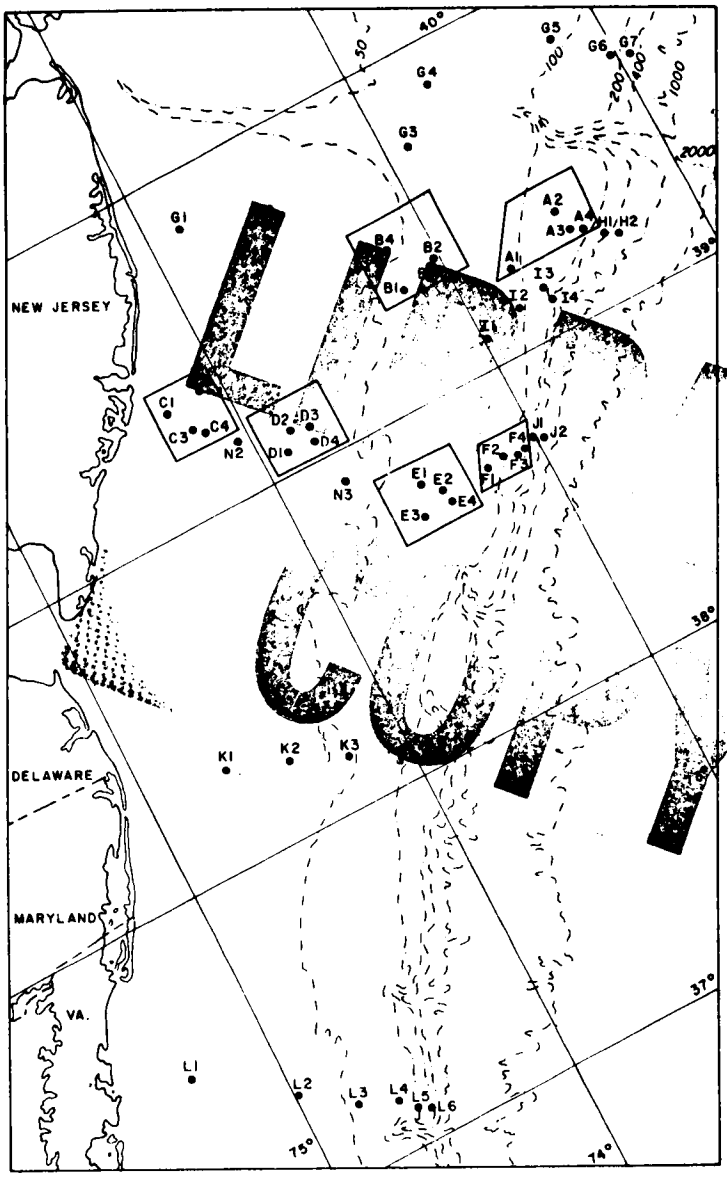
MIDDLE ATLANTIC OUTER CONTINENTAL SHELF ENVIRONMENTAL STUDIES

VOLUME II-A. CHEMICAL AND BIOLOGICAL BENCHMARK STUDIES



Conducted by the

Virginia Institute of Marine Science
Under Contract No. 08550-CT-5-42

With the

Bureau of Land Management
United States Department of Interior

M.P. LYNCH
Program Manager

B.L. LAIRD
Report Coordinator

VIRGINIA INSTITUTE OF MARINE SCIENCE
Gloucester Point, Virginia 23062

William J. Hargis, Jr., Director

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This report has been reviewed by the Bureau of Land Management and approved for publication. The opinions expressed in this report are those of the authors and not necessarily those of the Bureau of Land Management, U. S. Geological Survey, U. S. Department of Interior, the Virginia Institute of Marine Science, or the Commonwealth of Virginia.

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ACKNOWLEDGEMENTS

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M. P. Lynch
B. L. Laird

LIST OF ABBREVIATIONS

AA	atomic absorption
AIBS	American Institute of Biological Sciences
AMP	acid mucopolysaccharide
AOML	Atlantic Oceanographic & Meteorological Laboratories
APHA	American Public Health Administration
API	American Petroleum Institute
ATP	adenosine triphosphate
BCTWCM	Baltimore Canyon Trough Wave Climate Model
BGM	basal growth medium
BLM	Bureau of Land Management
CBL	Coastal Boundary Layer
CNA	Center for Natural Areas
CPY	chitin peptone yeast
CTD	conductivity/temperature/depth
DHPS	differential hydrostatic pressure sensor
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DOC	dissolved organic carbon
EDS	Environmental Data Service
EOF	end of file
EPA	Environmental Protection Agency
ESWB	enriched seawater broth
GC-MS	gas chromatography-mass spectrometry
GMA	glycol methacrylate
GMT	Greenwich Mean Time
HC	petroleum degrading bacteria
HET	heterotrophic bacteria
HM	heterotrophic medium
HMPM	hexamethyl phosphoramide
IEEE	Institute of Electrical & Electronics Engineers
MESA	Marine Ecosystems Analysis Program
MPN	most probable number
NASA	National Aeronautics & Space Administration
NBS	National Bureau of Standards
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic & Atmospheric Administration
NODC	National Oceanographic Data Center
NSF	National Science Foundation
OCS	Outer Continental Shelf
PAF	phosphate-buffered, acrolein-formaldehyde
PDR	precision depth recorder
PIXE	proton-induced x-ray emissions
POC	particulate organic carbon
SAG	seawater acrolein-gluteraldehyde
SBT	small biological trawl
TRIGOM	The Research Institute of the Gulf of Mexico
TOC	total organic carbon
URI	University of Rhode Island
USCG	United States Coast Guard
USGS	United States Geological Survey
VARC	Virginia Associated Research Campus
VIMS	Virginia Institute of Marine Science
VSWCM	Virginian Sea Wave Climate Model
WHOI	Woods Hole Oceanographic Institution
XBT	expendable bathythermograph

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[1]Detailed Tables of Contents are provided at the beginning of each chapter.

[2]Appendices are provided on microfiche at the end of Volume IIB.

CHAPTER 1

INTRODUCTION

M. P. Lynch

CHAPTER 1

INTRODUCTION

M. P. Lynch

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. Outer continental shelves of the United States hold great interest among the oil companies for possible exploration and development of oil and gas resources to meet these needs. It is imperative, however, that environmental protection be provided from impacts associated with such activities.

The primary purpose of the Bureau of Land Management (BLM) Environmental Studies Program is to collect and analyze environmental information for inclusion in the decision making process associated with exploration and development of oil and gas resources on the outer continental shelf (OCS). 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. The determination of significant changes.

4. Location of concentrations of economically important living resources in proposed lease areas.

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

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

This report summarizes the research efforts of the Virginia Institute of Marine Science (VIMS) in the outer continental shelf region of the Middle Atlantic Bight from 1 October 1975 to 30 September 1976 under Contract No. 08550-CT5-42 with the Bureau of Land Management, U.S. Department of the Interior.

The principal objectives of the field studies conducted are to provide chemical and biological benchmark or baseline data against which

possible changes as a result of oil and gas exploration and exploitation activities in the region can be measured.

More specifically, the Middle Atlantic chemical and biological benchmark studies and their supporting special studies had as goals during the initial year:

--- to characterize the water column in terms of the 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.

--- to characterize the bottom community in terms of 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.

--- to summarize the shelf hydrographic and meteorological characteristics such as temperature, salinity, dissolved oxygen, and micronutrients during the four sampling seasons with particular emphasis on frontal systems and water mass identification.

--- to describe the histopathology of selected epifaunal and infaunal species and discuss histopathological conditions in relation to hydrocarbon and trace metal concentrations in the selected species.

--- to characterize 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 hydrocarbons and trace metals in the water column.

--- to discuss temporal and spatial hydrocarbon degradation potential of microbial populations in surficial water and sediments and to determine the effect of hydrocarbon products on this potential and the mineralization of chitin and cellulose, the normal substrates for microbial populations.

--- to extend the Virginian Sea Wave Climate Model for the region from Cape Henlopen, Delaware to Cape Hatteras, North Carolina, to Long Island, New York.

The major portion of the benchmark and special studies 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 trace metal analysis and the University of Virginia for foraminifera analysis. A listing of responsbile principal investigators and associate principal investigators is provided in Table 1-1.

Liaison was established between VIMS and the USGS and the Environmental Data Service (EDS) 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.

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 a Memorandum of Understanding (08550-MU5-33) 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. An executive summary of the USGS work during the period 1 July 1975 - 30 June 1976 follows this summary. The final report of their work is included as Volume III with the final report of the VIMS contract (Volume II).

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.

Sediments collected during the 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 disgestates were analyzed for barium and vanadium.

VIMS attempted to collect 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 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 Agreement No. AA-550-IA6-3 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, will be used by VIMS in continuing wave model studies. The Environmental Data Service (EDS) 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 the comparable element in the BLM benchmark study.

Report Format

This report is presented in 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 organic carbon and nitrogen data. The remaining

Table 1-1. Program Elements and Responsible Principal Investigators, Contract 08550-CT5-42.

Program Elements	Principal Investigator(s) Associate Principal Investigator(s)
I. Principal Elements	
Benthic Studies	D. F. Boesch J. Kraeuter (megabenthos) K. Serafy (macrobenthos) L. Watling (Univ. Delaware, taxonomic consultant) R. Ellison (Univ. Virginia, foraminifera) M. Nichols
Hydrocarbon Studies	C. Smith W. MacIntyre (December 1976 - May 1977) C. Su (laboratory analyses) R. Bieri (GC-MS) K. Cueman
Trace Metal Studies	R. Huggett R. Harris R. Jolly (VARC, PIXE analysis) G. Grant (VARC, AA analysis)
Zooplankton-Neuston Studies	G. Grant
Bacteriological Studies	H. Kator
Histopathological Studies	F. Perkins C. Ruddell
II. Supporting Elements	
Physical Oceanography and Meteorology	E. P. Ruzecki C. Welch D. Baker
Carbon Analysis	M. Champ (American University)
Nitrogen Analysis	R. Wetzel
Sediment Grain Size	R. Byrne

Table 1-1 (concluded)

Program Elements	Principal Investigator(s) Associate Principal Investigator(s)
II. Supporting Elements (cont'd)	
Program Management	M. P. Lynch J. Jacobson (January 1976 - September 1976) B. Laird (reports) J. Brokaw (logistics)
Data Management	G. Engel
III. Special Studies	
Baltimore Cnayon Trough Wave Climate Model	V. Goldsmith
Degradation (Bacterial) Studies	H. Kator

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

Agency (Project)	Agency Liaison	VIMS Liaison
USGS	D. Folger	M. P. Lynch
EDS	K. Hughes	G. Engel
Middle Atlantic Physical/ Meteorological Summary	G. Falk	E. P. Ruzecki
NODC Archiving	S. Marcus	G. Engel

chapters discuss the major program elements Zooplankton-Neuston (Chapter 4), Benthos (Chapters 6 and 7), Trace Metals (Chpater 8), Hydrocarbons (Chapter 9), Histopathology (Chapter 10), Bacteriological Benchmark and Special Studies (Chapter 11), and the Baltimore Canyon Trough Wave Climate Model (Chapter 12).

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 IIB as Appendices I, II, and III, respectively. Computer programs developed for this contract have been submitted to BLM.

Personnel

Contract monitoring personnel within BLM responsible for this contract were Contracting Officers Authorized Representatives - Dr. J. Snyder and Dr. A. Horowitz; 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.

CHAPTER 2

BENCHMARK SAMPLING

D. F. Boesch
J. G. Brokaw

CHAPTER 2

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CHAPTER 2

BENCHMARK SAMPLING

Donald F. Boesch
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, 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 region to be studied during the first year of benchmark studies 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 in the Request for Proposal (RFP) and subsequent contract, VIMS was responsible for selection of the actual location of stations.

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 we will detail the rationale of station selection, list general station location data, and outline field methodology.

STATION LOCATIONS

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 sale (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. Additional water column studies have been added to cover these areas in the second year benchmark sampling program.

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

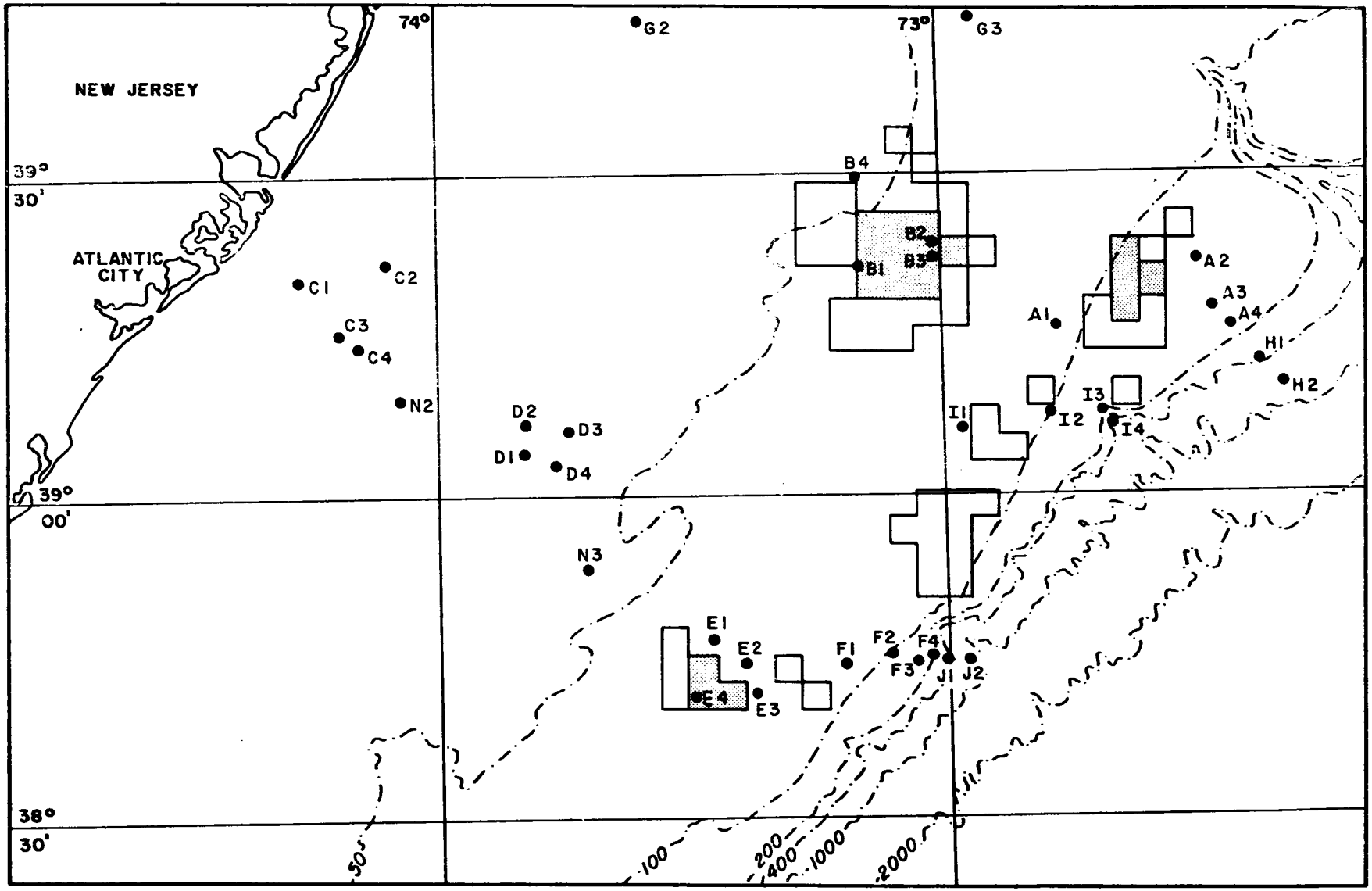

Figure 2-1. Stations in the central study area and tracts leased for oil and gas development in BLM sale 40. Shaded tracts are those of high industry interest as indicated by accepted bids of more than $100,000.

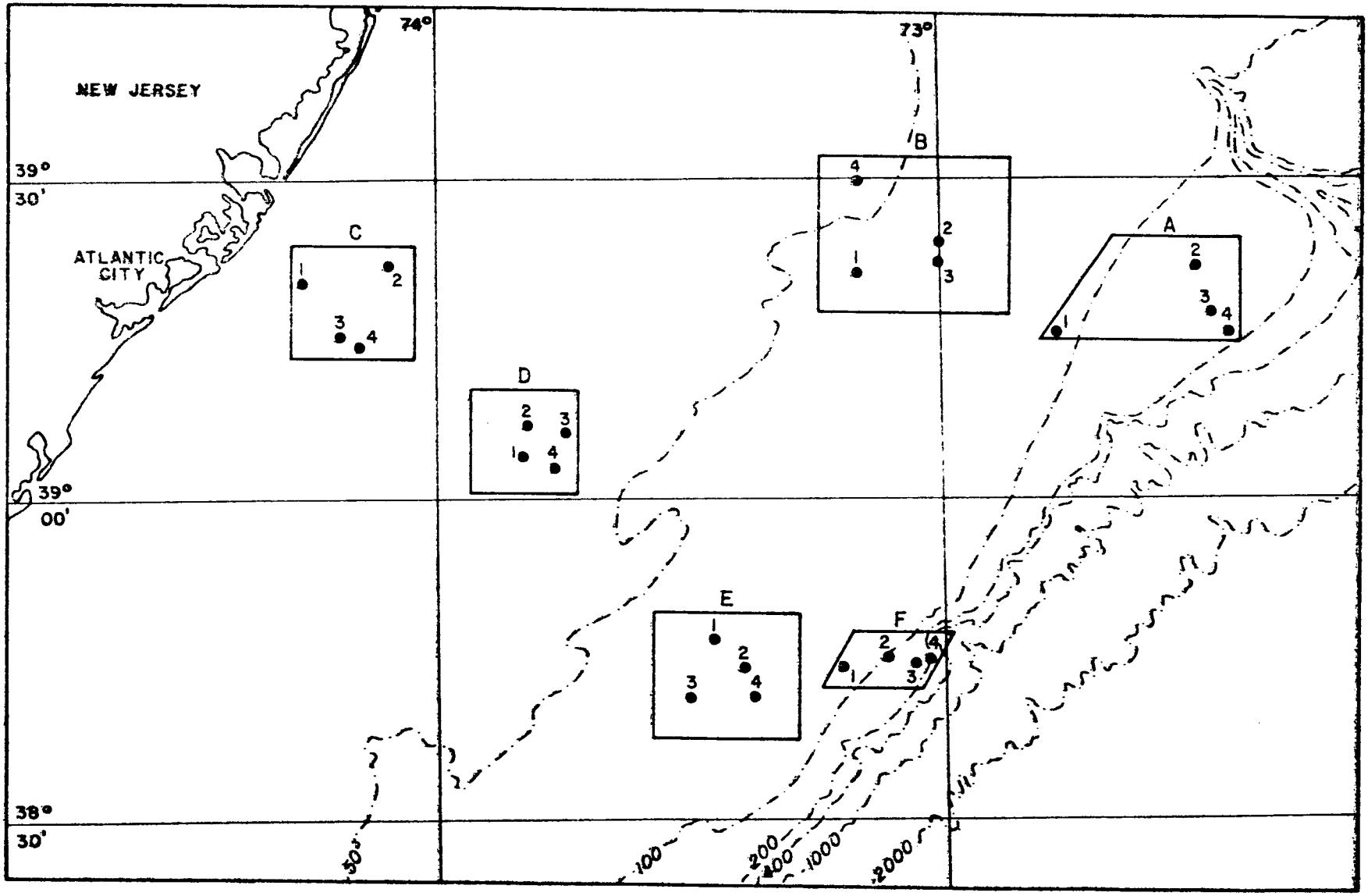

Figure 2-2. Cluster stations quarterly sampled for macrobenthos.

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 5-2.

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 1972; 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 (<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 (AOML) 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

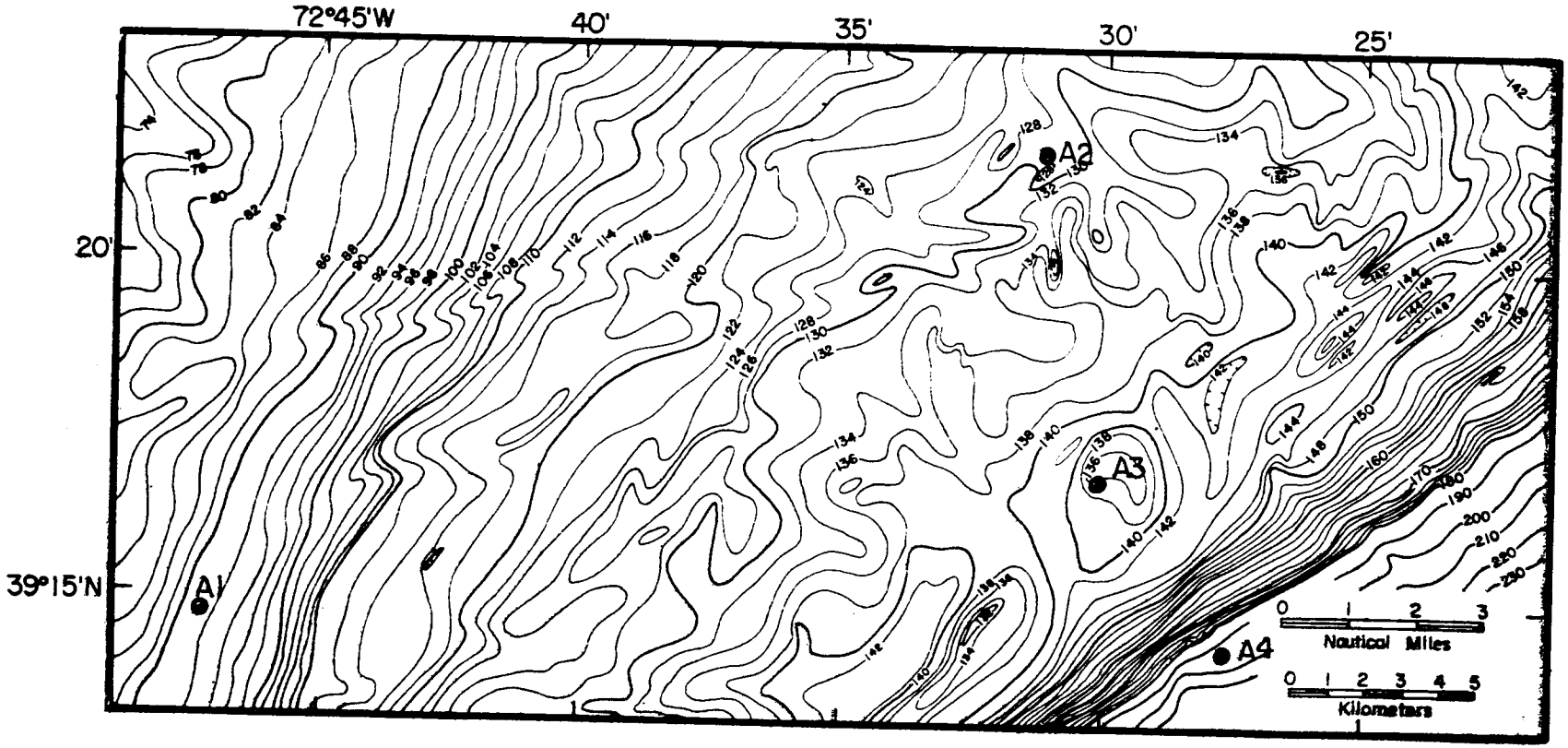

Figure 2-3. Cluster area A, bathymetry in meters. Source: U. S. Geological Survey.

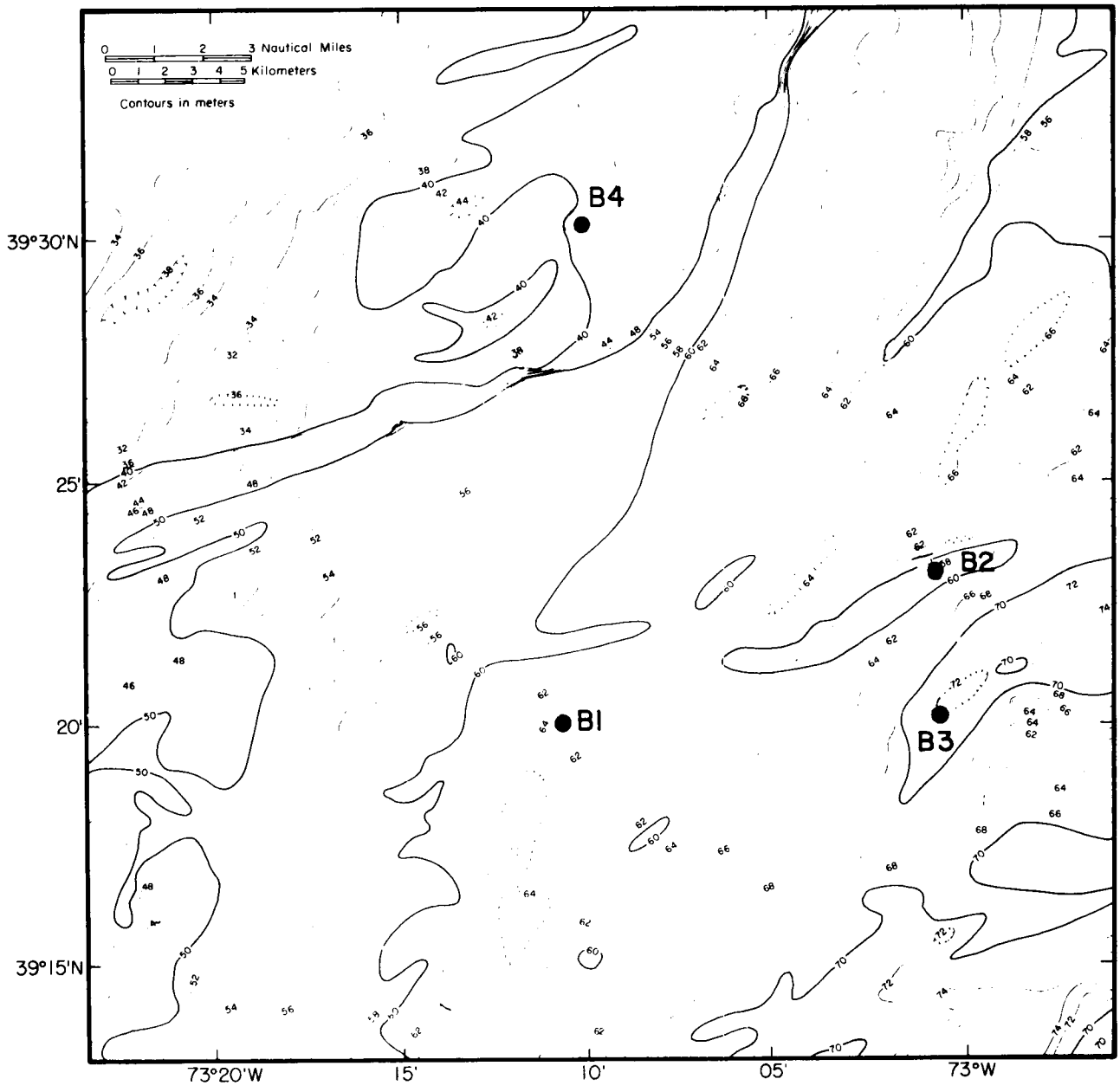

Figure 2-4. Cluster area B, bathymetry in meters. Source: U. S. Geological Survey.

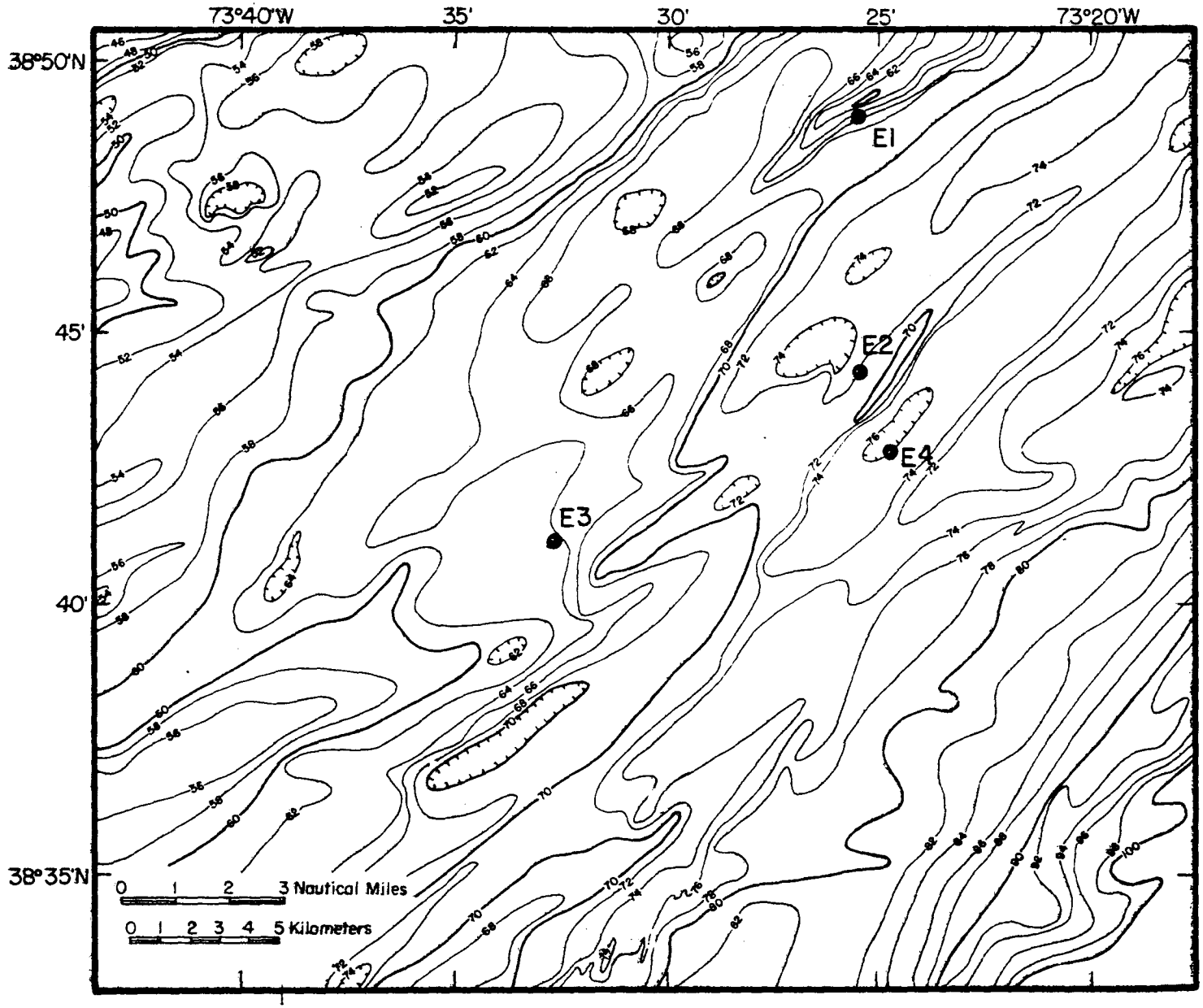

Figure 2-5. Cluster area E, bathymetry in meters. Source: U. S. Geological Survey.

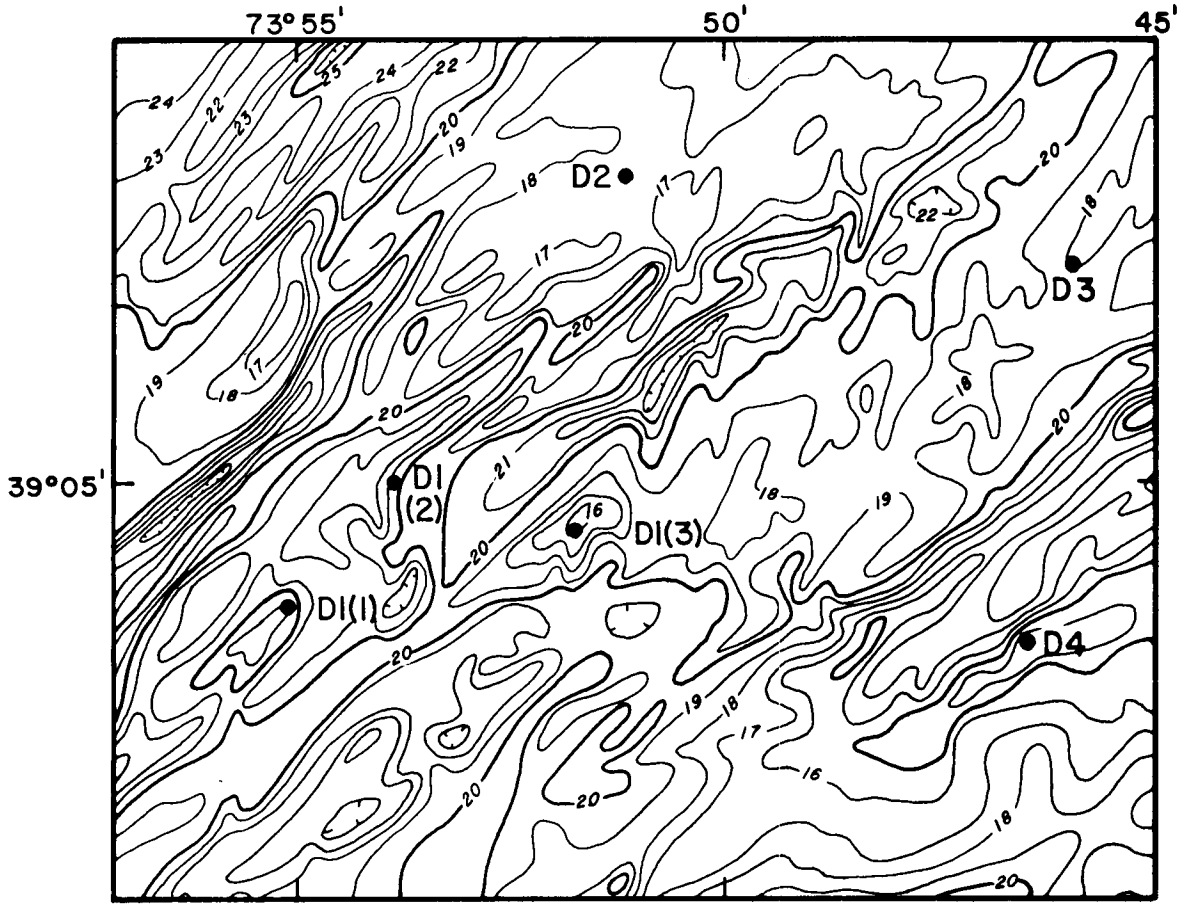

Figure 2-6. Cluster area D, bathymetry in fathoms. Source: U. S. Coast and Geodetic Survey and U. S. Bureau of Commercial Fisheries 1967.

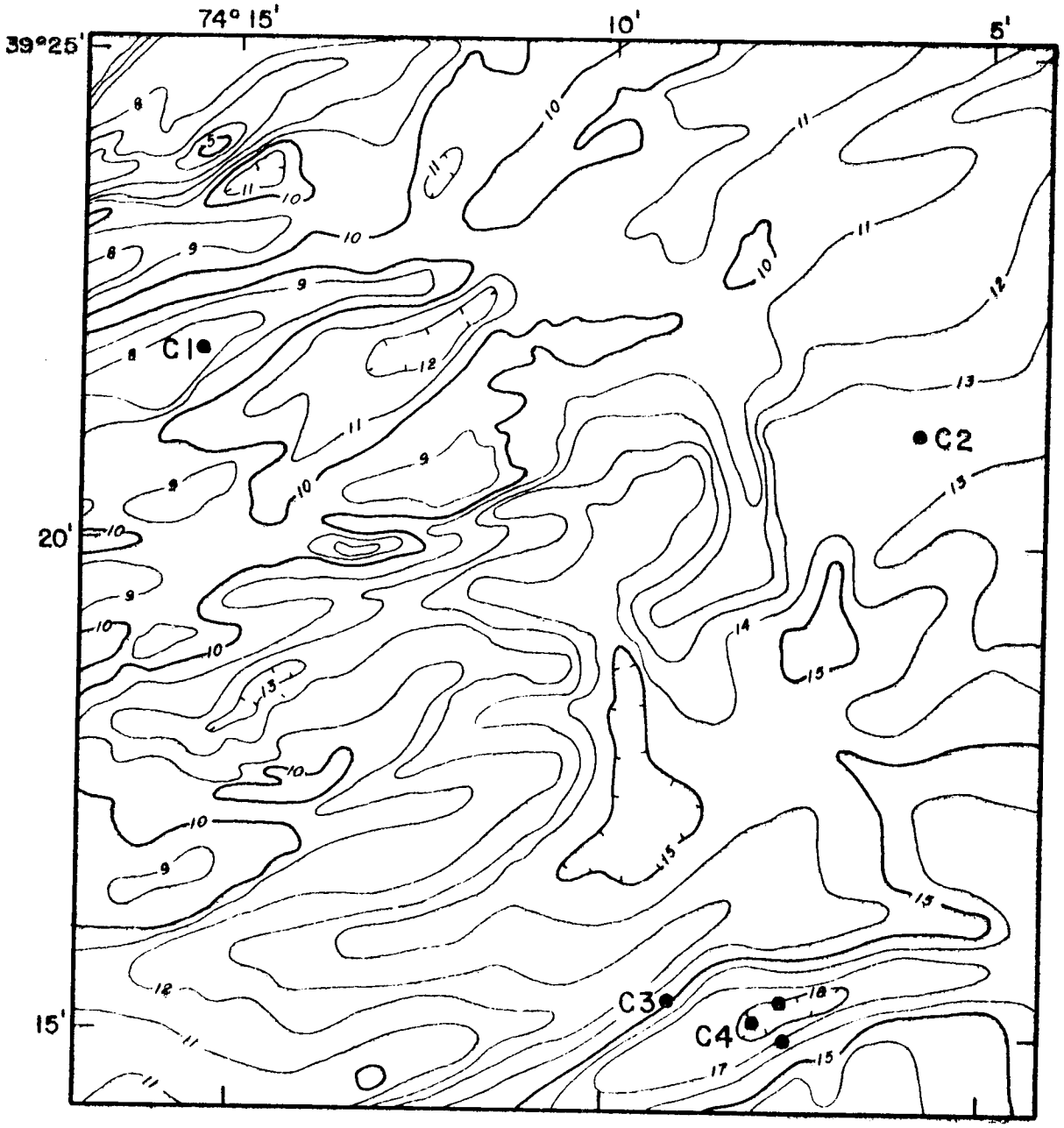

Figure 2-7. Cluster area C, bathymetry in fathoms. Source: U. S. Coast and Geodetic Survey and U. S. Bureau of Commercial Fisheries 1967.

