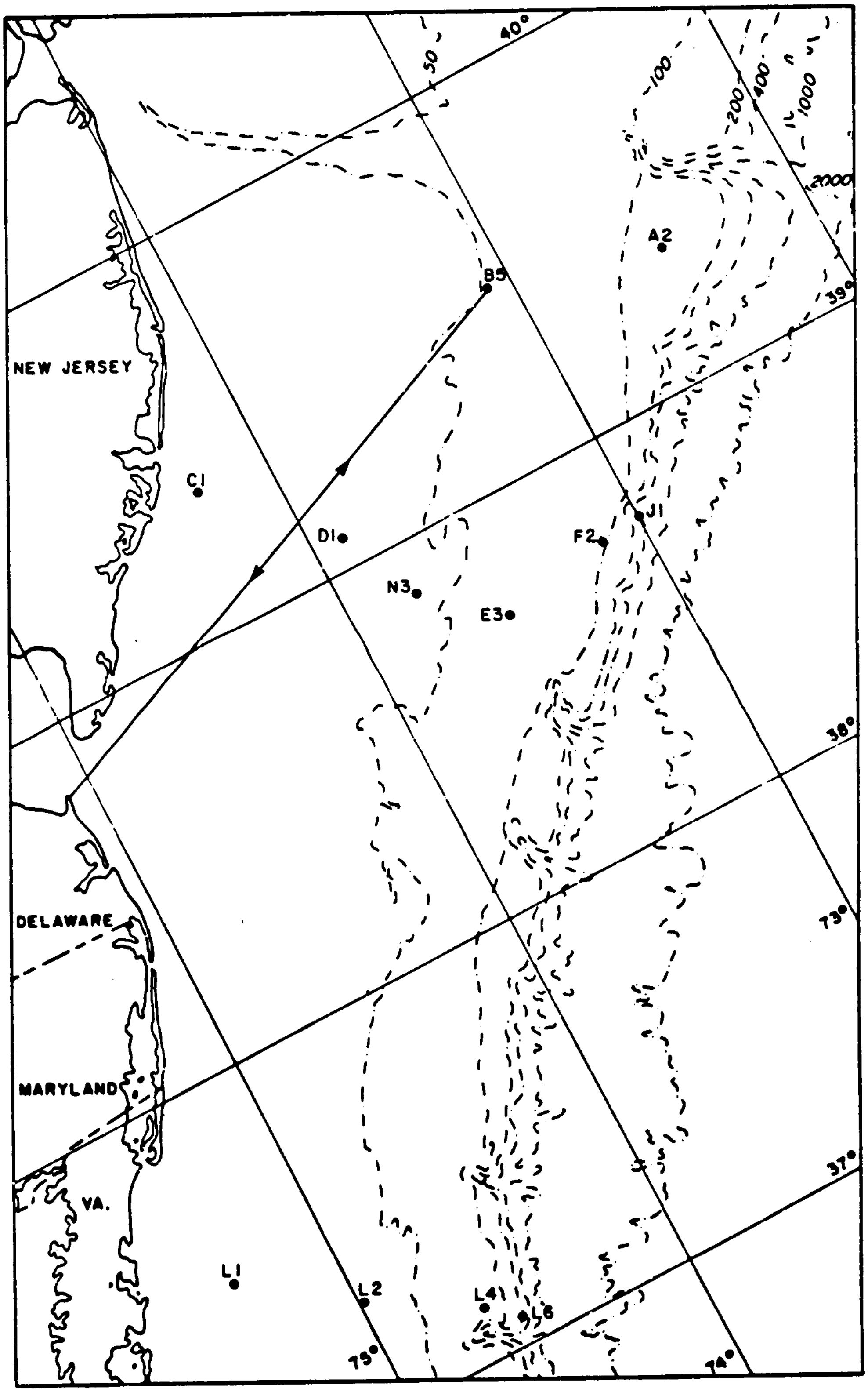

Figure 2-40. Cruise track, R/V Cape Henlopen, BLM07R, 2-6 June 1977.

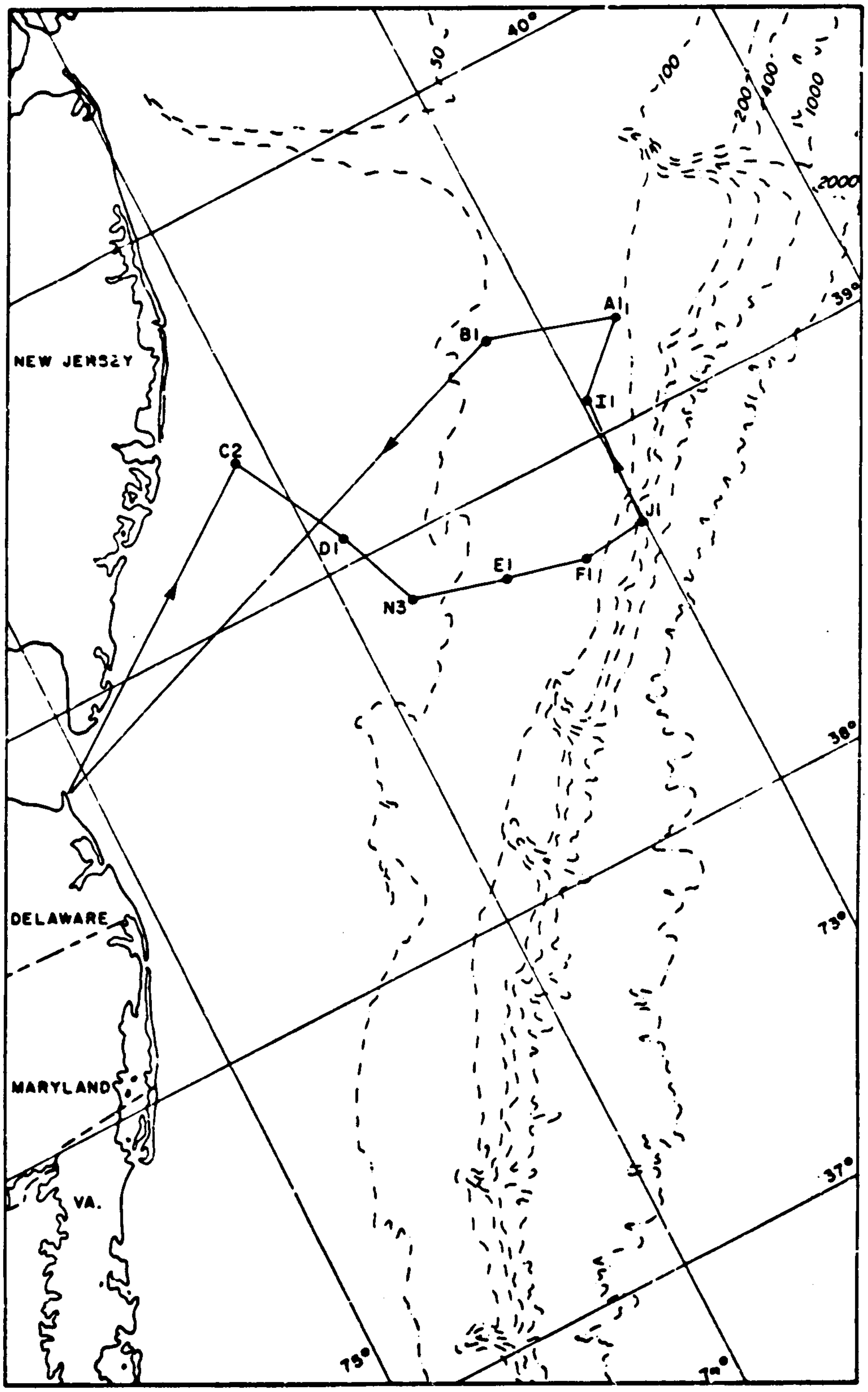

Figure 2-41. Cruise track, R/V Cape Henlopen, BLM07T, 16-21 May 1977.

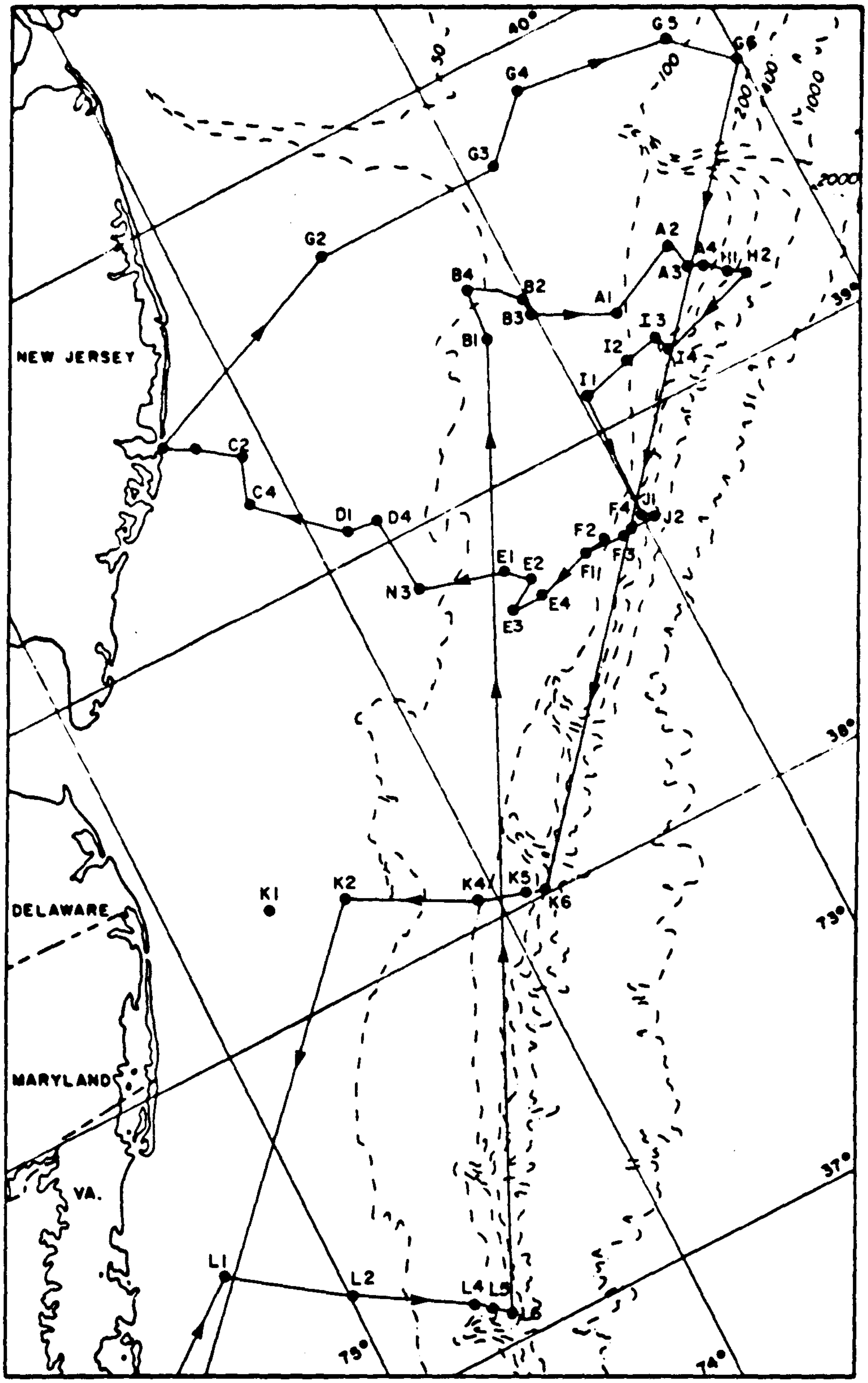

Figure 2-42. Cruise track, R/V H. J. W. Fay, BLM08B, 4-17 August 1977.

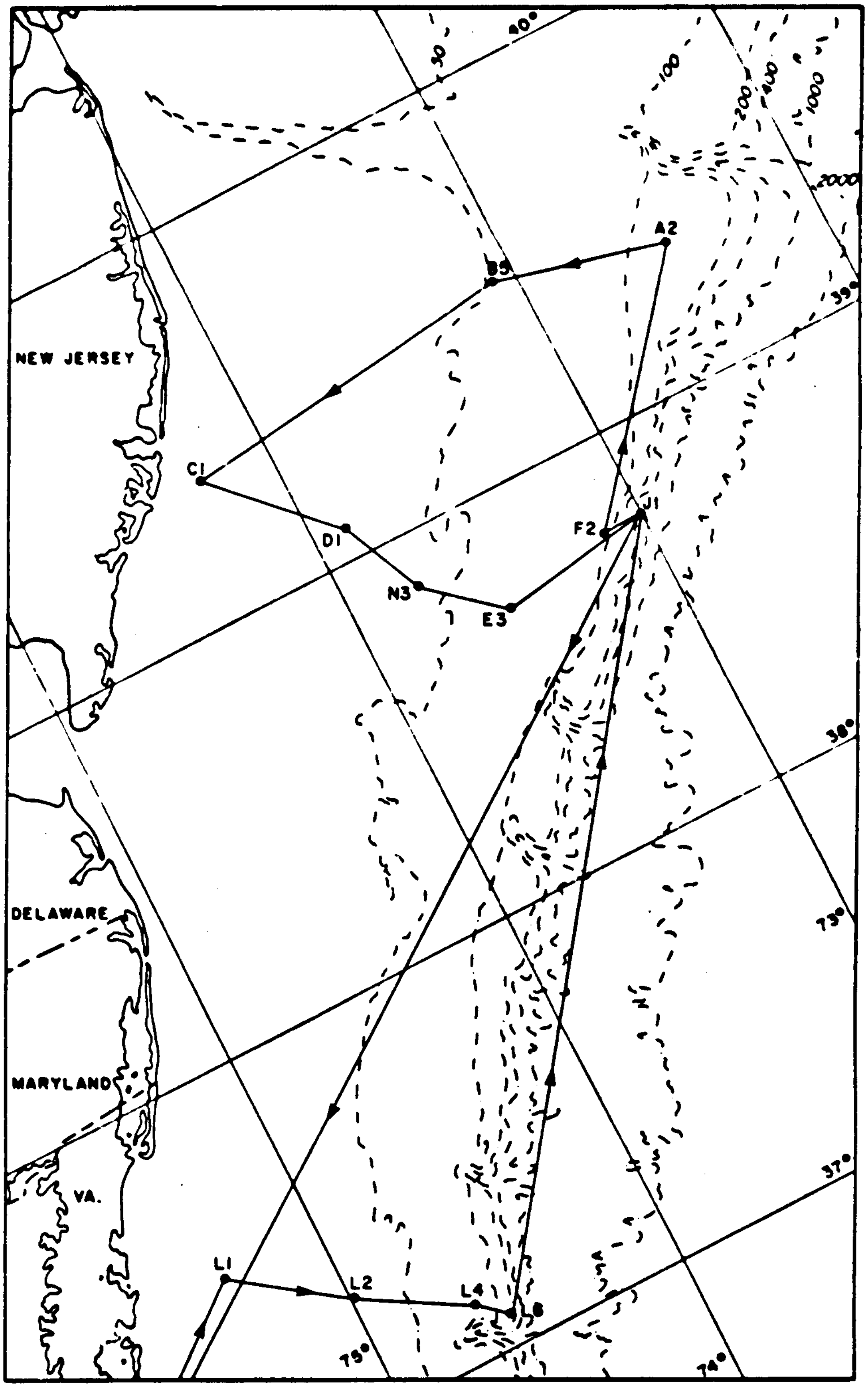

Figure 2-43. Cruise track, R/V H. J. W. Fay, BLM08W, 19-30 August 1977.

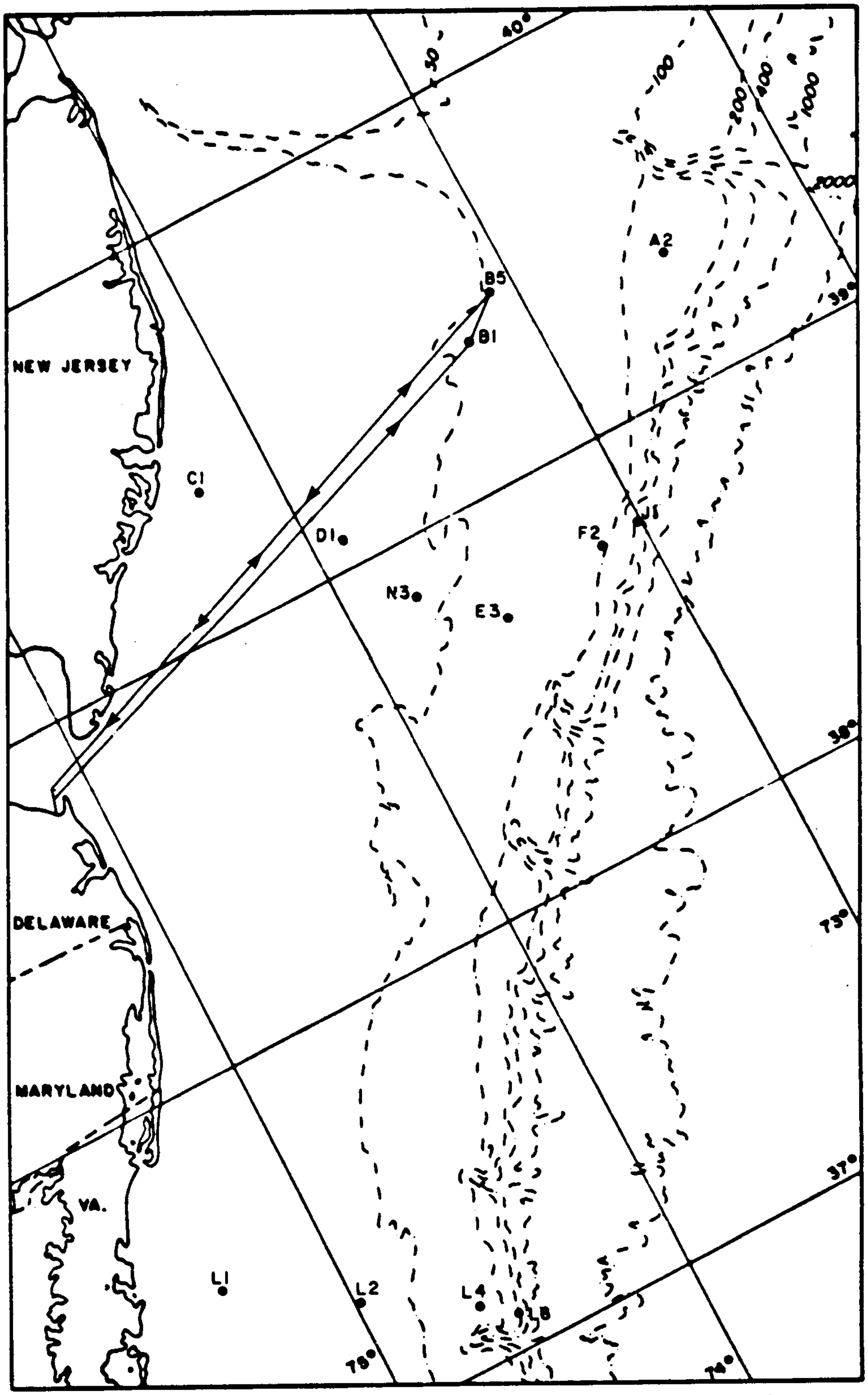

Figure 2-44. Cruise track, R/V Cape Henlopen, BLM08R, 11-18 August 1977.

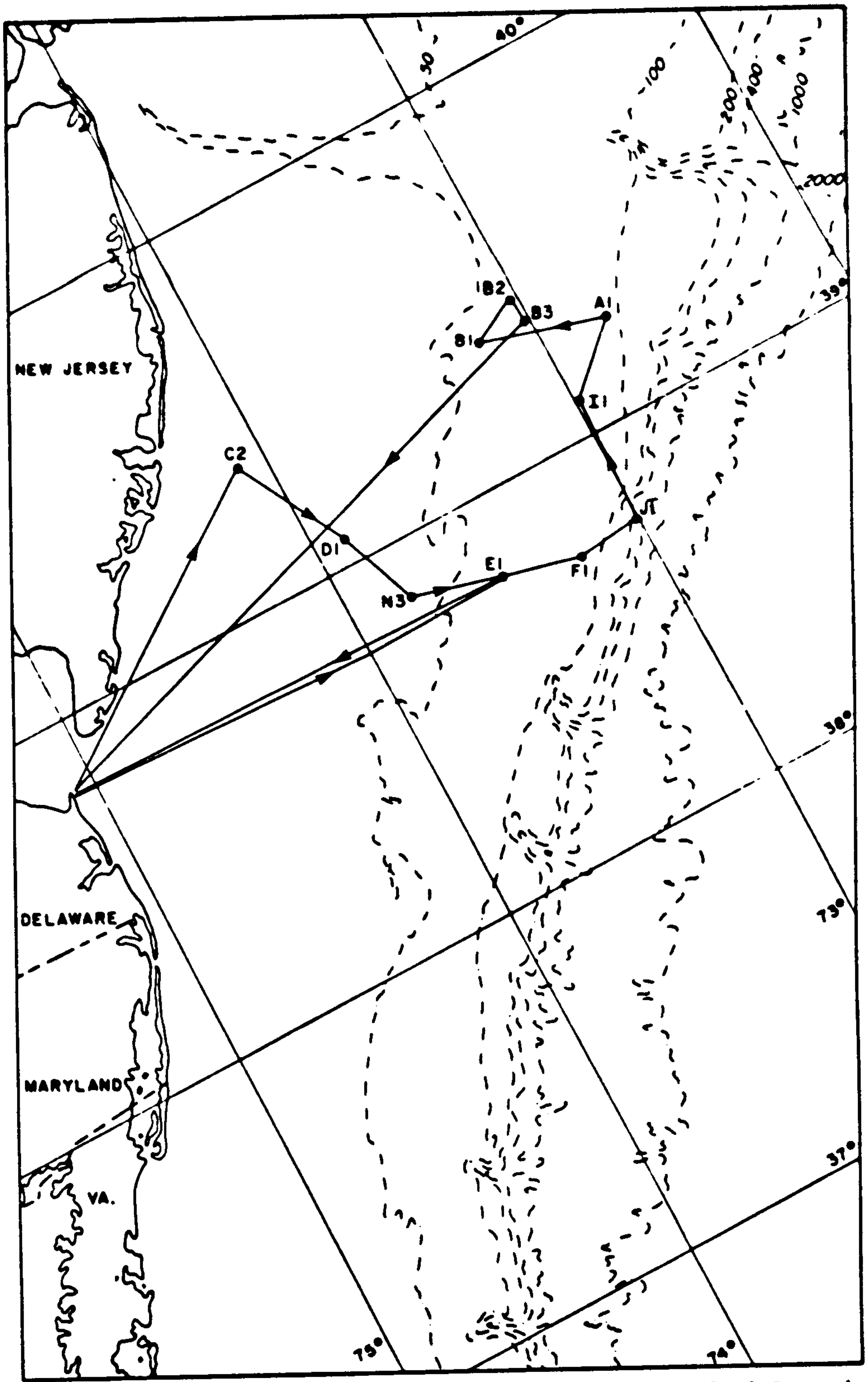

Figure 2-45. Cruise track, R/V Cape Henlopen, BLM08T, 7-15 September 1977.

chemistry. Each discipline was headed by a group leader or member skilled in field sampling procedure. All members of the scientific party were divided into watch sections, supervised by a watch captain or party chief. This shipboard party was supported by a shoreside logistics team at VIMS consisting of logistics assistant, logistics technician, and graduate assistants.

Mobilization for all cruises occurred at VIMS and, where applicable, at the chartered vessel's home port. All vessels except R/V Cape Henlopen embarked and debarked at VIMS facilities or nearby U. S. Government installations. Crew changes and equipment repair or replacement were effected at Atlantic City, New Jersey, or Lewes, Delaware.

Shipboard Procedures

Because a three-cruise system was elected, the mission and sequence of events differed for each cruise. Table 2-11 illustrates the procedures followed.

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Table 2-11. Sequence of sampling procedures followed at each station on benthic, trawl and water column cruises.

Benthic Cruises	Trawl Cruise	Water Column Cruises
Station acquisition by Loran C	Station acquisition	Station acquisition
Bathymetric verification by precision depth recorder (PDR)	Bathymetric verification by precision depth recorder (PDR)	Bathymetric verification
Buoy deployment or ship anchored	Hydrographic cast, meteorological data	Neuston (1200 hrs)
Loran C & PDR recheck	Anchor dredging	Hydrographic cast
Hydrographic cast, meteorological data	Small biological trawling	Neuston (1500 hrs)
Microbiological water sampling	Otter trawling	Surface & Bottom water collections
Benthic (grab) sampling		Neuston (1800 hrs)
Buoy or anchor recovery		Hydrographic cast
		Neuston (2100 hrs)
		Zooplankton (bongo) tows
		Neuston (2400 hrs)
		Hydrographic cast
		Neuston (0300 hrs)
		Neuston (0600 hrs)
		Hydrographic cast
		Neuston (0900 hrs)

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CHAPTER 3

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* Provided on microfiche at the end of Volume II.

CHAPTER 3

PHYSICAL OCEANOGRAPHY AND CLIMATOLOGY

C. S. Welch
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INTRODUCTION

The physical oceanographic portion of the Baltimore Canyon Trough Baseline Study was designed to support the biological-chemical study. Primarily, the task was to characterize the meteorological and hydrographic environment in which the biological samples were obtained. The results of this primary work over the two year period of study are a discussion of seasonal variability in the study regions and a guide to identifications of water types found at the sampling stations. In this effort, we were fortunate enough to encounter a warmer than usual and a colder than usual winter during the two year period. Also, the signature of warm core Gulf Stream rings was encountered on some, but not all, of our sampling periods. The sampling work thus encountered a substantial range of the two phenomena which may be the primary causes of natural oceanographic variability in the study region.

In order to realize this primary objective, the physical team on each cruise operated a device for obtaining water samples at a set of selected depths through the water column. The opportunity presented by this apparatus and its operation was used to gather samples for other investigations. These included samples for dissolved and particulate organic carbon analysis, sediment analysis, and some of the heavy metal and hydrocarbon analysis.

Beyond these tasks, the physical teams operated and maintained the Loran C navigation system, operated a nephelometer-transmissometer instrument for an outside investigation, and provided a field capability for maintenance of instrumentation and equipment for the entire scientific party as needed.

The bulk of this chapter is devoted to documenting the methods used for obtaining and analyzing the various samples and presenting the results in a useful, graphical form. It is anticipated that other investigators will be utilizing the data gathered under this project. To facilitate this use, the analyzed data are being forwarded in computer-accessible form to the National Oceanographic Data Center. In addition, the raw data and a record of processing techniques are being maintained at VIMS should a reanalysis of the data be of use in a future investigation.

Beyond this, some interpretations of the data are presented, primarily in support of the central tasks of characterization of hydrographic conditions and the recognition of origins of water at a sampling site through water mass analysis.

During the course of the two field years of this study, the sampling techniques did not remain static. They evolved under the desires to improve accuracy of results and efficiency of operations. These changes are noted under the discussion of each sample or analysis type in the "Methods and Materials" section of this chapter. As a subtheme of this improvement, an effort to reduce the time between sample capture and sample analysis produced an increasing capability to perform laboratory analyses on shipboard. The "Laboratory Analysis" part of the report thus discusses both shipboard and land-based laboratory environments.

METHODS AND MATERIALS

Nomenclature

This section is included to define abbreviations used in this chapter.

Abbreviation	Definition
CTD/DO	Conductivity, temperature, and depth instrument fitted with an in situ dissolved oxygen sensor. This nomenclature pertains to the instrument manufactured by Neil Brown Instruments, Inc.
CTD-P	Conductivity, temperature, and depth instrument manufactured by Plessey Instruments. The instrument does not have a dissolved oxygen sensor.
DO	Dissolved oxygen
Micronutrients	Unless otherwise specified, micronutrients refer to nitrates, nitrites, and dissolved organic phosphates.
POC-DOC	Particulate organic carbon and dissolved organic carbon.
XBT	Expendable bathythermograph used to obtain a temperature vs. depth trace.

PDR, PFR	Precision depth recorder.
KH_z	Kilohertz (thousand cycles per second).

Station Designation and Location

All of the stations occupied under this study are given a unique name of the form BLM XXY-ZZW, where the letters W, X, Y, and Z give coded information regarding the time and location of the stations. The code follows:

XX - Cruise number. There were eight cruises, one each quarter, during the study. They are numbered 01-08.

Y - Cruise type. Each cruise was either a benthic cruise (B), a water column cruise (W), or a trawl cruise (T). When a cruise of a given type required several legs, as BLM02B did, no distinction between legs was included in the code. The schedules for the water column and benthic cruises are shown in Table 3-1.

ZZ - Station location name. The stations are arranged in groups, divided by letters of the alphabet. Within each group, the stations are assigned consecutive numbers (e.g. Station B5 is the fifth station in the B group). The station location chart is shown as Figure 3-1. Some of the station groups are clusters while some are cross-shelf transects. Missing stations in the letter-number sequences correspond to proposed stations which were not chosen for sampling.

W - This character was optionally included to indicate several occupations of a station during a cruise. Occupations of a station were designated sequentially by letters. For example, the four occupations of Station J1 on the fifth water column cruise are designated BLM05W-J1A, BLM05W-J1B, BLM05W-J1C and BLM05W-J1D. Within a discussion of the fifth water column cruise, the designation is shortened to J1A, J1B, J1C, J1D, or collectively J1A-D.

Field Sampling

Meteorological Parameters

Observed Quantities. Meteorological parameters measured consisted of wind speed and direction, sea level atmospheric pressure, wet and dry bulb air temperature, sea surface temperature, and direction, period, and height of wind waves and swell. Additionally, estimates of visibility, cloud cover and type and concurrent weather conditions (fog, precipitation, formation or dissipation of clouds, etc.) were made and recorded.

Table 3-1. Dates of Benthic and Water Column Cruises

Cruise		Date
BLM01B		27 October 1975 - 6 November 1975
BLM01W		23 October 1975 - 29 October 1975
BLM02B	leg 1	19 February 1976 - 22 February 1976
	leg 2	2 March 1976 - 12 March 1976
	leg 3	15 March 1976 - 23 March 1976
BLM02W		5 February 1976 - 14 February 1976
BLM03B		15 June 1976 - 25 June 1976
BLM03W		8 June 1976 - 16 June 1976
BLM04B	leg 1	15 August 1976 - 24 August 1976
	leg 2	26 August 1976 - 2 September 1976
BLM04W		1 September 1976 - 9 September 1976
BLM05B		5 November 1976 - 18 November 1976
BLM05W	leg 1	5 November 1976 - 6 November 1976
	leg 2	19 November 1976 - 28 November 1976
BLM06B	leg 1	5 February 1977 - 17 February 1977
	leg 2	8 March 1977 - 13 March 1977
BLM06W		20 February 1977 - 6 March 1977
BLM07B		30 May 1977 - 5 June 1977
BLM07W		18 May 1977 - 28 May 1977
BLM08B		4 August 1977 - 16 August 1977
BLM08W		19 August 1977 - 28 August 1977

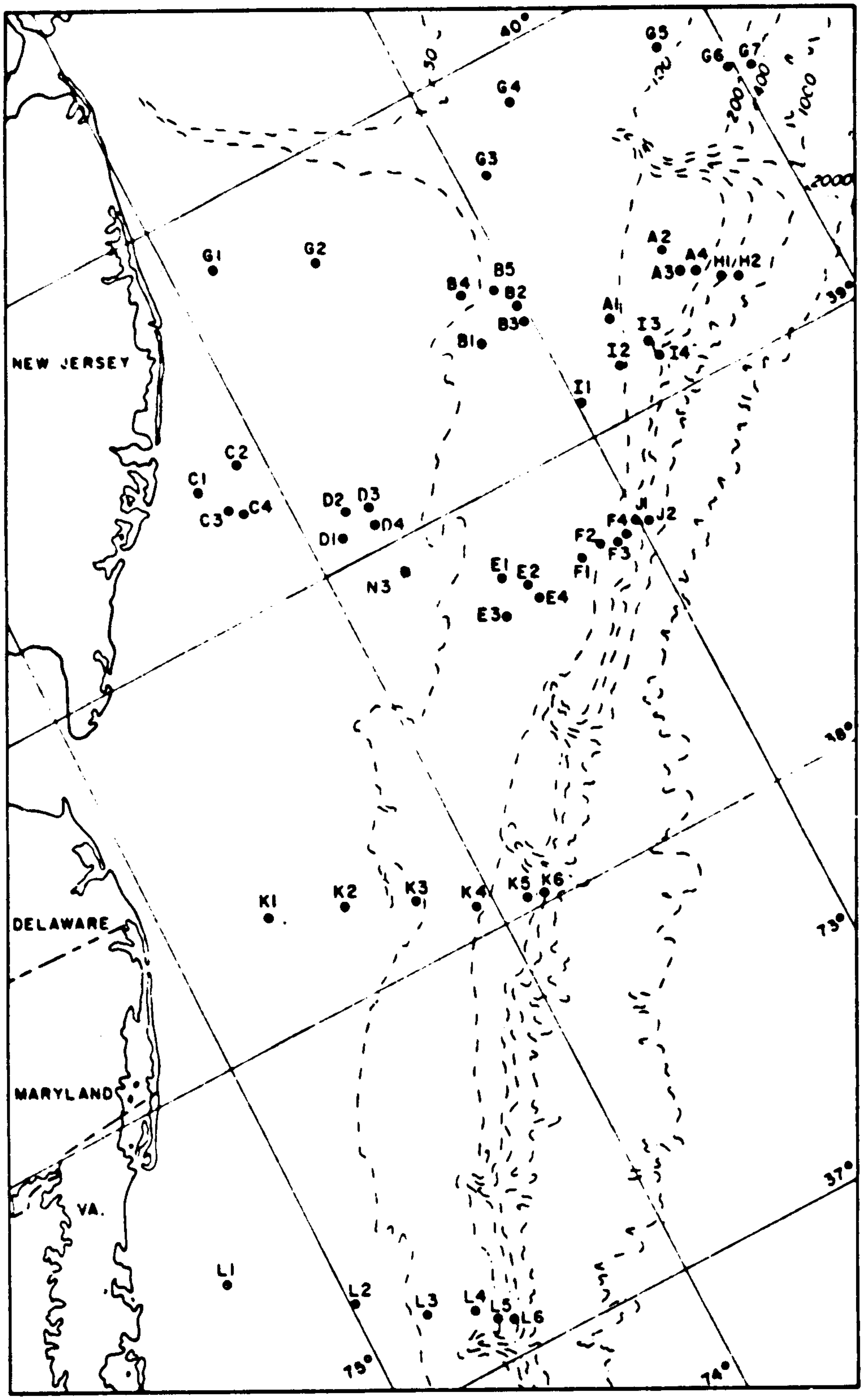

Figure 3-1. Station Location Chart. The locations and designations of stations occupied during the eight cruises which comprise this study are given.

Sampling Schedule. Meteorological measurements were made every three hours on the water column cruises. The nominal station times started at 0000 hours local time, which was Eastern Standard or Eastern Daylight times as appropriate. An effort was made to obtain the barometric pressure value close to the nominal station time, although the observations were not transmitted to the meteorological data network used for predictions. In addition atmospheric pressure was monitored also on a continuous basis during the water column cruises. The resulting data are synchronized to the biological sampling rhythms of water column cruises and possess sufficient resolution to record the significant meteorological events encountered.

For the benthic sampling cruises, meteorological observations were recorded at each sampling station. This sampling schedule, while variable, produced data which are representative of conditions encountered during the stations. As benthic stations seldom lasted longer than several hours, the progression of meteorological events encountered on the cruise is well documented by the observations.

For both cruises, wave and cloud cover observations required visibility. For these data, the values obtained during hours of darkness are more sparse than those obtained during hours of daylight.

Instrumentation. Values of atmospheric pressure and wind speed and direction were obtained from the ship's aneroid barometer and anemometer respectively. The anemometer values were corrected for vessel speed and heading prior to entry on the data sheet. Wet and dry bulb air temperatures were measured with a ventilated psychrometer (Bendix Model 566). Barographs used were obtained from Weather Measure, Inc. (Model 8201). Sea surface temperature was measured with a variety of methods. On early cruises, a thermistor bridge (Hydrolab ARA Model ET 100) was used. In addition, several stem thermometers were employed. At first, protectively mounted thermometers in "buckets" were used, but as attrition occurred during the program, these were replaced by exposed stem thermometers placed in fresh buckets of sea water. On water column cruises, some of the reported sea surface temperatures were copied from the observations associated with the simultaneous neuston tows.

Oceanographic Parameters

Observed Quantities. Measured oceanographic parameters were: water temperature, conductivity, pressure, electrical current generated in a dissolved oxygen electrode probe, temperature of the dissolved oxygen probe, light transmission, and light scattering. In addition to these in situ measurements, water samples were obtained from various levels in the water column. Near surface and near bottom levels were always sampled with as many as ten additional samples taken at intermediate levels. Water samples were processed, as described below, for laboratory analyses of salinity, concentrations of dissolved oxygen (DO), nitrites, nitrates, total dissolved organic phosphates (micronutrients), dissolved and particulate organic carbon (POC-DOC), and suspended sediments.

Measurements of water temperature as a function of depth were made independently of the other samples, and position (Loran C) coordinates were supplied on demand.

Sampling Schedule. Several sets of measurements were commmonly taken in groups, and these groups were the scheduled events. The conductivity, temperature, oxygen related measurements, and pressure were all measured by a CTD/DO instrument (the CTD/P on BLM01W) which was lowered through the water column. This event is called a cast and is divided into a down-cast and an up-cast. The temperature vs. depth measurement was made independently of the cast, and is referred to as an XBT launch. A surface water sample was generally obtained as part of a launch. Its temperature was measured, and a salinity sample was obtained from the bucket. Navigation data were recorded for CTD casts and XBT launches.

I. Water Column Cruises. The water column stations were of two kinds: 24 hour stations and single occupancy stations. For the 24 hour stations, four CTD casts were done subsequent to the neuston tows at 0000 hr., 0600 hr., 1200 hr., and 1800 hr. For the single occupancy stations, a single CTD cast was done immediately following the neuston tow. An exception to this rule occurred during BLM01W and BLM02W, when only a single CTD cast was performed at each station. At each station, bottle samples were obtained for various parameters according to several schedules. Samples for oxygen and salinity analysis were drawn from every cast. Samples for nutrient analysis were drawn from the first cast at each station. Finally, samples for DOC-POC were drawn in duplicate from the highest and lowest level of the first cast sampled at each station. The vertical disposition of intermediate samples was chosen by the physical party chief, but a set of standard levels was used as a default option. These levels were, in meters, subsurface, (5), 10, (15), 20, 30, (40), 50, (75), 100, 150, 200, 250, 300, near bottom, with the levels in parentheses sampled if bottles were available. In later cruises, a plot of temperature and conductivity vs. pressure, produced during the down-cast, was used to guide the selection of depths on the subsequent up-cast, and sample depths were chosen in regions of relatively small vertical gradients of temperature and conductivity. All samples were obtained during the up-casts. XBT launches were performed between each water column station. In addition, XBT surveys were performed in three patterns: Shelf Edge Front Finding (SEFF) surveys, Norfolk Canyon (NC) surveys, and a Larger Area Synoptic Sample (LASS).

II. Benthic Cruises. The benthic sampling occurred once per occupied station. In comparison with the water column sampling schedule, the DOC-POC samples were omitted, and suspended sediment samples of two kinds were included. Near surface and bottom sediment samples were obtained in bottles, and a nephelometer-transmissometer recorder was added to the CTD cast package to obtain continuous records of light transmission and scattering as a function of depth. The sediment samples were obtained at one station from each cluster of benthic stations. This was usually the first numbered station from each lettered group (A1, B1, C1, etc.). Suspended sediment samples were obtained from all stations in the G, K, and L groups because they were arranged as transects rather than as clusters. When a distinct thermocline was evident at a suspended sediment station, an additional suspended sediment sample was obtained at the station near or in the thermocline. During cruises BLM07B and BLM08B, additional samples were obtained at the request of an investigator visiting from U. S. Geological Survey, Woods Hole, Massachusetts.

Instrumentation. Three instrument groups were used to obtain the in situ measurements and water samples which produced the physical oceanography data. Water samples and in situ measurement of conductivity, temperature, pressure, and DO were obtained with a CTD/DO-Rosette Sampler combination. Optical properties of the water column (only measured during the benthic sampling cruises) were obtained with a nephelometer-transmissometer. During the first benthic cruise (BLM01B), this instrument was attached below the supporting structure of the CTD/DO-Rosette unit. On cruises BLM02B to BLM04B, it was used as a separate unit. During second year sampling (cruises BLM05B - BLM08B) the BLM01B configuration was again used. An expendable bathythermograph (XBT) system was used to obtain depth dependent temperatures in XBT launches.

I. CTD/DO-Rosette system. This system consists of two independent instrument configurations, each containing an underwater portion (sometimes referred to as a "fish") and a deck control-readout portion. The underwater portions are interfaced through electrical cable connections as are the deck units. Underwater and deck units are connected by an electro-mechanical cable. The CTD/DO portion of the system measures conductivity, temperature, pressure, and two additional parameters used to calculate dissolved oxygen. The rosette portion is essentially a triggering system to close water sampling bottles on command from the surface. Three primary configurations of the CTD/DO-Rosette system were used during the study. They are schematically represented in Figure 3-2a to 3-2c. Each configuration contained an underwater pinger (Benthos Model 2216) which could be used to determine the distance of the sensing package from the bottom.

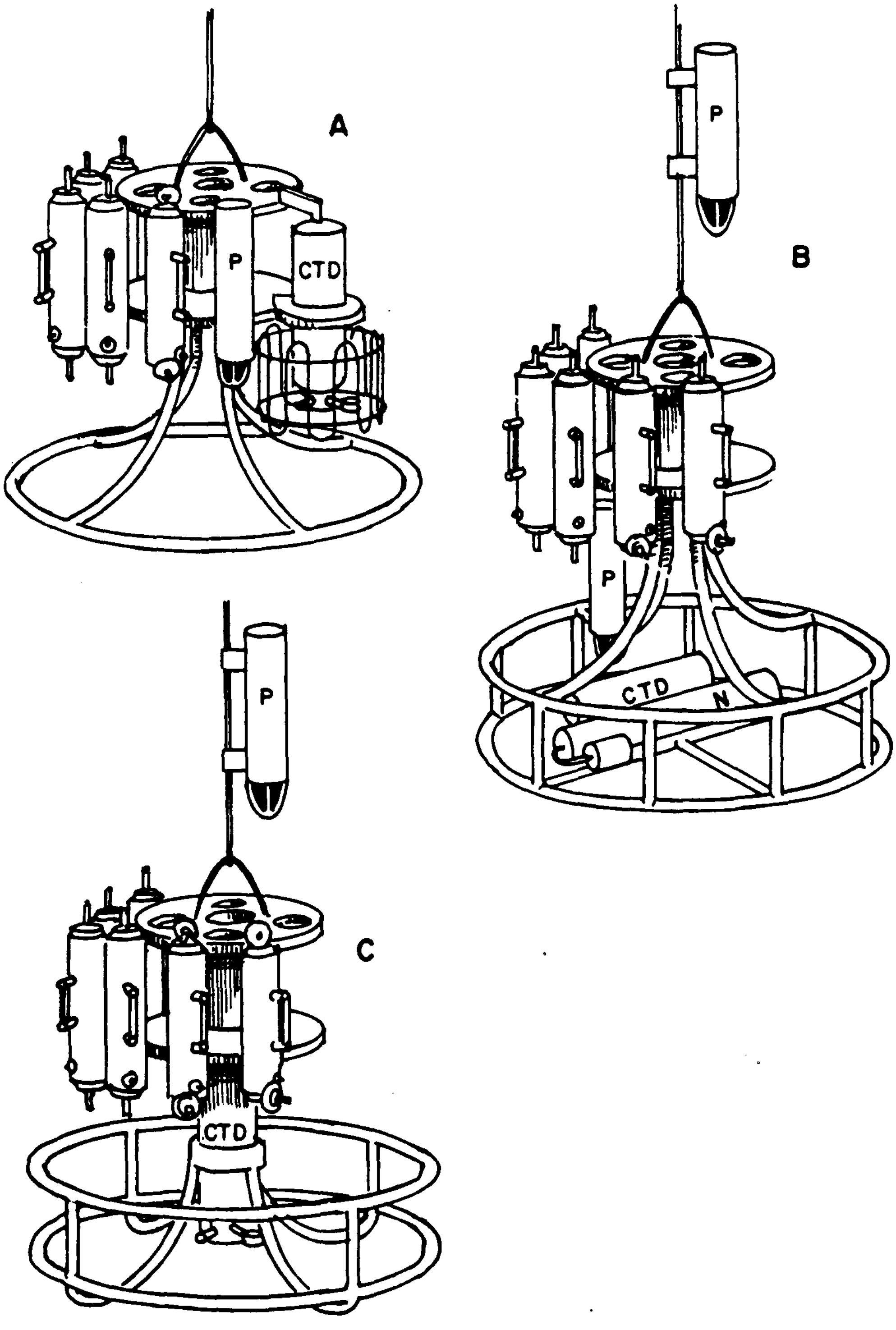

Figure 3-2. Various configurations of Rosette Sampler, CTD/DO sensor, and pinger used in surveys. (A) CTD/DO and pinger each occupy a bottle position; (B) CTD/DO is mounted horizontally below the Rosette Sampler; (C) CTD/DO is mounted vertically below the Rosette Sampler.

During cruises BLM01W and BLM02W, the configuration of the underwater portion of the system was as shown in Figure 3-2a with the CTD/DO "fish" and the pinger occupying sampling bottle positions on the rosette sampler. Figure 3-2b shows the configuration used during water column cruises BLM03W and BLM04W. During these cruises, the CTD/DO "fish" was placed horizontally below the Rosette sampler. This was also the configuration used during the first two benthic cruises with the following exceptions: the pinger was mounted on the electromechanical cable above the CTD/DO-Rosette package and, during the first benthic cruise, the nephelometer was mounted beside the horizontal CTD/DO "fish". A third configuration was used for the third and fourth benthic cruises. This is shown in Figure 3-2c, where the CTD/DO "fish" was mounted vertically below the Rosette unit and the pinger was attached to the electromechanical cable above the sampling unit. During cruises 05W to 08W, the configuration "B" in Figure 3-2 was used with the pinger mounted inside the "cage" rather than on the wire. During cruise BLM05W, a protective metal ring was included which surrounded the sample bottles and protected them during shipboard handling operations. Also, starting with cruise BLM05B, a bottom finding switch was included in the package. The housing for this switch was mounted in the bottom ring opposite the CTD, and a wire with a weight was hung below the package. When the weight reached the bottom, a switch inside the housing sent an indication up the electrical cable which triggered an audible alarm on deck. The pinger was still included in the package to serve as a beacon in case the electromechanical cable parted.

A. CTD/DO sensing instrumentation. The CTD/DO instrumentation used during all cruises except the first water column cruise was a Neil Brown Mark III CTD interfaced with a Beckman Minos Dissolved Oxygen sensor. Interfacing was accomplished by the CTD manufacturer. The CTD system is described in detail by Brown (1974) and the DO sensor is described by Green et al. (1970). In the underwater unit, temperature, conductivity and pressure were measured 32 times a second. While the DO parameters were allowed to change only once a second, 32 samples were taken each second. Measurements were digitized in the underwater unit, and the data was transmitted up the electromechanical sea cable to the deck unit which also served as a power supply. Digitized data were processed in the deck unit which has output options of display on a digital panel, recording as digital information on an analog tape recorder, recording as digital information on a digital tape recorder, and display on graphic recorders as XY, XYY or time dependent plots of measured variables. Options used during this study were the digital panel display, analog tape and XYY graphic recorders.

During the cruise BLM01W, a Plessey 9040 Model STD (CTD-P) was used in lieu of the Brown CTD/DO system. This was done because fabrication and testing of a second Brown instrument had not been completed prior to sailing time. The CTD-P is described in publications by Plessey Environmental Systems (undated). This instrument had recently been modified to a CTD configuration and calibrated by the NOAA instrument facility (NOIC) in San Diego, California. Data from this unit were obtained by recording on a data sheet ten second averages of frequencies resulting from measurement of pressure, conductivity, and temperature at frequent depths throughout the water column at each station.

B. Rosette Sampling Unit. The rosette sampler is a two part system composed of an underwater ("fish") portion and a deck command portion. Both portions were interfaced to the "fish" and deck portions of the CTD/DO system. The sampler, described by Niskin (1968), is essentially a pulse signal generator connected, via the sea cable, to a stepping switch. When the trigger button on the deck unit is depressed, power to the CTD/DO deck unit and "fish" is turned off and a capacitor is charged in the rosette deck unit. When a specified charge is reached in the capacitor, it is discharged sending a pulse down the sea cable. This pulse steps a stepping motor in the "fish" while being isolated from the CTD/DO "fish". The stepping motor releases a triggering device in the rosette "fish" which in turn, releases halyards which had been holding a sampling bottle open. A water sample is thus captured at a desired depth. Completion of the operation is signalled on the deck unit by movement of a counting switch and illumination of a "ready" light. The entire process takes eight to ten seconds to complete. Once the process is completed, power is returned to the CTD/DO system.

During the operation of the rosette sampler, power is removed from the CTD/DO "fish". On return of this power, the sensors undergo a "start-up transient", which is seen as a period of time after the bottle trip during which the measurements are not correct. This time, particularly for the dissolved oxygen sensor, can amount to several minutes. In order to eliminate this period of inaccuracy, a back-up battery pack was added to the CTD electronics package during the second year of the study. This battery pack kept power continuously supplied to the CTD "fish" electronics during the time when the rosette bottles were being triggered and virtually eliminated the major cause of uncertainty in the data during the upcast.

The rosette unit used during this study was designed to obtain twelve five-liter water samples. During the first year of sampling, up to three 30 liter sample bottles of the Niskin type were employed to obtain samples for other investigators. During the second year, at the request of the U. S. Geological Survey for the suspended sediment samples, the Niskin samples were supplemented with 10 liter "GO-FLO" bottles, also manufactured by General Oceanics.

GO-FLO bottles are designed to prevent contamination of a water sample taken at depth from the portion of the surface film which clings to the inner wall of the sample bottle as it enters the water. To achieve this goal, the end-caps of a standard Niskin bottle are replaced with ball valves which undergo a two step closing process. When the bottle is cocked on deck, the valves are in a closed position, so that surface water is never in contact with the interior of the bottle. When the bottle passes beyond a certain depth, on the order of 10 meters, a pressure-activated release allows the ball valves to rotate one quarter of a turn to an open position. When the desired sample position is reached, the command to the rosette releases halyards which permit the ball valves to close again, capturing the sample.

II. Expendable bathythermograph (XBT) system. A Sippican XBT system was used during this study. It consisted of a MK2A recorder and a hand held launcher. To operate the system, an XBT, with its canister, is placed in the hand held launcher, and a locking mechanism in the launcher is closed. This closure completes an electrical circuit between the XBT probe and the recorder via the launcher. When the circuit is complete, the recorder advances its chart paper approximately one quarter inch (to where the recorder stylus is at the zero depth mark on the chart paper) and a "launch" light is illuminated. To launch the XBT, a retention pin is removed from the canister releasing the probe. When the probe strikes the water, a second circuit is completed which supplies power to the thermistor in the probe and begins the advance of the recorder chart paper. As the probe falls through the water column, temperature changes sensed by the thermistor are relayed through a pair of thin connecting wires to the recorder. The chart advance speed on the recorder is at a constant rate, and the chart paper is scaled to coincide with the slightly nonlinear fall rate of the probe. As temperature changes are sensed by the probe on its descent, the stylus in the recorder moves across the temperature scale. The result is a recording of temperature vs. depth at the launch site. Two spools of thin wire, one in the probe and the other in the canister, allow the launching of an XBT while the ship is underway. As the probe descends, wire is payed off the spool in the probe and, as the ship moves away from the launch site, wire is payed off the spool in the canister. When the recorder has advanced through a predetermined number of cycles, the system is turned off, and a reload light is illuminated indicating that the system is ready for loading another probe.

The amount of wire in the spools determines the depth to which the XBT will operate. Also, the length of the chart recording and the chart speed are variable. Our equipment included "fast" and "slow" motors for the chart as well as a choice of 1, 2, or 3 page size "cycles" of chart paper for recording. The probes used during the study had depth capabilities of 200 meters, 460 meters and 1830 meters. The particular combination of choices selected for a given cast was chosen by the hydrographic party chief on each cruise. The lowest cost combination, consisting of the 200 meter probe, the fast motor, and a single cycle was suitable for the majority of the stations because of limited depth.

III. Nephelometer-Transmissometer. The Nephelometer-Transmissometer used to measure optical properties of the water column on the benthic cruise was supplied by the U. S. Geological Survey and used according to their instructions. For information about this instrument, its use and the resulting data, the reader is referred to the report on this study which has been prepared by USGS. In brief, the nephelometer transmissometer is a self-recording instrument which samples pressure and at least two light intensity levels on some regular time schedule. The two light levels are related to a collimated beam of light produced by the instrument. The transmission of light over about a 1 meter path is measured as well as the amount of light scattered at 90° to the beam. From these measurements, inferences can be made regarding the material suspended in the water column.

IV. Navigation System. Navigation was done in different ways on the benthic and water column cruises. In both instances, the Loran C navigation system was used, but on the benthic cruises the Loran position was supplemented with traces from a recording depth sounder.

The receiver for the Loran navigation was an Internav Model 101, which displays selected time differences alternately at 1 second intervals with a resolution of .01 microsecond. It was powered by a twelve volt source consisting of an automobile battery and a battery charger. This combination acted as an uninterruptable power supply insuring continuity in the operation of the receiver. The display from the receiver was also supplied to a digital printer, Newport Laboratories Model 810. In operation the printer could be run at any time to record any event of scientific interest on 30 seconds notice.

During later cruises, an X-Y position plotter was also available. This plotter accepted Loran coordinates, which locally form a grid of parallel, but not orthogonal, lines and transformed them to a rectangular coordinate system, which it plotted directly onto scale charts.

Shipboard Protocol

Personnel Task Assignments. The chief of the physical party on all cruises during the BLM project was a physical oceanographer experienced in obtaining hydrographic data. The other key member of the party was an electronics engineer or technician, experienced generally in instrument development and maintenance and particularly in the operations and maintenance of the instruments used on the cruise. Because of this background and training, the electronics-oriented member of the party was frequently called upon to repair various items of scientific equipment not specifically related to the physical part of the study but essential to the proper execution of the cruise. These items included depth measuring equipment (PDR, PFR, or fathometer), navigation equipment (Loran C), and underwater camera equipment. Two other people filled the complement for the physical party to ensure 24 hour operation with two party members on duty at all times.

Sequential Activities. The occupation of a station was nearly the same for both benthic and water column cruises. Differences were that meteorological data were recorded every three hours on water column cruises and during every station for benthic cruises. Suspended sediment and nephelometer data were obtained only on benthic cruises. Otherwise, the sequential activities for a station proceeded as follows:

I. On notification of the chief scientist or watch captain of arrival on station within five minutes, the CTD/DO and nephelometer units were turned on for warm up. Prior to warm up, the optics of the nephelometer were cleaned with distilled water. Also, the rosette sampling bottles were cocked for the cast. During the first benthic cruise (BLM01B) turning the nephelometer on or off required opening the instrument case. This constituted a hazard to the instrument electronics because the activity had to be accomplished on deck and risked possible saltwater contamination of the internal portion of the instrument. As a consequence of this hazard, great care was taken to prevent salt spray or splash from reaching the "naked" instrument. Turn on times were recorded.

During the second year, the CTD/DO electronics were left running all the time. On hot summer days, the CTD/DO "fish" had to be cooled when it was left on deck in direct sunlight.

II. When the desired geographical location was reached (as determined by the combination of Loran C and depth readings) a printout of the Loran C position was obtained. This printout consisted of at least ten pairs of Loran coordinates and was attached to a page in a Loran C Log Book. Information pertaining to date, time, cruise number, station number, and type of activity (grab, CTD/DO cast, neuston tow, XBT cast, etc.) was entered on the same page. Loran pages were consecutively numbered, and field data sheets contained provisions for entering the Loran C log page number (see Appendix 3A for a Loran log facsimile).

III. On cruises BLM02B, BLM03B, and BLM04B, the next step was the nephelometer cast. This order was chosen so that the optical properties of the water column would be sampled before sediment plumes were generated by the bottom grab sampling. At the conclusion of the nephelometer cast, the instrument was turned off. Times of turn-on and turn-off were recorded and accumulated times for the battery pack and the cassette tape were monitored so that fresh supplies would be introduced as needed.

IV. After the nephelometer cast the CTD/DO "fish" was placed in the water and allowed to soak until the temperature of the DO sensor equilibrated to within 1°C of ambient water temperature. This usually took five to ten minutes. On the benthic cruise this equilibration period was used to record meteorological data. Once the DO sensor temperature equilibrated, the CTD/DO cast was taken, and water samples were captured with the rosette sampler. The "fish" was brought on deck and water samples were removed from the rosette mounted Niskin bottles for field processing as described below.

CTD/DO Cast. During the pre-cast CTD/DO soak period the data recording analog tape recorder was turned on, and the tape counter was allowed to advance through ten units. This was done to allow a definite break between recordings of successive casts on any one tape. The recorder was then switched to the "record" mode, and a voice recording was made which included cruise and station identification, date, and time. The recorder was then switched to the "pause" mode which stopped the tape transport. The recording convention followed throughout all cruises was to wire the CTD/DO output into the right channel of the audio stereo tape and to make verbal comments on the left channel. After the soak period, the recorder was switched off "pause", and the recorder output was switched to the "tape" mode. At the same time, the CTD/DO deck unit was switched from the "internal" to the "external" mode. With this arrangement of switch settings the data stream came from the "fish", through the sea cable, and was recorded directly on tape by the recording head. The tape deck playback head then played back the previously recorded data (after about a 0.2 second delay) into the CTD/DO deck unit where the recorded signals were processed, displayed on the deck read out, and used to drive the plotter. The display of recorded data assured us of producing usable recordings. Any malfunction of the CTD/DO system or the recording system could then be immediately detected. A simpler arrangement would have been to read the data from the "fish" on the deck unit and then to record it. This, however, would not have assured us of having usable data on the tape.

At the "fish", the bottom finding pinger was turned on prior to the cast, the DO sensor cap was removed, and the conductivity sensor was rinsed with 0.05 N HCl and distilled water. The "fish" was then placed in the water for DO sensor equilibration. Prior to the "fish" entering the water, the pressure sensor offset (if any) was noted verbally on tape. Time of entry into water and tape count of entry time were recorded on the field data sheet (VIMS Form 200, see Appendix 3A). The "fish" was allowed to soak at a depth where all Niskin bottles remained below the surface (sensor depth of three to five meters depending on sea conditions) until the desired equilibration temperature (a difference of ±1°C between ambient and DO sensor temperature) had been reached.

Once equilibration had been reached, the downcast was started and the start noted verbally on tape. This notation also indicated station depth as discerned from the PDR. At stations over 50 meters deep and at shallow stations when a wire angle was evident due to station keeping maneuvers of the ship, the descent of the "fish" was sometimes observed on the PDR by switching this instrument to a "listen" mode. In this mode, two trace lines were recorded on the PDR chart, one resulting directly from the sonic emission of the bottom finding pinger and the other from the reflection of this sound off the bottom. As the "fish" approached the bottom the two lines came together.

This indication of the bottom, although quite accurate, required a certain amount of skill in interpretation, as other lines and multiple reflections were also evident on the PDR trace. In order to be an effective cast monitoring procedure, it required the full attention of an operator during a lowering. This operator then had to relay messages to the winch operator, who was frequently far removed from the location of the depth finder. To alleviate the uncertainties and misunderstandings resulting from this loose control chain, the bottom sensing switch described in the Instrumentation section of this chapter was devised. In operation, this switch unit is initialized before the cast. When the "fish" package approaches about 20 meters from the bottom, the cast operator tells the winch operator to slow down. When the switch is tripped because the weight hits the bottom, an audible alarm signals the winch operator directly, and he halts the winch with no further direction required. This procedure in conjunction with the bottom finding switch greatly increased the uniformity of distances above the bottom at which near bottom measurements and samples were obtained. It was added for the sixth and subsequent cruises. After the winch was halted the CTD/DO deck unit display was switched to the "hold" position, the announcement of a pending rosette sample was spoken into the tape recorder, the plotter was switched to the standby position, and a rosette sample was taken. A bottom navigation reading was also frequently obtained. While the rosette sample was being taken, the time and reading from the tape counter were recorded on the field data sheet as were the readings of pressure, conductivity, temperature, DO, current, and DO sensor temperature. During the water column cruises, three additional samples of 30 liters each were taken at the end of the downcast during the first year. This water was obtained for other investigators for chemical analysis. Once bottom water samples were taken, the graphic recorder was switched to the "record" mode, the pens were lifted and the CTD/DO deck unit was switched off the "hold" position. Values of DO current were observed and, when they approached the just previously recorded values, the upcast was started. This delay for the DO sensor usually took one minute and was necessary because, as previously stated, during a rosette sample, power to the "fish" is turned off. When the power is turned back on the output from the DO sensor oscillates greatly and takes approximately one minute to recover.

Estimation of full recovery was done by the hydrographer in charge of the cast. As the estimate was of a level from a transient event for which the asymptotic value was unknown, the estimate varied from cast to cast. Starting with cruises BLM06B and BLM06W, the inclusion of the battery pack in the CTD/DO fish eliminated the transient behavior and its associated uncertainty. The upcast was then started by telling the winch operator the next depth to be sampled. These instructions were also recorded verbally to assist in tape translation. When the next depth was reached, the sampling procedure was repeated. The final sample was taken at three to five meters below the surface (depending on sea conditions). During periods of extremely calm weather, the near surface sample was taken at a bottle depth of one meter.

After the CTD/DO cast was completed, all instrumentation was turned off, and water samples were removed from the Niskin bottles for various types of processing.

Water Sample Processing. Water samples captured with the Rosette sampling system were contained in Niskin or GO-FLO bottles. Figure 3-3 schematically shows opened (cocked) and closed (tripped) Niskin bottles mounted on a rosette sampler. Water samples were removed from the Niskin bottles in the following order for specific ship-board processing: DO, salinity, micronutrients, and POC-DOC or suspended sediment. Each sample bottle and cap used was thoroughly rinsed with 100 to 200 ml of sample water prior to being filled.

I. DO Samples. DO samples were processed according to the Azide modification of the Winkler method (APHA 1976). Samples were removed by first placing a six-inch length of rubber hose over the Niskin bottle spigot and inserting the free end into a rinsed 4 oz. (∿125 ml) sample bottle. Water was allowed to drain into the sample bottle by opening the spigot and vent, taking care that the rubber hose remained at the bottom of the bottle and was free of air bubbles. The bottle was filled and allowed to flush at least twice before the hose was removed. The hose

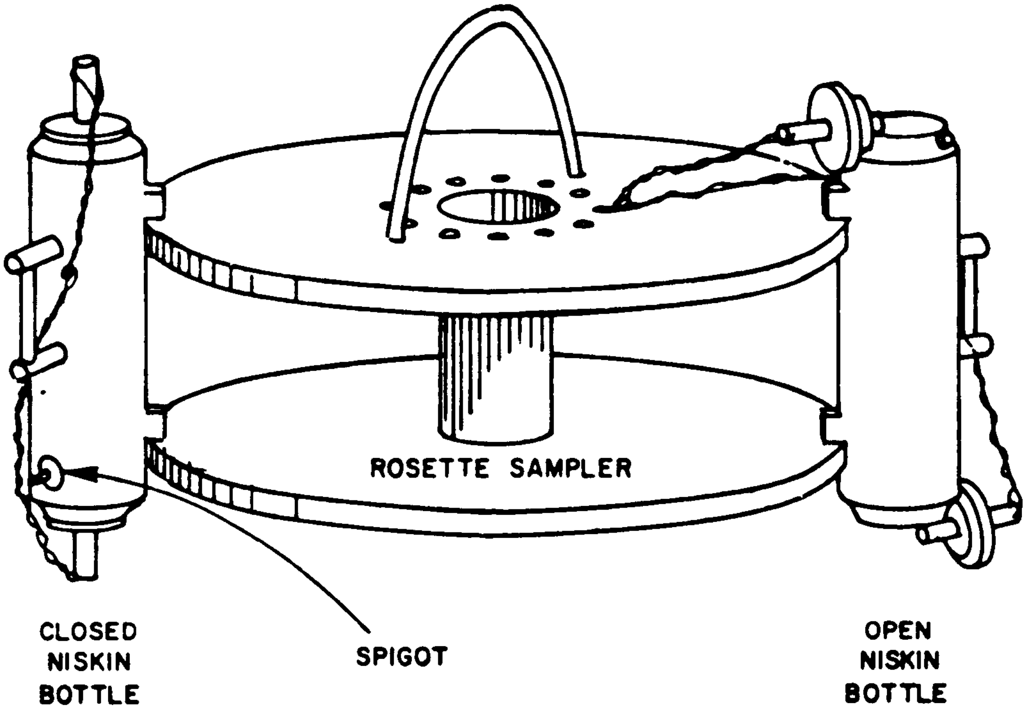

Figure 3-3. Schematic representations of a Rosette sampler with two Niskin bottles (one open and one closed) attached.

was removed slowly, again taking care that no air bubbles entered the bottle, and a screw cap was secured to the bottle. (Screw caps had conical polyethylene inserts which forced a portion of the sample out of the bottle as the cap was attached). The sample bottle was then inverted to check for air bubbles. If bubbles were evident, the bottle was emptied and the process repeated. Sample bottle numbers were recorded on the VIMS Form 200.

Shipboard processing of DO samples consisted of carefully adding 1 ml of manganese sulfate solution then 1 ml of alkali-iodide-azide reagent sodium iodide, recapping the bottles and shaking vigorously until the sample was thoroughly mixed and a white floc precipitate appeared. The samples were allowed to stand until the precipitate settled to the lower two-thirds of the bottle then were shaken again and allowed to settle a second time, 1 ml of sulfuric acid was carefully added, the bottles capped and shaken again. During the first year (1975-1976), samples were then placed in a covered container and stored for titration ashore.

The possibility of degradation of sample values during storage and handling led to a decision to analyze oxygen samples on board as soon after sampling as possible, usually within twelve hours. An on-board laboratory was then used, and the sample processing subsequent to the precipitation of the white floc was done in the laboratory. For this processing, 300 ml BOD bottles were used to carry and process samples. These bottles have a glass stopper which forces some sample out of the bottle as it is inserted. The stopper also has a conical tip, so bubbles are not easily trapped in the collecting process. The rapid analysis of the samples permitted the analyzed DO value to be entered on the form 200 data sheet during the cruise, eliminating a potential source of transcription error.

II. Salinity Samples. Once DO samples had been obtained from the Niskin bottles, salinity samples were removed. These were placed in sample-rinsed 4 oz. (~125 ml) bottles allowing an air space for sample expansion. Bottle numbers were recorded on the VIMS Form 200 and samples were stored for onshore analysis during the first year. Again, during the second year, an on-board laboratory was used for sample processing. Also, specialized salinity bottles with rubber gasketed ceramic caps were used to gather the samples. The data resulting from the processing were conductivity ratios between the samples and standard seawater vials. Salinities were calculated as part of the data analysis.

III. Micronutrients. Field processing of micronutrient samples consisted of filtering and freezing the samples. Samples were drained from the Niskin bottles into rinsed polyethylene transfer bottles. Prior to each cruise, the transfer bottles and all glassware used in the filtering process were acid washed and rinsed in glass distilled water. Samples were filtered through 0.45 micron millipore filters. Approximately 200 ml of sample was filtered through a new filter and the filtrate used to rinse the filter flask. This filtrate was discarded and a second 200 ml aliquot of the sample was filtered through the same apparatus. This second sample was used to rinse an acid washed, pre-numbered polyethylene sample bottle (4 oz. (∿125 ml) size). The numbered sample bottle was then filled two-thirds full of filtered sample, capped, and frozen. Bottle numbers were recorded on VIMS Form 200, and samples were kept frozen until analyzed ashore.

IV. Suspended Sediment Samples. Samples for suspended sediment analysis were obtained at one station from each group of clustered stations and from each station on a transect (the G, K, and L stations) during the benthic cruises. Samples were obtained from near surface, near bottom, and the vicinity of the thermocline when one existed. Shipboard processing was in accordance with written and verbal instructions from the U. S. Geological Survey. Attempts were made to filter four liters of sample through a pre-weighed 0.45 micron millipore or Nuclepore filter (depending on which was furnished by USGS or available at VIMS). Water was drained from the Niskin bottles into a pre-rinsed, four liter polyethylene bottle with 0.1 liter calibration marks on the side. The starting volume was recorded and the sample was filtered until either all four liters had passed through the filter or the filter had clogged. In the latter case, the volume of unfiltered water was also recorded. Filters and filter holders were washed with 100 ml or more of filtered distilled water, upper portions of filter holders were removed, and the filter was again washed with 10 to 20 ml of filtered distilled water to remove salt water from the filter edge. Filters with their suspended sediment loads were then placed in their original numbered plastic petri dishes, labeled according to station, cruise, depth (and, occasionally volume of water filtered), and frozen until transferred to USGS. Suspended sediment samples furnished USGS were accompanied by lists containing identification of filters (by number), cruise, station, depth, and volume of water filtered.

The only variation in this procedure was with respect to source and type of filter and type of filter holder. These variations are explained below.

A. Cruise BLM01B. No filters or filtering apparatus was supplied by USGS. Filters were obtained from Dr. M. Nichols of VIMS. They were numbered, washed, dried, and weighed 0.45 micron millipore filters. A list of filter numbers and successive weights for each filter was sent to USGS with the previously mentioned cruise and station data. During this cruise, filters were placed in millipore filter funnel arrangements as shown in Figure 3-4a. Samples were poured from the transfer bottles into the funnels.

B. Cruises BLM02B and BLM03B. USGS furnished pre-weighed Nuclepore filters. Each filter was in a numbered petri dish and every tenth dish contained three filters, two Nuclepore filters separated by a millipore filter. The filtering apparatus used was the same as during the previous cruise except that samples were siphoned from the transfer bottle to the filter funnel.

C. Cruise BLM04B. In addition to pre-weighed filters, USGS furnished filter holders, valving, and various lengths of vacuum tubing from which the apparatus pictured in Figure 3-4b was assembled. This arrangement was a vast improvement over previous set-ups in that it did not need constant attention.

A large (20 liter) bottle was evacuated to serve as a vacuum chamber and overflow reservoir. The in-line filter holders were attached to this bottle in parallel with valves for each filter holder. Sample water was drawn into the top of the in-line filter holder as shown, passed through the filter, and into the reservoir.

D. Cruises BLM05B-BLM08B. For these cruises, the apparatus used for cruise BLM04B was still used. The technique was altered slightly to assure that the suspended sediment captured in the sample bottle was uniformly distributed through the water being filtered. The alteration consisted of shaking the Niskin bottle immediately prior to decanting the sample into the transfer bottle and shaking to transfer bottle periodically during the filtering operation to suspend any material which might have settled out.

V. Dissolved and Particulate Organic Carbon (DOC and POC). A 1 liter graduated cylinder was rinsed with about 50-100 ml of sample. The rinse water was discarded, and the graduated cylinder was filled to the 300 ml level. The foil wrapping (used on all DOC and POC apparatus to prevent dust, diesel smoke, and other material from contaminating the samples) was removed from a clean filter and holder assembly, and the assembly placed in line (position B in Figure 3-5). The foil wrap and cap from a sample bottle were removed, and the bottle was placed in line next to the filter holder (position C, Figure 3-5) taking care to keep the bottle cap clean by rewrapping it in foil. The overflow reservoir was carefully placed in line between the sample bottle and vacuum pump (position D, Figure 3-5). Next, the foil wrap was removed from the suction tube (position A, Figure 3-5) and

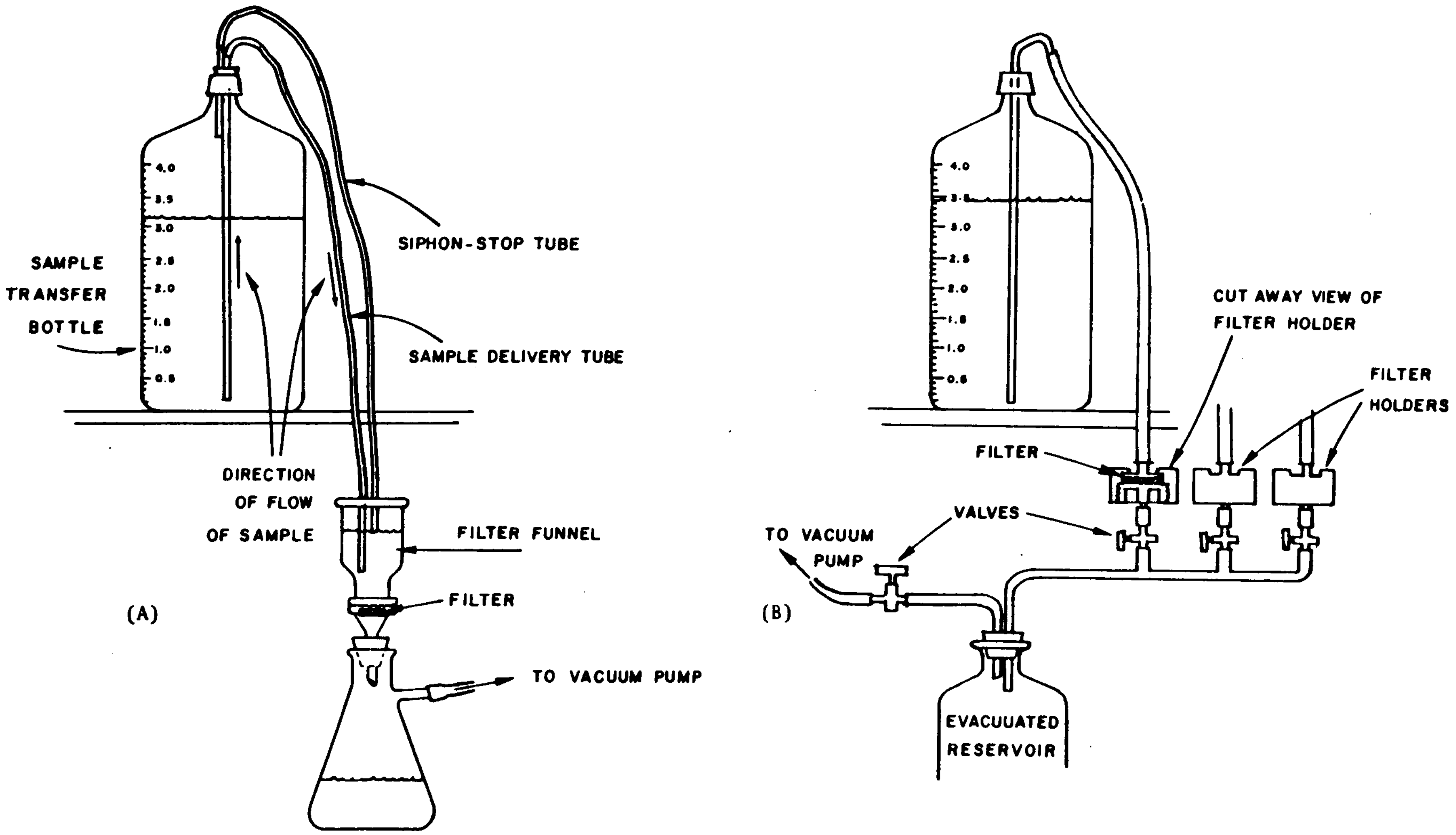

Figure 3-4. (A) Filter-siphon arrangement used for suspended sediment filtering for cruises BLM02B and BLM03B. A similar arrangement was used for BLM01B except that sample was poured into filter funnel, siphon was not used (clamp not shown on filter funnel). (B) Filtering arrangement used for suspended sediment filtering for cruises 04B-08B, showing filter holders, reservoir, and valving

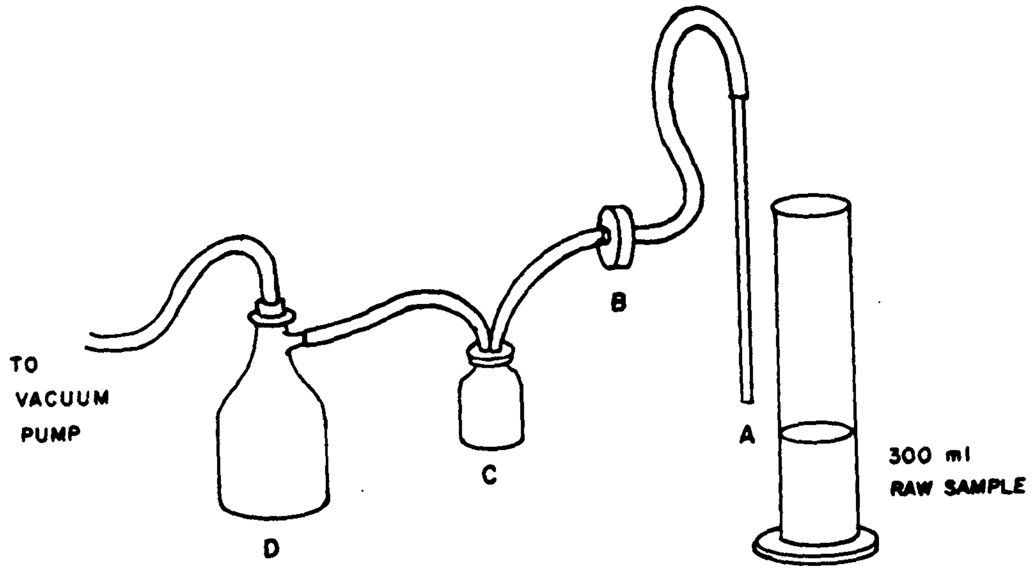

Figure 3-5. Arrangement of equipment for field processing of POC-DOC samples. (A) suction tube; (B) pre-combusted glass filter in holder; (C) DOC sample bottle; and (D) overflow reservoir.

300 ml of sample was siphoned through the filter into the sample bottles. The excess filtrate was drawn into the overflow reservoir. When all the sample had passed through the filter, the vacuum was turned off and the filter assembly removed and wrapped in foil. This was replaced with a new filter holder assembly and the graduated cylinder was refilled to the 300 ml level with more sample which was filtered through the sample bottle as before. The process was repeated a third time, the foil wrap was replaced on the siphon tube, and the filter and holder assembly was removed from the line and wrapped in foil. The sample bottle was removed from the line and enough filtrate was discarded to bring the level down to the shoulder of the bottle. The cap and foil wrap were replaced on the bottle and both filters and bottle were labeled with cruise number, station number, sample depth, and date and time the sample was taken. The filters and sample bottles were placed upright in a freezer for transport to shore. Once a sample had been processed, glassware and connecting tubing were rinsed by siphoning 100 ml of 0.3 normal HCl through the system followed by 100 ml of glass distilled water. Foil wrappings were then replaced.

VI. XBT Launch. The XBT launches were performed while the survey vessel was underway, either between stations or on a special XBT survey track. The launches were initiated by an announcement from the bridge that the desired position had been reached or that the beginning of a designated track line had been reached. Then a sequence of events was performed. First, a new canister was inserted into the XBT launcher and the deck unit checked to determine that the system was ready for launch. Then, a bucket sample was obtained and the thermometer inserted. The XBT was then launched to pierce the water surface as close to the bucket sample location as possible. The launcher was held over the side near the stern of the vessel for a minute or until notification of a finished record was obtained. The wire from the launcher over the side was then broken, and the bucket temperature was read. A salinity sample was taken from the bucket and the bottle number entered in the data. Generally, surface temperature, salinity bottle number, cruise, date, time, and Loran book page number were noted on the XBT chart while salinity bottle number, temperature, and time were noted on the Loran book for redundancy. If the instrument laboratory was manned during the launch, a navigation fix was started at the beginning of the chart trace. Otherwise, it was started immediately after the bottle sample had been drawn. The trace was then examined to verify that a plausible trace had been produced.

Meteorological Station. A complete meteorological station was started by wetting the wick on the wet bulb thermometer with deionized water, starting the battery run motor, and moving to a position on the ship where fresh air could flow through the aspirated psychrometer without sun striking the thermometer bulbs. The heading of the ship was noted. While the psychrometer was equilibrating, observations of wave and swell heights, directions, and periods were made. With the wet/dry bulb readings obtained, the observer noted the data and obtained wind speed and direction from the bridge, where a calibrated barometer and ship's anemometer were located as well as speed/heading information needed to correct the apparent wind. The observer noted the time of the pressure reading as the station time and obtained a navigation fix. After these were noted, a bucket sample was taken. While the bucket thermometer was equilibrating, the cloud observtions were made as well as the visibility and present weather estimates. The timing of the entire procedure was planned so that the pressure reading would correspond as closely as possible with the nominal time of the stations for water column cruises.

Navigation Fix. The Loran C system included a digital printer which repeated the panel display of Loran time delays (which correspond to times of position or LOP'S) with a precision of .01 microsecond. These readings are subject to noise and the resulting fluctuations of the indicated LOP'S provide a measure of the quality of the fix. The protocol for obtaining Loran C fixes was based on the desire to calculate an improved position from an averaged set of readings and estimate the accuracy of the fix. It was followed during the second and subsequent cruises. A series of successive displays of LOP was recorded on the printer. This series was typically 22 readings corresponding to eleven sequential samples of each LOP. The printer tape was then torn off and taped to a prenumbered page in the navigation log (Loran book). The date and time, recorded event, and stations used for the fix were also entered on the page (see Appendix 3A for a sample form).

Laboratory Processing

This portion of the work includes the tasks needed to convert the samples taken and numbers obtained to estimates of the values of the various quantities of interest in an accessible form. As experience was gained, an increasing amount of the work was done aboard the ship. The work can be grouped into three general categories, sample analysis, conversion and correction, and information file creation and display.

Sample Analysis

Salinity.

I. Cruise BLM01 to BLM04W. Water samples secured at sea for salinity analysis were allowed to thermally equilibrate in the laboratory for a minimum of 24 hours. Temperature and conductivity ratio (relative to Copenhagen standard sea water) of the samples were measured with a laboratory salinometer (Beckman model R57-B) and the latter recorded on laboratory work sheets along with bottle number, cruise and date of collection. Conductivity ratios were converted to salinity (in parts per thousand or ppt) using a computer program based on salinity vs conductivity ratio tables furnished by the manufacturer (see Appendix 3). The laboratory salinometer has a rated accuracy of ± 0.003 parts per thousand; however, this is only applicable to salinities in the vicinity of 35 parts per thousand. Salinities higher and lower than this are measured to less accuracy with a maximum error of ± 0.01 part per thousand (A. Cline, 1974, pers. communication). For this reason, salinities determined with this instrument are reported to the nearest 0.01 part per thousand. The laboratory salinometer was calibrated, at the beginning of each day's use, with Copenhagen standard sea water.

Salinity values thus obtained were posted to field data sheets (VIMS Form 200) beside the appropriate bottle number.

II. Cruises BLM05B to BLM08W. For these cruises, the GUILDLINE AUTOSAL was available to us for analysis of salinity samples aboard the survey vessel. The sample analysis was much simplified, as temperature equilibration was accomplished as a part of the automatic operation of the instrument. The instrument was calibrated with Copenhagen standard water every day, and the resulting conductivity ratios and scales were noted in the laboratory log book for each bottle analyzed. The analysis procedure consists of wiping a small inlet hose dry, mounting one of the special salinity bottles in a sealed clamp, flushing the measurement cell, visible through a window, several times and reading the conductivity ratio from the digital display. This procedure was so reliable that a new operator could be trained in about half an hour to obtain reproducible results consistent with those of experienced operators. The accuracy reported by the manufacturer for these measurements is ± .003 ppt equivalent salinity at 35 ppt. Stability over a 24 hour period is ± .002 ppt equivalent salinity while resolution is ± .0002 ppt, so the accuracy was about 15 least count intervals.

Dissolved Oxygen. Water samples which had been field processed for DO analysis were titrated in the laboratory with sodium thiosulfate solution (using starch as an indicator) according to procedures outlined in APHA (1976). Thiosulfate was standardized each morning, after every fiftieth sample and when a new solution was made. Quantity of titer used was recorded on laboratory sheets along with bottle number, date of analysis, cruise number and date as well as thiosulfate standardization information. Values of DO in mg/liter were determined from this information and posted in appropriate locations on field data sheets. The method and the analysis were moved onto the ship starting with cruise BLM05W. This move, motivated by concern about degradation of the samples before analysis, was made possible largely by the introduction of a piston-type burette associated with a hypodermic needle modified to serve as a titer dispenser. The resulting shipboard titrations were reproducible for a given operation to within 0.5% for subsamples of a given sample. This random error was well under the 2% accuracy of the standardized solution. The resulting titration was time-consuming still, with the oxygen analysis barely keeping pace with the sample collection. A further modification to the method was introduced for cruises BLM08W and BLM08B which relied on pre-measured solutions and a marked 300 ml sample bottle with a lower concentration of titer. The resulting analysis was much more rapid and gave the numerical value of dissolved oxygen in mg/l as the amount of titer added in ml, except for a slight standardization correction.

Micronutrients. Frozen field samples were stored in a freezer until they could be processed. Samples were removed from the freezer (in quantities up to fifty) and placed in a refrigerator to thaw overnight. Thawed samples were analyzed on a Technicon Auto Analyzer (model AAII). Analyses for nitrite and nitrate were run in accordance with Technicon Industrial method 158-71W AAII while those for orthophosphate plus arsenate were run in accordance with Technicon Industrial method 155-71W AAII with modifications of the EPA methodology for the AAII applicable to saline waters (APHA 1976).

Preparation of standard solutions for micronutrient analyses.

I. Nitrate and nitrite. The following procedure was used: 0.0691 g of sodium nitrite ($NaNO_2$) was dissolved in one liter of deionized distilled water. This concentration was 1000 μgat N/l and was called stock standard A for nitrite.

0.101 g of potassium nitrate (KNO_3) was dissolved in one liter of deionized, distilled water. This concentration was 1000 μgat N/l and was called stock standard A for nitrate.

Stock standard B for both parameters was prepared by pipetting 10 ml of stock standard A into separate 200 ml volumetric flasks and adding deionized distilled water to the 200 ml mark. Concentrations of each were 50 μgat N/l.

There were three working standards prepared daily in concentrations of 5.0, 2.5, and 1.0 μgat N/l. 20 ml of stock standard B was pipetted into a 200 ml volumetric flask for 5.0 μgat N/l concentration; 10 ml of stock standard B was pipetted into a 200 ml volumetric flask for 2.5 μgat N/l concentration; and 5 ml of stock standard B was pipetted into a 250 ml volumetric flask for 1.0 μgat N/l concentration.

Working standards were then run on an autoanalyzer with the instrument set at 5.0 μgat N/l giving peak height of 100. Concentrations of 2.5 and 1.0 μgat N/l reached peak heights of 50 and 20 respectively.

II. <u>O-Phosphate</u>. 0.136 g of anhydrous potassium dihydrogen phosphate (KH_2PO_4) was dissolved in one liter of deionized distilled water. This concentration was 1000 μgat P/l and was called stock standard A for phosphate. Stock standard B was 10 ml of stock standard A pipetted into a 200 ml volumetric flask and diluted to 200 ml. This concentration was 50 μgat P/l.

There were the three working standards prepared daily in concentrations of 4.0, 2.0. 1.0 μgat P/l. 20 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted to 250 ml for 4.0 μgat P/l concentration; 10 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted for 2.0 μgat P/l concentration; and 4.0 ml of stock standard B was pipetted into a 200 ml volumetric flask and diluted for 1 μgat P/l concentration. Working standards were run on an autoanalyzer with the instrument set at 4.0 μgat P/l giving peak height of 100, and 2.0 and 1.0 μgat P/l reaching peak heights of 50 and 25 respectively.

<u>Particulate and dissolved organic carbon</u>. Frozen filters and water samples were allowed to thaw at room temperature. The filters were air dried with a water aspirator. Glass ampules (10 ml, Owens-Illinois) were prepared for use by being tapped upside down on a clean surface (to remove any particles of foreign material) and the top of the neck of each ampule wrapped with a piece of lightweight (one-inch square) aluminum foil twisted to form a cover for the ampule. Ampules were precombusted at 550°C for four hours. Six ampules were used for each sample giving triplicate analysis for each POC and DOC. To each ampule, 0.2 gm of potassium persulfate and 0.25 ml of 6% phosphoric acid was added.

For POC analysis, a filter was placed in an ampule and 5 ml of distilled water added. For DOC analysis, a 5 ml aliquot of thawed filtrate was added. Both POC and DOC were done in triplicate. Ampules thus filled were purged of inorganic carbon constituents for four to six minutes with purified oxygen (400°C) flowing at a rate of 60 ml/min., and then sealed in an apparatus especially designed to prevent CO_2 contamination from the sealing flame. Sealed ampules were heated at 125°C in an autoclave for four hours to oxidize the organic carbon to CO_2.

CO_2 content of each ampule was then analyzed in an ampule breaking apparatus (manufactured by Oceanography International Corp., College Station, Texas) which allowed the CO_2 to be flushed through an infrared analyzer (Model 524, Oceanography International Carbon Analyzer).

The carbon dioxide content of each ampule was determined by flushing the gas content of the ampule with nitrogen into the gas stream of a non-dispersive infrared analyzer sensitized to carbon dioxide. The detector output of the analyzer was recorded as a peak on a Hewlett-Packard (Model 724A) potentiometric strip chart recorder equipped with an integrator.

Standard carbon dioxide conversion graphs were made by plotting the integrated area versus carbon for standardized sodium carbonate solutions. These solutions were made by injecting a known volume of the sodium carbonate standard through a rubber septum in a special vial containing 25% phosphoric acid solution.

The organic carbon concentration of each ampule was determined by comparing the integrated area to the standard carbon dioxide conversion graph.

The deviation for triplicate DOC determination on the same water sample was generally 5% or lower, with POC usually 10% or lower. A reagent blank value was determined with each set of water samples sealed. The DOC reagent blank value usually varied from 0.003 mg carbon to 0.004 mg carbon. The POC reagent blank usually varied from 0.003 mg carbon to 0.006 mg carbon. Triplicate values of POC and DOC were averaged and reported in mg/liter concentrations.

Data Analysis

Conversion and Posting of Sample Data

Navigation Data. The navigation data was received from the field in the form of numbered pages in a Loran book. Each page (see Appendix 3A) contained a strip of paper tape with several sets of alternate LOP readings and a notation for sample time and purpose. The mean values for each set of position reports were calculated and used as input for a Loran C to geographic coordinate conversion program. The results of the program were listed by page number in the original book and sent to the various principal investigators and other interested parties. These results were in the form of latitude and longitude in degrees, minutes, seconds with a least count of .001 second, to eliminate round-off errors. For the CTD and XBT stations, the navigation data was posted to the form 200's and the XBT data graphs to the nearest second.

Salinity samples. The salinity samples from cruises BLM01W through BLM05W were run on a Beckman laboratory salinometer which produced in a conductivity ratio to standard seawater at the analysis temperature. The corresponding salinities were read from tables supplied by the manufacturer and posted to the field sheets. The shipboard salinity analyses, performed on the Guildline Autosal, produced in another conductivity ratio, and they were converted to salinity using a BASIC implementation of a salinity algorithm supplied by the manufacturer (see Appendix 3C). The resulting salinity values were posted to the field sheets.

Dissolved oxygen data. The conversion of amount of titer required in the Winkler process to dissolved oxygen concentration in mg/l with the standardization correction was done using a pocket calculator with the results noted on the laboratory notebook. The resulting values for dissolved oxygen were posted to the field sheet with a resolution of 0.1 mg/l.

Micronutrient data. The analysis for each of these samples was done by separate laboratories, and the results reported to the nearest .01 μg-atom/l. The resulting values were posted to the field sheets.

Sample data editing and recording. The completed field sheets were then keypunched, verified, and entered into the computer file at the VIMS computer center. On completion, the data were printed out and sent back to the physical group in station alphabetical/numerical order for an entire cruise. These printouts were checked item-by-item for each station against the original field sheets, and differences were noted on the printouts. The printouts were resubmitted to the VIMS computer center, changes made, and new printouts generated and checked until all differences between the field data sheets and the printouts were resolved. The resulting data set was then released for inclusion in the production data file.

Analysis of CTD/DO Data

Computation of Parameters from Measured Value on CTD/DO Tapes. Reported values of temperature, salinity, depth, DO, and σ_t were computed from measured values recorded at sea on audio tape from CTD/DO casts. Signals on the audio tape were actually frequencies indicative of coded digital values of pressure, temperature, conductivity and the two DO associated variables. Two frequencies are used: $5kH_z$ and $10kH_z$ with one cycle of $5kH_z$ representing a zero and two $10kH_z$ cycles representing a one.

The digital data stream originates in the Neil Brown CTD underwater probe. For cruises BLM01 through BLM03, the basic sample (frame) consisted of 10 binary words, each containing 3 bits. For subsequent cruises, the sample consisted of 11 words, due to a modification to the CTD system increasing the resolution of O_2 probe current digitization from 8 to 12 bits. These words are sent from the CTD probe to the deck terminal unit in bit-serial, teletype format with one start bit preceding and two stop bits following each eight bit word. The transmission is by frequency coding each bit so that it can be stored on an audio tape deck (AKAI Model GX-630D). The data is played back off the tape, about one second after it is recorded, into the Neil Brown deck terminal.

The terminal decodes the data and provides four outputs: visual displays of CTD sensor variables in engineering units; folding scale analog voltages proportional to pressure, conductivity and temperature; bit-serial teletype and clock digital signals; and TTL logic compatible bit-parallel outputs, with separate strobe signals, for each eight bit word in the sample. There are also a number of test points and front-panel jacks for observing various signals in the deck terminal.

The frame is generated and transmitted by the CTD probe at the rate of 31.25 per second. The bits are transmitted at the rate of 5000 per second. The first word in the frame is the "frame sync" and alternates between 00001111 and 11110000 binary from one frame to the next. The next six words are the 16-bit digitizations of pressure, temperature, and conductivity. These and the remaining words in the frame are transmitted least significant bit first (Table 3-2). The eighth word contains the sign bits (+ or -) for pressure, temperature and oxygen probe temperature in the lowest three bits. The highest five are wired to identify the different CTD units (done after cruises BLM02). The ninth word is the eight bit digitization of the O_2 probe current. The tenth is the eight bit digitization of O_2 probe temperature. In all cruises starting with BLM04, the ninth and tenth words contain the twelve bit digitization of O_2 probe current and the eleventh is the eight bit O_2 temperature word (Table 3-3).

The Neil Brown deck terminal provides each eight bit word, one at a time, with a clock pulse indicating when the word is present for output. Baker, of VIMS, designed and built an interface which transfers each word to a Digi-Data Model 1300/800-PPB-400 nine track digital tape recorder. The interface provides counting and trigger circuits to set tape record lengths at any size up to the 400 word tape input buffer limit. Each record is started with a frame sync word and set to be an integral number of frames in length. Record lengths for BLM01-03 cruise tapes have been 250 or 320 words. Front panel switches on the interface allow single-record or continuous recording. When the recording is stopped, the record in progress is allowed to complete. The digital recording is IBM-compatible with a density of 800 characters per inch.

The audio tapes of the CTD cast are brought in from the field and transcribed to 9-track tape in the lab using the VIMS-built interface. The transcription procedure is to record, at the beginning of a cast, a single record of data made when the CTD was still in air, but turned on long enough for the electronics and sensors to stabilize. The rest of the records in a downcast are recorded continuously. Recording

Table 3-2. CTD Frame Format (Cruises BLM001 through BLM003).

Word	Sensor	Bits
1	(Frame sync)	0001111 or 11110000
2	Pressure (dbar)	least significant eight bits binary
3	Pressure	most significant eight bits binary
4	Temperature (°C)	.s. bits
5	Temperature	m.s. bits
6	Conductivity (mmho/cm)	.s. bits
7	Conductivity	m.s. bits
8	(Signs)	sb, pressure, sb+1, temperature sb+2, O_2 temp. 1 for - 0 for +
8	(Unit No.)	five most significant bits, 0 for CTD S/N 1295, 1 for CTD S/N 1495
9	O_2 current (A)	eight bits binary
10	O_2 temp. (°C)	eight bits binary

Table 3-3. Changes to CTD Frame Format (Cruises BLM004 and subsequent)

Word	Sensor	Bits
9	O_2 current (A)	least significant eight bits binary
10	O_2 current	0000XXXX, lowest four bits of words are most significant four bits of O_2 current digitization
11	O_2 temp. (°C)	eignt bits binary

starts at the end of the soak period. The downcast recording terminates with one End of File (EOF) mark on the digital tape just before or after the first rosette bottle sample.

Rosette samples interrupt the data and cause long-lasting transients in the O_2 probe current prior to the use of the battery pack. They occur only on the upcast. The upcast data is recorded continuously on the digital tape, starting before the first rosette sample. The upcast ends after the CTD probe has been removed from the water and is terminated with two EOF marks on the digital tape. Aborted casts are terminated with two EOF marks. The last upcast recorded on the tape is terminated with three EOF marks to mark the end of the tape. The digital tape is then rewound and labeled for filing. About three 90-minute audio tape records can be transcribed onto one 1200 ft. digital tape.

The transcribed digital tapes, labeled CTDXXX starting with CTD001, are then processed on the VIMS IBM 370/115 computer. The processing is done in two passes. The first pass generates pressure sorted oceanographic variables of depth (m), pressure (dbar), temperature (°C), salinity (ppt), time (sec), partial pressure of oxygen (atm), dissolved oxygen concentration (ml/l) and the number of samples per output. Conductivity is corrected for pressure and temperature effects. Time is generated from the number of samples. Depth, salinity, partial pressure of oxygen and dissolved oxygen concentration are calculated from the observed values and the most recent calibrations. All the variables are ordered by 0.5 meter depth slots into which the samples (frames) are averaged with equal weight.

The second pass involves correcting the calculated DO values to bottle sample measurements and calculating values for sigma-t and potential temperature.

First Pass Calculations. The first pass program in present use is called CTDRAV, written by Baker. CTDRAV reads a record at a time from the binary digital tape and generates FORTRAN variables containing the frame sync, unit number and measured sensor values. In each record, the consecutive frames are checked for proper length and consistent frame syncs. Data that does not check out is dropped. Rate limits are applied from frame to frame on each variable to eliminate noise spikes. Frames with more than one rate limit exception in pressure, temperature and conductivity are dropped. Because the remaining probe values are digitized in the CTD every 32 frames or 1.024 seconds, a separate set of similar averages is kept and used to generate partial pressure and dissolved concentration of oxygen for every 1.024 seconds of raw data.

As the records are averaged, their values are sorted into 0.5 meter wide depth slots.* The records are weighted according to the number of frames per record. At appropriate times, when the program sorting storage is full, each slot is adjusted to give each frame an equal weight in a slot average, and the storage is printed out and dumped onto an output tape in FORTRAN-compatible format. At the end of each downcast and upcast, the sorting storage is dumped and the minima and maxima of the frame values used for output are written at the printer and on the output tape. There is also an indicator for cast direction and CTD unit number. The output tape is given an End of File (EOF) mark and rewound. For early versions of CTDRAV, the output tape was also listed.

A copy of CTDRAV with flowcharts is included in Appendix 3C.

Second Pass Calculations. The second pass of the data in the CTD processing cycle consists of program CTDCR1. This program operates in a user-chosen way on the pressure-averaged data coming from CTDRAV to produce corrected tapes of the parameters calculated from CTDRAV. It also computes the potential temperature and σ_t of the data in each pressure-averaged record and places them on the output tape. It accepts up to six user-defined constants for each station for use in the correction. CTDCR1 concatenates a header card with each input tape station record on the output tape. The printout from CTDCR1 acts both as a record of the concatenation and as a listing, in an easily readable form, of a selected subset of values of oceanographic (as opposed to engineering) interest.

The record correction is done in a subroutine named CORR, which transfers the input record to the output buffer. This subroutine has access to an input record and an array of up to six constants which are entered on an input card for each station. The user of CTDCR1 can then choose any correction scheme desired by writing an appropriate version of CORR and running it with CTDCR1. An entry to CORR, called CORPRT, allows the writer of a version of CORR to document the action of the subroutine on the output printout using appropriate write statements and Hollerith format. As this operation is programmed, it can use as many lines of free format as required.

In the actual use of CTDCR1 for the BLM cruises, the second pass corrections were performed only on values of dissolved oxygen, with

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* The high data rate requires the employment of an averaging process unless microstructure is being investigated. Had these averaging procedures not been employed, a CTD/DO cast lasting one hour would result in 112,500 frames of data. These data, printed one frame per line, would generate a 1562.5 ft (or approx. 1/4 mile) computer printout.

the purpose of updating the calibration data by using sample values to fit the CTD/DO-produced values.

The procedure for this correction was to select, from the CTDRAV printed output, calculated values of dissolved oxygen corresponding to sampled values. Prior to the installation of the battery pack, the values sampled on the upcast were compared with measured values from the downcast. The resulting pairs of corresponding values were thus plotted as a scatter diagram to produce a visual indication of the correlation between the instrument and the samples. Points which were outliers on the correlated groups were identified and labelled on the correspondence list. The remainder of the points were entered in a Hewlett-Packard Model 9810 programmable printing calculator program to produce statistical measures of the correspondence and estimates of a straight least squares regression line. These points were chosen from several casts on each cruise, depending on the visual impression of long term drift obtained from the scatter diagrams, which were coded by station. No more than an entire cruise was used to produce a given regression line. The slope and intercept of the resulting regression line were obtained from this step as well as the correlation coefficient and standard error for the correspondence. Correlations of .95 and standard errors less than 0.5 mg/l were typically achieved in this step. The slope and intercept of the regression line were punched on correction cards as input to CORR.

The resulting output tapes were then displayed on a plotting program of the downcast only to obtain a visual impression of salinity, temperature and dissolved oxygen as a function of depth. On some occasions, instrumental errors were evident on these curves as "spikes" in the data. The computed values of density were very useful in distinguishing between instrumental artifacts and fine (∿1 meter) hydrographic structure, as they almost invariably increased monotonically with depth in fine structure regions. To remove these spikes, the data were edited by locating the spikes on the printout from CTDCR1, flagging the specific depth value corresponding to the error, and removing the erroneous record from the tape. If only some of the parameters were faulty, they were flagged in the output stream with a string of 9's.

The edited data were then concatenated onto a single tape for each cruise, containing half meter averages of measured and computed variables by station. These tapes were copied and transmitted to NODC. The same data were displayed in a final plot of station data. The plotted station data are included in Appendix 3B of this report for the second year of the study. Plotted variables include temperature, salinity, dissolved oxygen, and sigma-t as a function of depth to 100 meters, temperature vs salinity, and dissolved oxygen vs salinity. Where the station depth exceeds 100 meters, a second depth plot is provided on a 0-800 meter scale.

Analysis of XBT Data

The Expendable Bathythermograph (XBT) data are received directly from the field in the form of rolls of chart paper on which a stylus trace has been made of temperature as a function of time starting when the XBT probe hits the water. Header information is noted or referenced on the chart. Also on the chart is a grid of temperature and depth, the depth scale of which may not correspond to the depth of the probe used for the cast. During the first year of operation, the data from these charts were digitized by hand, the method being to mark significant points on the curve with a pencil dot and then read the dots from the chart. If the chart was inappropriate to the probe used or if the zero depth did not correspond to the zero time point, the points on the chart were read from a transparent overlay of the appropriate scale which could be correctly placed. The resulting points were listed on a special form (VIMS form 201, see Appendix 3A) which was suitable for keypunching. The data were sent to keypunching with printed results verified from the form 201's in the same manner that was used for the sample data.

During the second year, the XBT data analysis was refined to produce more consistent results more quickly with fewer opportunities for an error to occur and at substantially reduced operating cost. The detailed description and operation of the system is included as Appendix 3D of this report. The approach was to use an X-Y digitizer, already part of the VIMS equipment, to place selected points from the XBT trace directly on computer compatible magnetic tape. The digitizer has the capability to put header information from a separate key entry onto the same magnetic tape that the digitized points are on. The resulting transcription was verified with a plot of the points which could be overlayed directly onto the original trace to verify the digitized points. Once verified, the XBT station data were released to be sent to NODC and other users.

RESULTS

Two methods of presenting meteorological and hydrographic data have been employed: digital magnetic tape and graphs. Digital tapes were used to generate data listings and plots of temperature, salinity, and DO versus depth as well as T-S and DO-S diagrams. Data listings were, in turn, used to develop various contour plots. A listing of all meteorological and hydrographic data is not included with this report because of its size. Magnetic tapes containing all data have been furnished to NODC for inclusion in their data file.

Graphics

Meteorological and hydrographic data (including results of micronutrient analysis) have been presented in several ways to meet contract requirements and assist possible users. Graphics are combined for each cruise with individual station data ordered numerically by station within any given cruise. The graphical results for the second year only are presented in this report, although the interpretation and discussion includes both years of data and conditions. The graphical results for the first year are presented in the first year report. The CTD and XBT station data plots are included in Appendix 3B of the current report.

Meteorological Parameters

Time histories of atmospheric pressure, wind speed and direction, wet and dry bulb air temperature, and cloud cover are plotted first in the series for each cruise. All parameters were plotted on the same figure to give a complete picture of meteorological conditions during each cruise.

Hydrographic and Micronutrient Results

Hydrographic and micronutrient data are presented in groups by cruises. Each group contains the following plots:

1) Surface and bottom distribution of temperature, salinity, DO, NO_2, NO_3, and $O\text{-}PO_4$.

2) Contour plots of temperature, salinity, DO, and density (σ_t) as functions of distance and depth along sections I through V as shown in Figure 3-6.

3) Plots of the variation of temperature, salinity, DO, NO_2, NO_3, and $O\text{-}PO_4$ at near surface, mid-depth, and near bottom along sections I through V (Figure 3-6).

Surface and bottom distributions as well as sectional contours (1 and 2 above) should be treated with caution. These "summary" type displays of data suffer greatly from discontinuous sampling experienced during the longer (winter and summer) benthic cruises. Several instances arose where a temporal "gap" of from three to fifteen days existed between adjacent stations on a transect. These "gaps" resulted from either weather conditions which made safe sampling impossible or adjacent stations being occupied on separate legs of the benthic cruise. When the disparity resulting from these conditions is evident in distributions of parameters, definite discontinuities in isopleths were left at appropriate locations. Similarly, discontinuities in isopleths are incorporated in sectional plots (2 above) when isopleths could not reasonably be constructed. Specific conditions are given in notes for individual cases.

All contouring was done by hand and assumed linear horizontal gradients at all depths. Vertical gradients were determined from half meter averages of CTD/DO data. Plots of individual parameters as

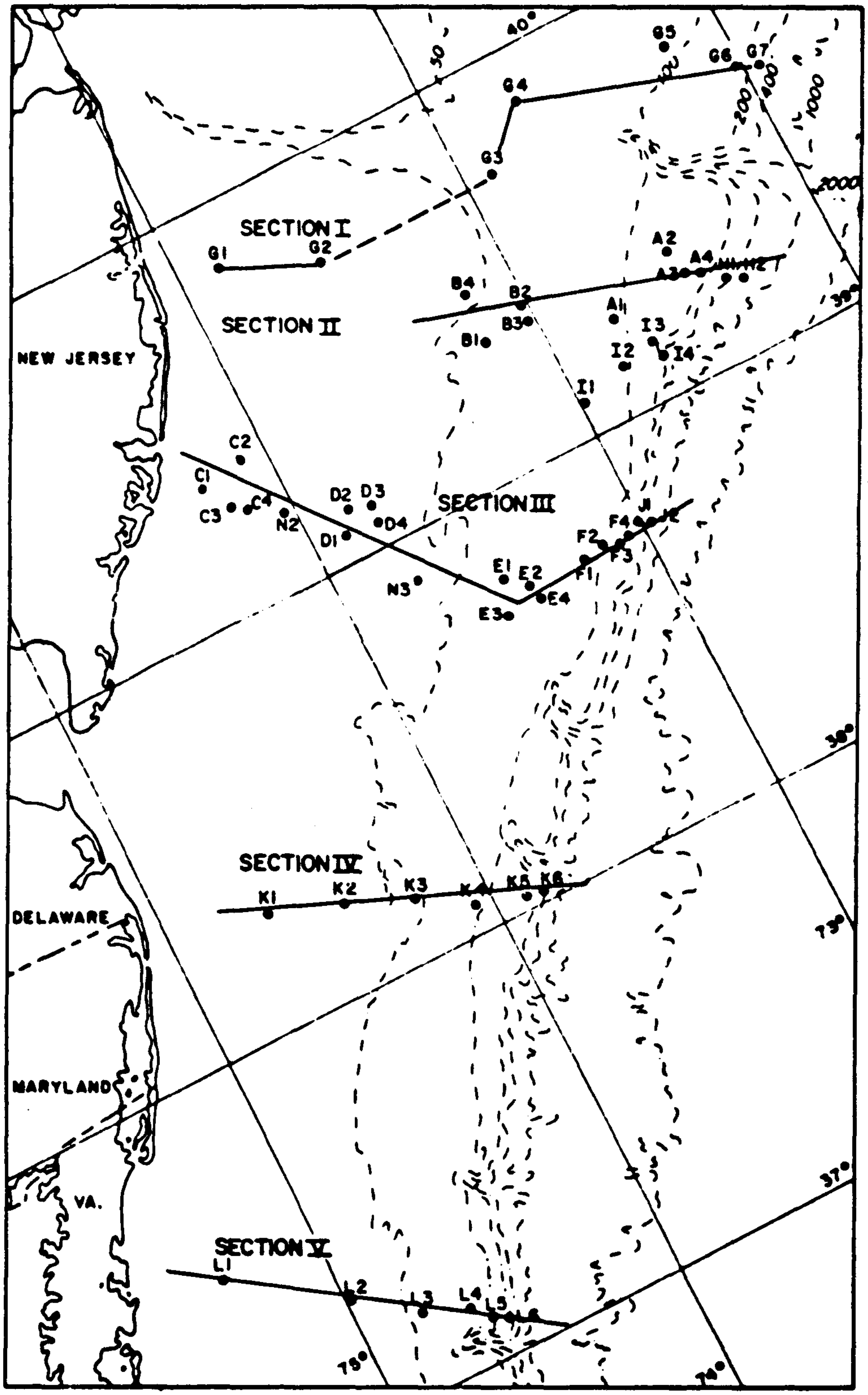


Figure 3-6. Chart of Baltimore Canyon trough study area showing Sections (I through IV) along which isopleths and surface, mid-depth, and bottom values of temperature, salinity, DO, and σ_t were plotted.

functions of depth and T-S, DO-S figures were generated by computer using results of CTD/DO casts.

Sequential Presentation of Results

As previously indicated, graphic results for the second year are ordered according to the alphameric coding of cruises (BLM05B, 05W, 06B, 06W, etc.). Subgroupings within each order are arranged in the following sequence:

1) Meteorological data

2) Surface distributions (arranged by temperature, salinity, DO, NO_2, NO_3, and $O-PO_4$)

3) Bottom distributions (following the above arrangement)

4) Sectional plots (in sequence and arranged by temperature, salinity, DO and σ_t for each section)

5) Values of temperature, salinity, and DO at near surface, mid-depth and near bottom as well as variations of NO_2, NO_3, and $O-PO_4$ at near surface and near bottom. These are grouped by sections and plotted as a function of distance offshore.

   Values of temperature, salinity, and DO are plotted by parameter with each plot representing near surface, mid-depth, and near bottom values of one parameter along a section. Micronutrient data are plotted similarly, but the NO_3 scale is extended to about 30 μgm-at/l, where the others are plotted on a scale of 0-5 μgm-at/l. This plot range is motivated by the large values of NO_3 associated with offshore water.

(TEXT CONTINUES ON PAGE 3-220)

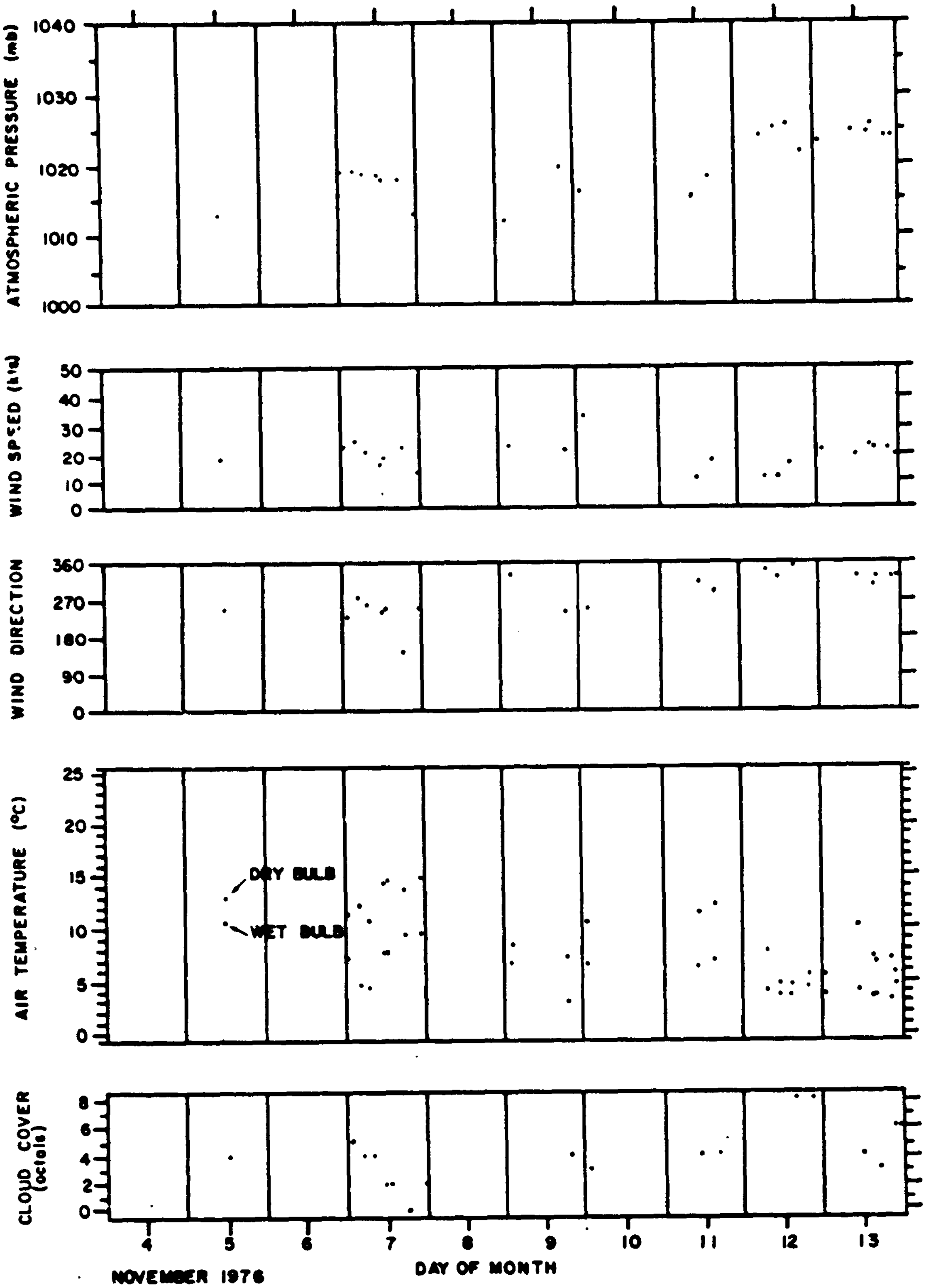


Figure 3-7a. Meteorological data collected during cruise BLM05B from 4-13 November 1976.

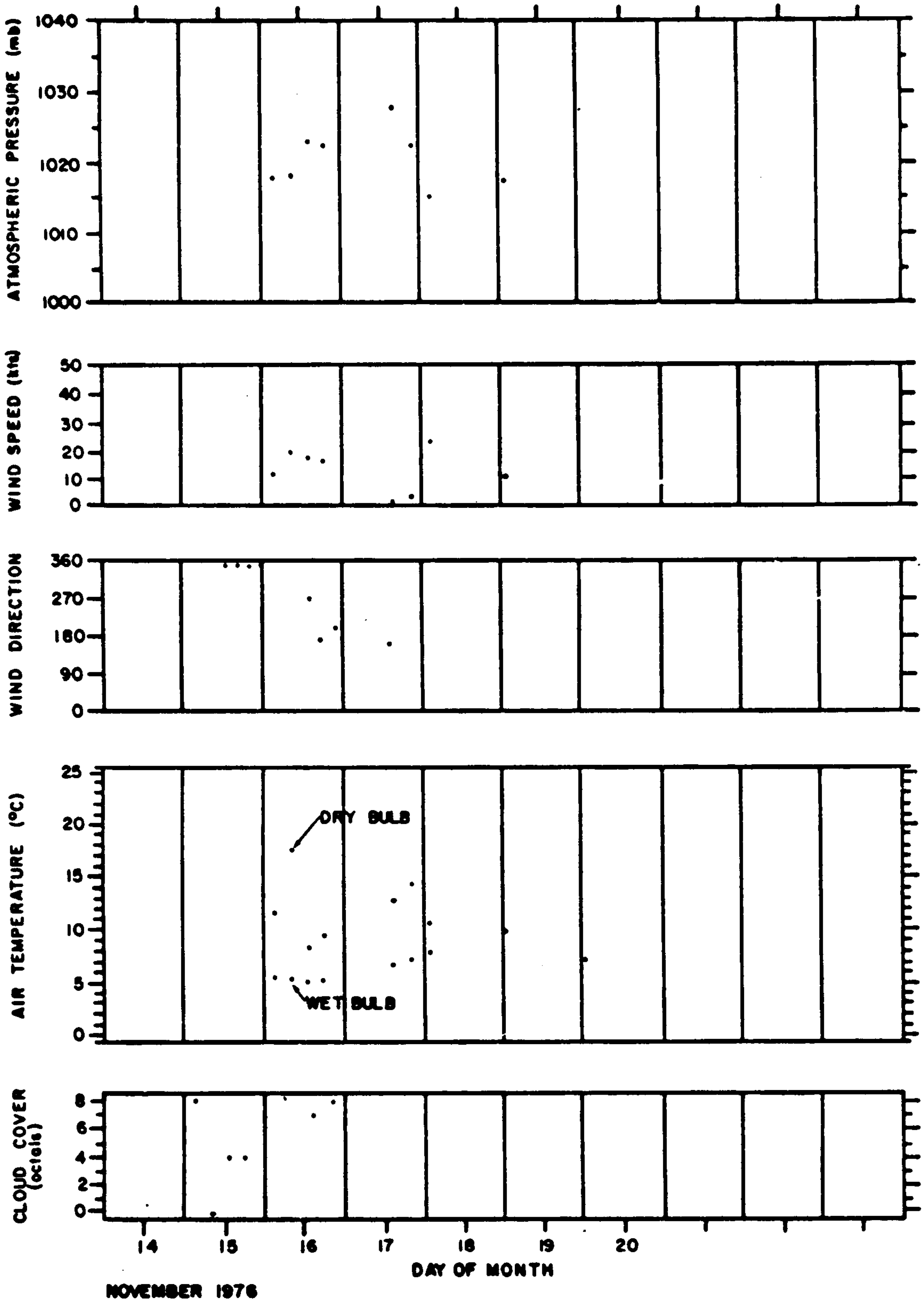


Figure 3-7b. Meteorological data collected during cruise BLM05B from 14-20 November 1976.

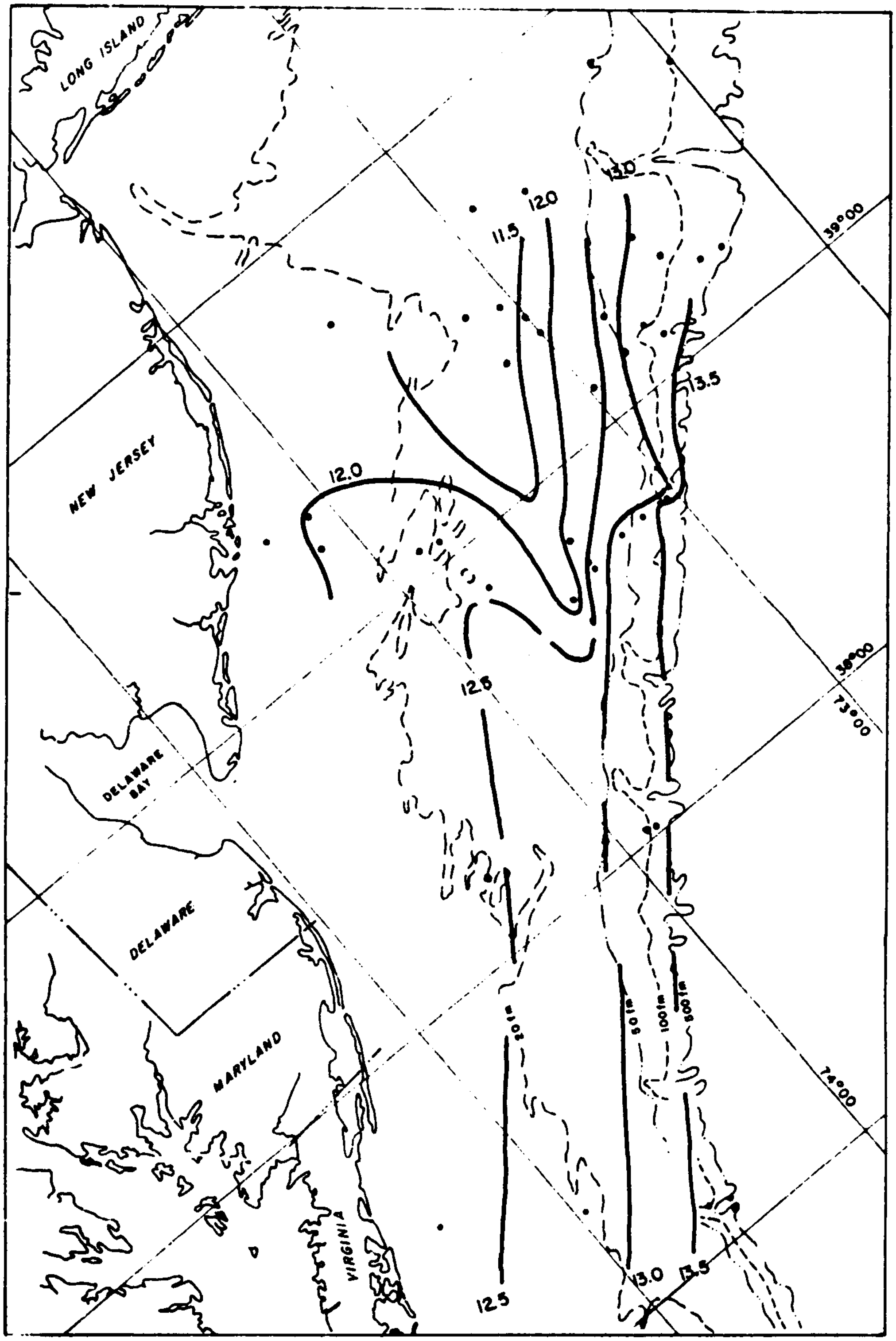


Figure 3-8a. Surface temperature (°C) distributions in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

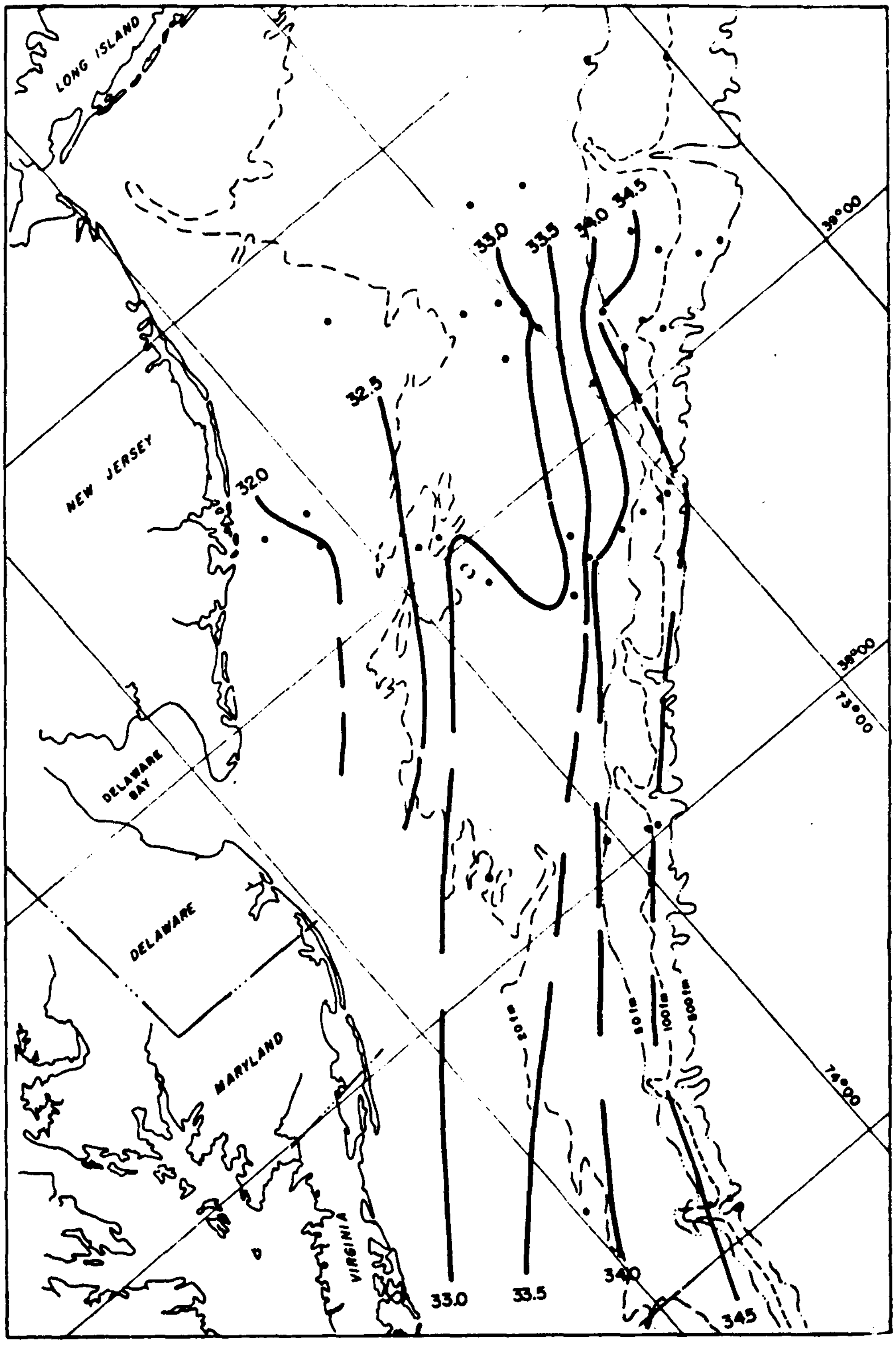


Figure 3-8b. Surface salinity (ppt) distribution in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

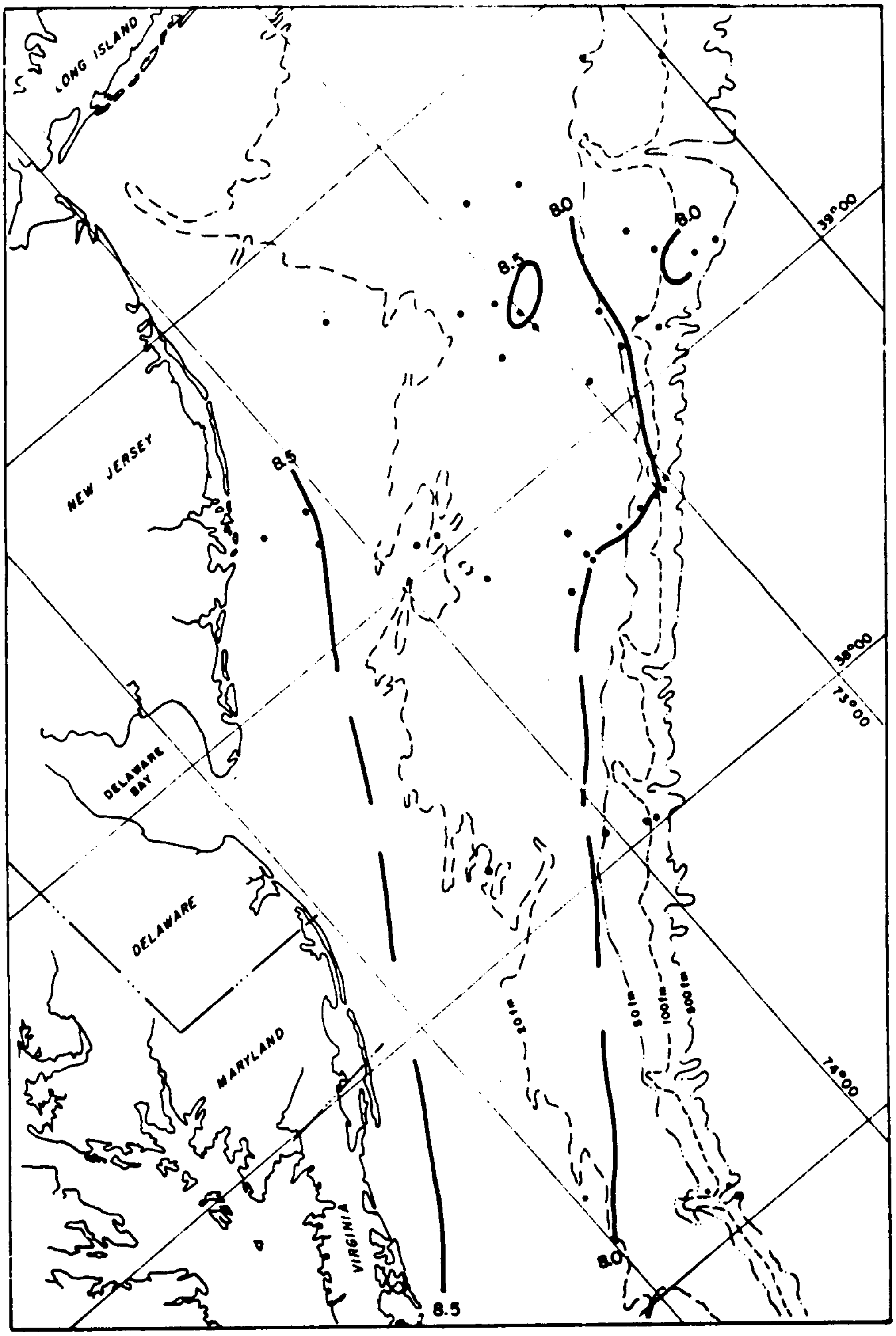


Figure 3-8c. Surface dissolved oxygen (μg/l) distribution in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

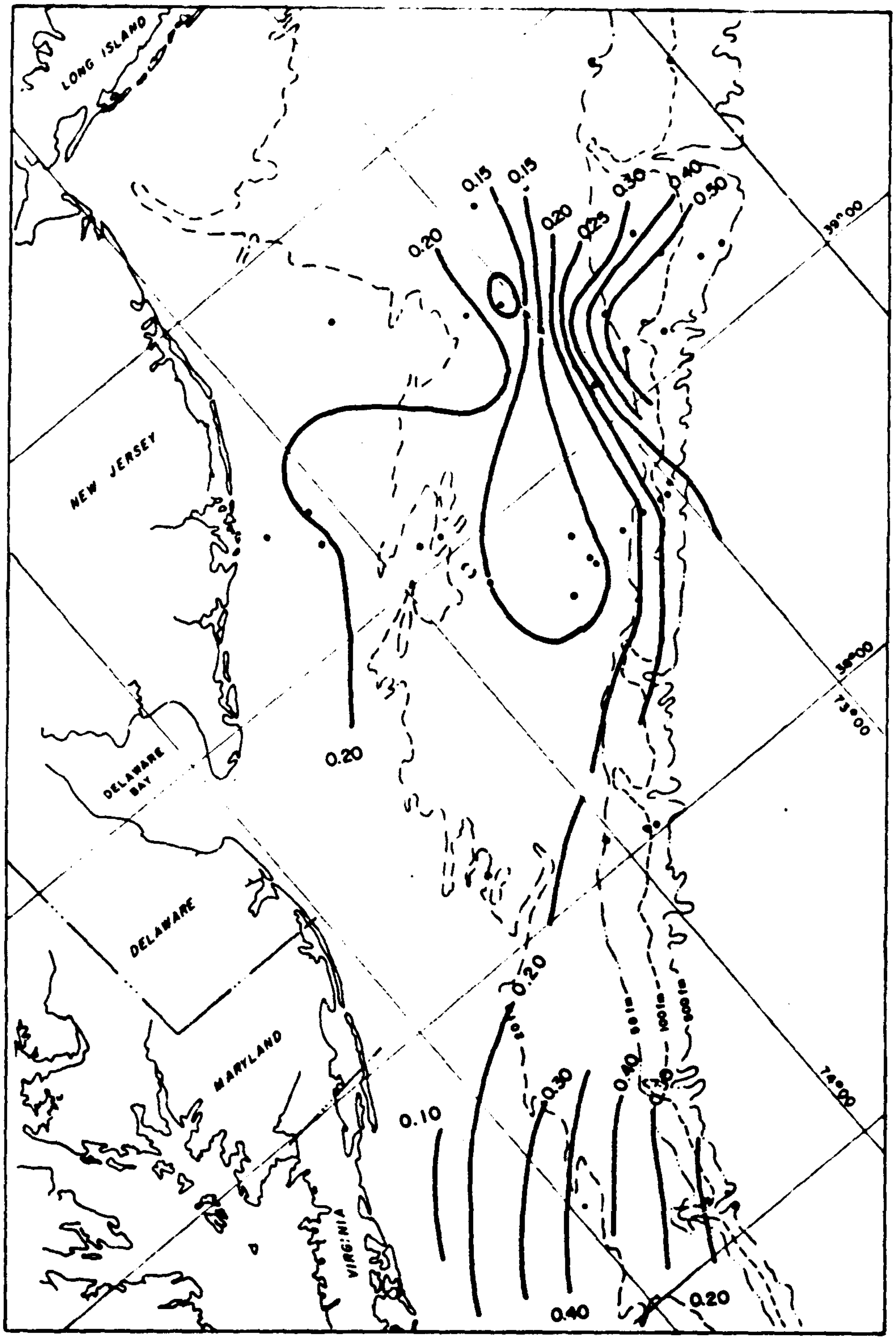


Figure 3-8d. Surface dissolved nitrite (µgm-at/l) distributions in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

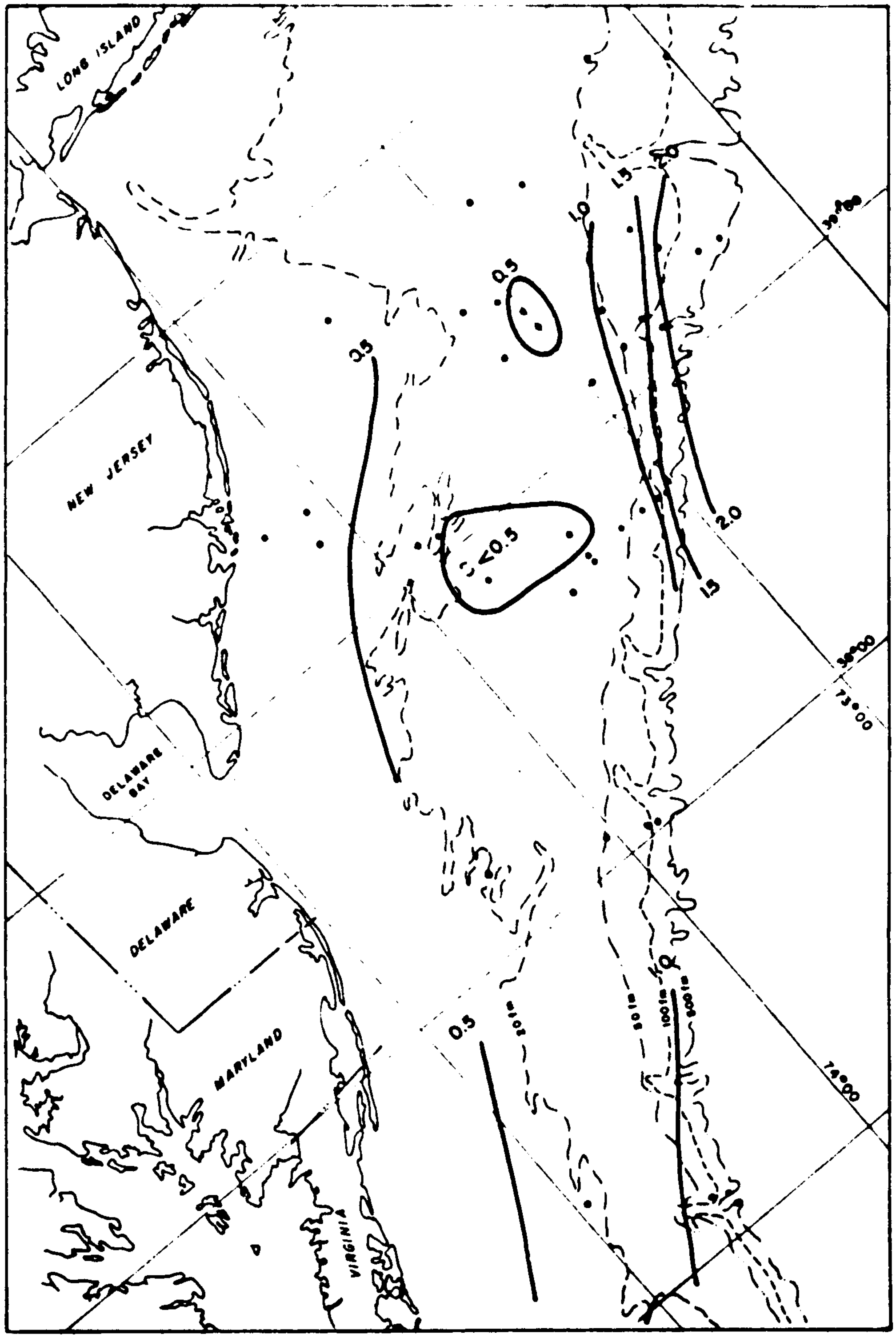


Figure 3-8e. Surface dissolved nitrate (μgm-at/l) distributions in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

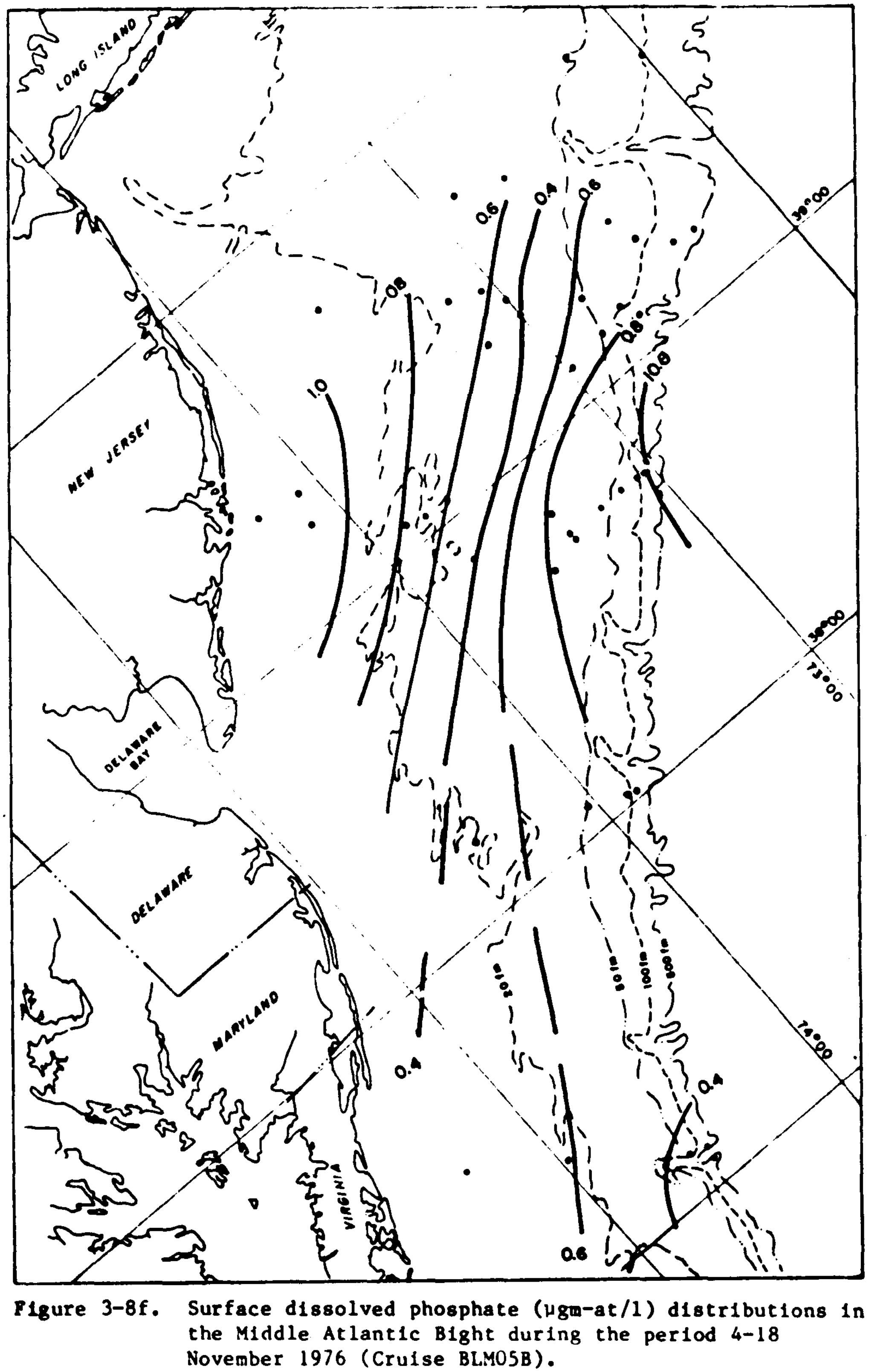


Figure 3-8f. Surface dissolved phosphate (μgm-at/l) distributions in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

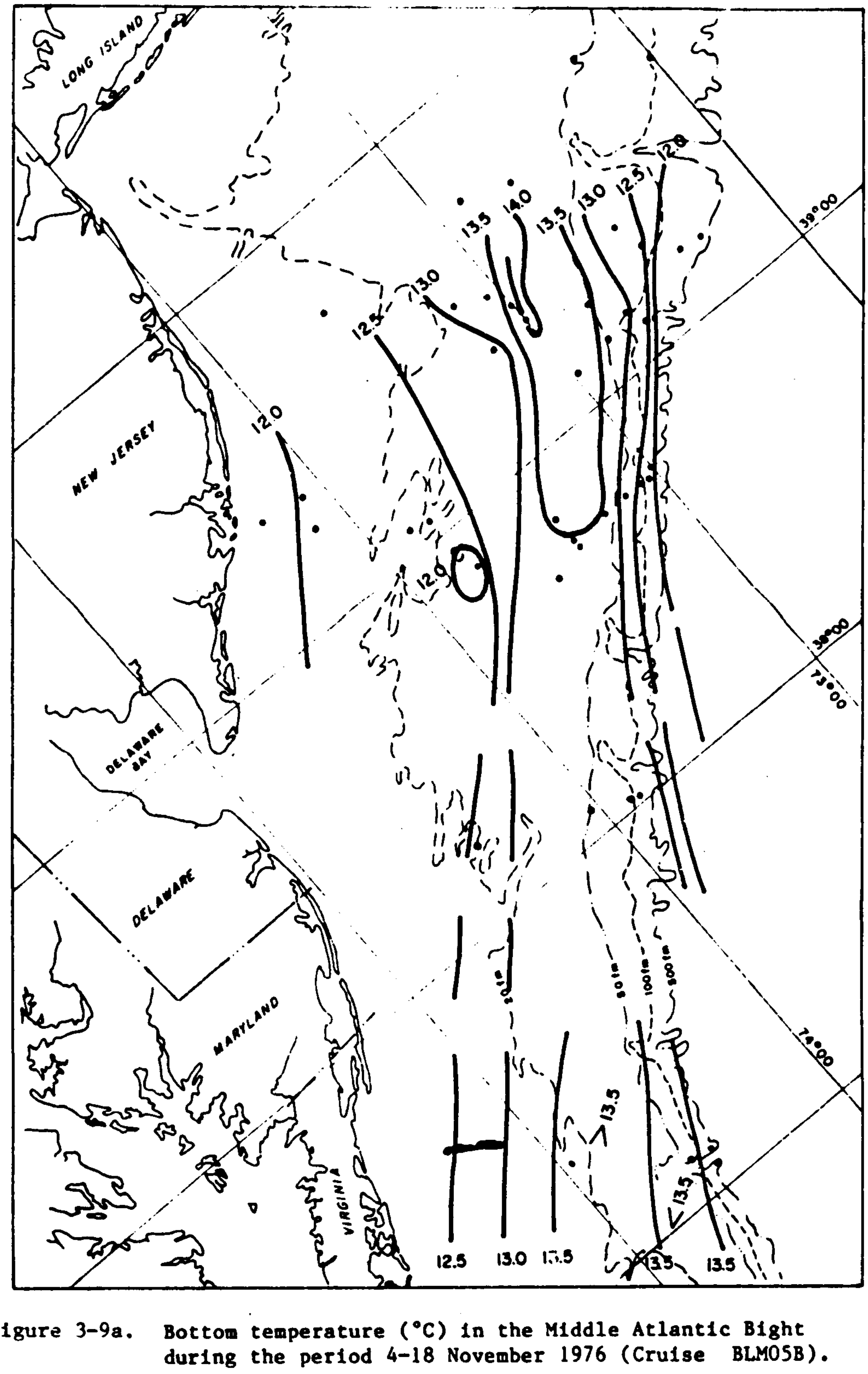


Figure 3-9a. Bottom temperature (°C) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

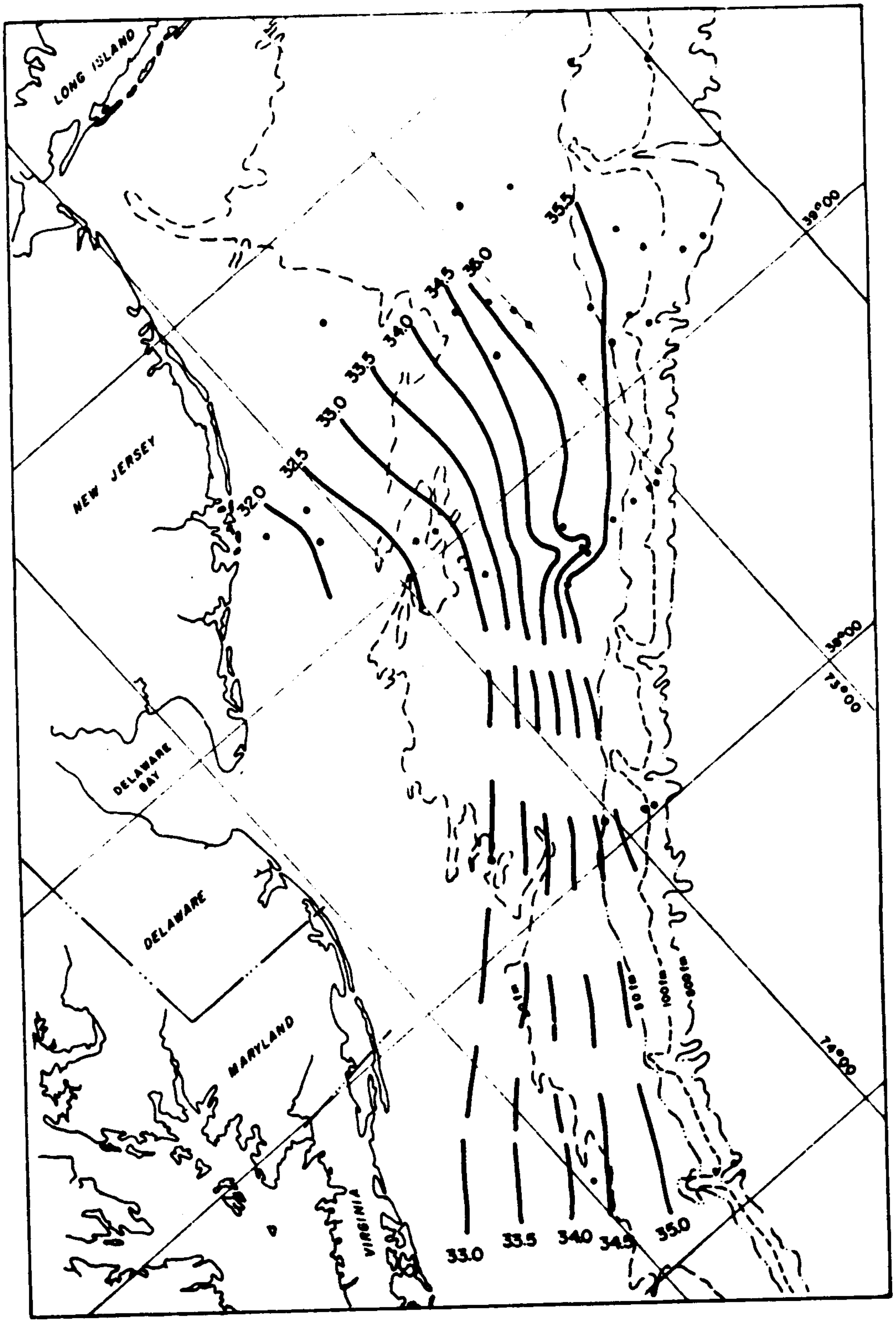


Figure 3-9b. Bottom salinity (ppt) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

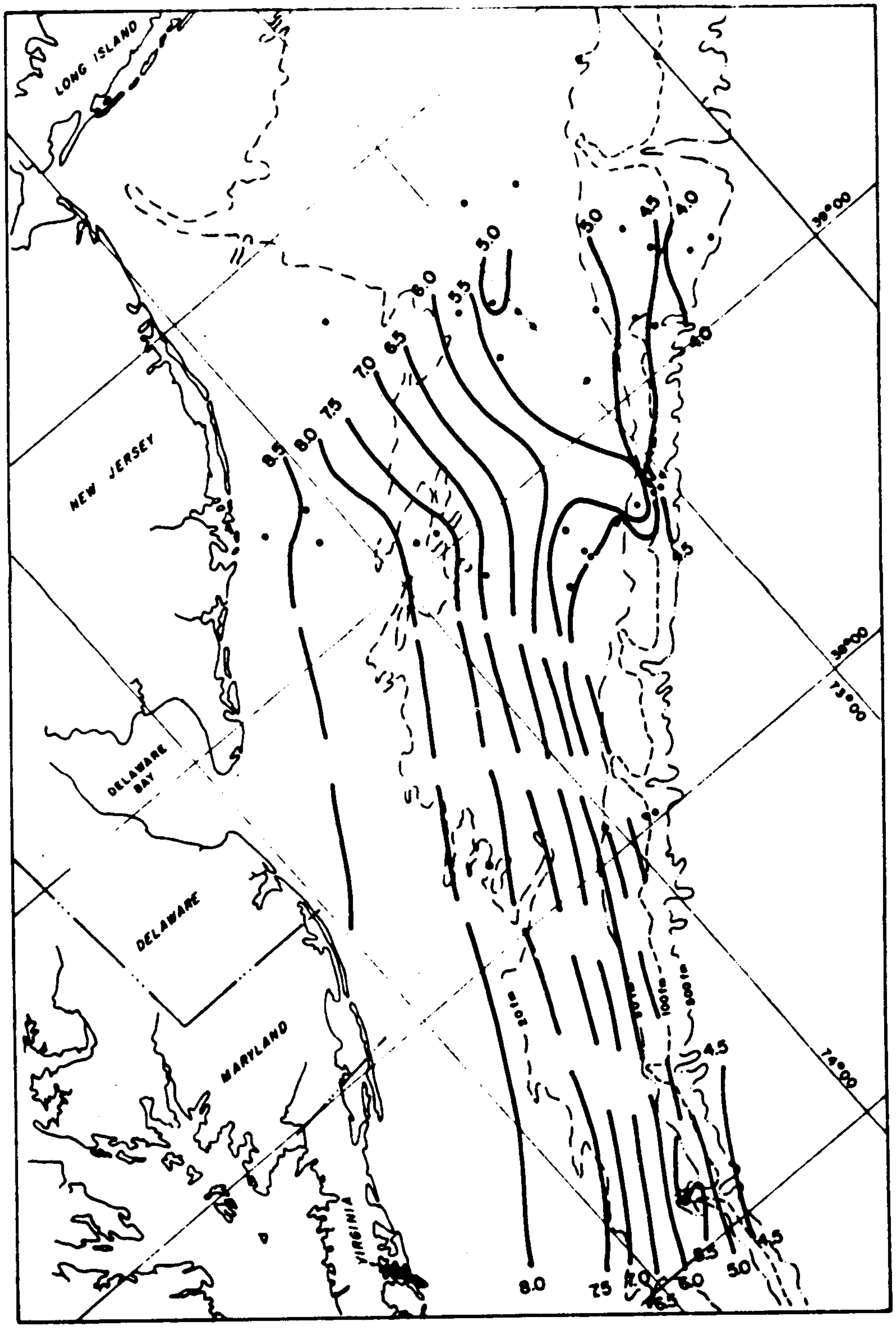


Figure 3-9c. Bottom dissolved oxygen (mg/l) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

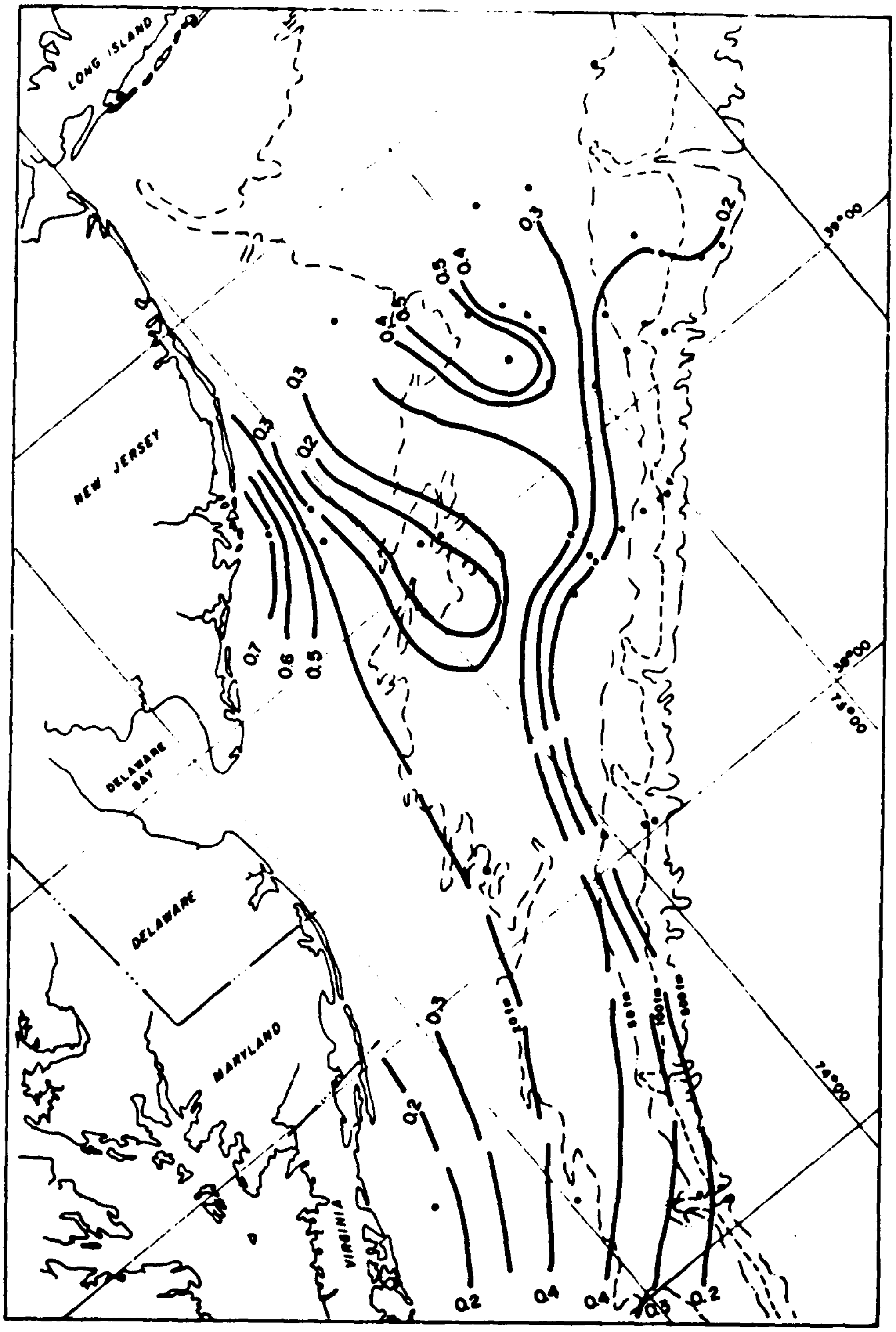


Figure 3-9d. Bottom dissolved nitrite (μgm-at/l) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

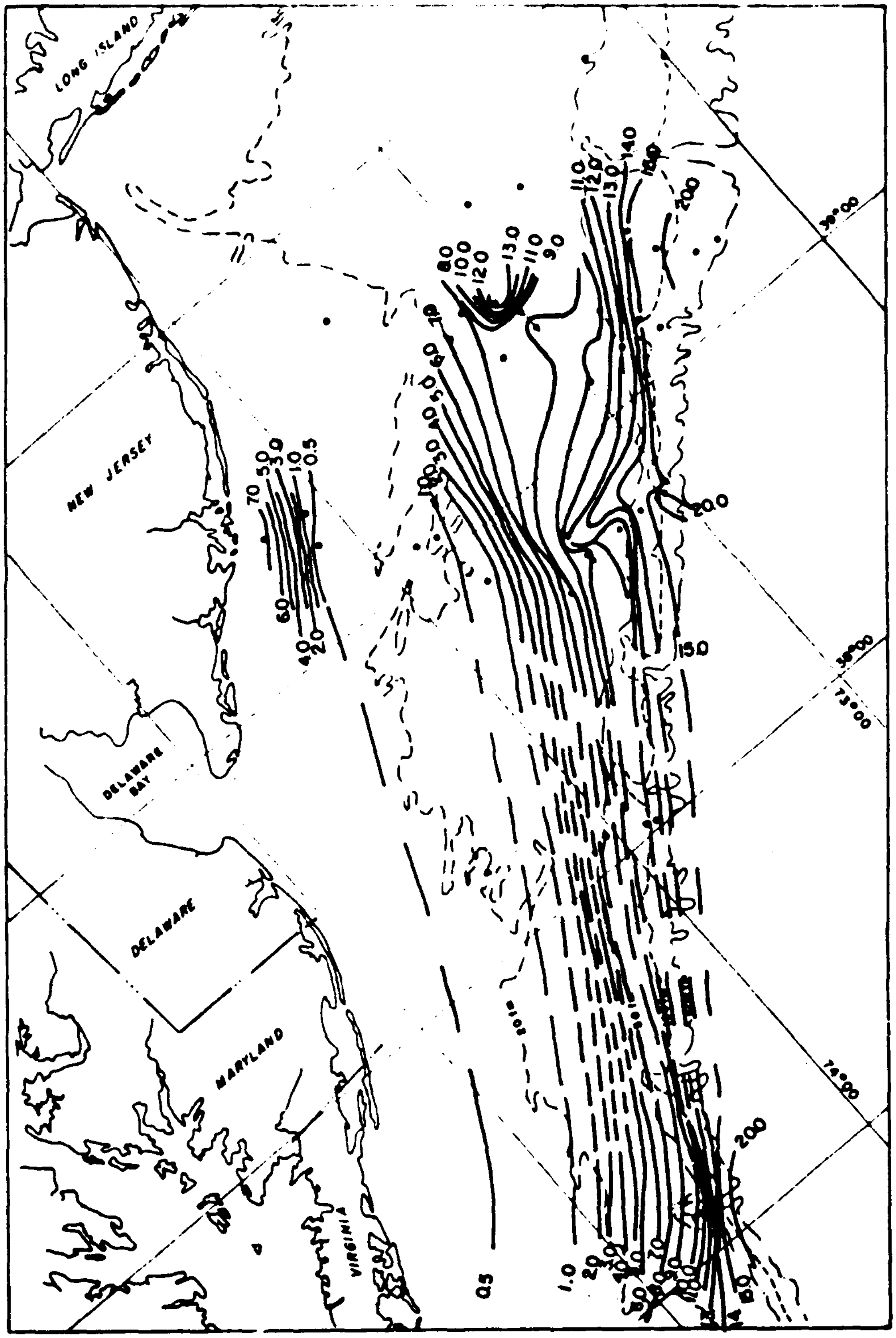


Figure 3-9e. Bottom dissolved nitrate (μgm-at/l) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).

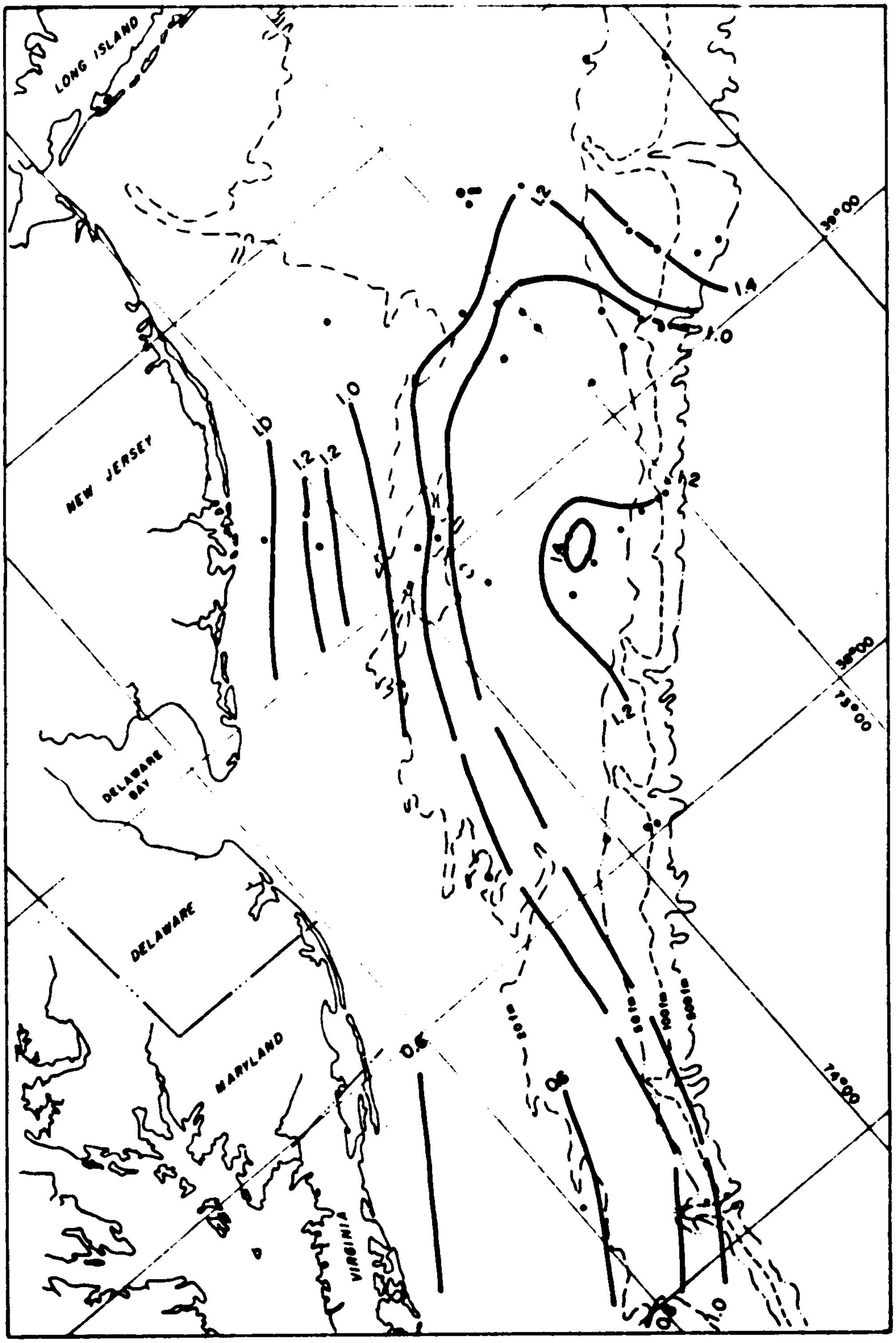
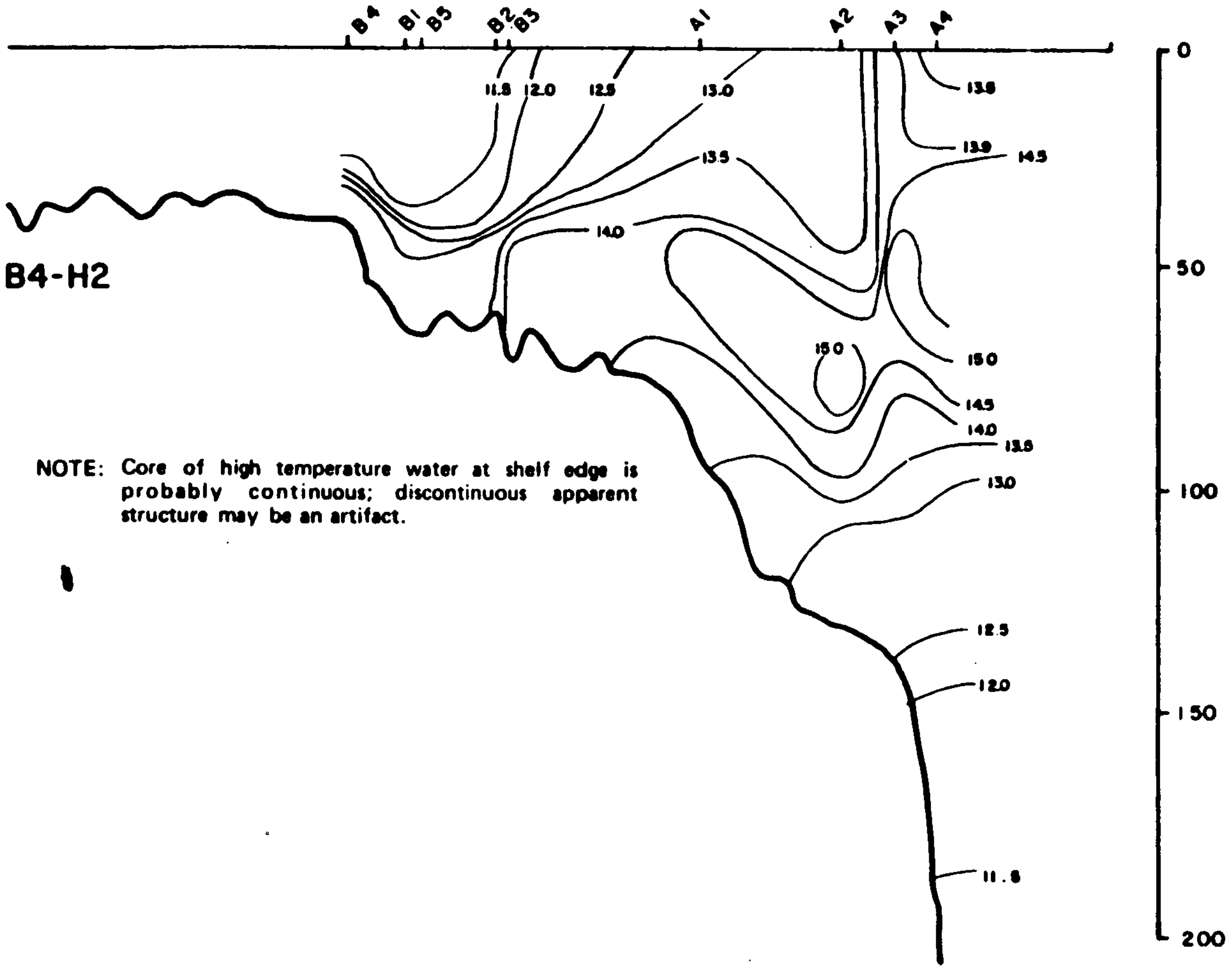


Figure 3-9f. Bottom dissolved phosphate (μgm-at/l) in the Middle Atlantic Bight during the period 4-18 November 1976 (Cruise BLM05B).



NOTE: Core of high temperature water at shelf edge is probably continuous; discontinuous apparent structure may be an artifact.

Figure 3-10a. Temperature (°C) contours for section II (Figure 3-6) during cruise BLM05B. Station locations on the sections and designations are indicated at the top of sections. Depths are in meters.

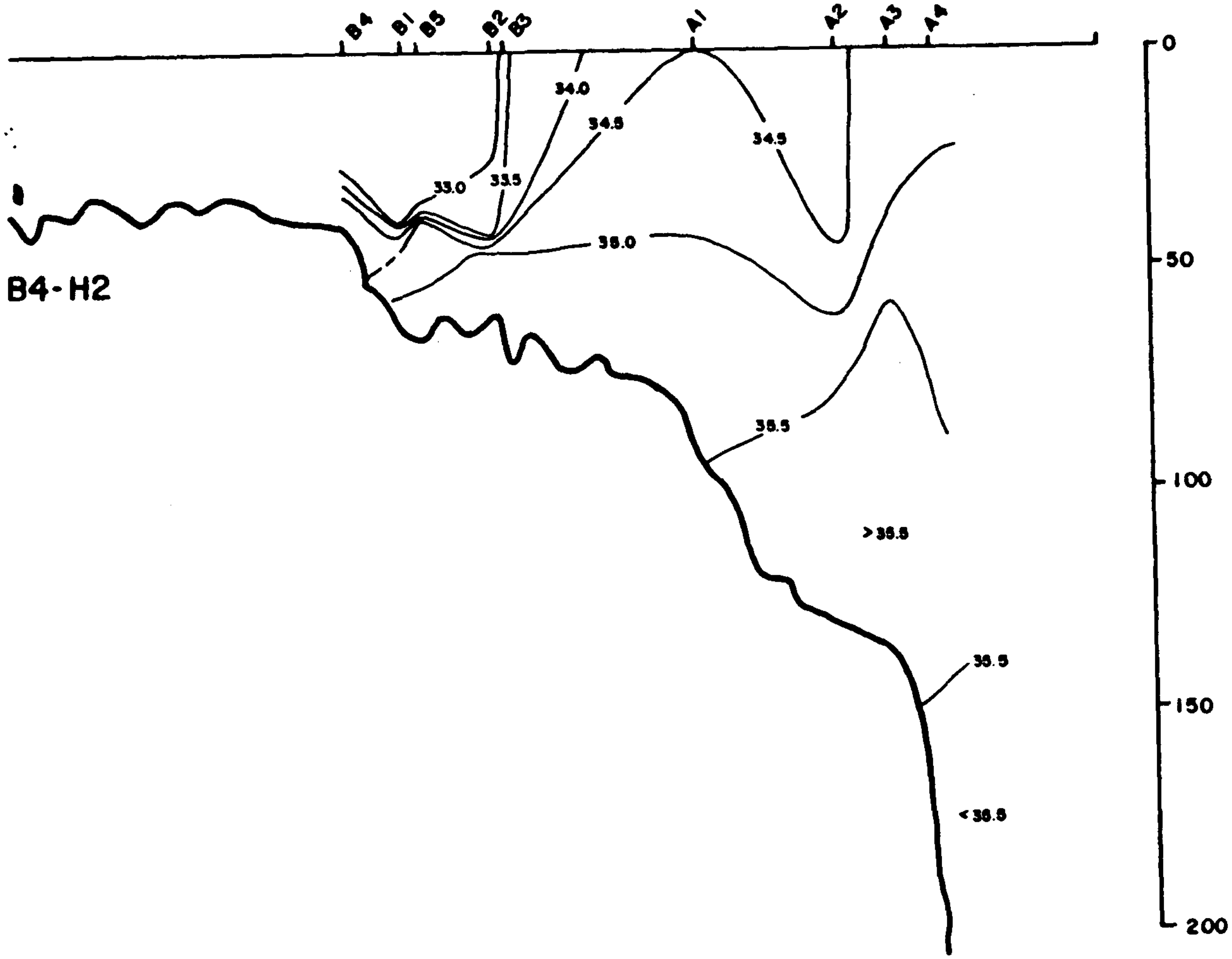


Figure 3-10b. Salinity (ppt) contours for section II (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

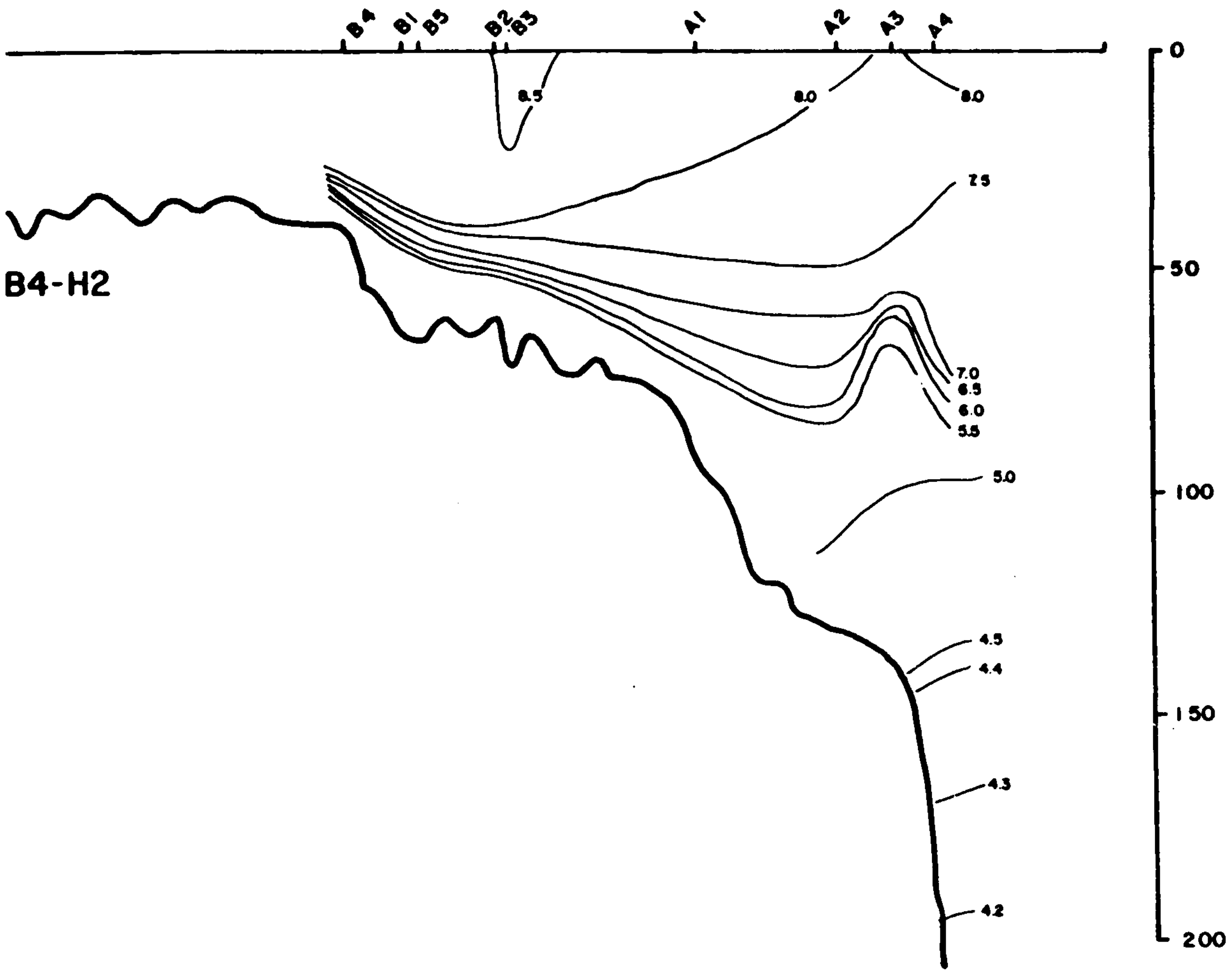


Figure 3-10c. Dissolved oxygen (mg/l) contours for section II (Figure 3-6) during Cruise BLM05B. Station locations on the section and designations are indicated at the top of the sections. Depths are in meters.