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.

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.

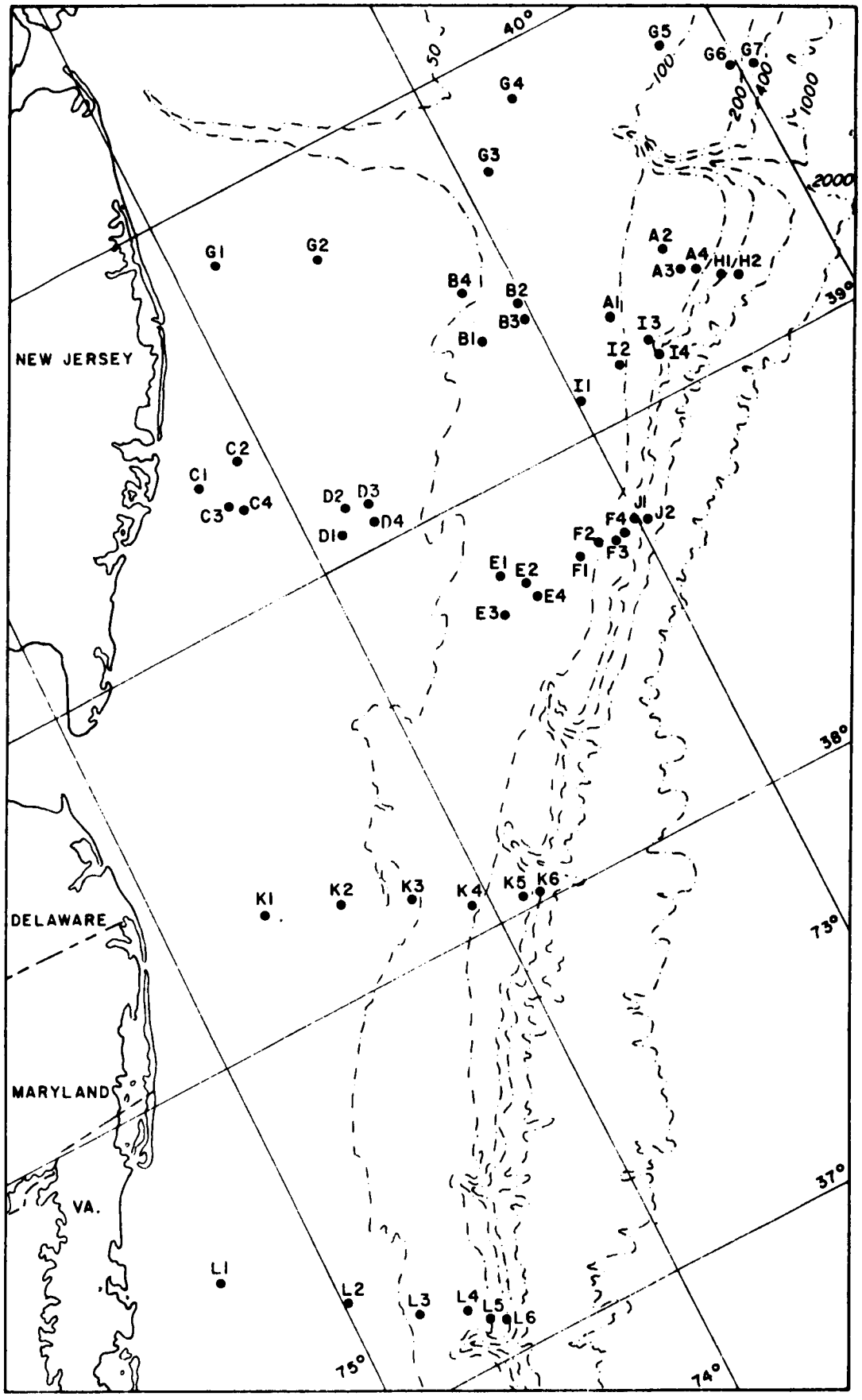

Figure 2-8. Stations sampled for macrobenthos.

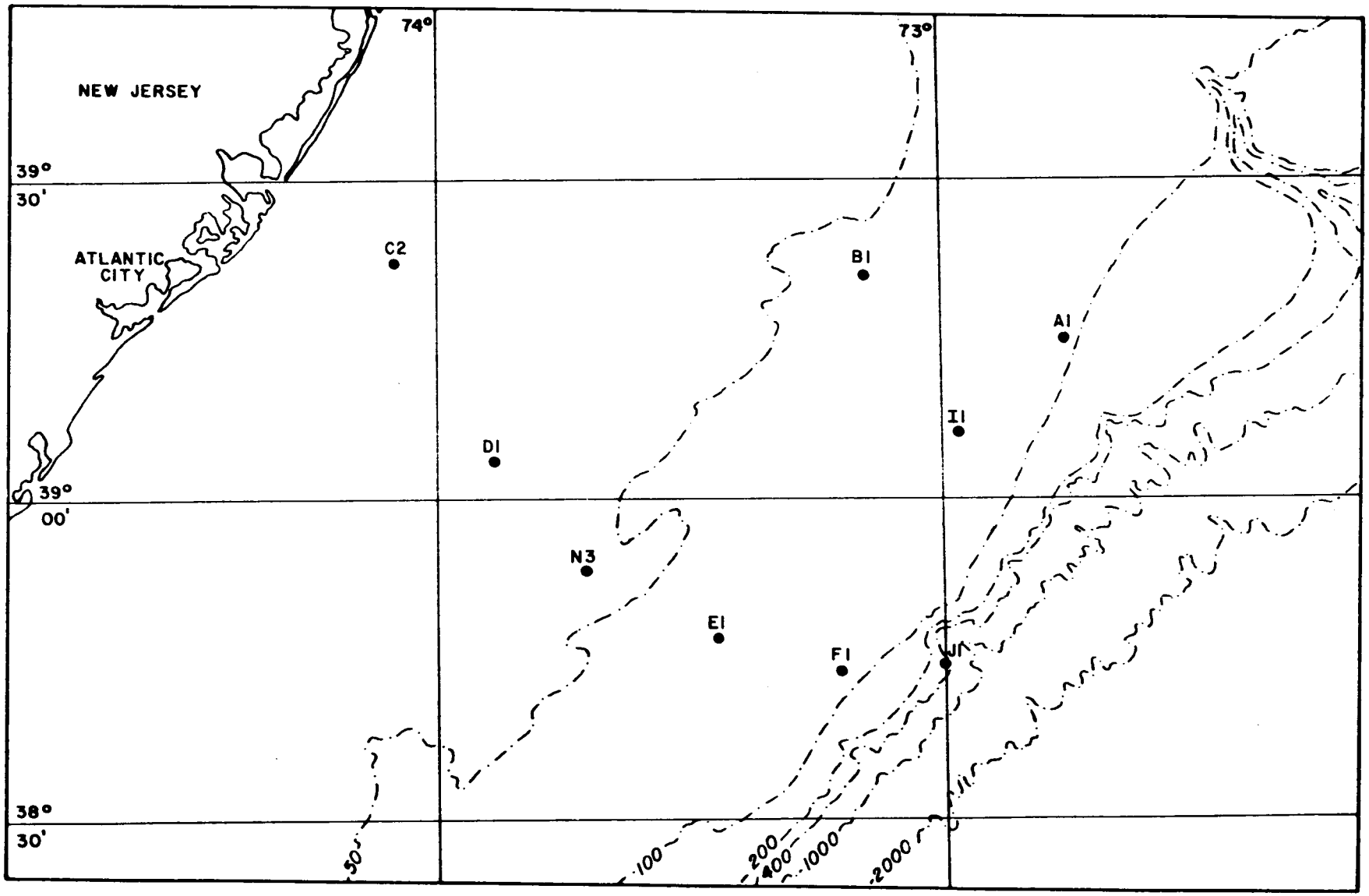

Figure 2-9. Stations sampled for megabenthos with dredge and trawl.

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, E2, 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).

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 recorder (PDR). Too strict adherence to previous Loran fixes and Loran and PDR malfunctions caused some minor problems during earlier cruises, 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.

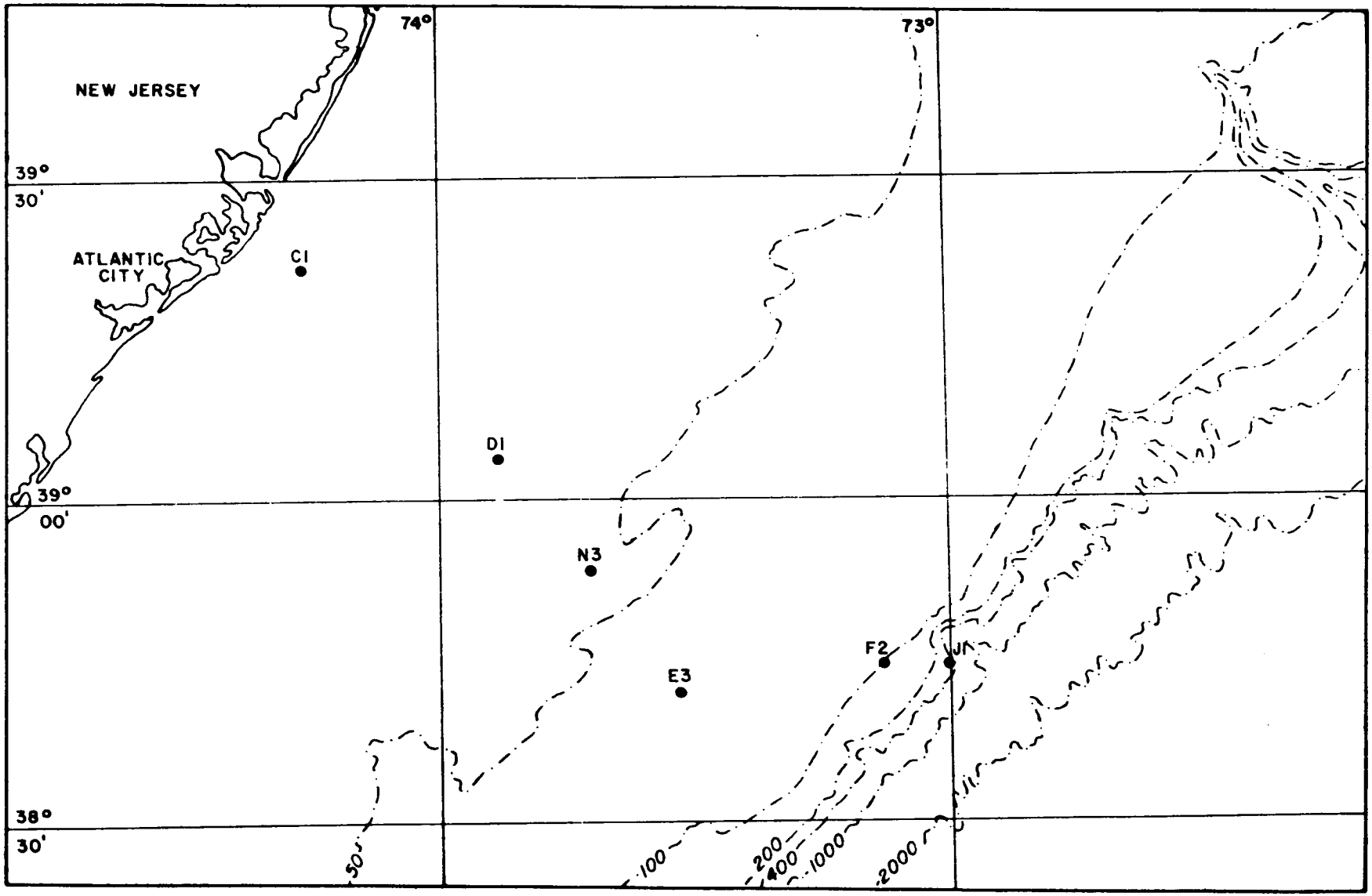

Figure 2-10. Water column stations.

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

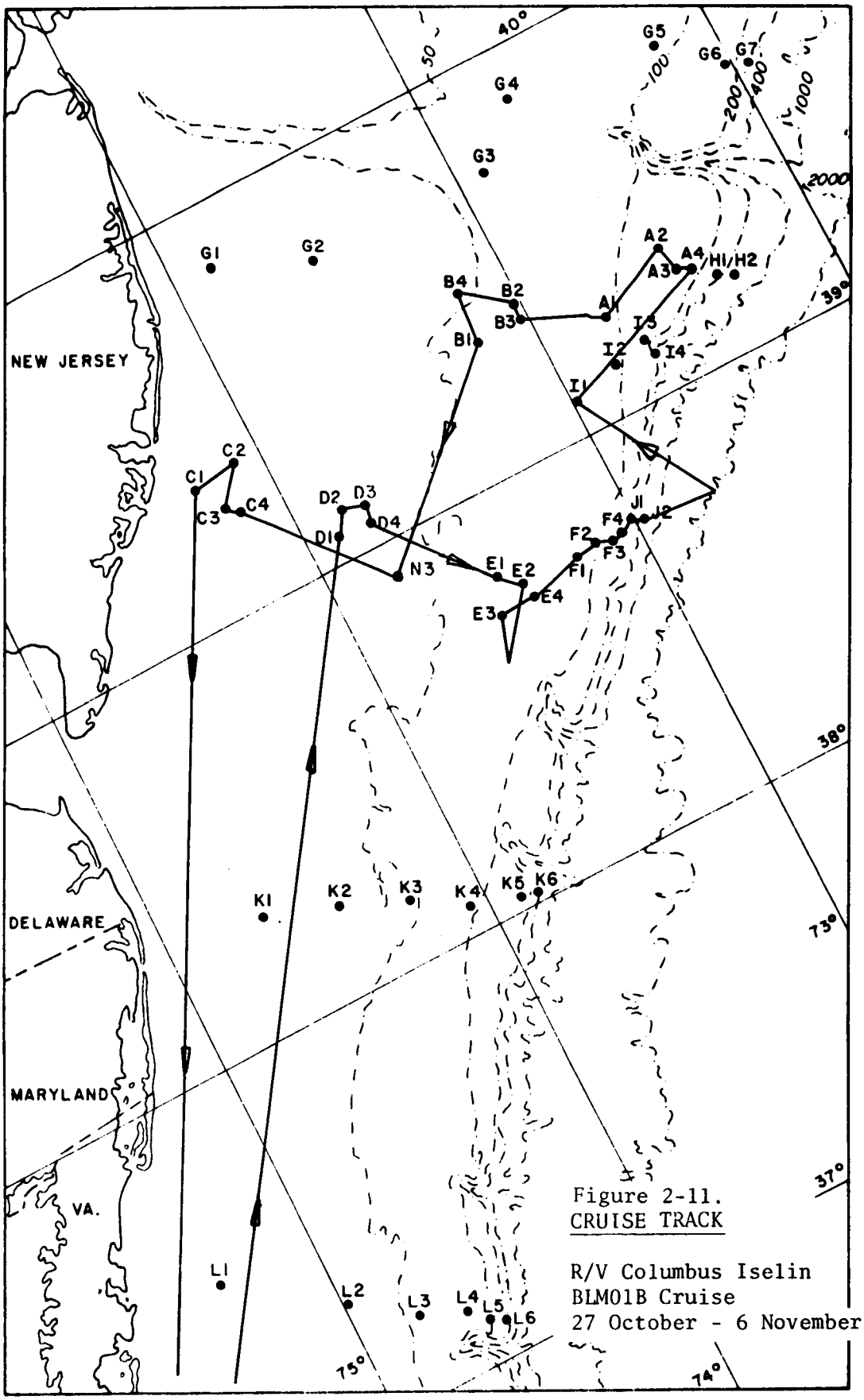

Figure 2-11.
CRUISE TRACK

R/V Columbus Iselin
BLM01B Cruise
27 October - 6 November 1975

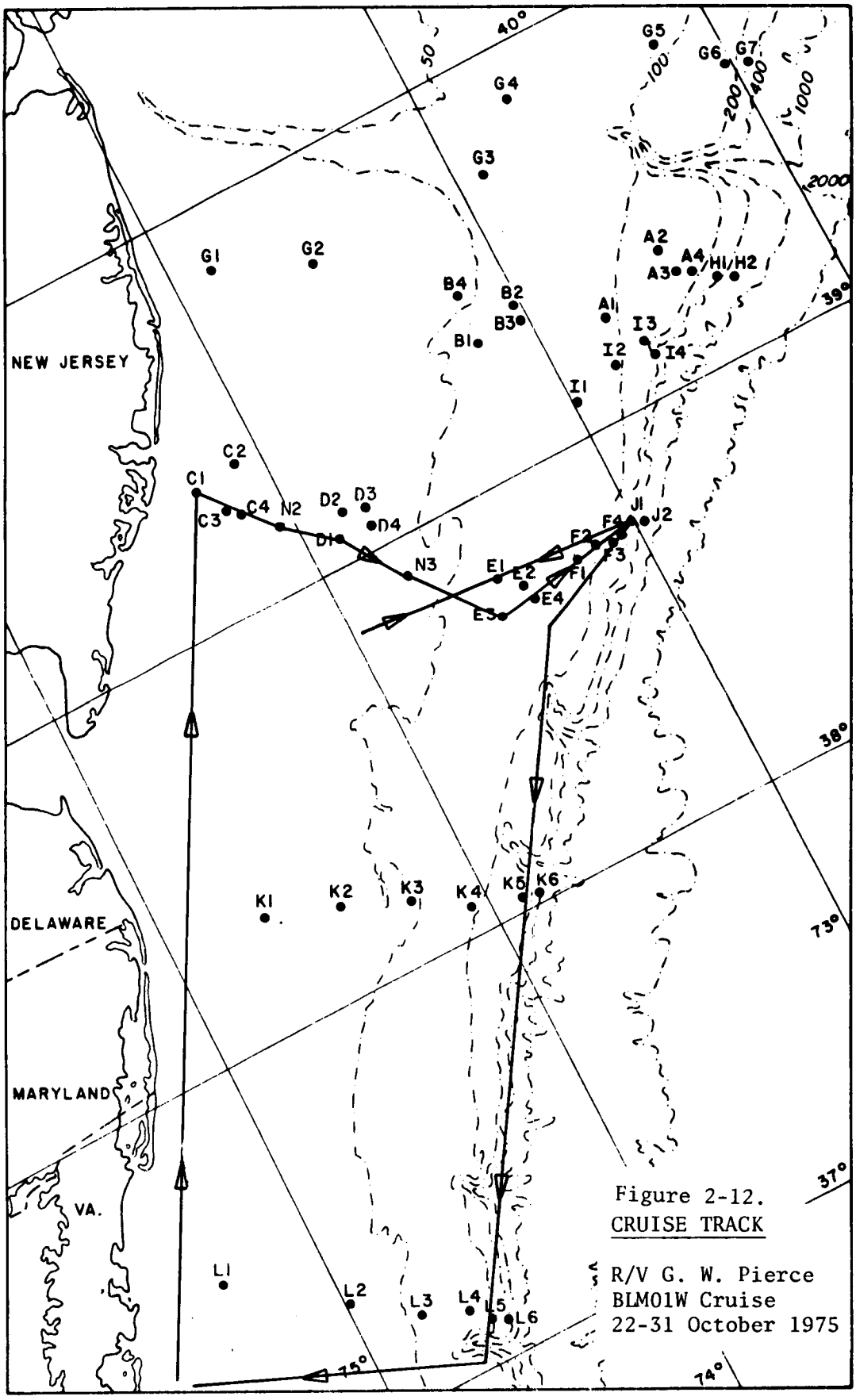

Figure 2-12.
CRUISE TRACK

R/V G. W. Pierce
BLM01W Cruise
22-31 October 1975

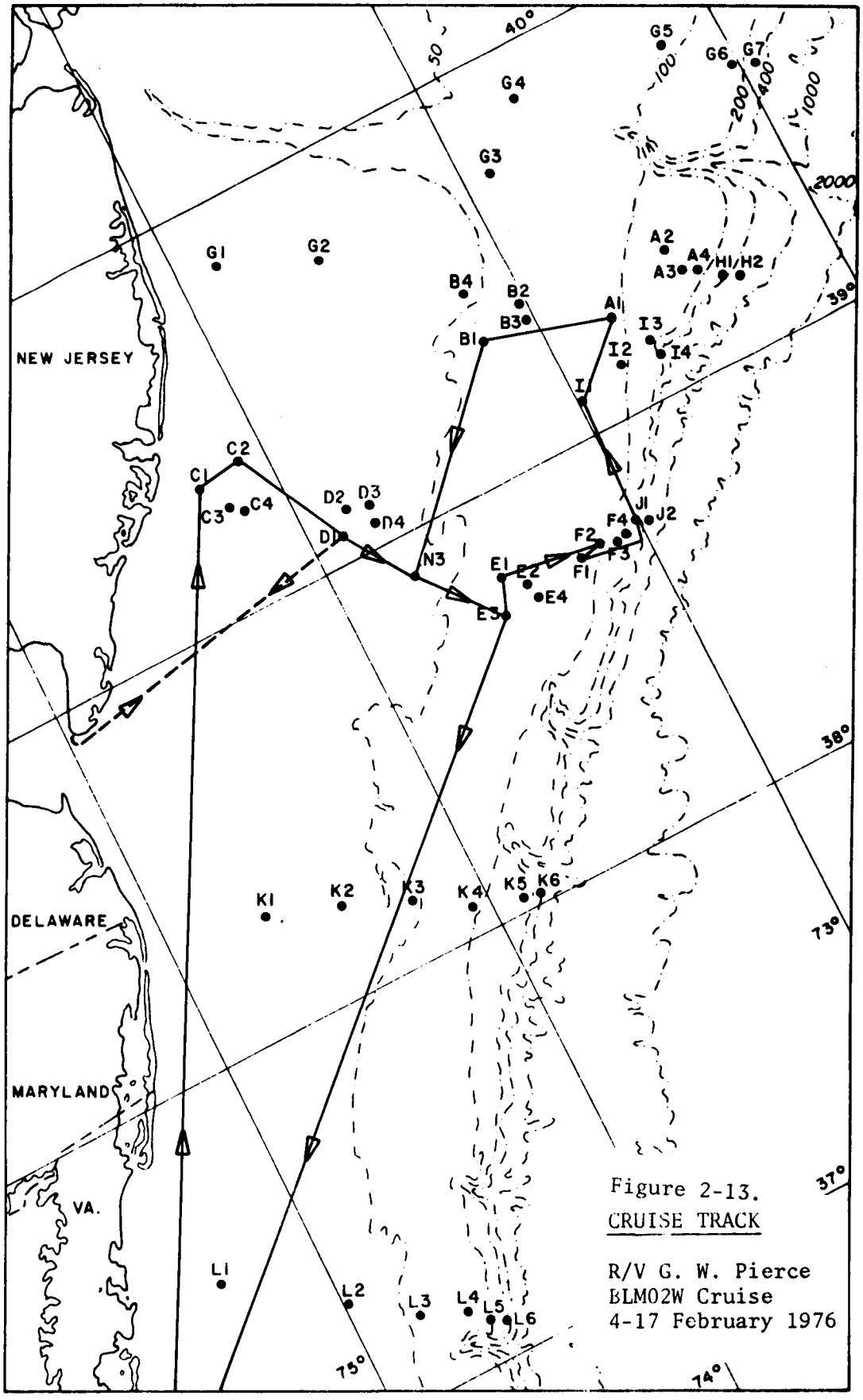

Figure 2-13.
CRUISE TRACK

R/V G. W. Pierce
BLM02W Cruise
4-17 February 1976

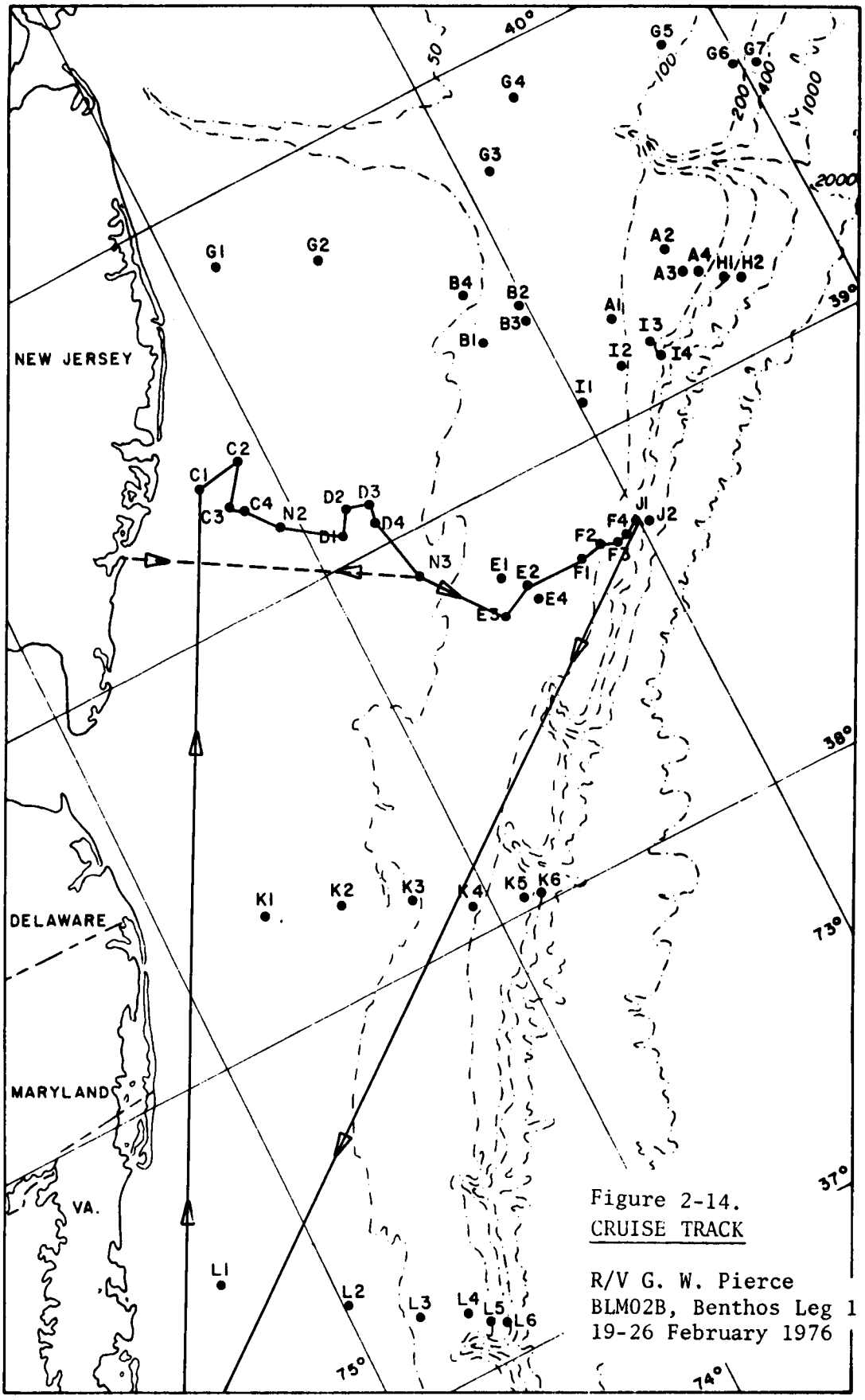

Figure 2-14.
CRUISE TRACK

R/V G. W. Pierce
BLM02B, Benthos Leg 1
19-26 February 1976

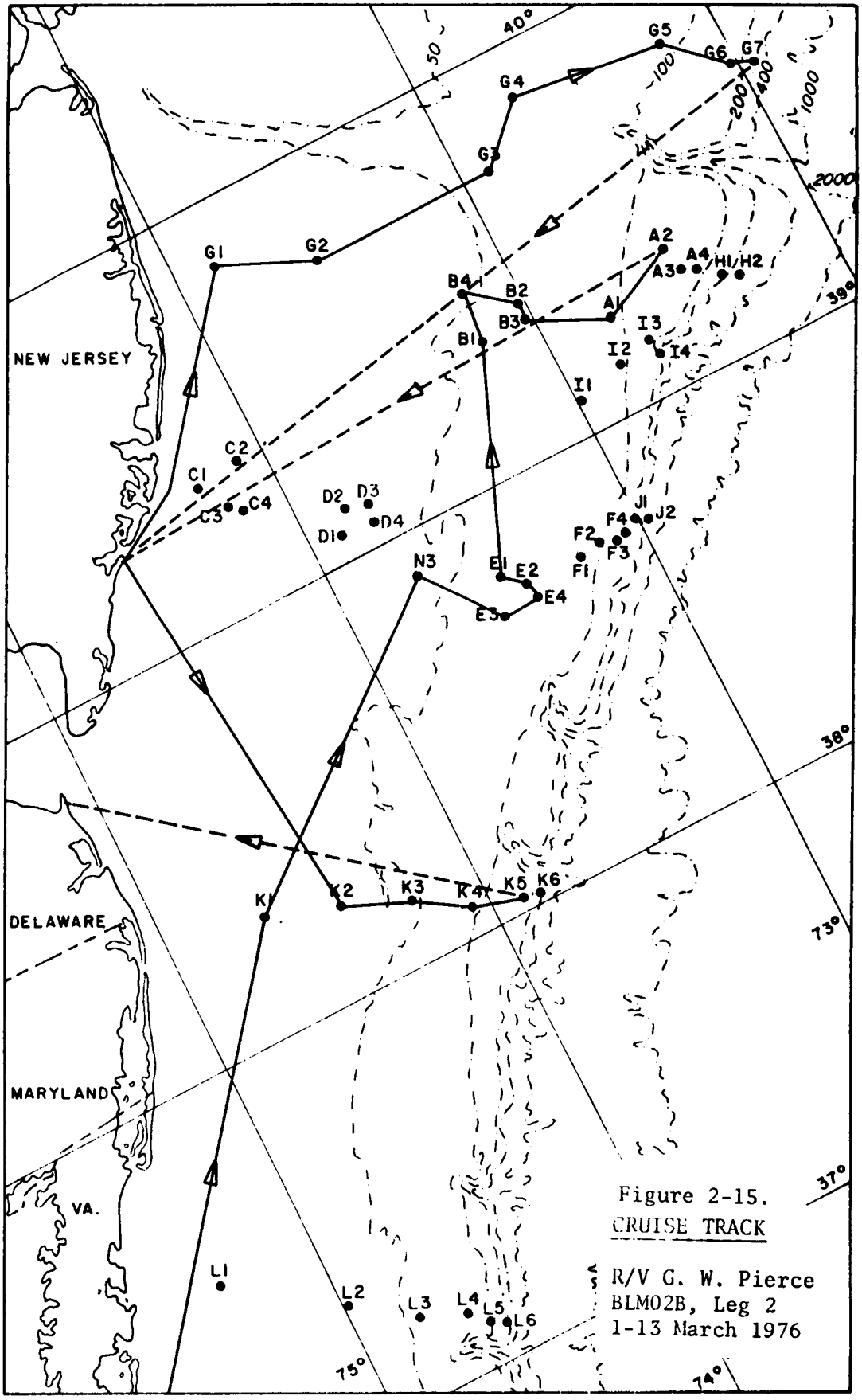

Figure 2-15.
CRUISE TRACK

R/V G. W. Pierce
BLM02B, Leg 2
1-13 March 1976

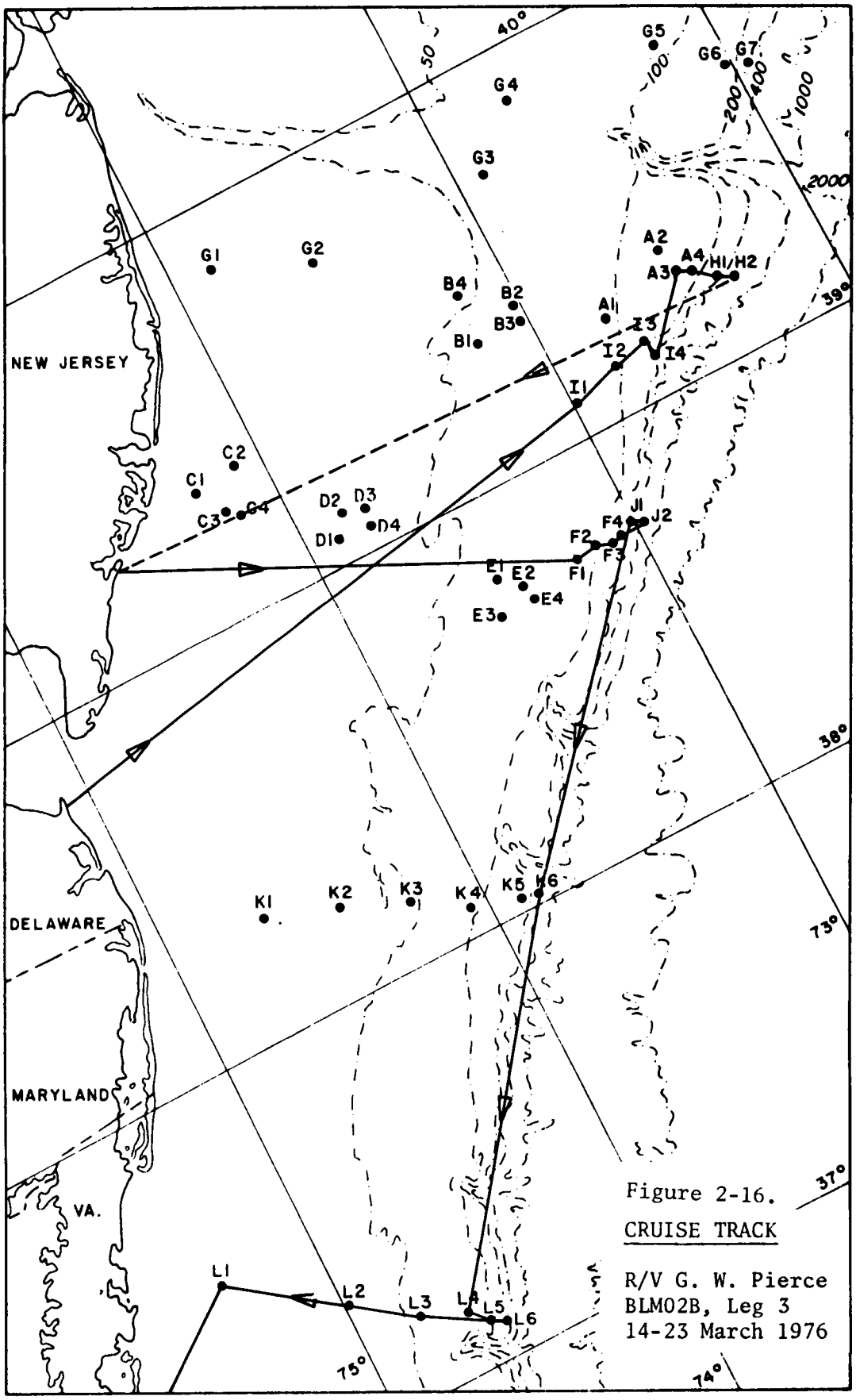

Figure 2-16.

CRUISE TRACK

R/V G. W. Pierce
BLM02B, Leg 3
14-23 March 1976

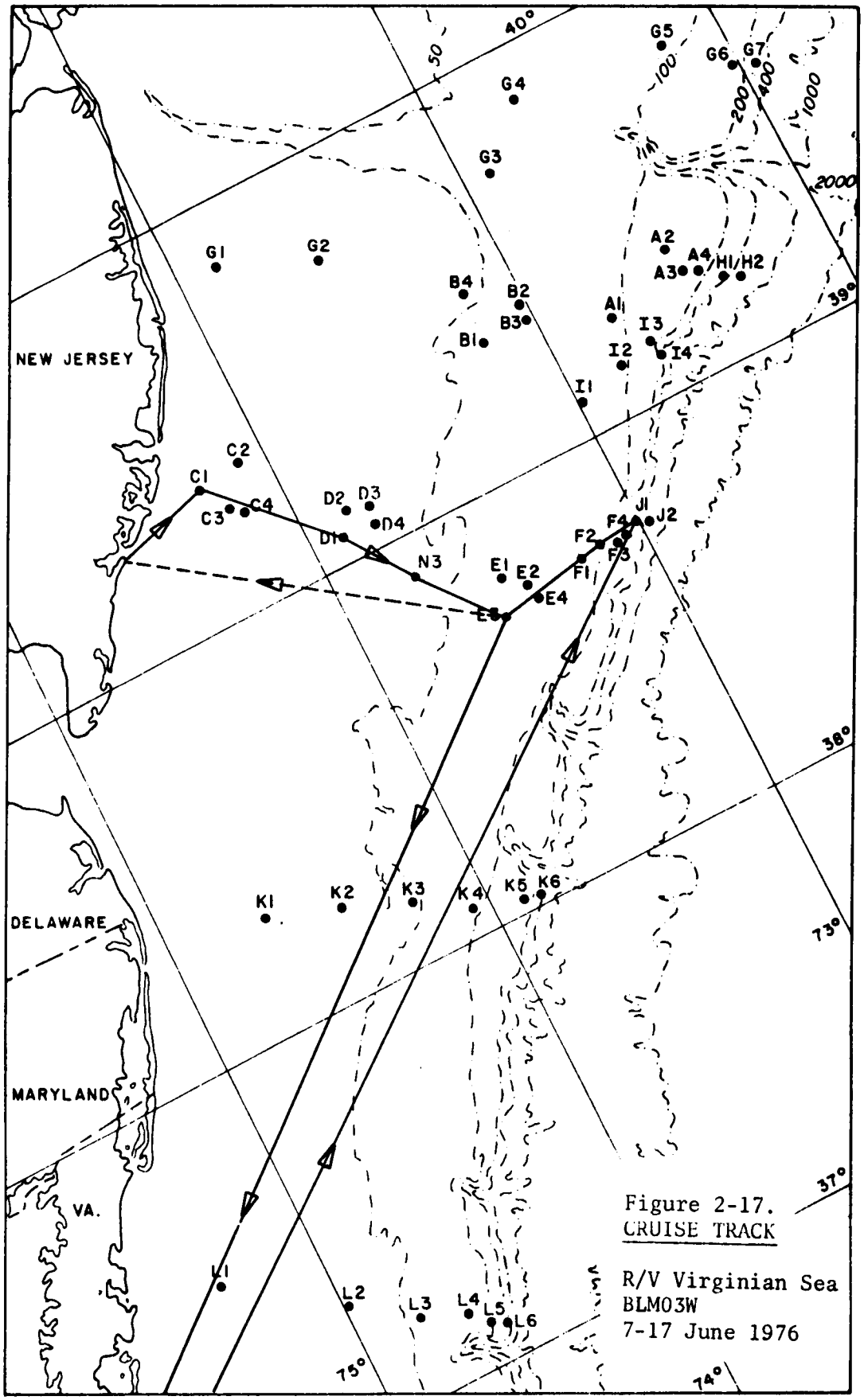

Figure 2-17.
CRUISE TRACK

R/V Virginian Sea
BLM03W
7-17 June 1976

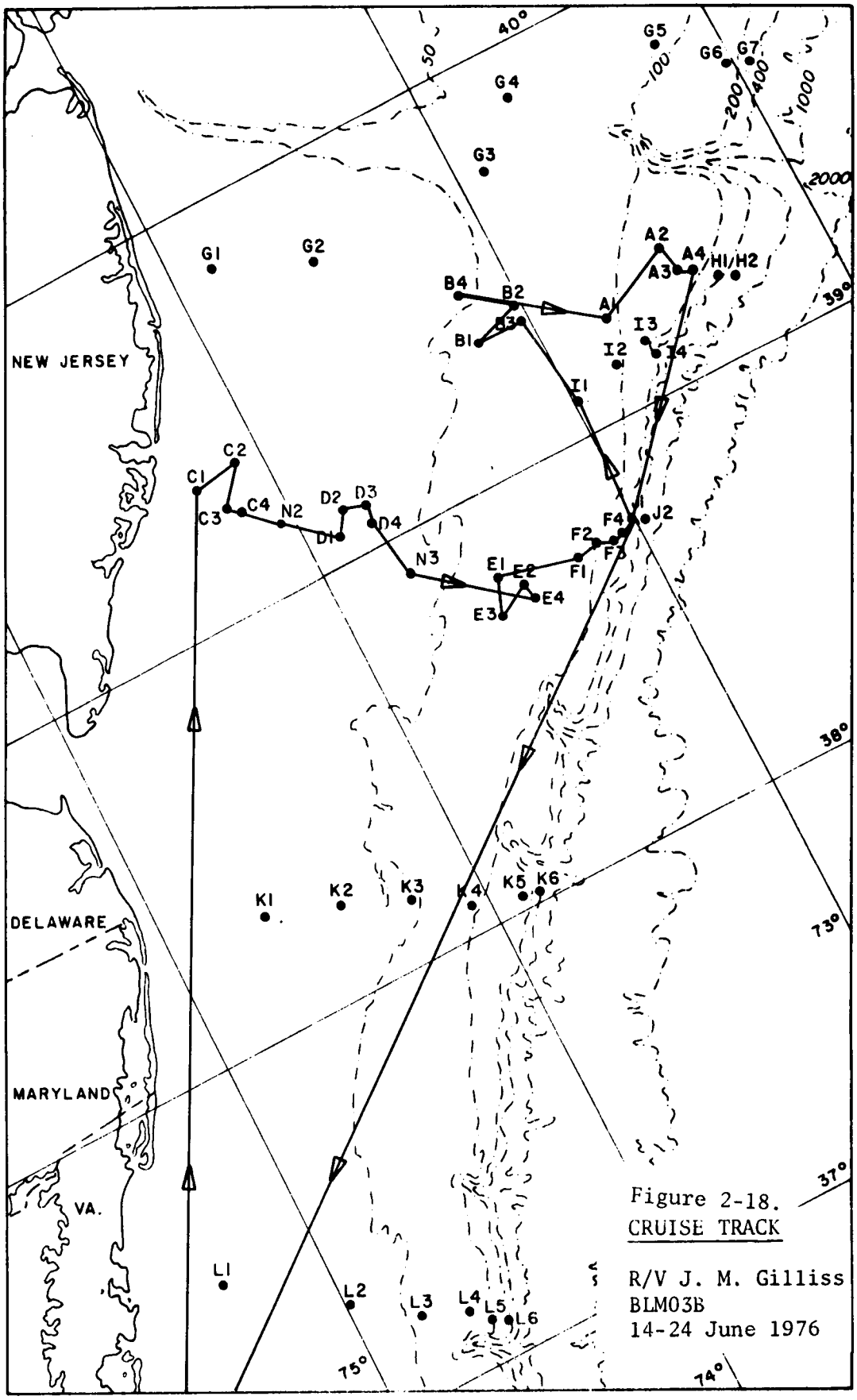

Figure 2-18.
CRUISE TRACK

R/V J. M. Gilliss
BLM03B
14-24 June 1976

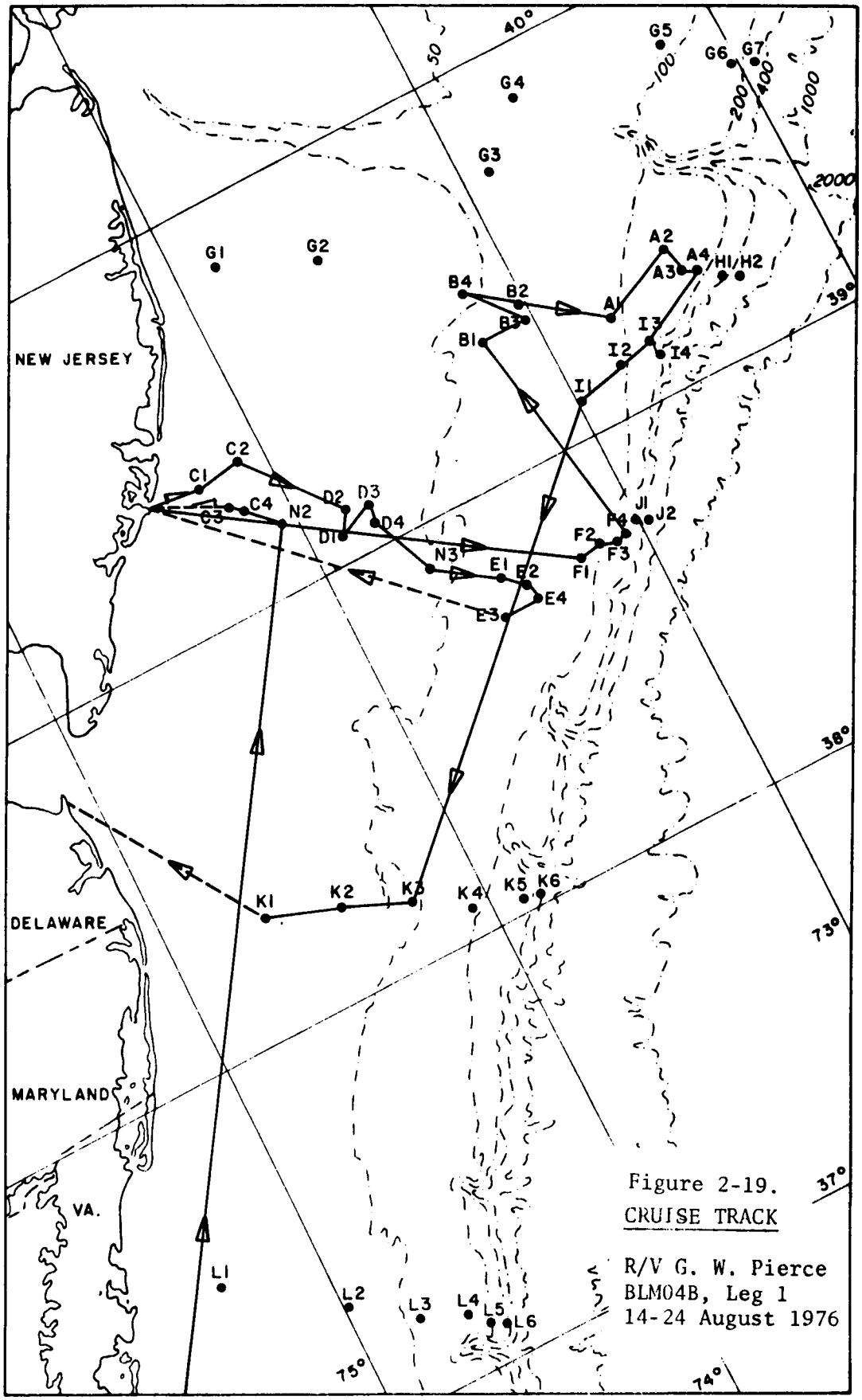

Figure 2-19.
CRUISE TRACK

R/V G. W. Pierce
BLM04B, Leg 1
14-24 August 1976

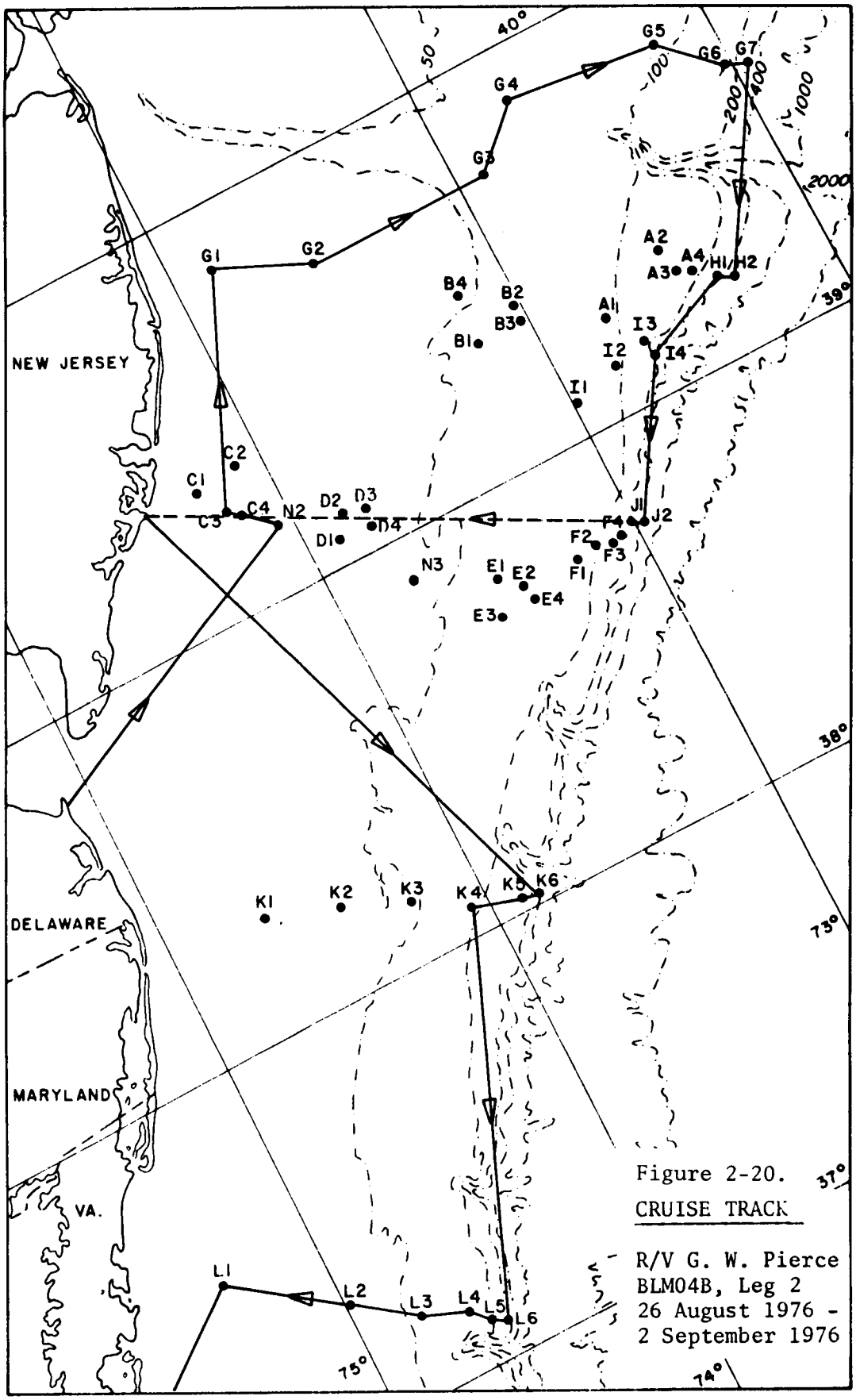

Figure 2-20.

CRUISE TRACK

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

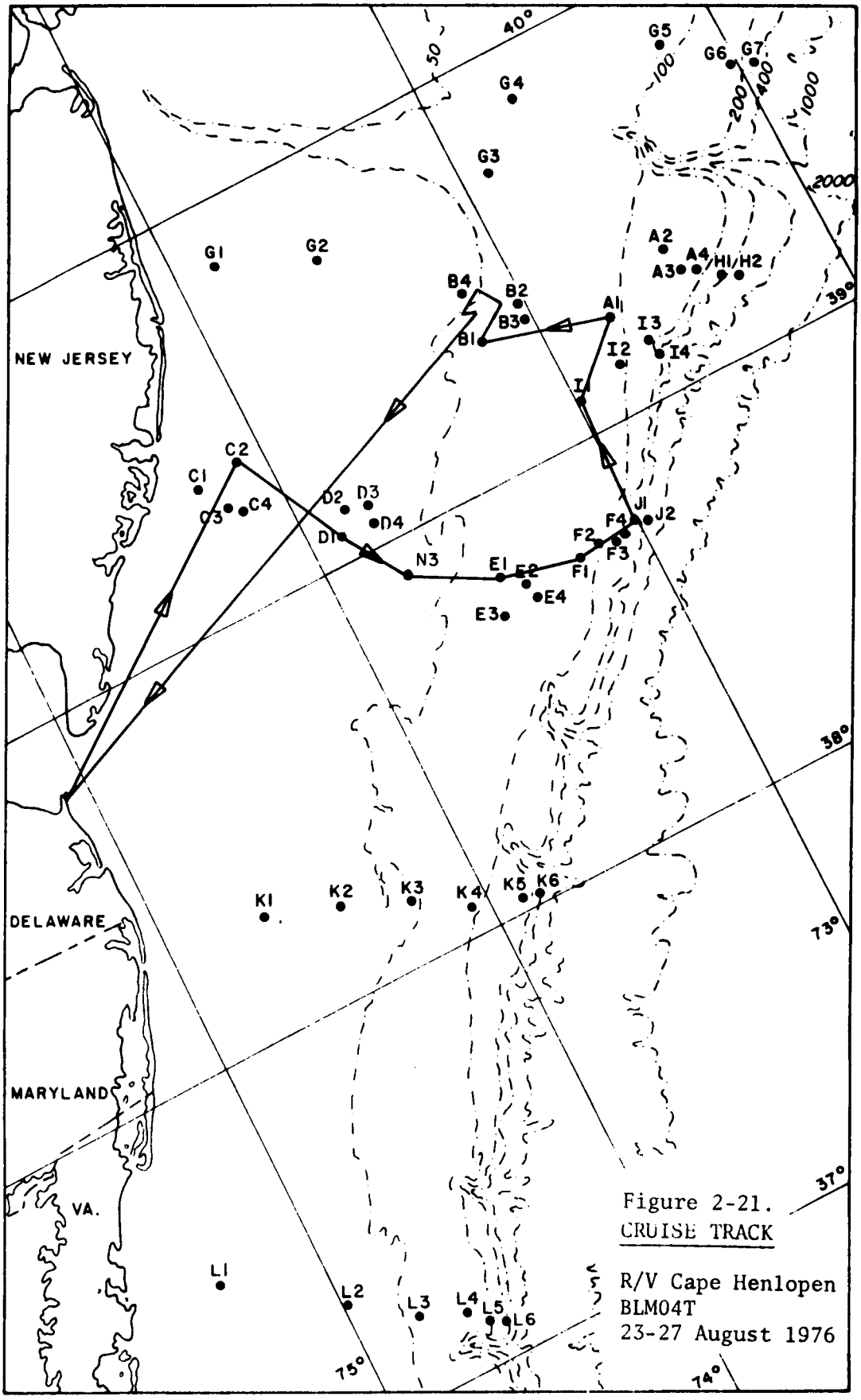

Figure 2-21.
CRUISE TRACK

R/V Cape Henlopen
BLM04T
23-27 August 1976

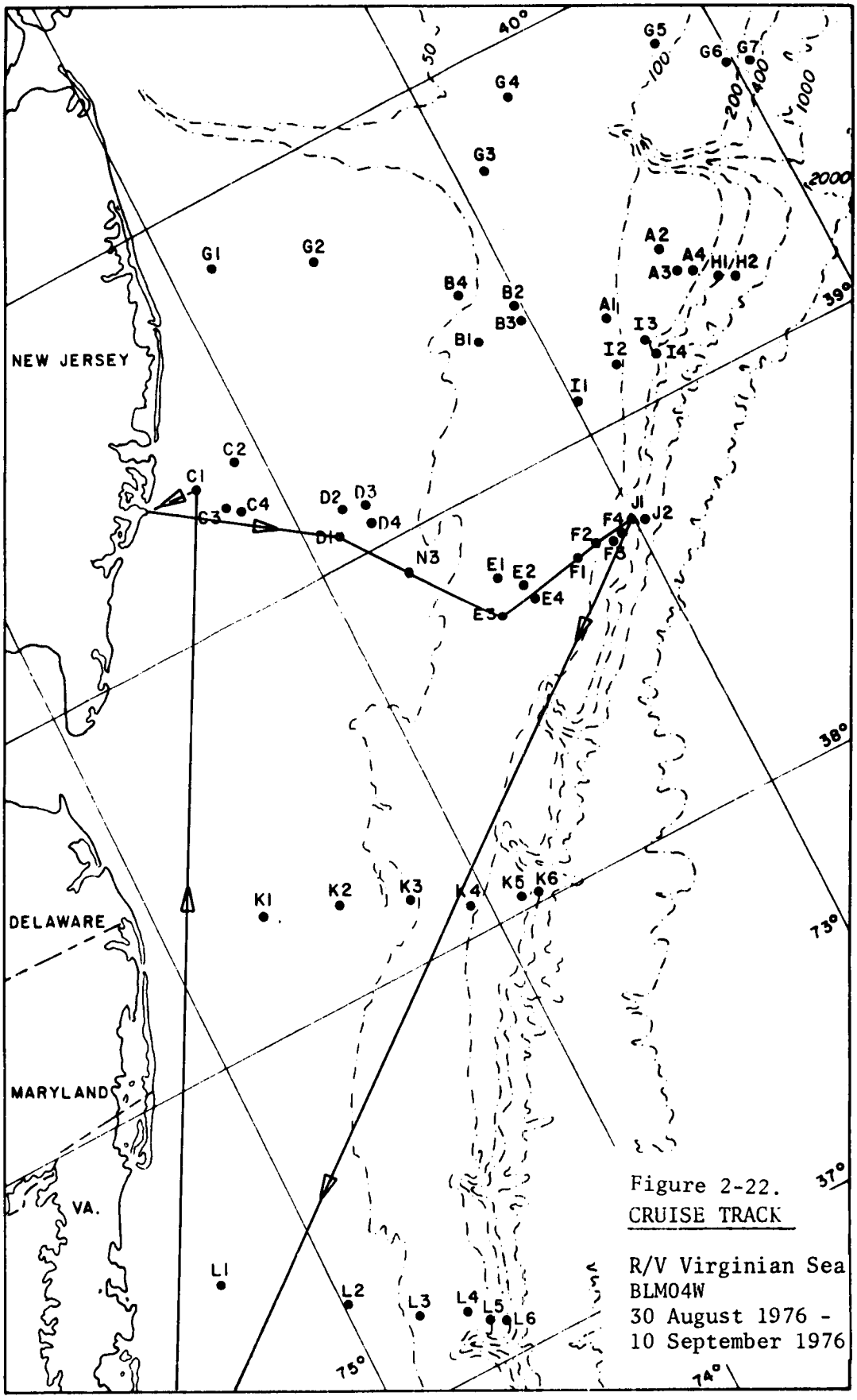

Figure 2-22.
CRUISE TRACK

R/V Virginian Sea
BLM04W
30 August 1976 -
10 September 1976

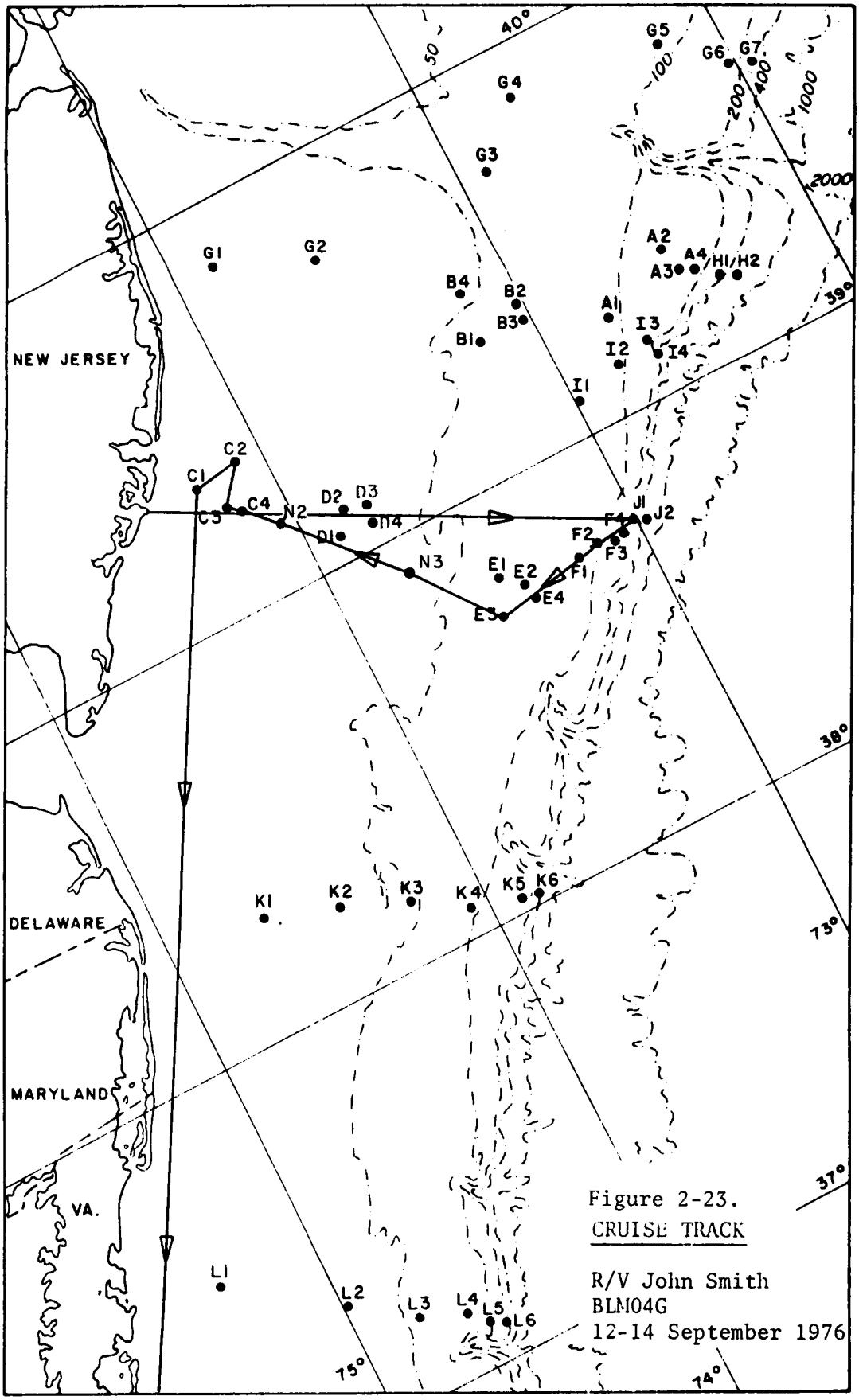

Figure 2-23.
CRUISE TRACK

R/V John Smith
BLM04G
12-14 September 1976

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.

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 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 two-cruise system was elected, the mission and sequence of events differed for each cruise. Table 2-5 illustrates the procedures followed.

Table 2-5. 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

PHYSICAL OCEANOGRAPHY AND CLIMATOLOGY

E. P. Ruzecki
C. S. Welch
D. L. Baker

CHAPTER 3

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CHAPTER 3

PHYSICAL OCEANOGRAPHY AND CLIMATOLOGY

E. P. Ruzecki
C. S. Welch
D. L. Baker

INTRODUCTION

The physical oceanographic portion of this study was designed to achieve, as its primary purposes, identification of water masses in the study area during the sampling period and characterization of hydrographic and meteorological conditions at sampling locations when biological and chemical samples were taken. To aid in water mass identification, samples of near surface and near bottom water taken at each station were analyzed for dissolved micronutrient concentrations.

Two secondary tasks were assigned to the physical oceanography group: obtaining and field processing water samples for dissolved and particulate organic carbon content and measuring optical characteristics of the water column. The former was done in conjunction with the water column cruises while the latter was accomplished during the benthic sampling cruises. All samples and field data from these secondary tasks were transferred to other investigators for further processing and analysis.

METHODS AND MATERIALS

Nomenclature

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

Abbreviation	Definition
BCD	Binary Coded Decimal
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 Plessy Instruments. The instrument does not have a dissolved oxygen sensor.
DO	Dissolved oxygen
GMT	Greenwich Mean Time

Micronutrients	Unless otherwise specified, micronutrients refer to nitrates, nitrites, and dissolved organic phosphates-arsenates.
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).

Field Sampling

Meteorological Parameters

Measurements. Meteorological parameters measured consisted of wind speed and direction, atmospheric pressure (sea level), 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. All meteorological data were entered on VIMS Form 200 (see Appendix I) and, with the exception of wind speed, converted to metric units. (Wind speed was recorded in knots.) Time of meteorological observations was entered as local time and converted to GMT (hours and tenths). Those parameters which required a judgment by the observer (visibility, present weather, cloud cover, and type) were coded according to the World Meteorological Organization guidelines (Anonymous 1972). Specific codes for each of these observations are listed on the VIMS Form 200 at the location where the data are recorded.

Frequency. Measurements were made at three hour intervals while sampling was conducted on the water column cruises and once per station on the benthic cruises. The latter were occasionally augmented by ship's weather records from the bridge log. Continuous records of sea level pressure were obtained with a barograph; however, these records suffered from contamination resulting from ship motion and opening and closing of doors.

Instrumentation. Values of atmospheric pressure and wind speed and direction were obtained from the ship's aneroid barometer and anemometer respectively. The latter values were corrected for ship's 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 manufactured by Weather Measure (Model 8201), and sea surface temperature was measured with a thermistor type thermometer manufactured by Hydrolab of Austin, Texas (ARA Model ET 100).

Oceanographic Parameters

Measurements. Measured oceanographic parameters were: water temperature, conductivity, pressure, electrical current generated as a result of dissolved

oxygen permeation through a membrane, temperature of a 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 (upper 5 m) and near bottom levels (within 5 m of bottom) were always sampled, with as many as ten additional samples taken at various intermediate levels]. Water samples were processed, as described below, for independent laboratory analyses of concentration of salinity, dissolved oxygen (DO), nitrites, nitrates, total dissolved organic phosphates (micronutrients), particulate and dissolved organic carbon (POC-DOC), and suspended sediments.

Measurements of water temperature as a function of depth were made at positions halfway between water column and benthic sampling stations as they were occupied.

Frequency. Sampling frequencies varied between water column and benthic stations as well as within each type of station for various types of water samples taken.

I. Water Column Stations. During the first two cruises (BLMØ1W and BLMØ2W) in situ measurements and water samples were taken once at each station. On subsequent cruises (BLMØ3W and BLMØ4W) four sets of in situ measurements were made at each station (at approximately six-hour intervals). Each set of in situ measurements was augmented with near surface and near bottom water sampling for salinity and DO determinations. Additionally, water samples for determination of micronutrients as well as POC-DOC concentrations were obtained near surface and near bottom once at each station.

II. Benthic Stations. In situ measurements and near surface and near bottom water samples were taken at all benthic stations. Water samples were field-processed (as described below) for laboratory determinations of concentrations of salinity, DO, and micronutrients. Water samples for determination of suspended sediment load were obtained at near surface and near bottom depths at one station from each cluster of four stations. This was usually the first numbered station from each lettered group (i.e. stations 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 clusters. When a thermocline was evident at a station scheduled for suspended sediment sampling, an additional sample was taken in the vicinity of the thermocline.

Instrumentation. Three instrument groups were used to obtain the in situ measurements and water samples which resulted in 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, this instrument was attached below the supporting structure of the CTD/DO-Rosette unit. On subsequent benthic cruises, it was used as a separate unit. An expendable bathythermograph (XBT) system was used to obtain depth-dependent temperatures between benthic and water column stations.

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 parameters used to calculate dissolved oxygen. The rosette portion is essentially a triggering system to close water sampling bottles at desired depths. Three configurations of the CTD/DO-Rosette system were used during the study. They are schematically represented in Figure 3-1a to 3-1c. Each configuration contained an underwater pinger (Benthos Model 2216) which was used to determine the distance of the sensing package from the bottom.

During the first two water column cruises, the configuration of the underwater portion of the system was as shown in Figure 3-1a with the CTD/DO "fish" and the pinger occupying sampling bottle positions on the rosette sampler. Figure 3-1b shows the configuration used during the final two water column cruises. During these cruises, the CTD/DO "fish" was placed horizontally below the Rosette sampler, and the pinger was mounted vertically 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 3-1c, 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.

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 Greene et al. (1970). Previously enumerated measurements were sensed with the underwater unit. Temperature, conductivity, and pressure were measured 32 times a second. While the DO parameters were allowed to change once a second, 32 measurements were made each second. Measurements were digitized in the underwater unit, and data are 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 with output options for a digital panel display, recording as digital information on an analog tape recorder, recording as digital information on a digital tape recorder, and recording on graphic recorders as XY, XYY or time dependent plots. Options used during this study were the digital panel display and analog tape and XYY graphic recorders. At sea, data on both the downcast and the upcast of the CTD/DO sensing package were recorded on magnetic tape, while plots of temperature and conductivity as functions of pressure were made only on the downcast to indicate the location of a thermocline or halocline. Resulting plots were used to assist in determining depths at which water samples were to be taken.

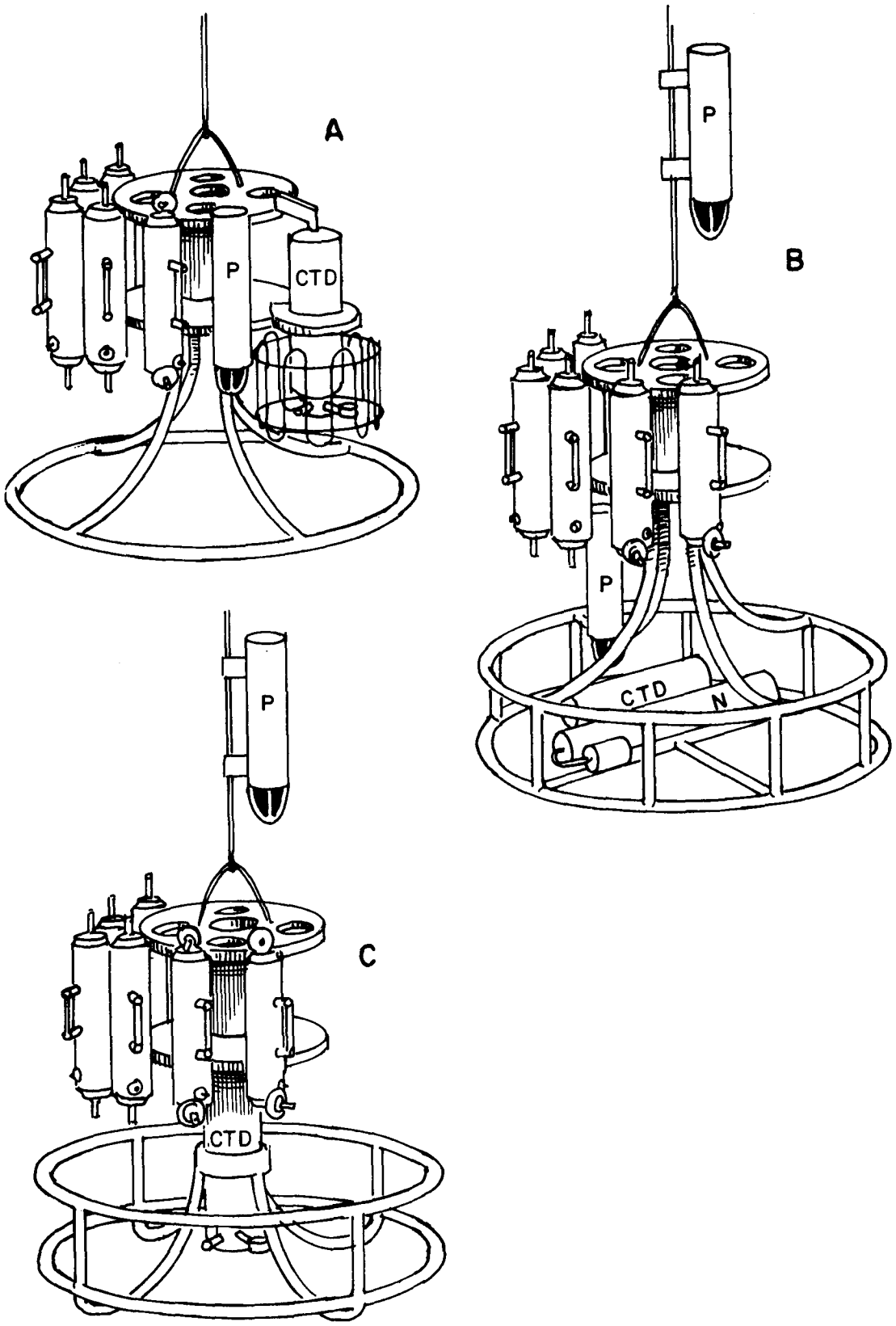


Figure 3-1. Various configurations of CTD/DO and Rosette sampler and underwater units with pinger used. (A) CTD/DO unit and pinger each occupy a bottle position; (B) CTD horizontally below Rosette; (C) CTD vertically below Rosette.

During the first water column cruise, 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 in San Diego, California. Data from this unit were obtained by recording ten second averages of frequencies resulting from measurement of pressure, conductivity, and temperature at frequent depths throughout the water column at each station. Water samples for laboratory analysis of salinity and DO were obtained at these depths as described below.

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 from the CTD/DO deck unit "fish" is turned off, and a capacitor to the "fish" is charged in the rosette. When a specified charge is reached in the capacitor, it is discharged into a stepping motor. The stepping motor in the "fish" is isolated from the CTD/DO "fish". The stepping motor releases a triggering device in the rosette "fish" which in turn releases haliards which had been holding the end caps on a Niskin 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 fifteen seconds to complete. Once the process is completed, power is returned to the CTD/DO system. The rosette unit used during this study was designed to obtain twelve five-liter water samples.

C. Expendable Bathythermograph (XBT) Systems. 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 cannister, is placed in the hand-held launcher and a locking mechanism in the launcher 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 stylis 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 cannister allowing the probe to fall into the water. On striking 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 are sensed by the thermistor and relayed through a seawater ground and a pair of thin connecting wires to the recorder. The chart advance 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 stylis in the recorder moves across the temperature scale. The result is a recording of depth-dependent

temperature at the launch site. Two spools of thin wire, one in the probe and the other in the cannister, allow the operator to launch 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 cannister. When the recorder has advanced through a predetermined number of cycles, the system is turned off, and a reload light is illuminated indicating the system is ready for launching another probe.

D. Nephelometer-Transmissometer. The Nephelometer-Transmissometer used to measure optical properties of the water column on the 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 resulting data, the reader is referred to the report on this study which has been prepared by USGS.

Shipboard Protocol

Sequential Activities. Responsibility for obtaining the in situ measurements and water samples which constituted the field program for physical oceanography rested with two individuals on each cruise: an hydrographer trained in physical oceanography and an electronics engineer or electronics technician trained in instrument operation and maintenance. Assistance in placing gear over the side and retrieving gear was obtained from other members of the field scientific party and ship's crew. Because of his background and training, the electronics-oriented member of this team was frequently called upon to repair various items of scientific or shipboard equipment not specifically related to physical oceanography or meteorology but essential to proper execution of the cruise. These items included depth measuring equipment (PDR, PFR or Fathometer), positioning equipment (Loran C) and, on several occasions, the underwater camera and strobe used to obtain bottom photographs.

The following sequence of events occurred at each station occupied on either water column or benthic cruises with two exceptions. Meteorological data were recorded every three hours during water column cruises, and the nephelometer-suspended sediment activities were confined to the benthic cruises.

(1) 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. 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 allowed for 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.

(2) 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.