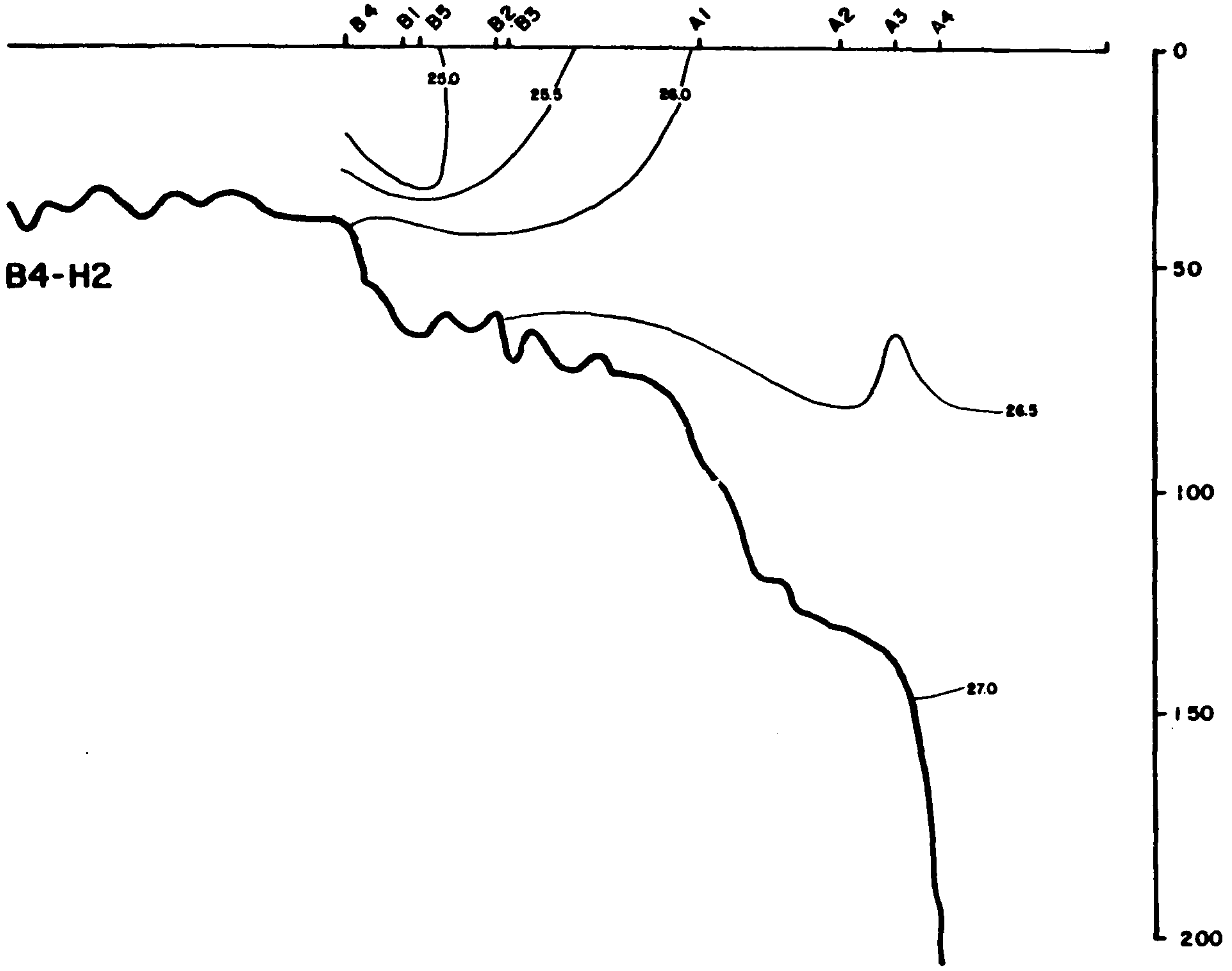
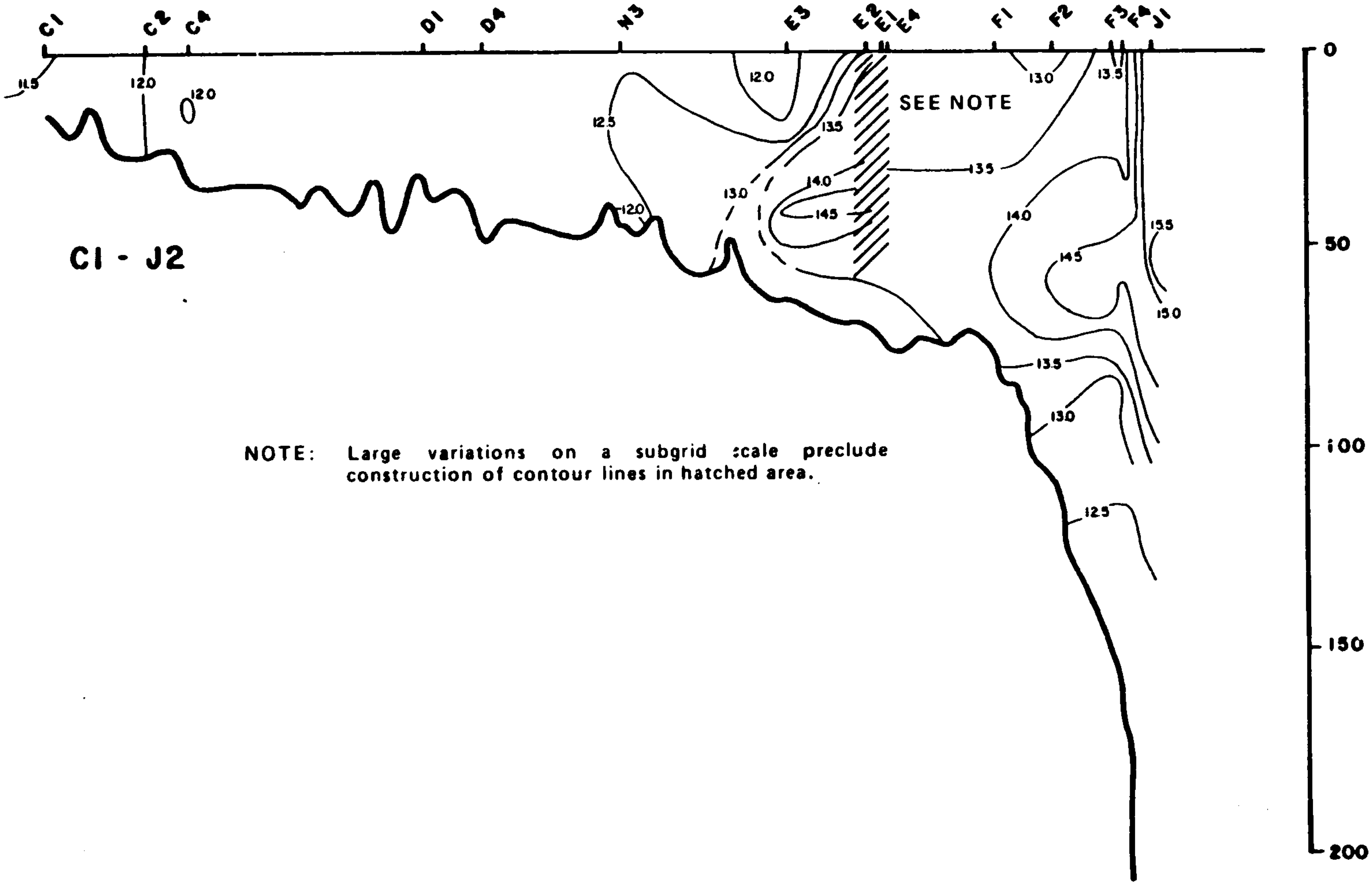
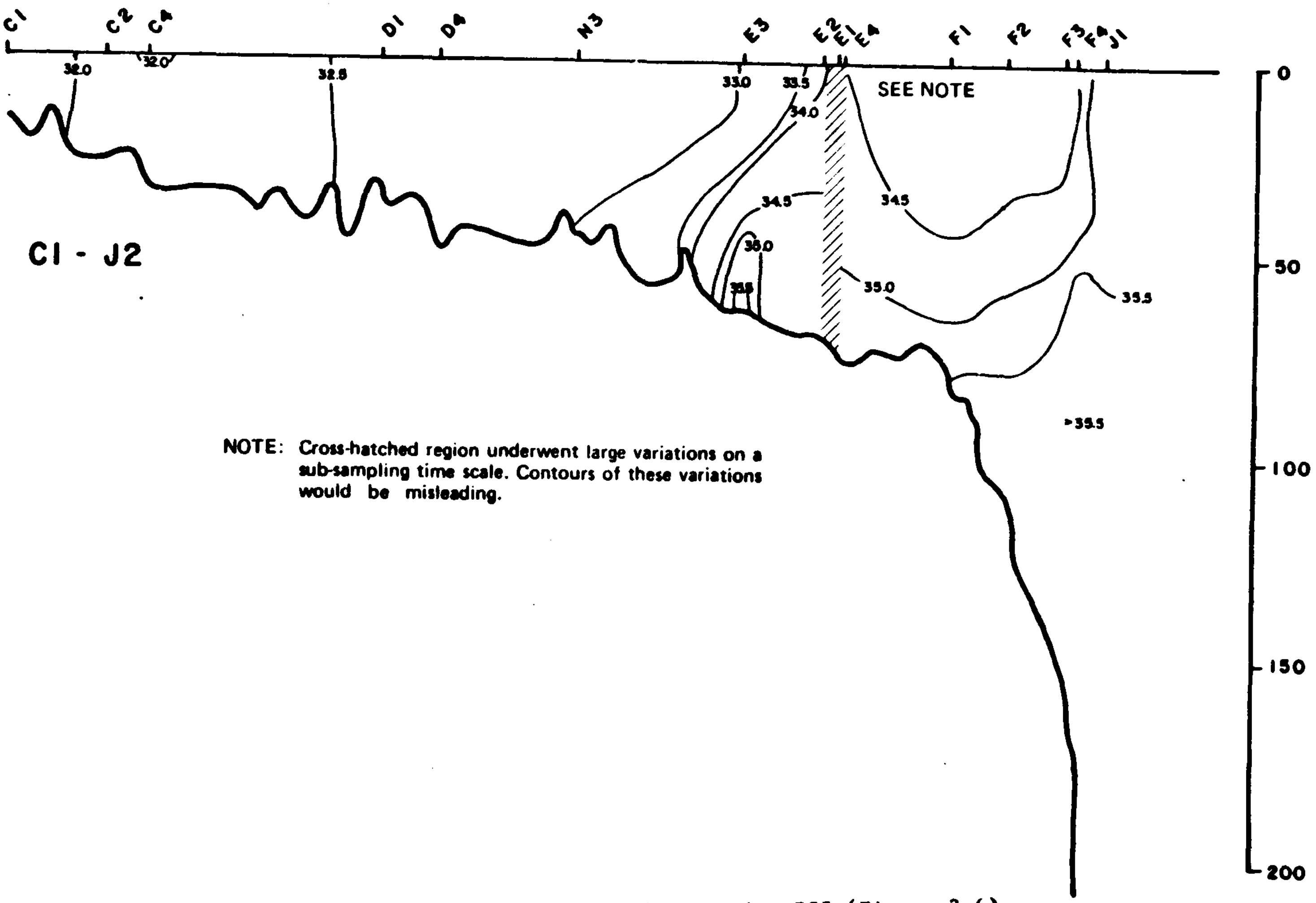


Figure 3-10d. Density (sigma-t units) contours for section II (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the sections. Depths are in meters.



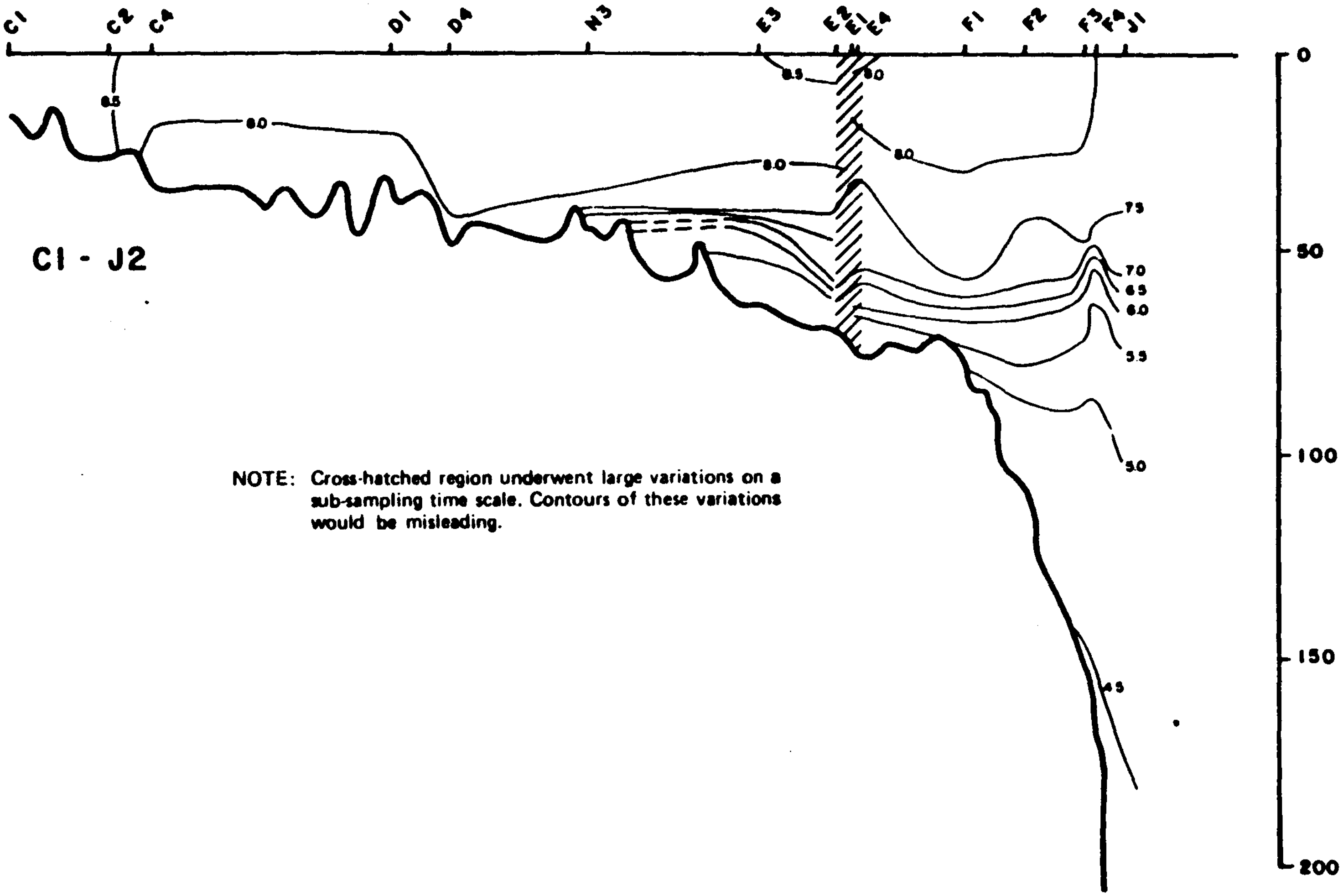
NOTE: Large variations on a subgrid scale preclude construction of contour lines in hatched area.

Figure 3-11a. Temperature (° C) contours for section III (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the sections. Depths are in meters.



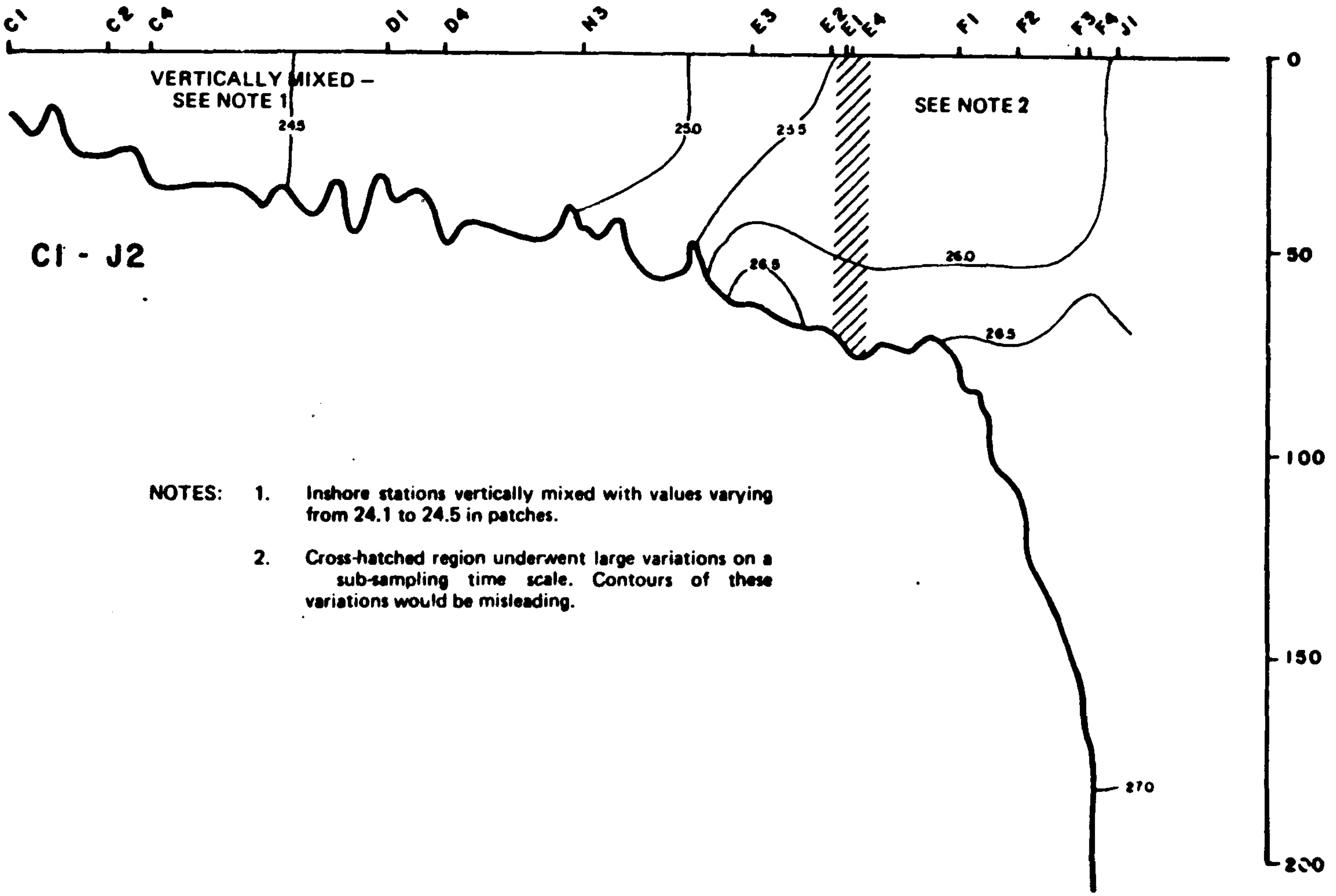
NOTE: Cross-hatched region underwent large variations on a sub-sampling time scale. Contours of these variations would be misleading.

Figure 3-11b. Salinity (ppt) contours for section III (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Cross-hatched region underwent large variations on a sub-sampling time scale. Contours of these variations would be misleading.

Figure 3-11c. Dissolved oxygen (mg/l) contours for section III (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES:
1. Inshore stations vertically mixed with values varying from 24.1 to 24.5 in patches.
2. Cross-hatched region underwent large variations on a sub-sampling time scale. Contours of these variations would be misleading.

Figure 3-11d. Density (sigma-t units) contours for section III (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

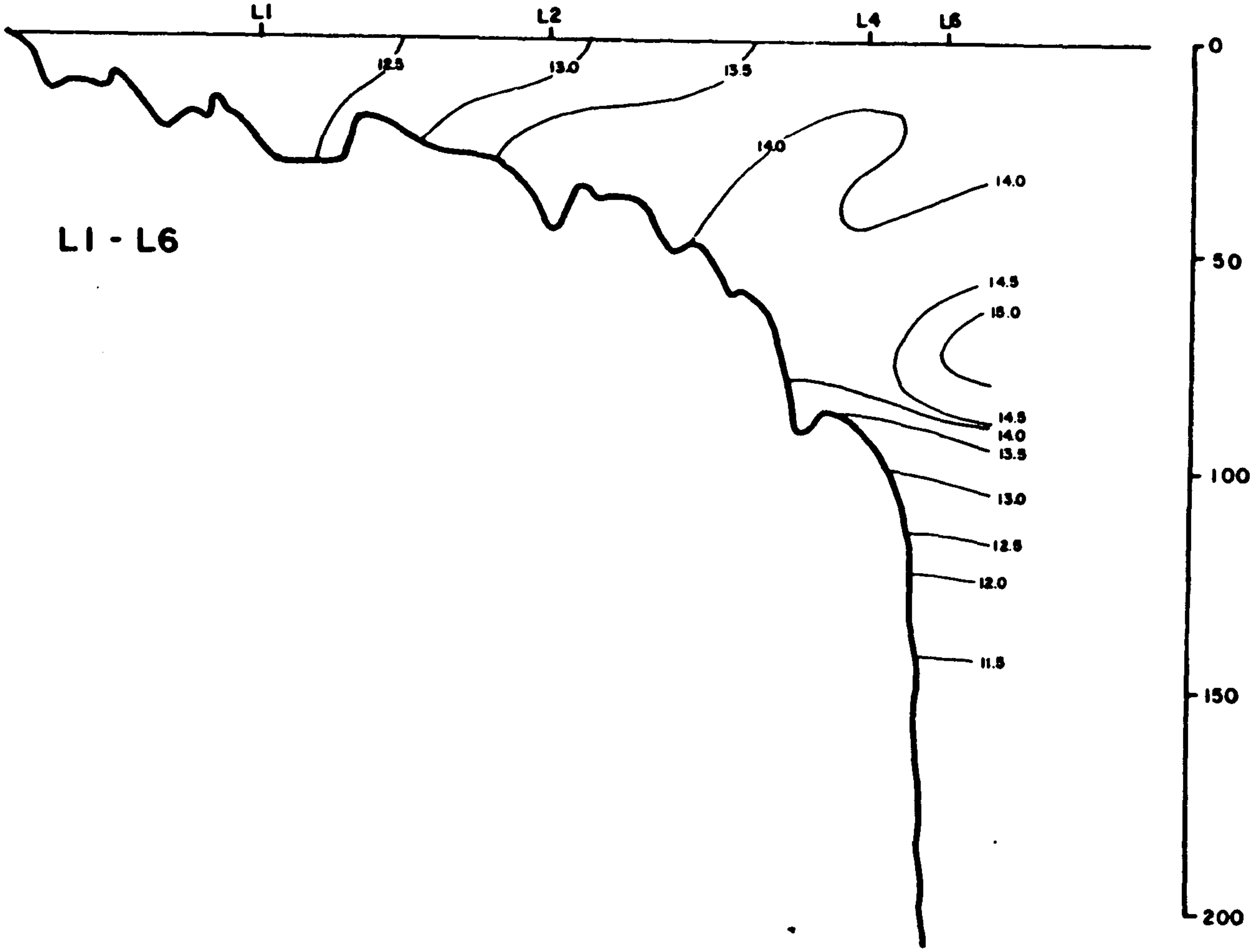


Figure 3-12a. Temperature (°C) contours for section V (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

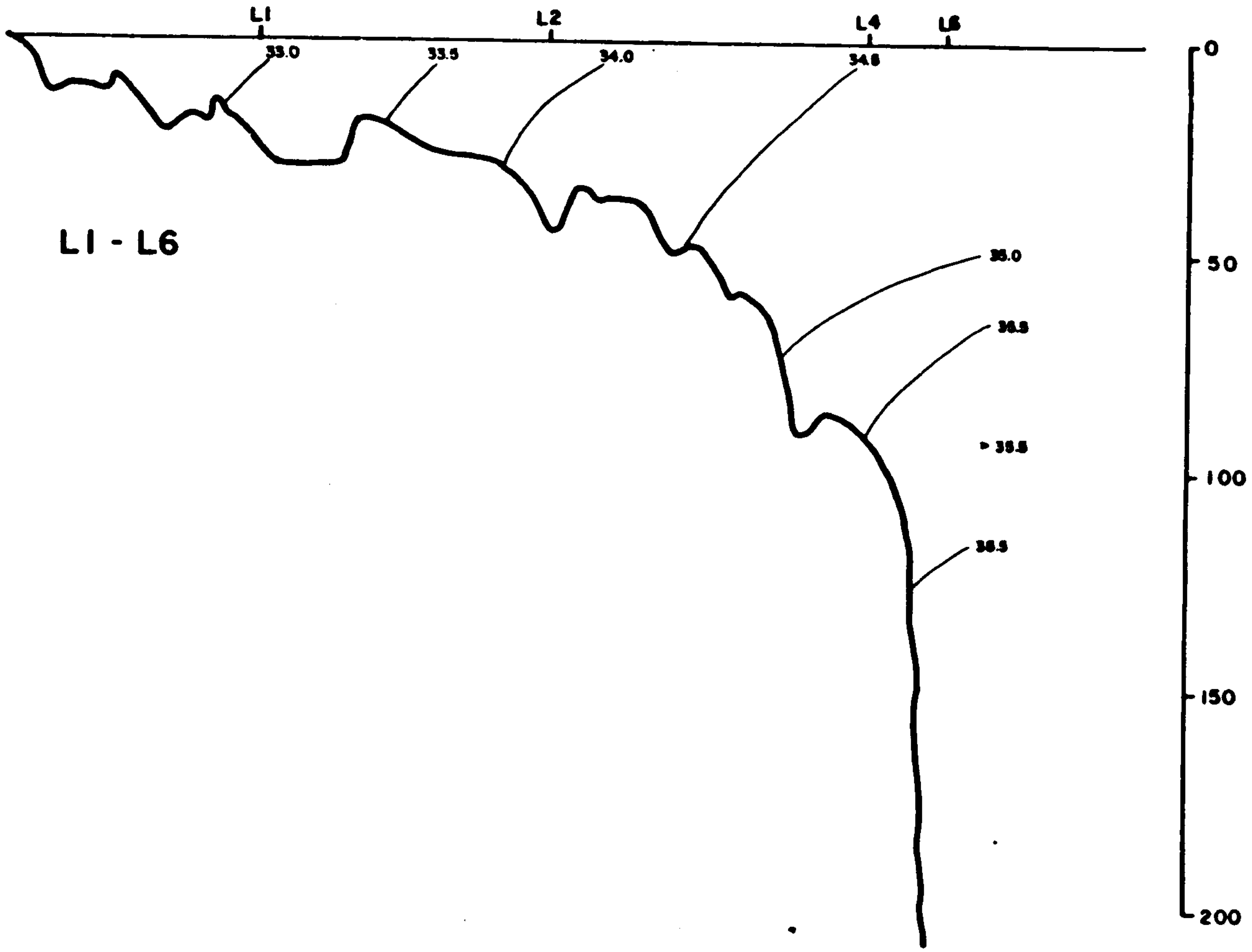


Figure 3-12b. Salinity (ppt) contours for section V (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

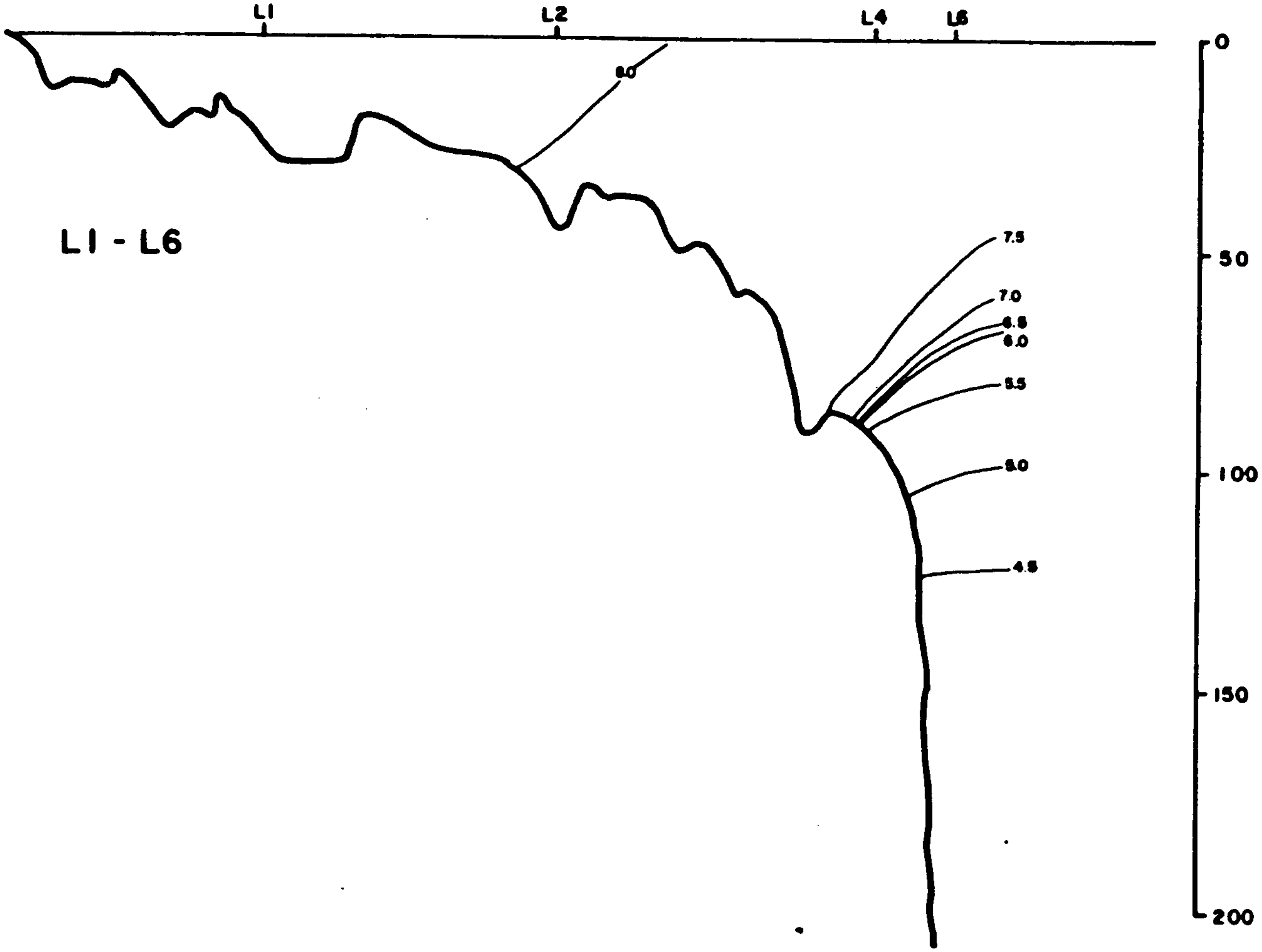


Figure 3-12c. Dissolved oxygen (mg/l) contours for section V (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

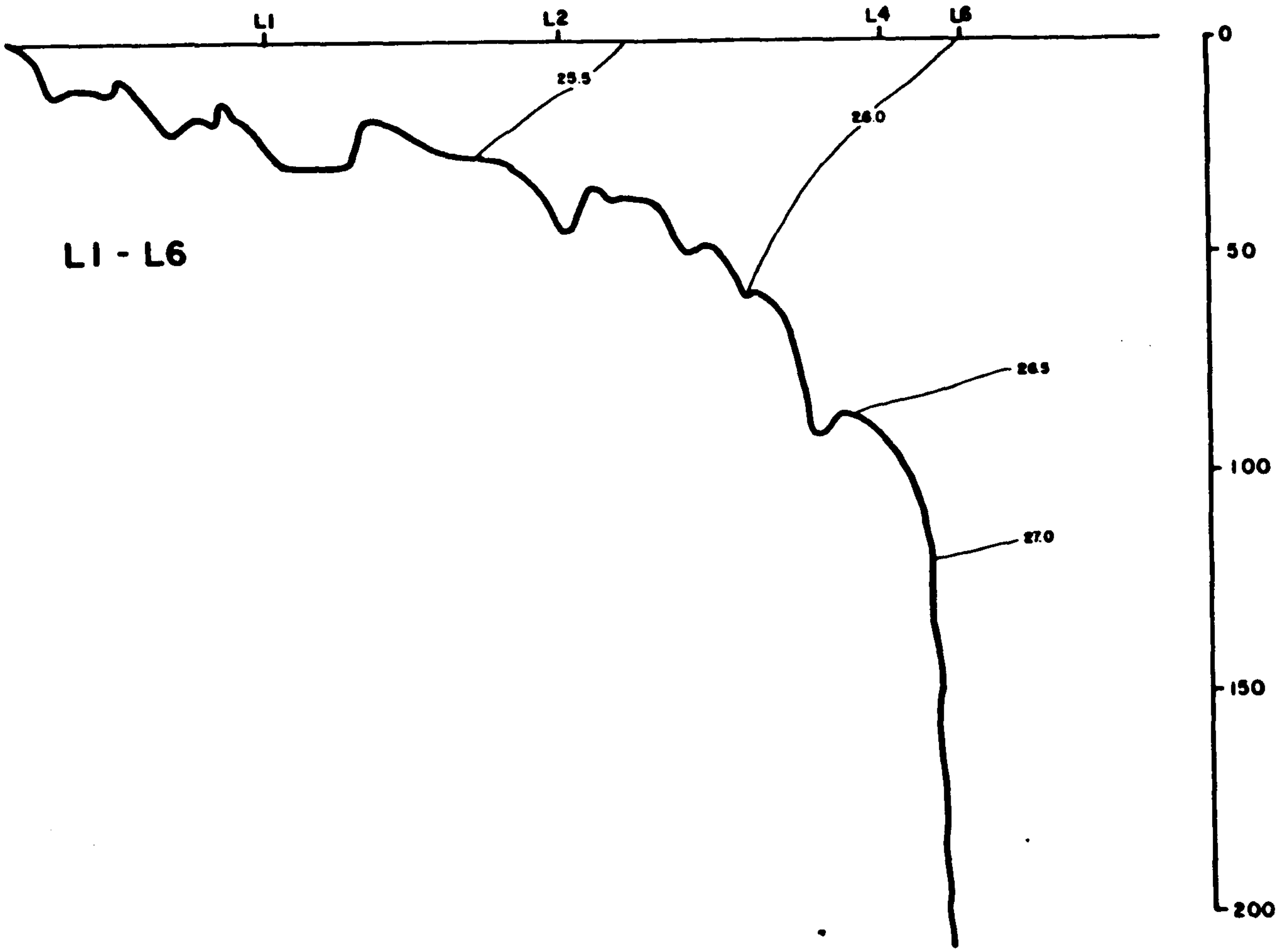


Figure 3-12d. Density (sigma-t units) contours for section V (Figure 3-6) during cruise BLM05B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

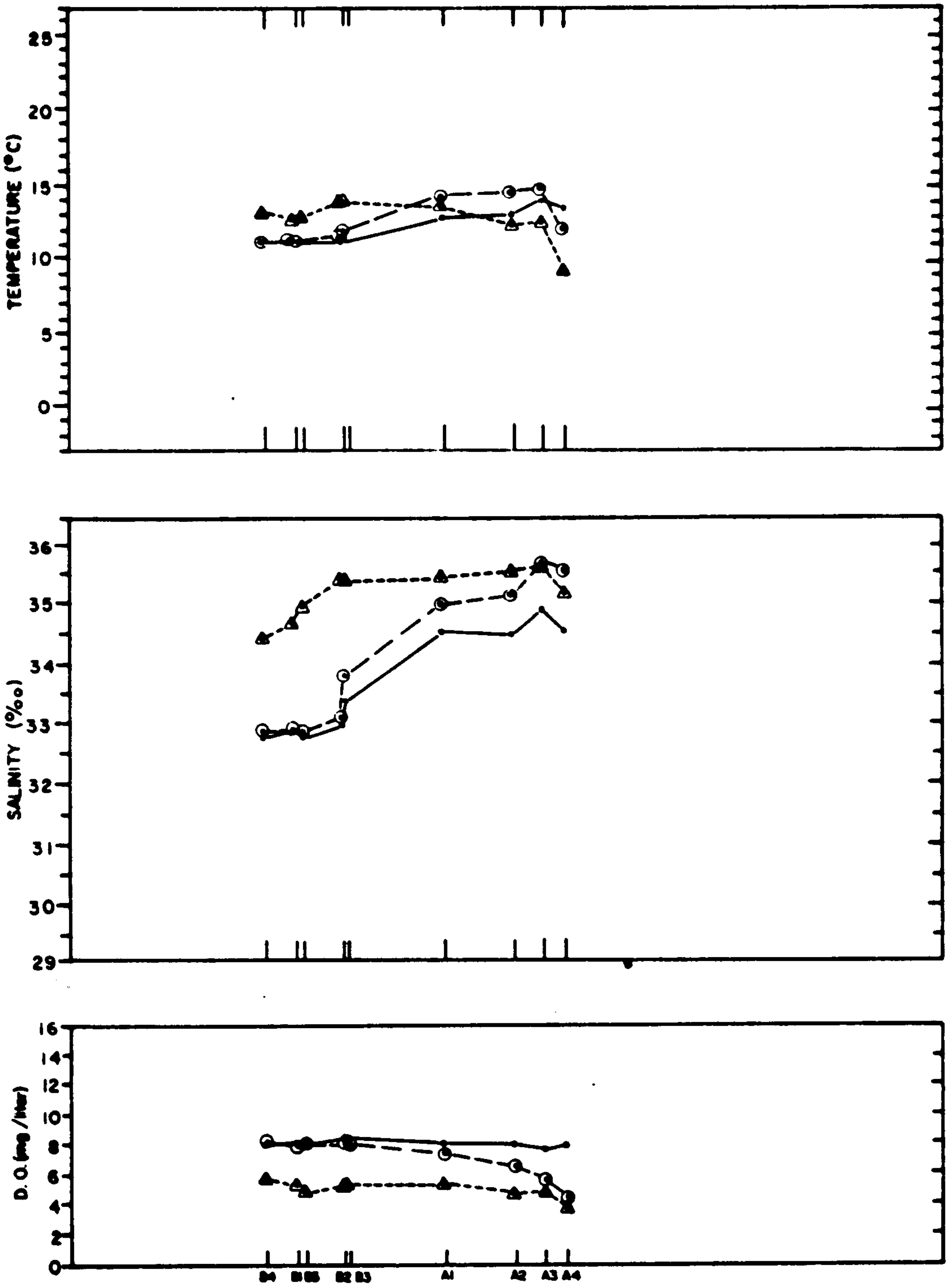


Figure 3-13. Surface (·), mid depth (θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-5) during cruise BLM05B.

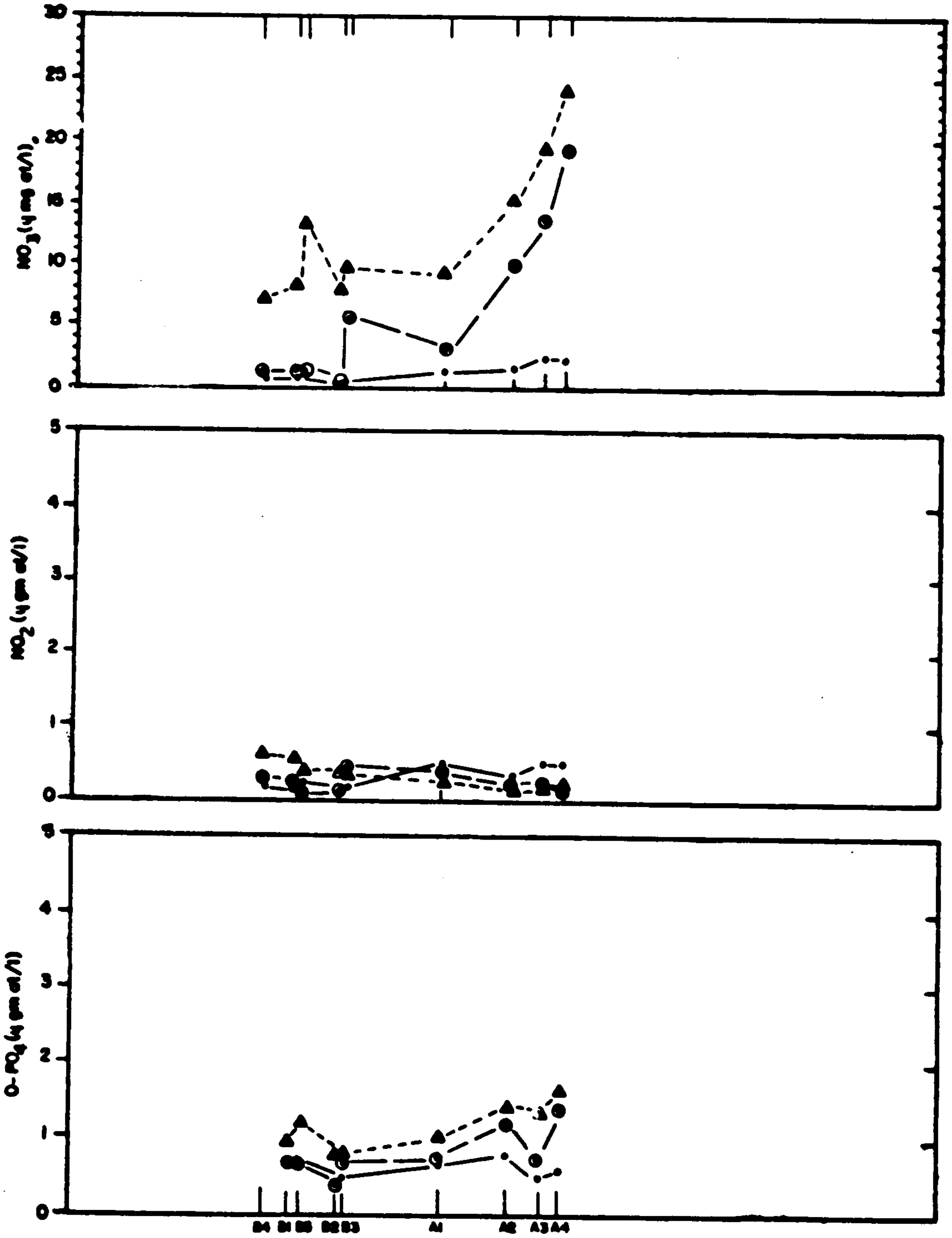


Figure 3-14. Surface (•), mid depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-1) during cruise BLM05B.

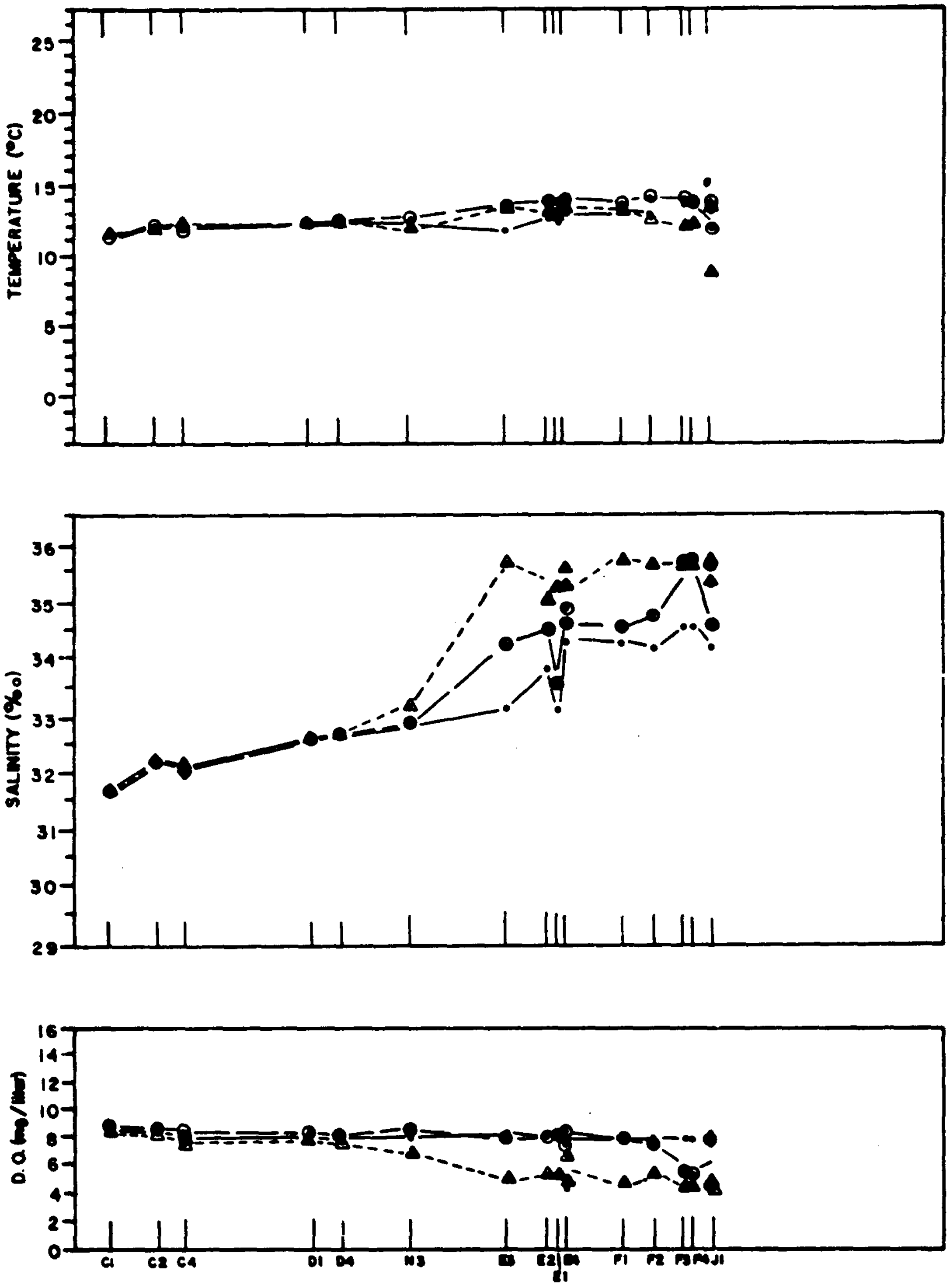


Figure 3-15. Surface (•), mid depth (Θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM05B.

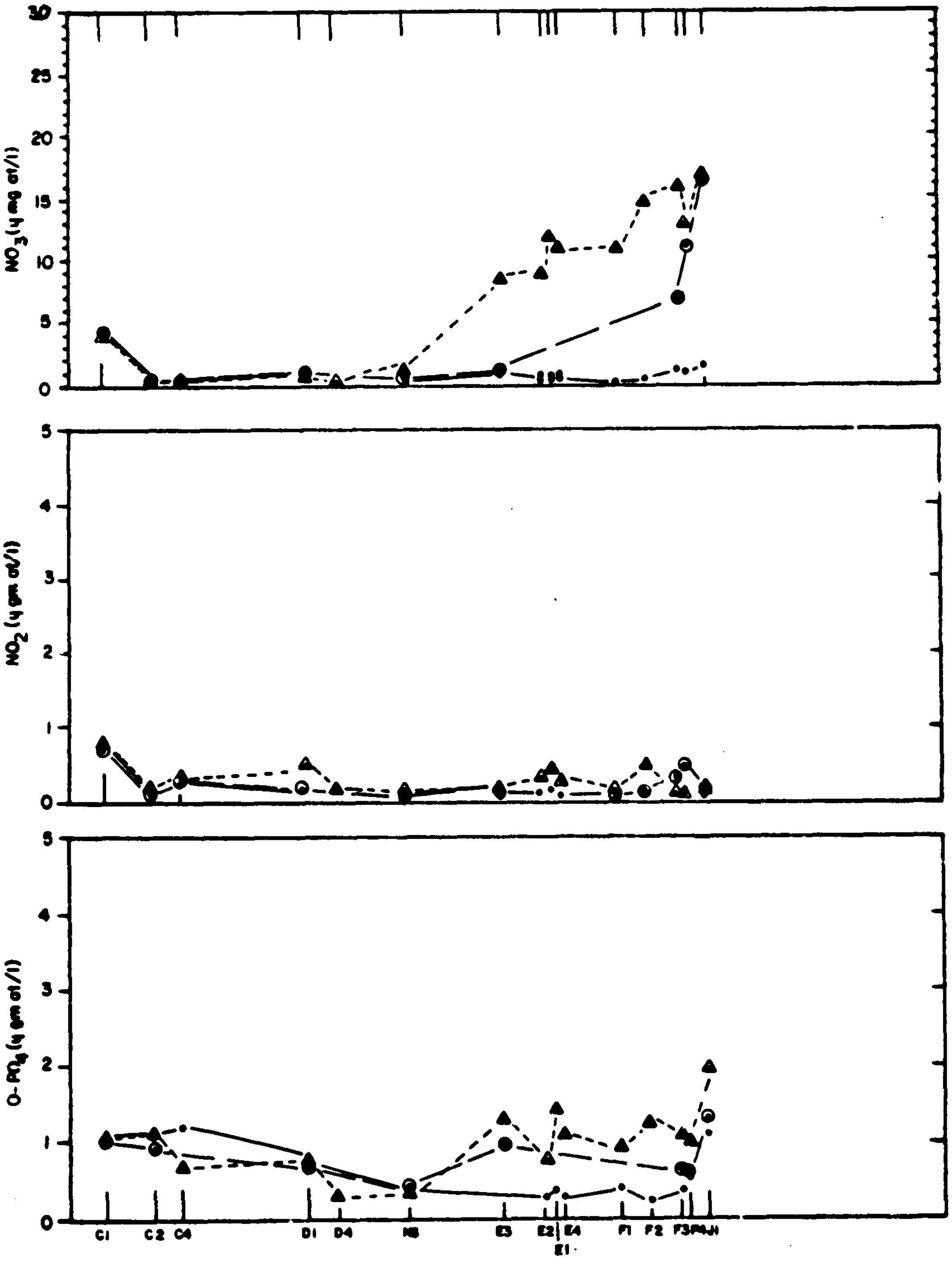


Figure 3-16. Surface (•), mid-depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM05B.

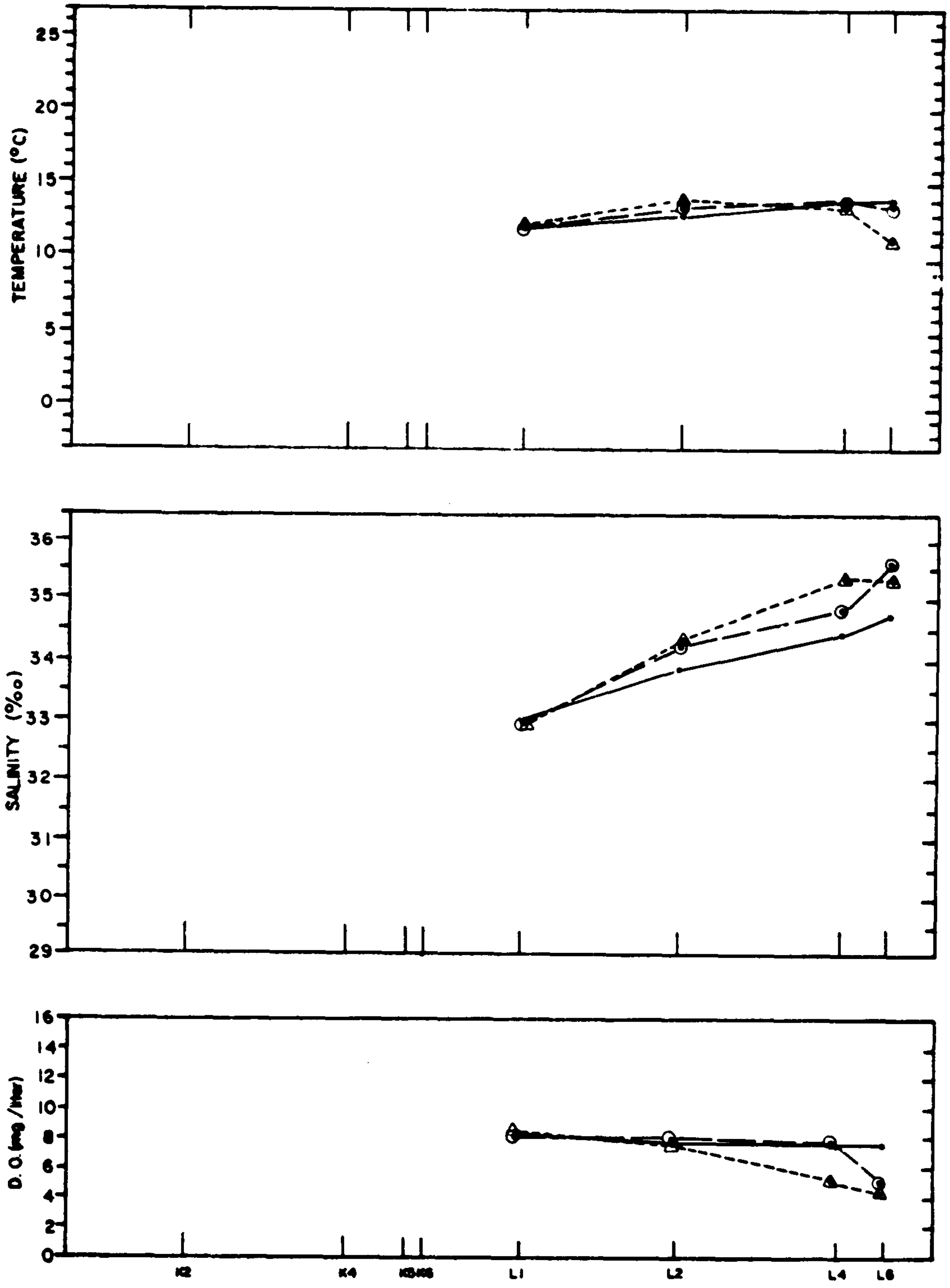


Figure 3-17. Surface (•), mid-depth (⊙), and bottom (Δ) values of temperature, salinity and dissolved oxygen measured along section V (Figure 3-6) during cruise BLM05B.

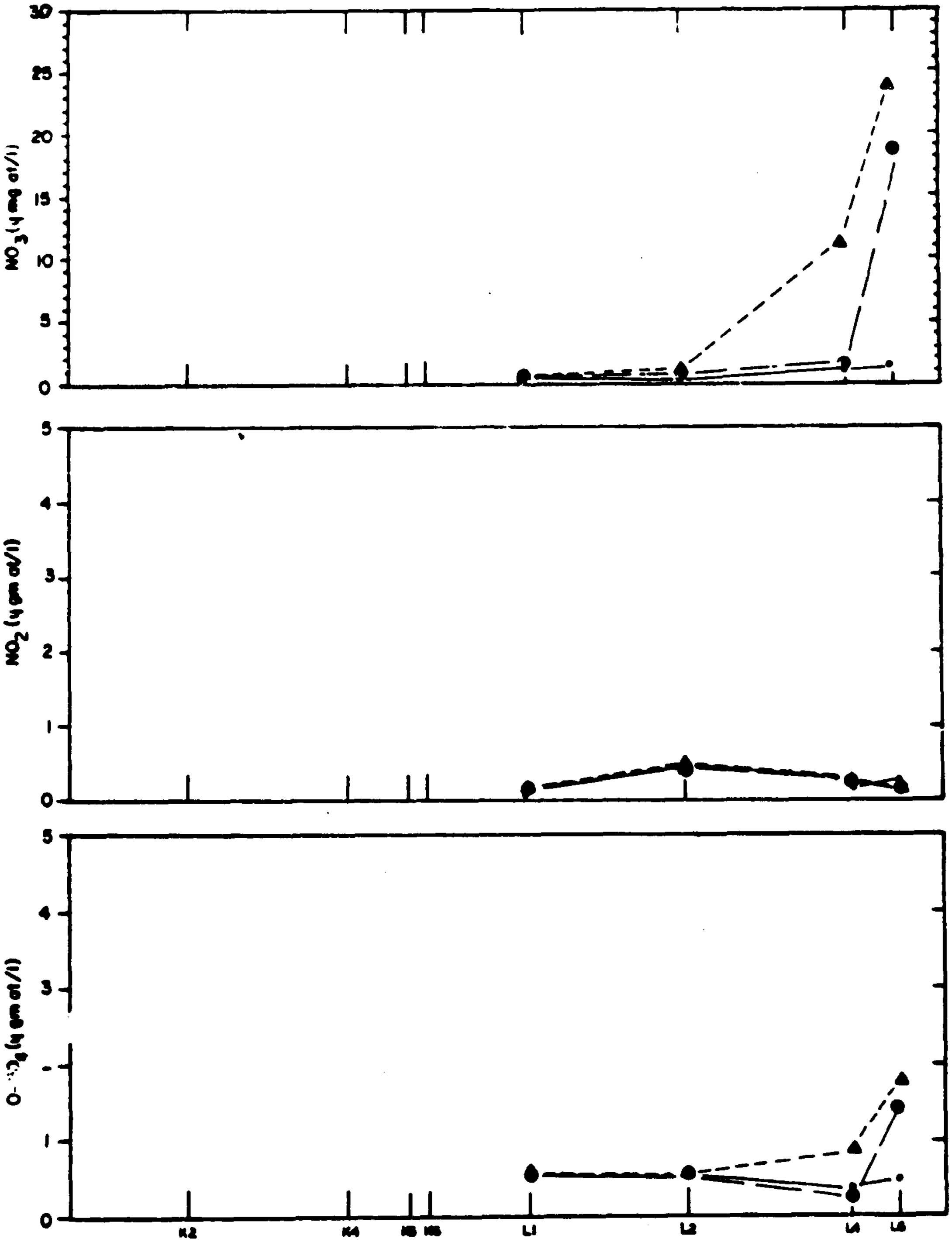


Figure 3-18. Surface (•), mid-depth (θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM05B.

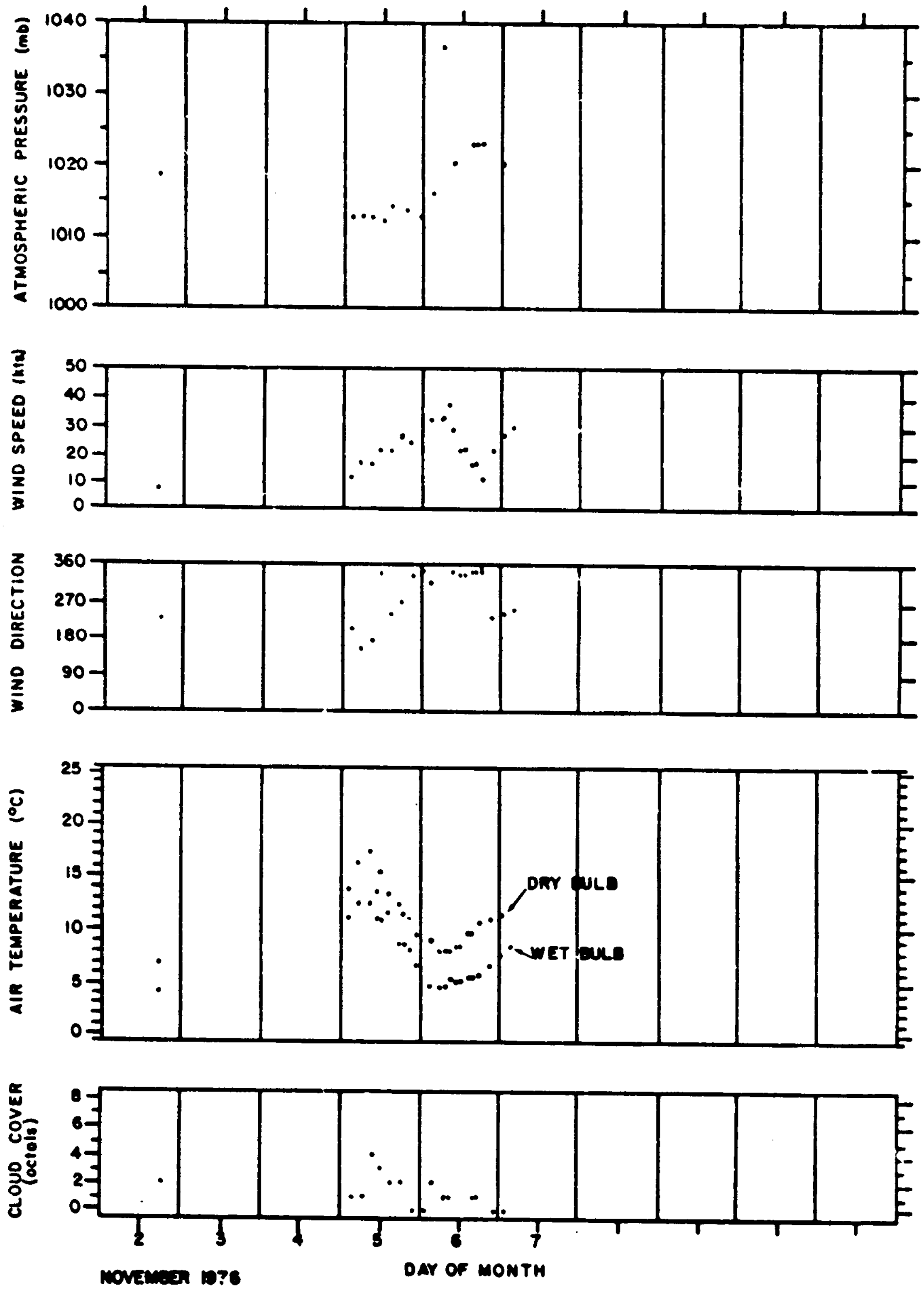


Figure 3-19a. Meteorological data collected during cruise BLM05W from 2 November to 7 November 1976.

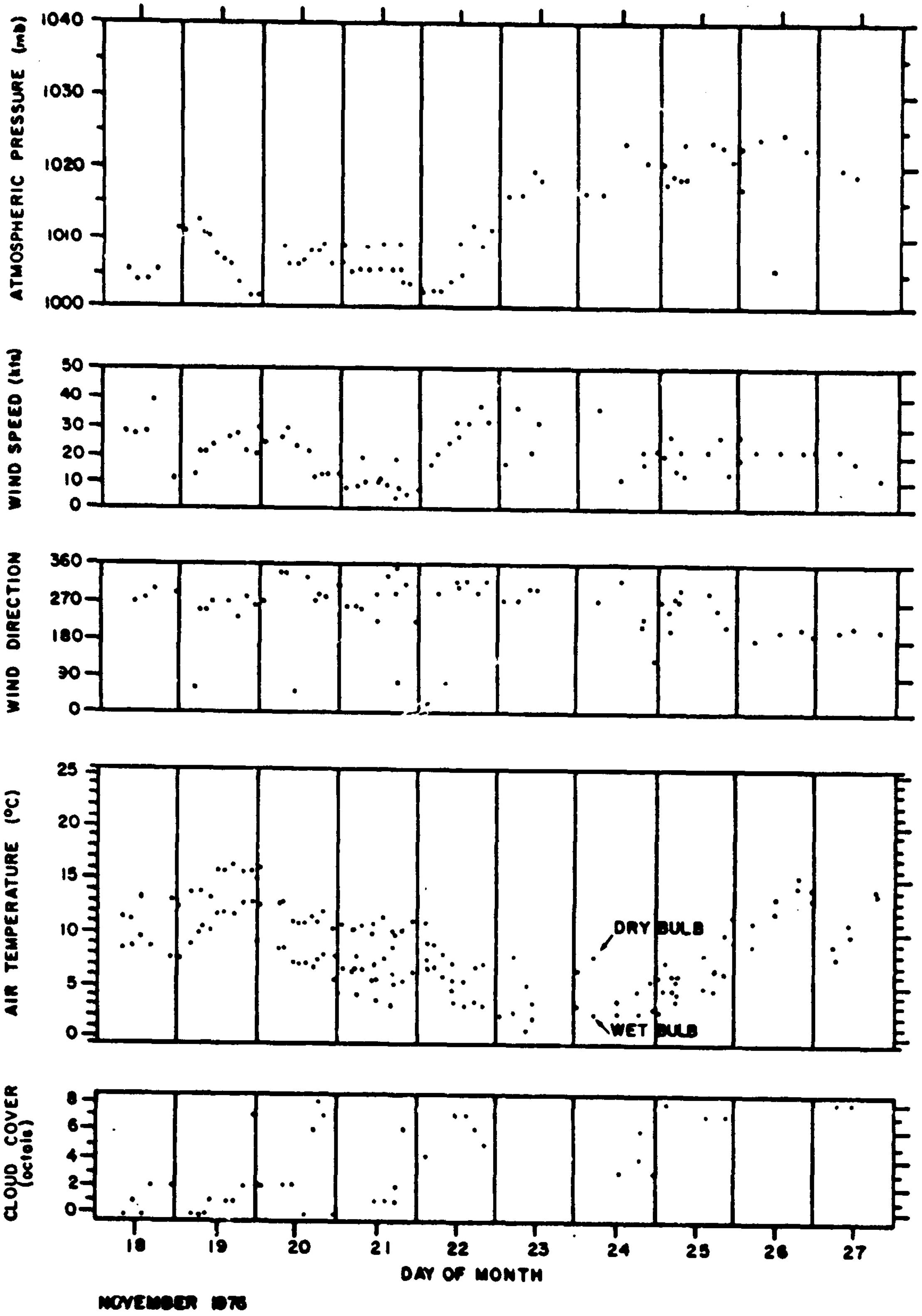


Figure 3-19b. Meteorological data collected during cruise BLM05W from 18 November to 27 November 1976.

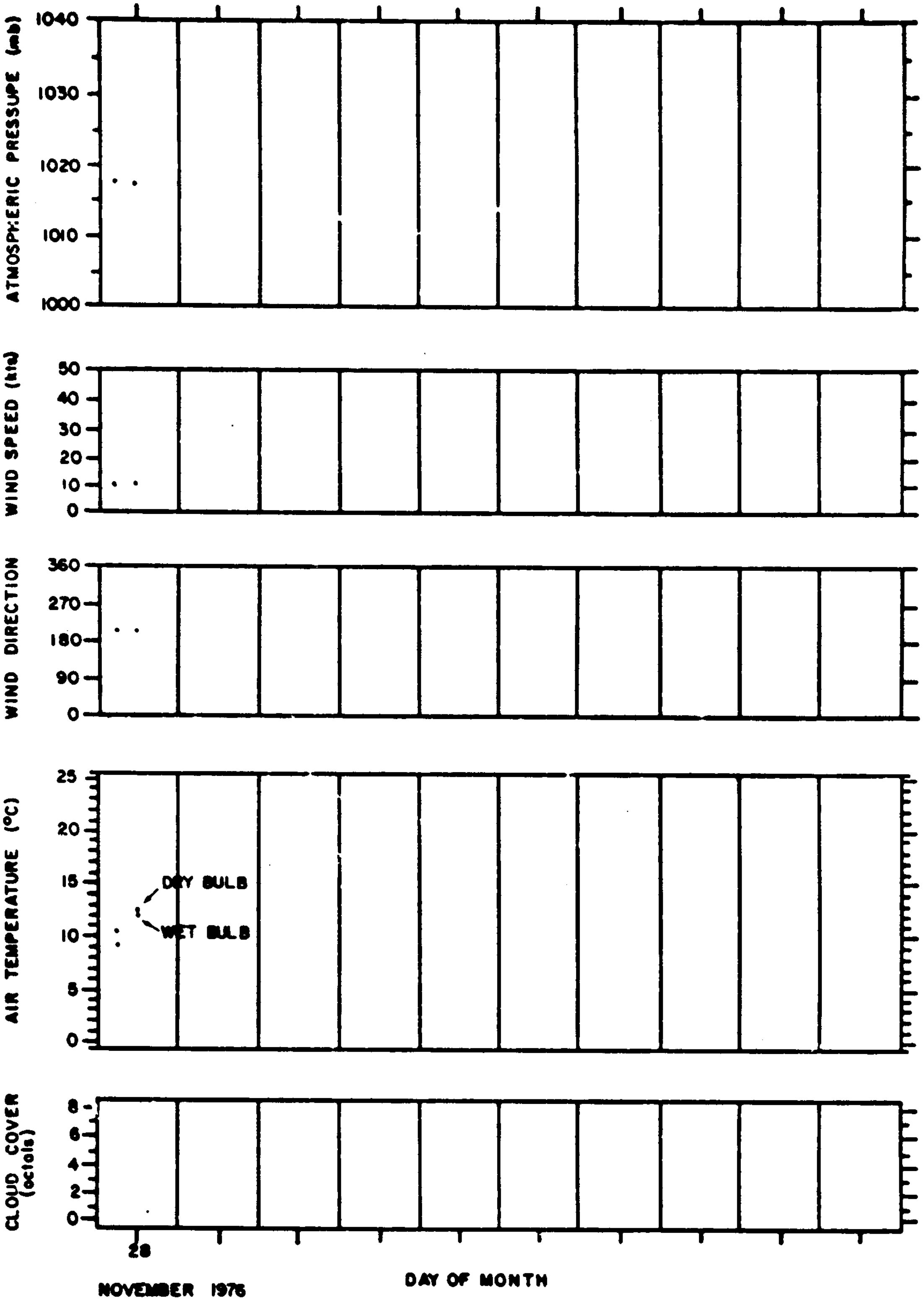


Figure 3-19c. Meteorological data collected during cruise BLM05W on 28 November 1976.

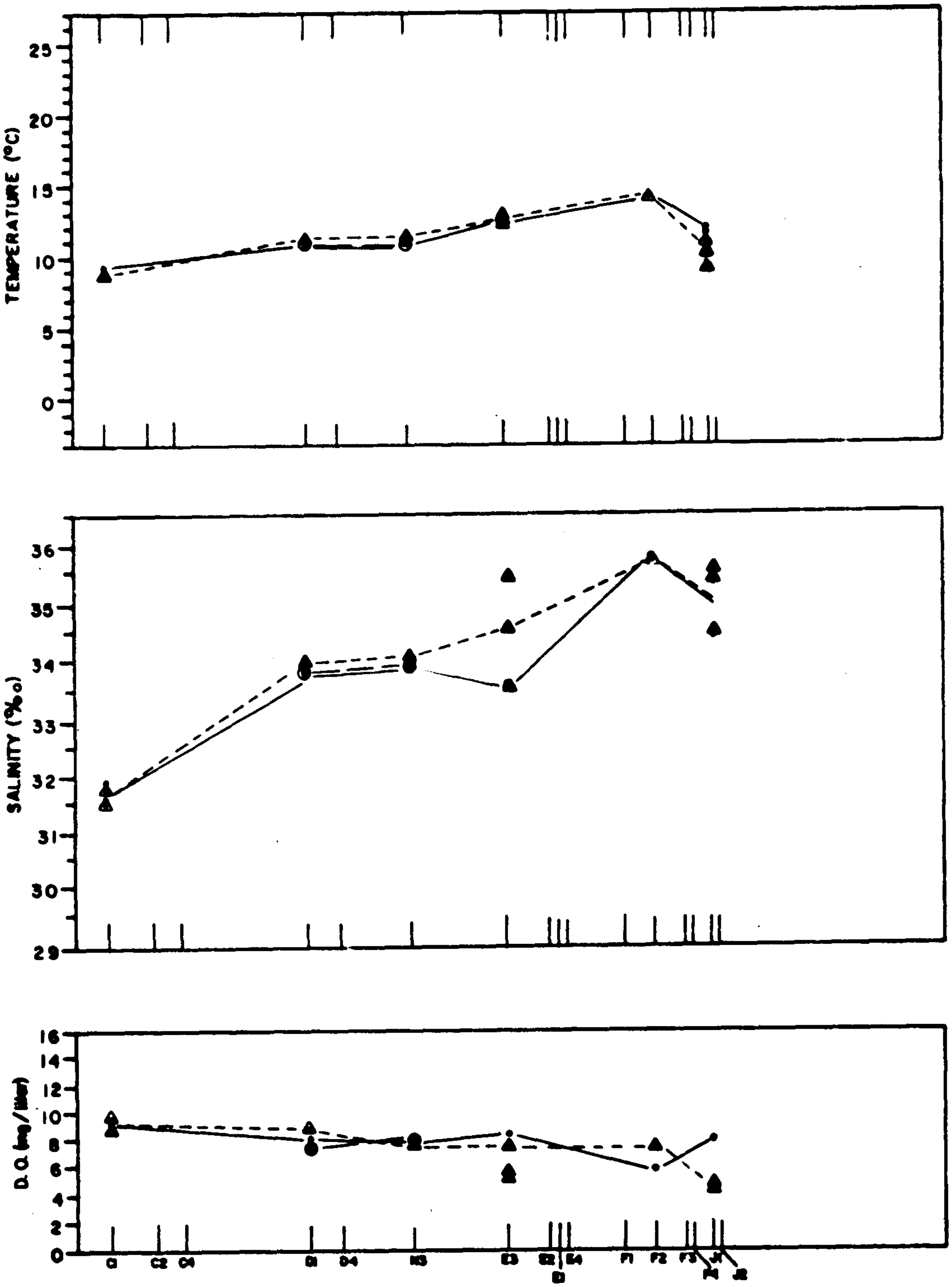


Figure 3-20. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM05W.

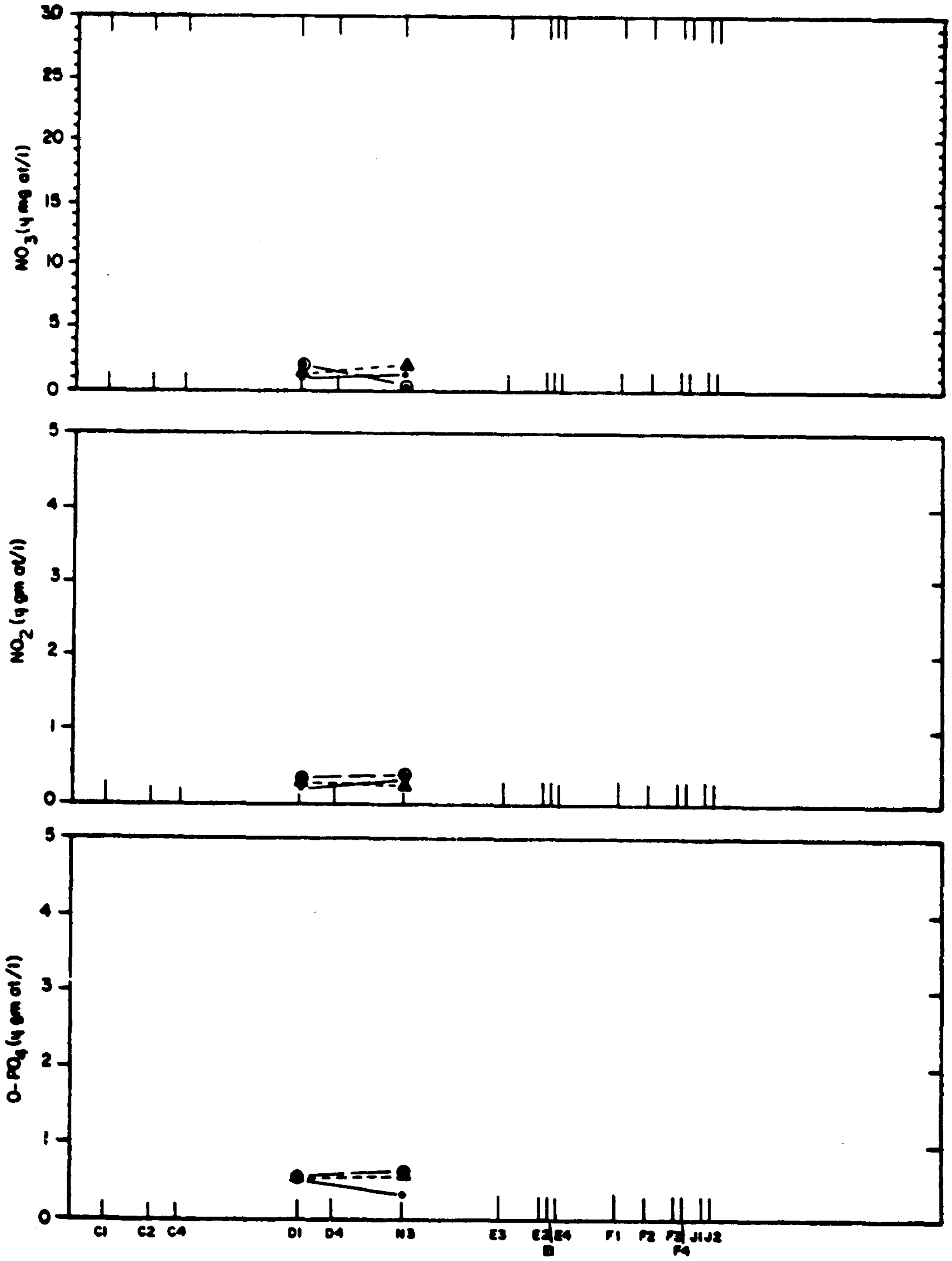


Figure 3-21. Surface (·), mid-depth (θ) and bottom (Å) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM05W.

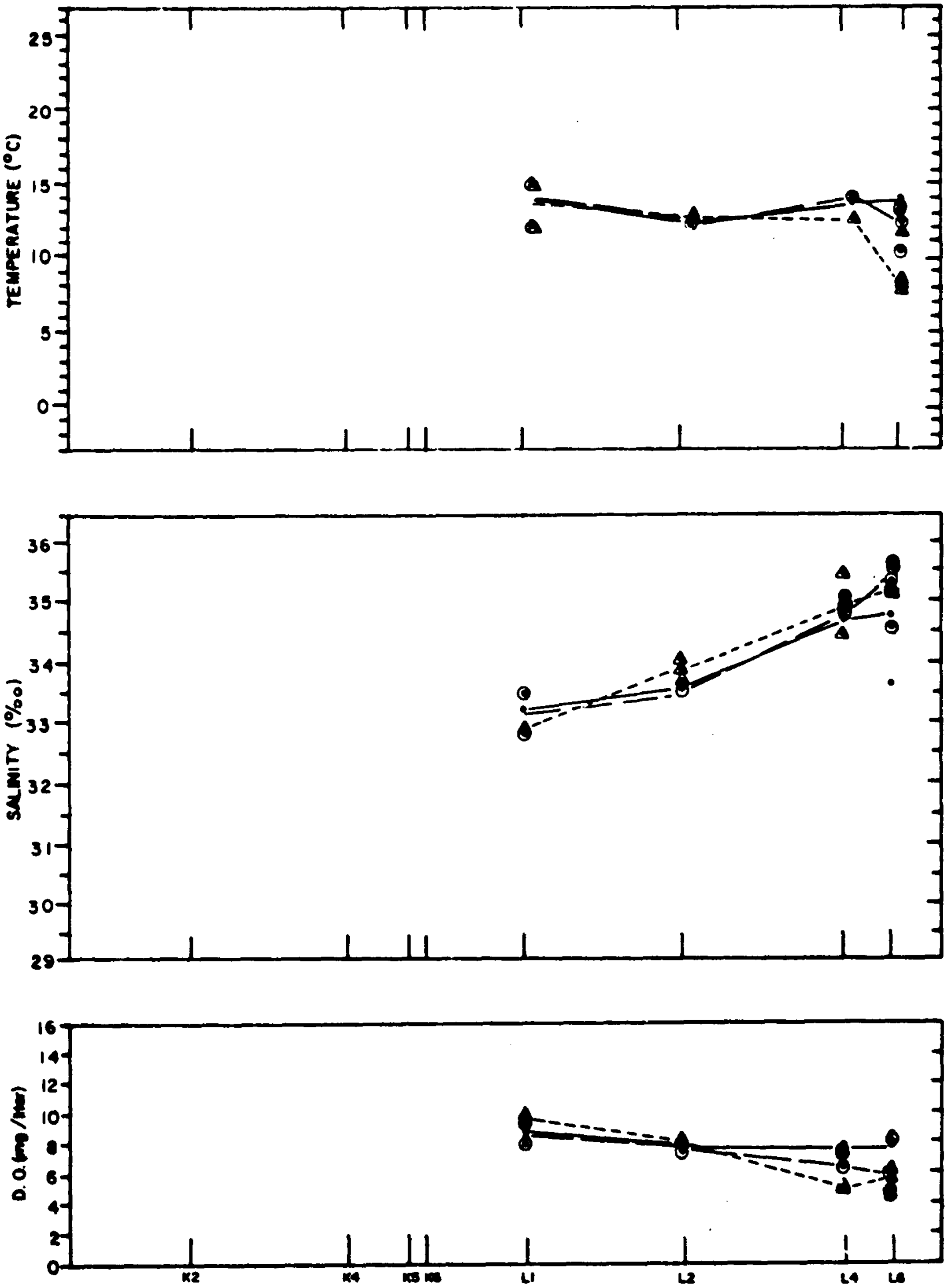


Figure 3-22. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section V (Figure 3-6) during cruise BLM05W.

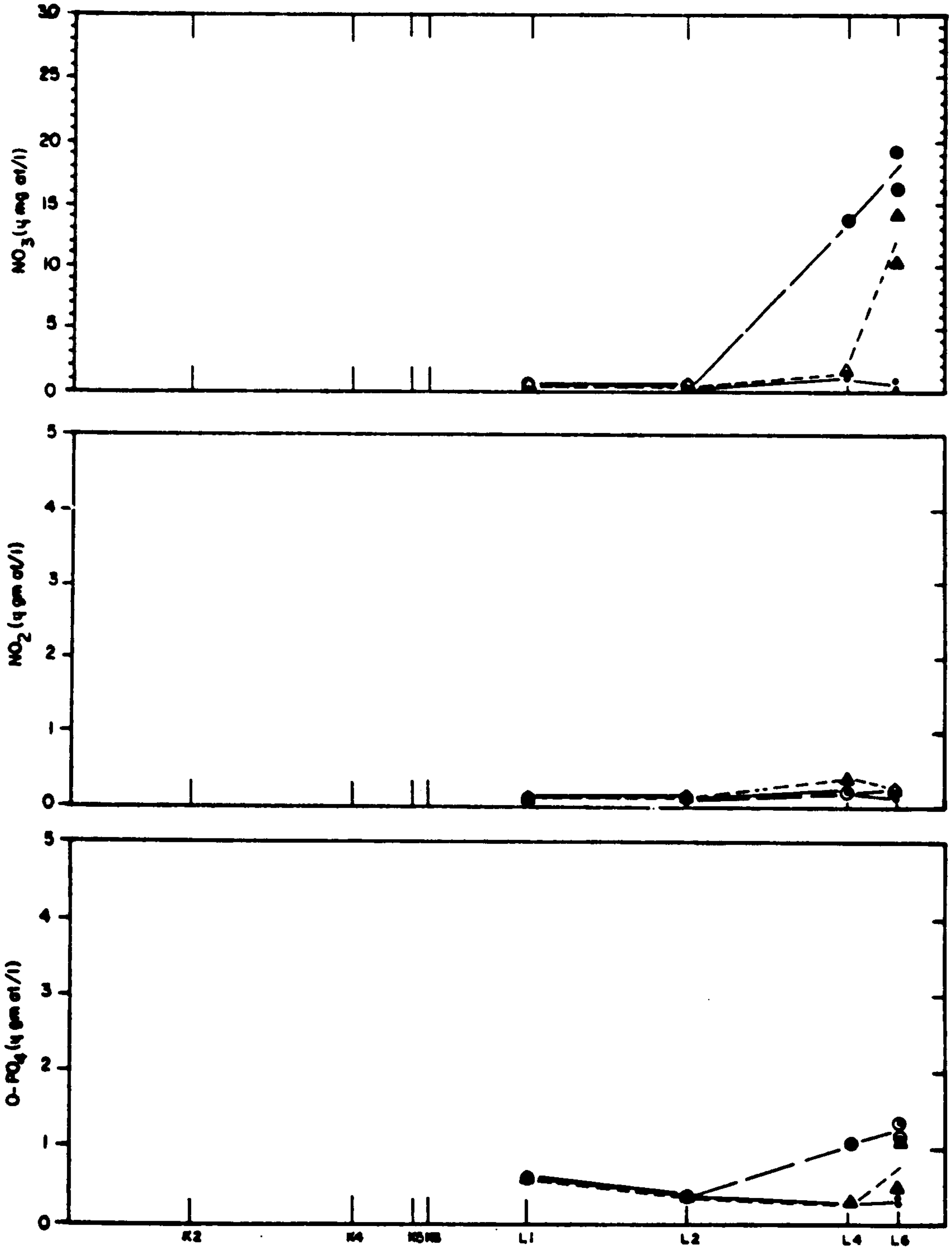


Figure 3-23. Surface (•), mid-depth (θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM05W).

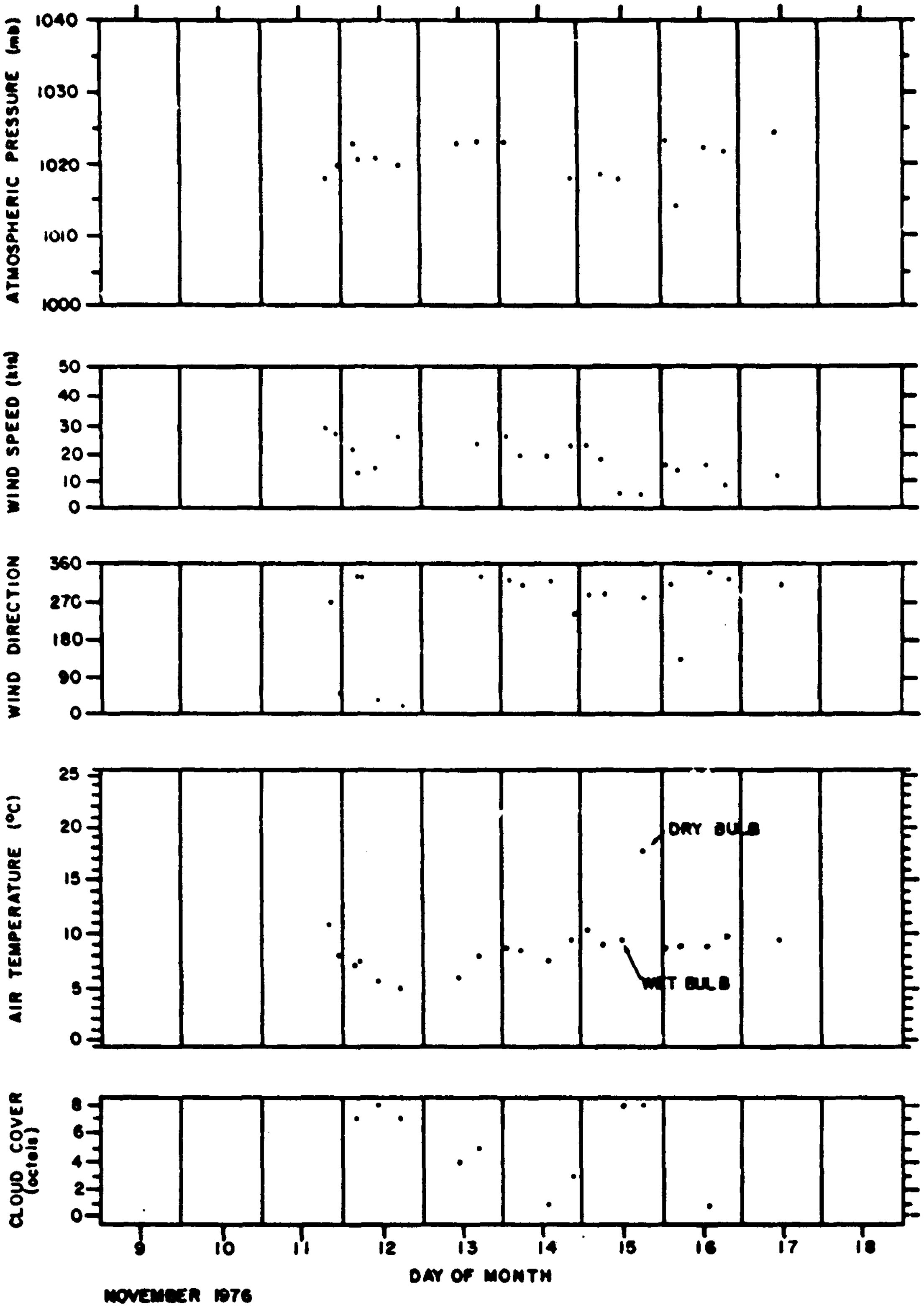


Figure 3-24. Meteorological data collected during cruise BLM05T from 11-17 November 1976.

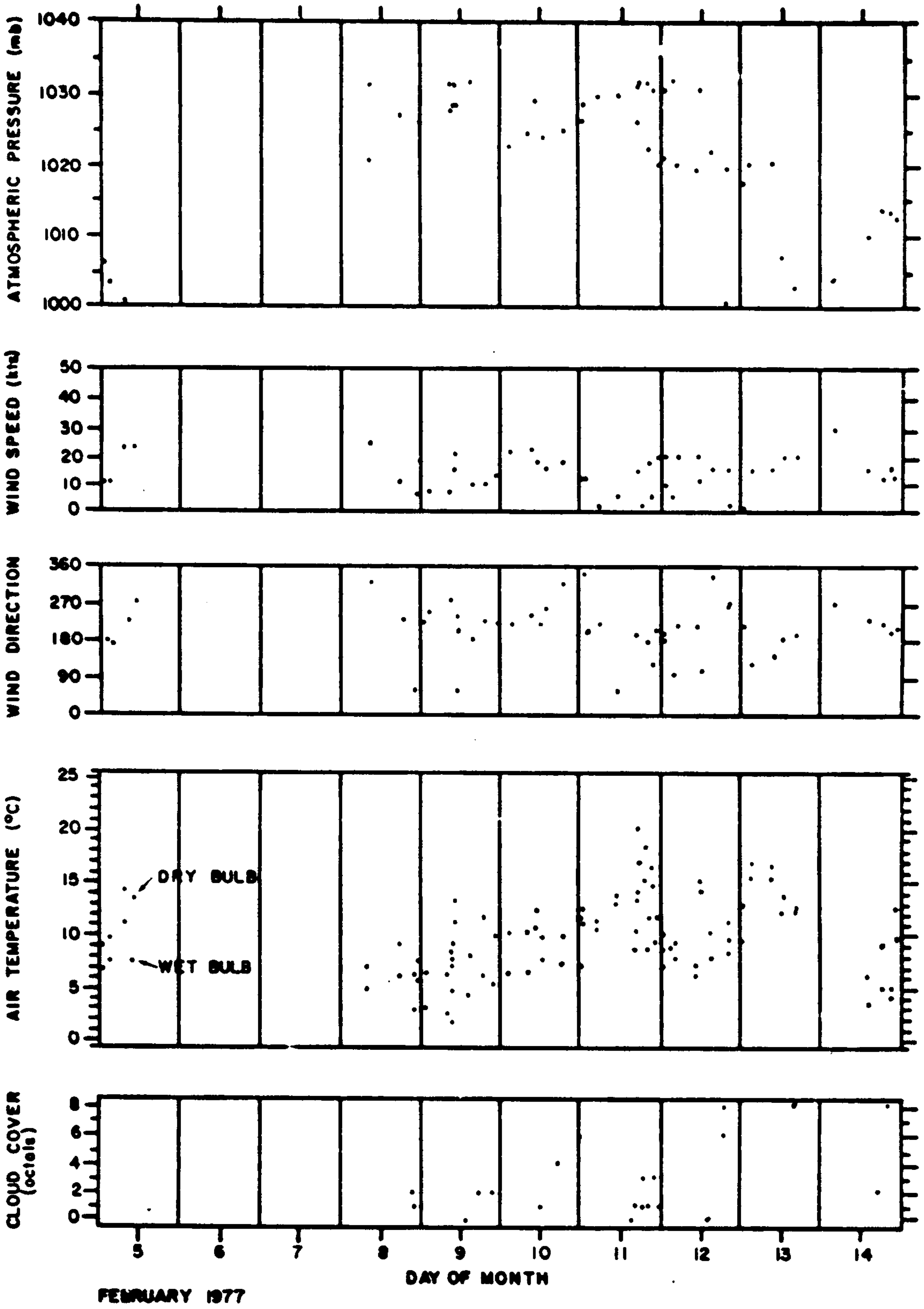


Figure 3-25a. Meteorological data collected during cruise BLM06B from 5-14 February 1977.

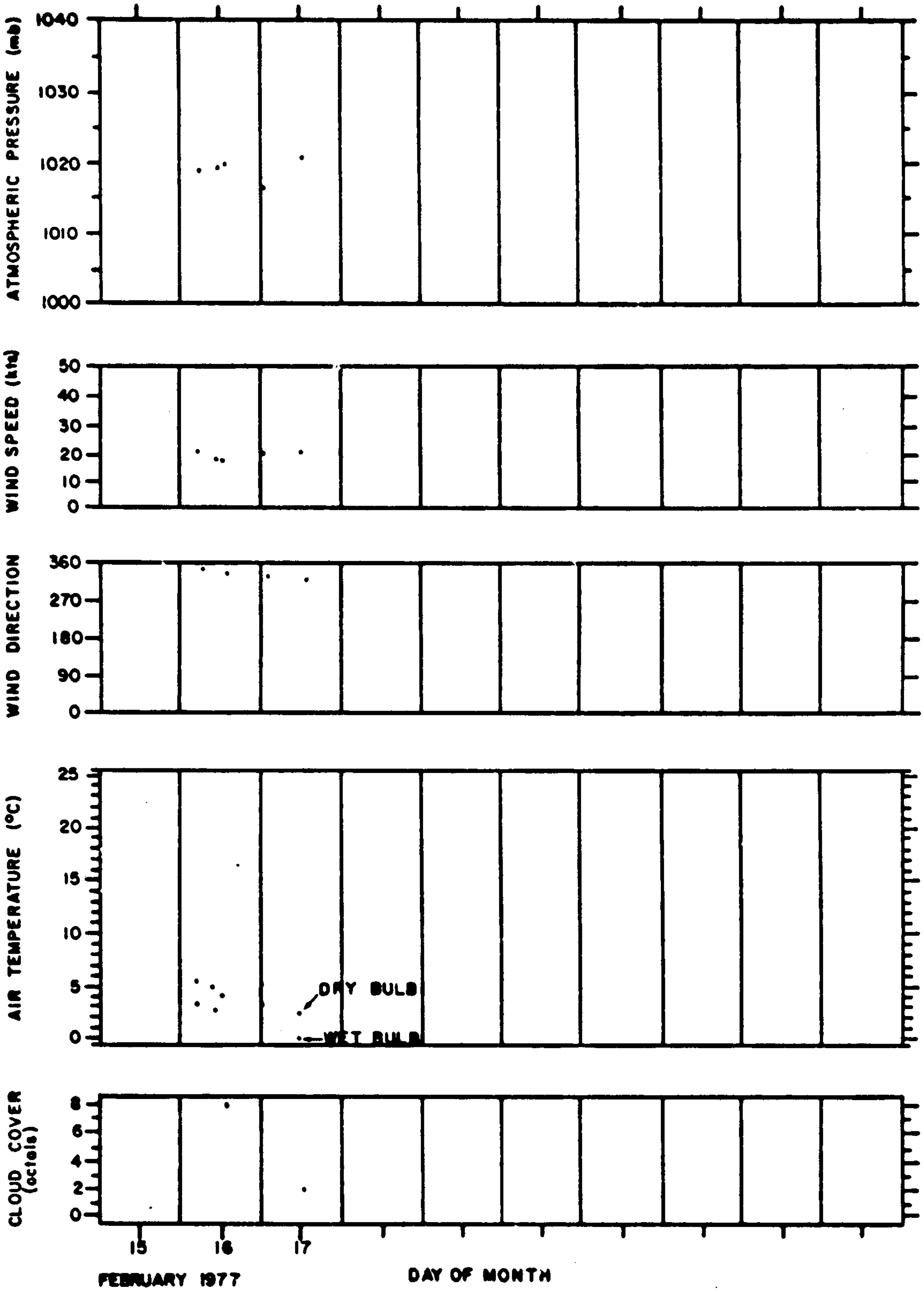


Figure 3-25b. Meteorological data collected during cruise BLM06B from 15-17 February 1977.

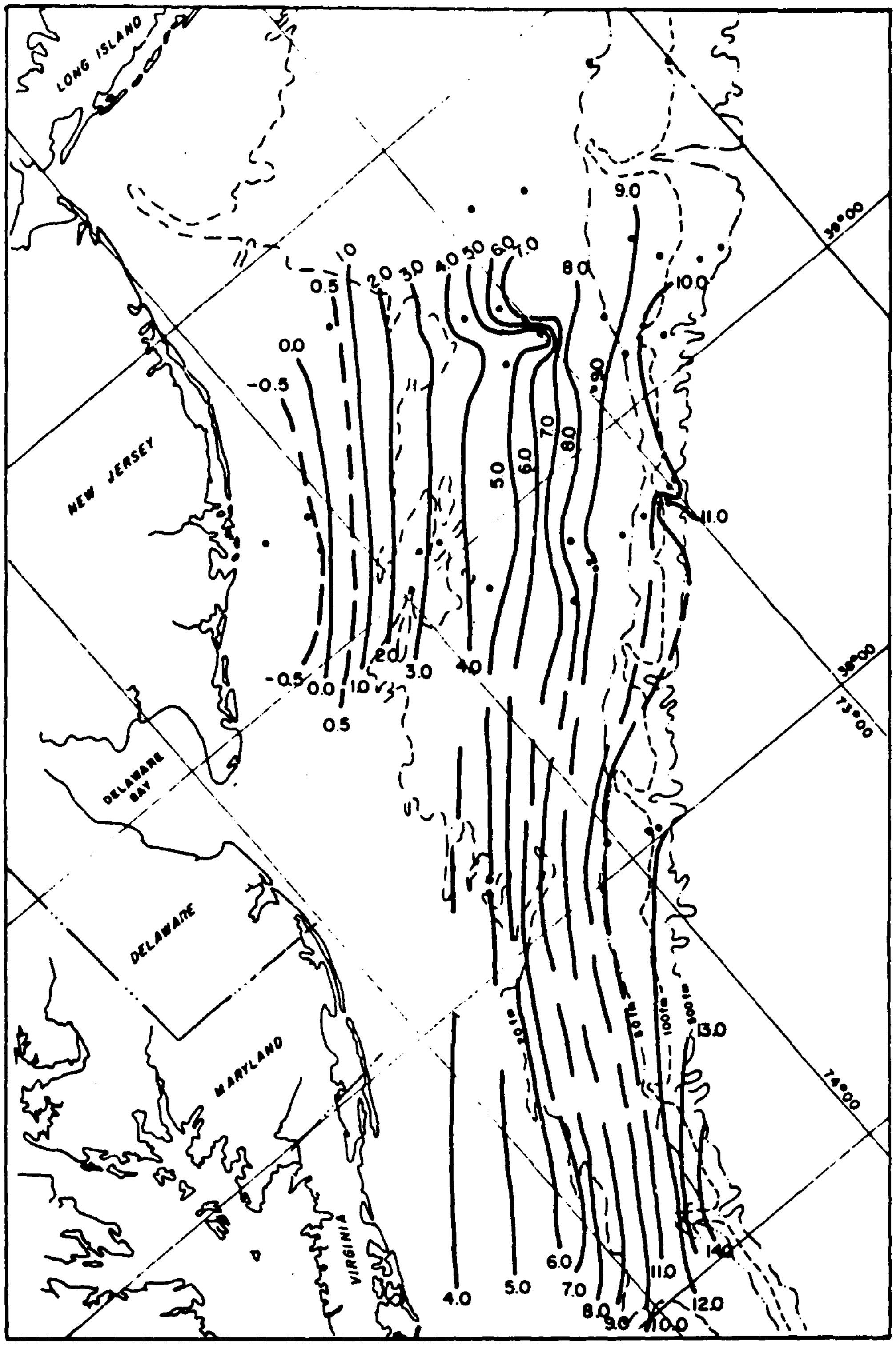


Figure 3-26a. Surface temperature (°C) distribution in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

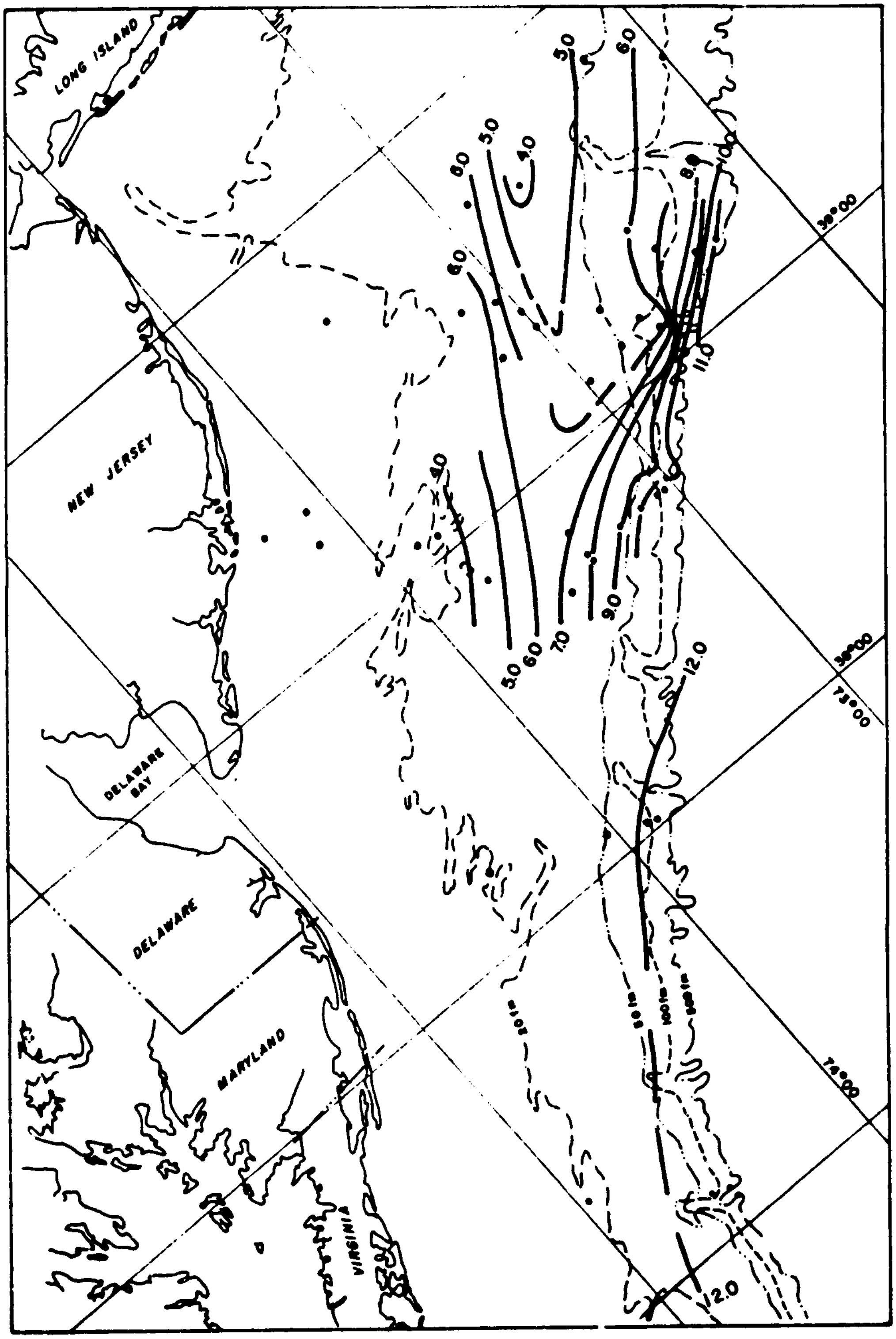


Figure 3-26b. Surface temperature (°C) distribution in the Middle Atlantic Bight during the period 8-13 March 1977 (Cruise BLM06B).

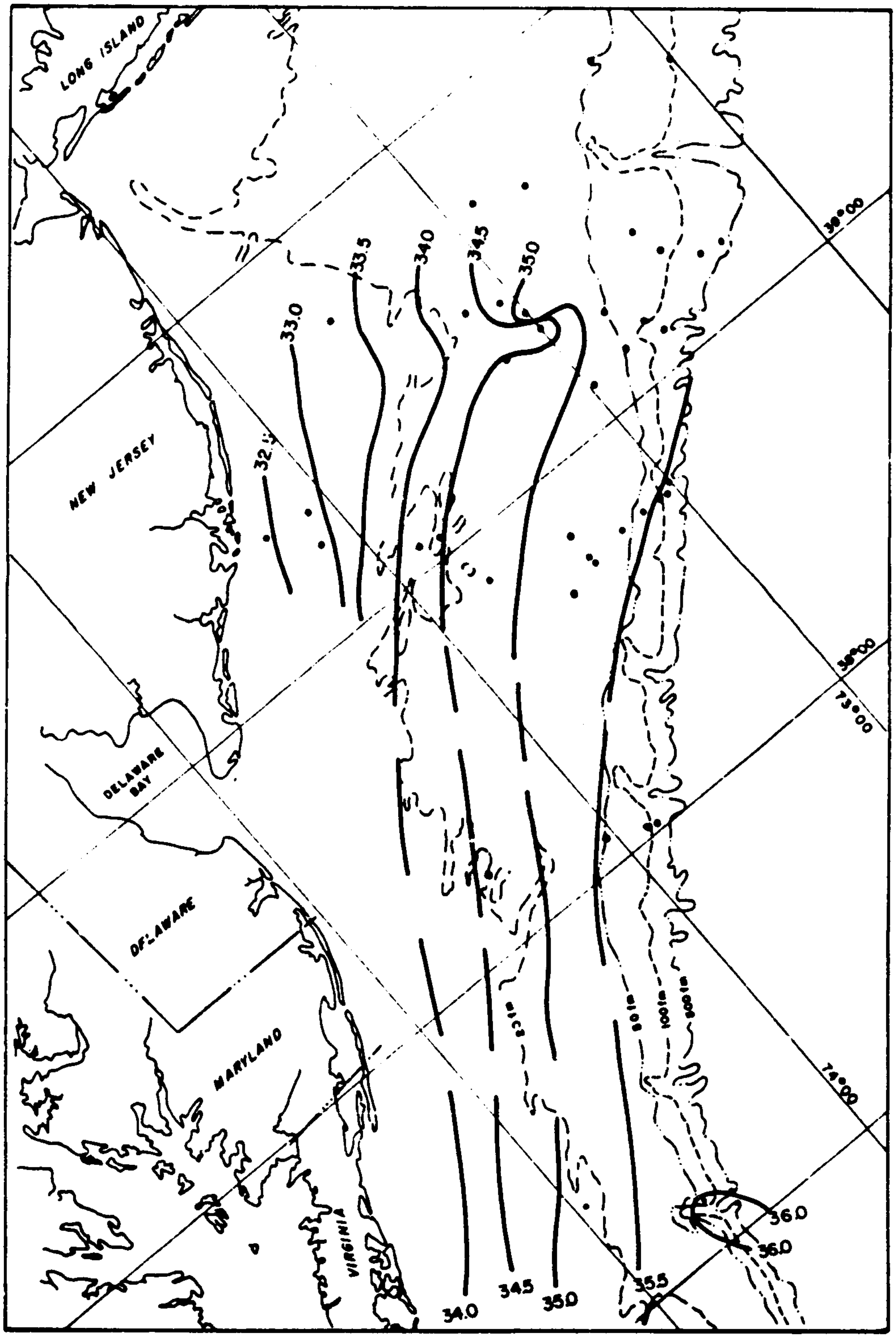


Figure 3-26c. Surface salinity (ppt) distributions in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

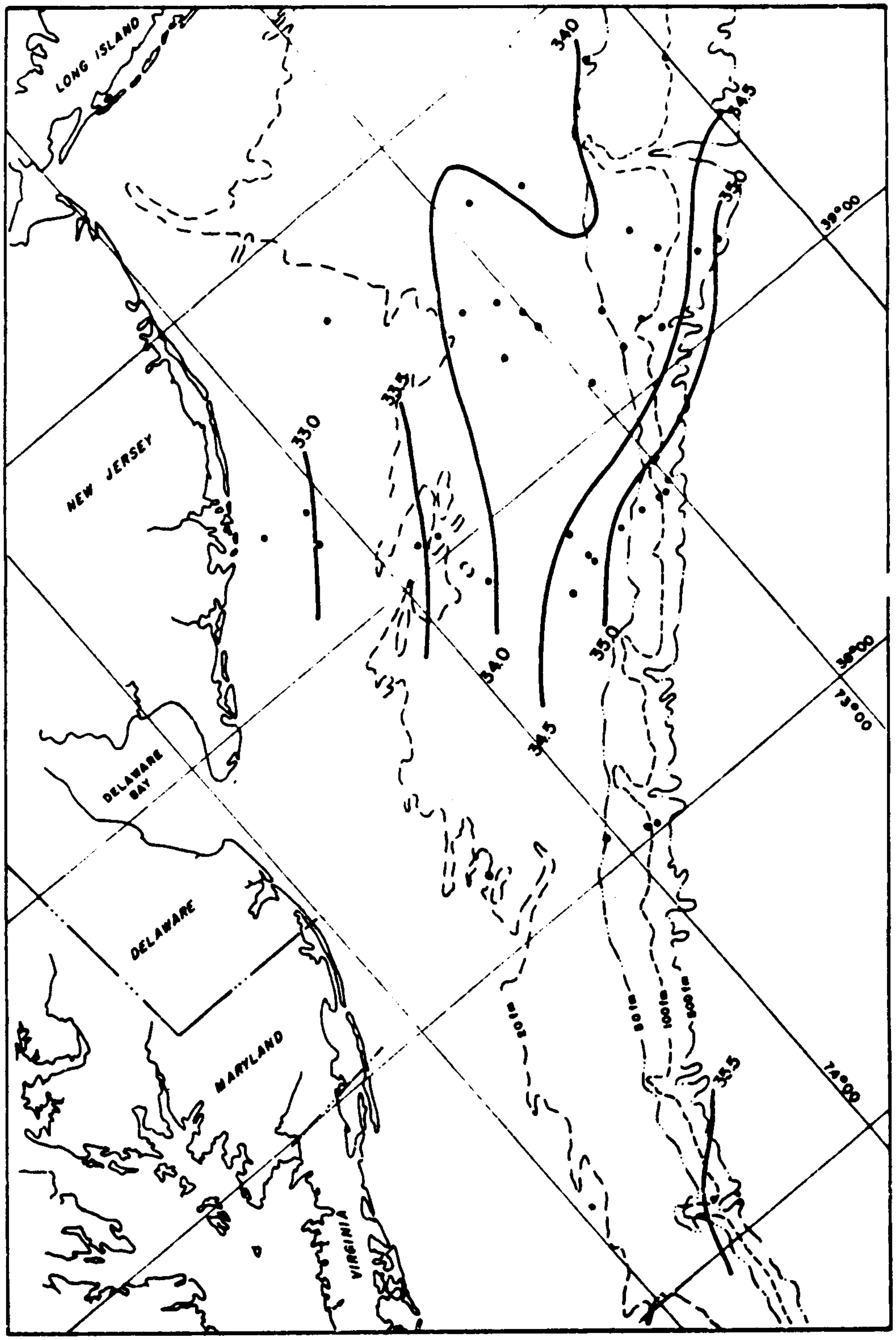


Figure 3-26d. Surface salinity (ppt) distribution in the Middle Atlantic Bight during the period 8-13 March 1977 (Cruise BLM06B).

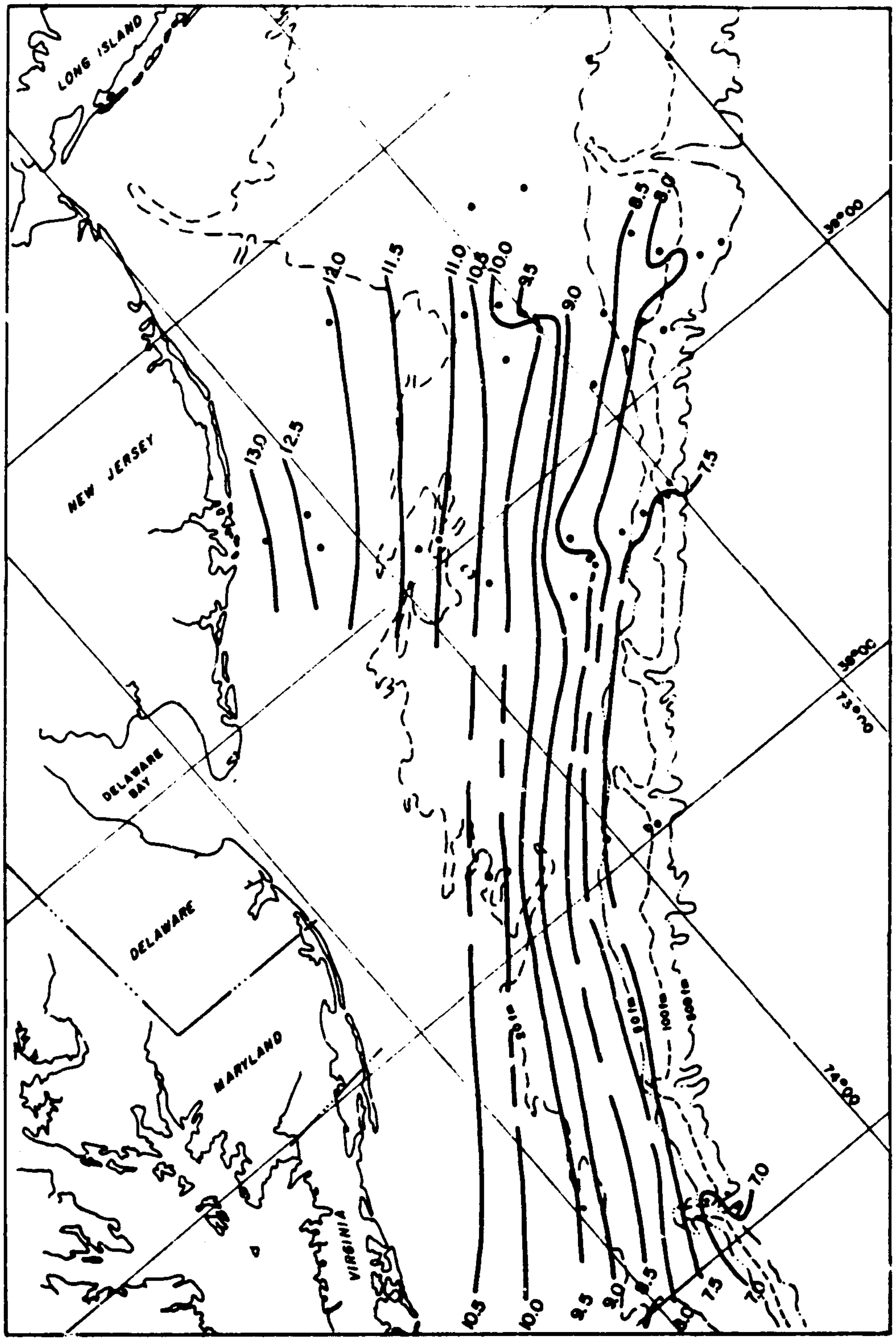


Figure 3-26e. Surface dissolved oxygen distributions (mg/l) in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

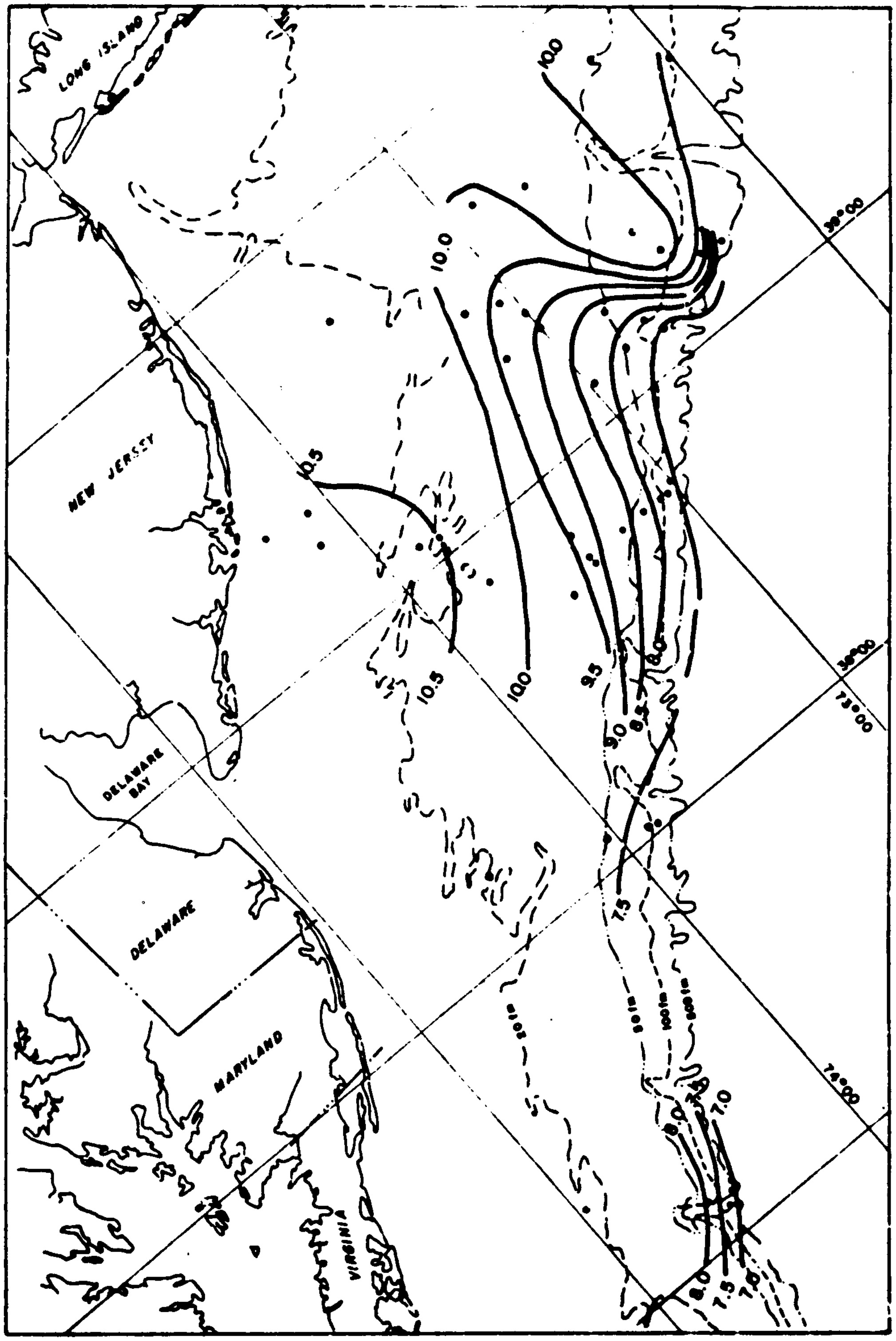


Figure 3-26f. Surface dissolved oxygen distributions (mg/l) in the Middle Atlantic Bight during the period 8-13 March 1977 (Cruise BLM06B).

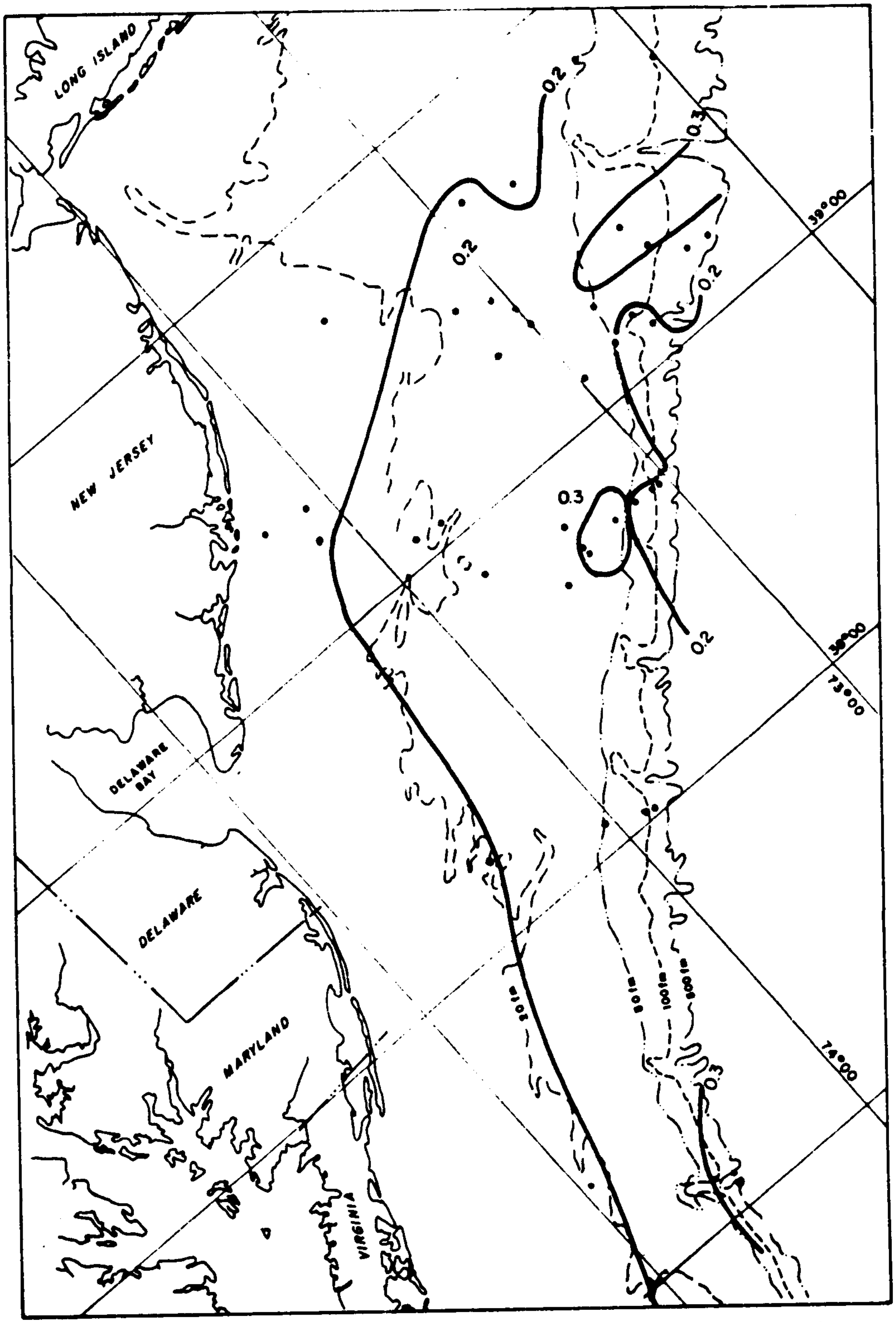


Figure 3-26g. Surface dissolved nitrite (μgm-at/l) in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.

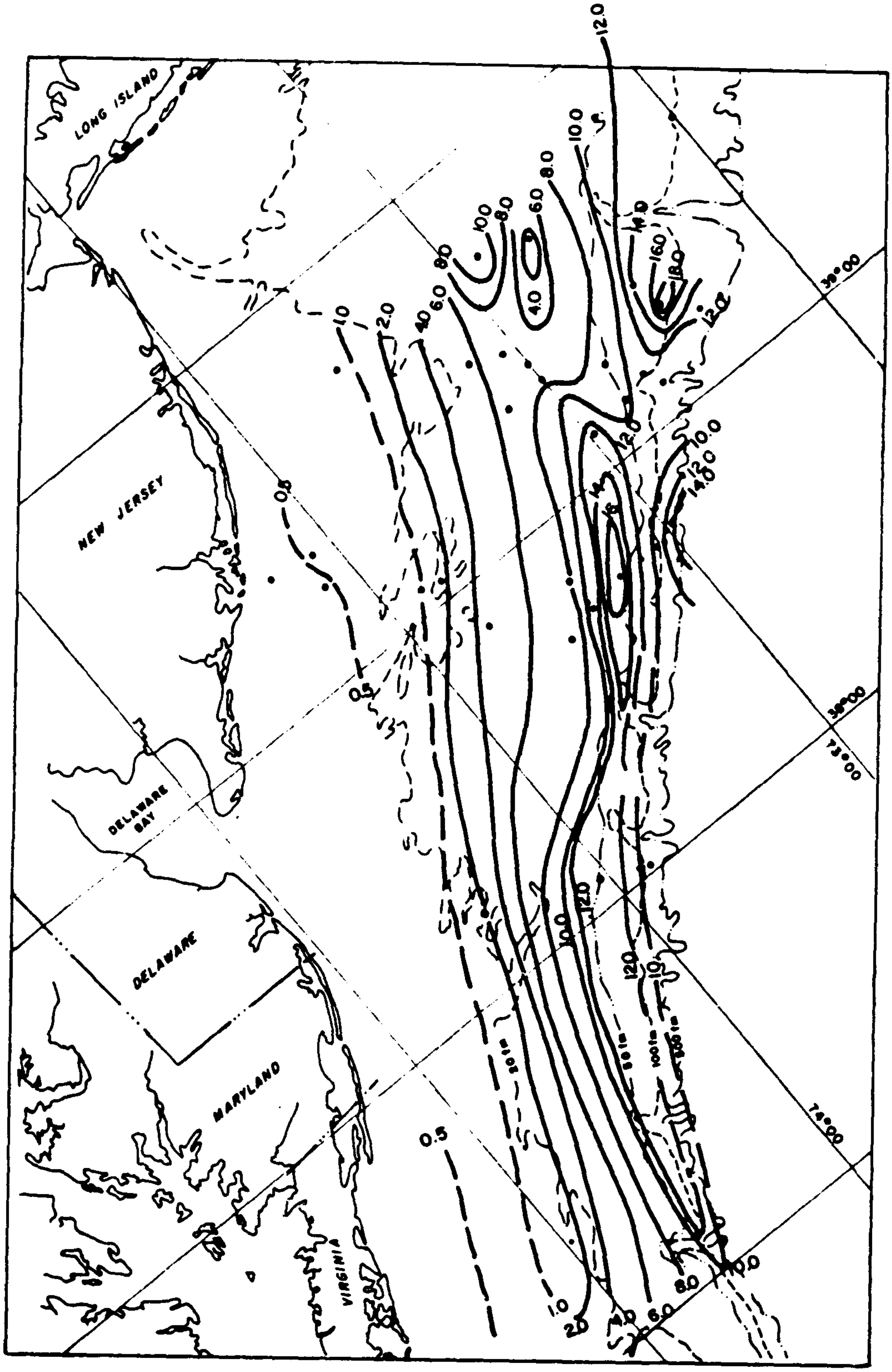


Figure 3-26h. Surface dissolved nitrate (μgm-at/l) in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.

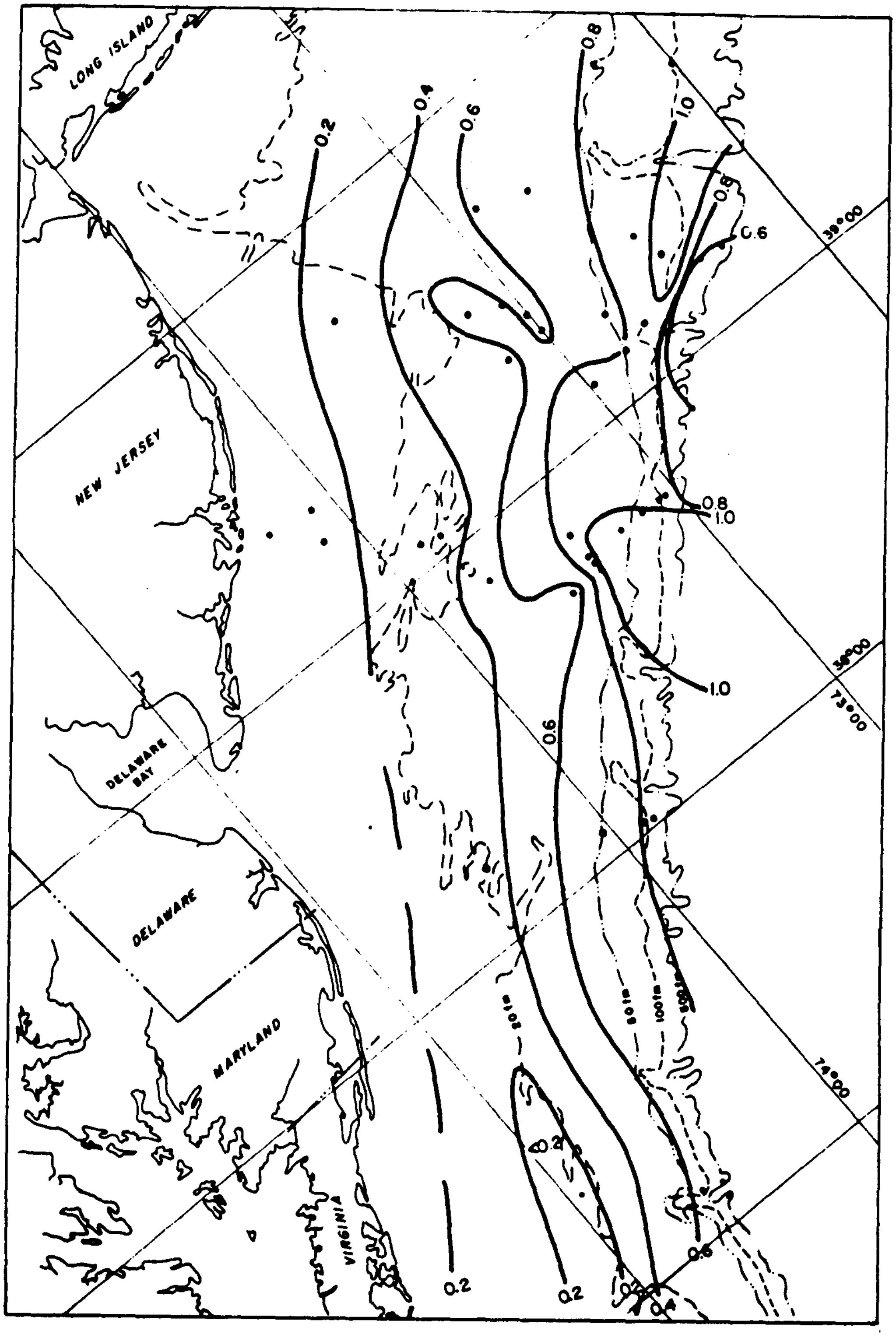


Figure 3-26i. Surface dissolved ortho-phosphate (μgm-at/l) in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.

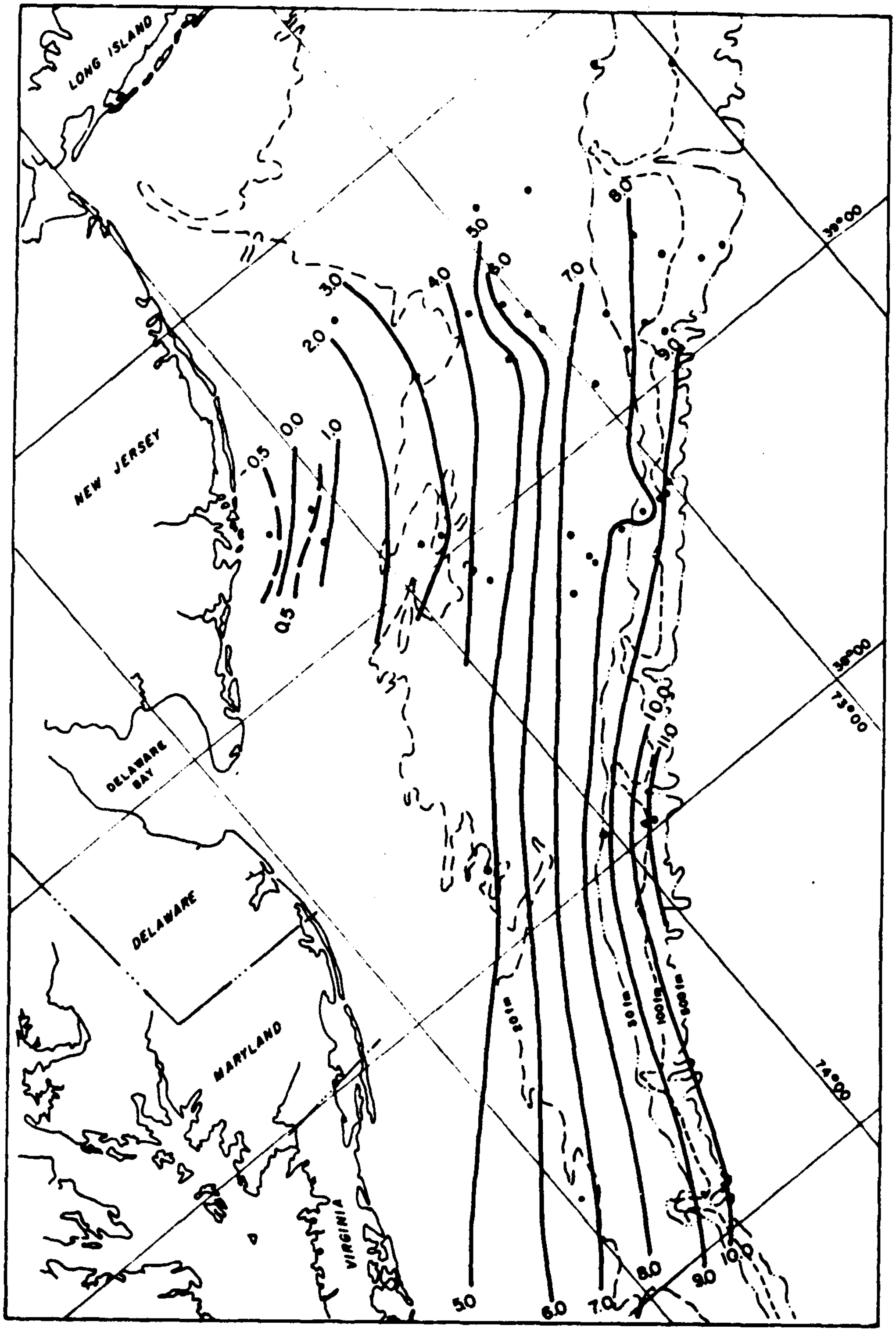


Figure 3-27a. Bottom temperature (°C) distributions in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

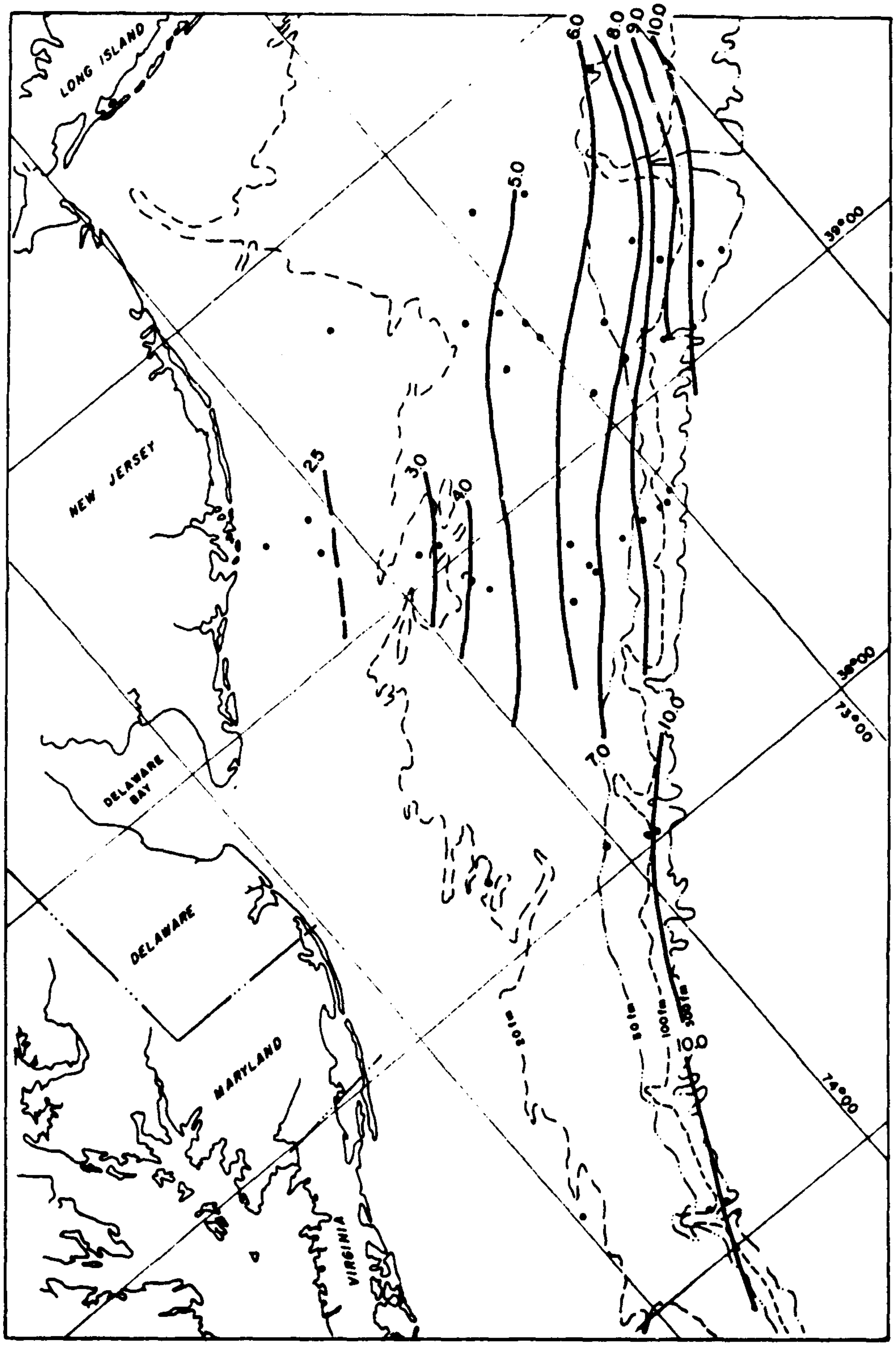


Figure 3-27b. Bottom temperature (°C) distribution in the Middle Atlantic Bight during the period of 8-13 March 1977 (Cruise BLM06B).

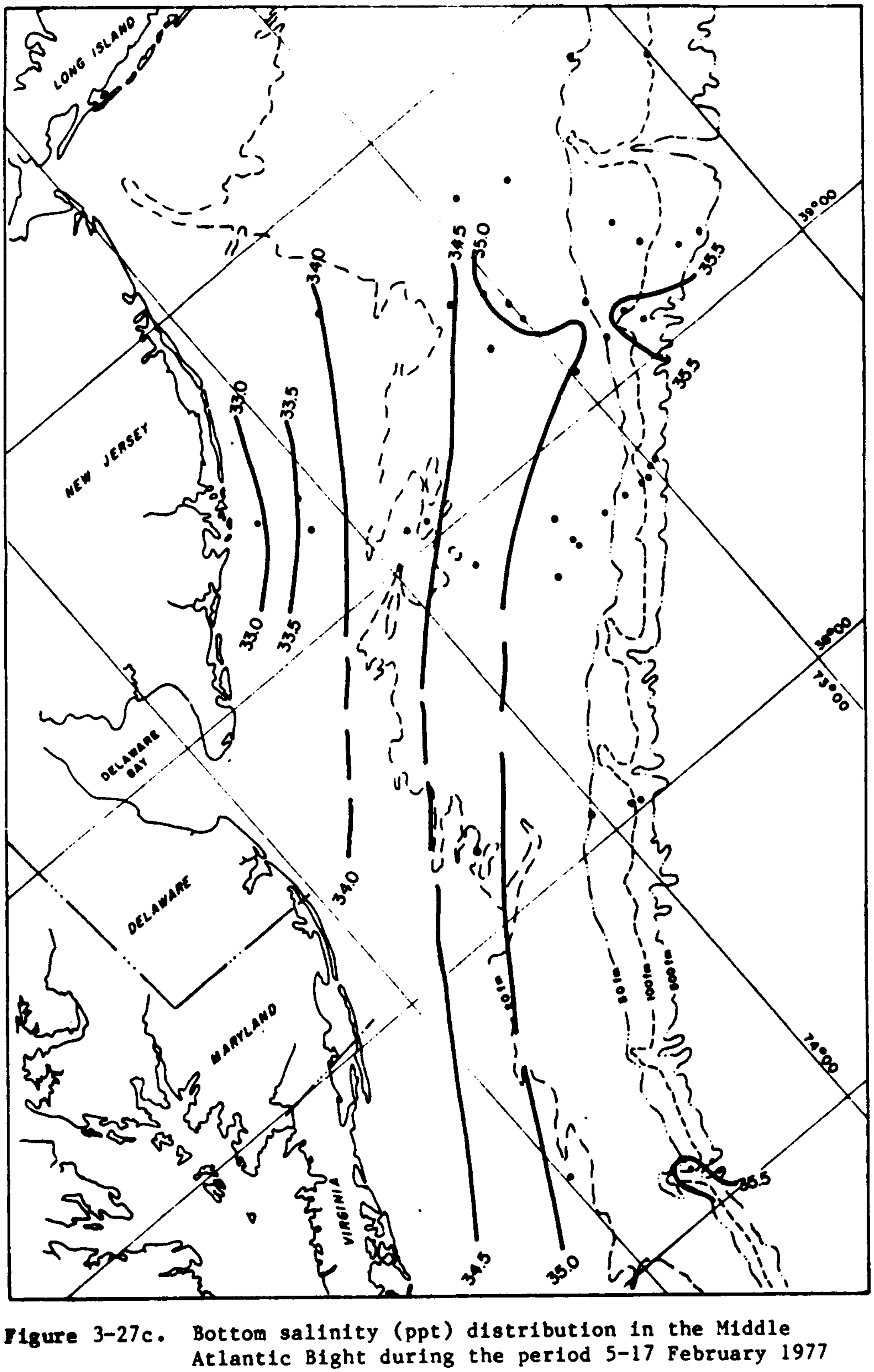


Figure 3-27c. Bottom salinity (ppt) distribution in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

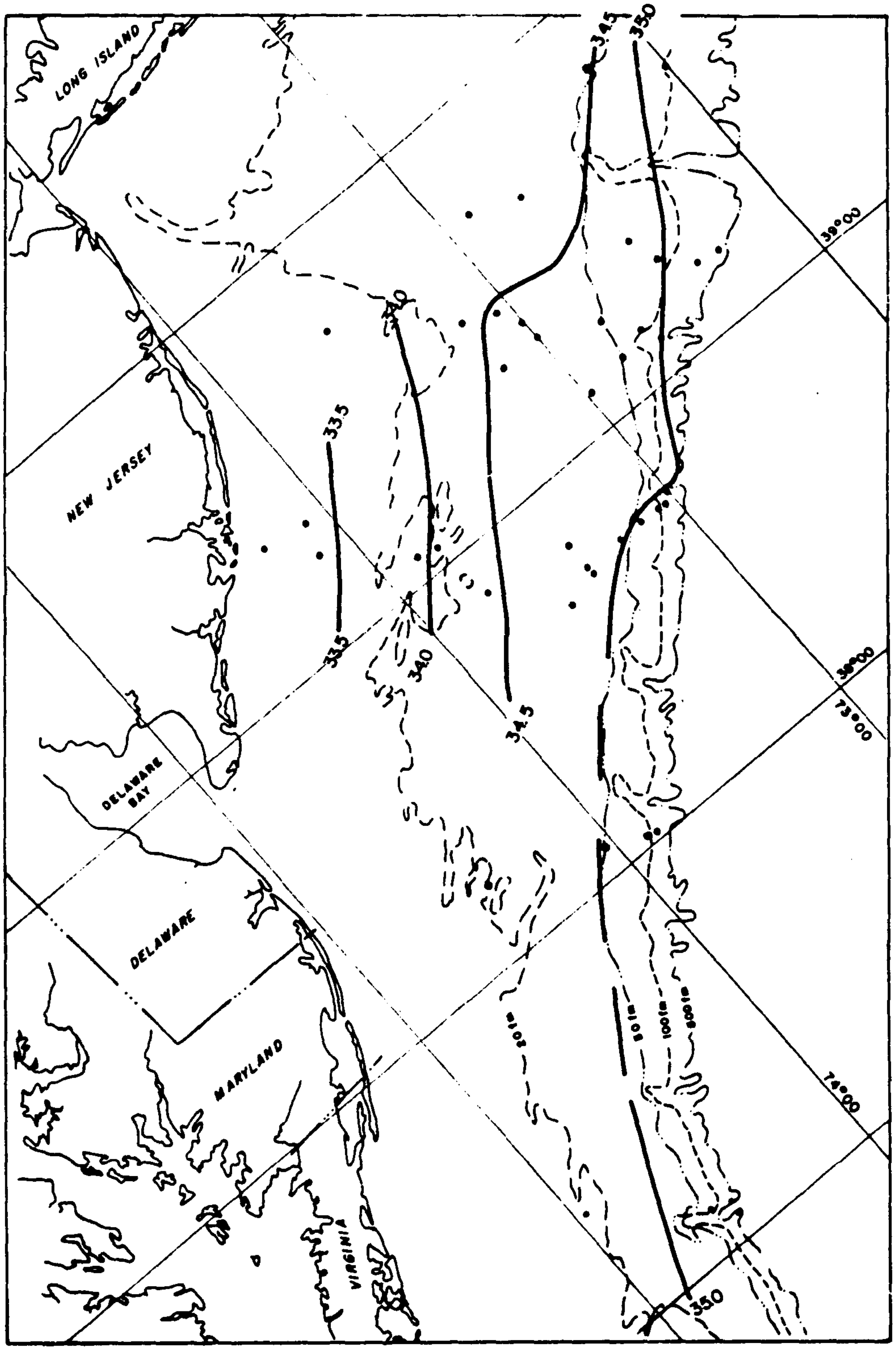


Figure 3-27d. Bottom salinity (ppt) distributions in the Middle Atlantic Bight during the period 8-13 March 1977 (Cruise BLM06B).

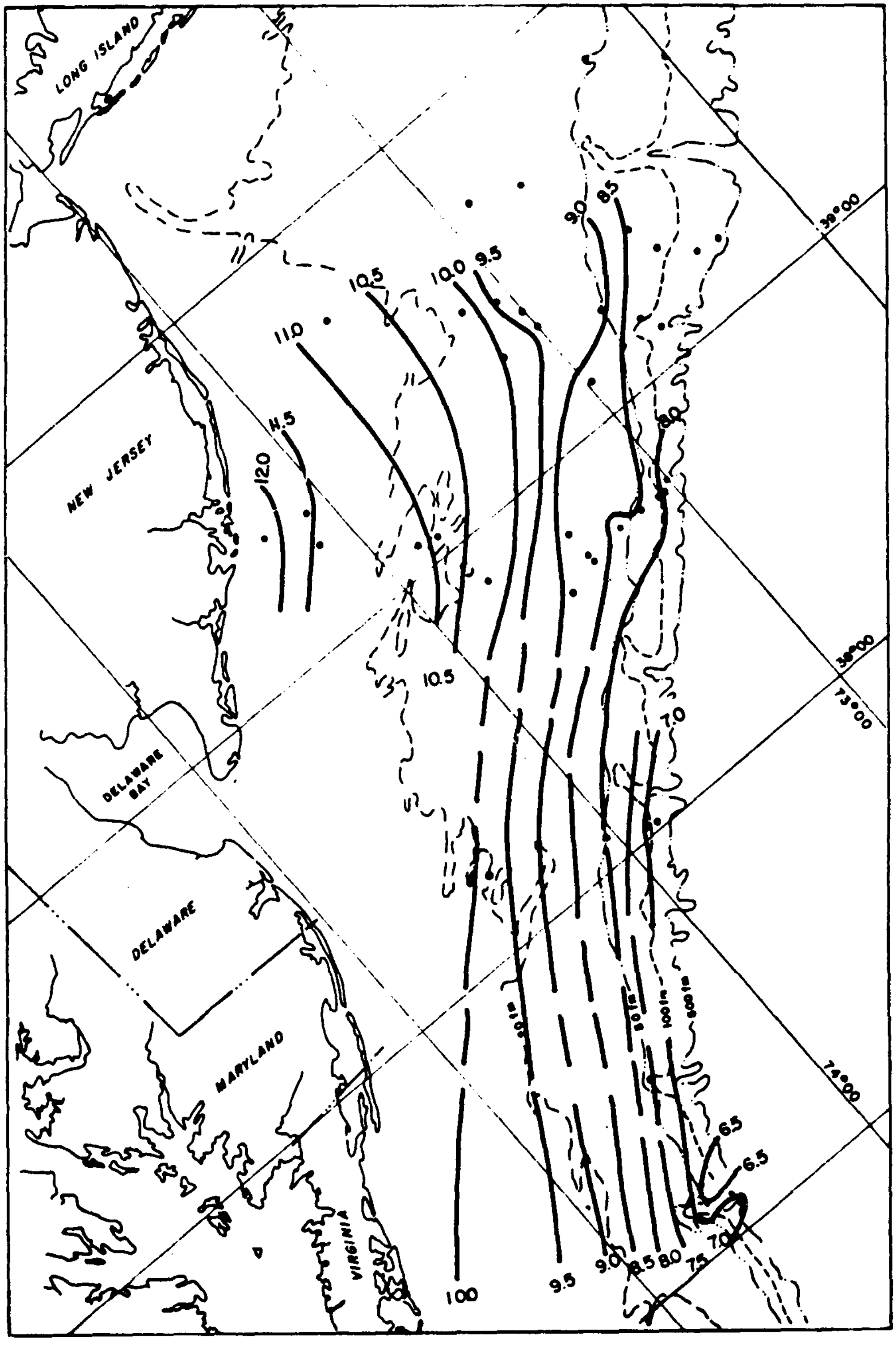


Figure 3-27e. Bottom dissolved oxygen (mg/l) distribution in the Middle Atlantic Bight during the period 5-17 February 1977 (Cruise BLM06B).

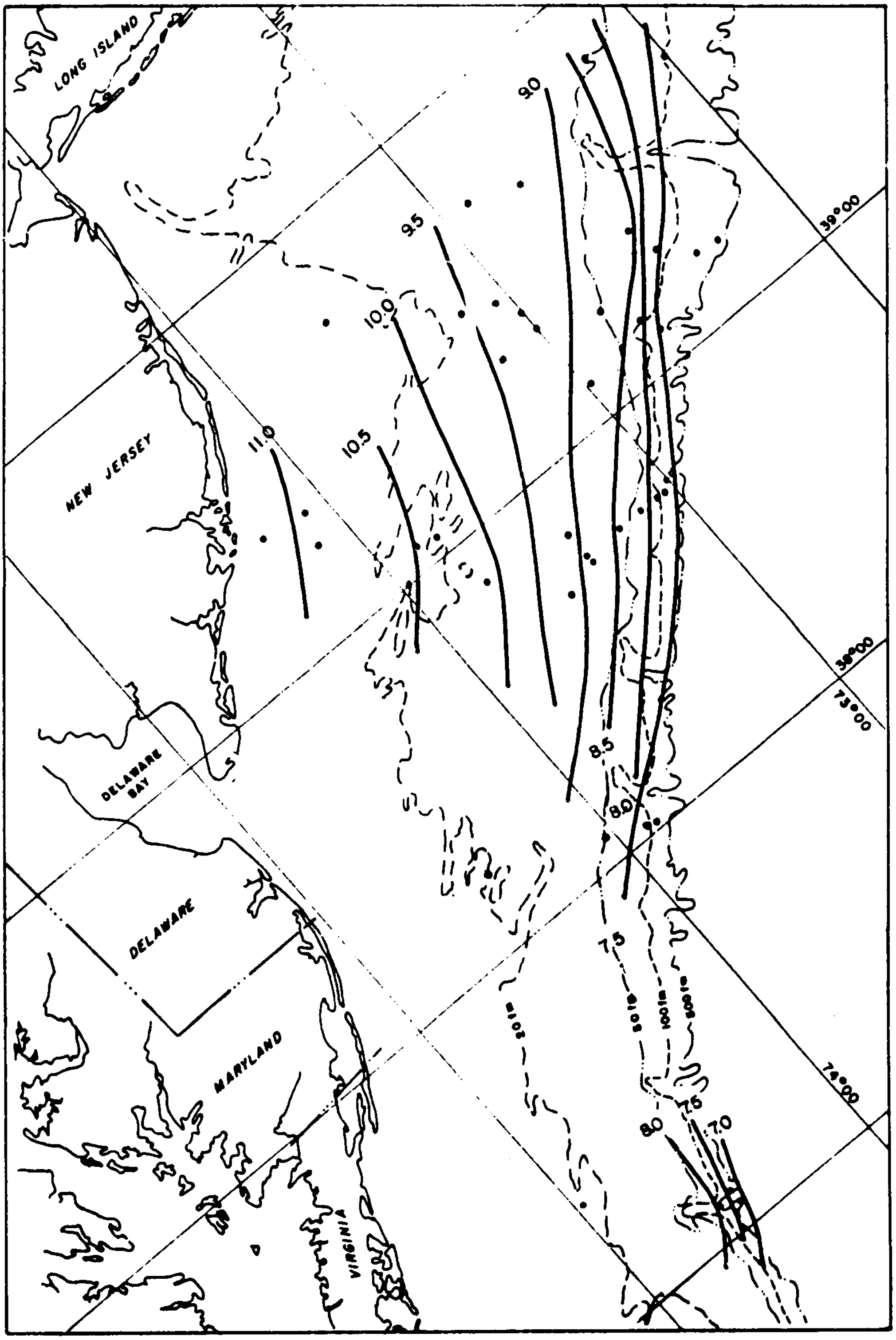


Figure 3-27f. Bottom dissolved oxygen (mg/l) distribution in the Middle Atlantic Bight during the period 8-13 March 1977 (Cruise BLM06B).

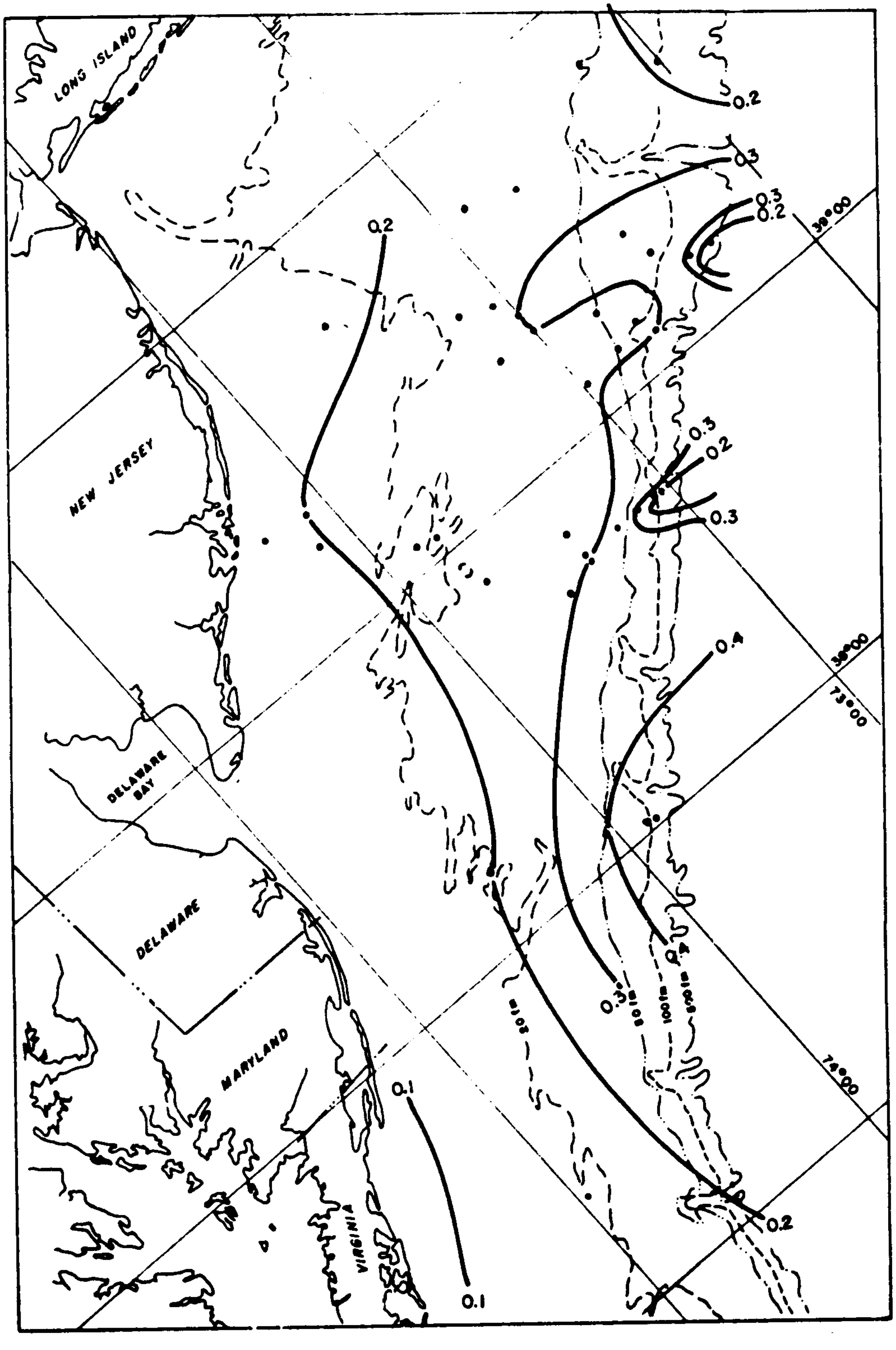


Figure 3-27g. Bottom dissolved nitrite (μgm-at/l) distribution in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.

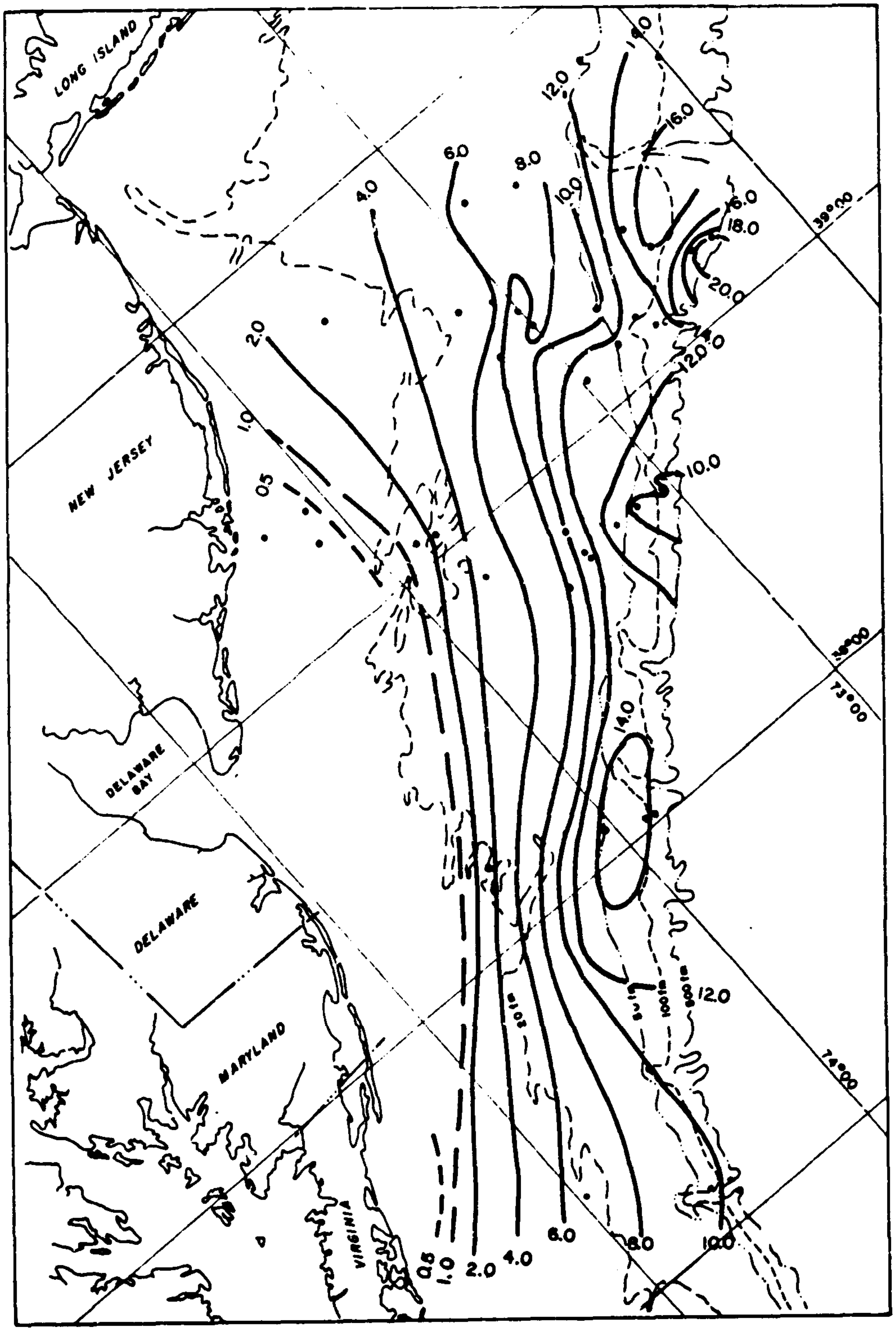


Figure 3-27h. Bottom dissolved nitrate (μgm-at/l) distribution in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.

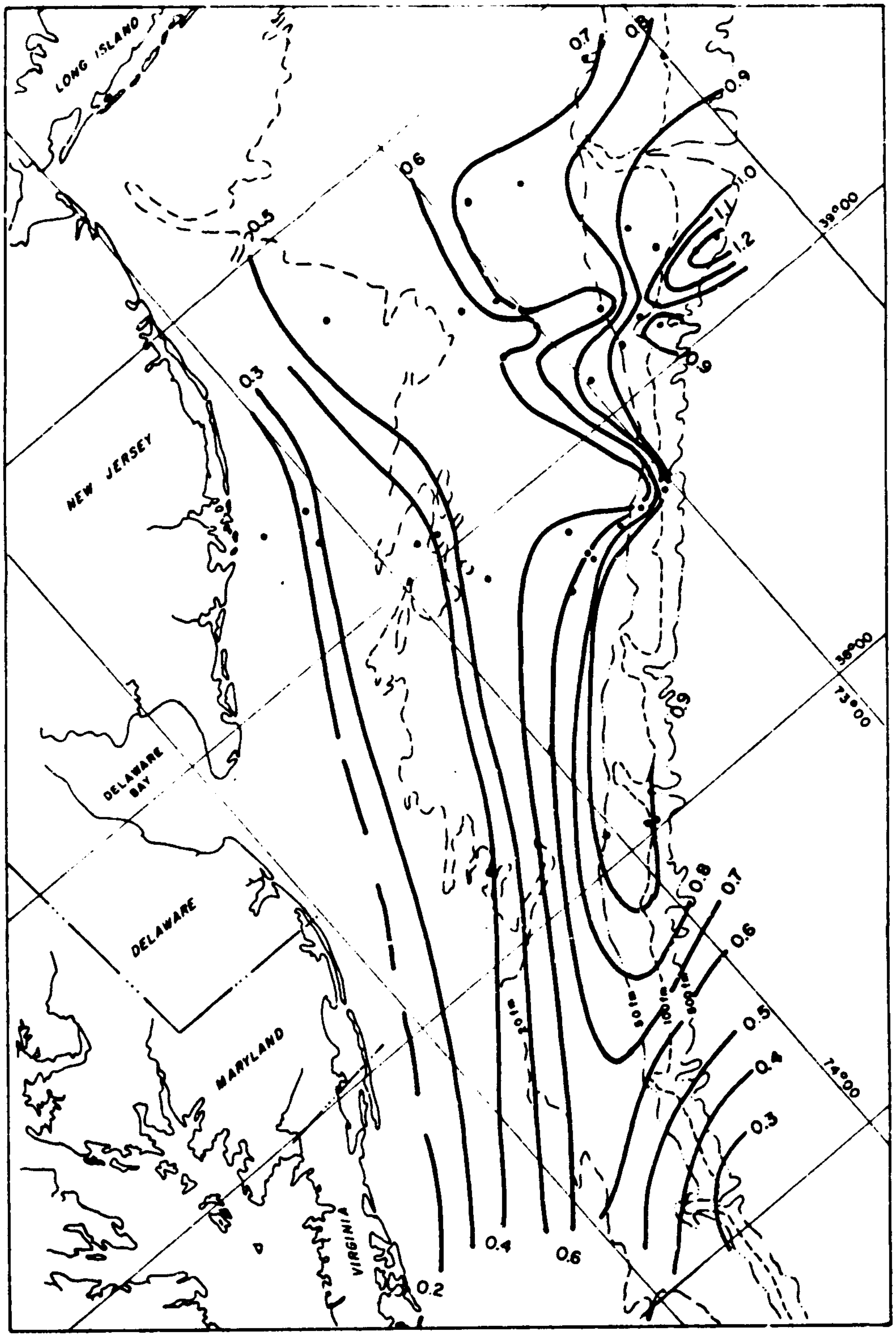
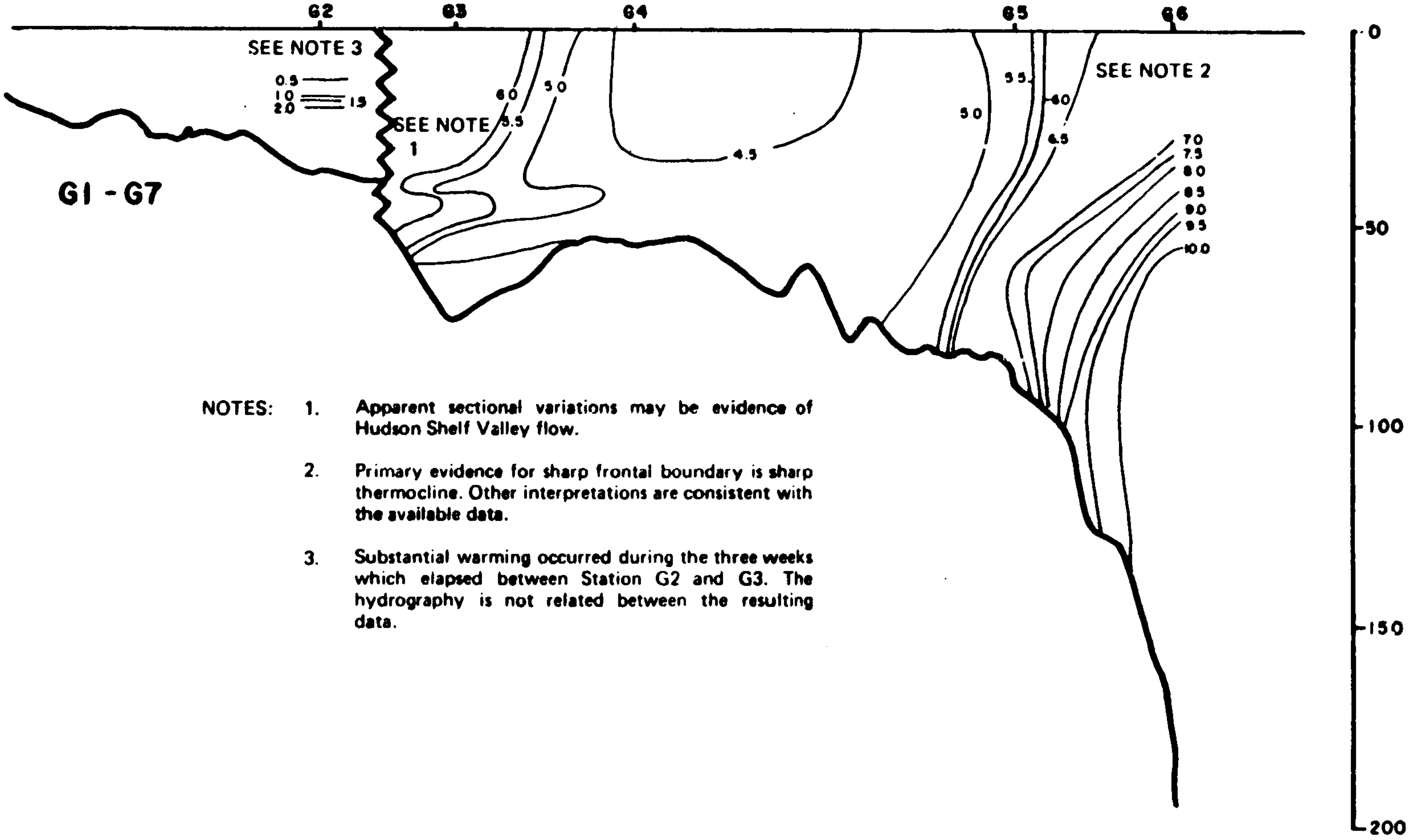


Figure 3-27i. Bottom dissolved ortho-phosphate (μgm-at/l) distribution in the Middle Atlantic Bight during cruise BLM06B, 5 February to 13 March 1977.



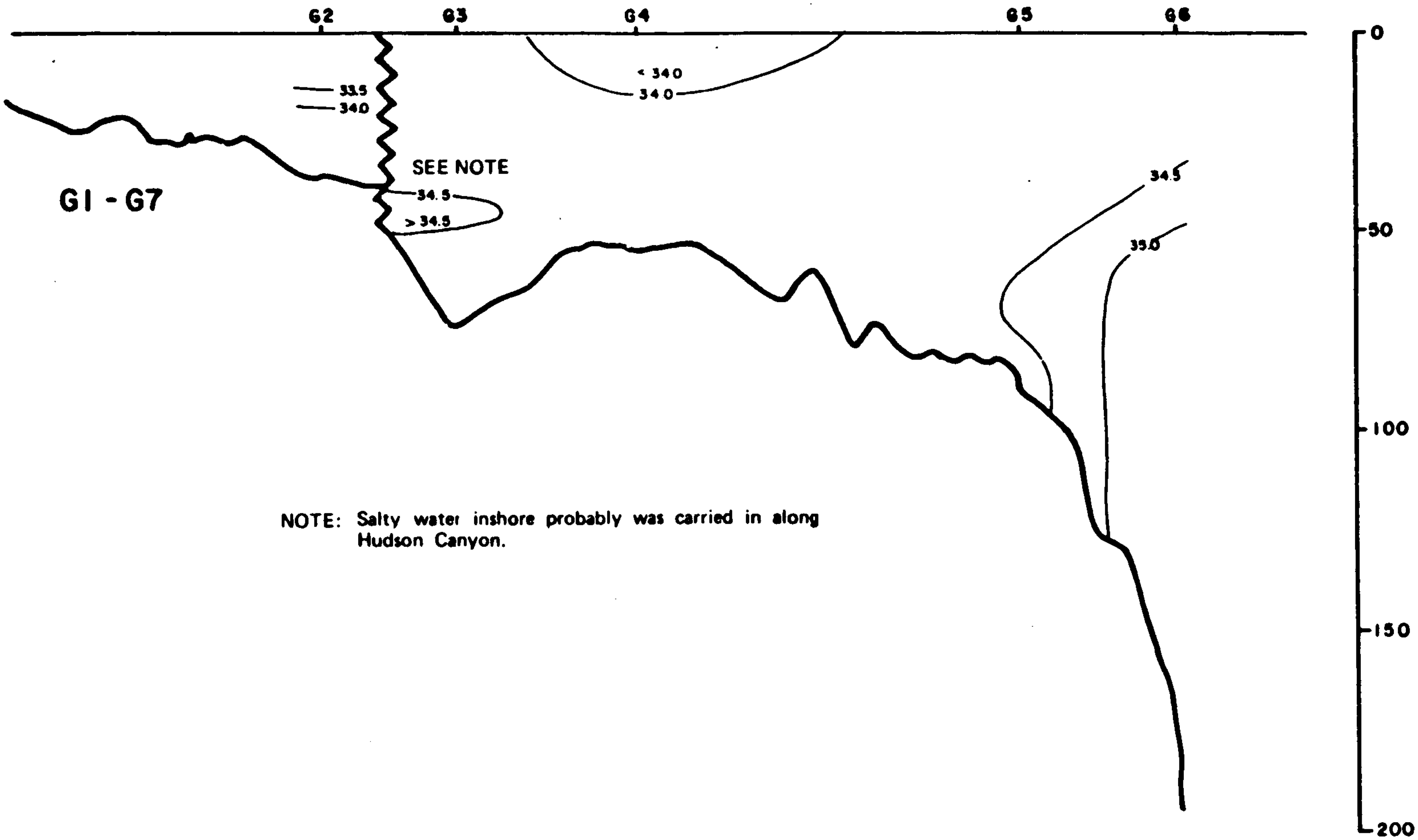
NOTES:

1. Apparent sectional variations may be evidence of Hudson Shelf Valley flow.

2. Primary evidence for sharp frontal boundary is sharp thermocline. Other interpretations are consistent with the available data.

3. Substantial warming occurred during the three weeks which elapsed between Station G2 and G3. The hydrography is not related between the resulting data.

Figure 3-28a. Temperature (°C) contours for section I (Figure 3-6) during cruise BLM06B. Station locations on the section and designatiors are indicated at the top of the section. Depths are in meters.



NOTE: Salty water inshore probably was carried in along Hudson Canyon.