(3) With the exception of the first benthic cruise (BLM01B) the first instrument cast made was the nephelometer cast to measure optical characteristics of the water column prior to contamination by sediment plumes resulting from grab operations. During cruise BLM01B, the nephelometer was lowered in conjunction with the CTD/DO instrument suite. At the conclusion of each nephelometer cast, the instrument was turned off and time was recorded.

(4) 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 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 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 warmup period the data recording analog tape recorder was turned on, and the tape was allowed to run for approximately 30 seconds (or until the tape counter advanced 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 made which gave information on cruise, station, 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 connect the CTD/DO output into the right channel of the audio tape and make verbal comments on the left channel. After the warmup period, the recorder was switched off "pause", and the recorder input was switched to the "tape" mode. At the same time, the CTD/DO deck unit was switched from the "CTD Direct" to the "replay" mode. With this arrangement of selectable switching 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 1 second delay) into the CTD/DO deck unit where the recorded signals were processed, displayed on the deck readout, and were used to drive the plotter. This somewhat involved procedure assured us of having recordings of usable data. 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 record it. This, however, would not assure us of having usable data on the tape.

The bottom finding pinger was turned on, the DO sensor cap removed and 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). 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 $\pm 0.5^{o}C$ between ambient and DO sensor temperature) had been reached.

Once equilibration had been reached, the downcast was started with verbal notation 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 watched 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. The downcast was stopped by announcing "stop!" to the winch operator when all available depth indicating sources (PDR, meter wheel, and CTD/DO pressure reading) indicated the "fish" was within three to five meters of the bottom. At this time the CTD/DO deck unit display was switched to the "hold" position, the announcement of a pending Rosette sample was made into the tape recorder, the plotter was switched to the standby position, and a Rosette sample taken. 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. This water was obtained for other investigators for chemical analysis. Once the 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 taken 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 cast, power to the CTD/DO "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 "settle down." The upcast was then started by telling the winch operator the next depth to be sampled. These instructions were also recorded 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.

Once 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 bottles. Figure 3-2 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 (Standard Methods 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. sample bottle.

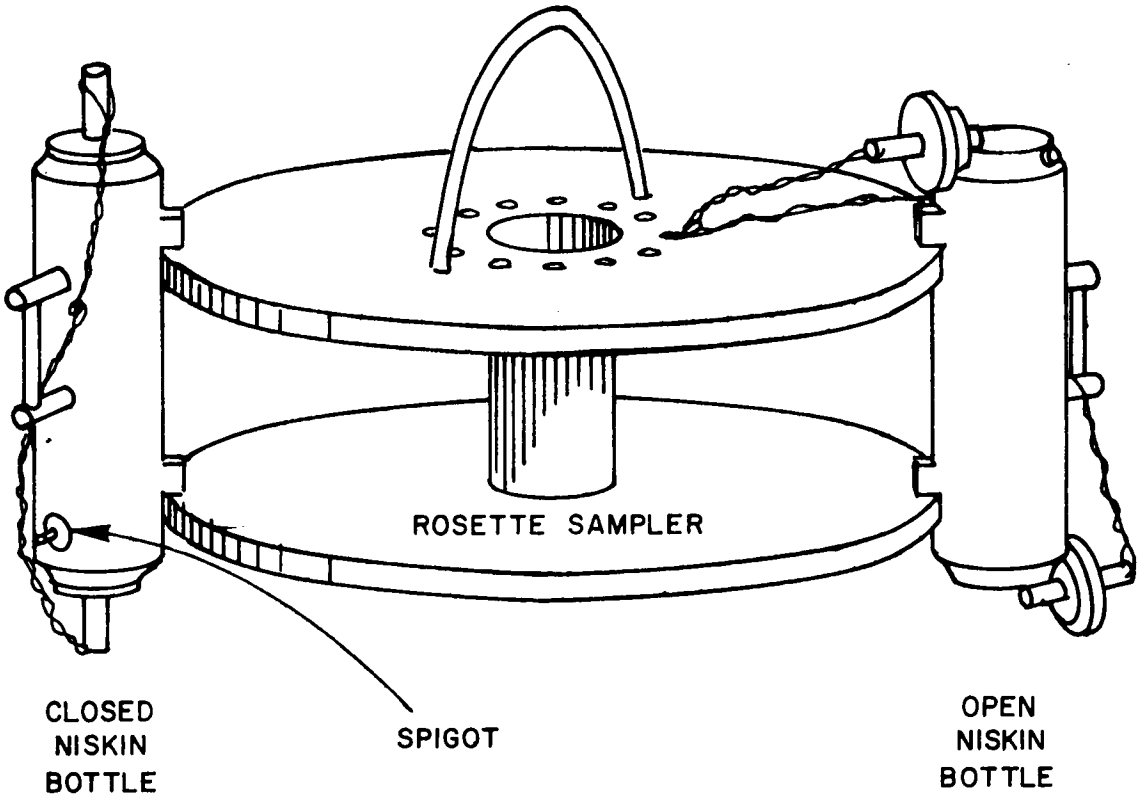


Figure 3-2. Schematic representation of a Rosette sampler with two Niskin bottles (one open and one closed) attached.

Water was allowed to drain into the sample bottle 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 was removed, 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. Once the precipitate had settled a second time, 1 ml of sulfuric acid was carefully added, the bottles capped and shaken again. Samples were then placed in a covered container and stored for titration ashore.

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. bottles allowing an air space for sample expansion. Bottle numbers were recorded on the VIMS Form 200 and samples stored for onshore 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. size). The numbered sample bottle was then filled two-thirds full of 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 from the VIMS Geology Department). 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 all four liters had passed through the filter or the filter 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, labelled 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 3-3a. Samples were poured from the transfer bottles into the funnels.

B. Cruises BLM02B and 03B. 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 3-3b was assembled. This arrangement was a vast improvement over previous set-ups in that it did not need constant attention.

A large (5-gallon) 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.

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 placed

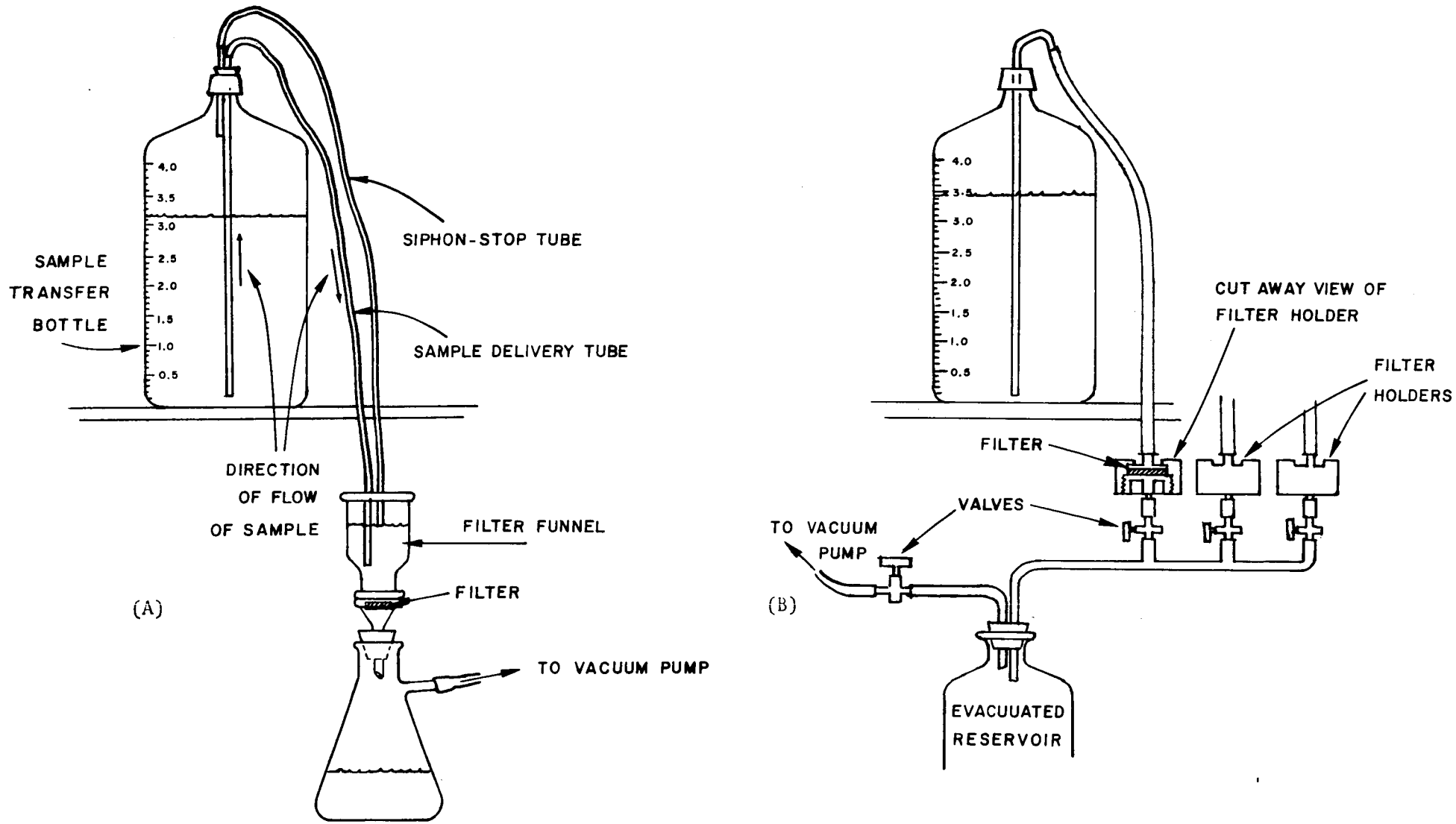


Figure 3-3. (A) Filter-siphon arrangement used for suspended sediment filtering for cruises BLM02B and 03B. Similar arrangement was used for BLM01B except that sample was poured into filter funnel, siphon was not used (clamp not shown on filter funnel). (B) Filtering arrangement used in suspended sediment filtering for cruise 04B showing filter holders, reservoir, and valving arrangement.

in line (position B in Figure 3-4). The foil wrap and cap from a sample bottle were removed and placed in line next to the filter holder (position C, Figure 3-4) taking care to keep the bottle cap clean by re-wrapping it in foil. The overflow reservoir was carefully placed in line between the sample bottle and vacuum pump (position D, Figure 3-4). Next, the foil wrap was removed from the suction tube (position A, Figure 3-4), and 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; then the foil wrap was replaced on the siphon tube, and the filter and holder were removed from line and wrapped in foil. The sample bottle was removed from 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 labelled 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.

Laboratory Processing

Shore-based activities applied to records of in situ readings and water samples secured and treated at sea are grouped into three broad categories: analyses of samples to determine concentrations of various constituents, posting of these results to field data sheets and editing of the data sheets, and conversion of tape readings of in situ measurements to (nominal) half meter average of temperature, salinity, and dissolved oxygen.

Sample Analysis

Salinity. 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) using a computer program based on salinity vs. conductivity ratio tables furnished by the manufacturer. The laboratory salinometer has a rated accuracy of $\pm$ 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 $\pm$ 0.01 part per thousand (A. Cline, 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.

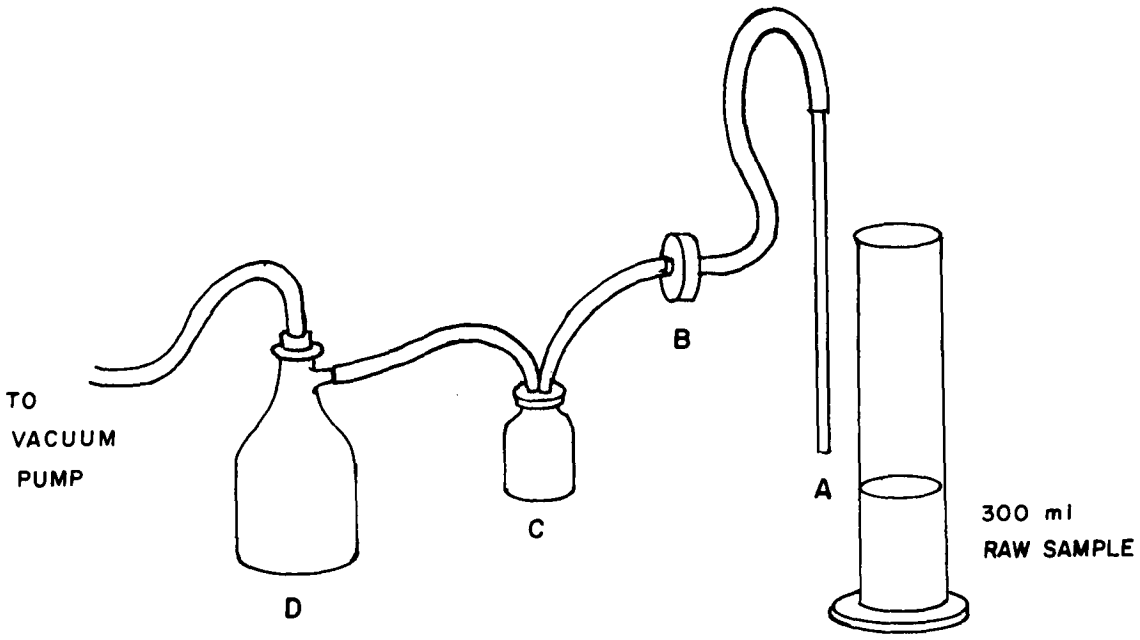


Figure 3-4. Arrangement of equipment for field processing of POC-DOC samples. A, suction tube; B, pre-combusted POC glass filter in holder; C, DOC sample bottle; and D, overflow reservoir.

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 Standard Methods (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.

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 + 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 (Standard Methods 1976).

I. Preparation of Standard Solutions for Micronutrient Analyses.

A. 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.

B. O-Phosphate. 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, and 1.0 µgat P/1. 200 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted to 250 ml for 4.0 µgat P/1 concentration; 10 ml of stock standard B was pipetted into a 250 ml volumetric flask and diluted for 2.0 µgat P/1 concentration; and 40 ml of stock standard B was pipetted into a 200 ml volumetric flask and diluted for 1 µgat P/1 concentration. Working standards were run on an autoanalyzer with the instrument set at 4.0 µgat P/1 giving peak height of 100 and 2.0 and 1.0 µgat P/1 reaching peak heights of 50 and 20 respectively.

Particulate and Dissolved Organic Carbon. 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 were 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 values 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.

Conversion, Posting, and Editing of Data

Entries of in situ measurements on field data sheets (VIMS Form 200) were coupled, in the laboratory, with Latitude-Longitude information derived from Loran "C" readings and results of water sample analysis. Data sheets were then checked for completeness and correctness and sent to the VIMS Data Processing Center for keypunching. Printouts of keypunched data were obtained from data processing along with the original data sheets and the two compared. Errors were noted and appropriate corrections made. XBT traces were digitized by determining depth-temperature combinations for local maxima, minima, and inflection points as well as surface and bottom temperatures. These values were entered on VIMS XBT data sheets (VIMS Form 201) along with bucket temperature, surface salinity, and other appropriate information (date, time, location, station designation, etc.). When isothermal conditions were indicated, data entries were made at frequent intervals. Completed XBT data sheets were checked and sent to Data Processing for keypunching and printouts. These results were checked against the original data sheets and corrections made when necessary.

Computation of Parameters from Values on CTD/DO Tapes

Reported values of temperature, salinity, depth, DO, and σ_t were computed from measurements recorded at sea on audio tape from CTD/DO casts. Signals on the audio tape were actually (bit-serial binary) values of pressure, temperature, conductivity, and two DO associated measurements.

The digital data stream originates in the Neil Brown CTD underwater probe. For cruises BLM01 through BLM03, the basic sample consists of ten, eight-bit binary words. For subsequent cruises, the sample consists of eleven words, due to a modification to the CTD system increasing the digitization of O_2 probe current 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 a stereo tape deck (AKAI Model GX-630D). 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 data is played back off the tape, about one second after it is recorded, and fed to 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, one 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 sample is also called a frame. It is generated and transmitted by the CTD probe at the rate of 31.25 frames 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 3-1). 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 0_2 probe current. The tenth is the eight bit digitization of 0_2 probe temperature. In all cruises starting with BLM04, the ninth and tenth words contain the twelve bit digitization of 0_2 probe current, and the eleventh is the eight bit 0_2 temperature word (Table 3-2).

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. This interface provides counting and trigger circuits to set tape record lengths at any size up to the 400 word recorder 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 select single-record or continuous recording. When the recording is stopped, the record in progress is allowed to complete its cycle. The resulting digital tape is IBM-compatible with a density of 800 characters per inch.

The audio tapes of the CTD casts are brought in from the field and transcribed on 9-track tape in the lab using the same audio recorder and CTD deck terminal (recorders and terminals are interchangeable among themselves). The transcription procedure is to record, at the beginning of a cast, a single record of data made when the CTD was still in the air, but turned on long enough for the electronics and sensors to stabilize. The rest of the records in a downcast are recorded continuously. They start when the CTD probe has been in the water long enough for the water and 0_2 probe temperature readings to close within 0.5°C. The downcast 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 0_2 probe current. They are only taken 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 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 tapes can be transcribed onto one 1200 ft. digital tape.

The transcribed digital tapes are labeled CTD 001 through CTD 999 and then processed on the VIMS IBM 370/115 computer. The processing must be done in two passes. The first program CTDRAV, generates oceanographic variables of depth (m), pressure (dbar), temperature (°C), conductivity (mmho/cm) 0_2 probe current (μA), 0_2 probe temp. (°C), salinity (ppt), time (sec), 0_2 partial pressure (atm), 0_2 dissolved concentration (ml/l), and the number of samples per output.

Table 3-1. 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 (^{o}C)	ℓ.s. bits
5	Temperature	m.s. bits
6	Conductivity (mmho/cm)	ℓ.s. bits
7	Conductivity	m.s. bits
8	(Signs)	ℓsb, pressure, ℓsb+1, temperature ℓsb+2, 0_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	0_2 current (μA)	eight bits binary
10	0_2 temp. (^{o}C)	eight bits binary

Table 3-2. Changes to CTD Frame Format (Cruises BLM004 and subsequent).

Word	Sensor	Bits
9	0_2 current (μA)	least significant eight bits binary
10	0_2 current	0000XXXX, lowest four bits of words are most significant four bits of 0_2 current digitization
11	0_2 temp. (^{o}C)	eight bits binary

Conductivity is corrected for pressure and temperature effects. Time is generated from the sampling rate. Depth, salinity, O_2 partial pressure, and dissolved oxygen are calculated from the measurements 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 salinity and oxygen variables to depth and bottle sample measurements. This was done only for sufficiently accurate bottle samples; otherwise correlations were performed.

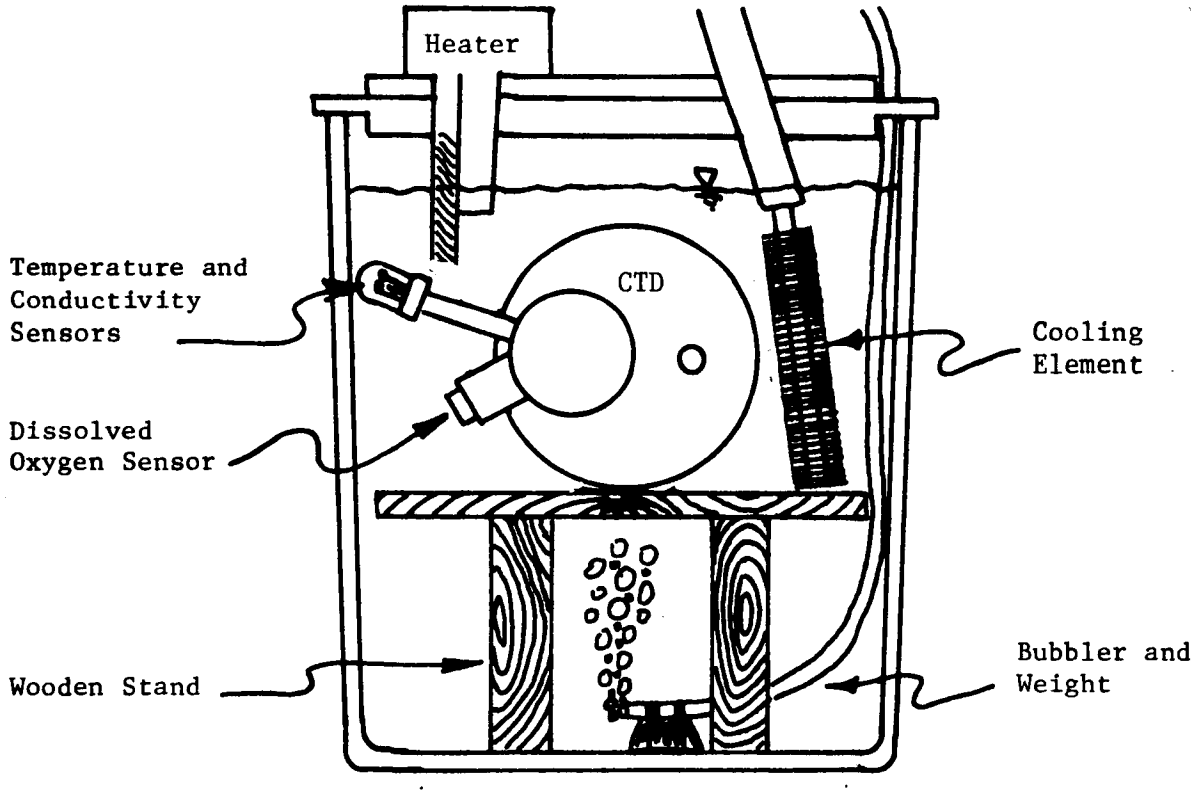
The data processing programs discussed here were developed with the help of three primary sources: the GEOSECS Operations Group of Scripps Oceanographic Institution, the Woods Hole Oceanographic Institution, and Neil Brown Instrument Systems, Inc. In particular, Dr. Arnold Bainbridge of Scripps provided information and program examples for processing and calibrating data from the Beckman pressure-compensated polarigraphic dissolved oxygen sensor. He also provided some early processing of VIMS data and general guidance on CTD cast and data processing procedures. Also of great help in the processing and calibration of oxygen data were Beckman technical memoranda provided by Mr. J. C. Burgess of Beckman's Advanced Technology Operations, Anaheim, California, and consultations with Dr. Rudolph Bieri of the VIMS Environmental Chemistry Department.

Mr. Douglas Moore of Woods Hole provided copies of WHOI CTD editing and processing programs for the Neil Brown CTD and also a copy of Publication WHOI-74-89, "WHOI/Brown CTD Microprofiler: Methods of Calibration and Data Handling". The Woods Hole publications were particularly helpful in setting up cast and calibration procedures. Help and manuals provided by Neil Brown Instrument systems were instrumental in data calibration and data translation from audio to digital tapes.

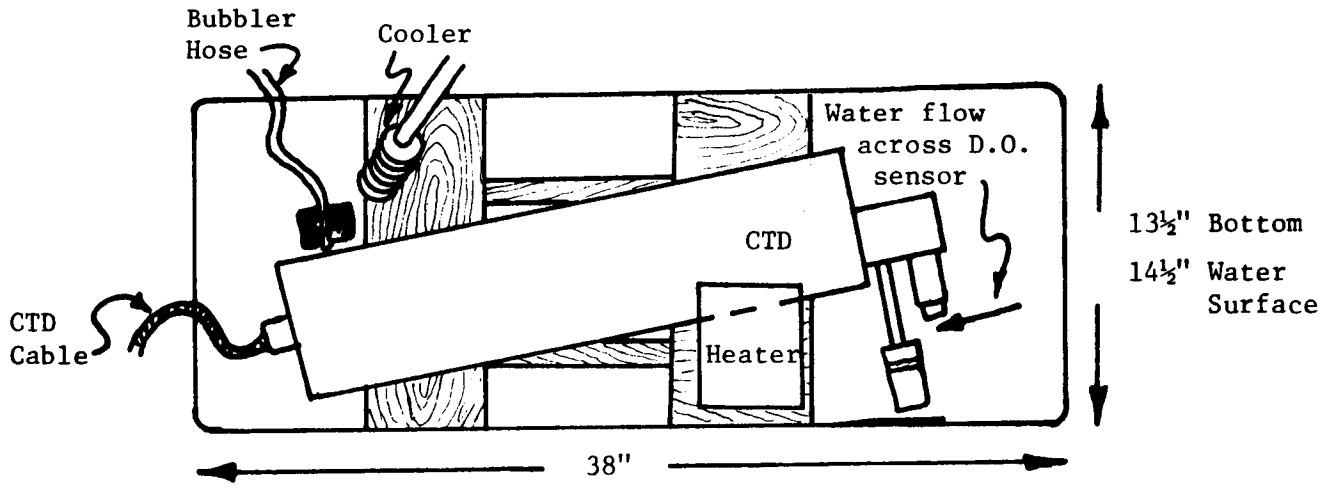
Instrument Calibration and First Pass Calculations. Oxygen calibration curves were taken from Neil Brown CTD's S/N 1495 and S/N 1295. The data were recorded verbally and directly from the CTD on audio tapes BLM034 and BLM035 and on VIMS Form 200's.

The physical set-up (Figures 3-5a and 3-5b) consisted of placing the CTD on a wooden stand inside a "giant" Igloo chest full of slightly saline (2.3-3.0 ppt) tap water. The water was supplied with a steady stream of bubbles from a ¼ in. tygon tube connected to a Gelman Inst. Co. Model 13154 air pump giving about 1.3 CFM. Heating was accomplished with Techne model TU-12 temperature controlled immersion heater. Cooling was accomplished with a Techne model RU-8 dip cooler. Circulation for the oxygen probe was done with a Jabasco model 12560 "Water Puppy" 12VDC bilge pump, rated at 5 GPM. Flow over the oxygen probe was channeled with a suction head (Figure 3-6) made of PVC and galvanized plumbing parts. The suction head was placed over the oxygen probe and connected to the inlet of the bilge pump with 5/8 in. diameter garden hose; the water was returned to the opposite end of the igloo chest. The flow was sufficient to attain at least 94% of the full probe output current according to information provided by Beckman Instruments.

The procedure followed was similar to that used on regular CTD casts such that time, display readings, and audio tape counter number were recorded on the voice channel of the tape and on VIMS Form 200's. A water sample for



a) End view of probe in Igloo Chest.



b) Top view of Igloo Chest.

Figure 3-5. Physical arrangement for calibration of DO sensor on CTD/DO probe.

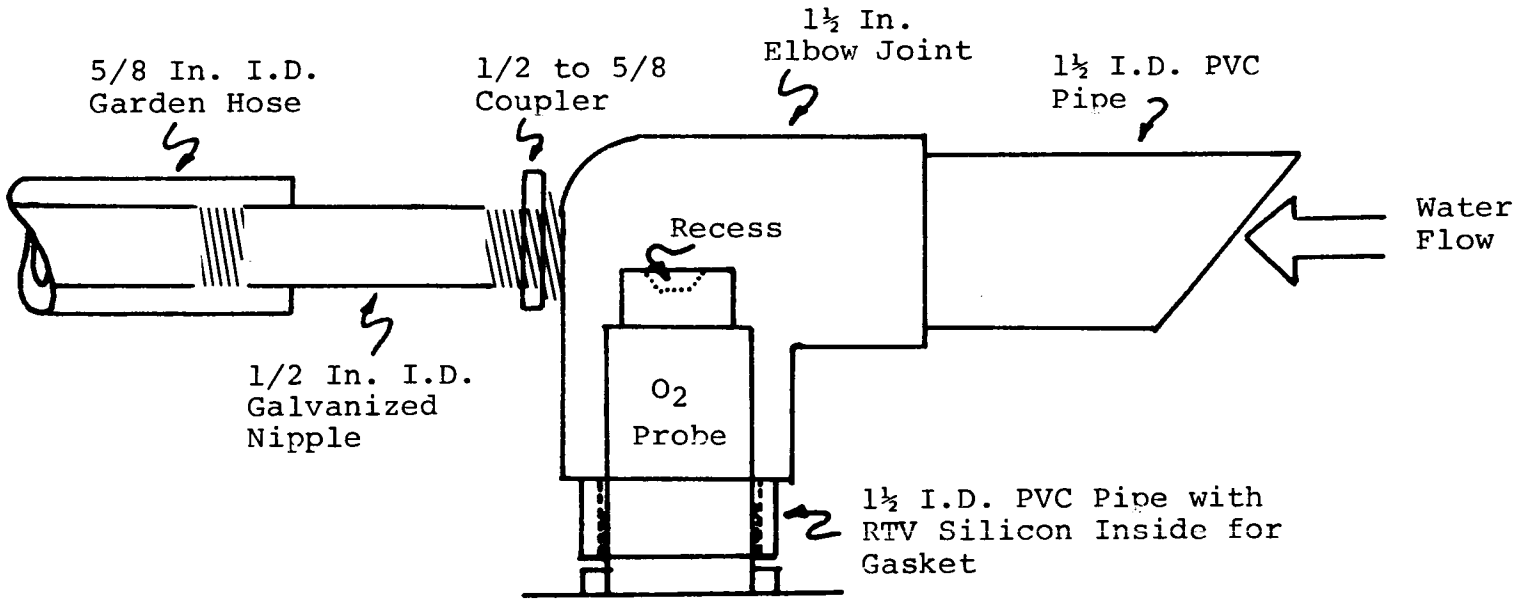


Figure 3-6. O_2 sensor suction head used in calibrating DO section of CTD/DO underwater unit.

dissolved oxygen (Winkler analysis) was taken immediately after the recorded information for each point of temperature and was fixed within 5 minutes. At various points salinity bottle samples and barometric pressure readings were taken.

The first reading for one sitting was usually near room temperature. The water was then heated or cooled to the next data point temperature. Data was then taken and the water temperature lowered. The highest temperature was about 30.5°C and the lowest about 4.5°C. In cooling, the bath temperature was lowered to the next point or a little below and the dip cooler turned off. When the oxygen sensor temperature was within 0.3°C of ambient, data was taken. Occasionally the bath was reheated a few tenths of a degree to match the oxygen sensor temperature. The CTD deck unit display was then held constant five times for verbal and written readings and bottle samples taken. It was observed that the oxygen sensor display temperature was consistently lower than the displayed water temperature at the lower temperatures and did not exhibit the time lag seen at higher temperatures.

The time response of the oxygen sensor current was observed to be about 15 seconds to full output in the CTD S/N 1295 sensor. This was measured by leaving the bilge pump off for a sufficiently long period and then timing the rise in current after the pump was turned back on. The stagnant water in the suction head tended to cause the probe current to drop to 50 or 60% over a period of several minutes after shutoff of the pump. The probe in CTD S/N 1495 was not so tested, but is believed to be about as fast.

CTD S/N 1495 was calibrated first. The results are the averages of the five displayed values for each variable at each point shown in Table 3-3. The pertinent values for O_2 calibration with the results of the bottle sample measurements are shown in Table 3-4. Values in parentheses are estimates of data not taken. Similar tabulations are made for CTD S/N 1295 in Tables 3-5 and 3-6.

The curves for I_{O_2} are much smoother than earlier attempts, and the curves for ΔT, (where $\Delta T = T_{O_2} - T$) show the increasing negative offset of the probe temperature, T_{O_2}, with decreasing water temperature. Calibration results are given in Figures 3-7 and 3-8.

According to Beckman Technical Memorandum ATO-1019A, "Beckman Dissolved Oxygen Monitor Polarigraphic Oxygen Sensor", the current through the sensor is defined by:

$$I_{O_2}\ (\mu A) = K p_m p_{O_2}, \qquad (1)$$

where K = sensitivity factor,

p_m = membrane permeability, a function of water pressure and temperature, and

p_{O_2} = partial pressure of oxygen (atm), a function of the dissolved oxygen, Bunsen's coefficient, and water pressure.

Table 3-3. 5 point averages of display readings, S/N 1495 CTD 0_2 calibration, 5-7 July 1976.

P(d bar)	C(mmho)	T(°C)	I_{0_2}(μA)	T_{0_2}(°C)	Barometer (m bar)
+0.12	4.3326	26.1148	0.692	26.20	
+0.06	4.6882	30.0494	0.738	30.02	
0.52	4.6054	29.0390	0.712	29.16	
0.40	4.5240	28.0948	0.700	28.14	
0.52	4.4276	26.9618	0.688	26.98	1017
0.40	4.3420	25.9624	0.676	26.08	
0.42	4.1686	23.9420	0.648	23.90	
0.20	4.0154	22.2004	0.620	22.36	1016
0.30	3.8304	19.9334	0.582	19.78	1016
0.30	3.6736	17.9820	0.552	17.60	1015.5
0.00	3.5180	15.9722	0.530	15.72	1015
0.12	3.3600	13.7506	0.496	13.52	1015
0.00	3.2358	12.2112	0.472	11.90	1015
-0.24	2.9718	8.8968	0.430	8.52	1015
-0.20	2.8008	6.7626	0.414	6.28	1014
-0.22	2.7526	6.0454	0.402	5.72	
-0.32	2.6772	4.9062	0.404	4.38	1013.5
-0.36	2.6586	4.5850	0.400	4.06	1013

Table 3-4. S/N 1495 CTD 0_2 Calibration.

I_{0_2}(μA)	T(°C)	T_{0_2}-T	Barometer (m bar)	Bottle Salin. (ppt)	Titrated Bottle 0_2 (mg/l)
0.692	26.1148	.0852	1017		7.024
0.738	30.0494	-.0294	1017		6.829
0.712	29.0390	.1210	1017		6.302
0.700	28.0948	.0452	1017	2.322	6.673
0.688	26.9618	.0182	1017		6.829
0.676	25.9624	.1176	1016.5		7.141
0.648	23.9420	-.0420	1016		7.551
0.620	22.2004	.1596	1016	2.319	7.610
0.582	19.9334	-.1534	1016		7.688
0.552	17.9820	-.3820	1015.5	2.319	8.293
0.530	15.9722	-.2522	1015	2.359	8.488
0.496	13.7506	-.2306	1015		9.112
0.472	12.2112	-.3112	1015	2.350	9.639
0.430	8.8968	-.3768	1015		10.049
0.414	6.7626	-.4826	1014	2.350	10.517
0.402	6.0454	-.3254	1014		10.693
0.404	4.9062	-.5262	1013.5	2.368	10.966
0.400	4.5850	-.5250	1013	2.395	11.024

Table 3-5. 5 point averages of display readings, S/N 1295 CTD O_2 Calibration, 9-10 July 1976.

P(d bar)	C(mmho)	T(°C)	I_{O_2} (μA)	T_{O_2} (°C)	Barometer (m bar)
+0.28	5.3022	23.6816	0.676	23.88	-
0.22	5.9390	30.0820	0.792	30.28	-
0.22	5.7143	27.8290	0.738	28.02	1013
0.32	5.5025	25.8904	0.702	26.14	1013
0.32	5.2898	23.8722	0.668	23.96	1013
0.24	4.8038	18.5464	0.576	18.36	1016
0.18	5.0420	22.0722	0.640	22.10	-
0.40	4.8232	19.9580	0.598	19.90	1016
0.38	4.6174	18.0032	0.564	17.90	1016
0.40	4.4228	16.1074	0.536	15.88	-
0.38	4.2320	14.2466	0.492	13.78	1015.5
0.50	3.9890	11.8206	0.474	11.40	1015
0.50	3.8020	9.9028	0.448	9.72	1014.5
0.54	3.6080	7.8885	0.416	7.64	1014
0.40	3.6956	8.8592	0.424	8.34	1014
0.56	3.4876	6.6260	0.392	6.06	1014
0.60	3.3344	5.0274	0.368	4.38	1014
0.60	3.2844	4.4922	0.364	3.78	1014

Table 3-6. S/N 1295 CTD O_2 Calibration.

I_{02} (μA)	T(°C)	T_{02}-T	Barometer (m bar)	Bottle Salin. (ppt)	Titrated Bottle O_2 (mg/l)
0.676	23.6816	.1984	1013	3.028	8.355
0.792	30.0820	.1980	1013	2.960	7.366
0.738	27.8290	.1910	1013	2.982	7.568
0.702	25.8904	.2496	1013	2.982	7.588
0.668	23.8722	.0878	1013	2.969	7.972
0.576	18.5464	-.1864	1016	3.021	8.880
0.640	22.0722	.0278	1016	2.936	8.174
0.598	19.9580	-.0058	1016	-	8.779
0.564	18.0032	-.1032	1016	2.933	9.586
0.536	16.1074	-.2274	1016	2.930	9.869
0.492	14.2466	-.4666	1015.5	2.926	9.707
0.474	11.8206	-.4206	1015	2.920	10.554
0.448	9.9028	-.1828	1014.5	2.917	10.494
0.416	7.8885	-.2485	1014	2.939	11.302
0.424	8.8592	-.5192	1014	2.945	12.916
0.392	6.6260	-.566	1014	2.945	11.604
0.368	5.0274	-.6474	1014	2.954	11.726
0.364	4.4922	-.7122	1014	2.942	11.504

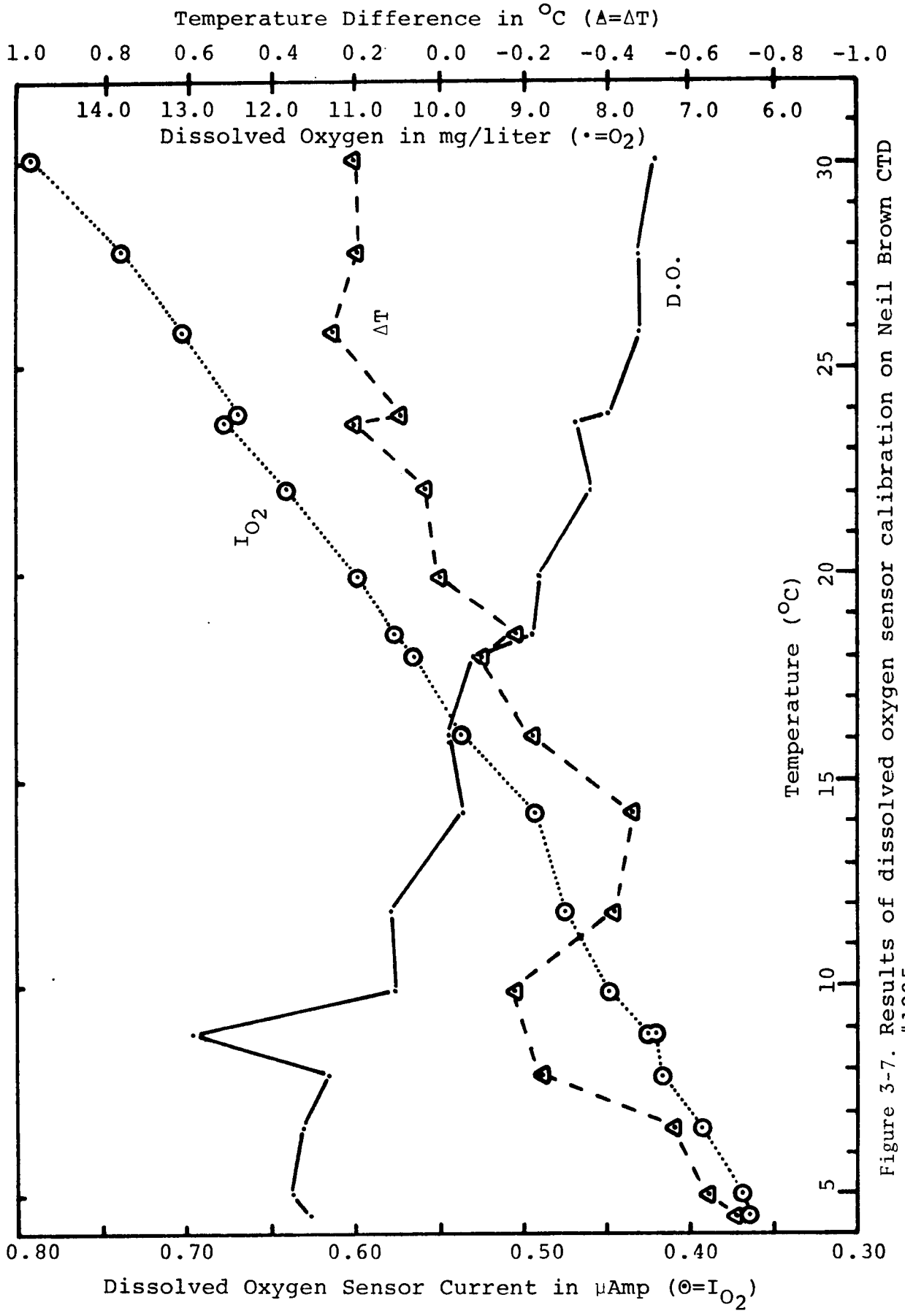


Figure 3-7. Results of dissolved oxygen sensor calibration on Neil Brown CTD #1295.

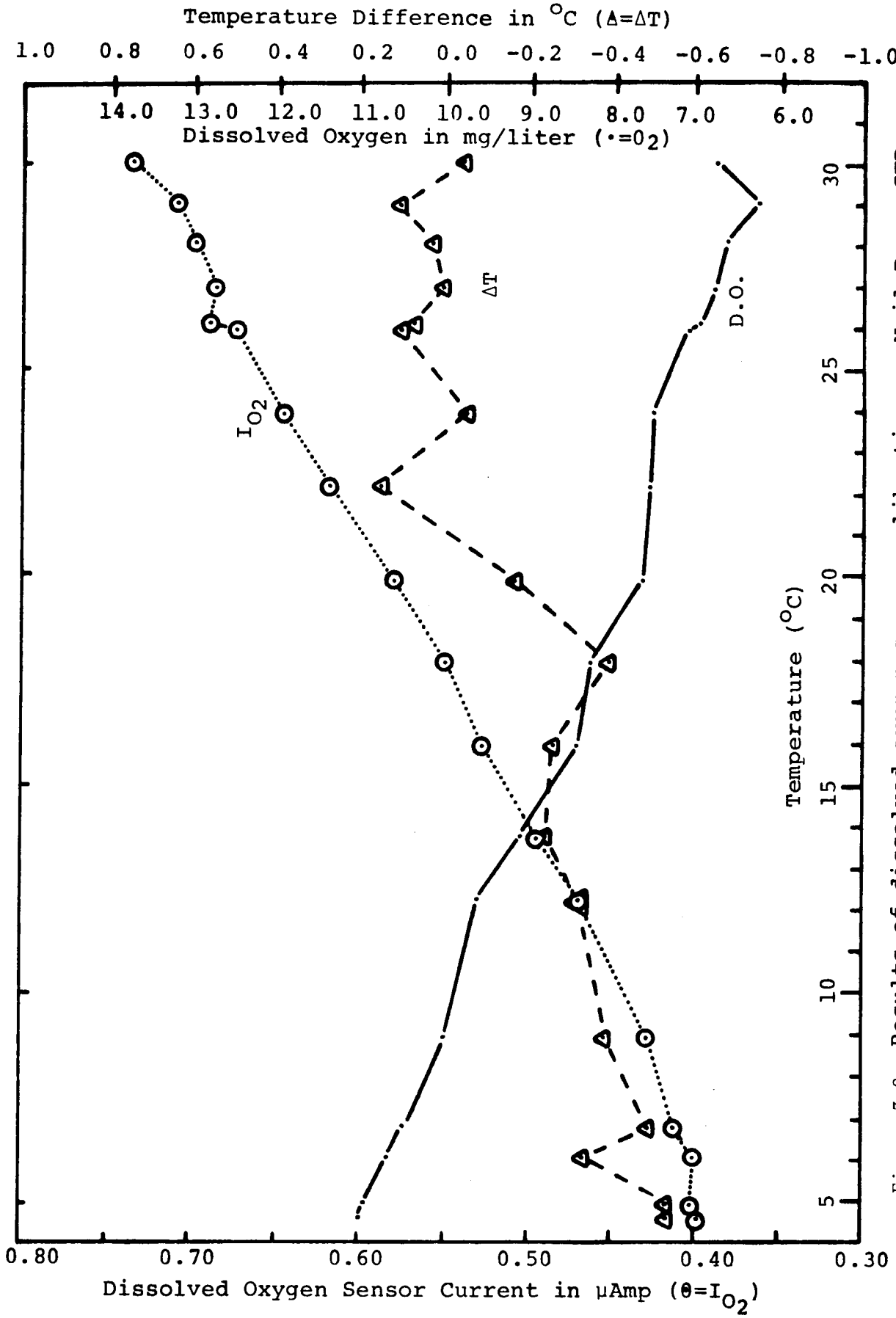


Figure 3-8. Results of dissolved oxygen sensor calibration on Neil Brown CTD #1495.

Bunsen's coefficient is a function of salinity and temperature. It is not mentioned in the Beckman ATO-1019A, but was given to us in the PROB2 Fortran subroutine by Dr. Arnold Bainbridge (Scripps GEOSECS Operations Group) in one consultation with him.

By separating the pressure and temperature effects, and approximating the temperature effects by an inverse polynomial, the O_2 probe current equation is:

$$I_{O_2} = \frac{e^{\gamma p} p_{O_2}}{F(T)}, \qquad (2)$$

where: p_{O_2} = partial pressure of oxygen (atm),

p = sea water pressure (dbar),

$F(T)$ = polynomial function of temperature in ^{o}C, and

γ = exponential coefficient of pressure effects.

The dissolved oxygen is found by applying Bunsen's coefficient to the partial pressure:

$$D_{O_2} = B\, p_{O_2} \qquad (3)$$

where: D_{O_2} = dissolved oxygen (mℓ/ℓ),

B = Bunsen's coef., a function of salinity and temperature, and

$$1 \text{ mℓ/ℓ } O_2 = 1.42953 \text{ mg/ℓ } O_2 \qquad (4)$$

Bunsen's coefficient is defined by Bainbridge in PROB2 as:

$$B = 1000.\, e^{x}, \qquad (5)$$

where: $x = -58.3877 + 8580.79/u + 23.8439\, \ell n(v) + S(-0.034892 + v(0.015568 - 1.9387(10^{-3})v))$,

S = salinity of the water (ppt)

u = absolute temperature of the water (^{o}K), and

v = u/100.

Note that for temperature, $T(^{o}C)$,

$$u = T + 273.16 \qquad (6)$$

It is assumed that the entire oxygen probe is at temperature T in the above calculations.

If the entire probe is at temperature T and the pressure can be assumed to be zero (compared to the accuracy of the pressure measurement and the pressures encountered in actual operation), the partial pressure can be found from the oxygen current by the sensitivity function:

$$p_{O_2} = I_{O_2} F(T) \tag{7}$$

If the entire probe is not at temperature T, the sensitivity function can be approximated by the average of the sensitivity at the water temperature, T, and the sensitivity of the backend probe temperature, T_{O_2}:

$$\overline{F} = \frac{F(T) + F(T_{O_2})}{2}, \tag{8}$$

according to the method of PROB2. Equation 7 is rewritten:

$$p_{O_2} = I_{O_2} \overline{F} \tag{9}$$

The temperature T_{O_2} is measured by a thermistor in the screw contact socket of the oxygen probe (not in the probe itself), it is taken that the temperature varies in such a way from the membrane, water temperature, T, to the temperature at the other end of the probe, T_{O_2}, that Equations (8) and (9) hold true. The back-end probe temperature, T_{O_2}, is highly dependent on the CTD case and internal temperature. The thermal masses and conductivities involved are such that T_{O_2} lags T by about 15 minutes with the CTD in well-stirred water.

The Scripps subroutine, PROB2, also makes predictive calculations on the partial pressure to correct for the oxygen probe time constant, which is on the order of six to fifteen seconds at room temperature and is also a function of temperature. No data was taken in this regard in the O_2 calibrations. Therefore, no calculations are made in our present subroutines to correct for time lag.

Equations (3) through (9) are used as a basis for calculating dissolved oxygen concentration and oxygen partial pressure in CTDRAV. The calculations are also based on which CTD was used. For each CTD, the sensitivity function, F(T), and a corrected probe temperature, T_{O_2}, are calculated based on the calibration data.

For each probe, a first-order least squares fit of T_{O_2} to T was made using a Hewlett Packard 9810A calculator. The calculated value of T by the linear fit was taken to be the corrected probe temperature, T_{O_2}. For CTD S/N 1295, the correction is:

$$T_{O_2C} = 0.7443 + 0.9656 T_{O_2} \tag{10}$$

For CTD S/N 1495, the correction is:

$$T_{O_2C} = 0.5859 + 0.9768 T_{O_2} \tag{11}$$

All data points were used for each fit. The program used to make the fit came from the Hewlett Packard library.

In order to get a function of F(T) for each CTD, two programs were used. The first was written in BASIC on the NOVA 1220 minicomputer. The inputs are the oxygen probe current, and temperature, water temperature, bottle sample salinity, and bottle sample dissolved oxygen from the 0_2 calibration data. The oxygen probe temperature is corrected and then averaged with the water temperature:

$$\overline{T} = \frac{T + T_{0_2}}{2} \qquad (12)$$

The averaged temperature and the bottle salinity are used to calculate Bunsen's coefficient for that sample point (by Equations (5) & (6)). The bottle sample dissolved oxygen is divided by the calculated Bunsen's coefficient (Equation (3)) to get the partial pressure of oxygen at that point.

The sensitivity at that point is calculated by dividing the calculated partial pressure by the measured oxygen probe current:

$$F(\overline{T}) = p_{0_2}/I_{0_2} \qquad (13)$$

By printing out the appropriate variables, a tabulation of probe current, averaged temperature, sensitivity function, Bunsen's coefficient, and partial pressure of oxygen can be made for each CTD.

A least-squares polynomial fit of sensitivity function to temperature was made using the IBM FORTRAN Scientific Subroutine Program library on the VIMS IBM 370 computer. The sample main program POLRG with the subroutines GDATA, ORDER, MINV, and MULTR was used, omitting subroutine PLOT and changing the polynomial coefficient output to E15.6 format. One data point at I_{0_2} = 0.424μA in the CTD S/N 1295 data was omitted because of a titrated DO value that was too high. The best fit for CTD S/N 1295 was a second-order polynomial:

$$F(T) = 0.596878 - 0.015579T + 0.000130268T^2 \qquad (14)$$

The best fit for CTD S/N 1495 was a third-order polynomial, but the second-order polynomial was chosen to maintain consistency:

$$F(T) = 0.509933 - 0.0112861T + 0.0000715741T^2 \qquad (15)$$

The pressure effects lumped together as an exponential in Equation (12) may be calculated from the fitting of pressure-sorted CTD cast data to the titrated DO bottle samples from the same cast:

$$\frac{D_{0_2\ CTD}}{D_{0_2\ Bottle}} = \beta e^{\gamma p} \qquad (16)$$

Plots of F(T) vs. T for both CTD units are given in Figure 3-9.

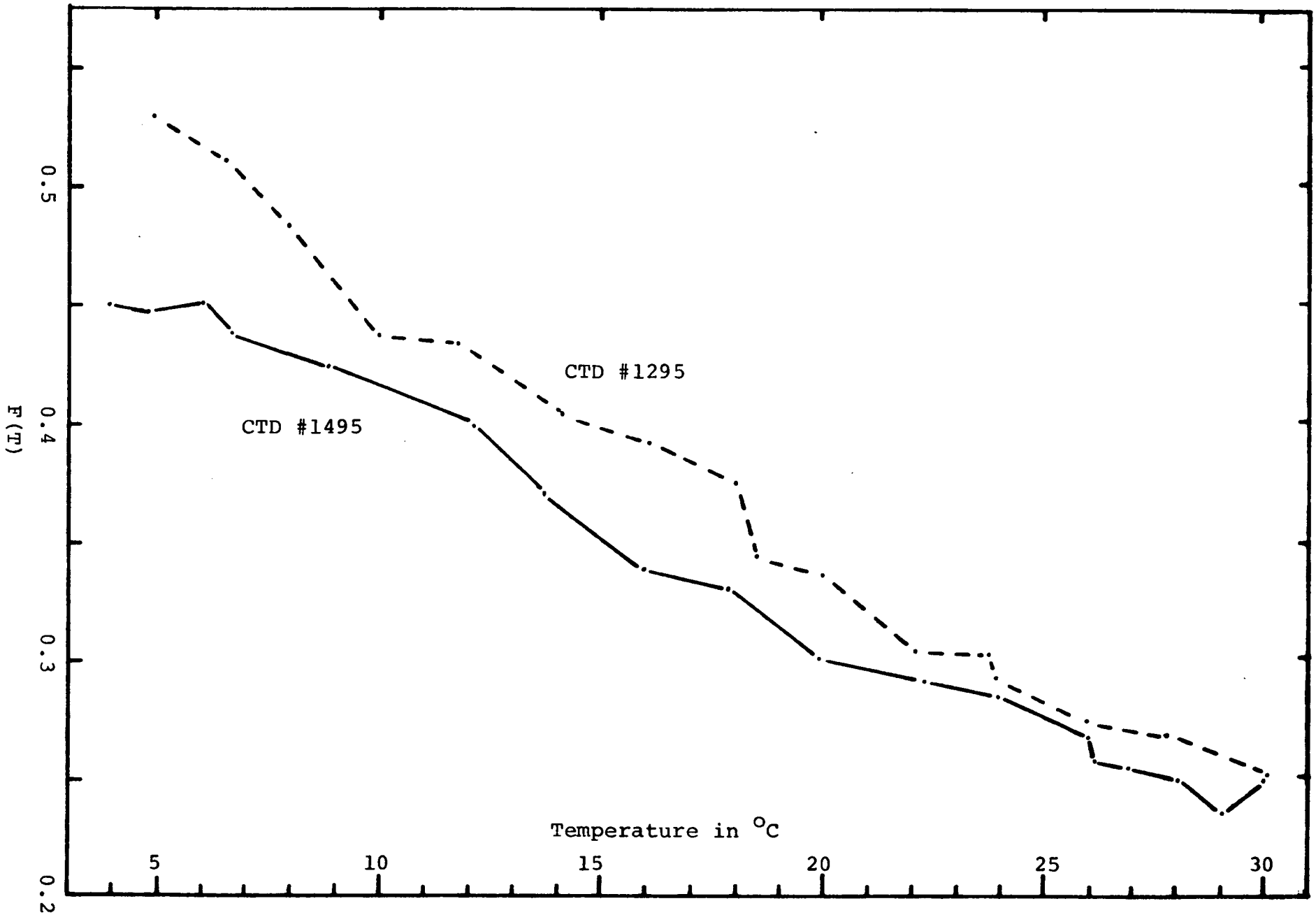


Figure 3-9. F(T) vs. temperature.

First Pass Calculations. The first pass program in present use is called CTDRAV, written by Baker. In brief, CTDRAV reads a record at a time from the binary digital tape and generates FORTRAN floating point 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 measurement 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.[1] 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, rewound, and printed out.

A copy of CTDRAV with flowcharts is included as Appendix 3-A.

Program CTDCR1. The final pass of the data in the CTD processing cycle consists of program CTDCR1.[2] 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 mechanism for correcting the record is implemented in a subroutine CORR, which transfers the input record to the output buffer. This subroutine has access to the input data and an array of up to six constants which are entered in a card for each station. An entry to CORR, designated as 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.

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[1] 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. This data, printed one frame per line, would generate a 1562.5 ft (or approx. ¼ mile) computer printout.

[2] Written by C. Welch.

Thus, CTDCR1 was used to correct values of temperature, salinity, or DO calculated by CTDRAV. The method used to correct DO values was to determine a line of best fit between bottle DO and CTD/DO values (as calculated in CTDRAV) for each station sampled and apply the equation for this line to the CTDRAV output.

The output of CTDCR1 is contained on a "final digital" tape, which is used to generate plots and as entry to the NODC transmission process.

RESULTS

Two methods of presenting meteorological and hydrographic data have been employed: digital magnetic tape and graphic. 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. (A complete listing of all data would result in an eighteen inch thick printout.) Magnetic tapes containing all data have been furnished to NODC for inclusion in their data file.

Graphics

Meteorological and hydrographic data (to include results of micronutrient analysis) have been presented in several ways to meet contract requirements and assist possible users. Graphics are combined on a cruise basis with individual station data ordered numerically by station identification within any given cruise.

Meteorological Parameters

Time histories of atmospheric pressure, wind speed and direction, wet and dry bulb air temperature, and cloud cover are plotted on a per-cruise basis. They are presented as the first figure(s) 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. Wind data for cruise BLM02B is missing after 21 March 1976 because the anemometer was blown away by winds greater than 60 knots.

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 3-10.
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 3-10).
4) Plots of temperature, salinity, DO, and density (σ_t) as functions of depth for numerically ordered stations on each cruise.
5) Plots of temperature vs. salinity and DO vs. salinity for numerically ordered stations on each cruise.
6) Results of XBT casts taken on each cruise.

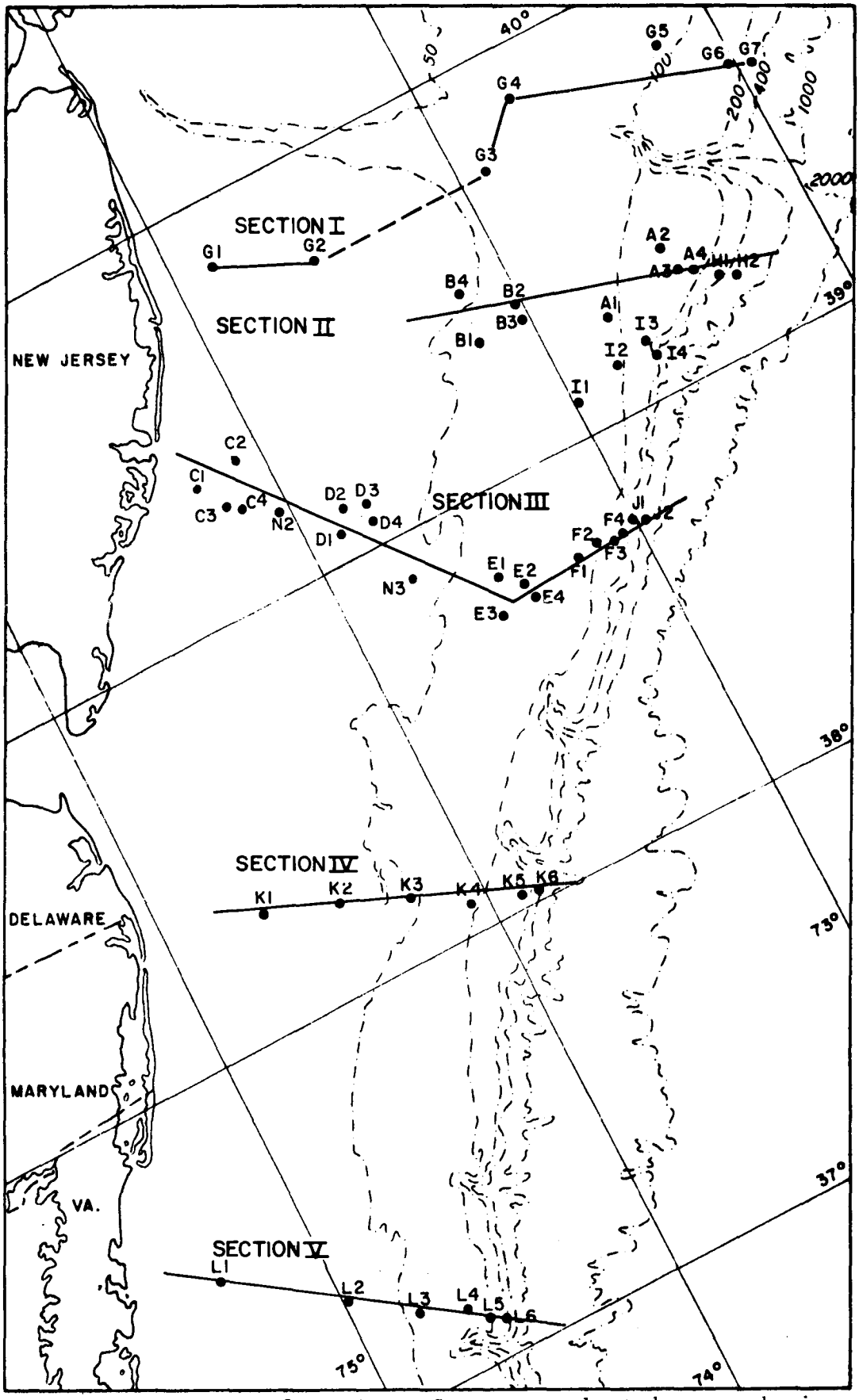

Figure 3-10. Chart of Baltimore Canyon trough study area showing Sections (I through IV) along which isopleths and surface, mid-depth, and bottom values of temperature, salinity, DO, and σ_t were plotted.

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. The greatest disparity resulting from these conditions is evident in surface distributions of parameters measured during BLM02B. In these plots, definite discontinuities in isopleths were left at appropriate locations. (Similar treatment was not given to the bottom distributions for this cruise because it was felt that bottom conditions would change at a slower pace than surface conditions. This, however, is indeed a moot decision.) Similarly, discontinuities in isopleths are incorporated in sectional plots (2 above) when sampling of adjacent stations occurred at intervals greater than five days. In these cases, sampling periods are indicated at the top of the figure.

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 functions of depth and T-S, DO-S figures were generated by computer using results of CTD/DO casts. XBT plots were also computer generated and used recorded data points obtained from XBT traces as previously described.

All plots of individual parameters at each station and XBT's are not included in the main body of this report because their number exceeds 1000. They are, however, available on microfiche. These plots are arranged by station in the following sequence: temperature, salinity, DO, and σ_t vs. depth; temperature vs. salinity; and DO vs. salinity. Depth dependent plots were plotted from zero to 160 meters. When a given station was greater than 160 meters deep, additional depth dependent plots were made which went from zero to 800 meters. Similar treatment was given to XBT plots.

Sequential Presentation of Results

As previously indicated, graphic results are ordered according to the alphameric coding of cruises (BLM01B, 01W, 02B, 02W, 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 $O\text{-}PO_4$)
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) Variations of temperature, salinity, and DO at near surface, mid-depth and near bottom as well as variations of NO_2, NO_3, and $O\text{-}PO_4$ at near surface and near bottom (grouped by section)

Lateral variations 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. Similar data for micronutrients are arranged as plots of near surface values of NO_2, NO_3, and $O\text{-}PO_4$; near bottom plots of the same constituents; and an additional plot giving near bottom variations of NO_3 along each section. This latter plot was included because near bottom values of NO_3 ranged from 0.00 to nearly 30 µgm atoms per liter while NO_2 and $O\text{-}PO_4$ only varied between 0.00 and less than 5 µgm atoms per liter.

Cruise BLMØ1B

Fall 1975

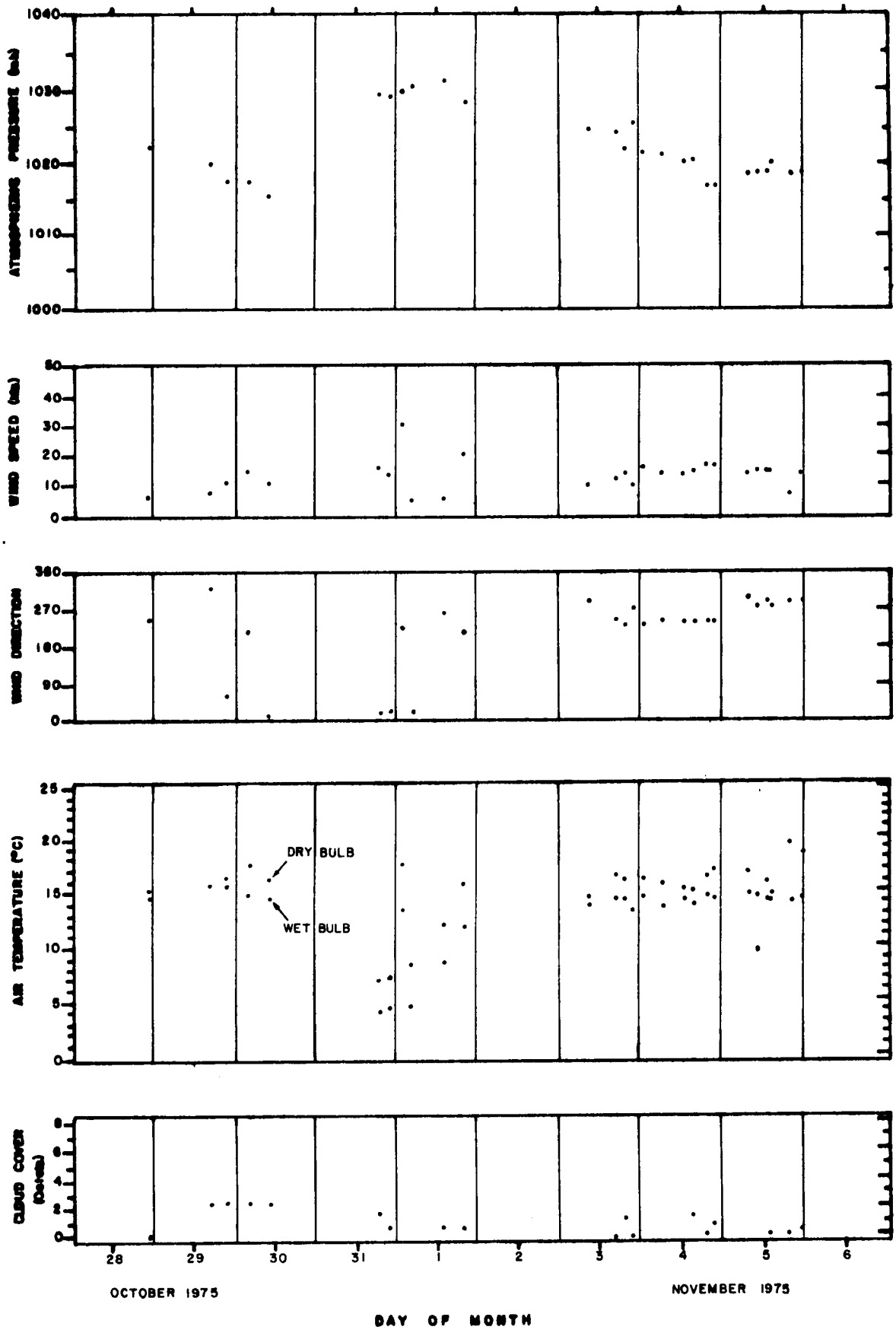

Figure 3-11. Meteorological data collected during cruise BLM Ø1B 28 October to 5 November 1975.

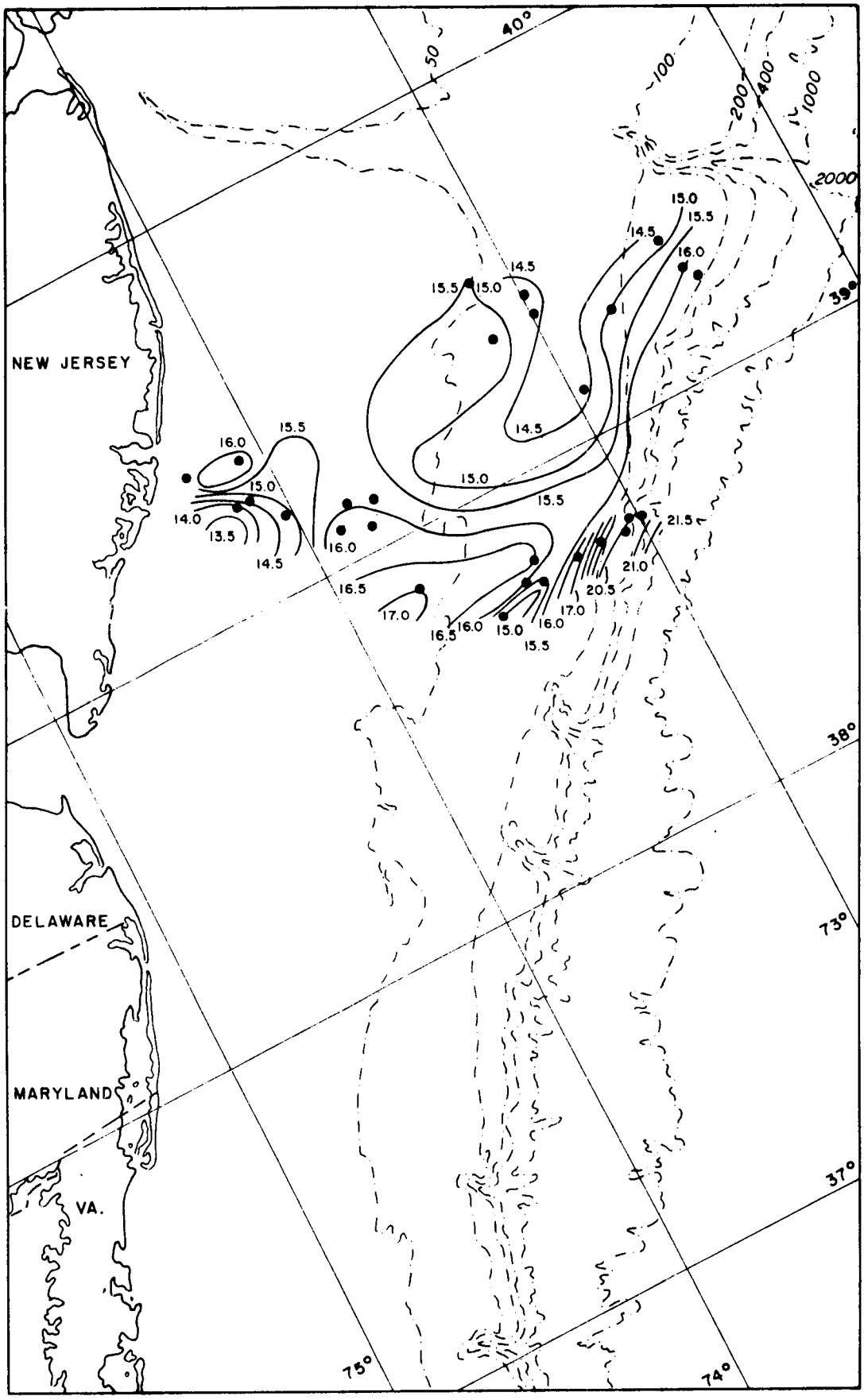

Figure 3-12. Surface temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

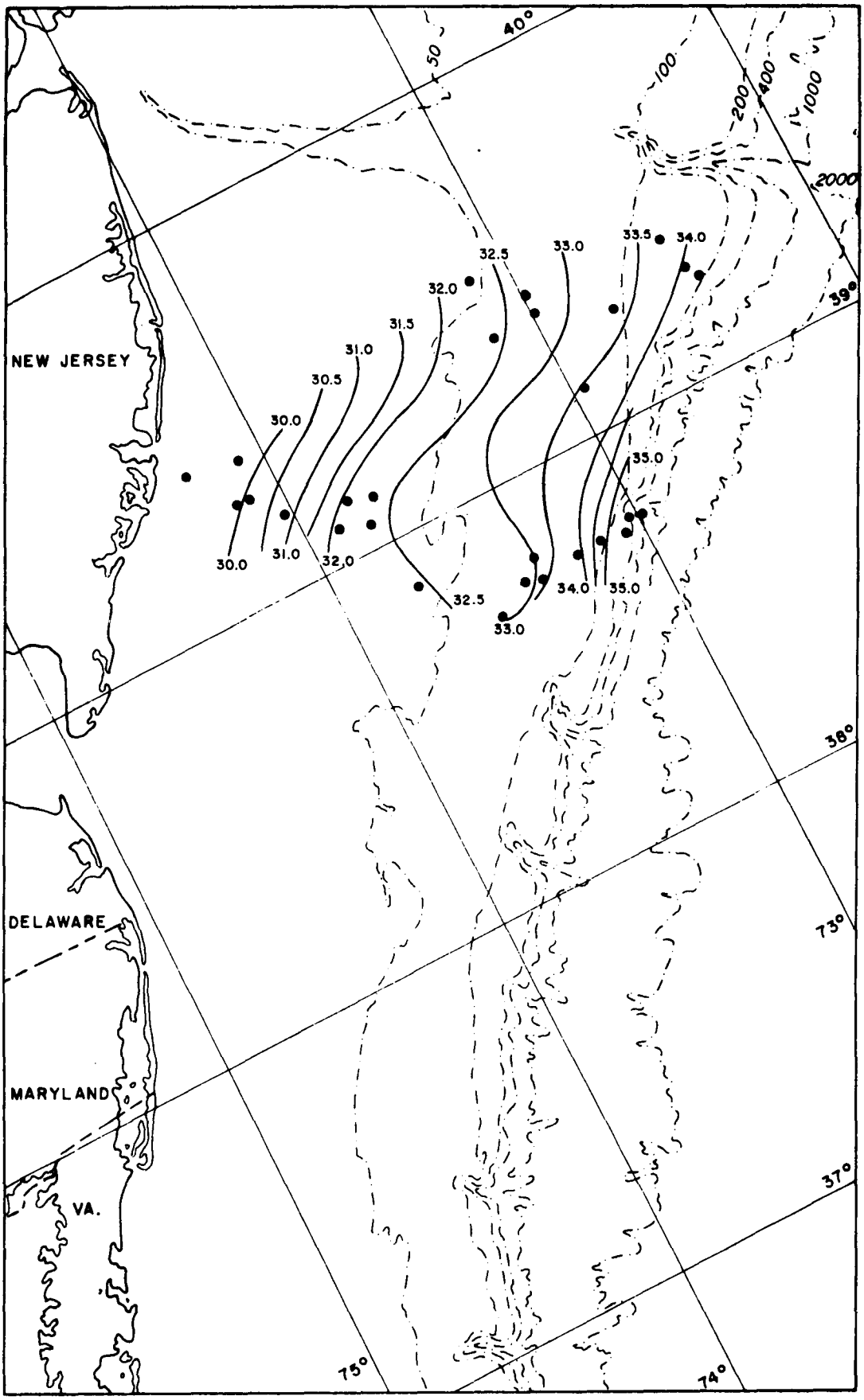

Figure 3-13. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

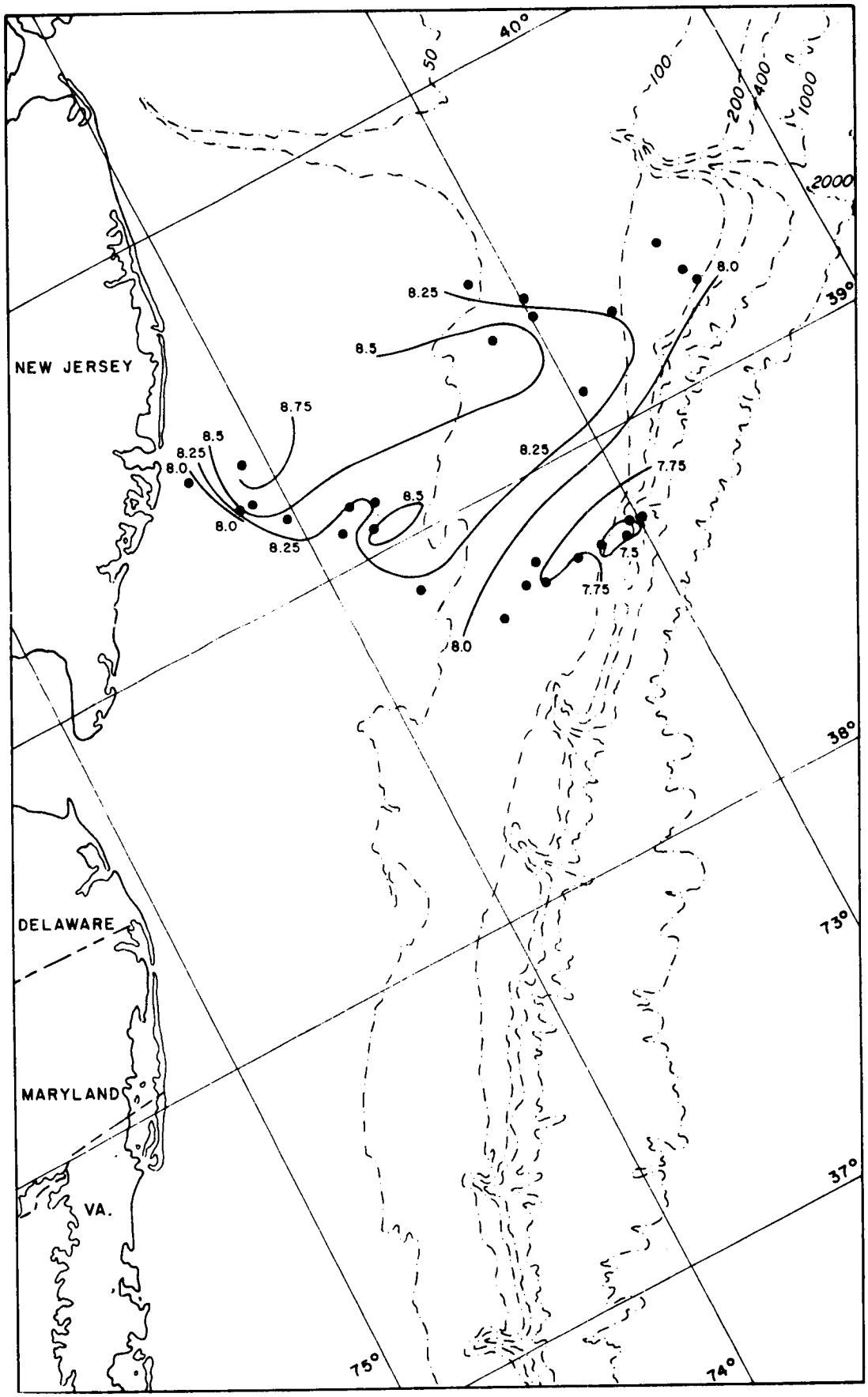

Figure 3-14. Surface dissolved oxygen (mg/1) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