Figure 3-28b. Salinity (ppt) contours for section I (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

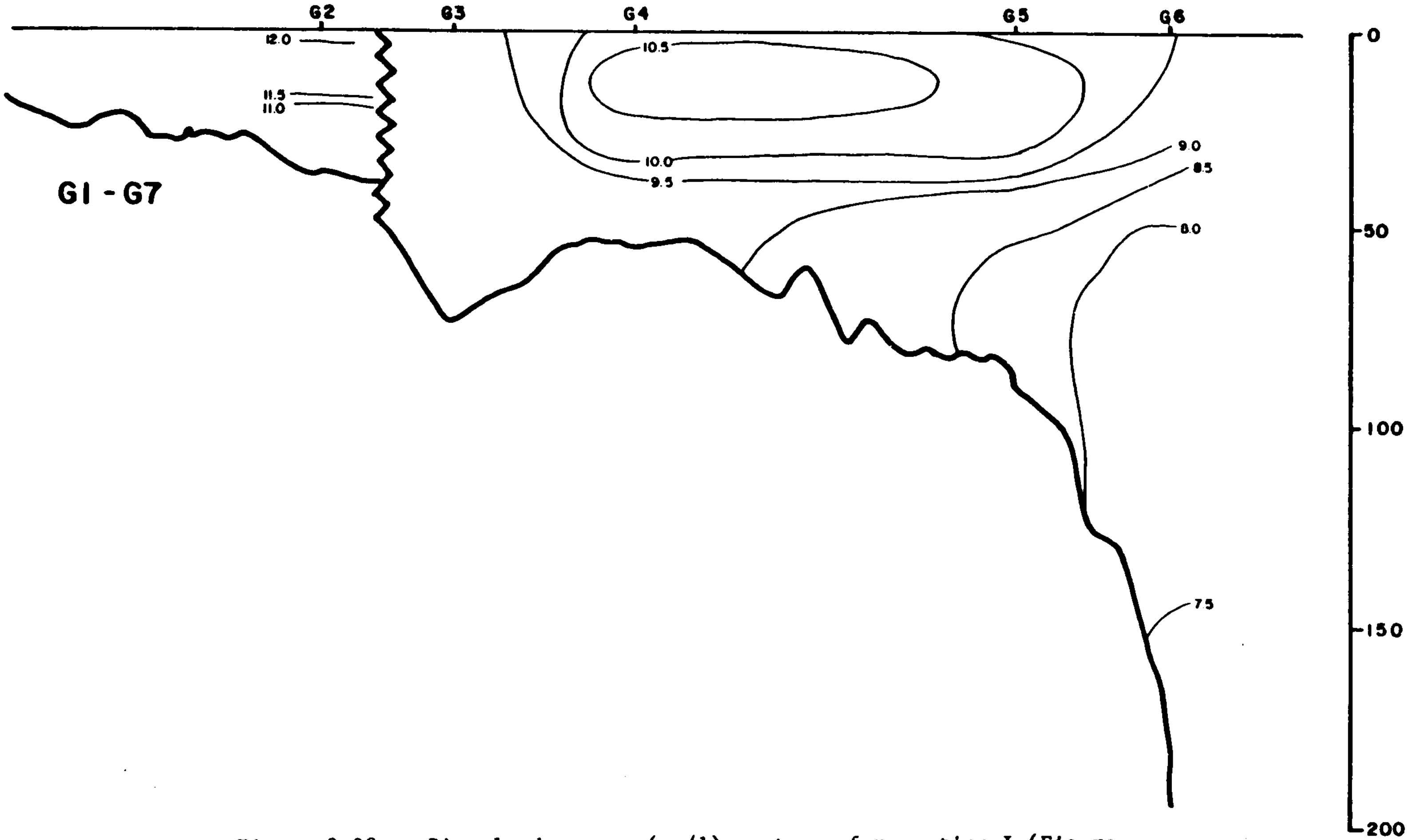


Figure 3-28c. Dissolved oxygen (mg/l) contours for section I (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

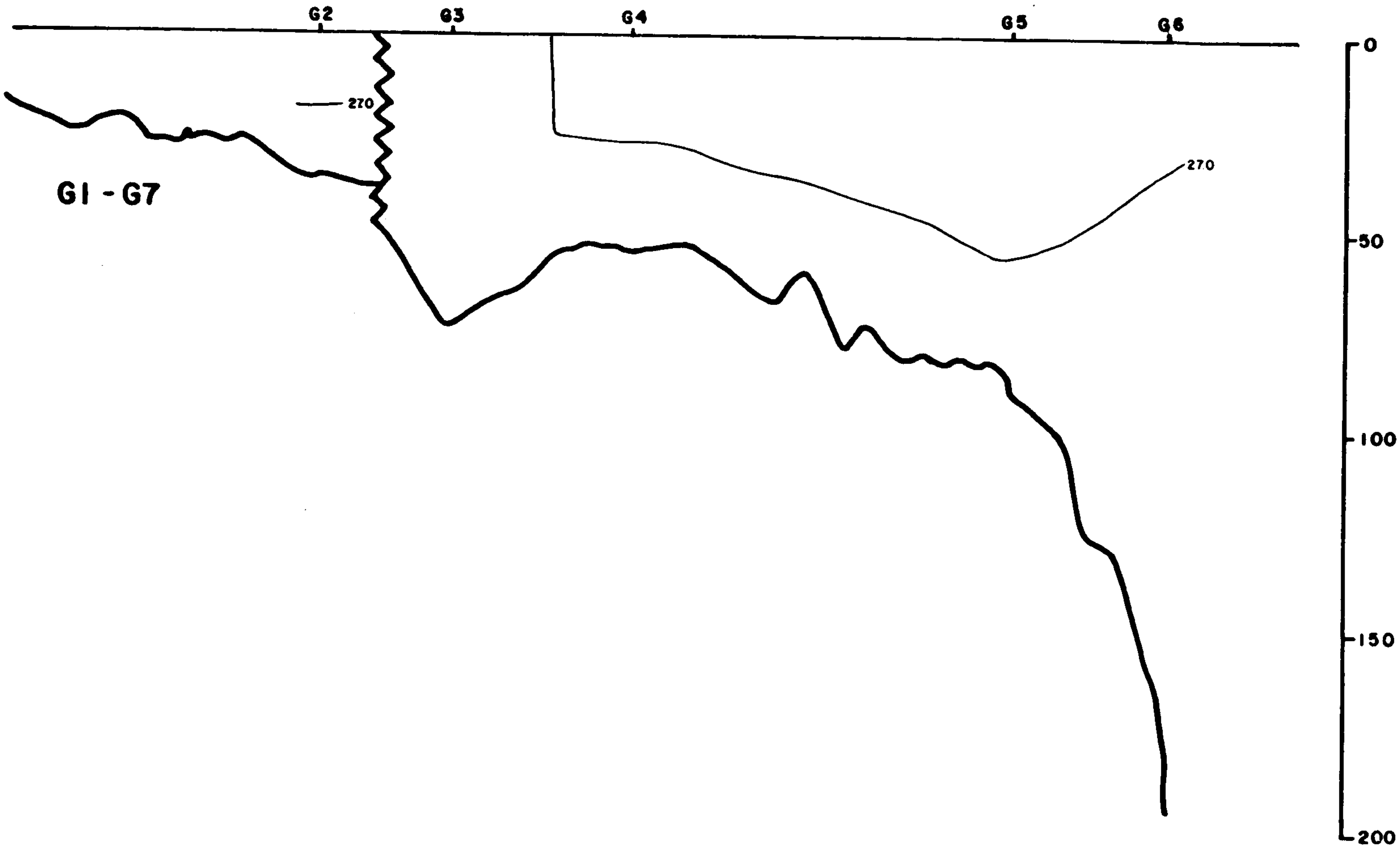
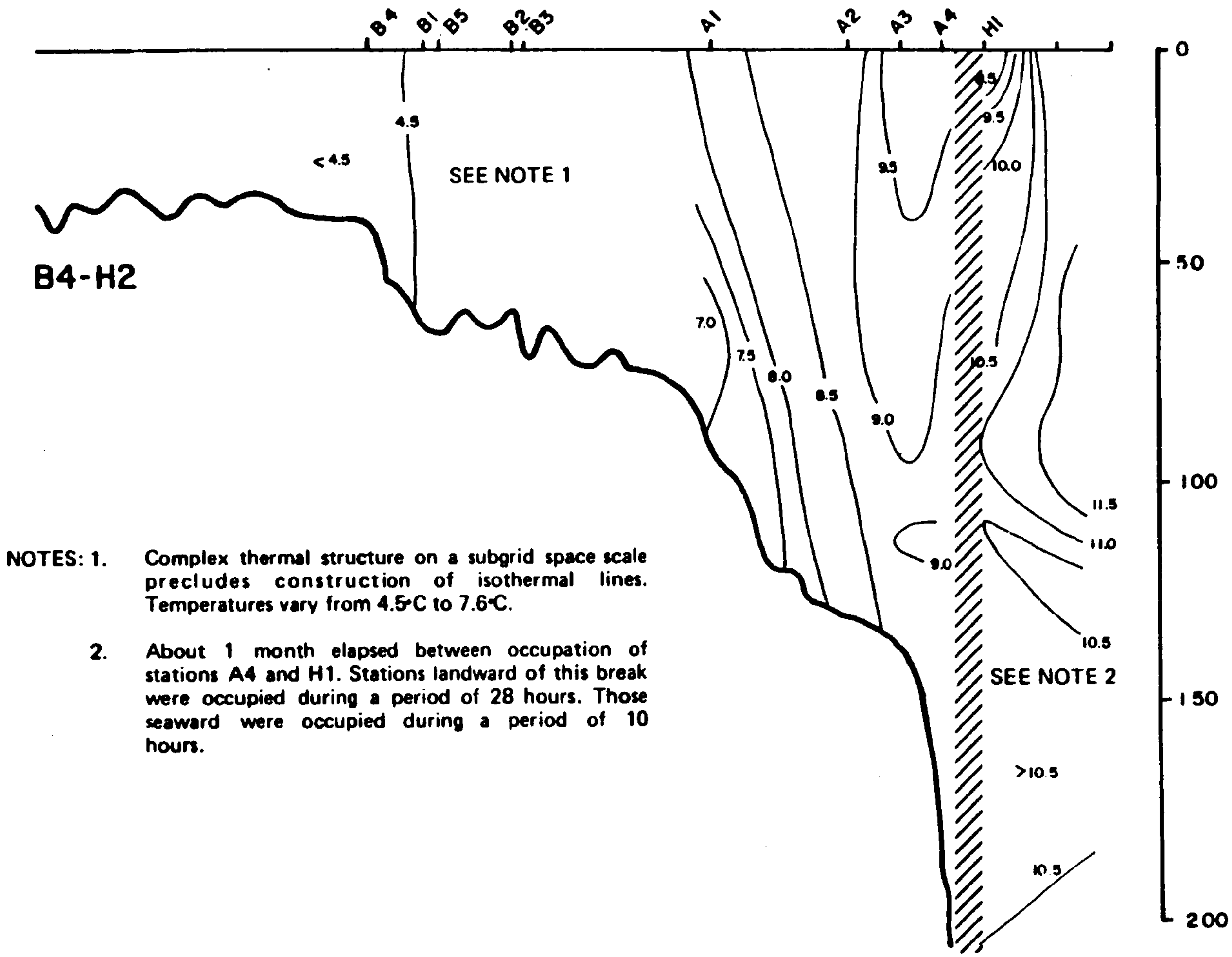


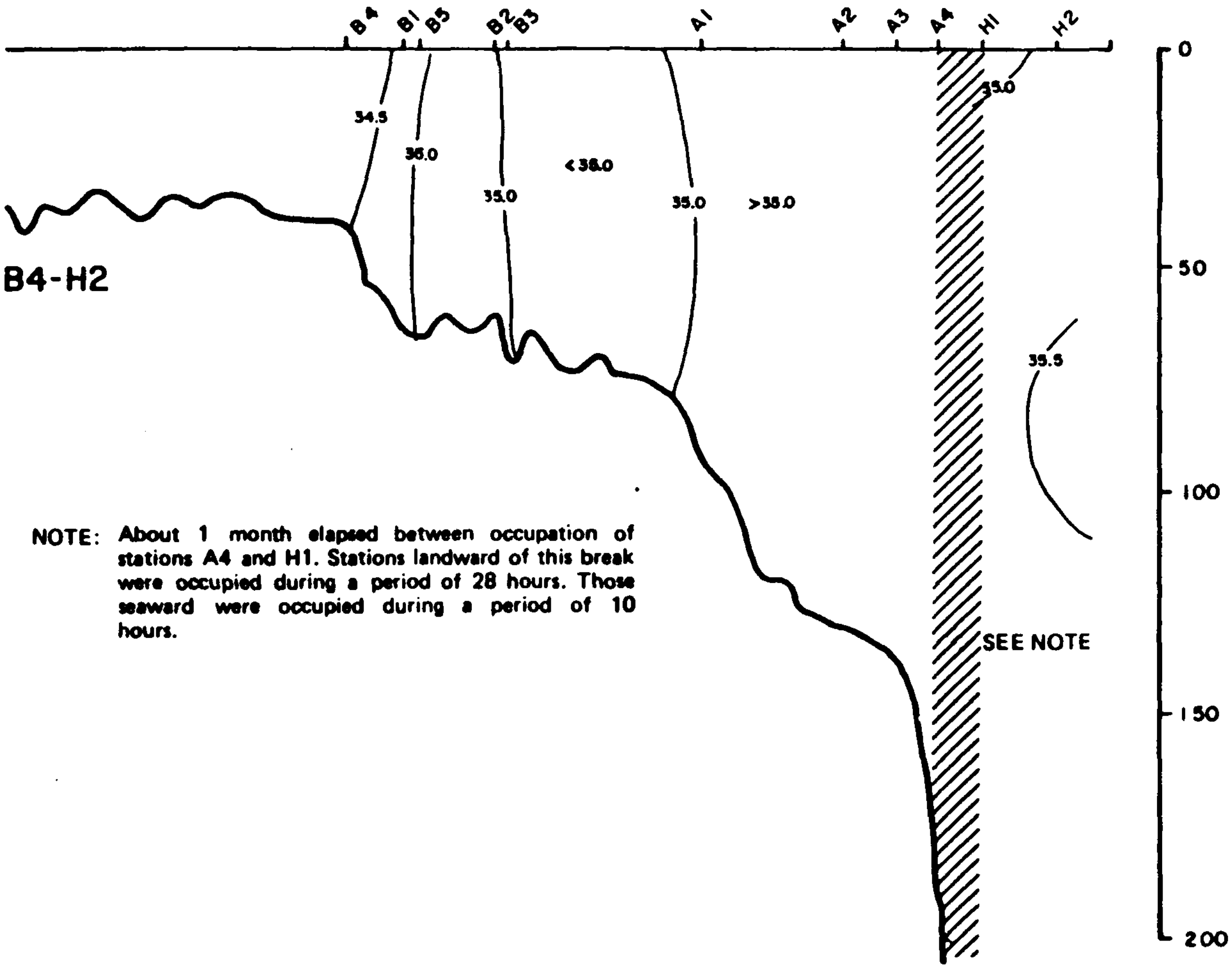
Figure 3-28d. Density (sigma-t units) contours for section I (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES: 1. Complex thermal structure on a subgrid space scale precludes construction of isothermal lines. Temperatures vary from 4.5°C to 7.6°C.

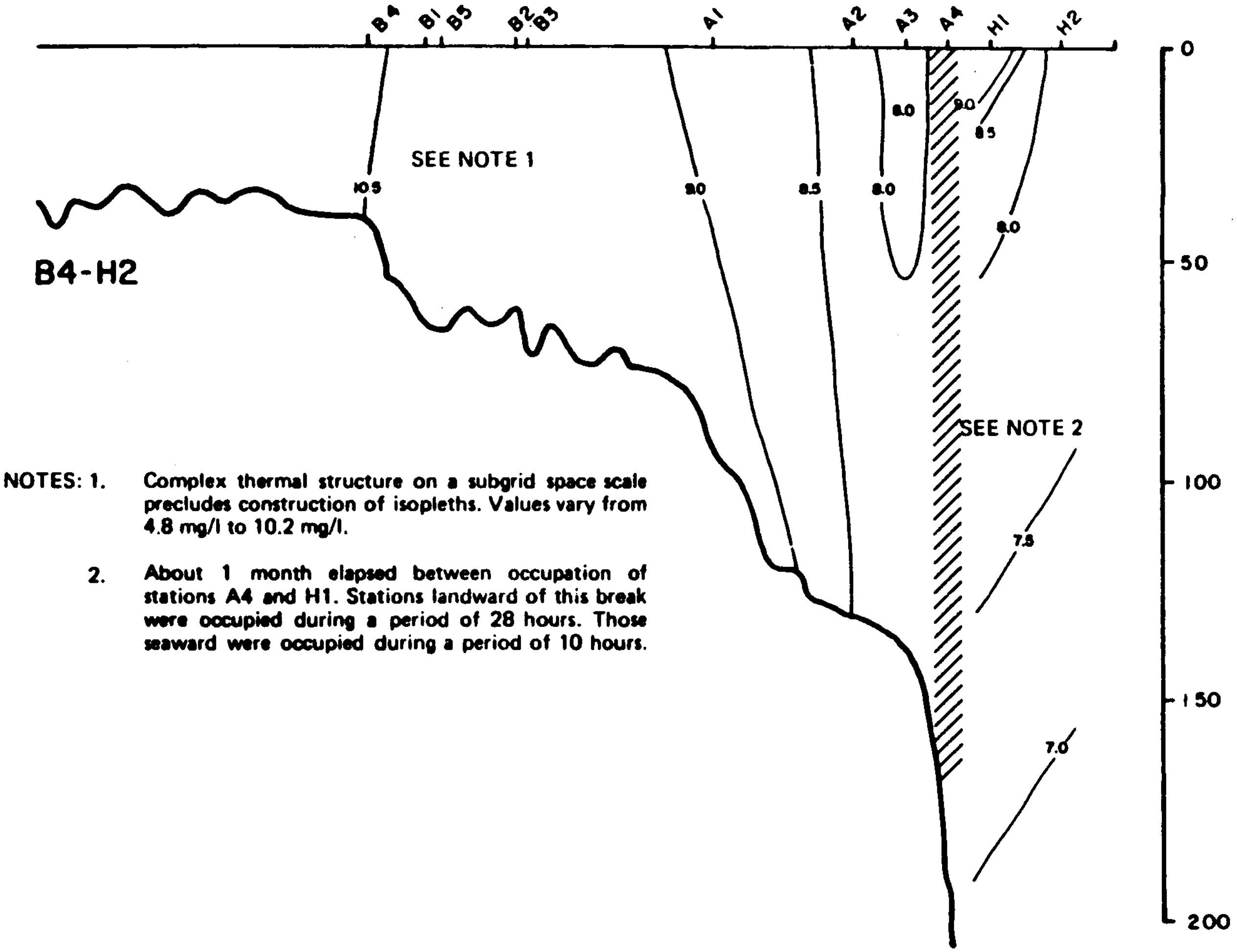
2. About 1 month elapsed between occupation of stations A4 and H1. Stations landward of this break were occupied during a period of 28 hours. Those seaward were occupied during a period of 10 hours.

Figure 3-29a. Temperature (°C) contours for section II (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: About 1 month elapsed between occupation of stations A4 and H1. Stations landward of this break were occupied during a period of 28 hours. Those seaward were occupied during a period of 10 hours.

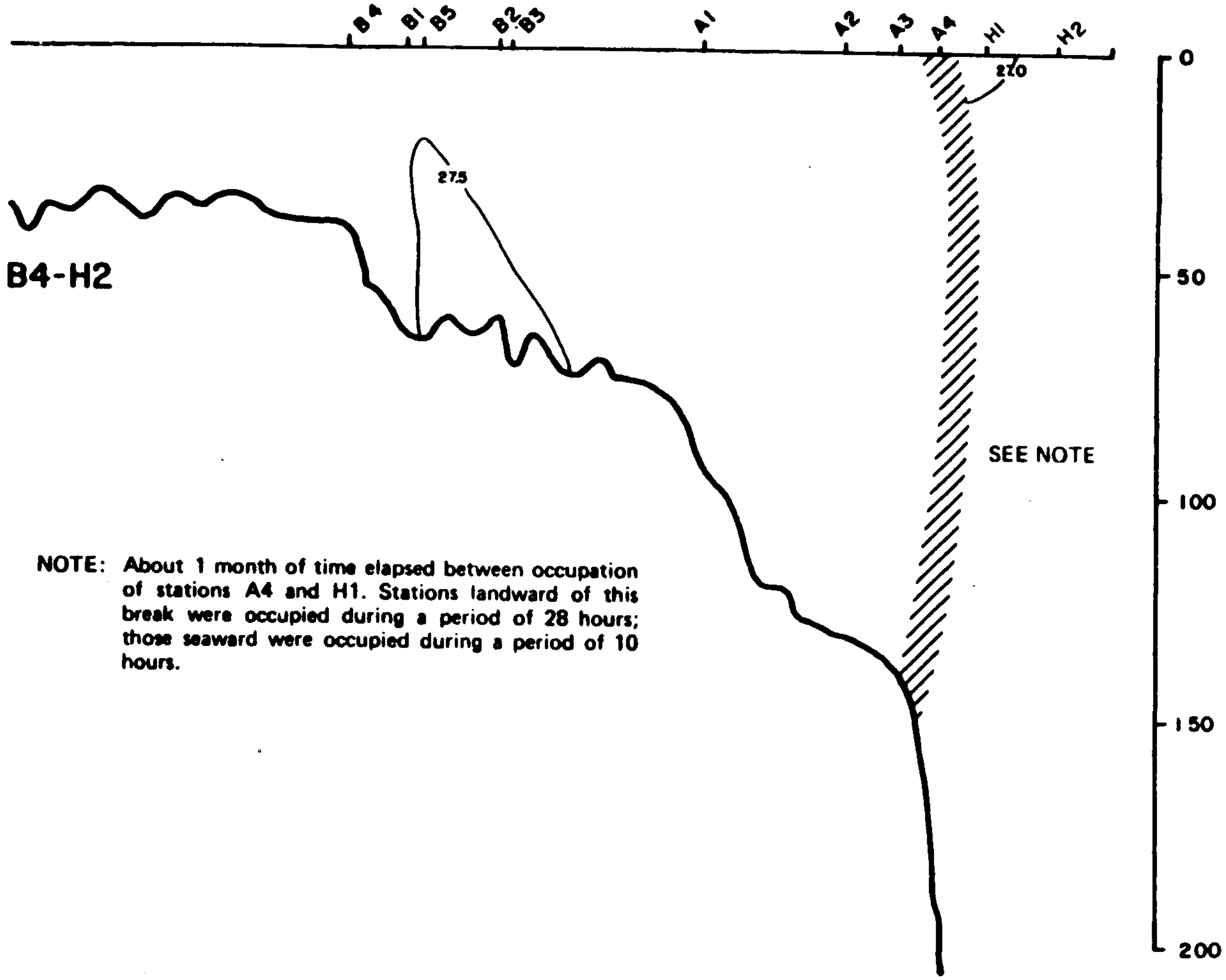
Figure 3-29b. Salinity (ppt) contours for section II (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES: 1. Complex thermal structure on a subgrid space scale precludes construction of isopleths. Values vary from 4.8 mg/l to 10.2 mg/l.

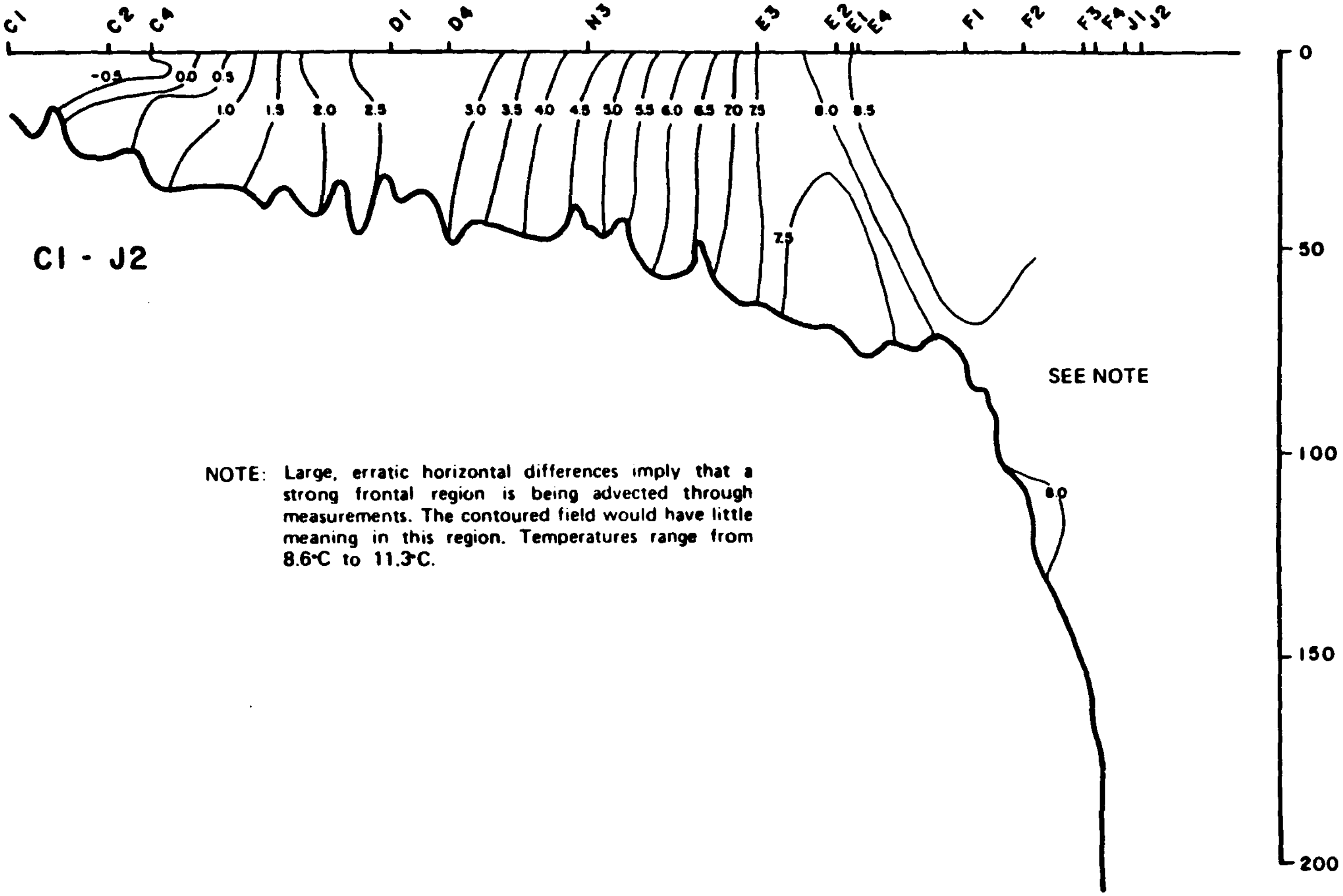
2. About 1 month elapsed between occupation of stations A4 and H1. Stations landward of this break were occupied during a period of 28 hours. Those seaward were occupied during a period of 10 hours.

Figure 3-29c. Dissolved oxygen (mg/l) contours for section II (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of



NOTE: About 1 month of time elapsed between occupation of stations A4 and H1. Stations landward of this break were occupied during a period of 28 hours; those seaward were occupied during a period of 10 hours.

Figure 3-29d. Density (sigma-t units) contours for section II (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Large, erratic horizontal differences imply that a strong frontal region is being advected through measurements. The contoured field would have little meaning in this region. Temperatures range from 8.6°C to 11.3°C.

Figure 3-30a. Temperature (°C) contours for section III (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

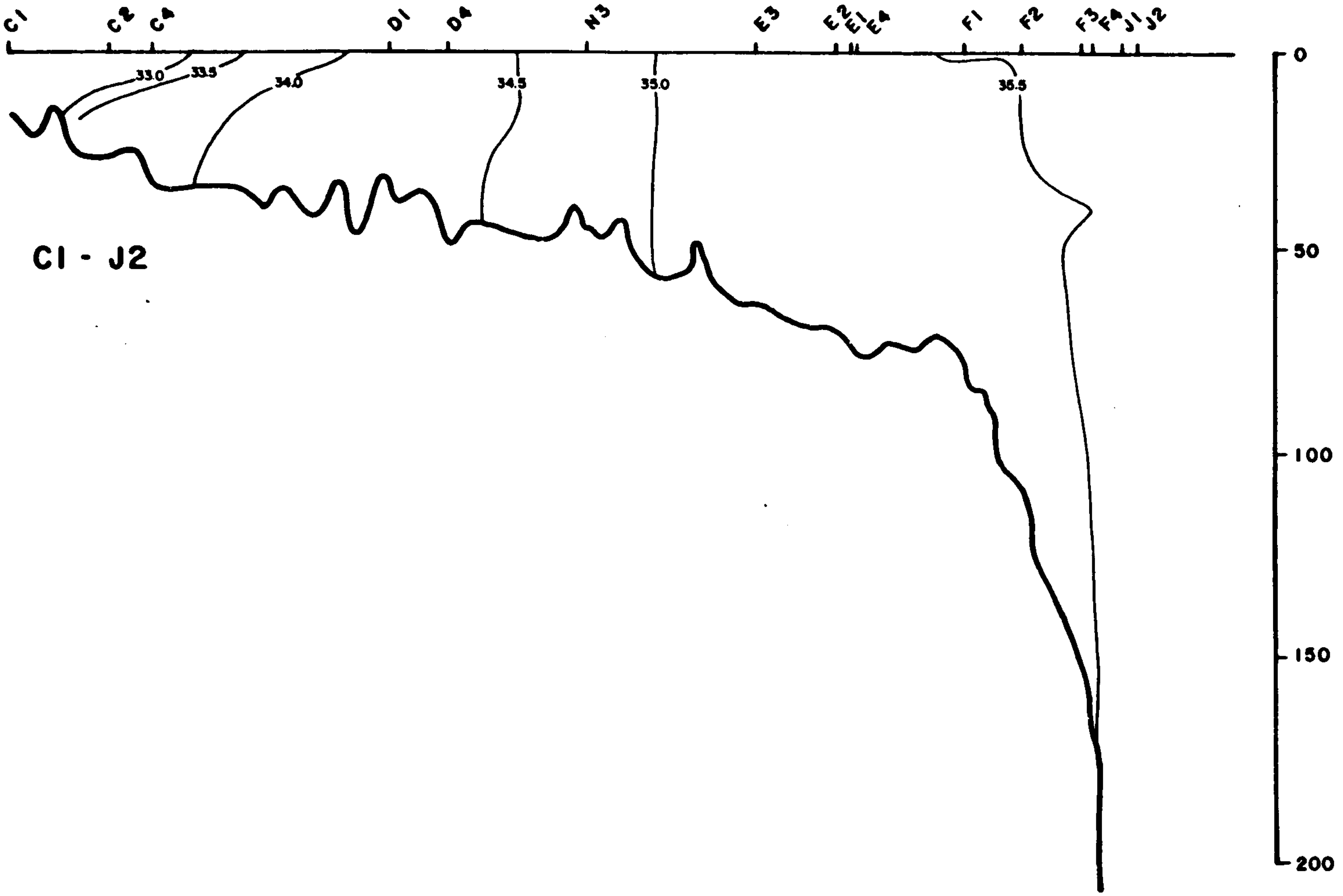


Figure 3-30b. Salinity (ppt) contours for section III (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

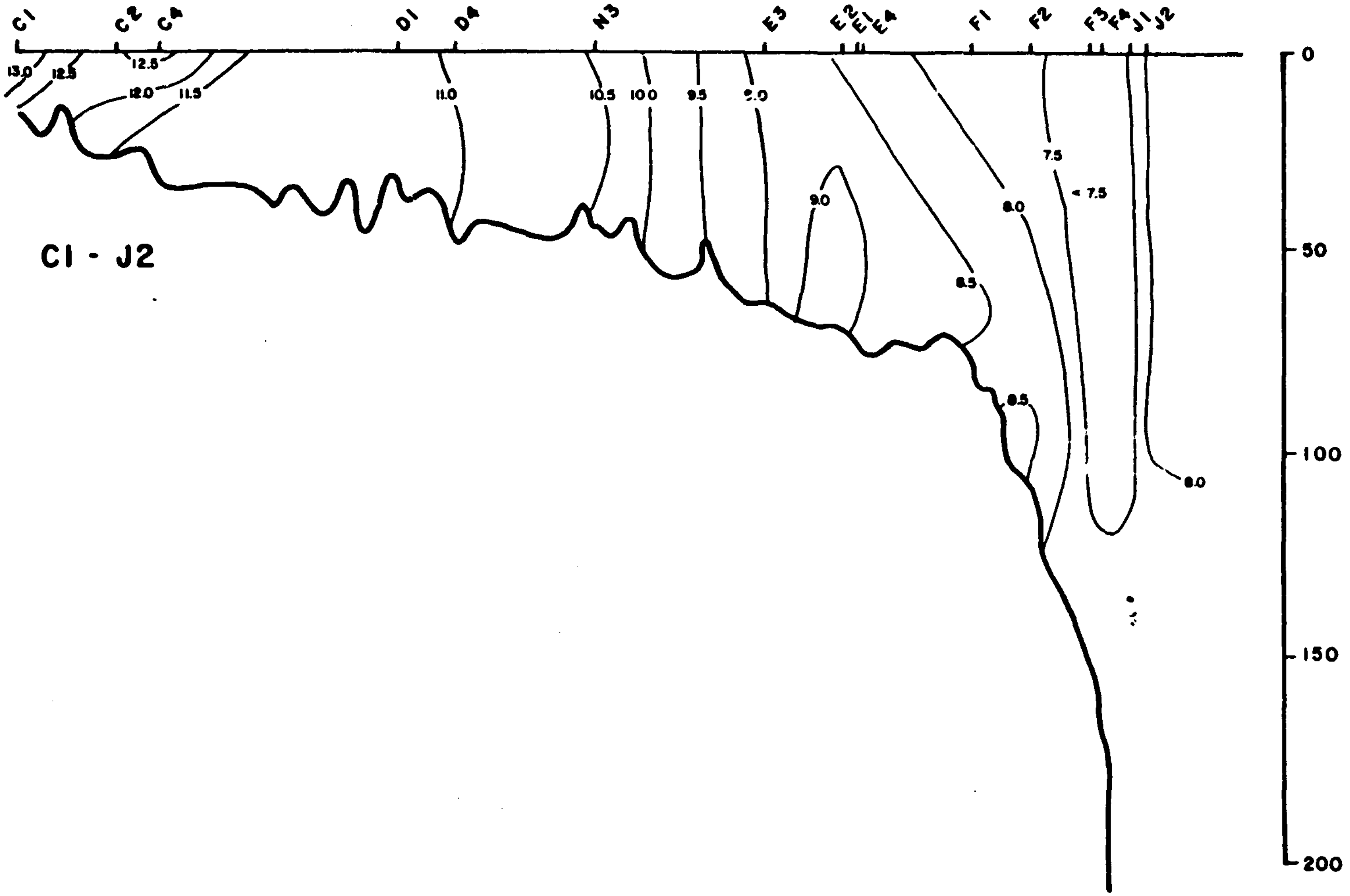


Figure 3-30c. Dissolved oxygen (mg/l) contours for section III (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

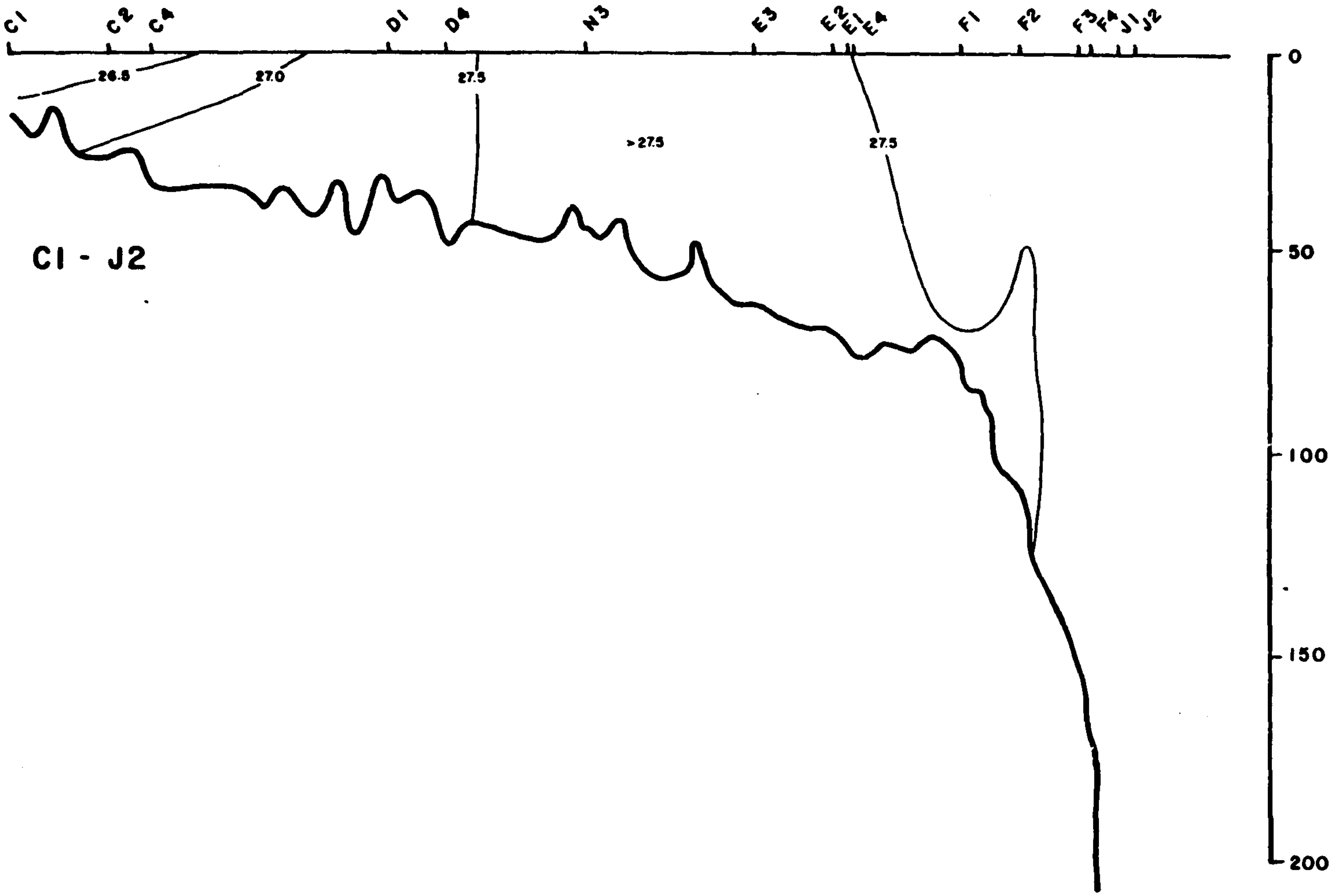
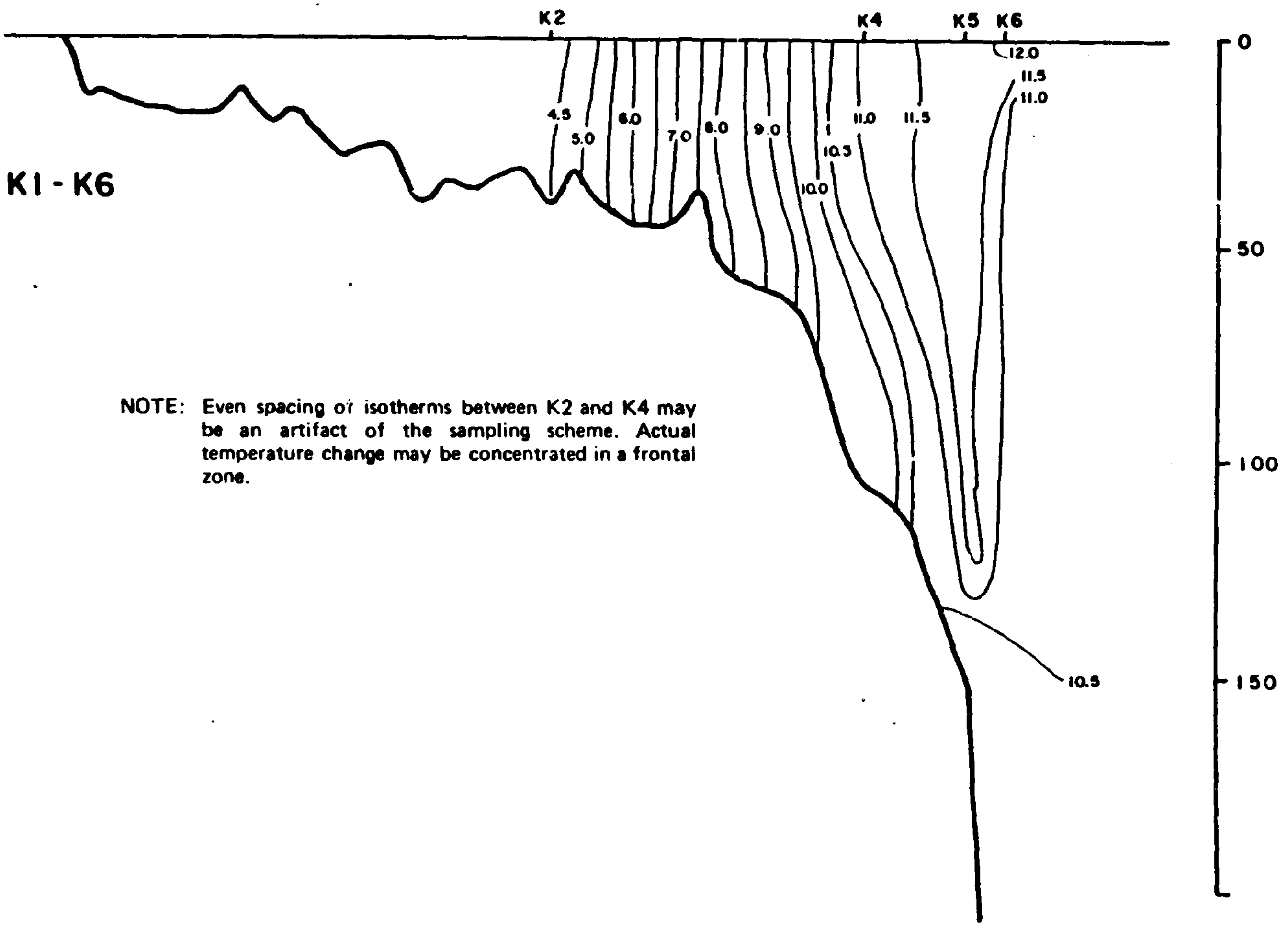


Figure 3-30d. Density (sigma-t units) contours for section III (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Even spacing of isotherms between K2 and K4 may be an artifact of the sampling scheme. Actual temperature change may be concentrated in a frontal zone.

Figure 3-31a. Temperature (°C) contours for section IV (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

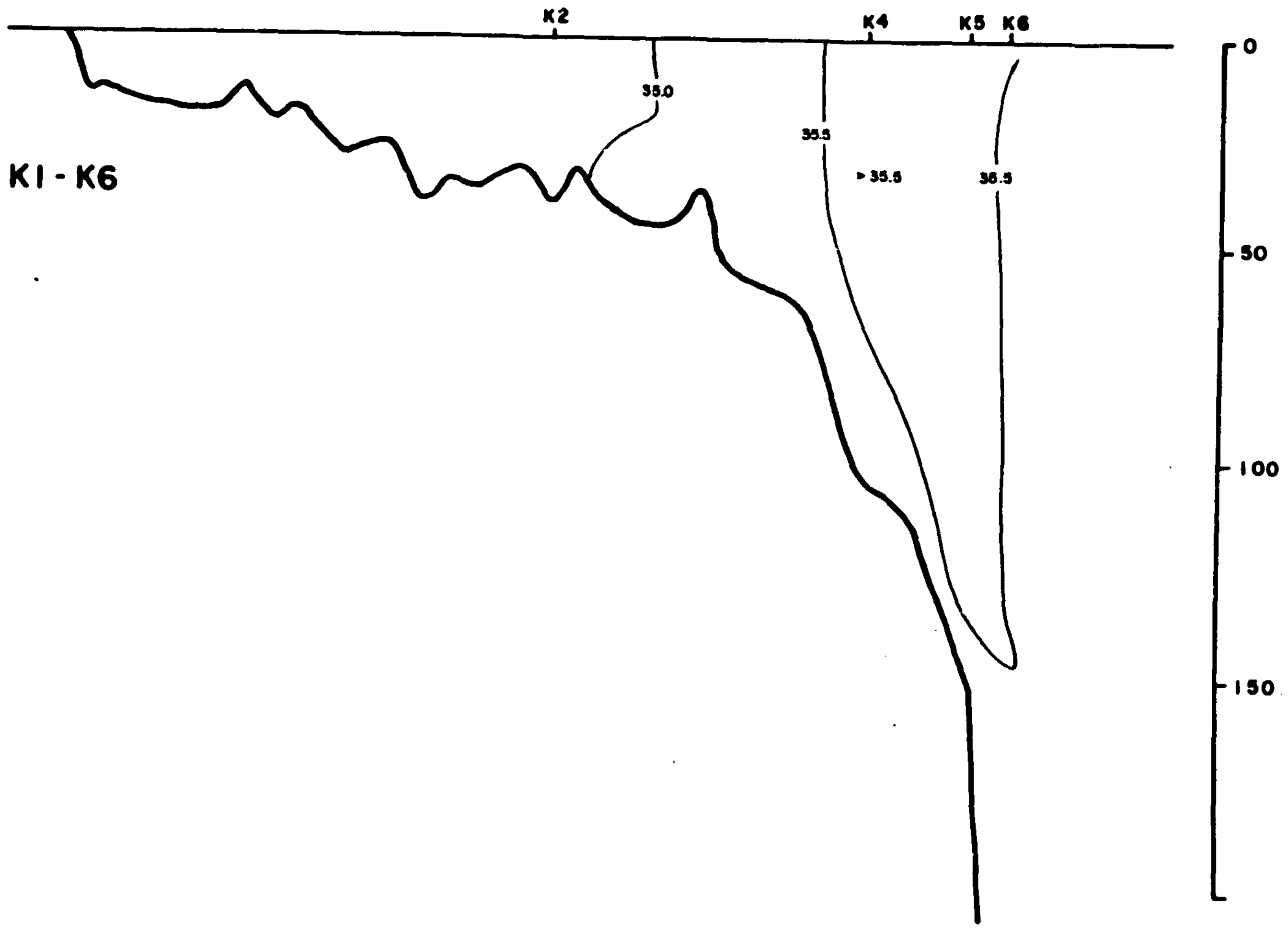


Figure 3-31b. Salinity (ppt) contours for section IV (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

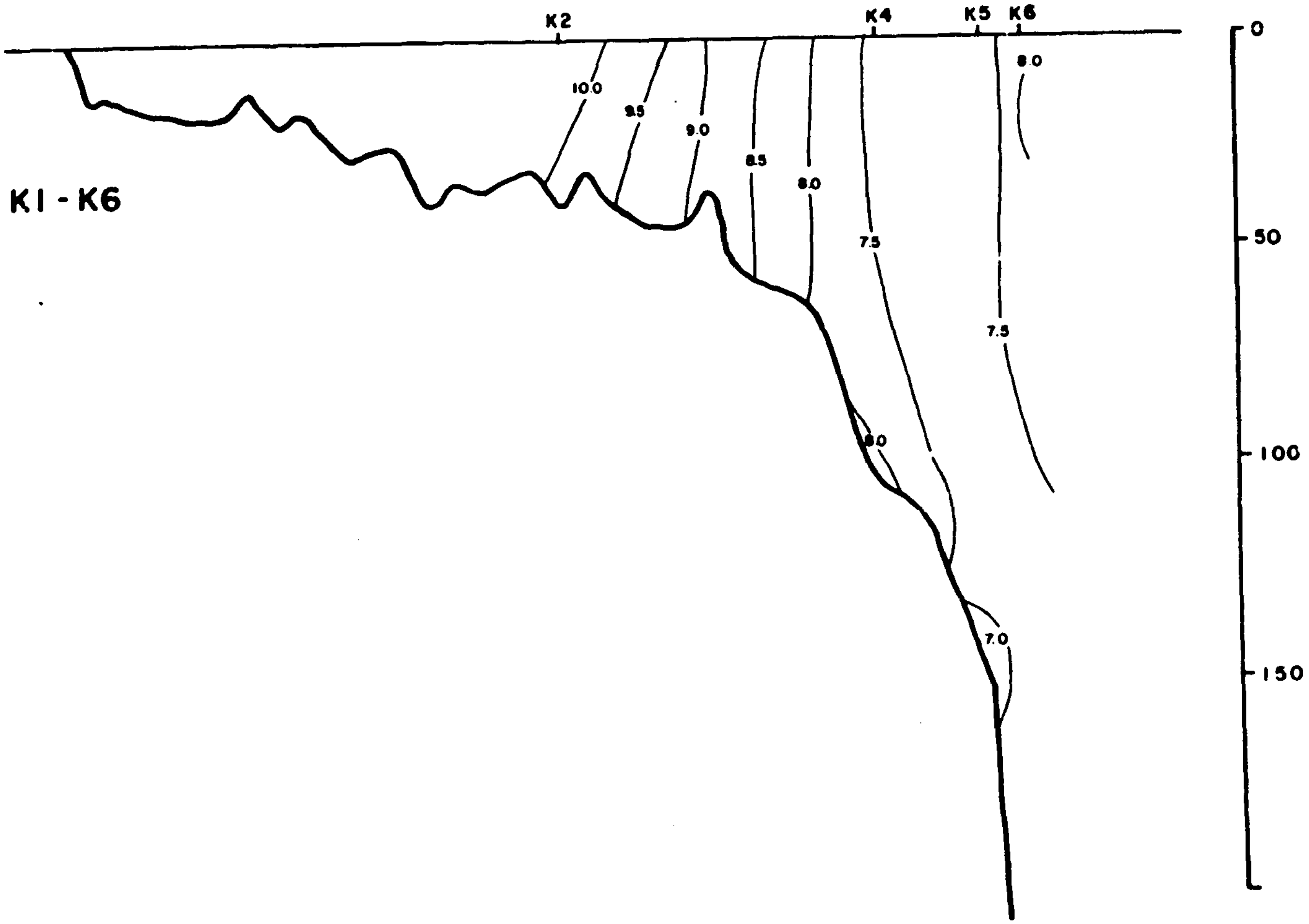
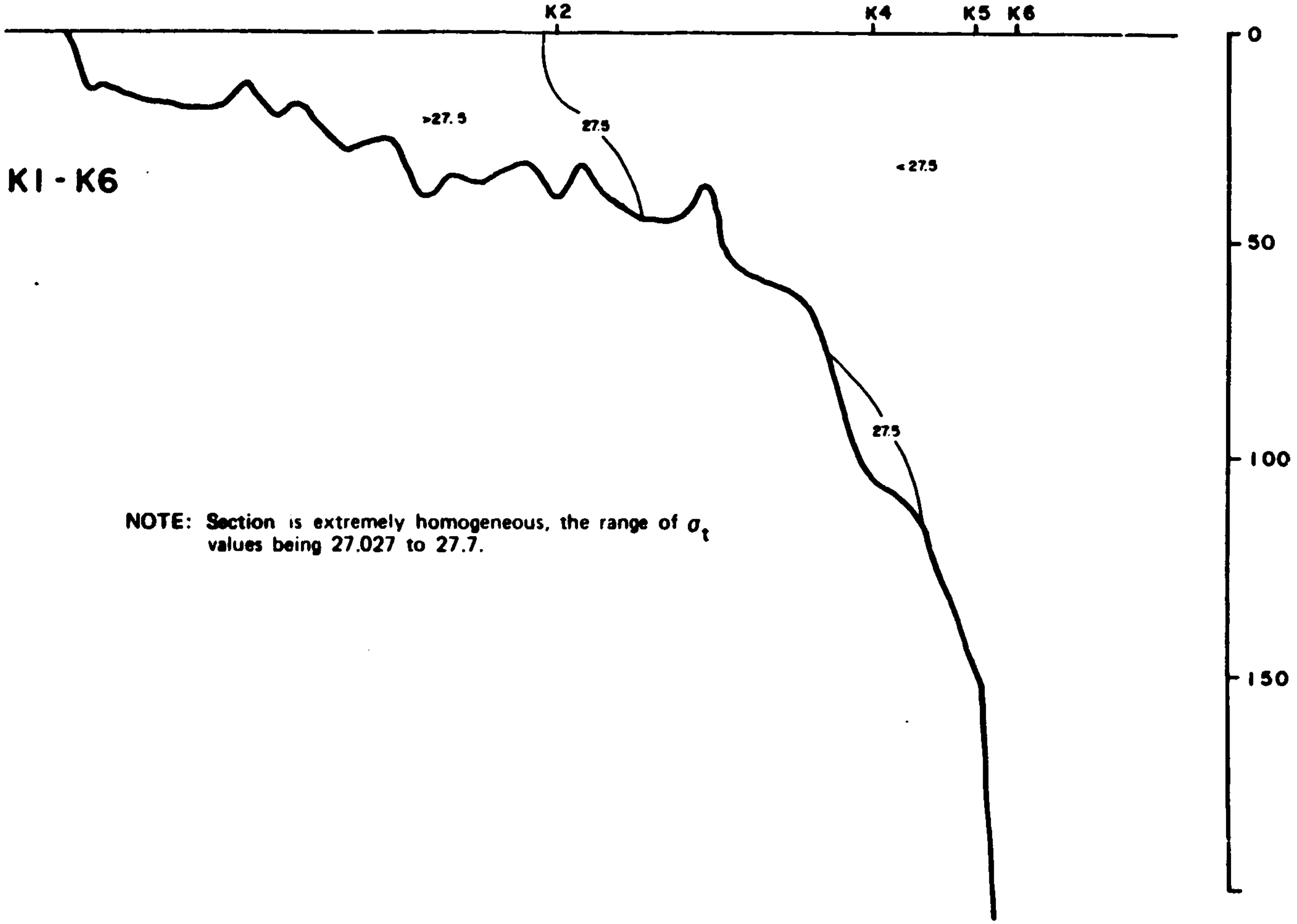


Figure 3-31c. Dissolved oxygen (mg/l) contours for section IV (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Section is extremely homogeneous, the range of σ_t values being 27.027 to 27.7.

Figure 3-31d. Density (sigma-t units) contours for section IV (Figure 3-6) during cruise BLM06B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

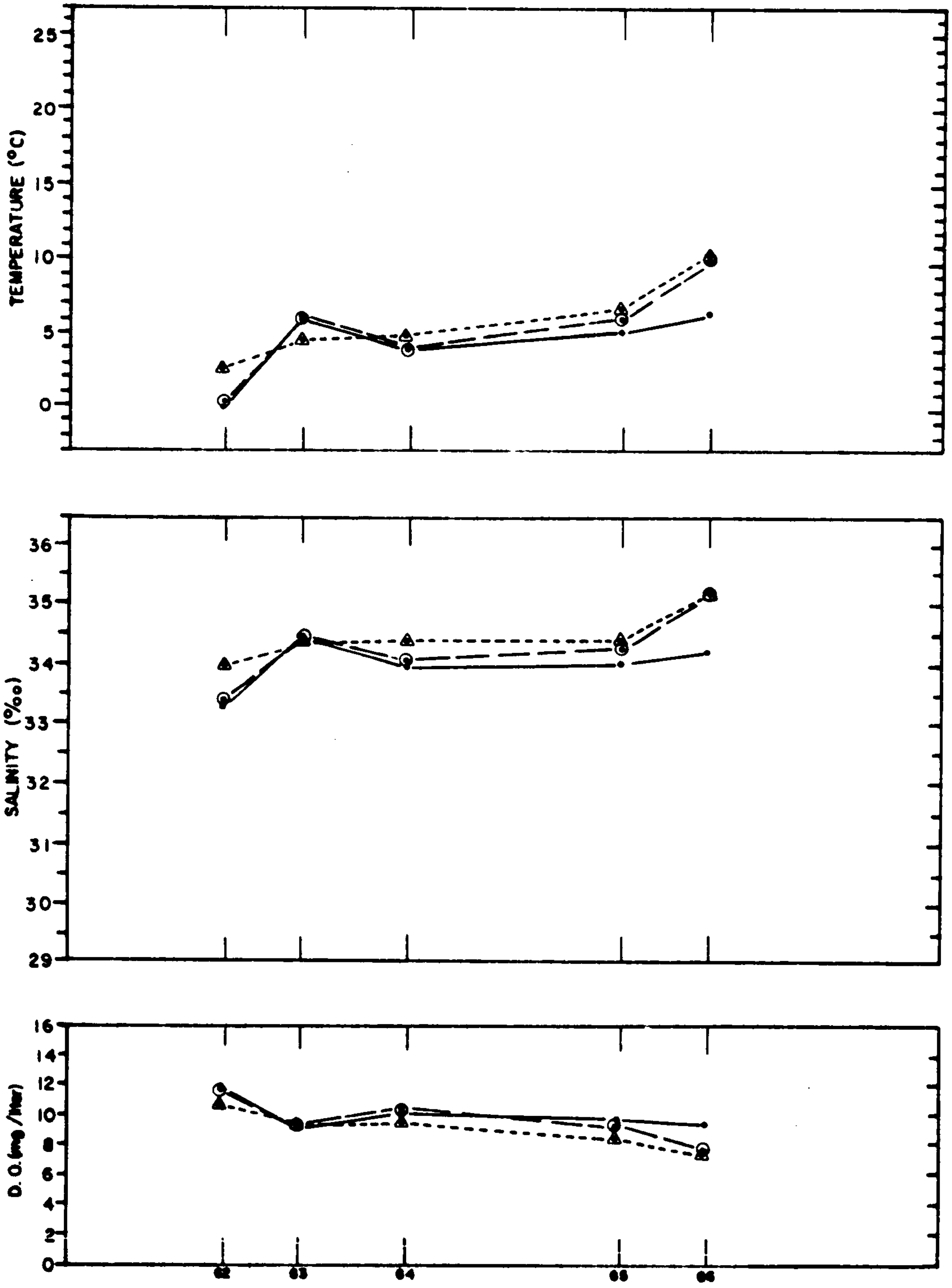


Figure 3-32. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section I (Figure 3-6) during cruise BLM06B.

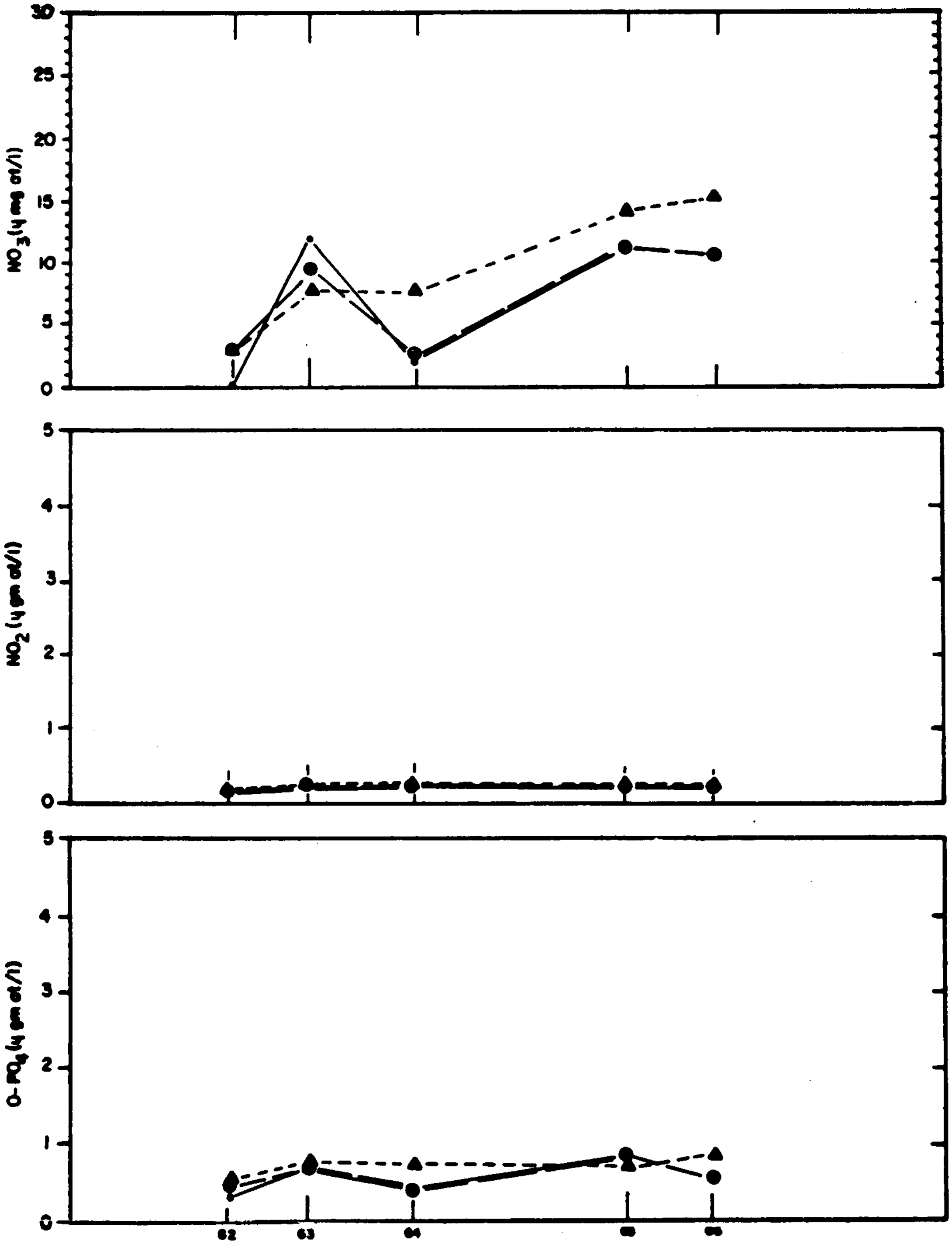


Figure 3-33. Surface (•), mid-depth (θ), and bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section I (Figure 3-6) during cruise BLM06B.

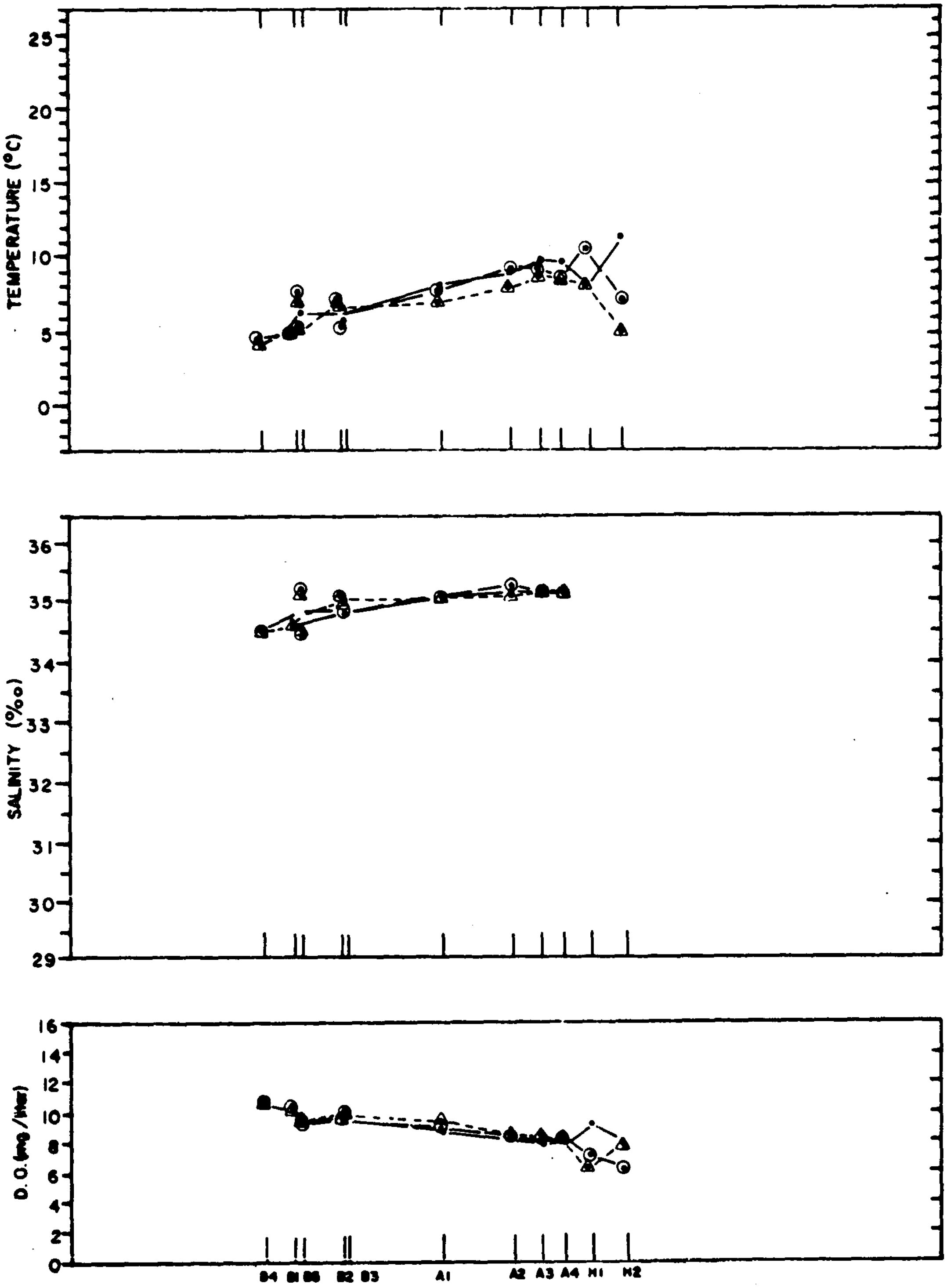


Figure 3-34. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM06B.

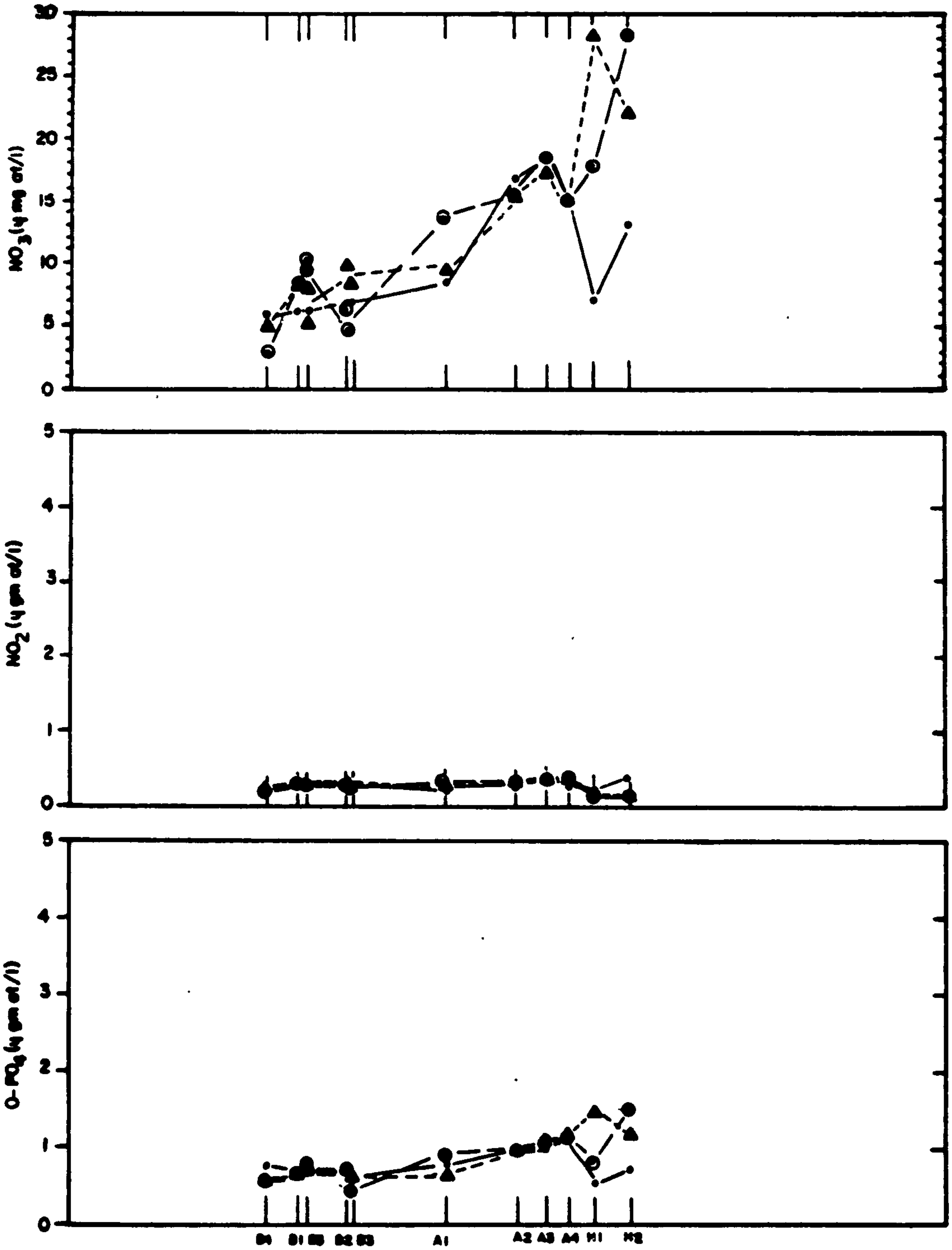


Figure 3-35. Surface (·), mid-depth (Θ), and bottom (▲) values of nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM06B.

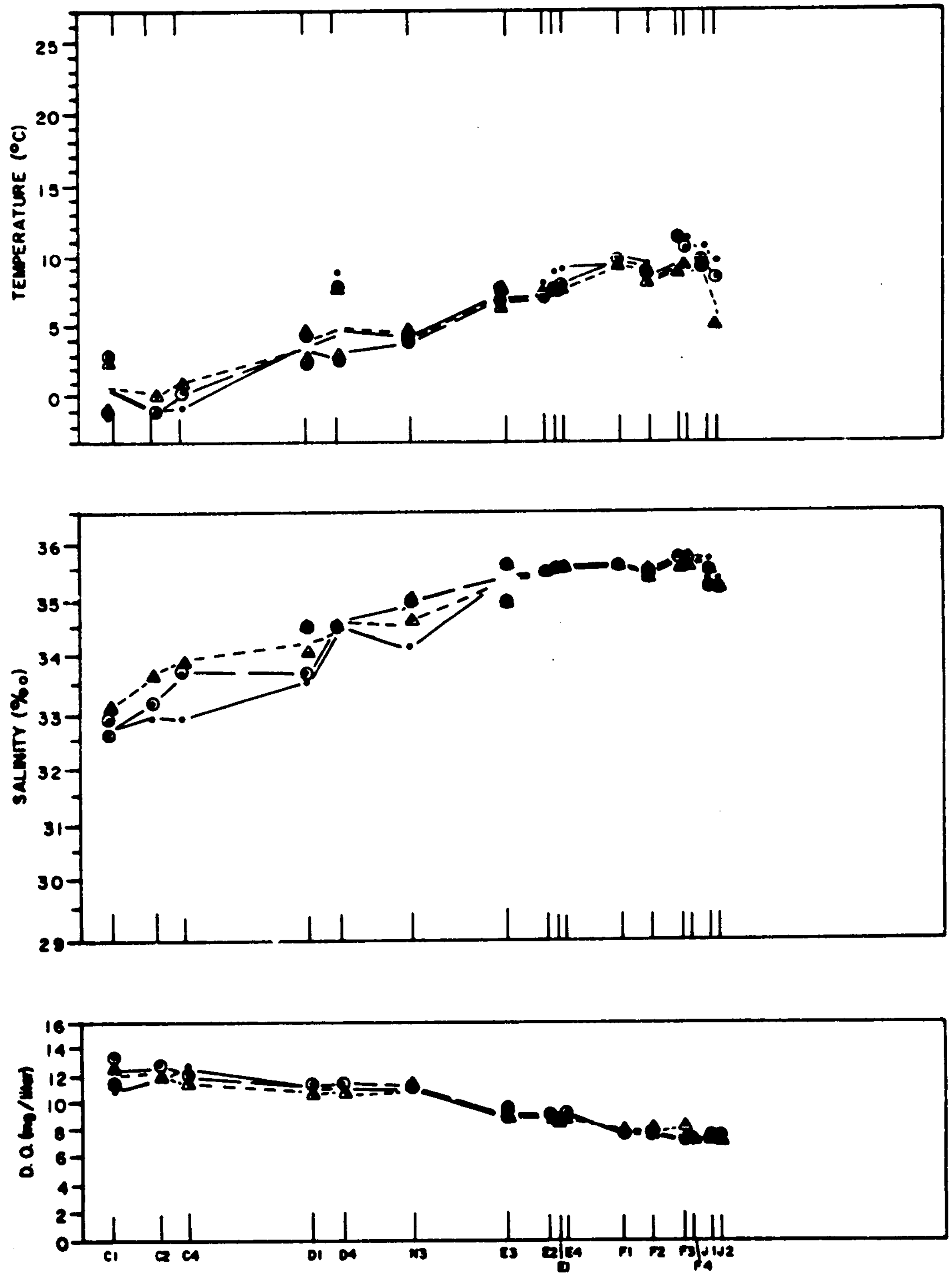


Figure 3-36. Surface (•), mid-depth (⊙), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM06B.

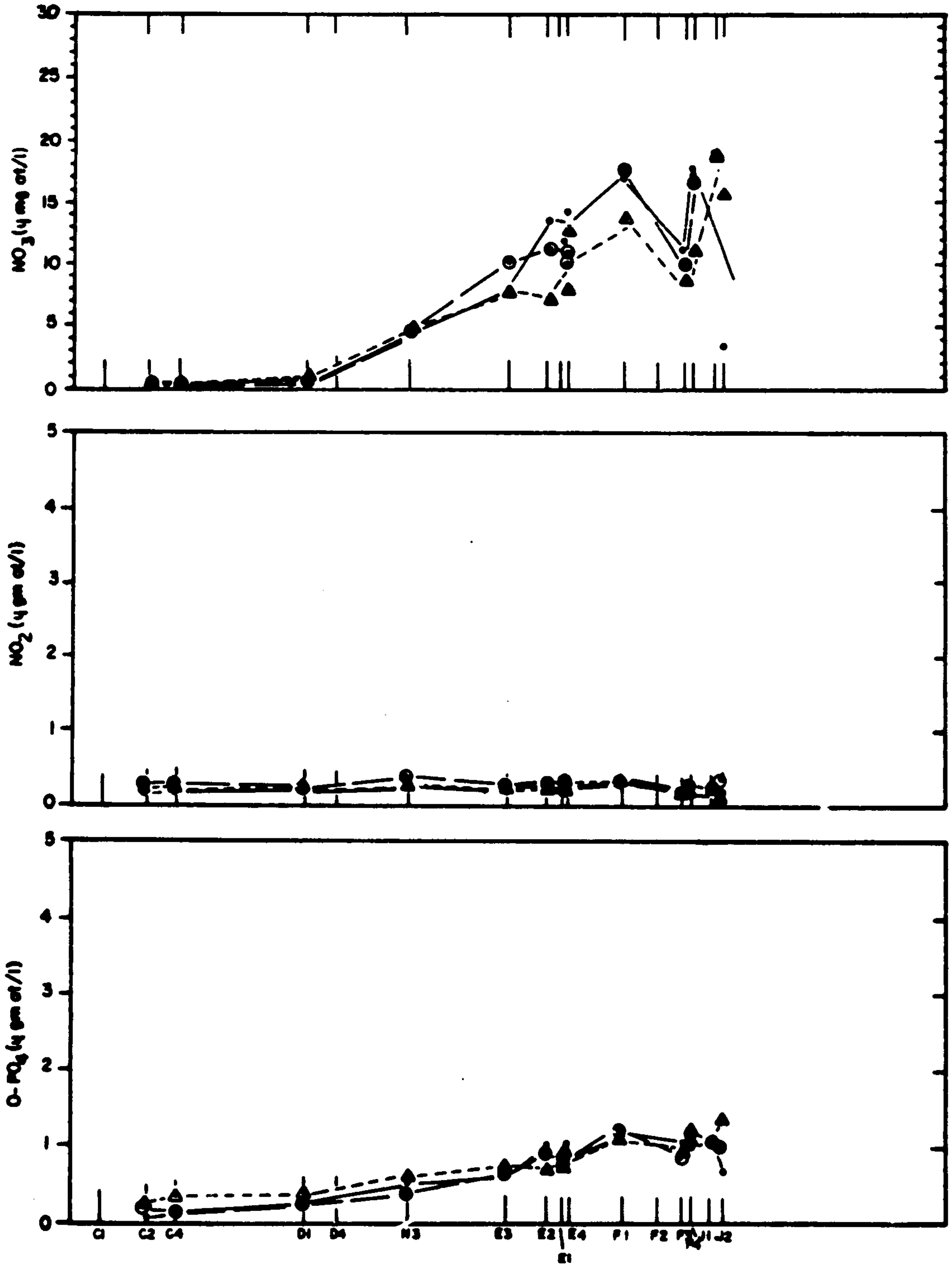


Figure 3-37. Surface (·), mid-depth (θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM06B.

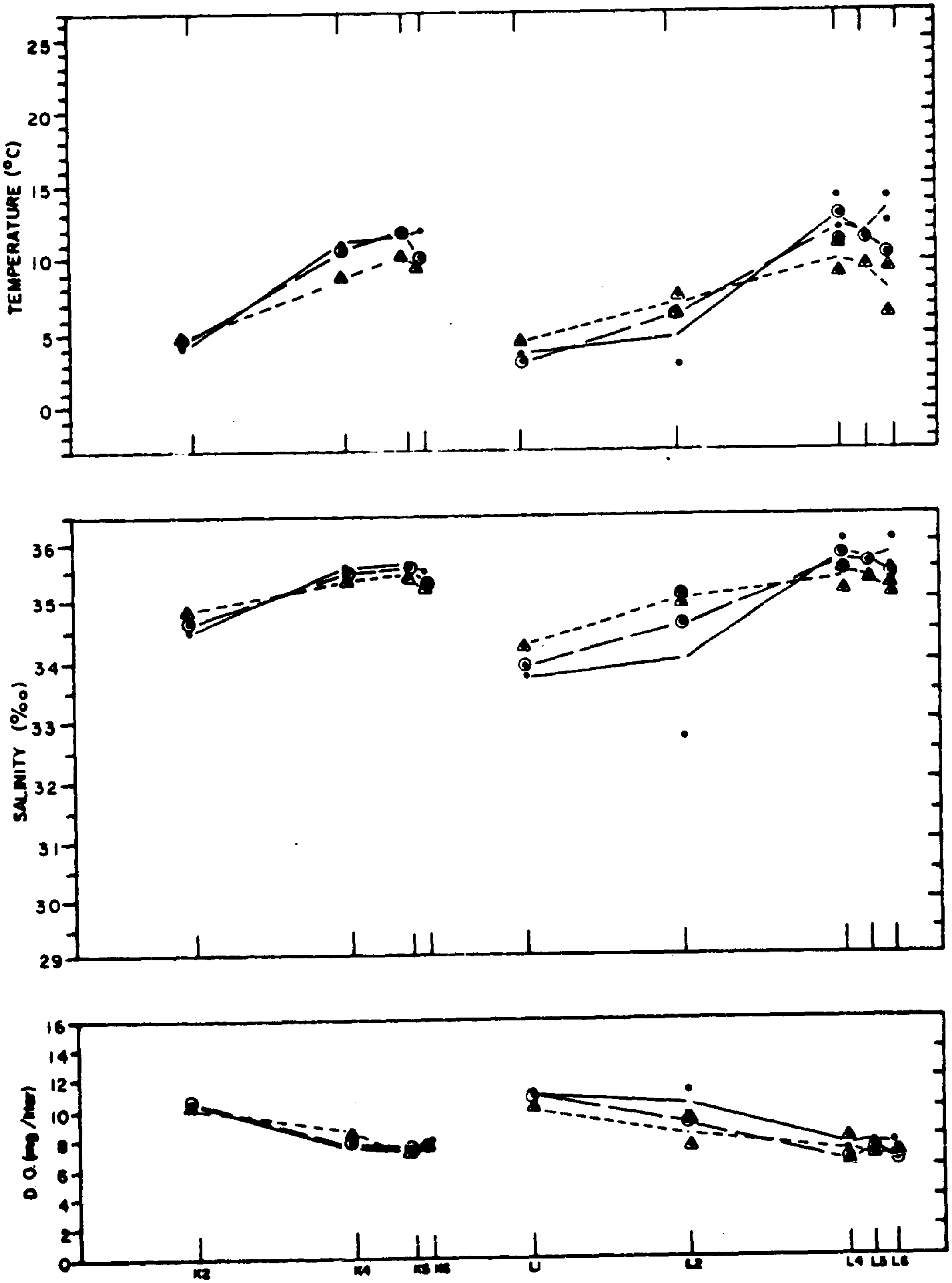


Figure 3-38. Surface (·), mid-depth (Θ), and bottom (Δ) values of temperature, salinity and dissolved oxygen measured along sections IV and V (Figure 3-6) during cruise BLM06B.

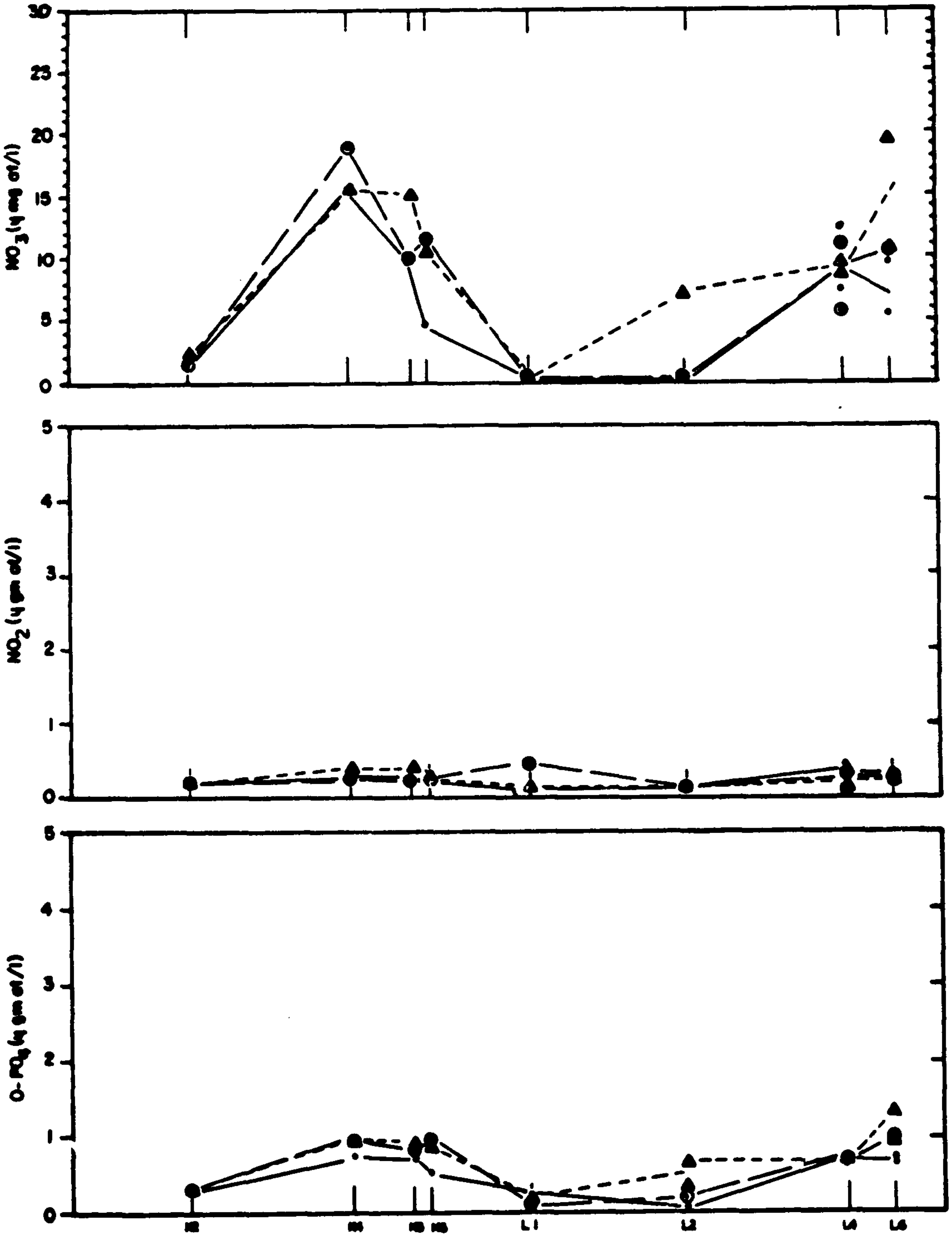


Figure 3-39. Surface (•), mid-depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite and ortho-phosphate measured along sections IV and V (Figure 3-6) during cruise BLM06B.

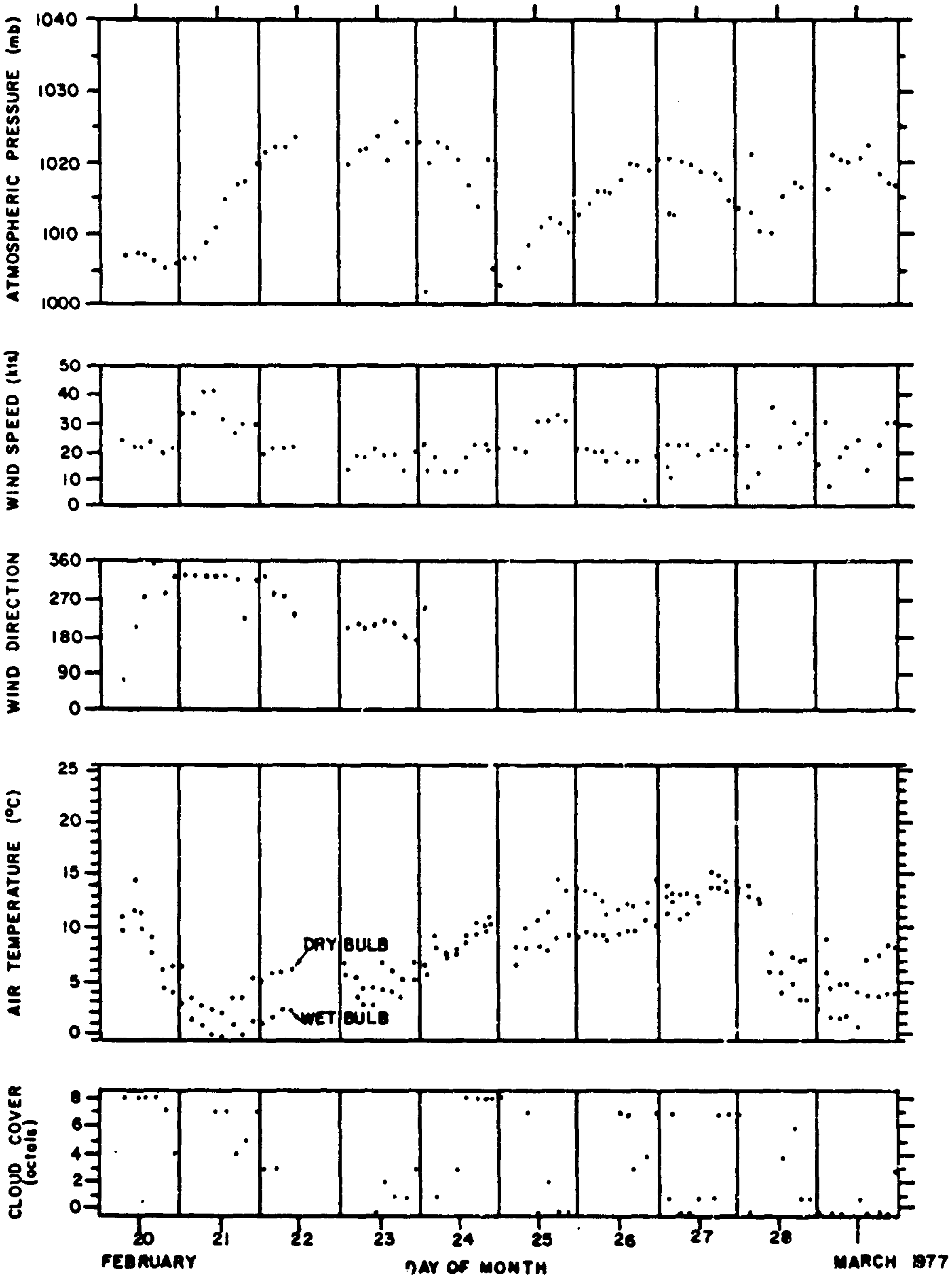


Figure 3-40a. Meteorological data collected during cruise BLM06W from 20 February to 1 March 1977.

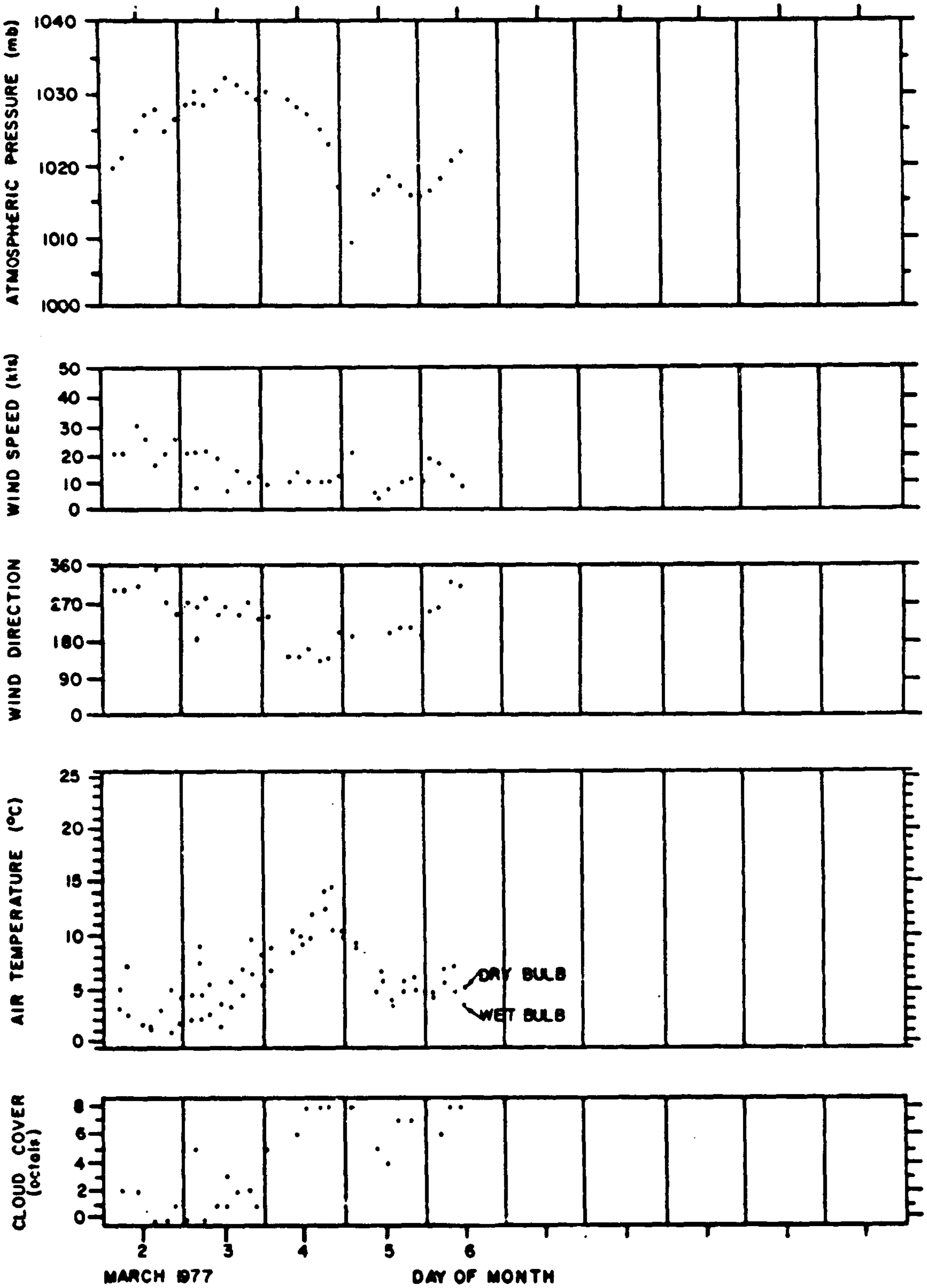


Figure 3-40b. Meteorological data collected during cruise BLM06W from 2-6 March 1977.

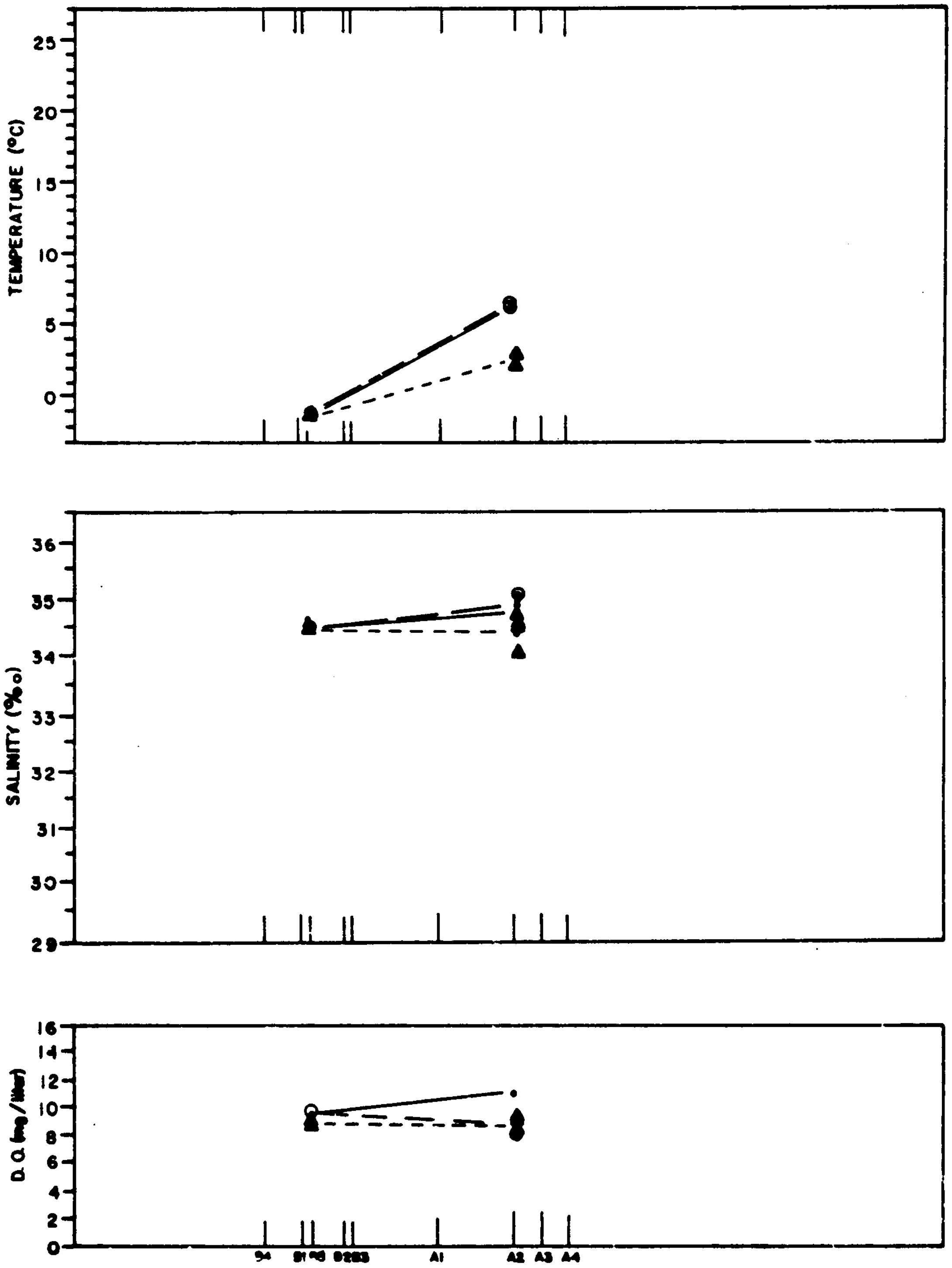


Figure 3-41. Surface (•), mid-depth (Θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM06W.

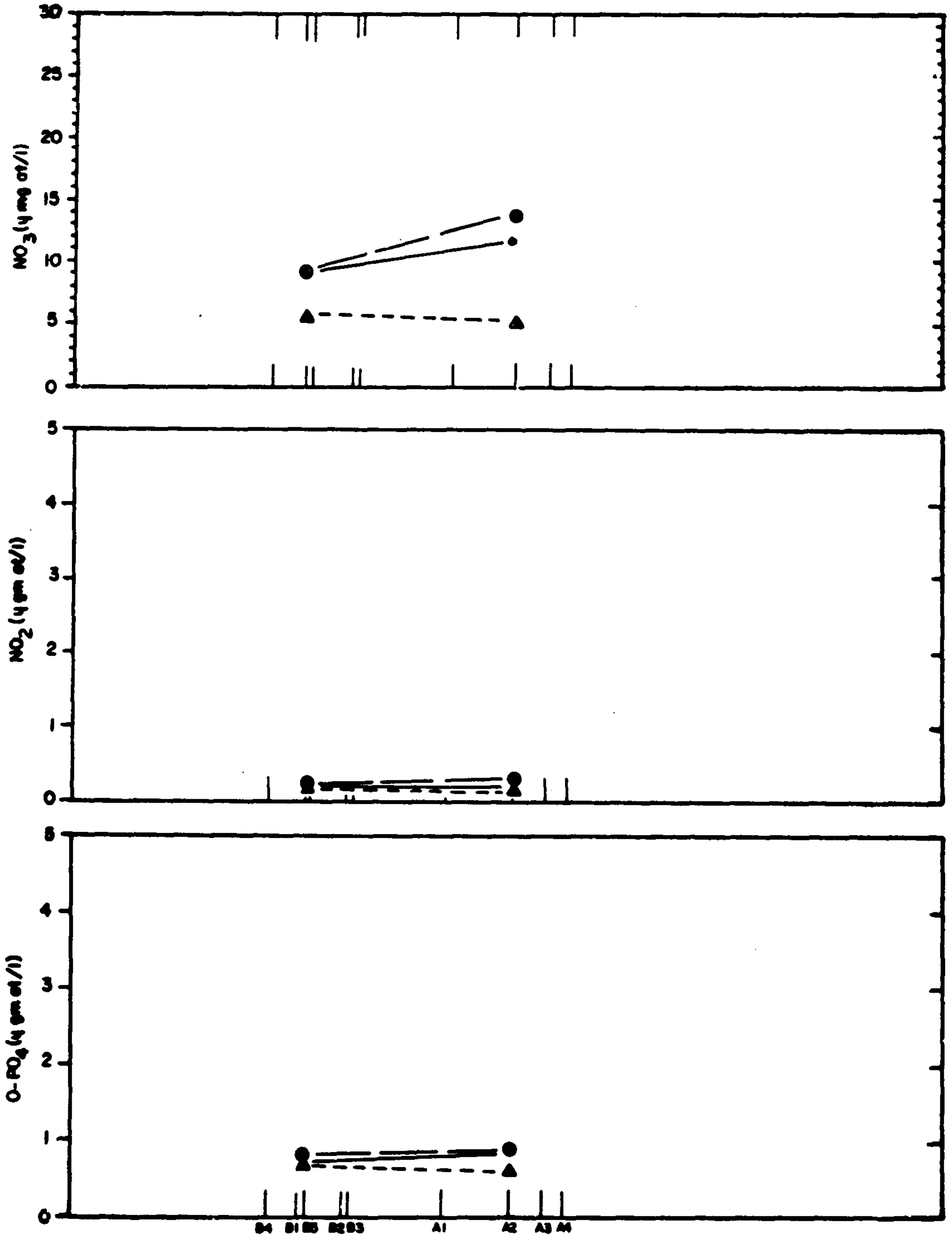


Figure 3-42. Surface (•), mid-depth (Θ), and bottom (▲) values of nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM06W.

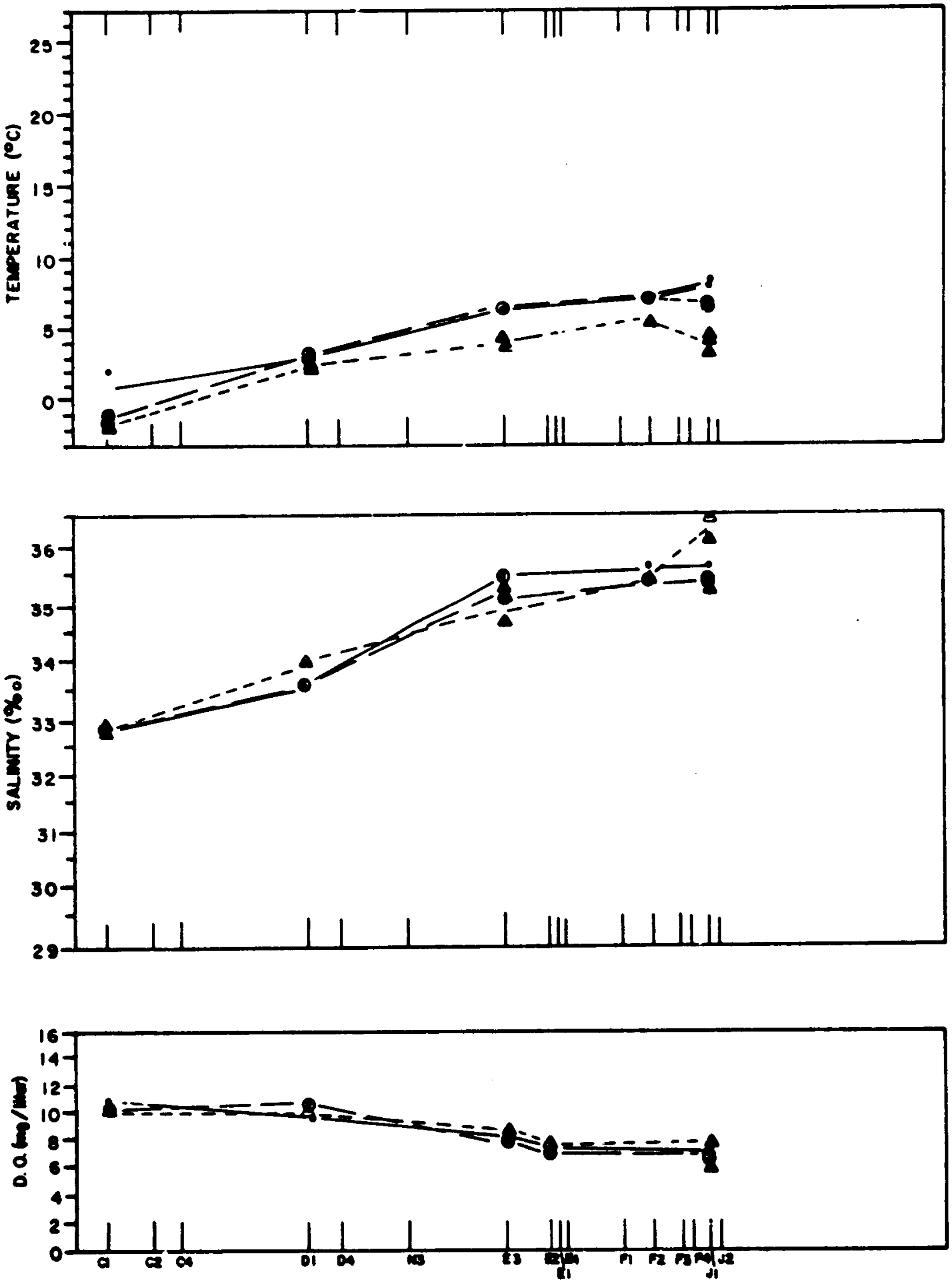


Figure 3-43. Surface (·), mid-depth (Θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM06W.

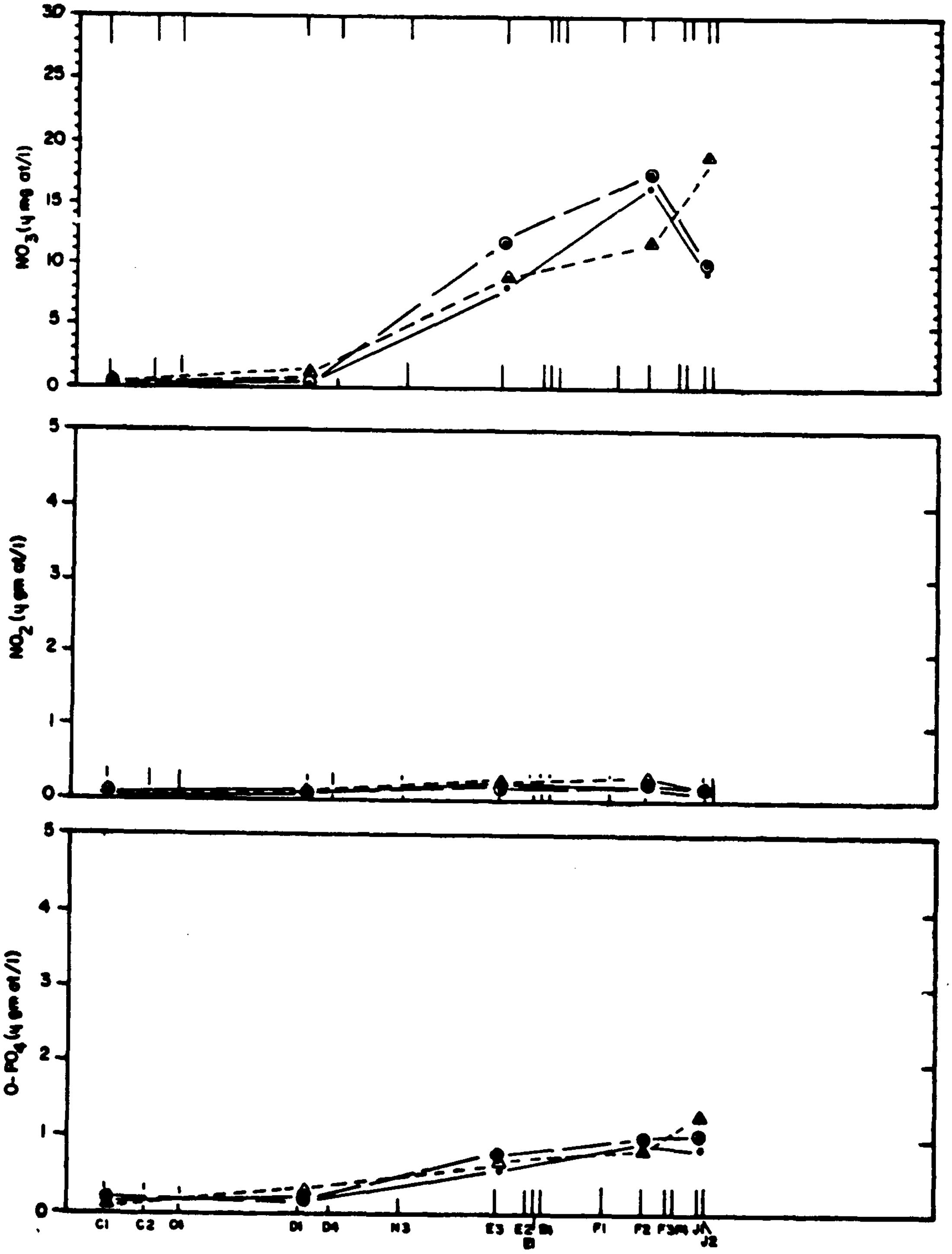


Figure 3-44. Surface (·), mid-depth (θ), and bottom (▲) values of dissolved nitrate, nitrite and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM06W.

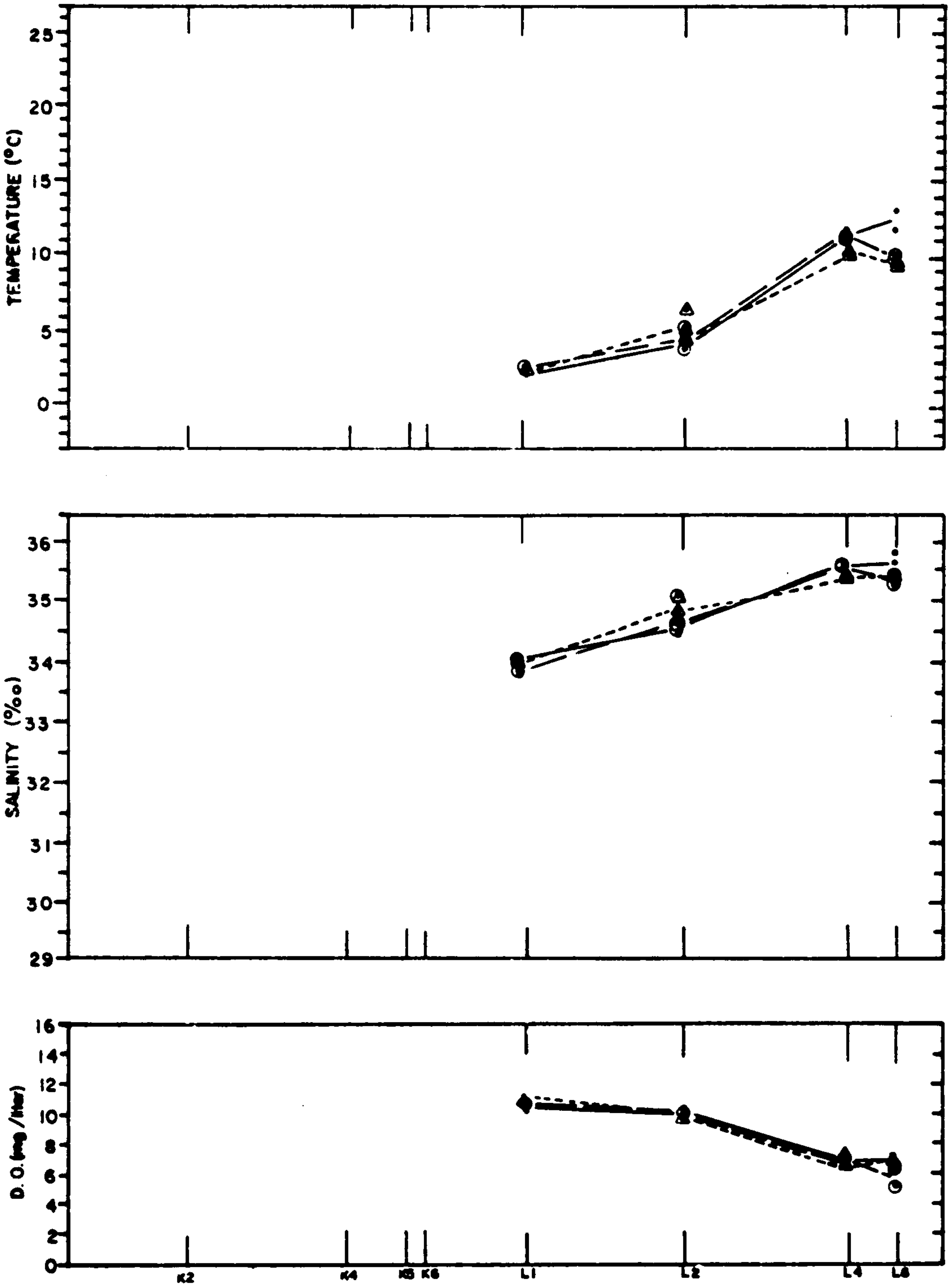


Figure 3-45. Surface (•), mid-depth (Θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section V (Figure 3-6) during cruise BLM06W.

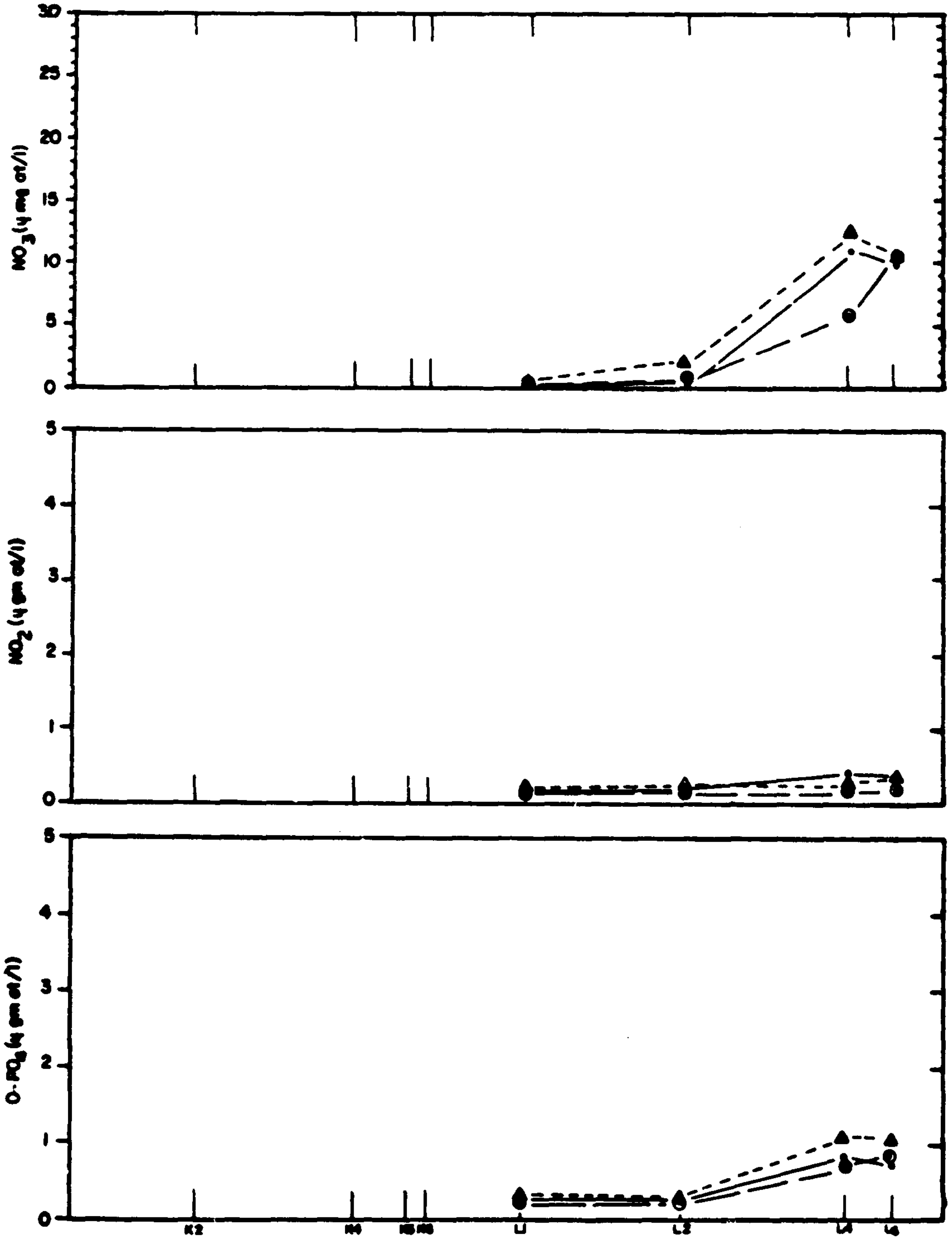


Figure 3-46. Surface (•), mid-depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM06W.

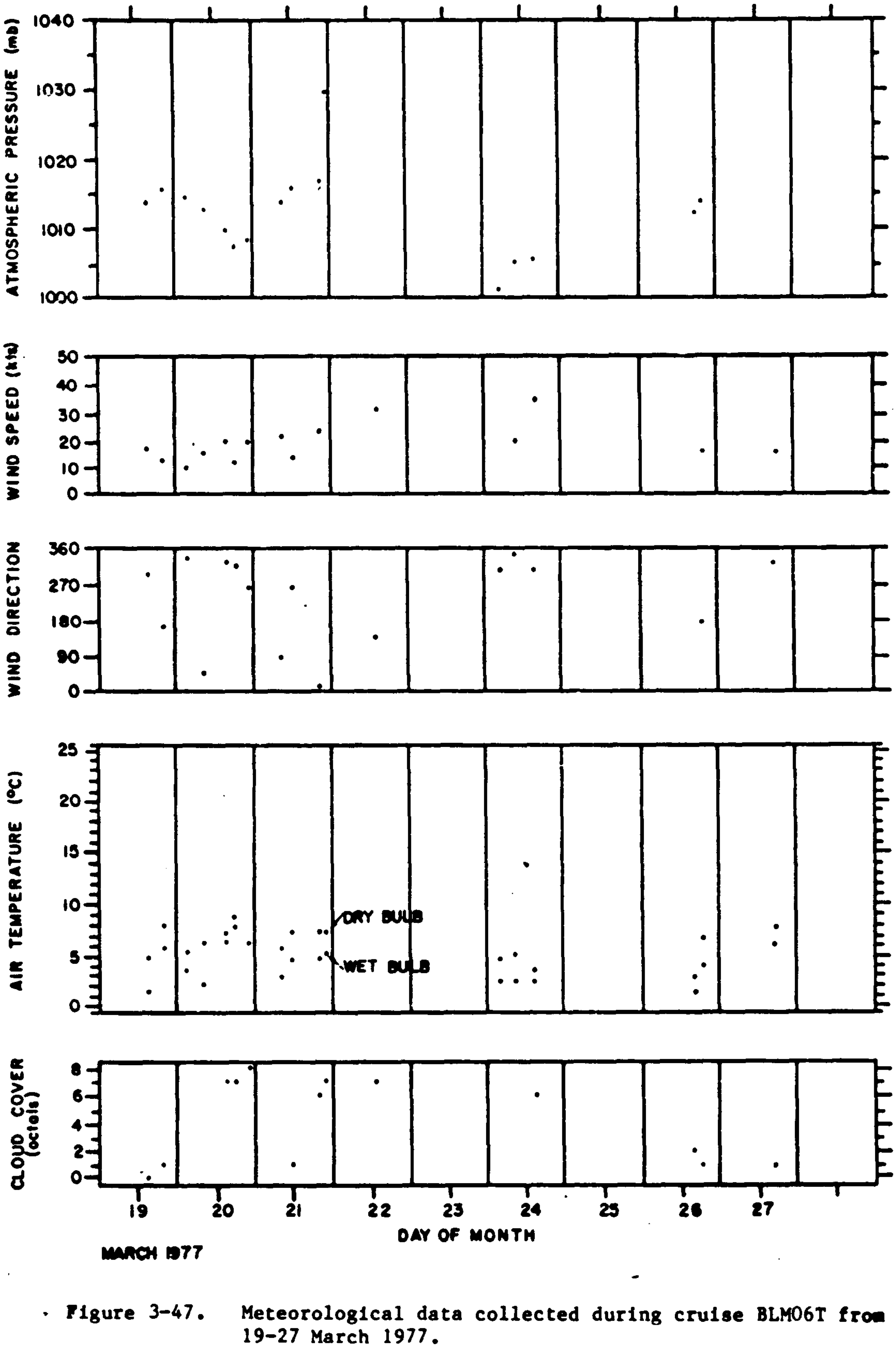


Figure 3-47. Meteorological data collected during cruise BLM06T from 19-27 March 1977.

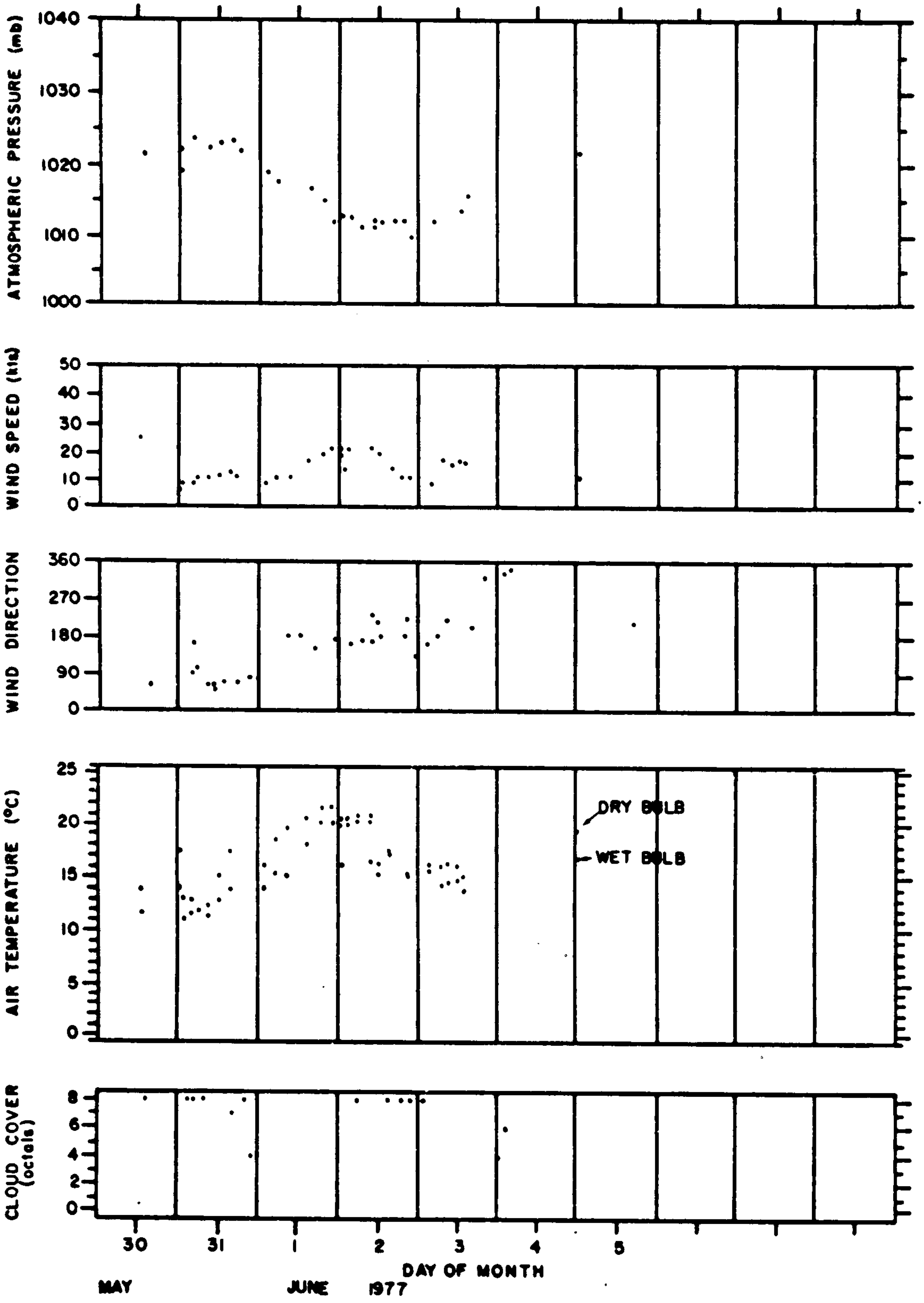


Figure 3-48. Meteorological data collected during cruise BLM07B from 30 May to 5 June 1977.

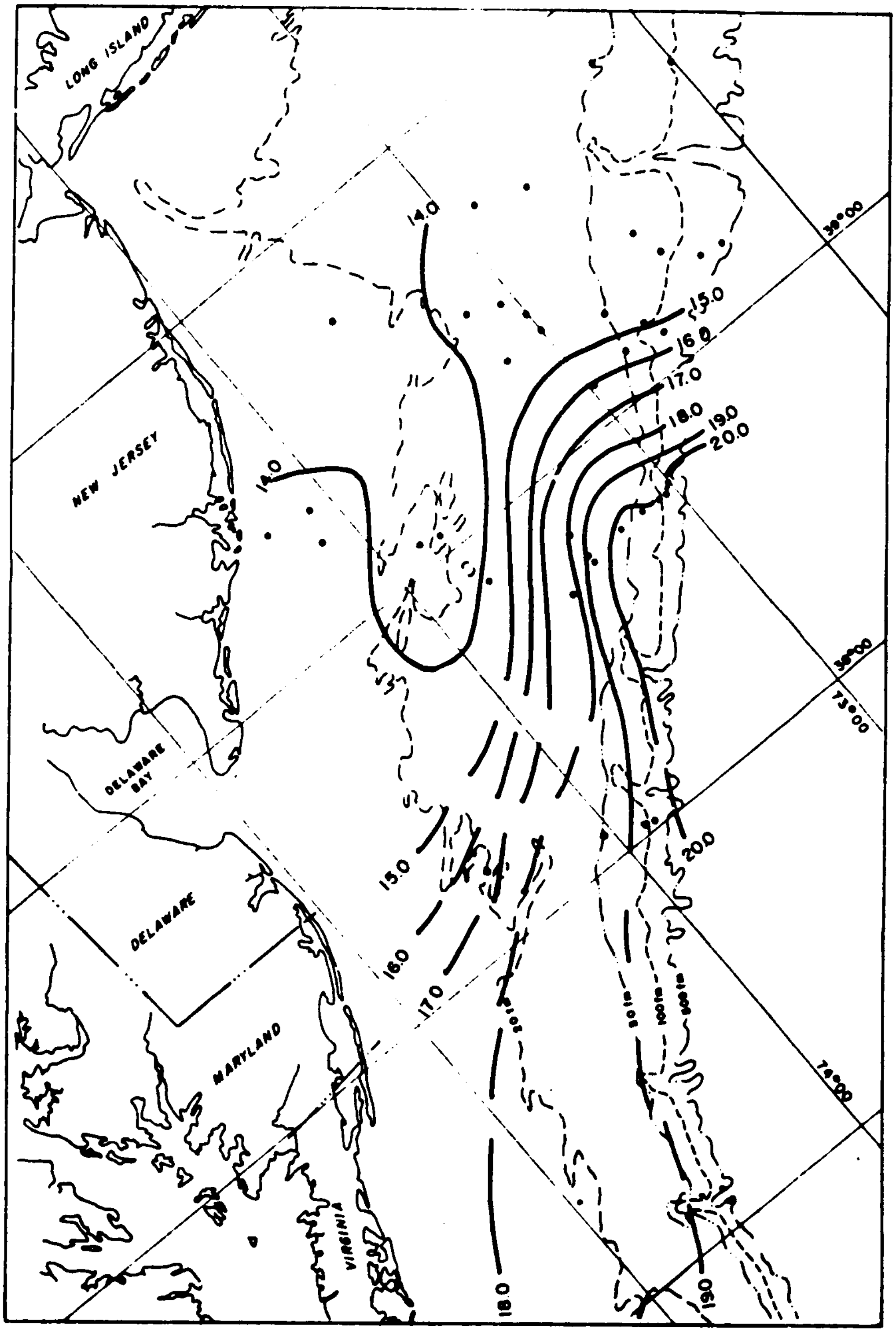


Figure 3-49a. Surface temperature (°C) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

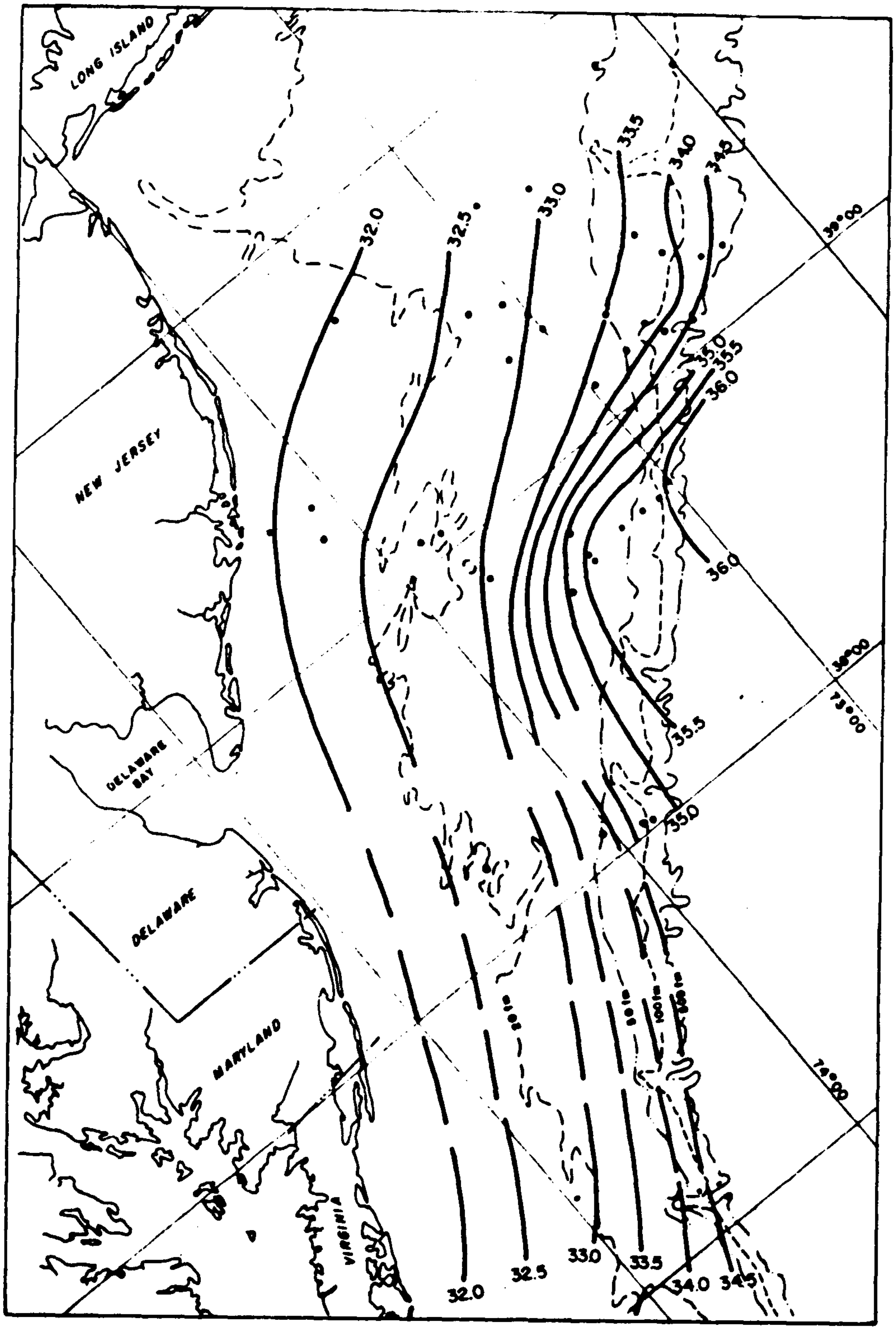


Figure 3-49b. Surface salinity (ppt) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

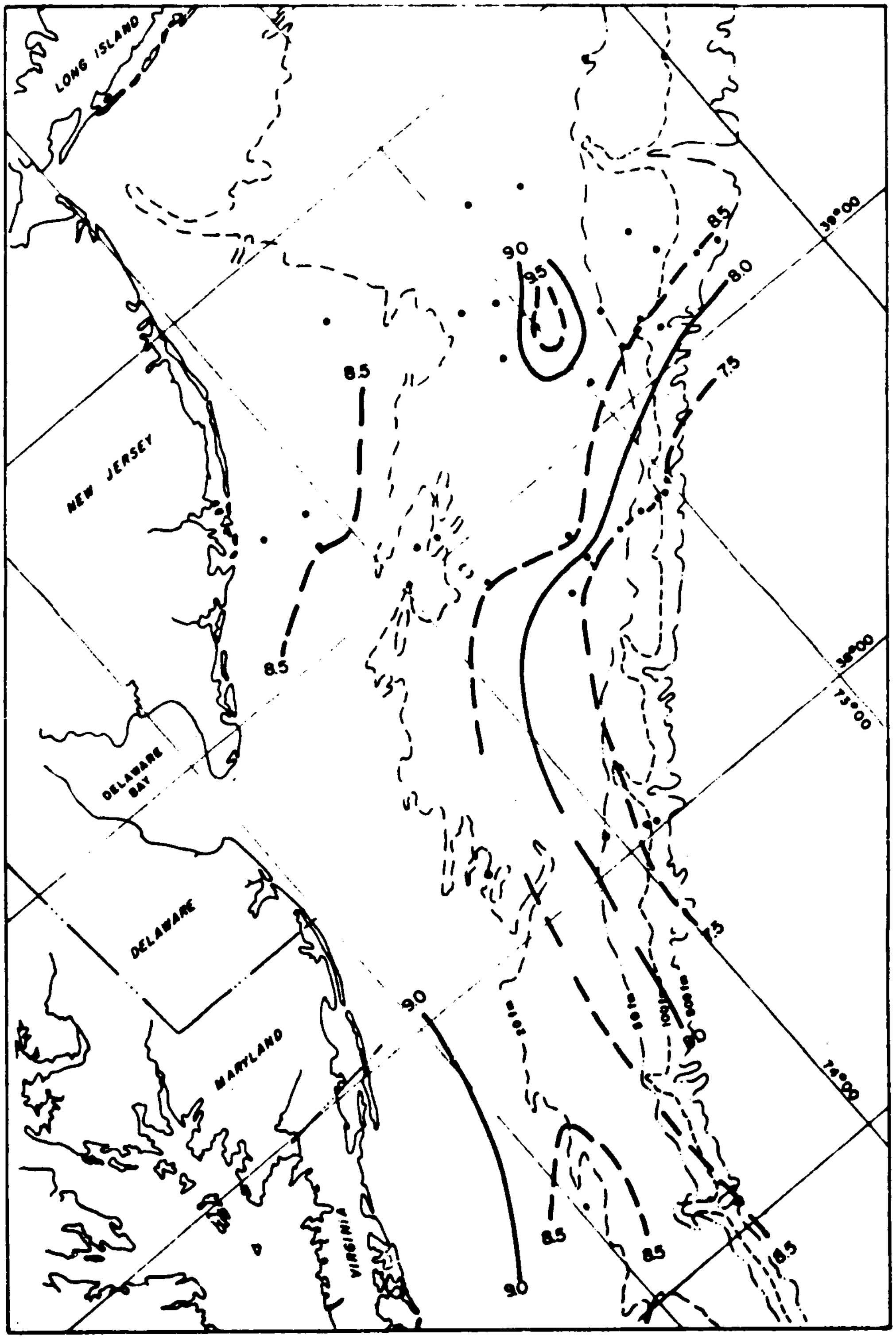


Figure 3-49c. Surface dissolved oxygen (mg/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

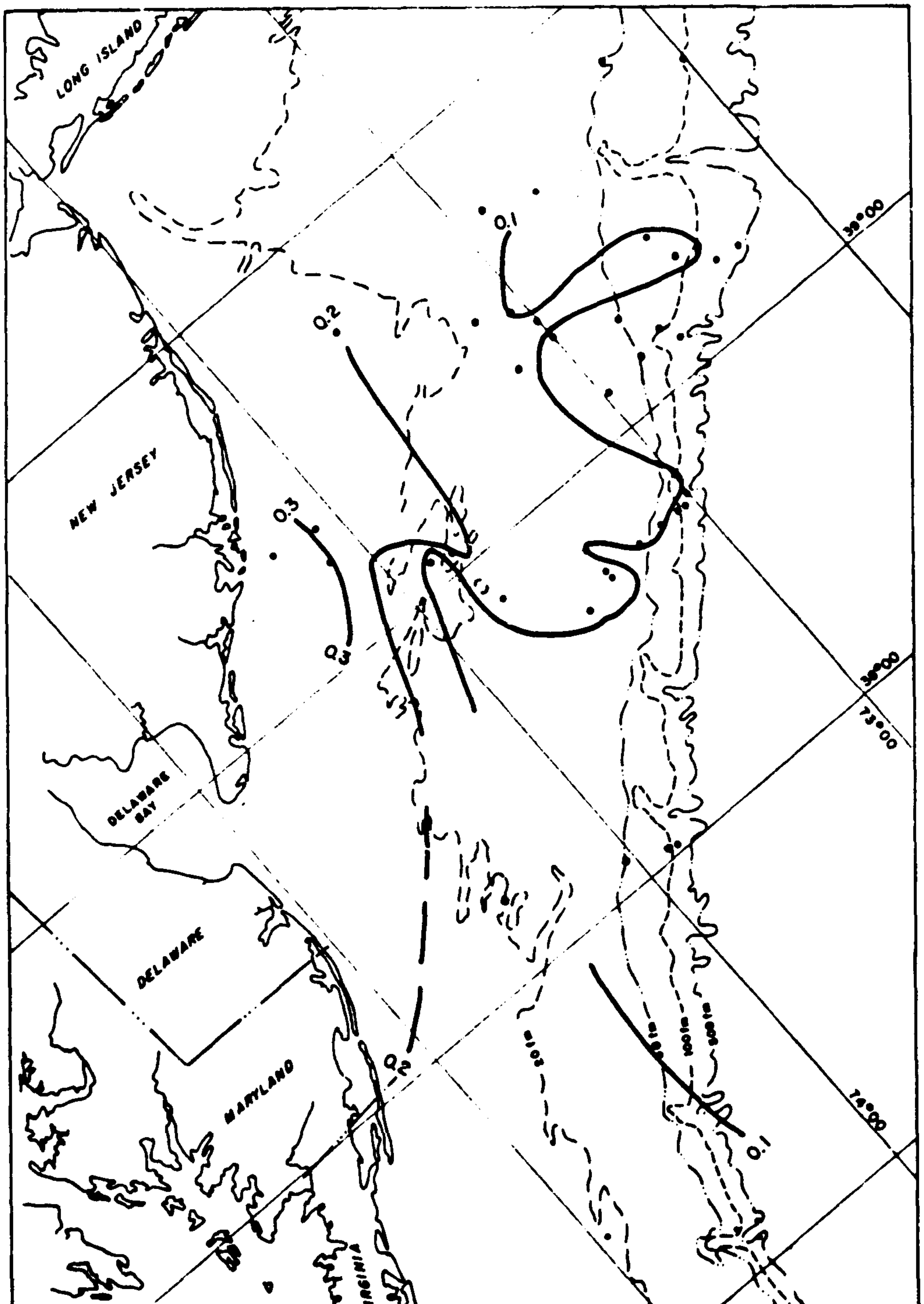


Figure 3-49d. Surface dissolved nitrite (μgm-at/l) distribution in the Middle Atlatnic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

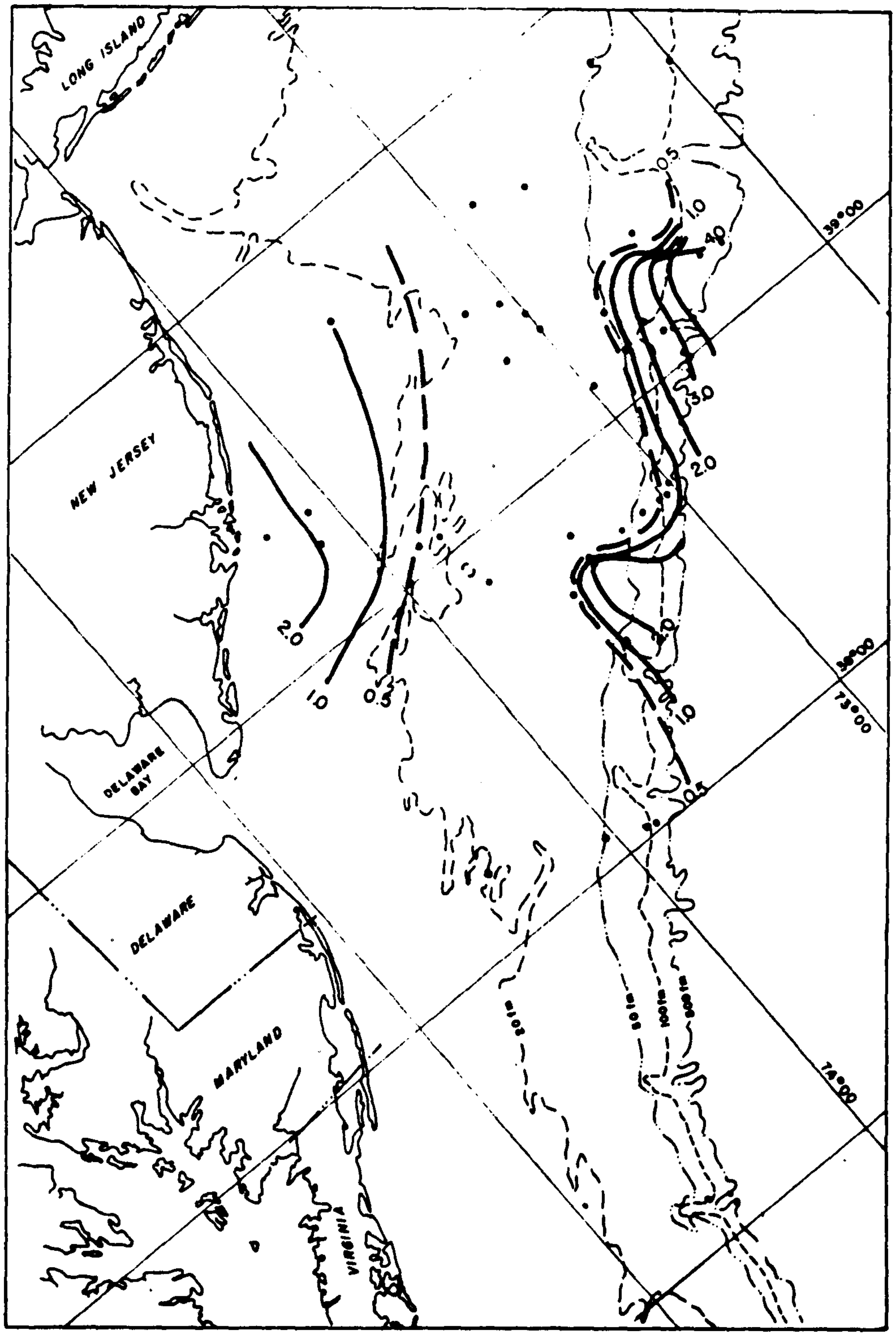


Figure 3-49e. Surface dissolved nitrate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

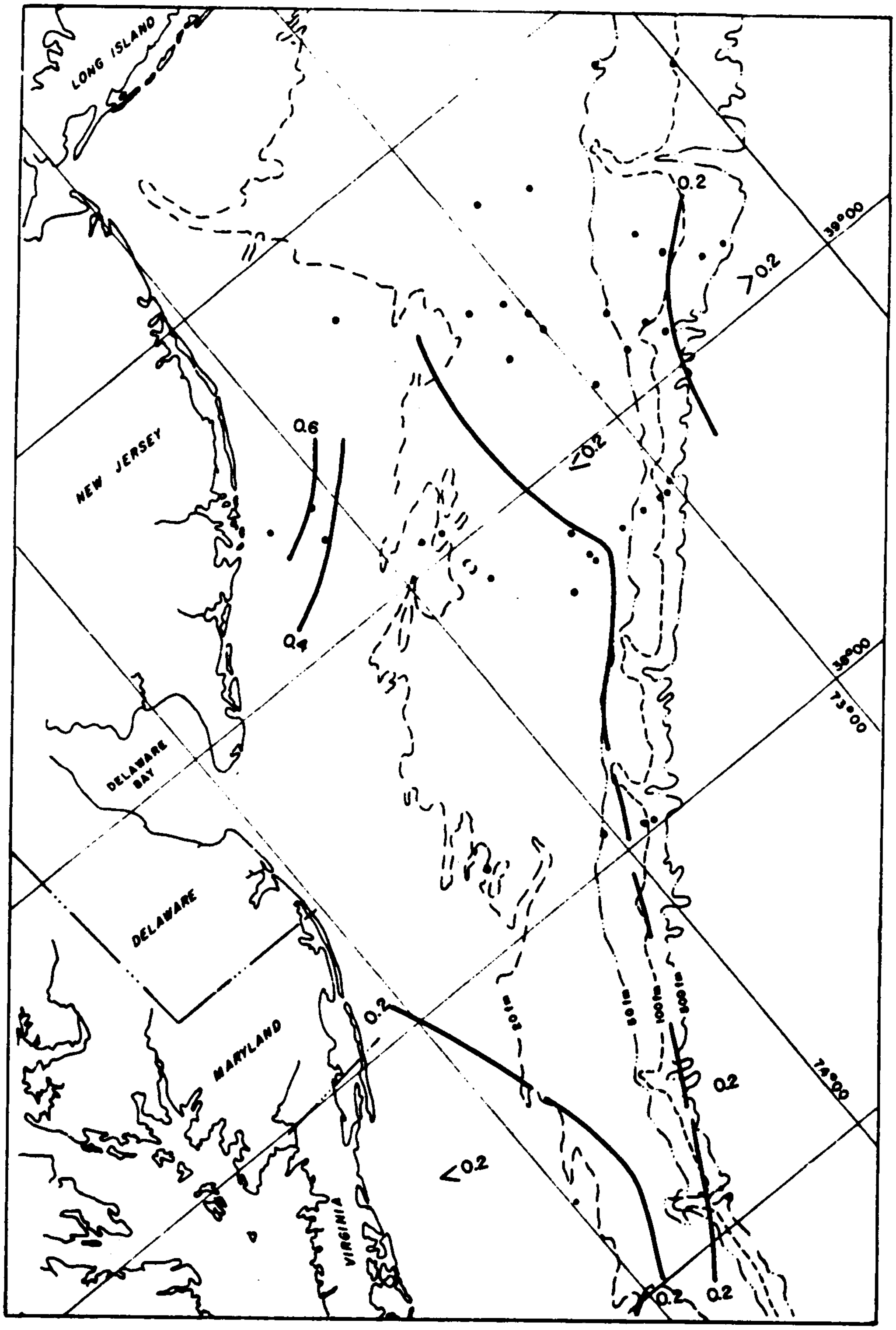


Figure 3-49f. Surface dissolved ortho-phosphate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

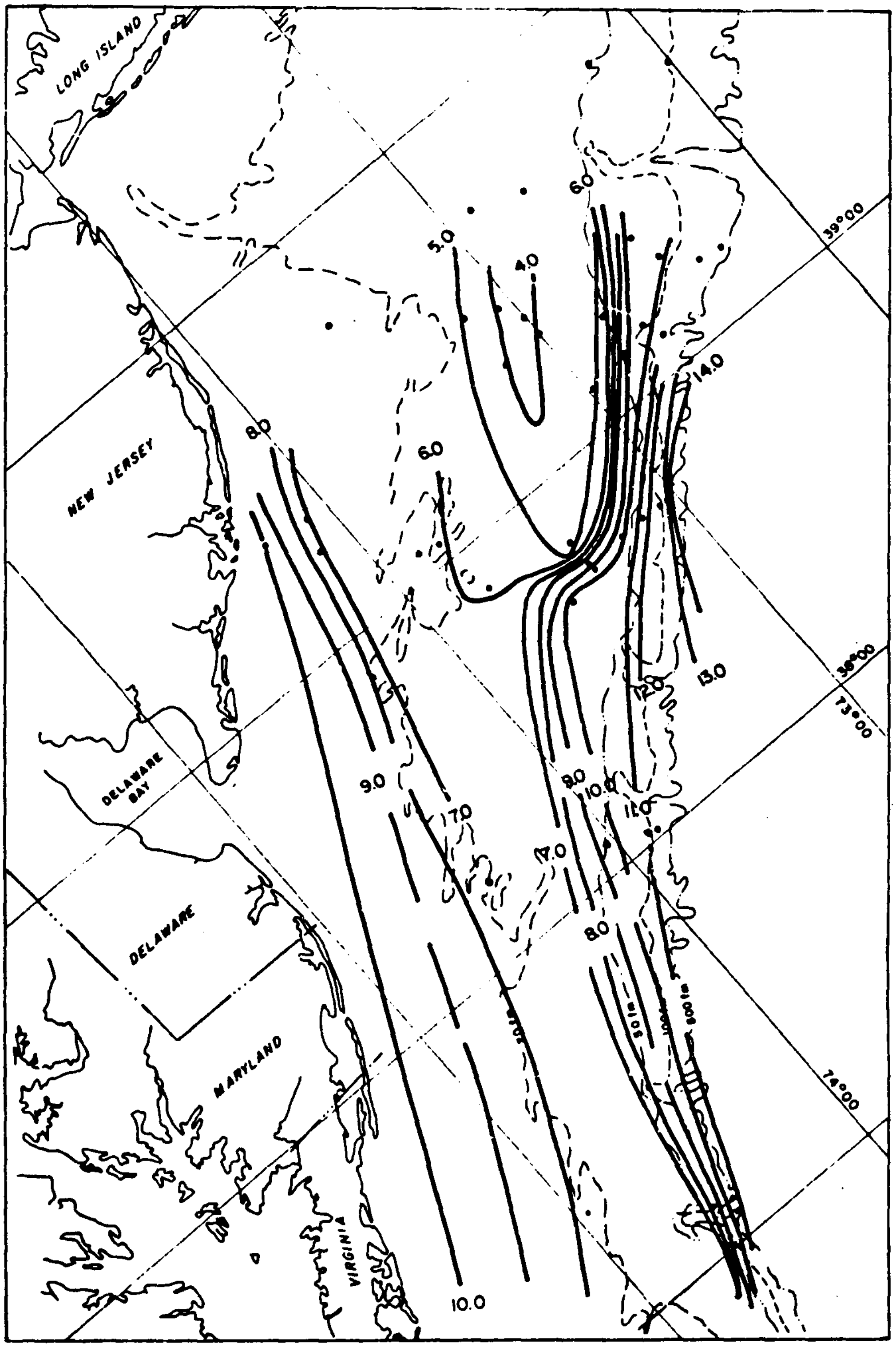


Figure 3-50a. Bottom temperature (°C) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

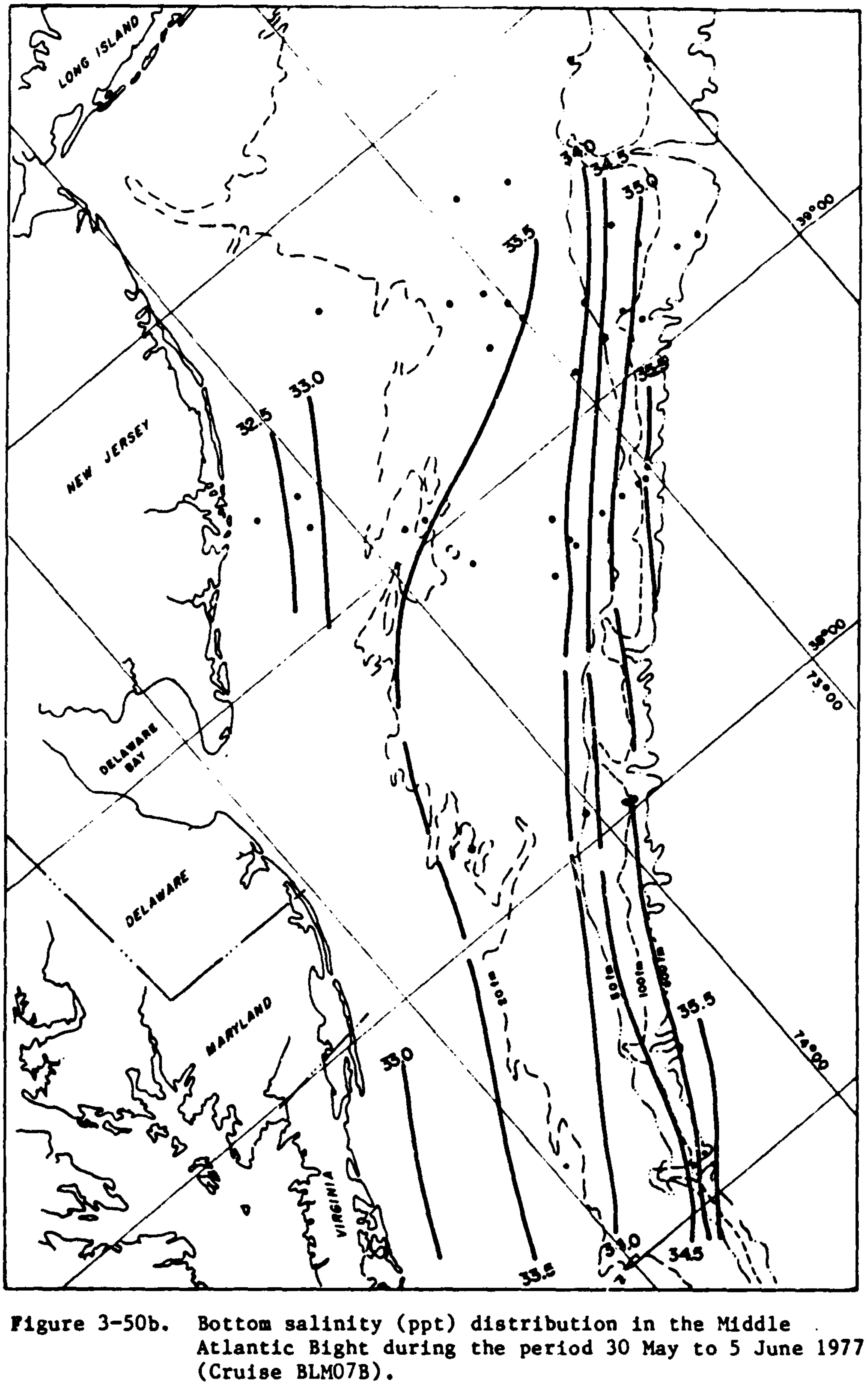


Figure 3-50b. Bottom salinity (ppt) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

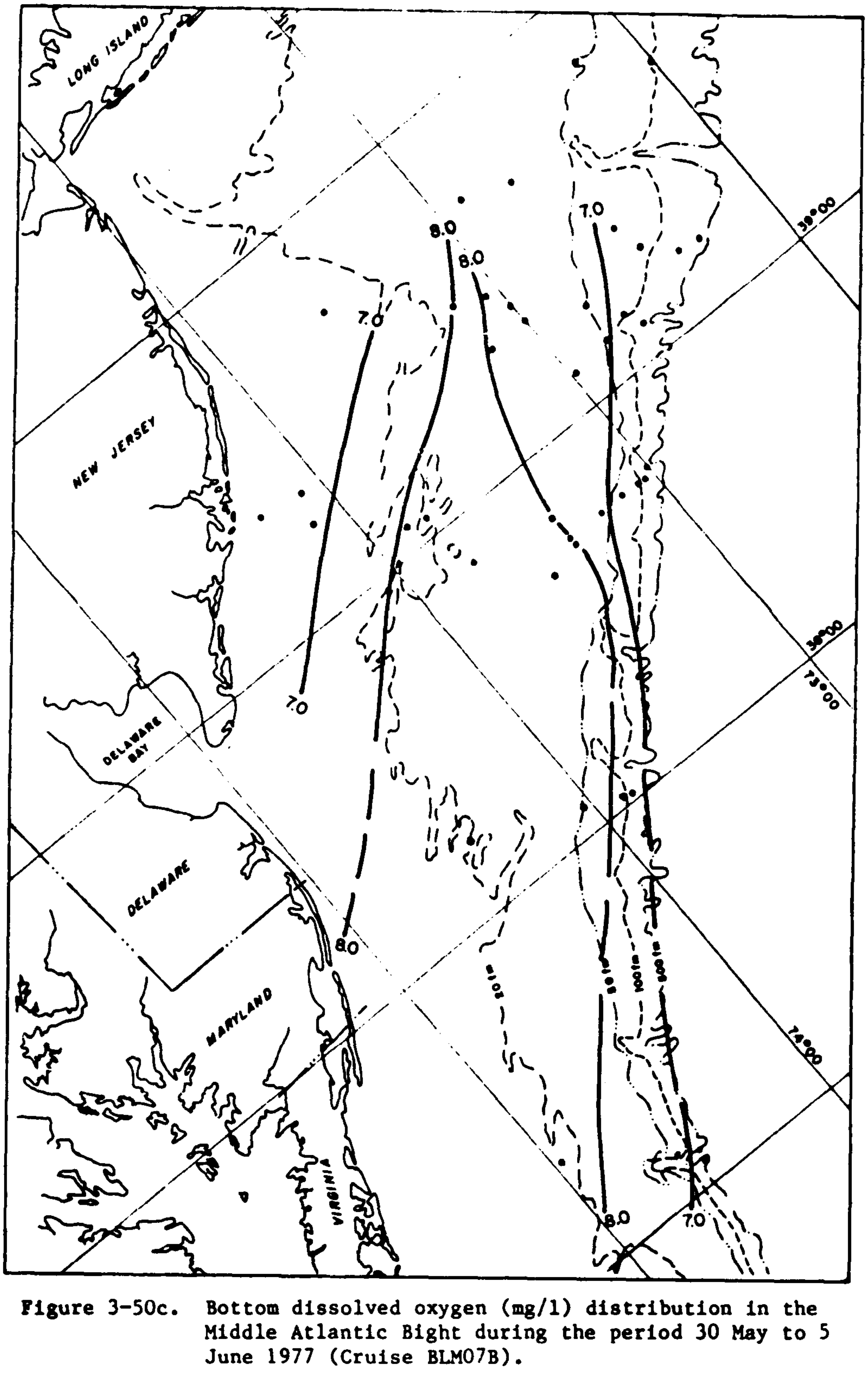


Figure 3-50c. Bottom dissolved oxygen (mg/1) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

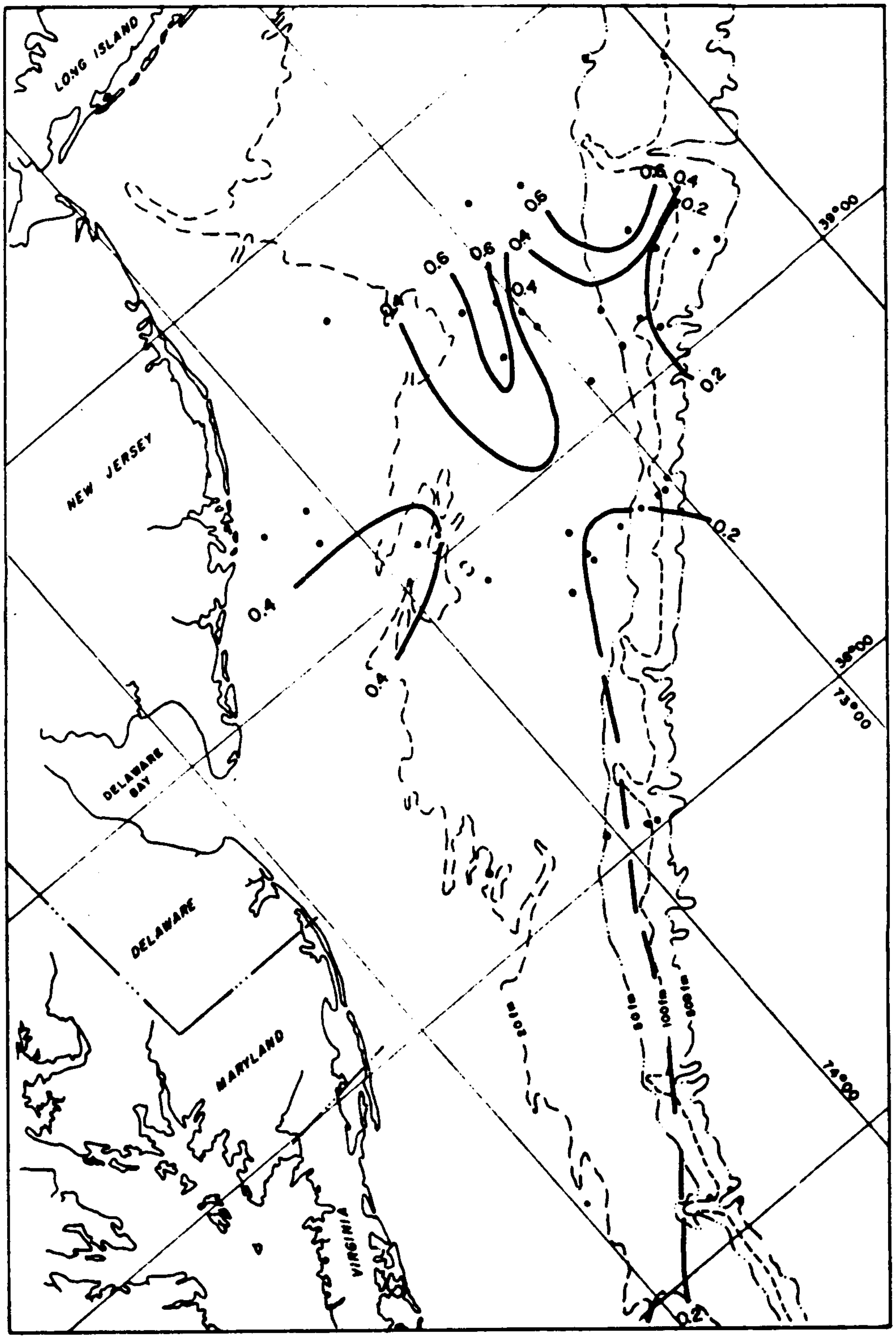


Figure 3-50d. Bottom dissolved nitrite (μgm-at/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

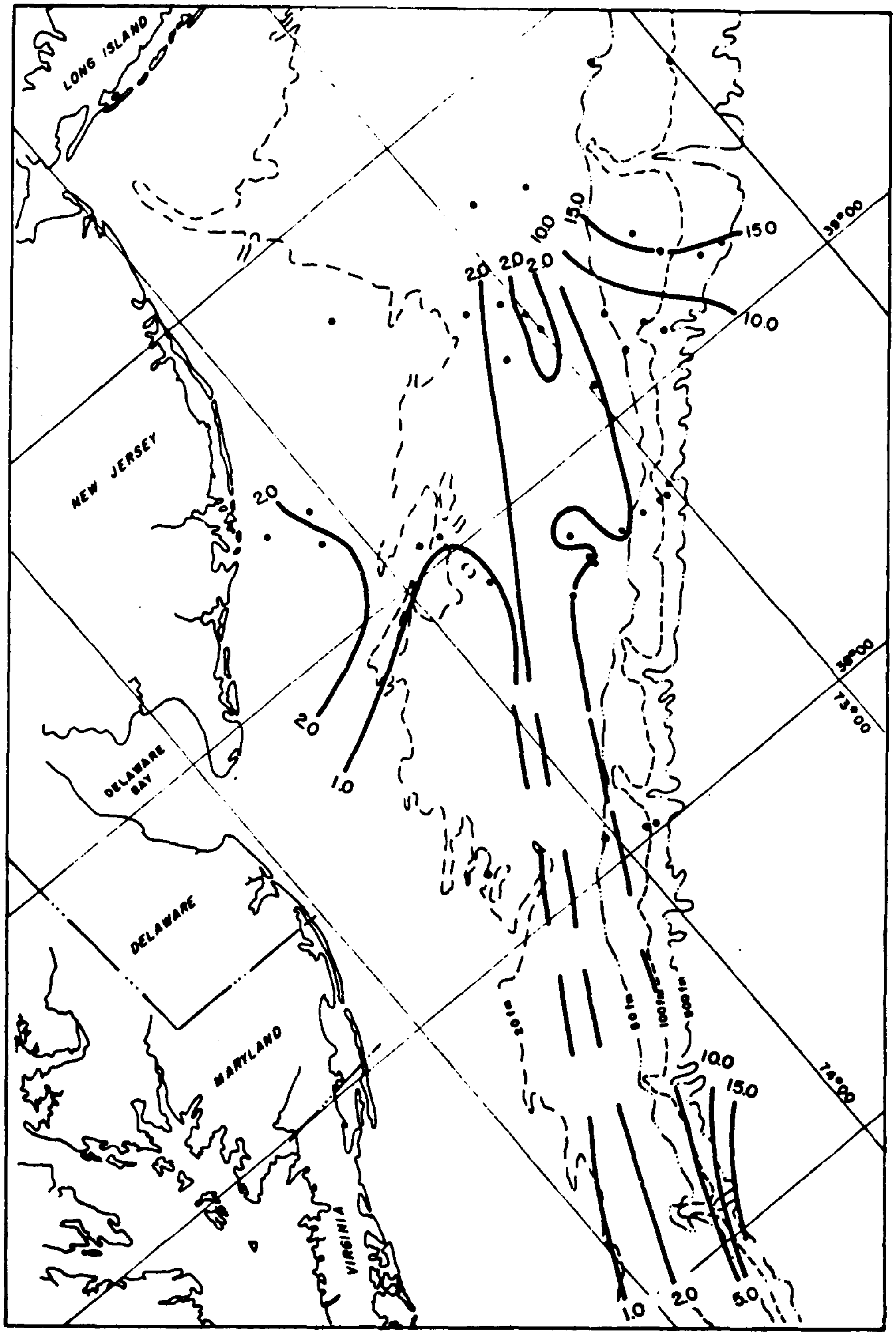


Figure 3-50e. Bottom dissolved nitrate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

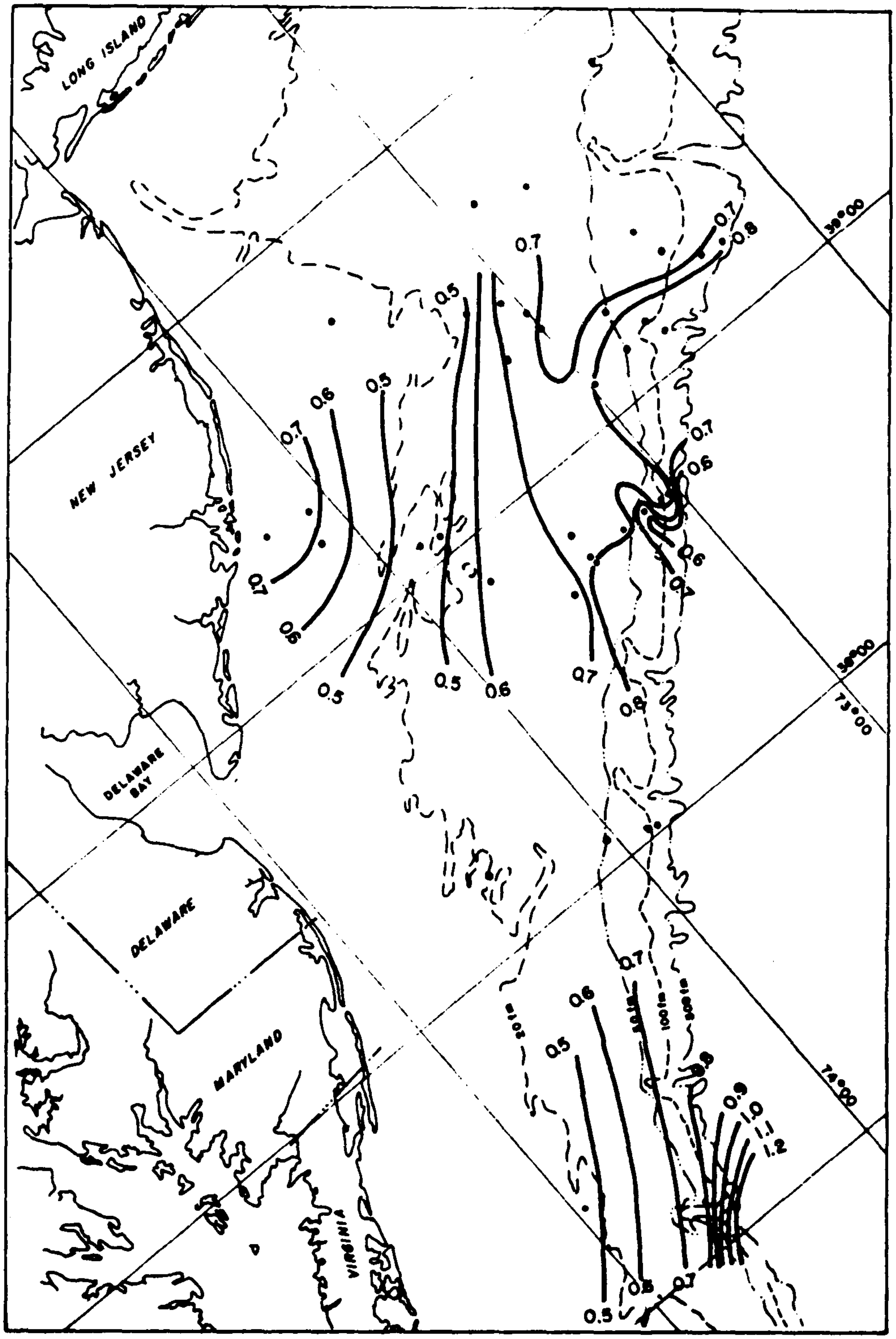


Figure 3-50f. Bottom dissolved ortho-phosphate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 30 May to 5 June 1977 (Cruise BLM07B).

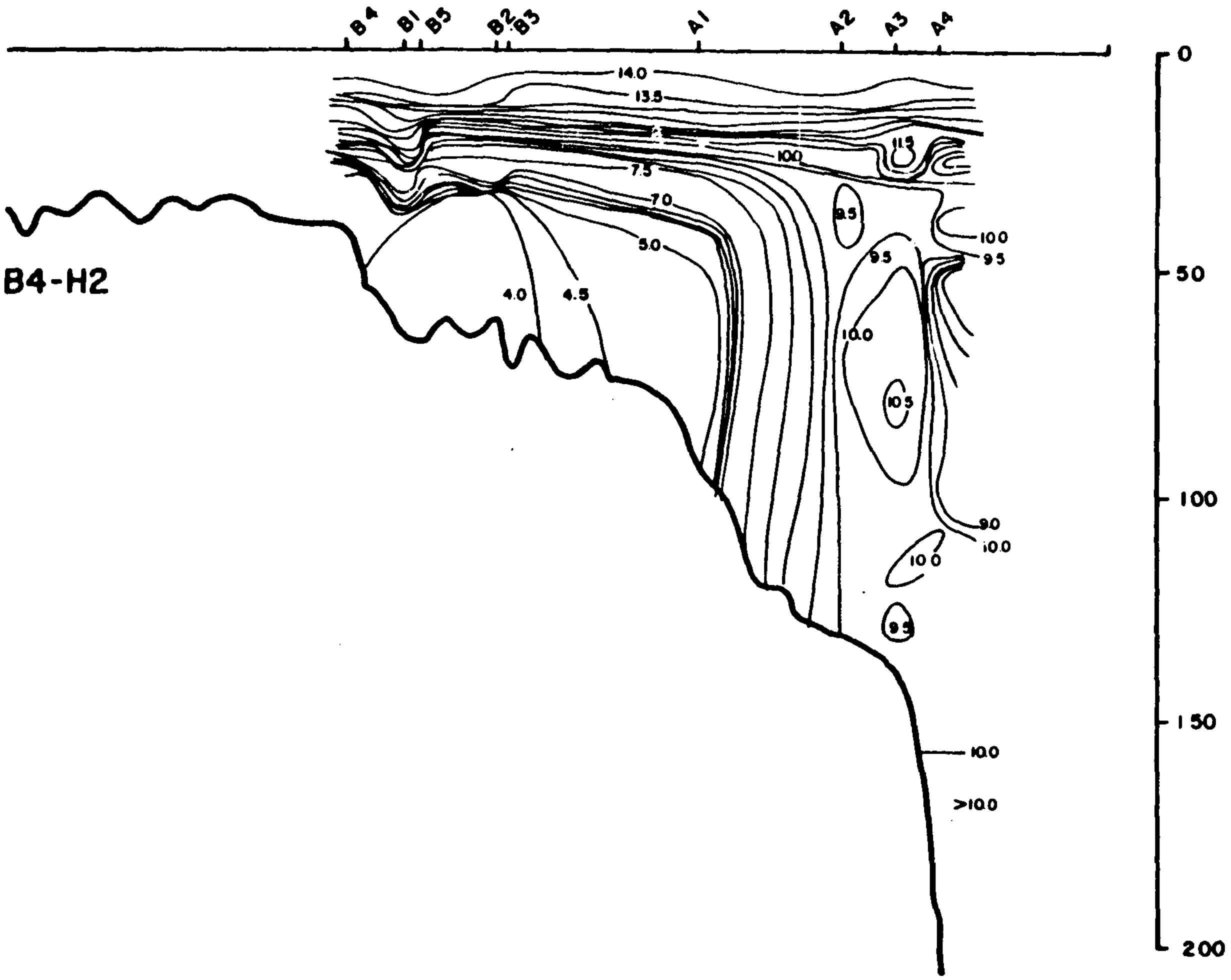


Figure 3-51a. Temperature (°C) contours for section II (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

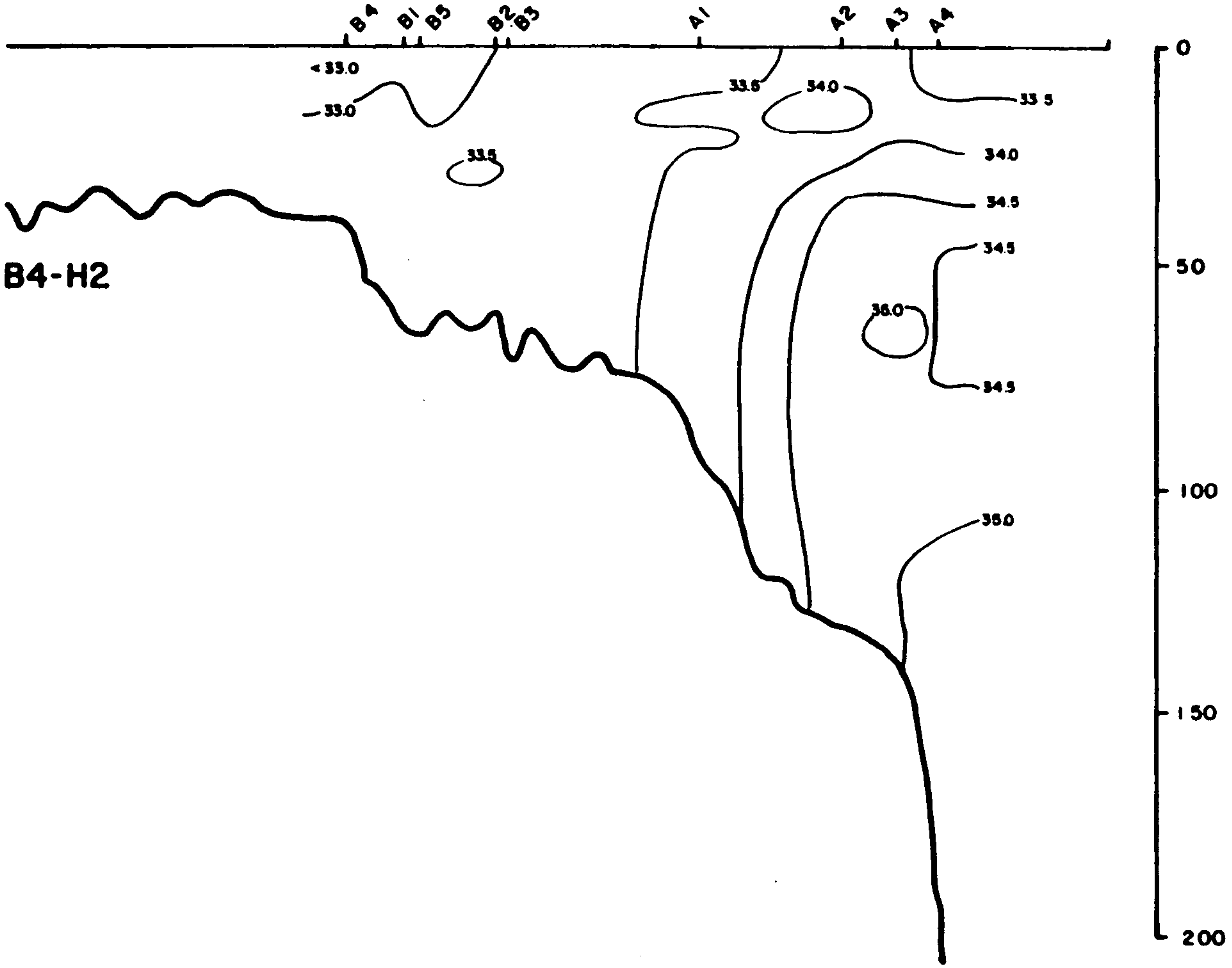


Figure 3-51b. Salinity (ppt) contours for section II (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

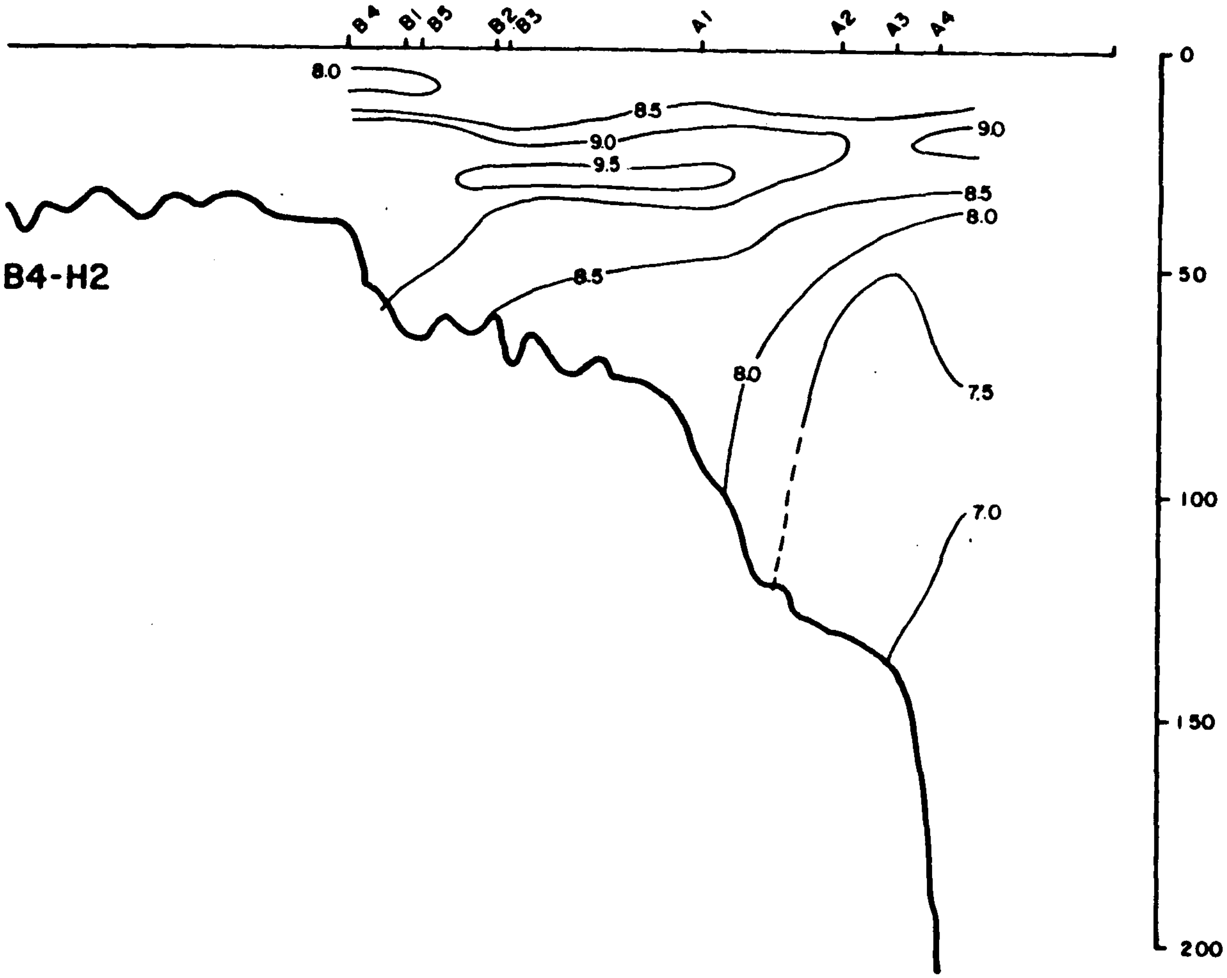


Figure 3-51c. Dissolved oxygen (mg/l) contours for section II (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

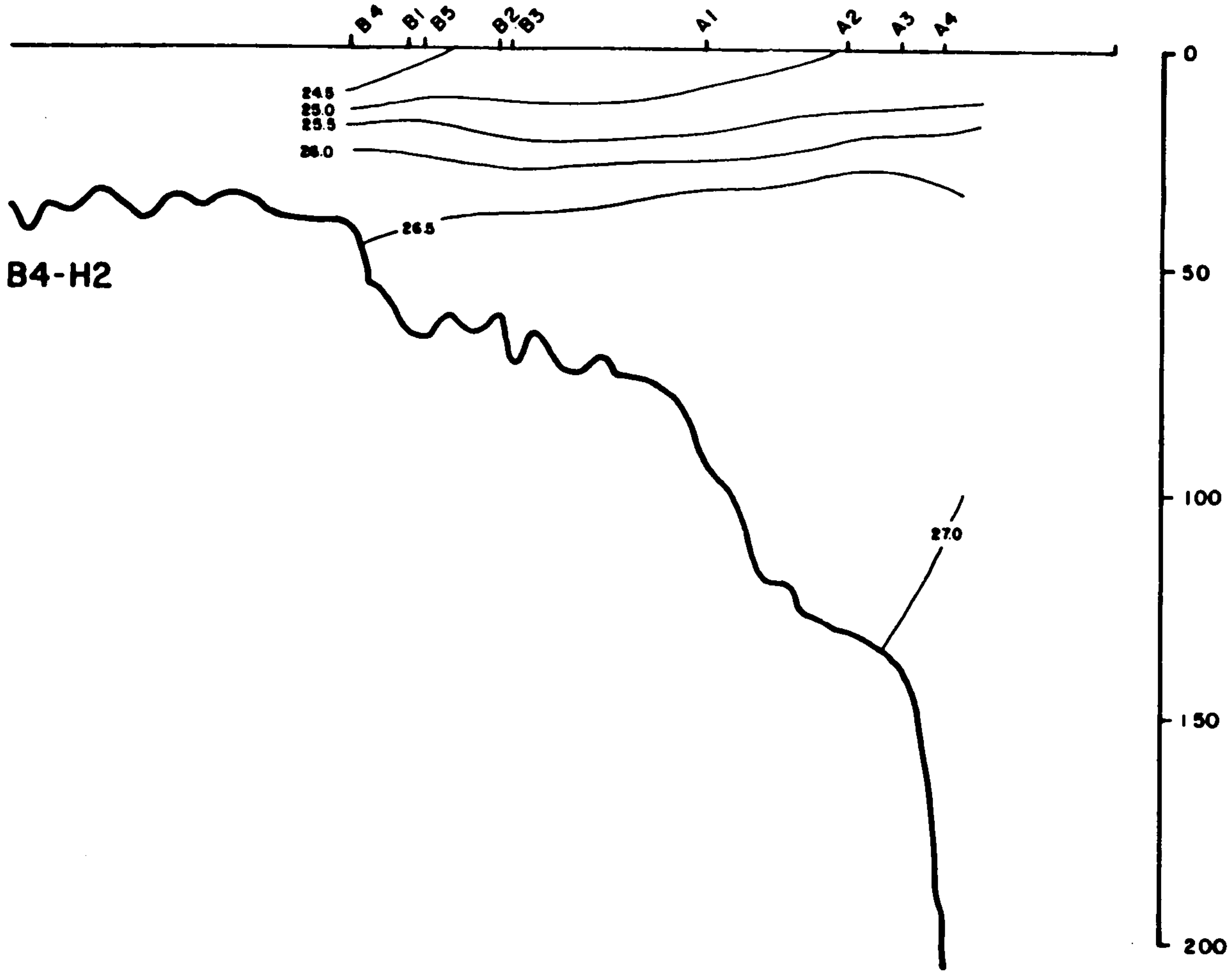
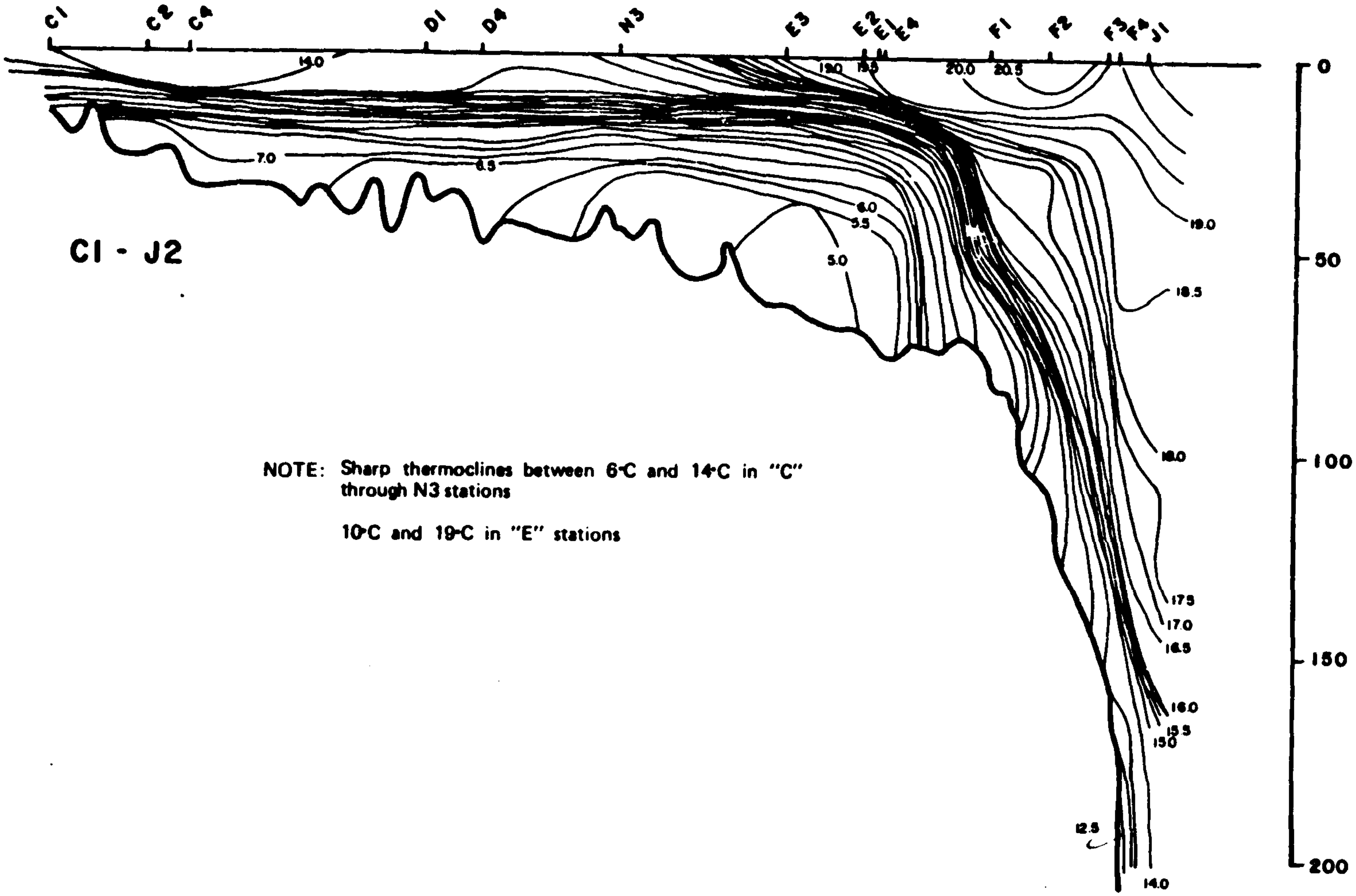


Figure 3-51d. Density (sigma-t units) contours for section II (Figure 3-6) during cruise BLM07B. Station locations are on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Sharp thermoclines between 6°C and 14°C in "C" through N3 stations

10°C and 19°C in "E" stations

Figure 3-52a. Temperature (°C) contours for section III (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

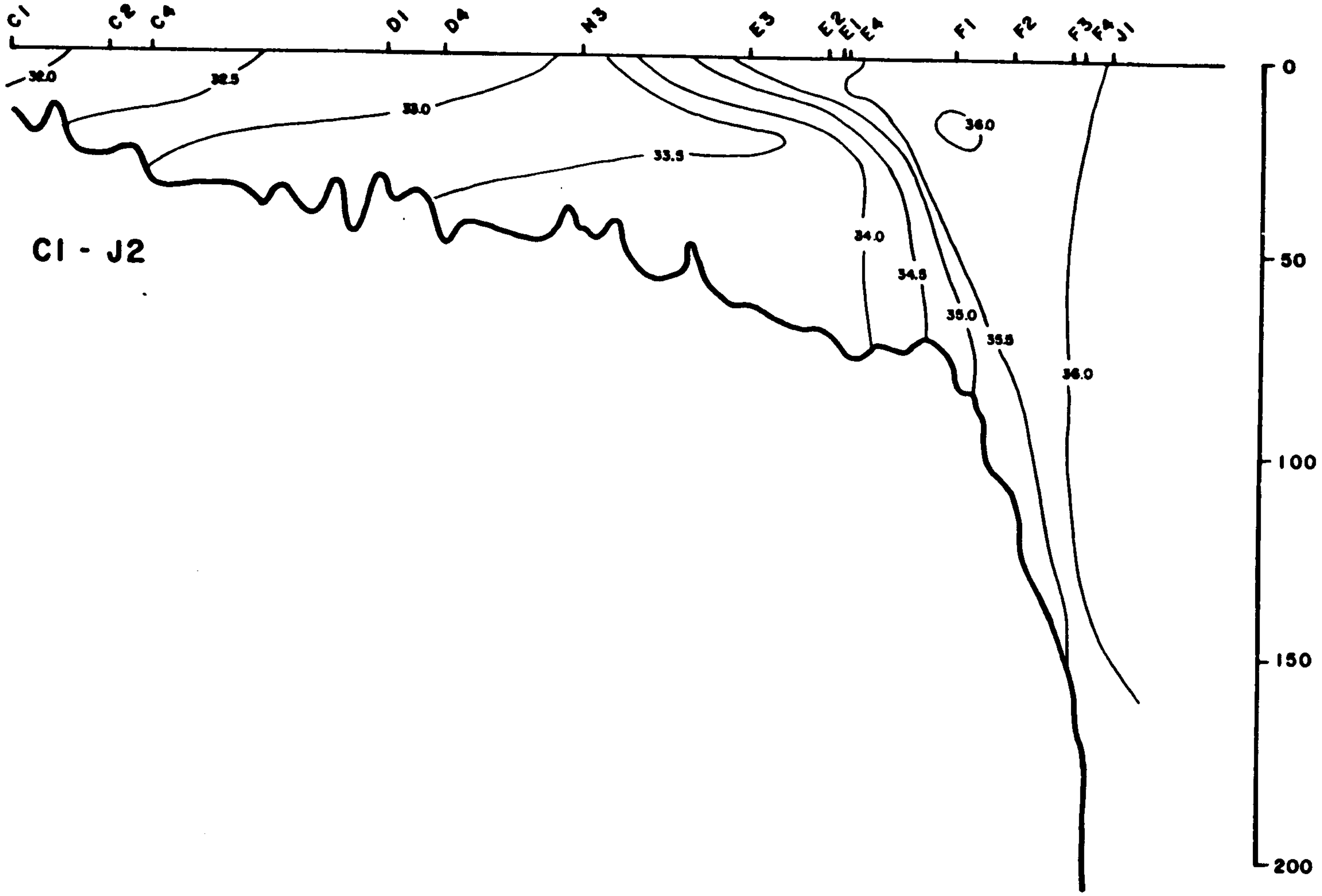
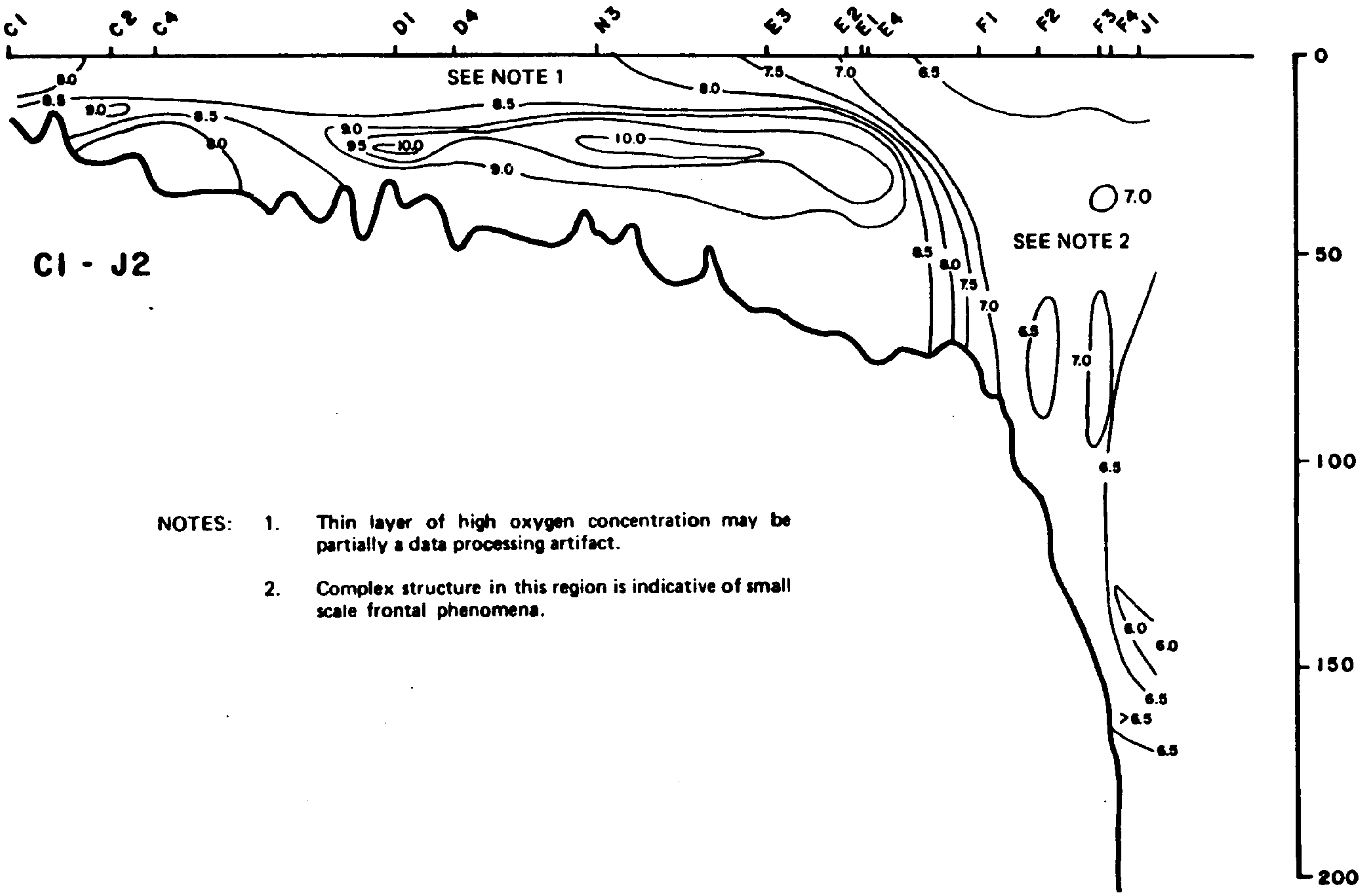


Figure 3-52b. Salinity (ppt) contours for section III (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES:
1. Thin layer of high oxygen concentration may be partially a data processing artifact.
2. Complex structure in this region is indicative of small scale frontal phenomena.

Figure 3-52c. Dissolved oxygen (mg/l) contours for section III (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

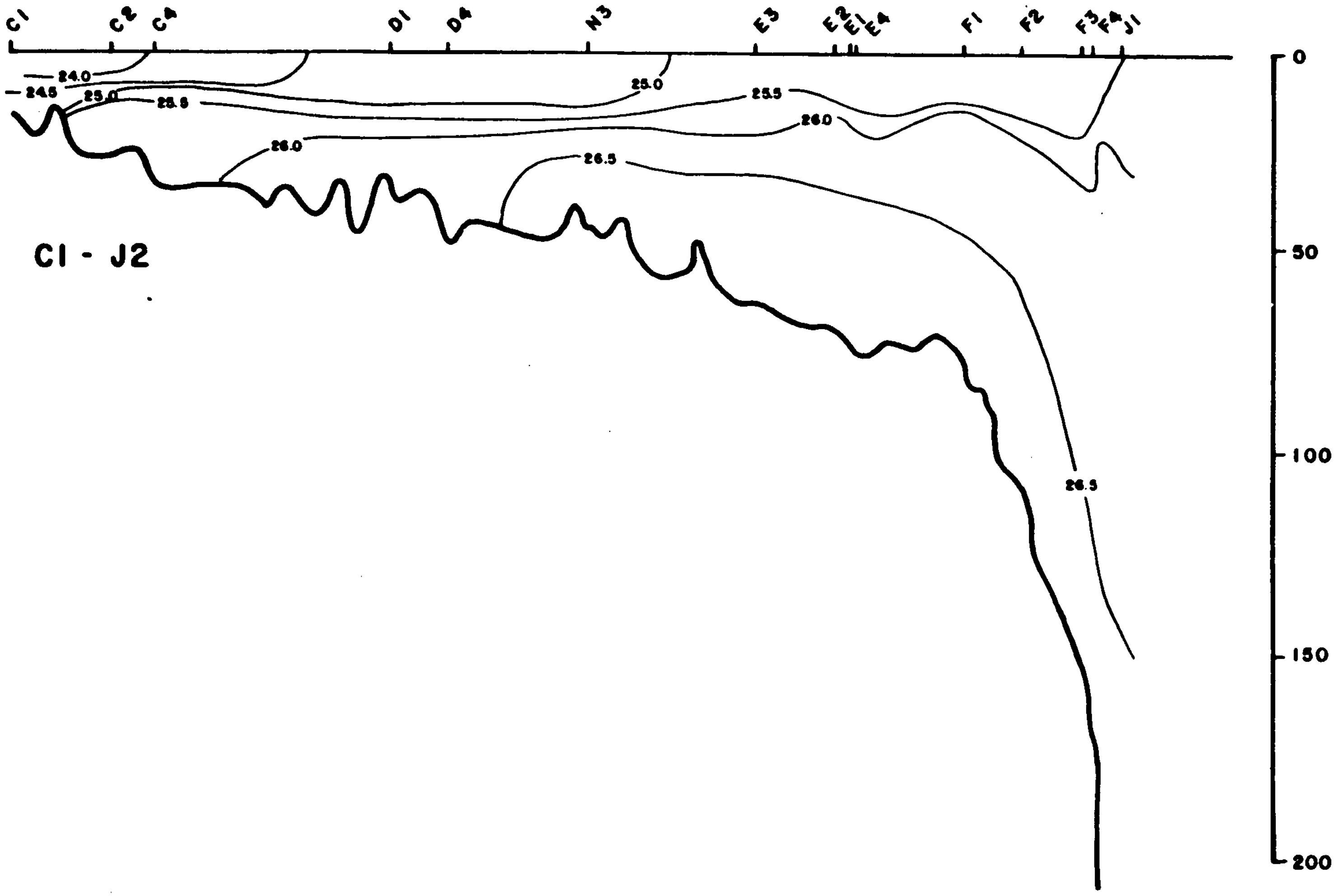
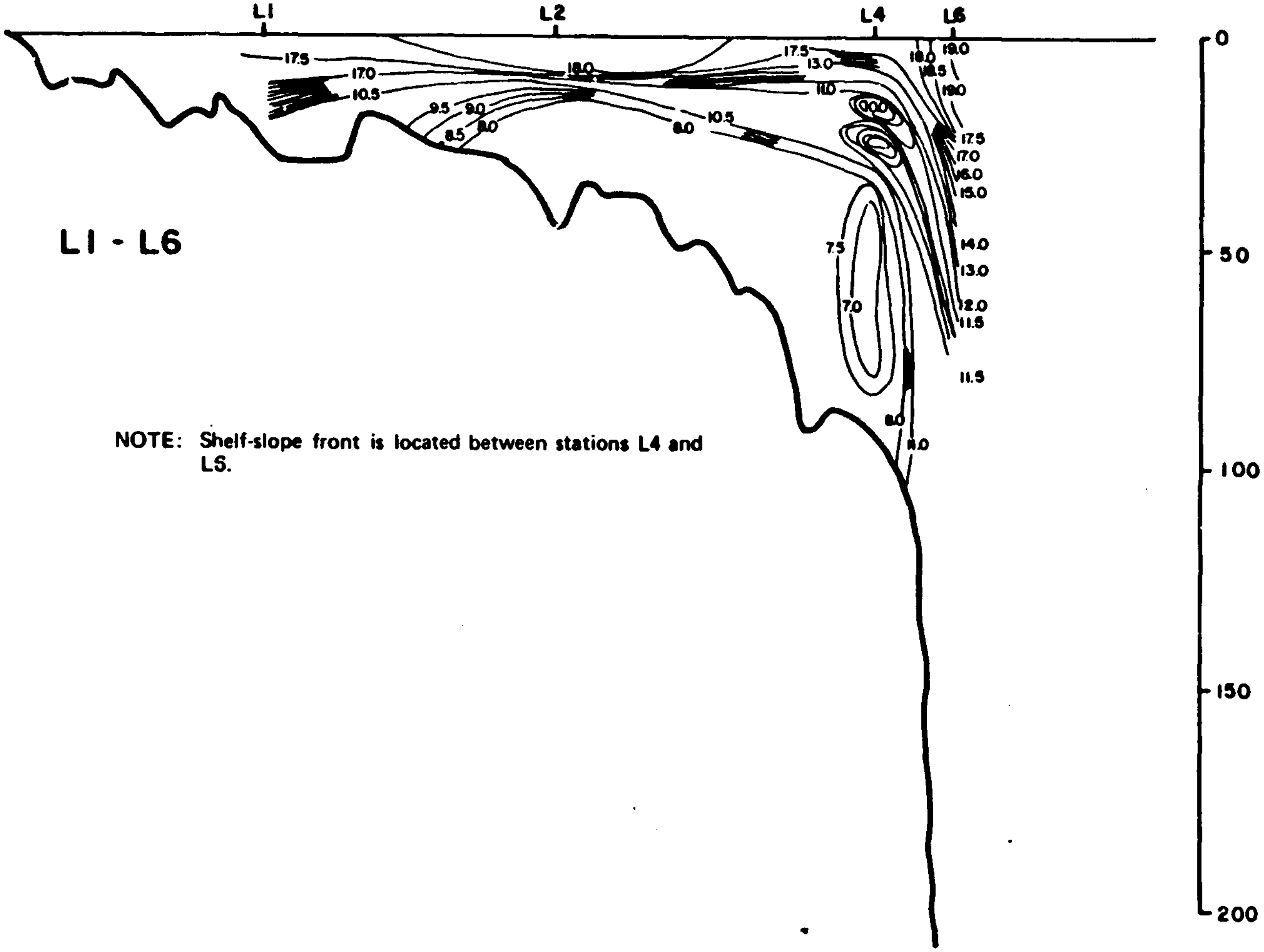


Figure 3-52d. Density (sigma-t units) contours for section III (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Shelf-slope front is located between stations L4 and L5.

Figure 3-53a. Temperature (°C) contours for section V (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

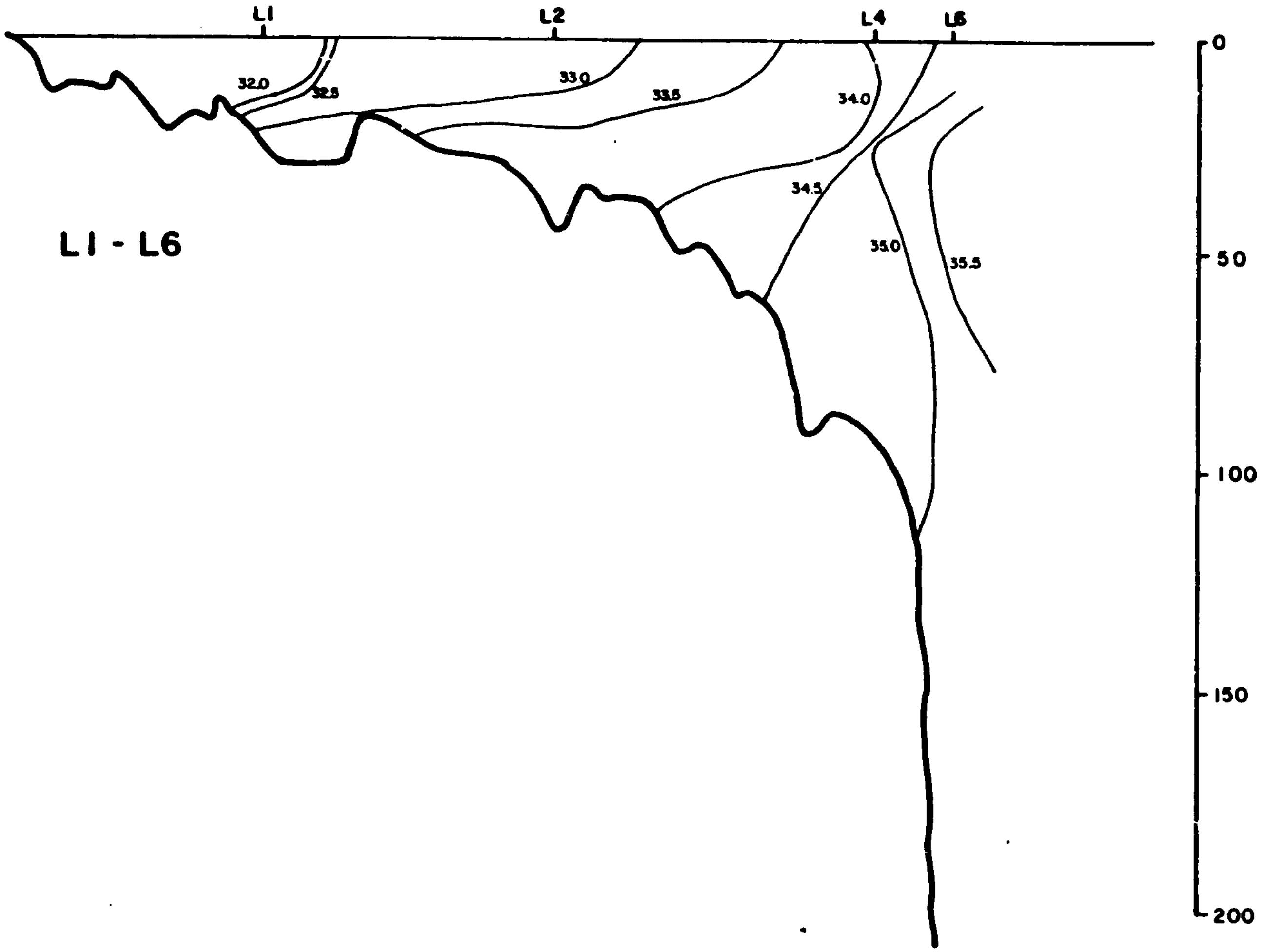


Figure 3-53b. Salinity (ppt) contours for section V (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

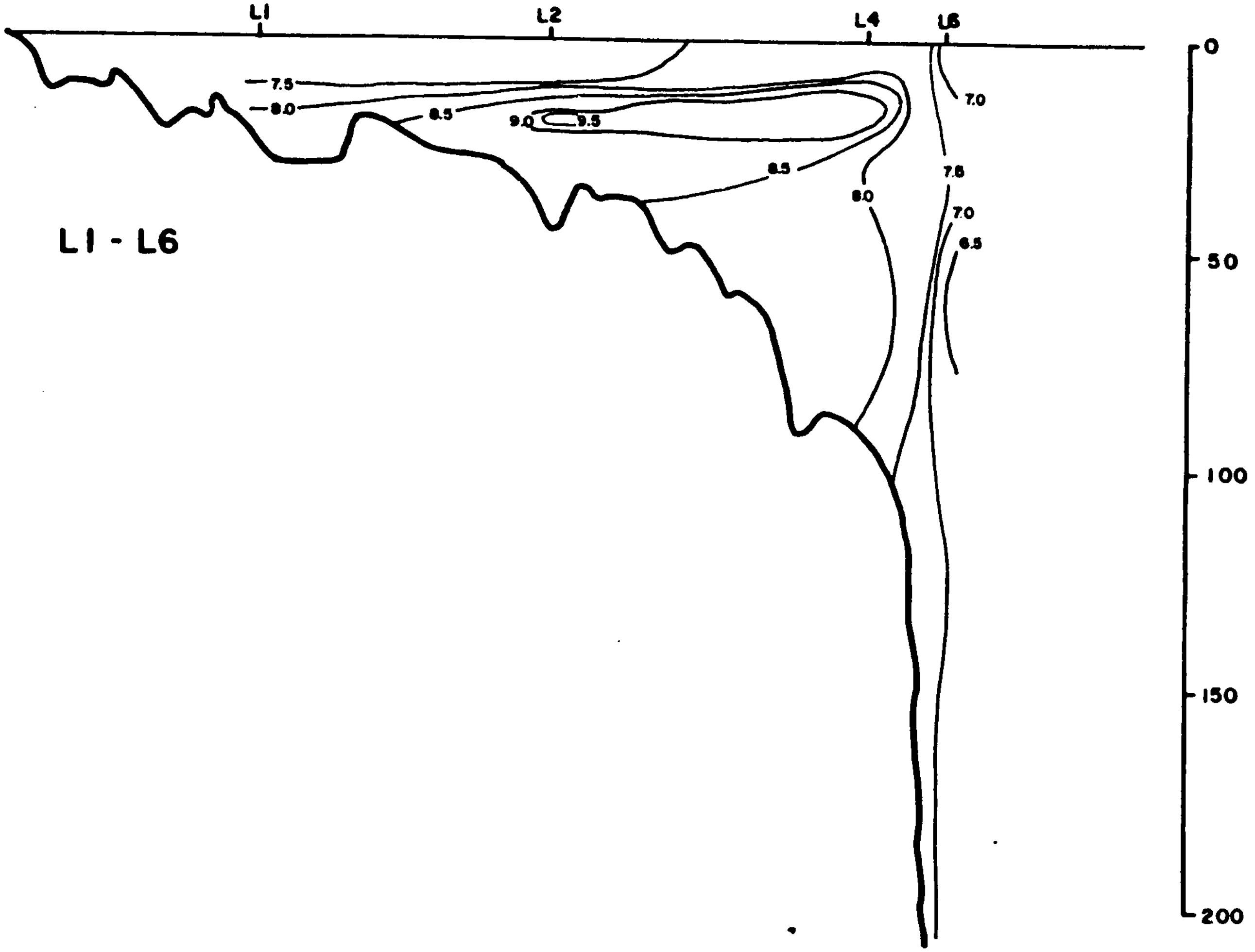


Figure 3-53c. Dissolved oxygen (mg/l) contours for section V (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

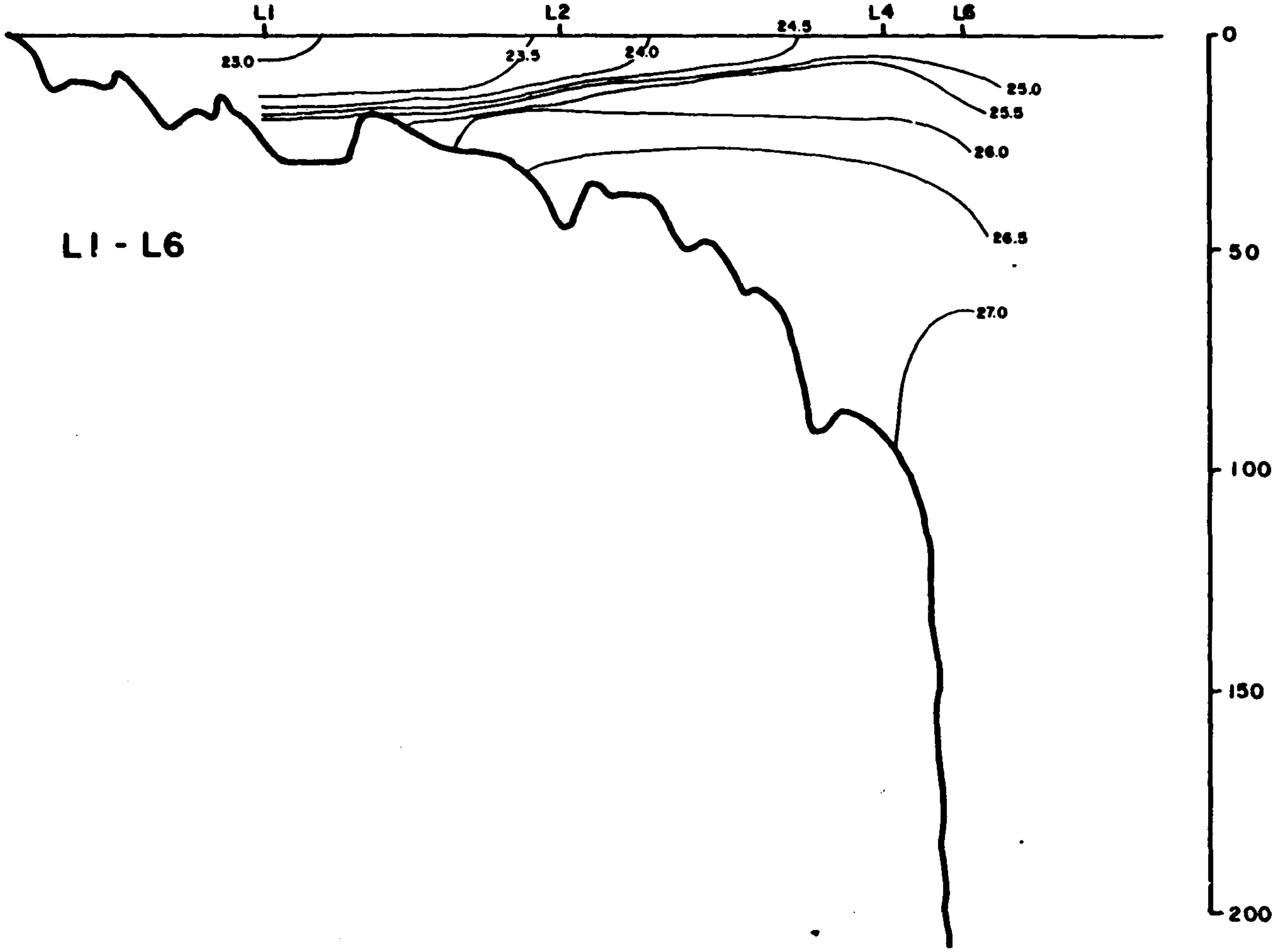


Figure 3-53d. Density (sigma-t units) contours for section V (Figure 3-6) during cruise BLM07B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

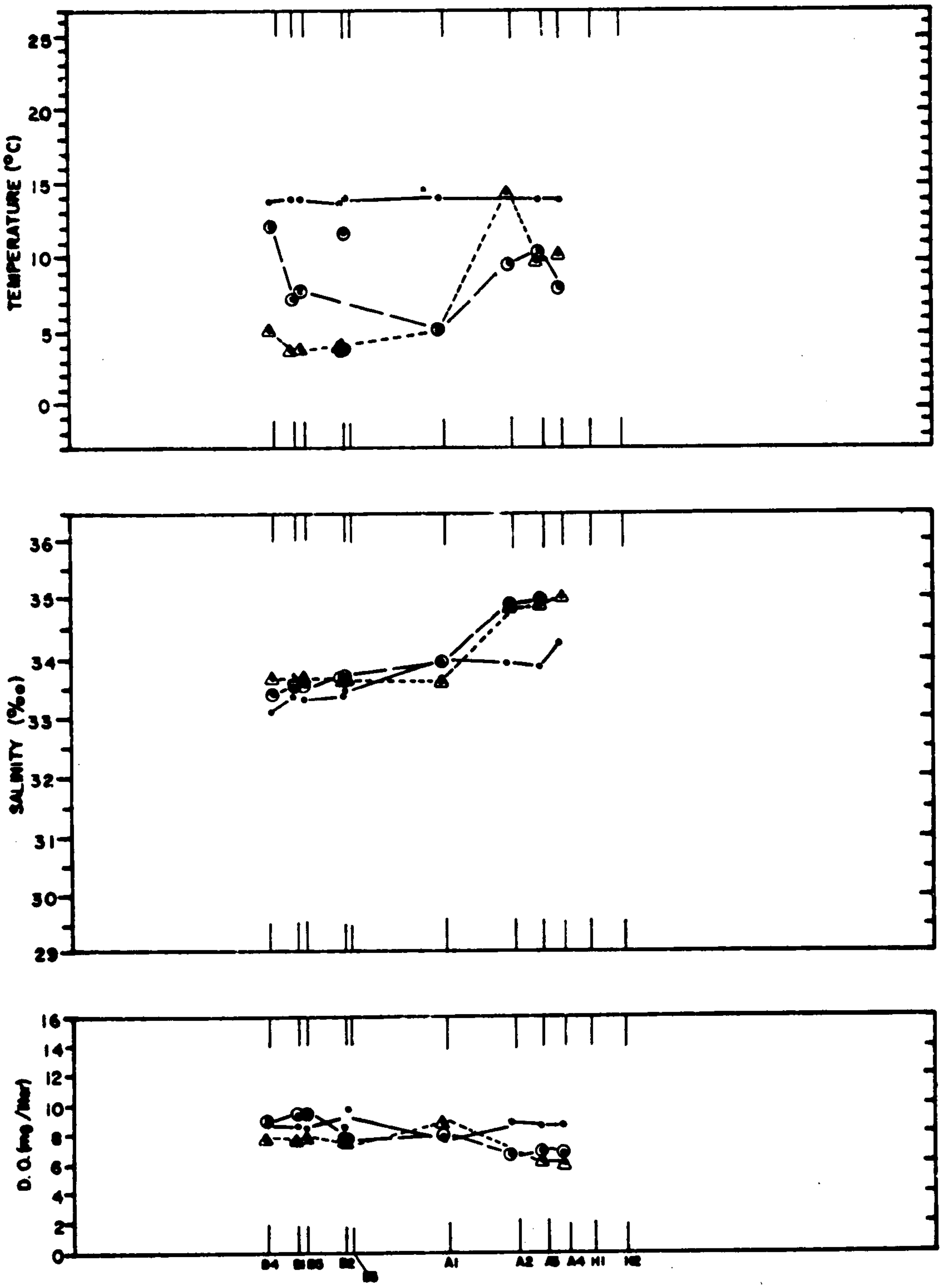


Figure 3-54. Surface (·), mid-depth (θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM07B.

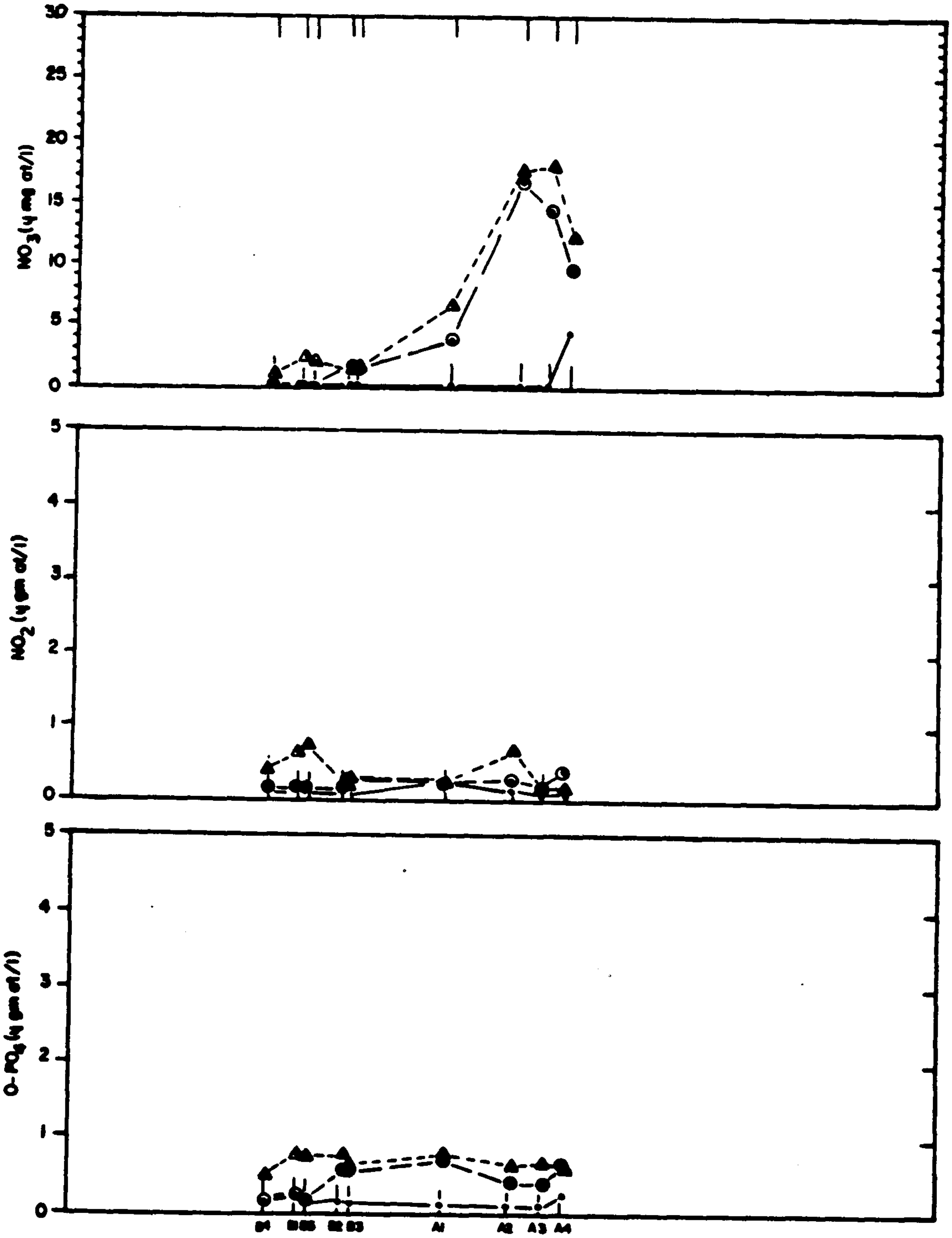


Figure 3-55. Surface (·), mid-depth (θ), and bottom (Δ) values of dissolved ntirate, nitrite and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM07B.

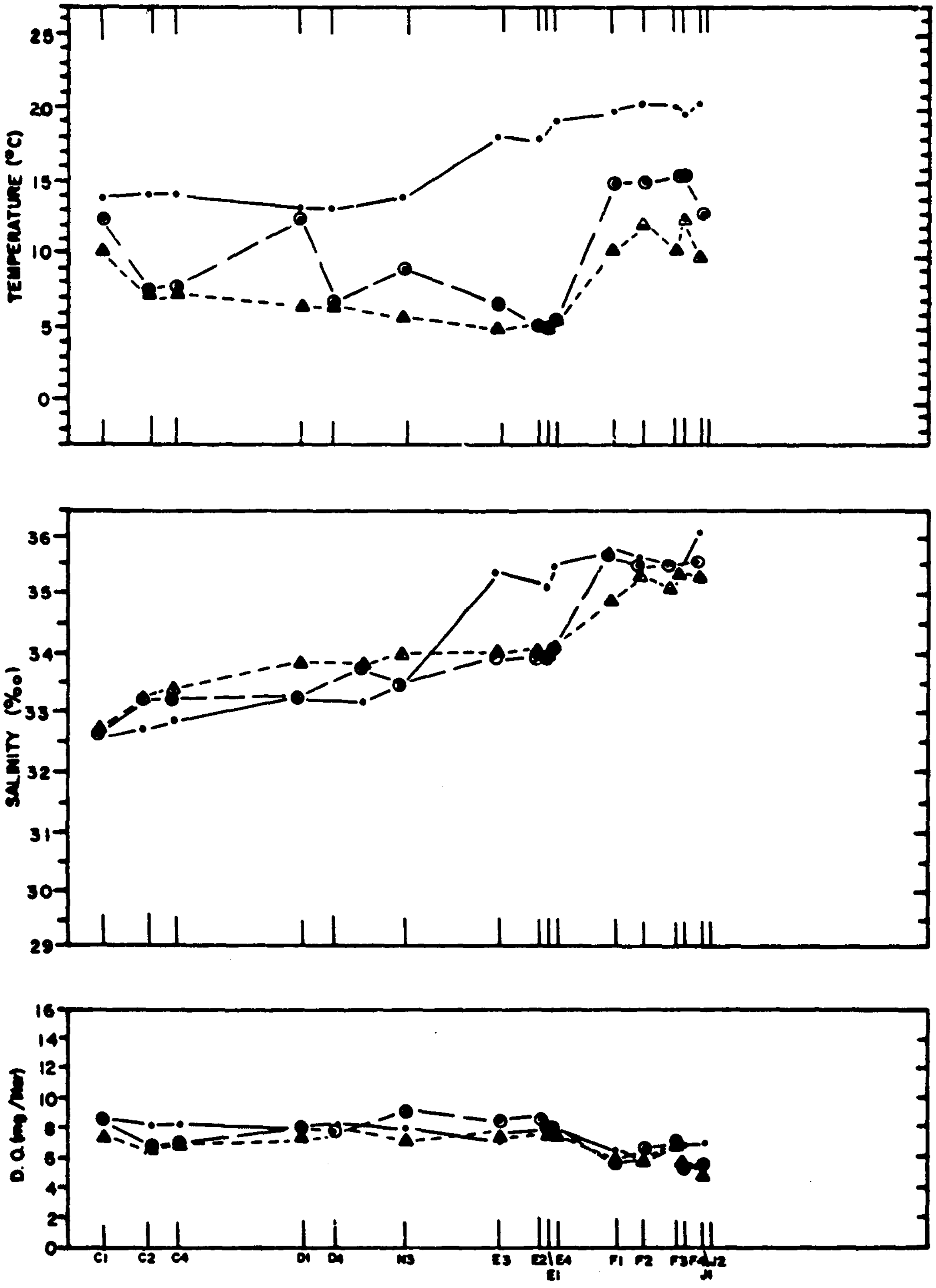


Figure 3-56. Surface (•), mid-depth (⊖), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM07B.

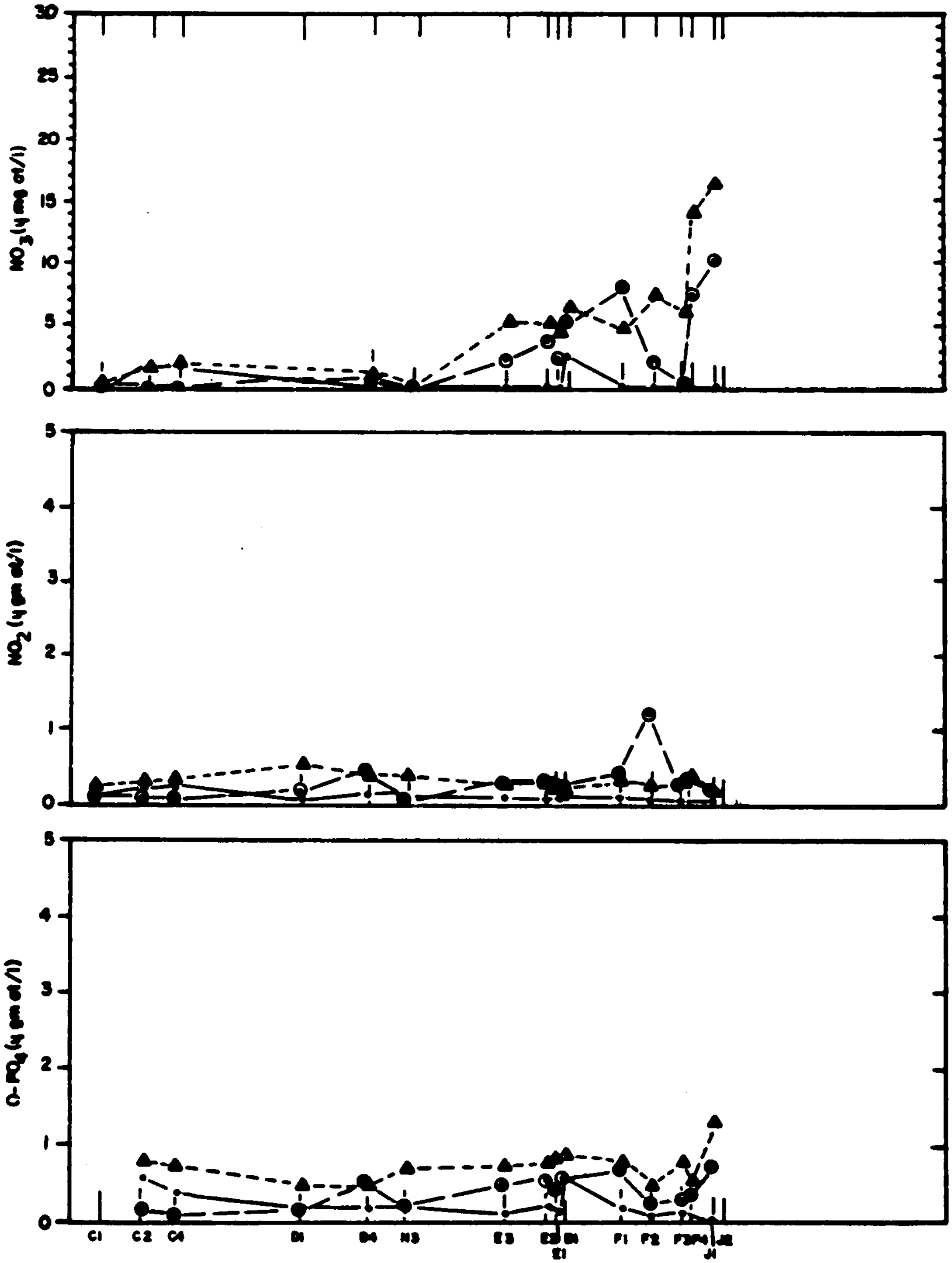


Figure 3-57. Surface (•), mid-depth (ʘ), and bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM07B.

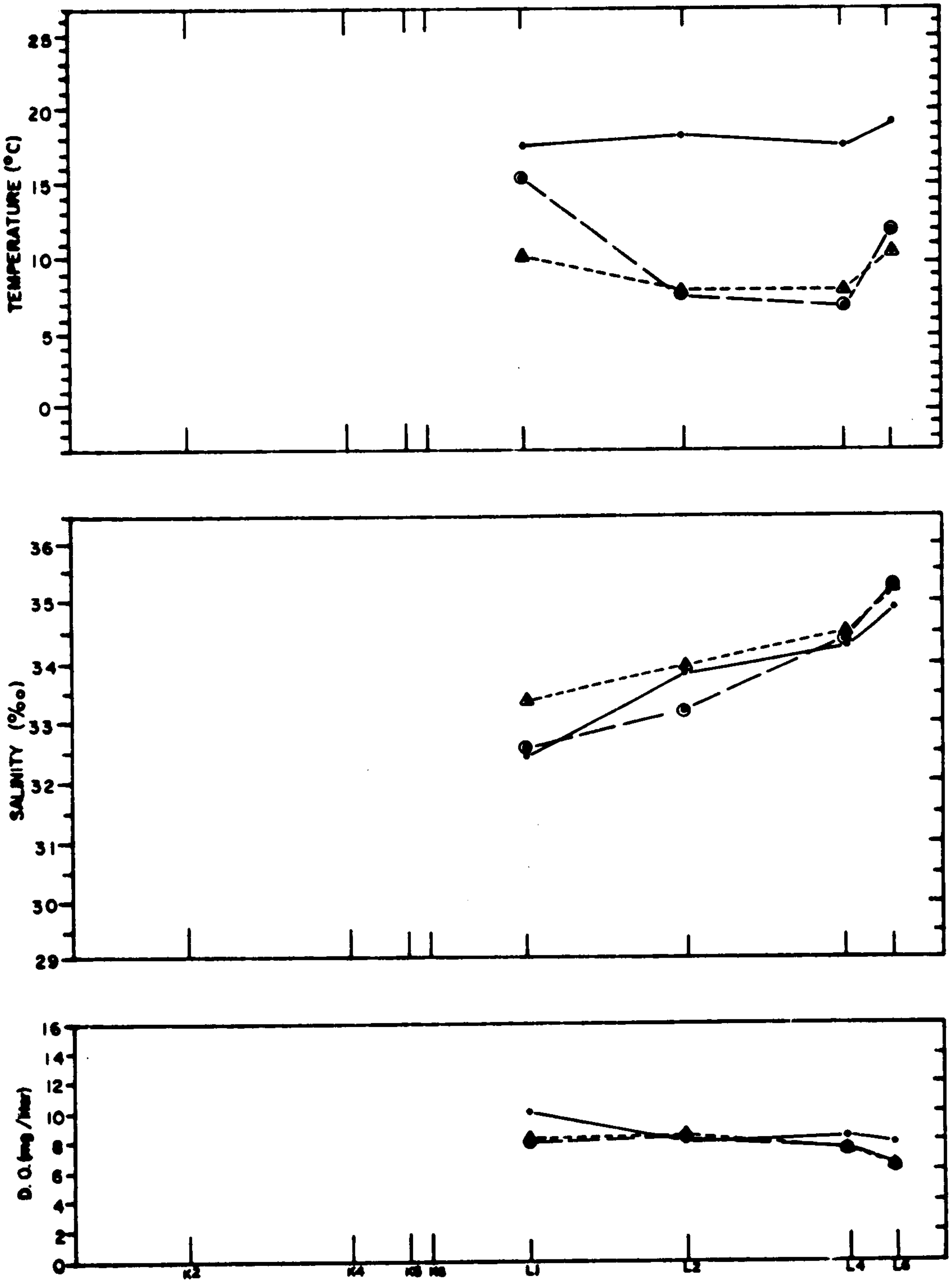


Figure 3-58. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolve doxygen measured along section V (Figure 3-6) during cruise BLM07B.

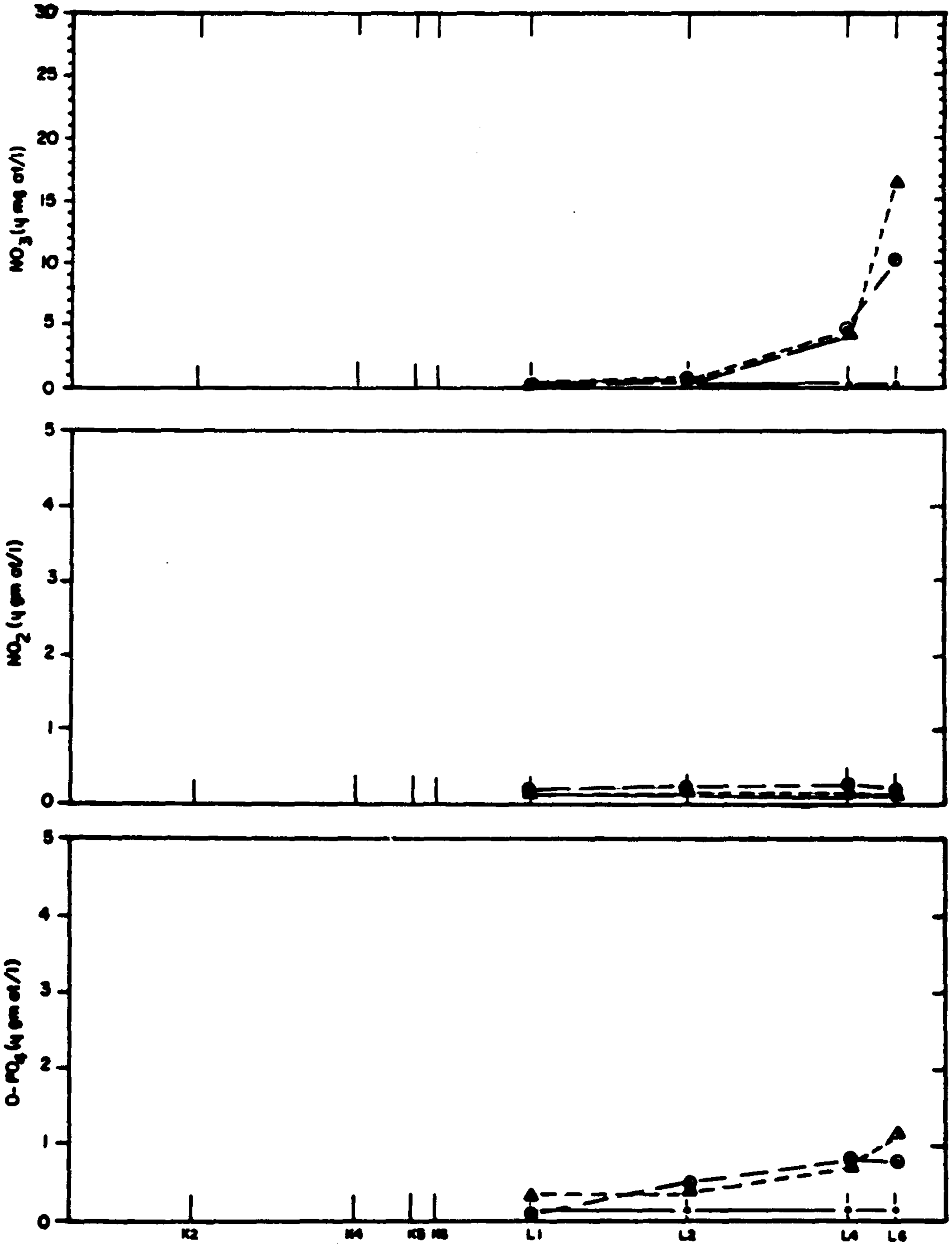


Figure 3-59. Surface (·), mid-depth (θ), anv bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM07B.

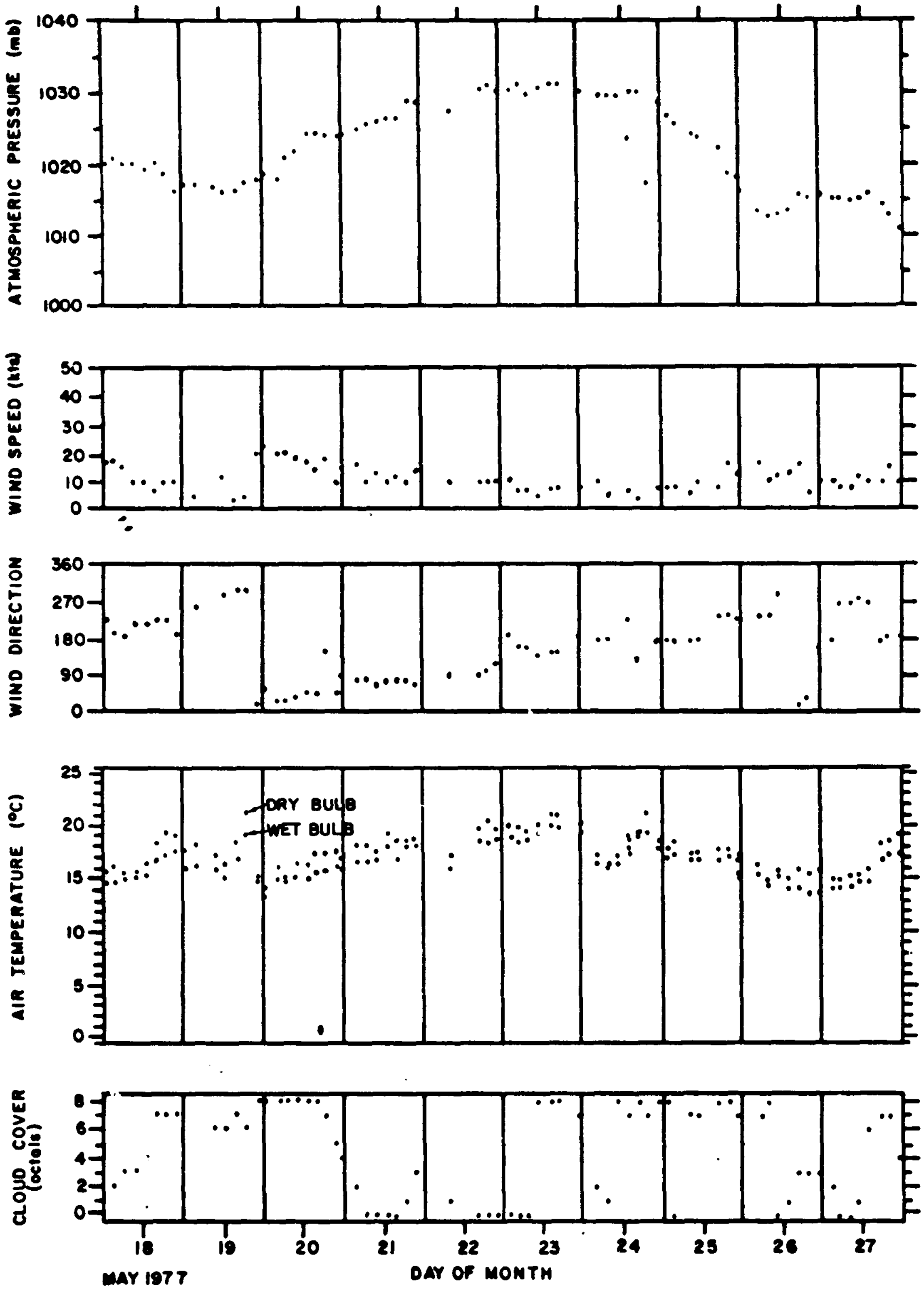


Figure 3-60a. Meteorological data collected during cruise BLM07W from 18-27 May 1977.

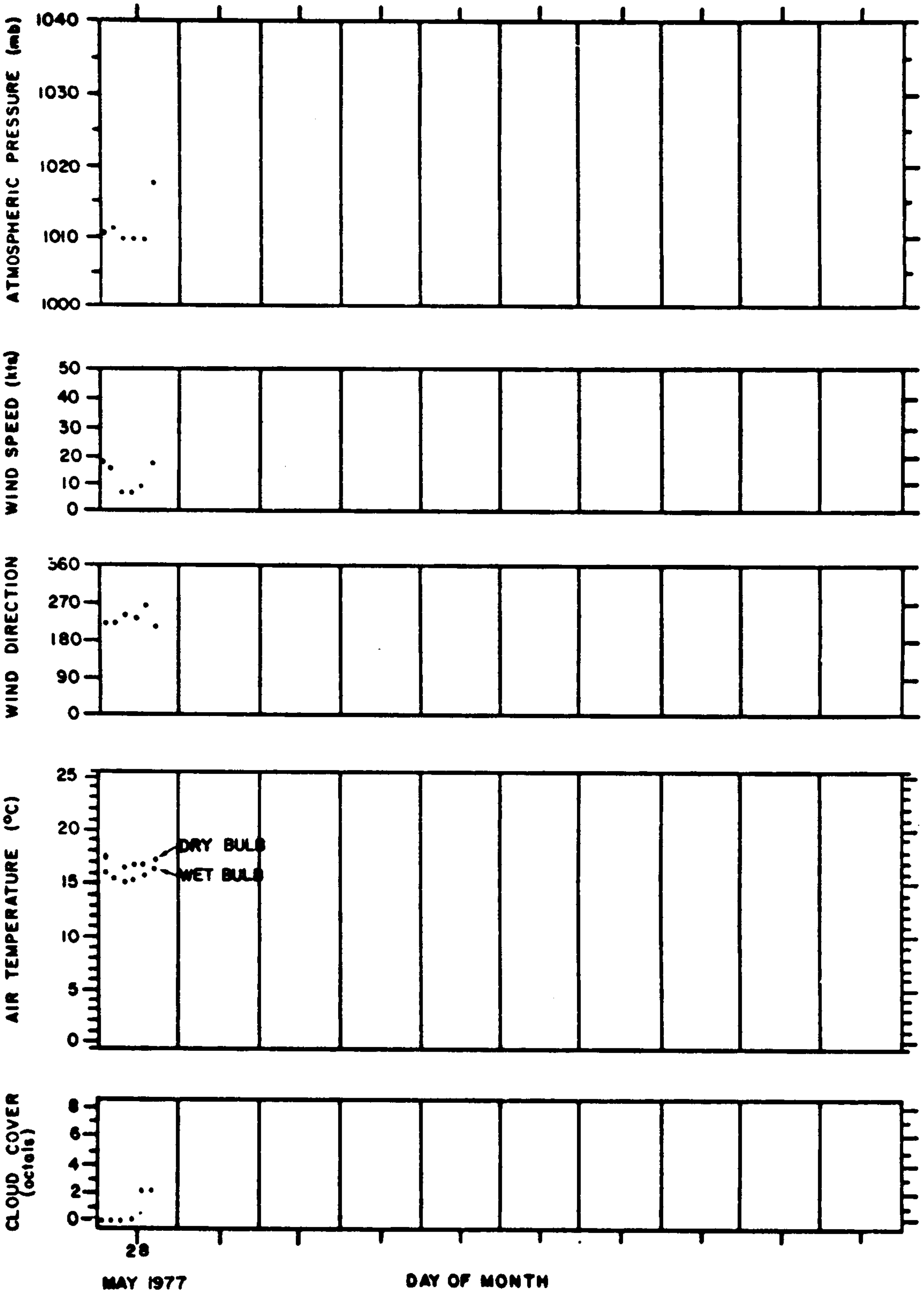


Figure 3-60b. Meteorological data collected during cruise BLM07W on 28 May 1977.

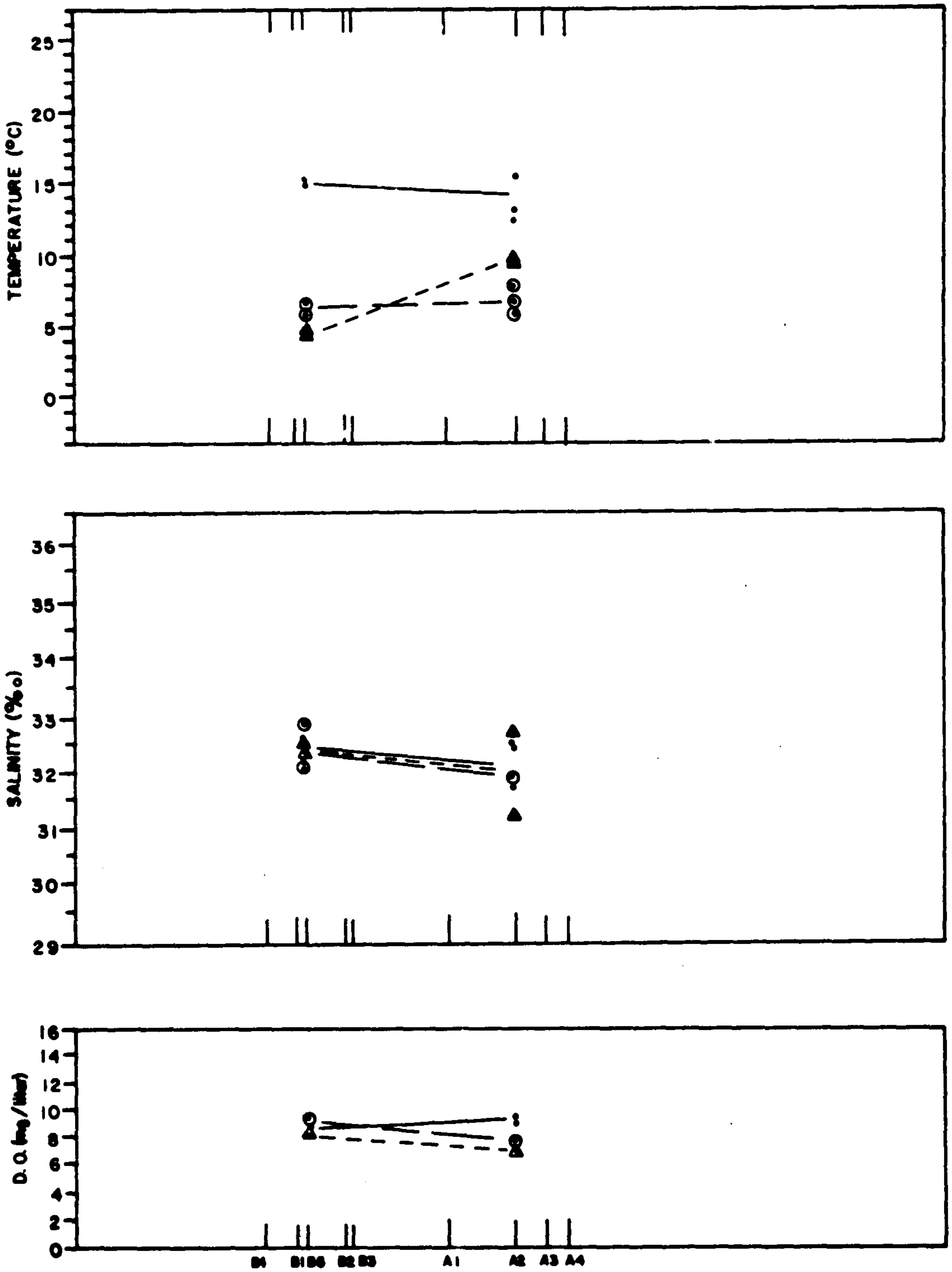


Figure 3-61. Surface (·), mid-depth (Θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM07W.

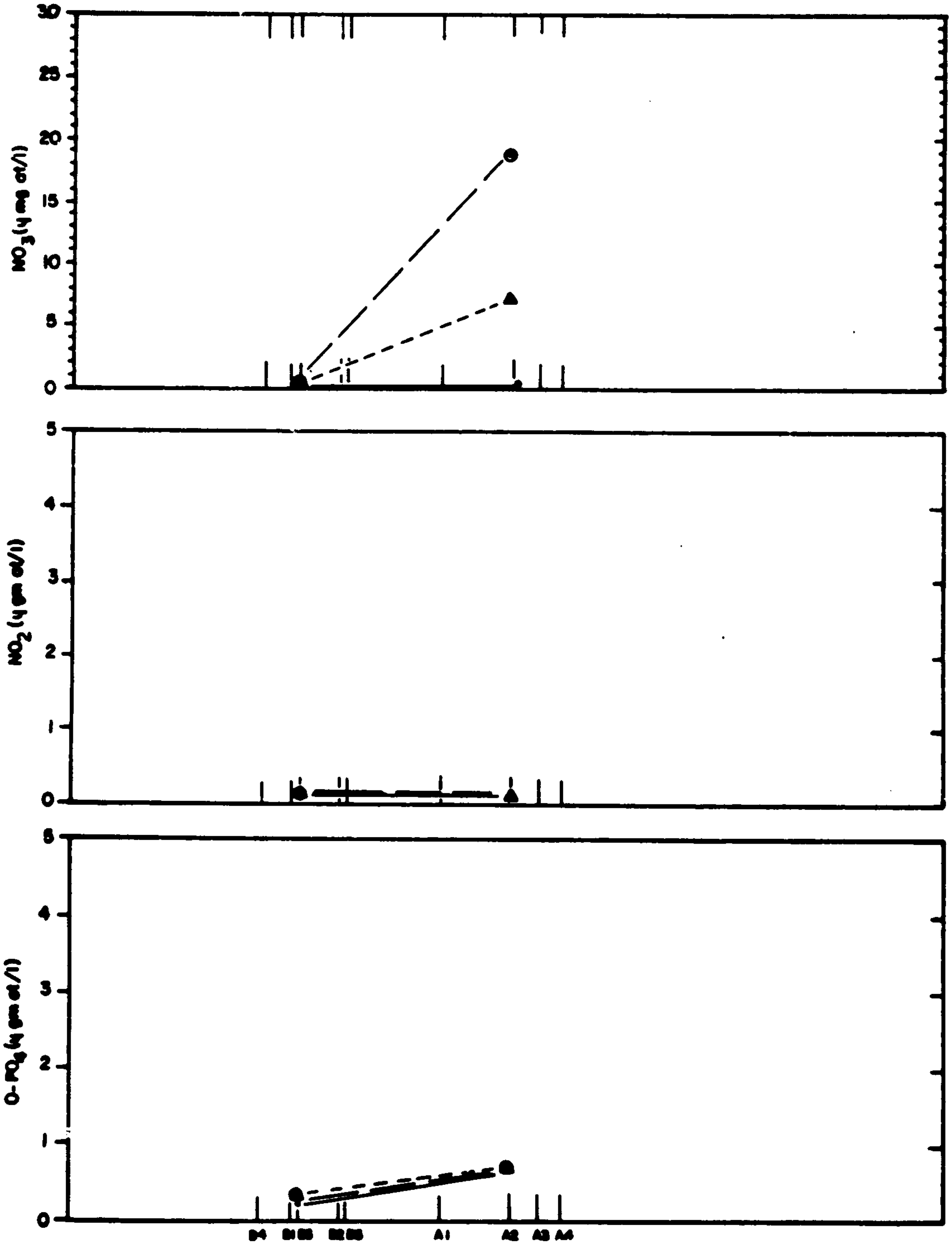


Figure 3-62. Surface (•), mid-depth (Θ), and bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM07W.

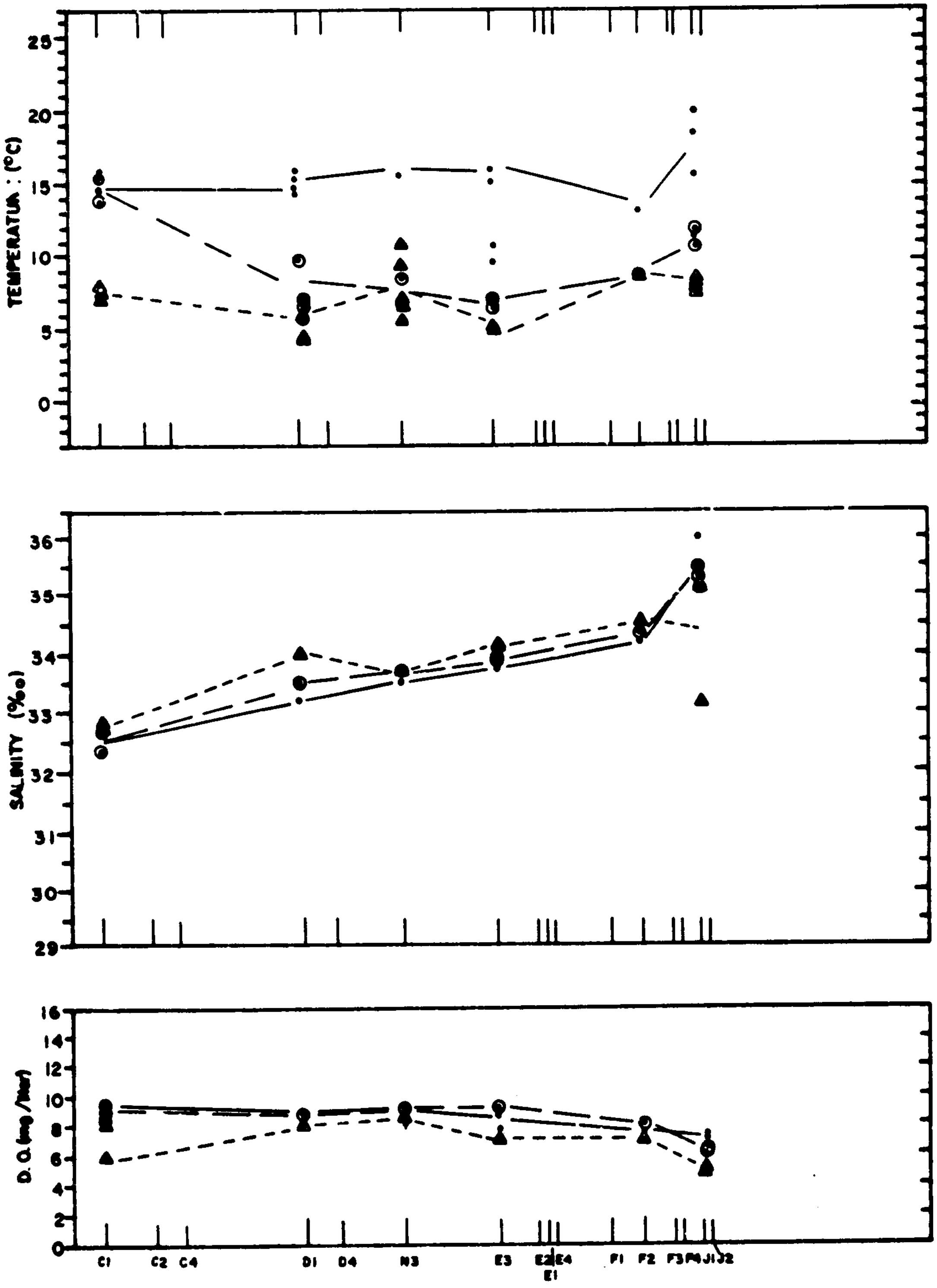


Figure 3-63. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM07W.

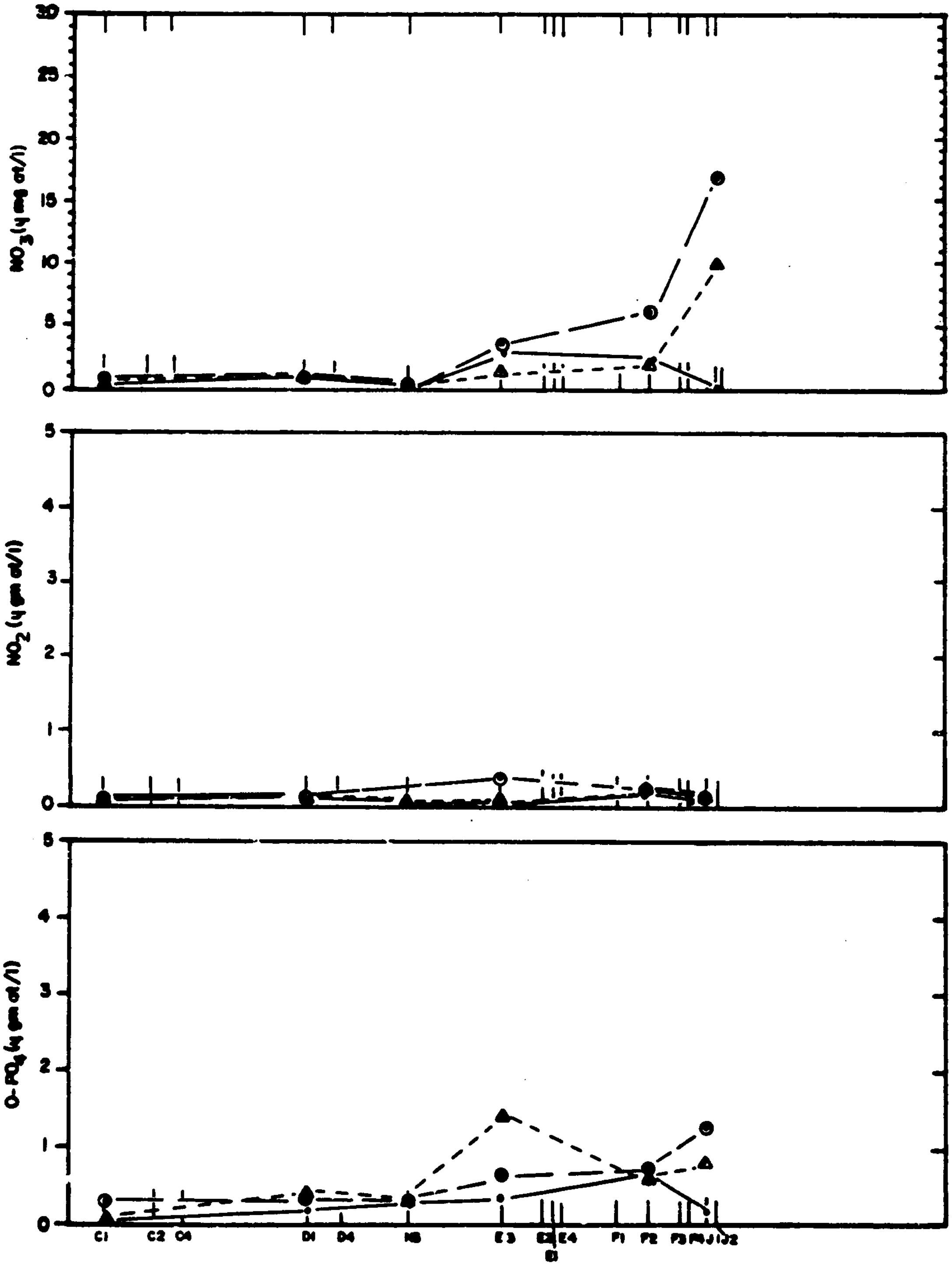


Figure 3-64. Surface (·), mid-depth (θ), and bottom (Δ) values of nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM07W.

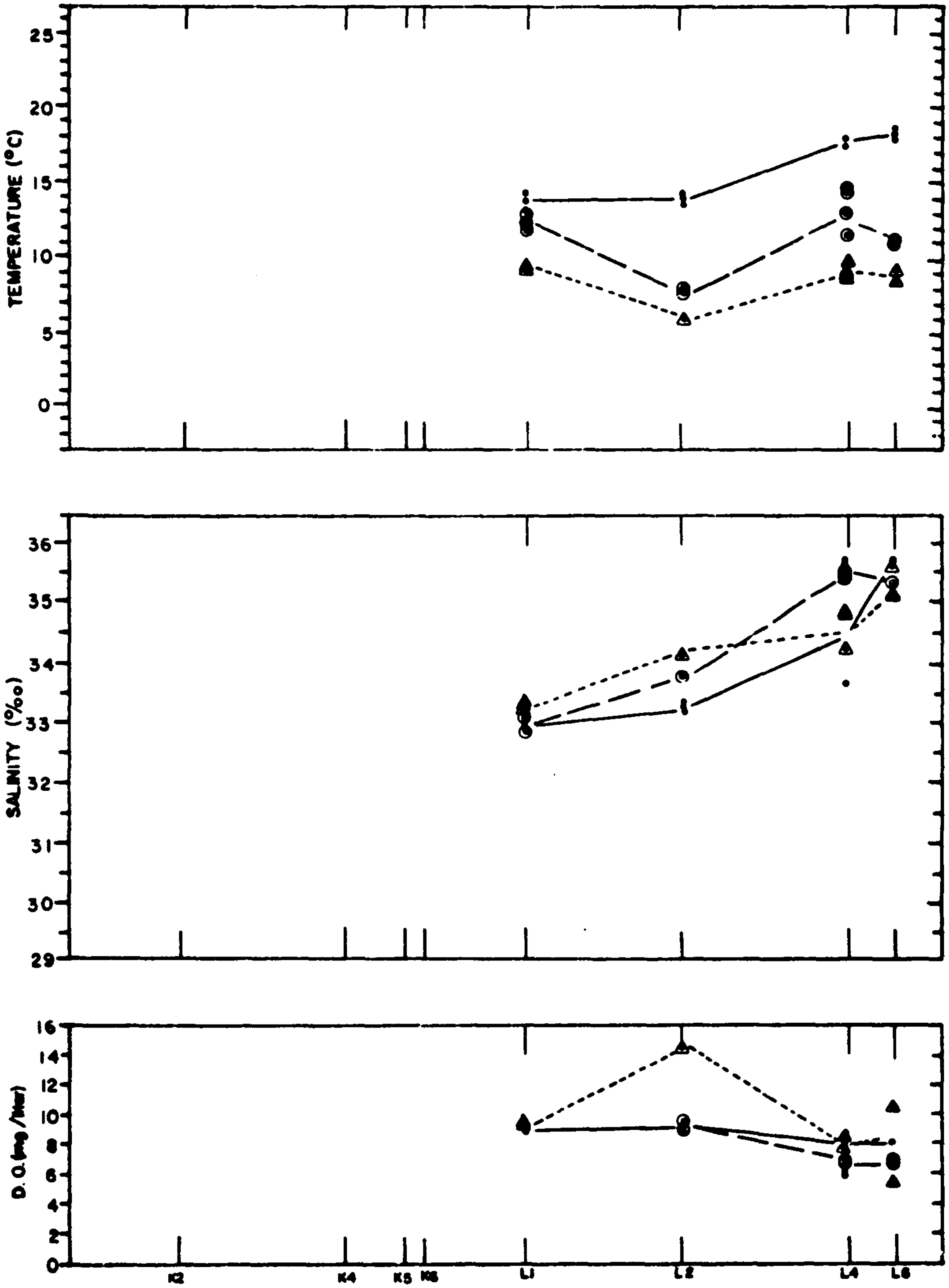


Figure 3-65. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section V (Figure 3-6) during cruise BLM07W.

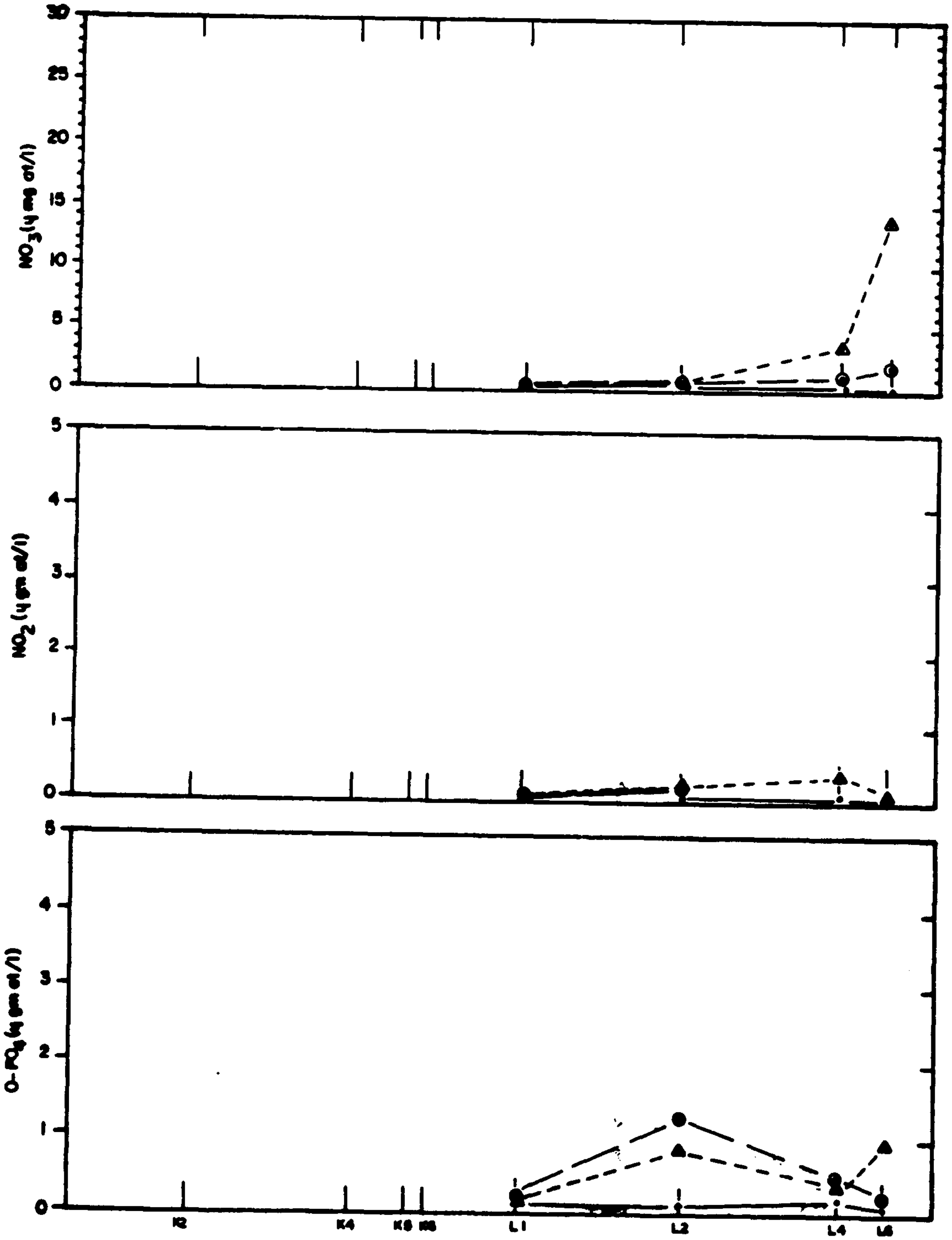


Figure 3-66. Surface (•), mid-depth (θ), and bottom (Δ) values of nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM07W.

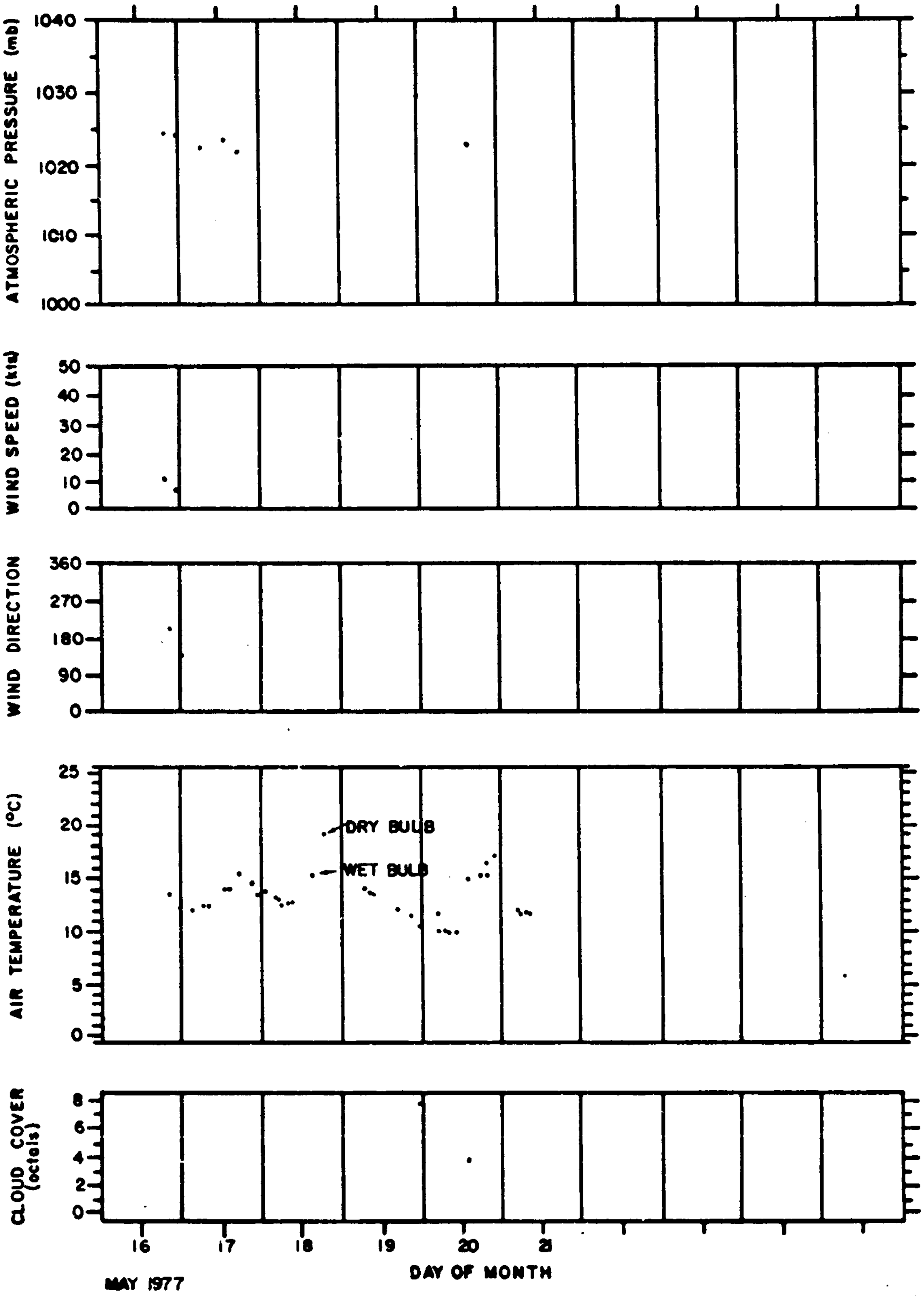


Figure 3-67. Meteorological data collected during cruise BLM07T from 16-21 May 1977.

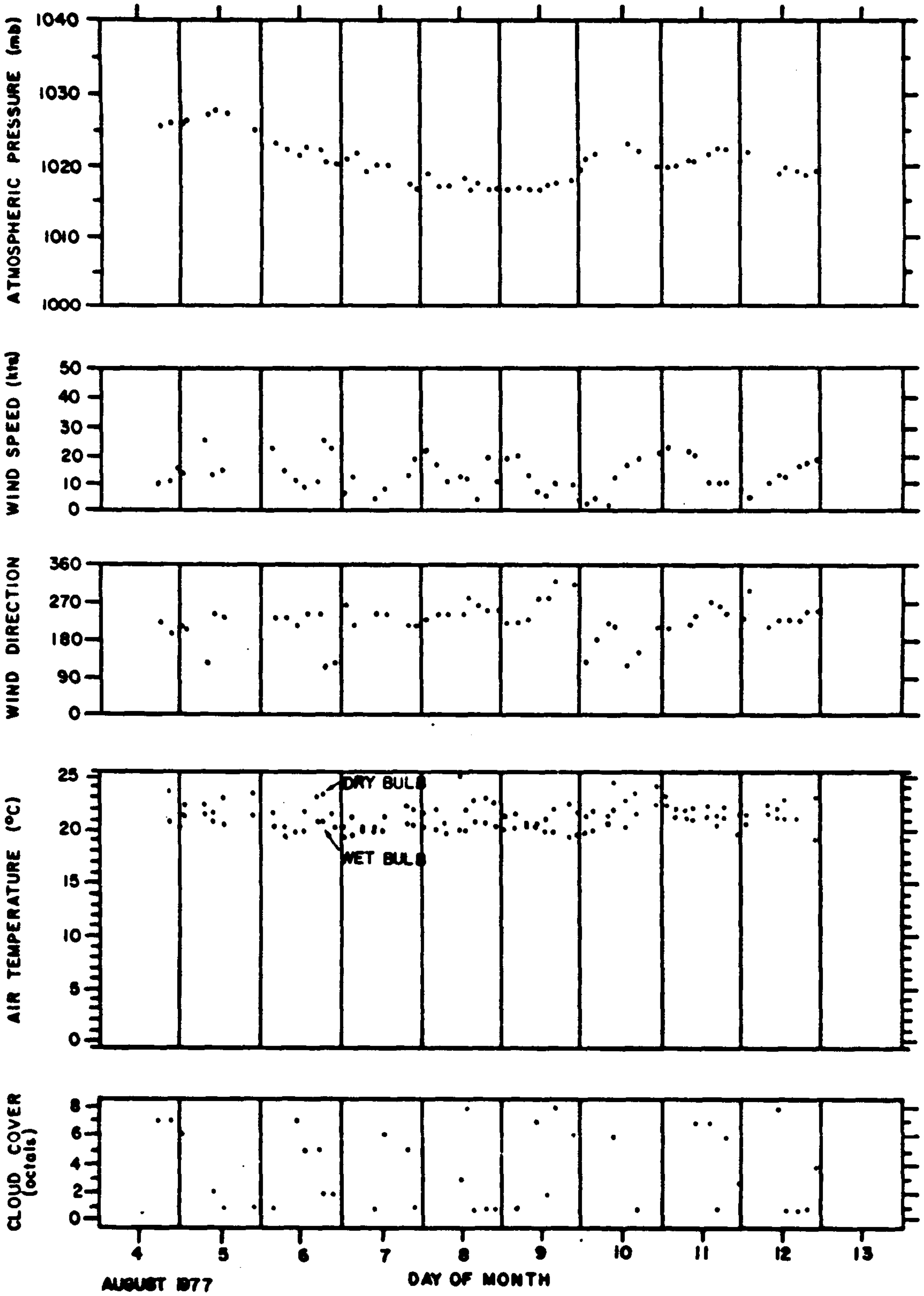


Figure 3-68a. Meteorological data collected during cruise BLM08B from 4-12 August 1977.

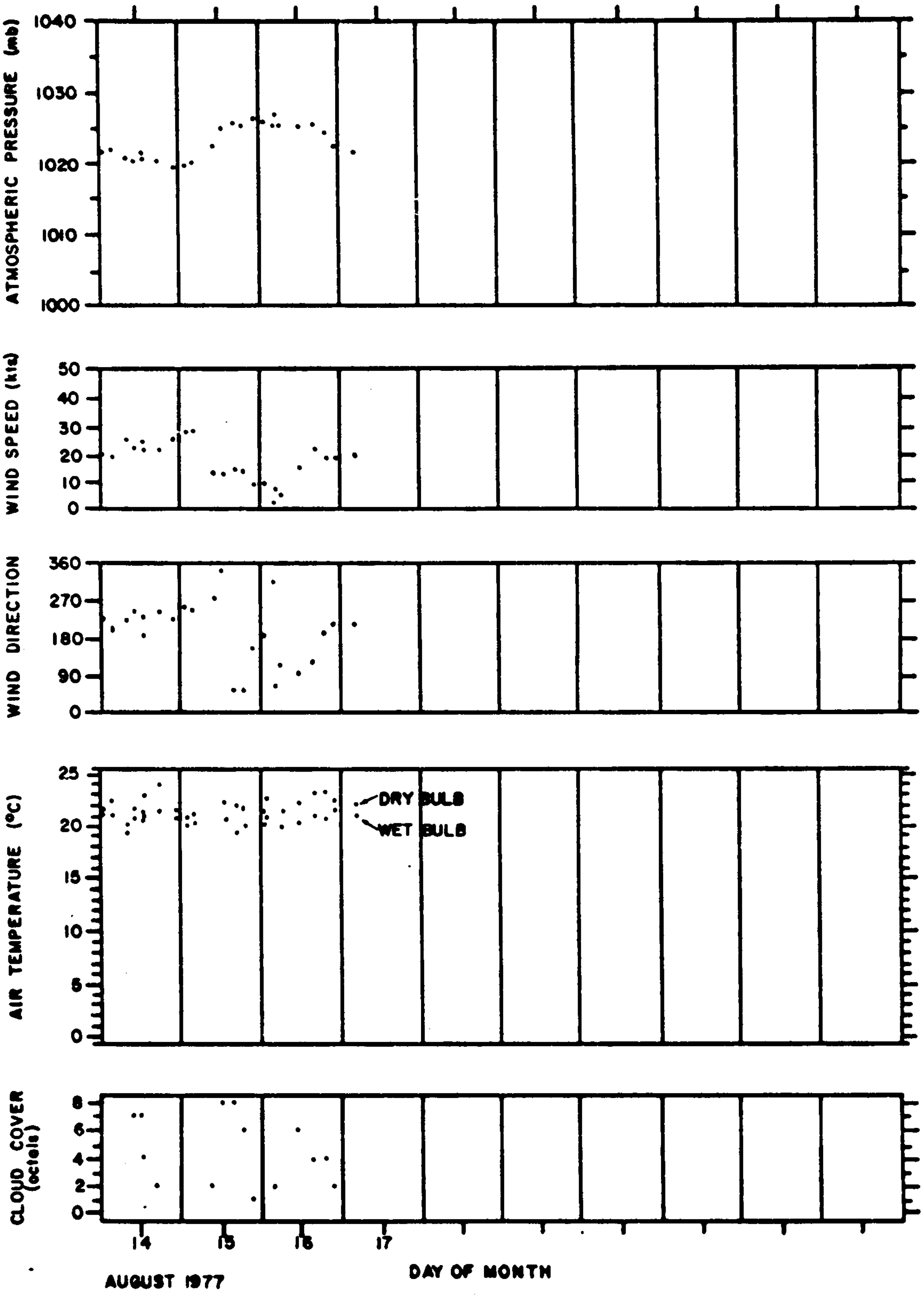


Figure 3-68b. Meteorological data collected during cruise BLM08B from 14-17 August 1977.

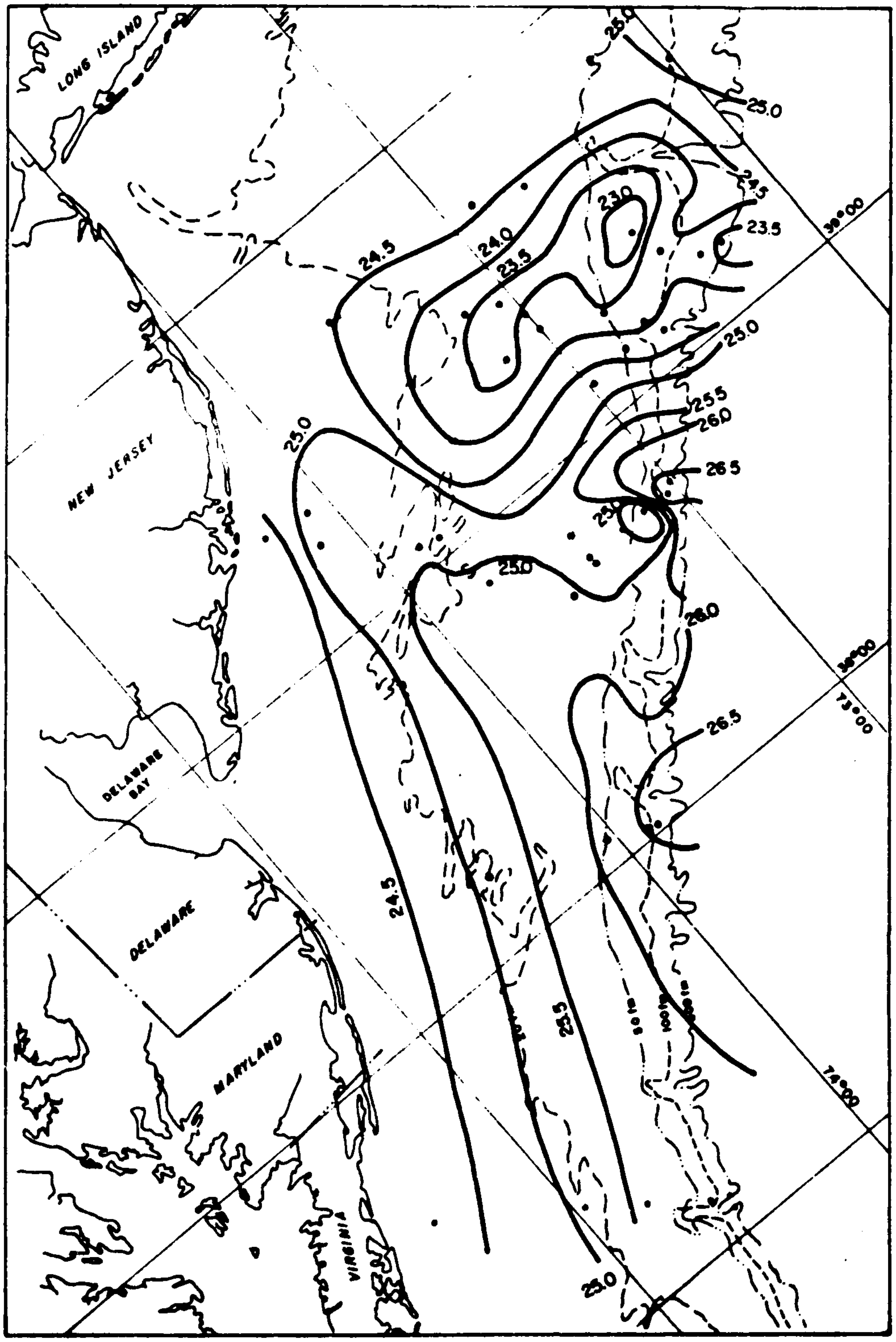


Figure 3-69a. Surface temperature (°C) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

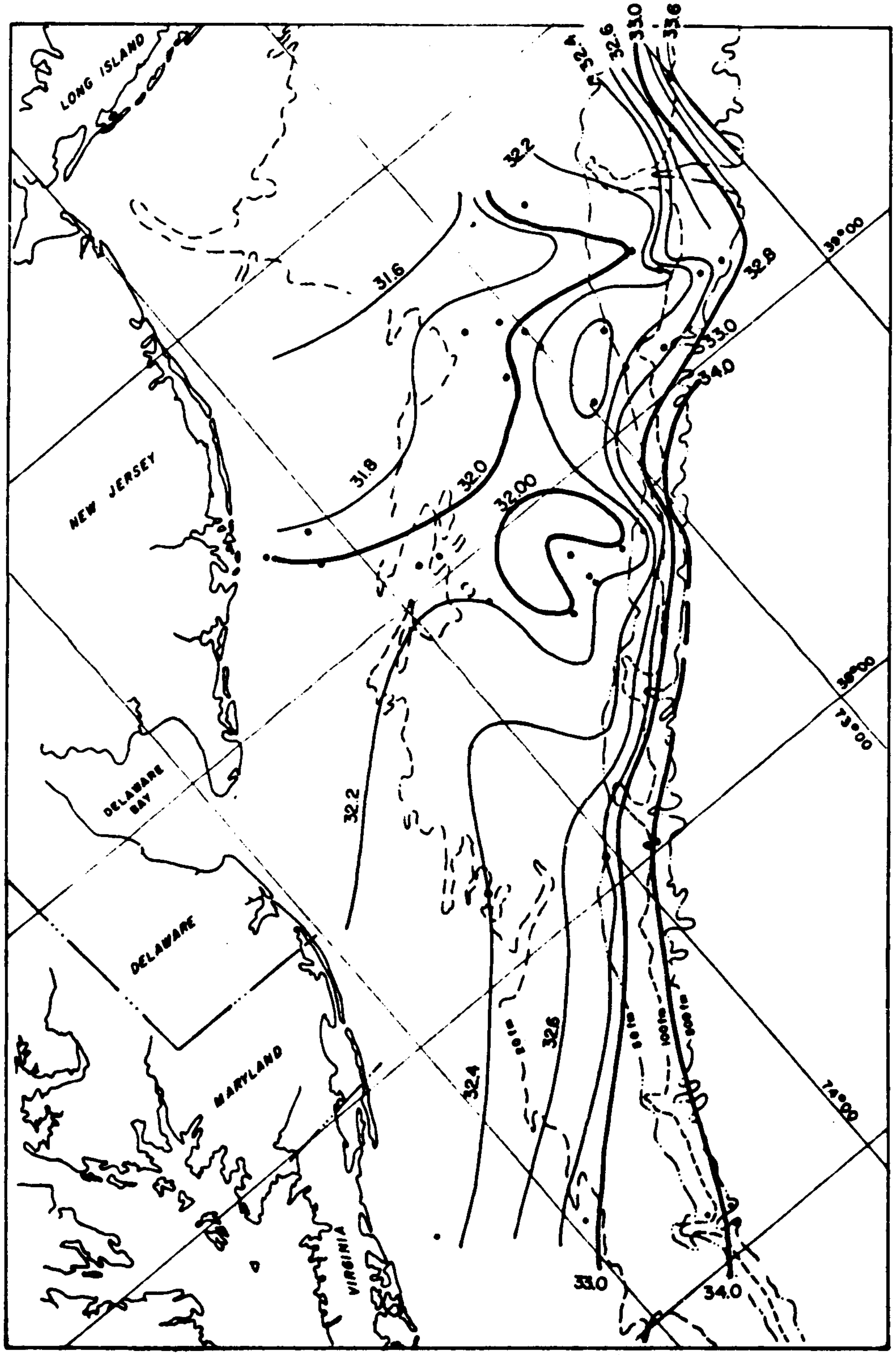


Figure 3-69b. Surface salinity (ppt) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

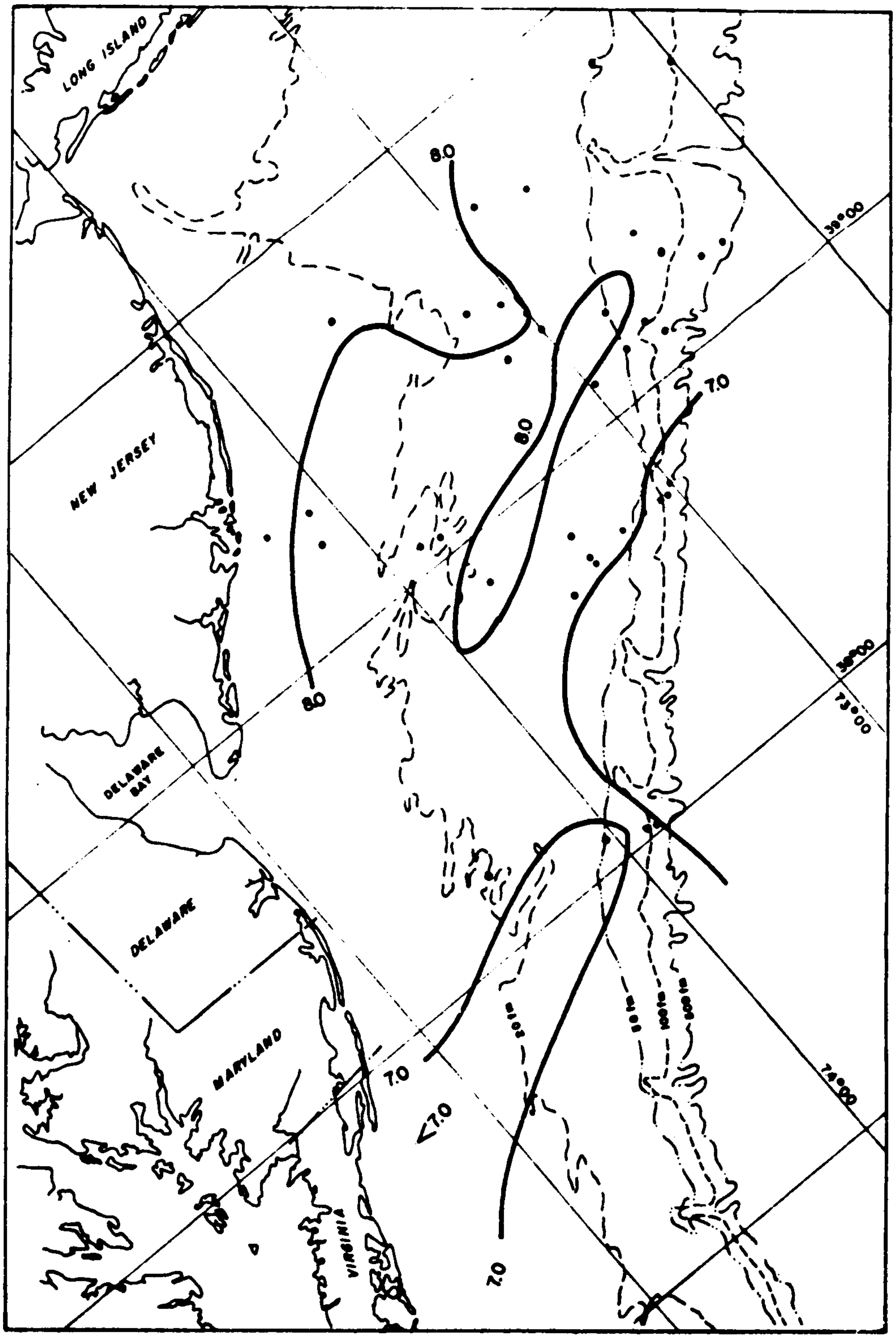


Figure 3-69c. Surface dissolved oxygen (mg/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

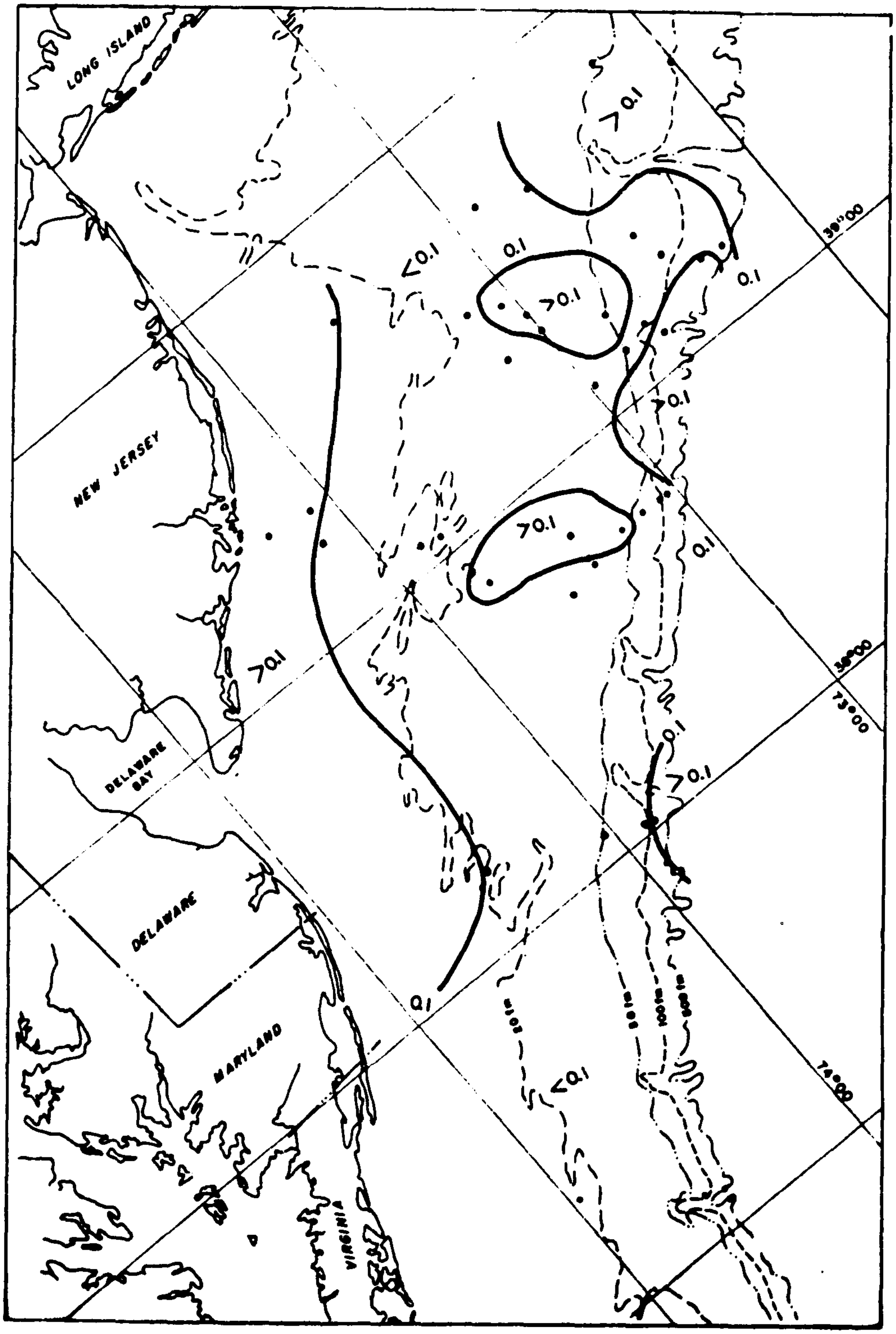


Figure 3-69d. Surface dissolved nitrite (μgm-at/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

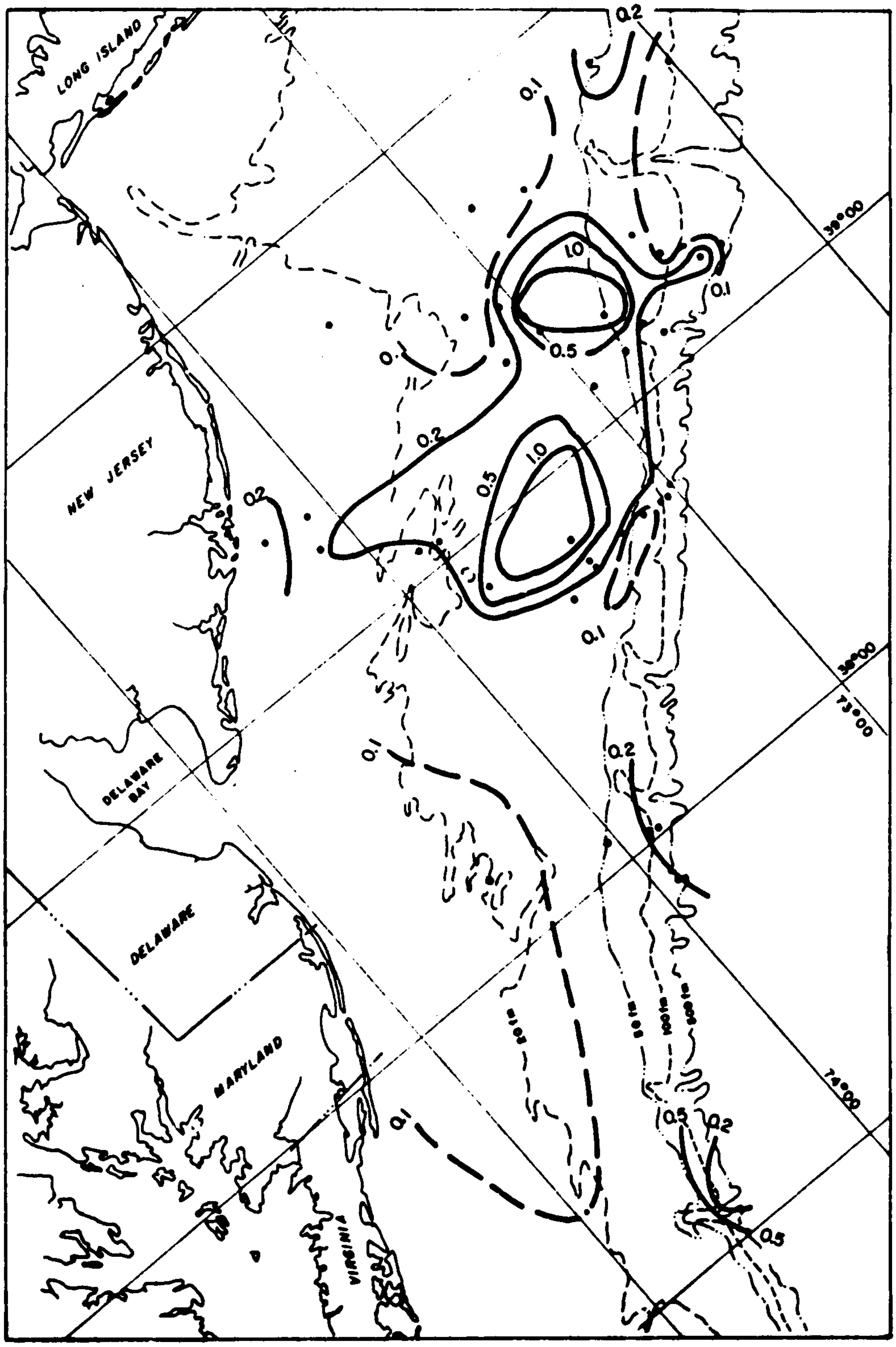


Figure 3-69e. Surface dissolved nitrate (μgm- [illegible] 1) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

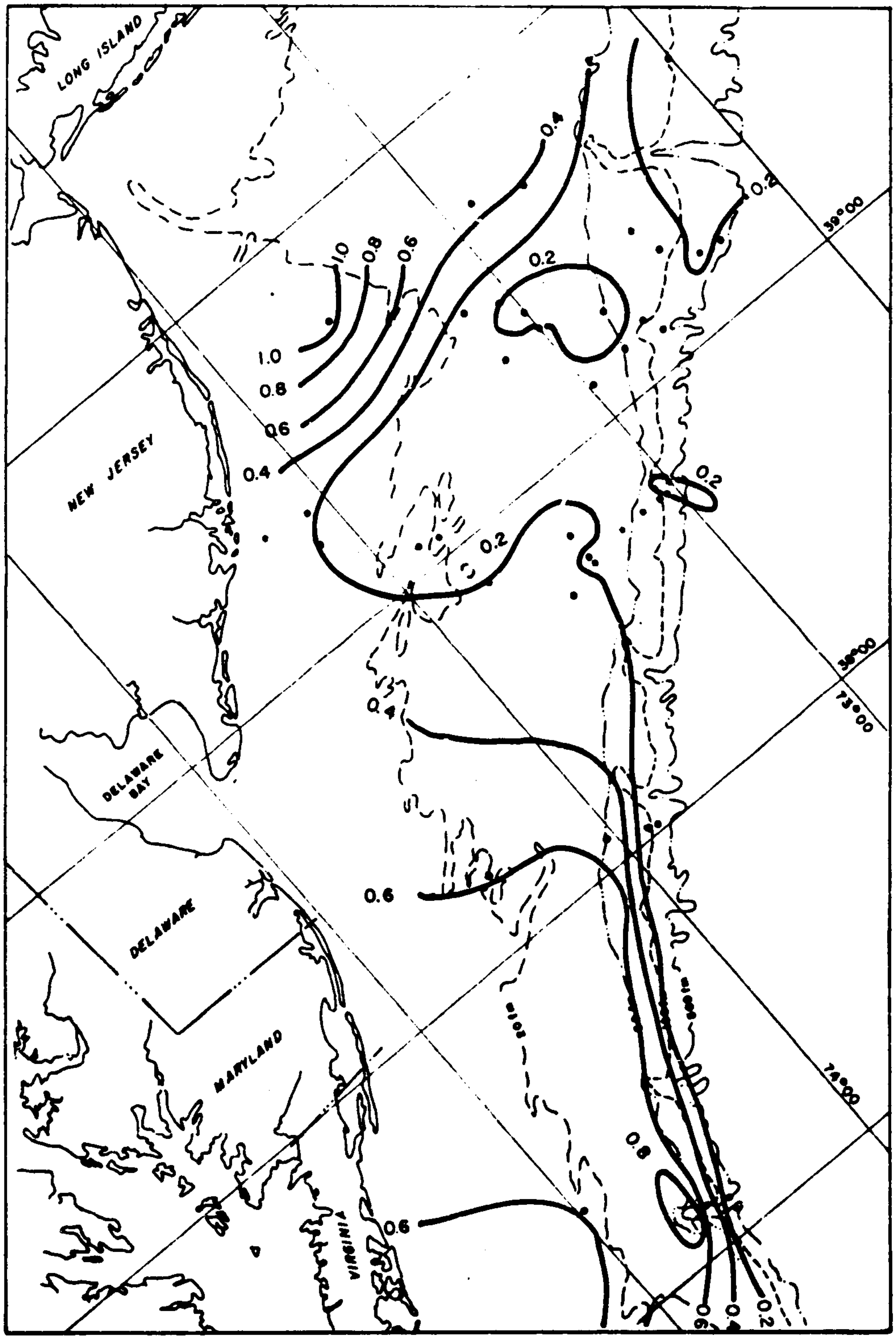


Figure 3-69f. Surface dissoled ortho-phosphate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

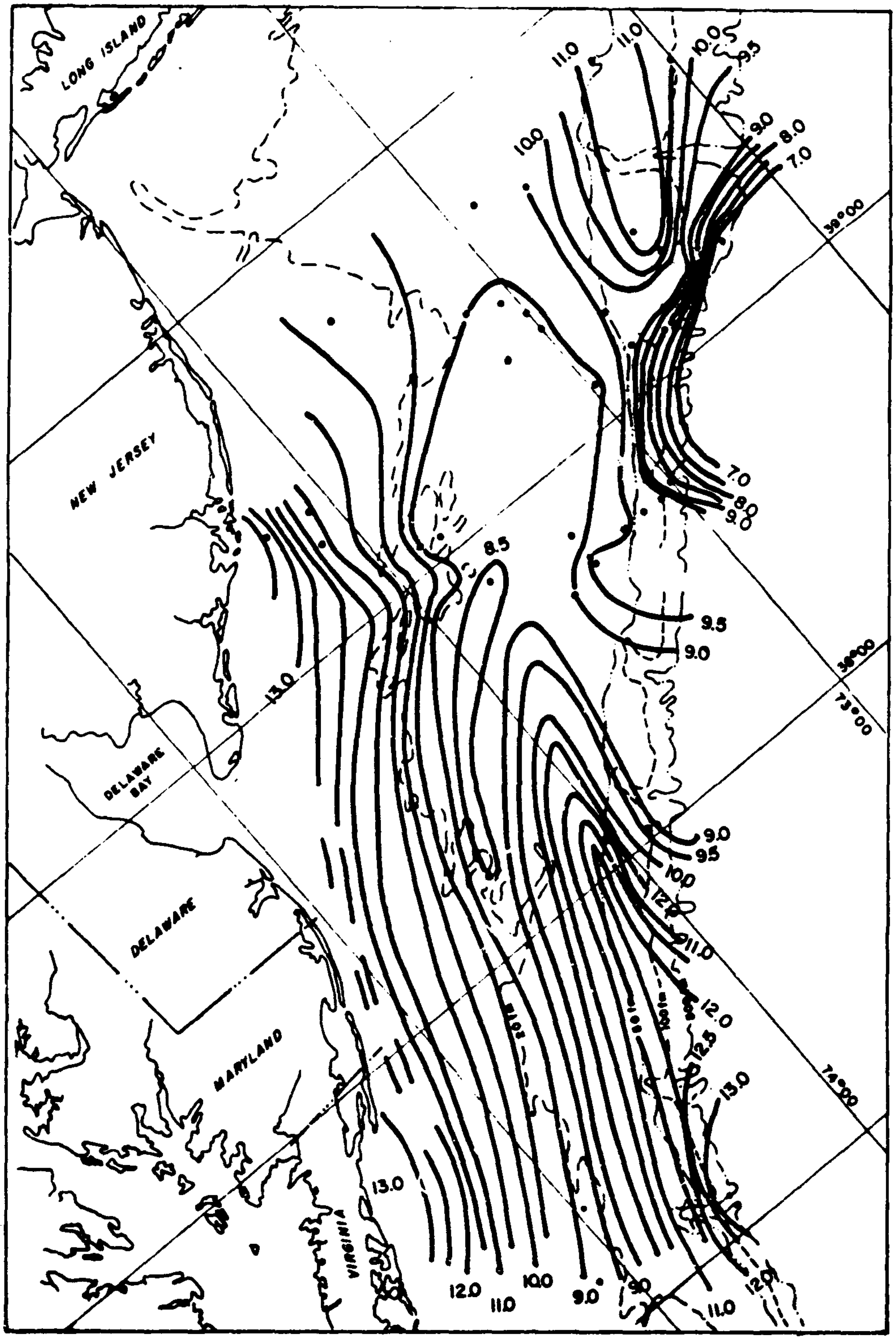


Figure 3-70a. Bottom temperature (°C) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

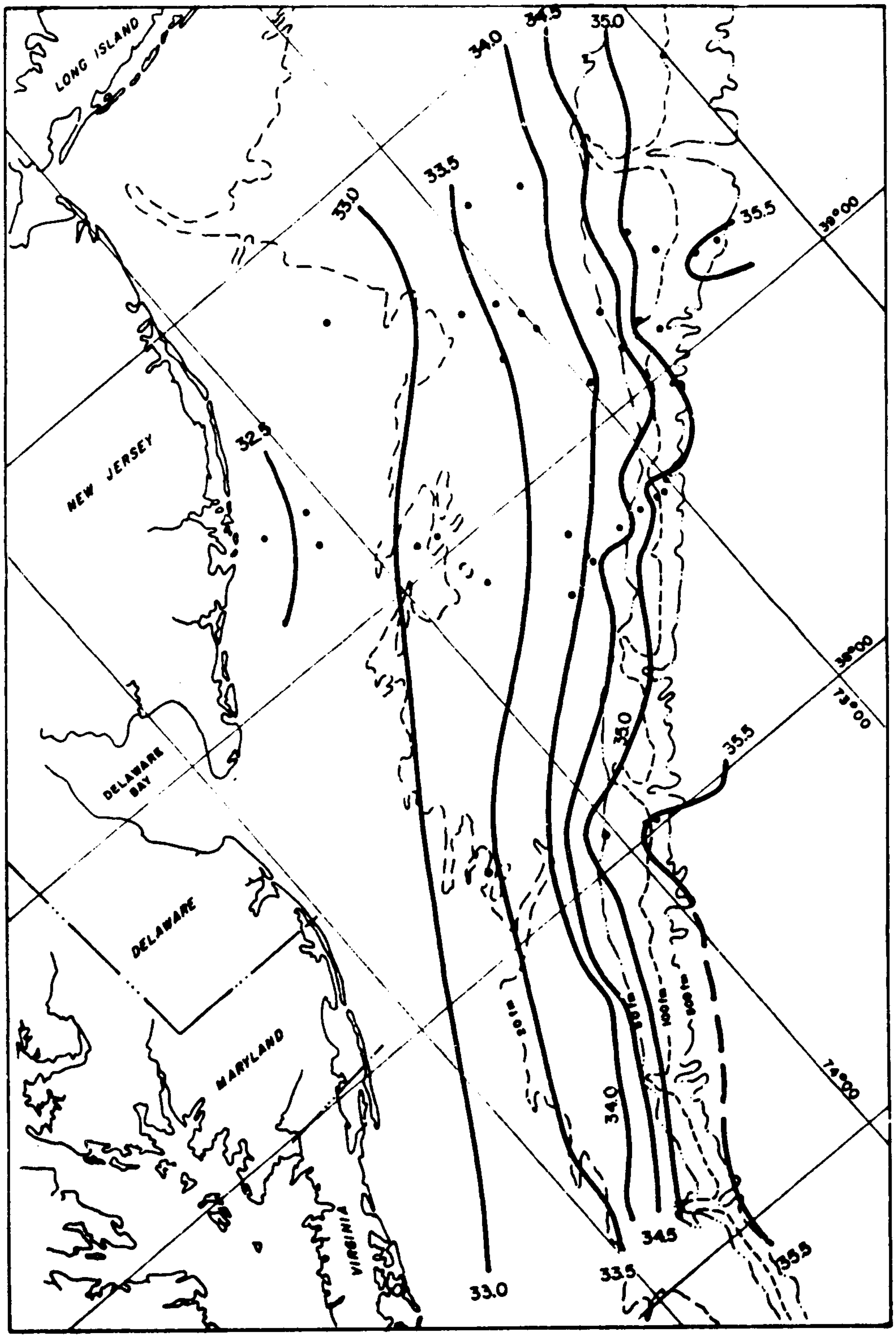


Figure :-70h. Bottom salinity (ppt) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

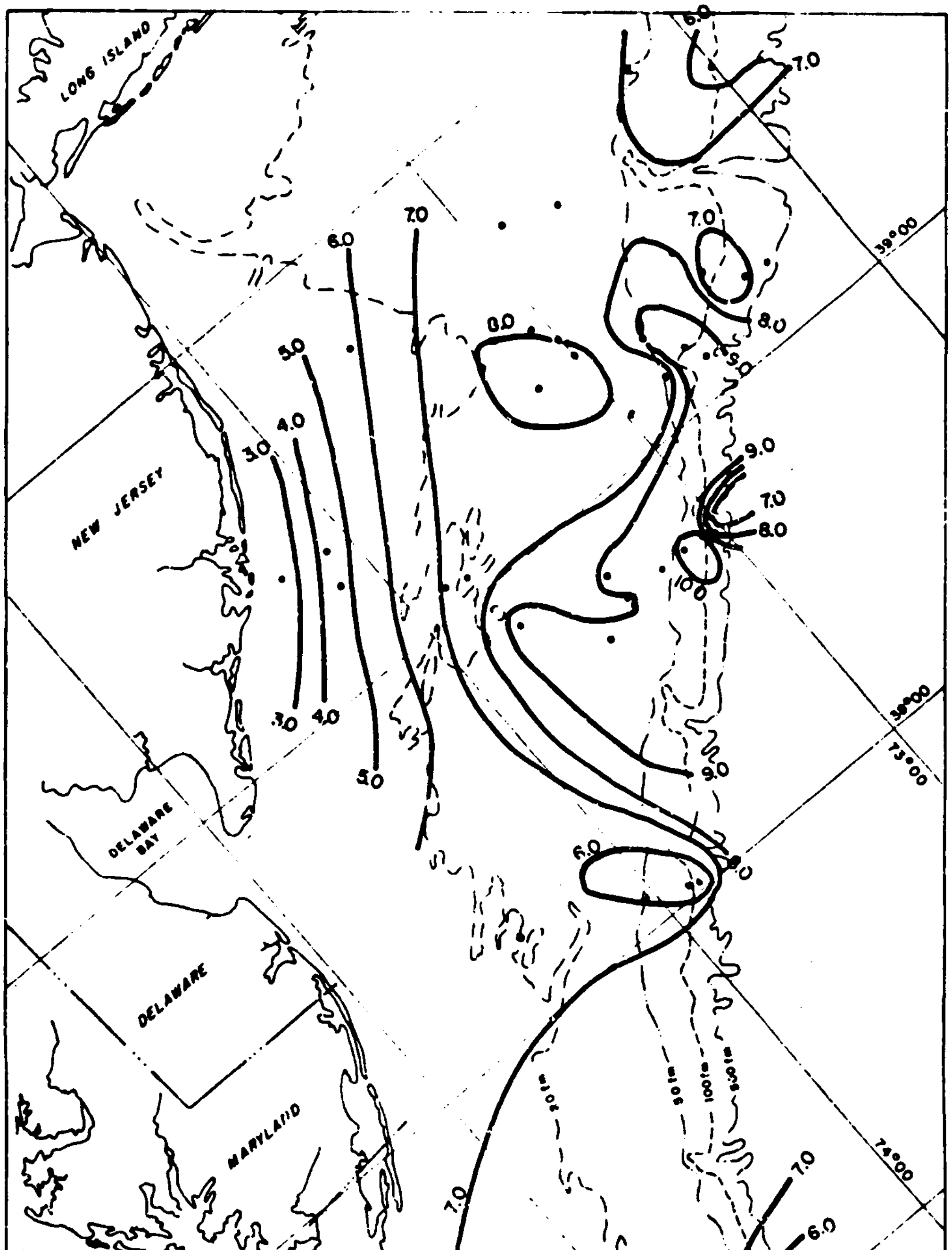


Figure 3-70c. Bottom dissolved oxygen (mg/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

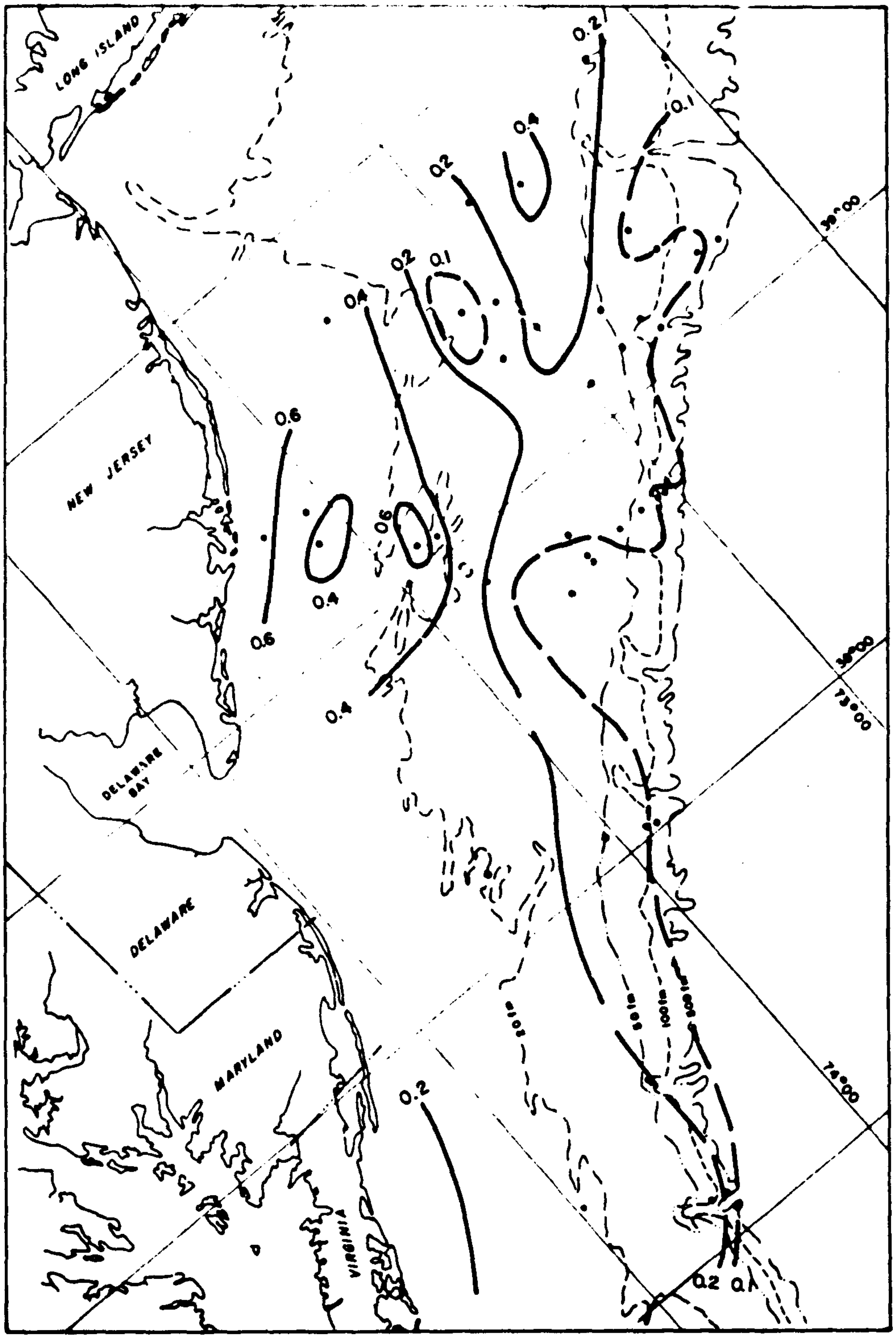


Figure 3-70d. Bottom dissolved nitrite (μgm-at/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

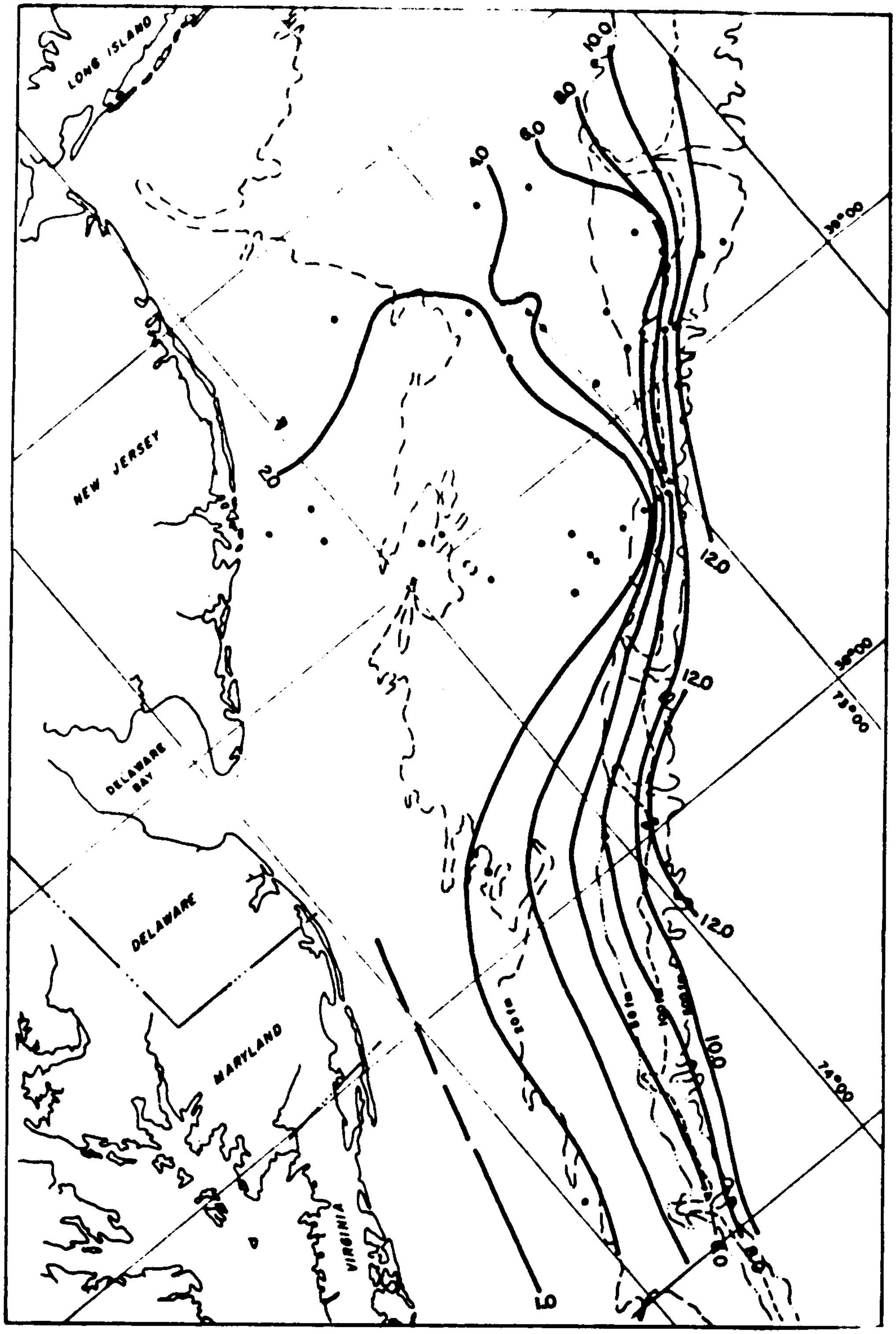


Figure 3-70e. Bottom dissolved nitrate (µgm-at/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).

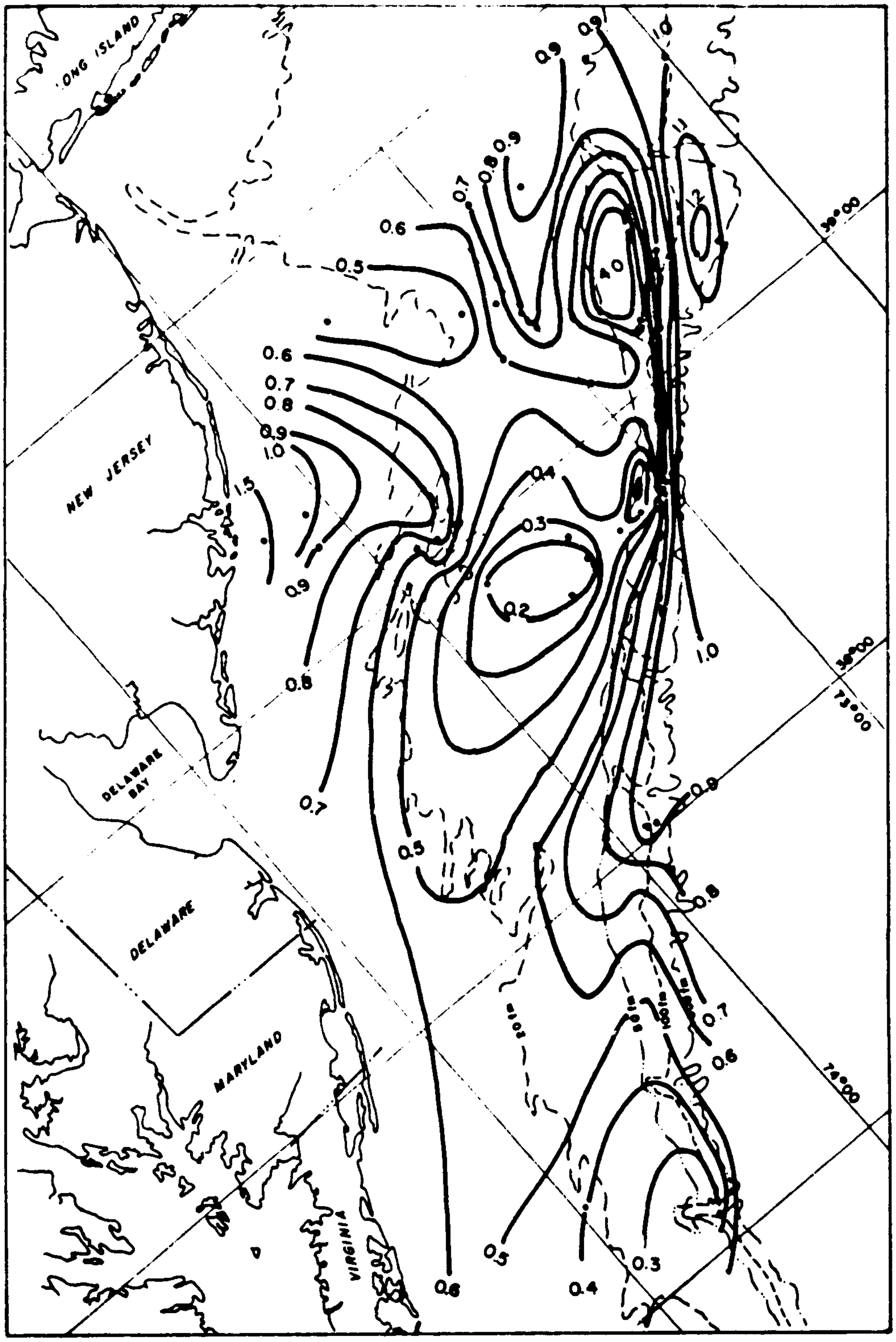
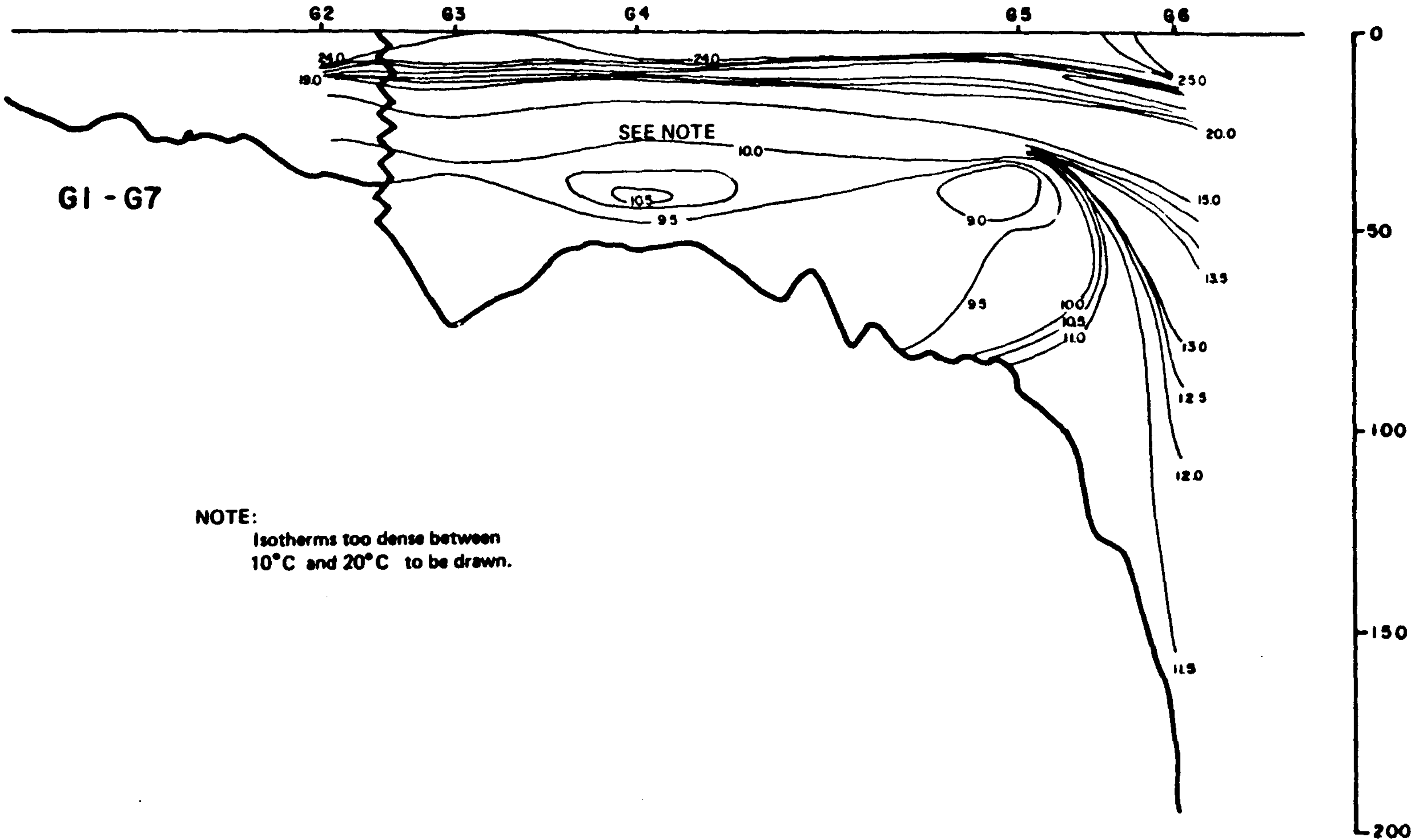


Figure 3-70f. Bottom dissolved ortho-phosphate (μgm-at/l) distribution in the Middle Atlantic Bight during the period 4-16 August 1977 (Cruise BLM08B).



NOTE:
Isotherms too dense between
10°C and 20°C to be drawn.

Figure 3-71a. Temperature (°C) contours for section I (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

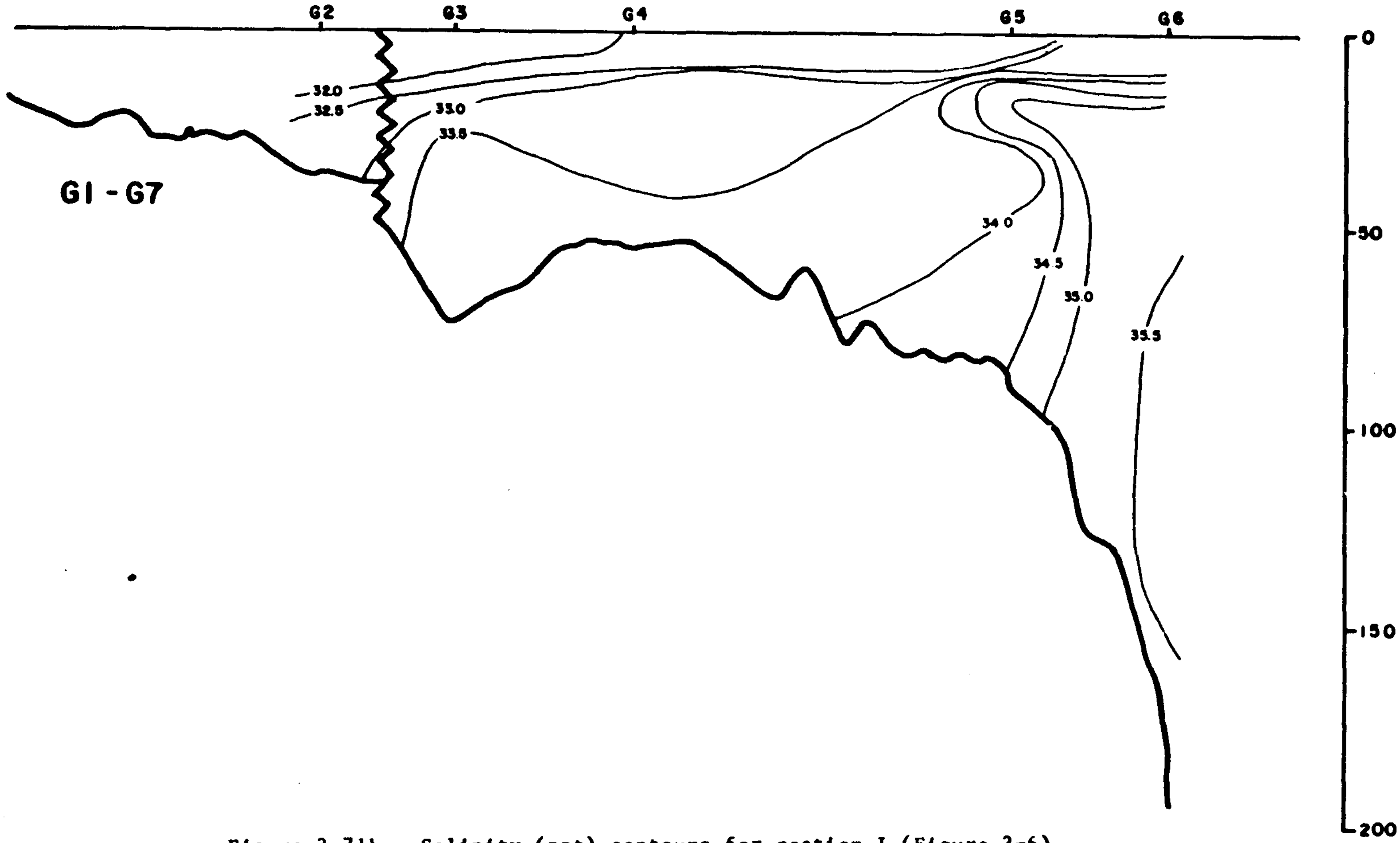


Figure 3-71b. Salinity (ppt) contours for section I (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

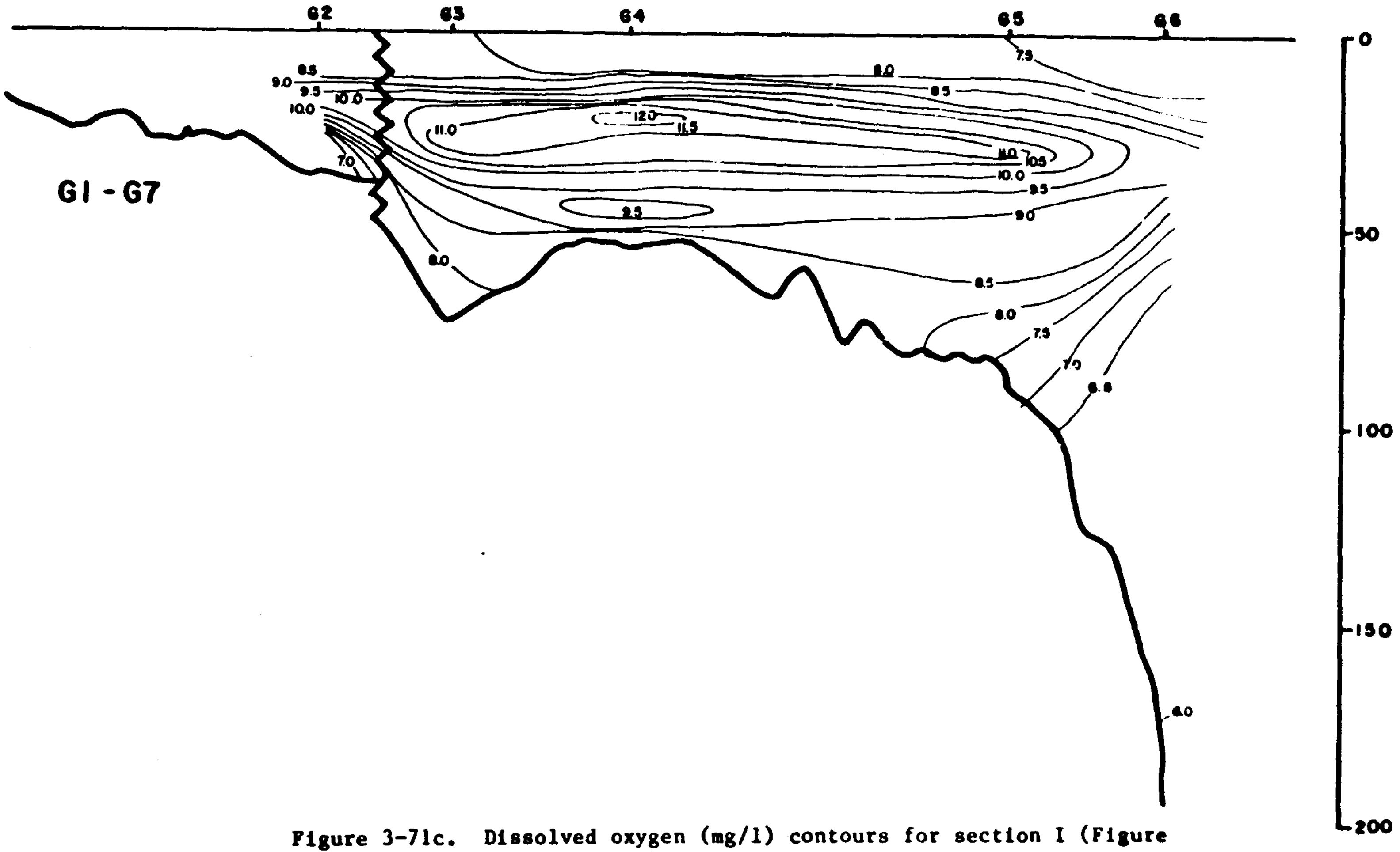


Figure 3-71c. Dissolved oxygen (mg/l) contours for section I (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

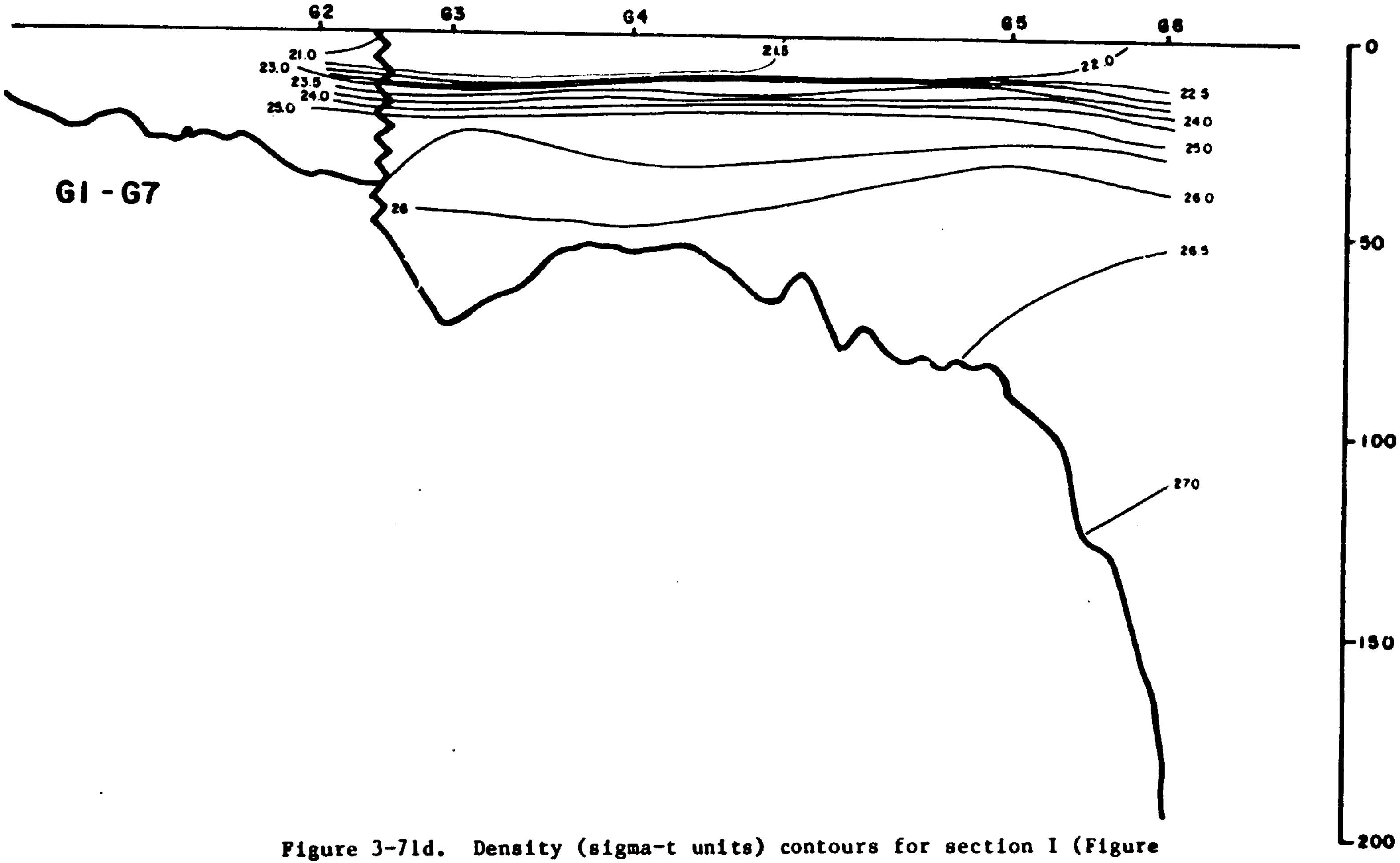
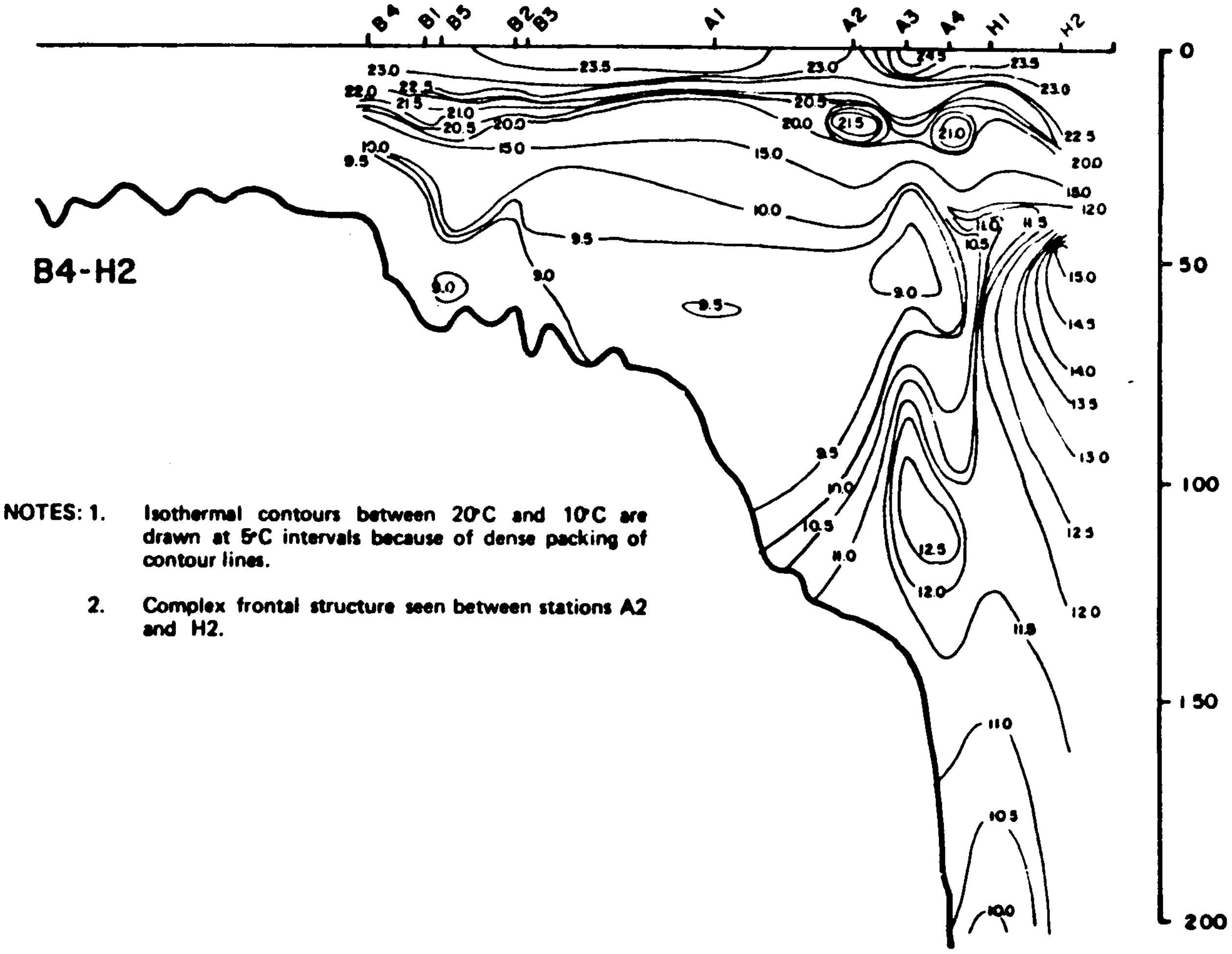


Figure 3-71d. Density (sigma-t units) contours for section I (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES: 1. Isothermal contours between 20°C and 10°C are drawn at 5°C intervals because of dense packing of contour lines.

2. Complex frontal structure seen between stations A2 and H2.

Figure 3-72a. Temperature (°C) contours for section II (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

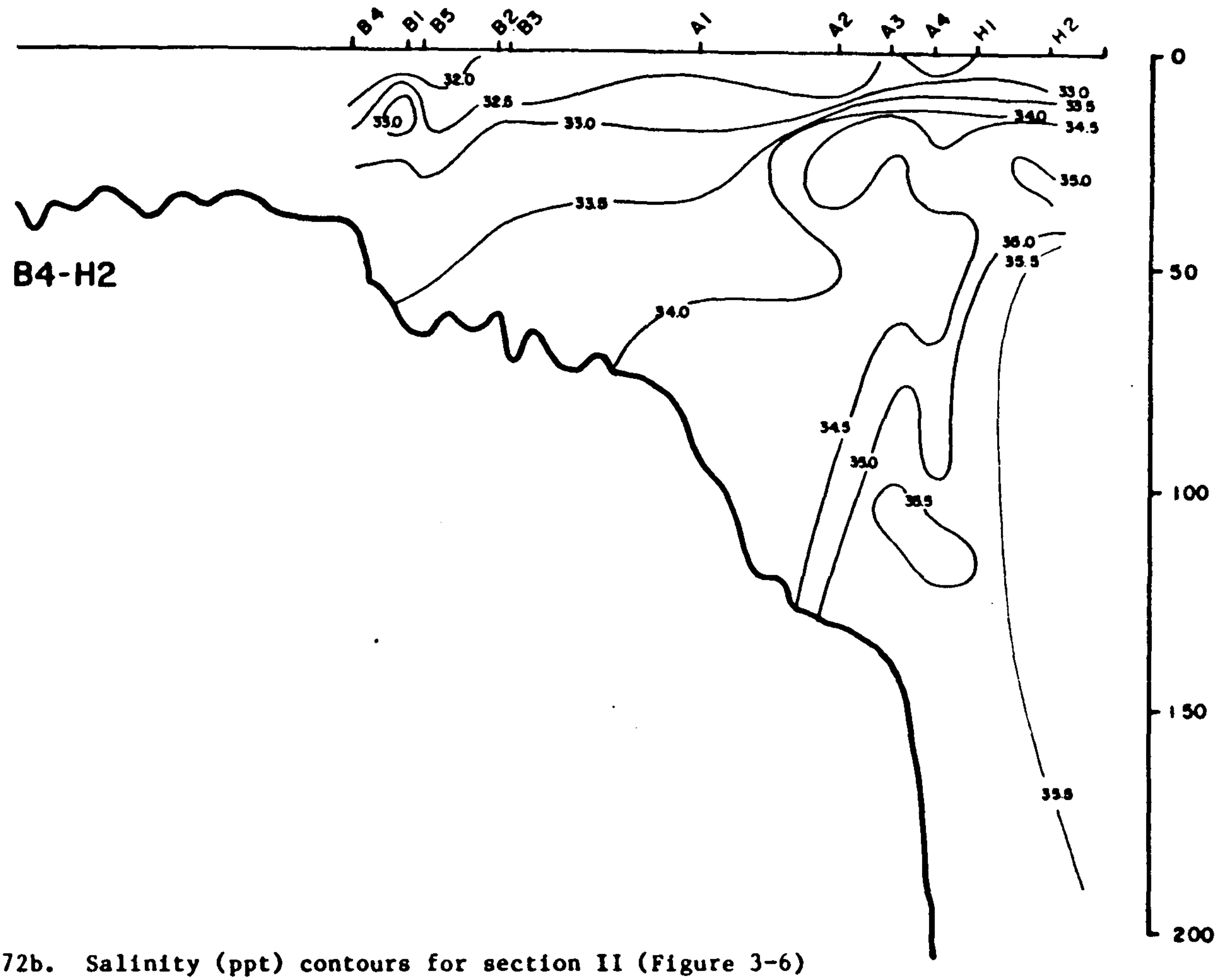
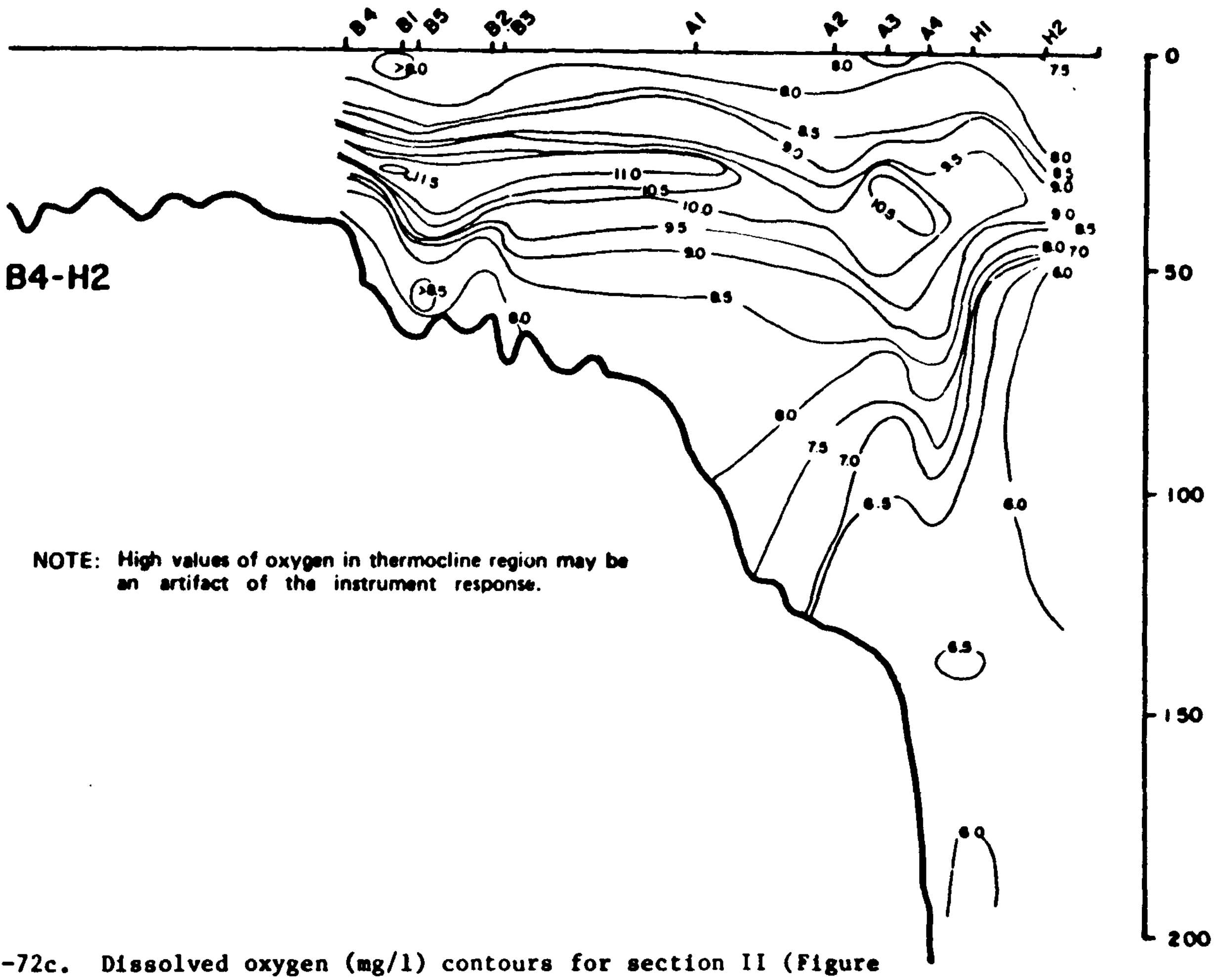


Figure 3-72b. Salinity (ppt) contours for section II (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: High values of oxygen in thermocline region may be an artifact of the instrument response.

Figure 3-72c. Dissolved oxygen (mg/l) contours for section II (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

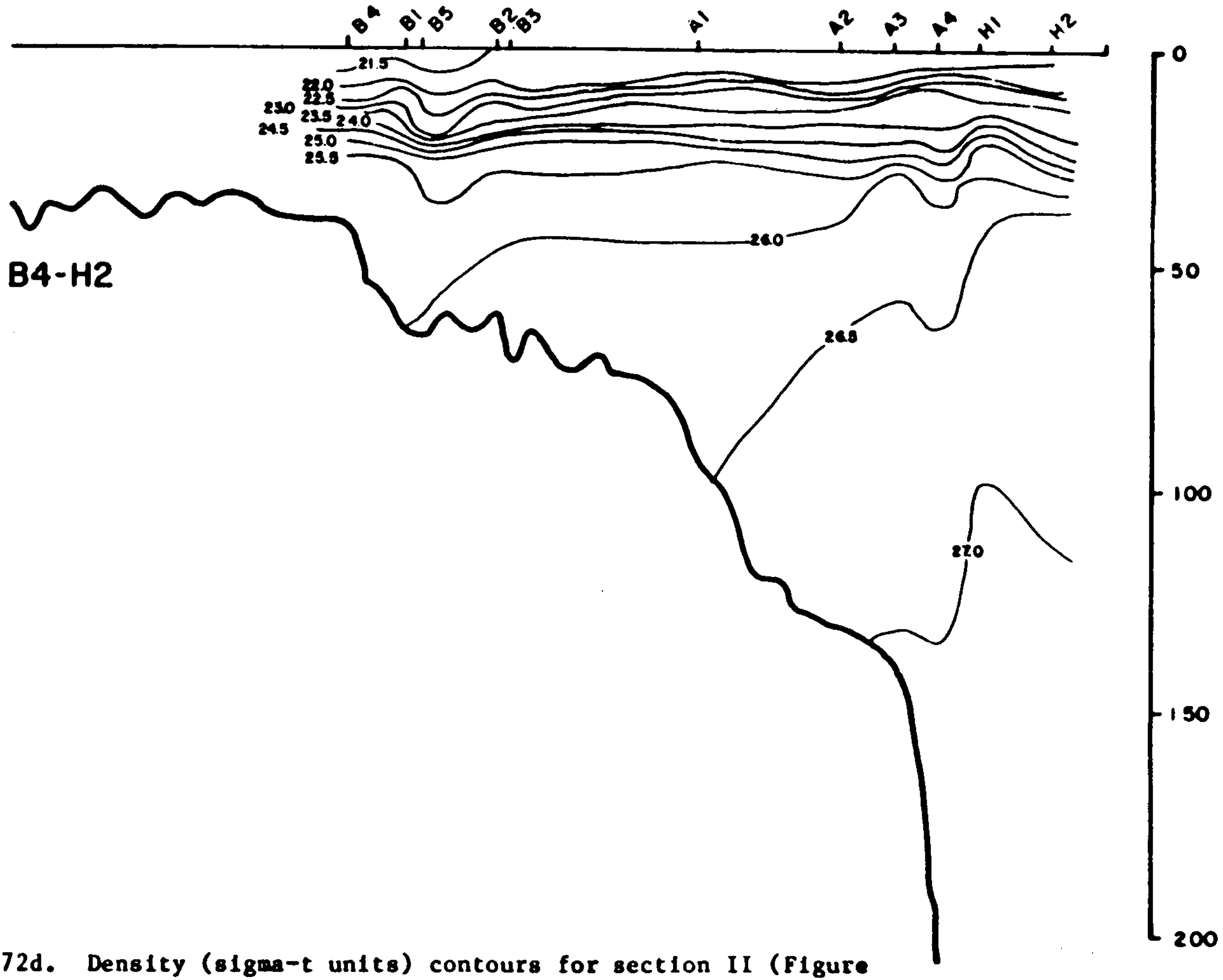
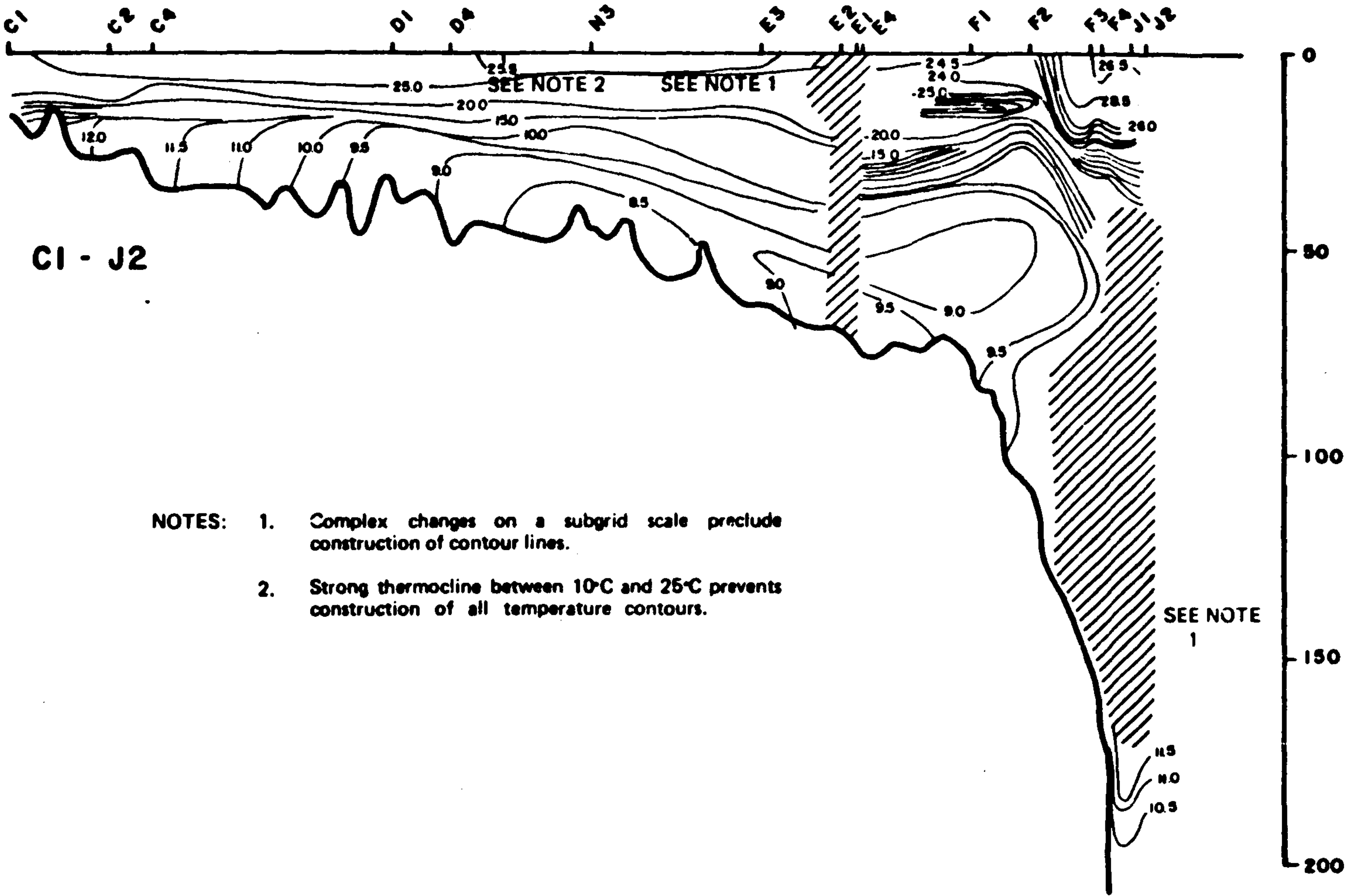


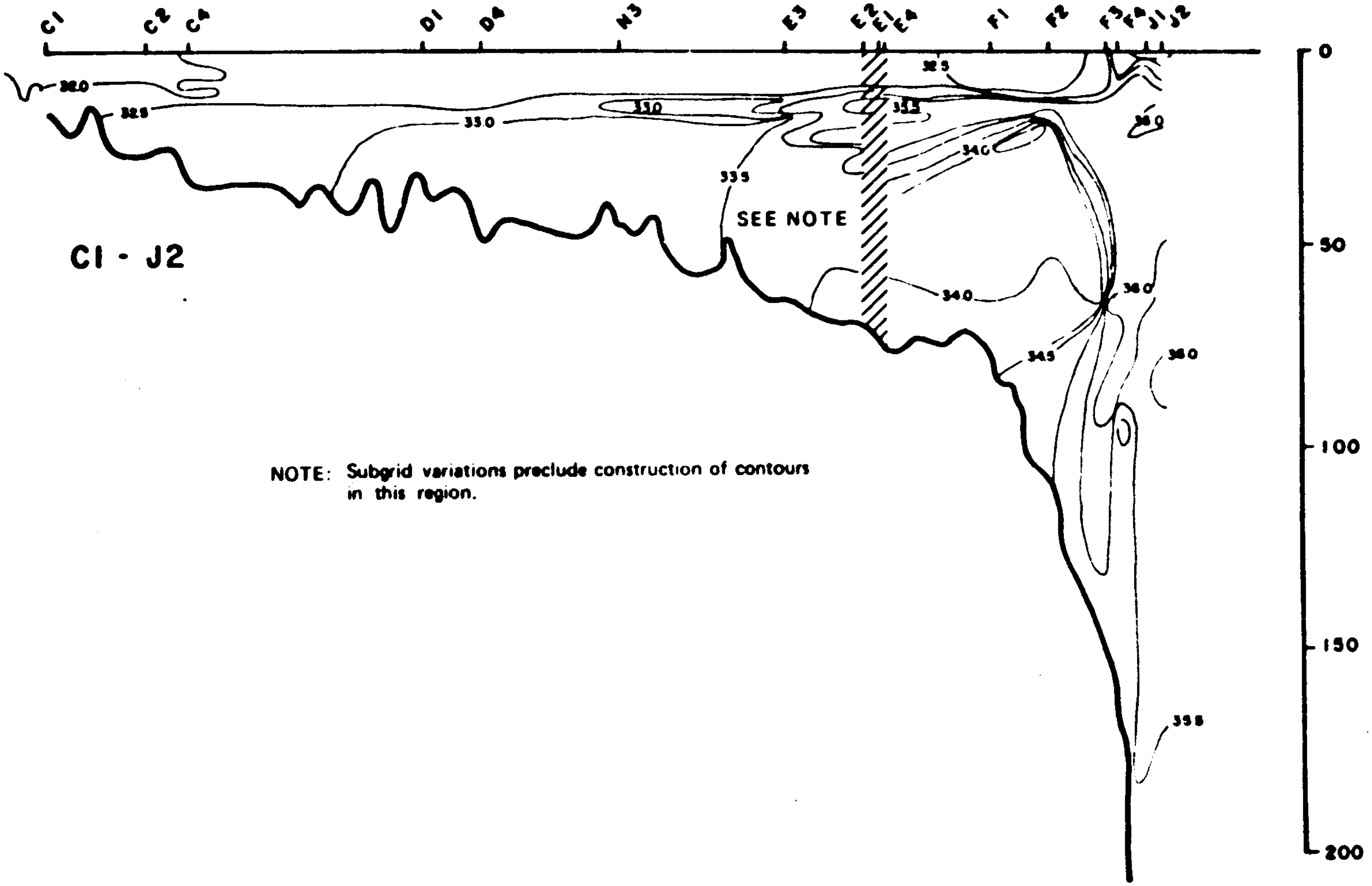
Figure 3-72d. Density (sigma-t units) contours for section II (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES: 1. Complex changes on a subgrid scale preclude construction of contour lines.