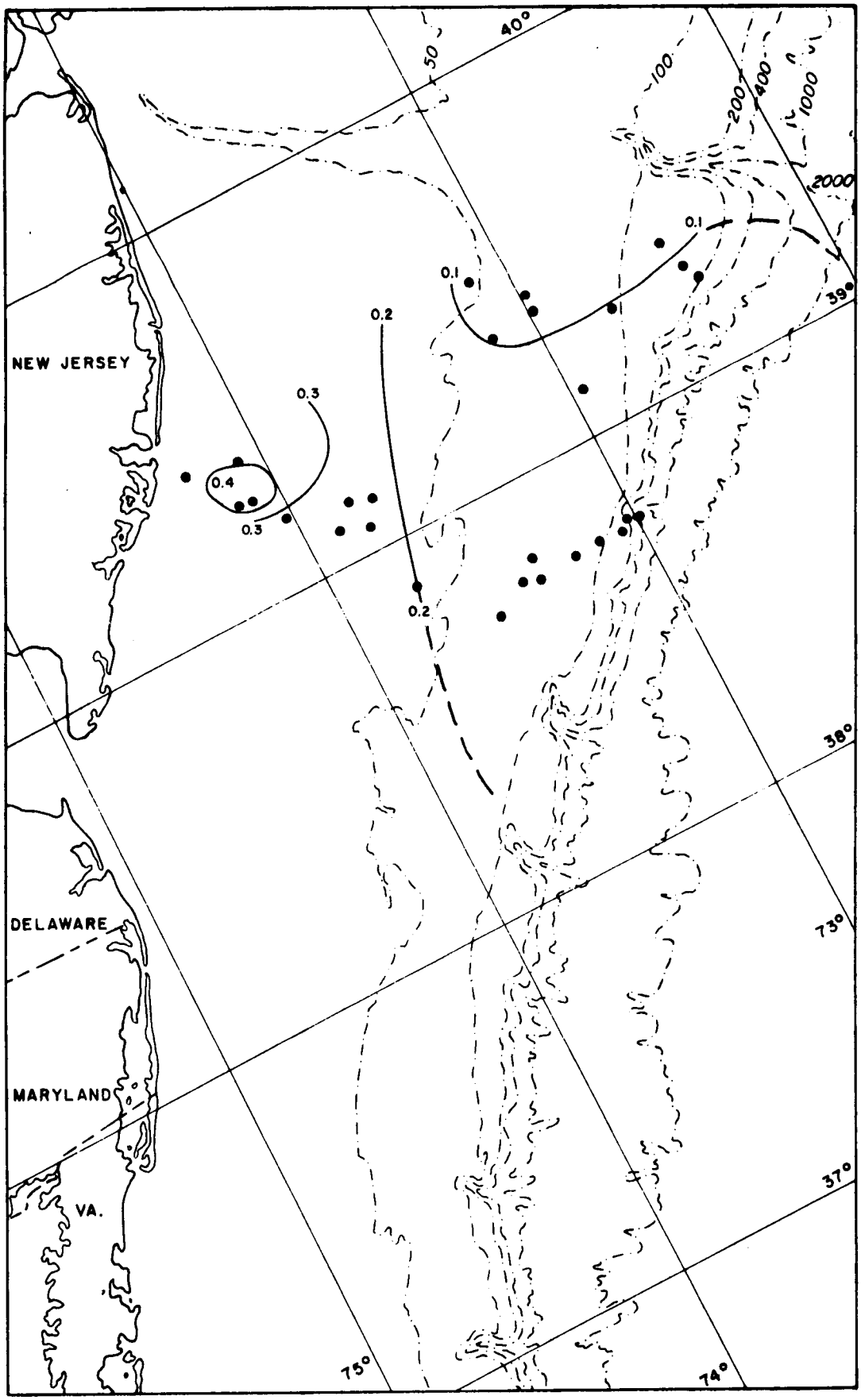

Figure 3-15. Surface NO_2 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

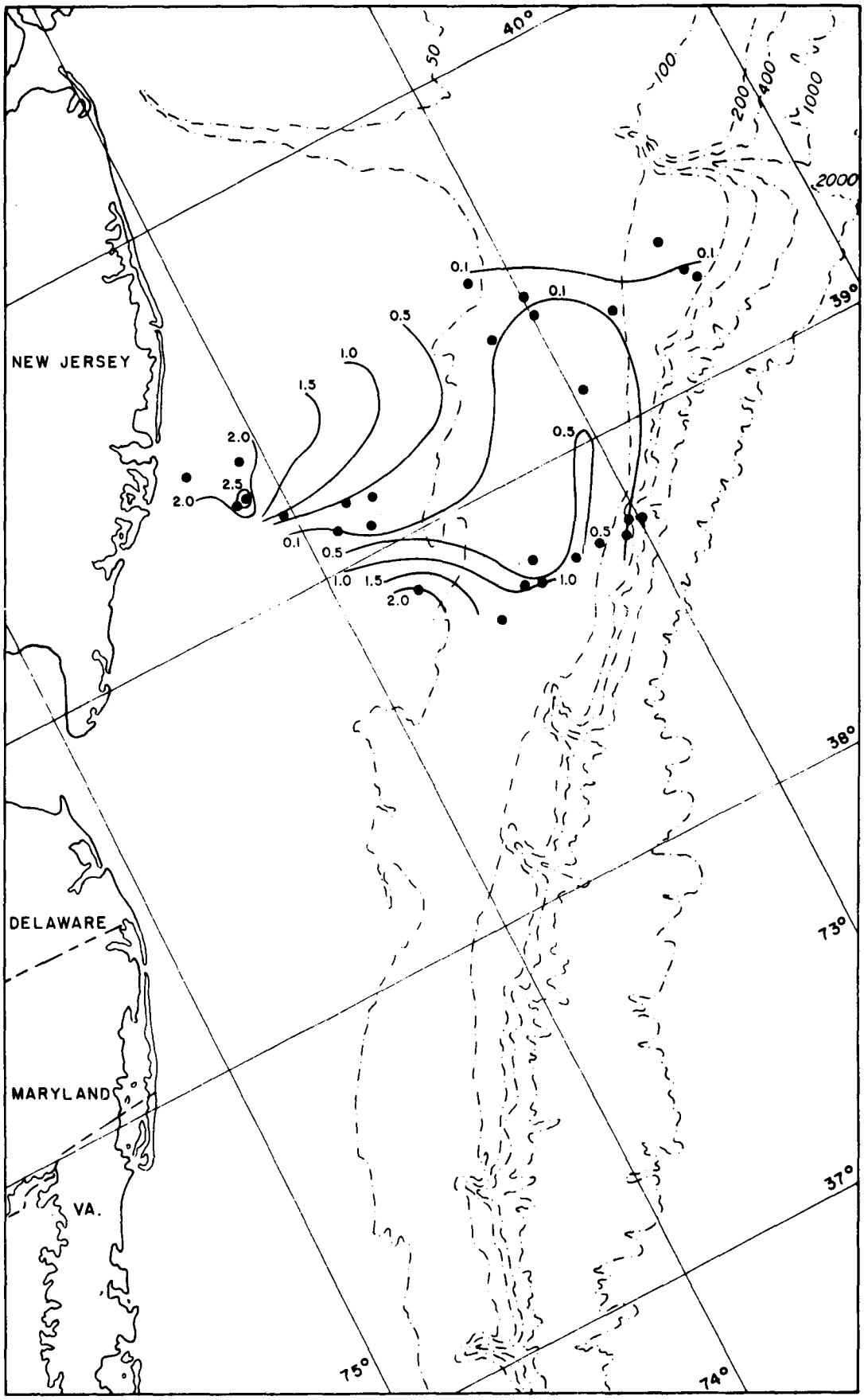

Figure 3-16. Surface NO_3 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

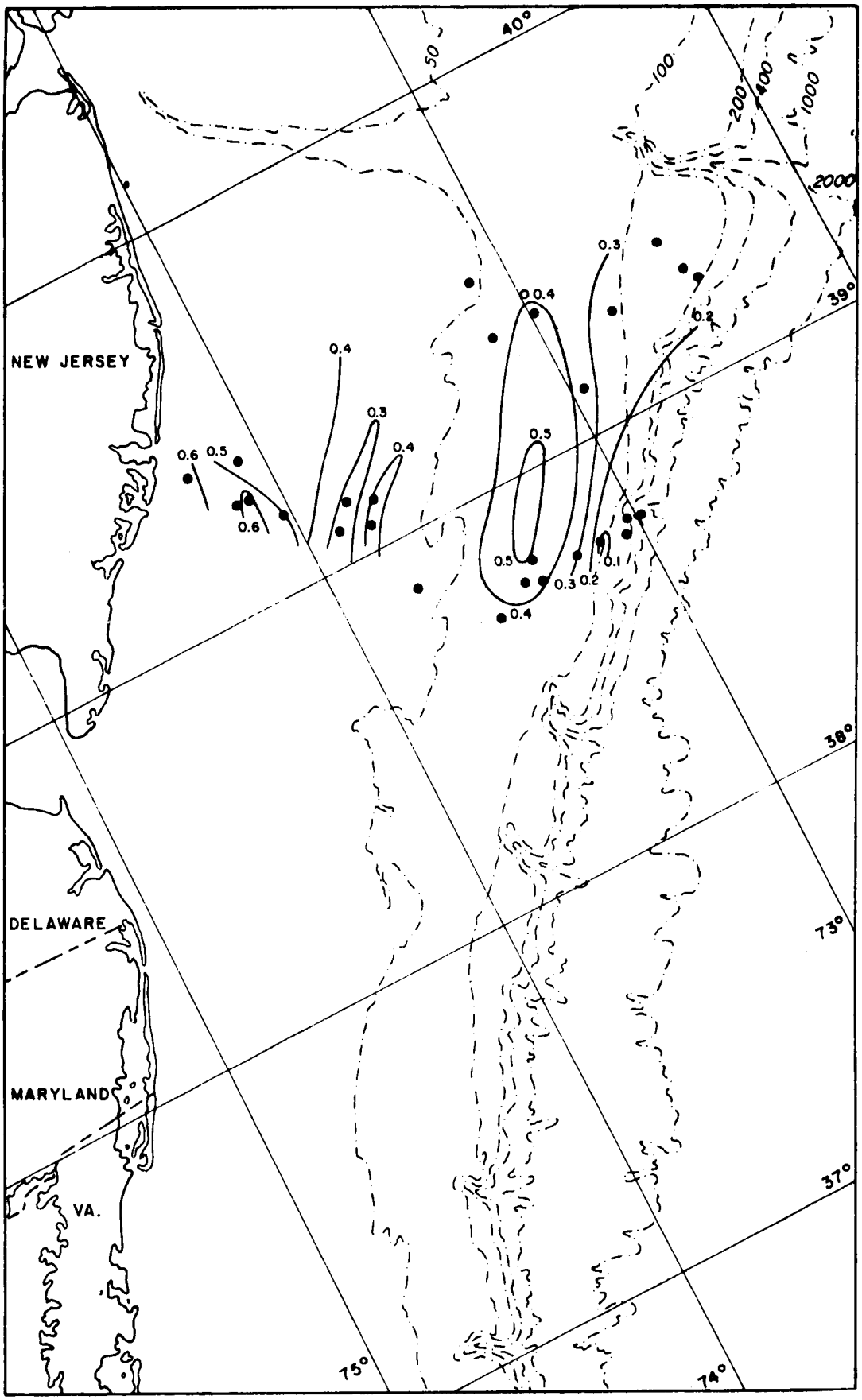

Figure 3-17. Surface O-PO_4 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

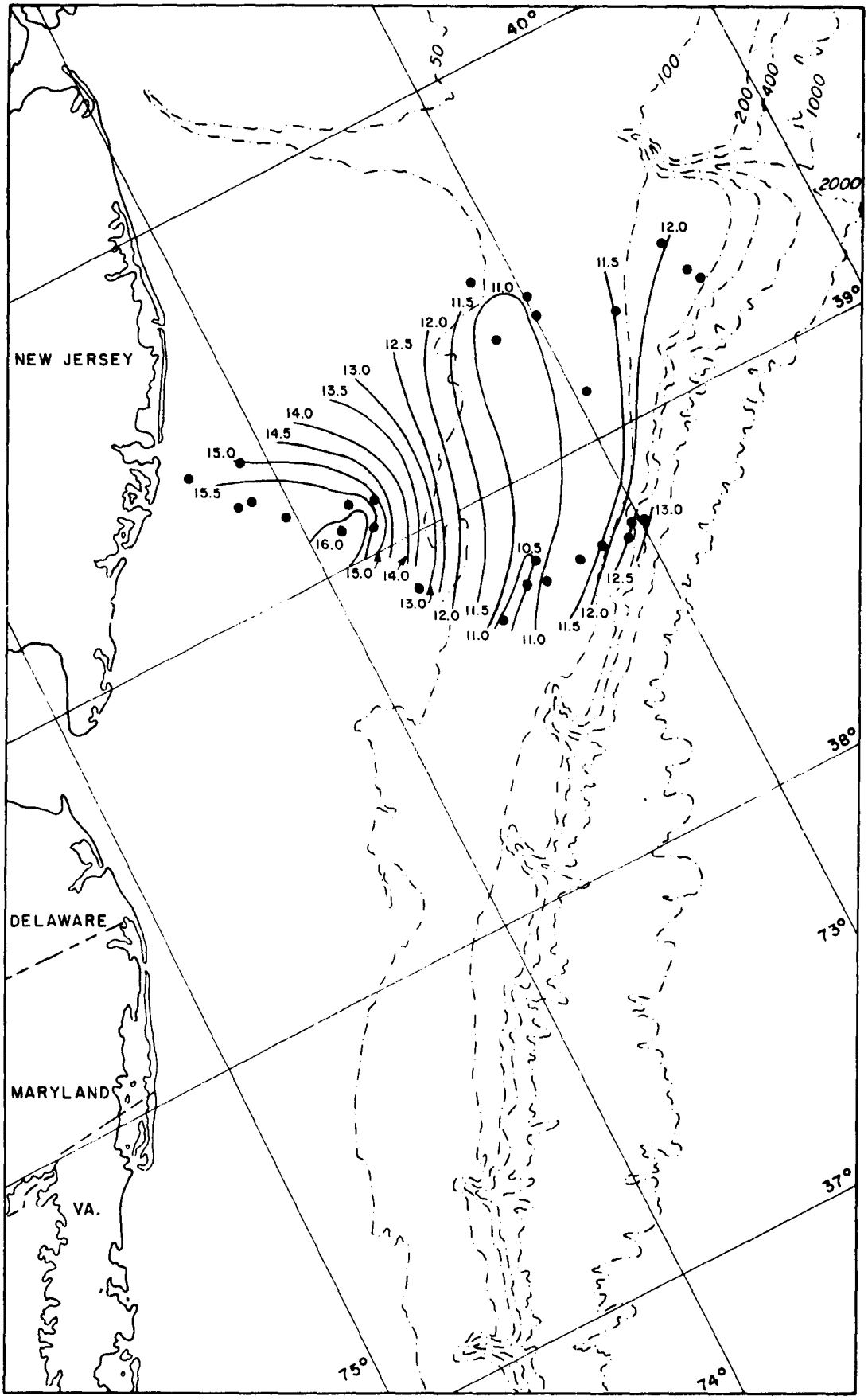

Figure 3-18. Bottom temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

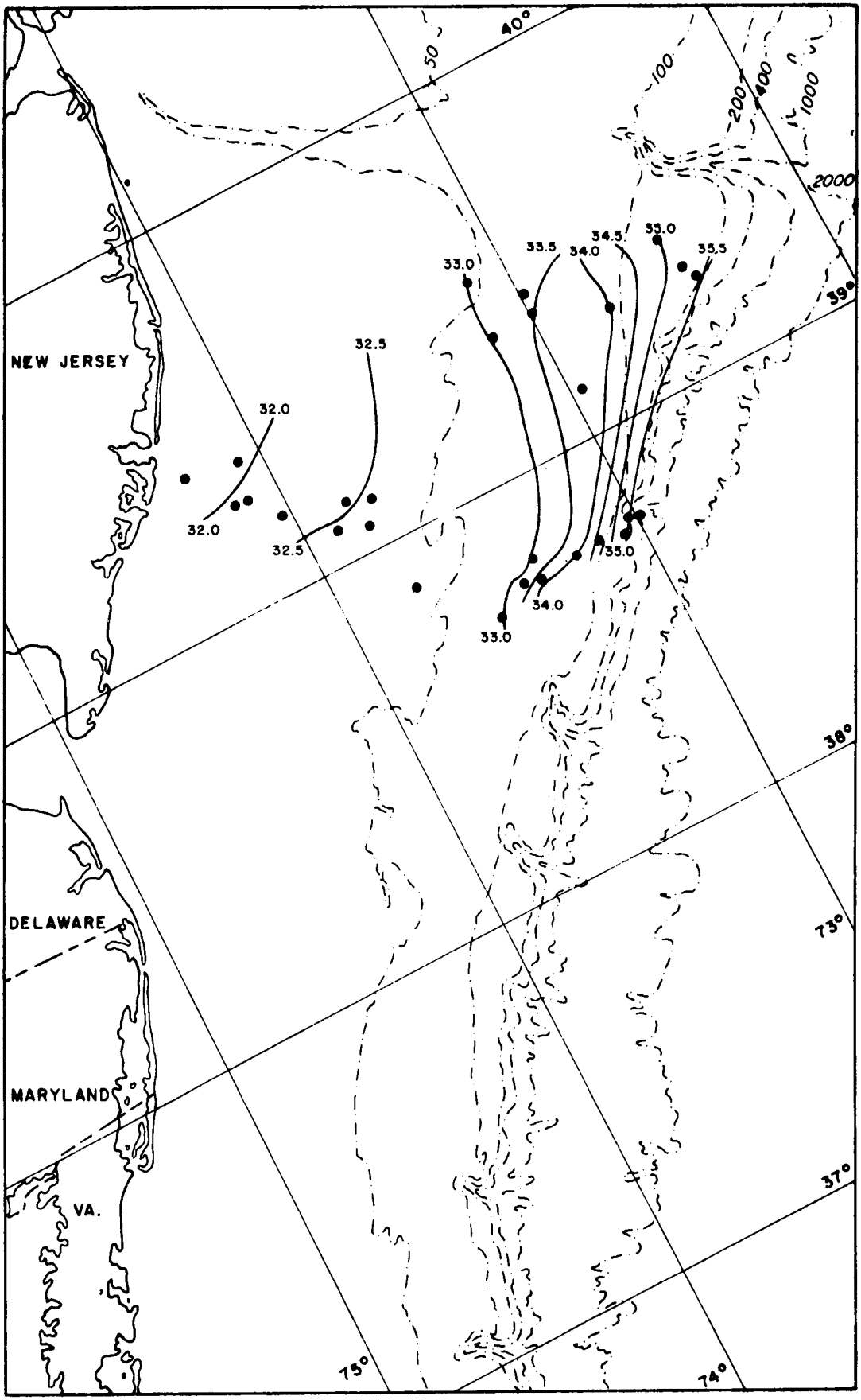

Figure 3-19. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

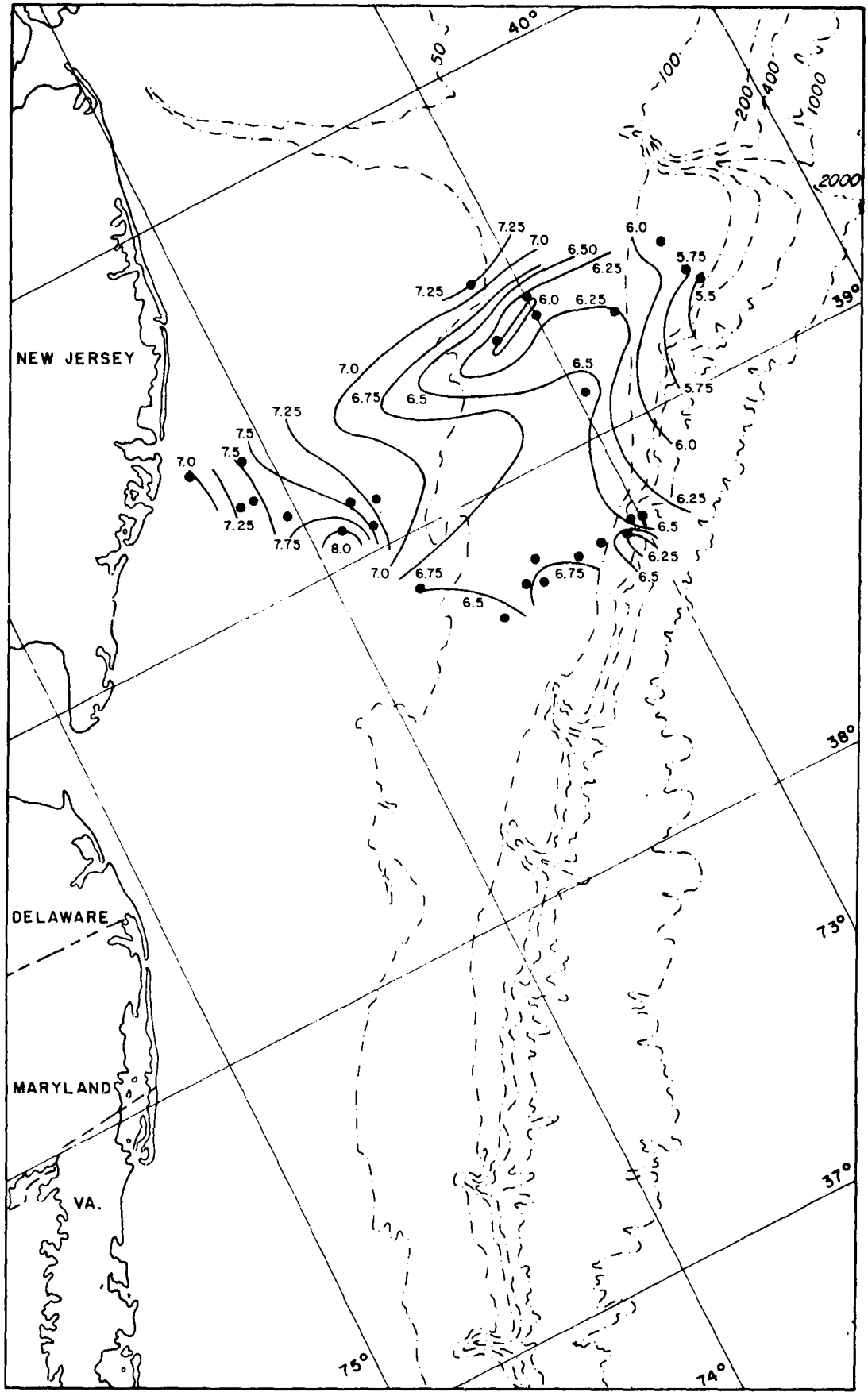

Figure 3-20. Bottom dissolved oxygen (mg/1) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

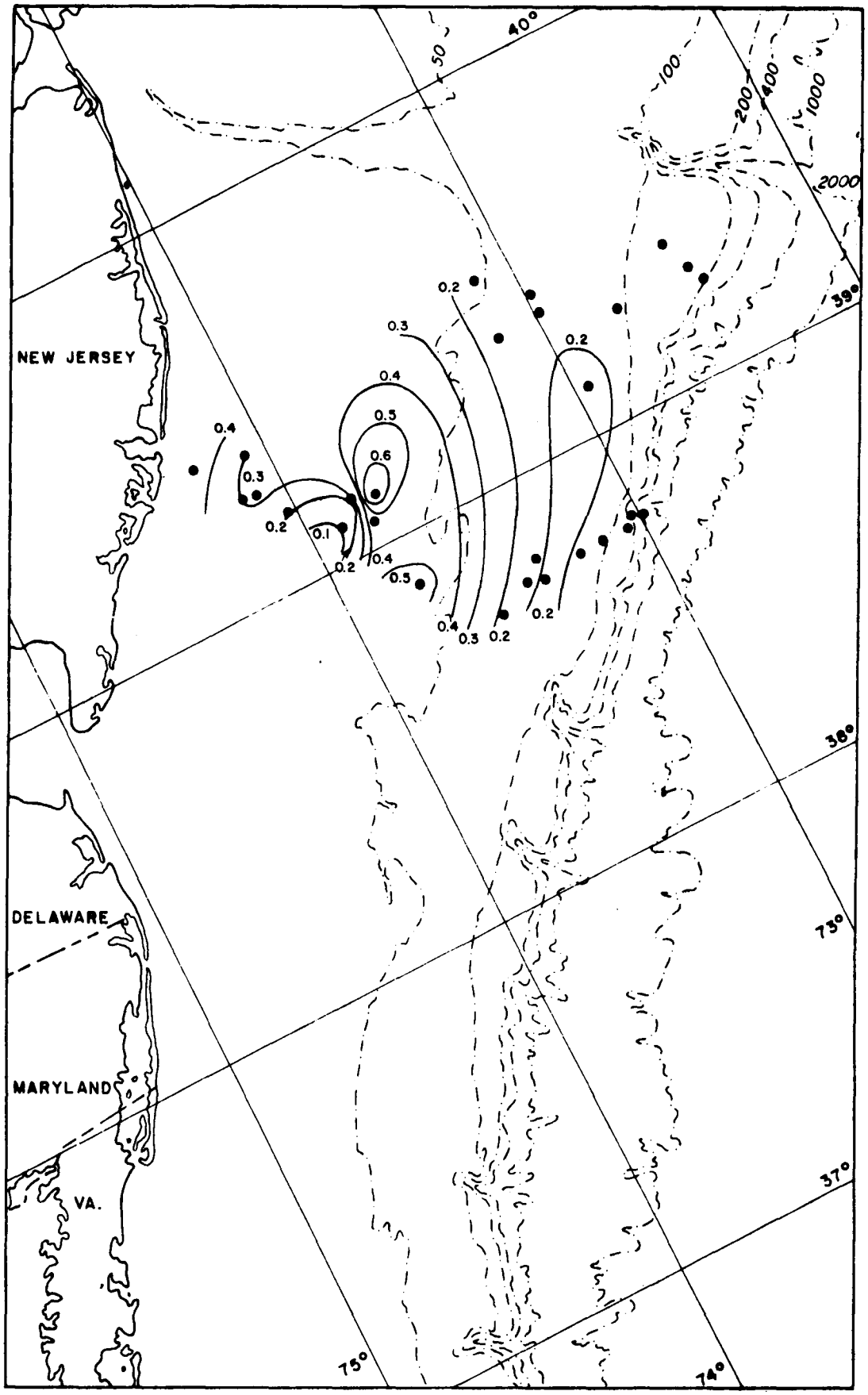

Figure 3-21. Bottom NO_2 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

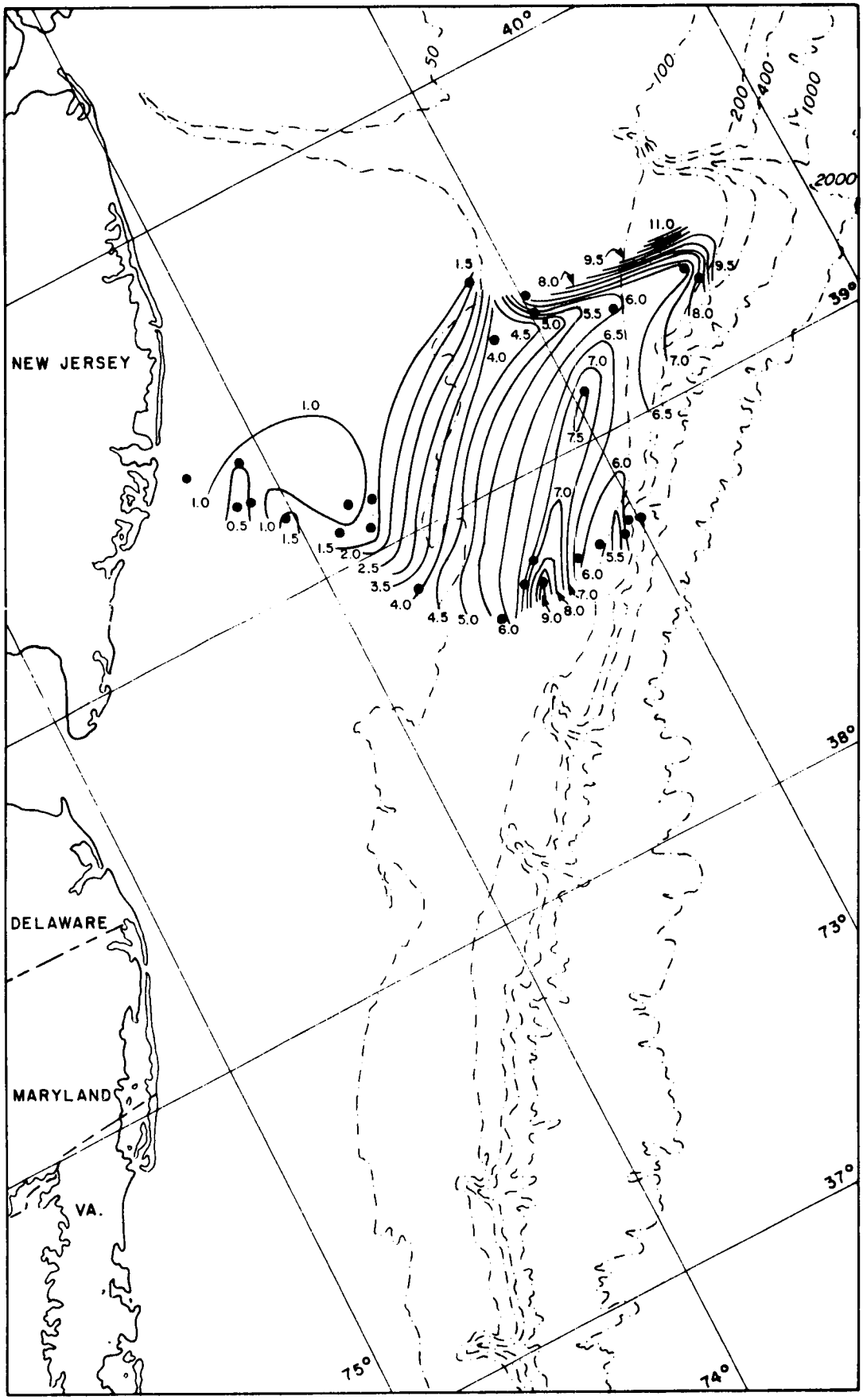

Figure 3-22. Bottom NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

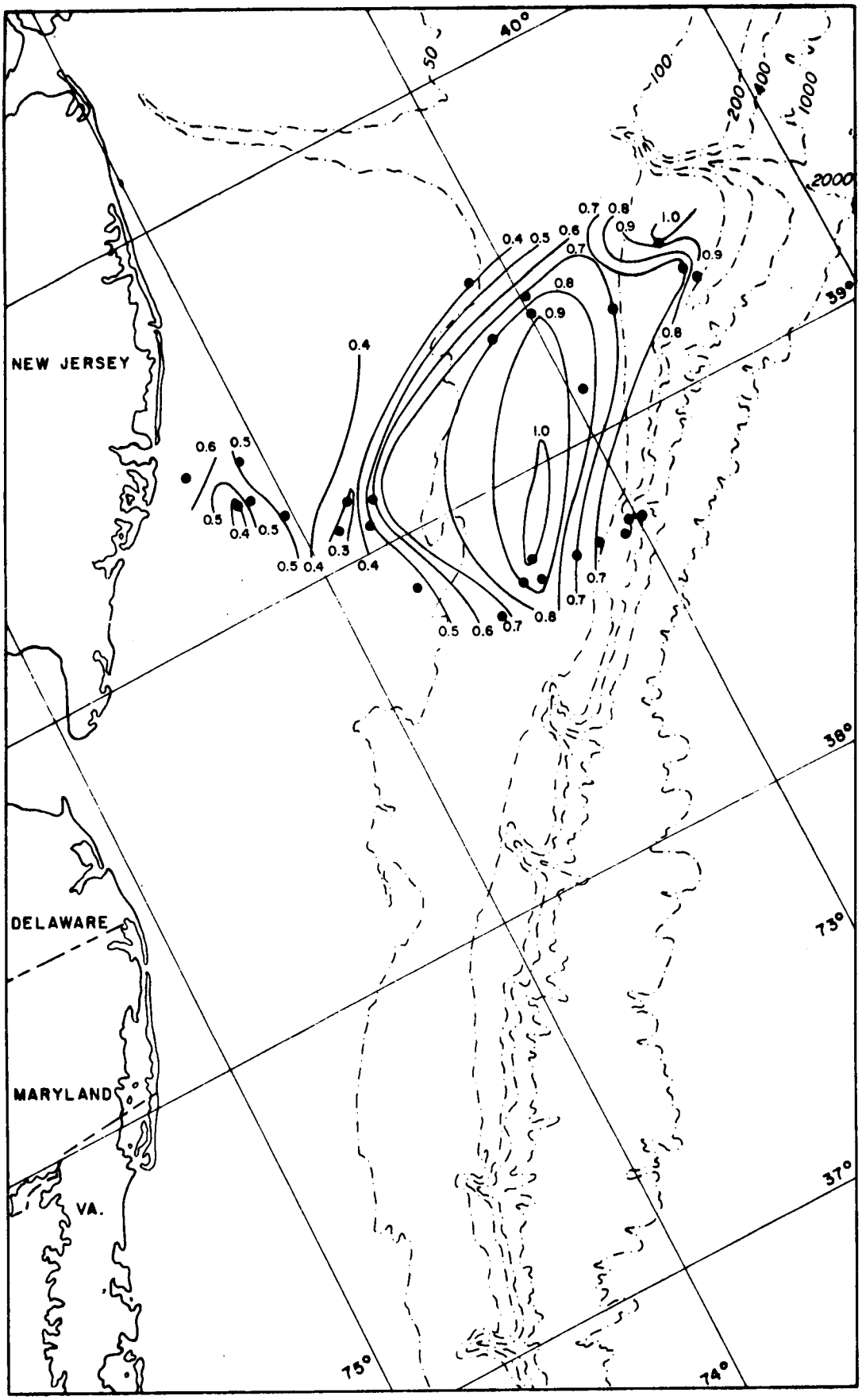

Figure 3-23. Bottom O-PO_4 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 27 October to 6 November 1975 (Cruise BLMØ1B)

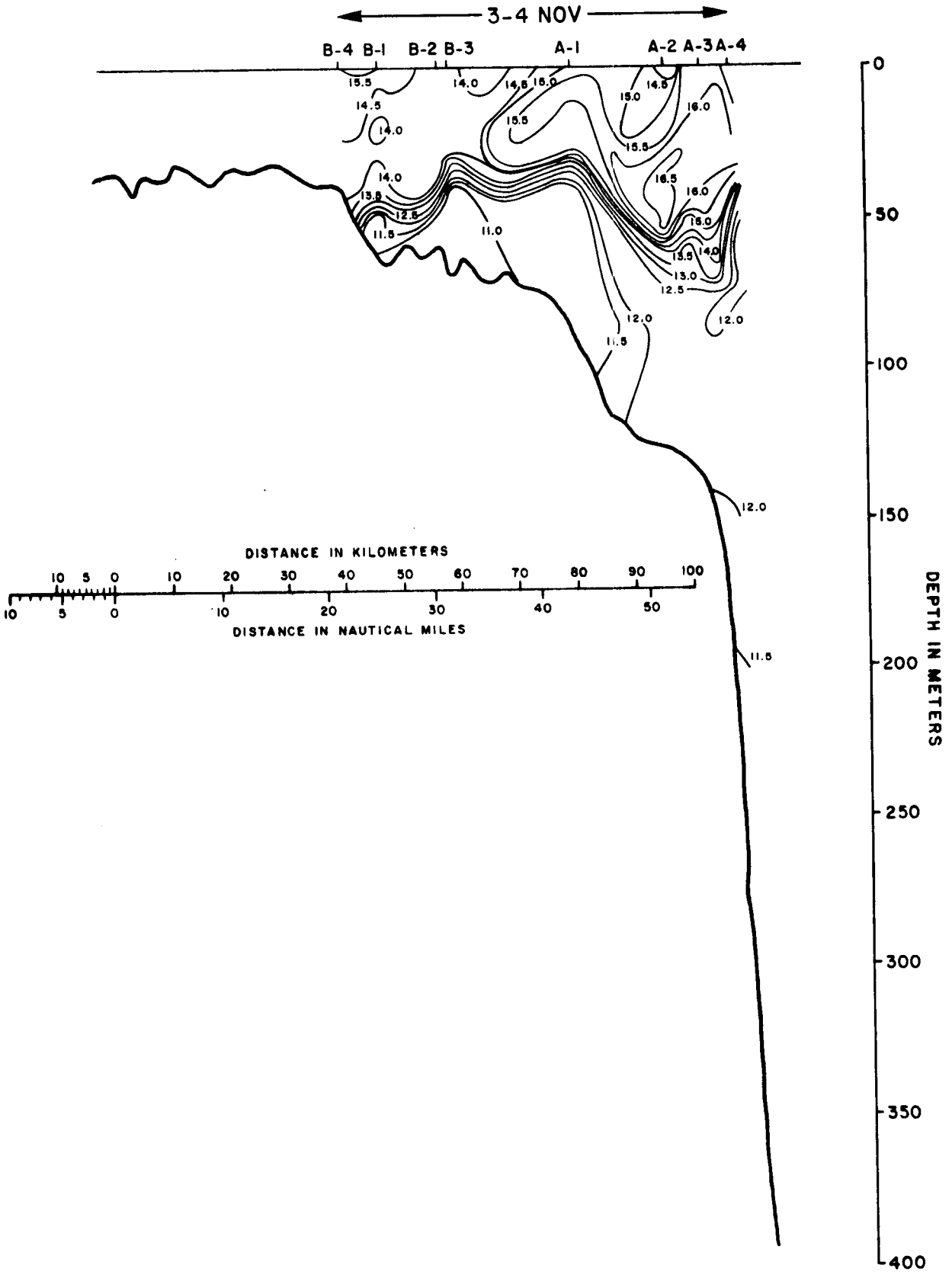

Figure 3-24. Temperature (^{o}C) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLMØ1B. Section location is is shown in Figure 3-10.