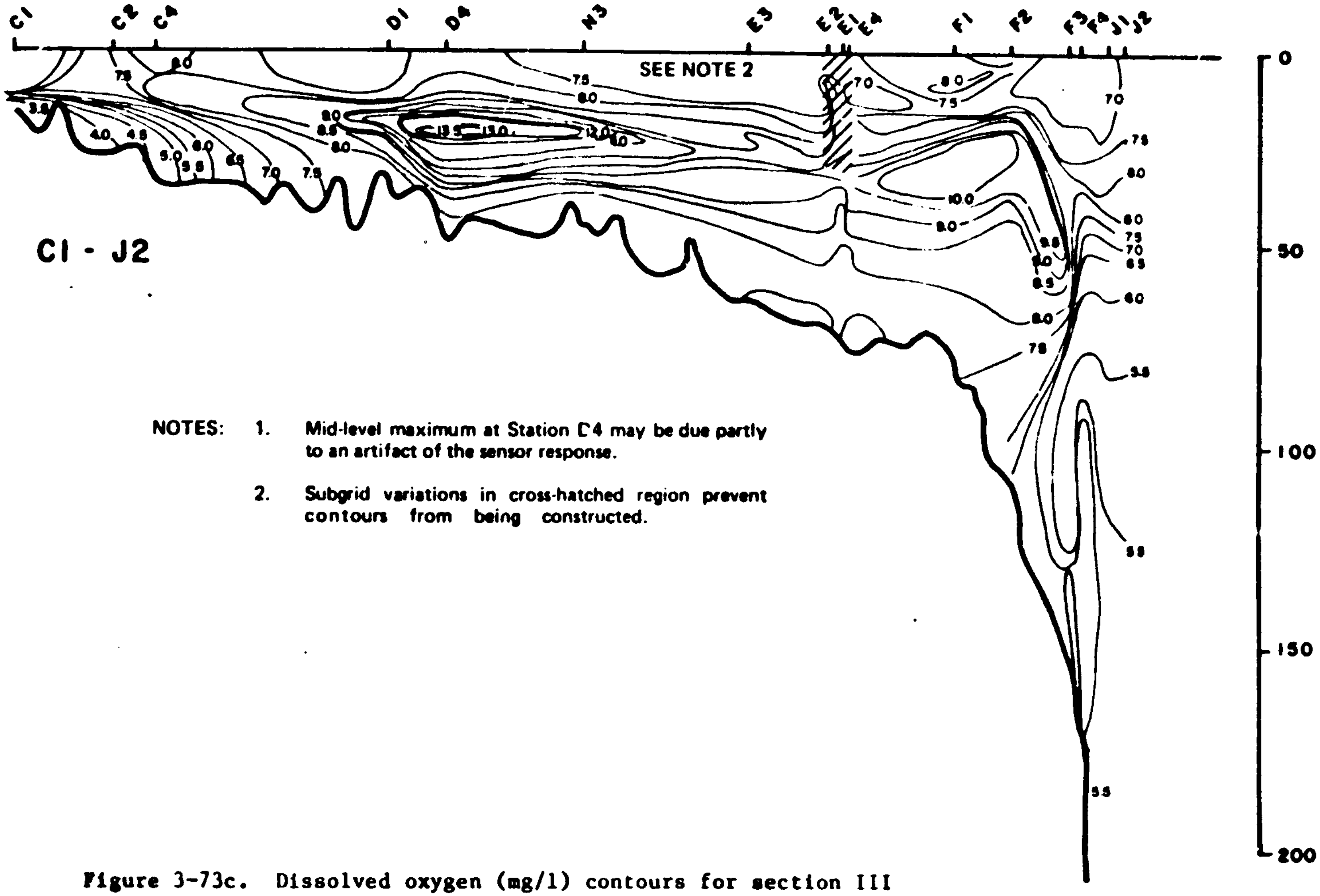
2. Strong thermocline between 10°C and 25°C prevents construction of all temperature contours.

Figure 3-73a. Temperature (°C) contours for section III (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Subgrid variations preclude construction of contours in this region.

Figure 3-73B. Salinity (ppt) contours for section III (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTES:
1. Mid-level maximum at Station D4 may be due partly to an artifact of the sensor response.
2. Subgrid variations in cross-hatched region prevent contours from being constructed.

Figure 3-73c. Dissolved oxygen (mg/l) contours for section III (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

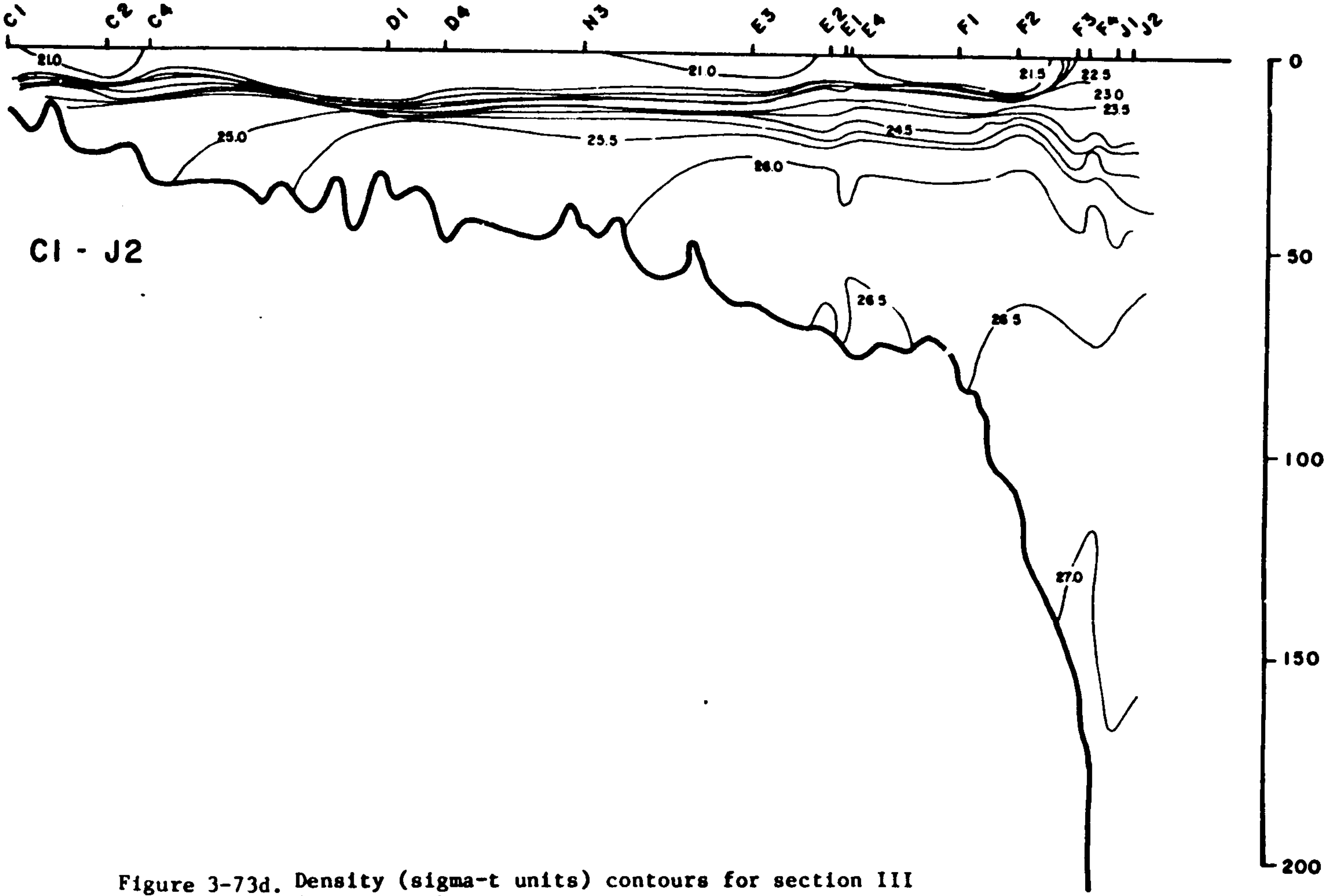


Figure 3-73d. Density (sigma-t units) contours for section III (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

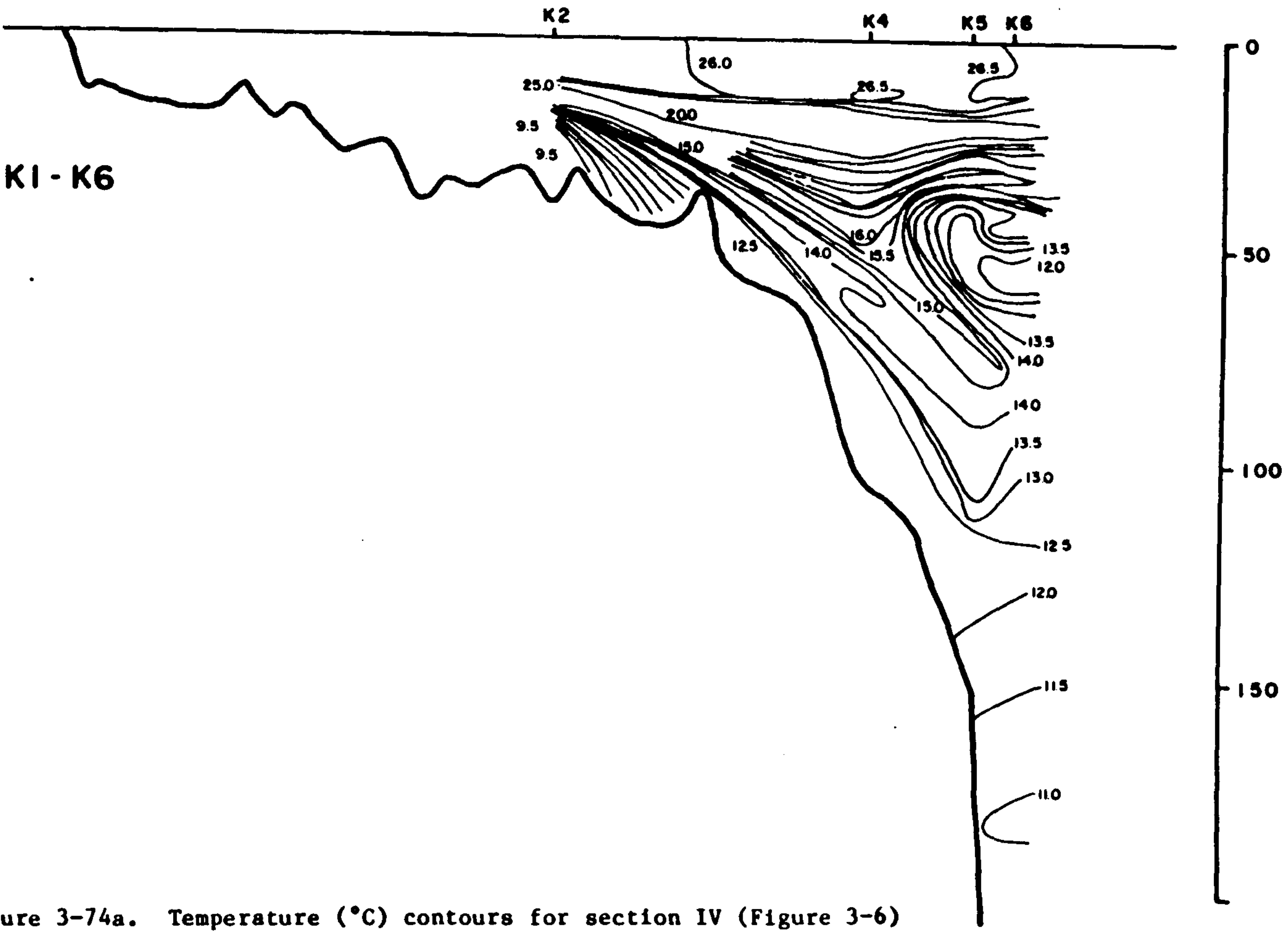


Figure 3-74a. Temperature (°C) contours for section IV (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

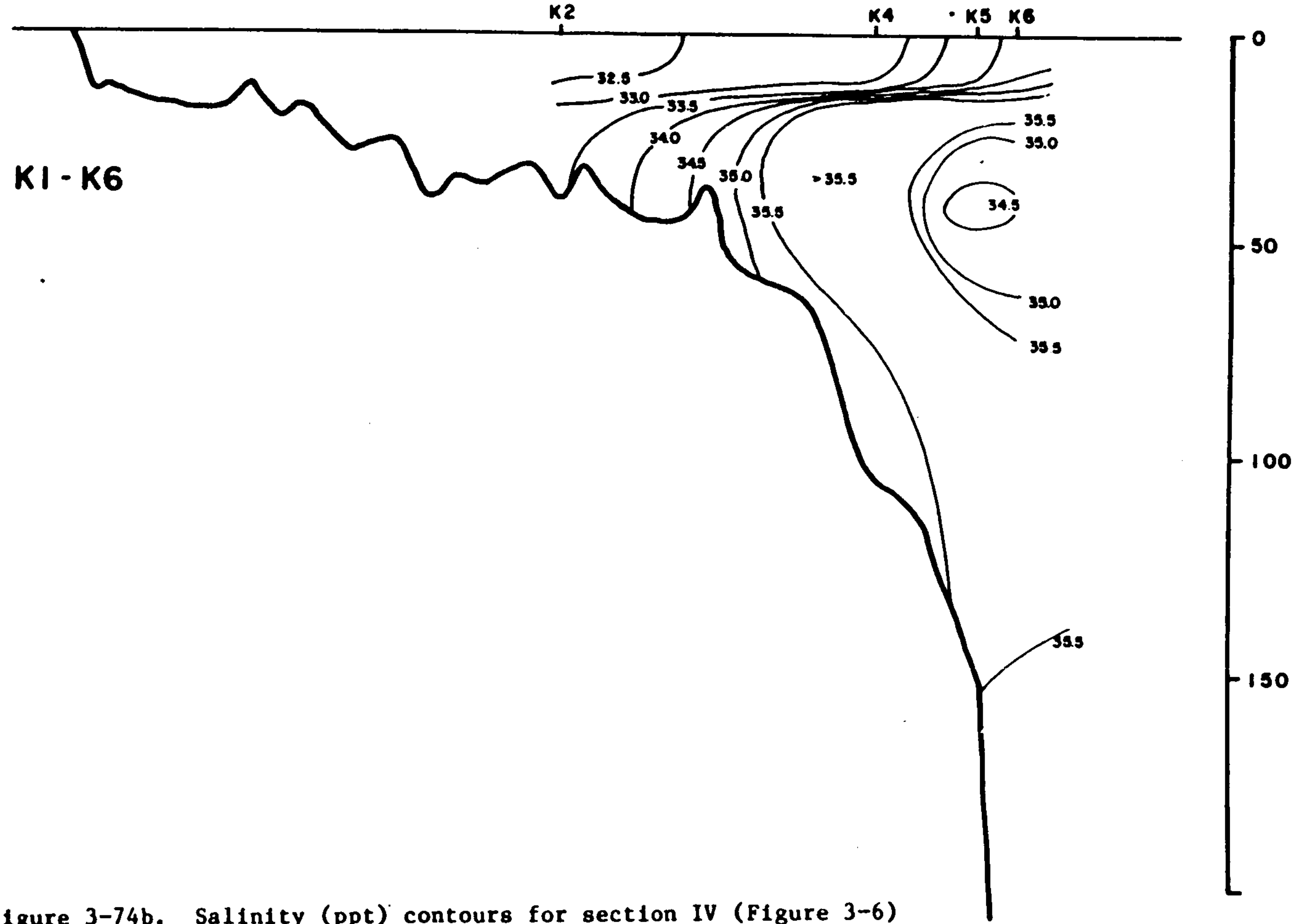
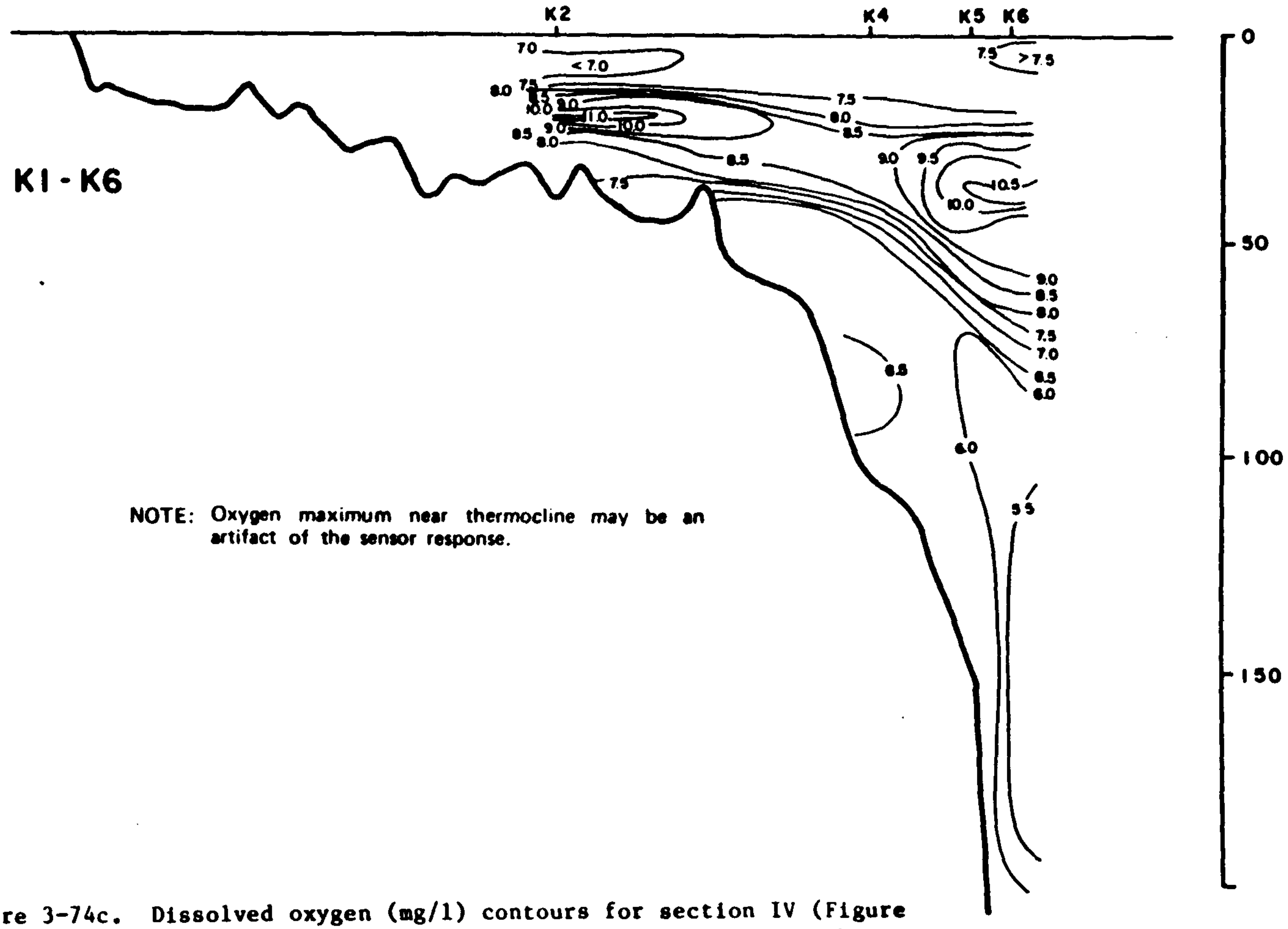


Figure 3-74b. Salinity (ppt) contours for section IV (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.



NOTE: Oxygen maximum near thermocline may be an artifact of the sensor response.

Figure 3-74c. Dissolved oxygen (mg/l) contours for section IV (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

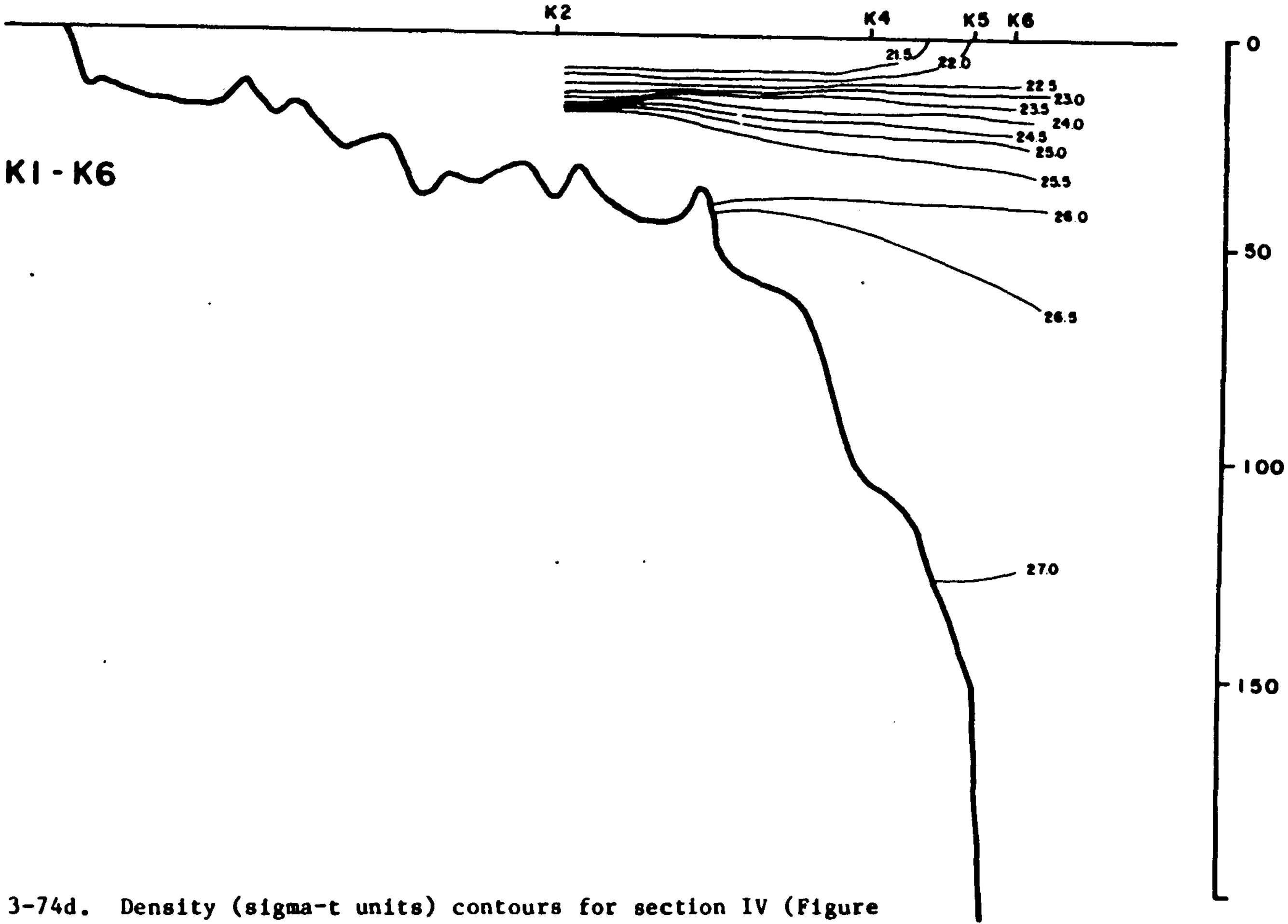


Figure 3-74d. Density (sigma-t units) contours for section IV (Figure 3-6) during cruise BLM08B. Station locations on the section and designations are indicated at the top of the section. Depths are in meters.

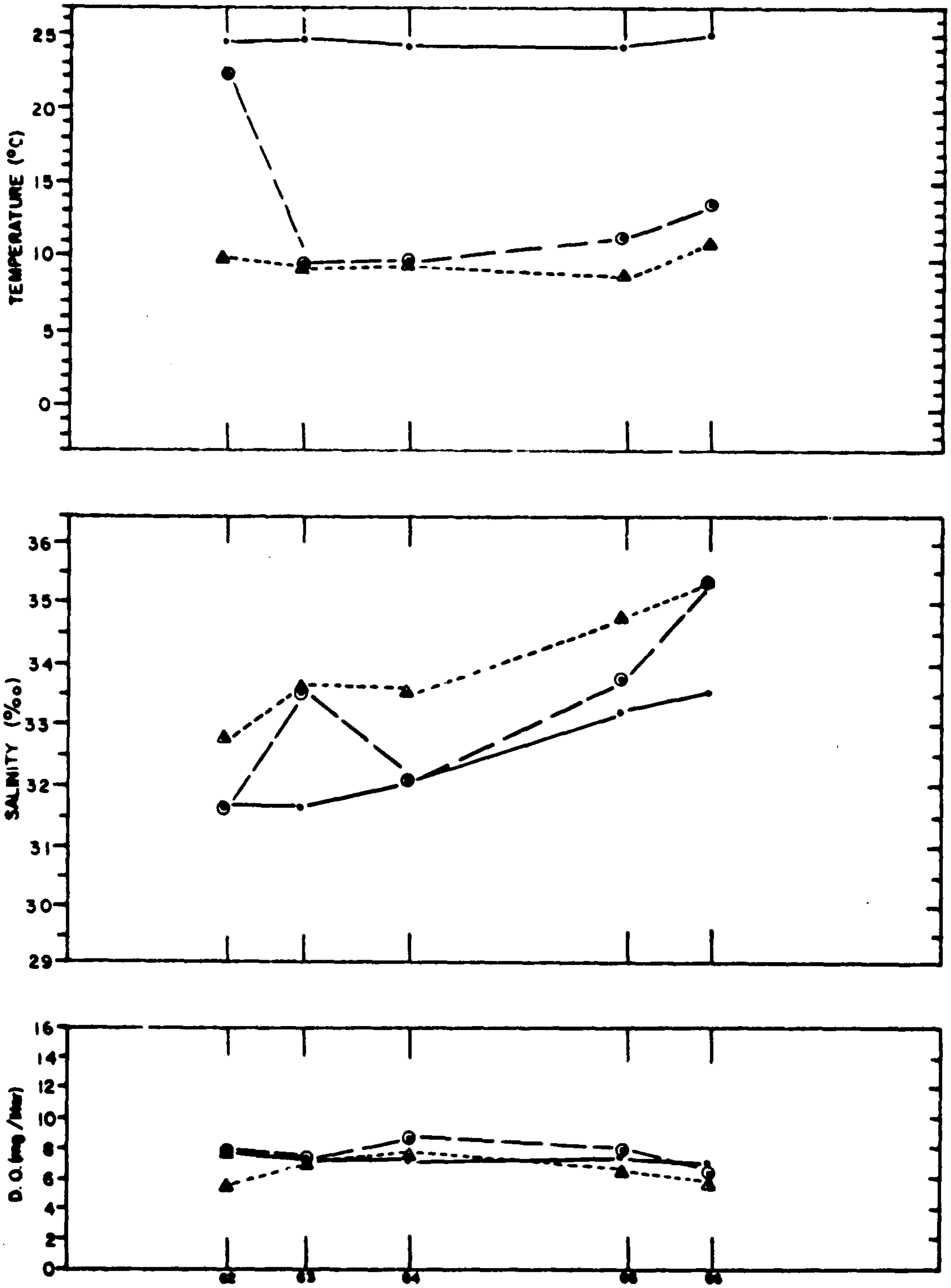


Figure 3-75. Surface (•), mid-depth (θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section I (Figure 3-6) during cruise BLM08B.

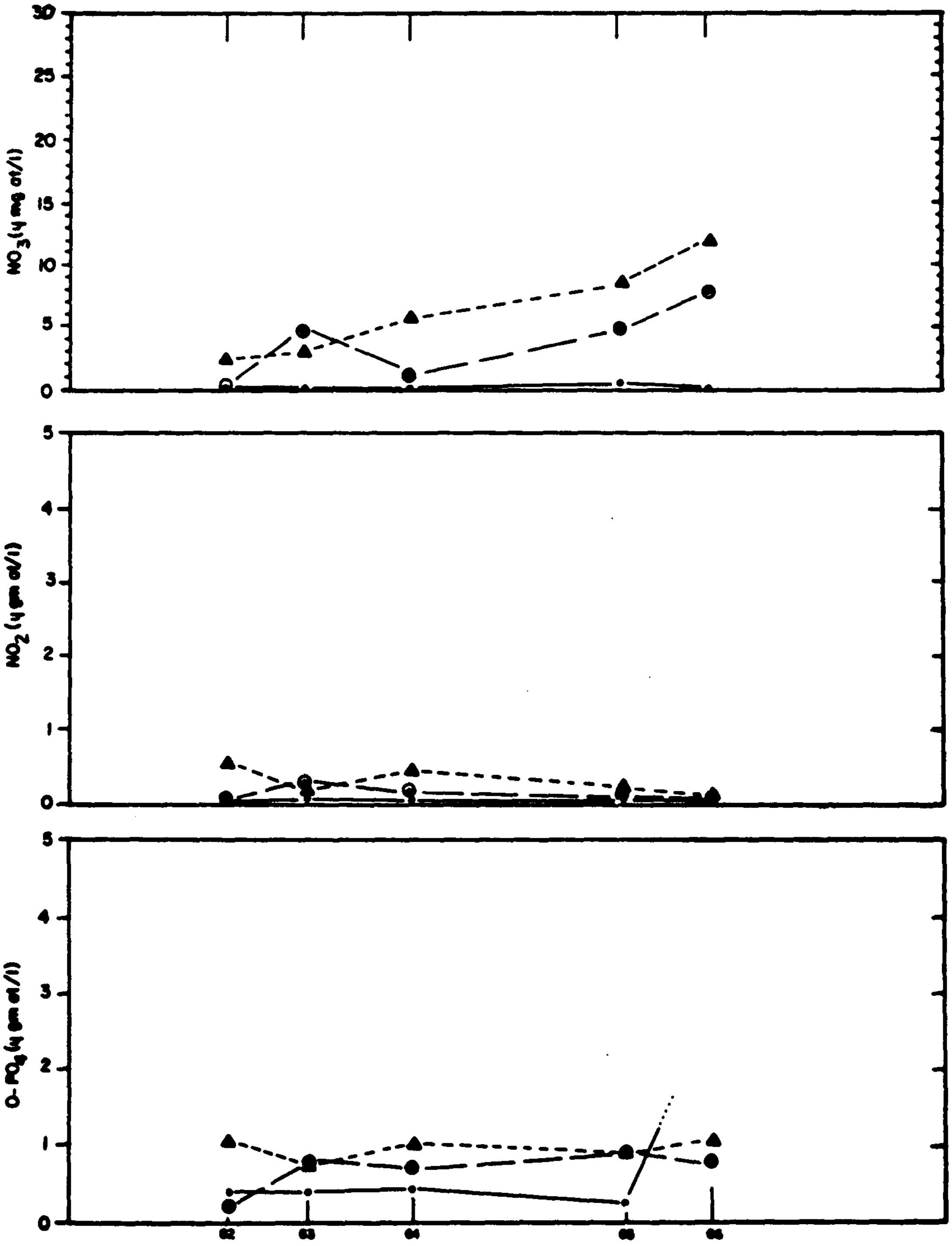


Figure 3-76. Surface (•), mid-depth (θ), and bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section I (Figure 3-6) during cruise BLM08B.

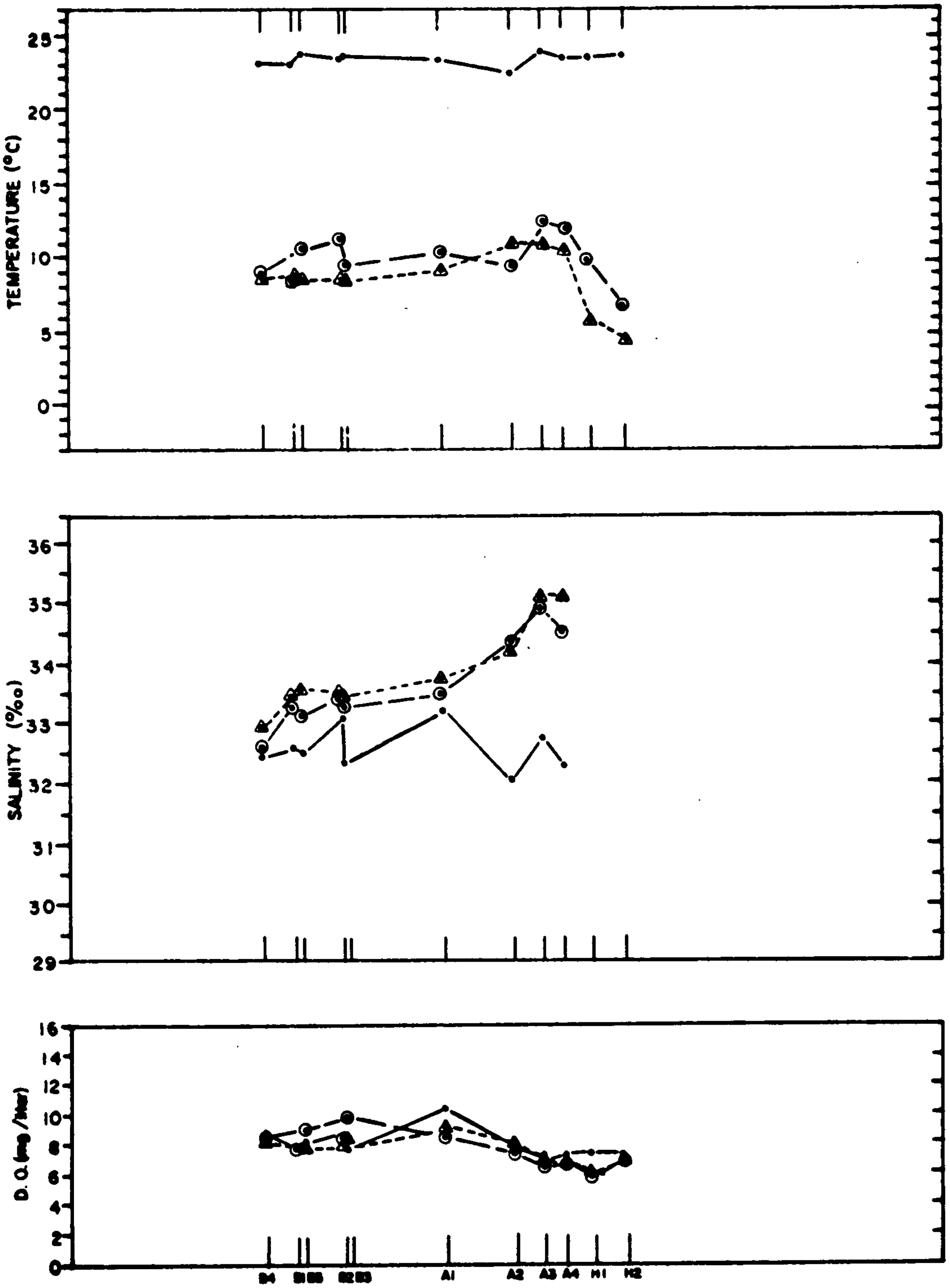


Figure 3-77. Surface (·), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM08B.

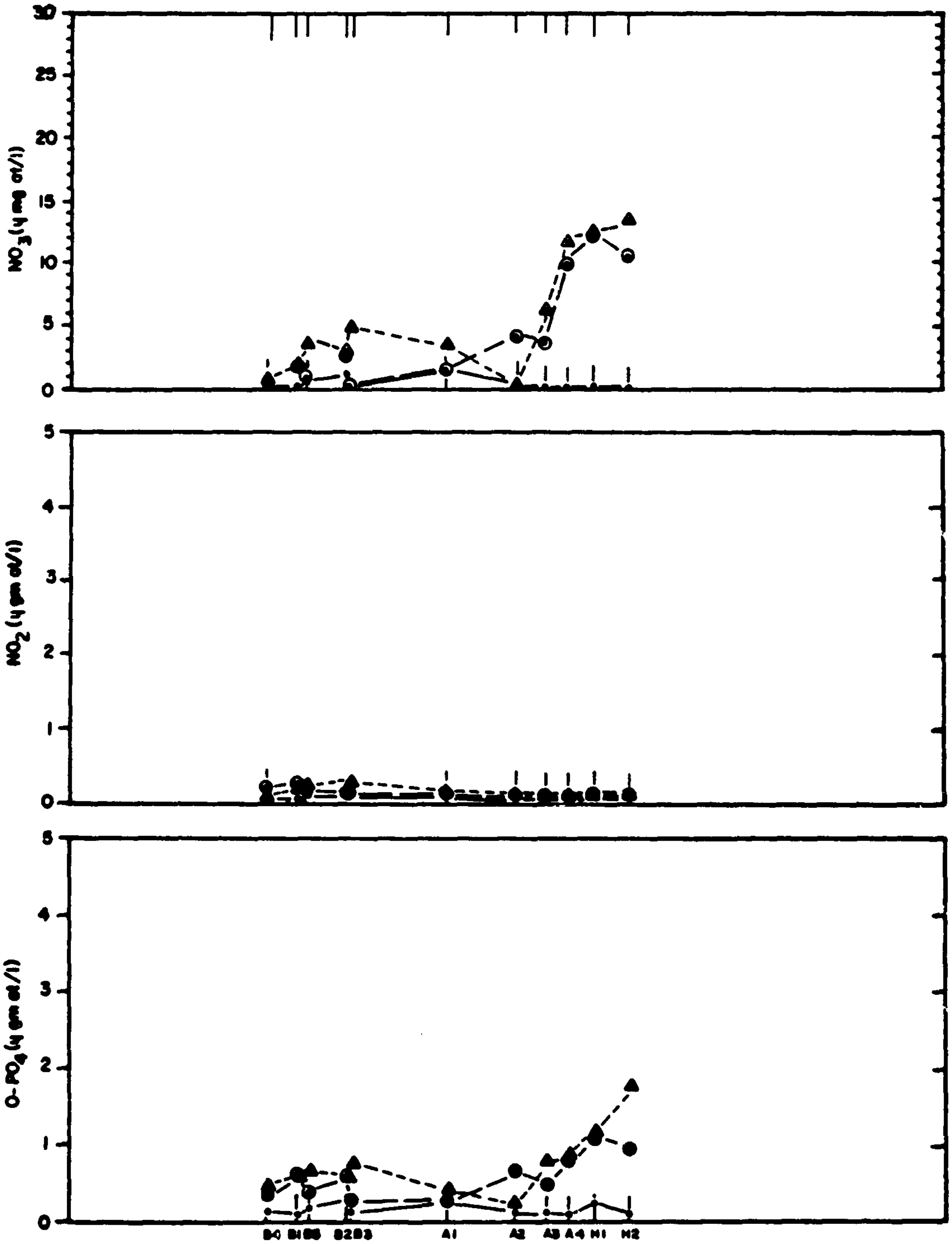


Figure 3-78. Surface (·), mid-depth (θ), and bottom (▲) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM08B.

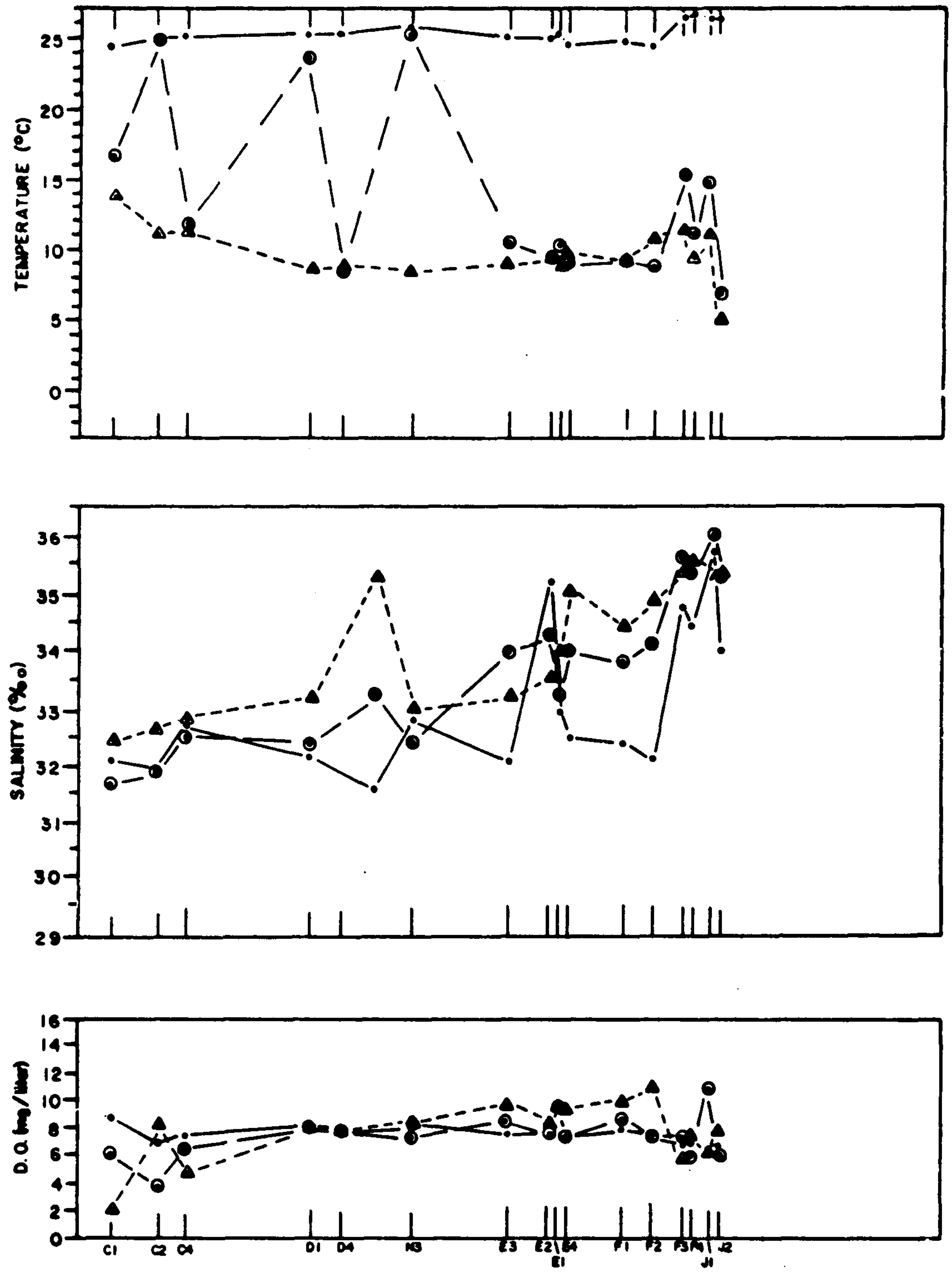


Figure 3-79. Surface (•), mid-depth (Θ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM08B.

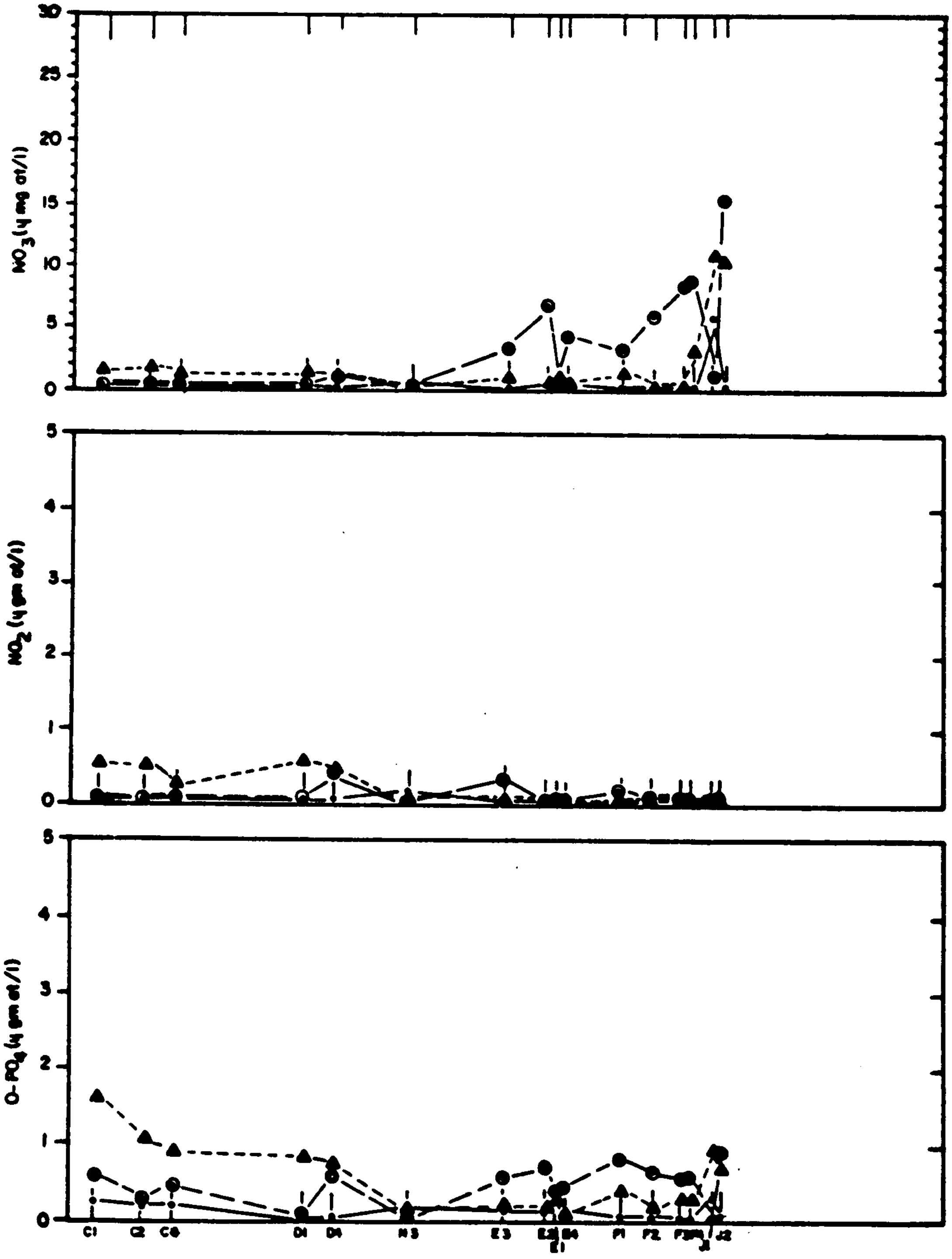


Figure 3-80. Surface (•), mid-depth (θ), and bottom (A) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM08B.

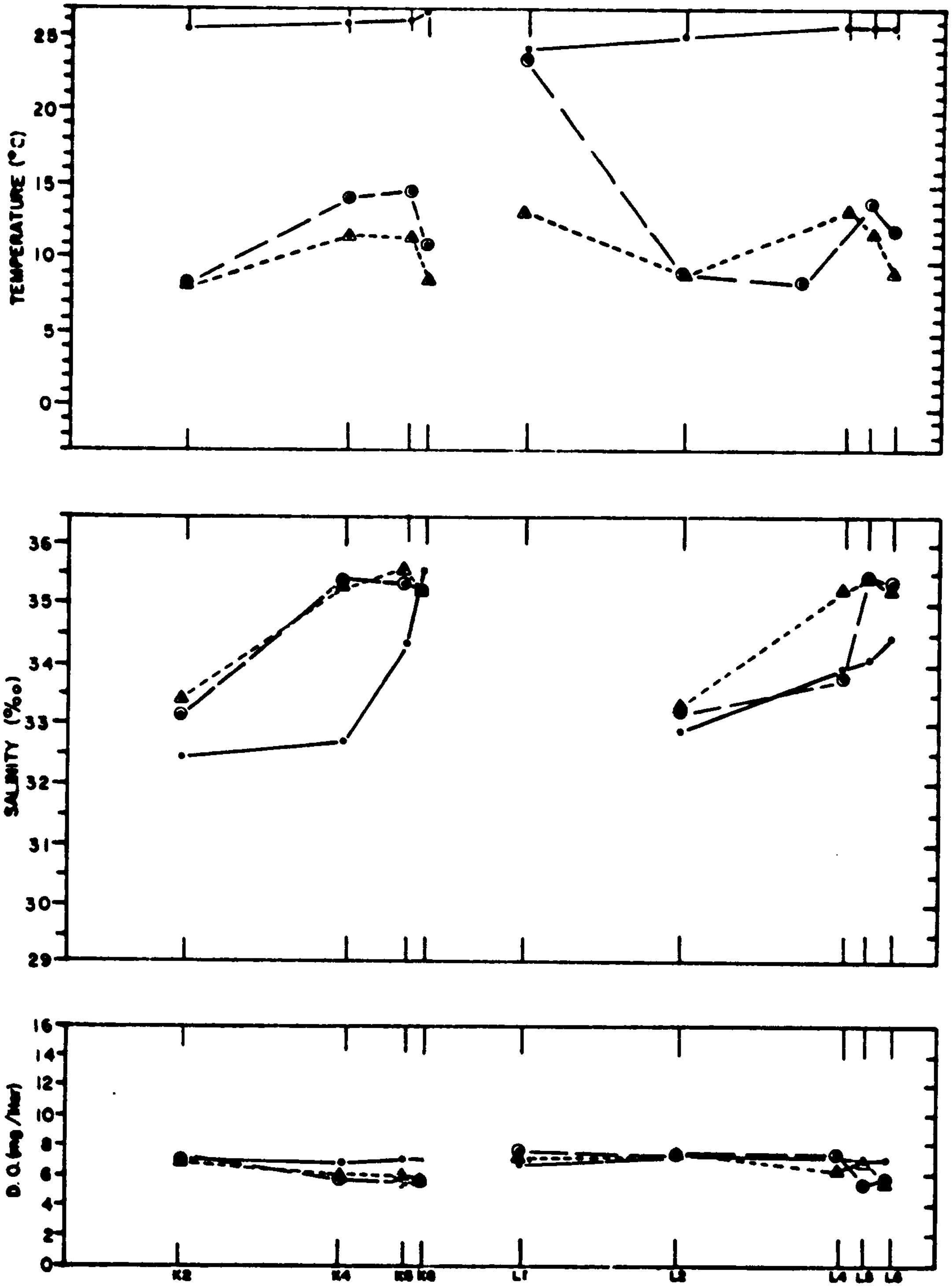


Figure 3-81. Surface (·), mid-depth (θ), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along sections IV and V (Figure 3-6) during cruise BLM08B.

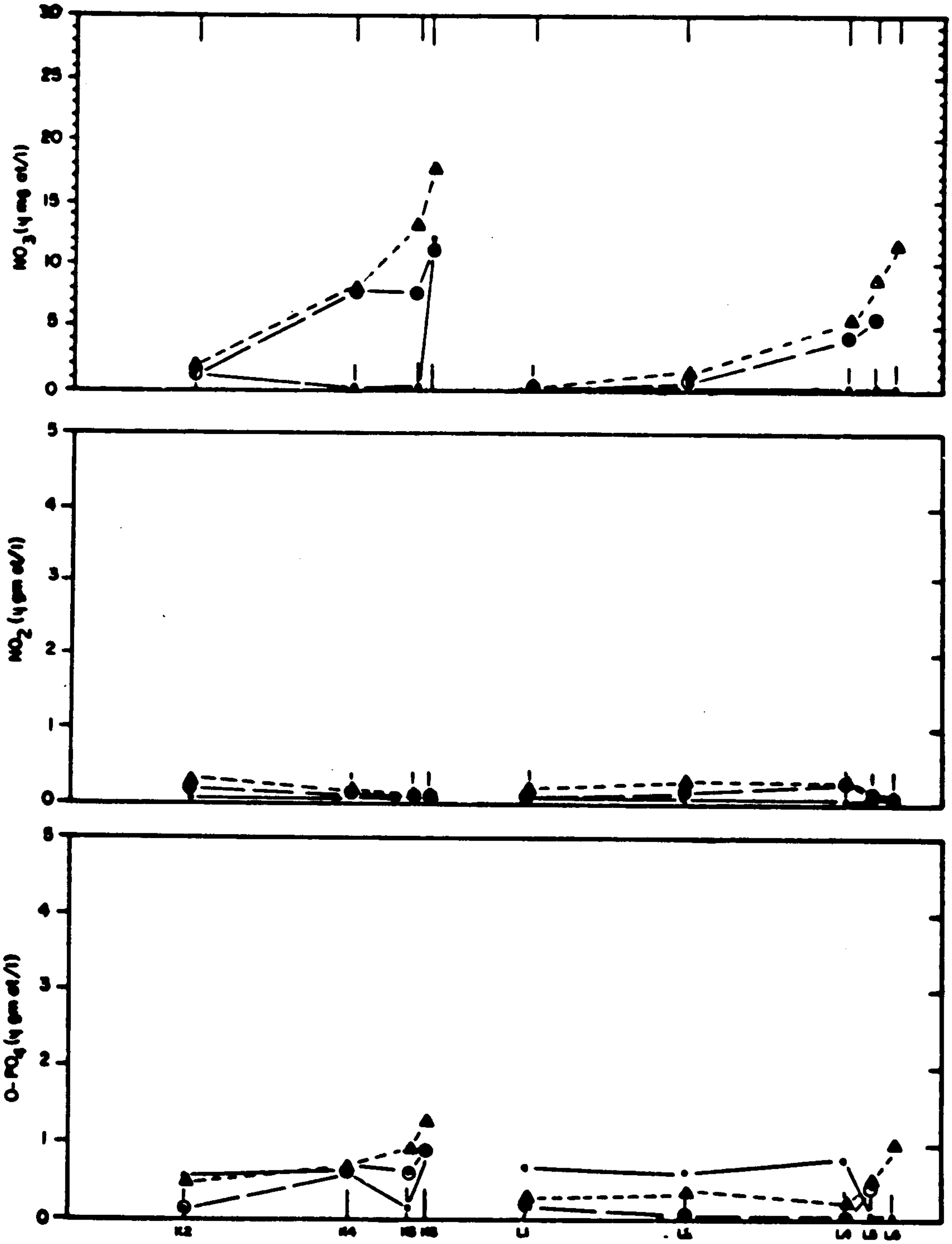


Figure 3-82. Surface (•), mid-depth (θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along sections IV and V (Figure 3-6) during cruise BLM08B.

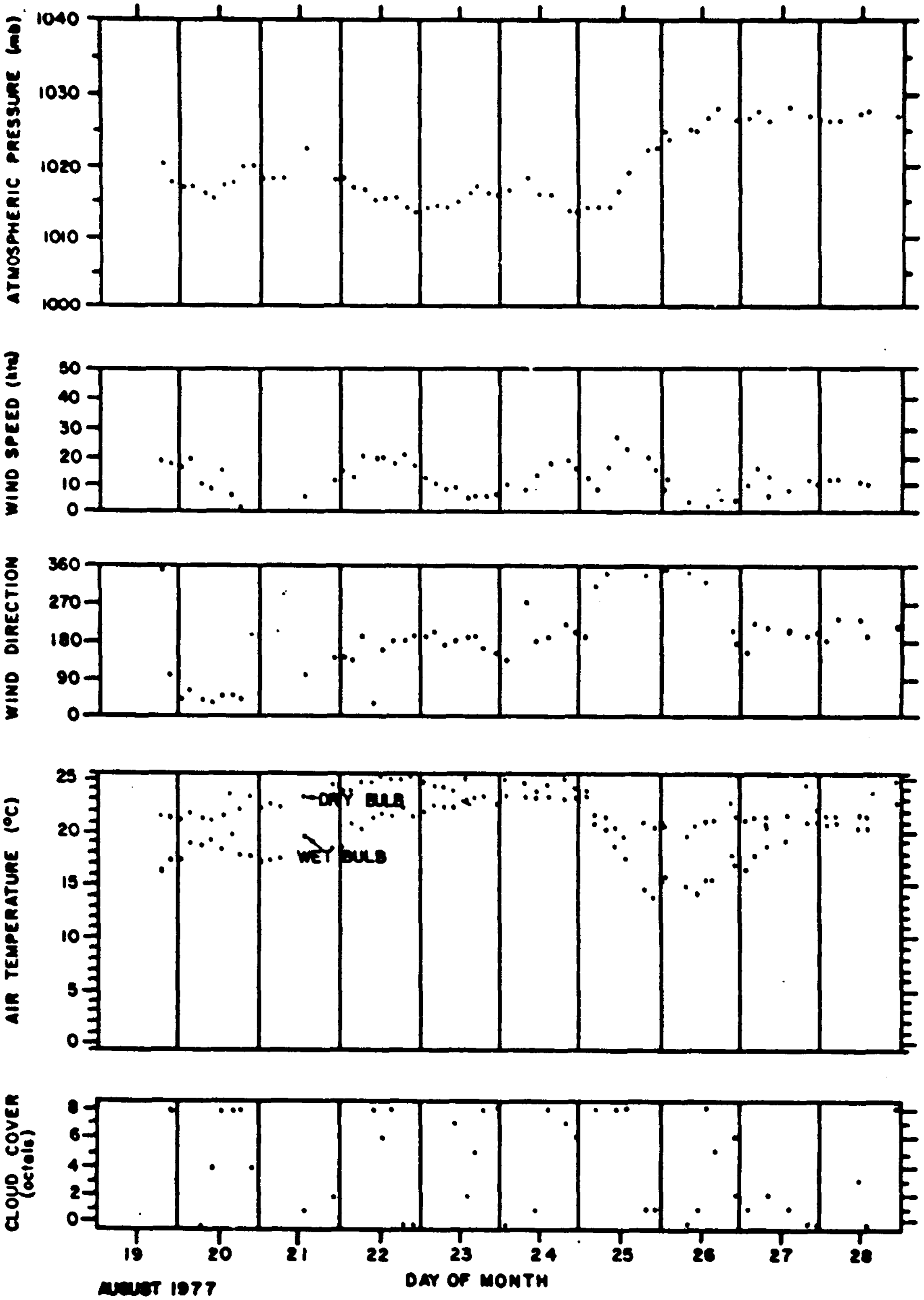


Figure 3-83a. Meteorological data collected during cruise BLM08W from 18-28 August 1977.

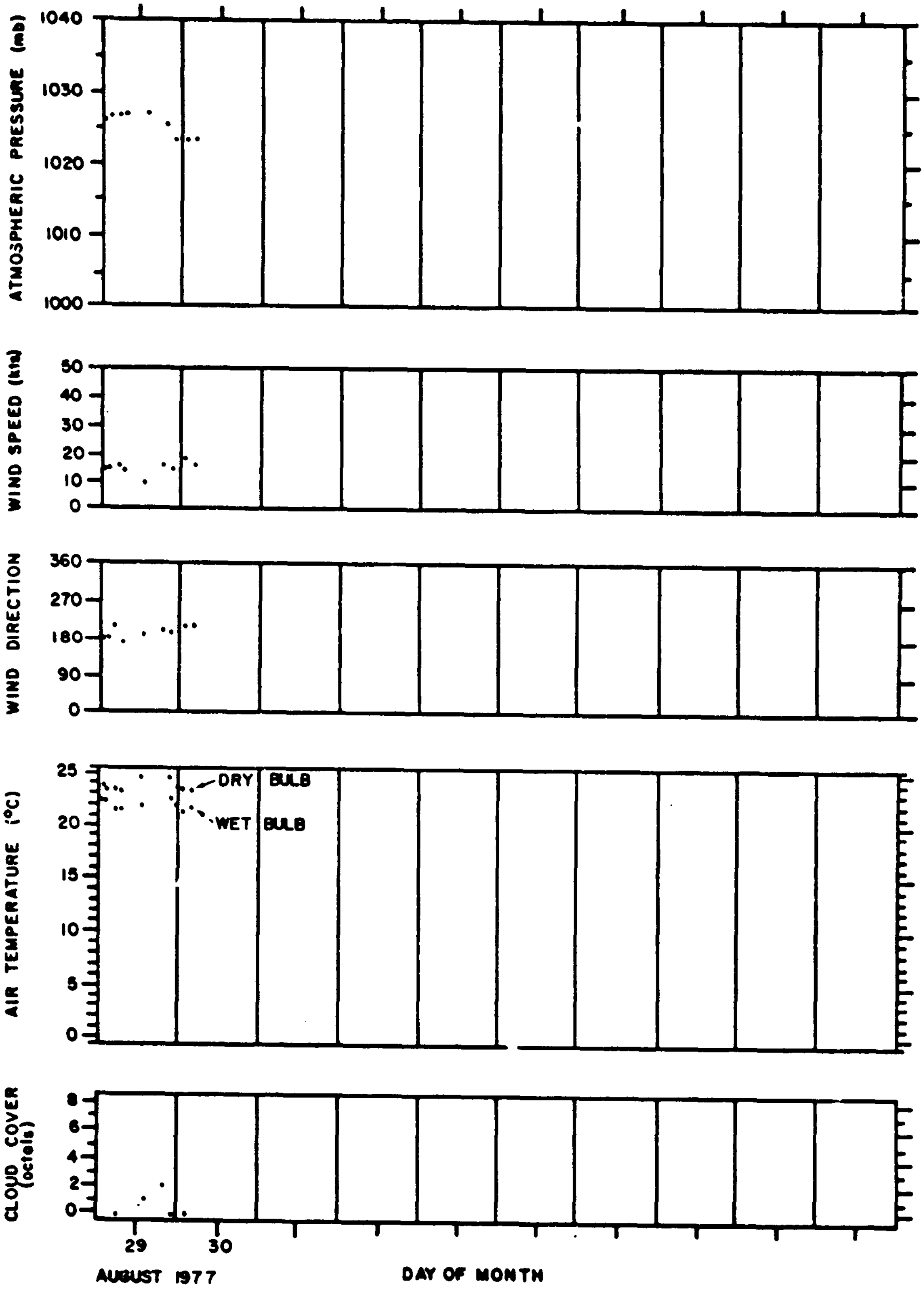


Figure 3-83b. Meteorological data collected during cruise BLM08W from 29-30 August 1977.

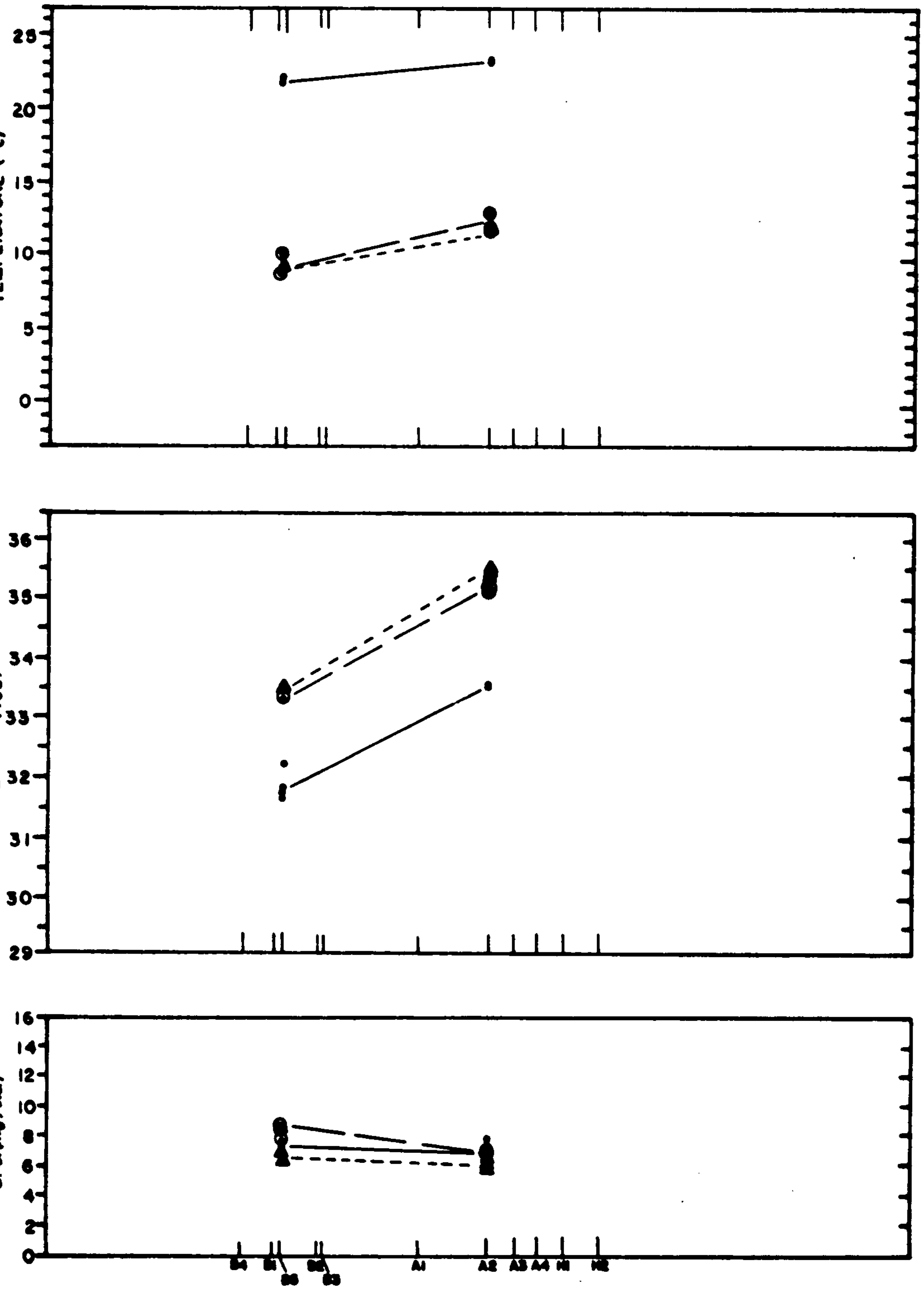


Figure 3-84. Surface (•), mid-depth (θ), and bottom (▲) values of temperature, salinity and dissolved oxygen measured along section II (Figure 3-6) during cruise BLM08W.

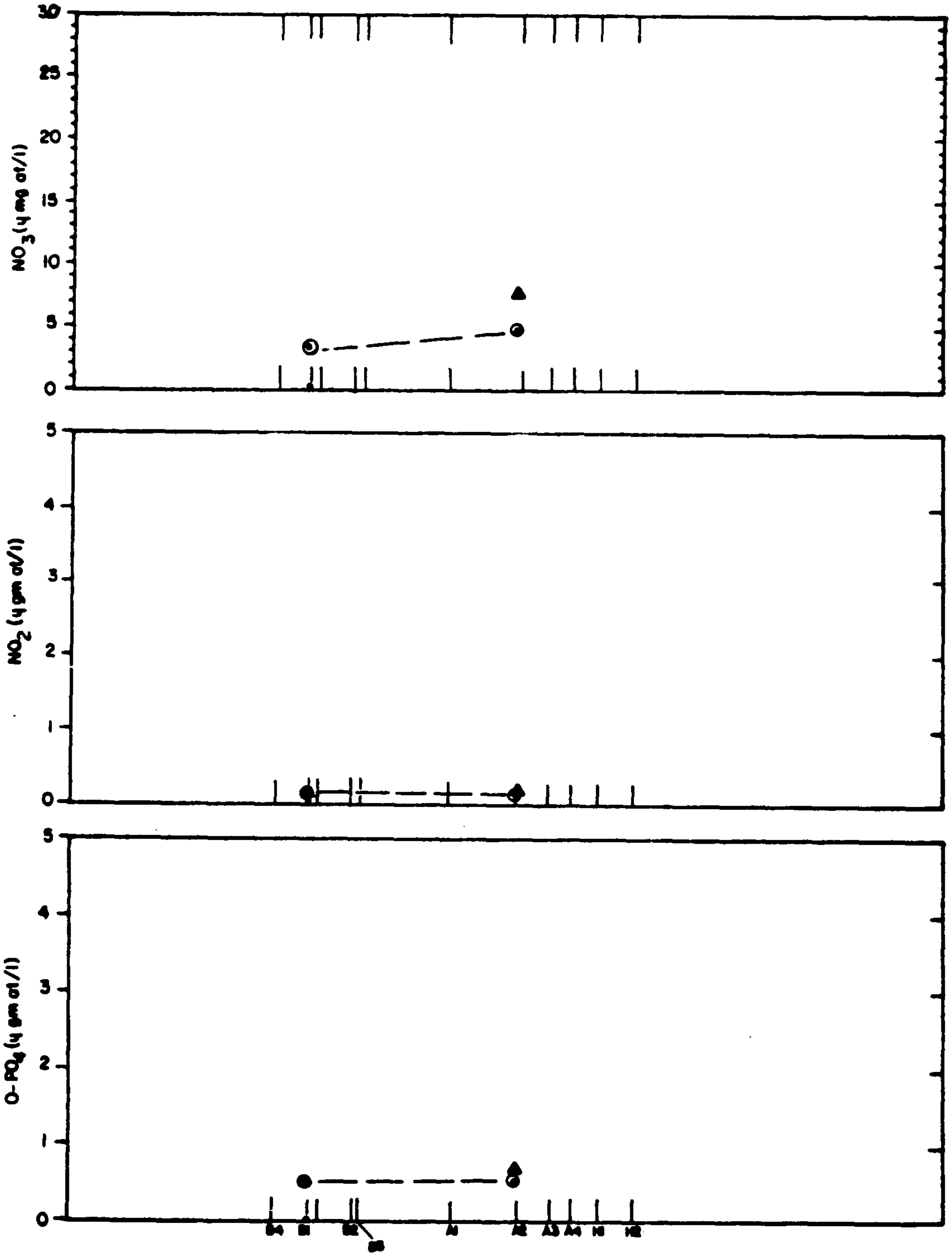


Figure 3-85. Surface (·), mid-depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section II (Figure 3-6) during cruise BLM08W.

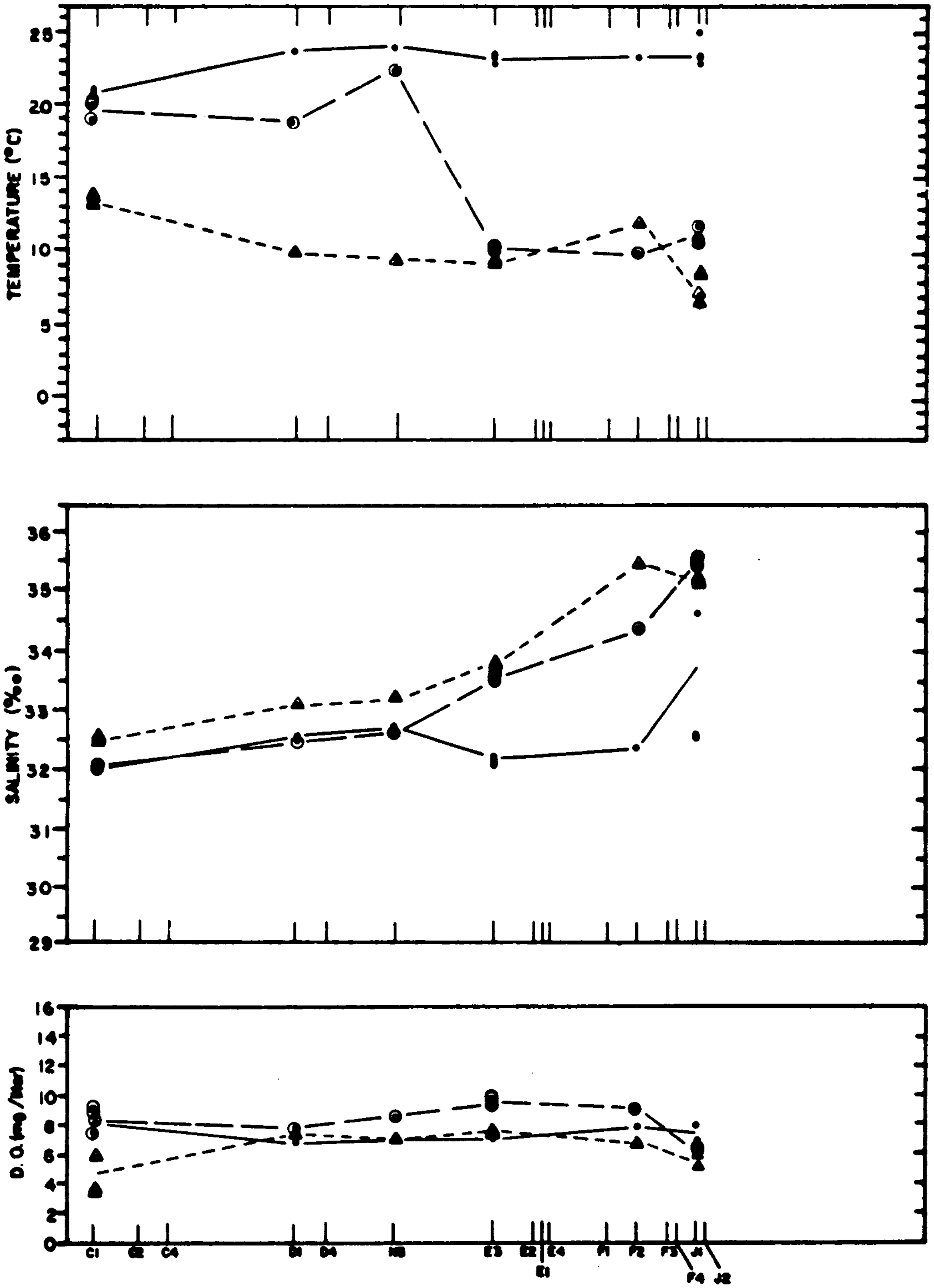


Figure 3-86. Surface (•), mid-depth (⊖), and bottom (▲) values of temperature, salinity, and dissolved oxygen measured along section III (Figure 3-6) during cruise BLM08W.

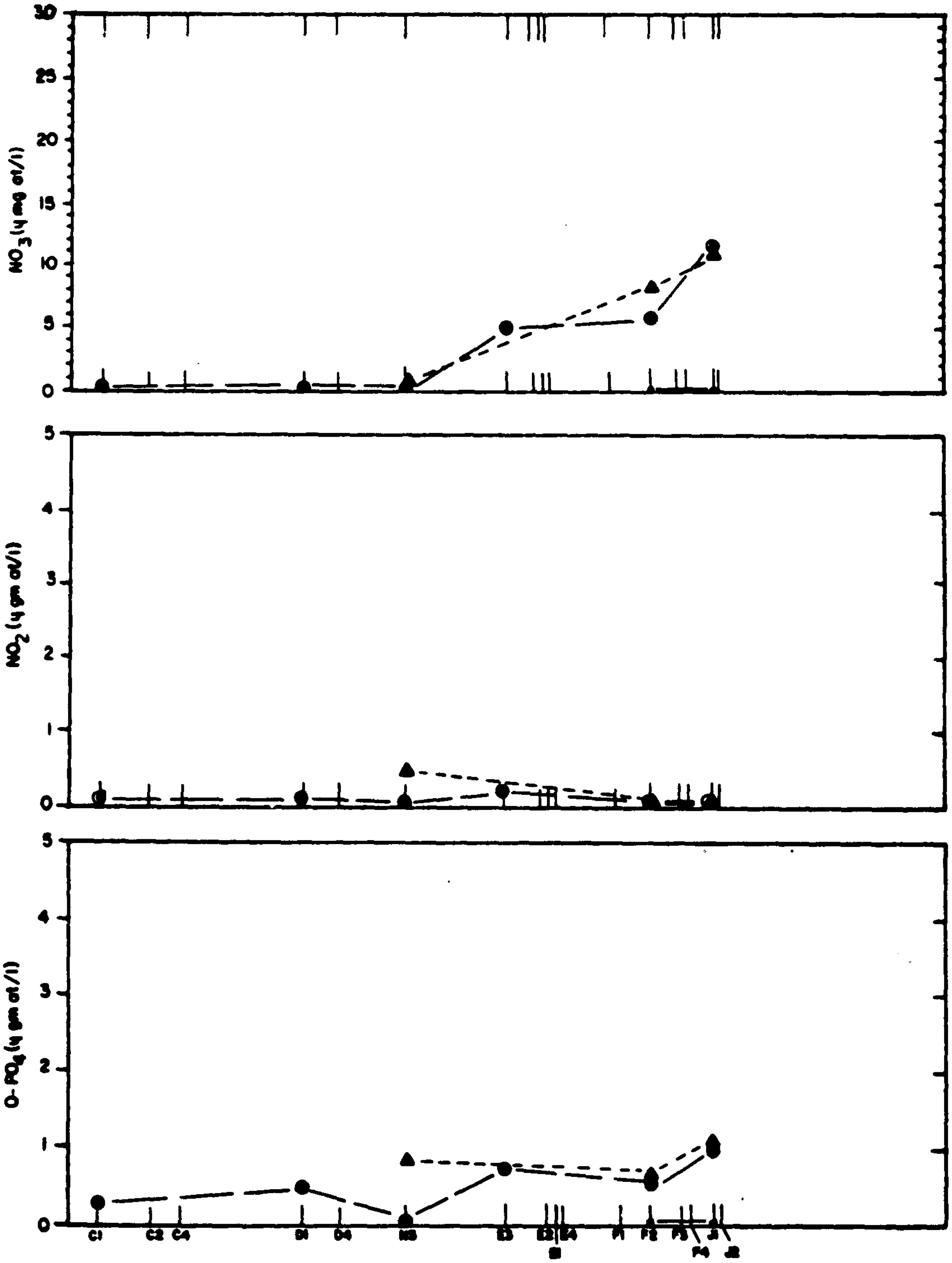


Figure 3-87. Surface (·), mid-depth (Θ), and bottom (Δ) values of nitrate, nitrite, and ortho-phosphate measured along section III (Figure 3-6) during cruise BLM08W.

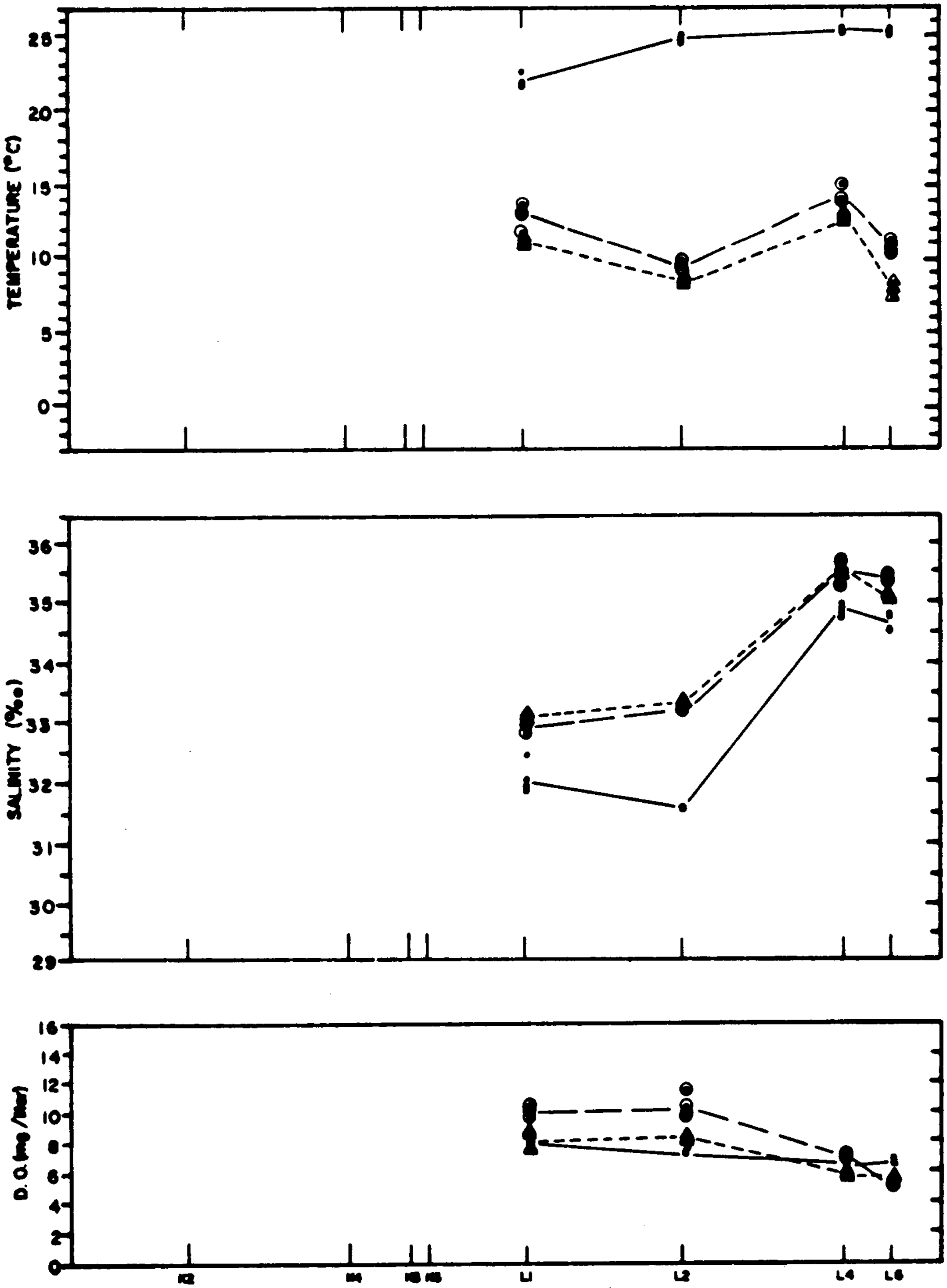


Figure 3-88. Surface (•), mid-depth (ϴ), and bottom (Δ) values of temperature, salinity, and dissolved oxygen measured along section V (Figure 3-6) during cruise BLM08W.

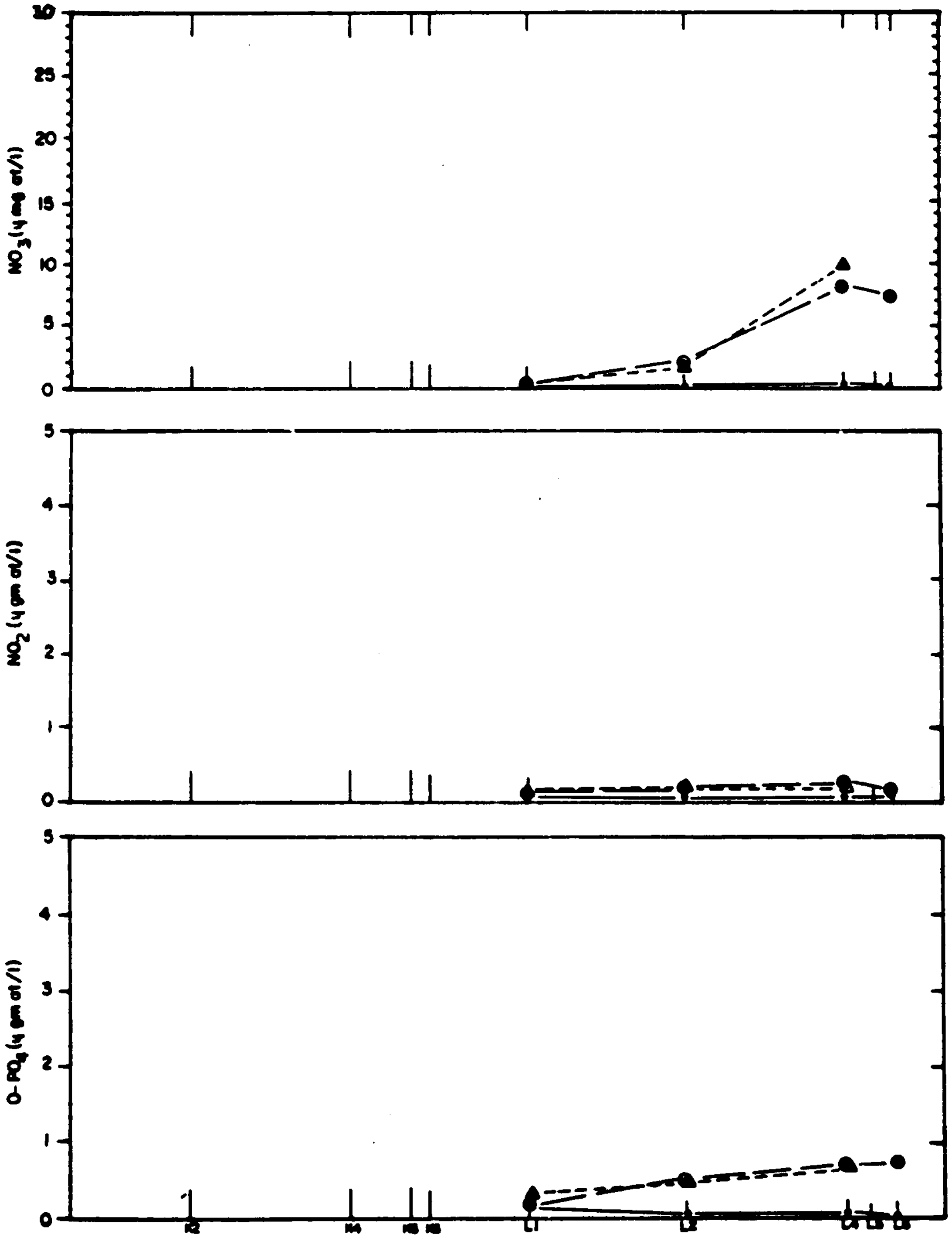


Figure 3-89. Surface (·), mid-depth (Θ), and bottom (Δ) values of dissolved nitrate, nitrite, and ortho-phosphate measured along section V (Figure 3-6) during cruise BLM08W.

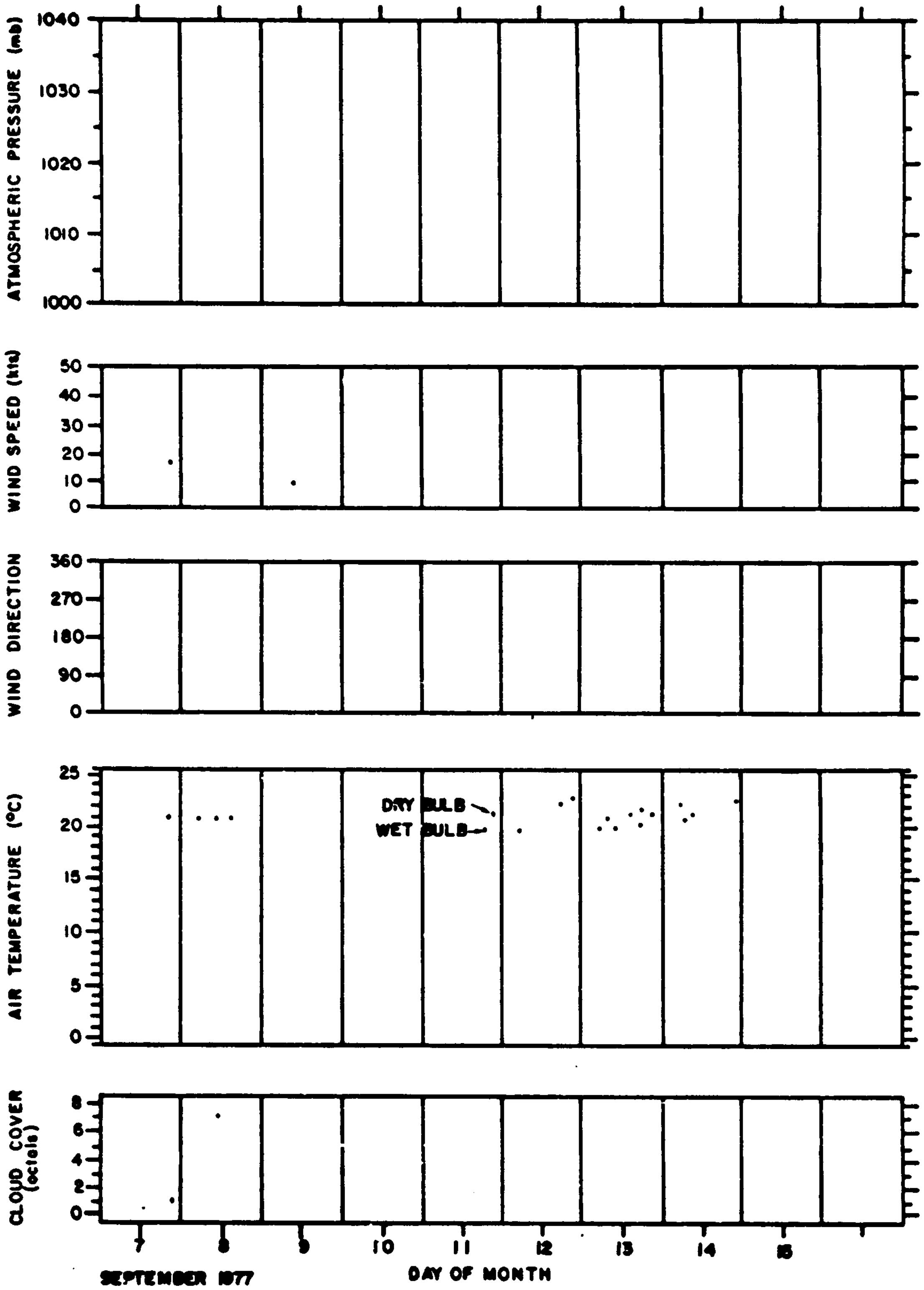


Figure 3-90. Meteorological data collected during cruise BLM08T from 7-14 September 1977.

DISCUSSION

Fall 1976

The plan views of temperature show a tongue of cold water at the surface and a corresponding band of warm water at the bottom, apparently moving into the study region from the north along the shelf. The temperature of the surface cold core was 11.3°C in mid-November. A similar surface core was apparent in the 1975 fall cruise for early November with temperatures of 14.5°C (Ruzecki et al. 1977). The warmth of the bottom layer appears, from the sections, to be associated with a mid-level intrusion of water from offshore. The 1976 section II shows cold water overlying warm water while the 1975 section II shows the opposite basic temperature stratification, warm over cold. Despite this destabilizing temperature gradient, the corresponding salinity gradient beneath the surface core was enough greater that the 1976 section II had 50% more density stratification than the one in 1975.

The "cold pool" phenomenon has attracted enough interest that its absence during this cruise is worth noting. In the first year (1975) report, the cold pool during fall was apparent in Figure 3-18 as a core of water of low temperature (<10.5°C) extending northward across the study region between the 50–100 m isobaths. During fall 1976, the same region was occupied by a "warm pool", a core of warm water extending southward from the north. In fact, a "cold pool" feature was not seen in any part of this cruise, which is a distinct contrast to the previous year.

The southern section (section V) was not sampled during the first year. In the second year, the temperature section shows the features of a relatively calm period during fall cooling. Cooler water inshore was evidence of winter conditions, although temperatures well above 12°C throughout the sections indicate that little cooling of the entire water column had yet occurred. The isotherms are rounded and evenly spaced, indicating that a near equilibrium had been achieved across the shelf. The small destabilizing vertical temperature gradient was slightly over-balanced by the salinity gradient to produce a marginally stable density gradient with very little horizontal variations, 1.5 sigma-t units across the entire shelf. These conditions are what would be expected after a period of relatively calm weather. The 5 day period preceding this section was marked by air temperatures above 9°C and winds under 20 knots (10 mps), unusual for the season in general.

The main transect (section III) was occupied during a more active time, as shown by the general vertical homogeneity of the inshore stations. The inshore parts of the study region were being rapidly cooled enough during the period, 5 November to 7 November 1976. The entire transect III shows evidence of rapid change and small scale along-shelf variations of properties. The most severe sign of these features was at the E stations, during which a two day break occurred in the sampling during cruise 05B. The property contours could not be represented here due to small scale variability, and the contours in and off-shore of these stations were best constructed as independent data sets, due to the change in the water properties which occurred during the intervening period.

The other measured variables, dissolved oxygen and nutrients, reflect transports which are consistent with the interpretations based on temperature and salinity alone. Surface nutrients (nitrite, nitrate, and ortho-phosphate) were at minimum in the vicinity of the apparent intrusion of cold, fresh surface water. Corresponding bottom values give an ambiguous pattern subject to several different interpretations. An exception is values of nitrate on the bottom which, along with nitrite, showed a coastal minimum and a great increase offshore of the 100 m contour. This increase and a single sample value at Station B5 indicate that the water forming the "warm pool" of this cruise had an offshore source. This interpretation is consistent with the indications of tongues in the cross-shelf temperature section II plot.

Winter 1977

The winter of 1976-77 was, in general, one of the coldest and most severe on record for the continental shelf environment. It provides a sharp contrast with the winter of 1975-76, which was marked by the extremely warm February with strong southerly winds. Signs of the severity of the winter of 1976-77 were an early snow, record breaking amounts of ice with attendant damage to coastal port facilities, and the near closing of Chesapeake Bay because of the sea ice. The severity of the winter was indicated in the cruise 06B data on transect III, which had subzero water temperatures near the coast. Two further indications of the severity of the winter were experienced during operations. The fresh water in the keel coolers of one of our vessels froze during a brief stop for a crew change and resupply in Atlantic City, New Jersey. During the subsequent June cruise, coastal water near the shelf edge was identified by rafts of marsh grass and ice-pulled pilings, which were still floating in it from the previous winter.

The winter cruise during the second year (cruise 06) consisted of two benthic legs with the water column cruise scheduled between them. The entire cruise spanned the period from 5 February to 13 March 1977, with the trawl cruise added between 19 March and 27 March. This period was marked by the passage of about eight winter storm systems and winds were predominantly northerly throughout February and the first week of March. Because of the separation into two sampling periods, the data from the benthic cruise are presented, in some cases, as two sets of partial data. In general, the physical data indicate that the study area was influenced by severe wintertime conditions during this period.

This influence is well illustrated by the generally vertical orientation of the isotherms in sections II, III, and V. The isotherm surfaces were also oriented distinctly parallel to the edge of the shelf, the coldest temperatures were found at the inshore stations where the width of the shelf is greatest within the study region. In contrast to the temperature structure, the density structure was relatively featureless. The highest densities were associated with fairly high salinities towards the inshore region of the southern transect (transect IV). This pool of high density water ($\sigma_t > 27.5$) occupied the inshore half of transect IV to the south, the middle part of transect III off Atlantic City, New Jersey, and a small portion of the midshelf region of transect II, the same relatively flat part which seems to be associated with other hydrographic cores. It was not at all present in the northern sections, which crosses the Hudson Shelf Valley. Also of note is that the temperature field became increasingly more complex in the northern sections. Its complexity reached the point that much of the temperature field could not be contoured in section II. Section I was sampled largely during the second leg of the benthic cruise, so its lack of consistency with the pattern of the other sections may reflect differences in time rather than in space.

Compared with the previous year, the temperatures along the inshore part of the study area were 4°C lower in 1977, although the temperatures at the shelf break were perhaps only one degree colder. The corresponding salinities were about 3 ppt higher at the inshore parts of the sections during 1977 than 1976. With this difference in properties at the low temperature encountered, the importance of temperature in determining density compared to that of salinity was about one-third of its 1976 value in 1977. Thus, the wintertime shelf became much like an estuary with salinity being the prime density-determining variable and temperature becoming almost a passive marker. The special nature of the temperature field in section II, vertically homogeneous with horizontal structure on a subgrid scale in a basic field of horizontal stratification, indicates that advective processes may induce meso-scale two-dimensional displacements in the region where the contour lines are not drawn. This is the same region, where hydrographic cores are frequently observed.

The pattern of salinity structure in the 1977 winter is also of some interest. As already noted, salinity values during 1977 were several parts per thousand greater than those during 1976. This may well be due to the difference in runoff between the two years, 1976 having more than three times the winter runoff of 1977. It may also be an indication of substantial cross shelf mixing during the second year, as suggested by the small density contrast throughout the study region, almost half that of the first year survey. Another strong suggestion from the data is that the shelf mixing processes act sporadically in a manner to smooth out the density field and then cease.

The salinity structure to the south shows an intrusion of warm, high salinity water at the surface. Water in this region of T-S space is of ambiguous origin, being a mixture of slope water and Gulf Stream water in the winter and a mixture of slope and coastal water during the summer. The origin of this particular water seems to be associated with a tongue of modified Gulf Stream water extending north of Cape Hatteras along the shelf edge during the first half of February, 1977. This tongue, visible on the Naval Oceanographic Office Experimental Frontal Analysis, does not correspond to any described oceanographic phenomenon, so it may be a candidate for further study.

The oxygen and nutrient contours reflect the temperature and salinity data for the most part, indicating high oxygen and low nutrient values in the nearshore regions with a nearly cross-shelf gradient of parameters, oxygen decreasing and nutrients increasing. The dissolved oxygen values decrease for increasing temperature as would be the case if the entire study region were essentially saturated. The trend is altered slightly at the edge of the shelf where three patterns of ocean water intrusion appear at the shelf edge. The northernmost intrusion occurs just south of Hudson Canyon. It is marked by high values of all three nutrient salts, nitrate, nitrite, and ortho-phosphate, at both surface and bottom levels. The second intrusion, at the end of transect III near Lindenkohl Canyon, shows high values of nitrate at the surface with relative lows of nitrite and ortho-phosphate and low values of all nutrients at the bottom. It may represent a separated pool of shelf water leaving the shelf rather than an intrusion. The final feature is located near Baltimore Canyon. It has no surface expression, but its expression at the bottom is that of an intrusion, with a relative maximum of all the nutrients.

The observed nutrient patterns are of some interest for physical interpretation, in that they appear to preserve some information during a time when oxygen seems to be saturated and the density-determining variables appear to be involved in an interaction which reduces their value as tracers. With a note of caution that the described phenomenon has its major structure at the spatial sampling wave number, an interpretation of two exchange events which preserve cross-shelf mass transport can be made. This interpretation consists of an intrusion throughout the water column south of Hudson Canyon balanced by an extrusion throughout the water column at Lindenkohl Canyon. An additional intrusion near Baltimore Canyon may also be balanced by the extrusion at Lindenkohl, which appears to be more intense at the bottom than at the surface. This interpretation is further supported by the relative absence of all nutrients near the coast during this cruise.

Spring 1977

The spring cruise in 1977 was conducted at the end of May and into the first week in June. The weather during this period was almost uniformly calm and fair. The ocean response to this showed late spring and early summer conditions. In particular, a very strong pycnocline had formed below a mixed layer of depth 10-12 meters. The pycnocline had a characteristic summer transverse pattern of a pool of light water extending out from shore overlying a pool of heavy water extending in from the shelf edge. The density stratification amounted to 2.5 sigma-t units over section V and 1.5 sigma-t units over sections II and III. The density stratification in the first year spring cruise was greater, at 2 to 2.5 sigma-t units. A fairly level isopycnal (26.5) was located at the 30 to 40 m level in all three sections. During the first year, the analogous isopycnal had a value of 25.5, a full sigma-t unit lower.

Beneath this isopycnal, the salinity increased seaward, the density being maintained constant by an increasing temperature. The result of these variations was a distinct temperature minimum in the bottom water, the cold pool. After the extremely cold winter of 1976-77, the cold pool had temperatures below 4°C in section II. The corresponding temperature for 1976 was 7.5°C. The core temperatures increased towards the south, and the coldest water in section V was located above the bottom in the 40 to 80 m depth region.

The density field at some distance from shore departed substantially from the nearly horizontal character it possessed over the shelf. The isopycnals had more variability and appeared to become vertical in places. This appearance should be tempered by the 1:500 aspect ratio distortions used in our section presentations. This region, geographically near the 100 meter depth contour, is the shelf edge frontal zone. It terminates the hydrographic shelf region on the seaward side. During spring and summer, the shelf front separates cold, relatively fresh cold pool water from the warmer, saltier slope water. Because the temperature and salinity gradients across the front have opposing effects on density, the hydrographic expression of the front is always more prominent in the temperature and salinity fields than in the density field. During the 1977 spring cruises, the water in section III, seaward of the shelf front, was Gulf Stream water from the surface to a depth of at least 100 meters. This region of the study area was occupied by the edge of a Gulf Stream warm core ring, named eddy "P" in the Naval Oceanographic Office Experimental Frontal Analysis. The same analyses indicate that this eddy was about a month old at the time and had broken off from the parent Gulf Stream between the study area and Georges Bank. At the contact point between the eddy water and the underlying water, seen at a depth of 90 meters in the station plot for F2, for example, the temperature and salinity gradients were quite large and in the correct sense for double diffusion (salt finger) convection to occur.

The oxygen values in June 1977 were lowest in the offshore deep water. They were everywhere above 6 mg/l. In particular, oxygen values were measured at greater than 8.5 mg/l in the core of the cold pool. This contrasts strongly with the previous year, when oxygen values were only 3.5 mg/l both in the cold pool core and in the offshore deep water. The nutrients during this cruise had generally moderate values with slight increases in the surface coastal water. The high nitrate indicator is found only in the offshore segment of the northern part of the study area south of Hudson Canyon. Of some interest is that nutrient values during the second year are comparable to those found during the first year during springtime. Surface nitrate and phosphate values were somewhat greater during the second year than during the first year. In general, dissolved oxygen showed maximum values in the mid-shelf region with lower values in and offshore. Nitrate and phosphate showed opposite patterns, with maxima at the shelf edge and coast, and nitrite showed maxima near the coast (and Hudson shelf valley) with values decreasing seaward.

Summer 1977

Temperature and salinity during the summer continued to evolve towards more complex patterns. Density, which is a function of temperature and salinity, evolved towards a simple pattern, which is substantially the same at all sections (I, II, III, IV). This evolution is fully apparent during the summer cruises, 4-16 August 1977 for BLM 08B and 19-30 August for BLM 08W. This pattern included a well-mixed surface layer at about a sigma-t value of 21.0, a thin but strong pycnocline, and a well mixed bottom layer, with sigma-t values slowly increasing in the offshore direction. During the summer cruise, the pycnocline was at about 10 meters to 15 meters inshore and 30 meters offshore. Surface density had a sigma-t of 21.0 to 21.5 throughout the region, and the sigma-t below the pycnocline varied from 24.5 near the coast to 26.0 offshore. A comparison with the first year study shows the density patterns to be remarkably similar for the two years. Differences are that the pycnocline was nearer the surface during the second year than the first (a depth of 10 meters as compared to 20-25 meters), the density difference across the pycnocline was larger the second year than the first (4 instead of 2-3 sigma-t units), and the definition of the pycnocline extended further offshore during the second year than the first. An example of this offshore extension is given by a comparison of density vs. depth at Station F1 between cruise 04B and 08B, the summer cruises near the shelf edge during both summers.

The strong suggestion from the study of the density field is that a summer hydrographic regime, quite different from the winter regime, is produced each year. This regime is dynamically maintained by motions which act to produce a particular kind of density field. In this action, large lateral displacements of water can occur nearly independently above and below the pycnocline. The resulting patterns of temperature and salinity are quite complex and contain, in some fashion, a history of the particular movements which occurred to arrange the density structure.

The resulting temperature field showed a thin layer of very warm water near the surface. The surface temperatures of 23.5°C to 26.5°C were generally 2° higher than those of the first year; (the pattern of variation of this temperature was much different during summer 1977 than it was in summer 1976). This warmer temperature at the end of the summer after a colder start at the beginning is consistent with the shallower pycnocline during the second year, with a similar amount of heat input warming a smaller volume of water. The bottom temperatures show a cold pool with temperatures between 8.5°C and 9°C close to the 50 meter isobath in the region south of the Hudson Shelf Valley. The analogous pattern during the first year was colder towards the north and warmer towards the south, with a longshore increase of 2°C, rather than the 1°C seen during the second year. Bottom temperatures also increased toward shore, but the maximum values reached only 13°C, a full four degrees lower than those of the first year. The high temperatures produced during the first year on the bottom nearshore may well be a reflection of the lower pycnocline level at that time. In the cross-sections, the temperature during the second year was quite complex in pattern, particularly near the shelf edge. The bottom core of "cold pool" water lifted off the bottom in the northern sections, remaining associated with the 26.0 sigma-t surface, and was found just shoreward of the shelf edge front, the zone of highest horizontal temperature gradient. Complexity of some of the temperature structure was great enough that meaningful contours could not be constructed in the cross-sections.

The isohalines along the bottom were generally shelf parallel, varying from 32.5 ppt at the coastal stations to 35.5 ppt at the shelf edge. The direct effect of Gulf Stream rings was not seen during this cruise. The Naval Oceanographic Office Frontal Analysis Charts for this period indicate that several of these rings were present, but they were a few tens of miles offshore from the shelf edge. The bottom salinity values were substantially the same during the second year as during the first year. The surface salinity values for the second year show two small pools of low salinity water located near the edge of the shelf. In general, surface salinities increased from shore to the shelf edge and from north to south, in agreement with previous findings. With the exception of the low salinity pools, both years have similar surface salinity patterns. Below the pycnocline and above the bottom, however, the second year salinity region was so complex that it was in some places impossible to draw contour lines. This is consistent with the generally smooth density curves and the complex temperature structure.

The dissolved oxygen contours were generally simple at the surface, in keeping with the other surface variations. At the bottom, they showed a pattern of general decrease towards shore, with the minimum values found at Station C1 of less than 3 mg/l. The bottom pattern for the first year had a region of oxygen depletion, but the pattern was generally similar, differing mainly by having lower values during the first year. During the second year, the main transect (section III) showed a core of low oxygen, consistent with high bottom demand, near its coastal end at Atlantic City, New Jersey. A similar local reduction was observed during the first year study, but it could, within our sampling scheme, have been a widespread nearshore feature. The dissolved oxygen values for both years show a maximum just beneath the pycnocline. This maximum may be in part an artifact of the sampling instruments.

Nutrient values on the surface tend to repeat the salinity patterns. The low salinity pools on the outer shelf were mirrored by local maxima of all three nutrient salts (nitrate, nitrite, and ortho-phosphate). The highest values of surface phosphate were found towards the northeast corner of the study region, approaching the New York Apex. No high values of nitrate were found on the surface at the shelf edge, indicating a lack of upwelling at the shelf edge. Nitrogen values at the bottom were generally shelf parallel, with nitrate increasing and nitrite decreasing in the offshore direction. The high nitrate shelf edge value was 12 µg-at/l. The corresponding shelf edge maximum during the first year was 20 µg-at/l. The nitrogen nutrients had a greater concentration at the bottom than at the surface, but ortho-phosphate showed little relation between top and bottom values. The northern part of the remnant bottom "cold pool" feature was marked by a broader minimum in bottom phosphate. There was a slight suggestion that high values of bottom phosphate were correlated with low values of dissolved oxygen, and that bottom phosphate was increased near heavily populated areas, but the sampling scheme employed did not allow more than a suggestion to be made. The correlation was evident in both years.

Water Mass and Type Analysis

Part of the purpose of the physical sampling under this study was to provide estimates of the hydrographic environment from which the biological samples were captured. The hydrographic seasonal progression was illustrated during the first year sampling by a set of seasonal "agglomeration" diagrams (Ruzecki et al. 1977, Figures 3-210 a-d). The motivation for constructing agglomeration diagrams in temperature-salinity space is that individual casts frequently appear to consist of a set of nearly homogenous layers separated by high gradient regions. The homogenous layers are water types in the classical oceanographic sense but they change from day to day and cast to cast. A standard temperature-salinity plot emphasizes the regions of vertical change, which might be the result of coincidental juxtapositions of water types. When T-S plots are constructed from points representing half meter averages of properties, the points tend to cluster or agglomerate at the values of temperature and salinity which correspond to the water types and much of the total water column. The agglomeration diagram is a plot of all of the agglomeration points encountered on a given cruise.

The agglomeration diagrams for the first year study showed that the same agglomeration points did not tend to be found at groups of stations, but rather that the set of agglomeration points tended to fill in the shape of the seasonal T-S curves over an entire cruise. This pattern is consistent with the hypothesis that water types over the shelf in the study region are formed locally rather than imported from a large volume reservoir. The formation process is not specified by the analysis, however.

In general, the pattern of agglomeration points for the shelf follows the pattern described by Beardsley and Flagg (1976) and Voorhis et al. (1976) for the distribution of T-S curves in the Mid-Atlantic Bight. The most consistent part of the pattern is the high salinity, deep water found off the shelf. This is called slope water, and in it the step structure leading to agglomeration points is virtually absent. This curve generally extends to a 'knee' at about 13.5°C, 35.7 ppt. Beyond this knee, the agglomeration points form a nearly straight line decreasing in both temperature and salinity. This line terminates in another knee at about 3-10°C and 32-33 ppt. This segment of the line is a combination of shelf and slope water, and its termination point, determined apparently by the severity of the preceeding winter, is termed winter coastal water. A persistent feature of the winter coastal water is sometimes called the cold pool or cold band. During spring warming, it is this water which is warmed to cover the shelf area above the thermocline, and this broad region of T-S space is termed coastal water.

On occasion, agglomeration points are found which extend well above the knee of the slope water curve, but still follow the trend of the curve. The high salinities (>36 ppt) and temperature (>20°C) of this water suggest the Gulf Stream as a source. When coupled with the occurrence of warm core Gulf Stream eddies, the hypothesis is strengthened. Some lateral mixing appears to occur between the coastal water and the Gulf Stream water, and this region of the T-S plane has consequently been termed shelf-Gulf Stream water in the analysis.

These boundaries are shown on Figure 3-91 with the various regions assigned to their appropriate labels. The station data taken

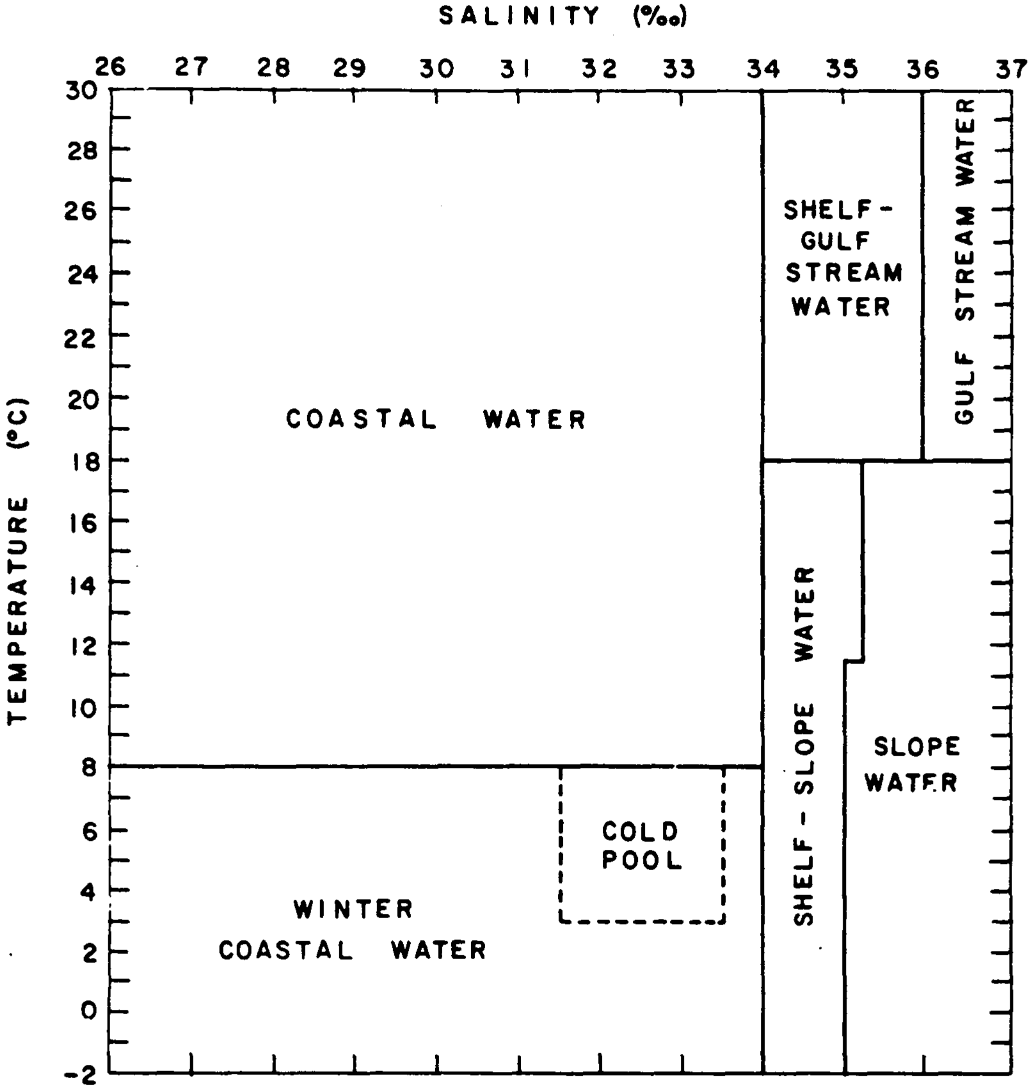


Figure 3-91. **Water mass identification diagram used to interpret data on the Mid Atlantic Bight. Water mass labels are shown within the regions for which they are applicable.**

during the second year of sampling were all divided into depth segments corresponding to regions of each water type throughout the water column. These water type analyses are presented as Tables 3-4 to 3-11, one table being used to characterize stations from each cruise.

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Table 3-4. BLM water type analysis. Cruise BLM05B, 5 November 1976 - 18 November 1976. Depths in meters.

Station	Depth from	Depth to	Water Type
A1	Surface	40.4	Shelf-slope
A1	40.4	Bottom (82.9)	Slope water
A2	Surface	61.5	Shelf-slope
A2	61.5	Bottom (129.8)	Slope Water
A3	Surface	51.2	Shelf-slope
A3	51.2	Bottom (127.5)	Slope-water
A4	Surface	64.7	Shelf-slope
A4	64.7	Bottom (271.8)	Slope-water
B1	Surface	41.6	Coastal Water
B1	41.6	Bottom (48.4)	Shelf-slope
B2	Surface	42	Coastal Water
B2	42	45	Shelf-slope
B2	45	Bottom (55.4)	Slope Water
B3	Surface	31.9	Coastal Water
B3	31.9	50.4	Shelf-slope
B3	50.4	Bottom (68.8)	Slope Water
B4	Surface	32.6	Coastal Water
B4	32.6	Bottom (37.3)	Shelf-slope
B5	Surface	36	Coastal Water
B5	36	Bottom (54.4)	Shelf-slope
C1			Coastal Water
C2			Coastal Water
C4A			Coastal Water
C4B			Coastal Water
D1			Coastal Water
D4			Coastal Water
E1			Coastal Water
E2	Surface	43.4	Coastal Water
E2	43.4	Bottom (62.3)	Shelf-slope
E3	Surface	44.0	Coastal Water
E3	44.0	Bottom (64)	Shelf-slope
E4A	Surface	54	Shelf-slope
E4A	54.0	Bottom (74.4)	Slope Water
E4B			Shelf-slope
F1	Surface	66	Shelf-slope
F1	66	Bottom (80.3)	Slope Water
F2	Surface	60.3	Shelf-slope
F2	60.3	Bottom (102)	Slope Water
F3	Surface	56.5	Shelf-slope
F3	56.5	Bottom (147.9)	Slope Water
F4	Surface	56.0	Shelf-slope
F4	56.0	Bottom (158.5)	Slope Water
J1A	Surface	42.8	Shelf-slope
J1A	42.8	Bottom (371.3)	Slope Water
J1B	Surface	47	Shelf-slope
J1B	47	Bottom (incomplete cast)	Slope Water

Table 3-4. (continued)

Station	Depth from	Depth to	Water Type
L1			Coastal Water
L2	Surface	9.2	Coastal Water
L2	9.2	Bottom (38.9)	Shelf-slope
L4	Surface	79	Shelf-slope
L4	79	Bottom (88.3)	Slope water
L6	Surface	69	Shelf-slope
L6	69	Bottom (184)	Slope Water
N3			Coastal Water

Table 3-5. BLM water type analysis. Cruise BLM05W, 5 November 1976 - 28 November 1976. Depths in meters.

Station	Depth from	Depth to	Water type
A2A	Surface	54.5	Shelf-slope
A2A	54.9	Bottom (99.9)	Slope Water
A2B	Surface	76.4	Shelf-slope
A2B	76.4	Bottom (107.4)	Slope Water
A2C	Surface	71.8	Shelf-slope
A2C	71.8	Bottom (120.9)	Slope Water
A2D	Surface	86.2	Shelf-slope
A2D	86.2	Bottom (113.5)	Slope Water
B5A	Surface	42.8	Coastal Water
B5A	42.8	Bottom (57.1)	Shelf-slope
B5B	Surface	42.6	Coastal Water
B5B	42.6	Bottom (52.4)	Shelf-slope
B5C	Surface	46.1	Coastal Water
B5C	46.1	Bottom (55.4)	Shelf-slope
B5D	Surface	45.9	Coastal Water
B5D	46.9	Bottom (52.3)	Shelf-slope
C1A			Coastal Water
C1B			Coastal Water
C1C			Coastal Water
C1D			Coastal Water
D1			Coastal Water
E3A	Surface	20.5	Coastal Water
E3A	20.5	50.4	Shelf-slope
E3A	50.4	Bottom (57.5)	Slope Water
E3B	Surface	26.7	Coastal Water
E3B	26.7	Bottom (50.9)	Shelf-slope
E3C	Surface	19	Coastal Water
E3C	19	48.5	Shelf-slope
E3C	48.5	Bottom (50.0)	Slope Water
E3D	Surface	20.1	Coastal Water
E3D	20.1	49.9	Shelf-slope
F2A	Surface	70.9	Shelf-slope
F2A	70.9	Bottom (80.9)	Slope Water
J1A	Surface	72.7	Shelf-slope
J1A	72.7	Bottom (269)	Slope Water
J1B	Surface	106.9	Shelf-slope
J1B	106.9	Bottom (192)	Slope Water
J1C	Surface	100.7	Shelf-slope
J1C	100.7	Bottom (224)	Slope Water
J1D	Surface	110.1	Shelf-slope
J1D	110.1	Bottom (258.9)	Slope Water
L1A			Coastal Water
L1B			Coastal Water
L1C			Coastal Water
L1D			Coastal Water

Table 3-5. (continued)

Station	Depth from	Depth to	Water Type
L2A	Surface	32.7	Coastal Water
L2A	32.7	Bottom (40)	Shelf-slope
L2B	Surface	24.9	Coastal Water
L2B	24.9	Bottom (39.8)	Shelf-slope
L2C			Coastal Water
L2D			Coastal Water
L4A	Surface	59.6	Shelf-slope
L4A	59.6	Bottom (88.8)	Slope Water
L4B	Surface	82.7	Shelf-slope
L4B	82.7	Bottom (93.8)	Slope Water
L4C	Surface	65	Shelf-slope
L4C	65.0	Bottom (86.9)	Slope Water
L4D	Surface	50.9	Shelf-slope
L4D	50.9	Bottom (93)	Slope Water
L6A	Surface	58.5	Shelf-slope
L6A	58.5	Bottom (316)	Slope Water
L6B	Surface	64.3	Shelf-slope
L6B	64.3	Bottom (304.8)	Slope Water
L6C	Surface	69.4	Shelf-slope
L6C	69.4	Bottom (299.6)	Slope Water
L6D	Surface	67.6	Shelf-slope
L6D	67.6	Bottom (303.2)	Slope Water
L6E	Surface	63.8	Shelf-slope
L6E	63.8	Bottom (197)	Slope Water
N3	Surface	33.5	Coastal Water
N3	33.5	Bottom (41.5)	Shelf-slope

Table 3-6. BLM water type analysis. Cruise BLM06B, 5 February 1977 - 13 March 1977. Depths in meters.

Station	Depth to	Depth from	Water Type
A1			Slope Water
A2			Slope Water
A3			Slope Water
A4			Slope Water
B1			Shelf-slope
B2			Slope Water
B3	Surface	59.9	Shelf-slope
B3	59.9	Bottom (66.8)	Slope Water
B4			Shelf-slope
B5B			Slope Water
C1A			Winter Coastal
C2			Winter Coastal
C4			Winter Coastal
D1A			Shelf-slope
D4			Shelf-slope
E1			Slope Water
E2			Slope Water
E3A			Slope Water
E4			Slope Water
F1			Slope Water
F2A			Slope Water
F3			Slope Water
F4			Slope Water
G2	Surface	19	Winter Coastal
G2	19	Bottom (28.9)	Shelf-slope
G3			Shelf-slope
G4	Surface	16.4	Winter Coastal
G4	16.4	Bottom (49.3)	Shelf-slope
G5			Shelf-slope
G6	Surface	48.9	Shelf-slope
G6	48.9	Bottom (165.3)	Slope Water
H1	Surface	92.2	Shelf-slope
H1	92.2	Bottom (384)	Slope Water
H2	Surface	485	Slope Water
H2	485	Bottom (713)	Shelf-slope
I1			Slope Water
I2			Slope Water
I3			Slope Water
I4	Surface	98.1	Shelf-slope
I4	98.1	Bottom (485.3)	Slope Water
J1A			Slope Water
J2	Surface	273	Slope Water
J2	273	329	Shelf-slope
J2	329	660	Slope Water
J2	660	Bottom (735.4)	Shelf-Slope

Table 3-6. (continued)

Station	Depth from	Depth to	Water Type
K2			Shelf-slope
K4			Slope Water
K5			Slope Water
K6			Slope Water
L1A	Surface	14.9	Winter Coastal
L1A	14.9	Bottom (23.3)	Shelf-slope
L2A	Surface	13	Winter Coastal
L2A	13	Bottom (36.3)	Shelf-slope
L2B			Slope Water
L4A			Slope Water
L5			Slope Water
L6A			Slope Water
N3A			Shelf-slope

Table 3-7. BLM water type analysis. Cruise BLM06W, 20 February 1977 - 6 March 1977. Depths in meters.

Station	Depth from	Depth to	Water Type
A2			Shelf-slope
B5A			Shelf-slope
C1B			Winter Coastal
D1B			Winter Coastal
E3B			Shelf-slope
F2B			Slope Water
J1B			Slope Water
L1A			Shelf-slope
L1B	Surface	17.5	Winter Coastal
L1B	17.5	Bottom (19.3)	Shelf-slope
L1C			Winter Coastal
L1D	Surface	19	Winter Coastal
L1D	19	Bottom (20.3)	Shelf-slope
L2A	Surface	27.6	Shelf-slope
L2A	27.6	Bottom (38.9)	Slope Water
L2B			Shelf-slope
L2C			Shelf-slope
L2D			Shelf-slope
L4A			Slope Water
L4B			Slope Water
L4C			Slope Water
L4D			Slope Water
L6A			Slope Water
L6B			Slope Water
L6C			Slope Water
L6D			Slope Water
N3B			Shelf-slope

Table 3-8. BLM water type analysis. Cruise BLM07B, 30 May 1977 - 5 June 1977. Depths in meters.

Station	Depth from	Depth to	Water Type
A1	Surface	25.9	Coastal Water
A1	25.9	Bottom (86.3)	Winter Coastal
A2	Surface	25.4	Coastal Water
A2	25.4	Bottom (128.5)	Shelf-slope
A3	Surface	22.7	Coastal Water
A3	22.7	61	Shelf-slope
A3	61	Bottom (138)	Slope Water
A4	Surface	23.6	Coastal Water
A4	23.6	107.9	Shelf-slope
A4	107.9	189.3	Slope Water
B1	Surface	26.7	Coastal Water
B1	26.7	Bottom (60.3)	Winter Coastal
B2	Surface	22.2	Coastal Water
B2	22.2	Bottom (57.9)	Winter Coastal
B3A	Surface	28.2	Coastal Water
B3A	28.2	Bottom (68.4)	Winter Coastal
B3B	Surface	23.3	Coastal Water
B3B	23.3	Bottom (68.9)	Winter Coastal
B4	Surface	23.2	Coastal Water
B4	23.2	Bottom (34.9)	Winter Coastal
B5	Surface	22	Coastal Water
B5	22	Bottom (64.8)	Winter Coastal
C1			Coastal Water
C2	Surface	14.2	Coastal Water
C2	14.2	Bottom (25)	Winter Coastal
C4	Surface	14.5	Coastal Water
C4	14.5	Bottom (30.8)	Winter Coastal
D1	Surface	21.9	Coastal Water
D1	21.9	Bottom (31.9)	Winter Coastal
D4	Surface	21	Coastal Water
D4	21	Bottom (47.3)	Winter Coastal
E1	Surface	23.8	Coastal Water
E1	23.8	Bottom (65.9)	Winter Coastal
E2	Surface	8.5	Shelf Gulf Stream
E2	8.5	14.6	Shelf-slope
E2	14.6	21	Coastal Water
E2	21	Bottom (71.8)	Winter Coastal
E3	Surface	4.5	Shelf Gulf Stream
E3	4.5	10.3	Shelf-slope
E3	10.3	22.0	Coastal Water
E3	22.0	Bottom (63.4)	Winter Coastal
E4	Surface	13.9	Shelf Gulf Stream
E4	13.9	19.9	Shelf-slope
E4	19.9	24.5	Coastal Water
E4	24.5	Bottom (76.5)	Winter Coastal

Table 3-8. (continued)

Station	Depth from	Depth to	Water Type
F1	Surface	18.4	Shelf Gulf Stream
F1	18.4	20.8	Gulf Stream
F1	20.8	57.6	Slope Water
F1	57.6	Bottom (84.9)	Shelf-slope
F2	Surface	25	Shelf Gulf Stream
F2	25	106.3	Slope Water
F3	Surface	41.7	Shelf Gulf Stream
F3	41.7	55	Gulf Stream
F3	55	160.6	Slope Water
F3	160.6	Bottom (169.9)	Shelf-slope (Benthic Boundary Layer)
F4	Surface	11.4	Shelf Gulf Stream
F4	11.4	30.4	Gulf Stream
F4	30.4	Bottom (192.3)	Slope Water
J1	Surface	98.9	Gulf Stream
J1	98.9	Bottom	Slope Water
L1			Coastal Water
L2	Surface	16	Coastal Water
L2	16	Bottom (35.3)	Winter Coastal
L4	Surface	7	Shelf-slope
L4	7	14	Coastal Water
L4	14	24	Shelf-slope
L4	24	28	Slope Water
L4	28	Bottom (91)	Shelf-slope
L6	Surface	23.3	Shelf Gulf Stream
L6	23.3	Bottom (325)	Slope Water
N3	Surface	19.6	Coastal Water
N3	19.6	Bottom (44.4)	Winter Coastal

Table 3-9. BLM water type analysis. Cruise BLM 07W, 18 May 1977 - 28 May 1977. Depths in meters.

Station	Depth to	Depth from	Water Type
A2A	Surface	25	Coastal Water
A2A	25	56.2	Winter Coastal
A2A	56.2	Bottom (126)	Shelf-slope
A2B	Surface	16.2	Coastal Water
A2B	16.2	21.5	Winter Coastal
A2B	21.5	24.0	Coastal Water
A2B	24.0	37.2	Winter Coastal
A2B	37.2	40.0	Shelf-slope
A2B	40.0	47.9	Winter Coastal
A2B	47.9	122.0	Shelf-slope
A2B	122.0	Bottom (132.9)	Slope Water
A2C	Surface	24.2	Coastal Water
A2C	24.2	53.3	Winter Coastal
A2C	53.3	122.6	Shelf slope
A2C	122.6	Bottom (126.4)	Slope Water
A2D	Surface	17	Coastal Water
A2D	17.0	62.6	Winter Coastal
A2D	62.6	Bottom (127.4)	Shelf-slope
B5A	Surface	20.4	Coastal Water
B5A	20.4	Bottom (64.3)	Winter Coastal
B5B	Surface	19.5	Coastal Water
B5B	19.5	Bottom (62.4)	Winter Coastal
B5C	Surface	20.9	Coastal Water
B5C	20.9	Bottom (61.9)	Winter Coastal
B5D	Surface	18.7	Coastal Water
B5D	18.7	Bottom (61.4)	Winter Coastal
C1A	Surface	12.1	Coastal Water
C1A	12.1	Bottom (13.4)	Winter Coastal
C1B	Surface	9.6	Coastal Water
C1B	9.6	Bottom (10.9)	Winter Coastal
C1C	Surface	9	Coastal Water
C1C	9	Bottom (11.4)	Winter Coastal
C1D	Surface	10.5	Coastal Water
C1D	10.5	Bottom (11.8)	Winter Coastal
D1A	Surface	23.6	Coastal Water
D1A	23.6	Bottom (34.3)	Winter Coastal
E3A	Surface	26.4	Coastal Water
E3A	26.4	Bottom (61.4)	Winter Coastal
E3B	Surface	21.4	Coastal Water
E3B	21.4	Bottom (60.3)	Winter Coastal
E3C	Surface	28.5	Coastal Water
E3C	28.5	Bottom (63.3)	Winter Coastal
E3D	Surface	24.4	Coastal Water
E3D	24.4	Bottom (60.9)	Winter Coastal
F2	Surface	31.3	Coastal Water
F2	31.3	40.4	Winter Coastal
F2	40.4	48	Shelf-slope

Table 3-9. (continued)

Station	Depth from	Depth to	Water Type
F2	48	77	Winter Coastal
F2	77	Bottom (105.9)	Shelf-slope
J1A	Surface	5.6	Gulf Stream
J1A	5.6	14	Shelf Gulf Stream
J1A	14	18	Slope Water
J1A	18	19	Shelf-slope
J1A	19	29	Slope Water
J1A	29	39	Shelf-slope
J1A	39	77	Slope Water
J1A	77	82	Shelf-slope
J1A	82	Bottom (349)	Slope Water
J1B	Surface	7.5	Shelf Gulf Stream
J1B	7.5	13.3	Gulf Stream
J1B	13.3	Bottom (333)	Slope Water
J1C	Surface	11.5	Shelf Gulf
J1C	11.5	Bottom (303.9)	Slope Water
J1D	Surface	24	Gulf Stream
J1D	24	Bottom (367)	Slope Water
L1A			Coastal Water
L1B			Coastal Water
L1C			Coastal Water
L1D			Coastal Water
L2A	Surface	14.6	Coastal Water
L2A	14.6	Bottom (39.4)	Winter Coastal
L2B	Surface	16.7	Coastal Water
L2B	16.7	34.4	Winter Coastal
L2B	34.4	Bottom (42)	Shelf-slope
L2C	Surface	20	Coastal Water
L2C	20	Bottom (43)	Winter Coastal
L2D	Surface	23	Coastal Water
L2D	23	Bottom (39.3)	Winter Coastal
L4A	Surface	20.9	Gulf Stream
L4A	20.9	Bottom (90)	Slope Water
L4B	Surface	59.3	Slope Water
L4B	59.3	Bottom (93.9)	Shelf-slope
L4C	Surface	52	Slope Water
L4C	52.0	Bottom (92.0)	Shelf-slope
L4D	Surface	69	Slope Water
L4D	69	Bottom (91.3)	Shelf-slope
L6A	Surface	14.5	Shelf Gulf Stream
L6A	14.5	Bottom (303.4)	Slope Water
L6B	Surface	12.4	Shelf Gulf Stream
L6B	12.4	Bottom (306.5)	Slope Water
L6C	Surface	10.6	Shelf Gulf Stream
L6C	10.6	Bottom (303.4)	Slope Water
L6D	Surface	12.4	Shelf Gulf Stream
L6D	12.4	Bottom (304)	Shelf-slope
N3	Surface	19.3	Coastal Water
N3	19.3	Bottom (41.8)	Winter Coastal

Table 3-10. BLM water mass analysis. Cruise BLM08B, 4 August 1977 - 16 August 1977. Depths in meters.

Station	Depth from	Depth to	Water Type
A1	Surface	57.7	Coastal Water
A1	57.7	Bottom (81.9)	Shelf-slope
A2	Surface	14	Coastal Water
A2	14	22	Shelf-Gulf Stream
A2	22	25	Coastal Water
A2	25	111	Shelf-slope
A2	111	126	Slope Water
A3	Surface	12.5	Coastal Water
A3	12.5	25.6	Shelf-Gulf Stream
A3	25.6	106.7	Shelf-slope
A3	106.7	Bottom (141)	Slope Water
A4	Surface	13	Coastal Water
A4	13	30.3	Shelf-Gulf Stream
A4	30.3	110.7	Shelf-slope
A4	110.7	Bottom (178.8)	Slope Water
B1			Coastal Water
B2			Coastal Water
B3			Coastal Water
B4			Coastal Water
B5			Coastal Water
C1			Coastal Water
C2			Coastal Water
C4			Coastal Water
D1			Coastal Water
D4			Coastal Water
E1			Coastal Water
E2	Surface	17	Coastal Water
E2	17	24.3	Shelf-Gulf Stream
E2	24.3	53.6	Coastal Water
E2	53.6	Bottom (73.8)	Shelf-slope
E4	Surface	9.6	Coastal Water
E4	9.6	23	Shelf-Gulf Stream
E4	23	25	Gulf Stream
E4	25	28	Shelf-Gulf Stream
E4	28	38	Shelf-slope
E4	38	58	Coastal Water
E4	58	Bottom (75.3)	Shelf-slope
F1	Surface	11	Coastal Water
F1	11	22.4	Shelf-Gulf Stream
F1	22.4	23.9	Shelf-slope
F1	23.9	66	Coastal Water
F1	66	Bottom (73)	Shelf-slope
F2	Surface	11.9	Coastal Water
F2	11.9	18.5	Shelf-Gulf Stream

Table 3-10. (continued)

Station	Depth from	Depth to	Water Type
F2	18.5	54.6	Coastal Water
F2	54.6	Bottom (110)	Shelf-slope
F3	Surface	37.6	Shelf-Gulf Stream
F3	57.6	76.2	Shelf-slope
F3	76.2	Bottom (164.4)	Slope Water
F4	Surface	7.9	Coastal Water
F4	7.9	40	Shelf-Gulf Stream
F4	40	91	Slope Water
F4	91	105	Shelf-slope
F4	105	Bottom (191.8)	Slope Water
G2			Coastal Water
G3			Coastal Water
G4			Coastal Water
G5	Surface	9.7	Coastal Water
G5	9.7	21.4	Shelf-Gulf Stream
G5	21.4	31	Shelf-slope
G5	31	70	Coastal Water
G5	70.0	Bottom (87.3)	Shelf-slope
G6	Surface	12.3	Coastal Water
G6	12.3	30	Shelf-Gulf Stream
G6	30	83	Shelf-slope
G6	83	Bottom (174)	Slope Water
H1	Surface	18	Coastal Water
H1	18	73	Shelf-slope
H1	73	Bottom (372)	Slope Water
H2	Surface	15.6	Coastal Water
H2	15.6	28.3	Shelf-Gulf Stream
H2	28.3	43	Shelf-slope
H2	43	Bottom (703)	Slope Water
I1			Coastal Water
I2	Surface	12	Coastal Water
I2	12	23	Shelf-Gulf Stream
I2	23	25	Shelf-slope
I2	25	Bottom (95)	Coastal Water
I3	Surface	11	Coastal Water
I3	11	18.5	Shelf-Gulf Stream
I3	18.5	122	Shelf-slope
I3	122	Bottom (162.7)	Slope Water
I4	Surface	46	Coastal Water
I4	46	130	Shelf-slope
I4	130	473	Slope Water
J1	Surface	3	Coastal Water
J1	3	18	Shelf-Gulf Stream
J1	18	22.5	Gulf Stream
J1	22.5	51.8	Shelf-Gulf Stream
J1	51.8	Bottom (318)	Slope Water
J2	Surface	5	Coastal Water
J2	5	17	Shelf-Gulf Stream
J2	17	20	Gulf Stream

Table 3-10.(continued, page three)

Station	Depth from	Depth to	Water Type
J2	20	42	Shelf-Gulf Stream
J2	42	Bottom (706)	Slope Water
K2			Coastal Water
K4	Surface	14	Coastal Water
K4	14	37.6	Shelf-Gulf Stream
K4	37.6	Bottom (100.8)	Slope Water
K5	Surface	29	Shelf-Gulf Stream
K5	29	71	Shelf-slope
K5	71	Bottom (153)	Slope Water
K6	Surface	30.7	Shelf-Gulf Stream
K6	30.7	84	Shelf-slope
K6	84	Bottom (330)	Slope Water
L1			Coastal Water
L2			Coastal Water
L4	Surface	6	Coastal Water
L4	6	26	Shelf-Gulf Stream
L4	26	38	Gulf Stream
L4	38	45	Shelf-Gulf Stream
L4	45	56	Coastal Water
L4	56	64	Winter Coastal
L4	64	72	Coastal Water
L4	72	81	Shelf-slope
L4	81	93	Slope Water
L5	Surface	5	Coastal Water
L5	5	35	Shelf-Gulf Stream
L5	35	37	Gulf Stream
L5	37	Bottom (148)	Slope Water
L6	Surface	27.6	Shelf-Gulf Stream
L6	27.6	35	Gulf Stream
L6	35	45	Shelf-Gulf Stream
L6	45	Bottom (358)	Slope Water

Table 3-11. BLM water mass analysis. Cruise BLM08W, 19 August 1977 - 30 August 1977. Depths in meters.

Station	Depth from	Depth to	Water Type
A2A	Surface	14	Coastal Water
A2A	14	21	Shelf-Gulf Stream
A2A	21	77.5	Shelf-slope
A2A	78	Bottom (129)	Slope Water
A2B	Surface	19	Coastal Water
A2B	19	27	Shelf-Gulf Stream
A2B	27	87.3	Shelf-slope
A2B	87.3	128	Slope Water
A2C	Surface	10	Coastal Water
A2C	10	25.7	Shelf-Gulf Stream
A2C	25.7	82.4	Shelf-slope
A2C	82.4	Bottom (129)	Slope Water
A2D	Surface	19	Coastal Water
A2D	19	27	Shelf-Gulf Stream
A2D	27	92	Shelf-slope
A2D	92.0	Bottom (130)	Slope Water
B5A			Coastal Water
B5B			Coastal Water
B5C			Coastal Water
B5D			Coastal Water
C1A			Coastal Water
C1B			Coastal Water
C1C			Coastal Water
C1D			Coastal Water
D1			Coastal Water
E3A	Surface	20.2	Coastal Water
E3A	20.2	23	Shelf-slope
E3A	23	Bottom (62)	Coastal Water
E3B	Surface	20.4	Coastal Water
E3B	20.4	22	Shelf-slope
E3B	22	Bottom (61)	Coastal Water
E3C	Surface	17	Coastal Water
E3C	17	18	Shelf-slope
E3C	18	Bottom (65)	Coastal Water
E3D	Surface	21	Coastal Water
E3D	21	22	Shelf-Gulf Stream
E3D	22	Bottom (64)	Coastal Water
F2A	Surface	17	Coastal Water
F2A	17	26	Shelf-Gulf Stream
F2A	26	48	Shelf-slope
F2A	48	Bottom (109)	Slope Water
J1A	Surface	20	Coastal Water
J1A	20	30	Shelf-Gulf Stream
J1A	30	74	Shelf-slope
J1A	74	Bottom (361)	Slope Water

Table 3-11.(continued)

Station	Depth from	Depth to	Water Type
J1B	Surface	14.4	Coastal Water
J1B	14.4	28.5	Shelf-Gulf Stream
J1B	28.5	38	Shelf-Slope Water
J1B	38	Bottom (360)	Slope Water
J1C	Surface	16	Coastal Water
J1C	16	29	Shelf-Gulf Stream
J1C	29	67	Shelf Slope Water
J1C	67	Bottom (372)	Slope Water
J1D	Surface	45	Shelf-Gulf Stream
J1D	45	Bottom (351.4)	Slope Water
L1A			Coastal Water
L1B			Coastal Water
L1C			Coastal Water
L1D			Coastal Water
L2A	Surface	14	Coastal Water
L2A	14	15	Shelf-Gulf Stream
L2A	15	Bottom (41)	Coastal Water
L2B	Surface	14.5	Coastal Water
L2B	14.5	16	Shelf-Gulf Stream
L2B	16	17	Coastal Water
L2B	17	18	Shelf-slope
L2B	18	Bottom (41)	Coastal Water
L2C			Coastal Water
L2D			Coastal Water
L4A	Surface	36	Shelf-Gulf Stream
L4A	36	40	Slope Water
L4A	40	66	Shelf Slope
L4A	66	Bottom (96.4)	Slope Water
L4B	Surface	35	Shelf-Gulf Stream
L4B	35	Bottom (94)	Slope Water
L4C	Surface	34	Shelf-Gulf Stream
L4C	34	Bottom (94)	Slope Water
L4D	Surface	30	Shelf-Gulf Stream
L4D	30	60	Shelf-slope
L4D	60	Bottom (96)	Slope Water
L6A	Surface	36	Shelf-Gulf Stream
L6A	36	Bottom (359)	Slope Water
L6B	Surface	38	Shelf-Gulf Stream
L6B	38	Bottom (361)	Slope Water
L6C	Surface	37	Shelf-Gulf Stream
L6C	37	Bottom (325)	Slope Water
L6D	Surface	40.5	Shelf-Gulf Stream
L6D	40.5	Bottom (344)	Slope Water
N3			Coastal Water

CHAPTER 4

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CHAPTER 4

MIDDLE ATLANTIC BIGHT ZOOPLANKTON: SECOND YEAR RESULTS AND A DISCUSSION OF THE TWO-YEAR BLM-VIMS SURVEY

G. C. Grant

INTRODUCTION

A baseline survey of zooplankton in Middle Atlantic Bight waters subject to impact from development of oil and gas resources was initiated in the fall of 1975. Sampling in the first year was conducted quarterly along a transect of six stations extending from near the coast of southern New Jersey to the continental shelf edge. Location of this initial transect was chosen to pass through an area of the outer shelf expected to be of high interest to the leasing oil corporations.

Results of the first year's study (Grant 1977a) demonstrated that Middle Atlantic Bight zooplankton has been much neglected and is, therefore, poorly described. Findings also confirmed our suspicions that the neustonic, or surface layer, habitat is a critically important one for early developmental stages of many fishes and decapod crustaceans in continental shelf waters. Community analyses of zooplankton collections revealed the continual presence of a coastal assemblage of species, presumably associated with the Coastal Boundary Layer, a flow-trapped structure best known from physical studies (Csanady 1976), and a Central Shelf community. Offshore or shelf-break species were less well-defined, except in the fall of 1975, when a distinct community of oceanic species occurred at the shelf-break and slope stations.

These results and a better definition of the localities that were of prime interest to oil companies dictated an expansion of zooplankton sampling in the second year. The original transect was again included in the sampling plan, although with a reduction in 24-hour neuston collections, two new stations were added to the north of that transect, and a transect of four stations extending from the coast of Virginia to the shelf-edge near Norfolk Canyon was also added. Biomass estimates and replication of bongo tows were further implementations.

This report presents the results of the second year of seasonal zooplankton sampling in Middle Atlantic Bight waters, obtained from four seasonal cruises starting in November 1976 and ending in September 1977, and discusses conclusions based on data from both sampling years.

METHODS AND MATERIALS

Sampling Locations

Twelve stations were occupied each quarter for sampling of surface and subsurface zooplankton (Figure 4-1). These stations extended from the coasts of New Jersey and Virginia to the continental shelf edge and from south of Hudson Canyon to the vicinity of Norfolk Canyon. Sampling regimes at these stations were of three types as indicated on Figure 4-1 and detailed below.

Shipboard Procedure

Subsurface Zooplankton

Double-oblique tows, from surface to near-bottom and back to surface, were made at each of the 12 stations with 60 cm opening-closing bongo systems (McGowan and Brown 1966), first with paired 202 μm nets, then with 505 μm nets. The track of tows followed a broad arc, except in heavy weather when waves were quartered. All tows were taken using a 1/4-inch stainless steel cable, towed at a vessel speed of approximately 1.5 knots. To avoid surface contaminants, samples were submerged in closed position, opened below the surface, then re-closed before retrieval through the surface layer. Flowmeters (General Oceanics, Inc.) were excluded from the net utilized for chemical analysis.

Precautions against contamination of collections for chemical analysis also included minimizing contact between nets and ship surfaces, through use of a bongo rigging stand (Ocean Instruments, Inc.) and sailbags to contain nets not in active use. Collections for analysis of trace metals and hydrocarbons were emptied into stainless steel buckets before net wash-down to avoid contamination from the ship's seawater system. These collections were then concentrated on 110 μm netting, split into two roughly equal portions (one each for hydrocarbons and trace metals), then transferred with teflon-coated utensils into acid-washed glass jars. Jars were sealed with teflon-lined caps and immediately frozen. At quality control stations (one randomly-selected station in each quarterly cruise), each collection for chemistry was doubly split to provide extra samples for a BLM-designated laboratory.

Samples collected in the metered half of bongo net pairs and reserved for taxonomy were washed down with the ship's seawater system into collecting buckets, concentrated on 110 μm netting, transferred to glass jars and preserved in 5-8 percent buffered formaldehyde in seawater.

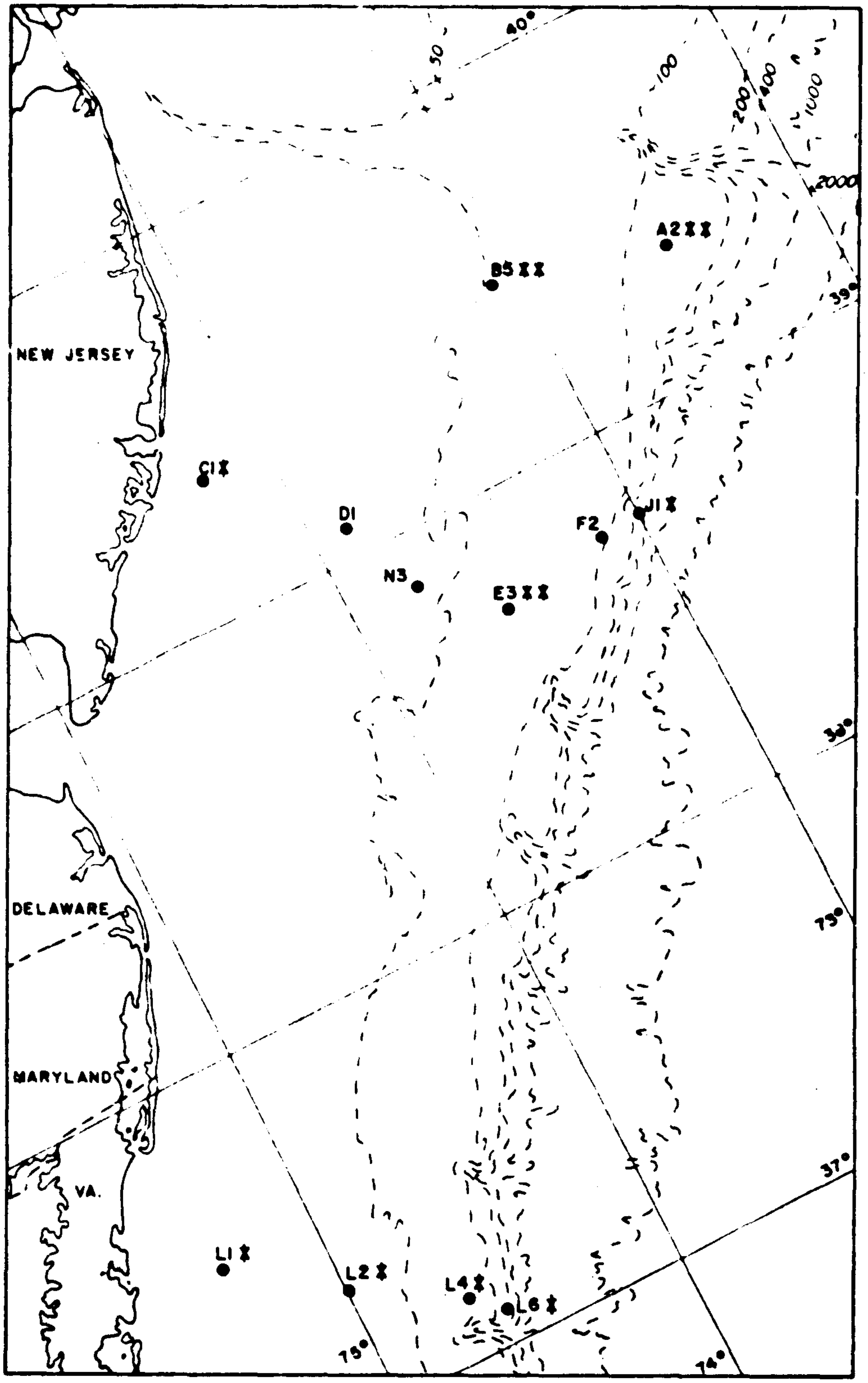

Figure 4-1. Sampling locations for subsurface and surface (neuston) zooplankton in the Middle Atlantic Bight, 1976-1977. Routine collections of 202 μm and 505 μm bongo nets and an accompanying neuston tow were augmented as indicated: *24-hr neuston station, **24-hr neuston plus 3 replicate bongo tows.

Additional bongo collections were made at stations A2, B5 and E3 on each cruise to provide replicate samples for statistical purposes. At these stations the initial two bongo tows (202 µm and 505 µm nets) were followed in succession by three additional tows. The latter utilized an array of two 60 cm bongo samplers and a time-depth recorder. Efficient operation of the messenger-actuated, opening-closing device on the bongo systems was possible only with the uppermost system, due to the necessary close spacing of bongo systems on the towing wire. Bongos were fitted with paired 202 µm and 505 µm nets, the upper pair closed on descent for chemistry samples and unmetered, the lower pair open on descent and with both sides metered for taxonomy and biomass collections. After immersion below the surface layer, the upper bongo system was opened by messenger, the array towed obliquely to near-bottom, then back to below the surface. The upper bongo system was then closed before retrieval through the surface layer. All such tows were conducted at night, usually between the hours of 2000 and 2400 EST.

Surface Zooplankton (Neuston)

At nine stations (Figure 4-1, stations L1, L2, L4, L6, C1, E3, J1, A2, and B5) neuston collections were obtained every three hours for a 24-hour period during each quarterly cruise. At stations D1, N3 and F2 only a single neuston tow was made, in conjunction with bongo sampling. The neuston sampler, designed at Woods Hole Oceanographic Institution, consists of two hydrodynamically-shaped, foam-filled floats connected by an endless fiberglass belt, accommodating a standard one-meter plankton net and towed by a four-point bridle. A 505 µm net was employed in all neuston sampling. The unit samples the surface layer to an approximate depth (floating depth) of 12 cm and a width of one meter. Tows were of 20 minutes duration, except where abundance of salps or ctenophores dictated a shorter tow, made from an extended boom, and in a widely circular track to keep the net away from the ship's wake.

Collected samples were washed into buckets, where they were inspected for tarballs and large, readily identified species. Tarballs, if present, were removed to labelled plastic zip-bags and frozen. Large species, if present, were transferred to acid-washed, teflon-capped jars and frozen for trace metal and hydrocarbon analysis. A maximum of two species was selected at each station, with specimens accumulated for a given station through the eight neuston tows at 24-hour stations. Numbers and identity of removed specimens and the occurrence of tarballs were noted on collection log sheets. Removed specimens were tallied with preserved samples for later analyses (clusters and diversity).

Laboratory Procedure

Frozen Collections

Samples for hydrocarbon and trace metal analyses and all frozen tarballs were placed in the hands of chemists upon return of collections to the laboratory.

Biomass Measurements

Collections preserved for taxonomic study were also utilized for biomass estimates. The non-destructive measurement of displacement volume was employed, after allowing a minimum of one week after collection for stabilization of zooplankton volume. Although some shrinkage can be expected to occur for a year or two in preservative, contract requirements prohibited further delay of volume measurement. The method described by Kramer (1972) was followed: Total volume of the sample in preservative was measured and recorded. The plankton and preservative was placed into a draining cone of 110 µm mesh netting and funnel, with a graduated cylinder used to catch the filtrate. When the draining preservative had slowed to an occasional drip, the volume of filtrate was recorded and subtracted from the original volume to yield the zooplankton displacement volume in ml. Filtrate and drained zooplankton were then recombined for storage and taxonomic studies.

Sorting of Preserved Samples

Large and rarer taxa such as fish larvae were sorted from whole collections. Collections were then quantitatively split into successively smaller aliquots, for the progressively smaller and more numerous taxa, using a VIMS splitter (Burrell et al. 1974). Where samples were large, one-half the collection (from first split) was archived. Taxa were sorted in the above manner into major categories such as copepods, fish larvae, decapod larvae, etc., enumerated and preserved in separate vials or small jars.

Sorted major taxa were then distributed among specialists for identification and counts of species. Resulting identifications were entered on identification log sheets, with counts recorded under the column reserved for the proper aliquot size. Representatives of identified species were separated for inclusion in an archived reference collection. Principal references used in identification of species were listed by Grant (1977a).

Data Analysis

Data Cards and Storage

Two basic data card types were used for storage, reduction, and analysis of collected data. The first, a station/sample card, was prepared for each sample, and contained sample number, position of station, date, time (EST), surface temperature and salinity, depth of station, number of species, number of individual zooplankters, sample type, type of sampling gear, net mesh size, type of tow, maximum depth of tow, duration of tow, and volume of water sampled.

The second card type, a species card, was punched for each species (or higher taxon) occurrence. Included on these cards were sample number, species code number (10-digit code expanded after Swartz, Wass, and Boesch 1972), number of individuals, and order of magnitude. Numbers of individuals entered on these cards were the expanded numbers for the total collection, based upon the size of aliquot examined. In the case of shortened neuston tows, numbers were also expanded to a standard 20-minute tow.

Diversity Measurements

Three measures of diversity in zooplankton and neuston communities were used (Pielou 1975): the Shannon index (H') using base-2 logs, evenness (J'), and the Margalef species richness index ($S-1/\log_e N$). Computer programs for their calculation are provided in Appendix III. All diversity measures were based on total number of species and individuals in each sample.

Cluster and Nodal Analyses

The principal method of community analysis used in this study was a cluster analysis, both normal and inverse, based on a matrix of Bray and Curtis (1957) similarity coefficients. Data employed in these analyses were first standardized to numbers of individuals per 100 m^3 in the case of subsurface zooplankton (bongo tows) and to numbers per standard 20-minute tows for surface zooplankton (neuston). The normal analyses provided a clustering of samples according to their similarity in species composition and abundance; the inverse analysis provided a clustering of species according to similarity in sample distribution. Resulting sample groups and species groups were related by use of a nodal analysis (Boesch 1977) that yielded measures of density (percent of species groups occurring in station groups), fidelity (relative preference for sample groups by species groups), and abundance (relative concentration of species in the sample groups).

In interpretation of the results of neuston sample clustering, tows at 0900, 1200, 1500 and 1800 hrs were initially classified as day tows; those at 2100, 2400, 0300 and 0600 were termed night tows. During certain cruises, due to lengthened daylight hours, slight alterations in time of sampling, or obvious similarity of 1800 and 0600 hr collections with those of night and day tows, respectively, description of the latter samples was altered to dusk and dawn.

RESULTS

Fall 1976 Cruise No. BLM05W

Summary of Collections

The twelve designated water column stations (L1, L2, L4, L6, C1, D1, N3, E3, F2, J1, B5, and A2) were sampled for surface and subsurface zooplankton between 5 November and 28 November 1976. A total of 43 bongo collections (including 1 extra 202 μm at Station L1 and replicate tows at stations A2, B5, and E3) were obtained for biomass estimates and taxonomy. Subsurface collections for chemistry totalled 44 each for trace metals and hydrocarbons, including extra splits at the designated quality control station (B5). Collections were evenly divided between 202 μm and 505 μm nets.

Neuston collections (505 μm nets) were obtained at 3-hr intervals over a 24-hr period at all but stations D1, N3, and F2, where single tows were taken, for a total of 75 collections. Species selected from neuston tows for chemical analysis included Pelagia noctiluca (scyphozoan), Idotea metallica (isopod), and the fishes Menidia menidia, Urophycis sp., Peprilus triacanthus, and unidentifed myctophids. Tarballs were not noted in neuston collections, except for a single occurrence at Station J1.

Biomass

The biomass of zooplankton, estimated by the non-destructive method of displacement volume, is given in Table 4-1. Estimates from the finer mesh 202 μm bongo nets were consistently higher than paired 505 μm nets, due to the added retention of smaller and immature zooplankters. In general, zooplankton volume decreased from south to north and from inshore to offshore over the study area. Exceptions to the inshore-offshore trend occurred at Station C1 and in the 505 μm net at Station L1 where volumes were low. Variation among replicate samples from stations E3, B5 and A2 was considerably less than that between stations.

Zooplankton volume in the surface layer (neuston collections) was quite variable, without the offshore decrease evident in subsurface

Table 4-1. Displacement volume of zooplankton collections, fall 1976 (BLM05W). Standardized to ml/100m^3 for 60 cm bongos and to ml/20 minute tow for neuston collections.

			Neuston 505 µm (ml/20 min. tow)							
	Bongo (ml/100 m^3)		Approx. hour of collection							
Station	202 µm	505 µm	0300	0600	0900	1200	1500	1800	2100	2400
L1	392	3	320	245	230	250	260	185	200	135
L2	211	70	530	725	10	65	80	1540	95	225
L4	41	24	100	35	30	10	90	10	60	40
L6	60	15	175	130	30	70	740	890	70	150
C1	44	36	40	15	75	50	60	70	75	175
D1	244	101							210	
N3	186	76								500
E3	59	59	585	455	135	30	5	60	590	480
	81	66								
	70	53								
	79	60								
F2	8	4							70	
J1	14	4	40	10	10	5	5	40	70	435
B5	93	29	45	45	100	25	190	70	70	85
	72	24								
	69	28								
	93	44								
A2	98	15	15	30	30	45	30	40	10	5
	39	12								
	34	9								
	31	9								

zooplankton. At most stations that were sampled over a 24 hr. period, volumes were highest at night or in late afternoon.

Faunal Description

Over 300 taxa were identified from neuston and bongo tows (Table 4-2), including at least 72 species of copepods, 53 amphipods, 27 decapods, 13 chaetognaths, and 26 fishes. These counts of species exclude identifications to genus or family where species within that higher taxon have also been identified. Among those species occurring only in neuston collections, most were infrequent in occurrence. Surface-layer restricted species occurring in more than 5% of the 75 neuston tows included the pontellid copepods Anomalocera ornata, A. patersonii,* Labidocera acutifrons, Pontella meadii, and Pontellopsis villosa; the mysid Bowmaniella sp.; the decapod Dromidia antillensis; and the fish Menidia menidia. Species found only in subsurface collections were more frequent among the annelids, deeper-living copepods, cumaceans, amphipods and euphausiids.

Dominant species in the 118 analyzed bongo and neuston tows are listed in Table 4-3. All of the subsurface collections were numerically dominated by copepods, usually by the small Paracalanus sp. in 202 μm mesh nets and by Centropages typicus in 505 μm nets. Nannocalanus minor was particularly important along the southern L-transect and in northern Central Shelf stations. Pleuromamma gracilis assumed dominance at outer shelf and shelf-break stations. Dominants other than copepods were limited to Neomysis americana at Station C1 and Parathemisto gaudichaudii at Station B5.

Dominant species in neuston collections were typically much more diverse and included, in addition to the copepods that were dominant in subsurface collections, decapods (Lucifer faxoni, Cancer sp., Leptochela sp., Ovalipes sp.), copepods associated more closely with the surface layer (Centropages furcatus,* Labidocera aestiva, A. ornata, A. patersonii), chaetognaths (Sagitta enflata, S. helenae, S. tasmanica), fish larvae (Urophycis sp.) and eggs, and pelagic tunicates (Doliolum).

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* Name changes: Western Atlantic populations of copepods referred to in this report as Anomalocera patersonii and Centropages furcatus have been redesignated as A. opalus and C. velificatus, respectively, by Pennell (1976) and Fleminger and Hulsemann (1973).

(TEXT CONTINUES ON PAGE 4-20)

Table 4-2. List of zooplankton identified from bongo and neuston collections, fall 1976 (BLM05W). Species from subsurface collections only (*); from surface collections only (**).

CNIDARIA
- Abylopsis eschscholtzii
- Abylopsis tetragona
- *Aequorea sp.
- Agalma elegans
- Aglantha sp.
- Bassia bassensis
- **Ceratocymba leuckarti
- Chelophyes appendiculata
- **Chelophyes contorta
- Diphyes bojani
- *Diphyes chamissoni
- Diphyes dispar
- Diphyopsis campanulifera
- Eudoxides spiralis
- Lensia conoidea
- *Lensia fowleri
- *Lensia multicristata
- **Liriope sp.
- *Liriope tetraphylla
- Muggiaea kochei
- Pelagia noctiluca
- *Sulculeolaria chuni
- unid. hydrozoans
- *unid. scyphozoans
- unid. anthozoans

TURBELLARIA
- *unid. flatworms

RHYNCHOCOELA
- *unid. nemerteans

ANNELIDA
- *Glycera capitata
- *Glycera robusta
- *Onuphis sp.
- *Tomopteris helgolandica
- *Tomopteris sp.
- unid. polychaetes

MOLLUSCA
- *Atlanta inflata
- Atlanta peroni
- Cavolina inflexa
- **Cavolina longirostris
- Cavolina quadridentata
- **Cavolina uncinata

MOLLUSCA (continued)
- *Clione limacina
- *Crassinella mactracea
- Creseis virgula
- **Diacria trispinosa
- Dosinia discus
- Hyalocyclis striata
- **Illex illecebrosus
- Lima tenera
- Limacina bulimoides
- Limacina inflata
- Limacina leseuri
- Limacina retroversa
- Limacina trochiformis
- Loligo pealii
- Melampus bidentatus
- **Musculus corrugatus
- *Natica sp.
- Notobranchaea macdonaldi
- Paedoclione doliiformis
- *Polinices duplicatus
- Spisula solidissima
- unid. gastropod larvae
- *unid. bivalve larvae
- **unid. cephalopods

CLADOCERA
- Evadne tergestina
- Penilia avirostris
- *Podon intermedius

OSTRACODA
- Conchoecia sp.
- Conchoecia curta
- Euconchoecia chierchiae
- Halocypris brevirostris
- unid. ostracods

COPEPODA
- Acartia sp.
- Acartia danae
- Acartia tonsa
- Aetideus armatus
- **Anomalocera sp.
- **Anomalocera ornata
- **Anomalocera patersonii (=opalus)
- **Calanopia americana
- Calanus finmarchicus

Table 4-2. (Continued)

COPEPODA (continued)
Calocalanus pavo
Candacia sp.
Candacia armata
Candacia curta
**Candacia pachydactyla
Centropages furcatus
Centropages hamatus
Centropages typicus
Centropages violaceus
Clausocalanus sp.
**Clausocalanus arcuicornis
*Clytemnestra scutellata
Copilia mirabilis
Corycaeus sp.
*Corycaeus clausi
*Corycaeus flaccus
**Corycaeus lautus
Corycaeus speciosus
Eucalanus sp.
Eucalanus attenuatus
Eucalanus crassus
**Eucalanus elongatus
Eucalanus pileatus
Euchaeta marina
*Euchirella sp.
*Euchirella messinensis
*Euterpina acutifrons
Heterorhabdus sp.
Heterorhabdus papilliger
*Heterorhabdus spinifrons
Labidocera sp.
**Labidocera acutifrons
Labidocera aestiva
*Lucicutia flavicornis
*Macrosetella gracilis
Mecynocera clausi
Metridia lucens
*Microsetella rosea
Nannocalanus minor
*Oculosetella gracilis
Oithona spp.
*Oncaea sp.
*Oncaea conifera
*Oncaea mediterranea
Oncaea venusta
**Pachos sp.
Paracalanus sp.
*Paracalanus crassirostris
Paracalanus parvus

COPEPODA (continued)
Paracalanus quasimodo?
*Pareuchaeta norvegica
*Pleuromamma sp.
Pleuromamma abdominalis
Pleuromamma gracilis
Pleuromamma piseki
*Pleuromamma robusta
*Pleuromamma xiphias
**Pontella sp.
**Pontella meadii
**Pontellina plumata
**Pontellopsis regalis
**Pontellopsis villosa
Pseudocalanus sp.
*Pseudodiaptomus coronatus
Rhincalanus cornutus
Rhincalanus nasutus
**Sapphirina sp.
Sapphirina nigromaculata
**Scolecithricella ovata
Scolecithrix danae
Scottocalanus securifrons
Temora longicornis
Temora stylifera
Temora turbinata
Undeuchaeta sp.
*Undeuchaeta major
*Undeuchaeta minor
**Undeuchaeta plumosa
Undinula vulgaris
unid. caligid
unid. copepodites

CIRRIPEDIA
Lepas sp.
unid. cypris larvae

STOMATOPODA
*Platysquilla enodis
unid. stomatopod larvae

MYSIDACEA
**Bowmaniella sp.
*Heteromysis formosa
*Lophogaster americanus
Mysidopsis bigelowi
Neomysis americana
Promysis atlantica
*Pseudomma sp.
unid. mysids

Table 4-2. (Continued)

CUMACEA
*Diastylis sp.
Diastylis quadrispinosa
*Diastylis sculpta
*Leptocuma minor
*Leucon americanus
Oxyurostylis smithi

ISOPODA
*Edotea sp.
**Edotea triloba
Idotea metallica

AMPHIPODA
*Ampelisca sp.
*Ampelisca abdita
*Ampelisca agassizi
*Ampelisca vadorum
*Amphithyrus sculpturatus
Anchylomera blossevilli
*Argissa hamatipes
Brachyscelus sp.
**Brachyscelus macrocephalus
*Byblis serrata
Corophium sp.
*Erichthonius rubricornis
*Eriopisa elongata
Eupronoe armata
Eupronoe minuta
*Harpinia propinqua
Hemityphus rapax
**Hypereitta sp.
*Hypereitta vosseleri
**Iulopis loveni
*Leptocheirus pinguis
*Leptocotis tenuirostris
Lestrigonus bengalensis
**Lestrigonus crucipes
**Lestrigonus schizogeneois
*Liljeborgia sp.
**Lycaeopsis neglecta
Lycaeopsis zamboangae
*Monoculodes sp.
*Monoculodes edwardsi
*Monoculodes intermedius
*Monoculodes norvegica
**Oxycephalus sp.
**Oxycephalus clausi
*Paraphronima sp.
*Paraphronima gracilis

AMPHIPODA (continued)
Parascelus sp.
Parathemisto gaudichaudii
*Paratyphus parvus
Phronima sp.
Phronima atlantica
Phronima colletti
*Phronima pacifica
Phronima sedentaria
*Phronimella elongata
Phronimopsis sp.
*Phrosina semilunata
*Primno macropa
*Primno rectumenus
*Rhabdosoma whitei
*Scina sp.
*Scina nana
*Scina stenopus
**Stenothoe sp.
*Streetsia sp.
*Streetsia challengeri
*Streetsia steenstrupi
Tetrathyrus forcipatus
Themistella fusca
**Thyropus sphaeroma
*Tryphana malmi
*Unciola irrorata
*unid. gammarids
*unid. corophiids
*unid. hyperiids
*unid. synopiids
unid. caprellids
*unid. amphipods

EUPHAUSIACEA
Euphausia sp.
*Euphausia hemigibba
Euphausia krohnii
Euphausia mutica
*Euphausia tenera
Meganyctiphanes norvegica
*Nematoscelis atlantica
*Nematoscelis megalops
*Nematoscelis microps
*Stylocheiron sp.
*Stylocheiron abbreviatum
*Stylocheiron carinatum
Thysanoessa sp.
Thysanoessa gregaria
*Thysanoessa longicaudata
unid. euphausiids

Table 4-2. (Continued)

DECAPODA
**_Callianassa_ sp.
Callinectes sp.
Cancer sp.
Crangon septemspinosa
Dissodactylus mellitae
**_Dromidia antillensis_
*_Emerita_ sp.
Ethusa sp.
**_Homarus americanus_
**_Homola barbata_
**_Latreutes fucorum_
Leptochela sp.
Leptochela bermudensis
Leptochela papulata
Libinia sp.
Lucifer faxoni
Lucifer typus
Munida sp.
Ovalipes sp.
Parthenope sp.
Pinnixa cylindrica
*_Pinnixa sayana_
Pontophilus brevirostris
Portunus sp.
Processa sp.
Sergestes sp.
*_Solenocera_ sp.
*unid. axiids
unid. hippolytids
**unid. leucosiids
unid. majids
unid. pagurids
*unid. pandalids
unid. penaeids
unid. scyllarids
unid. xanthids
*unid. decapods

ECHINODERMATA
unid. asteroids
**unid. ophiuroids

CHAETOGNATHA
*_Eukrohnia hamata_
**_Krohnitta subtilis_
Pterosagitta draco
**_Sagitta_ sp.
*_Sagitta decipiens_
Sagitta elegans
Sagitta enflata

CHAETOGNATHA (continued)
Sagitta helenae
Sagitta hispida
*_Sagitta lyra_
Sagitta minima
Sagitta serratodentata
Sagitta tasmanica
Sagitta tenuis
**unid. chaetognaths

TUNICATA
Doliolum nationalis
Oikopleura sp.
Salpa fusiformis
**unid. thaliaceans

PISCES
Anchoa sp.
Anchoa mitchilli
*_Anguilla rostrata_
**_Astroscopus guttatus_
*_Benthosema glaciale_
Bothus sp.
*_Citharichthys arctifrons_
Cynoscion regalis
*_Gobionellus_ sp.
*_Gobiosoma_ sp.
Gobiosoma ginsburgi
**_Gonichthys cocco_
Hippocampus sp.
**_Menidia menidia_
Merluccius sp.
**_Myctophum affine_
Paralichthys dentatus
Peprilus triacanthus
*_Prionotus_ sp.
*_Rissola marginata_
**_Scomberesox saurus_
Scophthalmus aquosus
**_Sphoeroides_ sp.
Syacium sp.
**_Symbolophorus veranyi_
*_Syngnathus_ sp.
**_Syngnathus fuscus_
Urophycis sp.
**_Urophycis regius_
unid. bothids
**unid. clupeids
unid. engraulids
*unid. gadiforms
unid. gobioids

Table 4-2. (Concluded)

PISCES (continued)
unid. myctophids
*unid. ophidiids
*unid. paralepidids
**unid. serranids
*unid. sternoptychids
*unid. leptocephali
*unid. fish larvae
unclassified fish eggs

Table 4-3. Numerically dominant zooplankters in fall 1976 collections (BLM05W). Drawn from the three most abundant taxa in each tow (Day = day, N = night).

Station L1

Bongo 202	Bongo 505	Neuston 505
(5 Nov 76)	(21 Nov 76)	*Eucalanus pileatus* (4N,3D)
Paracalanus sp.	*Centropages typicus*	*Lucifer faxoni* (4N,1D)
Eucalanus pileatus	*Nannocalanus minor*	*Lestrigonus bengalensis* (2N,2D)
Centropages furcatus	*Eucalanus pileatus*	*Centropages furcatus* (2N,2D)
(21 Nov 76)		*Cancer* sp. (2D)
Nannocalanus minor		*Sagitta enflata* (1D)
Paracalanus sp.		*Sagitta helenae* (1D)
C. furcatus		

Station L2

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*C. typicus*	*C. furcatus* (4N)
Centropages typicus	*N. minor*	*Centropages typicus* (2N,1D)
Oncaea sp.	*E. pileatus*	*Nannocalanus minor* (2N,1D)
		Urophycis sp. (1N,1D)
		Parathemisto gaudichaudii (1N,1D)
		S. enflata (2D)
		Pelagia noctiluca (2D)
		Leptochela sp. (1N)
		Sagitta tasmanica (1D)
		E. pileatus (1D)
		Doliolum nationalis (1D)
		Ovalipes sp. (1D)
		Cancer sp. (1D)
		Euphausia sp. (1D)

Table 4-3. (Continued)

Station L4

Bongo 202	Bongo 505	Neuston 505
Pleuromamma gracilis	N. minor	C. typicus (4N,2D)
Paracalanus sp.	C. typicus	N. minor (3N,1D)
Rhincalanus nasutus	Pleuromamma gracilis	Pleuromamma gracilis (3N)
		D. nationalis (2D)
		Rhincalanus nasutus (1N)
		P. gaudichaudii (1N)
		unid. fish eggs (1D)
		unid. siphonophores (1D)
		S. enflata (1D)
		Urophycis sp. (1D)
		Temora stylifera (1D)
		Idotea metallica (1D)
		Euphausia sp. (1D)

Station L6

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	P. gracilis	P. gaudichaudii (4N,4D)
P. gracilis	N. minor	P. gracilis (3N,1D)
C. typicus	Pleuromamma robusta	C. typicus (2N,2D)
		N. minor (2N)
		unid. fish eggs (2D)
		L. bengalensis (1N)
		T. stylifera (1D)
		Thysanoessa sp. (1D)
		Thysanoessa gregaria (1D)

Table 4-3. (Continued)

Station C1

Bongo 202	Bongo 505	Neuston 505
C. typicus	*C. typicus*	*C. typicus* (4N,4D)
Paracalanus sp.	*E. pileatus*	*S. enflata* (4N,3D)
Acartia tonsa	*Neomysis americana*	*Labidocera aestiva* (3N,2D)
		E. pileatus (1N,2D)
		Neomysis americana (1D)

Station D1

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*C. typicus*	*C. typicus* (1N)
C. typicus	*N. minor*	*N. minor* (1N)
E. pileatus	*Metridia lucens*	*Metridia lucens* (1N)

Station N3

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*C. typicus*	*C. typicus* (1N)
C. typicus	*N. minor*	*M. lucens* (1N)
E. pileatus	*Rhincalanus nasutus*	*R. nasutus* (1N)

Station E3

Bongo 202 (4 tows)	Bongo 505 (4 tows)	Neuston 505
Paracalanus sp. (4)	*C. typicus* (4)	*C. typicus* (4N,1D)
C. typicus (4)	*N. minor* (4)	*M. lucens* (4N,1D)
immature *N. minor* (3)	*R. nasutus* (4)	*P. gaudichaudii* (3D)
Oithona spp. (1)		*Cancer* sp. (3D)
		N. minor (2N)
		I. metallica (1D)
		Anomalocera ornata (1D)
		Thysanoessa sp. (1D)
		Euphausia sp. (1N)

Table 4-3. (Continued)

Station F2

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*P. gracilis*	*P. gracilis* (1N)
P. gracilis	*C. typicus*	*C. typicus* (1N)
Oithona spp.	*M. lucens*	*M. lucens* (1N)

Station J1

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*P. gracilis*	*C. typicus* (4N,4D)
C. typicus	*C. typicus*	*P. gracilis* (4N,1D)
P. gracilis	*M. lucens*	*P. gaudichaudii* (3N,1D)
		N. minor (1N,2D)
		I. metallica (1D)
		Paracalanus sp. (1D)
		R. nasutus (1D)
		Anomalocera patersonii (1D)

Station B5

Bongo 202 (4 tows)	Bongo 505 (4 tows)	Neuston 505
Paracalanus sp. (4)	*C. typicus* (4)	*C. typicus* (4N,4D)
C. typicus (4)	*N. minor* (4)	*N. minor* (3N,1D)
imm. *N. minor* (3)	*P. gaudichaudii* (3)	*P. gaudichaudii* (3D)
N. minor (1)	imm. *N. minor* (1)	*Cancer* sp. (2D)
		M. lucens (1N,1D)
		imm. *N. minor* (2N)
		Paracalanus sp. (2N)
		Urophycis sp. (1D)

Table 4-3. (Concluded)

Station A2

Bongo 202 (4 tows)	Bongo 505 (4 tows)	Neuston 505
Paracalanus sp. (4)	*C. typicus* (4)	*C. typicus* (4N,4D)
C. typicus (4)	*P. gracilis* (4)	*P. gracilis* (3N,1D)
P. gracilis (4)	*N. minor* (3)	imm. *N. minor* (2D)
	R. nasutus (1)	*P. gaudichaudii* (2D)
		M. lucens (1N,1D)
		N. minor (1N)
		Calanus finmarchicus (1N)
		unid. calanoid (1D)
		unid majid (Decapoda) (1D)
		Euphausia sp. (1N)
		S. tasmanica (1N)

Diel Cycles of Dominant Neustonts

Station L1. Neuston tows at the coastal station off Virginia were taken approximately two weeks before other collections and might be expected to contain a higher predominance of warm-water fauna. Surface temperatures at Station L1 decreased 3°C (from 15.4 to 12.4°C) from November 5 to November 22; salinity remained at 33.2‰. However, certain key species such as Centropages furcatus and Sagitta enflata were among the dominants at both L1 and L2, suggesting little seasonal succession in that particular two-week period. Seven of the eight neuston collections at Station L1 were numerically dominated by the copepod Eucalanus pileatus; the mid-day tow was dominated by S. enflata (Figure 4-2).* All of the more abundant species were present throughout the 24-hr period, most of them increasing slightly in night collections.

Station L2. Although copepods as a group predominated in five of the eight collections at L2, counts of individual species showed dominance in only two of these, in both cases Centropages typicus. Numerical dominants in other tows included Pelagia noctiluca, Urophycis sp. larvae (2 tows), Sagitta enflata, Doliolum nationalis, and immature Euphausia sp. Other species occasionally abundant in the neuston and not shown on Figure 4-3 included Leptochela sp., Cancer sp. and Sagitta tasmanica. A greater daytime decrease in neuston numbers was evident at L2 compared with L1, with differences in day and night numbers of the more abundant species ranging between two and three orders of magnitude.