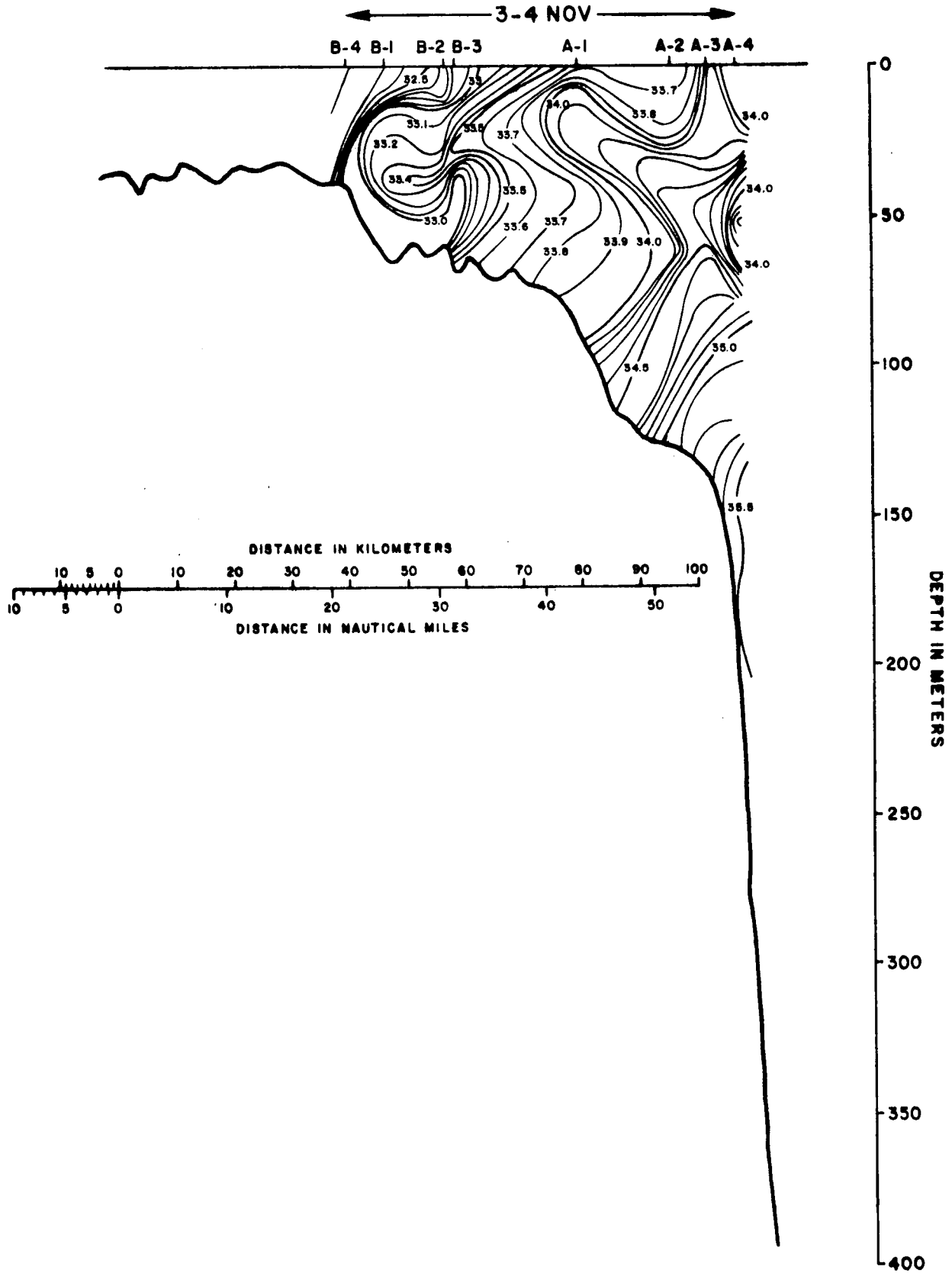

Figure 3-25. Salinity (ppt) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

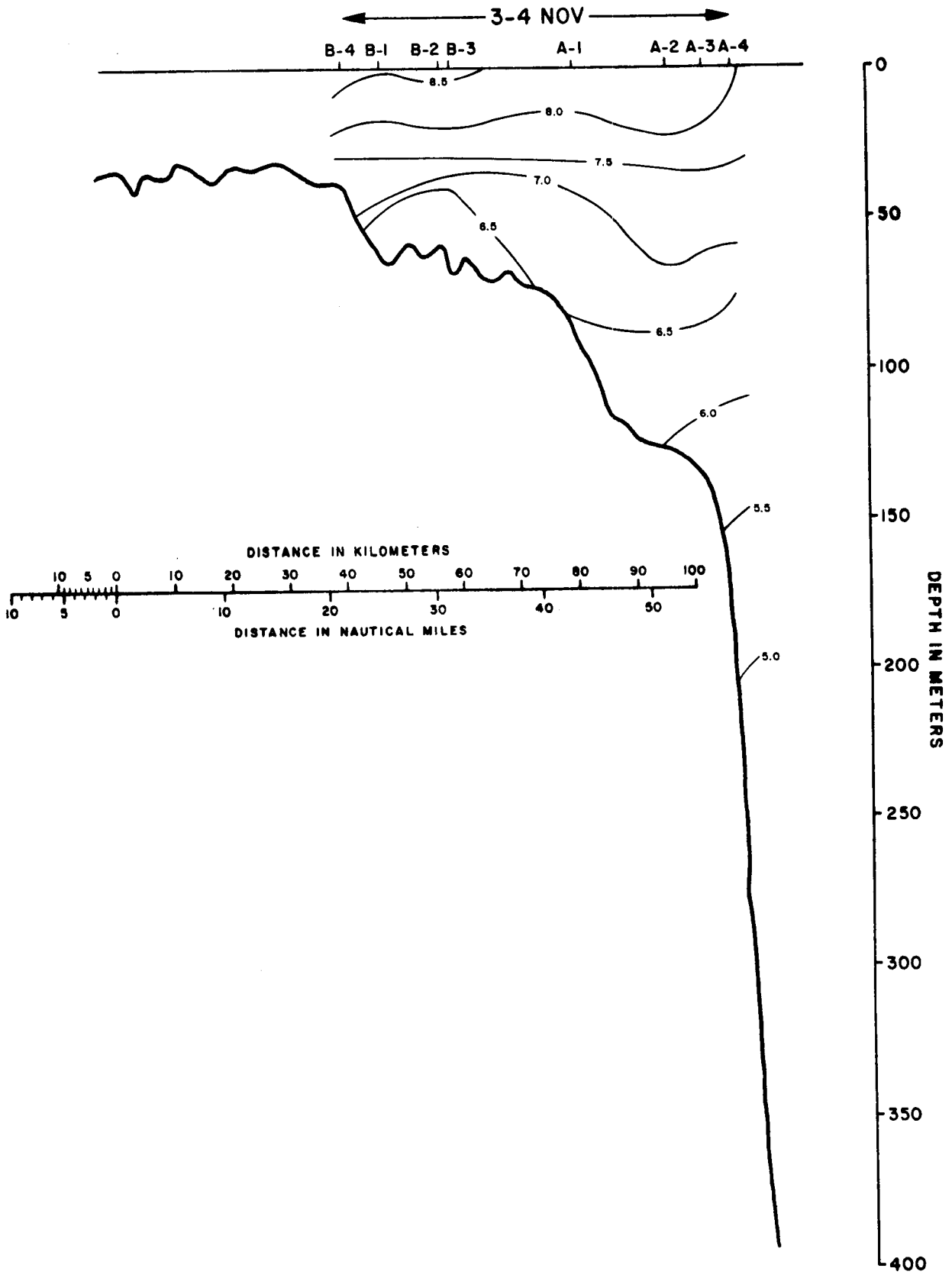

Figure 3-26. Dissolved oxygen (mg/l) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLM01B. Section location is shown in Figure 3-10.

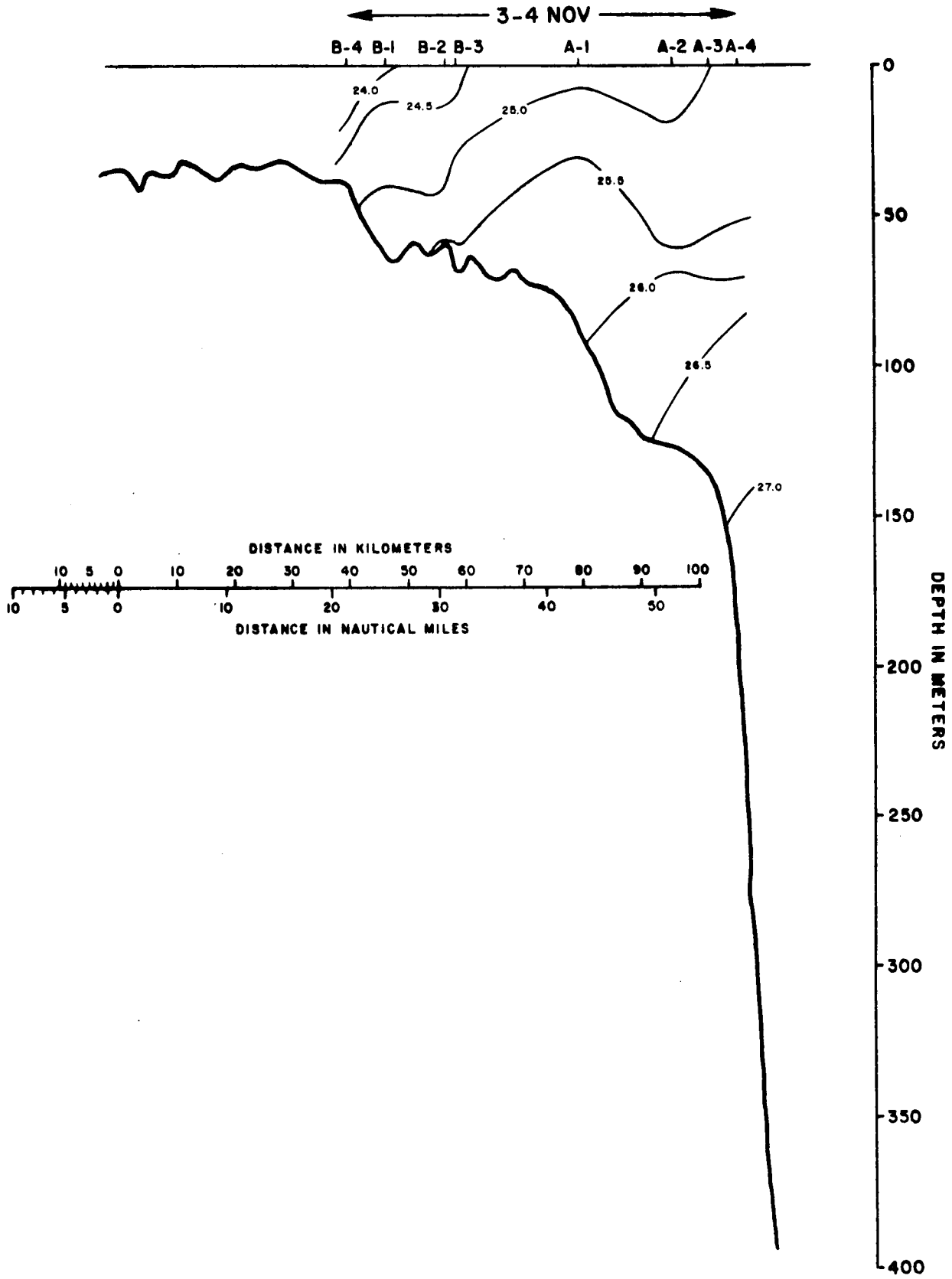

Figure 3-27. Density (σ_t units) along Section II (Stations B4 to A4, 3-4 November 1975) during cruise BLMØ1B. Section location is shown in Figure 3-10.

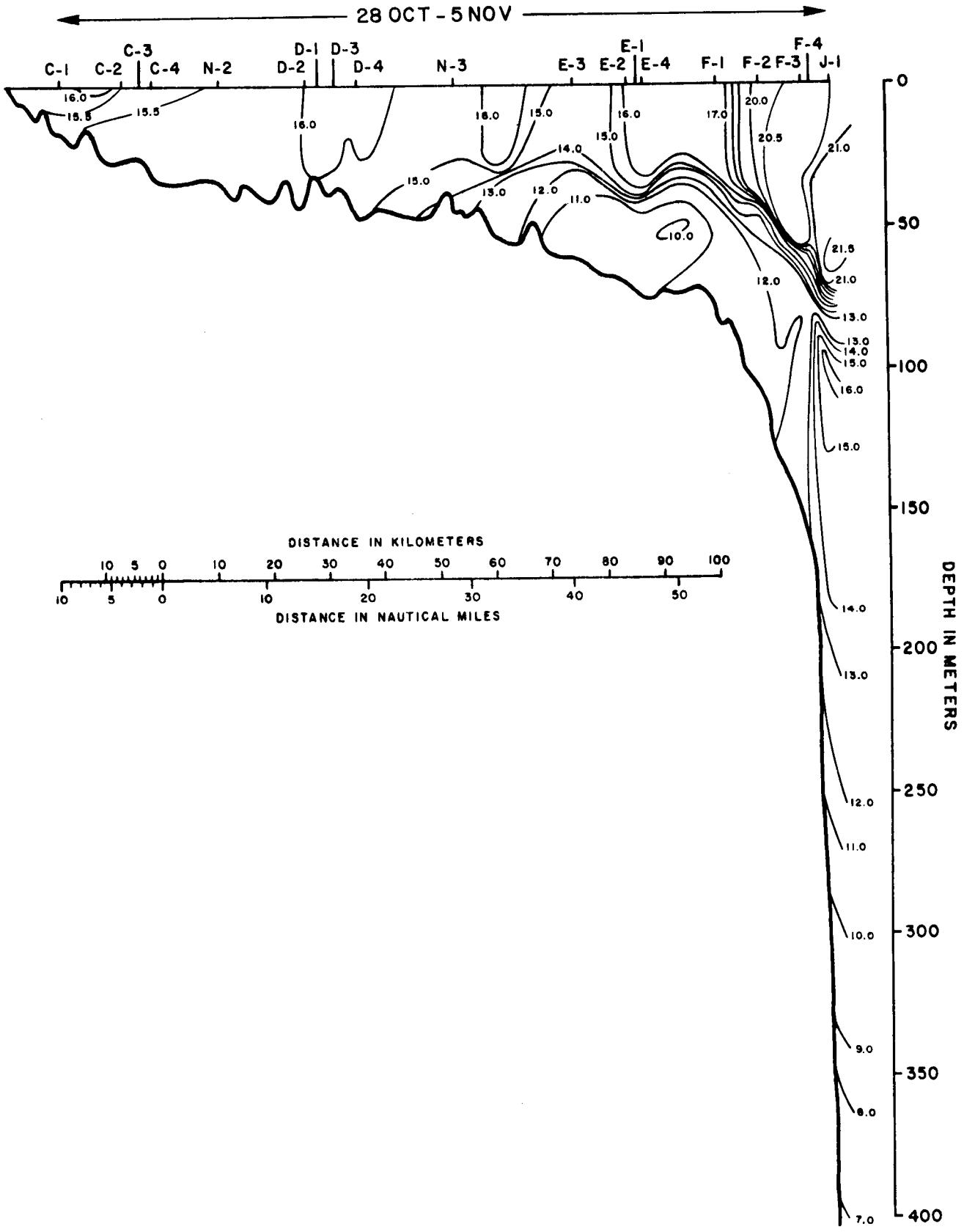

Figure 3-28. Temperature (^{o}C) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLMØ1B. Section location is shown in Figure 3-10.

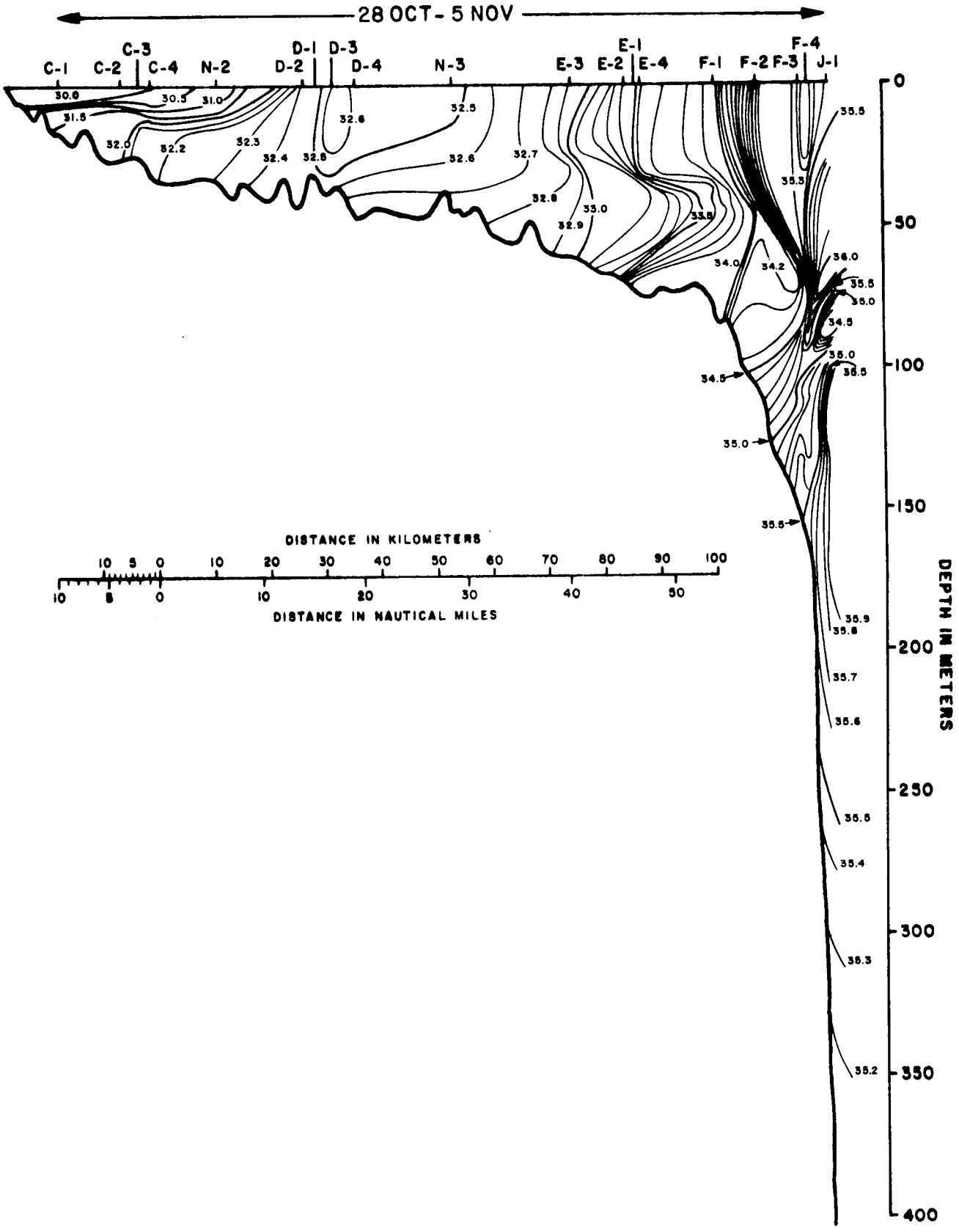

Figure 3-29. Salinity (ppt) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLMØ1B. Section location is shown in Figure 3-10.

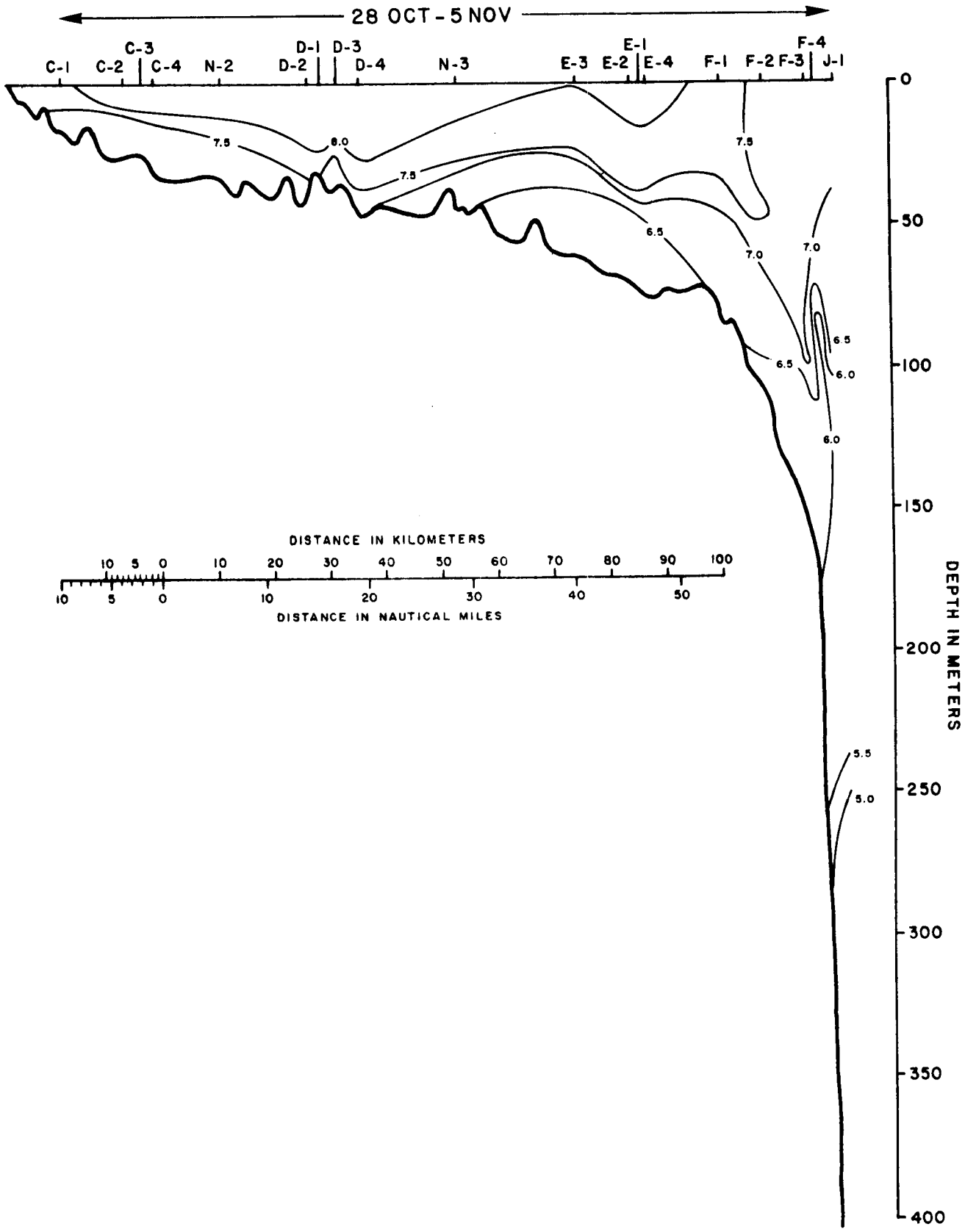

Figure 3-30. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLMØ1B. Section location is shown in Figure 3-10.

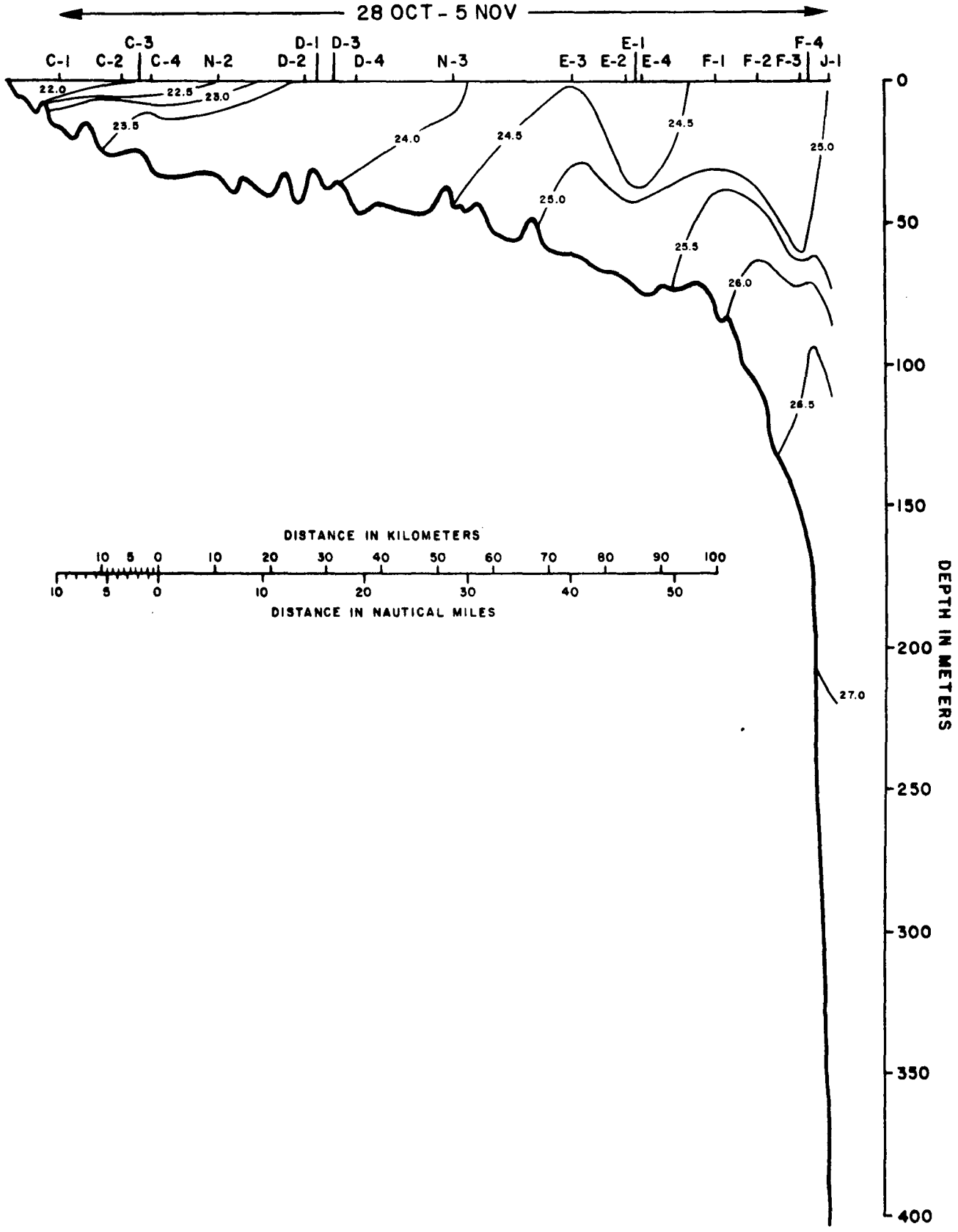

Figure 3-31. Density (σ_t units) along Section III (Stations C1 to J1, 28 October - 5 November 1975) during cruise BLMØ1B. Section location is shown in Figure 3-10.

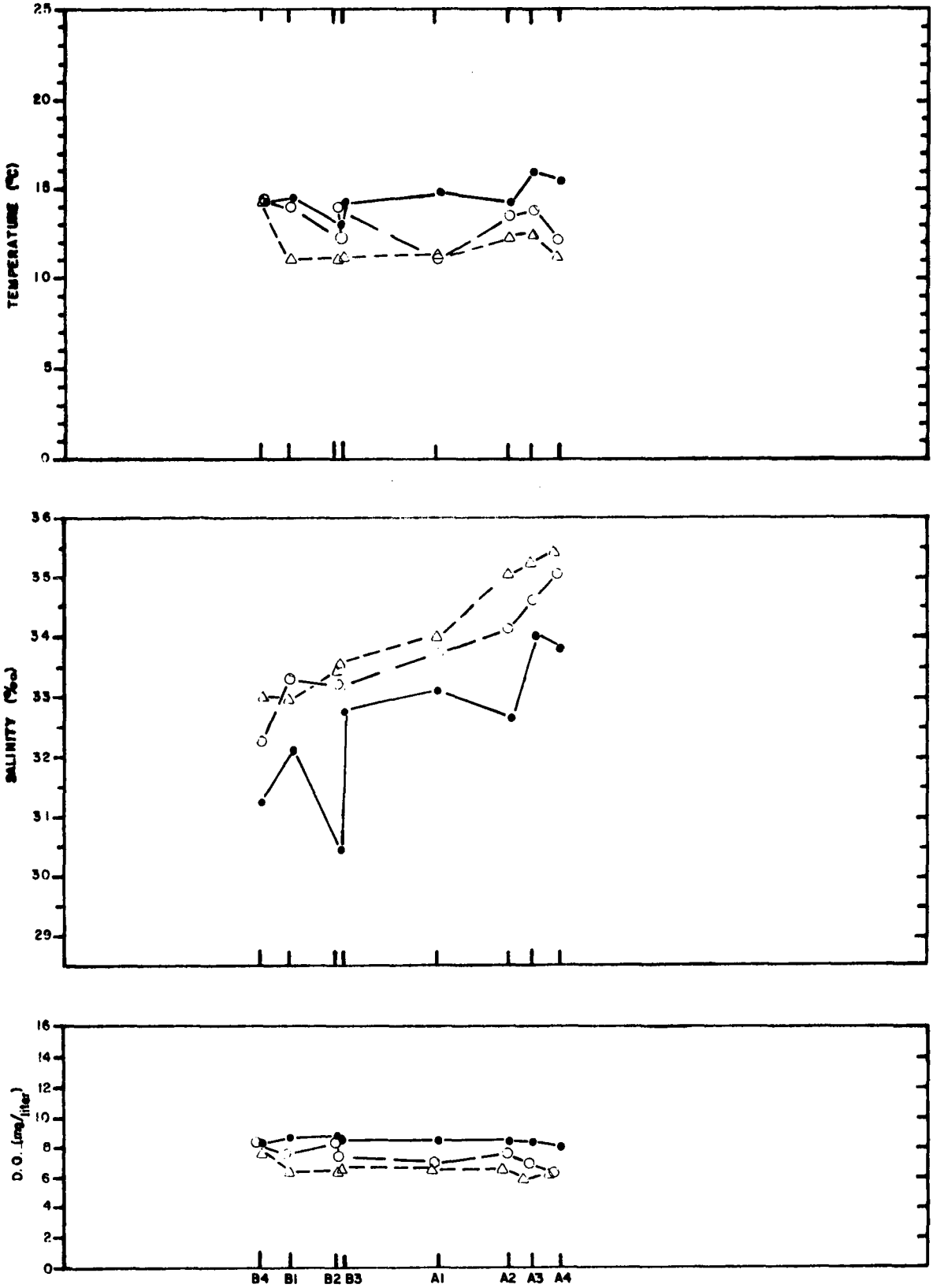

Figure 3-32. Surface (•), mid-depth (0) and bottom (Δ) values of temperature, salinity and DO measured along Section II on cruise BLM Ø1B.

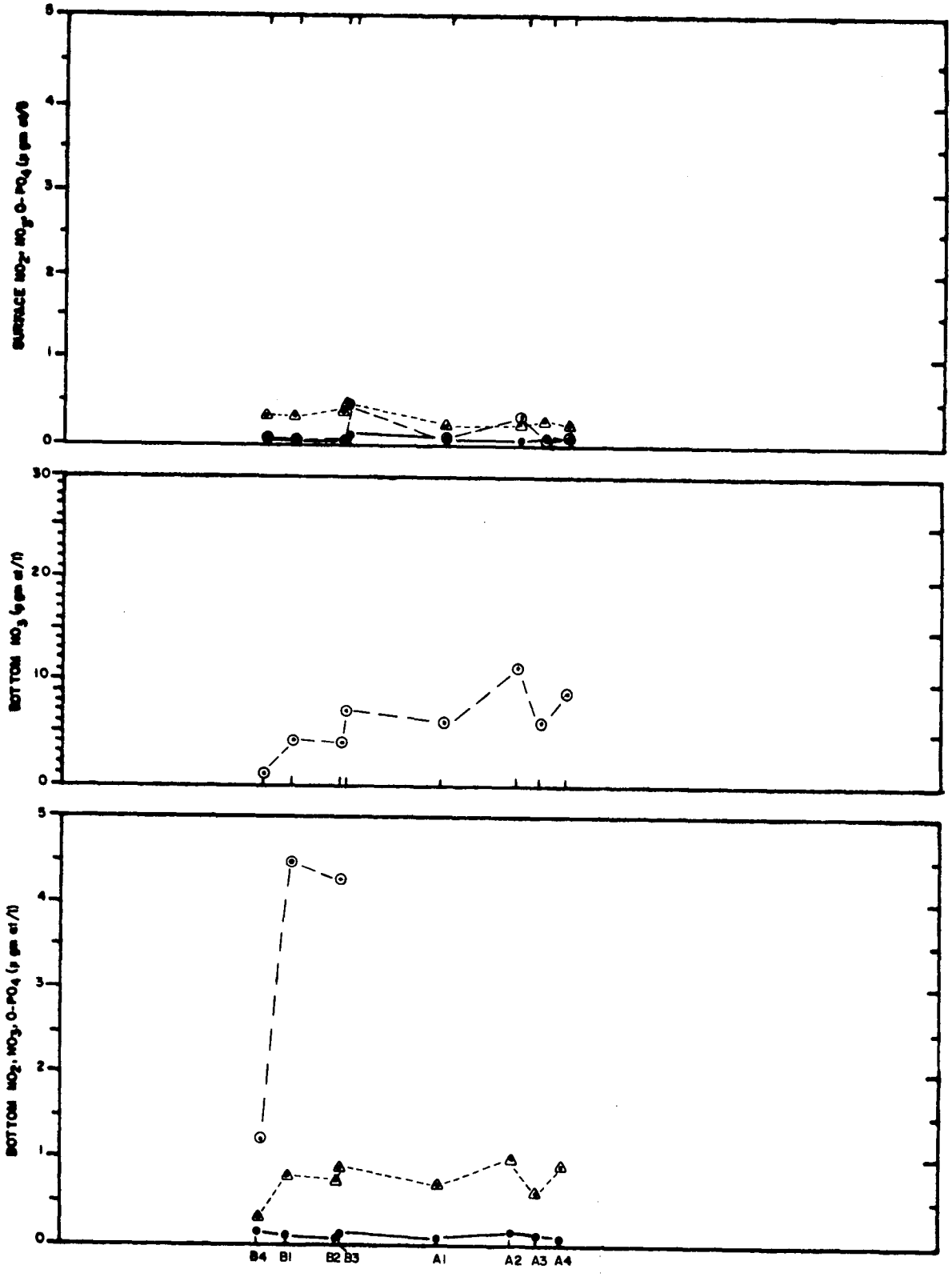

Figure 3-33 . Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section II during Cruise BLM ϕIB. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

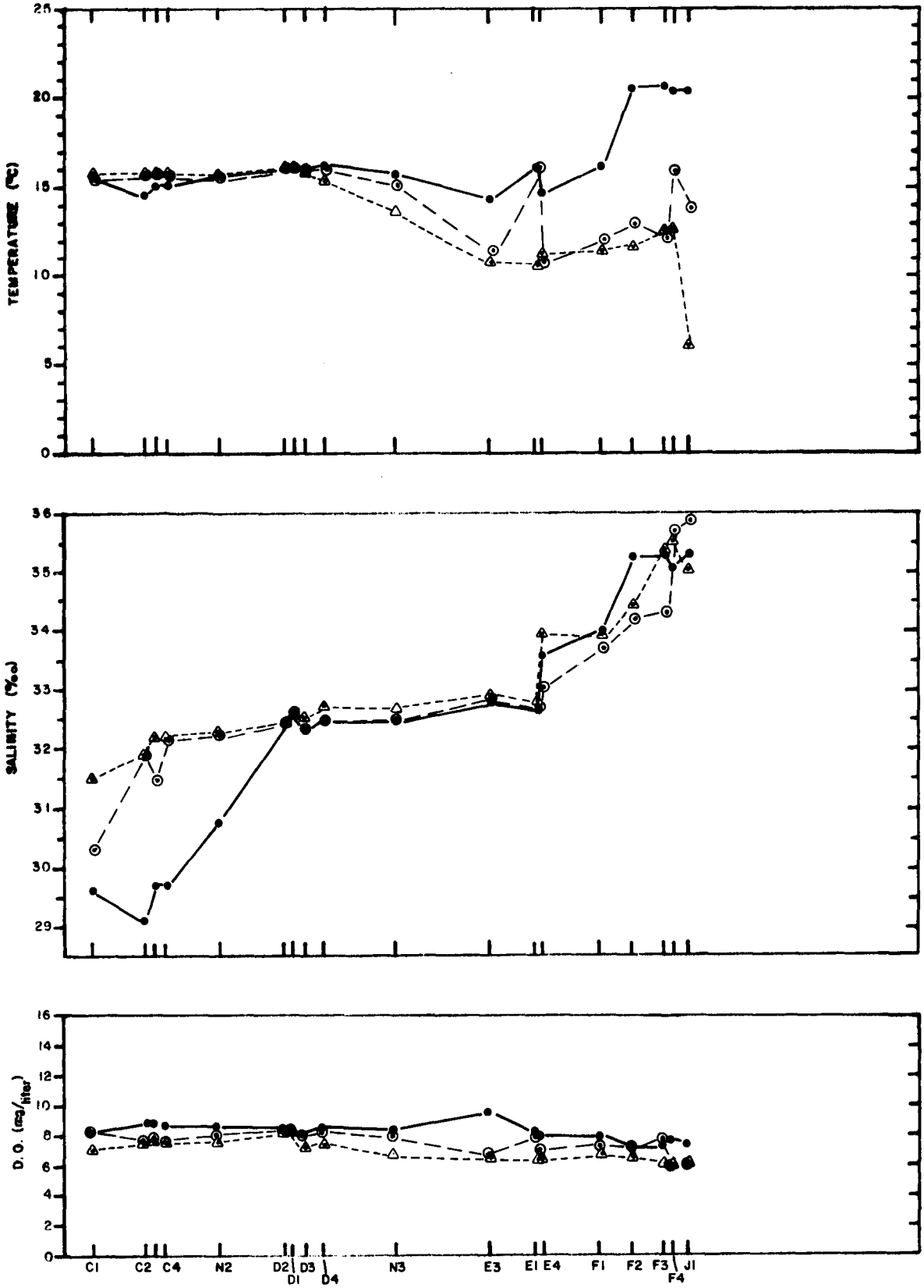

Figure 3-34. Surface (•), mid-depth (0) and bottom (Δ) values of temperature, salinity and DO measured along Section III on cruise BLM Ø1B.