Station L4. Copepods as a group dominated six of the eight neuston collections at L4. In four of these, an individual species of copepod ranked highest in abundance, Pleuromamma gracilis in three night tows, Centropages typicus in another tow. Other numerical dominants included Parathemisto gaudichaudii, Doliolum nationalis (2 tows), and Urophycis sp. larvae. The hyperiid amphipod, P. gaudichaudii, peaked near dawn (Figure 4-4) as it did also at Station L2. Other species shown on Figure 4-4 show a more typical rise in numbers at night. P. gracilis is a particularly strong vertical migrator, and increased in the surface layer from absence or very low abundance in daytime to over 35,000 per standard 20-min. tow at midnight.

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* In Figure 4-2 and all similar figures to follow in this report, species were selected for graphing according to the frequency of their dominance among the eight neuston tows at each station (those ranking among the three most abundant taxa). Thus, species numerically dominant in only one or two tows (patchy) may be excluded from the figures due to graphing limitations.

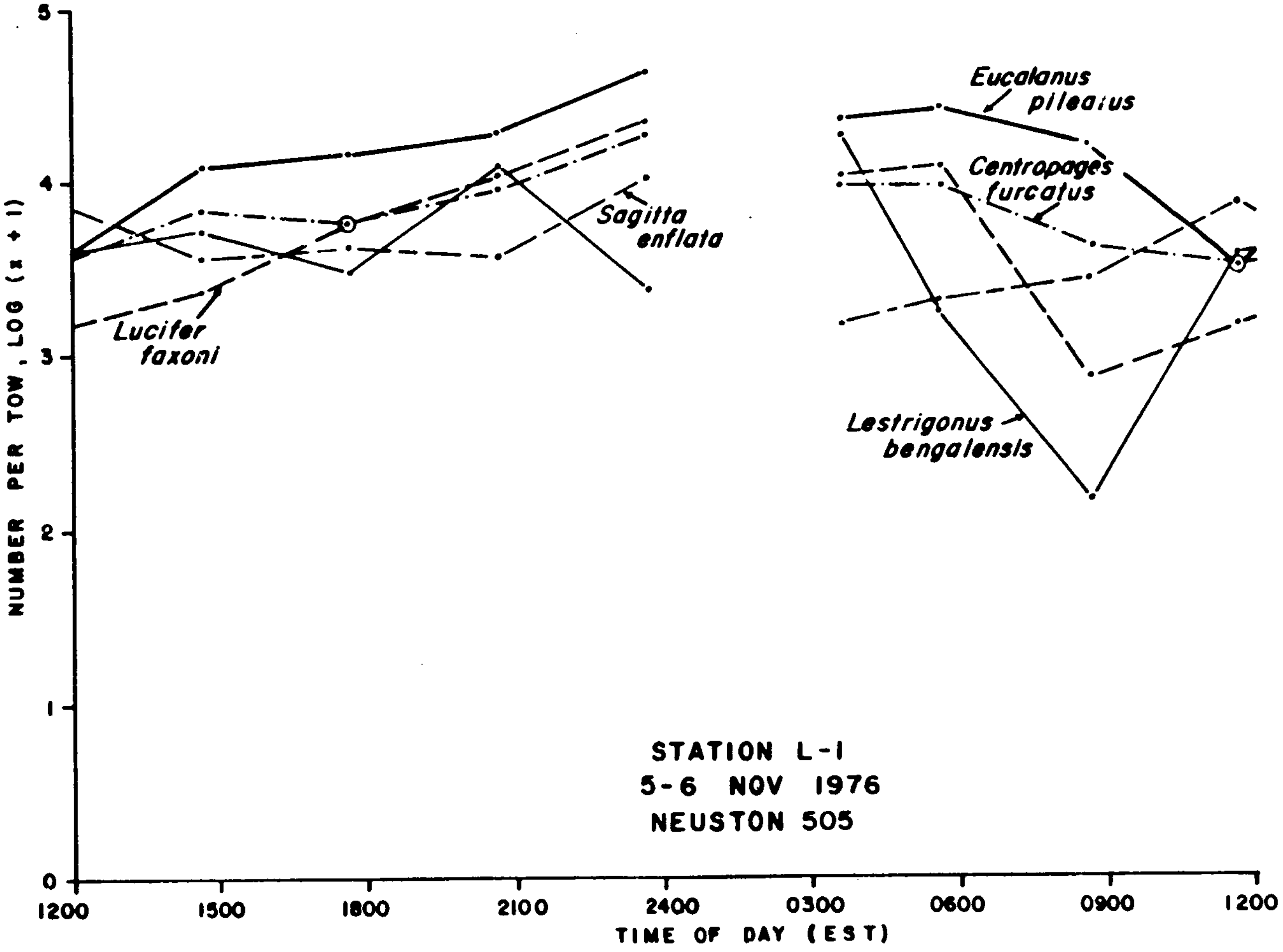

Figure 4-2. Diel cycle of dominant neustonts at Station L1, BLM05W.

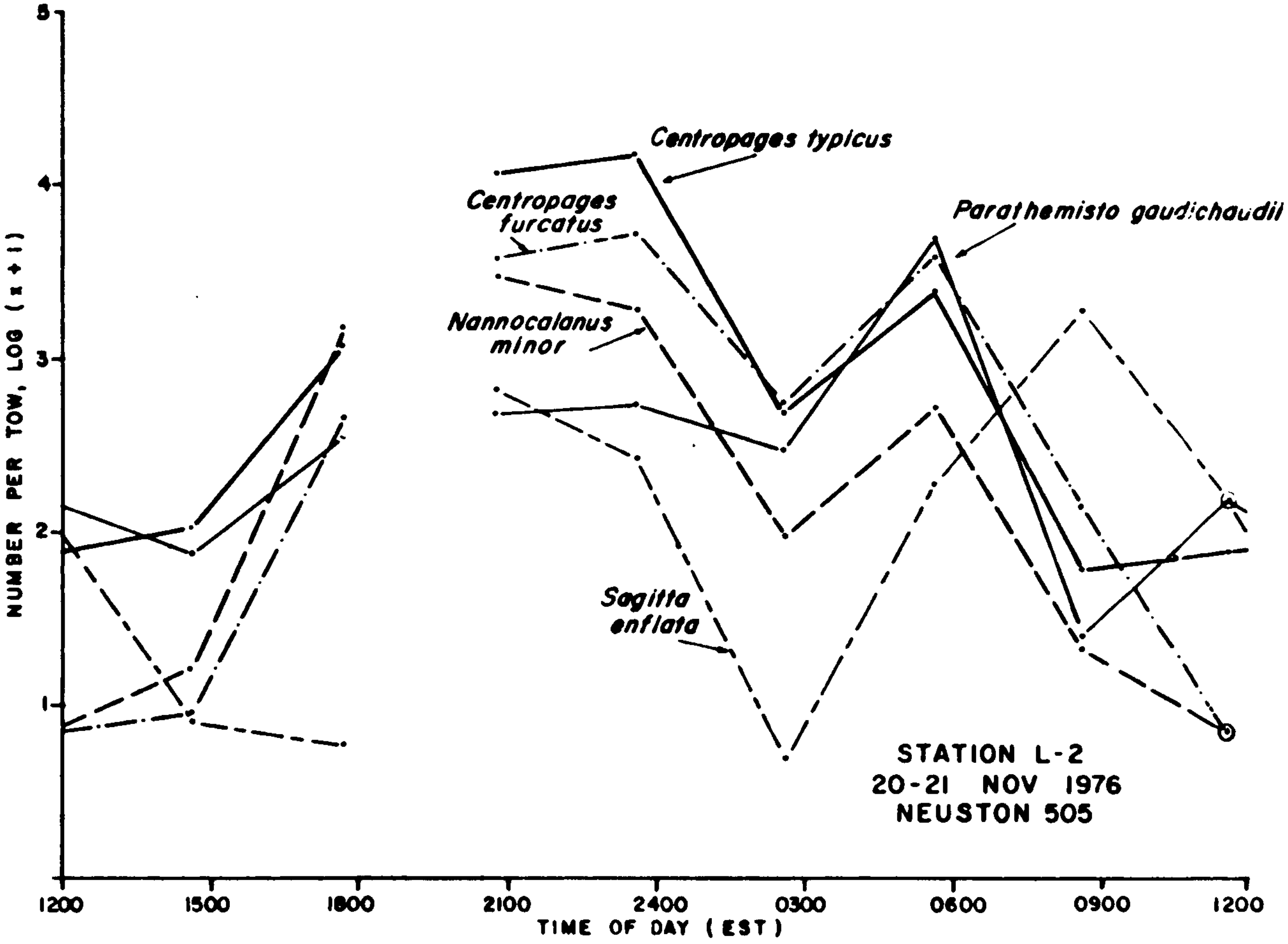

Figure 4-3. Diel cycle of dominant neustonts at Station L2, BLM05W.

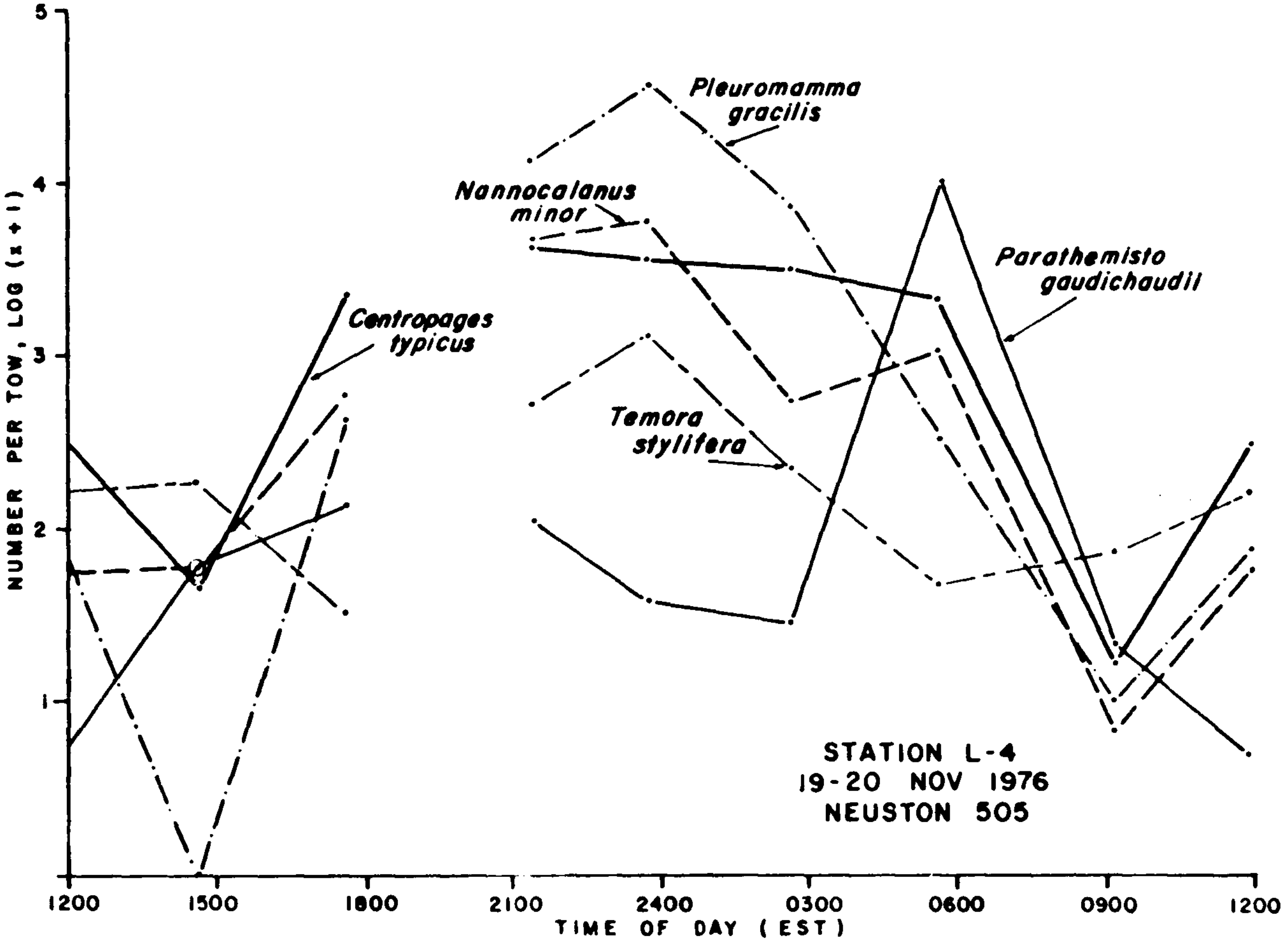

Figure 4-4. Diel cycle of dominant neustonts at Station L4, BLM05W.

Station L6. Four of the eight neuston collections were dominated by copepods as a group, and in each case by the individual species *Pleuromamma gracilis*. *Parathemisto gaudichaudii* was predominant in three tows, immature *Thysanoessa* sp. in the remaining tow. *P. gaudichaudii* exhibited a bimodal peak in late afternoon and at dawn (Figure 4-5).

Neuston collections in the southern L-transect showed a progression from a coastal community (*Eucalanus pileatus* - *Centropages furcatus* - *Lucifer faxoni*) that remained at relatively constant abundance during a 24-hr period, through a Central Shelf community typified by *Centropages typicus* that shows moderate increases at night, to an offshore group dominated by *P. gracilis* and *Parathemisto gaudichaudii*, strong vertical migrators. This change across the shelf is directly related to depth of the water column and to presence, at depth during daylight hours, of deeper-living communities containing active vertical migrators.

Station C1. Neuston at the coastal New Jersey station C1 was dominated by copepods (*Centropages typicus*) in seven of eight tows, and by the mysid *Neomysis americana* in the remaining collection. *N. americana* peaked at dusk, while other dominants were variable in number throughout the day (Figure 4-6).

Station E3. Five of the eight neuston tows were dominated by copepods (*Centropages typicus*), two by amphipods (*Parathemisto gaudichaudii*) and one by decapod larvae (*Cancer* sp.). Both *C. typicus* and *Metridia lucens* increased greatly at night, while *P. gaudichaudii* had an early morning peak as seen in the southern transect at stations L2 and L4. *Cancer* sp. was present at fairly level abundance throughout the sampling period (Figure 4-7). Other important neustonts included *Idotea metallica*, *Anomalocera ornata*, *Pleuromamma gracilis*, *Nannocalanus minor*, and immature stages of *Euphausia* sp., and *Thysanoessa* sp.

Station J1. Copepods were predominant in all eight neuston collections, with *Centropages typicus* the most abundant species, outranked in only one tow by *Pleuromamma gracilis*. The former species was present in abundance throughout the day of sampling; other abundant species (*P. gracilis*, *Nannocalanuus minor* and *Parathemisto gaudichaudii*) showed increases in early evening hours (Figure 4-8). Other important neustonts included *Urophycis* sp. larvae, *Anomalocera patersonii*, and *Rhincalanus nasutus*.

Station B5. Five neuston tows were dominated by copepods (*Centropages typicus*), the remaining three by amphipods (*Parathemisto gaudichaudii*). The latter species was bimodally abundant, in afternoons and early morning tows, similar to its diel distribution at Station L6. The dominant and subdominant copepods *C. typicus* and *Nannocalanus minor* and the larvae of *Cancer* sp. increased sharply in night tows, with a slight decrease in midnight tows (Figure 4-9).

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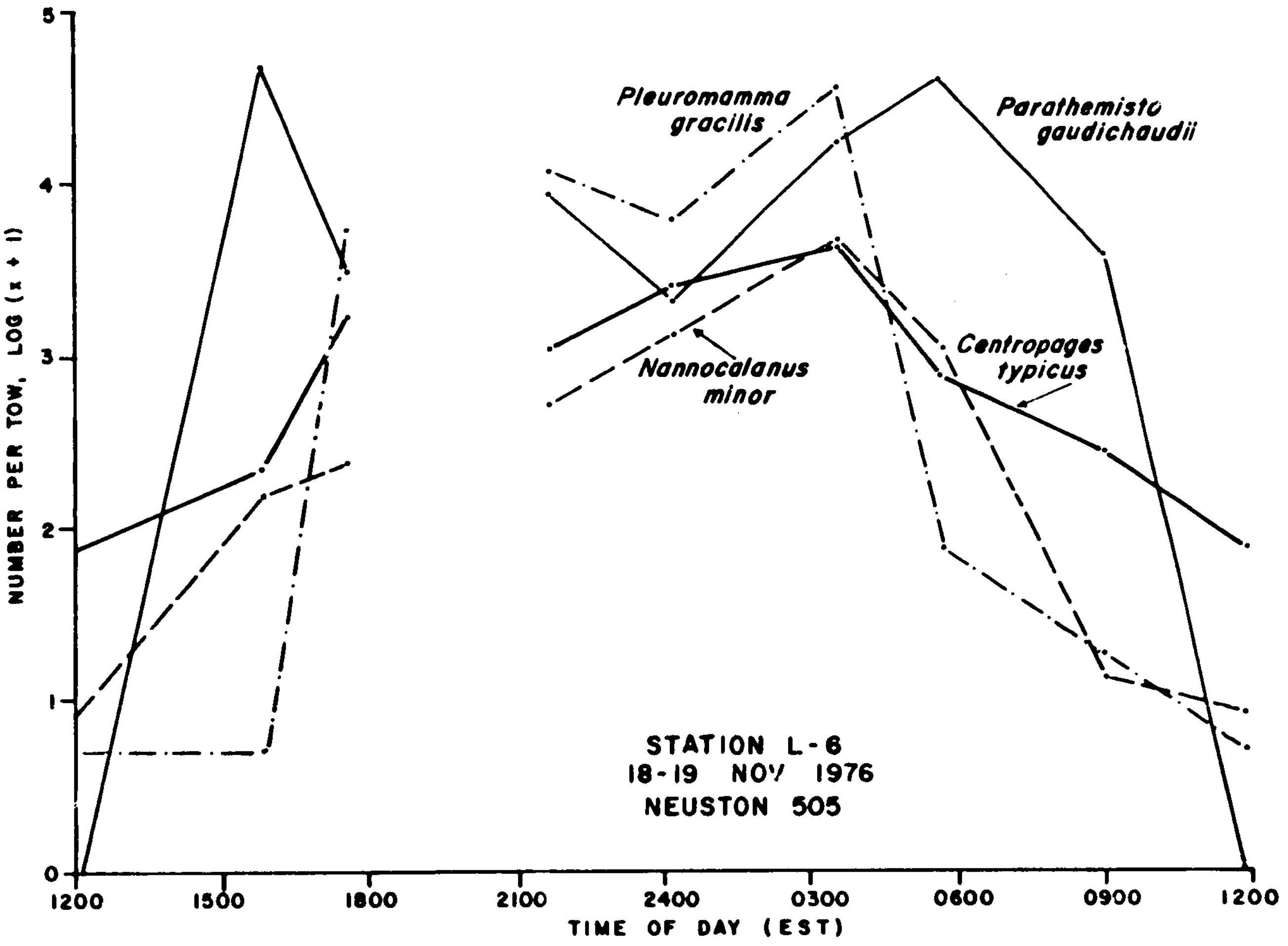

Figure 4-5. Diel cycle of dominant neustonts at Station L6, BLM05W.

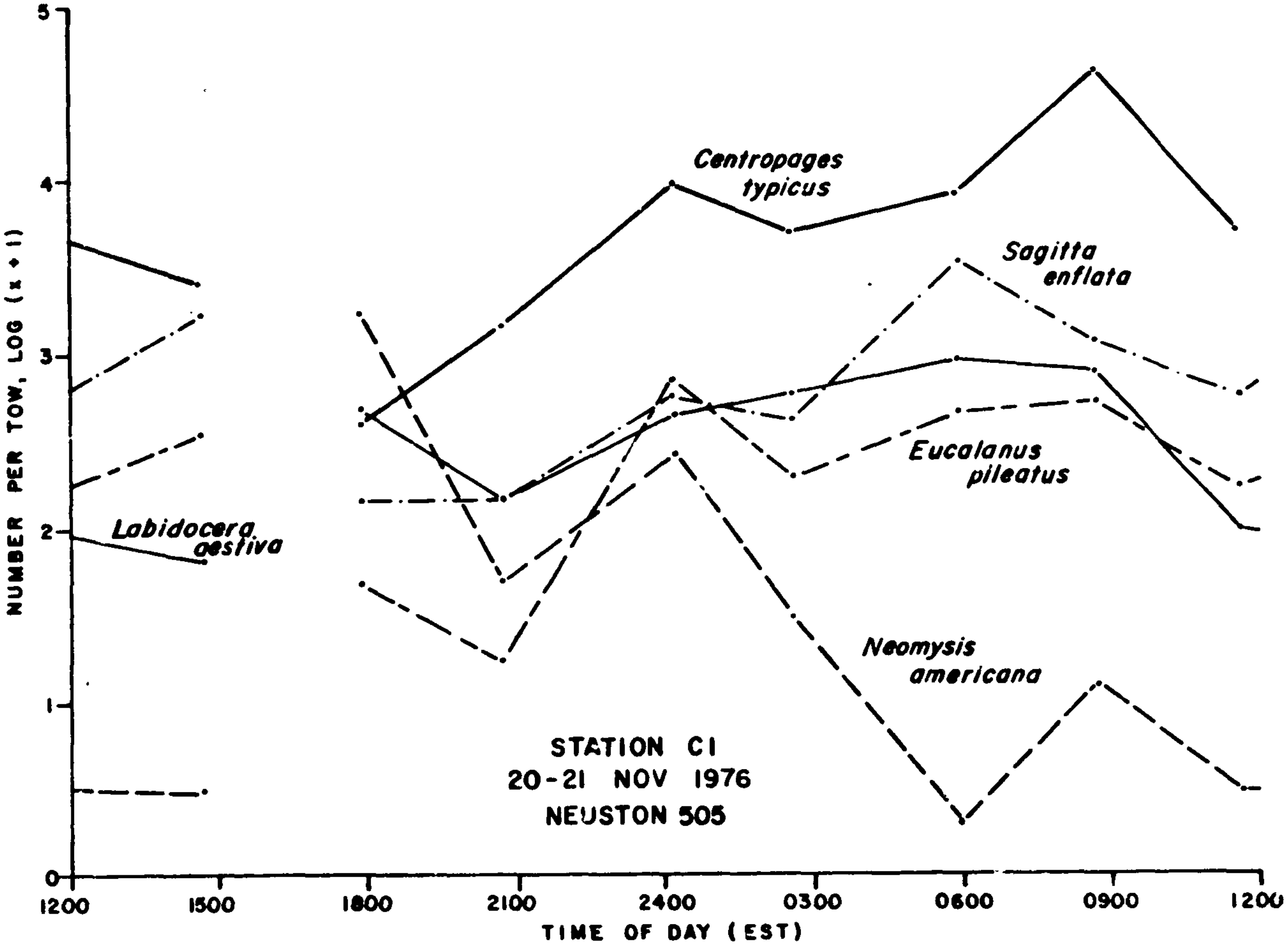

Figure 4-6. Diel cycle of dominant neustonts at Station C1, BLM05W.

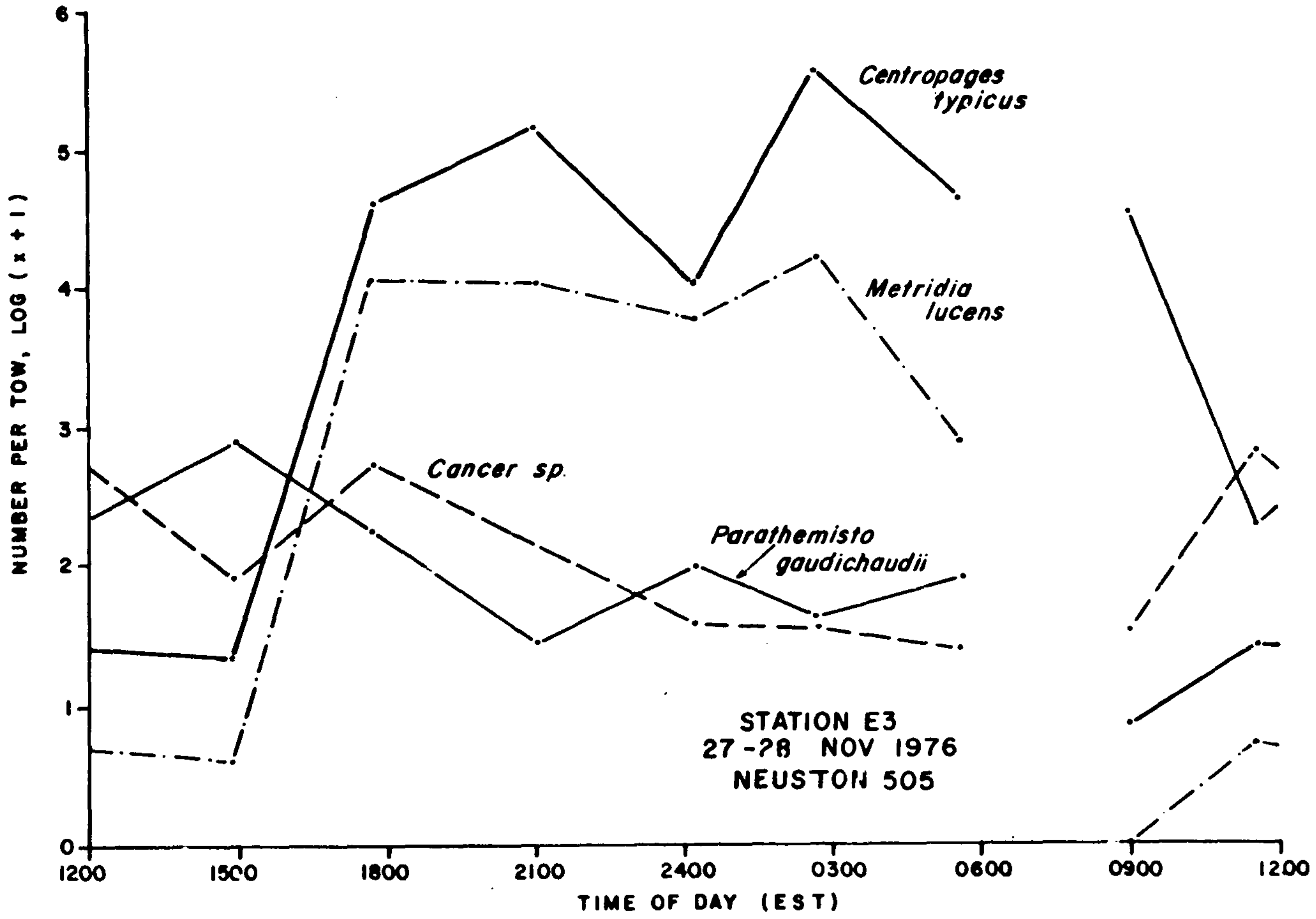

Figure 4-7. Diel cycle of dominant neustonts at Station E3, BLM05W.

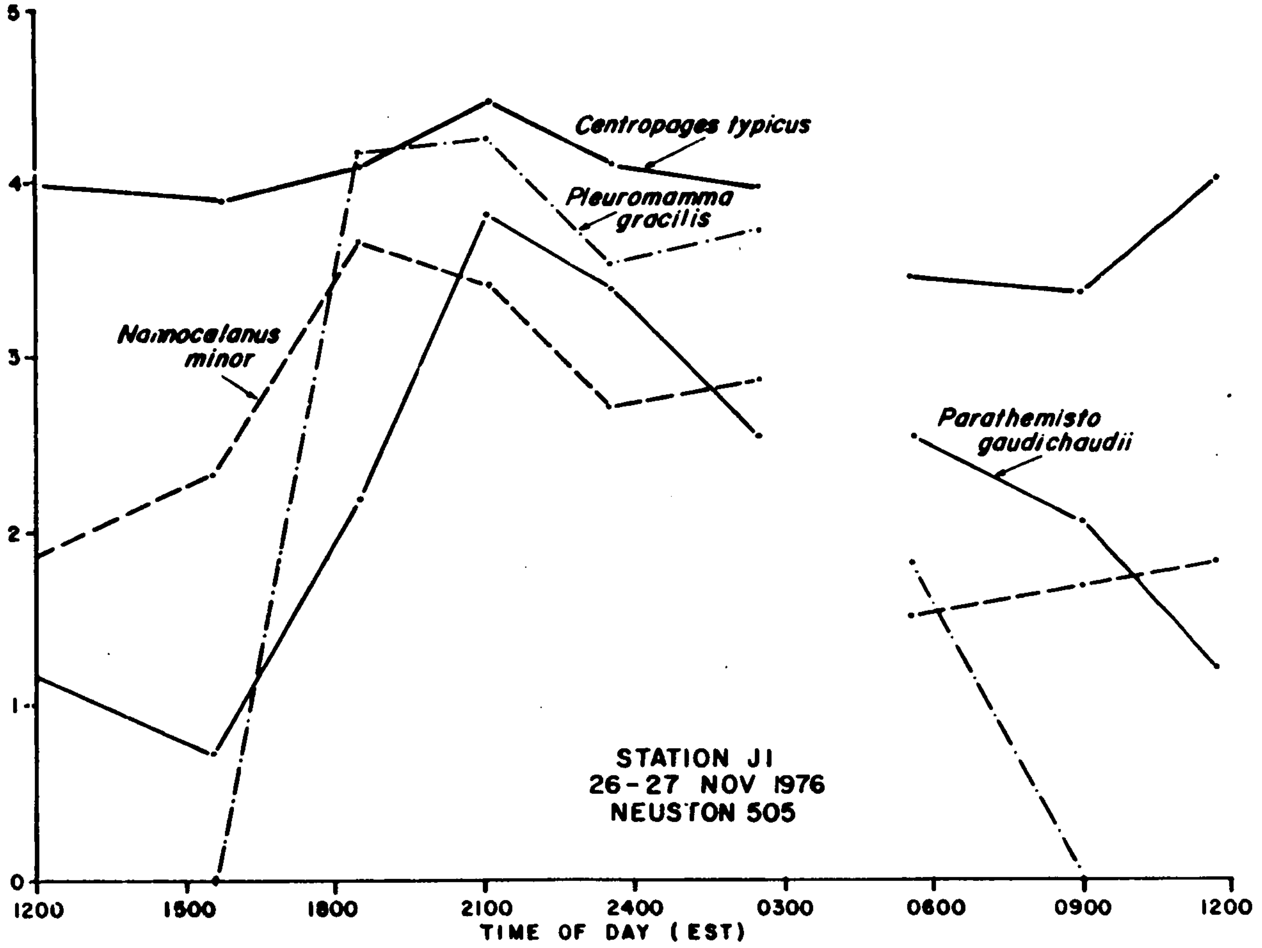

Figure 4-8. Diel cycle of dominant neustonts at Station J1, BLM05W.

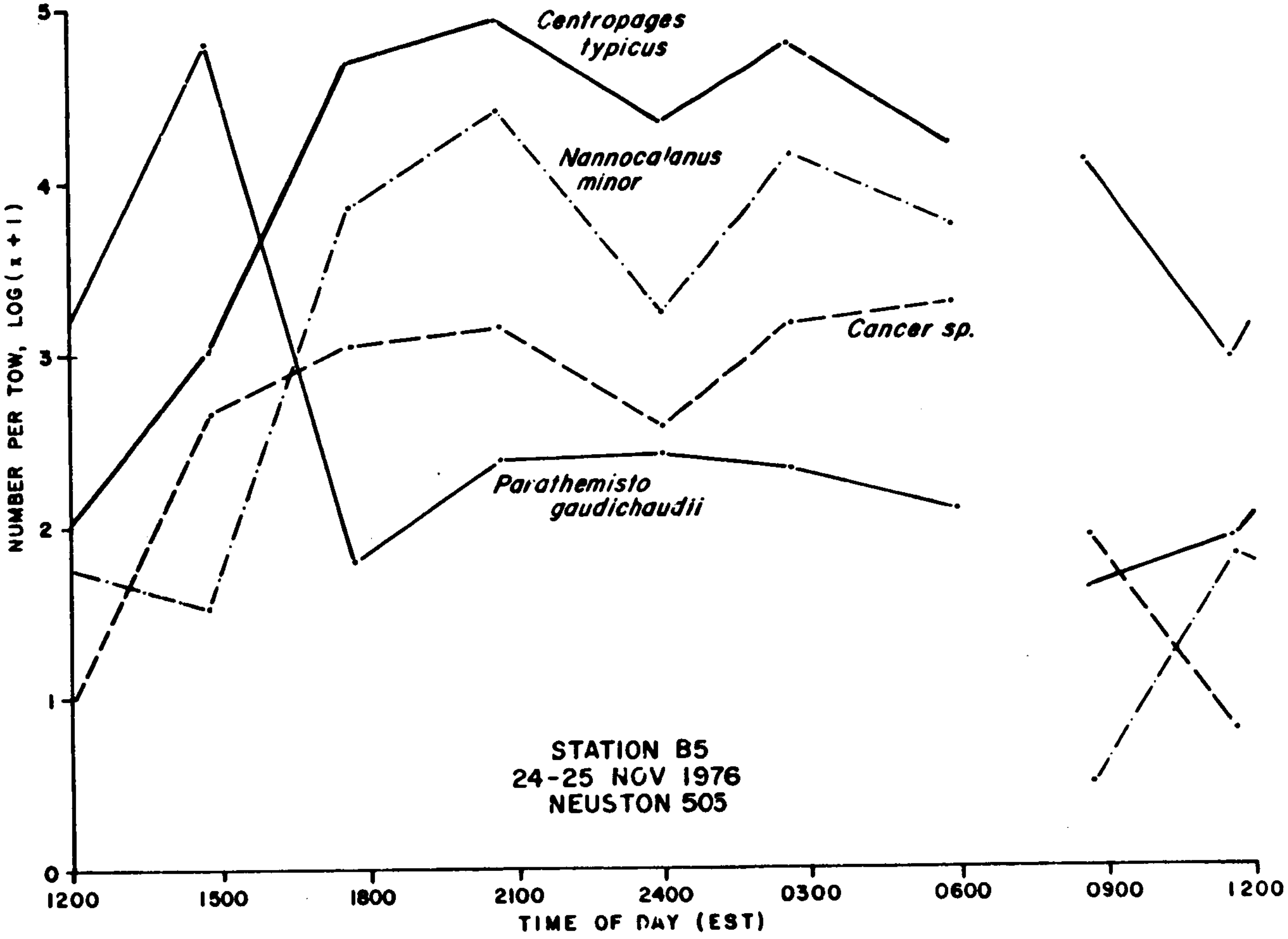

Figure 4-9. Diel cycle of dominant neustonts at Station B5, BLM05W.

Other important species included Urophycis sp., Metridia lucens and Paracalanus sp.

Station A2. As a group, copepods predominated in all eight neuston tows at A2, although Parathemisto gaudichaudii was the most abundant species in the noontime tow. Centropages typicus was most numerous among copepods in four of the tows; Pleuromamma gracilis predominated in the remainder. C. typicus remained numerous throughout the day as at Station J1, while P. gracilis and Metridia lucens displayed the nighttime increase typical of strong vertical migrators. P. gaudichaudii at this station showed a midday maximum (Figure 4-10), in contrast to the patterns of surface abundance observed at other stations.

Neuston collections off New Jersey were more heavily dominated by C. typicus than those from the southern transect. An increase in the strength of vertical migration was again evident with distance from the coast. Differences included a maintenance of abundance levels throughout the day by C. typicus in offshore stations J1 and A2, and a variety of diel patterns displayed by P. gaudichaudii.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent species in fall 1976 bongo collections are listed in Table 4-4, and those from neuston collections in Table 4-5. Centropages typicus was the most frequently occurring species in both bongo and neuston collections. Eight of the 11 most frequent neuston species are also found in the list of common bongo species, many of them with similar occurrence frequencies. The other three most frequent neuston species (Idotea metallica, Urophycis sp., and Eucalanus pileatus) were more closely associated with the surface layer.

Estimates of average abundance from 202 μm bongo nets nearly always exceeded those from 505 μm nets. Loss of small organisms through the 505 μm mesh was evident in catches of adult and immature Nannocalanus minor:

	Average Catch/100m^3	
	505 μm	202 μm
adults	5,455	18,670
copepodites	96	27,533

and in the catches of unidentified polychaetes. Apparent losses through the 505 μm mesh of the larger, listed species also occurred.

Diversity. Three measurements of diversity are listed for each collection in Table 4-6, with stations arranged from inshore to

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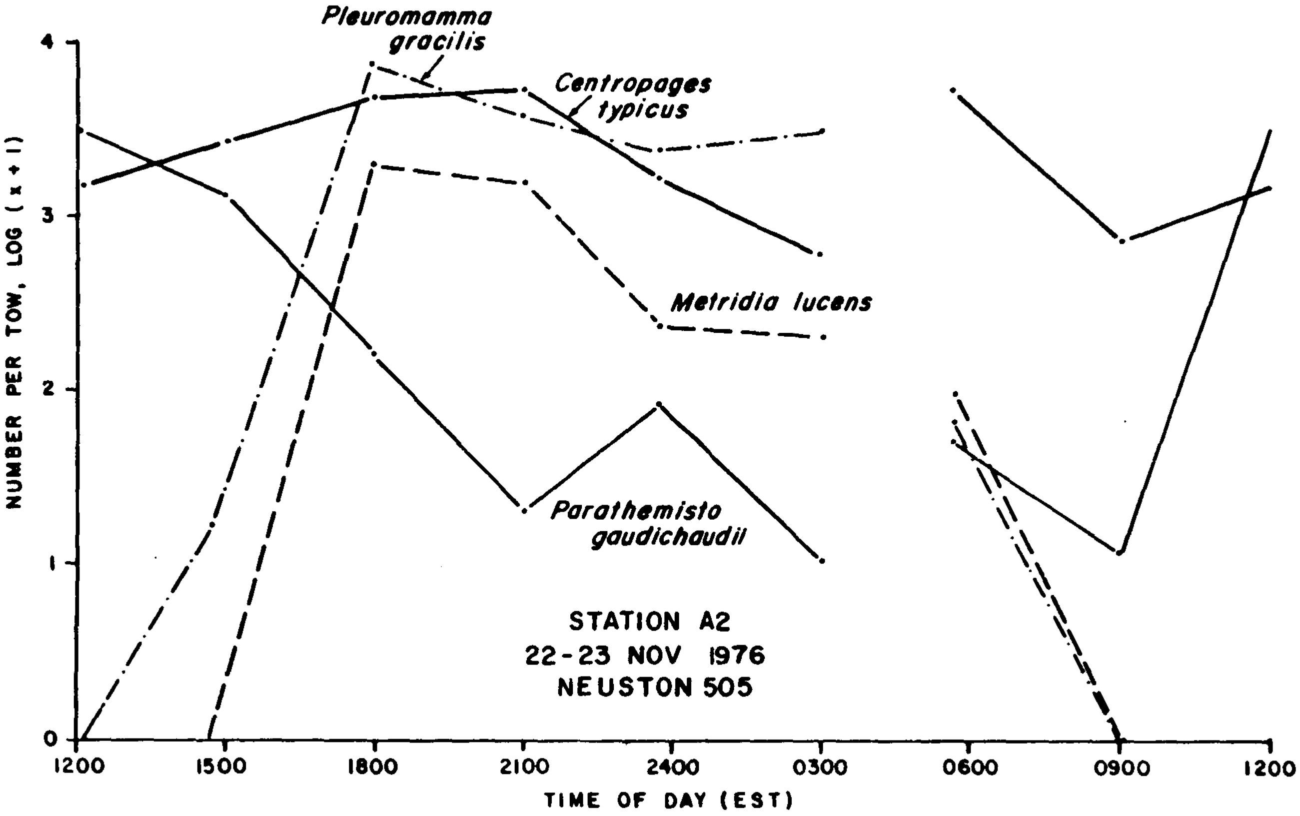

Figure 4-10. Diel cycle of dominant neustonts at Station A2, BLM05W.

Table 4-4. Frequency of occurrence and abundance of common species in bongo collections, BLM05W.

Species	Percent Occurrence	Mean Catch per 100 m^3		Max. Catch per 100 m^3
		505 μm	202 μm	
Centropages typicus	100	61,052	159,622	974,189
Parathemisto gaudichaudii	95	1,434	2,366	7,688
Sagitta tasmanica	95	472	1,566	5,816
Nannocalanus minor (adults)	91	5,455	18,670	443,901
Euphausia sp.	91	395	520	4,298
Thysanoessa sp.	88	196	338	2,017
Cancer sp.	84	126	184	755
Pleuromamma gracilis	81	1,594	13,396	163,838
Metridia lucens	77	1,963	4,485	29,521
Rhincalanus nasutus	72	1,831	3,623	20,916
Sagitta enflata	72	101	220	22,756
unid. polychaetes	70	2	87	625
Sagitta minima	65	10	55	356
Conchoecia curta	65	18	15	123
Ovalipes sp.	56	11	107	4,114
N. minor (copepodites)	53	96	27,533	265,270
Centropages violaceus	53	221	840	10,458
Diphyes dispar	53	3	7	77
Atlanta peroni	53	2	2	89
Candacia armata	51	955	1,070	10,067
unid. euphausiids	49	18	13	221
Acartia danae	44	170	1,315	11,378
Scolecithrix danae	44	261	481	3,486

Table 4-5. Frequency of occurrence and average abundance of common species in neuston collections, BLM05W.

Species	Percent Occurrence	Mean Catch per Standard Tow	Max. Catch per Standard Tow
Centropages typicus	99	19,269	358,910
Nannocalanus minor	89	1,859	31,744
Parathemisto gaudichaudii	85	3,323	61,440
Idotea metallica	84	23	174
Cancer sp.	79	639	14,208
Sagitta enflata	77	645	11,008
Urophycis sp.	77	122	5,184
Pleuromamma gracilis	67	3,645	113,660
Metridia lucens	67	1,291	15,872
Sagitta tasmanica	67	82	936
Eucalanus pileatus	63	2,266	44,032
Rhincalanus nasutus	60	261	4,608
Euphausia sp.	59	233	2,816
Thysanoessa sp.	55	904	67,072
Candacia armata	51	120	3,584
Scolecithrix danae	51	45	1,024
Sagitta minima	51	6	84
Lucifer faxoni	49	1,095	22,592
Diphyes dispar	47	38	704
Calanus finmarchicus	44	97	1,536
Conchoecia curta	44	1	16
Centropages violaceus	43	72	1,408

Table 4-6. Diversity of surface and subsurface zooplankton collections, BLM05W. H' = Shannon index (base-2); J' = evenness; Richness = Margalef's index of species richness; N = night, D = day, Ns = neuston, B = bongo.

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L1	Z76-273	Ns, N	3.0615	0.6069	2.8195
	-274	Ns, N	2.9281	0.5162	4.4984
	-275	Ns, D	2.8025	0.5556	2.9573
	-276	Ns, D	3.4682	0.6279	4.3254
	-277	Ns, D	3.0992	0.6144	3.0144
	-278	Ns, D	2.9447	0.5245	4.5359
	-279	Ns, N	3.2749	0.5544	5.3038
	-280	B202, N	2.7357	0.5377	2.6264
	-281	Ns, N	2.7851	0.5269	3.2617
	-317	B505, N	3.2502	0.7185	3.6688
	-318	B202, N	1.8899	0.3576	2.6989
L2	Z76-307	Ns, N	3.1016	0.5415	5.1103
	-308	B505, N	2.8929	0.4550	6.1756
	-309	B202, N	2.2379	0.4007	3.4395
	-310	Ns, N	2.7404	0.4881	4.6746
	-311	Ns, N	3.2578	0.6208	4.2964
	-312	Ns, N	3.2747	0.5863	4.6524
	-313	Ns, D	2.5968	0.5402	3.3487
	-314	Ns, D	3.5015	0.7068	4.4308
	-315	Ns, D	1.7706	0.3374	4.5683
	-316	Ns, D	3.3131	0.6408	3.9541
L4	Z76-297	Ns, N	2.5818	0.4407	5.5843
	-298	B202, N	4.0798	0.7386	4.1791
	-299	B505, N	3.6234	0.5568	7.8131
	-300	Ns, N	2.0792	0.3613	4.8541
	-301	Ns, N	2.3932	0.4308	4.8106
	-302	Ns, N	1.8165	0.3202	5.2246
	-303	Ns, D	4.1441	0.7546	6.5096
	-304	Ns, D	3.3849	0.6128	5.6096
	-305	Ns, D	4.3943	0.7709	6.8574
	-306	Ns, D	3.1472	0.5521	5.8663
L6	Z76-288	Ns, N	3.0615	0.6069	2.8195
	-289	B505, N	3.4593	0.5931	5.6723
	-290	B202, N	2.9815	0.4593	6.4503
	-291	Ns, N	3.0204	0.5143	6.0343
	-292	Ns, N	2.2612	0.3844	5.2164
	-293	Ns, N	0.8773	0.1498	5.3462
	-993	Ns, D	1.2753	0.2365	4.8938
	-294	Ns, D	3.2355	0.5891	6.7048

Table 4-6 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L6	Z76-295	Ns, D	1.8623	0.3081	5.4617
	-296	Ns, D	2.6022	0.4588	5.2868
C1	Z76-327	Ns, D	2.3526	0.5066	2.9735
	-328	Ns, N	1.9064	0.4158	3.0164
	-329	B202, N	2.6894	0.4956	3.1447
	-330	B505, N	1.5218	0.2921	3.5009
	-331	Ns, N	1.6216	0.3537	2.4449
	-332	Ns, N	1.8026	0.4104	2.2587
	-333	Ns, N	1.9070	0.4011	2.7265
	-334	Ns, D	0.5353	0.1338	1.4051
	-335	Ns, D	1.1172	0.2733	1.8457
	-336	Ns, D	1.8734	0.4265	2.3448
D1	Z76-320	B505, N	1.0457	0.2073	2.1054
	-321	B202, N	-	-	-
	-322	Ns, N	0.9260	0.1791	2.7038
N3	Z76-323	B505, N	1.7826	0.3285	3.0070
	-324	Ns, N	2.8738	0.6188	2.3052
	-325	B202, N	1.4708	0.2997	1.8658
E3	Z76-396	Ns, D	0.0270	0.0085	0.7699
	-397	Ns, D	1.9152	0.4234	3.1853
	-398	Ns, D	1.5353	0.3194	3.8980
	Z76-399	Ns, D	1.9832	0.4589	1.6904
	-400	B505, N	1.0355	0.2203	1.9317
	-401	B202, N	2.1518	0.4693	1.7490
	-402	B202, N	2.2480	0.4728	1.6911
	-403	B505, N	1.1590	0.2298	2.4266
	-404	B505, N	0.8520	0.1835	1.7267
	-405	B202, N	1.7938	0.3773	1.7315
	-406	B505, N	1.2453	0.2649	1.9614
	-407	B202, N	1.9318	0.4160	1.7143
	-408	Ns, N	1.0223	0.2407	1.4966
	-417	Ns, N	2.7268	0.5872	2.3445
	-418	Ns, N	0.7331	0.1644	1.6283
	-419	Ns, N	0.3784	0.0994	1.2120
F2	Z76-388	Ns, N	1.1816	0.2363	2.5946
	-389	B202, N	1.8204	0.3095	4.6601
	-390	B505, N	1.9588	0.3706	3.6674

Table 4-6 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
J1	Z76-383	Ns, N	1.1443	0.2464	2.9495
	-384	Ns, D	1.1268	0.2653	2.2750
	-385	Ns, D	0.4294	0.1030	1.8341
	-386	Ns, D	0.3950	0.0988	1.6644
	-387	Ns, D	1.7985	0.3479	3.3640
	-391	Ns, N	1.8479	0.3547	3.2861
	-392	B202, N	2.3397	0.3792	5.5795
	-393	B505, N	3.3052	0.5887	4.8371
	-394	Ns, N	1.9518	0.3643	4.0316
	-395	Ns, N	1.9131	0.3595	4.0082
B5	Z76-345	Ns, D	0.1591	0.0389	1.6963
	-346	Ns, D	1.3755	0.3521	1.9880
	-347	Ns, D	0.2247	0.0562	1.3571
	-348	Ns, D	1.4048	0.3369	1.5338
	Z76-349	B505, N	1.3008	0.2626	2.2466
	-350	B202, N	1.4828	0.3052	1.9048
	-351	B505, N	2.1213	0.4103	3.0223
	-352	B202, N	1.6954	0.3455	2.0430
	-353	Ns, N	1.7810	0.4055	1.6980
	-354	B505, N	2.0060	0.3851	2.9310
	-355	B202, N	1.5062	0.2712	3.1230
	-356	B505, N	1.6283	0.3387	2.4144
	-357	B202, N	1.7387	0.4093	1.2261
	-366	Ns, N	1.0527	0.2576	1.5768
	-367	Ns, N	1.9789	0.4261	2.0922
	-368	Ns, N	2.3240	0.5069	2.1756
A2	Z76-337	Ns, N	2.1147	0.4310	3.1788
	-338	Ns, D	2.3340	0.5400	2.6594
	-339	Ns, D	1.3958	0.3347	1.9321
	-340	Ns, D	1.9002	0.3873	3.4193
	-341	Ns, D	2.0805	0.4814	1.9580
	-342	Ns, N	2.7263	0.5671	2.7985
	-343	Ns, N	2.3592	0.4718	3.5822
	-344	Ns, N	2.1194	0.4509	2.9849
	-369	B505, N	2.8446	0.4759	5.5098
	-370	B202, N	2.5455	0.4275	4.0620
	-371	B505, N	2.9892	0.4910	5.7942
	-372	B202, N	2.9034	0.4803	4.9708
	-373	B505, N	3.0828	0.5717	3.6318

Table 4-6 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
A2	Z76-374	B202, N	2.9535	0.4756	5.5876
	-375	B505, N	3.1074	0.5105	5.8505
	-376	B202, N	2.5713	0.4556	3.7365

offshore within southern to northern transects. Diversity of collections obtained with 505 μm bongo nets tended to be greater than collections taken with 202 μm nets (higher H' in 12 of 20 pairs; higher richness index in 13 of 20 pairs). The greater efficiency of 202 μm mesh nets in capture of the generally abundant smaller forms probably contributed to these lower diversity indices. Diversity was highest in the southern transect (L-stations), and generally increased from the coast offshore. Maximum richness (7.8131) occurred in a bongo 505 collection at Station L4 that included 91 identified taxa, minimum richness (0.7699) in a daytime neuston collection from Station E3 containing only nine taxa.

Cluster Analyses. Clustering of subsurface bongo and surface neuston collections was performed separately. In both cases, species occurring in less than 5% of the collections were omitted from the analysis.

I. Bongo collections. Clusters of 43 bongo samples from BLM05W are shown in Figure 4-11. Basic divisions of samples included samples from:

1. Coastal and southern
2. Northern central shelf
3. Outer shelf and slope

Within these principal clusters were subgroups of southern transect samples; samples from stations D1 and N3; replicate samples from stations B5, E3, and A2; and samples from the shelf-break and slope stations L6, F2, and J1.

Inverse species clusters and results of a nodal analysis that relates species groups to sample clusters are shown in Figures 4-12 and 4-13, respectively. Individual collections and species comprising the sample and species clusters are identified in Table 4-7. The diagonal of dense cells in the abundance side of Figure 4-13 shows that relative abundance within sample groups was the prime factor in positioning species groups. Species group A is a small group of species closely associated with Sample group I, i.e. inshore stations C1 and L1, and included well-recognized coastal species *Acartia tonsa*, *Neomysis americana*, *Sagitta tenuis* and a few others. Species groups A-D, collectively, were most typical of Sample groups I-III, which together include all inner shelf sites (C1, D1, N3, L1, L2) and most remaining southern samples. Species groups B-D included warm-water representatives of all the major taxonomic groups, including *Pelagia noctiluca*, *Euconchoecia chierchiae*, *Centropages furcatus*, *Eucalanus pileatus*, *Temora stylifera*, *T. turbinata*, *Corycaeus* spp., *Oncaea* spp., *Lestrigonus bengalensis*, *Lucifer faxoni*, *Sagitta enflata*, *S. helenae*, and *S. hispida*. Remaining species groups were a mix of cooler water species and offshore species, particularly evident at the replicate stations A2, B5,

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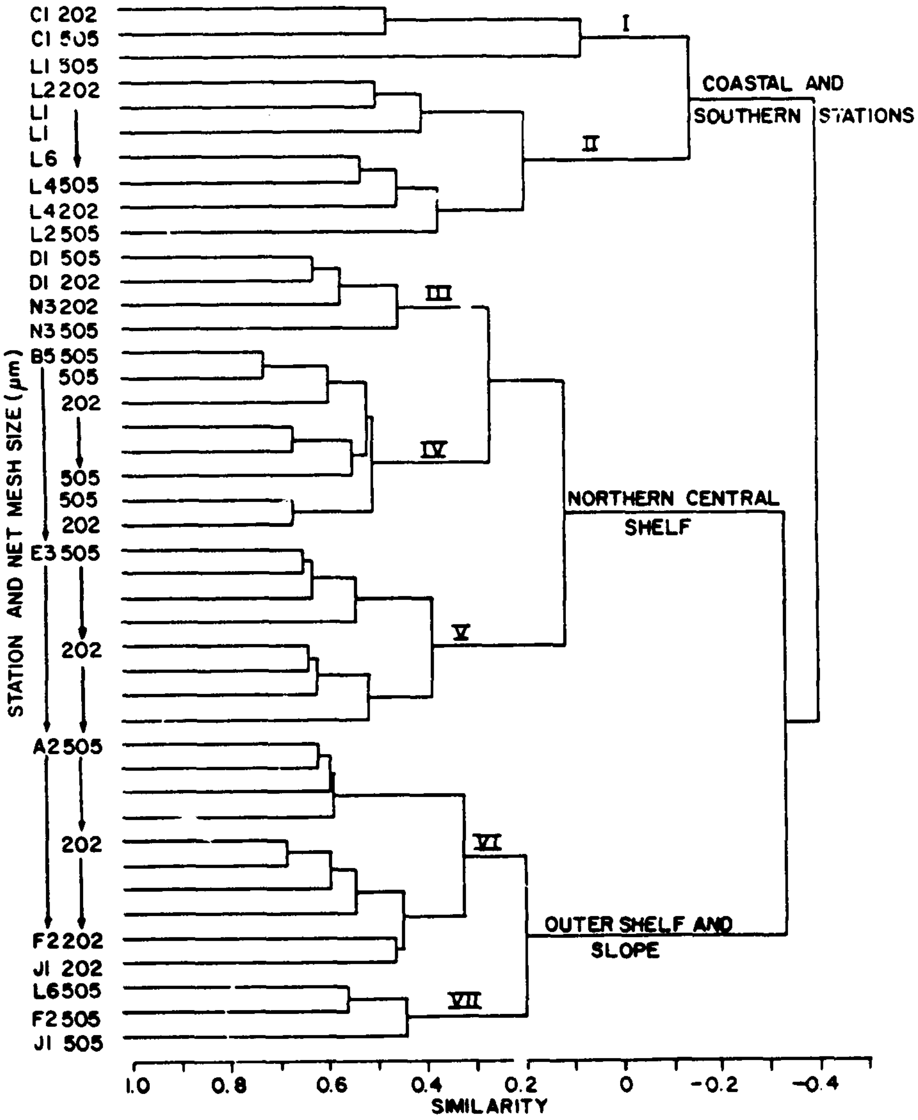

Figure 4-11. Bongo sample clusters, BLM05W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to numbers per $100m^3$.

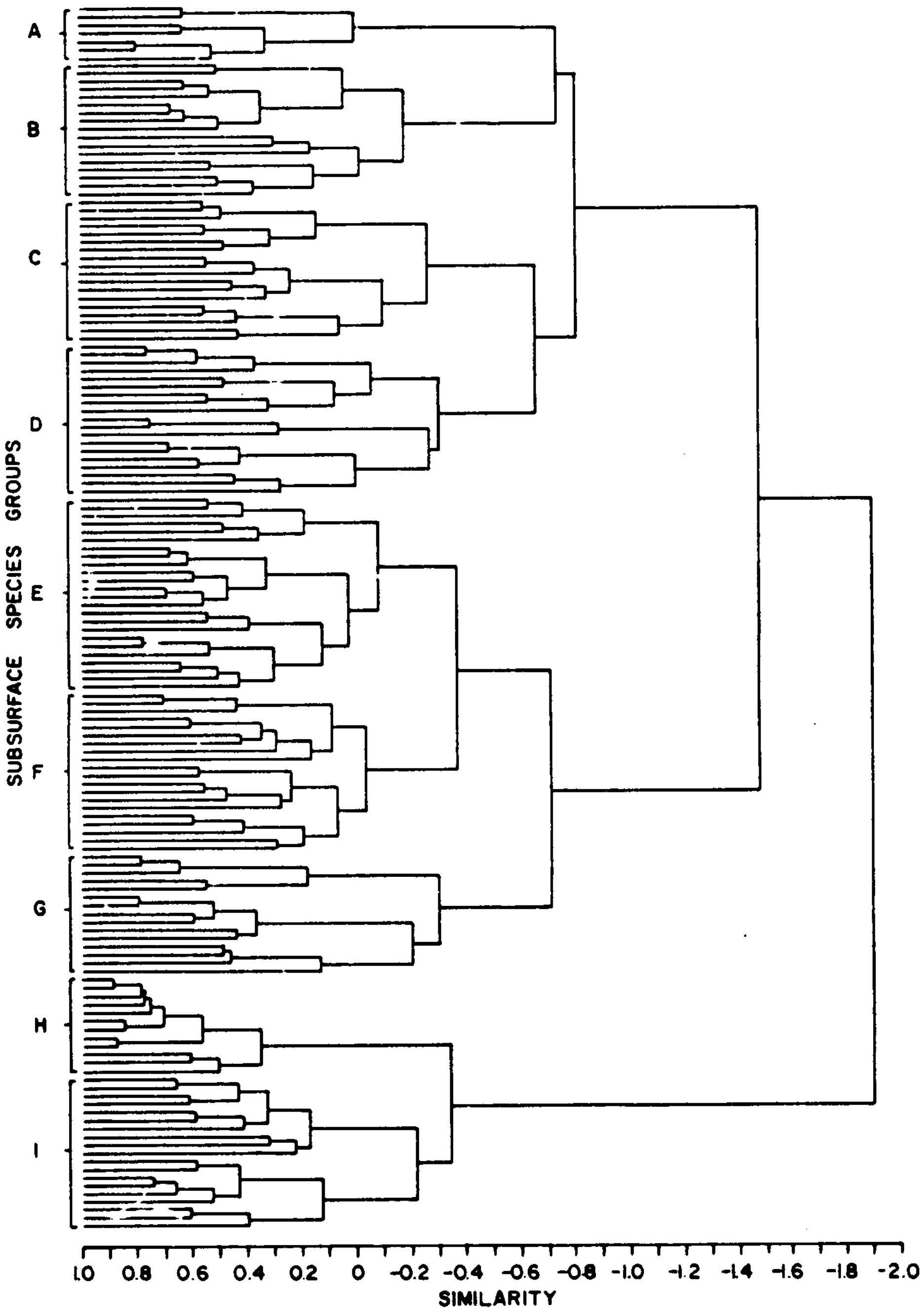

Figure 4-12. Inverse species clusters, bongo tows, BLM05W. See Table 4-7 for identification of species within groups A-I.

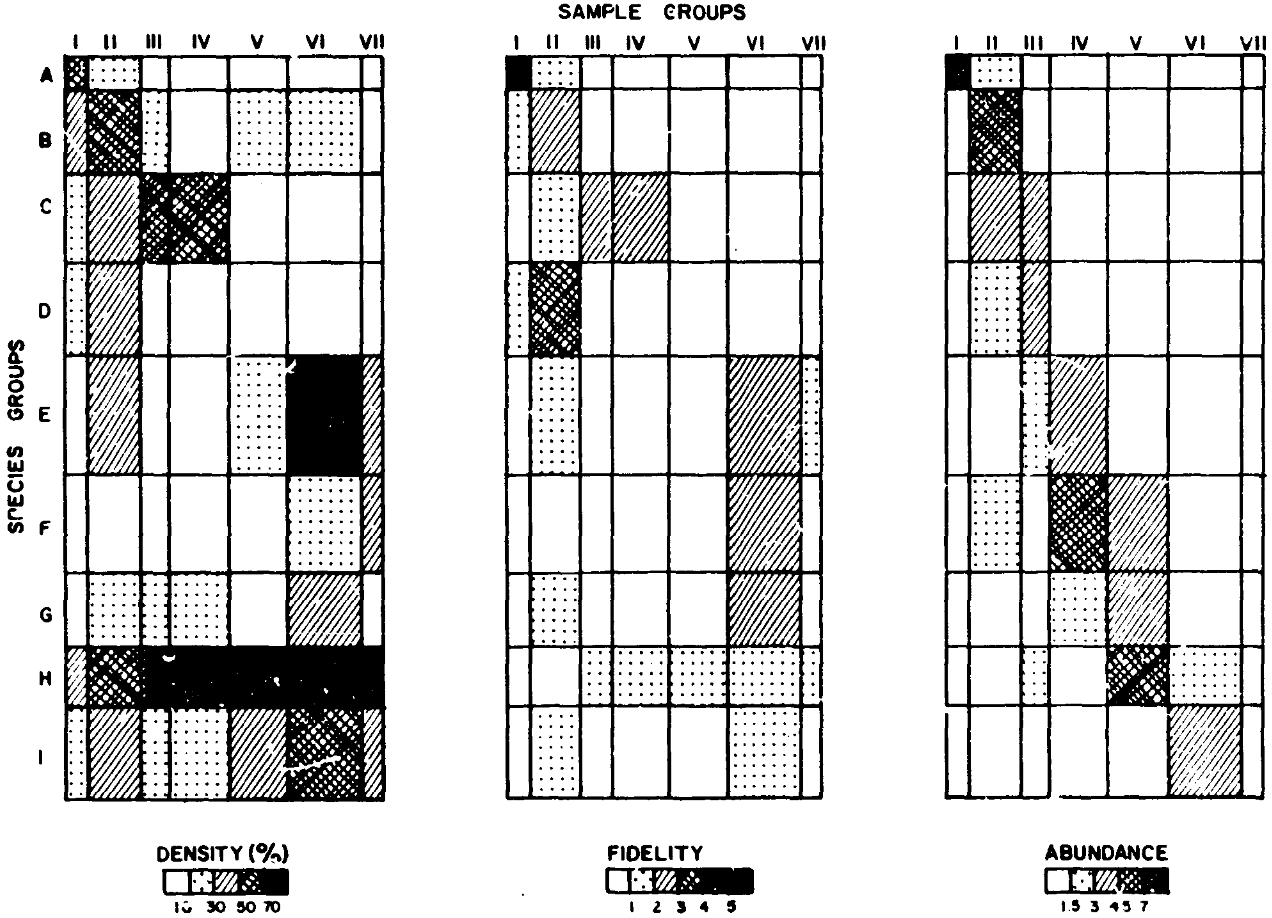

Figure 4-13. Nodal density (or constancy), fidelity and abundance of species groups within sample groups from the bongo cluster analyses of BLM05W.

Table 4-7. Identification of elements in sample and species groups from cluster analysis of bongo collections, BLM05W.

Sample Cluster	Mesh Size and Station Number
I	202 µm: C1; 505 µm: L1, C1
II	202 µm: L1 (2 tows), L2, L4, L6; 505 µm: L2, L4
III	202 µm: D1, N3; 505 µm: D1, N3
IV	202 µm: B5 (4 tows); 505 µm: B5 (4 tows)
V	202 µm: E3 (4 tows); 505 µm: E3 (4 tows)
VI	202 µm: A2 (4 tows), F2, J1; 505 µm: A2 (4 tows)
VII	505 µm: L6, F2, J1

Species Cluster	Taxa (listed in phylogenetic order within clusters)		
A	unid. bivalve larvae *Penilia avirostris* *Acartia tonsa*	*Leptocuma minor* *Mysidopsis bigelowi*	*Neomysis americana* *Sagitta tenuis*
B	*Euconchoecia chierchiae* *Acartia danae* *Centropages furcatus* *Eucalanus pileatus* *Paracalanus parvus* *Pseudocalanus* sp.	*Rhincalanus cornutus* *Temora turbinata* *Clytemnestra scutellata* *Corycaeus* sp. *Corycaeus speciosus* *Oncaea mediterranea*	*Oncaea venusta* *Lestrigonus bengalensis* *Lucifer faxoni* *Sagitta enflata* *Sagitta helenae*
C	*Diphyes dispar* *Tomopteris helgolandica* *Clione limacina* *Limacina retroversa* *Loligo pealeii* *Diastylis sculpta*	*Ampelisca vadorum* *Byblis serrata* *Corophium* sp. *Monoculodes* sp. *Unciola irrorata* unid. Euphausiacea	*Thysanoessa longicaudata* *Crangon septemspinosa* *Leptochela* sp. *Ovalipes* sp. *Paralichthys dentatus* *Urophycis* sp.
D	*Diphyes bojani* *Pelagia noctiluca* *Temora stylifera* *Sapphirina nigromaculata* *Promysis atlantica* *Leucon americanus* *Idotea metallica*	*Parascelus* sp. *Phronimella elongata* *Parthenope* sp. *Portunus* sp. unid. xanthids *Pterosagitta draco*	*Sagitta hispida* *Doliolum nationalis* *Bothus* sp. *Cynoscion regalis* unid. engraulids *Gobiosoma ginsburgi*
E	*Abylopsis tetragona* *Agalma elegans* *Bassia bassensis* *Chelophyes appendiculata* unid. polychaetes unid. gastropod larvae *Atlanta peroni* *Cavolina inflexa*	*Dosinia discus* *Limacina inflata* *Limacina trochiformis* *Conchoecia* sp. *Eupronoe minuta* *Phronima atlantica* *Stylocheiron carinatum* *Thysanoessa gregaria*	unid. decapods unid. majids *Munida* sp. unid. pagurids *Pontophilus brevirostris* *Solenocera* sp. *Sagitta elegans* *Salpa fusiformis*

Table 4-7. (Continued)

Species Cluster	Taxa		
F	*Abylopsis eschscholtzii* *Creseis virgula* *Limacina bulimoides* *Limacina leseuri* *Halocypris brevirostris* unid. ostracods unid. stomatopods	unid. mysids *Pseudomma* sp. *Diastylis quadrispinosa* *Ampelisca agassizi* unid. gammarids *Phronima* sp. *Phrosina semilunata*	*Primno macropa* unid. axiids unid. scyllarids *Citharichthys arctifrons* unid. gobioids *Merluccius* sp.
G	*Lensia conoidea* *Lensia fowleri* *Tomopteris planctonis* *Paedoclione doliiformis* *Lepas* sp.	*Pleuromamma abdominalis* *Pleuromamma xiphias* *Paraphronima gracilis* *Euphausia krohnii* *Meganyctiphanes norvegica*	unid. penaeids *Eukrohnia hamata* *Sagitta hexaptera* unid. leptocephali unid. myctophids
H	*Calanus finmarchicus* *Candacia armata* *Centropages typicus* *Metridia lucens*	*Nannocalanus minor* *Pleuromamma gracilis* *Rhincalanus nasutus* *Parathemisto gaudichaudii*	*Euphausia* sp. *Thysanoessa* sp. *Cancer* sp. *Sagitta tasmanica*
I	*Conchoecia curta* *Aetideus armatus* *Calocalanus pavo* *Candacia* sp. *Centropages violaceus* *Clausocalanus* sp. unid. copepodites	*Eucalanus* sp. *Euchaeta marina* *Mecynocera clausi* *Nannocalanus minor* (imm.) *Paracalanus* sp. *Pleuromamma piseki*	*Scolecithrix danae* *Oithona* spp. *Oncaea* sp. unid. euphausiids *Sagitta minima* *Oikopleura* sp.

and E3 and in shelf-break and slope stations. Species groups H and I were widespread, including some of the more common Middle Atlantic Bight zooplankton, such as Centropages typicus, Parathemisto gaudichaudii, Sagitta tasmanica, S. minima, and Cancer sp. larvae, but tended toward greater relative abundance offshore.

II. Neuston collections. Clusters of 75 neuston samples from BLM05W are shown in Figure 4-14. Basic clusters of samples were:

1. Coastal
    a) southern Sta. L1
    b) northern Sta. C1
2. Central Shelf to Slope
    a) southern stations L2, L4, L6
    b) northern dusk and night tows
    c) northern dawn and day tows

The cluster of southern offshore stations was divided into day and night tows; the northern night tows were subdivided between stations F2 and J1 and stations A2, B5, D1, N3, and E3; and the northern dawn and day tows were subclustered into central shelf and shelf edge stations.

Inverse species clusters and results of a nodal analysis are shown in Figures 4-15 and 4-16, respectively, with an identification of collections and species within groups in Table 4-8. The association of Species groups A and B with Sample groups I and II, i.e. stations L1 and C1, is obvious in Figure 4-16. The first species group was characterized by several species of inshore decapod larvae and by the larvae of anchovies, grey trout, summer flounder, and windowpane flounder. Species of the second group (associated with Station C1) included a mix of warm-water species (Labidocera aestiva, Acartia tonsa, Sagitta tenuis) and cold-water species (Temora longicornis, Centropages hamatus, Crangon septemspinosa).

The third species group (C) corresponded most closely with day tows over the southern stations L2, L4, and L6, and included the pontellid copepods Labidocera acutifrons, Pontella meadii, Anomalocera ornata, and Pontellopsis villosa. Species groups D and E were associated with night tows at these stations and included several siphonophores, two species of Limacina, ostracods, some of the rarer copepods, euphausiids, and the chaetognaths Sagitta elegans, S. hispida, and Pterosagitta draco.

Species group F, a small group containing Salpa fusiformis and Anomalocera patersonii, was associated with night tows at stations F2 and J1 (Sample group V). Species groups G and H were

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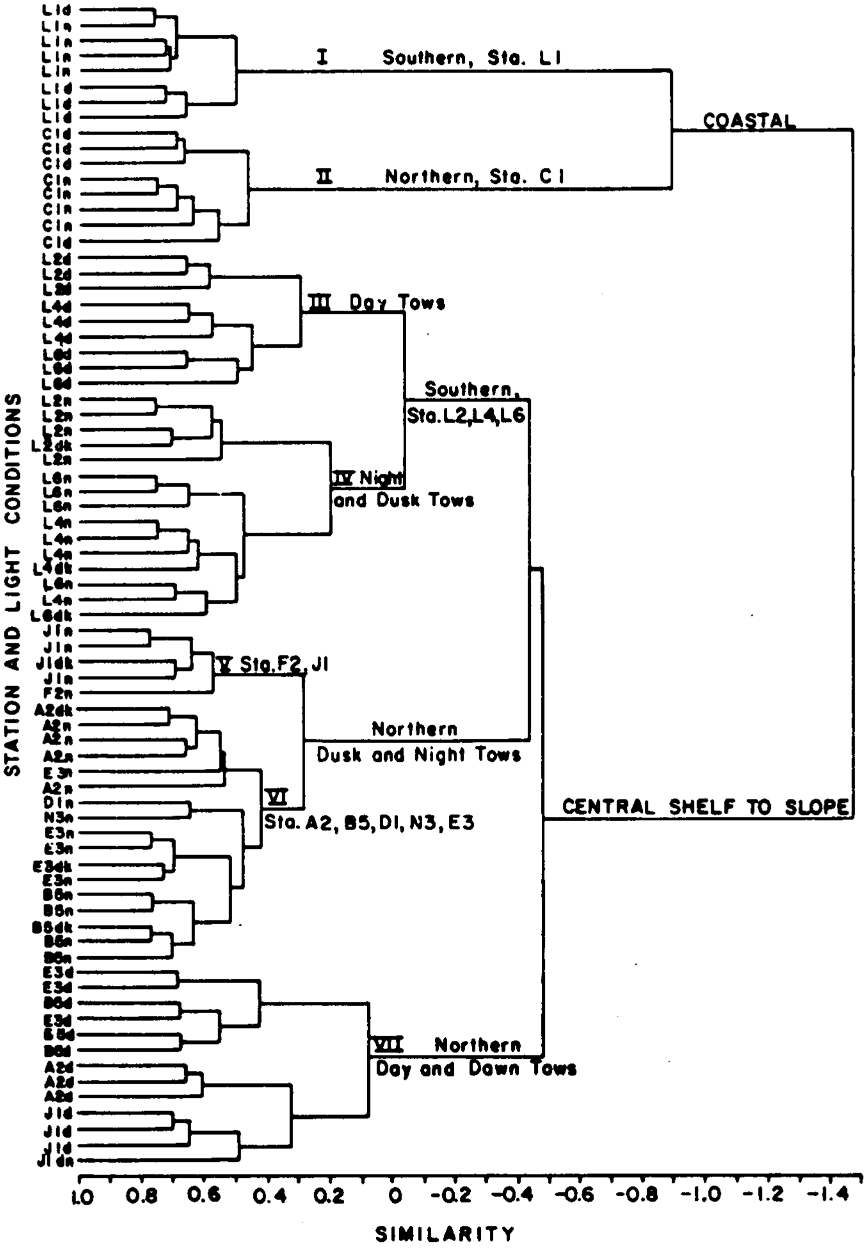

Figure 4-14. Neuston sample clusters, BLM05W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to 20 min. tows. Lettering after station number indicates: n=night, d=day, dk=dusk, dn=dawn.

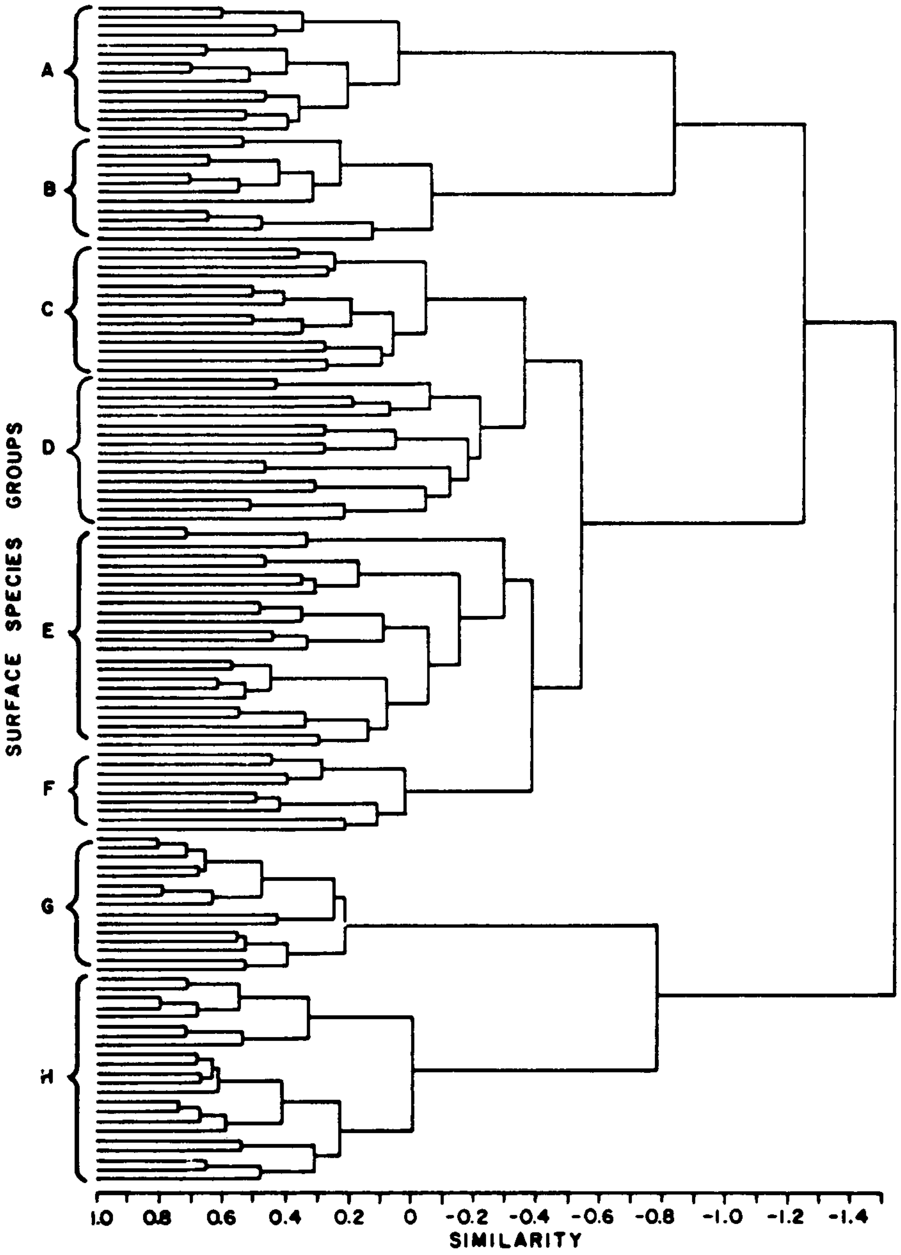

Figure 4-15. Inverse species clusters, neuston tows, BLM05W. See Table 4-8 for identification of species within groups A-H.

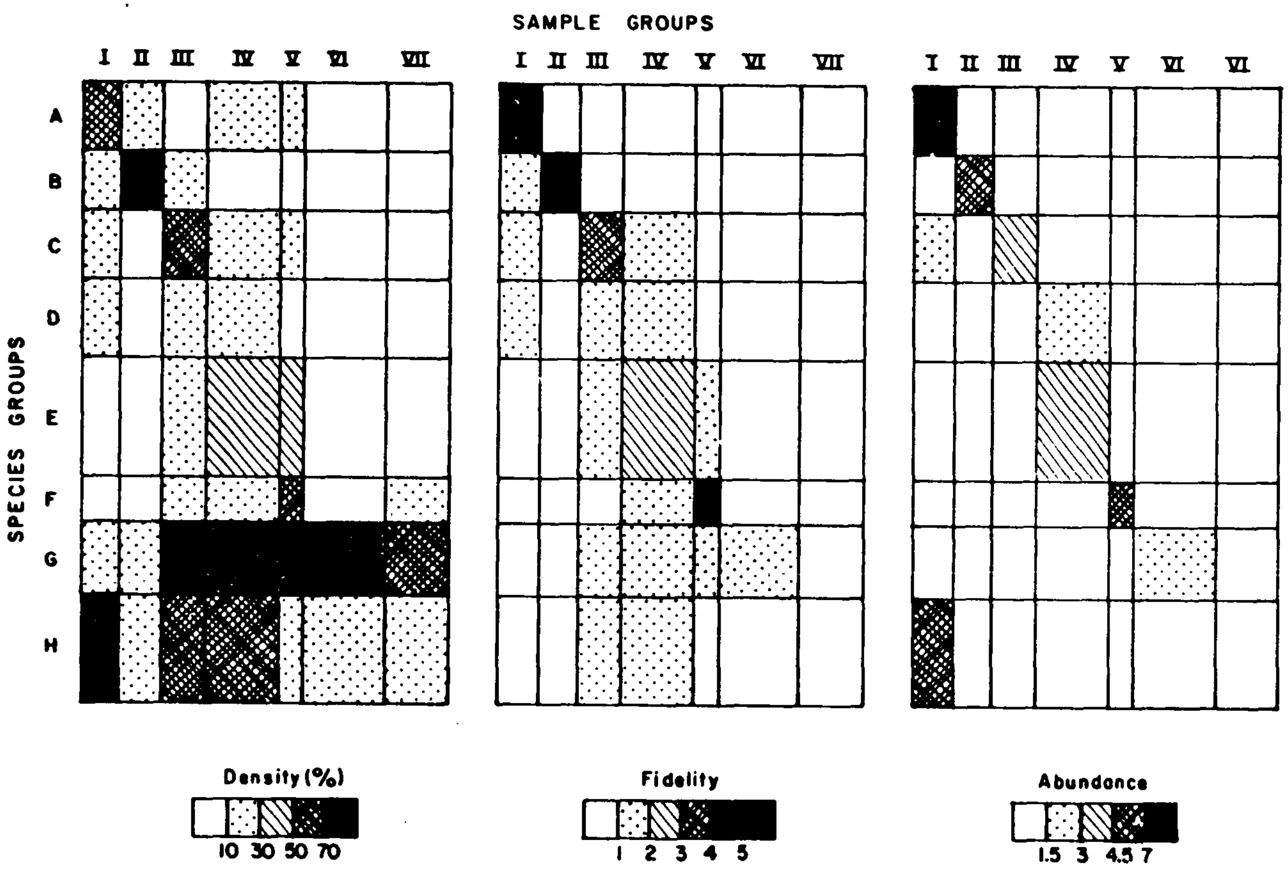

Figure 4-16. Nodal density (or constancy), fidelity, and abundance of species groups within sample groups from the neuston cluster analyses of BLM05W.

Table 4-8. Identification of elements in sample and species groups from cluster analyses of neuston collections, BLM05W.

Sample Cluster	Station Numbers and Time of Day (N=night, D=day)
I	L1N(4), L1D(4)
II	C1N(4), C1D(4)
III	L2D(3), L4D(3), L6D(3)
IV	L6N(4), L6D, L4N(4), L4D, L2N(4), L2D
V	F2N, J1N(3), J1D
VI	D1N, N3N, E3N(4), E3D, B5N(4), B5D, A2N(4), A2D
VII	E3D(3), J1N, J1D(3), B5D(3), A2D(3)

Species Cluster	Taxa (listed in phylogenetic order within clusters)		
A	Muggiaea kochei unid. polychaetes Loligo pealeii Eucalanus crassus Bowmaniella sp.	unid. decapods Sergestes sp. pagurids xanthids Libinia sp.	Anchoa sp. Cynoscion regalis Paralichthys dentatus Scophthalmus aquosus
B	Penilia avirostris Paracalanus sp. Temora longicornis Centropages hamatus	Labidocera aestiva Acartia tonsa Neomysis americana Mysidopsis bigelowi	Crangon septemspinosa Pinnixa cylindrica Sagitta tenuis Menidia menidia
C	Creseis virgula Undinula vulgaris Calocalanus pavo Euchaeta marina Labidocera acutifrons	Pontella meadii Anomalocera ornata Pontellopsis villosa Corycaeus speciosus Lepas sp.	Euphausiidae Dromidia antillensis Oikopleura sp. Engraulidae
D	unid. hydrozoans Agalma elegans Limacina retroversa unid. copepodites Eucalanus sp. Rhincalanus cornutus	Paracalanus parvus Candacia curta Aetideus armatus Themistella fusca Tetrathyrus forcipatus	unid. euphausiids Leptochela papulata Munida sp. Sagitta elegans unid. gobioids
E	Chelophyes appendiculata Diphyes bojani Eudoxides spiralis Abylopsis eschscholtzii Abylopsis tetragona Bassia bassensis unid. anthozoans unid. gastropod larvae	Limacina inflata Dosinia discus unid. ostracods Halocypris brevirostris Conchoecia curta Eucalanus attenuatus Clausocalanus sp. Copilia mirabilis	unid. barnacles unid. stomatopods Euphausia krohnii Thysanoessa gregaria Portunus sp. Sagitta hispida Pterosagitta draco unid. myctophids

Table 4-8. (Concluded)

Species Cluster	Taxa		
F	*Cavolina inflexa*	*Pleuromamma piseki*	*Acartia danae*
	Conchoecia sp.	*Anomalocera* sp.	*Leptochela bermudensis*
	Clausoclanaus arcuicornis	*Anomalocera patersonii*	*Salpa fusiformis*
G	*Calanus finmarchicus*	*Centropages violaceus*	*Euphausia* sp.
	Rhincalanus nasutus	*Candacia armata*	*Thysanoessa* sp.
	Nannocalanus minor	*Metridia lucens*	*Parathemisto gaudichaud*
	5th copepodite *N. minor*	*Pleuromamma gracilis*	*Sagitta minima*
	Centropages typicus	*Scolecithrix danae*	*Sagitta tasmanica*
H	*Diphyes dispar*	*Centropages furcatus*	*Ovalipes* sp.
	Pelagia noctiluca	*Promysis atlantica*	*Cancer* sp.
	Atlanta peroni	*Idotea metallica*	*Sagitta enflata*
	Limacina trochiformis	*Lestrigonus bengalensis*	*Sagitta helenae*
	Euconchoecia chierchiae		*Doliolum nationalis*
	Eucalanus pileatus	*Lucifer faxoni*	*Urophycis* sp.
	Temora stylifera	*Leptochela* sp.	
	Temora turbinata	*Processa* sp.	
		Callinectes sp.	

widespread, with H somewhat more predominant in the southern sector. The former included dominant shelf species Centropages typicus and Parathemisto gaudichaudii.

Synopsis of Cruise BLM05W

1. Biomass decreased from south to north, and from inshore to offshore (subsurface bongo collections). Highest displacement volumes occurred at stations L1 and L2 in the southern transect and at stations D1 and N3 to the north. Estimates ranged from 8 to 392 ml/100m^3 among 202 μm collections and from 3 to 101 ml/100m^3 among 505 μm collections.

Neuston biomass was highly variable without an obvious decrease offshore. Volumes, ranging from 5 to 1540 ml/standard 20 min. tow, were highest at night or in late afternoon at 24-hr. stations.

2. Subsurface collections were numerically dominated by Paracalanus sp. (202 μm nets), Centropages typicus (most 505 μm collections), Pleuromamma gracilis (offshore 505 μm collections), or Nannocalanus minor (505 μm net at Station L4). C. typicus and P. gracilis were also dominants in the majority of neuston collections. Neuston catches along the southern transect were also dominated by Eucalanus pileatus, Sagitta enflata, Centropages furcatus, Parathemisto gaudichaudii, Temora stylifera and Nannocalanus minor. Northern dominants other than C. typicus and P. gracilis included Neomysis americana (one inshore tow), P. gaudichaudii and Cancer sp. larvae.

3. The most frequent and abundant species in both subsurface and neuston tows was Centropages typicus.

4. Diversity was highest along the southern transect and near the shelf-edge.

5. Principal clusters of subsurface collections included (a) coastal and southern stations, (b) northern central shelf stations and (c) outer shelf and slope stations. Neuston collections were clustered into two primary groups: coastal stations and central shelf to slope stations.

Winter 1977 Cruise No. BLM06W

Summary of Collections

The 12 designated water-column stations were sampled for surface and subsurface zooplankto between 20 February and 6 March 1977. A total of 42 bongo collections, including replicate samples at stations A2, B5 and E3, were obtained for biomass estimates and taxonomy. Subsurface collections for chemistry totalled 44 each for hydrocarbons and trace metals, including two extra splits each from the quality control station (Station A2). Samples were evenly divided between 202 µm and 505 µm nets.

Neuston collections (all 505 µm nets) were obtained at 3 hr. intervals at nine stations, all but stations D1, N3 and F2, where single tows were made, for a total of 75 collections. Large, removable species were largely lacking in the neuston, so only Ammodytes sp. was selected for hydrocarbon analysis. Six samples of tarballs from stations L4, L6, E3 and A2 were frozen for later analysis.

Biomass

The observed biomass of winter zooplankton, measured by displacement volume, is given in Table 4-9. Estimates of biomass from 202 µm bongo nets were always higher than those from paired 505 µm nets, and where replicate tows were made, were much more variable, e.g. 17-147 ml/100m^3 at Station A2. Zooplankton volumes were reduced in the southern inner shelf compared with fall cruise observations. In the northern transects, volumes were fairly even from the coast to offshore, except at stations F2 and J1 where low biomass was evident. Highest volumes in subsurface zooplankton occurred in central shelf locations (L2, N3, E3 and B5).

Neuston volumes were generally lower than in the fall, and especially reduced in the coastal Virginia locations (L1 and L2). Volumes in excess of 0.5 liter/standard tow were limited to two offshore Virginia collections which encountered dawn and dusk swarms of the hyperiid amphipod Parathemisto gaudichaudii.

Faunal Description

Nearly 300 taxa, only slightly less than that from the fall survey, were identified from winter neuston and bongo collections (Table 4-10). They included at least 59 species of copepods, 25 amphipods, 27 decapods, 15 chaetognaths, and 27 fishes. Most of those restricted to the neuston were rare. Neuston-restricted species that occurred in more than 5% of the neuston collections included only Ovalipes sp., Mugil curema and Scomberesox saurus.

Dominant species in the 117 analyzed collections are listed in Table 4-11. All subsurface collections were dominated by copepods, by Centropages typicus in most 505 µm samples and several 202 µm samples as well. Fine-meshed bongo collections, however, were more often dominated by Oithona spp. or Paracalanus

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Table 4-9. Displacement volume of zooplankton collections, winter 1976 (BLM06W). Standardized to ml/100m^3 for 60 cm bongos and to ml/20 minute tow for neuston collections.

	Bongo (ml/100m^3)		Neuston 505 µm (ml/20 min. tow)							
			Approx. hour of collection							
Station	202 µm	505 µm	0300	0600	0900	1200	1500	1800	2100	2400
L1	80	56	20	10	30	21	30	25	45	60
L2	118	42	40	45	38	30	25	30	22	60
L4	44	17	50	555	45	48	48	300	30	35
L6	86	21	60	30	65	20	86	558	110	145
C1	71	48	170	51	45	<5	<5	80	20	105
D1	95	35		50						
N3	189	29							60	
E3	93	21	30	110	50	40	58	68	20	40
	108	34								
	174	37								
	137	44								
F2	22	17	50							
J1	31	16	82	105	79	19	68	68	85	65
B5	120	23	35	60	41	21	5	100	20	18
	136	31								
	116	14								
	183	40								
A2	17	13	120	128	45	39	41	330	150	40
	113	26								
	131	27								
	147	32								

Table 4-10. List of zooplankton identified from bongo and neuston collections, winter 1977 (BLM06W). Species from subsurface collections only (*); from surface collections only (**).

CNIDARIA
**Abyla sp.
*Abyla trigonia
Abylopsis eschscholtzii
Abylopsis tetragona
Agalma elegans
**Agalma okeni
*Aglantha digitale
Bassia bassensis
**Ceratocymba leuckarti
Chelophyes appendiculata
Diphyes bojani
Diphyes dispar
**Eudoxides mitra
Eudoxides spiralis
*Lensia sp.
*Lensia conoidea
*Lensia hotspur
*Lensia multicristata
**Liriope tetraphylla
Muggiaea kochei
**Sulculeolaria sp.
Sulculeolaria choni
**Sulculeolaria quadrivalvis
unid. hydrozoans
unid. siphonophores
unid. scyphozoans
unid. anthozoans

CTENOPHORA
Pleurobrachia pileus
unid. ctenophores

TURBELLARIA
unid. flatworms

RHYNCOCOELA
*unid. nemerteans

ANNELIDA
Tomopteris sp.
*Tomopteris helgolandica
unid. polychaetes

MOLLUSCA
*Argopecten glyptus
*Atlanta sp.
*Carinaria lamarcki
Cavolina inflexa

MOLLUSCA (continued)
Cavolina tridentata
Cavolina uncinata
Cerastoderma pinnulatum
*Clio pyrimidata
Creseis virgula
**Cuvierina columnella
*Diaphana minuta
Dosinia discus
Ensis directus
**Hyalocyclis striata
**Illex sp.
Illex illecebrosus
*Lima tenera
*Limacina helicina
Limacina inflata
Limacina leseuri
Limacina retroversa
Macoma balthica
**Melampus bidentata
**Octopodoteuthis megaptera
Paedoclione doliiformis
*Peraclis reticulata
Pneumoderma atlanticum
**Pterygioteuthis giardi
*Pterotrachea scutata
*Rossia tenera
Spisula solidissima
*Stoloteuthis leucoptera
unid. gastropod larvae

CLADOCERA
*Evadne nordmanni

OSTRACODA
Conchoecia sp.
Conchoecia bispinosa
Conchoecia curta
**Conchoecia loricata
Euconchoecia chierchiae
**Fellia bicornis
Halocypris brevirostris
**unid. ostracods

COPEPODA
*Acartia danae
Acartia tonsa
Aetideus armatus
**Anomalocera sp.

Table 4-10. (Continued)

COPEPODA (continued)
Anomalocera ornata
*Arietellus setosus
*Calanus sp.
Calanus finmarchicus
*Caligus sp.
*Calocalanus pavo
Candacia sp.
Candacia armata
**Candacia pachydactyla
**Centropages furcatus
Centropages hamatus
Centropages typicus
*Chirundina streetsi
*Clausocalanus sp.
Clausocalanus arevicornis
*Clytemnestra rostrata
*Clytemnestra scutellata
*Copilia sp.
*Copilia mirabilis
Corycaeus sp.
Corycaeus speciosus
Eucalanus sp.
Eucalanus attenuatus
Eucalanus crassus
Eucalanus elongatus
Eucalanus pileatus
Euchaeta sp.
Euchaeta marina
Euchaeta media
Euchirella rostrata
**Eurytemora americana
*Euterpina acutifrons
*Haloptilus sp.
**Haloptilus longicornis
**Haloptilus mucronatus
Heterorhabdus sp.
**Heterorhabdus longicornis
Heterorhabdus papilliger
*Labidocera sp.
**Labidocera aestiva
*Lucicutia clausii
*Macrosetella gracilis
*Mecynocera clausi
Metridia lucens
Nannocalanus minor
*Oculosetella gracilis
Oithona spp.
**Oithona setigera
*Oncaea sp.
*Oncaea mediterranea

COPEPODA (continued)
**Pachos punctatum
Paracalanus sp.
*Pareuchaeta norvegica
*Pleuromamma sp.
Pleuromamma abdominalis
Pleuromamma gracilis
Pleuromamma piseki
*Pleuromamma robusta
Pseudocalanus sp.
Rhincalanus cornutus
Rhincalanus nasutus
*Sapphirina sp.
*Sapphirina nigromaculata
Scolecithricella sp.
Scolecithrix danae
Scottocalanus sp.
Scottocalanus securifrons
*Temora sp.
Temora longicornis
Temora stylifera
Temora turbinata
**Tortanus discaudatus
*Undeuchaeta major
unid. calanids
unid. copepodites

CIRRIPEDIA
Chthamalus fragilis
Lepas sp.
unid. barnacle larvae

STOMATOPODA
*Platysquilla enodis
**unid. stomatopod larvae

MYSIDACEA
**Anchialina typica
*Heteromysis formosa
Mysidopsis bigelowi
Neomysis americana

CUMACEA
*Campylaspis sp.
*Cyclaspis sp.
*Diastylis sp.
*Diastylis polita
*Diastylis quadrispinosa
*Diastylis sculpta
Leptocuma minor

Table 4-10. (Continued)

ISOPODA
*Cirolana concharum
*Edotea sp.
**Idotea metallica

AMPHIPODA
Ampelisca agassizi
*Ampelisca vadorum
Anchylorera blossevilli
*Argissa hamatipes
*Brachyscelus sp.
*Byblis serrata
*Erichthonius brasiliensis
*Erichthonius rubricornis
**Eupronoe minuta
**Lestrigonus sp.
Lestrigonus bengalensis
*Lestrigonus schizogeneois
*Lycaea pulex
Monoculodes sp.
*Monoculodes edwardsi
*Orchomenella minuta
*Oxycephalus piscator
Parathemisto gaudichaudii
Phronima sp.
*Phronima atlantica
*Phronimopsis spinifera
*Phrosina semilunata
*Primno macropa
**Primno rectumenus
*Rhachotropis inflata
*Scina sp.
Sympronoe parva
**Themistella fusca
*unid. corophiids
unid. gammarids
unid. hyperiids

EUPHAUSIACEA
Euphausia sp.
*Euphausia hemigibba
Euphausia krohnii
Euphausia pseudogibba
*Euphausia tenera
Meganyctiphanes norvegica
*Nematoscelis atlantica
Nematoscelis megalops
*Nematoscelis microps
*Nematoscelis tenella
Stylocheiron sp.
Stylocheiron abbreviatum

EUPHAUSIACEA (continued)
Stylocheiron elongatum
**Stylocheiron longicorne
**Stylocheiron suhmii
Thysanoessa sp.
Thysanoessa gregaria
Thysanoessa inermis
*Thysanoessa longicaudata
unid. euphausiids

DECAPODA
Bathynectes superba
*Callianassa sp.
Callinectes sp.
Cancer sp.
Crangon septemspinosa
Dichelopandalus leptocerus
*Ethusa sp.
*Eualus sp.
*Gennadas sp.
**Leptochela sp.
Leptochela bermudensis
**Leptochela papulata
Lucifer faxoni
*Lucifer typus
*Munida sp.
**Ovalipes sp.
Parthenope sp.
Pinnixa sp.
*Pontophilus brevirostris
Portunus sp.
*Sergestes sp.
Sergestes arcticus
Solenocera sp.
*unid. alpheids
*unid. majids
unid. pagurids
unid. penaeids
unid. scyllarids
unid. xanthids
unid. decapods

ECHINODERMATA
*unid. ophiuroids

CHAETOGNATHA
Eukrohnia hamata
Krohnitta subtilis
Pterosagitta draco
**Sagitta sp.
Sagitta decipiens

Table 4-10. (Concluded)

CHAETOGNATHA (continued)
Sagitta elegans
Sagitta enflata
Sagitta helenae
Sagitta hexaptera
Sagitta lyra
*_Sagitta maxima_
Sagitta minima
Sagitta serratodentata
Sagitta tasmanica
*_Sagitta tenuis_
*_Sagitta zetesios_

TUNICATA
Doliolum nationalis
Oikopleura sp.
Salpa fusiformis
**_Thalia democratica_

PISCES
Ammodytes sp.
*_Ammodytes hexapterus_
Anguilla rostrata
Argyropelecus sp.
*_Benthosema glaciale_
**_Bothus_ sp.
*_Citharichthys arctifrons_
*_Cyclothone_ sp.
*_Echiodon_ sp.
*_Etropus microstomus_
*_Evermannella_ sp.
*_Gobiosoma ginsburgi_
**_Gonichthys cocco_
**_Linophyrne_ sp.
*_Liparis_ sp.
**_Menidia menidia_
*_Merluccius albidus_
**_Mugil cephalus_
**_Mugil curema_
**_Myctophum affine_
Paralichthys dentatus
**_Scomber scombrus_
**_Scomberesox saurus_
**_Symbolophorus veranyi_
Urophycis sp.
*unid. leptocephali
*unid. bothids
unid. engraulids
*unid. gobioids

PISCES (continued)
*unid. gobiids
*unid. lutjanids
unid. myctophids
unid. paralepidids
unid. fishes

Table 4-11. Numerically dominant zooplankters in winter 1977 collections (BLM06W). Drawn from the three most abundant taxa in each tow (D = day, N = night).

Station L1

Bongo 202	Bongo 505	Neuston 505
Centropages typicus	Centropages typicus	Centropages typicus (4N,4D)
Oithona spp.	Metridia lucens	Metridia lucens (4N)
Paracalanus sp.	Parathemisto gaudichaudii	Centropages hamatus (3D)
		Oithona spp. (1N,1D)
		Crangon septemspinosa (1N)
		Parathemisto gaudichaudii (1D)
		Pleuromamma gracilis (1N)
		unid. copepodites (1N)
		Rhincalanus nasutus (1N)
		Clausocalanus arcuicornis (1D)
		Paracalanus sp. (1D)

Station L2

Bongo 202	Bongo 505	Neuston 505
Oithona spp.	C. typicus	C. typicus (4N,4D)
C. typicus	P. gaudichaudii	M. lucens (4N,1D)
Paracalanus sp.	Sagitta tasmanica	P. gracilis (3N)
		P. gaudichaudii (3D)
		Sagitta tasmanica (1N,2D)
		Paracalanus sp. (1D)
		Oithona spp. (1D)

Station L4

Bongo 202	Bongo 505	Neuston 505
Oithona spp.	C. typicus	C. typicus (3N,4D)
Paracalanus sp.	Rhincalanus nasutus	Anomalocera ornata (3N,4D)
C. typicus	Euchirella rostrata	P. gaudichaudii (2N,4D)
		R. nasutus (2N)
		C. arcuicornis (1N)
		P. gracilis (1N)

Table 4-11. (Continued)

Station L6

Bongo 202	Bongo 505	Neuston 505
C. typicus	*C. typicus*	*C. typicus* (4N,1D)
Paracalanus sp.	*M. lucens*	*A. ornata* (1N,4D)
Oithona spp.	*E. rostrata*	*P. gaudichaudii* (4D)
		Euchirella rostrata (2N)
		M. lucens (2N)
		Urophycis sp. (2D)
		Calanus finmarchicus (1N)
		P. gracilis (1N)
		Nannocalanus minor (1N)
		C. arcuicornis (1D)

Station C1

Bongo 202	Bongo 505	Neuston 505
Centropages hamatus	*Centropages hamatus*	*Centropages hamatus* (4N,4D)
Acartia tonsa	*Temora longicornis*	barnacle cypris larvae (3N,3D)
Temora longicornis	*C. typicus*	*Temora longicornis* (2N,3D)
		C. typicus (1N,1D)
		Neomysis americana (1N)
		M. lucens (1N)

Station D1

Bongo 202	Bongo 505	Neuston 505
C. typicus	*C. typicus*	*C. typicus* (1N)
Oithona spp.	*M. lucens*	*M. lucens* (1N)
Pseudocalanus sp.	*Pseudocalanus* sp.	*C. finmarchicus* (1N)

Table 4-11. (Continued)

Station N3		
Bongo 202 *C. typicus* *Paracalanus* sp. *Oithona* spp.	Bongo 505 *C. typicus* *Paracalanus* sp. unid. copepodites	Neuston 505 *C. typicus* (1N) *M. lucens* (1N) *Pseudocalanus* sp. (1N)
Station E3		
Bongo 202 (4 reps) *Paracalanus* sp. (4) *Oithona* spp. (3) *Pleuromamma gracilis* (3) unid. copepodites (1) *C. typicus* (1)	Bongo 505 (4 reps) *C. typicus* (4) *R. nasutus* (4) *E. rostrata* (2) *Euphausia* sp. (1) *M. lucens* (1)	Neuston 505 *C. typicus* (4N,4D) *A. ornata* (3N,4D) *P. gaudichaudii* (1N,4D) *C. finmarchicus* (2N) *Euphausia* sp. (1N) *P. gracilis* (1N)
Station F2		
Bongo 202 *Oithona* spp. unid. copepodites *Paracalanus* sp.	Bongo 505 *R. nasutus* *C. typicus* *M. lucens*	Neuston 505 *A. ornata* (1N) *M. lucens* (1N) *C. typicus* (1N)
Station J1		
Bongo 202 *Paracalanus* sp. *Pseudocalanus* sp. *Euchirella rostrata*	Bongo 505 *C. typicus* *R. nasutus* *M. lucens*	Neuston 505 *A. ornata* (4N,4D) *P. gaudichaudii* (1N,4D) unid. euphausiids (2N) *P. gracilis* (2N) *C. typicus* (1N,1D) *M. lucens* (1N) *Euphausia* sp. (1N) *C. arcuicornis* (1D) *R. nasutus* (1D) *Scolecithrix danae* (1D)

Table 4-11. (Concluded)

Station B5

Bongo 202 (4 reps)	Bongo 505 (4 reps)	Neuston 505
Paracalanus sp. (4)	*C. typicus* (4)	*C. typicus* (4N,3D)
Oithona spp. (3)	*M. lucens* (4)	*P. gaudichaudii* (1N,4D)
C. typicus (3)	*S. tasmanica* (3)	*M. lucens* (3N)
C. arcuicornis (1)	*Clausocalanus arcuicornis* (1)	*S. tasmanica* (3N)
P. gracilis (1)		*Ammodytes* sp. (1N,2D)
		A. ornata (2D)
		C. finmarchicus (1D)

Station A2

Bongo 505 (4 reps)	Bongo 505 (4 reps)	Neuston 505
Oithona spp. (3)	*C. typicus* (4)	*A. ornata* (4N,4D)
C. typicus (3)	*M. lucens* (4)	*P. gaudichaudii* (1N,4D)
unid. copepodites (3)	*R. nasutus* (2)	*C. typicus* (3N,1D)
Paracalanus sp. (2)	*S. tasmanica* (1)	*M. lucens* (2N)
Metridia lucens (1)	*Calanus finmarchicus* (1)	*C. arcuicornis* (1N)
		P. gracilis (1N)
		Ammodytes sp. (1D)
		Eucalanus attenuatus (1D)
		Rhincalanus cornutus (1D)

sp. C. typicus was largely replaced by C. hamatus at the northern coastal station (C1). Rhincalanus nasutus assumed more importance over the outer shelf off New Jersey. Dominants other than copepods were limited to Parathemisto gaudichaudii and Sagitta tasmanica at the southern inner shelf stations.

Dominant species in neuston collections were more variable, and included, in addition to copepods dominating subsurface collections, a number of other taxa. Anomalocera ornata, a pontellid copepod, was particularly important at all outer shelf stations. The vertically migrating copepod, Pleuromamma gracilis, was among the dominants in southern stations and at stations J1 and A2. P. gaudichaudii was among the dominant neustonts at all offshore stations; larvae of Urophycis sp. were important at Station L6; and neuston at the inshore New Jersey station C1 was dominated by barnacle cypris larvae.

Diel Cycles of Dominant Neustonts

Station L1. All of the eight neuston tows at L1 were numerically dominated by Centropages typicus (Figure 4-17). Other species were found in small numbers. The cold-water Centropages hamatus was replaced at night by Metridia lucens and Crangon septemspinosa.

Station L2. All surface tows at the next offshore station in the southern transect were again dominated by Centropages typicus, with a general increase in abundance. Pleuromamma gracilis and Metridia lucens, both absent at mid-day, rose to the surface at night to peak in abundance at 0300. The northern chaetognath, Sagitta tasmanica, also peaked at this hour, but was present at the surface throughout the day. Parathemisto gaudichaudii was at maximal numbers at dusk and dawn (Figure 4-18).

Station L4. Five of the eight tows at this outer shelf station were numerically dominated by the amphipod Parathemisto gaudichaudii, while three night tows were dominated by Centropages typicus. Peaks in the former again occurred at dawn and dusk, but at an augmented level of abundance, 42,500 and 22,000 per tow, respectively (Figure 4-19). Pleuromamma gracilis was narrowly restricted to the hours of darkness, while Anomalocera ornata, a surface restricted pontellid, was reduced only near midnight.

Station L6. Four neuston collections at L6 were dominated by Parathemisto gaudichaudii, which peaked at dawn and dusk (Figure 4-20), two by Centropages typicus, and one each by Euchirella rostrata and Metridia lucens. Dawn and dusk maxima were evident in collections of Anomalocera ornata and larvae of

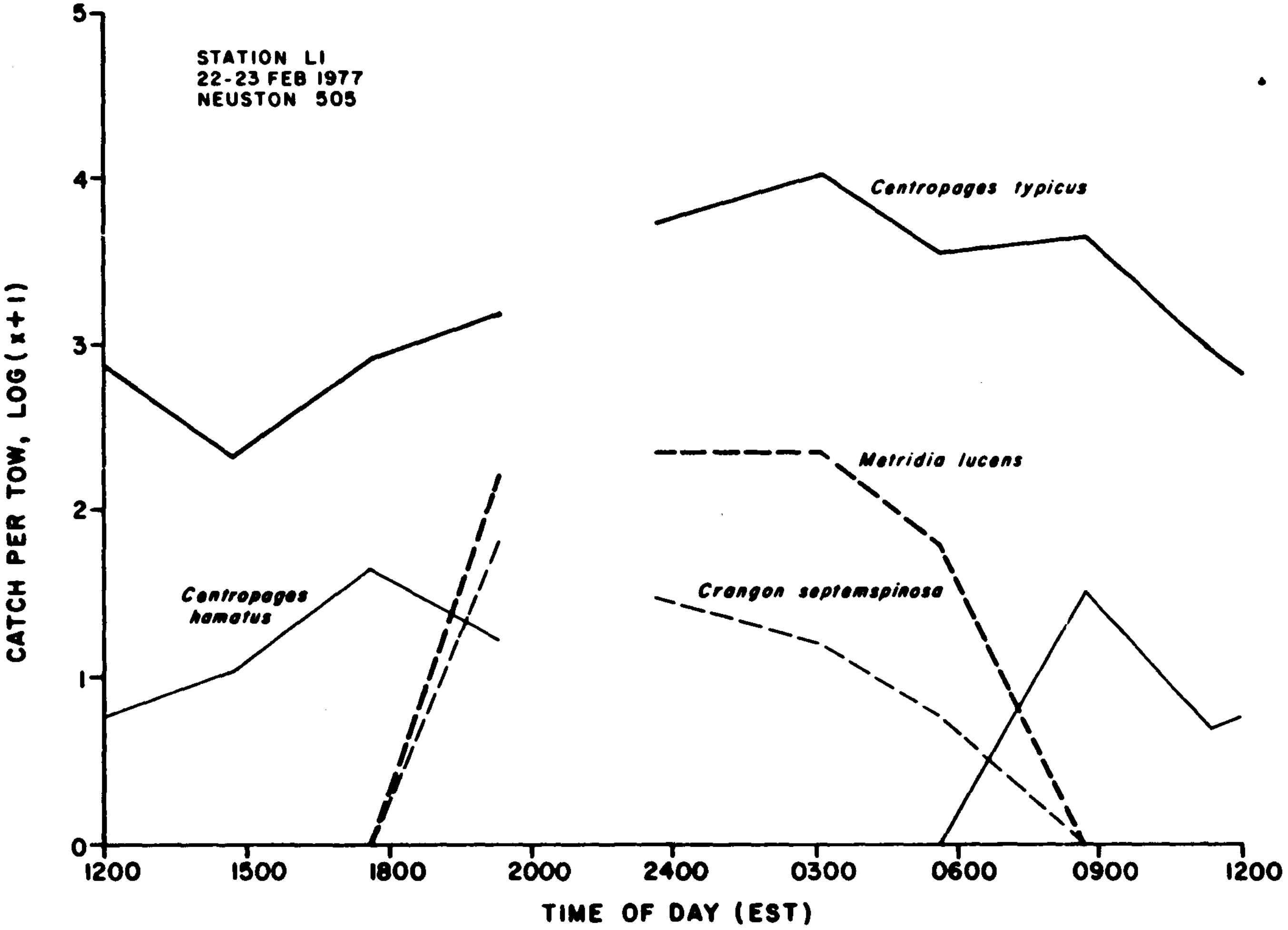

Figure 4-17. Diel cycle of dominant neustonts at Station L1, BLM06W.

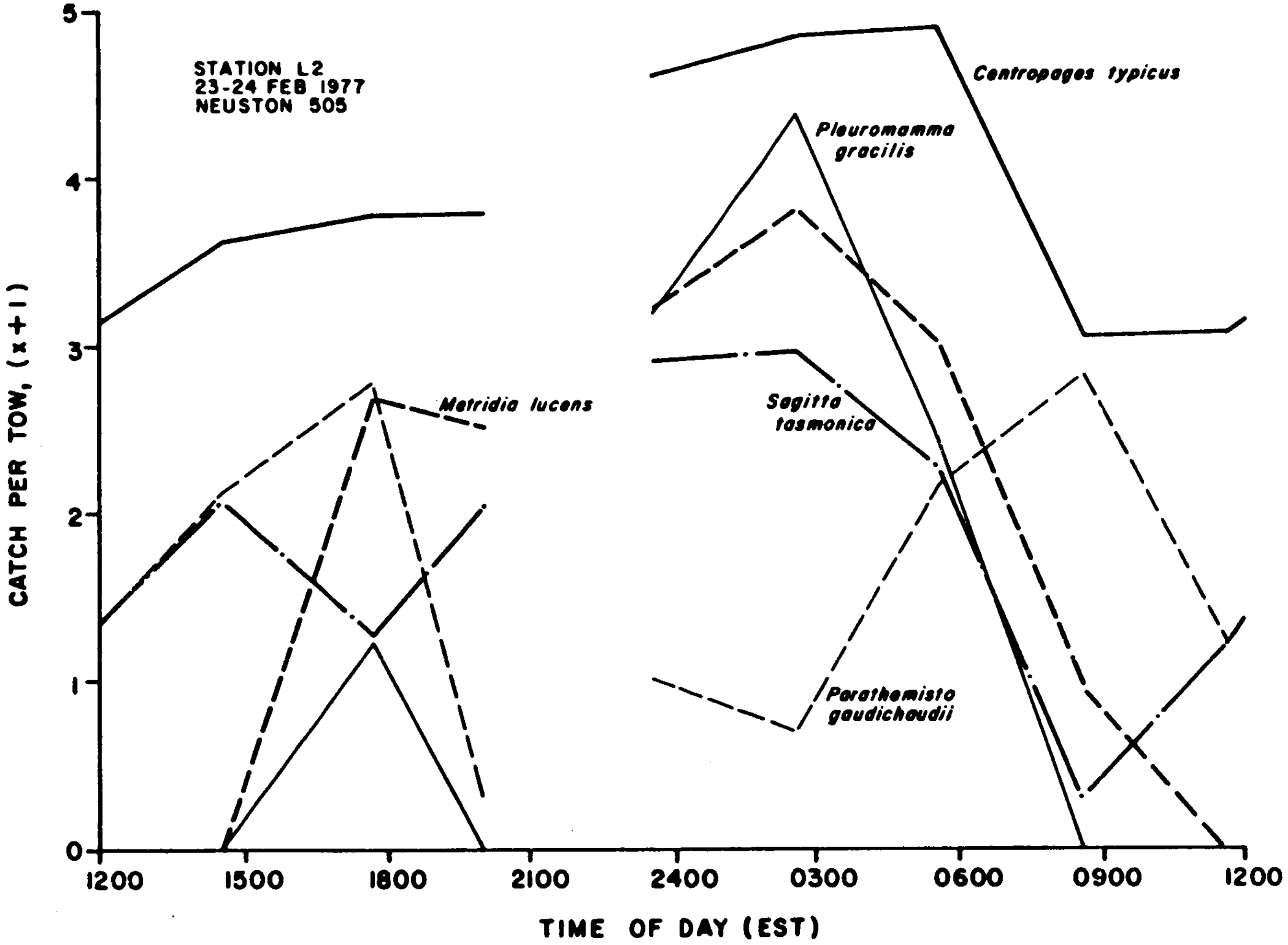

Figure 4-18. Diel cycle of dominant neustonts at Station L2, BLM06W.

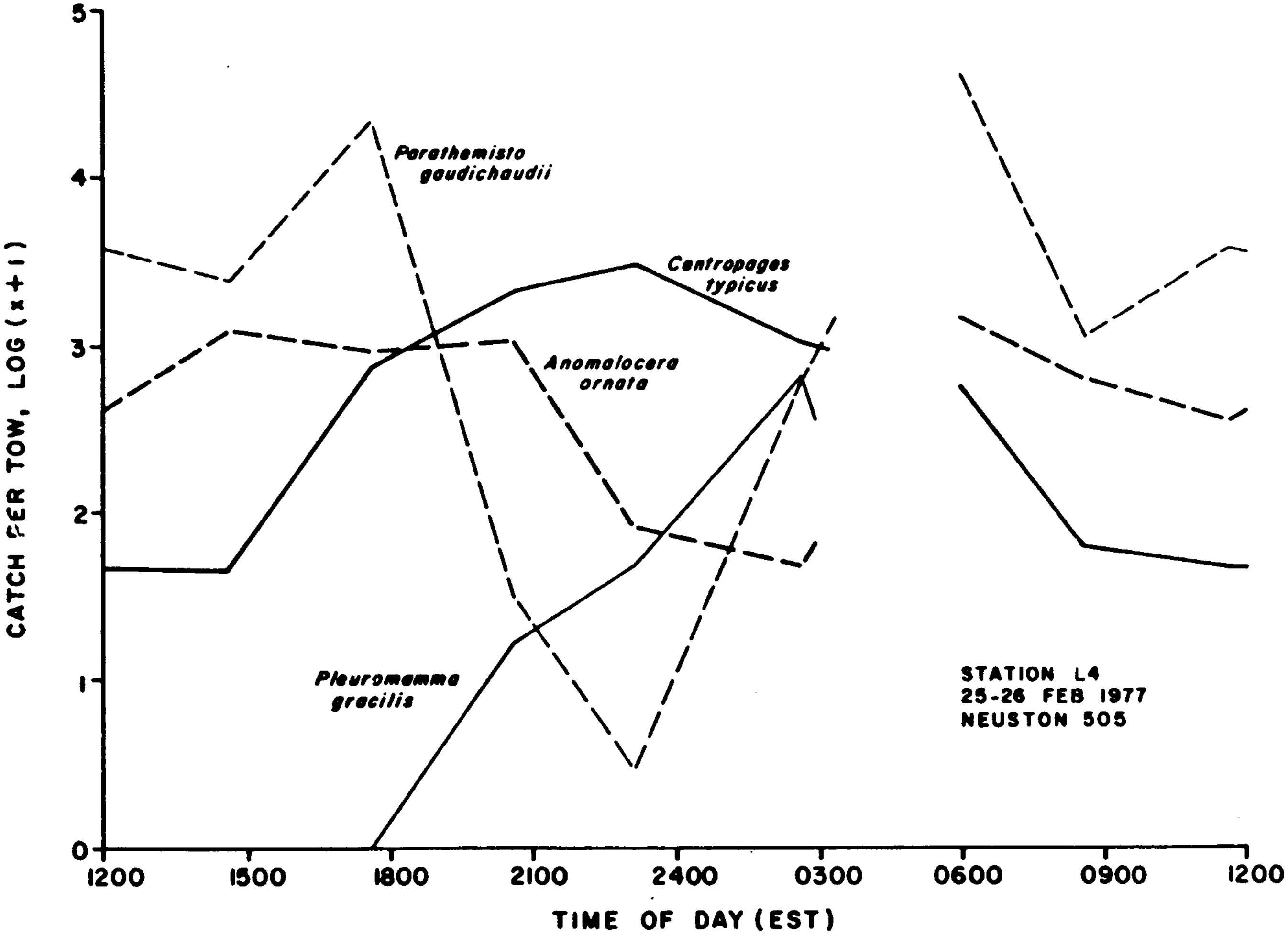

Figure 4-19. Diel cycle of dominant neustonts at Station L4, BLM06W.

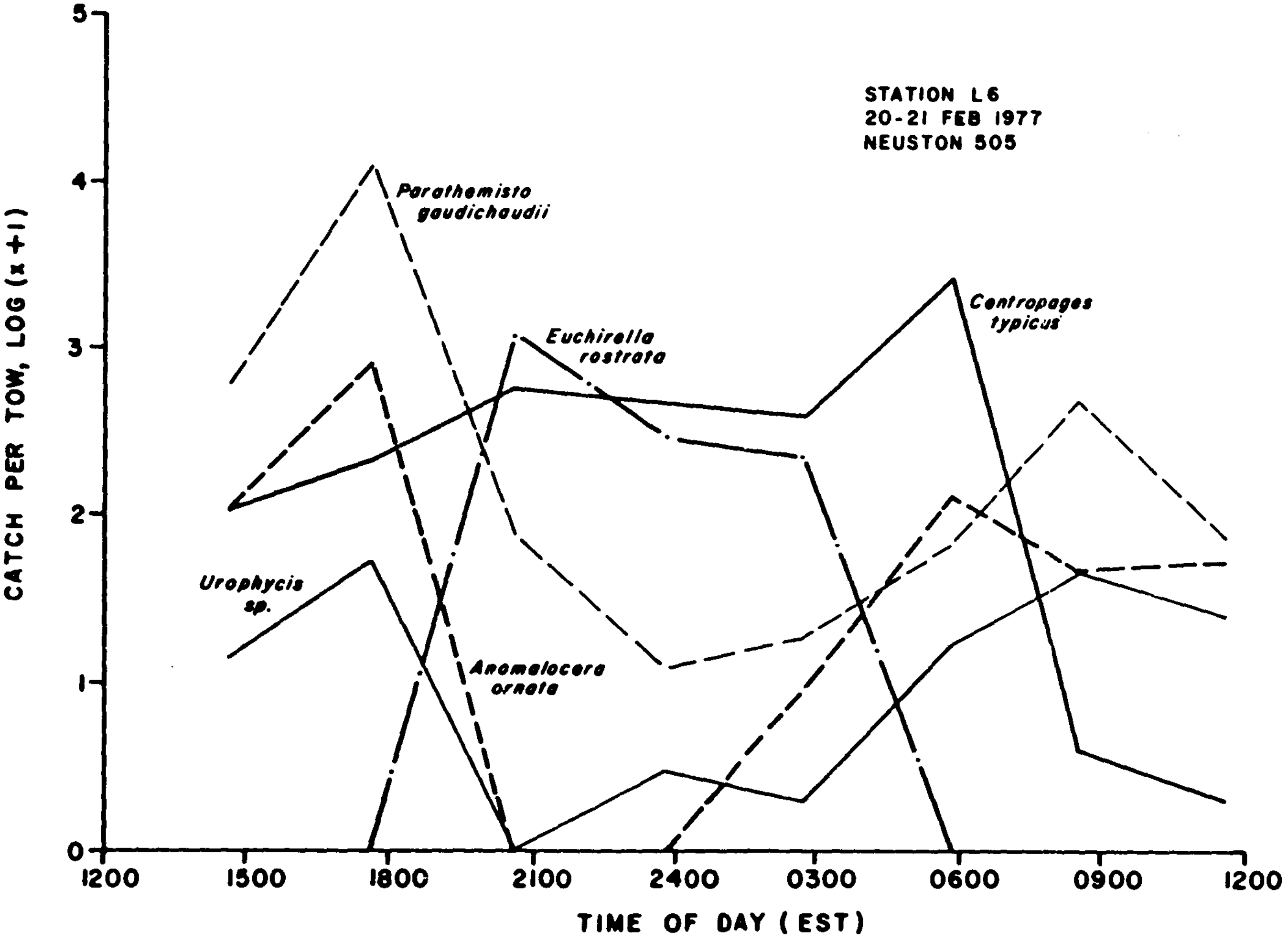

Figure 4-20. Diel cycle of dominant neustonts at Station L6, BLM06W.

Urophycis sp., in addition to P. gaudichaudii. E. rostrata was an evident night migrator to the surface.

Neuston in the southern L-transect progressed from an inshore community typified by C. hamatus and Crangon larvae (although mixed with central shelf species), through the central shelf fauna (C. typicus, M. lucens, P. gaudichaudii) to an offshore group containing A. ornata and E. rostrata. P. gaudichaudii exhibited a bimodal (dawn and dusk) pattern of diel abundance at every station. The copepods M. lucens and E. rostrata increased sharply in abundance during night hours.

Station C1. Seven of the eight coastal New Jersey neuston collections were dominated by the cold-water Centropages hamatus, in contrast to its low abundance in the comparable Virginia coastal station L1. The remaining tow was dominated by cypris larvae of barnacles (presumably Balanus sp.). All of the more abundant species at this station were cold-water species, except Acartia tonsa, and included Pseudocalanus sp., Temora longicornis and Neomysis americana (Figure 4-21). The persistance of A. tonsa into winter has been noted previously (Grant 1977a).

Station E3. Neuston at this central shelf station was similar to that at the southern station L4, except for the addition of Calanus finmarchicus among the important surface fauna. Three tows were numerically dominated by Centropages typicus, three by Parathemisto gaudichaudii and two by Anomalocera ornata. P. gaudichaudii was bimodally distributed, with peaks at dawn and dusk (Figure 4-22).

Station J1. Six of the eight neuston collections from the slope station off New Jersey were dominated by Anomalocera ornata, one each by immature euphasiids and Parathemisto gaudichaudii. Night migrants to the surface layer included Centropages typicus, euphausiids and Pleuromamma gracilis (Figure 4-23). P. gaudichaudii peaked at dawn.

Station B5. Three neuston tows were dominated by Centropages typicus, two by Parathemisto gaudichaudii, two by Metridia lucens and one by Anomalocera ornata (Figure 4-24). The latter was most abundant in morning and afternoon, while Ammodytes sp. larvae and P. gaudichaudii peaked at dawn and dusk. M. lucens and Sagitta tasmanica (not shown) increased at night.

Station A2. Neuston collections at this, our most northeasterly station were numerically dominated by Parathemisto gaudichaudii (3 tows), Centropages typicus (3 tows) and Anomalocera ornata (2 tows). As seen previously at Station J1, C. typicus was absent in the surface layer at mid-day. Both Ammodytes sp. and P. gaudichaudii were bimodally abundant at dawn and dusk (Figure 4-25). Not included in Figure 4-25 is Eucalanus

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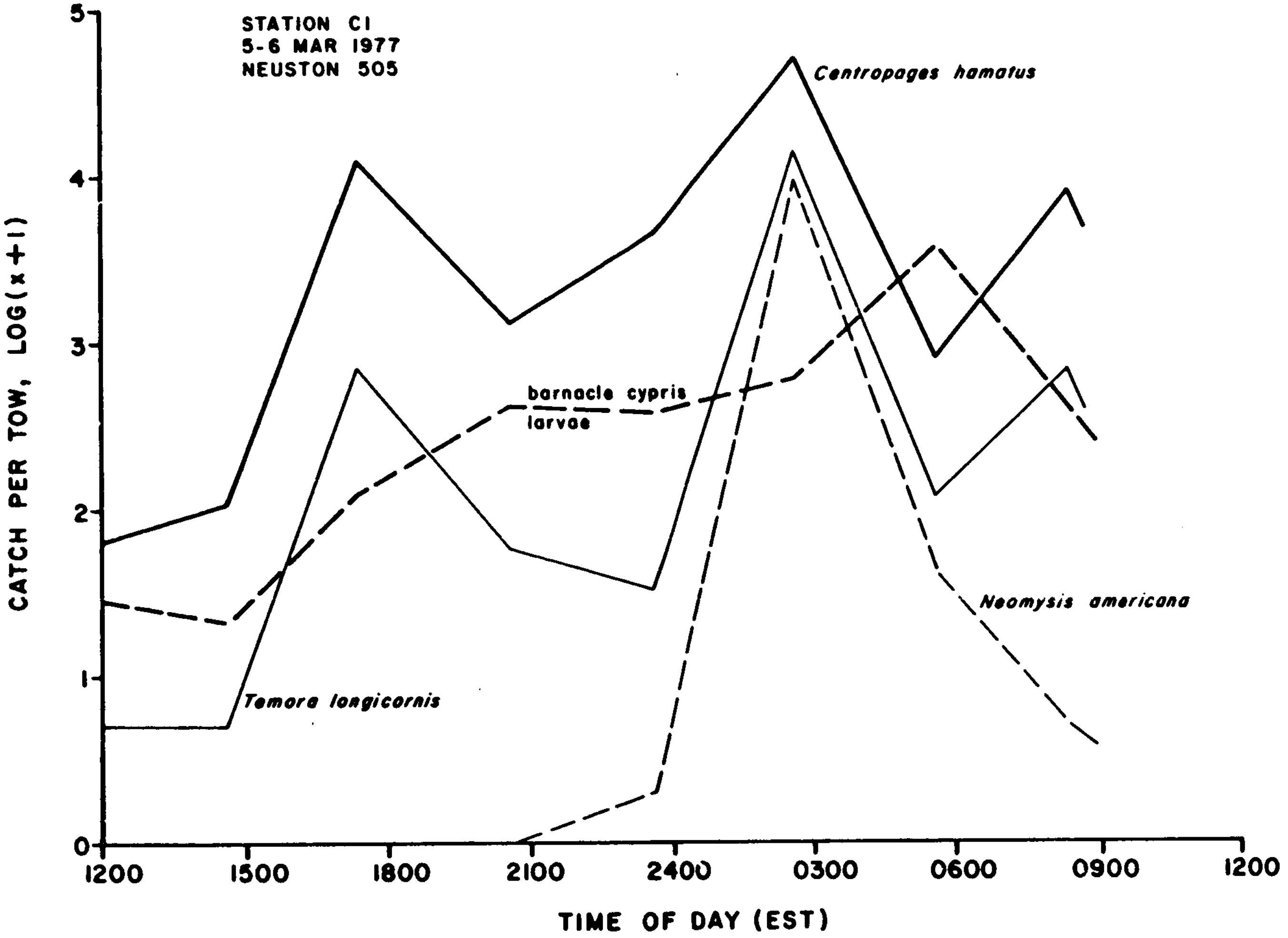

Figure 4-21. Diel cycle of dominant neustonts at Station C1, BLM06W.

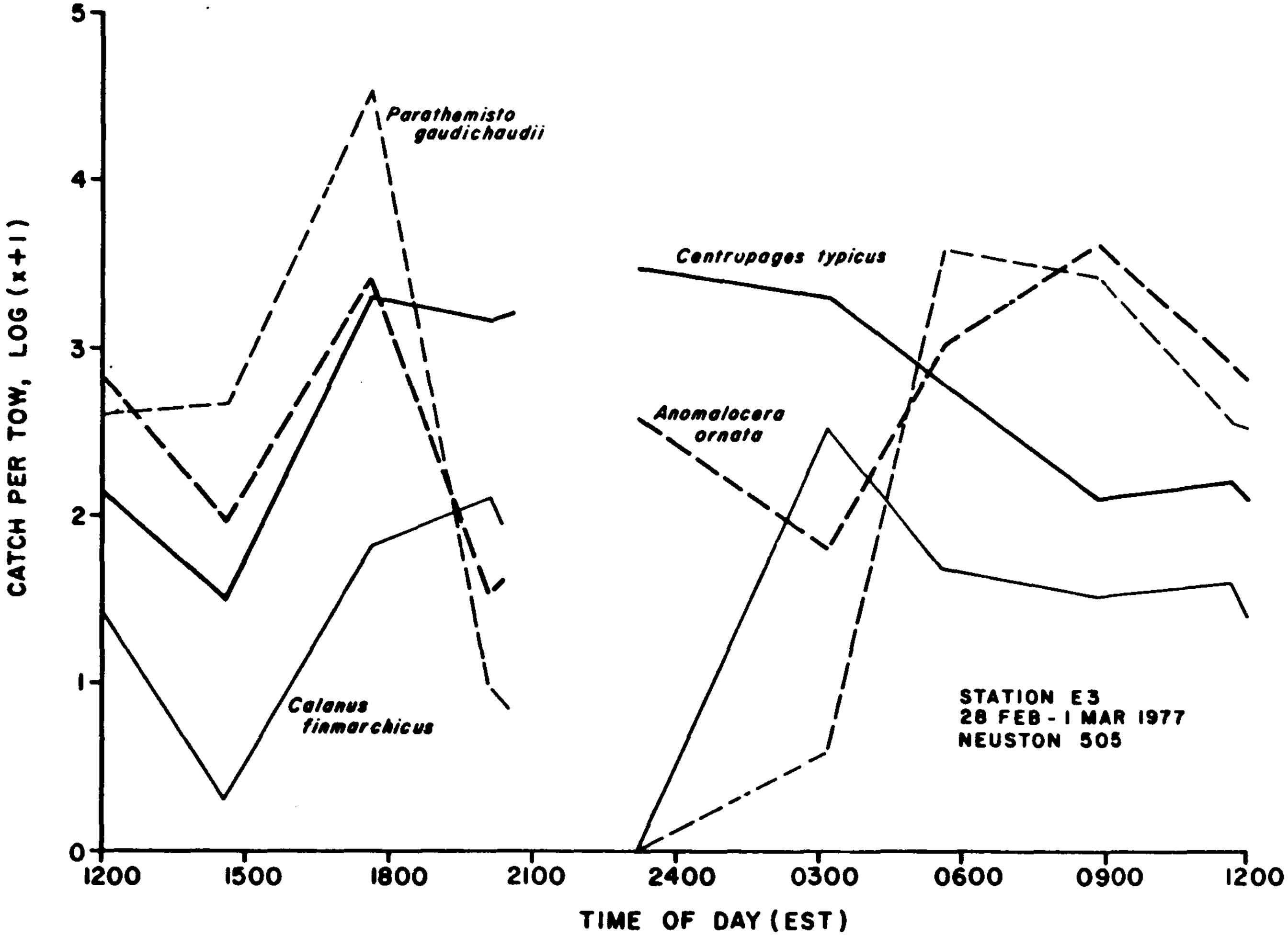

Figure 4-22. Diel cycle of dominant neustonts at Station E3, BLM06W.

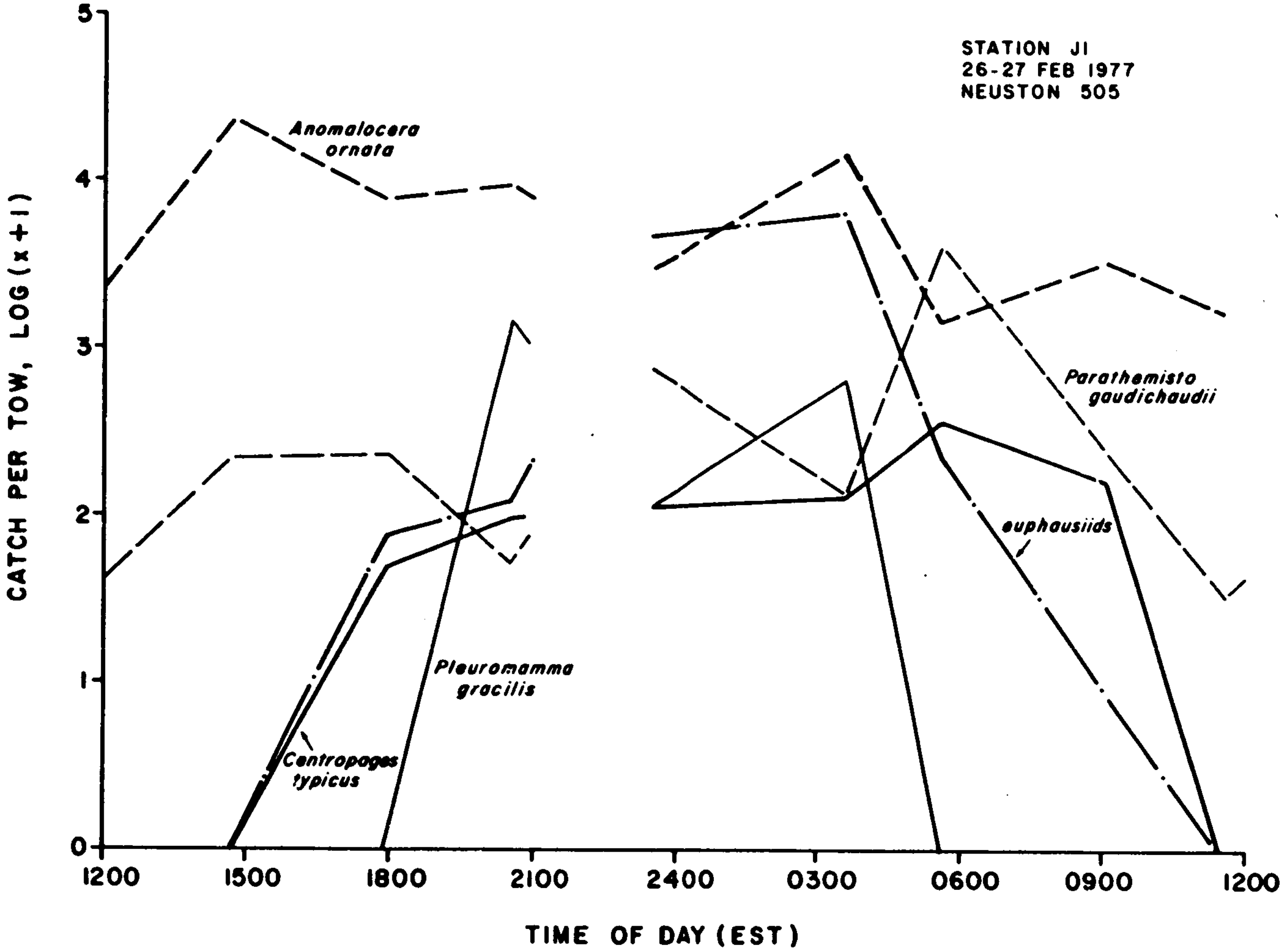

Figure 4-23. Diel cycle of dominant neustonts at Station J1, BLM06W.

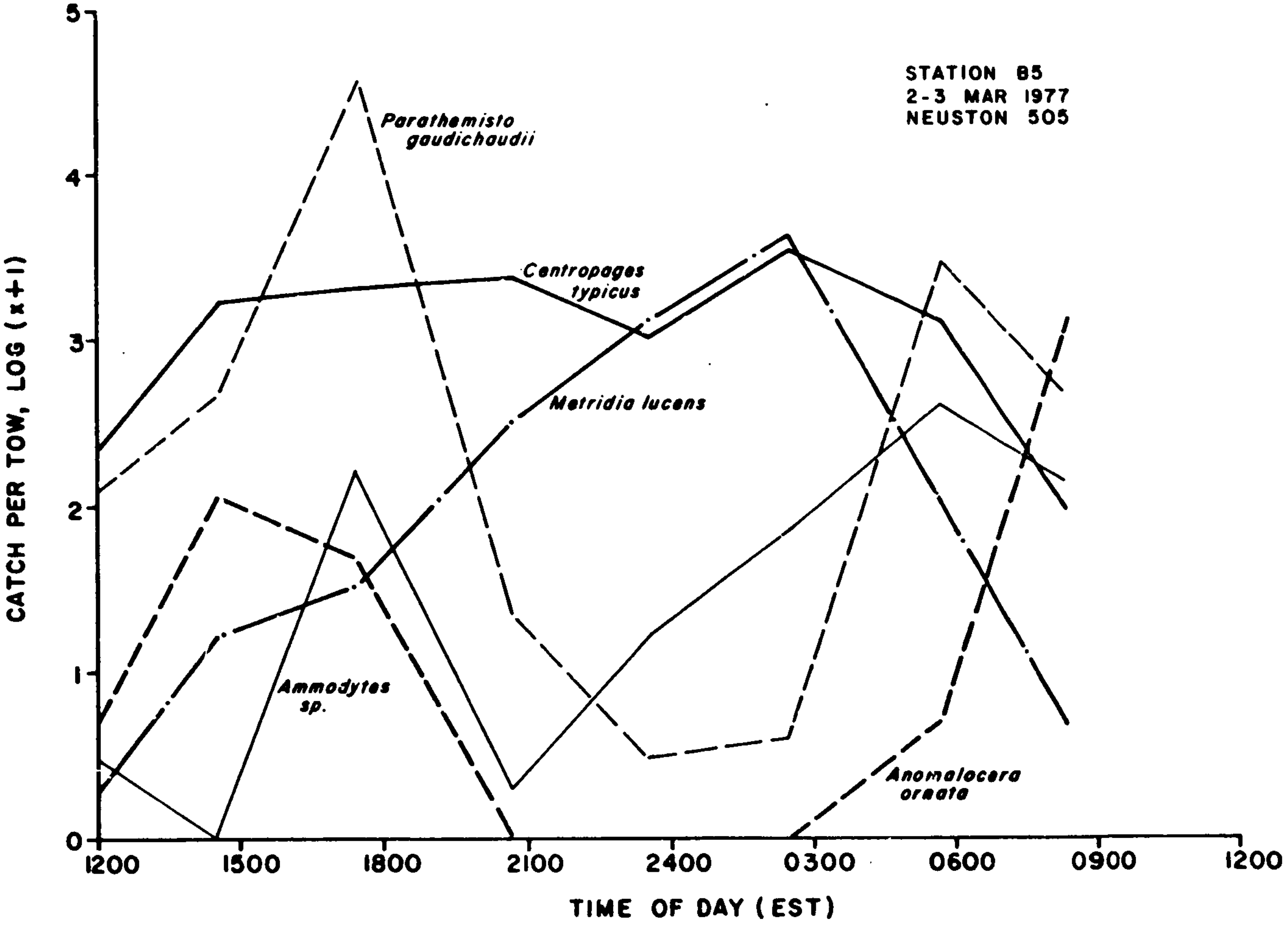

Figure 4-24. Diel cycle of dominant neustonts at Station B5, BLM06W.

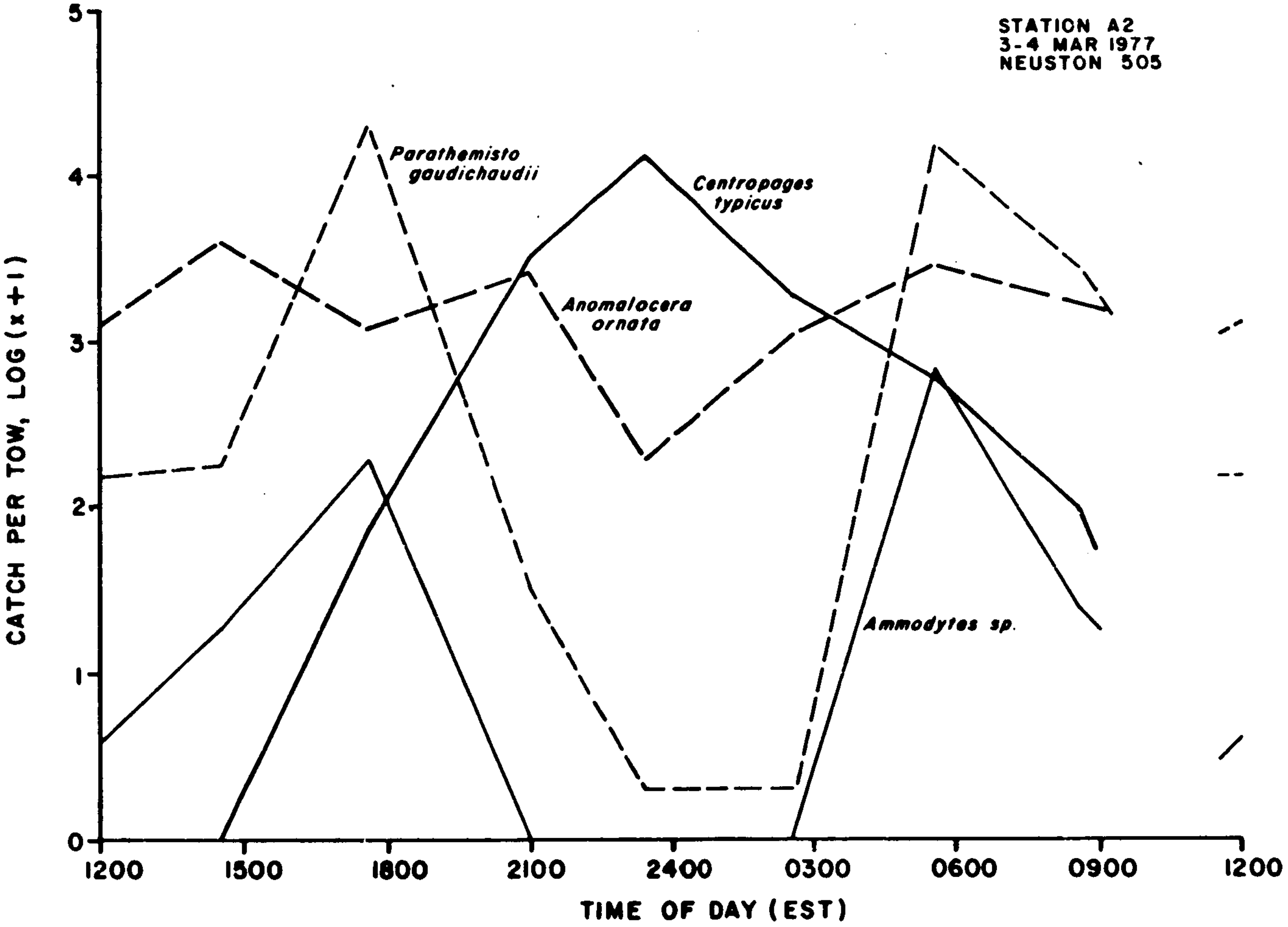

Figure 4-25. Diel cycle of dominant neustonts at Station A2, BLM06W.

attenuatus, which was present in the surface layer throughout the day in low abundance.

Neuston off New Jersey differed from that off Virginia mostly at coastal locations. Station C1 was dominated by C. hamatus rather than C. typicus and larger numbers of T. longicornis, another cold-water species, were also present. The occurrence and distribution of A. ornata and P. gaudichaudii was similar in offshore neuston at both southern and northern transects.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent species in winter 1977 bongo collections are listed in Table 4-12, and those from neuston collections in Table 4-13. Centropages typicus, Parathemisto gaudichaudii and Sagitta tasmanica were ranked 1, 2 and 3 in both lists according to frequency of occurrence. Half of the dozen most frequent neuston species are not in the list of common bongo species, including the copepods Anomalocera ornata and Nannocalanus minor, the fishes Urophycis sp. and Mugil curema, the siphonophore Abylopsis tetragona and cypris larvae of barnacles.

Fall collections (BLM05W) showed a consistently higher estimate of abundance from 202 μm bongos, compared with 505 μm collections. In the present winter collections, however, higher estimates from 202 μm nets were restricted to the smaller species (Oithona spp., Paracalanus sp., Pleuromamma gracilis, Clausocalanus arcuicornis, e.g.). Certain of the larger species were caught in greater relative numbers in the 505 μm net: P. gaudichaudii, Calanus finmarchicus and Rhincalanus nasutus are examples.

Diversity. The Shannon index, evenness and species richness are listed for each winter collection in Table 4-14, with stations arranged inshore to offshore and south to north. Diversity estimates, H' and species richness, gave opposite results in comparison of 202 μm and 505 μm bongo collections: 20 of 21 paired observations yielded greater species richness indices for 505 μm collections, whereas only four of the 21 pairs had higher H' indices in the coarser-meshed collections. Diversity increased from the coast to offshore stations, but the south to north decrease evident in the fall of 1976 was reversed in winter collections. Maximum richness (8.6902) occurred in a bongo 505 collection at Station J1 with 92 identified taxa. Minimum richness (0.4335) was found in a daytime neuston collection from Station L1, containing only four species. Sharp decreases in diversity were evident in dawn and dusk neuston tows at stations where Parathemisto gaudichaudii was abundant.

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Table 4-12. Frequency of occurrence and abundance of common species in bongo collections, BLM06W.

Species	Percent Occurrence	Mean Catch per 100 m^3		Max. Catch per 100 m^3
		505 µm	202 µm	
Centropages typicus	100	13,786	26,921	173,887
Parathemisto gaudichaudii	100	191	80	1,356
Sagitta tasmanica	95	285	308	1,347
Metridia lucens	86	647	940	7,358
Ammodytes sp.	86	27	34	553
Thysanoessa sp.	79	16	12	74
Calanus finmarchicus	76	456	257	4,069
Sagitta minima	69	6	17	97
Limacina retroversa	64	9	5	70
unid. polychaetes	64	1	5	24
Euphausia sp.	62	120	112	871
Dichelopandalus leptocerus	60	9	8	45
Conchoecia curta	60	2	3	29
Clausocalanus arcuicornis	57	568	3,649	23,670
unid. euphausiids	57	10	14	77
Pleuromamma gracilis	55	66	2,026	12,646
Rhincalanus nasutus	55	248	171	1,226
unid. copepodites	52	885	2,009	19,008
Sagitta elegans	52	24	17	160
Paracalanus sp.	50	873	13,696	41,427
Oithona spp.	50	90	42,002	542,756
Sagitta enflata	50	7	6	32
Thysanoessa gregaria	50	7	7	34
Euchirella rostrata	45	139	262	2,453
Sergestes arcticus	45	1	3	34

Table 4-13. Frequency of occurrence and average abundance of common species in neuston collections, BLM06W.

Species	Percent Occurrence	Mean Catch per Standard Tow	Max. Catch per Standard Tow
Centropages typicus	93	5,216	85,632
Parathemisto gaudichaudii	84	2,850	42,496
Sagitta tasmanica	61	48	912
Anomalocera ornata	58	1,318	22,816
Ammodytes sp.	57	31	656
Metridia lucens	55	353	6,656
Calanus finmarchicus	55	61	512
Nannocalanus minor	42	36	288
Urophycis sp.	42	15	643
Mugil curema	41	2	14
Abylopsis tetragona	41	2	11
unid. barnacle cypris larvae	39	77	3,808
Pleuromamma gracilis	36	414	24,576
Clausocalanus arcuicornis	34	56	992
Rhincalanus nasutus	34	17	176
Sagitta enflata	34	4	59
Idotea metallica	34	1	8
unid. euphausiids	30	157	6,432
Eucalanus pileatus	30	13	288
Conchoecia sp.	30	3	53
Sagitta minima	30	1	15

Table 4-14. Diversity of surface and subsurface zooplankton collections, BLM06W. H' = Shannon index (base-2); J' = evenness; Richness = Margalef's index of species richness; N = night, D = day, Ns = neuston, B = bongo.

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L1	Z77-012	Ns, N	0.5533	0.1416	1.6104
	-013	B505, N	0.3576	0.0915	1.1407
	-014	B202, N	1.0852	0.2850	0.9525
	-015	Ns, N	0.3302	0.0892	1.2843
	-016	Ns, N	0.3771	0.1090	1.2104
	-017	Ns, D	0.1038	0.0402	0.5922
	-018	Ns, D	0.2652	0.1326	0.4335
	-019	Ns, D	0.4180	0.1800	0.7391
	-020	Ns, D	0.5515	0.1965	0.8798
	-021	Ns, N	0.9649	0.3044	1.0620
L2	Z77-022	Ns, N	0.6723	0.1681	1.3978
	-023	B505, N	0.2744	0.0559	2.2084
	-024	B202, N	0.9956	0.2615	0.8542
	-025	Ns, N	1.2274	0.3224	1.1246
	-026	Ns, N	0.2054	0.0594	0.8826
	-027	Ns, D	1.1251	0.3750	0.9307
	-028	Ns, D	0.5607	0.1769	1.1157
	-029	Ns, D	0.5281	0.1881	0.7127
	-030	Ns, D	1.0255	0.2860	1.2354
	-031	Ns, N	0.4529	0.1510	0.7945
L4	Z77-032	Ns, N	0.5806	0.1678	0.9309
	-033	Ns, D	1.4602	0.3572	2.1181
	-034	Ns, D	0.6858	0.1615	2.1497
	-035	Ns, D	1.1497	0.3323	1.2166
	-036	Ns, D	0.4714	0.1571	0.6948
	-037	Ns, N	1.7389	0.3579	3.4250
	-038	B505, N	1.0597	0.1953	3.7519
	-039	B202, N	2.3797	0.4803	2.5019
	-040	Ns, N	1.1517	0.2371	3.4279
	-041	Ns, N	2.7395	0.5699	3.3594
L6	Z77-001	Ns, D	2.0353	0.4190	4.0913
	-002	Ns, D	1.1406	0.2488	2.3891
	-003	Ns, N	2.9982	0.5492	5.2558
	-004	Ns, N	3.4351	0.6331	5.7311
	-005	Ns, N	3.5669	0.6615	5.2174
	-006	Ns, N	1.2969	0.2549	4.0612
	-007	Ns, D	1.1356	0.3069	1.8659
	-008	Ns, D	2.2049	0.5791	2.5198
	-009	B202, N	2.3306	0.4544	2.7962

Table 4-14 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L6	Z77-011	B505, N	2.1418	0.3722	5.2030
C1	Z77-110	Ns, D	1.8345	0.6115	1.5041
	-111	Ns, D	1.0798	0.4117	1.0148
	-112	Ns, D	0.5217	0.2018	0.5258
	-113	Ns, N	1.9119	0.5022	1.6949
	-114	B202, N	0.8844	0.2323	1.0321
	-115	B505, N	0.4328	0.1082	1.1949
	-116	Ns, N	0.9398	0.2621	1.2815
	-117	Ns, N	1.4155	0.4092	0.8861
	-118	Ns, N	1.2032	0.3622	1.0567
	-119	Ns, D	0.7494	0.2669	0.6551
D1	Z77-107	B505, N	0.9240	0.1943	2.2033
	-108	Ns, N	0.2301	0.0665	1.1122
	-109	B202, N	2.3164	0.4988	2.1333
N3	Z77-056	Ns, N	0.4258	0.1151	1.0510
	-057	B505, N	2.1151	0.4815	1.4659
	-058	B202, N	1.6264	0.3900	1.2115
E3	Z77-059	B505, N	2.3364	0.4119	4.4490
	-060	Ns, N	2.3503	0.4416	4.5836
	-061	B202, N	2.9844	0.5434	3.4279
	Z77-062	B505, N	2.8066	0.4643	6.4522
	-063	B202, N	3.0144	0.5925	2.5975
	-064	B505, N	2.7607	0.4775	5.2034
	-065	B202, N	3.1033	0.5719	3.8078
	-066	B505, N	2.3901	0.4327	4.5762
	-067	B202, N	2.8641	0.5312	3.3548
	-068	Ns, N	3.0096	0.5546	5.0345
	-069	Ns, N	1.7309	0.3601	3.0989
	-070	Ns, D	1.2270	0.3316	1.3505
	-071	Ns, D	1.9340	0.4638	2.3172
	-072	Ns, D	1.5394	0.3505	3.0930
	-073	Ns, D	0.9485	0.2233	1.6986
	-074	Ns, N	2.1286	0.4382	3.6173
F2	Z77-053	B505, N	3.7713	0.6285	7.4248
	-054	B202, N	2.8001	0.4616	5.3080
	-055	Ns, N	1.4281	0.2846	3.6607

Table 4-14 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
J1	Z77-042	B505, N	3.4795	0.5334	8.6902
	-043	Ns, N	2.3143	0.3902	6.4779
	-044	B202, N	3.4683	0.5621	6.2945
	-046	Ns, N	1.5740	0.2775	4.9680
	-047	Ns, N	1.7998	0.3509	3.8470
	-048	Ns, D	1.0000	0.2354	2.1794
	-049	Ns, D	0.5053	0.1263	2.0131
	-050	Ns, D	0.1407	0.0331	1.7910
	-051	Ns, D	0.8039	0.1731	2.6411
	-052	Ns, N	1.4538	0.3310	2.1040
B5	Z77-075	Ns, D	1.5321	0.4274	1.8485
	-076	Ns, D	1.2946	0.3897	1.1545
	-077	Ns, D	0.4076	0.1178	0.9416
	-078	B202, N	2.3115	0.5110	1.7282
	Z77-079	B505, N	1.4043	0.3249	1.7256
	-080	B505, N	1.1644	0.2694	1.7941
	-081	B202, N	2.1074	0.4726	1.5200
	-082	B505, N	1.3840	0.2698	2.8276
	-083	B202, N	2.1121	0.4809	1.5408
	-084	Ns, N	1.4645	0.3846	1.6078
	-085	B505, N	1.3196	0.2716	2.3909
	-086	B202, N	2.4112	0.5676	1.4418
	-087	Ns, N	1.9997	0.4892	1.9963
	-088	Ns, N	1.7266	0.4666	1.3151
	-089	Ns, N	1.5270	0.3817	1.7631
	-090	Ns, D	1.5810	0.4272	1.5749
A2	Z77-091	Ns, D	1.1114	0.2779	2.0819
	-092	Ns, D	0.5025	0.1286	1.6745
	-093	Ns, D	0.5681	0.1256	2.2002
	-094	B505, N	1.7048	0.3086	3.9625
	-095	B202, N	3.1281	0.6314	2.6281
	-096	B202, N	2.4993	0.5199	2.3245
	-097	B505, N	1.7596	0.3431	3.0396
	-098	Ns, N	2.3845	0.4451	4.4882
	-099	B505, N	2.7029	0.5045	3.9479
	-100	B202, N	1.9535	0.4207	1.8524
	-101	B505, N	2.0686	0.3836	4.3938
	-102	B202, N	2.7878	0.4915	4.2195
	-103	Ns, N	0.4927	0.0939	3.8713
	-104	Ns, N	2.8364	0.5000	5.9580

Table 4-14 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
A2	Z77-105	Ns, N	1.3561	0.3138	1.9098
	-106	Ns, D	1.4417	0.3690	1.6537

Cluster Analyses. As in the previous cruise, bongo and neuston winter collections were clustered separately, dropping species that occurred in less than 5% of the respective collections.

I. Bongo collections. Clusters of 42 bongo samples from BLM06W are shown in Figure 4-26. The primary division of samples was into two groups:

1. Coastal and Central Shelf
2. Outer Shelf to Slope

Subdivisions within these major groups included the coastal New Jersey station C1, southern stations L1 and L2 plus D1, samples from N3 and B5, and clusters of 505 μm and 202 μm collections within the outer shelf to slope group.

Inverse species clusters and a nodal analysis for bongo collections are shown in Figures 4-27 and 4-28. The individual collections and species comprising the sample and species groups are listed in Table 4-15. Sample groups I and II, that include all coastal stations (C1, D1, L1, L2) were characterized most closely with Species group A with its inshore mysids, the copepods *Centropages hamatus* and *Temora longicornis*, barnacle larvae and larvae of the sand shrimp, *Crangon septemspinosa*. Central shelf stations N3 and B5 (Sample group III) were populated by species groups B, C and D, as well as the wide-spread species groups J and K. The latter (J and K) include all the common species listed in Table 4-12. Sample groups IV (offshore 505 μm collections) and V (offshore 202 μm collections) contained elements of every species group except A, the coastal community.

II. Neuston collections. Clusters of 76 neuston samples from BLM06W are shown in Figure 4-29. As in bongo clustering, the principal clusters of neuston samples were:

1. Coastal and Central Shelf
2. Outer Shelf to Slope

Coastal New Jersey collections (Station C1) were linked to other coastal and inner shelf samples (all L1, L2, D1, N3 and some from B5) at a relatively low level of similarity. Night tows at B5 were linked to coastal collections, while day tows at that station were clustered with daytime offshore tows. Outer shelf samples were equally divided between day and night tows.

Inverse species clusters and results of a nodal analysis are shown in Figures 4-30 and 4-31, with an identification of collections and species in Table 4-16. Species group A was characteristic of samples from Station L1 (sample groups I and

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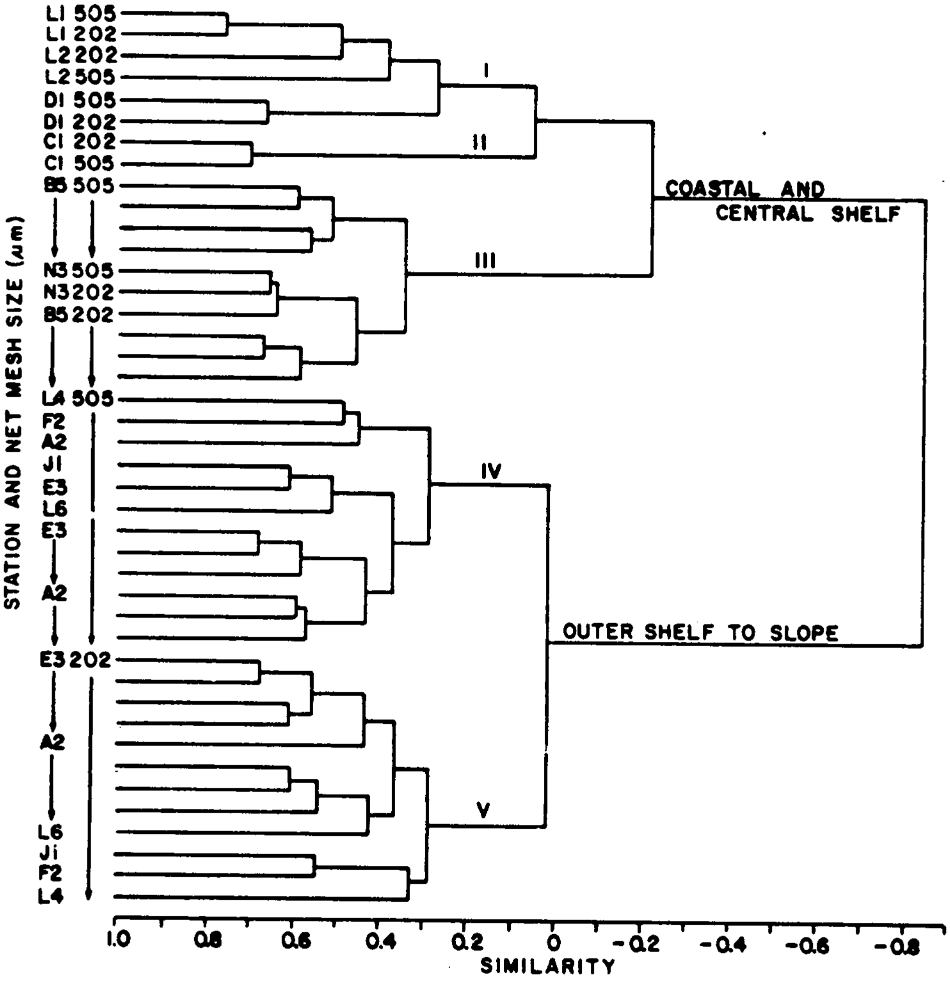

Figure 4-26. Bongo sample clusters, BLM06W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to numbers per 100m^3.

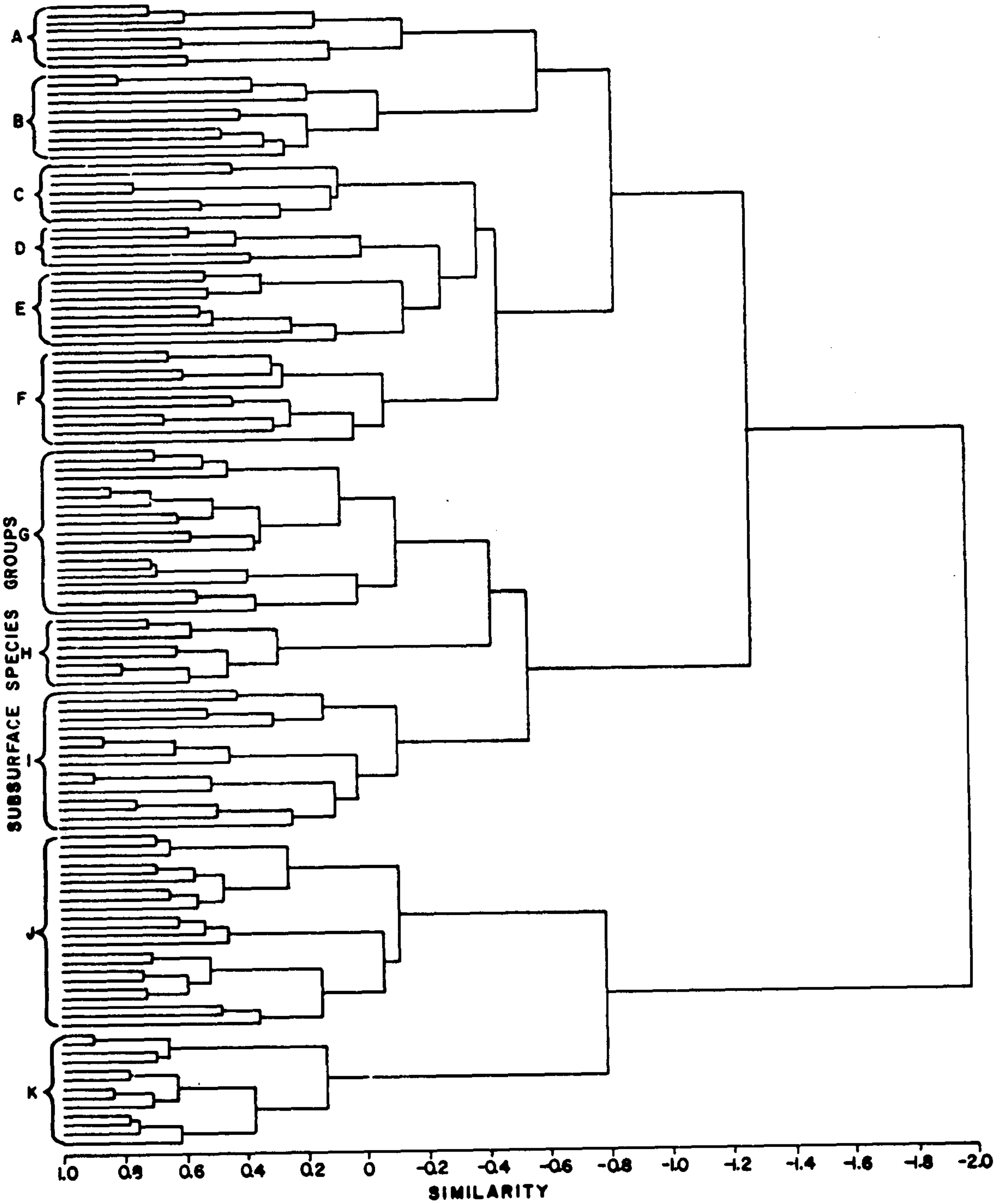

Figure 4-27. Inverse species cluster, bongo tows, BLM06W. See Table 4-15 for identification of species within groups A-K.

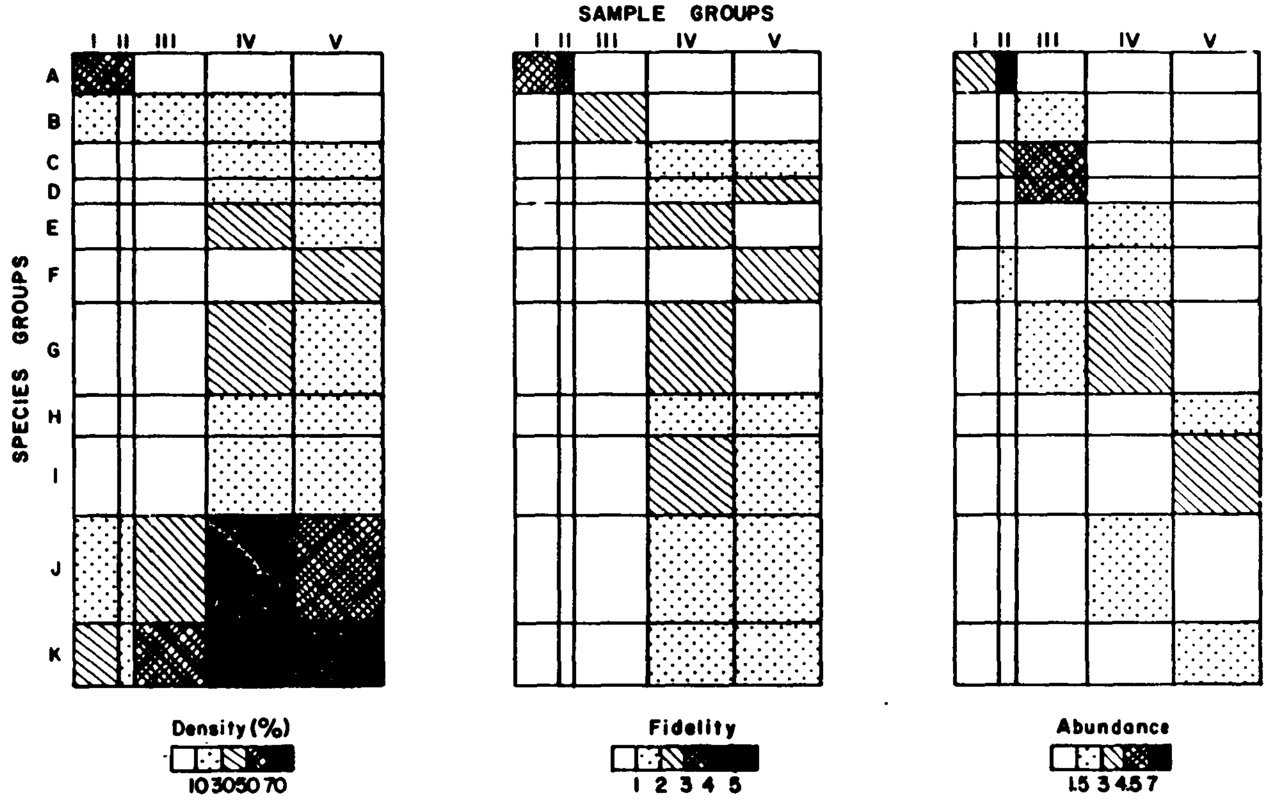

Figure 4-28. Nodal density (or constancy), fidelity, and abundance of species groups within sample groups from the bongo cluster analyses of BLM06W.

Table 4-15. Identification of elements in sample and species groups from cluster analyses of bongo collections, BLM06W.

Sample Cluster	Mesh Size and Station Numbers
I	202 μm: L1, L2, D1; 505 μm: L1, L2, D1
II	202 μm: C1; 505 μm: C1
III	202 μm: N3, B5 (4 tows); 505 μm: N3, B5 (4 tows)
IV	505 μm: L4, L6, E3 (4 tows), F2, J1, A2 (4 tows)
V	202 μm: L4, L6, E3 (4 tows), F2, J1, A2 (4 tows)

Species Cluster	Taxa (listed in phylogenetic order within clusters)		
A	*Ensis directus* *Centropages hamatus* *Temora longicornis*	barnacle larvae *Mysidopsis bigelowi* *Neomysis americana*	*Leptocuma minor* *Crangon septemspinosa*
B	unid. nemerteans *Campylaspis* sp. *Diastylis sculpta* unid. cumaceans	*Ampelisca vadorum* *Byblis serrata* *Unciola irrorata*	*Cancer* sp. *Anguilla rostrata* *Paralichthys dentatus*
C	*Euchaeta* sp. *Heterorhabdus* sp. *Pleuromamma abdominalis*	*Euphausia krohnii* *Meganyctiphanes norvegica*	*Nematoscelis megalops* *Eualus* sp.
D	*Gennadas* sp. *Sagitta decipiens*	*Sagitta hexaptera* *Sagitta lyra*	*Oikopleura* sp.
E	*Rossia tenera* *Anomalocera ornata* *Euchaeta marina*	*Rhincalanus cornutus* *Scolecithrix danae* unid. calanids	unid. gammarids *Thysanoessa longicaudata* *Portunus* sp.
F	*Paedoclione doliiformis* *Aetideus armatus* *Calocalanus pavo* *Eucalanus* sp.	*Mecynocera clausi* *Pseudocalanus* sp. *Temora turbinata* *Clytemnestra rostrata*	*Euterpina acutifrons* *Corycaeus speciosus* *Oncaea* sp.
G	*Abylopsis eschsholtzii* *Abylopsis tetragona* *Bassia bassensis* *Eudoxides spiralis* *Illex illecebrosus* *Muggiaea kochei* unid. hydrozoans	*Halocypris brevirostris* *Lepas* sp. *Lestrigonus bengalensis* *Lucifer faxoni* *Parthenope* sp. *Solenocera* sp.	unid. pagurids unid. xanthids unid. decapods *Doliolum nationalis* *Gobiosoma ginsburgi* unid. fish larvae

Table 4-15. (Concluded)

Species Cluster	Taxa		
H	*Chelophyes appendiculata* *Diphyes dispar* *Limacina inflata*	*Phrosina semilunata* unid. majids unid. penaeids	*Salpa fusiformis* *Cyclothone* sp.
I	*Agalma elegans* *Diphyes bajani* *Lensia conoidea* *Lensia multicristata* *Sulculeolaria chuni* *Tomopteris helgolandica*	*Cavolina inflexa* *Peraclis reticulata* unid. gastropod larvae *Diastylis* sp. *Diastylis quadrispinosa*	*Primno macropa* *Krohnitta subtilis* *Pterosagitta draco* *Urophycis* sp. unid. myctophids
J	*Tomopteris* sp. unid. polychaetes *Limacina retroversa* *Conchoecia* sp. *Conchoecia curta* *Euconchoecia chierchiae* *Eucalanus attenuatus* *Eucalanus pileatus*	*Nannocalanus minor* *Diastylis polita* *Monoculodes* sp. *Thysanoessa* sp. *Thysanoessa gregaria* unid. euphausiids *Dichelopandalus leptoceras*	*Sergestes arcticus* *Eukrohnia hamata* *Sagitta elegans* *Sagitta enflata* *Sagitta helenae* *Sagitta minima* *Ammodytes* sp.
K	*Calanus finmarchicus* *Centropages typicus* *Clausocalanus arcuicornis* *Euchirella rostrata* *Metridia lucens*	*Paracalanus* sp. *Pleuromamma gracilis* *Rhincalanus nasutus* unid. copepodites	*Oithona* spp. *Parathemisto gaudichaudii* *Euphausia* sp. *Sagitta tasmanica*

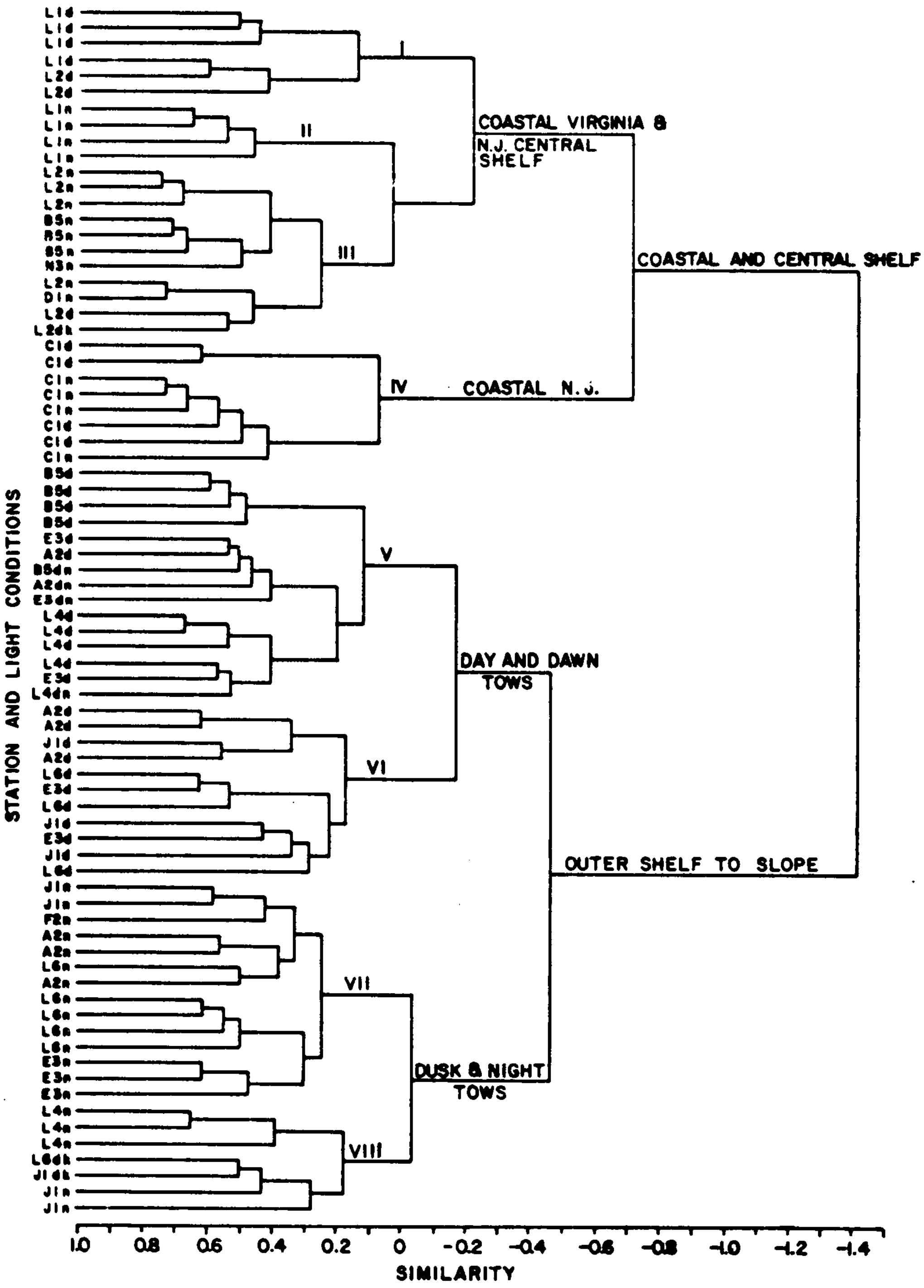

Figure 4-29. Neuston sample clusters, BLM06W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to 20 min. tows. Lettering after station numbers indicates: n=night, d=day, dk=dusk, dn=dawn.

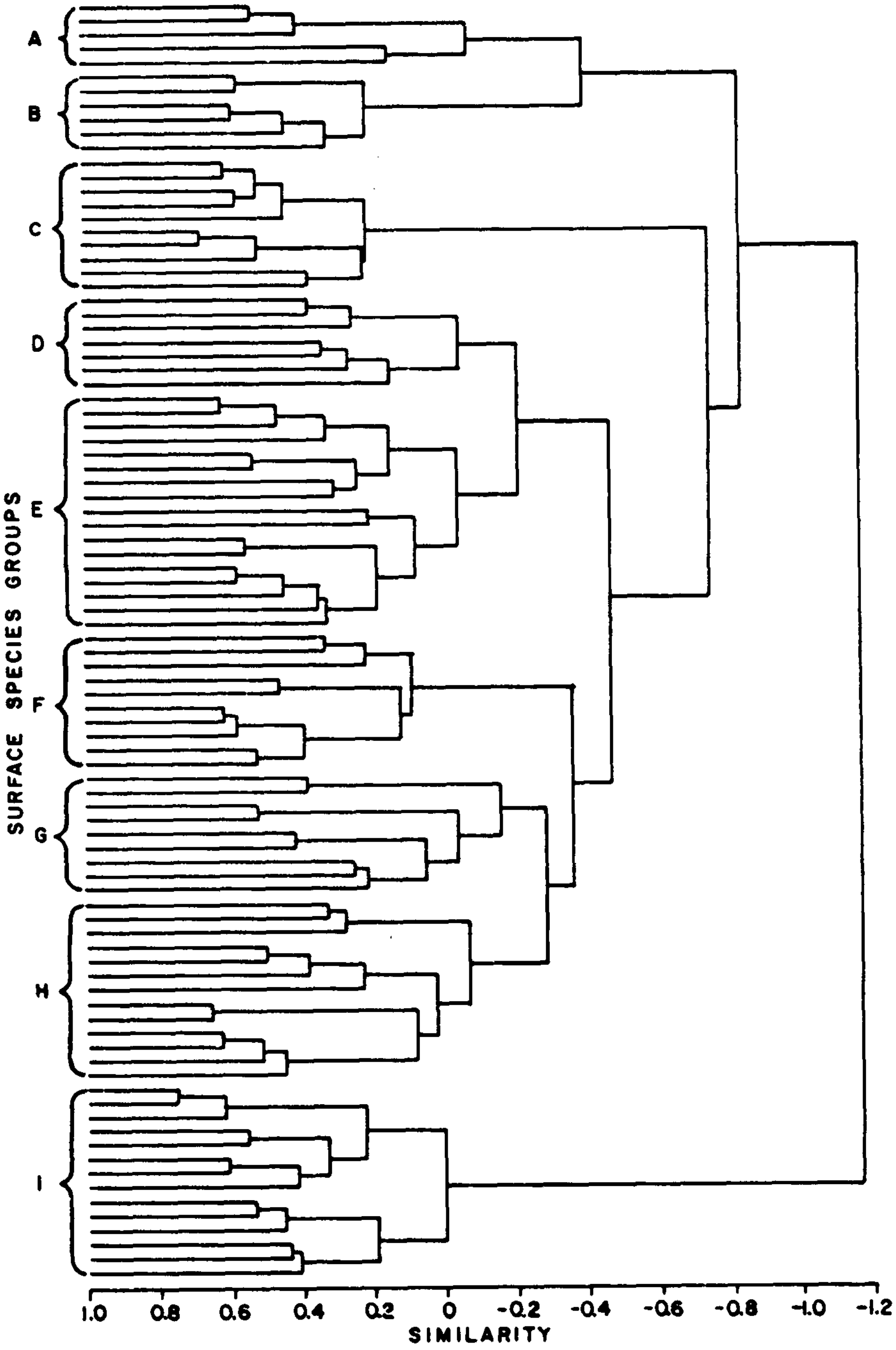

Figure 4-30. Inverse species clusters, neuston tows, BLM06W. See Table 4-16 for identification of species within groups A-I.

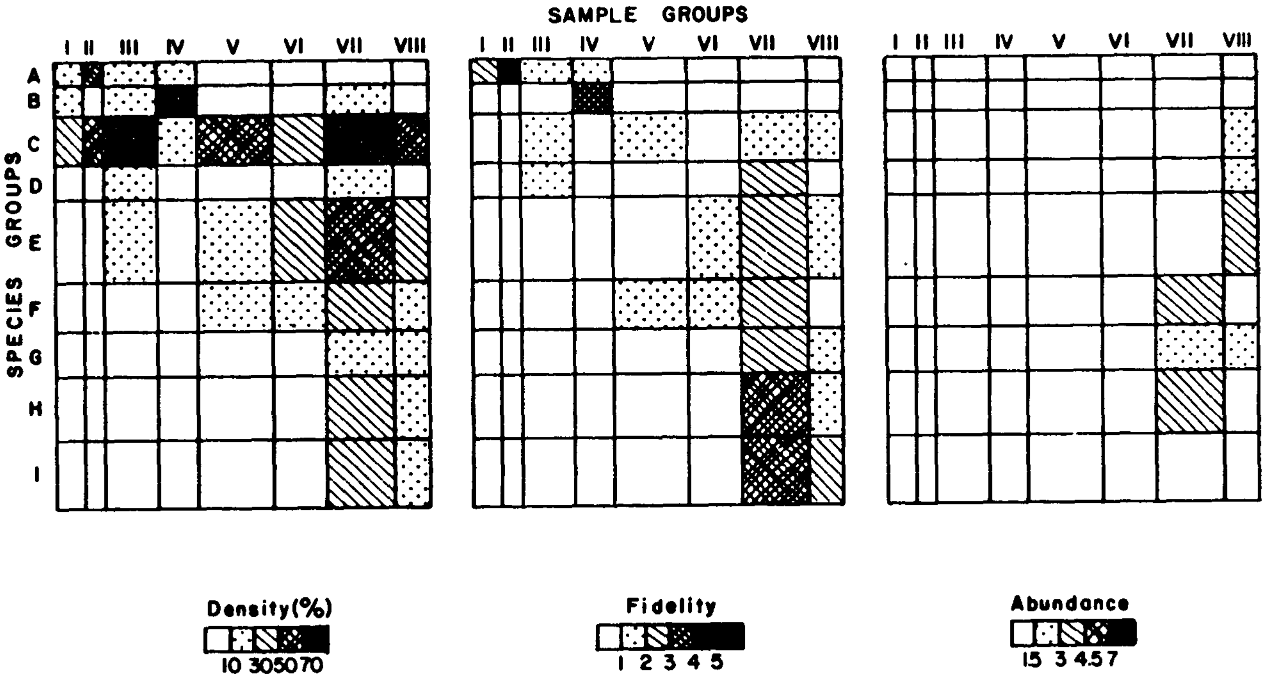

Figure 4-31. Nodal density (or constancy), fidelity, and abundance of species groups within sample groups from the neuston analyses of BLM06W.

Table 4-16. Identification of elements in samples and species groups from cluster analyses of neuston collections, BLM06W.

Sample Cluster	Station Numbers and Time of Day (N=night, D=day)
I	L1D(4), L2D(2)
II	L1N(4)
III	L2N(4), L2D(2), D1N, N3N, B5N(3)
IV	C1N(4), C1D(4)
V	L4N(4), L2D, E3N, E3D(2), B5N, B5D(4), A2N, A2D
VI	L6D(3), E3D(2), J1D(3), A2D(3)
VII	L6N(5), E3N(3), F2N, J1N(2), A2N(3)
VIII	L4N(3), L6D, J1N(2), J1D

Species Cluster	Taxa (listed in phylogenetic order within clusters)		
A	Ensis directus Eucalanus sp.	Oithona spp. Mysidopsis bigelowi	Crangon septemspinosa
B	Acartia tonsa Centropages hamatus	Pseudocalanus sp. Temora longicornis	unid. barnacle larvae Neomysis americana
C	Anomalocera ornata Calanus finmarchicus Centropages typicus Clausocalanus arcuicornis	Metridia lucens Nannocalanus minor Pleuromamma gracilis	Parathemisto gaudichaudii Sagitta tasmanica Ammodytes sp.
D	Limacina retroversa Cancer sp. Dichelopandalus leptoceras	Sagitta decipiens Sagitta elegans	Doliolum nationalis Oikopleura sp.
E	Abylopsis eschscholtzii Abylopsis tetragona Bassia bassensis Eudoxides spiralis Conchoecia sp. Conchoecia curta	Temora stylifera Lepas sp. Idotea metallica Euphausia sp. Thysanoessa sp. unid. euphausiids	Sergestes arcticus Sagitta enflata Sagitta minima Mugil curema Urophycis sp.
F	Eucalanus attenuatus Eucalanus pileatus Euchaeta sp. Euchaeta marina	Euchirella rostrata Pleuromamma abdominalis Pleuromamma piseki	Rhincalanus cornutus Rhincalanus nasutus unid. calanids

Table 4-16. (Concluded)

Species Cluster	Taxa		
G	*Aetideus armatus* *Labidocera aestiva* *Paracalanus* sp.	*Scolecithrix* danae *Temora turbinata* unid. copepodites	*Lestrigonus bengalensis* *Meganyctiphanes norvegica* *Sagitta* sp.
H	*Chelophyes appendiculata* *Tomopteris* sp. unid. polychaetes *Limacina inflata* *Candacia* sp.	*Lucifer faxoni* unid. penaeids *Pterosagitta draco* *Sagitta helenae*	*Sagitta hexaptera* *Sagitta serratodentata* *Salpa fusiformis* *Scomberesox saurus*
I	*Diphyes bojani* *Diphyes dispar* unid. hydrozoans *Pleurobrachea pileus* *Cavolina uncinata*	*Euconchoecia chierchiae* *Halocypris brevirostris* unid. stomatopod larvae *Callinectes* sp. *Ovalipes* sp.	*Parthenope* sp. *Portunus* sp. unid. xanthids unid. decapods

II) and contained Ensis, Mysidopsis and Crangon as inshore types. Samples from Station C1 (sample group IV) were characterized by species group B (Acartia tonsa, Centropages hamatus, Temora longicornis and Neomysis americana, the winter coastal community). Remaining inshore samples (sample group III) were dominated by representatives of the widespread species group C, and also contained species from groups A, B, D and E. Species group C contained many of the dominants, including Centropages typicus, Parathemisto gaudichaudii, Pleuromamma gracilis, Anomalocera ornata and Metridia lucens. Offshore day tows (sample groups V and VI were represented by species groups C, E and F; offshore night tows added species from groups G, H and I.

Synopsis of Cruise BLM06W

1. Subsurface zooplankton biomass was relatively uniform from north to south over the study area, being particularly reduced only at the offshore New Jersey stations F2 and J1. Biomass estimates (17-189 ml/100m^3 in 202 μm nets, and 13-56 ml/100m^3 in 505 μm nets) were considerably lower than those in the fall 1976 cruise. Neuston volumes were also reduced in winter, especially in coastal Virginia locations, stations L1 and L2. At 24-hr stations, volumes were again highest at night or in late afternoon.

2. Centropages typicus numerically dominated all but two of the bongo 505 tows, 32 of the 75 neuston tows, and 5 of the 21 bongo 202 tows. C. hamatus was dominant at Station C1 in all tows except one neuston tow dominated by barnacle larvae. Oithona spp. and Paracalanus sp. dominated remaining bongo 202 tows; Rhincalanus nasutus was the most abundant species in the bongo 505 tow at Station F2.

Along the outer shelf and slope, Centropages spp. were largely replaced as dominants in the neuston by Parathemisto gaudichaudii (18 tows), Anomalocera ornata (12 northern tows) and Metridia lucens (3 tows).

3. The most frequent species in both bongo and neuston tows were Centropages typicus, Parathemisto gaudichaudii and Sagitta tasmanica, in that order. C. typicus was, by far, the most abundant species in bongo 505 tows, but was outnumbered in bongo 202 tows by Oithona spp. C. typicus, P. gaudichaudii and A. ornata were most abundant in neuston tows.

4. Diversity was much reduced in coastal and inner shelf waters, highest along the outer shelf and shelf-break off southern New Jersey.

5. Principal clusters of both subsurface and neustron collections were (a) coastal and central shelf stations and (b) outer shelf to sloper stations.

Spring 1977 Cruise No. BLM07W

Summary of Collections

Subsurface and surface collections of zooplankton in the spring 1977 cruise were obtained from the 12 designated water column stations during the period 17-28 May 1977. Replicate bongo sampling for both taxonomy and chemistry was conducted at stations A2, B5, and E3, all such tows taken at night, usually between 2000 hours and midnight. Additional bongo tows with a single system were made twice at each of the 12 stations, once each with 202 μm and 505 μm nets. Total samples for taxonomy and biomass numbered 42; 88 samples were frozen for chemistry, evenly split between 202 μm and 505 μm nets and between samples for hydrocarbons and trace metals, and including extra splits from each mesh size from the quality control station L4.

A 24-hour cycle of neuston collections (one every three hours) was obtained from nine stations (all but D1, N3, and F2, where single tows were made) for a total of 75 collections. As in the winter cruise, there were few large organisms in the neuston for chemical analysis. Idotea metallica were obtained from stations L1 and L6, Pelagia noctiluca from Station J1. Eleven samples of tarballs were obtained from outer shelf and slope stations L6, E3, F2, J1, B5, and A2.

Biomass

Biomass of spring zooplankton, expressed as displacement volume in $ml/100m^3$ for subsurface zooplankton and ml/standard 20 minute tow for neuston, is given in Table 4-17. Estimates of biomass from 202 μm bongo nets were usually, but not always (16 of 21 paired tows), higher than from 505 μm nets. Biomass of subsurface zooplankton was much higher than in winter at all stations except B5, where volumes were similar and at L1, where volumes were even lower than winter. Order of magnitude increases from winter to spring were evident in several central and outer shelf stations.

Neuston volumes were particularly low at the inner Virginia shelf stations L1 and L2 (average of ca 20 ml/tow), about the same as winter or slightly higher at inner and central shelf stations off New Jersey and greatly augmented at outer shelf and slope stations, north and south. Volumes per standard tow exceeded one liter at stations L4, L6, and J1. Many of the neuston tows in this cruise had to be shortened to 10 minutes because of the high volume in catches.

Table 4-17. Displacement volume of zooplankton collections, spring 1977 (BLM07W). Standardized to ml/100m^3 for 60 cm bongos and to ml/20 min. tow for neuston collections.

	Bongo (ml/100 m^3)		Neuston 505 μm (ml/20 min. tow)							
			Approx. hour of collection							
Station	202 μm	505 μm	0300	0600	0900	1200	1500	1800	2100	2400
L1	14	42	25	23	5	3	5	10	85	50
L2	323	6	15	40	10	<3	25	25	5	5
L4	351	88	445	2088	620	1930	822	1654	640	190
L6	195	127	1110	3908	1600	422	706	4970	858	660
C1	317	373	290	15	25	38	45	<3	300	45
D1	732	495	216							
N3	700	826							235	
E3	184	173	256	16	15	25	50	74	175	195
	105	87								
	147	119								
	133	99								
F2	286	195							322	
J1	51	49	850	2775	1683	260	130	940	5600	864
B5	148	58	55	35	35	5	<3	27	108	25
	90	53								
	101	53								
	40	74								
A2	199	230	135	45	25	20	65	75	225	117
	254	121								
	242	155								
	188	142								

Neuston collections with higher volumes were dominated in every case by the salp, Thalia democratica.

Faunal Description

Over 300 species were identified from spring bongo and neuston collections (Table 4-18), including at least 47 species of molluscs, 57 copepods, 50 amphipods, 31 decapods, 15 chaetognaths, and 54 fishes. A large number of those species that were restricted to neuston also occurred in more than 5% of the neuston tows, including Anomalocera sp., A. ornata, Labidocera aestiva, Pontellopsis sp., P. regalis, and Sapphirina pyrosomatis (copepods); the mysid Siriella thompsoni; the isopod Idotea metallica; the amphipod Pseudolycaea sp.; decapods Ovalipes sp. and Latreutes fucorum; and the fishes Gasterosteus aculeatus, Mugil curema, Scomberesox saurus, Sphoeroides sp., and unidentified balistids and blenniids.

Dominant species in the spring collections are listed by station in Table 4-19. All subsurface collections (bongo nets) were dominated by copepods, except a single 202 μm collection from Station C1 that was dominated by an unidentified hydromedusa. The effect of the cold winter of 1977, not reflected in February collections, was clearly evident in spring collections. A northern community of zooplankton, in which Calanus finmarchicus, Sagitta elegans, and Pseudocalanus sp. are prominent components, extended southward over most of the New Jersey transect. C. finmarchicus was dominant at stations D1, N3, E3, F2, J1, B5, and A2 (505 μm nets). This was the first instance in seven seasonal cruises of dominance by C. finmarchicus rather than Centropages typicus. The latter retained its usual dominant role, however, along the southern L-transect, and was among the subdominants in northern stations. Crab larvae (Cancer sp.) dominated 505 μm collections at coastal stations off New Jersey and Virginia (C1 and L1). Cold-water species in coastal collections included Centropages hamatus and Crangon septemspinosa at the southern station L1, and Temora longicornis at Station C1. Fine-mesh collections (202 μm) were dominated by either Oithona spp., Paracalanus sp., or unidentified copepodites throughout the study area.

Surface dominants from neuston collections along the southern transect included crab larvae (Cancer sp.), fish eggs, and barnacle larvae at the inshore stations. Offshore neuston was heavily dominated by the salp Thalia democratica. Fish eggs and Cancer sp. larvae were also important in the surface layer of coastal New Jersey waters, but most northern central shelf collections were dominated by those species important in subsurface plankton (C. finmarchicus, S. elegans, C. typicus, etc.). The slope station (J1) collections of neuston were similar to those off Virginia, with an abundance of the salp T. democratica.

(TEXT CONTINUES ON PAGE 4-102)

Table 4-18. List of zooplankton identified from bongo and neuston collections, spring 1977 (BLM07W). Species from subsurface collections only (*); from surface collections only (**).

COELENTERATA
**Pelagia noctiluca
**Porpita porpita
unid. hydrozoans
unid. scyphozoans
unid. siphonophores

CTENOPHORA
**Beroe sp.
Beroe ovata

TURBELLARIA
**Gnesioceros sargassicola
*unid. flatworms

RHYNCHOCOELA
*unid. nemerteans

ANNELIDA
*Tomopteris sp.
Tomopteris helgolandica
unid. polychaetes

MOLLUSCA
Atlanta gaudichaudi
Atlanta peroni
*Brachioteuthis beanii
Cavolina inflexa
Cavolina longirostris
Cavolina tridentata
Cavolina uncinata
**Clio cuspidata
*Clione limacina
Creseis acicula
Creseis virgula
**Crucibranchaea sp.
Diacria quadridentata
**Doridella obscura
Dosinia discus
**Doto pygmaea
Ensis directus
**Fiona pinnata
**Firoloida leseurii
*Histioteuthis reversa
*Hyalocyclis striata
**Illex sp.
**Janthina eniqua
**Limacina inflata
**Limacina leseuri

MOLLUSCA (continued)
Limacina retroversa
Limacina trochiformis
**Litiopa melanostoma
Loligo pealeii
*Lunatia triseriata
*Macoma balthica
**Melampus bidentatus
*Mulinia lateralis
Notobranchaea macdonaldi
*Paedoclione sp.
Paedoclione doliiformis
**Paraclione longicaudata
*Pleurobranchaea tarda
*Pneumoderma atlanticum
**Proatlanta souleyet
**Pterotraches scutata
*Rossia tenera
**Scyllaea pelagica
*Spisula solidissima
**Thelidioteuthis allessandrina
unid. bivalves
unid. gastropods
unid. runcinids

CLADOCERA
Evadne nordmanni
Evadne spinifera
Penilia avirostris
*Podon leuckartii

OSTRACODA
Conchoecia sp.
*Conchoecia curta
*Euconchoecia sp.
Euconchoecia chierchiae
*Halocypria globosa
Halocypris brevirostris

COPEPODA
*Acartia sp.
*Acartia danae
Acartia tonsa
Aetideus armatus
**Anomalocera sp.
**Anomalocera ornata
Anomalocera patersonii
Calanus finmarchicus
*Calocalanus pavo

Table 4-18. (Continued)

COPEPODA (continued)
Candacia sp.
Candacia armata
Candacia curta
**Candacia pachydactyla
*Centropages sp.
**Centropages furcatus
Centropages hamatus
Centropages typicus
Centropages violaceus
Clausocalanus sp.
Clausocalanus arcuicornis
Eucalanus sp.
*Eucalanus attenuatus
**Eucalanus elongatus
Eucalanus pileatus
Euchaeta sp.
Euchirella rostrata
**Labidocera sp.
**Labidocera acutifrons
**Labidocera aestiva
**Labidocera nerii
Mecynocera clausi
Metridia lucens
Nannocalanus minor
Paracalanus sp.
Pareuchaeta norvegica
*Pleuromamma abdominalis
Pleuromamma gracilis
**Pleuromamma piseki
*Pleuromamma robusta
**Pontella sp.
**Pontella meadii
**Pontella securifer
**Pontellopsis sp.
**Pontellopsis regalis
Pseudocalanus sp.
Rhincalanus nasutus
Scolecithrix danae
Temora sp.
Temora longicornis
Temora stylifera
Temora turbinata
Tortanus discaudatus
Undinula vulgaris
unid. copepodites
*Clytemnestra rostrata
*Microsetella sp.
**Microsetella norvegica
*Copilia quadrata
*Copilia vitrea

COPEPODA (continued)
Corycaeus sp.
Corycaeus clausi
**Corycaeus ovalis
Corycaeus speciosus
Oithona spp.
Oncaea sp.
Oncaea venusta
Sapphirina sp.
**Sapphirina angusta
Sapphirina nigromaculata
Sapphirina ovatolanceolata
**Sapphirina pyrosomatis
*Caligus sp.
*Caligus schistonyx

BRANCHIURA
**Argulus sp.

CIRRIPEDIA
Lepas sp.
Lepas fascicularis
**Lepas pectinata
unid. barnacle larvae

STOMATOPODA
unid. stomatopod larvae

MYSIDACEA
*Heteromysis formosa
Mysidopsis bigelowi
**Neomysis americana
**Siriella thompsoni

CUMACEA
Cyclaspis sp.
*Diastylis polita
Diastylis quadrispinosa
Diastylis sculpta
*Eudorella sp.
Leptocuma minor
Oxyurostylis smithi

ISOPODA
**Bagatus minutus
**Chiridotea arenicola
**Chiridotea tuftsi
Edotea triloba
**Idotea metallica

Table 4-18. (Continued)

AMPHIPODA
Acanthostepheia sp.
**Allorchestes sp.
*Ampelisca abdita
Ampelisca agassizi
Ampelisca vadorum
Amphithyrus sculpturatus
Anchylomera blossevilli
Argissa hamatipes
**Brachyscelus sp.
Brachyscelus crusculum
**Brachyscelus rapacoides
*Byblis serrata
**Calliopius leaviusculus
**Caprella sp.
**Corophium acheruscium
*Cranocephalus sp.
**Dairella californica
*Erichthonius brasiliensis
Erichthonius rubricornis
**Eupronoe sp.
**Eupronoe armata
Gammarus sp.
*Hemityphus rapax
*Hypereitta vosseleri
*Hyperoche sp.
Iulopis loveni
Lestrigonus bengalensis
**Lestrigonus latissimus
Lycaea sp.
Lycaea bovalli
**Lycaea pulex
**Lycaea serrata
**Lycaeopsis sp.
**Lycaeopsis neglecta
**Lycaeopsis zamboangae
*Monoculodes sp.
*Monoculodes edwardsi
*Monoculodes latimanus
Oxycephalus clausi
*Paracaprella tenuis
*Paralycaea sp.
**Paralycaea gracilis
*Parametopella cypris
**Paraphronima gracilis
Parathemisto gaudichaudi
**Phronima sp.
Phronima atlantica
Phronima sedentaria
Phronimella elongata
*Phrosina semilunata

AMPHIPODA (continued)
*Primno latreillei
*Primno macropa
*Protohaustorius wigleyi
**Pseudolycaea sp.
**Tetrathyrus forcipatus
**Themistella fusca
*Vibilia sp.
Vibilia armata
unid. amphipods
unid. gammarids
unid. hyperiids
unid. lycaeids
unid. platyscelids

EUPHAUSIACEA
Euphausia sp.
Euphausia krohnii
*Euphausia mutica
Meganyctiphanes norvegica
Nematoscelis sp.
Nematoscelis megalops
*Thysanoessa sp.
**Thysanoessa gregaria
*Thysanoessa inermis
*Thysanoessa longicaudata
unid. euphausiids

DECAPODA
*Bathynectes superbus
Callinectes sp.
Cancer sp.
*Caridion sp.
Crangon septemspinosa
Dichelopandalus leptocerus
Dromidia antillensis
**Ethusa sp.
*Gennadas sp.
Geryon quinquedens
**Homarus americanus
Hyas sp.
**Latreutes fucorum
**Leptochela bermudensis
Lucifer faxoni
*Lucifer typus
**Ovalipes sp.
Parthenope sp.
*Pontophilus brevirostris
Portunus sp.
*Scyllarus sp.
Sergestes sp.

Table 4-18. (Concluded)

DECAPODA (continued)
*_Sergestes arcticus_
*_Solenocera muelleri_
unid. calappids
unid. decapods
unid. glyphocrangonids
unid. grapsids
unid. majids
unid. pagurids
unid. penaeids
unid. scyllarids
unid. xanthids

CHAETOGNATHA
*_Eukrohnia hamata_
Krohnitta pacifica
Pterosagitta draco
**_Sagitta bipunctata_
Sagitta elegans
Sagitta enflata
Sagitta helenae
*_Sagitta hexaptera_
**_Sagitta hispida_
*_Sagitta lyra_
Sagitta minima
Sagitta serratodentata
Sagitta tasmanica
**_Sagitta tenuis_
**_Sagitta zetesios_

TUNICATA
Doliolum nationalis
Oikopleura sp.
Thalia democratica
**unid. salps

PISCES
Ammodytes sp.
*_Benthosema glaciale_
Bothus sp.
*_Brosmiculus imberbis_
Clupea harengus harengus
*_Conger oceanicus_
**_Coryphaena_ sp.
Enchelyopus cimbrius
*_Ephinephelus_ sp.
**_Gasterosteus aculeatus_
*_Glyptocephalus cynoglossus_
*_Gobiosoma ginsburgi_
**_Gonichthys cocco_
*_Hemipteronotus novacula_

PISCES (continued)
**_Hippocampus_ sp.
*_Hippoglossina oblonga_
*_Hippoglossoides platessoides_
Hygophum hygomi
*_Lampanyctus_ sp.
Limanda ferruginea
Liparis sp.
*_Lophius americanus_
Merluccius sp.
**_Mugil curema_
Myctophum affine
Peprilus triacanthus
*_Pholis gunnellus_
Pollachius virens
Pomatomus saltatrix
Scomber scombrus
**_Scomberesox saurus_
Scophthalmus aquosus
**_Seriola zonata_
**_Sphoeroides_ sp.
**_Symphurus_ sp.
**_Syngnathus_ sp.
**_Trachinotus carolinus_
Urophycis sp.
Urophycis chuss
**unid. balistids
**unid. blenniids
*unid. bothids
unid. engraulids
*unid. gadids
*unid. gonostomatids
**unid. labrids
*unid. myctophids
*unid. paralepidids
unid. pleuronectiforms
*unid. sciaenids
*unid. scombrids
**unid. scorpaenids
unid. scorpaeniforms
unid. synodontids
**unid. tetraodontids
unid. fishes
unclassified fish eggs

Table 4-19. Numerically dominant zooplankters in spring 1977 collections (BLM07W). Drawn from the three most abundant taxa in each tow (D = day, N = night).

Station L1

Bongo 202	Bongo 505	Neuston 505
Oithona spp.	*Cancer* sp.	*Cancer* sp. (4N,2D)
unid. copepodites	*Centropages typicus*	fish eggs (2N,4D)
Centropages hamatus	*Crangon septemspinosa*	*Evadne nordmanni* (2D)
		barnacle larvae (1N,1D)
		Oithona spp. (1N,1D)
		Crangon septemspinosa (1N)
		Centropages typicus (1N)
		Centropages hamatus (1N)
		unid. copepodites (1N)
		Anomalocera sp. (1D)
		Anomalocera ornata (1D)

Station L2

Bongo 202	Bongo 505	Neuston 505
Oithona spp.	*C. typicus*	fish eggs (3N,4D)
unid. copepodites	pagurid larvae	*C. typicus* (3N,3D)
Centropages typicus	*Diastylis quadrispinosa*	*Cancer* sp. (4N)
		barnacle larvae (1N,2D)
		Tortanus discaudatus (1N)
		Anomalocera sp. (1D)
		Oithona spp. (1D)
		Parathemisto gaudichaudii (1D)

Station L4

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	*C. typicus*	*Thalia democratica* (4N,4D)
Oithona spp.	*Metridia lucens*	*C. typicus* (4N,3D)
Clausocalanus arcuicornis	*Doliolum nationalis*	*Doliolum nationalis* (2N)
		P. gaudichaudii (1N,1D)
		Sapphirina ovatolanceolata (2D)
		unid. salp (2D)
		Temora stylifera (1N)

Table 4-19. (Continued)

Station L6

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	C. typicus	T. democratica (4N,4D)
Paracalanus sp.	M. lucens	C. typicus (4N,4D)
C. typicus	Thalia democratica	P. gaudichaudii (4N)
		S. ovatolanceolata (2D)
		Anomalocera sp. (1D)
		D. nationalis (1D)

Station C1

Bongo 202	Bongo 505	Neuston 505
unid. hydrozoans	Cancer sp.	Temora longicornis (4N,4D)
Temora sp. (immature)	Temora longicornis	Cancer sp. (3N,2D)
Temora longicornis	unid. hydrozoans	fish eggs (3D)
		C. hamatus (2N)
		T. discaudatus (2N)
		C. typicus (2D)
		Calanus finmarchicus (1D)
		unid. hydrozoans (1N)

Station D1

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	Calanus finmarchicus	C. finmarchicus (1N)
Pseudocalanus sp.	C. typicus	C. typicus (1N)
Calanus finmarchicus	M. lucens	E. nordmanni (1N)

Station N3

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	C. finmarchicus	C. finmarchicus (1N)
Sagitta elegans	S. elegans	C. typicus (1N)
Pseudocalanus sp.	C. typicus	Scomber scombrus

Table 4-19. (Continued)

Station E3

Bongo 202 (4 reps.)	Bongo 505 (4 reps.)	Neuston 505
unid. copepodites (3)	*C. finmarchicus* (4)	*C. typicus* (4N,4D)
Oithona spp. (3)	*C. typicus* (4)	*C. finmarchicus* (4N,3D)
C. finmarchicus (3)	*S. elegans* (4)	fish eggs (2N,4D)
Pseudocalanus sp. (2)		*E. nordmanni* (1N,1D)
Faracalanus sp. (1)		unid. euphausiids (1N)

Station F2

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	*C. finmarchicus*	*C. finmarchicus* (1N)
C. finmarchicus	*M. lucens*	*C. typicus* (1N)
Pseudocalanus sp.	*Pseudocalanus* sp.	*M. lucens* (1N)

Station J1

Bongo 202	Bongo 505	Neuston 505
Paracalanus sp.	*C. finmarchicus*	*T. democratica* (4N,4D)
Oithona spp.	*M. lucens*	*C. typicus* (2N,3D)
Metridia lucens	*T. democratica*	*T. stylifera* (1N,1D)
		Pleuromamma gracilis (2N)
		unid. siphonophores (2D)
		C. finmarchicus (1N)
		unid. euphausiids (1N)
		Portunus sp. (1N)
		S. ovatolanceolata (1D)
		D. nationalis (1D)

Table 4-19. (Concluded)

Station B5

Bongo 202 (4 reps)	*Bongo 505* (4 reps)	*Neuston 505*
unid. copepodites (4)	*C. finmarchicus* (4)	*C. finmarchicus* (3N,4D)
Oithona spp. (3)	*C. typicus* (4)	*S. elegans* (4N,1D)
Pseudocalanus sp. (3)	*S. elegans* (4)	*C. typicus* (3N,1D)
S. elegans		*C. hamatus* (4D)
		T. discaudatus (2D)
		T. longicornis (1N)
		Limacina retroversa (1N)

Station A2

Bongo 202 (4 reps)	*Bongo 505* (4 reps)	*Neuston 505*
unid. copepodites (4)	*C. finmarchicus* (4)	*C. finmarchicus* (4N,4D)
C. finmarchicus (4)	*M. lucens* (4)	*C. typicus* (3N,4D)
Pseudocalanus sp. (2)	*S. elegans* (2)	*S. elegans* (3N,1D)
Oithona spp. (2)	*C. typicus* (1)	fish eggs (1N,2D)
	Pseudocalanus sp. (1)	*L. retroversa* (1N)
		C. hamatus (1D)

Diel Cycles of Dominant Neustonts

Station L1. Four of the eight neuston tows at the coastal Virginia station were numerically dominated by fish eggs (Figure 4-32). Three collections were dominated by Cancer sp. larvae and the remaining one by Oithona spp. Meroplankton was particularly important at this neritic station, including Evadne nordmanni and barnacle larvae in addition to fish eggs and Cancer sp. larvae. Cancer sp., Evadne and fish eggs all peaked in early evening hours, the former at over 180,000 in a standard tow. Barnacle larvae were bimodally abundant at dawn and dusk.

Station L2. Dominants were similarly distributed offshore at L2 (four tows dominated by fish eggs, three by Cancer sp.). The eighth, tow, a very sparse collection, was numerically dominated by relatively low numbers of Centropages typicus. Numbers of crab larvae were much reduced from the inshore observation (max. 2,100/tow) and were more sharply restricted to night tows. Barnacle larvae again were bimodally abundant at dawn and dusk (Figure 4-33).

Station L4. A sharp distinction between inner shelf and outer shelf neuston was evident in comparison of collections from stations L2 and L4. At L4, seven of the eight neuston collections were heavily dominated by Thalia democratica (32,000 - 114,000 per tow). The eighth tow (midnight) was numerically dominated by Centropages typicus, but by only a few thousand individuals (Figure 4-34). C. typicus, joined by the warm-water Temora stylifera, was found in increased abundance throughout the day, but most abundant at night. The amphipod Parathemisto gaudichaudii peaked strongly at dusk with a slight rise also at dawn, while the cyclopoid Sapphirina ovatolanceolata (perhaps associated with the dominant salp) was fairly even in abundance except at midnight when catches dropped sharply.

Station L6. Abundance of Thalia democratica was at a maximum at the furthest offshore station where it dominated seven of the eight neuston collections (10,000 - 360,000/standard tow); Centropages typicus was dominant in the eighth tow. Subdominant species were similar to those found at Station L4 (Figure 4-35). Parathemisto gaudichaudii was bimodally abundant at dawn and dusk.

Neuston in the southern transect was of two principal types: an inshore surface community consisting of meroplanktonic fish eggs, crab larvae, barnacle larvae, and cladocerans, and an offshore community heavily dominated by salps.

Station C1. Half the neuston tows at the coastal New Jersey station were dominated by larvae of Cancer sp., as at Station L1 of the southern transect. These larvae increased sharply at night, with over 300,000 occurring in the 0300 hour tow (Figure 4-36). Fish eggs were also abundant at Station C1, numerically dominating one daytime collection. The remaining three tows were dominated by the cold-water

(TEXT CONTINUES ON PAGE 4-108)

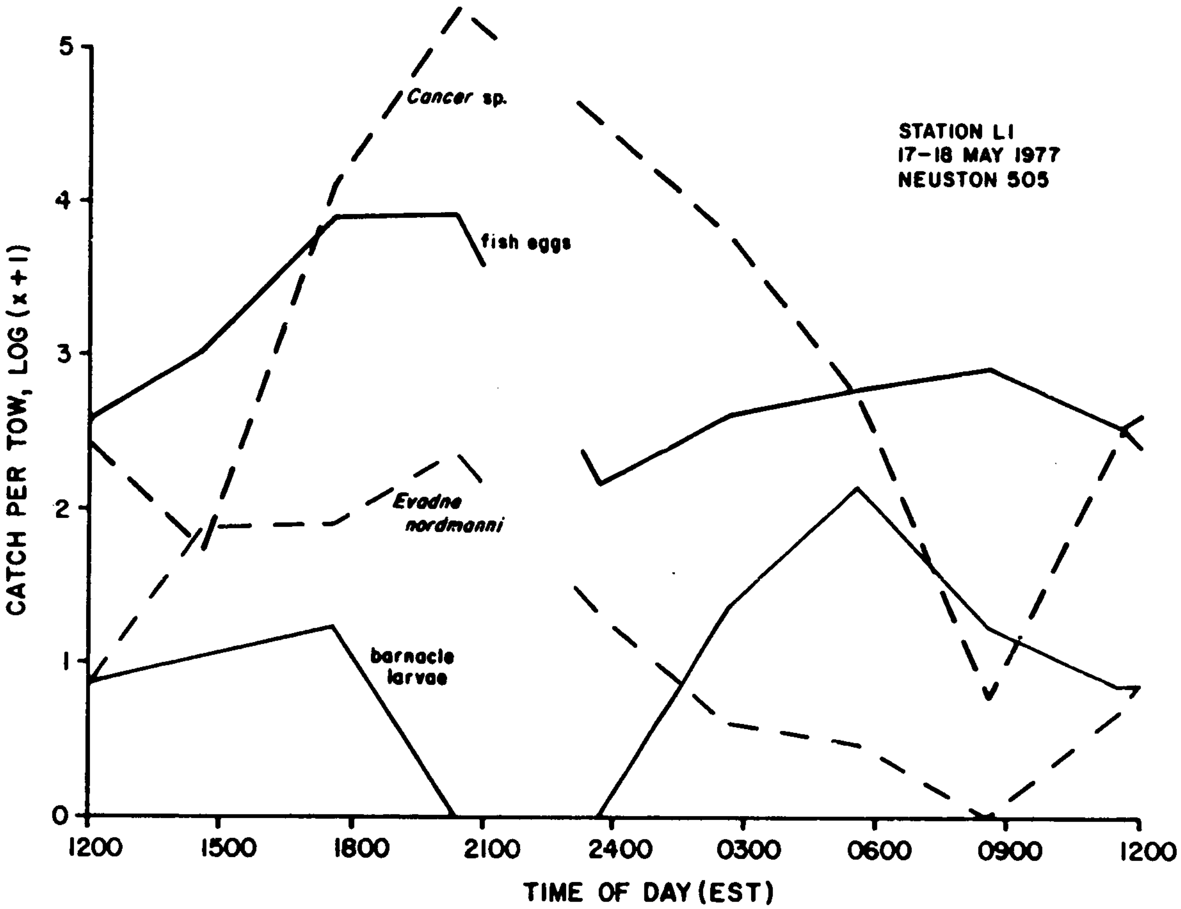

Figure 4-32. Diel cycle of dominant neustonts at Station L1, BLM07W.

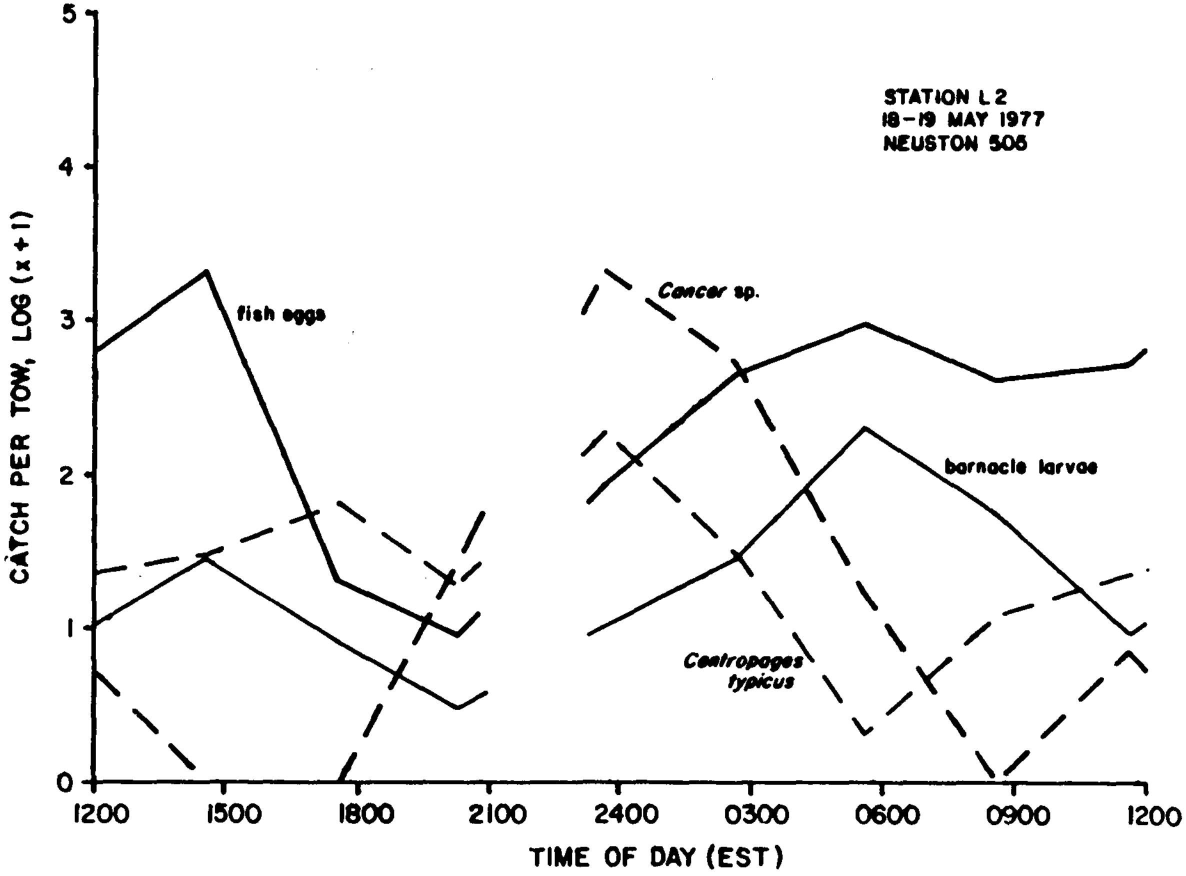

Figure 4-33. Diel cycle of dominant neustonts at Station L2, BLM07W.

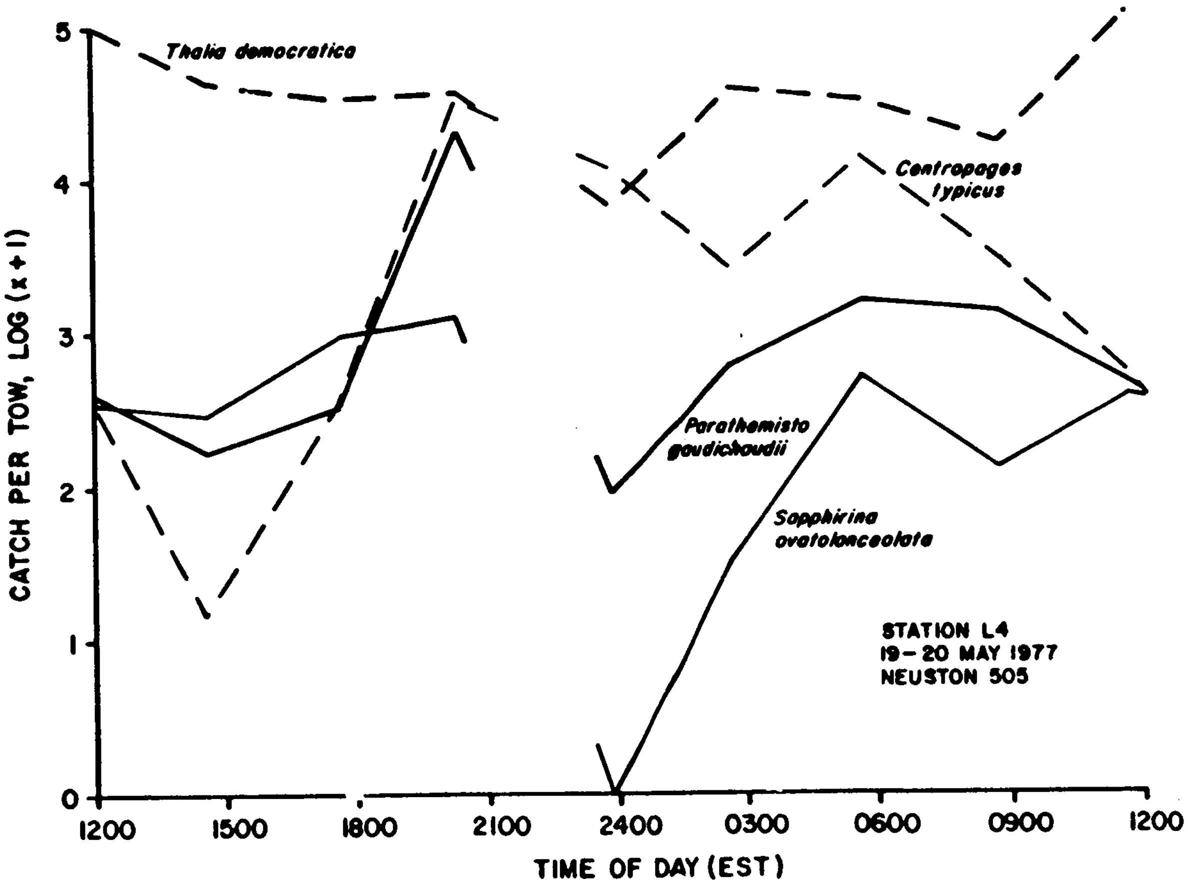

Figure 4-34. Diel cycle of dominant neustonts at Station L4, BLMO7W.

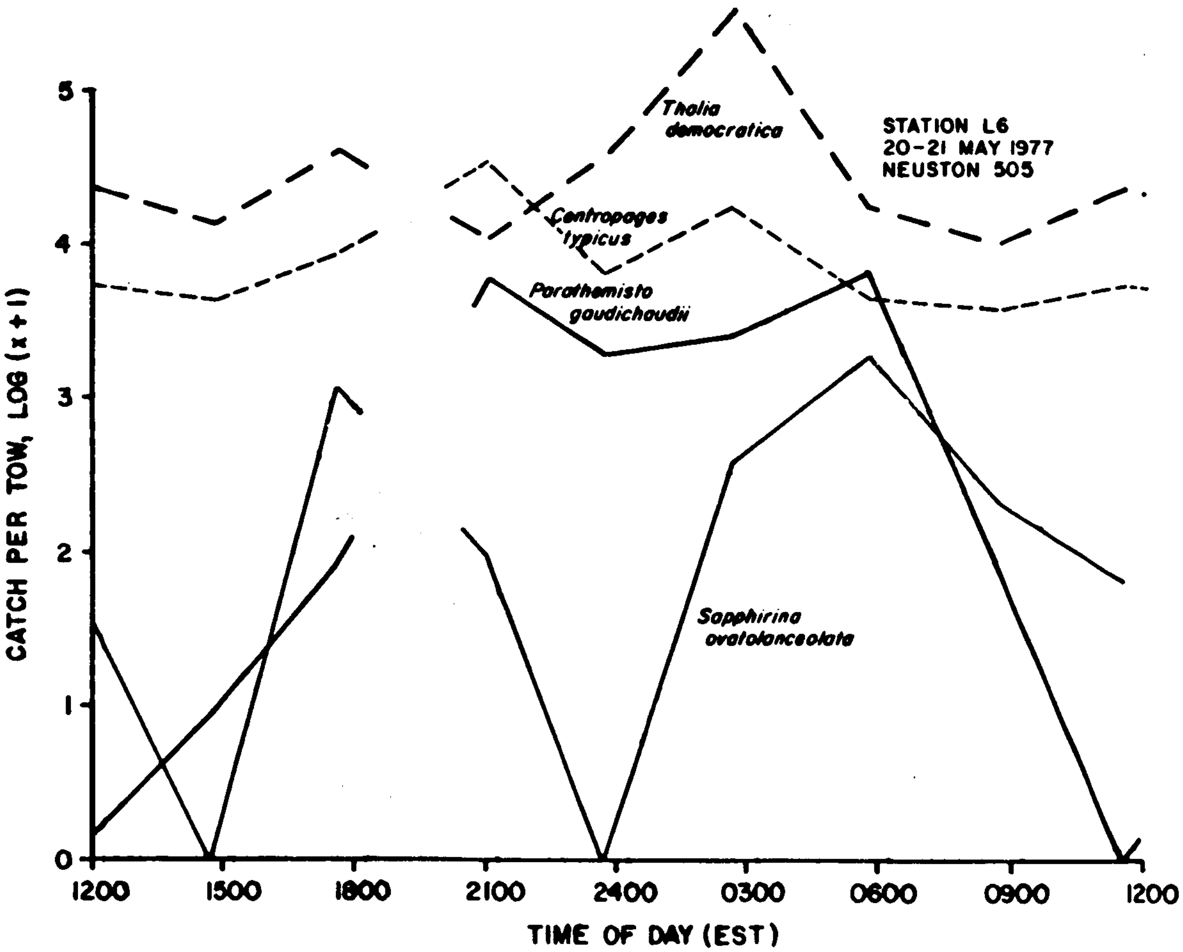

Figure 4-35. Diel cycle of dominant neustonts at Station L6, BLM07W.

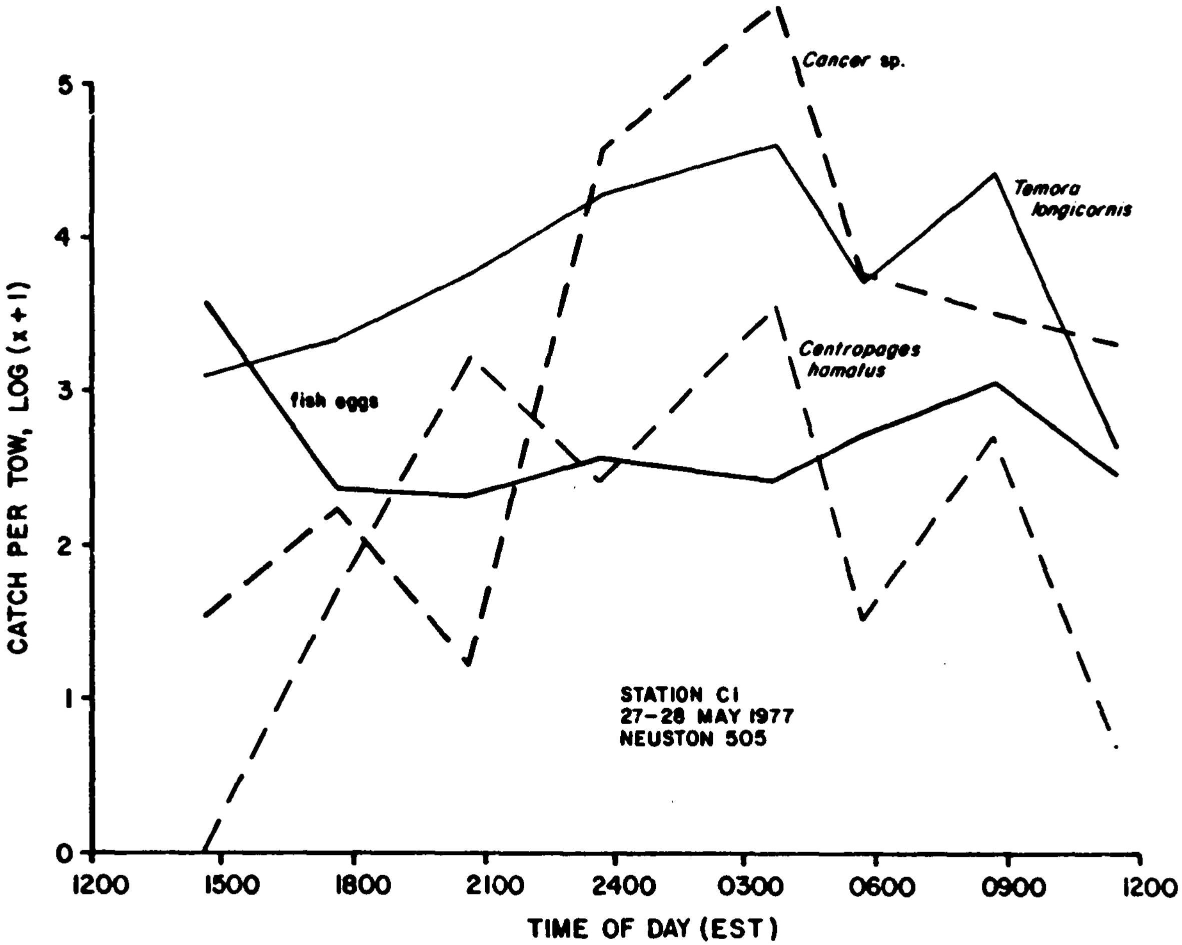

Figure 4-36. Diel cycle of dominant neustonts at Station C1, BLM07W.

copepod *Temora longicornis*. Other cold-water fauna in these neuston collections included *Centropages hamatus*, which was subdominant in most collections, *Tortanus discaudatus*, *Sagitta elegans*, and a few *Calanus finmarchicus*.

Station E3. Fish eggs were also abundant at the central shelf station E3 off New Jersey, where they numerically dominated half the neuston collections. Remaining collections were dominated by *Calanus finmarchicus*, the dominant subsurface copepod which migrated strongly to the surface layer at night (Figure 4-37). *Centropages typicus* and *Evadne nordmanni* were subdominants that peaked in the early evening. Mackerel larvae (*Scomber scombrus*) and immature, unidentified euphausiids were also numerous in the neuston.

Station J1. Neuston at the New Jersey slope station was most similar to the offshore Virginia community, with all eight collections dominated by the salp *Thalia democratica*, and other warm-water species present (*Temora stylifera*, *T. turbinata*, *Sapphirina ovatolanceolata* and larvae of *Portunus* sp.). The dominant salp was present in abundance throughout the day (5,000 - 54,000/tow), while other important species peaked in early evening (Figure 4-38).

Station B5. Five of the eight neuston tows at B5 were dominated by *Calanus finmarchicus*; the remaining three by the more strongly migrating *Centropages typicus* (Figure 4-39). All of the important species in the surface layer of this northern station were cold-water or temperate species also found in abundance in subsurface collections. They included (in addition to *C. finmarchicus* and *C. typicus*) *Centropages hamatus*, *Tortanus discaudatus*, *Temora longicornis*, *Sagitta elegans* and *Limacina retroversa*. *Temora* and *Sagitta* were particularly abundant at night.

Station A2. Seven of the eight neuston tows at A2 were dominated by *Calanus finmarchicus*; one daytime tow was dominated by fish eggs. *C. finmarchicus* was a strong vertical migrator, attaining an abundance of over 500,000/tow in early evening (Figure 4-40). *Centropages typicus* and *Sagitta elegans* also increased at night, while fish eggs were at a maximum at noon. *Limacina retroversa* occurred only in night collections at this station.

Neuston off New Jersey was similar to that off Virginia only at station J1 and C1, the former populated by the warm-water salp community, the latter by an abundance of *Cancer* sp. larvae. Remaining stations were heavily influenced by the incursion of the northern cold-water community characterized by *C. finmarchicus* and *S. elegans*. Neuston at stations D1, N3, E3, F2, B5, and A2 was composed mostly of species migrating from this community to the surface. Truly neustonic species were generally lacking over the shelf off New Jersey.

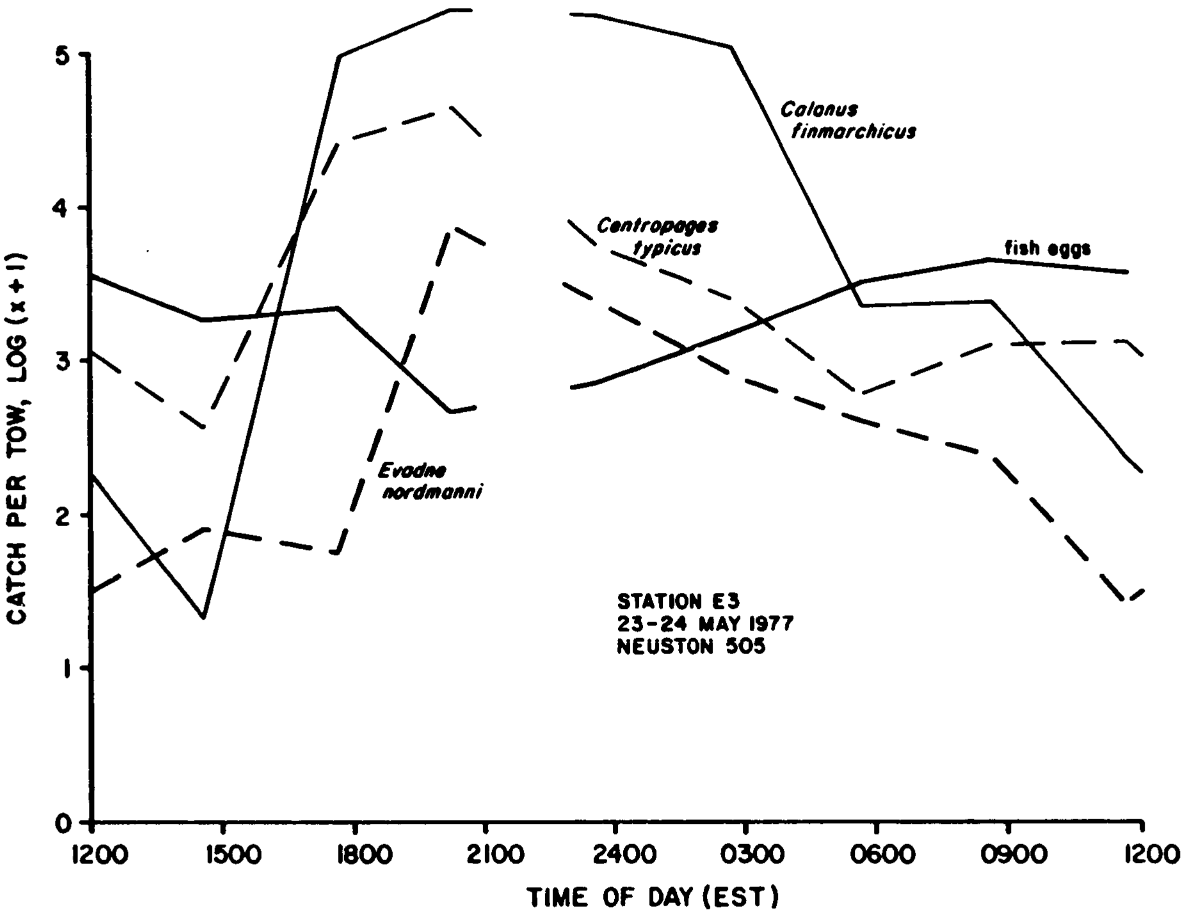

Figure 4-37. Diel cycle of dominant neustonts at Station E3, BLM07W.

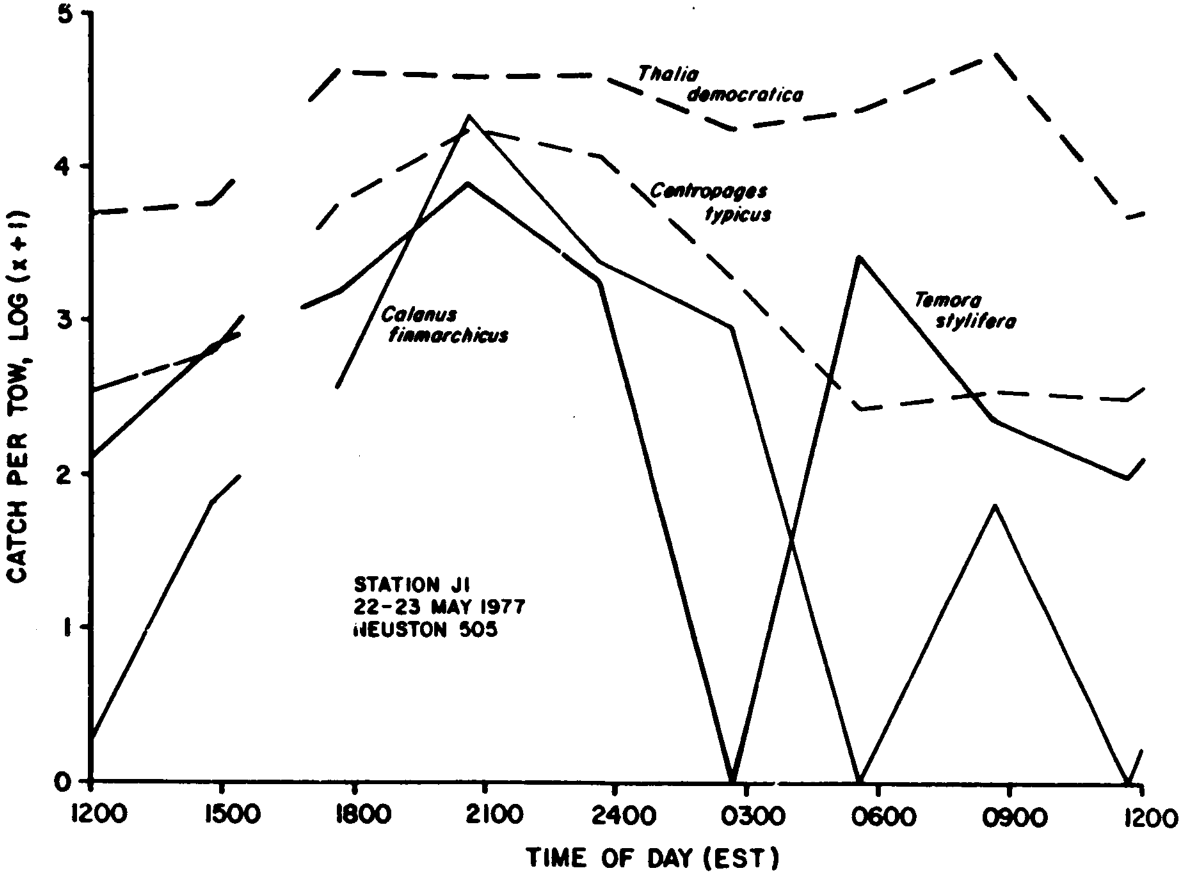

Figure 4-38. Diel cycle of dominant neustonts at Station J1, BLM07W.

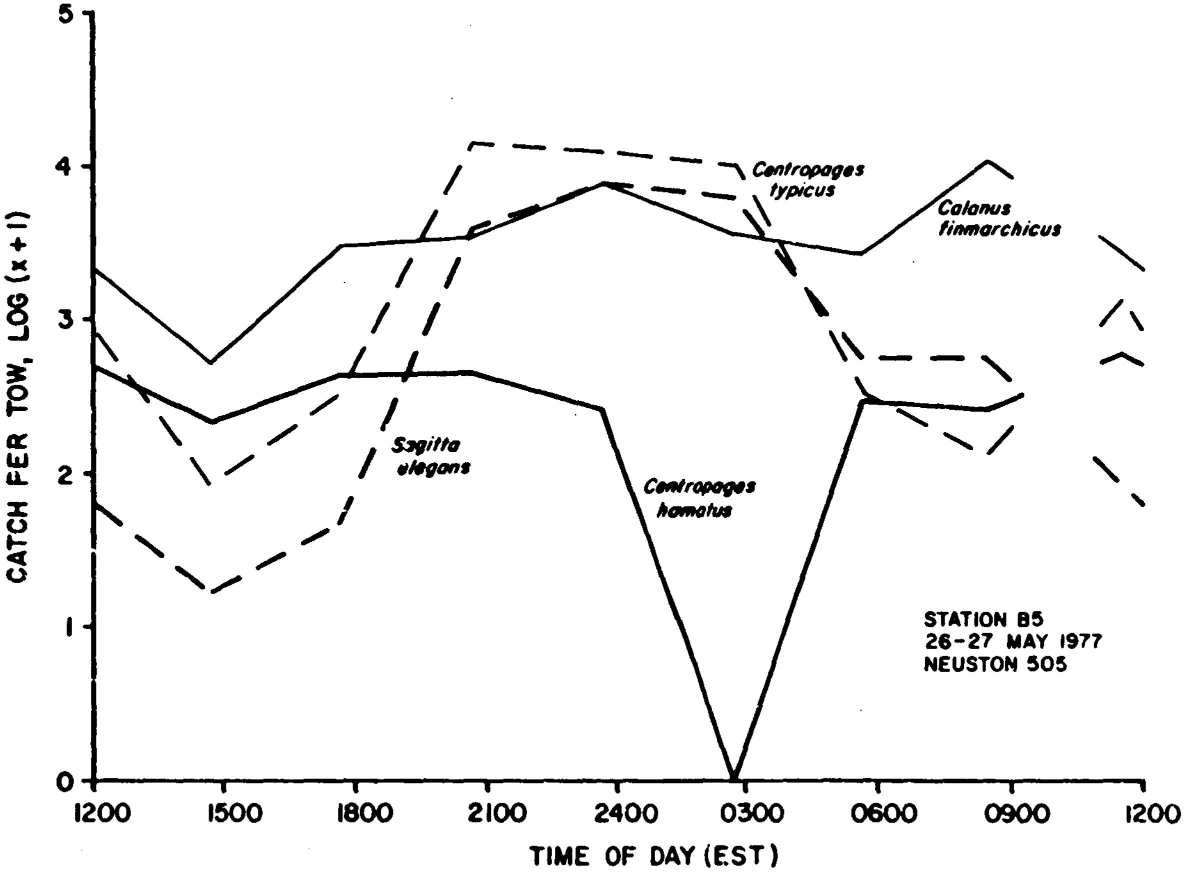

Figure 4-39. Diel cycle of dominant neustonts at Station B5, BLM07W.

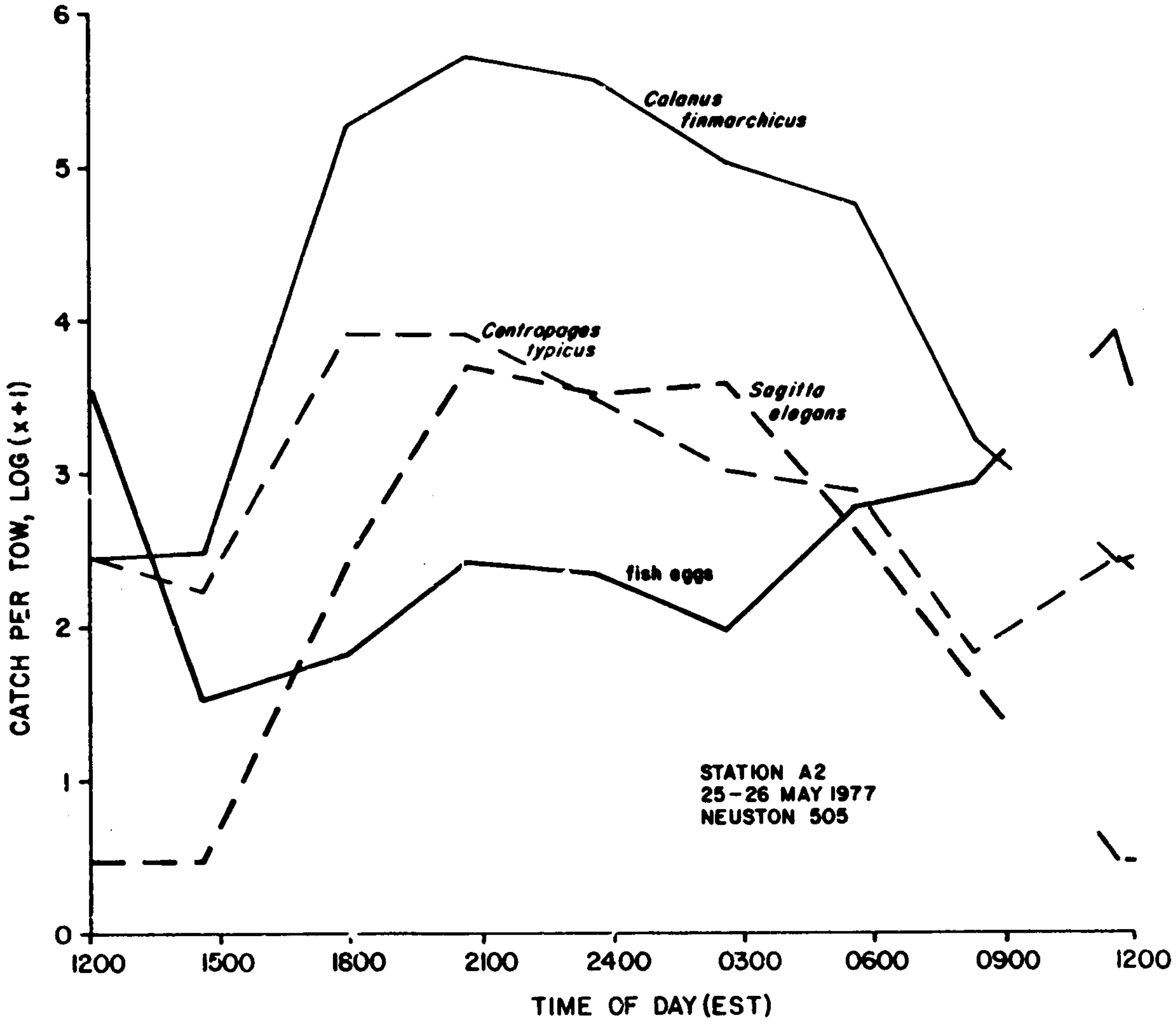

Figure 4-40. Diel cycle of dominant neustonts at Station A2, BLM07W.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent species in spring 1977 bongo collections are listed in Table 4-20, and those from neuston collections in Table 4-21. Six of the 12 most common taxa in neuston collections are not among the listed bongo species, including barnacle larvae, stomatopod larvae, Idotea metallica, the decapods Portunus sp. and Dromidia antillensis and larvae of Urophycis sp. Although Centropages typicus led the list of common neuston species in frequency of occurrence, it was present in less abundance than either Calanus finmarchicus or Cancer sp. larvae.

As in the previous cruise, certain of the larger, more active species were taken in larger quantity in 505 μm bongo nets than in paired 202 μm nets (Parathemisto gaudichaudii, unid. euphausiids, Cancer sp. in this cruise). Smaller species were again apparently more efficiently caught in the 202 μm nets (Table 4-20).

Diversity. Three measures of diversity (H', J', and species richness) are listed for each spring collection in Table 4-22. Stations are arranged from south to north, and, within transects, from the coast offshore. Comparisons of diversity indices from paired 202 μm and 505 μm collections yielded mixed results: Shannon indices were mostly higher in 505 μm collections from the Virginia transect, mixed along the southern New Jersey transect, and mostly higher in 202 μm collections from stations A2 and B5. Indices of species richness were all higher in 505 μm collections from the Virginia transect and in most from stations A2 and B5; higher indices alternated between 202 μm and 505 μm collections from the southern New Jersey transect. Diversity (H') of subsurface zooplankton increased from the coast to the slope in the Virginia transect; remained relatively low from coastal New Jersey to the shelf-edge, then increased sharply at Station J1; and decreased from station B5 to A2. Zooplankton in the southern sector was generally more diverse than in the north, except for Station J1. Maximum richness (7.3068) occurred in the bongo 505 collection at J1, which contained 76 taxa among 28,693 individuals. The maximum number of species found in any one bongo collection was 85, from the 202 μm collection at J1. Minimum richness (0.6347) occurred in a daytime neuston tow at Station C1, containing only six species. Species richness indices higher than 4.0 were limited to bongo collections at stations L2, L4, L6, and J1, and to night neuston collections at L4, L6, and J1 (also one day neuston at J1).

Cluster Analyses: A 5% occurrence was again utilized in reducing the number of taxa used in clustering of bongo and neuston collections.

I. Bongo collections. Clusters of the 42 bongo samples from BLM07W are shown in Figure 4-41. There were three primary clusters of collections.

(TEXT CONTINUES ON PAGE 4-120)

Table 4-20. Frequency of occurrence and abundance of common species in bongo collections, BLM07W.

Species	Percent Occurrence	Mean Catch per 100 m^3		Max. Catch per 100 m^3
		505 μm	202 μm	
Sagitta elegans	95	11,318	15,555	104,344
Parathemisto gaudichaudii	93	460	416	2,000
Centropages typicus	90	17,270	30,599	264,258
unid. euphausiids	88	708	338	3,181
Calanus finmarchicus	86	94,674	88,666	445,898
Evadne nordmanni	83	367	2,690	41,478
Limacina retroversa	81	1,605	1,555	14,207
unid. copepodites	79	538	571,461	1,918,354
Metridia lucens	79	9,563	12,196	69,717
Meganyctiphanes norvegica	79	456	536	4,537
Scomber scombrus	74	123	132	879
Dichelopandalus leptocerus	71	91	158	1,235
Pseudocalanus sp.	69	2,416	75,526	518,481
Limanda ferruginea	62	57	69	158
Oithona spp.	60	197	492,961	7,927,738
Cancer sp.	60	15,297	6,358	305,196
unid. polychaetes	52	50	84	602
unid. pagurid larvae	50	148	108	1,471
Temora longicornis	45	5,924	38,361	362,937
Paedoclione doliiformis	40	20	1,259	17,013
Diastylis sculpta	38	65	46	663
Unciola irrorata	38	38	45	206
Liparis sp.	38	43	33	100
Diastylis quadrispinosa	36	41	40	215
Tomopteris helgolandica	36	43	29	100

Table 4-21. Frequency of occurrence and abundance of common species in neuston collections, BLM07W.

Species	Percent Occurrence	Mean Catch per Standard Tow	Max. Catch per Standard Tow
Centropages typicus	95	6,816	45,056
unid. barnacle larvae	73	20	200
Portunus sp.	65	42	990
Parathemisto gaudichaudii	64	749	20,496
Sagitta elegans	60	509	7,808
Urophycis sp.	60	12	110
Calanus finmarchicus	59	36,870	543,740
Idotea metallica	57	4	46
Evadne nordmanni	52	425	13,184
Cancer sp.	51	8,386	335,870
Dromidia antillensis	47	3	24
unid. stomatopod larvae	44	54	100
unid. euphausiids	44	587	18,304
Anomalocera sp.	43	27	384
unid. copepodites	40	94	2,688
unid. siphonophores	37	219	2,512
Limacina retroversa	35	169	3,600
Centropages hamatus	35	131	3,584
Anomalocera ornata	35	13	418
Metridia lucens	32	264	6,144
Scomber scombrus	32	105	2,272
unid. decapod larvae	32	4	92
Temora longicornis	31	1,519	41,472
Temora stylifera	31	401	7,864

Table 4-22. Diversity of surface and subsurface zooplankton collections, BLM07W. H' = Shannon index (base-2); J' = evenness; Richness = Margalef's index of species richness; N = night, D = day, Ns = neuston, B = bongo.

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L1	Z77-120	B505, N	1.4607	0.3072	2.7307
	-121	B202, N	1.5836	0.3113	2.2309
	-122	Ns, N	0.6151	0.1294	2.4783
	-123	Ns, N	1.6373	0.3788	1.8696
	-124	Ns, N	1.5170	0.3711	2.4159
	-125	Ns, D	3.1927	0.8172	3.5432
	-126	Ns, D	1.0052	0.3026	1.5003
	-127	Ns, D	2.5071	0.6585	2.3086
	-128	Ns, D	0.1385	0.0355	1.4721
	-129	Ns, N	0.0512	0.0125	1.3198
L2	Z77-130	B505, N	3.5041	0.6888	4.7905
	-131	B202, N	1.2177	0.2435	1.0655
	-132	Ns, N	1.1090	0.2451	2.7965
	-133	Ns, N	1.0872	0.2660	2.4762
	-134	Ns, N	1.3085	0.3437	2.3579
	-135	Ns, D	1.7070	0.5385	1.8154
	-136	Ns, D	2.4072	0.5889	2.9923
	-137	Ns, D	2.3905	0.6279	2.7991
	-138	Ns, D	1.1919	0.3973	1.5974
	-139	Ns, N	3.2109	0.8027	3.4039
L4	Z77-140	B505, N	3.3133	0.5462	5.8016
	-141	B202, N	2.8360	0.4709	4.5869
	-142	Ns, N	3.1606	0.5174	6.5025
	-143	Ns, N	1.7063	0.2938	5.0659
	-144	Ns, N	1.9070	0.3269	5.1387
	-145	Ns, D	0.7184	0.1528	2.2672
	-146	Ns, D	0.3141	0.0608	2.9961
	-147	Ns, D	0.4156	0.0786	3.5497
	-148	Ns, D	0.6864	0.1361	3.0357
	-149	Ns, N	3.0046	0.4739	6.7841
L6	Z77-949	Ns, N	1.8078	0.3237	4.1423
	-150	B505, N	3.2983	0.5400	6.1946
	-151	B202, N	2.9824	0.5207	4.1294
	-152	Ns, N	2.3062	0.3971	5.4947
	-153	Ns, N	2.1407	0.3970	3.6717
	-154	Ns, N	0.2740	0.0483	3.6991
	-155	Ns, D	0.6376	0.1430	1.9416
	-156	Ns, D	1.5218	0.3237	2.5671
	-157	Ns, D	1.5414	0.3173	2.5719

Table 4-22 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L6	Z77-158	Ns, D	0.7803	0.1680	2.0708
C1	Z77-227	Ns, D	1.1861	0.3429	1.3644
	-228	Ns, D	1.0579	0.3337	1.0120
	-229	Ns, N	1.6571	0.4478	1.3115
	-230	B505, N	1.3100	0.3353	1.1383
	-231	B202, N	1.8813	0.4512	1.2139
	-232	Ns, N	1.1600	0.2900	1.3626
	-233	Ns, N	0.6418	0.1686	1.0111
	-234	Ns, N	1.4836	0.4289	1.0620
	-235	Ns, D	0.8559	0.2474	0.9618
	-236	Ns, D	0.7393	0.2860	0.6347
D1	Z77-192	B505, N	2.0006	0.4162	2.0299
	-193	Ns, N	0.9348	0.2163	1.5087
	-194	B202, N	2.4124	0.5132	1.6728
N3	Z77-189	B505, N	2.0236	0.4473	1.6924
	-190	Ns, N	0.6253	0.1330	1.9692
	-191	B202, N	0.6429	0.1402	1.7861
E3	Z77-173	Ns, N	0.4223	0.1109	1.0700
	-174	B202, N	1.1607	0.2603	1.3819
	-175	B505, N	1.5109	0.3557	1.3630
	-176	B505, N	1.3585	0.3093	1.5210
	-177	B202, N	1.8570	0.3951	1.7356
	-178	Ns, N	0.3768	0.0887	1.5453
	-179	B505, N	1.7210	0.3859	1.6583
	-180	B202, N	1.5796	0.3401	1.5833
	-181	B505, N	1.5026	0.3126	2.1021
	-182	B202, N	1.1250	0.2423	1.5734
	-183	Ns, N	2.2894	0.5297	2.2784
	-184	Ns, D	1.9674	0.4918	1.7800
	-185	Ns, D	1.5750	0.3708	2.3819
	-186	Ns, D	1.8446	0.4200	3.1570
	-187	Ns, D	0.8498	0.2232	1.1078
	-188	Ns, N	1.3060	0.3074	1.4394
F2	Z77-170	B505, N	1.0852	0.2337	1.8611
	-171	Ns, N	0.5182	0.1243	1.3382
	-172	B202, N	1.7629	0.3667	1.8709

Table 4-22 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
J1	Z77-159	Ns, D	1.9353	0.3545	3.8599
	-160	Ns, N	1.8666	0.3700	2.6698
	-161	B505, N	3.4161	0.5468	7.3068
	-162	B202, N	3.2042	0.4999	6.6660
	-163	Ns, N	2.7429	0.4766	4.6593
	-164	Ns, N	2.5926	0.4668	4.3902
	-165	Ns, N	0.7140	0.1300	3.8380
	-166	Ns, D	0.1777	0.0327	3.3784
	-167	Ns, D	1.3640	0.2728	3.5604
	-168	Ns, D	2.0918	0.3541	6.4188
B5	Z77-211	Ns, D	2.1979	0.5271	1.9695
	-212	Ns, D	2.4957	0.6106	2.2763
	-213	Ns, D	1.6603	0.3982	2.0365
	-214	Ns, N	2.4457	0.5034	2.7155
	-215	B505, N	1.6316	0.3559	2.0201
	-216	B202, N	1.9653	0.4005	2.0168
	-217	B505, N	1.9624	0.3999	2.3033
	-218	B202, N	2.3799	0.4804	2.4829
	-219	B505, N	2.0552	0.4230	2.3951
	-220	B202, N	1.5103	0.2994	2.2199
	-221	Ns, N	2.4786	0.5406	2.2008
	-222	B505, N	1.7934	0.3862	1.9913
	-223	B202, N	2.3567	0.5210	1.6692
	-224	Ns, N	2.1661	0.4664	2.3924
	-225	Ns, N	2.1909	0.5477	1.7539
	-226	Ns, D	0.6389	0.1923	0.9581
A2	Z77-195	Ns, D	2.9755	0.6258	3.8336
	-196	Ns, D	2.9803	0.6500	3.3560
	-197	Ns, D	0.2820	0.0690	1.3153
	-198	Ns, N	0.3093	0.0716	1.4347
	-199	B505, N	0.9927	0.2195	1.6771
	-200	B202, N	1.7333	0.3832	1.4583
	-201	B505, N	0.7239	0.1579	1.8220
	-202	B202, N	1.7289	0.3678	1.6706
	-203	B505, N	0.7729	0.1760	1.6127
	-204	B202, N	1.8446	0.4200	1.3855
	-205	Ns, N	0.1778	0.0419	1.4000
	-206	B505, N	1.0706	0.2438	1.5410
	-207	B202, N	1.8517	0.4740	0.9528
	-208	Ns, N	0.5809	0.1222	2.2246

Table 4-22 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
A2	Z77-209	Ns, N	0.2909	0.0626	2.1837
	-210	Ns, D	1.1839	0.2787	2.3790

1. Coastal
2. Shelf-edge and Slope
3. Northern Central and Outer Shelf

Subdivisions within these major groups were 1) a separation by mesh size in the shelf-edge and slope cluster, 2) a division, mostly by mesh size, in the large cluster of northern shelf stations. Tertiary clusters in the latter group distinguished between outer and inner shelf collections.

Inverse species clusters and a nodal analysis for bongo collections are shown in Figures 4-42 and 4-43. Identification of collections and species that make up the sample and species groups are listed in Table 4-23. Sample group I (stations C1, L1, and L2) was characterized mostly by species groups C and D, including cold-water neritic species (Centropages hamatus, Temora longicornis, Tortanus discaudatus, Crangon septemspinosa), the razor clam Ensis directus, and cumaceans Diastylis polita, Leptocuma minor, and Oxyurostylis smithi.

Sample group II (stations L4, L6, and J1) was populated by the species-rich warm-water fauna of species group A, including several pteropods, hyperiid amphipods, chaetognaths, and tunicates, as well as representatives of deeper waters, such as Pleuromamma robusta, Eukrohnia hamata, and Sagitta lyra. It also contained elements of the wide-spread, northern community of species group F.

Sample groups III and IV, the northern central and outer shelf stations, were most clearly tied to species groups E and F, common cold-water species (Calanus finmarchicus, Evadne nordmanni, Sagitta elegans, and the larvae of the sand lance, four-bearded rockling, yellowtail flounder, sea snail, and the Atlantic mackerel.

II. Neuston collections. Clusters of the 75 neuston collections from BLM07W are shown in Figure 4-44. Principal clusters were the same as in bongo collections:

1. Coastal
2. Northern Central and Outer Shelf
3. Shelf-edge and Slope

Coastal New Jersey samples linked first with night tows from L1, then at relatively low similarity with L2 samples and remaining L1 samples. Other subdivisions were mostly according to time of sample (day vs. night).

Inverse species clusters and a nodal analysis for spring neuston collections are shown in Figures 4-45 and 4-46, with

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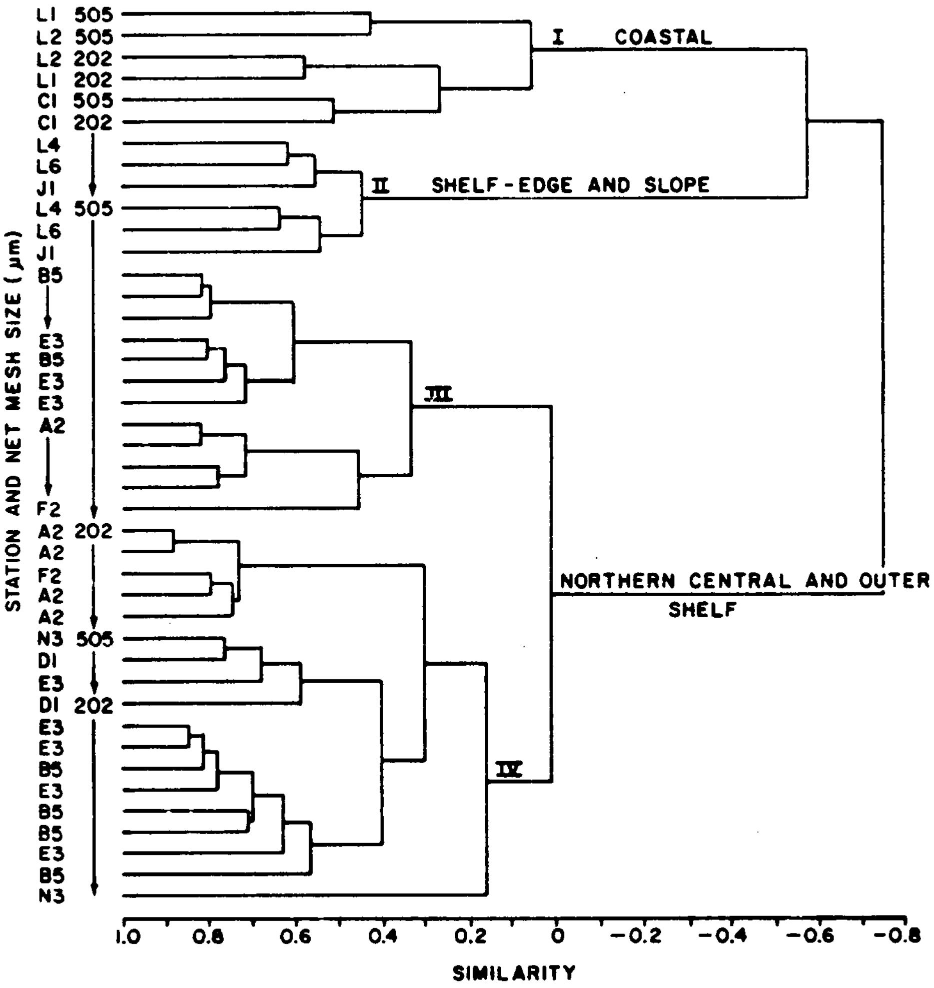

Figure 4-41. Bongo sample clusters, BLM07W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to numbers per $100m^3$.

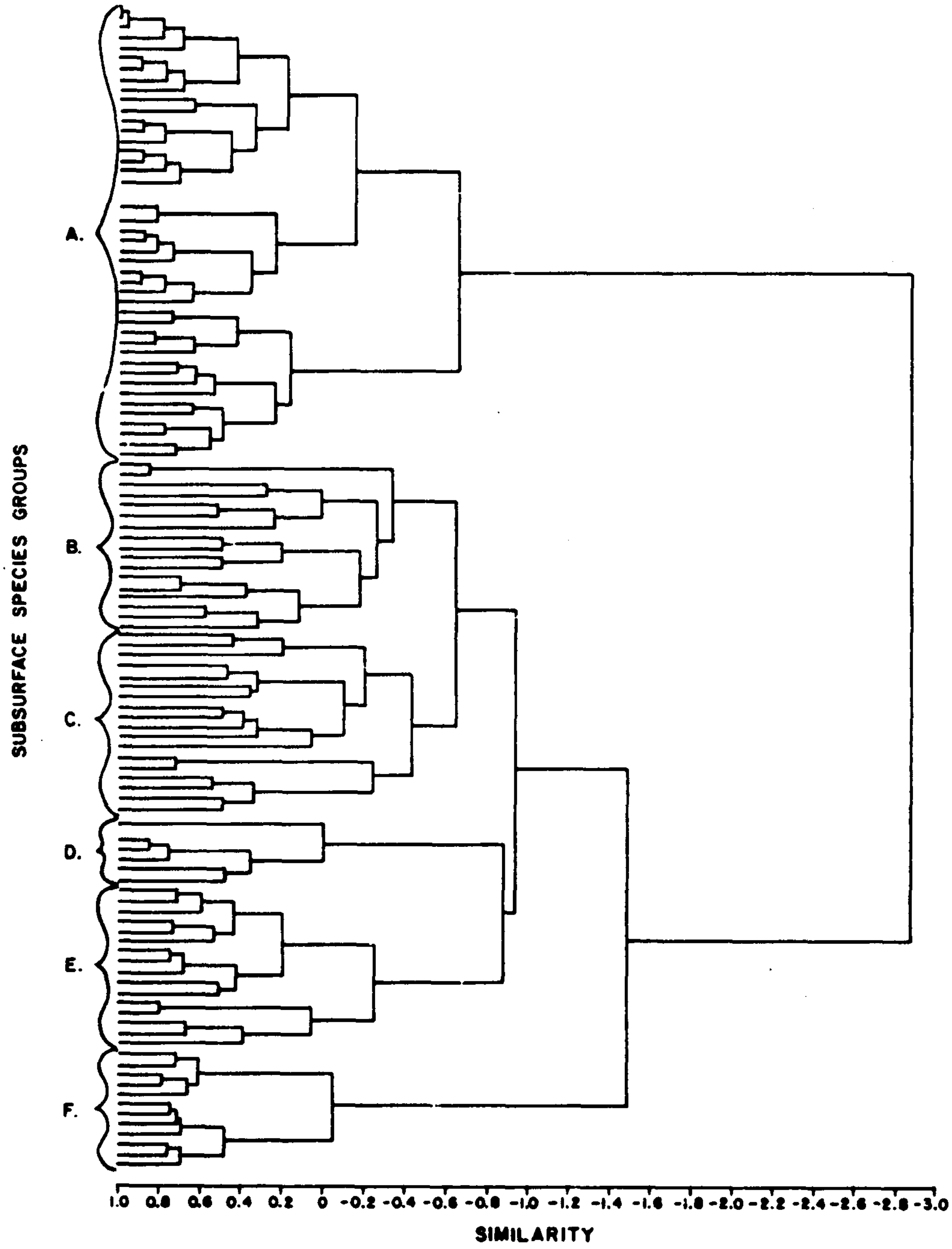

Figure 4-42. Inverse species clusters, bongo tows, BLM07W. See Table 4-23 for identification of species within groups A-F.

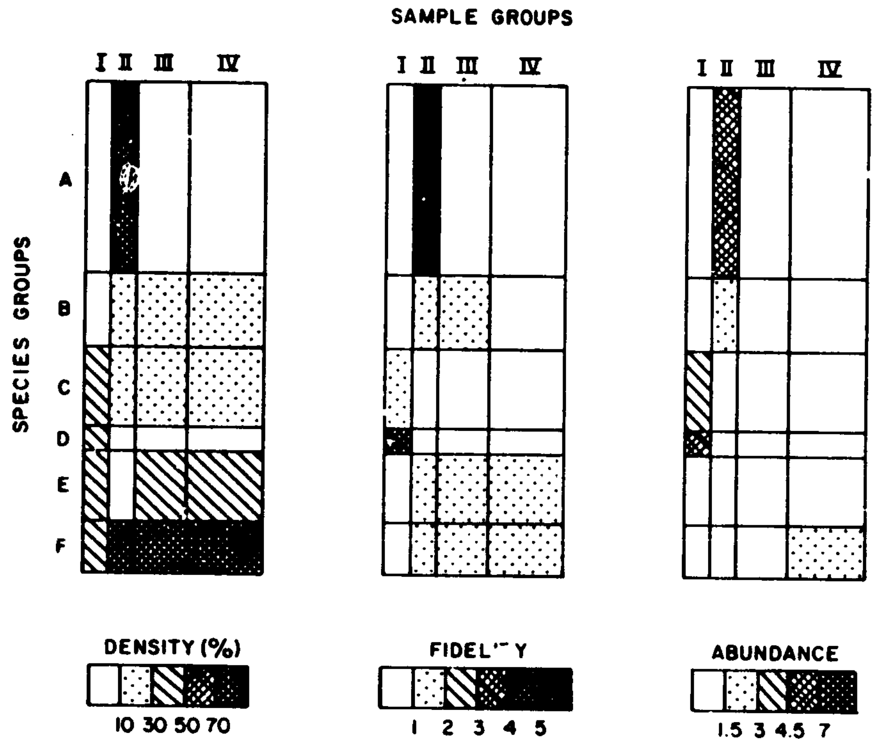

Figure 4-43. Nodal density (or constancy), fidelity, and abundance of species groups from the bongo cluster analyses of BLM07W.

Table 4-23. Identification of elements in sample and species groups from cluster analyses of bongo collections, BLM07W.

Sample Cluster	Mesh Size and Station Numbers
I	202 µm: L1. L2, C1; 505 µm: L1, L2, C1
II	202 µm: L4, L6, J1; 505 µm: L4, L6, J1
III	505 µm: E3 (3 tows), F2, B5 (4 tows), A2 (4 tows)
IV	202 µm: D1, N3, E3 (4 tows), F2, B5 (4 tows), A2 (4 tows); 505 µm: D1, N3, E3

Species Cluster	Taxa (listed in phylogenetic order within clusters)
A	unid. siphonophores *Tomopteris* sp. *Atlanta peroni* *Cavolina inflexa* *Cavolina longirostris* *Cavolina uncinata* *Creseis virgula* *Diacria quadridentata* unid. gastropods *Evadne spinifera* *Euconchoecia chierchiae* *Candacia armata* *Eucalanus attenuatus* *Euchirella rostrata* *Nannocalanus minor* *Pleuromamma gracilis* *Pleuromamma robusta* *Rhincalanus nasutus* *Temora stylifera* *Sapphirinia nigromaculata* *Anchylomera blossevilli* *Lestrigonus bengalensis* *Lycaea bovalli* *Oxycephalus clausi* *Phronima atlantica* *Phrosina semilunata* *Euphausia* sp. *Euphausia krohnii* *Nematoscelis megalops* *Lucifer faxoni* *Sergestes* sp. *Eukrohnia hamata* *Pterosagitta draco* *Sagitta enflata* *Sagitta helenae* *Sagitta lyra* *Sagitta minima* *Sagitta tasmanica* *Doliolum nationalis* *Oikopleura* sp. *Thalia democratica* *Hygophum hygomi* unid. myctophids unid. synodontids
B	*Tomopteris helgolandica* *Clione limacina* *Conchoecia curta* *Halocypria globosa* *Clausocalanus* sp. *Eudorella* sp. *Parthenope* sp. *Pontophilus brevirostris* *Portunus* sp. unid. calappids unid. majids unid. decapods *Glyptocephalus cynoglossus* *Merluccius* sp. *Urophycis* sp. unid. bothids unid. engraulids
C	unid. scyphozoans *Mulinia lateralis* *Paedoclione doliiformis* *Pleurobranchaea tarda* *Centropages* sp. *Centropages hamatus* *Clausocalanus arcuicornis* *Paracalanus* sp. *Pseudocalanus* sp. *Temora* sp. *Temora longicornis* *Tortanus discaudatus* *Clytemnestra rostrata* unid. barnacle larvae *Erichthonius brasiliensis* *Monoculodes* sp. *Cancer* sp. *Crangon septemspinosa*

Table 4-23. (Concluded)

Species Cluster	Taxa		
D	*Ensis directus* *Macoma balthica*	*Diastylis polita* *Leptocuma minor*	*Oxyurostylis smithi* *Ampelisca abdita*
E	unid. polychaetes unid. stomatopod larvae *Diastylis quadrispinosa* *Diastylis sculpta* *Argissa hamatipes* *Byblis serrata*	*Erichthonius rubricornis* *Unciola irrorata* *Dichelopandalus leptoceras* *Hyas* sp. unid. pagurids	*Ammodytes* sp. *Enchelyopus cimbrius* *Limanda ferruginea* *Liparis* sp. *Scomber scombrus*
F	*Limacina retroversa* *Evadne nordmanni* *Calanus finmarchicus* *Centropages typicus*	*Metridia lucens* *Pseudocalanus minutus* unid. copepodites *Parathemisto gaudichaudii*	*Meganyctiphanes norvegica* unid. euphausiids *Sagitta elegans*

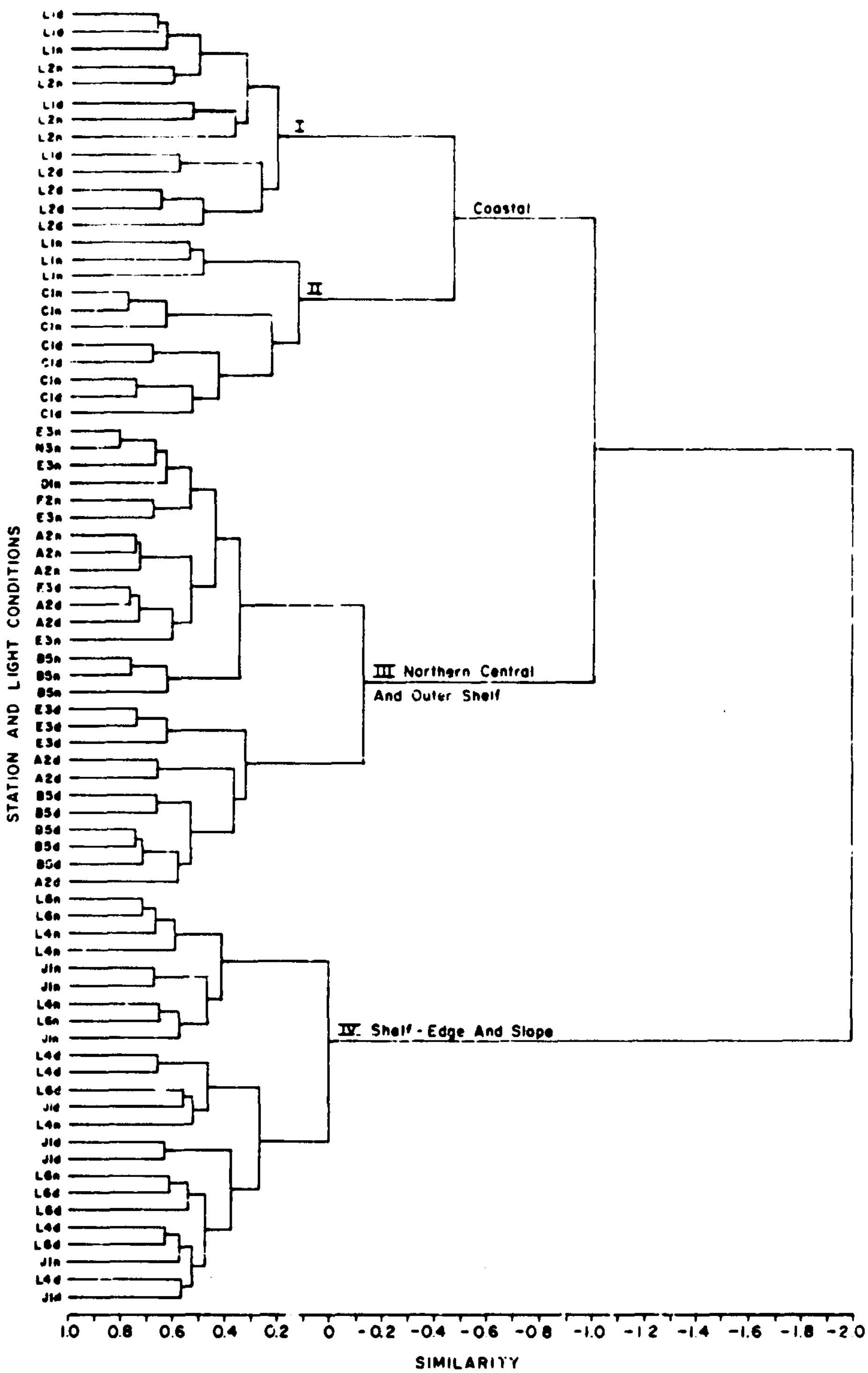

Figure 4-44. Neuston sample clusters, BLM07W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to 20 min. tows. Lettering after station numbers indicates: n=night, d=day.

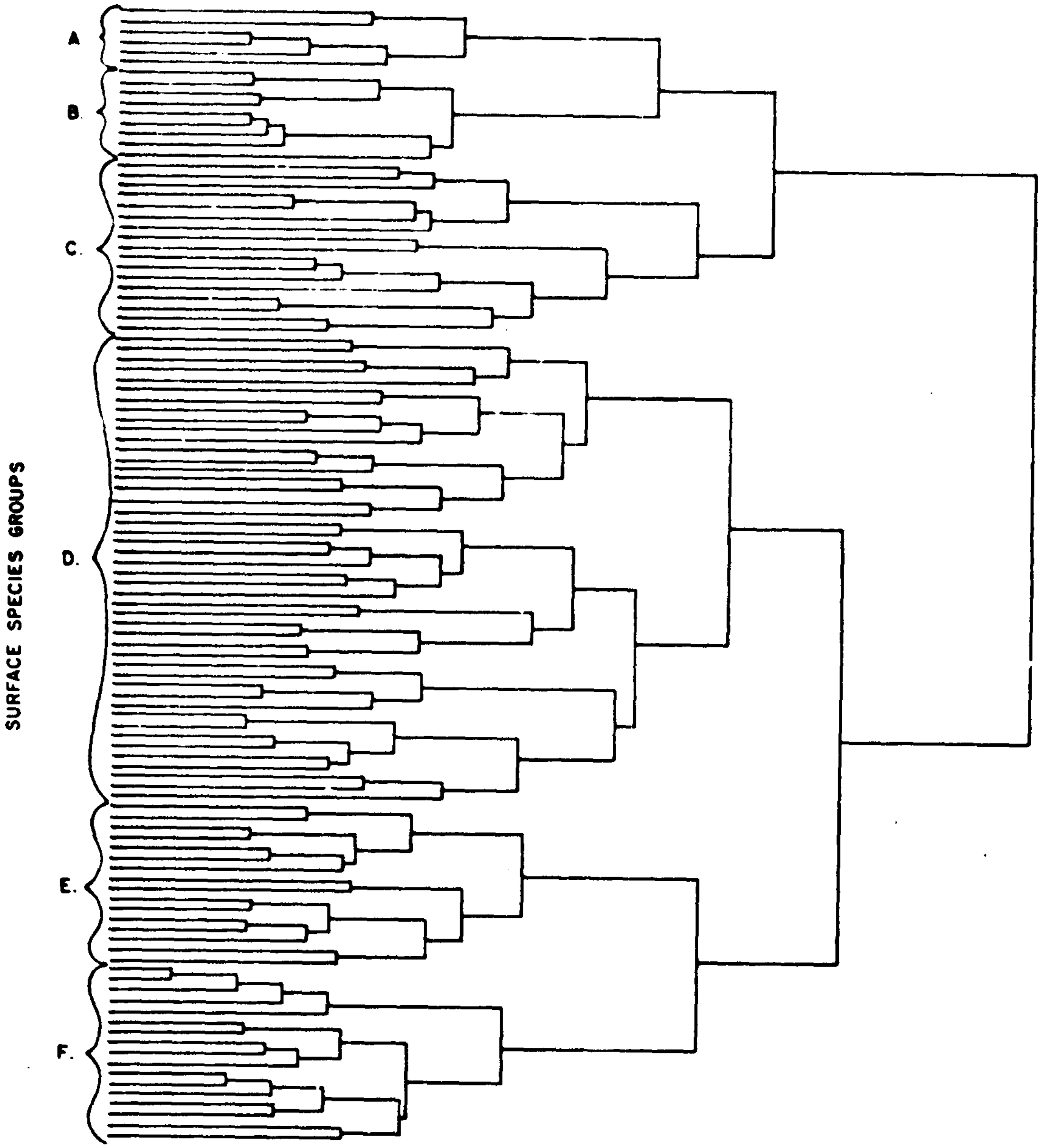

Figure 4-45. Inverse species clusters, neuston tows, BLM07W. See Table 4-24 for identification of species within groups A-F.

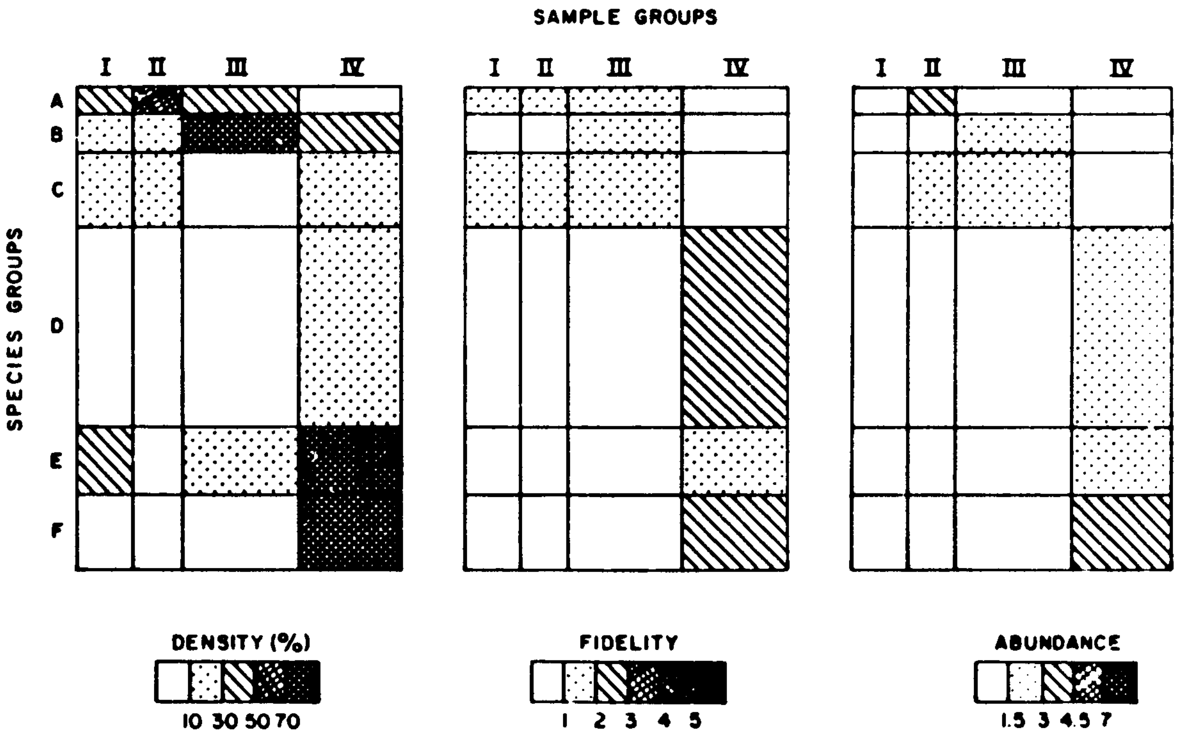

Figure 4-46. Nodal density (or constancy), fidelity and abundance of species groups within sample groups from the neuston cluster analyses of BLM07W.

Table 4-24. Identification of elements in sample and species groups from cluster analyses of neuston collections, BLM07W.

Sample Cluster	Station Numbers and Time of Day (N=night, D=day)
I	L1N, L1D(4), L2N(4), L2D(4)
II	L1N(3), C1N(4), C1D(4)
III	D1N, N3N, E3N(4), E3D(4), F2N, B5N(4), B5D(4), A2N(4), A2D(4)
IV	L4N(4), L4D(4), L6N(4), L6D(4), J1N(4), J1D(4)

Species Cluster	Taxa (listed in phylogenetic order within clusters)		
A	*Anomalocera patersonii* *Centropages hamatus*	*Pseudocalanus minutus* *Temora longicornis*	*Tortanus discaudatus* unid. copepodites
B	*Limacina retroversa* *Evadne nordmanni* *Calanus finmarchicus*	*Centropages typicus* *Parathemisto gaudichaudii* unid. euphausiids	*Cancer* sp. *Sagitta elegans* *Scomber scombrus*
C	*Paedoclione doliiformis* *Pseudocalanus* sp. *Temora* sp. *Oithona* spp. *Oxyurostylis smithi* *Edotea triloba*	*Meganyctiphanes norvegica* *Crangon septemspinosa* *Dichelopandalus leptocerus* *Hyas* sp. unid. pagurids *Sagitta tasmanica*	*Ammodytes* sp. *Enchelyopus cimbrius* *Gasterosteus aculeatus* *Limanda ferruginea* unid. balistids
D	unid. scyphozoans unid. polychaetes *Atlanta peroni* *Cavolina longirostris* *Diacria quadridentata* *Firoloida leseurii* *Limacina trochiformis* *Litiopa melanostoma* *Evadne spinifera* *Eucalanus pileatus* *Labidocera aestiva* *Paracalanus* sp. *Pontellopsis* sp. *Pontellopsis regalis* *Rhincalanus nasutus* *Undinula vulgaris*	*Sapphirina* sp. *Lepas fasicularis* *Erythrops erythrophthalma* *Anchylomera blossevilli* *Brachyscelus crusculum* *Pseudolycaea* sp. *Themistella fusca* *Vibilia* sp. unid. hyperiids *Euphausia krohnii* *Callinectes* sp. *Geryon quinquedens* *Latreutes fucorum* *Ovalipes* sp. *Parthenope* sp.	unid. calappids *Krohnitta pacifica* *Pterosagitta draco* unid. salps *Clupea harengus* *Mugil curema* *Myctophum affine* *Peprilus triacanthus* *Pomatomus saltatrix* *Scomberesox saurus* *Sphoeroides* sp. unid. blenniids unid. engraulids unid. synodontids unid. fishes

Table 4-24. (Concluded)

Species Cluster	Taxa
E	*Creseis virgula* *Anomalocera* sp. *Anomalocera ornata* *Sapphirina angusta* *Sapphirina nigromaculata* *Lepas* sp. unid. barnacle larvae unid. stomatopod larvae *Idotea metallica* *Lycaea bovalli* *Vibilia armata* *Dromidia antillensis* *Portunus* sp. unid. decapod larvae *Oikopleura* sp. *Urophycis* sp.
F	unid. siphonophores *Candacia armata* *Clausocalanus arcuicornis* *Metridia lucens* *Nannocalanus minor* *Pleuromamma gracilis* *Temora stylifera* *Temora turbinata* *Corycaeus speciosus* *Sapphirina ovatolanceolata* *Lestrigonus bengalensis* *Euphausia* sp. *Lucifer faxoni* *Sagitta enflata* *Sagitta helenae* *Doliolum nationalis* *Thalia democratica*

identification of samples and species within designated groups listed in Table 4-24.

Neuston at stations L1 and L2 (sample group I) was sparse, containing representatives from species groups A-C and E. The northern coastal group (species group A with Centropages hamatus, Temora longicornis, and Tortanus discaudatus) was most abundant in sample group II, which included all neuston samples from the coastal New Jersey station.

The northern central and outer shelf group (III) was characterized by species group B for the most part, as well as contributions from bordering coastal and offshore communities. Species group B contained the dominants of the northern cold-water community (Calanus finmarchicus, Evadne nordmanni, Sagitta elegans, mackerel larvae, etc.).

Offshore samples from stations L4, L6, and J1 (sample group IV) were dominated by species groups E and F, warm-water communities dominated by salps (Thalia democratica), pontellid copepods (Anomalocera ornata), and warm-water chaetognaths (Sagitta enflata and S. helenae). The diverse species group D was also largely restricted to this offshore belt.

Synopsis of Cruise BLM07W

1. Subsurface zooplankton biomass, except at stations L1 and B5 was elevated from winter levels in this spring cruise, by an order of magnitude at some stations off New Jersey. Highest estimates (700-732 ml/100m^3 in 202 μm nets and 495-826 ml/100m^3 in 505 μm nets) occurred in New Jersey central shelf stations D1 and N3.

Neuston volumes, generally low in coastal and inner shelf waters, were very high at shelf-edge stations off New Jersey and Virginia. The great increase in volume (to 5600 ml/standard tow) was due to swarming of the salp, Thalia democratica. Highest biomass occurred at night or late afternoon at 24-hr. stations.

2. The severe winter of 1977 was reflected in spring collections by a dominance of Calanus finmarchicus in 505 μm mesh collections. This boreal species dominated all New Jersey bongo 505 collections except for that at Station C1, which was dominated by Cancer sp. larvae. C. finmarchicus was also the most abundant species in 13 of the 43 northern neuston tows. Bongo 202 tows were dominated by Oithona spp. along the Virginia coast and by Paracalanus sp. or unidentified copepodids elsewhere. Bongo 505 tows off Virginia were still dominated by Centropages typicus away from the coast, but by Cancer sp. larvae at Station L1.

Neuston along the coast of both New Jersey and Virginia was dominated by *Cancer* sp. larvae (10 tows) and fish eggs (9 tows). Fish eggs also dominated 4 neuston tows at Station E3. Tows along the shelf-edge stations L4, L6 and J1 were dominated by the salp, *Thalia democratica*.

3. The most frequent species in bongo tows were *Sagitta elegans*, *Parathemisto gaudichaudii* and *Centropages typicus*. More abundant, however, were *Calanus finmarchicus* in 505 μm nets and unidentified copepodites, *Oithona* spp., *C. finmarchicus*, *Pseudocalanus* sp. and *Temora longicornis* in 202 m nets. In neuston tows, *C. typicus* was most frequent, but outnumbered by both *C. finmarchicus* and *Cancer* sp. lavae.

4. Diversity was highest in offshore waters off both New Jersey and Virginia (stations L2, L4, L6 and J1).

5. Primary clusters in both bongo and neuston collections were (a) coastal stations, (b) northern central and outer shelf stations, and (c) shelf-edge and slope stations.

Summer 1977 Cruise No. BLM08W

Summary of Collections

Subsurface zooplankton and neuston collections for the summer period were obtained from the 12 designated water column stations during the period 19-29 August 1977. Replicate bongo sampling was conducted at stations A2, B5, and E3 at night. Additional bongo tows with a single system were made at each of the 12 stations, one each with 202 μm and 505 μm nets. One neuston collection every three hours was obtained at nine stations over 24-hour periods. Single tows were made at the remaining three stations (D1, N3, and F2). Total collections numbered 42 bongo and 75 neuston, preserved for biomass and taxonomy, and 88 frozen bongo samples (44 each for hydrocarbons and trace metals, including extra splits from the quality control station, J1).

Species removed from neuston collections and frozen for chemical analysis included *Rhacostoma atlanticum*, a medusa from Station L1, and the isopod *Idotea metallica* from stations L4, L6, E3, F2, J1, B5, and A2. Thirteen samples of tarballs were obtained from neuston tows at stations L2, L4, L6, and A2.

Biomass

Displacement volumes of collected subsurface (ml/100m^3) and surface (ml/standard tow) zooplankton are listed in Table 4-25. Estimates of biomass from fine-meshed 202 μm bongo collections

Table 4-25. Displacement volume of zooplankton collections, summer 1977 (BLM08W). Standardized to ml/100m^3 for 60 cm bongos and to ml/standard 20 min. tow for neuston collections.

	Bongo (ml/100 m^3)		Neuston 505 µm (ml/20 min. tow)							
			Approx. hour of collection							
Station	202 µm	505 µm	0300	0600	0900	1200	1500	1800	2100	2400
L1	114	30	425	55	155	40	40	70	350	70
L2	49	37	120	60	45	5	5	150	60	100
L4	75	24	55	75	10	5	30	30	20	35
L6	24	30	45	160	25	70	15	30	10	50
C1	352	121	270	490	70	45	25	300	125	95
D1	285	46						105		
N3	221	94							65	
E3	68	78	30	115	25	50	25	115	90	45
	125	102								
	122	93								
	140	132								
F2	115	20								55
J1	30	23	10	40	30	15	15	15	825	280
B5	108	89	45	75	130	25	5	130	90	50
	105	91								
	128	108								
	165	64								
A2	55	33	105	115	50	10	5	25	35	60
	50	35								
	56	32								
	68	20								

exceeded those from 505 μm collections in 19 of 21 paired comparisons. Biomass was generally lower than in spring collections, except at Station B5 where spring volumes were not much higher than winter levels. Volumes at offshore stations were particularly reduced.

Neuston volumes were reversed in an inshore-offshore direction, compared with spring distribution of biomass. Highest volumes were observed at coastal stations L1 and C1, and the high volumes seen in spring at offshore stations (salp swarms) were generally absent, an exception occurring in a dusk tow at Station J1. No north-south trends in biomass levels were evident in summer collections. Neuston displacement volumes exceeding 0.3 liters/standard tow were limited to two at Station L1, two at Station C1 and one at Station J1.

Faunal Description

Nearly 400 species of zooplankton were distinguished among the summer bongo and neuston collections (Table 4-26), including at least 53 species of pelagic molluscs, 72 copepods, 49 amphipods, 13 euphausiids, 51 decapods, 15 chaetognaths, and 77 fishes. Species restricted to neuston collections, and also occurring in more than 5% of them, included coelenterates Aequorea sp. and Porpita porpita; copepods Anomalocera sp., A. patersonii, Pleuromamma piseki, Pontella sp., P. securifer, Pontellopsis sp., and P. villosa; the barnacle Chthalamus fragilis; isopods Idotea sp. and I. baltica; decapods Dromidia antillensis, Hexapanopeus angustifrons, Ocypode quadrata, and Palaemonetes sp.; and the fishes Hypsoblennius hentzi, Sarda sarda, unidentified exocoetids, and unidentified tetraodontids.

Dominant species in summer collections are listed in Table 4-27, by station. Many of the subsurface collections (bongo nets) were numerically dominated by the cladoceran, Penilia avirostris, a distinct change from previous cruises when nearly all subsurface collections were dominated by copepods. Cladocerans were particularly important at coastal stations (C1, D1, L1, L2), but also at the offshore station J1. They were subdominants at stations E3, F2, and B5.

The cold-water community dominated by Calanus finmarchicus and Sagitta elegans, and first found in abundance during the spring cruise, was dominant at stations N3, E3, B5, and A2. C. finmarchicus was also dominant (505 net) at Station L4 and subdominant at stations F2 and J1. S. elegans was abundant at Station L2.

Coastal transport of cold-water species was evident in the occurrence of Temora longicornis and Evadne nordmanni among dominants at Station L1 (202 net) and of T. longicornis at Station C1. Oithona spp. or unidentified small calanoids usually dominated in 202 μm collections other than those in which P. avirostris was dominant.

(TEXT CONTINUES ON PAGE 4-144)

Table 4-26. List of zooplankton identified from bongo and neuston collections, summer 1977 (BLM08W). Species from subsurface collections only (*); from surface collections only (**).

COELENTERATA
**Aequorea sp.
*Aglantha digitale
*Bougainvillea sp.
*Catablema vesicarium
Liriope tetraphylla
Obelia sp.
Pelagia noctiluca
**Porpita porpita
Rhacostoma atlanticum
unid. anthozoans
unid. hydrozoans
unid. siphonophores

CTENOPHORA
Beroe ovata

TURBELLARIA
*unid. flatworms

RHYNCHOCOELA
*unid. nemerteans

ANNELIDA
Tomopteris sp.
Tomopteris helgolandica
unid. polychaetes

MOLLUSCA
*Abralia veranyi
*Abraliopsis morisii
*Atlanta sp.
**Atlanta fusca
Atlanta gaudichaudii
Atlanta helicinoides
Atlanta inclinata
Atlanta peroni
*Bathyteuthis abyssicola
Carinaria lamarcki
Cavolina sp.
Cavolina inflexa
Cavolina longirostris
Cavolina tridentata
Cavolina uncinata
*Cerastoderma pinnulatum
*Clione limacina
Cliopsis krohni
*Corolla spectabilis
Crassinella mactracea

MOLLUSCS (continued)
Creseis acicula
Creseis virgula
*Crucibranchaea macrochidae
*Desmopterus papilla
**Discoteuthis discus
**Donax variabilis
Firoloida leseurii
Hyalocyclis striata
Lima tenera
Limacina sp.
Limacina bulimoides
Limacina inflata
*Limacina leseuri
*Limacina retroversa
Limacina trochiformis
**Litiopa melanostoma
Loligo pealeii
*Lunatia heros
Natica sp.
Notobranchaea macdonaldi
**Oxyeyrus keraudrenii
Paedoclione doliiformis
Paraclione longicaudata
*Peraclis reticulata
Pneumoderma atlanticum
Pneumodermopsis paucidens
Proatlanta souleyeti
*Rossia equalis
*Rossia tenera
*Thelidioteuthis alessandrina
*Thliptodon sp.
*Thliptodon diaphanus
*unid. bivalves
*unid. cephalopods
*unid. cymbuliids
unid. gastropods
**unid. molluscs
unid. ommastrephids

CLADOCERA
**Evadne sp.
Evadne nordmanni
Evadne spinifera
Evadne tergestina
Penilia avirostris
*Podon sp.
Podon intermedius

Table 4-26. (Continued)

OSTRACODA
Conchoecia sp.
Conchoecia curta
Euconchoecia chierchiae
Halocypris brevirostris

COPEPODA
Acartia sp.
Acartia clausi
Acartia danae
*Acartia longiremus
Acartia tonsa
*Acrocalanus longicornis
*Aetideus armatus
**Anomalocera sp.
**Anomalocera patersonii
Calanus finmarchicus
**Calanopia americana
Calocalanus pavo
Candacia sp.
Candacia armata
Candacia curta
Candacia pachydactyla
*Centropages sp.
Centropages furcatus
*Centropages hamatus
Centropages typicus
Centropages violaceus
**Clausocalanus sp.
Clausocalanus arevicornis
Eucalanus sp.
Eucalanus attenuatus
Eucalanus crassus
*Eucalanus elongatus
Eucalanus pileatus
Euchaeta sp.
Euchaeta marina
*Euchirella rostrata
Eurytemora sp.
*Heterorhabdus spinifrons
Labidocera sp.
Labidocera acutifrons
Labidocera aestiva
**Labidocera nerii
*Lucicutia flavicornis
*Mecynocera clausi
Metridia lucens
Nannocalanus minor
Paracalanus sp.
Paracalanus crassirostris

COPEPODA (continued)
*Pleuromamma sp.
Pleuromamma abdominalis
Pleuromamma gracilis
**Pleuromamma piseki
*Pleuromamma robusta
**Pontella sp.
Pontella meadii
**Pontella securifer
Pontellina plumata
**Pontellopsis sp.
Pontellopsis regalis
**Pontellopsis villosa
Pseudocalanus sp.
*Rhincalanus nasutus
Scolecithrix danae
*Temora sp.
Temora longicornis
Temora stylifera
Temora turbinata
Tortanus discaudatus
*Undeuchaeta sp.
Undinula vulgaris
unid. copepodites
*Aegisthus mucronatus
*Clytemnestra rostrata
Macrosetella gracilis
unid. harpacticoids
Copilia mirabilis
**Copilia quadrata
Corycaeus sp.
**Corycaeus clausi
**Corycaeus elongatus
Corycaeus lautus
Corycaeus speciosus
Farranula sp.
Farranula carinata
*Farranula gracilis
Oithona spp.
Oncaea sp.
Oncaea conifera
Oncaea mediterranea
Oncaea venusta
**Sapphirina sp.
Sapphirina nigromaculata
Sapphirina ovatolanceolata
**Caligus sp.
*Caligus chelifer

Table 4-26. (Continued)

CIRRIPEDIA
**_Chthamalus fragilis_
**_Lepas_ sp.
unid. barnacle larvae

STOMATOPODA
*_Heterosquilla_ sp.
unid. stomatopod larvae

MYSIDACEA
**_Bowmaniella_ sp.
Erythrops erythrophthalma
*_Mysidopsis bigelowi_
Neomysis americana

CUMACEA
*_Campylaspis_ sp.
*_Cyclaspis_ sp.
*_Diastylis_ sp.
*_Diastylis quadrispinosa_
*_Diastylis sculpta_
*_Eudorella truncatula_
*_Leptocuma minor_
Oxyurostylis smithi

TANAIDACEA
**_Leptochelia bermudensis_

ISOPODA
**_Chiridotea tuftsi_
Edotea triloba
**_Idotea_ sp.
**_Idotea baltica_
Idotea metallica
**unid. isopods

AMPHIPODA
*_Ampelisca agassizi_
*_Ampelisca vadorum_
*_Ampelisca verrilli_
*_Amphithyrus sculpturatus_
Ampithoe longimana
Anchylomera sp.
*_Argissa hamatipes_
Brachyscelus sp.
**_Brachyscelus rapacoides_
*_Byblis serrata_
Corophium sp.
**_Dairella_ sp.
*_Erichthonius rubricornis_
Eupronoe sp.

AMPHIPODA (continued)
Eupronoe minuta
*_Hippomedon serratus_
**_Hyale_ sp.
**_Hyperionyx macrodactylus_
Iulopis sp.
*_Iulopis loveni_
Lestrigonus sp.
Lestrigonus bengalensis
Lycaea sp.
Lycaea bovalli
Lycaeopsis sp.
**_Lycaeopsis neglecta_
**_Lycaeopsis themistoides_
*_Lycaeopsis zamboangae_
Microprotopus raneyi
*_Monoculodes_ sp.
*_Monoculodes packardi_
*_Orchomenella minuta_
Oxycephalus clausi
Oxycephalus piscator
Paralycaea sp.
Parathemisto gaudichaudii
Phronima sp.
*_Phronima atlantica_
Phronima colletti
*_Phronima sedentaria_
*_Phronimella_ sp.
Phronimella elongata
Phrosina semilunata
Platyscelus sp.
*_Primno_ sp.
Pseudolycaea sp.
Rhabdosoma armatum
*_Rhabdosoma brevicaudatum_
*_Rhabdosoma minor_
*_Rhabdosoma whitei_
*_Scina_ sp.
*_Synchelidium americanum_
**_Synopia_ sp.
Tetrathyrus forcipatus
**_Themistella fusca_
Thyropus sp.
**_Trichophoxus epistomus_
*_Unciola irrorata_
unid. amphipods
*unid. gammarids
unid. hyperiids
unid. lycaeids
unid. platyscelids

Table 4-26. (Continued)

EUPHAUSIACEA
Euphausia sp.
*Euphausia americana
*Euphausia gibboides
Euphausia krohnii
Euphausia mutica
Euphausia tenera
*Meganyctiphanes norvegica
*Nematoscelis sp.
*Nematoscelis megalops
*Nematoscelis microps
Stylocheiron sp.
*Stylocheiron carinatum
*Stylocheiron suhmii
Thysanoessa sp.
Thysanoessa gregaria
*Thysanoessa inermis
*Thysanoessa longicaudata

DECAPODA
Albunea sp.
**Albunea paretii
Arenaeus sp.
**Brachycarpus biumguiculatus
Callinectes sp.
*Caridion gordoni
Crangon septemspinosa
*Dichelopandalus leptocerus
**Dromidia antillensis
Emerita sp.
**Ethusa microphthalma
**Gennadas sp.
Geryon quinquedens
**Hexapanopeus angustifrons
**Homarus americanus
**Hymenopenaeus tropicalis
Latreutes fucorum
**Leptochela sp.
*Leptochela papulata
Libinia sp.
Lucifer faxoni
**Lucifer fucorum
Lucifer typus
Munida sp.
**Naushonia crangonoides
**Ocypode quadrata
Ovalipes sp.
**Ovalipes ocellatus
**Palaemonetes sp.
Parthenope sp.
*Penaeus aztecus aztecus

DECAPODA (continued)
**Pinnixa chaetopterana
**Pinnotheres maculatus
*Pontophilus brevirostris
Portunus sp.
**Portunus sayi
*Processa sp.
Sergestes sp.
*Sergestes arcticus
*Solenocera sp.
Uca sp.
Upogebia affinis
unid. alpheids
unid. callapids
unid. decapods
**unid. grapsids
unid. hippolytids
unid. leucosiids
unid. majids
unid. pagurids
unid. palaemonids
unid. penaeids
unid. raninids
unid. scyllarids
unid. sergestids
*unid. thalassinids
unid. xanthids

CHAETOGNATHA
*Eukrohnia hamata
Krohnitta pacifica
Krohnitta subtilis
*Pterosagitta draco
Sagitta sp.
Sagitta decipiens
Sagitta elegans
Sagitta enflata
Sagitta helenae
*Sagitta hexaptera
Sagitta hispida
*Sagitta lyra
Sagitta minima
Sagitta serratodentata
Sagitta tasmanica
Sagitta tenuis

TUNICATA
Dolioletta gegenbauri
Doliolum sp.
**Doliolum nationalis
Oikopleura sp.

Table 4-26. (Concluded)

TUNICATA (continued)
Salpa fusiformis
Thalia democratica

PISCES
**Ablennea hians
Anchoa sp.
Anchoa hepsetus
Anchoa mitchilli
Astroscopus guttatus
Auxis sp.
*Benthosema glaciale
Bothus sp.
*Callionymus agassizi
**Caranx crysos
Centropristis striata
Ceratoscopelus maderensis
*Citharichthys sp.
Citharichthys arctifrons
*Conger oceanicus
Corphaena hippurus
*Cyclothone sp.
**Cynoscion regalis
**Decapterus punctatus
*Diaphus sp.
Etropus microstomus
*Glyptocephalus cynoglossos
*Gobiosoma ginsburgi
**Gonichthys cocco
Hemipteronotus novacuia
**Hippocampus erectus
Hippoglossina oblonga
**Hygophum hygomi
**Hypsoblennius hentzi
*Lampanyctus sp.
*Liparis sp.
*Lophius americanus
*Maurolicus muelleri
**Megalops atlantica
*Merluccius sp.
*Merluccius albidus
*Merluccius bilinearis
**Myctophum affine
**Myctophum obtusirostre
**Myctophum punctatum
Ophichthus cruentifer
**Parerocoetus brachypterus
Peprilus triacanthus
*Pisodonophis cruentifer
Pomatomus saltatrix
Prionotus sp.

PISCES (continued)
**Pristigenys alta
**Sarda sarda
*Scophthalmus aquosus
*Syacium ovale
*Syacium papillosum
*Symbolophorus veranyi
Symphurus sp.
**Syngnathus fuscus
*Tautogolabrus adspersus
**Trachinocephalus myops
**Tylosurus acus
Urophycis sp.
*Vinciguerria attenuata
unid. balistids
*unid. blenniids
unid. branchiostegids
unid. carangids
**unid. chaetodontids
unid. congrids
**unid. exocoetids
unid. fishes
unid. fish eggs
unid. gadiformes
unid. gempylids
**unid. gerreids
*unid. gobiids
*unid. gobioids
unid. myctophids
*unid. ophichthids
unid. ophidiids
**unid. ostraciids
unid. paralepidids
unid. scorpaenids
*unid. sparids
**unid. stomiatoids
unid. synodontids
**unid. tetraodontids

Table 4-27. Numerically dominant zooplankters in summer 1977 collections (BLM08W). Drawn from the three most abundant taxa in each tow (D = day, N = night).

Station L1

Bongo 202	Bongo 505	Neuston 505
Temora longicornis	*Penilia avirostris*	*Penilia avirostris* (4N,3D)
Penilia avirostris	*Liriope tetraphylla*	*Labidocera aestiva* (3N,4D)
Evadne nordmanni	unid. siphonophores	*Liriope tetraphylla* (3N,2D)
		unid. siphonophores
		Callinectes sp. (1N)

Station L2

Bongo 202	Bongo 505	Neuston 505
P. avirostris	*P. avirostris*	*P. avirostris* (4N,4D)
unid. copepodites	*Sagitta elegans*	unid. siphonophores (4N,2D)
Oncaea venusta	unid. siphonophores	*L. tetraphylla* (1N,3D)
		Callinectes sp. (2N,1D)
		Eucalanus pileatus (1N)
		Temora stylifera (1D)
		Lucifer faxoni (1D)

Station L4

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	*Calanus finmarchicus*	*T. stylifera* (4N,2D)
Oncaea mediterranea	*Nannocalanus minor*	*Sagitta enflata* (1N,2D)
Temora turbinata	*Temora stylifera*	*Labidocera* sp. (1N,2D)
		Nannocalanus minor (2N)
		Lestrigonus benglaensis (2N)
		E. pileatus (1N,1D)
		Paraclione longicaudata (2D)
		Undinula vulgaris (2D)
		P. avirostris (1D)
		Centropages furcatus (1N)

Table 4-27. (Continued)

Station L6

Bongo 202
unid. copepodites
O. mediterranea
Clausocalanus arcuicornis

Bongo 505
N. minor
Eucalanus pileatus
Undinula vulgaris

Neuston 505
Labidocera sp. (4N,2D)
T. stylifera (2N,4D)
L. bengalensis (2N,1D)
U. vulgaris (3D)
S. enflata (2N)
E. pileatus 91D)
Limacina trochiformis (1N)
Lucifer faxoni (1N)
Pontellopsis sp. (1D)

Station C1

Bongo 202
P. avirostris
Centropages typicus
T. longicornis

Bongo 505
P. avirostris
Neomysis americana
Centropages typicus

Neuston 505
Centropages typicus (4N,2D)
Thalia democratica (2N,3D)
P. avirostris (2N,1D)
Labidocera aestiva (1N,1D)
Neomysis americana (2N)
Oithona spp. (2D)
Uca sp. (1D)
Tortanus discaudatus (1N)
Acartia tonsa (1D)
Limacina sp. (1D)

Station D1

Bongo 202
P. avirostris
unid. copepodites
C. typicus

Bongo 505
P. avirostris
C. typicus
N. minor

Neuston 505
P. avirostris (1N)
C. typicus (1N)
L. aestiva (1N)

Table 4-27. (Continued)

Station N3

Bongo 202	Bongo 505	Neuston 505
Oithona spp.	C. finmarchicus	L. bengalensis (1N)
unid. copepodites	S. elegans	P. avirostris (1N)
Oikopleura sp.	N. minor	C. typicus (1N)

Station E3

Bongo 202 (4 reps)	Bongo 505 (4 reps)	Neuston 505
Calanus finmarchicus (3)	C. finmarchicus (4)	P. avirostris (4N,3D)
P. avirostris (3)	P. avirostris (3)	Idotea metallica (2N,3D)
unid. copepodites (2)	S. elegans (3)	C. typicus (4N)
Paracalanus sp. (2)	Paracalanus sp. (1)	Candacia armata (3D)
Parathemisto gaudichaudii (1)	unid. copepodites (1)	T. stylifera (2D)
Evadne spinifera (1)		L. bengalensis (2N)
		Carolina longirostris (1D)

Station F2

Bongo 202	Bongo 505	Neuston 505
unid. copepodites	N. minor	L. bengalensis (1N)
Oithona spp.	C. finmarchicus	C. typicus (1N)
P. avirostris	P. avirostris	P. avirostris (1N)

Station J1

Bongo 202	Bongo 505	Neuston 505
P. avirostris	P. avirostris	P. avirostris (3N,4D)
unid. copepodites	N. minor	T. stylifera (2N,4D)
C. finmarchicus	C. finmarchicus	N. minor (3N)
		unid. siphonophores (2N)
		T. democratica (2D)
		I. metallica (1D)
		S. enflata (1N)
		C. typicus (1N)
		Salpa fusiformis (1D)

Table 4-27. (Concluded)

Station B5

Bongo 202 (4 reps)	Bongo 505 (4 reps)	Neuston 505
unid. copepodites (4)	*C. finmarchicus* (4)	*C. typicus* (4N,3D)
C. finmarchicus (4)	*S. elegans* (3)	*P. avirostris* (3N,3D)
P. avirostris (2)	*P. avirostris* (3)	*L. bengalensis* (2N,2D)
Oithona spp. (1)	*N. minor* (1)	*Pontella meadii* (2D)
Pseudocalanus sp. (1)	*C. typicus* (1)	*Urophycis* sp. (1N)
		Callinectes sp. (1N)
		Paralycaea sp. (1D)
		Oikopleura sp. (1N)
		T. democratica (1D)

Station A2

Bongo 202 (4 reps)	Bongo 505 (4 reps)	Neuston 505
unid. copepodites (4)	*C. finmarchicus* (4)	*T. stylifera* (4N,4D)
Oithona spp. (4)	*N. minor* (4)	*S. enflata* (3N,2D)
C. arcuicornis (3)	unid. siphonophores (2)	*I. metallica* (1N,3D)
C. finmarchicus (1)	*T. stylifera*	*N. minor* (3N)
	M. lucens	unid. siphonophores (2D)
		L. faxoni (1D)
		Labidocera sp. (1N)

P. avirostris was also an important dominant in surface collections at stations where it was abundant in subsurface waters. It was an important neustont at every station except L4, L6, and A2. These stations were dominated in the surface layer by Temora stylifera, immature Labidocera sp. and Sagitta enflata. Neustonts at stations where the northern Calanus community predominated were distinctly different from subsurface zooplankton (stations N3, E3, B5, and A2). Neuston at these stations was dominated by P. avirostris, Lestrigonus bengalensis, Centropages typicus, and other warm-water fauna (Idotea metallica, Pontella meadii, T. stylifera, S. enflata, etc.). Avoidance of the surface layer by the northern species was obvious. Fish and decapod larvae were in less abundance than noted in previous cruises. Callinectes sp. was among dominant neustonts at stations L1, L2, and B5; Urophycis sp. larvae were dominant in one night tow at Station B5.

Diel Cycles of Dominant Neustonts

Station L1. Half of the eight summer neuston tows at the coastal station off Virginia were numerically dominated by unclassified siphonophores, two tows by the hydrozoan Liriope tetraphylla and two by the cladoceran Penilia avirostris. Except for the siphonophores (not included in Figure 4-47), which were abundant only at dawn and in daylight tows, very little diel variation in abundance was evident. P. avirostris was somewhat more abundant at dusk, L. tetraphylla at dusk and early morning. Labidocera aestiva and larvae of Callinectes sp. fluctuated through the day without any apparent migration to or from the surface layer.

Station L2. Penilia avirostris was much more abundant at Station L2, where it dominated six of the eight neuston collections and reached a peak after midnight of over 200,000 per standard tow (Figure 4-48). Liriope tetraphylla slightly outnumbered the cladocerans at its late afternoon peak, and unidentified siphonophores (abundant only at night at this station), numerically dominated an early morning collection. Both P. avirostris and Callinectes sp. increased sharply at night in the surface layer; Temora stylifera showed very slight increases at dusk and dawn.

Station L4. Dominant species in neuston at Station L4 were mostly different than those at stations L2 and L1. Half the collections were numerically dominated by Temora stylifera, which again showed slight peaks at dusk and dawn (Figure 4-49); two daytime collections had Sagitta enflata as the most abundant species; one collection after midnight was dominated by the amphipod Lestrigonus bengalensis, and the final collection, a daytime tow with very low abundance, was numerically dominated by the mollusc Paraclione longicaudata. S. enflata and L. bengalensis both peaked around midnight, the latter more strongly. Labidocera sp., consisting of

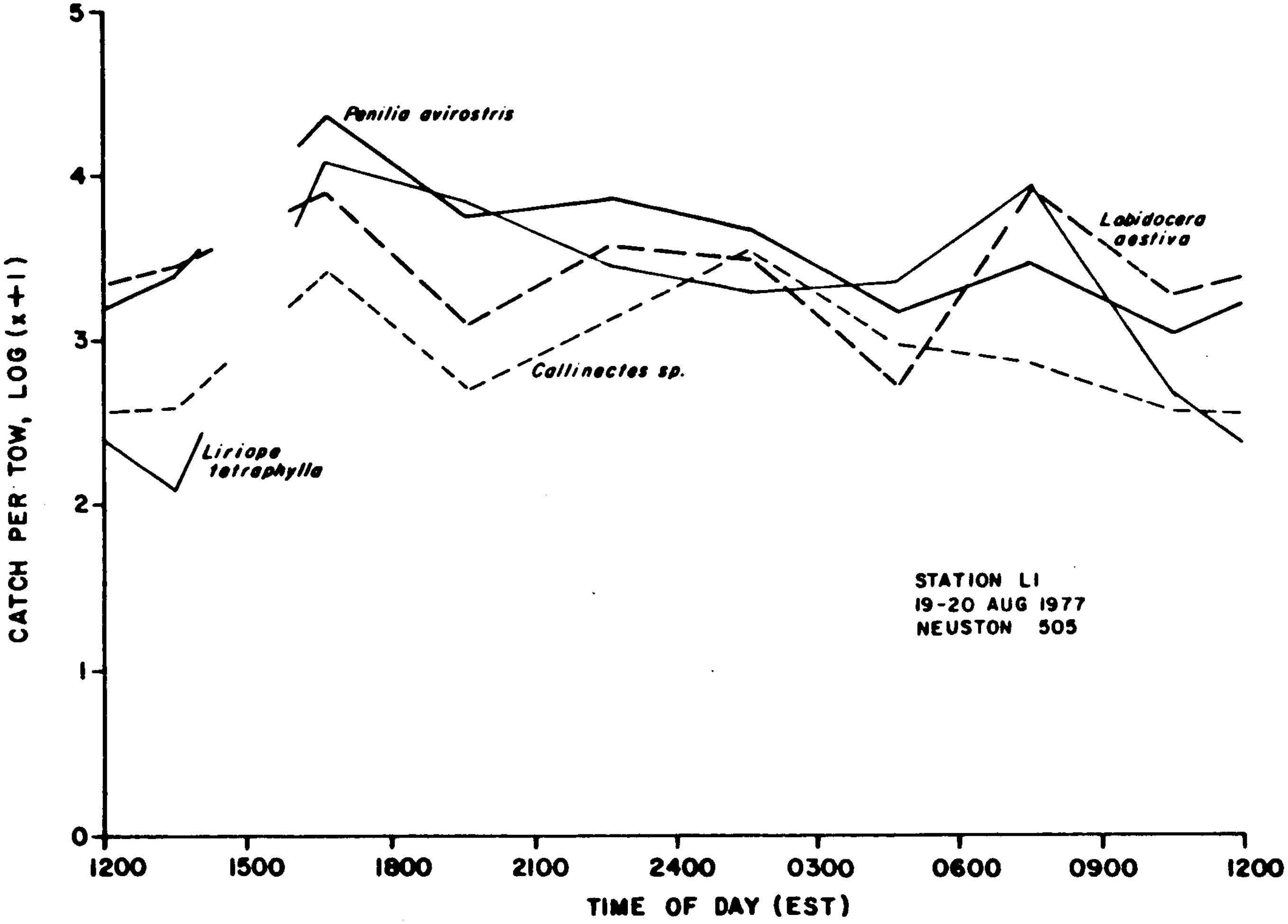

Figure 4-47. Diel cycle of dominant neustonts at Station L1, BLM08W.

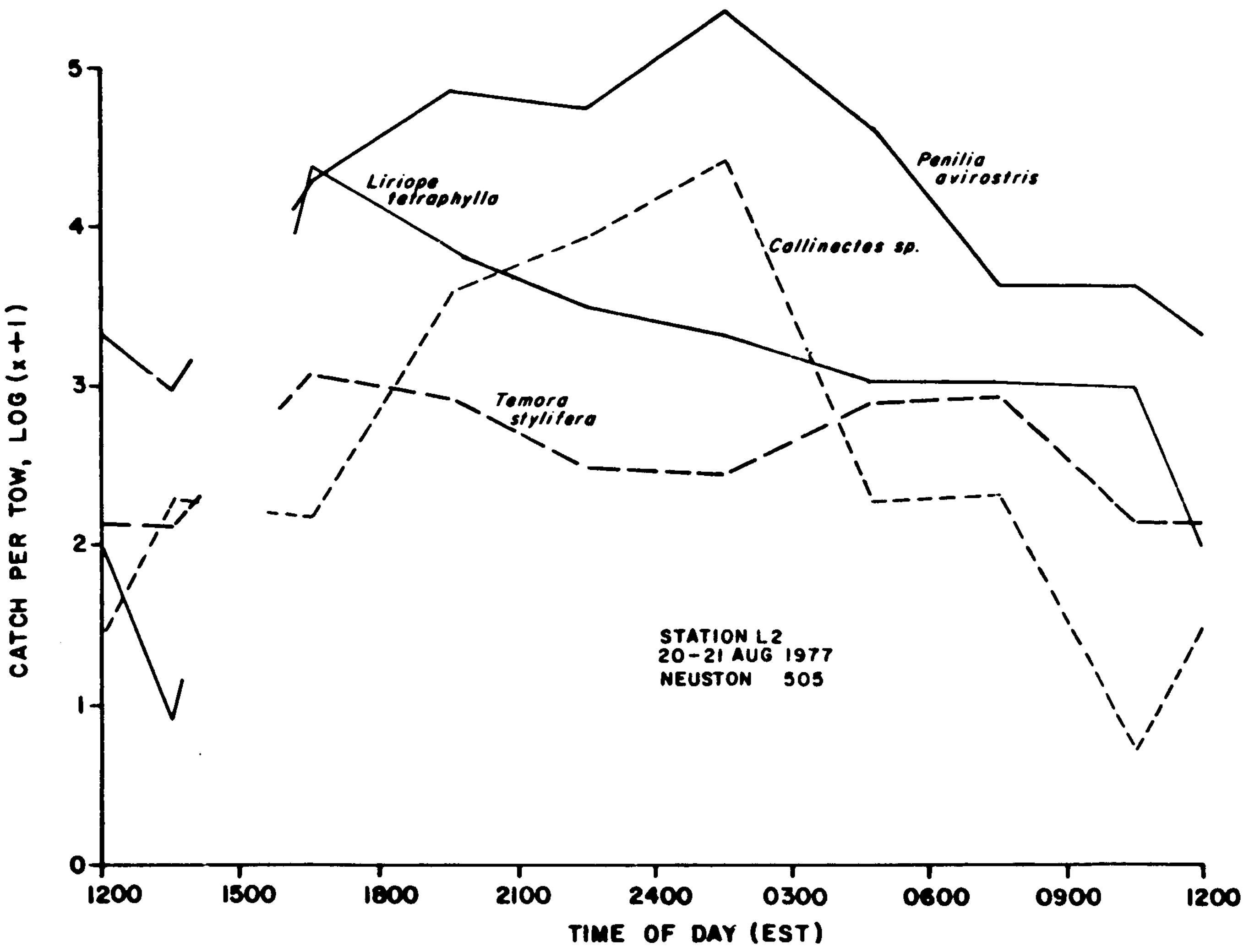

Figure 4-48. Diel cycle of dominant neustonts at Station L2, BLM08W.

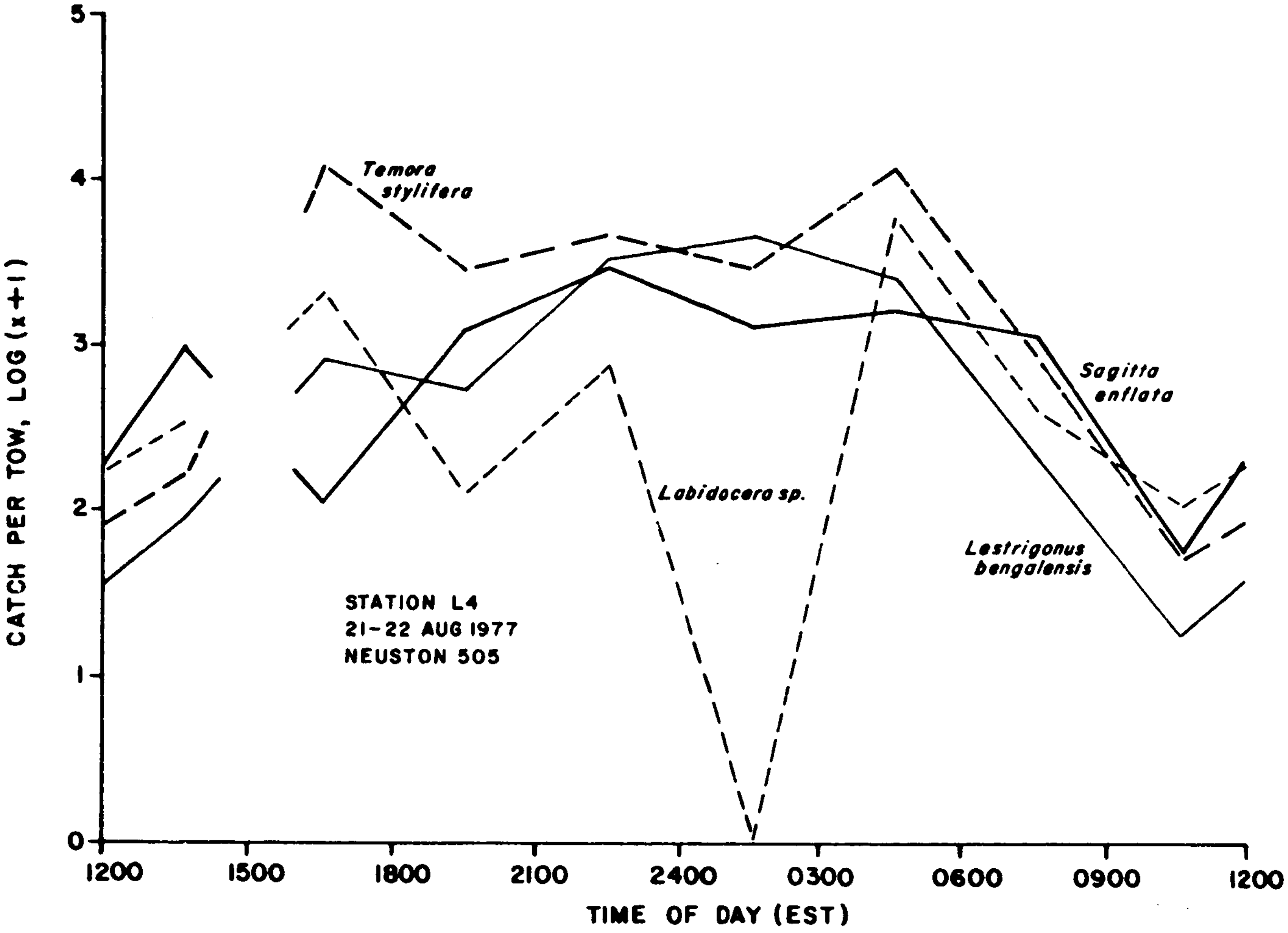

Figure 4-49. Diel cycle of dominant neustonts at Station L4, BLM08W.

immature specimens, probably of L. acutifrons, were present throughout the day in variable numbers, except the collection after midnight.

Station L6. Half of the neuston tows at the outermost Virginia station were dominated by the immature Labidocera sp., three by Temora stylifera, and one by Lestrigonus bengalensis. T. stylifera peaked in later afternoon and dawn (Figure 4-50), L. bengalensis and Sagitta enflata before midnight, and Labidocera sp. at dawn.

As in the spring cruise, neuston along the southern L-transect was sharply divided into two communities: an inshore surface community dominated by neritic forms, including P. avirostris, L. tetraphylla and Callinectes larvae; and an offshore group characterized by T. stylifera, L. bengalensis, S. enflata and immature Labidocera sp.

Station C1. Half of the neuston tows at the coastal New Jersey station were dominated by Thalia democratica, the salp that was, in spring, dominant in offshore neuston. Among remaining collections, two were numerically dominated by Penilia avirostris, one by Centropages typicus, and one by Oithona spp. Thalia democratica peaked at dawn, P. avirostris in late afternoon, and other dominants at night (Figure 4-51). Dominant species generally showed sharp increases in abundance at night. Neomysis americana was a particularly strong vertical migrator.

Station E3. Penilia avirostris numerically dominated seven of the eight neuston tows at this central shelf station; Temora stylifera was most abundant in the remaining collection. P. avirostris and Centropages typicus both increased at night, peaking around midnight (Figure 4-52). T. stylifera was bimodally, but slightly, more abundant in late afternoon and dawn. Idotea metallica, a true neustont (euneustonic) was evenly abundant throughout the 24-hour period.

Station J1. Dominant neustonts at the slope station included Penilia avirostris (four collections), Temora stylifera (two tows), and unidentified siphonophores (two tows). The latter were abundant only in early evening tows. Other important neustonts included Idotea metallica, Nannocalanus minor, Centropages typicus, Sagitta enflata, and Thalia democratica, the salp which was dominant at the coastal station C1. P. avirostris and N. minor peaked near midnight; T. stylifera and I. metallica remained at fairly constant abundance through the day (Figure 4-53). T. stylifera, as in previous stations, tended toward slightly higher abundance at dusk and dawn.

Station B5. Dominant neustonts at B5 included Centropages typicus (three tows), Penilia avirostris (two tows), Lestrigonus bengalensis (two tows), and Thalia democratica (one tow). Pontella meadii demonstrated (Figure 4-54) the pattern of even abundance typical of euneustonts. Other dominants dropped from fairly high

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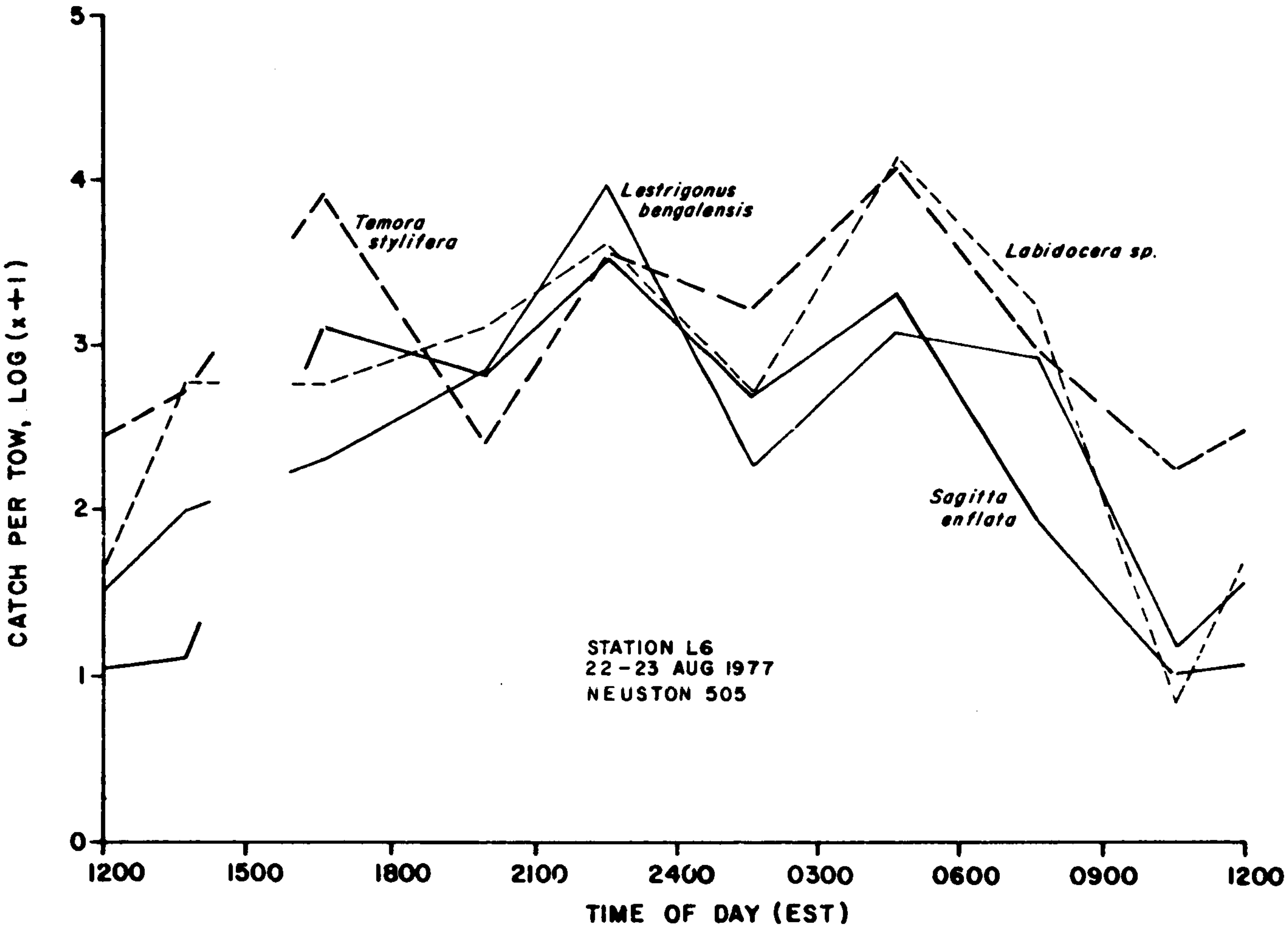

Figure 4-50. Diel cycle of dominant neustonts at Station L6, BLM08W.

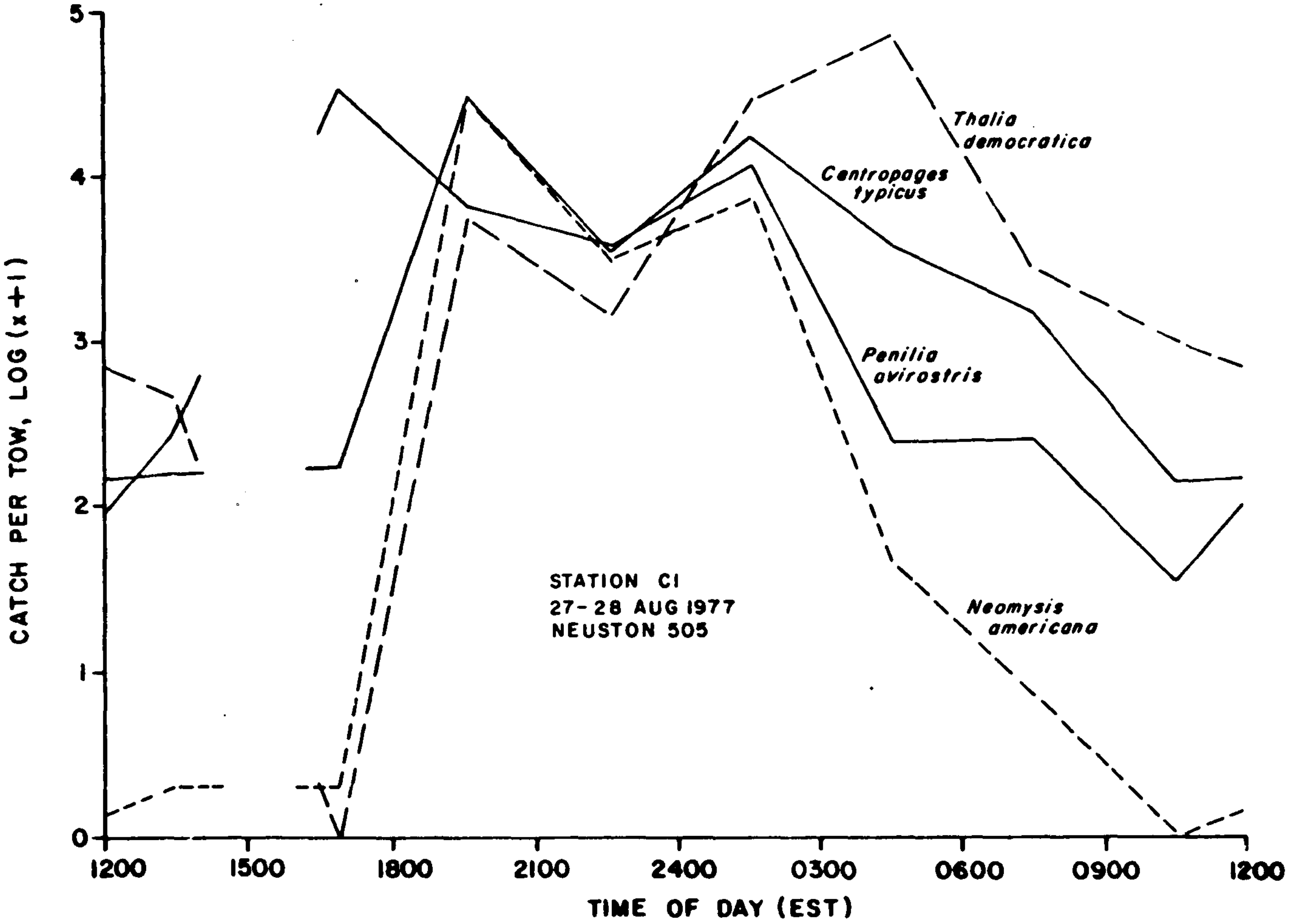

Figure 4-51. Diel cycle of dominant neustonts at Station C1, BLM08W.

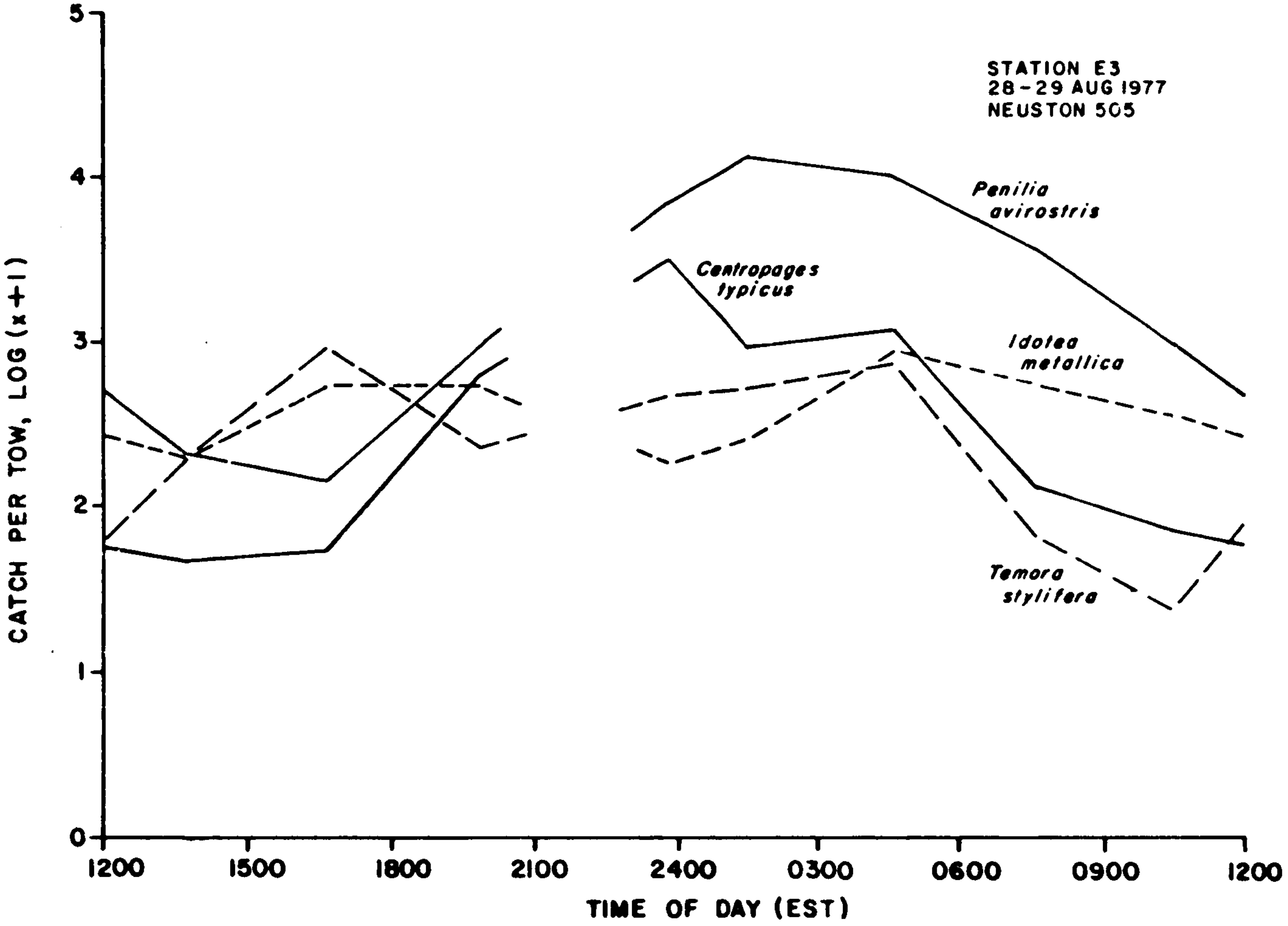

Figure 4-52. Diel cycle of dominant neustonts at Station E3, BLM08W.

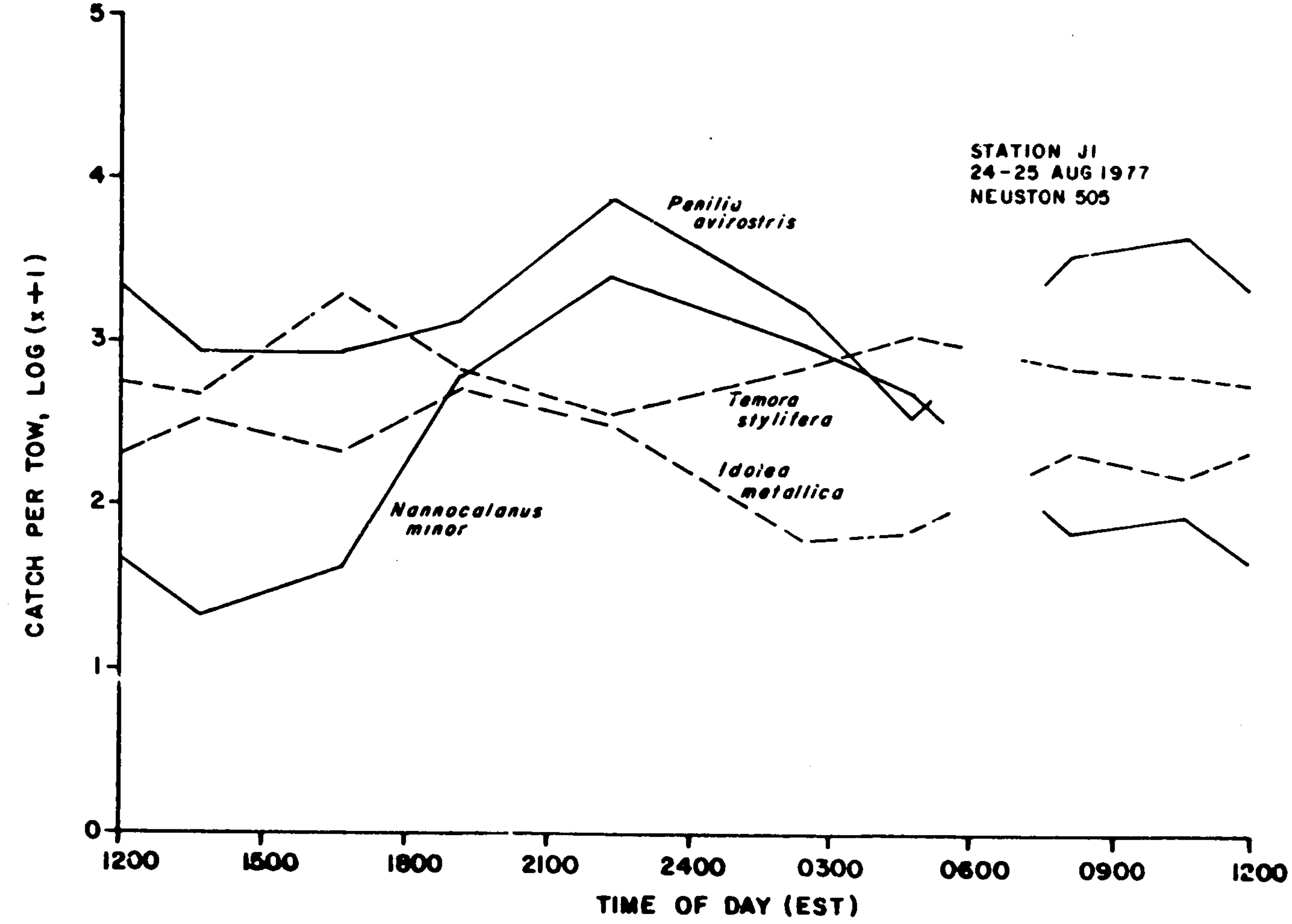

Figure 4-53. Diel cycle of dominant neustonts at Station J1, BLM08W.

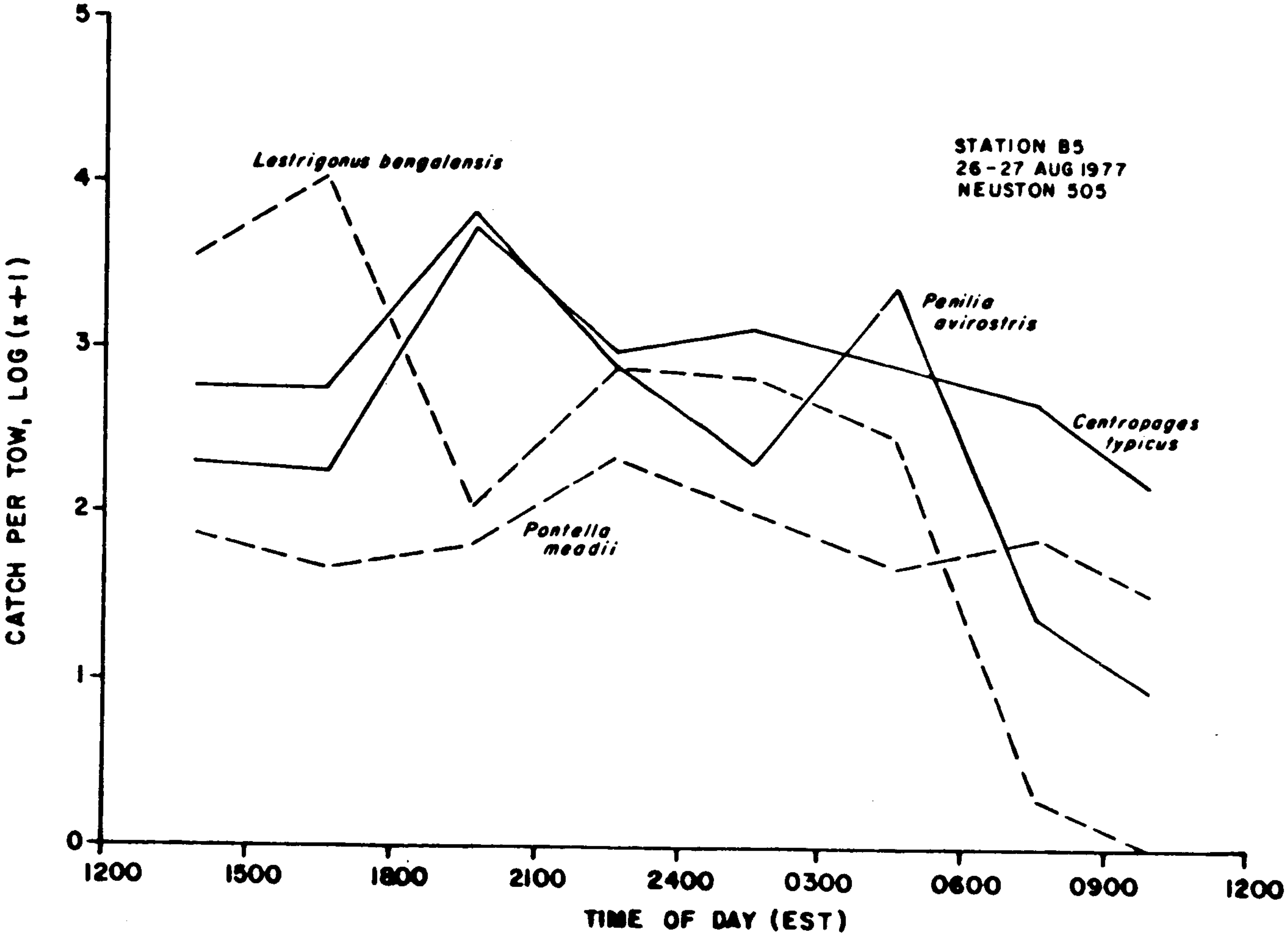

Figure 4-54. Diel cycle of dominant neustonts at Station B5, BLM08W.

abundance in late afternoon and peaks at dusk (*L. bengalensis*) or early evening to low abundance or absence in the morning. The 1000 hour of low abundance among these species was also the single collection dominated by *T. democratica* (not shown in Figure 4-54).

Station A2. *Temora stylifera* numerically dominated seven of the eight neuston collectons at Station A2, and was subdominant to *Sagitta enflata* in the eighth collection. At this station, *T. stylifera* was evenly abundant throughout the day (Figure 4-55) as was the less abundant *Idotea metallica*. *S. enflata* and *Nannocalanus minor* were both most abundant at night.

Neuston off New Jersey was characterized by an abundance of the cladoceran *P. avirostris*, which was among the dominants at every station except A2, and in contrast to Virginia stations where it dominated only inshore collections. The copepod *T. stylifera*, typical of offshore southern neuston, was also important at offshore New Jersey stations J1 and A2. *C. typicus* was the most abundant copepod in neuston tows at coastal and central shelf stations off New Jersey.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent species in summer 1977 bongo collections are listed in Table 4-28, those in neuston collections in Table 4-29. Four of the 16 most frequent neuston species are not among the listed bongo species (*Portunus* sp., *Pontella* sp., *Pontella meadii*, and *Idotea metallica*) and a fifth species (*Lucifer faxoni*) was considerably more frequent in neuston collections (93 vs. 64%). Siphonophores and the amphipod *Lestrigonus bengalensis* were the most frequent taxa in both bongo and neuston collections. The cold-water chaetognath, *Sagitta elegans*, one of the most frequent subsurface species, is absent from the list of the most frequent (>45%) neuston species.

Larger average catches were observed in 202 µm mesh bongo collections of several of the smaller species: *Centropages typicus*, *Penilia avirostris*, *Oikopleura* sp., *Evadne spinifera*, and unidentified copepodites were obvious examples of species that escape through the 505 µm meshes.

Diversity. The Shannon index (H'), evenness (J'), and species richness are listed for each summer collection in Table 4-30. Diversity indices (H') from 202 µm nets were generally higher (15 of 21 comparisons) than in 505 µm collections, whereas the opposite result was evident in indices of species richness. Only three of the 21 comparisons yielded a higher index (H') from 202 µm collections.

Species richness was generally high all along the southern L-transect, increasing somewhat offshore in subsurface collections.

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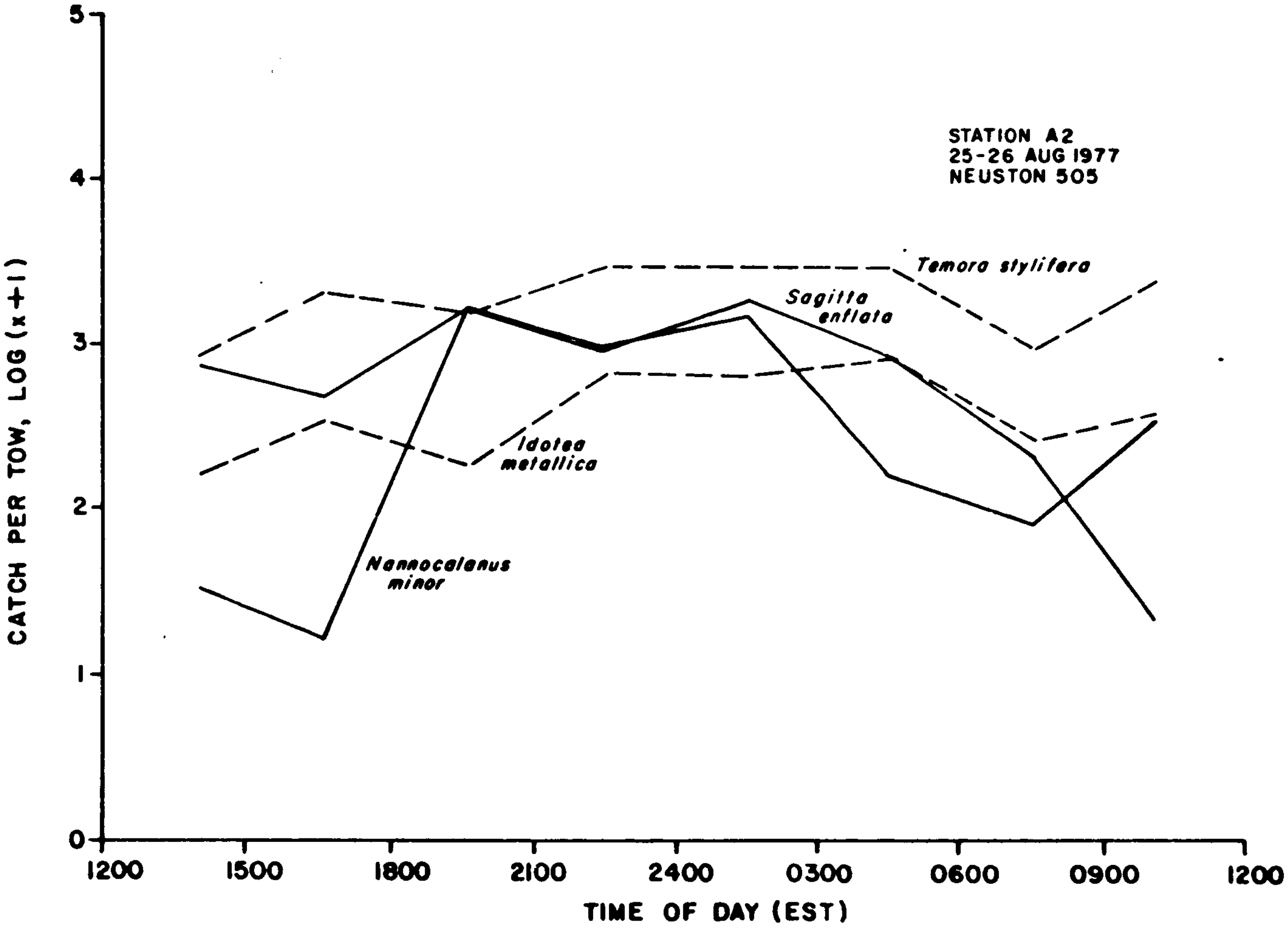

Figure 4-55. Diel cycle of dominant neustonts at Station A2, BLM08W.

Table 4-28. Frequency of occurrence and abundance of common species in bongo collections, BLM08W.

Species	Percent Occurrence	Mean Catch per 100 m^3		Max. Catch per 100 m^3
		505 μm	202 μm	
unid. siphonophores	93	352	737	4,037
Lestrigonus bengalensis	93	345	322	2,547
Sagitta elegans	90	1,837	2,200	10,723
Sagitta enflata	90	473	578	2,011
Callinectes sp.	90	124	117	808
Arenaeus sp.	90	91	90	100
Centropages typicus	88	1,867	12,705	147,270
Penilia avirostris	86	7,535	42,589	470,027
Calanus finmarchicus	86	13,349	19,679	88,561
Parathemisto gaudichaudii	86	539	1,308	6,746
Sagitta tasmanica	86	304	594	1,817
Nannocalanus minor	83	1,902	2,513	8,335
Oikopleura sp.	83	293	3,192	26,195
Urophycis sp.	83	103	106	268
unid. polychaetes	81	62	174	1,588
Citharichthys arctifrons	79	81	76	100
Creseis virgula	76	90	99	447
Auxis sp.	76	87	67	117
Atlanta gaudichaudii	74	83	70	174
Temora stylifera	69	620	951	4,477
unid. stomatopod larvae	69	71	67	100
Evadne spinifera	67	226	4,101	55,764
Sagitta minima	64	96	309	1,196
Lucifer faxoni	64	91	71	558
Cavolina longirostris	62	77	56	200
unid. copepodites	59	1,303	35,920	164,314

Table 4-29. Frequency of occurrence and abundance of common species in neuston collections, BLM08W.

Species	Percent Occurrence	Mean Catch per Standard Tow	Max. Catch per Standard Tow
unid. siphonophores	95	4,357	116,830
Lestrigonus bengalensis	93	831	10,636
Lucifer faxoni	93	236	6,993
Penilia avirostris	82	7,590	209,920
Temora stylifera	80	1,120	1,228
Sagitta enflata	75	376	3,392
Portunus sp.	72	11	140
Urophycis sp.	71	52	535
Callinectes sp.	70	687	8,384
Pontella sp.	70	64	480
Centropages typicus	68	1,075	28,864
Pontella meadii	68	74	512
unid. stomatopod larvae	68	49	664
Nannocalanus minor	67	338	3,712
Atlanta peroni	66	50	1,728
Idotea metallica	62	133	916
Oikopleura sp.	60	65	1,424
Corycaeus speciosus	55	41	448
Creseis virgula	54	34	640
Atlanta gaudichaudii	54	24	528
Limacina trochiformes	53	131	3,265
Candacia armata	53	88	1,056
Cavolina longirostris	51	34	368
Labidocera aestiva	51	33	1,024
Paraclione longicaudata	49	72	2,035
Doliolum sp.	47	70	1,792
Thalia democratica	45	1,891	69,632

Table 4-30. Diversity of surface and subsurface zooplankton collections, BLM08W. H' = Shannon index (base-2); J' = evenness; Richness = Margalef's index of species richness; N = night, D = day, Ns = neuston, B = bongo.

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L1	Z77-237	Ns, D	2.2225	0.4786	2.2831
	-238	Ns, N	2.5200	0.4644	4.2961
	-239	B505, N	1.2129	0.2014	6.1740
	-240	B202, N	3.2308	0.5992	3.7631
	-241	Ns, N	2.9086	0.5266	4.5550
	-242	Ns, N	3.2149	0.5586	5.3834
	-243	Ns, N	2.2527	0.4547	3.1718
	-244	Ns, D	2.3631	0.5299	2.0397
	-245	Ns, D	1.6123	0.3319	2.8209
	-246	Ns, D	2.0128	0.4657	2.0020
L2	Z77-247	Ns, D	1.8028	0.3674	2.6957
	-248	Ns, N	1.9342	0.3522	3.7638
	-249	B505, N	2.7604	0.4551	6.0910
	-250	B202, N	2.2161	0.3628	4.5896
	-251	Ns, N	1.7973	0.3312	3.6445
	-252	Ns, N	1.4170	0.2663	3.0491
	-253	Ns, N	1.5429	0.2899	3.4354
	-254	Ns, D	2.6397	0.5328	3.1865
	-255	Ns, D	1.9362	0.3872	3.5203
	-955	Ns, D	2.9664	0.6045	3.7270
L4	Z77-256	Ns, D	3.0980	0.5547	4.5728
	-257	Ns, N	4.1002	0.6583	7.6913
	-258	B505, N	4.1567	0.6217	8.9510
	-259	B202, N	3.8827	0.5870	7.4278
	-260	Ns, N	3.8364	0.6418	6.1949
	-261	Ns, N	3.6539	0.5961	7.1188
	-262	Ns, N	3.4634	0.5863	5.5953
	-263	Ns, D	4.0500	0.7291	5.3485
	-266	Ns, D	4.4785	0.8019	6.7874
	-267	Ns, D	3.6571	0.6826	4.8124
L6	Z77-268	Ns, D	2.6483	0.4742	4.8703
	-269	Ns, N	3.9766	0.6705	6.8423
	-270	B505, N	4.3797	0.6607	9.6969
	-271	B202, N	4.1272	0.6327	7.7086
	-272	Ns, N	3.5882	0.5874	6.4477
	-273	Ns, N	4.0700	0.6640	7.9871
	-274	Ns, N	3.3308	0.5491	6.1886
	-275	Ns, D	3.7299	0.6962	4.5763
	-276	Ns, D	3.8693	0.7271	5.8409

Table 4-30 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
L6	Z77-277	Ns, D	4.2795	0.7936	4.8907
C1	Z77-922	Ns, D	0.7100	0.1447	2.7605
	-323	Ns, N	2.7506	0.5407	2.8846
	-324	B505, N	1.4948	0.2938	2.7161
	-325	B202, N	3.0487	0.5944	2.5255
	-326	Ns, N	3.4255	0.6437	3.9421
	-327	Ns, N	3.0657	0.5930	3.0773
	-328	Ns, N	0.6271	0.1334	2.2236
	-329	Ns, D	2.9347	0.5818	3.6164
	-330	Ns, D	2.4422	0.5259	3.2019
	-331	Ns, D	3.3064	0.7034	3.2107
D1	Z77-332	Ns, D	4.0703	0.7073	5.4976
	-333	B505, N	2.8988	0.4831	5.3964
	-334	B202, N	3.2391	0.5769	3.7958
N3	Z77-335	B202, N	2.1487	0.3827	3.4562
	-336	Ns, N	3.4357	0.5943	5.3475
	-337	B505, N	3.2018	0.5377	5.2605
E3	Z77-338	Ns, N	2.5063	0.4678	4.1522
	-339	Ns, N	2.0024	0.3625	4.5493
	-340	Ns, N	2.5052	0.4295	5.7645
	-341	Ns, D	2.2503	0.4288	4.2552
	-342	Ns, D	3.2142	0.6760	3.1941
	-343	Ns, D	3.4462	0.7332	3.4859
	-344	Ns, D	3.2976	0.6239	4.7970
	-345	B505, N	3.3535	0.5973	3.7509
	-346	B202, N	1.7823	0.3227	3.7079
	-347	Ns, N	4.0922	0.7214	5.7757
	-348	B505, N	2.5939	0.4467	5.1529
	-349	B202, N	3.4246	0.5871	4.2964
	-350	B505, N	2.0812	0.3469	5.5609
	-351	B202, N	3.3985	0.5730	4.8566
	-352	B505, N	2.0534	0.3585	4.6533
	-353	B202, N	3.4134	0.5827	4.5895
F2	Z77-286	B202, N	3.3186	0.5328	5.7556
	-287	Ns, N	3.8670	0.7014	4.9896
	-288	B505, N	3.7149	0.6315	5.5384

Table 4-30 (continued)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
J1	Z77-278	Ns, D	2.5889	0.4801	4.6363
	-279	Ns, D	1.5157	0.2955	3.9340
	-280	Ns, D	3.0816	0.5872	4.6790
	-281	Ns, D	2.7017	0.5506	3.4874
	-282	Ns, N	1.8447	0.3098	5.6812
	-283	B505, N	1.9902	0.3148	7.2670
	-284	B202, N	2.6506	0.4339	6.3944
	-285	Ns, N	2.1300	0.3719	4.8437
	-289	Ns, N	3.8697	0.6551	6.6902
	-290	Ns, N	3.6113	0.6246	6.5095
B5	Z77-307	Ns, D	1.7409	0.3451	3.7512
	-308	Ns, D	1.3318	0.2439	4.5381
	-309	Ns, N	2.5744	0.4358	6.0563
	-310	B505, N	1.5465	0.2700	4.8383
	-311	B202, N	2.8927	0.4858	4.7092
	-312	B505, N	1.2111	0.2180	3.8891
	-313	B202, N	3.0707	0.5361	4.2123
	-314	B505, N	1.4111	0.2634	3.3259
	-315	B202, N	2.7187	0.4950	3.5485
	-316	B505, N	1.0425	0.1946	3.4683
	-317	B202, N	2.4215	0.4359	3.3962
	-318	Ns, N	3.7481	0.6426	6.6769
	-319	Ns, N	3.2122	0.6368	3.8922
	-320	Ns, N	3.3229	0.5829	5.9099
	-321	Ns, D	1.9186	0.4439	2.9191
	-322	Ns, D	0.0999	0.0215	2.3098
A2	Z77-291	Ns, D	2.5706	0.5141	4.0132
	-292	Ns, D	2.5263	0.4966	3.9607
	-293	Ns, N	3.5653	0.6384	5.1943
	-294	B505, N	2.6727	0.4463	6.6603
	-295	B202, N	3.6153	0.5822	5.8919
	-296	B505, N	3.2632	0.5177	7.4035
	-297	B202, N	3.6999	0.5713	7.1568
	-298	B505, N	3.7671	0.5634	9.7460
	-299	B202, N	3.7963	0.6076	6.2266
	-300	B505, N	3.7225	0.5579	9.8025
	-301	B202, N	3.7784	0.6029	5.8929
	-302	Ns, N	3.6981	0.6313	6.2118
	-303	Ns, N	3.5723	0.6207	5.6892
	-304	Ns, N	3.5128	0.6260	5.3547

Table 4-30 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
A2	Z77-305	Ns, D	2.9446	0.5461	5.2985
	-306	Ns, D	1.8163	0.4073	2.5226

An offshore increase was more evident in surface collections, with an abrupt increase in Station L4. Off New Jersey, species richness was low near the coast, moderately high and fairly constant at central shelf stations, and abruptly higher at the shelf-edge. Maximum richness (an index of 9.8025) occurred in a bongo 505 µm collection from Station A2 with 102 taxa and 29,837 individuals. The lowest such index in summer collections was 2.0020 from a daytime neuston collection at Station L1 containing 20 taxa and 13,235 individuals. Species richness indices higher than 7.0 were limited to bongo tows at stations L4, L6, J1, and A2 and to night neuston at stations L4 and L6.

Cluster Analysis. Taxa occurring in less than 5% of either neuston or bongo collections were omitted from the respective cluster analyses, as in previous cruises.

I. Bongo collections. Clusters of the 42 bongo samples from BLM08W are shown in Figure 4-56. There were three primary clusters of collections:

1. Coastal Stations L1, L2, and C1
2. Northern Central Shelf (stations D1, N3, E3, and B5)
3. Shelf-edge and Slope (stations L4, L6, F2, J1, and A2)

Subdivisions of collections within the last two primary clusters were principally by mesh size.

Inverse species clusters and a nodal analysis for bongo collections are shown in Figures 4-57 and 4-58. Individual collections and species comprising the sample and species groups are identified in Table 4-31. Sample group I, the coastal cluster, was most closely characterized by species group A that includes both warm- and cold-water coastal species (e.g. *Evadne tergestina* and *E. nordmanni*, *Acartia tonsa* and *A. clausi*, *Ovalipes* sp. and *Crangon septemspinosa*). Northern mid-shelf stations (sample group II) were populated by species groups B and C, for the most part, which include the dominant and wide-spread shelf species *Calanus finmarchicus* and *Sagitta elegans*, among the northern community, and *Penilia avirostris*, *Evadne spinifera*, *Centropages typicus*, *Temora stylifera*, a number of cyclopoid copepods, and *Sagitta enflata* as representatives of warmer-water fauna. Shelf edge and slope stations (202 µm collections in sample group III and 505 µm collections in sample group IV) were populated primarily by the remaining species groups (D-G). These groups collectively included over 20 pelagic molluscs, both subtropical and deep-living calanoid copepods and chaetognaths and the usual complement of offshore decapods and fishes.

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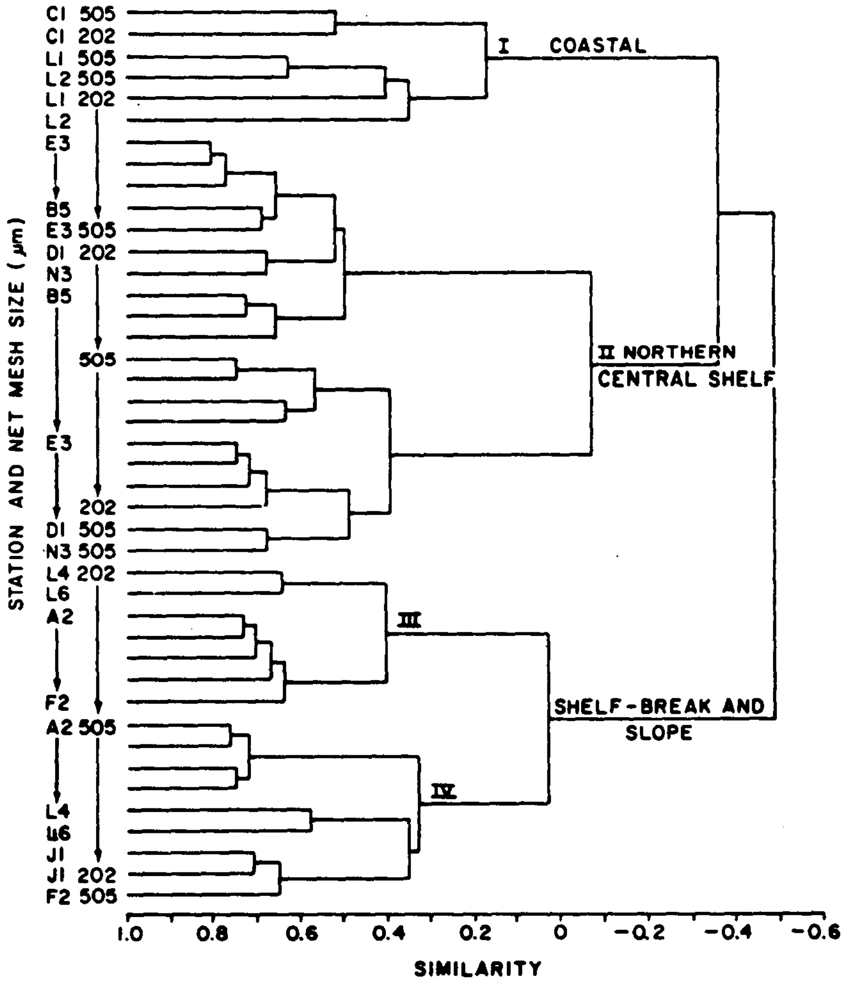

Figure 4-56. Bongo sample clusters, BLM08W, based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to numbers per 100m^3.

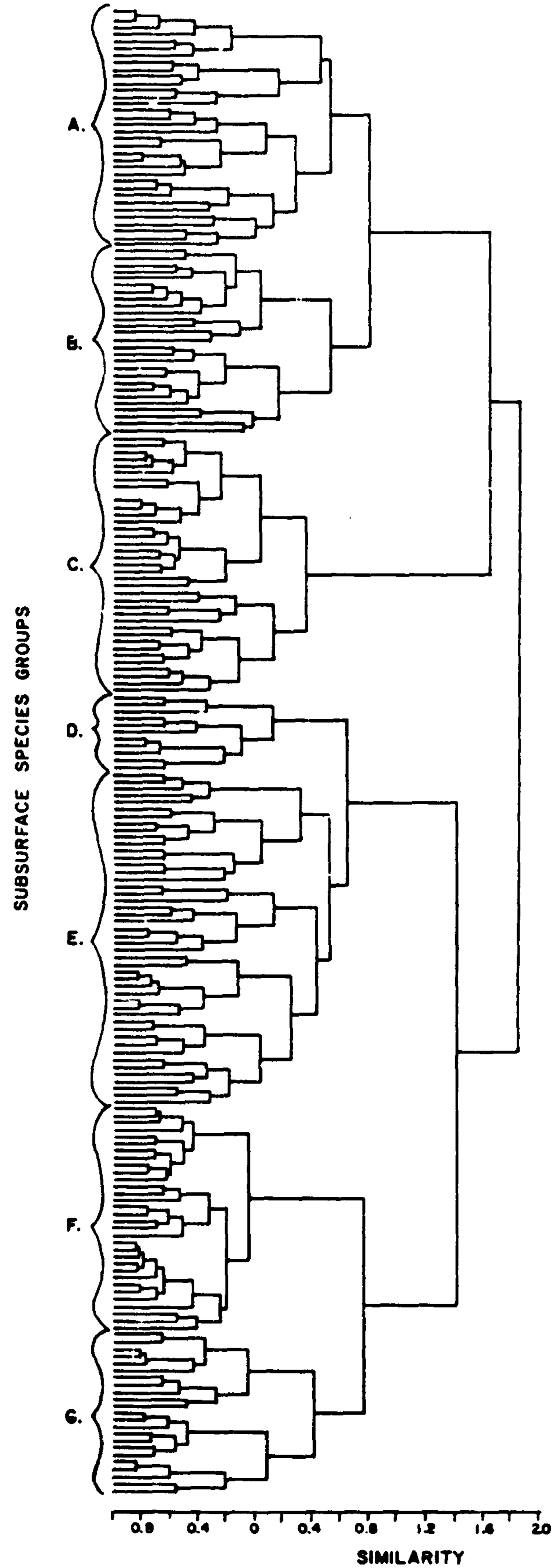

Figure 4-57. Inverse species clusters, bongo tows, BLMOBW. See Table

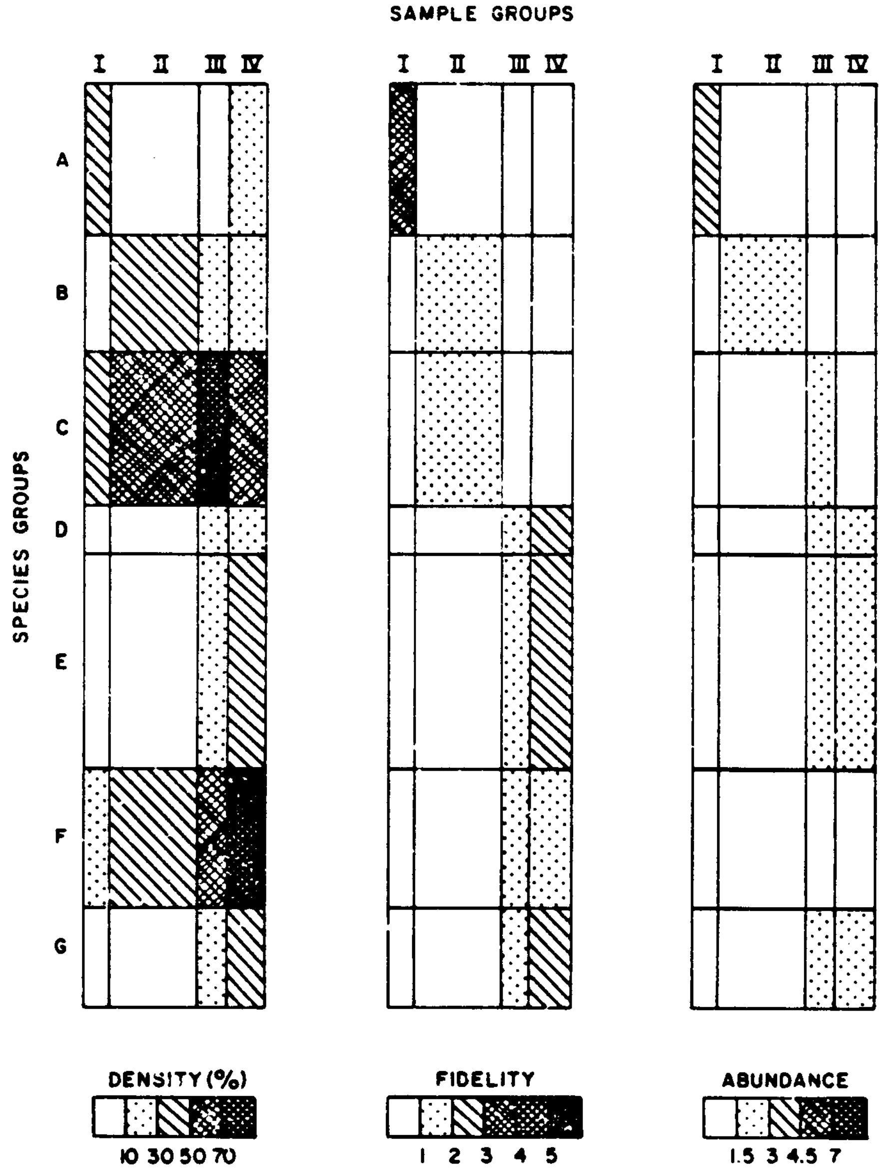

Figure 4-58. Nodal density (or constancy), fidelity, and abundance of species group within sample groups from the bongo cluster analyses of BLM08W.

Table 4-31. Identification of elements in sample and species groups from cluster analyses of bongo collections, BLM08W.

Sample Cluster	Mesh Size and Station Numbers
I	202 µm: L1, L2, C1; 505 µm: L1, L2, C1
II	202 µm: D1, N3, E3 (4 tows), B5 (4 tows); 505 µm: D1, N3, E3 (4 tows), B5 (4 tows)
III	202 µm: L4, L6, F2, A2 (4 tows)
IV	202 µm: J1; 505 µm: L4, L6, F2, J1, A2 (4 tows)

Species Cluster	Taxa (listed in phylogenetic order within clusters)
A	Liriope tetraphylla Tomopteris helgolandica Cavolina inflexa Cerastoderma pinnulatum Loligo pealeii Rossia tenera Evadne nordmanni Evadne tergestina Halocypris brevirostris Acartia clausi Acartia tonsa Eucalanus sp. Eucalanus crassus Labidocera sp. Temora longicornis Copilia mirabilis Sapphirina nigromaculata Sapphirina ovatolanceolata Neomysis americana Leptocuma minor Oxyurostylis smithi Edotea triloba Byblis serrata Crangon septemspinosa Ovalipes sp. Uca sp. unid. alpheids Dolioletta gegenbauri Doliolum sp. Thalia democratica Anchoa mitchilli Centropristis striata Etropus microstomus Prionotus sp. unid. synodontids
B	Bougainvillea sp. Beroe ovata Limacina retroversa Paracalanus crassirostris Diastylis quadrispinosa Diastylis sculpta Ampelisca vadorum Erichthonius rubricornis Monoculodes packardi Orchomenella minuta Phronimella elongata Unciola irrorata Euphausia tenera Thysanoessa inermis Caridion gordoni Dichelopandalus leptoceras Emerita sp. unid. calappids Bothus sp. Glyptocephalus cynoglossus Hemipteronotus novacula Merluccius sp. Merluccius bilinearis Ophichthus cruentifer Peprilus triacanthus Pomatomus saltatrix Tautogolabrus adspersus
C	unid. siphonophores Paedoclione doliiformis Evadne spinifera Penilia avirostris Acartia sp. Acartia danae Calanus finmarchicus Calocalanus pavo Candacia sp. Candacia armata Centropages typicus Centropages violaceus Clausocalanus arcuicornis Mecynocera clausi Metridia lucens Nannocalanus minor Paracalanus sp. Pseudocalanus sp. Temora stylifera unid. copepodites Clytemnestra rostrata Farranula sp. Farranula carinata Oithona spp. Oncaea conifera Oncaea mediterranea Oncaea venusta Lestrigonus bengalensis Parathemisto gaudichaudii Euphausia sp. unid. euphausiids Sagitta elegans Sagitta enflata Sagitta minima Sagitta tasmanica Oikopleura sp.

Table 4-31. (Concluded)

Species Cluster	Taxa		
D	Conchoecia sp. Eupronoe sp. Tetrathyrus forcipatus unid. hyperiids	unid. hippolytids unid. majids Sagitta sp. Citharichthys sp.	unid. gobioids unid. scorpaenids unid. fishes
E	unid. anthozoans Abraliopsis morisii Creseis acicula Limacina inflata Limacina leseuri Paraclione longicaudata Thelidioteuthis alessandrina unid. ommastrephids Conchoecia curta Euconchoecia chierchiae Aetideus armatus Candacia curta Centropages furcatus Eucalanus pileatus Euchaeta marina Pleuromamma sp.	Pleuromamma abdominalis Pleuromamma gracilis Pleuromamma robusta Rhincalanus nasutus Scolecithrix danae Temora sp. Temora turbinata Undinula vulgaris Corycaeus sp. Corycaeus speciosus Lycaeopsis sp. Phrosina semilunata Thyropus sp. Euphausia krohnii Euphausia mutica Meganyctiphanes norvegica	Albunea sp. Lucifer typus Parthenope sp. Sergestes sp. Solenocera sp. unid. penaeids unid. scyllarids Krohnitta pacifica Krohnitta subtilis Sagitta helenae Sagitta serratodentata Anchoa hepsetus Syacium ovale unid. ophichthids unid. paralepidids
F	unid. polychaetes Atlanta gaudichaudi Atlanta peroni Cavolina longirostris Cavolina spectabilis Cavolina uncinata Creseis virgula Firoloida leseurii Hyalocyclis striata Limacina trochiformis Notobranchaea macdonaldi	unid. gastropods unid. stomatopod larvae Idotea metallica Lycaea sp. Oxycephalus clausi Thysanoessa sp. Thysanoessa gregaria Thysanoessa longicaudata Arenaeus sp. Callinectes sp. Lucifer faxoni	Munida sp. Portunus sp. unid. decapods unid. pagurids Auxis sp. Ceratoscopelus maderensis Citharichthys arctifrons Hippoglossina oblonga Urophycis sp. unid. ophidiids
G	Catablema vesicarium Tomopteris sp. Atlanta helicinoides Cavolina tridentata Cymbulia calceola Pneumoderma atlanticum Pneumodermopsis paucidens unid. barnacle larvae	Amphithyrus sculpturatus Anchylomera sp. Iulopis loveni Lycaea bovalli Paralycaea sp. Rhabdosoma whitei Phronima atlantica Phronima colletti	Stylocheiron carinatum Pontophilus brevirostris unid. thalassinids Salpa fusiformis Lophius americanus Symphurus sp. unid. congrids

II. Neuston collection. Clusters of the 75 neuston collections from BLM08W are shown in Figure 4-59. Principal clusters were more numerous than in bongo collections and included:

1. Southern coastal
2. Northern coastal
3. Northern central shelf, day tows
4. Central and offshore, northern
5. Southern shelf-edge and slope

The fourth group was separated into two at a fairly low level of similarity, dividing central shelf collections from those taken at stations A2 and J1.

Inverse species clusters (Figure 4-60) and a nodal analysis (Figure 4-61) relating neuston species groups to sample groups were calculated as in previous cruises. Elements comprising the sample and species groups are listed in Table 4-32. Collections from southern inshore stations L1 and L2 (sample group I) were characterized mostly by sample groups B and C, containing Liriope tetraphylla, Rhacostoma atlanticum, several copepods (including Centropages furcatus, Labidocera aestiva, Acartia tonsa, and Eucalanus pileatus), meroplanktonic decapod larvae (Callinectes sp., Uca sp., Emerita sp., etc.) and larvae of a number of fishes. Northern coastal samples (sample group II) were more closely associated with species group C, which included all of the cooler-water coastal species (Acartia clausi, Temora longicornis, Neomysis americana, Crangon septemspinosa) as well as a long list of typical summer meroplankters.

Daytime tows in the northern central shelf (sample group III) were characterized by low abundance and species groups A, G (both widespread), and E. The latter species group contained dominants from the northern community (Calanus finmarchicus, Parathemisto gaudichaudii, Sagitta elegans) which were more abundant in night tows over the central shelf (sample group IV).

Northern shelf-edge collections (sample group V) contained fair numbers of species groups F and G, including Tomopteris planctonis?, Centropages violaceus, Labidocera acutifrons, Pleuromamma gracilis, Euphausia krohnii, offshore decapods and fishes, and Salpa fusiformis. Shelf-edge and slope collections off Virginia (sample group VI) was characterized by species group H and the wide-spread group A. Species group H contained a number of subtropical species: Porpita porpita, Euconchoecia chierchiae, Pontella securifer, Pontellina plumata, Sagitta helenae, Sagitta serratodentata, Coryphaena hippurus, and larvae of flying fishes.

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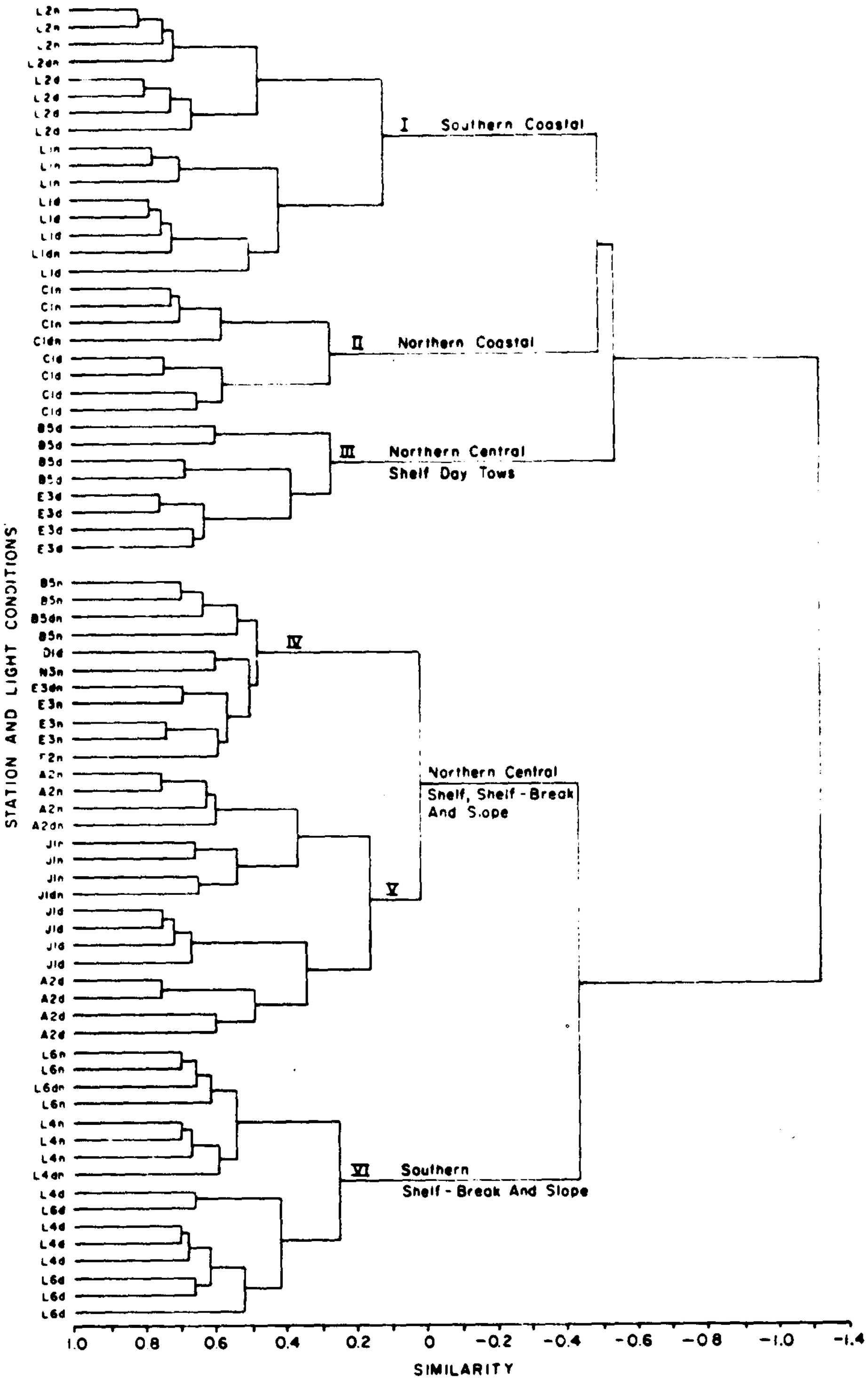

Figure 4-59. Neuston sample clusters, BLM08W, based on the Bray-Curtis coefficient, all identifed species occurring in at least 5% of the samples, and catch standardized to 20 min. tows. Lettering after station numbers indicates: n=night, d=day, dn=dawn.

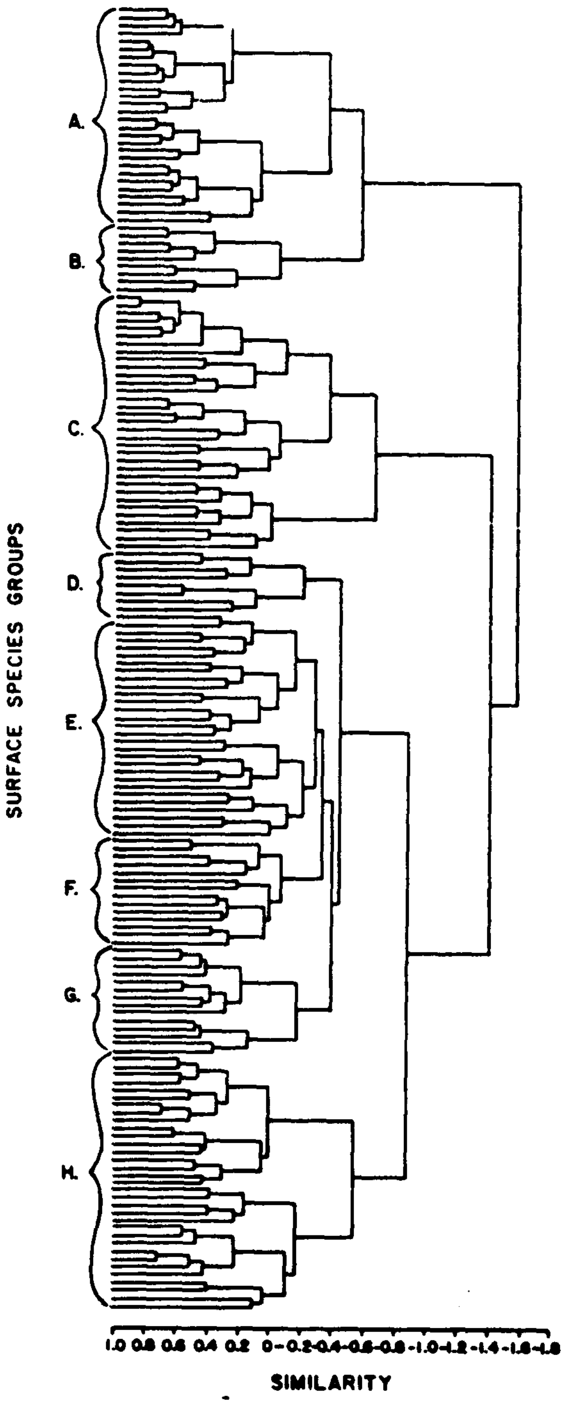

Figure 4-60. Inverse species clusters, neuston tows, BLM08W. See Table 4-32 for identification of species within groups A-H.

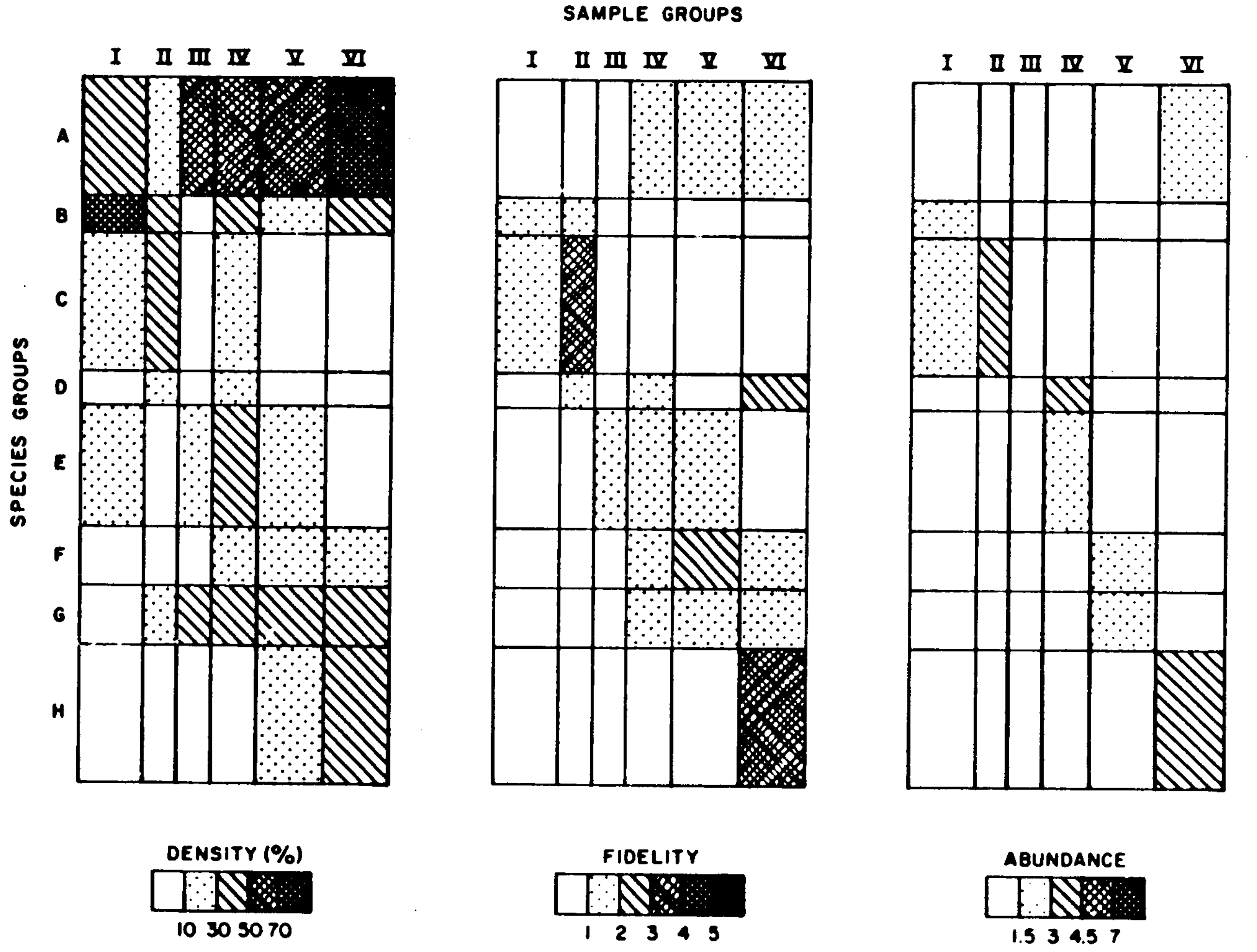

Figure 4-61. Nodal density (or constancy), fidelity, and abundance of species groups within sample groups from the neuston cluster analyses of BLM08W.

Table 4-32. Identification of elements in sample and species groups from cluster analyses of neuston collections, BLM08W.

Sample Cluster	Station Numbers and Time of Day (N=night, D=day)
I	L1N(4), L1D(4), L2N(4), L2D(4)
II	C1N(4), C1D(4)
III	E3D(4), B5D(4)
IV	D1D, N3N, E3N(4), F2N, B5N(4)
V	J1N(4), J1D(4), A2N(4), A2D(4)
VI	L4N(4), L4D(4), L6N(4), L6D(4)

Species Cluster	Taxa (listed in phylogenetic order within clusters)
A	unid. siphonophores Atlanta ga[illegible]ichaudi Atlanta [illegible] Cavolina longirostris Creseis virgula Limacina trochiformis Paraclione longicaudata Penilia avirostris Candacia sp. Candacia armata Centropages typicus Labidocera sp. Nannocalanus minor Pontella sp. Pontella meadii Pontellopsis sp. Pontellopsis villosa Temora stylifera Temora turbinata Undinula vulgaris Corycaeus speciosus Idotea metallica Lestrigonus bengalensis Lucifer faxoni Krohnitta pacifica Sagitta enflata Oikopleura sp. Urophycis sp.
B	Liriope tetraphylla Centropages furcatus Eucalanus crassus Eucalanus pileatus Labidocera aestiva Sapphirina nigromaculata unid. stomatopod larvae Callinectes sp. Uca sp.
C	Aequorea sp. Rhacostoma atlanticum Loligo pealeii Evadne spinifera Evadne tergestina Acartia clausi Acartia tonsa Temora longicornis Tortanus discaudatus Oithona spp. Chthalamus fragilis Neomysis americana Ampithoe longimana Microprotopus raneyi Arenaeus sp. Crangon septemspinosa Emerita sp. Hexapanopeus angustifrons Libinia sp. Ovalipes sp. Palaemonetes sp. unid. pagurids Doliolum sp. Thalia democratica Anchoa sp. Astroscopus guttatus Centropristis striata Etropus microstomus Hypsoblennius hentzi Peprilus triacanthus Prionotus sp. Symphurus sp.
D	Calocalanus pavo Paracalanus sp. Pseudocalanus sp. Farranula carinata Oncaea mediterranea Dolioletta gegenbauri Anchoa mitchilli Hippoglossina oblonga

Table 4-32. (Concluded)

Species Cluster	Taxa
E	*Obelia* sp. *Firoloida leseurii* *Hyalocyclis striata* unid. gastropods *Acartia danae* *Anomalocera* sp. *Anomalocera patersonii* *Calanus finmarchicus* *Clausocalanus arcuicornis* *Euchaeta marina* *Corycaeus* sp. unid. barnacle larvae *Idotea* sp. *Idotea baltica* *Lycaea* sp. *Lycaea bovalli* *Lycaeopsis* sp. *Oxycephalus clausi* *Oxycephalus piscator* *Paralycaea* sp. *Parathemisto gaudichaudii* *Phronima colletti* *Geryon quinquedens* *Sagitta elegans* *Sagitta minima* *Sagitta tasmanica* *Bothus* sp. *Pomatomus saltatrix* unid. tetraodontids
F	*Tomopteris* sp. *Atlanta helicinoides* *Cavolina uncinata* *Notobranchaea macdonaldi* *Pneumodermopsis paucidens* *Euchaeta* sp. *Sapphirina ovatolanceolata* *Euphausia krohnii* unid. euphausiids unid. penaeids *Salpa fusiformis* *Anchoa hepsetus* *Ceratoscopelus maderensis* *Sarda sarda*
G	*Centropages violaceus* *Labidocera acutifrons* *Pleuromamma gracilis* *Pontellopsis regalis* unid. copepodites unid. hyperiids unid. amphipods *Ocypode quadrata* unid. calappids *Portunus* sp. unid. decapods *Euphausia* sp. *Auxis* sp. *Ophichthus cruentifer*
H	*Pelagia noctiluca* *Porpita porpita* unid. anthozoans unid. polychaetes *Cavolina inflexa* *Creseis acicula* *Lima tenera* *Limacina bulimoides* *Paedoclione doliiformis* unid. ommastrephids *Conchoecia* sp. *Euconchoecia chierchiae* *Candacia curta* *Pleuromamma piseki* *Pontella securifer* *Pontellina plumata* *Scolecithrix danae* *Copilia mirabilis* *Erythrops erythropthalma* *Tetrathyrus forcipatus* *Euphausia mutica* *Dromidia antillensis* *Parthenope* sp. *Sergestes* sp. unid. scyllarids unid. xanthids *Sagitta helenae* *Sagitta hispida* *Sagitta serratodentata* *Coryphaena hippurus* unid. balistids unid. exocoetids unid. fishes

Synopsis of Cruise BLM08W

1. Subsurface zooplankton biomass in the summer of 1977 was highest along the coast, decreasing to lowest volumes along the shelf-edge. Volumes were lower along the Virginia transect than off New Jersey, and considerably reduced from spring levels. Maximum biomass of neuston at 24-hr stations occurred at night, dawn or dusk. The highest volume of observed in neuston tows (825 ml/standard tow) occurred at Station J1 in a salp swarm.

2. Lingering effects of the cold winter and spring of 1977 were still evident among the subsurface zooplankton in August. *Calanus finmarchicus* was dominant in the bongo 505 at Station L4 off Virginia and in 11 of the 17 such tows off New Jersey. It was also the most abundant species in 3 of the 4 bongo 202 tows at Station E3 and in one such tow at Station B5. *Penilia avirostris* was particularly abundant in subsurface zooplankton in coastal and inner shelf waters throughout the study area, but was also dominant at Station J1. This cladoceran was also the dominant species in 24 of the 75 neuston tows, over the inner shelf off Virginia, but all across the shelf off New Jersey. Other dominants in the neuston included *Temora stylifera* (17 tows) near the shelf edge off Virginia and along the outer shelf and shelf break off New Jersey, *Lestrigonus bengalensis* (6 tows) in central and outer shelf waters, and *Thalia democratica* at stations C1 and B5. *Centropages typicus* was dominant in only 4 tows.

Other dominants in subsurface tows included unidentified copepodites, *Nannocalanus minor*, *Oithona* spp. and *Temora longicornus* (cold-water holdover at Station C1).

3. The two most frequent taxa in both subsurface and surface collections were siphonophores and *Lestrigonus bengalensis*. The most abundant species in bongo 505 collections were *Calanus finmarchicus* and *Penilia avirostris*. In bongo 202 collections, *P. avirostris* and unidentified copepodites were most abundant; *P. avirostris* and siphonophores were most abundant in neuston tows.

4. Diversity was highest off Virginia where an offshore increase was clearly evident. Off New Jersey, higher diversity was found in central shelf locations, with a shelf-edge reduction occurring.

5. Primary clusters in bongo collections were (a) coastal stations L1, L2 and C1, (b) northern central shelf stations and (c) shelf edge and slope stations. Neuston collections were more finely divided, into clusters of (a) southern coastal, (b) northern coastal, (c) northern central shelf day tows, (d)

northern central shelf and offshore and (e) southern shelf edge and slope.

Replication of Bongo Sampling

Three additional bongo collections (both 202 and 505 μm) were obtained at stations A2, B5, and E3 in each of the seasonal cruises BLM05W-BLM08W. The replicates were collected to obtain an estimate of sampling variation in our subsurface collections. These additional tows were with paired 202 μm and 505 μm nets and were successively made immediately following the regular station bongo tows. Thus, although not perfect replicates, the tows were all made within hours of darkness and within a short period of time so as to minimize error due to diurnal variation and advective changes. There are three aspects of subsurface zooplankton collections that are of interest from the standpoint of variation: biomass estimates, species dominance, and species abundance.

Biomass

Zooplankton biomass was estimated by displacement volume of collections in $ml/100^3$. Results from bongo replicates are given in Table 4-33, where differences, primarily between mesh sizes and seasons (cruises), are apparent. A one-way analysis of variance (AOV) was performed to show the statistically significant difference between biomass estimates from 202 μm and 505 μm nets (Table 4-34). Estimates from 202 μm nets were almost always higher, due to retention in the fine mesh nets of smaller and immature zooplankton and, in some cases, phytoplankton. An applicable technique for distinguishing sources of variation among the biomass estimates is the three-way nested AOV, assuming a mixed model (Sokal and Rohlf 1969). Since no prior testing was done, pooling of the variances was omitted. Results of this analysis are in Table 4-35 and show significant differences among cruises and among stations within cruises. The non-significant difference between mesh sizes is an artifact of the nesting procedure and, since already shown to be highly significant in a one-way AOV, can be ignored. Partitioning of the variance shows that only 23% of the variance was found within replicate groups. This variance includes field errors, faunal patchiness, and inherent experimental error. Differences between stations accounted for 33% of the variance, while the remaining 44% resulted from cruise differences. The former demonstrates the importance of station location on the shelf, the latter the importance of seasonal differences in biomass. In summary, by using a given mesh size for estimates of biomass, progressively greater differences can be demonstrated for 1) replicates taken on a given night at a single location, 2) estimates among different station locations, and 3) estimates from different seasons. These results, at least, fall within the realm of expectations and lend confidence to the methods employed.

Table 4-33. Zooplankton displacement volume (ml/100m^3) from replicate bongo collections, BLM05W-BLM08W.

Cruise:	BLM05W		BLM06W		BLM07W		BLM08W	
Net Mesh (µm):	202	505	202	505	202	505	202	505
Station A2	98	15	17	13	199	230	55	33
	39	12	113	26	254	121	50	35
	34	9	131	27	242	155	56	32
	31	9	147	32	188	142	68	20
Station B5	93	29	120	23	149	58	108	89
	72	24	136	31	90	53	105	91
	69	28	116	14	101	53	128	108
	93	44	183	40	40	74	165	64
Station E3	59	59	93	21	184	173	68	78
	81	66	108	34	105	87	125	102
	70	53	174	37	147	119	122	93
	79	60	137	44	133	99	140	132

Table 4-34. One-way AOV for displacement volume measurements from replicated bongo collections, BLM05W-BLM08W.

Source of Variation	DF	SS	MS	F
Between Mesh Sizes	1	52,406.7	52,406.7	84.39*
Within Biomass Estimates (Error)	94	58,374.3	621.0	
Total	95	110,781.0		

$F_{.025[1,94]} = 5.22$

$H_o: \sigma^2_{among} = \sigma^2_{within}$

$H_a: \sigma^2_{among} \neq \sigma^2_{within}$

*Prob. (two tail) < 0.05

Table 4-35. Three-way AOV for displacement volume measurements from replicated bongo collections, BLM05W-BLM08W.

Source of Variation	DF	SS	MS	F
Between Mesh Sizes	1	52,406.7	52,406.7	2.83
Among Cruises within Mesh	6	111,141.1	18,523.5	3.38*
Among Stations within Cruises	16	87,769.5	5,485.6	6.77*
Within Biomass Estimates (Error)	72	58,374.3	810.8	
Total				

$F_{.025[1,6]} = 8.81$ $F_{.025[6,16]} = 3.34$ $F_{.025[16,72]} = 2.10$

$H_o: \sigma^2_a = \sigma^2_{a+1}$

$H_a: \sigma^2_a \neq \sigma^2_{a+1}$

Estimation of variance components (percentages):

Within estimates = 23.01
Within stations = 33.17
Within cruises = 43.81

*Prob. < 0.05

Replication and Species Dominance

Examination of the dominance by individual species in replicate tows is of interest for two principal reasons: 1) it is a measure of reliability in sampling for community structure, using single tows, and 2) it has application to studies of variation in hydrocarbon and trace metal content of mixed plankton samples. Early determinations of dominance in replicate samples (Tables 4-36 through 4-39) were used to advise against chemical analyses of replicate samples. However, the advice was offered too late in some instances, and performed chemical analyses showed wide differences among replicates where none would be expected, judging from taxonomic similarity (see Chapter 13 for details). It is the present author's opinion that if the chemical content of replicate samples is as different, or more so, than the content of samples at different stations or in different seasons, then the chemistry is not reflective of the taxonomy and there is little to be gained in such measurements.

The data shown in Tables 4-36 through 4-39 are, however, reassuring for ecological studies of zooplankton community structure. Repeated tows in a given location and time tend to collect species assemblages dominated by the same species. The most rigorous test possible for the data as presented would be repeated occurrences of the same three dominants, in the same order of abundance, in all of the four replicates at a given station. This test, surprisingly for biological data, was actually met in two instances, both with 505 μm nets: Station E3 (fall, Table 4-36) and Station B5 (spring, Table 4-38). The dominant species is usually the same, i.e. in all four replicate tows (17 of the 24 replicate sets); the same species was most dominant in at least three of the four replicates in 22 of the 24 replicate sets.

Species Abundance

Abundance estimates of plankton from net collections are notoriously variable. Application of formal statistical techniques to such data is usually discouraging, at best. Variation in abundance estimates incorporates not only field sampling errors associated with patchiness, net efficiency, tow speed, diurnal migration, etc., but also errors in laboratory processing (splitting of samples; variable identification of small, immature forms; misidentification; counting errors; errors in calculation). With such an array of possible pitfalls, it is little wonder that the variance of zooplankton abundance estimates usually equals or exceeds the mean, and that an investigator can feel pleased at estimates replicated within an order of magnitude. Our overall stress on dominance and community structure in this study as opposed to reliance on abundance estimates per se was in response to recognition of the above limitations. Nevertheless, we have performed an analysis of abundance for the five most abundant species common to each replicate tow within a set (same mesh, same

Table 4-36. Dominant species in replicate bongo collections at stations A2, B5 and E3, fall 1976 (BLM05W). Listed in order of abundance.

Station	202 μm Replicate 1	2	3	4
A2	Paracalanus sp. Centropages typicus Pleuromamma gracilis	Paracalanus sp. P. gracilis C. typicus	Paracalanus sp. C. typicus P. gracilis	Paracalanus sp. C. typicus P. gracilis
B5	C. typicus Paracalanus sp. Nannocalanus minor	Paracalanus sp. C. typicus N. minor (immature)	Paracalanus sp. C. typicus N. minor (immature)	Paracalanus sp. C. typicus N. minor (immature)
E3	Paracalanus sp. N. minor (immature) C. typicus	Paracalanus sp. C. typicus Oithona spp.	Paracalanus sp. C. typicus N. minor (immature)	Paracalanus sp. C. typicus N. minor (immature)

Station	505 μm Replicate 1	2	3	4
A2	C. typicus P. gracilis Rhincalanus nasutus	C. typicus P. gracilis N. minor	C. typicus N. minor P. gracilis	C. typicus P. gracilis N. minor
B5	C. typicus N. minor Parathemisto gaudichaudii	C. typicus N. minor P. gaudichaudii	C. typicus N. minor N. minor (immature)	C. typicus N. minor P. gaudichaudii
E3	C. typicus N. minor R. nasutus	C. typicus N. minor R. nasutus	C. typicus N. minor R. nasutus	C. typicus N. minor R. nasutus

Table 4-37. Dominant species in replicate bongo collections at stations A2, B5 and E3, winter 1977 (BLM06W). Listed in order of abundance.

Station	202 µm Replicate 1	2	3	4
A2	*Centropages typicus* *Metridia lucens* *Paracalanus* sp.	*Oithona* spp. *C. typicus* unid. copepodites	*Oithona* spp. *Paracalanus* sp. unid. copepodites	*Oithona* spp. *C. typicus* unid. copepodites
B5	*Paracalanus* sp. *Clausocalanus arcuicornis* *Oithona* spp.	*Oithona* spp. *Paracalanus* sp. *C. typicus*	*Oithona* spp. *C. typicus* *Paracalanus* sp.	*Paracalanus* sp. *C. typicus* *Pleuromamma gracilis*
E3	*Oithona* spp. *Paracalanus* sp. *P. gracilis*	*Paracalanus* sp. unid. copepodites *Oithona* spp.	*Paracalanus* sp. *C. typicus* *P. gracilis*	*Paracalanus* sp. *P. gracilis* *Oithona* spp.

Station	505 µm Replicate 1	2	3	4
A2	*C. typicus* *M. lucens* *Rhincalanus nasutus*	*C. typicus* *M. lucens* *Sagitta tasmanica*	*C. typicus* *M. lucens* *R. nasutus*	*C. typicus* *Calanus finmarchicus* *M. lucens*
B5	*C. typicus* *M. lucens* *S. tasmanica*	*C. typicus* *S. tasmanica* *M. lucens*	*C. typicus* *M. lucens* *C. arcuicornis*	*C. typicus* *M. lucens* *S. tasmanica*
E3	*C. typicus* *Euphausia* sp. *R. nasutus*	*C. typicus* *R. nasutus* *M. lucens*	*C. typicus* *R. nasutus* *Euchirella rostrata*	*C. typicus* *R. nasutus* *E. rostrata*

Table 4-38. Dominant species in replicate bongo collections at stations A2, B5 and E3, spring 1977 (BLM07W). Listed in order of abundance.

	202 µm Replicate			
Station	1	2	3	4
A2	unid. copepodites *Calanus finmarchicus* *Pseudocalanus* sp.	unid. copepodites *C. finmarchicus* *Pseudocalanus* sp.	unid. copepodites *C. finmarchicus* *Oithona* spp.	unid. copepodites *C. finmarchicus* *Pseudocalanus* sp.
B5	unid. copepodites *Oithona* spp. *Pseudocalanus* sp.	unid. copepodites *Sagitta elegans* *Oithona* spp.	unid. copepodites *Pseudocalanus* sp. *S. elegans*	unid. copepodites *Oithona* spp. *Pseudocalanus* sp.
E3	unid. copepodites *C. finmarchicus* *Oithona* spp.	unid. copepodites *Oithona* spp. *C. finmarchicus*	unid. copepodites *Oithona* spp. *Pseudocalanus* sp.	unid. copepodites *C. finmarchicus* *Pseudocalanus* sp.

	505 µm Replicate			
Station	1	2	3	4
A2	*C. finmarchicus* *Metridia lucens* *Centropages typicus*	*C. finmarchicus* *M. lucens* *S. elegans*	*C. finmarchicus* *S. elegans* *M. lucens*	*C. finmarchicus* *M. lucens* *Pseudocalanus* sp.
B5	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *C. typicus* *S. elegans*
E3	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *C. typicus* *S. elegans*	*C. finmarchicus* *S. elegans* *C. typicus*

Table 4-39. Dominant species in replicate bongo collections at stations A2, B5 and E3, summer 1977 (BLM08W). Listed in order of abundance.

	202 μm Replicate			
Station	1	2	3	4
A2	unid. copepodites *Oithona* spp. *Calanus finmarchicus*	unid. copepodites *Oithona* spp. *Clausocalanus arcuicornis*	unid. copepodites *C. arcuicornis* *Oithona* spp.	unid. copepodites *C. arcuicornis* *Oithona* spp.
B5	unid. copepodites *C. finmarchicus* *Penilia avirostris*	*C. finmarchicus* unid. copepodites *P. avirostris*	unid copepodites *C. finmarchicus* *Pseudocalanus* sp.	unid. copepodites *C. finmarchicus* *Oithona* spp.
E3	*C. finmarchicus* *P. avirostris* *Parathemisto gaudichaudii*	unid. copepodites *Evadne spinifera* *Paracalanus* sp.	*C. finmarchicus* *Paracalanus* sp. *P. avirostris*	*C. finmarchicus* *P. avirostris* unid. copepodites

	505 μm Replicate			
Station	1	2	3	4
A2	*C. finmarchicus* *Nannocalanus minor* unid. siphonophores	*C. finmarchicus* *N. minor* unid siphonophores	*N. minor* *C. finmarchicus* *Metridia lucens*	*N. minor* *C. finmarchicus* *Temora stylifera*
B5	*C. finmarchicus* *P. avirostris* *Sagitta elegans*	*C. finmarchicus* *S. elegans* *P. avirostris*	*C. finmarchicus* *S. elegans* *P. avirostris*	*C. finmarchicus* *N. minor* *Centropages typicus*
E3	*C. finmarchicus* unid. copepodites *Paracalanus* sp.	*C. finmarchicus* *P. avirostris* *S. elegans*	*C. finmarchicus* *S. elegans* *P. avirostris*	*C. finmarchicus* *P. avirostris* *S. elegans*

station, same season). The five species usually accounted for the majority of the total numerical catch. Data were converted to numbers per $100m^3$ and are given in Tables 4-40 through 4-43 for cruises BLM05W-BLM08W, respectively.

The experimental design was such that neither the treatments (replicate samples) nor the blocks (species) are completely random, so the Friedman Rank Sum analysis of variance (Steel and Torrie 1960) was used. Under the null hypothesis that there is no difference among population means of replicate samples, the statistic assumes that the species distributions are continuous and identical. These criteria were satistied by analyzing the replicates within separate sets (same mesh, same station, same season).

Results of the species abundance analyses (Table 4-44) indicate that 58% of the 202 μm and 42% of the 505 μm replicate sets contain significant ($\alpha = 0.05$) differences among population means. Calculated chi-square values were generally higher for the 202 m replicates. There does not appear to be any correlation between occurrences of significant differences and either station location or season of collection. Since there were 12 sets with significant differences among the total 24, it might be concluded that reliable and repeatable estimates of abundance are as likely as not, with a slight edge toward consistency for the 505 μm meshes.

In summary, reliability of subsurface collections with bongo nets was found to be highest in terms of community structure. Species dominance in replicate samples examined in this section, and clustering of replicate samples in the previous cruise report sections show a high degree of repeatibility in collections. Variability among biomass estimates was somewhat higher, although variance was lowest among replicate samples. Reliability of numerical estimates was poor.

DISCUSSION

Seasonal Succession of Zooplankton Communities

In the temperate regime of the Middle Atlantic Bight, estuarine and coastal waters contain zooplankton communities with a clear seasonal succession between a cold-water fauna present in winter and spring and a warm-water assemblage found in summer and fall. These semiannual changes in fauna have been described for embayments and coastal waters from southern New England to Chesapeake Bay (Cronin et al. 1962; Deevey 1956, 1960; Grant 1977b; Hulsizer 1976; Jacobs 1978; Jeffries 1962; Jeffries and Johnson 1973; Sage and Herman 1972), but for the deeper and less well-known waters of the central shelf and shelf edge, changes are much less predictable. Succession along the outer shelf is dependent, not only on seasonal temperature differences, but to a large degree on advection and mixing of coastal and offshore water types. Central shelf zooplankton may show annual

(TEXT CONTINUES ON PAGE 4-189)

Table 4-40. Numbers per 100 m^3 of dominant taxa in replicate bongo tows from stations A2, B5, and E3, fall 1976 (BLM05W).

		Replicate Collection Number			
Station A2	Dominant Taxa	6370	6372	6374	6376
202 nets	*Paracalanus* sp.	672,808	38,924	57,854	94,576
	Centropages typicus	282,362	11,501	15,211	19,911
	Pleuromamma gracilis	163,838	22,117	11,951	17,067
	Oithona spp.	34,860	2,654	10,865	1,422
	unid. copepodites	104,578	1,769	3,803	6,400
		6369	6371	6373	6375
505 nets	*C. typicus*	3,728	5,785	4,291	5,684
	P. gracilis	2,485	2,386	1,273	2,345
	Rhincalanus nasutus	1,349	1,193	1,127	398
	Nannocalanus minor	1,101	1,916	1,600	1,590
	Parathemisto gaudichaudii	275	233	136	219
Station B5		6350	6352	6355	6357
202 nets	*Paracalanus* sp.	174,590	200,658	429,005	430,388
	C. typicus	193,377	81,000	89,296	151,612
	unid. copepodites	5,372	17,489	27,177	78,251
	N. minor	8,058	12,886	9,706	34,236
	P. gaudichaudii	3,106	5,005	4,732	6,725
		6349	6351	6354	6356
505 nets	*C. typicus*	49,821	7,684	15,570	7,792
	N. minor	9,369	4,651	8,835	1,683
	P. gaudichaudii	2,182	2,832	2,444	661
	Sagitta tasmanica	195	120	217	72
	Cancer sp.	547	205	141	419
Station E3		6401	6402	6405	6407
202 nets	*C. typicus*	51,630	288,263	180,746	57,067
	unid. copepodites	76,724	72,979	297,777	13,805
	unid. calanids	75,724	7,275	265,265	7,364
	Oithona spp.	8,605	72,980	27,306	6,443
	N. minor	5,163	21,894	9,102	3,682
		6400	6403	6404	6406
505 nets	*C. typicus*	111,948	138,256	224,746	87,865
	N. minor	12,183	13,567	17,026	10,240
	R. nasutus	2,305	5,815	6,324	4,294
	P. gaudichaudii	1,894	787	1,763	1,652
	S. tasmanica	597	646	562	645

Table 4-41. Numbers per 100 m^3 of dominant taxa in replicate bongo tows from stations A2, B5, and E3, winter 1977 (BLM06W).

		Replicate Collection Number			
Station A2	Dominant Taxa	7095	7096	7100	7102
202 nets	*Oithona* spp.	710	9,364	5,008	9,413
	Paracalanus sp.	1,421	1,460	10,993	4,362
	Centropages typicus	3,907	3,007	7,736	7,577
	unid. copepodites	622	1,890	9,365	5,510
	Pseudocalanus sp.	414	344	2,850	459
		7094	7097	7099	7101
505 nets	*C. typicus*	6,834	8,034	1,899	1,571
	Metridia lucens	968	709	661	82
	Calanus finmarchicus	342	236	145	127
	Sagitta tasmanica	149	492	315	82
	Parathemisto gaudichaudii	16	15	23	17
Station B5		7078	7081	7083	7086
202 nets	*Paracalanus* sp.	27,189	29,846	15,106	29,659
	Oithona spp.	7,768	78,214	18,011	5,307
	C. typicus	7,415	26,757	16,268	24,663
	Clausocalanus arcuicornis	8,474	23,670	11,039	7,180
	M. lucens	353	686	581	1,873
		7079	7080	7082	7085
505 nets	*C. typicus*	6,971	4,392	16,270	13,328
	M. lucens	1,362	240	2,656	1,602
	S. tasmanica	391	257	614	1,347
	P. gaudichaudii	98	59	64	143
	Dichelopandalus leptocerus	33	20	18	41
Station E3		7061	7063	7065	7067
202 nets	*Paracalanus* sp.	13,594	27,593	6,612	17,581
	Oithona spp.	15,537	14,103	1,102	12,337
	Pleuromamma gracilis	12,535	3,679	2,670	12,646
	C. typicus	7,592	13,490	4,535	4,627
	unid. copepodites	1,942	19,008	805	617
		7059	7062	7064	7066
505 nets	*C. typicus*	6,464	3,099	4,201	3,509
	Rhincalanus nasutus	799	403	788	399
	Euphausia sp.	871	357	453	299
	Euchirella rostrata	654	310	656	399
	M. lucens	363	372	328	279

Table 4-42. Numbers per 100 m^3 of dominant taxa in replicate bongo tows from stations A2, B5, and E3, spring 1977 (BLM07W).

		Replicate Collection Number			
Station A2	Dominant Taxa	7200	7202	7204	7207
202 nets	unid. copepodites	896,000	958,464	456,358	462,894
	Calanus finmarchicus	172,801	278,530	142,146	170,539
	Pseudocalanus sp.	140,800	147,456	104,740	124,489
	Oithona spp.	115,200	147,456	127,182	121,814
	Metridia lucens	25,600	16,384	7,481	3,045
		7199	7201	7203	7206
505 nets	*C. finmarchicus*	219,812	97,279	91,551	124,014
	M. lucens	15,012	4,389	3,471	10,630
	Centropages typicus	8,578	731	868	2,835
	Pseudocalanus sp.	7,506	731	2,169	5,669
	Sagitta elegans	6,433	3,463	3,905	4,340
Station B5		7216	7218	7220	7223
202 nets	unid. copepodites	450,739	14,296	334,769	55,285
	Oithona spp.	125,205	5,763	122,092	40,306
	Pseudocalanus sp.	78,700	1,441	23,631	16,068
	S. elegans	23,252	12,523	16,738	8,919
	C. finmarchicus	46,505	443	15,754	11,711
		7215	7217	7219	7222
505 nets	*C. finmarchicus*	25,388	49,073	19,602	41,223
	S. elegans	2,340	5,265	4,352	4,165
	C. typicus	5,078	14,750	5,559	7,718
	M. lucens	846	3,688	1,755	3,012
	Temora longicornis	212	3,688	293	2,071
Station E3		7174	7177	7180	7182
202 nets	*C. finmarchicus*	120,016	30,696	69,391	80,015
	Oithona spp.	54,553	76,740	80,956	30,482
	C. typicus	5,455	19,185	19,275	15,241
	S. elegans	23,242	7,554	17,348	15,003
	Limacina retroversa	1,395	2,008	2,108	1,384
		7175	7176	7179	7181
505 nets	*C. finmarchicus*	157,729	97,251	58,596	74,777
	C. typicus	27,252	33,180	11,947	9,487
	S. elegans	18,374	7,544	8,604	9,905
	L. retroversa	2,529	302	1,351	1,090
	Euphausia sp.	2,116	371	289	227

Table 4-43. Numbers per 100 m^3 of dominant taxa in replicate bongo tows from stations A2, B5, and E3, summer 1977 (BLM08W).

		Replicate Collection Number			
Station A2	Dominant Taxa	7295	7297	7299	7301
202 nets	unid. copepodites	16,807	14,674	10,384	31,050
	Oithona spp.	12,761	8,613	4,327	14,534
	Clausocalanus arcuicornis	6,225	8,294	7,211	18,828
	Acartia danae	7,470	7,975	4,327	12,883
	Nannocalanus minor	6,847	5,742	2,596	6,276
		7294	7296	7298	7300
505 nets	*Calanus finmarchicus*	6,047	3,876	2,042	1,630
	N. minor	2,553	2,907	2,074	1,873
	Metridia lucens	470	808	875	520
	Temora stylifera	538	888	745	1,179
	Sagitta enflata	470	575	721	707
Station B5		7311	7313	7315	7317
202 nets	unid. copepodites	60,746	30,023	52,907	134,783
	C. finmarchicus	44,041	33,776	35,271	64,766
	Pseudocalanus sp.	15,186	12,331	12,516	28,007
	Penilia avirostris	25,166	13,939	7,964	2,024
	Oithona spp.	5,857	1,608	5,120	63,015
		7310	7312	7314	7316
505 nets	*C. finmarchicus*	11,415	37,881	45,292	29,134
	Sagitta elegans	661	3,459	4,028	603
	P. avirostris	1,511	1,578	3,222	129
	Centropages typicus	336	519	2,148	1,552
	N. minor	504	346	358	1,724
Station E3		7346	7349	7351	7353
202 nets	*C. finmarchicus*	88,562	35,446	30,573	43,055
	P. avirostris	13,146	15,754	27,258	35,685
	Evadne spinifera	886	57,764	16,944	5,430
	C. typicus	1,730	19,036	9,209	6,982
	S. elegans	5,535	3,118	3,039	5,818
		7345	7348	7350	7352
505 nets	*C. finmarchicus*	32,476	17,035	41,476	30,517
	P. avirostris	7,953	5,293	5,063	6,103
	S. elegans	3,438	3,080	6,747	2,967
	C. typicus	4,308	770	2,381	1,187
	Parathemisto gaudichaudii	2,651	674	1,104	1,102

Table 4-44. Results of Friedman Rank Sum AOV calculated for replicate bongo samples.

Cruise	Station	Calculated χ^2	
		202 nets	505 nets
BLM05W	A2	9.96*	4.92
	B5	7.80	5.40
	E3	7.08	3.48
BLM06W	A2	10.20*	5.16
	B5	7.80	9.00*
	E3	8.28*	8.76*
BLM07W	A2	9.24*	13.56*
	B5	14.04*	12.84*
	E3	4.20	7.32
BLM08W	A2	10.20*	2.04
	B5	8.28*	5.40
	E3	2.04	8.76*

*significant at $\alpha=0.05$ when compared with tabled $\chi^2_{.05} = 7.81$

differences depending on the severity of winter, while shelf-edge populations can be sub-tropical in composition at any season of the year, depending on the presence of anticyclonic eddies from the Gulf Stream. Thus, the predictable alternation of winter-spring and summer-fall communities evident in coastal waters is lost with distance from shore.

Two full years of seasonal collections are now available for the original 6-station southern New Jersey transect (stations C1, D1, N3, E3, F2, and J1). Subsurface bongo collections were obtained at all six stations in the second year, while the full 24-hour cycle of neuston collections was restricted to stations C1, E3, and J1 in the second year. Computer program modifications subsequent to the first year's report (Grant 1977a) have permitted a cluster analysis of all bongo collections along this transect (8 seasonal cruises) with all species occurring in at least 5% of the collections. Neuston data from stations C1, E3, and J1 (sampled for 24 hrs. in all 8 cruises) were separated by stations before clustering, because the resulting matrix of combined data exceeded the capacity of our computer. These two-year analyses will be discussed before pointing out similarities and differences between stations sampled only in the second year (A2, B5, L1, L2, L4, and L6).

Subsurface Zooplankton

The cluster analysis of bongo collections from all 8 cruises (fall 1975 through summer 1977) included 125 samples and 191 taxa that occurred in at least 5% of the collections. The principal division of collections was not between seasons but between inshore and offshore locations. Central shelf collections occurred in both primary clusters (Figure 4-62), reflecting the mixing that occurs across the shelf. The inshore primary cluster included a cluster of coastal samples, subdivided into winter-spring and summer-fall; and a cluster of mostly central shelf samples from fall (first year), winter, and spring. Among the latter, the most distinctive sub-group was a cluster of 15 spring samples (Sample Group V) all but one of which was from the second sampling year.

In the more offshore primary cluster of bongo collections, the most distinctive subcluster consisted of summer samples, divided between years (sample group VI, 1977; group VII, 1976). Also distinct were subclusters of fall 1976 central shelf samples and fall 1975 shelf-edge samples (groups VIII and IX).

From the normal cluster of bongo samples alone, it is evident that 1) coastal subsurface species form a distinct community that alternates semiannually, 2) second year spring collections from the central shelf (14 of 15 samples in group V) were distinctly different from those of the first year, and 3) summer collections from central shelf to slope waters are decidedly distinct from shelf and slope collections in other seasons.

Results of the inverse analysis of species were included in a nodal analysis of 11 species groups and the 12 sample groups (Figure 4-63). Individual collections and species comprising these groups are listed in Table 4-45. Species groups A-C were associated most closely with the coastal station C1 and consisted of the common fauna of the Coastal Boundary Layer. Group A was the summer-fall community of *Acartia tonsa* - *Labidocera aestiva* - *Sagitta tenuis* and others; group B included the typical winter-spring assemblage, with species such as *Centropages hamatus*, *Temora longicornis*, and *Crangon septemspinosa*. Group C was a small one of salps that was most abundant at the coast in summer and fall, but was also important all across the shelf in summer.

The distinctiveness of summer collections from the shelf and slope is attributed to inclusion of species groups D, E, F, and I. Annual differences were evident here, with groups D and F most important in summer 1977 and group I in summer 1976. The latter group (I) consisted of an offshore assortment of hyperiid amphipods, the decapod *Lucifer typus*, and other decapods. Also important in the first summer was group E, containing species that were common in both years, including several pteropods, *Callinectes* sp. larvae, and the larvae of *Merluccius* sp. and *Urophycis* sp. Shelf fauna was quite different in the second summer (1977), with heavier contributions from groups D (offshore decapod and fish larvae) and F, a group of abundant warm-water species including *Evadne spinifera* and *Penilia avirostris* (cladocerans), *Temora stylifera*, *Lestrigonus bengalensis*, and *Sagitta enflata*. The abundance of cladocerans over the shelf in the summer of 1977 was a striking change from 1976.

Species groups G and H were both widely occurring, but most abundant away from the coast and in the second year of sampling, group G in fall 1976 and group H in spring 1977. The latter is of particular interest in that it contains all the elements of the well-described northern community from southern New England and the Gulf of Maine (*Limacina retroversa*, *Evadne nordmanni*, *Calanus finmarchicus*, *Meganyctiphanes norvegica*, *Sagitta elegans*, and larvae of the Atlantic mackerel, *Scomber scombrus*). That it was most abundant in the spring of 1977 is direct evidence of the effect of cold winters on the southern extent of this community in the Middle Atlantic Bight. The spring cruise of 1977 (BLM07W) was the first of our seasonal cruises to yield more *Calanus finmarchicus* than *Centropages typicus*, which had dominated copepods in all previous cruises. The large differences between fauna in the two years of sampling also demonstrates the shortsightedness of short-term environmental assessments. Two years of data are insufficient for description of such annually variable plankton populations.

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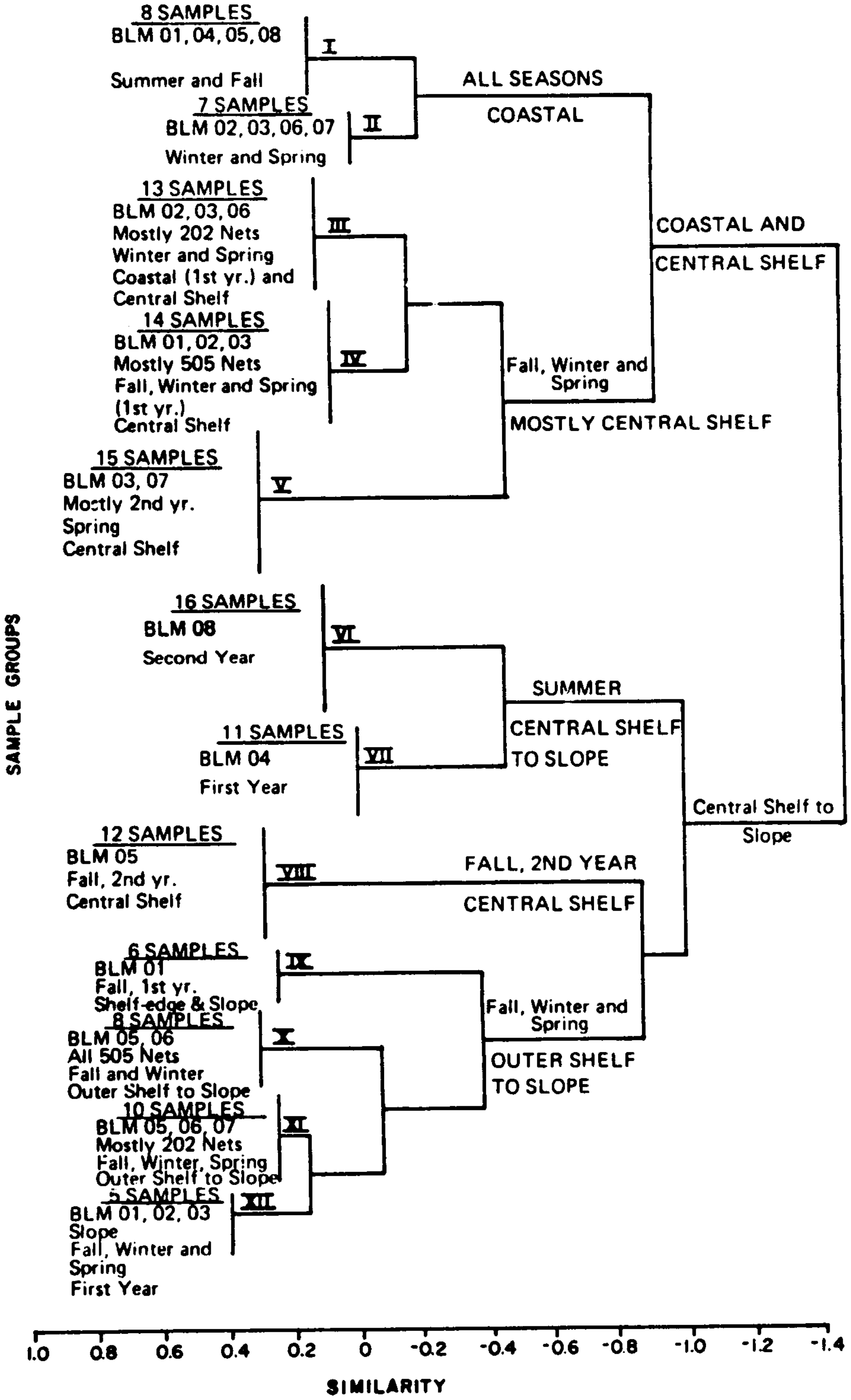

Figure 4-62. Bongo sample clusters, BLM01W-BLM08W (two years), southern New Jersey transect. Based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to numbers per 100m^3.

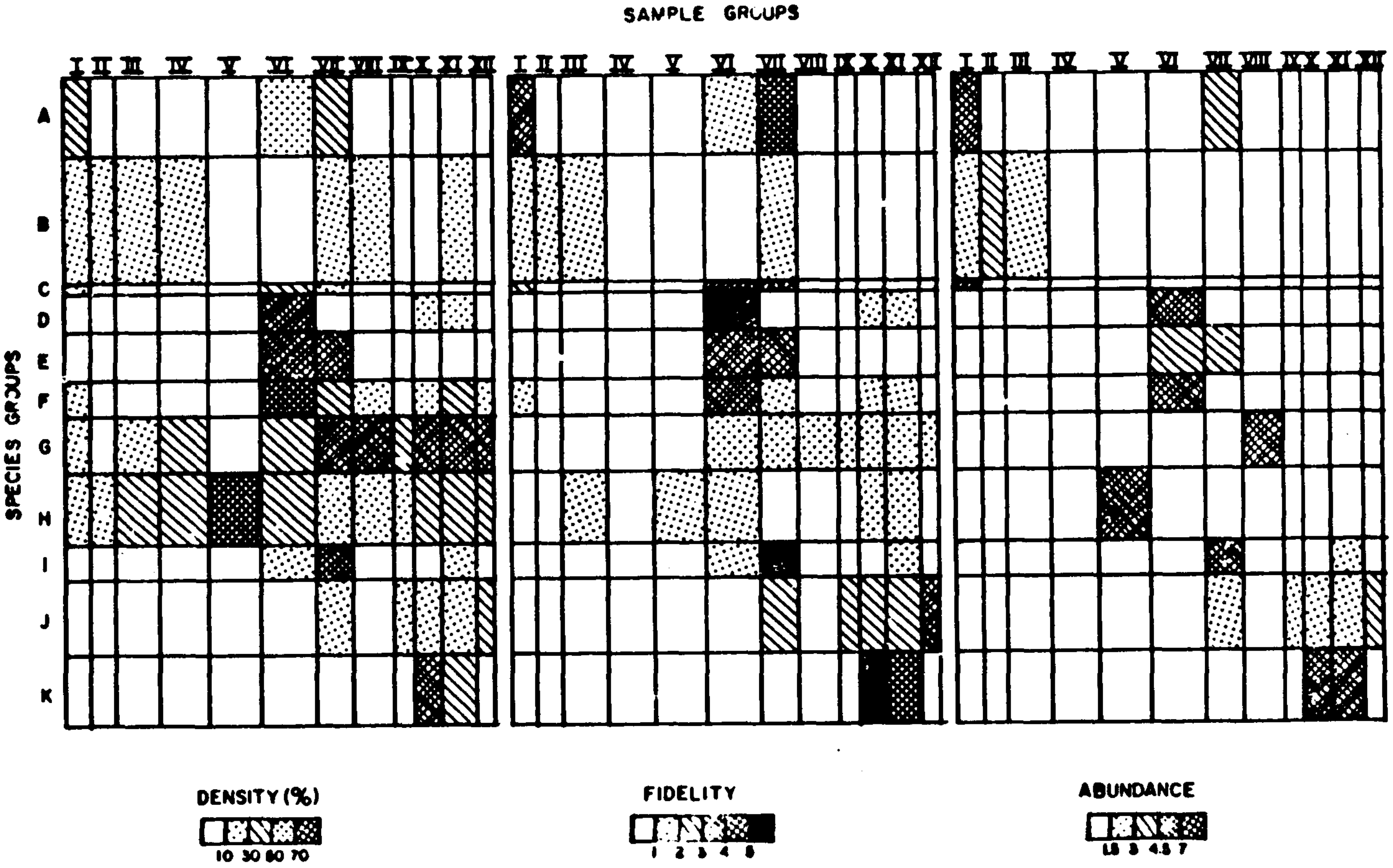

Figure 4-63. Nodal density, fidelity, and abundance of species groups within sample groups from the bongo cluster analyses, BLM01W-BLM08W, southern New Jersey transect. See Table 4-45.

Table 4-45. **Identification of elements within sample and species groups from nodal analysis of bongo collections, 1975-1977 cruises, BLM01W-BLM08W, New Jersey transect stations C1, D1, N3, E3, F2, and J1.**

Sample Group	Mesh Size and Station Numbers
I	202 μm: C1(4 tows); 505 μm: C1(4 tows)
II	202 μm: C1(2 tows); 505 μm: C1(5 tows)
III	202 μm: C1(2 tows), D1(3 tows), N3(3 tows), E3, F2; 505 μm: D1(2 tows), N3
IV	202 μm: D1, N3, E3, F2; 505 μm: D1(2 tows), N3(3 tows), E3(2 tows), F2(2 tows)
V	202 μm: D1, N3, E3(5 tows), F2; 505 μm: D1, N3, E3(4 tows), F2
VI	202 μm: D1, N3, E3(4 tows), F2, J1; 505 μm: D1, N3, E3(4 tows), F2, J1
VII	202 μm: D1, N3, E3, F2, J1; 505 μm: D1, N3, E3, F2(2 tows), J1
VIII	202 μm: D1, N3, E3(4 tows); 505 μm: D1, N3, E3(4 tows)
IX	202 μm: F2, J1; 505 μm: N3, F2, J1(2 tows)
X	505 μm: E3(4 tows), F2(2 tows), J1(2 tows)
XI	202 μm: E3(4 tows), F2(2 tows), J1(3 tows); 505 μm: J1
XII	202 μm: J1(3 tows); 505 μm: J1(2 tows)

Species Group	**Taxa (listed in phylogenetic order within clusters)**
A	*Muggiaea kochei* *Beroe ovata* *Atlanta peroni* *Creseis acicula* *Firoloida leseurii* gastropod larvae *Evadne tergestina* *Acartia tonsa* *Centropages furcatus* *Eucalanus crassus* *Labidocera aestiva* *Sapphirina nicromaculata* stomatopod larvae unid. euphausiids *Emerita* sp. *Lucifer faxoni* *Sagitta tenuis* *Doliolum nationalis* *Centropristis striata* *Etropus microstomus* *Peprilus triacanthus* *Pomatomus saltatrix* *Prionotus* sp.
B	*Diphyes dispar* scyphozoans nemerteans *Tomopteris helgolandica* *Clione limacina* *Limacina trochiformis* *Loligo pealeii* bivalve larvae *Centropages hamatus* *Clausocalanus arcuicornis* *Paracalanus parvus* *Pseudocalanus* sp. *Temora longicornis* *Tortanus discaudatus* *Clytemnestra* sp. *Corycaeus speciosus* *Oncaea* sp. *Caligus* sp. barnacle larvae *Neomysis americana* *Mysidopsis bigelowi* *Leptocuma minor* gammarids *Thysanoessa longicaudata* *Cancer* sp. *Crangon septemspinosa* *Libinia* sp. *Ovalipes* sp. pagurid larvae pandalid larvae *Ammodytes americanus* *Anchoa* sp. *Anchoa mitchilli* *Anguilla rostrata* *Scophthalmus aquosus* unid. fish larvae
C	*Dolioletta gegenbauri* *Doliolum* sp. *Thalia democratica*

Table 4-45. (Continued)

Species Group	Taxa
D	*Atlanta gaudichaudi* *Candacia* sp. *Euchaeta marina* *Lycaea* sp. *Arenaeus* sp. *Parthenope* sp. *Portunus* sp. calappid larvae unid. decapod larvae *Auxis* sp. *Ophichthus cruentifer*
E	*Cavolina longirostris* *Cavolina spectabilis* *Cavolina uncinata* *Creseis virgula* *Idotea metallica* *Oxycephalus clausi* *Callinectes* sp. *Bothus* sp. *Citharichthys arctifrons* *Glyptocephalus cynoglossus* *Hippoglossina oblonga* *Merluccius* sp. *Urophycis* sp. ophidiid larvae
F	unid. sophonophores *Evadne spinifera* *Penilia avirostris* *Acartia* sp. *Temora stylifera* *Farranula* sp. *Oncaea mediterranea* *Lestrigonus bengalensis* *Sagitta enflata* *Sagitta minima* *Oikopleura* sp.
G	*Acartia danae* *Calocalanus pavo* *Candacia armata* *Centropages violaceus* *Eucalanus* sp. *Eucalanus pileatus* *Mecynocera clausi* *Nannocalanus minor* *Pleuromamma gracilis* *Rhincalanus nasutus* *Parathemisto gaudichaudii* *Euphausia* sp. *Thysanoessa* sp. *Thysanoessa gregaria* *Sagitta tasmanica*
H	unid. polychaetes *Limacina retroversa* *Paedoclione doliiformis* *Evadne nordmanni* *Calanus finmarchicus* *Centropages typicus* *Metridia lucens* *Paracalanus* sp. *Pseudocalanus minutus* unid. copepodites *Oithona* spp. *Diastylis quadrispinosa* *Diastylis sculpta* *Unciola irrorata* euphausiids *Meganyctiphanes norvegica* *Dichelopandalus leptocerus* *Sagitta elegans* *Limanda ferruginea* *Liparis* sp. *Scomber scombrus*
I	*Diphyes bojani* *Anchylomera blossevilli* *Phronima atlantica* *Phronimella elongata* *Phrosina semilunata* *Tetrathyrus forcipatus* *Stylocheiron carinatum* *Lucifer typus* *Munida* sp. *Pontophilus brevirostris*
J	*Abylopsis eschscholtzii* *Abylopsis tetragona* *Chelophyes appendiculata* *Lensia conoidea* *Limacina inflata* *Aetideus armatus* *Pleuromamma abdominalis* *Pleuromamma robusta* *Scolecithrix danae* *Lepas* sp. *Eupronoe minuta* *Euphausia krohnii* *Euphausia mutica* *Nematoscelis megalops* *Thysanoessa inermis* *Eukrohnia hamata* *Pterosagitta draco* *Sagitta hexaptera* *Bothus ocellatus* *Ceratoscopelus maderensis* myctophids paralepidids

Table 4-45. (Concluded)

Species Group	Taxa
K	*Agalma elegans* *Bassia bassensis* *Tomopteris* sp. *Cavolina inflexa* *Dosinia discus* *Illex illecebrosus* *Conchoecia* sp. *Conchoecia curta* *Euconchoecia chierchiae* *Halocypris brevirostris* *Eucalanus attenuatus* *Euchaeta* sp. *Euchirella rostrata* *Diastylis polita* *Monoculodes* sp. *Sergestes arcticus* *Solenocera* sp. penaeid larvae xanthid larvae *Sagitta helenae* *Ammodytes* sp.

The remaining species groups, J and K, consisted of offshore species: J was a deep-water community important on the slope in cooler seasons of the first year, but also occurring over the outer shelf in similar seasons of the second year. Included are the copepods Pleuromamma abdominalis and P. robusta, euphausiids, the chaetognaths Eukrohnia hamata and Sagitta hexaptera, and myctophids. K was a group narrowly restricted to second-year outer shelf and slope collections, from fall through spring. It contained decidedly offshore species, some of them typically subtropical. Included were Tomopteris planctonis (?), ostracods, Euchirella rostrata, Sergestes arcticus, Solenocera sp., and Sagitta helenae.

In summary, subsurface zooplankton fauna, except at the coastal station C1, differed strongly between the two years of sampling in every season. One could not reasonably predict, beyond a few miles of the coastline, which of the various communities observed might be encountered in abundance in a third year.

The Neuston

Surface collections were obtained over 24-hour periods during all 8 cruises at 3 of the stations along the southern New Jersey transect. Station C1 was always distinct and a representative of the Coastal Boundary Layer; Station E3 occasionally clustered with offshore stations, but otherwise was typical of central shelf locations; and Station J1 is the most offshore of the transect's stations, located over the upper slope.

Station C1. The cluster analysis of neuston collections from all eight cruises included 64 samples and 77 species that occurred in at least 5% of the samples. These samples clustered into the classic picture shown in Figure 4-64, with eight clusters of samples (one for each seasonal cruise), comparable seasons of each year linking first, then fall clusters with summer and winter clusters with spring. This is a text-book example of faunal similarities and seasonal changes that would be anticipated from perusal of the coastal-oriented literature on Middle Atlantic Bight zooplankton. Elements within sample groups and the eight species groups selected from an inverse analysis are listed in Table 4-46. A nodal analysis relating species groups to sample groups (individual cruises in this particular case) is shown in Figure 4-65.

Neuston at the coastal station was never abundant in the winter-spring period, and in both sampled winters was characterized by species group A (Centropages hamatus, Pseudocalanus sp., Temora longicornis, barnacle larvae, and Ammodytes sp. larvae). Species group H, represented in all seasons, was represented in winter by Acartia tonsa, Centropages typicus, Neomysis americana, and Sagitta elegans, in particular. Spring fauna differed between the two years sampled, with spring 1977 neuston closely similar to that of winter

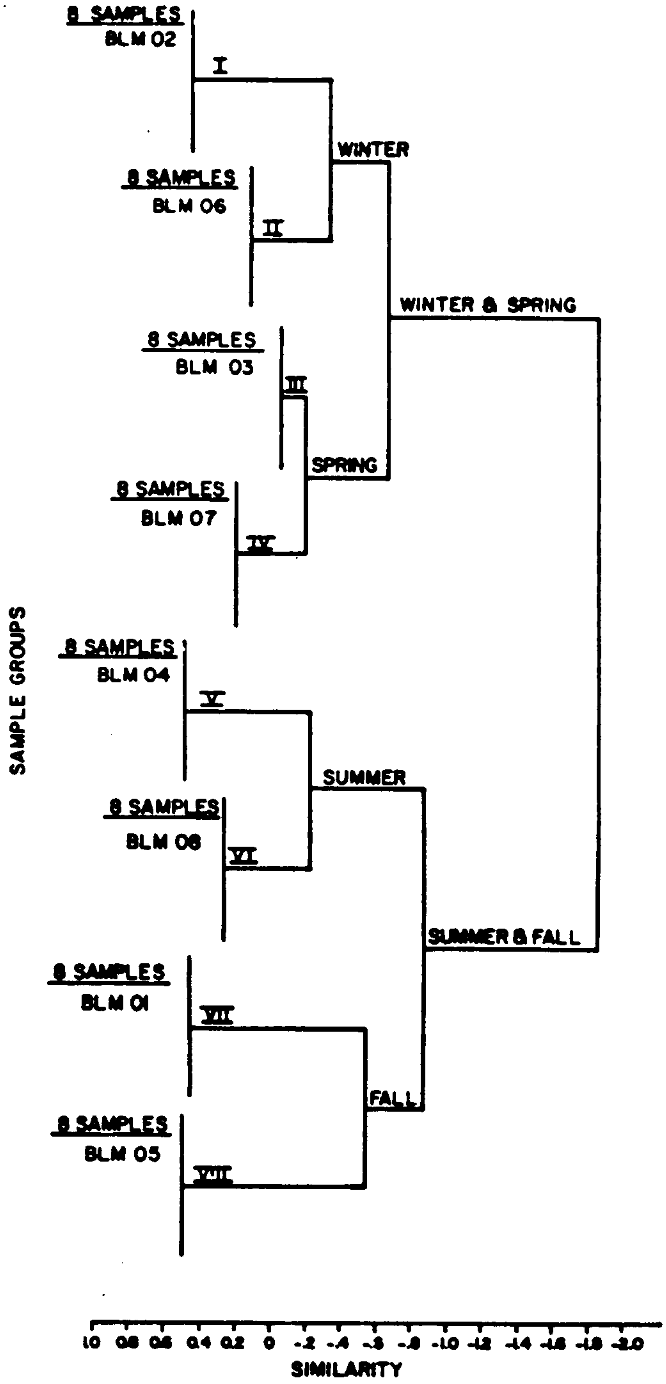

Figure 4-64. Neuston sample clusters, BLM01W-BLM08W (two years), Station C1. Based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to 20-min. tows.

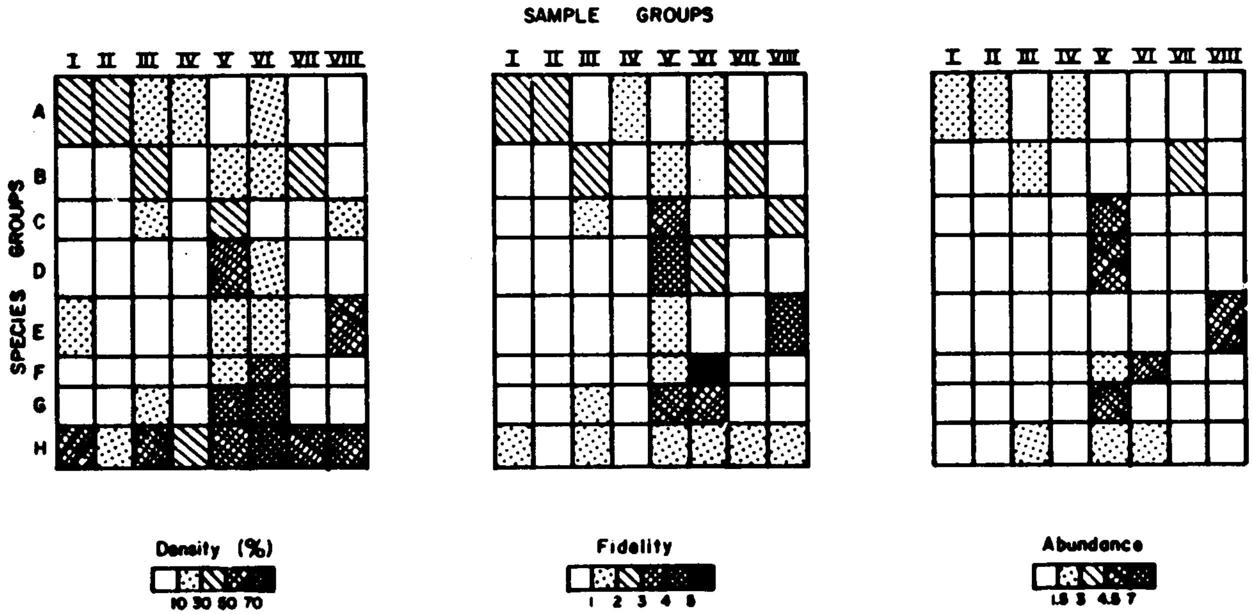

Figure 4-65. Nodal density, fidelity, and abundance of species groups within sample groups from the neuston cluster analyses, BLM01W-BLM08W, Station C1. See Table 4-46.

Table 4-46. Identification of elements within sample and species groups from nodal analyses of Station C1 neuston collections, cruises BLM01W-BLM08W.

Sample Group	Collection Numbers
I	6089-6091, 6094-6098
II	7110-7113, 7116-7119
III	6173-6180
IV	7227-7229, 7232-7236
V	6215-6222
VI	7323, 7326-7331, 7922
VII	5272-5274, 5277-5281
VIII	6327, 6328, 6331-6336

Species Group	Taxa		
A	*Calanus finmarchicus* *Centropages hamatus* *Metridia lucens* *Pseudocalanus* sp.	*Temora longicornis* unid. copepodites *Oithona* spp. unid. barnacle larvae	*Microprotopus raneyi* *Ammodytes* sp. *Anguilla rostrata*
B	*Bougainvillia* sp. *Beroe ovata* bivalve larvae *Anomalocera ornata*	*Anomalocera patersonii* *Pontella meadii* *Idotea metallica* *Carcinus maenas*	*Ovalipes ocellatus* *Enchelyopus cimbrius* *Urophycis* sp.
C	*Muggiaea kochei* *Limacina retroversa* *Idotea baltica*	*Sagitta helenae* *Doliolum nationalis* *Oikopleura* sp.	*Anchoa mitchilli* *Syngnathus fuscus*
D	*Aequorea aequorea* gastropod larvae *Atlanta peroni* *Loligo pealeii*	*Emerita* sp. *Hexapanopeus angustifrons* *Lucifer faxoni* *Upogebia affinis*	*Sagitta hispida* *Anchoa* sp. *Pomatomus saltatrix* *Prionotus* sp.
E	unid. polychaetes *Centropages furcatus* *Eucalanus pileatus* *Nannocalanus minor*	*Paracalanus* sp. *Mysidopsis bigelowi* *Parathemisto gaudichaudii* *Pinnixa cylindrica*	*Sagitta enflata* *Sagitta tasmanica* *Sagitta tenuis* *Menidia menidia*
F	unid. siphonophores stomatopod larvae	*Arenaeus* sp. *Portunus* sp.	*Doliolum* sp. *Thalia democratica*
G	*Evadne tergestina* *Lestrigonus bengalensis* *Callinectes* sp.	*Libinia* sp. *Ovalipes* sp. *Palaemonetes* sp.	*Uca* sp. pagurid larvae
H	*Penilia avirostris* *Acartia tonsa* *Centropages typicus*	*Labidocera aestiva* *Tortanus discaudatus* *Neomysis americana*	*Cancer* sp. *Crangon septemspinosa* *Sagitta elegans*

(species group A) and spring 1976 collections characterized best by species group B (including bivalve larvae, Anomalocera ornata and Carcinus maenas) and by a greater abundance of species group H (C. typicus, Labidocera aestiva, etc.). Differences may be attributable, in part, to the earlier sampling dates in 1977 (May vs. early June), but are most likely a result of the preceding cold winter.

Neuston in the two summers differed mostly by the presence in 1977 of large numbers of salps (species group F) and the retention of certain cold-water species from species group A (Temora longicornis is particularly noteworthy). In the summer of 1976, species groups C, D, and G were more important. Included species were Evadne tergestina, Lestrigonus bengalensis, assorted inshore decapod larvae and fishes, and the chaetognaths Sagitta helenae and S. hispida. Fall collections also differed between years, with 1975 samples characterized by species group B (Beroe ovata, Pontella meadii, Idotea metallica, etc.) and 1976 fall samples linked most closely with species group E (Centropages furcatus, Eucalanus pileatus, Mysidopsis bigelowi, and Sagitta enflata, among others).

Despite the above-mentioned differences between fauna in the spring, summer, and fall of different years, it should be stressed that overall similarity was closer between samples from a given season of the two years (e.g. winter 1976 and winter 1977) than between different seasons of the same sampling year, as depicted in Figure 4-64.

Station E3. Cluster analyses of neuston collections from all eight cruises at Station E3 included 69 samples and 104 species (or higher taxa) that occurred in 5% or more of the collections. The sample clusters are shown in Figure 4-66, where it is evident the principal clusters are summer collections on the one hand, and fall-spring collections on the other. The even division of collections into semi-annual clusters that occurred inshore is altered here to one of imbalance, weighted toward the winter fauna, perhaps a result of the smaller temperature range that occurs at deeper stations. Fall fauna is more similar to that of winter and spring than to summer fauna. Subclusters of collections included:

Summer - 1976 and 1977 collections

Fall to Spring - fall and winter 1976-1977
fall and spring 1975-1976
spring 1977

Summer collections (sample groups IX and X in Figure 4-67 and Table 4-47) were characterized by species groups E, F, G, and H, with differences between years attributable to a greater abundance of group E in 1976 and H in 1977. Species group G was essentially restricted to 1977 collections. Similarity of summer collections was due largely to species group F, containing Penilia avirostris, Labidocera aestiva,

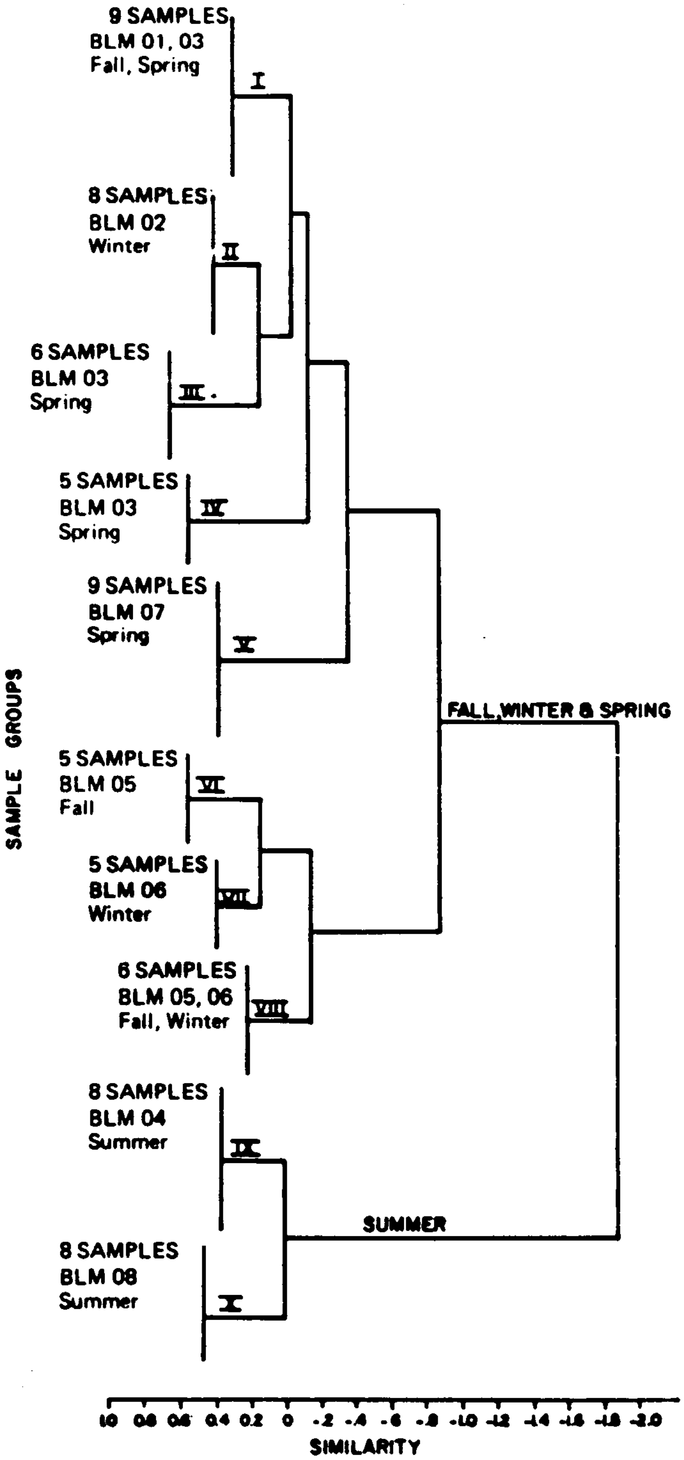

Figure 4-66. Neuston sample clusters, BLM01W-BLM08W (two years), Station E3. Based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data standardized to 20-min tows.

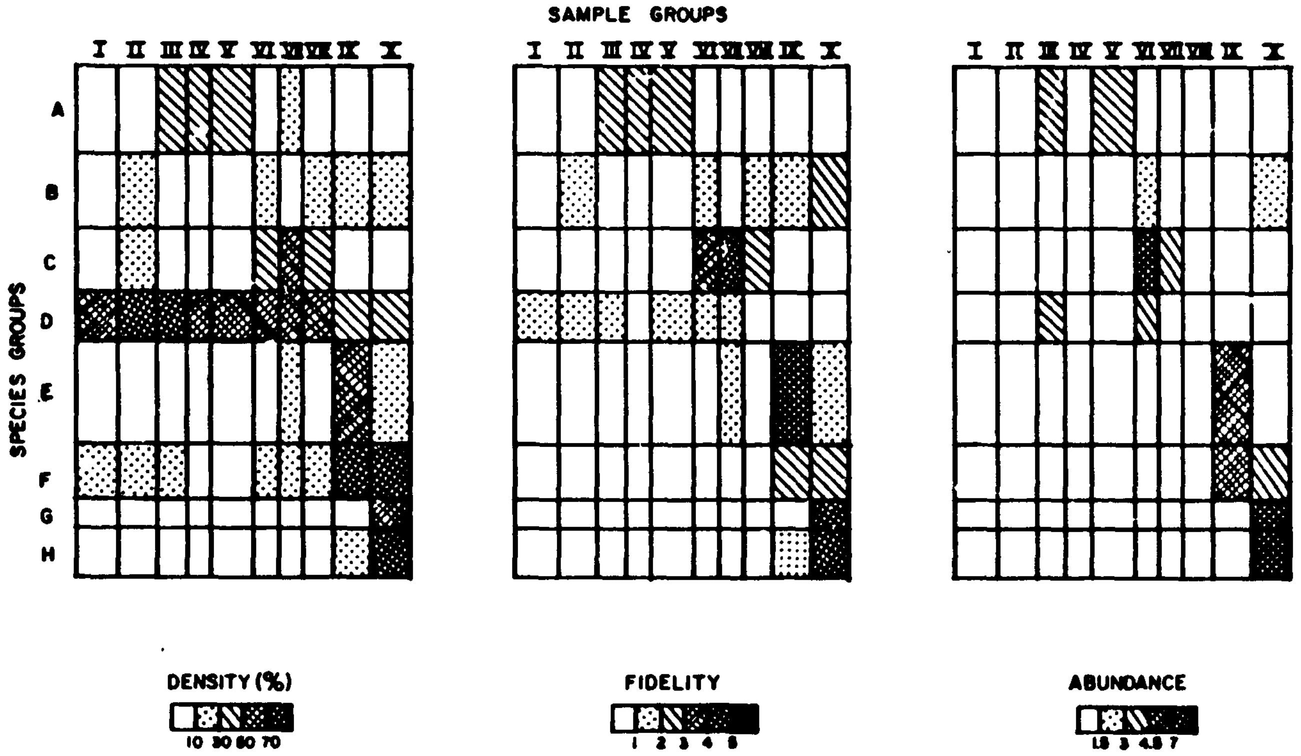

Figure 4-67. Nodal density, fidelity and abundance of species groups within sample groups from the neuston cluster analyses, BLM01W-BLM08W, Station E3. See Table 4-47.

Table 4-47. Identification of elements within sample and species groups from nodal analyses of Station E3 neuston collections, BLM01W-BLM08W.

Sample Group	Collection Numbers
I	5303-5309, 5312, 6211
II	6117-6121, 6124-6126
III	6168, 6171, 6172, 6206-6208
IV	6167, 6205, 6209, 6210, 6212
V	7173, 7178, 7183-7188, 7190
VI	6399, 6408, 6417-6419
VII	7060, 7068, 7069, 7073, 7074
VIII	6396-6398, 7070-7072
IX	6243-6246, 6249-6251, 6950
X	7338-7344, 7347

Species Group	Taxa
A	*Tomopteris helgolandica* *Paedoclione doliiformis* *Evadne nordmanni* *Paracalanus* sp. *Pseudocalanus* sp. *Temora longicornis* unid. barnacle larvae *Lepas fascicularis* *Meganyctiphanes norvegica* unid. euphausiids *Dromidia antillensis* *Homarus americanus* *Portunus* sp. pagurid larvae oikopleurids *Enchelyopus cimbrius* *Scomber scombrus* *Urophycis chuss*
B	*Paraclione longicaudata* *Acartia danae* *Anomalocera* sp. *Eucalanus* sp. *Pontellopsis villosa* *Rhincalanus cornutus* unid. copepodites *Lepas* sp. larvae *Leptochela* sp. *Ovalipes* sp. xanthid larvae *Sagitta hispida* *Sagitta minima* *Ammodytes* sp. *Pomatomus saltatrix*
C	*Conchoecia* sp. *Conchoecia* curta *Anomalocera ornata* *Clausocalanus arcuicornis* *Euchirella rostrata* *Paracalanus parvus* *Pleuromamma gracilis* *Rhincalanus nasutus* *Scolecithrix danae* unid. calanids *Euphausia* sp. *Thysanoessa* sp. *Mugil curema*
D	*Limacina retroversa* *Anomalocera patersonii* *Calanus finmarchicus* *Centropages typicus* *Metridia lucens* *Nannocalanus minor* *Parathemisto gaudichaudii* *Cancer* sp. *Sagitta elegans* *Sagitta tasmanica*
E	*Abylopsis eschscholtzii* *Abylopsis tetragona* *Bassia bassensis* *Atlanta peroni* *Creseis acicula* *Limacina trochiformis* *Centropages furcatus* *Eucalanus pileatus* *Labidocera acutifrons* *Corycaeus speciosus* *Sapphirina ovato-lanceolata* *Callinectes* sp. *Pterosagitta* draco *Sagitta decipiens* *Sagitta enflata* *Doliolum nationalis* *Thalia democratica*

Table 4-47. (Concluded)

Species Group	Taxa		
E (Cont.)	gastropod larvae	*Erythrops erythrophthalma*	unid. scombrid larvae
		unid. euphausiaceans	
F	*Penilia avirostris*	*Pontella meadii*	*Lucifer faxoni*
	Candacia armata	*Temora stylifera*	*Oikopleura* sp.
	Centropages violaceus	*Idotea metallica*	*Urophycis* sp.
	Labidocera aestiva	*Lestrigonus bengalensis*	
G	stomatopod larvae	*Ocypode quadrata*	*Doliolum* sp.
	Arenaeus sp.	penaeid larvae	*Auxis* sp.
H	unid. siphonophores	*Evadne spinifera*	*Pontella* sp.
	Atlanta gaudichaudii	*Candacia* sp.	*Pontellopsis* sp.
	Cavolina longirostris	*Labidocera* sp.	*Pontellopsis regalis*
	Firoloida leseurii		

Pontella meadii, *Idotea metallica*, *Lestrigonus bengalensis*, and *Urophycis* sp., some of the more common shelf neustonts.

Collections from fall and winter of the second year differed considerably from remaining collections, particularly in the heavy contribution of species group C in those seasons. This was a group of typically offshore species, with *Rhincalanus nasutus*, *Pleuromamma gracilis*, *Anomalocera ornata*, and immature *Euphausia* sp. in abundance. Fall, winter, and spring collections from the first year were dominated by central shelf, cold-water fauna (species group D).

The primary difference in fauna between spring 1976 and spring 1977 is somewhat masked by the inclusion of both *Centropages typicus* and *Calanus finmarchicus* in species group D of the nodal analysis. *Centropages typicus* was dominant in 1976, whereas the more northerly distributed *C. finmarchicus* was dominant in 1977. Representatives from species group A in the two years were also somewhat different, with *Temora longicornis* and *Meganyctiphanes norvegica* abundant in 1976, and *Evadne nordmanni*, euphausiids, and *Scomber scombrus* in 1977. Mean standard neuston catches at Station E3 of the principal dominant taxa were as follows:

	BLM03W	BLM07W
Centropages typicus	6,180	10,377
Calanus finmarchicus	90	72,992

Station J1. Cluster analyses of neuston collections at Station J1 from all eight cruises included 64 samples and 146 species occurring in at least 5% of the samples. Three principal clusters resulted from the normal analysis (Figure 4-68): 1) spring 1977 and all summer samples, 2) fall 1975 and winter 1977 samples, and 3) winter, spring, and fall 1976 samples. Comparison of these clusters with the principal groupings from Station E3 shows some similarity, but important differences. Summer samples from the two years are closely similar as at other examined stations, but are linked at Station J1 with spring 1977 samples. Recalling that BLM07W collections showed the first significant southward extension of the cold-water northern community, this similarity of spring 1977 slope neuston with summer fauna signals a distinct demarcation of faunal types between shelf and shope waters. While fall 1976 and winter 1977 samples were similar at Station E3, winter 1977 samples at J1 were most similar to those from the fall of 1975, when a Gulf Stream eddy was present. The final primary cluster of winter, spring, and fall 1976 samples is similar to a grouping at Station E3, except for the substitution of fall 1976 for fall 1975 samples.

Ten species groups were selected from an inverse analysis of J1 neuston collections and included in the nodal analysis shown in Figure 4-69, with listings of individual collections and species in Table

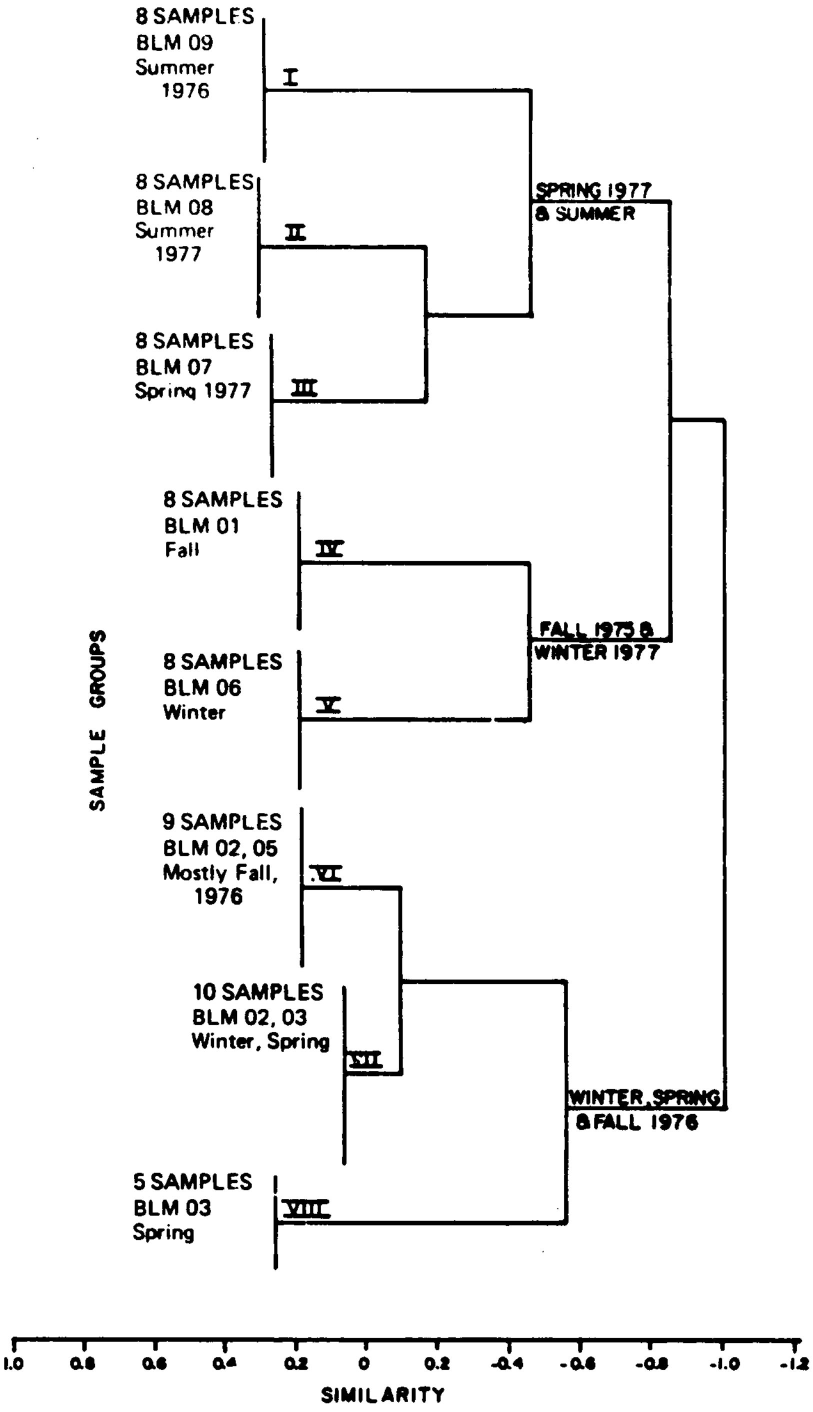

Figure 4-68. Neuston sample clusters, BLM01W-BLM08W (two years), Station J1. Based on the Bray-Curtis coefficient, all identified species occurring in at least 5% of the samples, and catch data reduced to 20-min. tows.

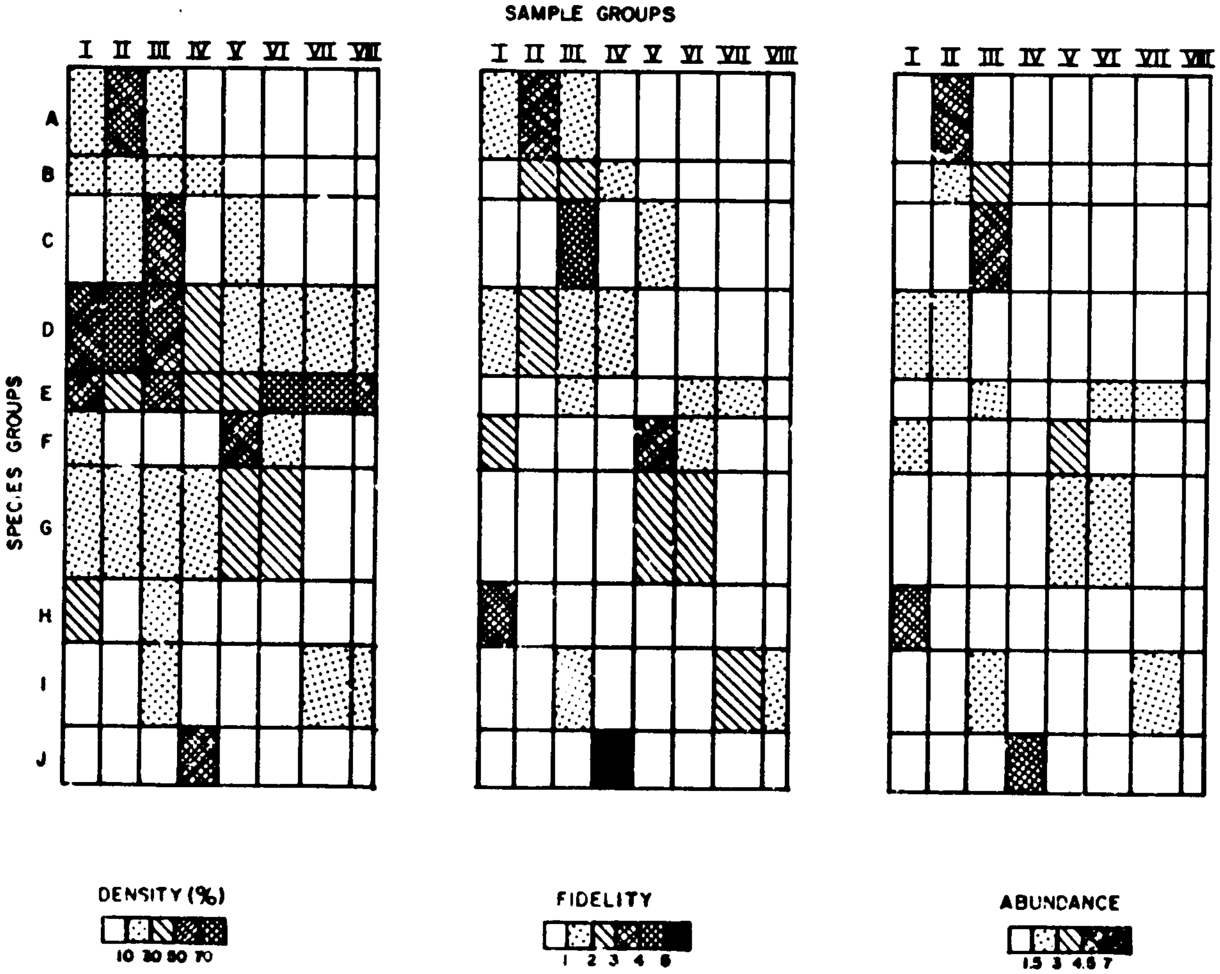

Figure 4-69. Nodal density, fidelity, and abundance of species groups within sample groups from the neuston cluster analyses, BLM01W-BLM08W, Station Ji. See Table 4-48.

Table 4-48. Identification of elements within sample and species groups from nodal analyses of Station J1 neuston collections, BLM01W-BLM08W.

Sample Group	Collection Numbers
I	6263-6266, 6269-6272
II	7278-7282, 7285, 7289, 7290
III	7159, 7160, 7163-7168
IV	5325-5328, 5330, 5332, 5335, 5336
V	7043, 7046-7052
VI	6146, 6383-6387, 6391, 6394, 6395
VII	6137, 6140-6145, 6149, 6151, 6152
VIII	6153, 6154, 6156, 6947, 6948

Species Group	Taxa		
A	*Atlanta gaudichaudi*	*Corycaeus speciosus*	*Euphausia mutica*
	Atlanta peroni	*Lycaea bovalli*	*Callinectes* sp.
	Creseis virgula	*Lycaea* sp.	*Ocypode quadrata*
	Firoloida lesueurii	*Oxycephalus clausi*	calappid larvae
	Limacina bulimoides	*Oxycephalus piscator*	*Anchoa hepsetus*
	Paraclione longicaudata	unid. amphipods	*Auxis* sp.
B	*Labidocera* sp.	*Pontellopsis* sp.	unid. hyperiids
	Pontella securifer	*Undinula vulgaris*	*Sphoeroides* sp.
	Pontella sp.	*Sapphirina ovatolanceolata*	
C	*Pelagia noctiluca*	*Vibilia armata*	unid. decapod larvae
	unid. scyphozoans	*Dromidia antillensis*	*Pterosagitta draco*
	unid. polychaetes	*Geryon quinquedens*	*Sagitta helenae*
	Eucalanus pileatus	*Ovalipes* sp.	*Oikopleura* sp.
	Temora turbinata	*Parthenope* sp.	*Peprilus triacanthus*
	Brachyscelus crusculum	*Portunus* sp.	*Scomberesox saurus*
D	unid. siphonophores	*Labidocera acutifrons*	*Lestrigonus bengalensis*
	Cavolina longirostris	*Pontella meadii*	*Euphausia krohnii*
	Limacina trochiformis	*Pontellopsis regalis*	*Lucifer faxoni*
	Penilia avirostris	*Temora stylifera*	*Sagitta enflata*
	Candacia armata	unid. barnacle larvae	*Thalia democratica*
	Centropages violaceus	*Idotea metallica*	*Urophycis* sp.
E	*Limacina retroversa*	*Centropages typicus*	*Pleuromamma gracilis*
	Anomalocera patersonii	*Metridia lucens*	*Parathemisto gaudichaudii*
	Calanus finmarchicus	*Nannocalanus minor*	
F	*Abylopsis eschscholtzii*	*Diphyes dispar*	xanthid larvae
	Abylopsis tetragona	*Pleurobranchia pileus*	*Bothus* sp.
	Bassia bassensis	*Lepas* sp.	*Mugil curema*
	Diphyes bojani	*Thysanoessa gregaria*	

Table 4-48. (Concluded)

Species Group	Taxa		
G	*Chelophyes appendiculata* *Cavolina inflexa* *Conchoecia curta* *Conchoecia* sp. *Euconchoecia chierchiae* *Halocypris brevirostris* *Acartia danae* *Anomalocera ornata*	*Anomalocera* sp. *Clausocalanus arcuicornis* *Pleuromamma piseki* *Rhincalanus nasutus* *Scolecithrix danae* unid. copepodites *Euphausia* sp. *Thysanoessa* sp.	unid. euphausiids *Leptochela bermudensis* *Sagitta minima* *Sagitta tasmanica* *Salpa fusiformis* *Myctophum affine* *Symbolophorus veranyi*
H	*Cavolina uncinata* *Limacina inflata* *Paedoclione doliiformis* gastropod larvae *Labidocera aestiva*	stomatopod larvae *Erythrops erythrophthalma* *Anchylomera blossevilli* *Phrosina semilunata*	*Tetrathyrus forcipatus* unid. euphausiaceans *Cancer* sp. *Munida* sp.
I	*Agalma elegans* *Eudoxides spiralis* *Eucalanus* sp. *Euchirella rostrata* *Paracalanus* sp. *Rhincalanus cornutus*	*Lepas fascicularis* *Meganyctiphanes norvegica* *Leptochela papulata* *Sagitta elegans* *Ammodytes* sp. *Pomatomus saltatrix*	*Urophycis chuss* engraulid larvae myctophid larvae synodontid larvae unid. fish larvae
J	*Velella velella* *Pontella spinipes* *Pontellopsis villosa* *Bagatus minutus*	*Latreutes fucorum* *Leander tenuicornis* *Leptochela* sp. *Portunus sayi*	*Gonichthys cocco* *Myctophum punctatum* *Decapterus* sp. balistids

4-48. Similarities of spring and summer 1977 collections at Station J1 were due mostly to joint occurrences of species group B, with its immature pontellid copepods, Pontella securifer and Sapphirina ovatolanceolata. These station groups (II and III) were in turn linked to collections from summer 1978 by joint occurrences of species group D, containing the common offshore and warm-water species Labidocera acutifrons, Pontella meadii, Temora stylifera, Idotea metallica, Sagitta enflata, and Thalia democratica. The most abundant group in each of these 3 cruises was different: species group H in summer 1976, group A in summer 1977 (both species groups consisting largely of different species of pteropods and amphipods), and group C in spring 1977 (Pelagia noctiluca, Eucalanus pileatus, decapod larvae, and Sagitta helenae, among others).

If the linking of fall 1975 and winter 1977 were due to the presence of anticyclonic eddies in those seasons, it is not evident from faunal analysis. Only the widespread species groups D, E, and G were common to both sets of collections. The species group characteristic of the fall 1975 warm-core eddy (species group J) was not present in winter 1977. The most abundant group in the latter season was group F, which included several siphonophores, Pleurobrachia pileus, Lepas sp. larvae, Thysanoessa gregaria, and Mugil curema larvae. Species groups A, H, and I were jointly absent from these two sets of collections. Sample groups VI-VIII (winter, spring, and fall 1976) were linked by joint occurrences of species groups E and I (consisting of elements of the northern cold-water community and deeper-living slope residents). Thus, the absence of species group I in winter collections of 1977 (and replacement by a warmer-water fauna) may have been of key importance in the grouping of winter 1977 and fall 1975 collections.

In summary, neuston collections obtained seasonally for two years at stations C1, E3, and J1 show a progressive offshore change from a highly structured and predictable coastal fauna to a much less predictable shelf-edge fauna that depends heavily on incursions and movements of offshore waters. Central shelf waters are intermediate, with the faunal year divided between summer and the remaining seasons, but showing pronounced annual differences depending on severity of winter.

Stations Sampled Only in Second Year

It is obvious from the above discussion that faunal predictions based on only one year of seasonal observations are, in the offshore portions of the Middle Atlantic Bight, of little value. We will, therefore, limit discussion of fauna at new station sites (stations A2, B5, L1, L2, L4, and L6) to their respective, seasonal similarity with collections from longer-term sampling locations.

Northern Stations B5 and A2. Fauna at the shallower of these two stations (B5) was similar to the southern New Jersey central shelf stations D1, N3, and E3. In winter 1977 (BLM06W), similarities of neuston collections were divided: day and dawn tows with outer shelf and slope collections, night tows with central shelf and coastal collections.

Subsurface collections at Station A2 fluctuated between similarity with central shelf and with slope collections. Offshore affinities were most often evident, in fall, winter, and summer. Neuston was similar to central shelf collections in fall and spring, to outer shelf and slope collections in winter and summer.

Southern Stations L1 and L2. The inner shelf stations from the southern transect off Virginia yielded similar fauna, except in fall 1976, when Station L2 was linked to the offshore stations L4 and L6. The usual affinity of both surface and subsurface populations was with the New Jersey coastal station C1. Exceptions were limited to winter neuston that was also similar to northern central shelf stations and to summer neuston which was comprised of a distinctly different species group.

Offshore Southern Stations. Subsurface collections at the shelf-edge and slope stations L4 and L6 were similar to those from the shelf-edge and slope off New Jersey. Neuston collections clustered with northern central shelf to slope stations in fall and winter, with Station J1 in spring 1977, and were populated with a distinct assemblage of species in summer 1977. The latter included a number of subtropical species.

One can hypothesize from observations at these sampling sites new to the second year of the study that fauna at Station B5 will be typically central shelf in character; that Station A2, as a "swing" station, can show affinities with either slope or central shelf fauna; that inner shelf stations off Virginia are similar in species composition to the coastal New Jersey station; and that offshore Virginia populations are usually common to the shelf-edge and slope off New Jersey, but may, at times be distinctly subtropical in nature and distinct from those at more northerly sites.

Zooplankton and Hydrography

Water Types and Neuston

Ruzecki et al. (Chapter 3 of this report) have classified observed Middle Atlantic Bight waters, by segmentation of T-S diagrams, into six water types: coastal, winter coastal, shelf-slope, slope, shelf-Gulf Stream, and Gulf Stream. Discrete sampling of zooplankton within these various water types is needed to directly relate community structure to hydrography. In the present sampling only neuston tows were made at a discrete depth; oblique bongo tows traversed from one to several water types, depending on the depth of sampling and relative homogeneity of the water column. Bongo collections from tows that sampled more than a single water type are a mixture of individuals and species residing in those water types, but in unknown proportions. Neuston tows, although discrete at the surface in a uniform water type, may at night capture species that have migrated from underlying and different water types. Vertical migration through different water types also occurs at greater depths, obviously, and thereby would influence the composition of even discrete-depth bongo collections. The degree to which this occurs, and identificaton of the species crossing water types, can only be determined by time series of discrete-depth sampling, a recommendation that was made to BLM for possible 3rd-year studies.

Despite the above limitations of present sampling design for any critical study of the relationship of hydrography to zooplankton community structure, it may still be of some benefit to compare results of neuston cluster analyses to the physical classification of surface water types. Do clusters of collections based on similarity of contained fauna correspond to different water types?

Temperatures and salinities from surface water at the time of neuston collections were summarized and superimposed on a T-S diagram showing the physical classification of water types (Figure 4-70). Envelopes enclose all observed values for a given cruise and station designations are plotted near the center of T-S measurements obtained at each station, thereby indicating the physical water type from which neuston was collected. Comparison of these results with the clustering of samples based on the composition and relative abundance of contained species shows that:

1. Coastal water, as defined physically, includes both Coastal Boundary Layer water and Central Shelf water, which are usually separable by an analysis of zooplankton. At times there are also distinctive offshore species within waters physically classified as "coastal".

2. Winter coastal water is not biologically very different from coastal water in the spring and in 1977 was limited at the surface to the CBL and inner shelf stations. The division at 8°C may, therefore, be quite artificial, although its persistence in subsurface waters in spring 1977 and the concomitant abundance of the northern zooplankton community suggests that the concept of winter coastal water may be more useful in analysis of subsurface collections.

3. Shelf-slope water, as defined, was sampled at the surface only in fall and winter of 1976-1977, and contained most central shelf to slope communities in the fall, including some distinctive offshore southern fauna. In the winter, the water type was limited to some inner shelf stations.

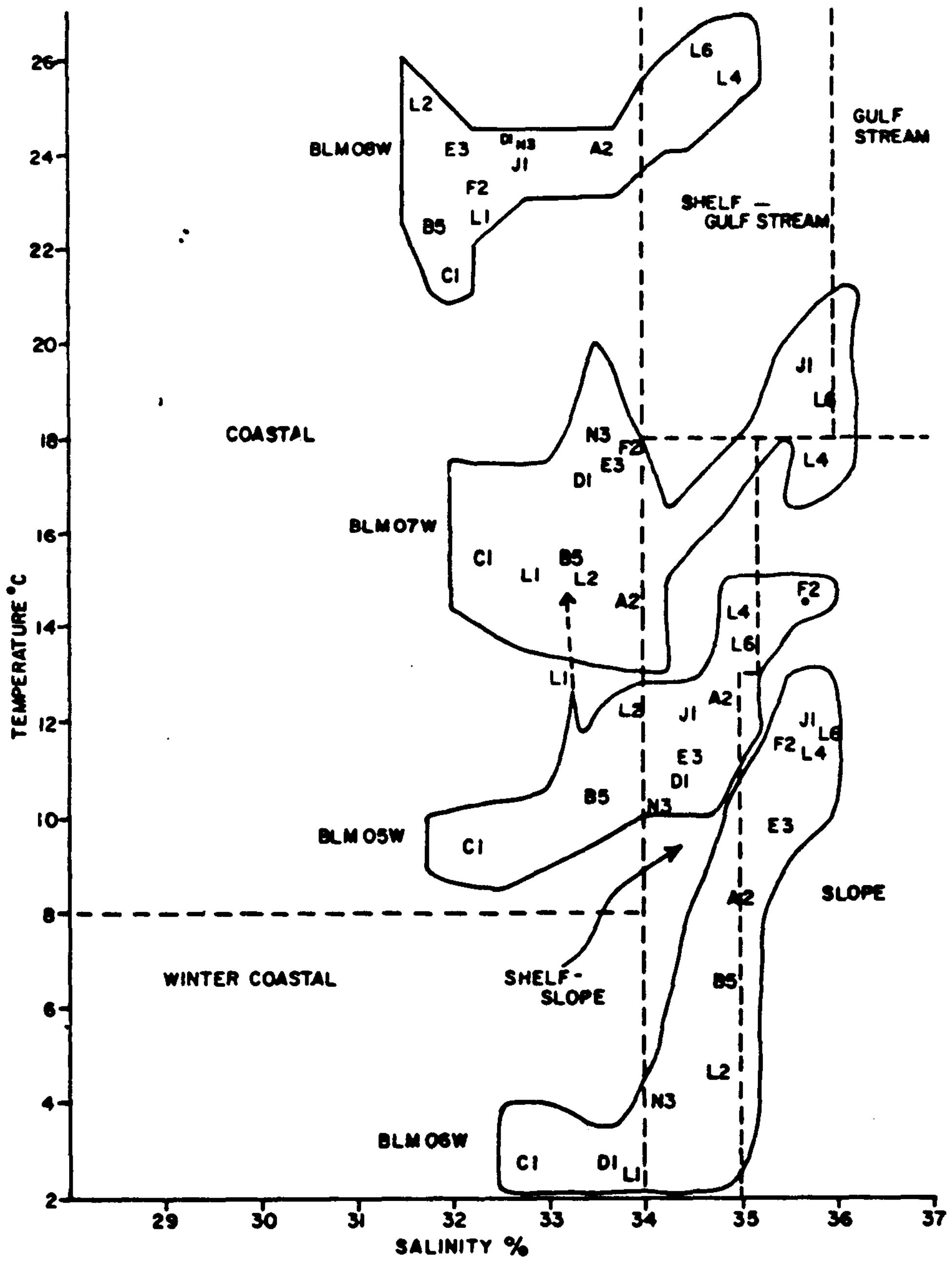

Figure 4-70. Physical classification of Middle Atlantic Bight water types and observed T-S relationships in surface waters sampled for neuston, cruises BLM05W-BLM08W.

4. Slope water was sampled at the surface, mostly in winter along the outer shelf and slope, matching a distinctive major cluster of offshore neuston collections. The direction of the line of stations from N3 to J1 within the winter envelope of Figure 4-70 suggests the possibility of some mixing with Gulf Stream water and perhaps the advisability of including yet another water type (slope-Gulf Stream) for high salinity waters between 12 and 18°C in winter. Winter neuston collections from Station J1 (BLM06W), as shown in another part of this discussion, clustered with J1 collections from fall 1975 (BLM01W) which were taken from an anticyclonic eddy.

5. Physically-defined Gulf Stream water was sampled at the surface only in spring and summer of 1977. Only the spring observations matched a distinctive cluster of neuston collections, from stations L4, L6 and J1.

In answer to the above-posed question, then, our clustering of neuston collections, based on their similarity in species composition and abundance, does correspond to physically classified water types, but not perfectly. The complexity of mixed shelf waters complicates attempts at subdivision into water types, but inclusion of all water less than 34 $^{0}/oo$ in the category "coastal" is, based on biological results, an obvious oversimplification. Most of the surface waters sampled in summer 1977 were fresher than 33 $^{0}/oo$, yet included both central shelf and offshore fauna within zones of the shelf, while offshore southern stations L4 and L6 with high surface salinity were faunally similar to northern offshore stations A2, F2, and J1 (classified physically as coastal). The salinity used to separate one water type from another would have to be varied seasonally to conform to biological information, i.e. elastic rather than rigid or at least curvilinear rather than linear physical boundaries, for water types. Some allowance must be made for the freshening of surface waters across the shelf in spring and summer, and the apparent tolerance of reduced salinity by offshore zooplankton species in higher temperatures.

Many of these apparent problems in relating fauna to water types are likely to be unique to the surface layer. A rigid definition of water types might be more applicable to zooplankton communities collected at depth, away from the effects of surface cooling and warming. But tows must be at discrete depths, selected according to simultaneous CTD data.

Indicators of Communities

First year studies of the southern New Jersey transect (Grant 1977a) included selection of a number of zooplankton species that could be used as indicators of the three principal communities of zooplankton found over the Middle Atlantic Bight: Coastal Boundary Layer, Central Shelf and Shelf-break and Slope. Clustering of bongo collections in the second year of sampling produced similar results, with primary division of samples into three groups: Coastal Boundary Layer, including stations C1, L1, and L2 in all seasons, joined by Station D1 in winter; Central Shelf stations N3 and B5 in all seasons, E3 and D1 in all seasons but winter, and joined with stations A2 and F2 in spring; and Shelf-break and Slope stations: J1 and L6 in all seasons; A2 and F2 in every season but spring; L4 in winter, spring and summer; and all of these joined by Station E3 in winter.

Coastal Boundary Layer. Clustering of samples from Station C1, the New Jersey coastal station, with Virginia stations L1 and L2 demonstrates that the CBL, previously shown to exist along the New Jersey coast (Csanady 1976), most likely extends southward throughout the Middle Atlantic Bight. If so, it is a feature of Middle Atlantic Bight circulation that is worthy of closer examination. Important coastal species in the second year included *Acartia tonsa* in fall and summer and *Centropages hamatus*, *Temora longicornis*, and *Tortanus discaudatus* in winter and spring. The distribution of CBL species (first-year selections as indicators) over the two second-year transects is given in Table 4-49. The three selected species of copepods were again good indicators of coastal water off New Jersey, but were not found useful in the southern Bight, except for *C. hamatus* in spring. It is also obvious that both *A. tonsa* and *C. hamatus* are poorly represented in the coarser 505 μm nets. Better indicators for coastal waters off Virginia could include the copepods *Centropages furcatus* and *Eucalanus pileatus* during warm seasons and *Temora longicornis*, *Mysidopsis bigelowi* (mysid), and *Crangon septemspinosa* (decapod) in cooler months.

Central Shelf Fauna. Species selected as indicators of the widely-distributed Central Shelf communities after the first year of seasonal sampling included *Centropages typicus*, *Calanus finmarchicus*, and *Sagitta elegans*. Abundance of these species during the second year is given in Table 4-50. The most obvious difference between the two years of sampling was the assumption of dominance in spring 1977 by the boreal *C. finmarchicus* and *S. elegans*. In 1975-1976 (Grant 1977a), *C. typicus* had remained dominant throughout the year. The persistence of the boreal species through the summer of 1977, even along the inner shelf off Virginia, is an important residual effect of the particularly cold winter of 1977.

Maximum densities of Central Shelf species usually occurred at stations D1 or N3 off New Jersey, or in the case of *C. typicus*, within the CBL at Station C1. Off Virginia, boreal species tended to be distributed further offshore with maximum densities on the outer shelf. A notable exception occurred in summer 1977 when *S. elegans* was restricted to the inner shelf, perhaps as a result of transport in

Table 4-49. Density of Coastal Boundary Layer indicators off southern New Jersey and Virginia, calculated from subsurface bongo tows (numbers per 100 m^3).

Cruise and	New Jersey Transect						Virginia Transect			
Mesh Size	C1	D1	N3	E3	F2	J1	L1	L2	L4	L6
					Acartia tonsa					
05W 202	20,790	0	0	0	0	0	0	0	0	0
505	276	0	0	0	0	0	0	0	0	6
06W 202	10,131	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0
07W 202	59,941	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0
08W 202	87,771	0	0	0	0	0	127	0	0	0
505	276	0	0	0	0	0	0	0	0	0
					Centropages hamatus					
05W 202	1,862	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0
06W 202	87,565	199	0	0	0	0	0	0	0	0
505	50,906	519	0	0	0	0	0	0	0	0
07W 202	0	10,370	0	0	0	0	86,646	0	0	0
505	2,510	3,376	0	0	0	0	161	3	0	0
08W 202	0	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	<1	0	0	0
					Tortanus discaudatus					
05W 202	0	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0
06W 202	0	0	0	0	0	0	0	0	0	0
505	0	0	0	0	0	0	0	0	0	0
07W 202	0	0	0	0	0	0	0	0	0	0
505	753	1,125	0	0	0	0	0	<1	0	69
08W 202	0	0	0	0	0	0	0	0	0	0
505	349	0	0	0	0	0	8	0	0	0

Table 4-50. Density of Central Shelf indicators off southern New Jersey and Virginia, calculated from subsurface bongo tows (numbers per 100 m^3).

Cruise and		New Jersey Transect					Virginia Transect			
Mesh Size	C1	D1	N3	E3	F2	J1	L1	L2	L4	L6
					Centropages typicus					
05W 202	84,402	974,184	221,244	51,630	1,645	9,680	11,378	20,378	522	18,797
505	15,747	508,382	154,275	111,949	1,340	725	83	26,168	2,110	174
06W 202	724	10,957	124,283	7,592	2	257	173,887	146,182	4,169	12,752
505	392	19,546	50,635	6,464	44	1,084	67,815	75,536	9,610	2,400
07W 202	0	103,696	0	5,455	13,768	3,670	23,631	264,258	87,149	36,447
505	2,259	118,154	80,457	27,252	2,424	417	6,508	66	13,146	11,217
08W 202	133,747	45,247	9,526	1,730	957	78	127	0	0	0
	6,161	12,530	5,093	4,308	1,210	113	11	<1	295	0
					Calanus finmarchicus					
05W 202	0	0	0	1,721	0	0	0	0	87	0
505	0	0	4,628	0	0	54	0	0	17	0
06W 202	0	199	0	177	0	171	0	0	167	0
505	0	173	4,069	145	10	212	339	316	80	95
07W 202	0	445,894	5,120	120,016	261,593	2,202	0	0	8,715	0
505	0	388,220	342,309	157,729	195,105	2,877	0	6	3,114	138
08W 202	0	0	0	88,562	7,018	601	0	4,477	1,021	0
505	0	216	17,960	32,476	2,898	387	7	107	4,424	0
					Sagitta elegans					
05W 202	97	0	0	0	0	0	0	0	0	0
505	0	0	0	0	1	6	0	0	0	0
06W 202	54	12	209	0	0	0	0	0	0	0
505	68	7	85	0	<1	5	0	0	0	0
07W 202	5,580	104,344	37,760	23,242	13,876	57	3	20	68	81
505	6,086	37,697	103,863	18,374	9,013	21	15	3	119	0
08W 202	6,727	2,530	4,912	5,535	239	10	2,186	385	0	0
505	32	891	10,723	3,438	255	16	31	952	0	0

the CBL. Densities of these Central Shelf indictors were considerably higher in the second year of sampling:

Maximum recorded density (number/100m^3)

	First Year	Second Year
C. typicus	245,000	974,184
C. finmarchicus	44,200	445,894
S. elegans	16,600	104,344

Shelf-break and Slope Fauna. Species selected as indicators of shelf-edge fauna in the first year included those with maximum densities at stations F2 and J1 off New Jersey. These species were found also in considerable quantity across the central shelf in cooler seasons, especially *Metridia lucens* in winter and *Meganyctiphanes norvegica* in spring. The density of first-year selections during the second year of expanded sampling is given in Table 4-51. *Metridia lucens* was spread over most of the shelf off New Jersey except in summer 1977, when its distribution was similar to summer 1976. Off Virginia, it was largely restricted to shelf-edge and slope locations; in winter, however, it exhibited a split distribution, occurring in the CBL and in the slope collection. *Pleuromamma gracilis* occurred closer inshore in fall 1976 than in any of the other seven cruises, and did so both off New Jersey and Virginia. *Euphausia krohnii*, the most restricted of the offshore indicators was largely limited to the furthest offshore station in each transect. *Meganyctiphanes norvegica*, as in the previous year off New Jersey, spread over the shelf in spring; in other seasons it was restricted to the slope station. Off Virginia, it was absent in summer 1977 and occurred in other seasons at either the shelf-edge (spring) or slope stations.

Maximum densities of *M. lucens*, *P. gracilis*, and *E. krohnii*, respectively, were 69,719, 34,788, and 1,308 per 100 m^3, all occurring in the newly sampled Virginia transect. An estimate of 366,056 per 100m^3 for *M. norvegica* was taken from a 202 μm net at Station D1. Primary differences in first and second year observations on this species group were the extension of *P. gracilis* on the shelf in fall 1976 and the nearly shelf-wide distribution of *M. lucens* in every season of the second year except summer. Our fall cruise in 1976 was one month later than in 1975 (November rather than October) which could account for the inshore distribution of both species in fall 1976. Spring sampling in 1977 was earlier (May) than in 1976 (June) so was conducted in cooler conditions, especially following the severe winter of 1977. *M. lucens* had not yet been excluded from the inner shelf by rising temperatures.

Table 4-51. Density of offshore indicators off southern New Jersey and Virginia, calculated from subsurface bongo tows (numbers per 100 m^3).

Cruise and	New Jersey Transect						Virginia Transect			
Mesh Size	C1	D1	N3	E3	F2	J1	L1	L2	L4	L6
					Metridia lucens					
05W 202	0	29,521	11,959	0	290	350	0	0	348	143
505	0	20,134	3,857	1,646	704	206	1	433	86	150
06W 202	0	598	1,336	2,119	598	799	552	0	0	386
505	392	692	452	363	44	399	1,017	0	0	591
07W 202	0	51,848	0	5,455	48,188	8,075	0	0	69,719	8,678
505	502	48,387	67,291	0	12,118	2,585	0	0	13,146	4,955
08W 202	0	0	0	346	638	194	0	0	0	999
505	18	0	0	331	287	363	0	0	531	106
					Pleuromamma gracilis					
05W 202	0	9,840	0	20,652	6,581	9,447	0	1,019	3,570	34,788
505	0	5,033	3,857	1,976	5,160	904	1	216	1,643	1,492
06W 202	0	0	0	12,535	<1	400	0	0	0	193
505	0	0	0	145	14	37	0	0	0	38
07W 202	0	0	0	0	0	5,138	0	0	0	3,471
505	0	0	0	0	0	334	0	0	0	551
08W 202	0	0	0	0	0	19	0	0	0	749
505	0	0	0	0	32	89	0	0	826	43
					Euphausia krohnii					
05W 202	0	0	0	0	0	3	0	0	0	26
505	0	0	0	0	0	2	0	0	0	26
06W 202	0	0	0	0	0	11	0	0	0	23
505	0	0	0	0	0	0	0	0	0	19
07W 202	0	0	0	0	0	75	0	0	0	434
505	0	0	0	0	0	146	0	0	0	1,308
08W 202	0	0	0	0	20	165	0	0	0	9
505	0	0	0	0	8	202	0	0	0	5

Table 4-51. (Concluded)

Cruise and Mesh Size	New Jersey Transect C1	D1	N3	E3	F2	J1	Virginia Transect L1	L2	L4	L6
					Meganyctiphanes norvegica					
05W 202	0	0	0	0	0	8	0	0	0	61
505	0	0	0	0	0	11	0	0	0	6
06W 202	0	0	0	0	0	3	0	0	0	0
505	0	0	0	0	0	19	0	0	0	2
07W 202	0	366,056	280	211	134	7	0	0	68	0
505	0	2,884	960	1,471	464	52	0	0	43	0
08W 202	0	0	0	0	0	11	0	0	0	0
505	0	0	0	0	0	8	0	0	0	0

Factors Affecting Distribution of Zooplankton

There are two principal sources of the zooplankton fauna observed in the Middle Atlantic Bight: offshore Gulf Stream and slope waters and the shelf waters of Georges Bank and southern New England. The offshore tropical and subtropical species are introduced to the shelf environment by the southwestward passage of anticyclonic eddies from the Stream, while the northern boreal community of zooplankton is transported in the generally southward drift of Middle Atlantic Bight shelf waters. Our observations in the past two years have led to the hypothesis that, while there is a continuous year-round source of these two very different communities, seasonal temperatures alternately limit their shelf distribution and survival. An additional feature of shelf circulation appears close to the coast in the form of a Coastal Boundary Layer that may concentrate and funnel species southward where they are seasonally added to the fauna of major estuaries such as Delaware and Chesapeake bays. Boreal fauna, typified by Calanus finmarchicus and Sagitta elegans, survives its southward mixing along the shelf only in winter and spring of normal years; its relative annual abundance may depend both on the severity of winter and on strength of flow in the Coastal Boundary Layer. Subtropical species limited to offshore waters, or to warm rings during winter and spring, survive mixing across the shelf in summer and fall. Several species found only in shelf-edge and slope stations in one season have been found limited to the Coastal Boundary Layer in the following season.

Biomass

It is evident, both from our tabulated results of displacement volume measurements (Tables 4-1, 4-9, 4-17, 4-25) and from the sparsely available literature, that biomass of zooplankton varies between hours of collection at a given station, between adjacent stations, between inshore and offshore regions of the shelf, and between seasons. A single year of observations at 12 stations in the Middle Atlantic Bight, sampled quarterly, is obviously insufficient for predictive purposes in the face of such variability. Nevertheless, it may be of some use to compare our findings with other reported studies.

Bigelow and Sears (1939) measured displacement volume of zooplankton samples taken between Cape Cod and Chesapeake Bay and reduced the data to volume in cc per "standard haul". A "standard haul" was defined as an oblique tow with a one-meter net, towed an average distance of 741 meters. Such a tow would sample $582m^3$ of water, assuming 100% efficiency. Their reported values for displacement volume should, therefore, be divided by 5.82 to be comparable to our data, reported in $ml/100m^3$, and similarly not adjusted for filtration efficiency. Meshes in the nets of Bigelow and

Sears (1939) were of a size mid-way between the ones employed in our study (366-417 μm vs. our 202-505 μm).

Only a portion of the Bigelow and Sears (1939) data is directly comparable to the present study. They divided the Bight into North, South, Inshore, and Offshore blocks. Most of our stations fall within the South sector of Bigelow and Sears or at the dividing line between North and South sectors. Only our stations A2 and B5 lie clearly within the North subdivision (offshore). Furthermore, most of the sampling by Bigelow and Sears (1939) was conducted in the winter-spring seasons (February-June), so that the months of most interest to us are February, comparable to our winter 1977 cruise, and May, comparable to our spring 1977 cruise. No comparisons are available for our November 1976 and August 1977 cruises.

February Biomass

Displacement volume of winter zooplankton generally decreased from inshore to offshore and from south to north in the three successive years (1930-1932) sampled by Bigelow and Sears. Average volumes in the southern sector in 1932 were more than twice as high as in the preceding two years (81 vs. 30 and 34 ml/100m^3). Our data for February 1977 (Table 4-9) show highest volumes inshore or at central shelf locations in both 202 μm and 505 μm bongo collections, and little difference in a north-south direction. Volumes in 202 μm collections averaged 82, 102, and 120 ml/100m^3, respectively in the southern transect, New Jersey transect and northern stations A2 and B5; comparable averages for 505 μm collections were 34, 31 and 26 ml/100m^3. In 1977, zooplankton volume was particularly low at the shelf-edge, possible due to incursion of offshore waters.

May Biomass

Bigelow and Sears (1939) sampled during May in four successive years (1929-1932). In each year volumes were considerably higher offshore; north-south differences varied from year to year. Average volumes in 1930 were about triple those of the low year (1929) in both the southern sector and the total study area, and intermediate in the next two years. Volumes were considerably higher than in winter with averages ranging from 34-128 ml/100m^3 in the southern sector, 47-123 ml/100m^3 in the total study area. Our data for May 1977 (Table 4-17) show very large increases from winter levels of biomass, at some stations by an order of magnitude. Inshore biomass was low off Virginia, but quite high further north. Individual collections yielded maximum estimates of 732 ml/100m^3 at Station D1 (202 μm net) and 826 ml/100m^3 at Station N3 (505 μm net). The maximum volume observed by Bigelow and Sears was 565 ml/100m^3 (3,288cc/standard haul).

Spring volumes in our 202 µm collections averaged 221, 295, and 158 ml/100m³, respectively, in the southern transect, the New Jersey transect, and at stations B5 and A2; comparable averages for 505 µm collections were 66, 268, and 111 ml/100m³. High offshore volumes off Virginia were due primarily to salps, while mid-shelf New Jersey peaks were due to an abundance of the boreal Calanus-S. elegans community, following the cold winter of 1977.

Averages of biomass in our survey were, therefore, similar to, or somewhat higher than those reported by Bigelow and Sears (1939) for the years 1929-1932. Our higher estimates, however, may stem from use of a bongo sampler, a well-recognized improvement in sampling gear over conventional conical nets.

Jeffries and Johnson (1973) summarized the available estimates of biomass from the Middle Atlantic Bight, but none of the tabulated studies, most of which are from estuarine or coastal areas, are directly comparable to this one. The two shelf stations of Grice and Hart (1962) lie beyond our most northerly stations; others within the latitudes of interest to us are in estuarine waters. The best source of information for biomass of zooplankton in the Middle Atlantic Bight should eventually be the MARMAP surveys currently being conducted by the National Marine Fisheries Service. Plankton volumes from some of the earliest cruises by the R/V Dolphin were included in a mistitled report by Clark et al. (1969), easily overlooked in a search for biomass data. Since none of the tows in these surveys, apparently, were extended below 33m, direct comparison with our data would be difficult. General trends in biomass are evident, however, from the plots in Clark et al. Highest plankton volumes occurred in spring and summer of 1966, particularly north of Delaware Bay. In fall, volumes were higher on the shelf off Chesapeake Bay. Variation across the shelf, as in our sampling, was conspicuous in the Dolphin data.

Diversity

There are several measures of diversity that may be applied to zooplankton collections. Three of these, the Shannon index (H'), evenness (J'), and Margalef's index, have been calculated and recorded, for each and every bongo and neuston collection obtained in this study. Diversity, as a characteristic of the collections, may vary with mesh size of nets, latitude of collecting sites, season of collection, and the heterogeneity of water masses being sampled. We have, through the course of this study, found Margalef's index of species richness to be somewhat more consistent and, with its larger range of values, more useful as a descriptor of zooplankton collections. Strömgren (1975), in a study of zooplankton diversity in Norwegian fjords, compared Shannon, Simpson, and Margalef indices and opted for the Simpson index (Simpson 1949) for ease of calculation. He found that the Shannon-Wiener index (H) and the Simpson index were closely correlated, as expected since both are based on probabilities, but found discrepancies in comparisons of Simpson's and Margalef indices. As noted also by Margalef (1961), these discrepancies occurred mostly in collections taken from waters of mixed origin. In a study of shelf waters, always mixed but in varying degree, the "discrepancies" may be of prime interest in characterizing collections and have contributed to our interest in Margalef's index.

Shannon and Margalef indices from bongo collections taken in the winter 1977 cruise (BLM06W) have been plotted in Figure 4-71 to demonstrate their relationship to each other, to the mesh size used for collection, and to independent results of sample clustering. The relationship between indices shows considerable scatter and is different in collections from 202 and 505 μm net. Generally, H' is higher in 202 μm collections at a given level of species richness than in 505 μm collections. The relationship also appears more curvilinear in 202 μm collections. The division between samples included in the two primary clusters of winter bongo collections is indicated on Figure 4-71 by a dashed line. Except for a single 202 μm collection at Station A2, this line is a straight diagonal through the point scatter. The fact that the divisional line is neither horizontal nor vertical rules out using only one index of diversity as a reliable separation of ecological entities; but, the lack of overlap between inner shelf and outer shelf and slope collections as plotted on Figure 4-71 demonstrates that, using combined indices, diversity is a characteristic of zooplankton collections that matches independent estimates of similarity based on species composition and abundance. By reference to Figure 4-70, it is also evident that collections of low diversity from the coastal and central shelf locations in winter were taken from stations having surface temperatures below 8°C and salinities <35 ppt. Higher diversity was found in collections at stations in mixed shelf-slope water. Diversity is, then, an ecologically meaningful characteristic of zooplankton collections, but apparently requires the measurement of more than a single index.

Species richness of neuston collections in the first year of sampling showed a seasonal offshore elevation in diversity (Grant 1977a) off New Jersey. Diversity of surface communities was relatively even across the shelf in winter and spring. Off Virginia (Figure 4-72), shelf-break and slope stations L4 and L6 yielded more diverse collections than inshore stations L1 and L2 throughout the year. In winter and spring the offshore increase in diversity occurred mostly in night collections.

Middle Atlantic Bight Neuston

The Importance of Neuston

The term "neuston", as broadly applied throughout this study, includes all the organisms subject to capture in the uppermost 10-12 cm of the sea. Neuston net collections include not only zooplankton

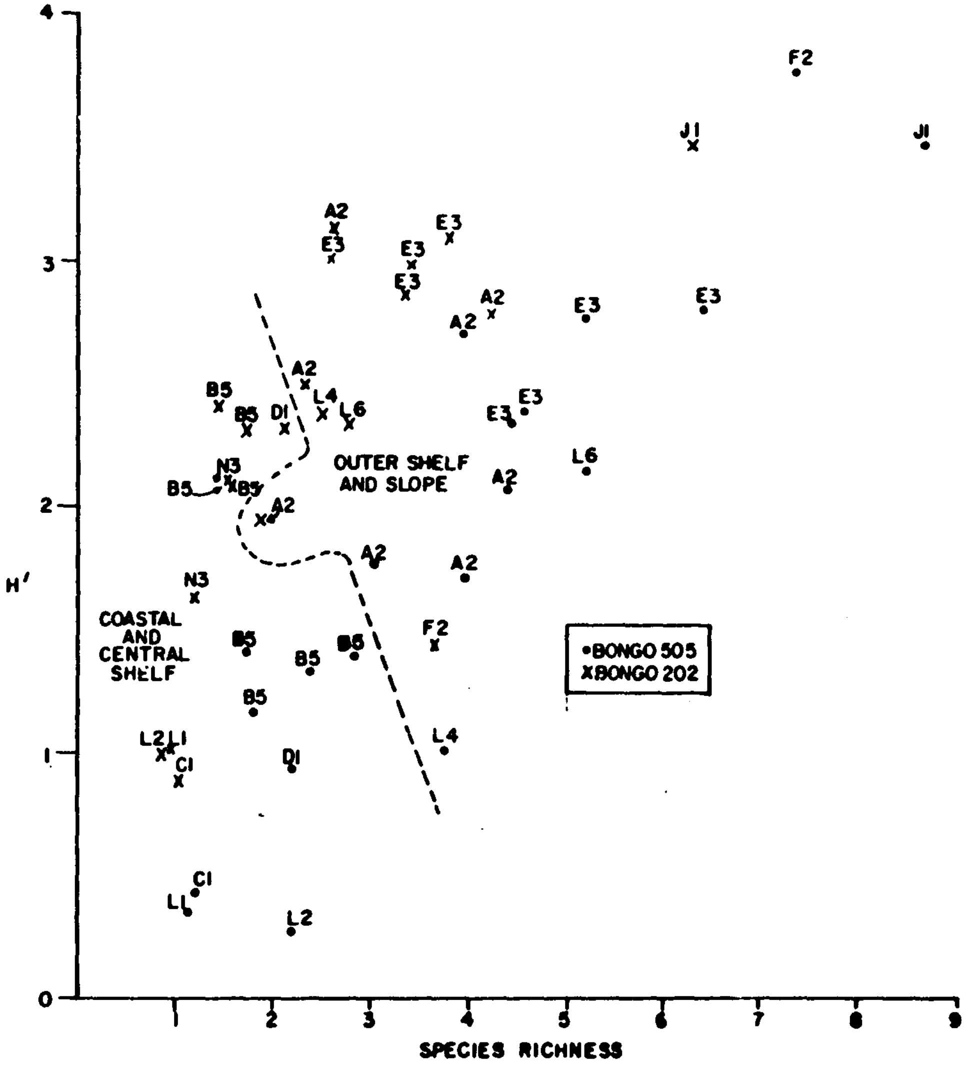

Figure 4-71. Relationship of Shannon (H') and Species Richness indices of diversity calculated from subsurface bongo collections, winter 1977. Dashed line separates primary clusters of collections from independent cluster

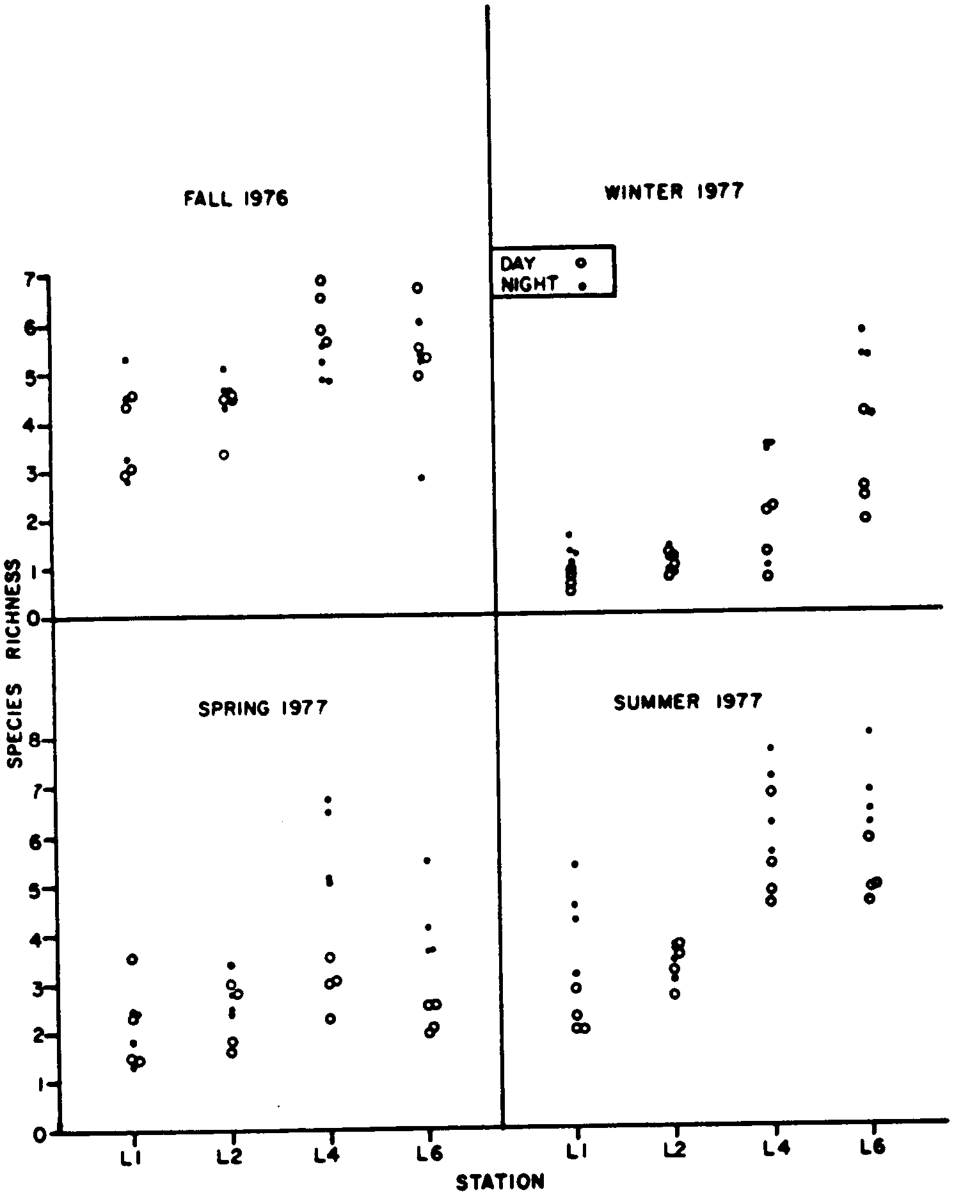

Figure 4-72. Diversity of neuston collections during four seasonal periods along the Virginia transect of water column stations.

species specially adapted to life at the surface, and thereby restricted to the upper few centimeters, but also species that migrate at night from deeper layers and early life stages of deeper-living, or benthic decapods and fishes. Because of its wide usage, we have retained the term "neuston" in this sense, rather than follow the perfectly logical suggestion of Banse (1975) to switch to the term "pleuston". Zaitsev (1970) first stressed the importance of the surface layer in reproduction of decapods and fishes. Although studies of open ocean neuston (Morris 1975; Berkowitz 1976) revealed the surface layer as relatively impoverished compared with the subsurface, the similarity of families and genera noted by Zaitsev to those of importance in the Middle Atlantic Bight suggested that the neuston of continental shelves might be somewhat richer, and of more significance to commercial fisheries, than that of the deep ocean. Our first year's results (Grant 1977a) showed that fish eggs and larvae of decapods numerically dominated 46.2% and 25.0%, respectively, of spring (June) 1976 neuston collections. In other seasons, copepods, dominants in most all conventional subsurface tows whatever the season, numerically dominated from 70 to 83% of neuston collections. The surface layer is of critical importance to the shelf decapods and fishes during the principal reproductive season of late spring and early summer.

Neuston sampling was expanded in our second year of sampling, when 300 collections were obtained and analyzed. Despite the earlier spring sampling dates (May) and generally cold conditions prevalent in 1977, a similar increase in dominance of fish eggs and decapod larvae was evident (Table 4-52). Primary differences in the two years were the added importance in 1977 of salps in spring and cladocerans in summer.

Obviously, any widespread degradation of the surface environment during the peak reproductive period of late spring and early summer could have a serious effect on survival and recruitment of those species important to the fisheries which depend on the surface layer as an early life habitat. Large oil spills such as the one resulting from grounding of the Argo Merchant could conceivably devastate a large portion of a species annual production of young, if occurring in the wrong place at the wrong time. Press reports after the Argo Merchant spill included statements to the effect that failure of the oil to sink prevented extensive damage, in apparent (and understandable) ignorance of neuston composition and abundance. Actually, two factors were influential in minimizing observable effects of this major (7.7 million gallons) spill: offshore winds and the season of occurrence (winter). Among the fishes, only cod and pollock eggs were present at the time of the spill (Grose and Mattson 1977) and the only abundant fish larvae were of *Ammodytes* sp., the sand launce. The latter were severely reduced in abundance within the immediate spill zone. There appeared to be differing effects of oil on the eggs of cod and pollock, with adherence of oil globules on the membranes of pollock eggs and subsequent death, but reduced evidence

Table 4-52. Percent of neuston collections, BLM05W-BLM08W, numerically dominated by copepods and other principal taxa in the Middle Atlantic Bight.

	Fall 1976	Winter 1977	Spring 1977	Summer 1977
Taxa N:	75	75	75	75
Copepods	76.0	73.3	37.3	34.7
Hyperiids	13.3	24.0	0	8.0
Salps	2.7	0	30.7	6.7
Fish Eggs	0	0	18.7	0
Decapod Larvae	1.3	0	13.3	0
Cladocerans	0	0	0	32.0
Chaetognaths	2.7	0	0	4.0
Siphonophores	0	0	0	9.3
Other	4.0	2.7	0	5.3

of oil contamination in cod eggs. Ingestion of oil was evident in copepods, not only in the visible slick area, but in surrounding stations as well. Since most decapods reproduce in warmer months, their larvae were not in the path of this December spill.

Information on neuston communities and the effects of floating oil on individual species is still too sparse to permit a realistic assessment of the economic impact of oil spills. The varying effects of oil on eggs of two closely-related fish species observed in the *Argo Merchant* study shows that all species may not be equally affected by oil spills. However, maximum effects can be expected among those species or life stages that are incapable of avoiding an oil spread. These include both species or stages lacking swimming capabilities (pelagic eggs and passively drifting zooplankton) and species highly adapted and restricted to the surface layer. Behavioral modifications in the presence of oil, as shown by Bigford (1977) for *Cancer irroratus* larvae, might also alter the normal diurnal migration of decapod larvae, conceivably increasing their exposure to, and entrapment in, floating oil.

Diel Patterns of Abundance

In the past two years of seasonal sampling, we have sampled 60 twenty-four hour stations to determine diel cycles of abundance among the dominant neustonts. Several patterns are evident from analysis of collected samples as diagrammed in Figure 4-73. The euneuston, species adapted to and restricted to the surface layer, along with meroneustonic floating fish eggs that are incapable of directed movement, are found in fairly equal numbers throughout the day and night (Figure 4-73, IA), as might be expected. Euneuston showing this diel pattern include the isopod *Idotea metallica*, the copepod *Pontella meadii* and other pontellid copepods. The variation of this pattern indicated as IB, with a dip in abundance near midnight, was exhibited by the cyclopoid copepod, *Sapphirina ovatolanceolata*. Night migrants, or those species increasing in abundance at the surface in darkness, vary from strong migrators absent in the daylight hours (IIA) to species present throughout the day but in maximum abundance at night (IIB). The first group includes *Nannocalanus minor*, *Pleuromamma gracilis*, *Metridia lucens* and *Euchirella rostrata*, common copepods of the outer shelf, and the larvae of crabs, *Cancer* spp. The second category includes the most common shelf zooplankters, among them *Centropages typicus*, *Calanus finmarchicus* and *Centropages hamatus* (copepods) and the chaetognath *Sagitta elegans*. The final pattern is one of maxima at dusk and/or dawn (III), observed for barnacle larvae (presumably *Balanus* sp.) and the hyperiid amphipod *Parathemisto gaudichaudii*. The appearance of the latter in this pattern of abundance is of particular interest in that Chebanov (1965) and Zaitsev (1970) found the same diel cycle in the surface occurrence of the related Pacific species, *P. japonica*. They linked the bimodal peaks of *P. japonica* to feeding activity. *P. japonica* guts were

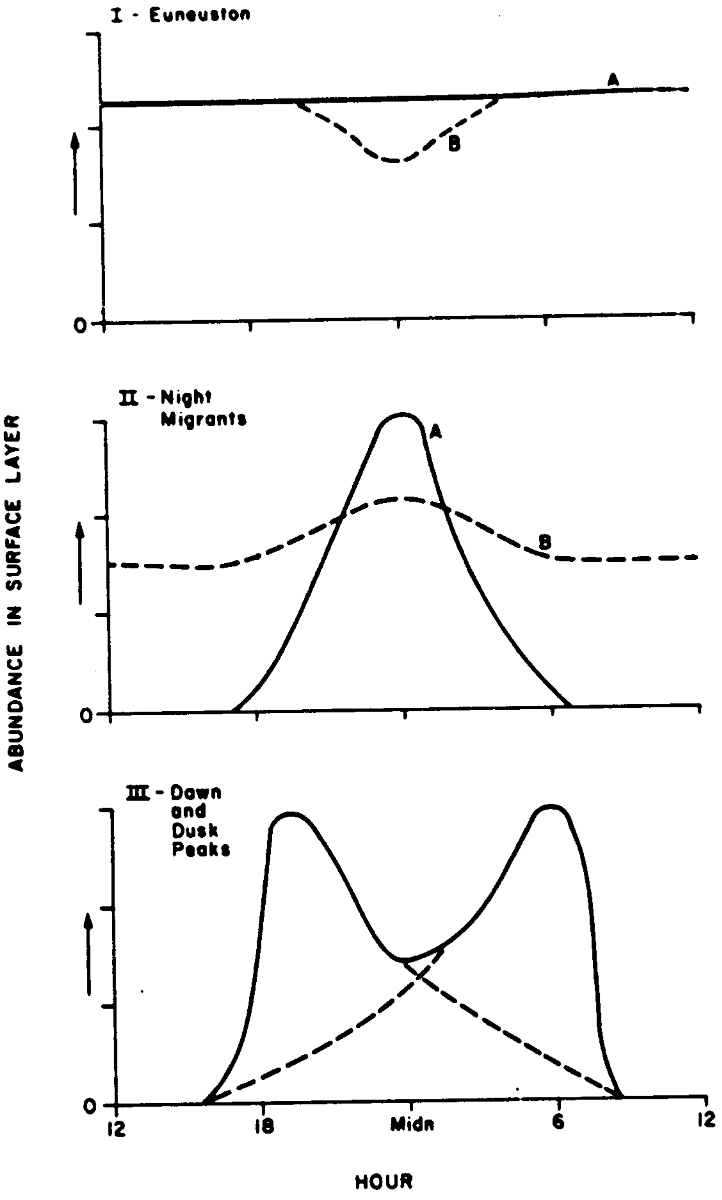

Figure 4-73. Diel patterns of abundance displayed by Middle Atlantic Bight neuston species.

packed with freshly ingested food at the dusk and dawn peaks. The primary prey species, Calanus tonsus, displayed a diel cycle similar to that of the night migrants shown in Figure 4-73 (IIA). The Middle Atlantic Bight species, P. gaudichaudii, may also be distributed in the neuston with maxima at dawn and dusk, as observed, because of feeding behavior. Their primary prey could be one of the strongly migrating copepods such as Nannocalanus minor or Pleuromamma gracilis.

Summary of Significant Findings

1. Biomass of zooplankton, measured as displacement volume, varied a) seasonally, with maximum in spring and minimum in winter, b) between north and south, with higher volumes in the south in fall and winter, but reversed in spring and summer, c) from inshore to offshore, with highest volumes along inner shelf in fall, at central shelf locations in winter and spring, then close inshore during summer, and d) with mesh size of net, volumes of 202 μm collections almost always higher than paired 505 μm collections.

2. Volume of neuston collections was extremely variable, usually increasing at a given station from midday low volumes to a maximum in late afternoon or night. Maximum catches occurred in swarms of the amphipod Parathemisto gaudichaudii or the salp Thalia democratica. Seasonal, latitudinal and inshore-offshore variation in neuston volume was superimposed on this general diurnal variation.

3. A general offshore increase in zooplankton diversity, evident in summer and fall off southern New Jersey during the first year of sampling, occurred throughout the year off Virginia in 1976-1977. Zooplankton was more diverse off Virginia, except in winter when diversity indices were at a minimum and were uniformly low along the shelf. In the second year, high diversity persisted through winter and spring at the most offshore stations L6 and J1. Diversity was highest throughout the study area in summer.

4. The year-round dominance of shelf zooplankton by Centropages typicus during the first year of sampling was halted in spring 1977 by the southward spread of the boreal Calanus finmarchicus - Sagitta elegans community. This distinct difference between the two sampling years was an obvious effect of the exceptionally cold winter of 1977. Remnants of this community were still evident off Virginia in late August. Such dramatic annual differences in species composition and abundance point out the fallacy of short-term baseline surveys.

5. Replication of bongo sampling showed only 23% of the variance occurring within replicate sets of biomass estimates, after discounting mesh size differences. Differences between stations accounted for 33% and seasonal differences the remaining 44% of

total variance. Species dominance was the same or similar in replicate tows at a given station, lending a degree of confidence to our stress in this study on community structure, rather than estimates of absolute abundance. Calculations showed that reliable and repeatable estimates of abundance could be expected in only half the replicated stations.

6. In any season of the year, Middle Atlantic Bight zooplankton tended to occur in three communities: 1) a coastal community presumably associated with the Coastal Boundary Layer, 2) a central shelf community comprised of the dominant shelf species, and 3) an offshore community of slope and occasionally Gulf Stream species.

7. A consistent linking of inshore samples off Virginia with those from off New Jersey in the cluster analyses of second year sampling suggests continuity of the Coastal Boundary Layer throughout the Middle Atlantic Bight, and an avenue for the southward transport of seasonally alternating coastal species.

8. Clustering of neuston samples from all eight seasonal cruises at the inshore station off New Jersey (C1) yielded a classic picture of temperate coastal zooplankton, with samples from a given season of the two years linking first, followed by clustering of winter and spring samples and summer and fall samples.

9. Subsurface zooplankton fauna, except at the coastal station C1, differed strongly between the two years of sampling. One could not reasonably predict, beyond a few miles of the coastline, which of the various communities observed might be encountered in a third year.

10. Neuston collections off New Jersey showed a progressive change from a highly structured and predictable pattern in coastal waters to a relatively unpredictable faunal structure at the shelf edge, the latter dependent on incursions of offshore waters and the presence or recent passage of anticyclonic Gulf Stream eddies.

11. There was a close correlation of surface fauna and physically-defined water types except in summer, when waters classified as "coastal" because of reduced salinity supported both central shelf and offshore fauna within zones of the shelf. Time series of discrete-depth bongo tows are needed to provide data useful in relating subsurface water types to zooplankton communities.

12. Principal factors influencing the faunal composition of Middle Atlantic Bight zooplankton are 1) the general southward drift of shelf waters and a northern source of the boreal Calanus finmarchicus - Sagitta elegans community, 2) the southwestward

passage of anticyclonic eddies from the Gulf Stream along the shelf edge, their transport of subtropical species and mixing with shelf waters, and 3) the Coastal Boundary Layer, a flow-trapped structure that concentrates species along the coast, and funnels them southward. The composition and abundance of zooplankton at any particular point in time apparently depend upon the relative strength of these factors in the immediate past and the existing seasonal water temperatures.

13. Diel cycles of the dominant species found in the surface layer fall into three generalized patterns: 1) a fairly even abundance throughout a 24-hour period, as seen for surface-restricted species such as pontellid copepods, 2) increases at night in varying degrees ranging from only slight increases to sharp increases following daytime absence, and 3) peaks at dawn and dusk.

14. Two years of neuston collections have confirmed the importance of the surface layer as a habitat ("incubator") for reproductive stages of Middle Atlantic Bight decapod crustaceans and fishes. These are often numerically dominant in spring and early summer collections. Any widespread degradation of the surface layer during this annual peak in reproduction could have a serious effect on survival and recruitment of many commercially and trophically important species, including:

    Loligo and *Illex*, squids
    Callinectes sapidus, blue crab
    Cancer spp., rock and jonah crabs
    Homarus americanus, American lobster
    Geryon quinquedens, deep sea red crab
    Urophycis spp., hakes
    Merluccius bilinearis, silver hake
    Pomatomus saltatrix, bluefish
    Coryphaena hippurus, dolphin
    Mugil curema, mullet
    Scomber scombrus, Atlantic mackerel
    Sarda sarda, Atlantic bonito
    Peprilus triacanthus, butterfish
    Centropristis striata, black sea bass
    Limanda ferruginea, yellowtail flounder

    all of which, along with countless other species, utilize the surface layer of Middle Atlantic Bight for development of young.

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