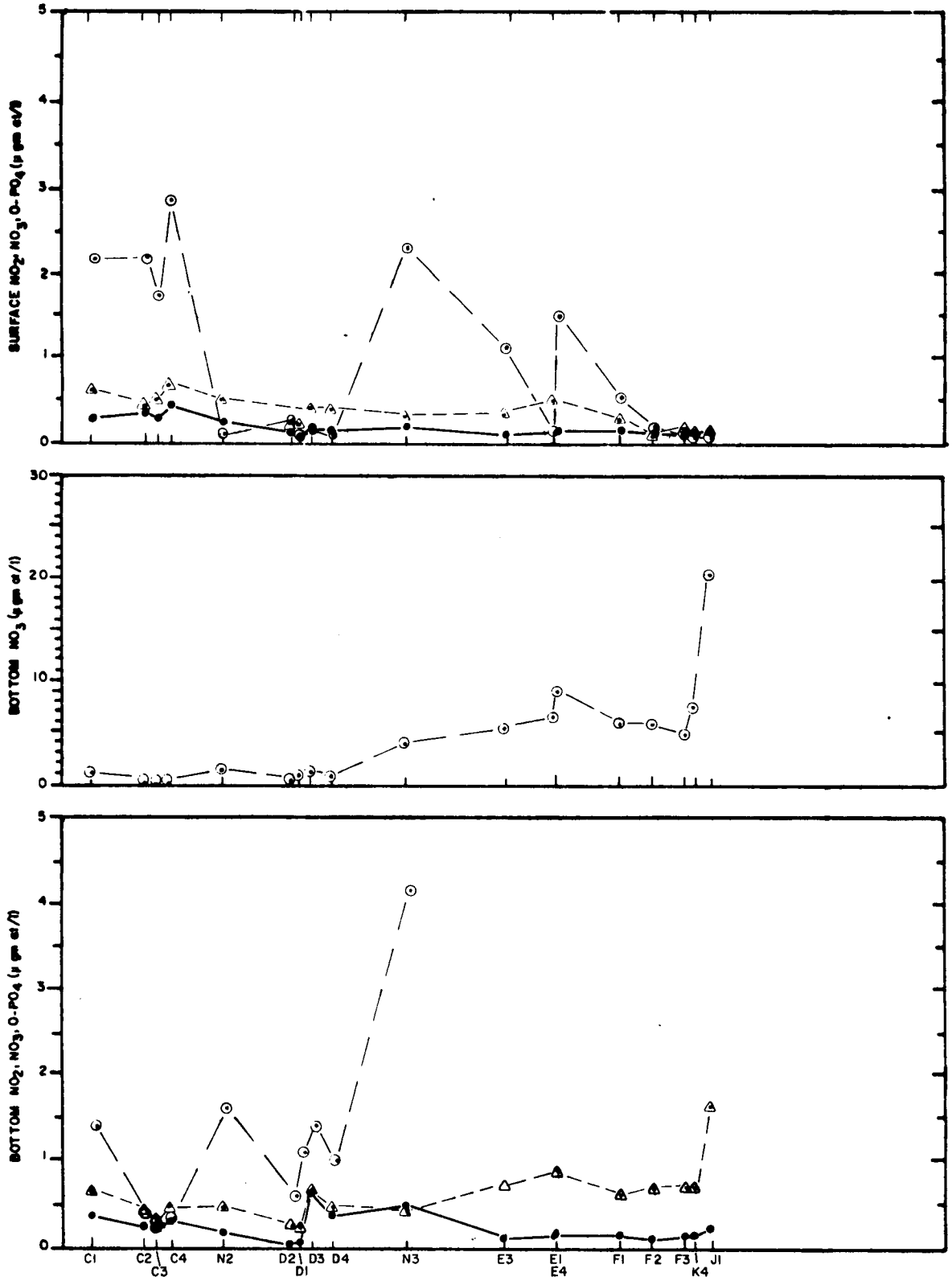

Figure 3-35 . Concentrations of dissolved NO_2 (▲), NO_3 (●), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM Ø1B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ1W

Fall 1975

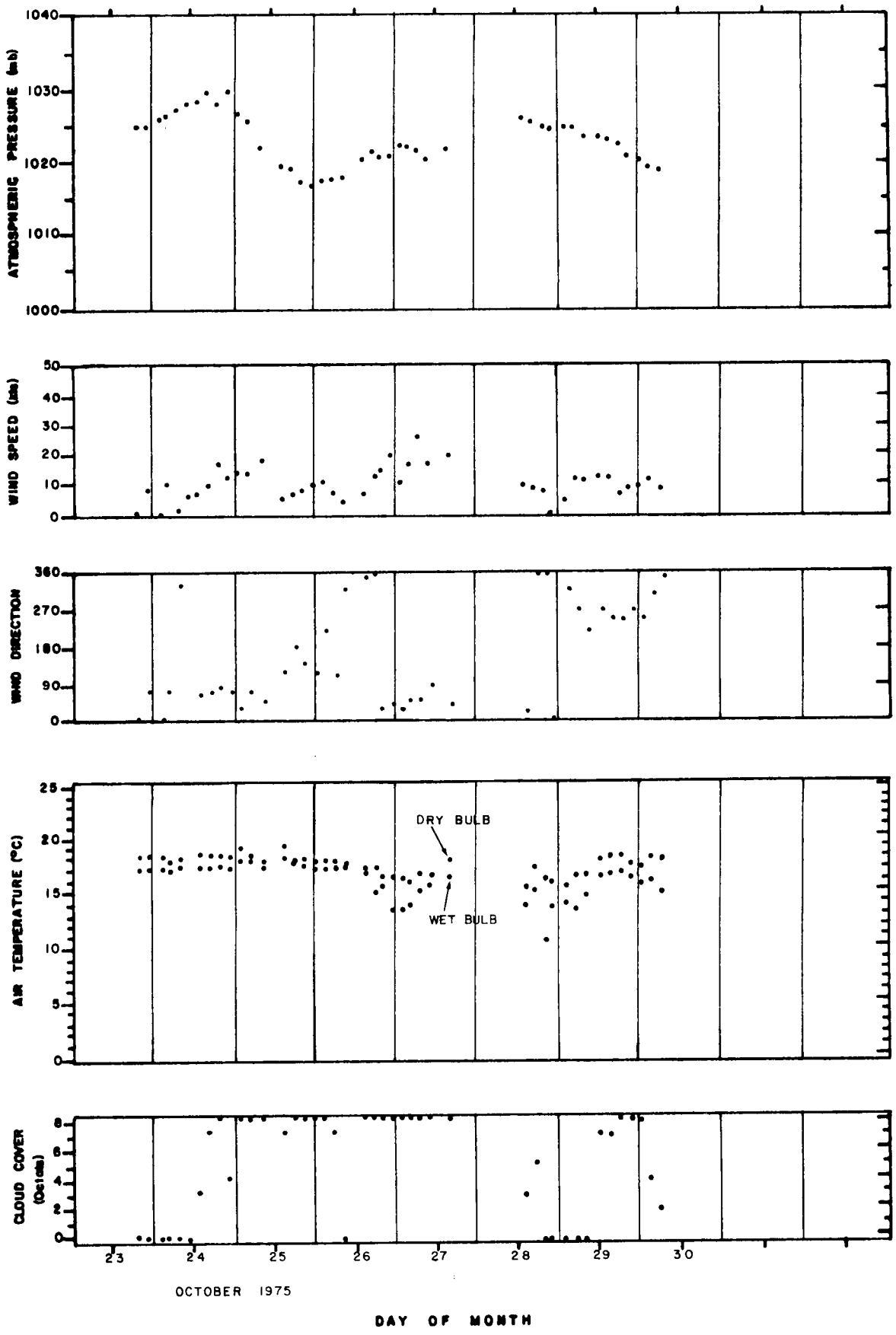

Figure 3-36. Meteorological data collected during cruise BLM 01W 23-30 October 1975.

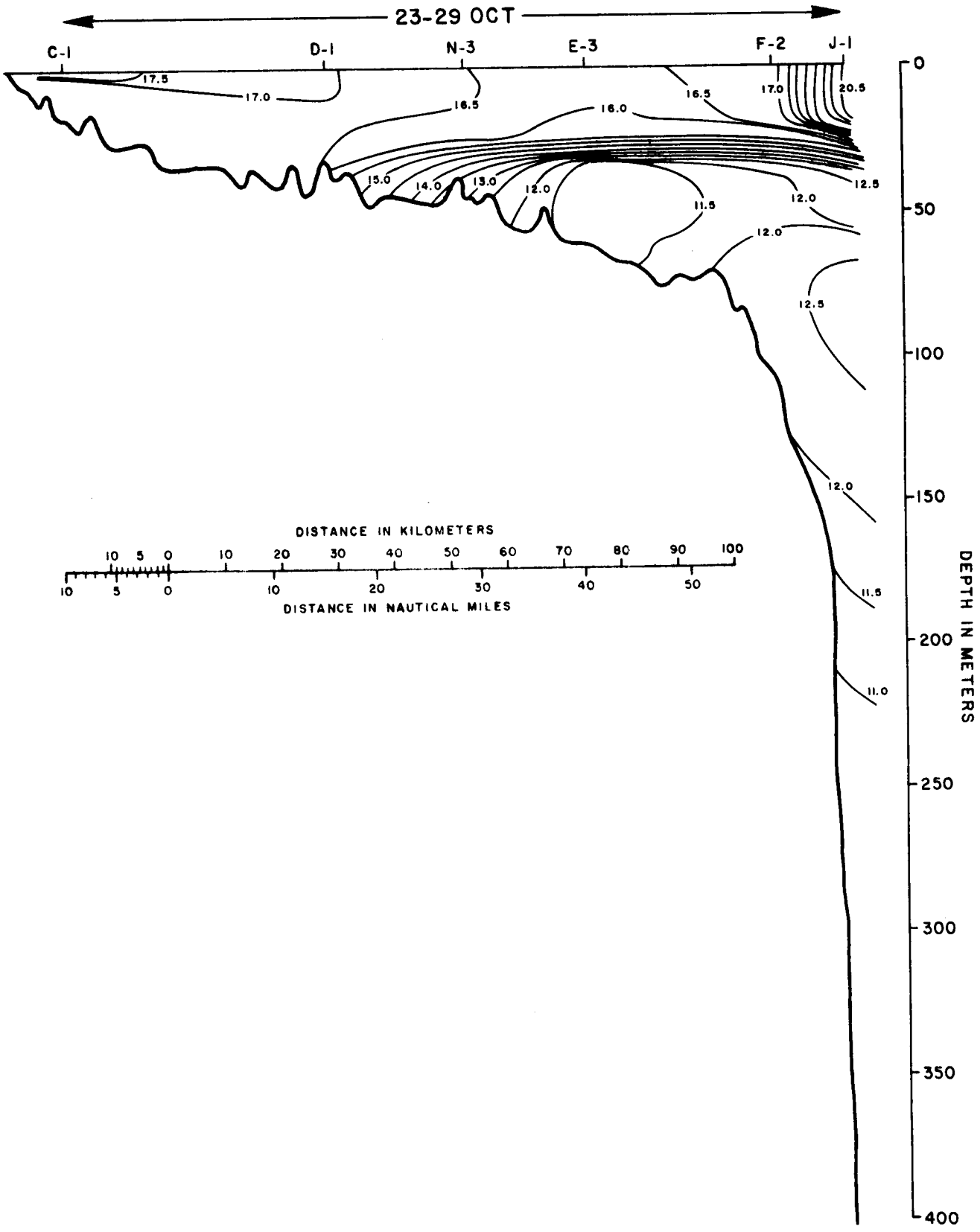

Figure 3-37. Temperature (^{o}C) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLMØ1W. Section location is shown in Figure 3-10.

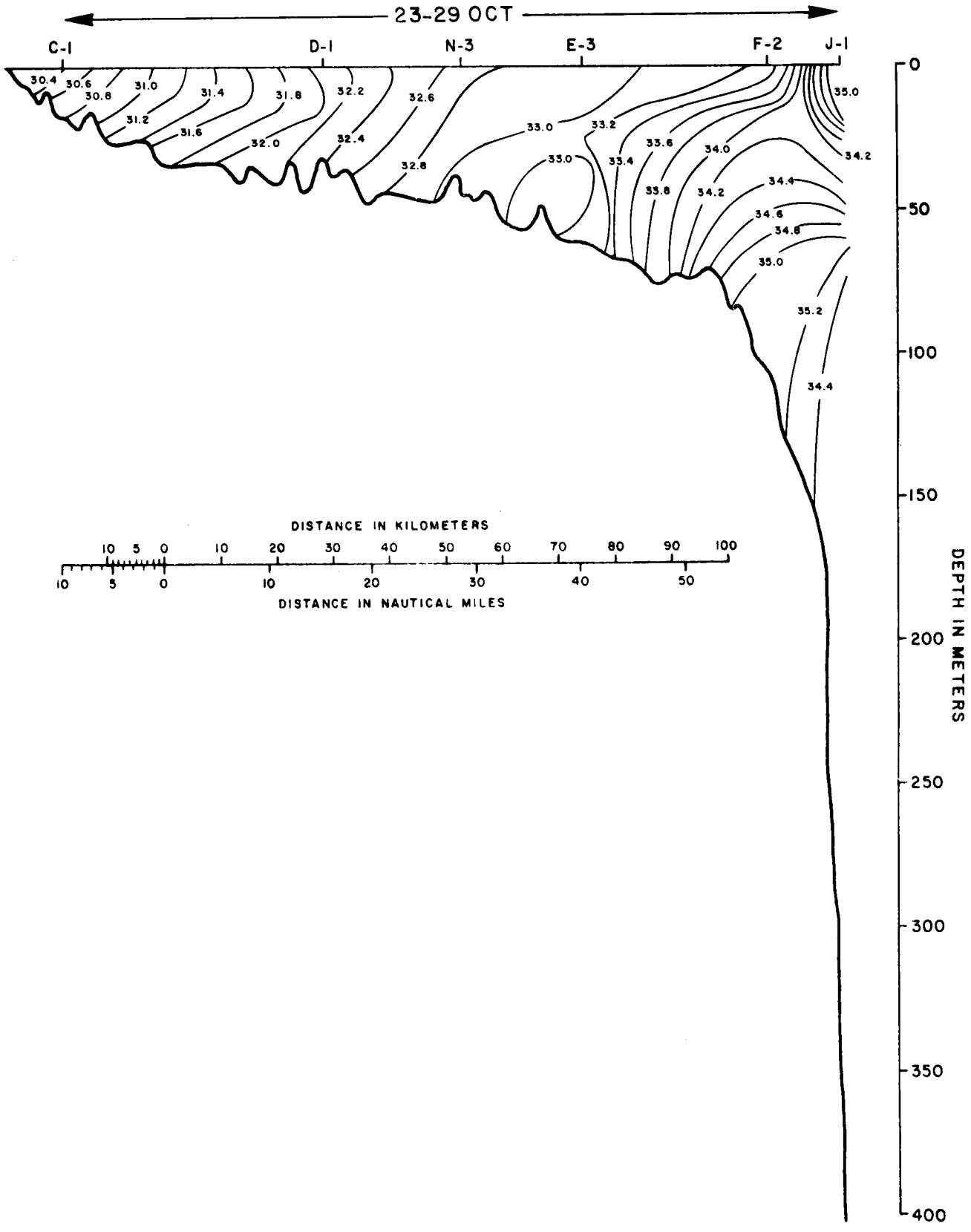

Figure 3-38. Salinity (ppt) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLMØ1W. Section location is shown in Figure 3-10.

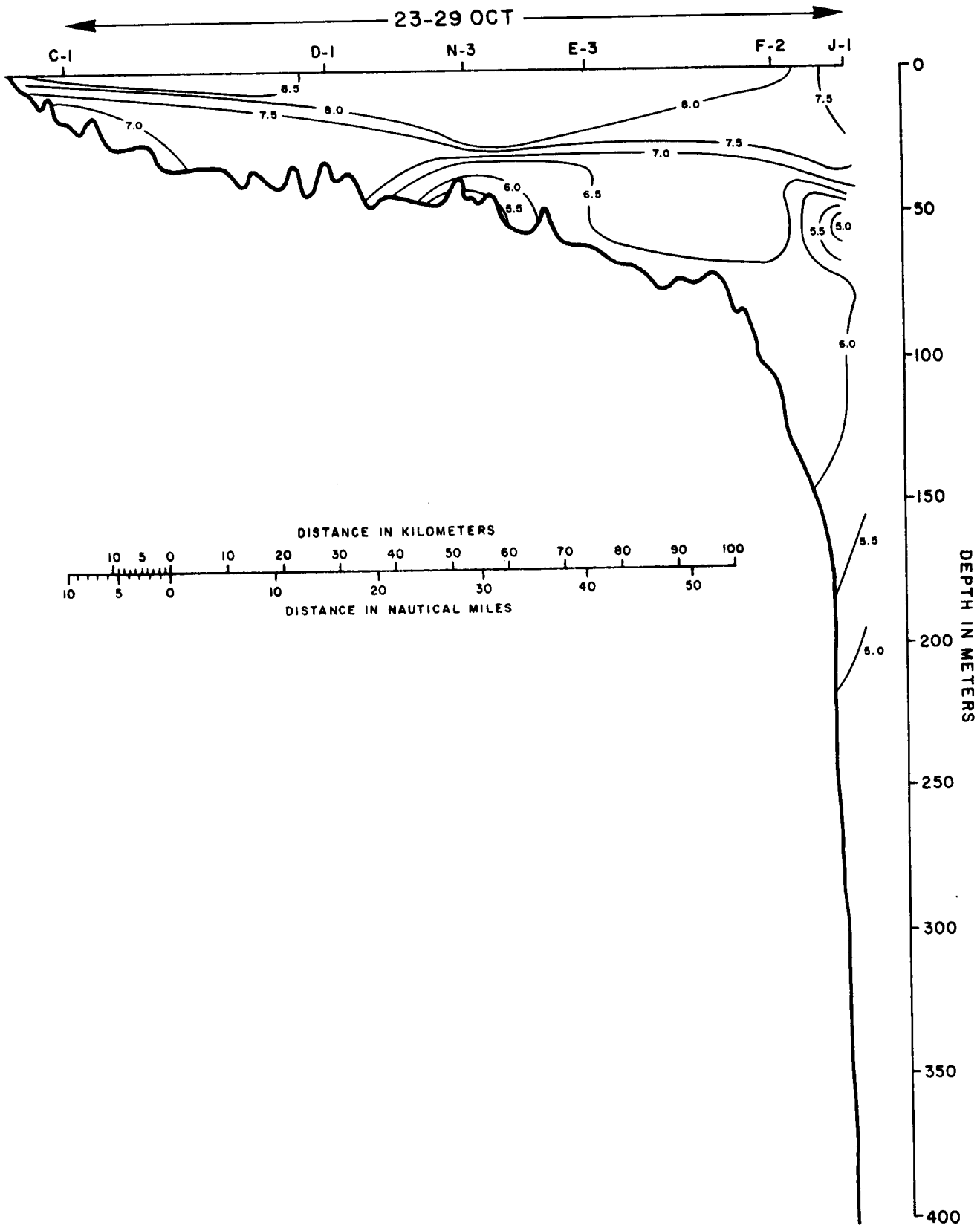

Figure 3-39. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLMØ1W. Section location is shown in Figure 3-10.

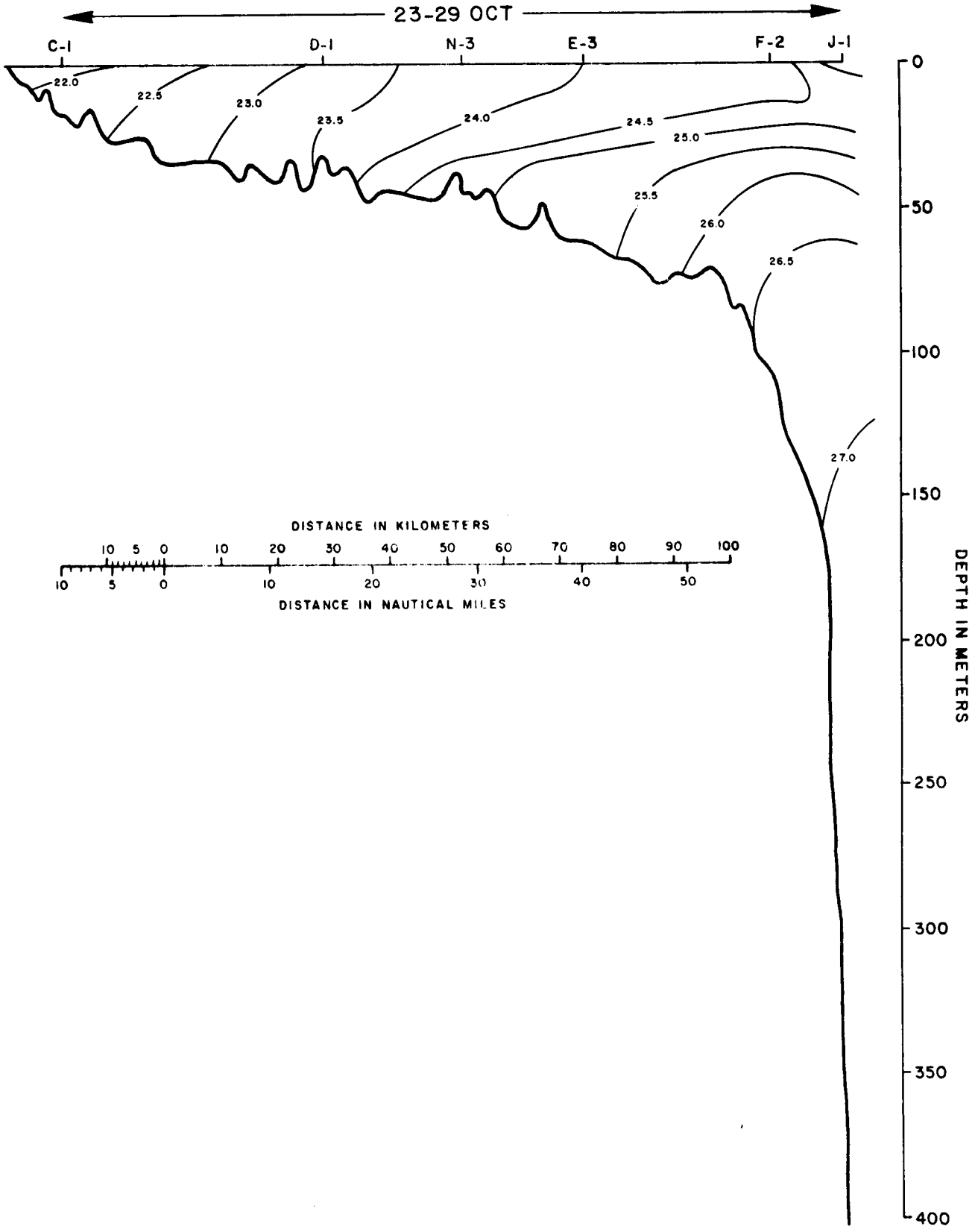

Figure 3-40. Density (σ_t units) along Section III (Stations C1 to J1, 23-29 October 1975) during cruise BLM01W. Section location is shown in Figure 3-10.

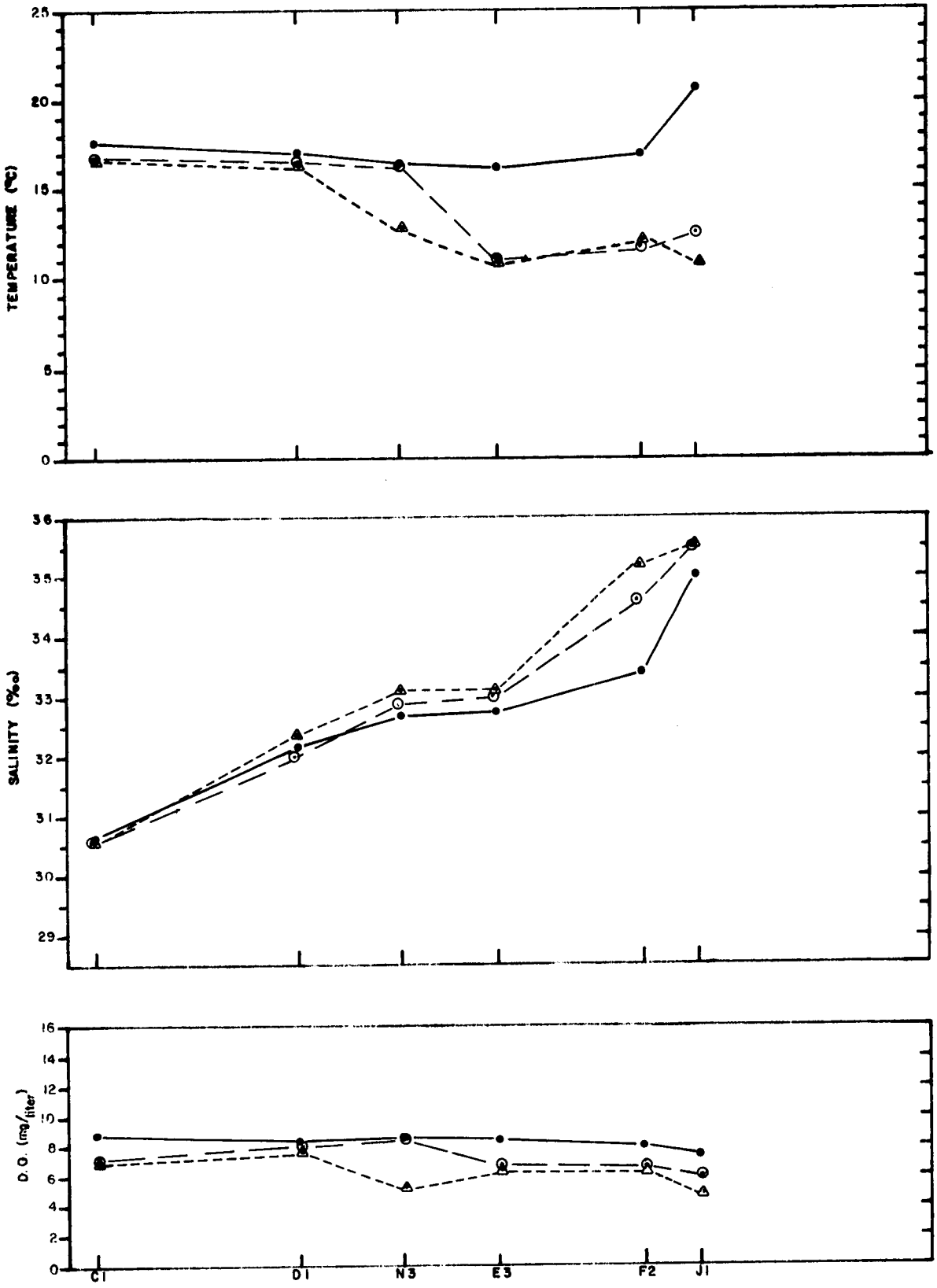

Figure 3-41. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Section III during cruise BLM Ø1W.

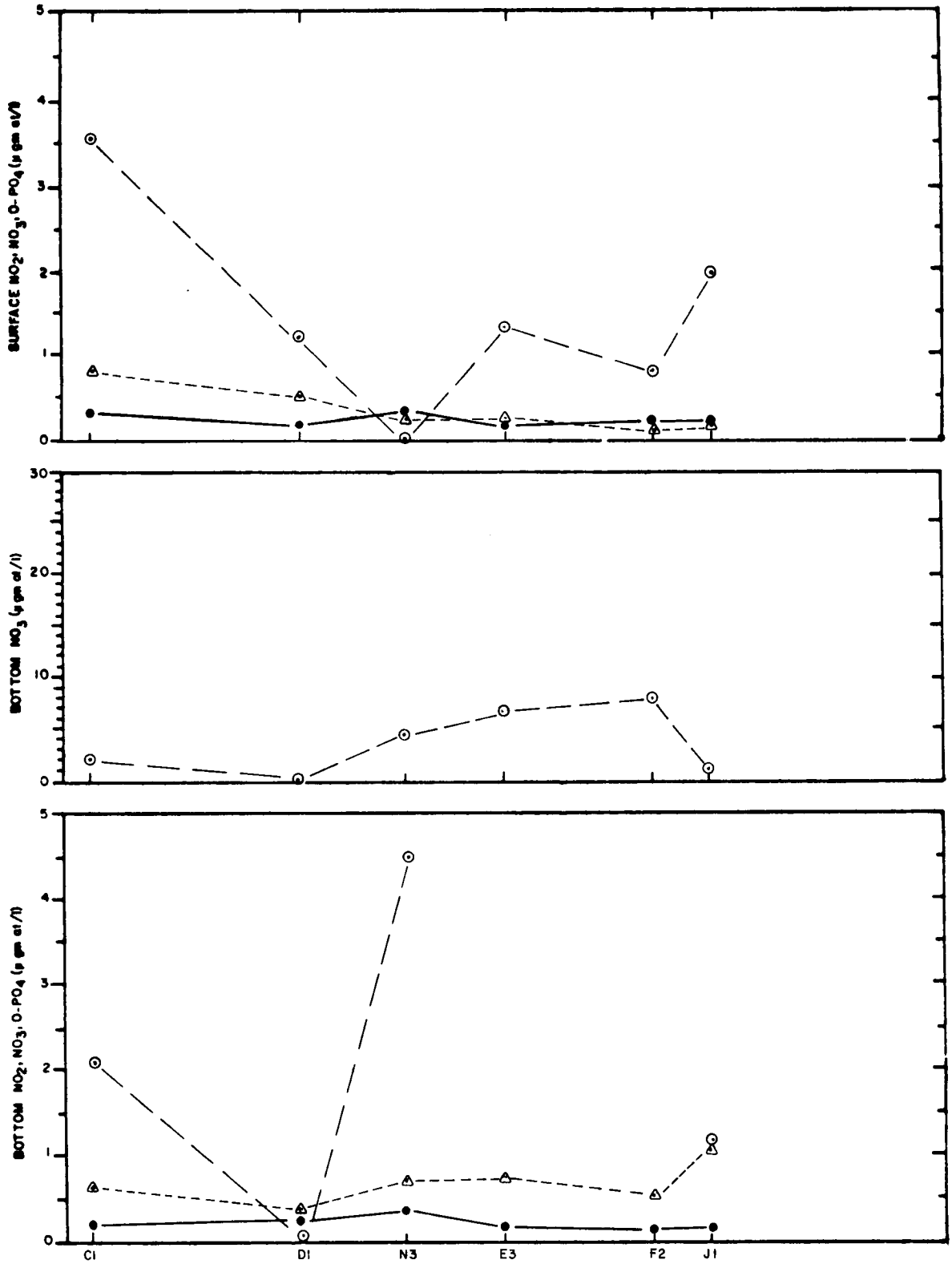

Figure 3-42 . Concentrations of dissolved NO_2 (◊), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Section III during Cruise BLM ϕ1W. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM02B

Winter 1976

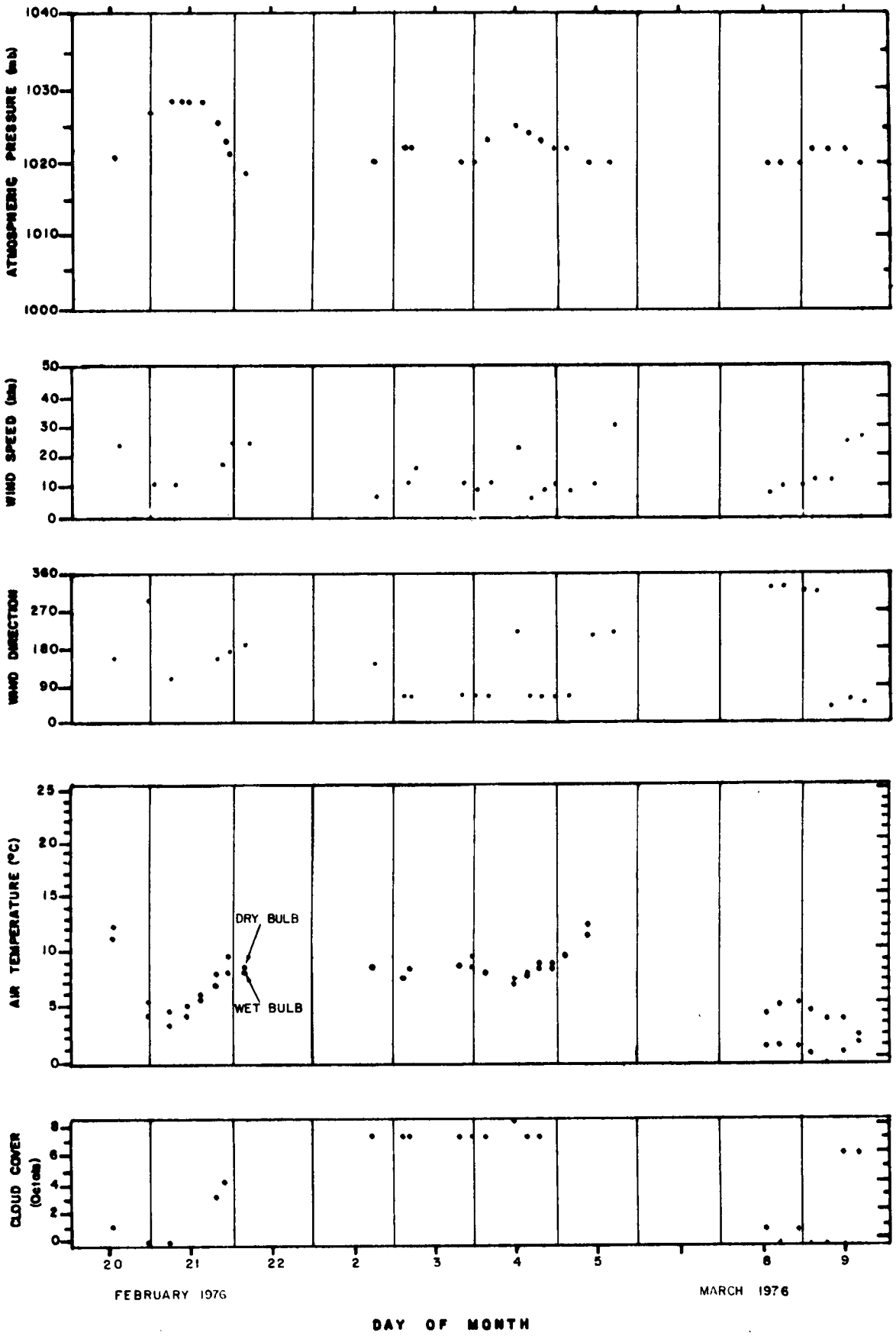

Figure 3-43. Meteorological data collected during cruise ϕ2B for the period 20 February to 9 March 1976. Note omissions of 23 February to 1 March and 6, 7 March.

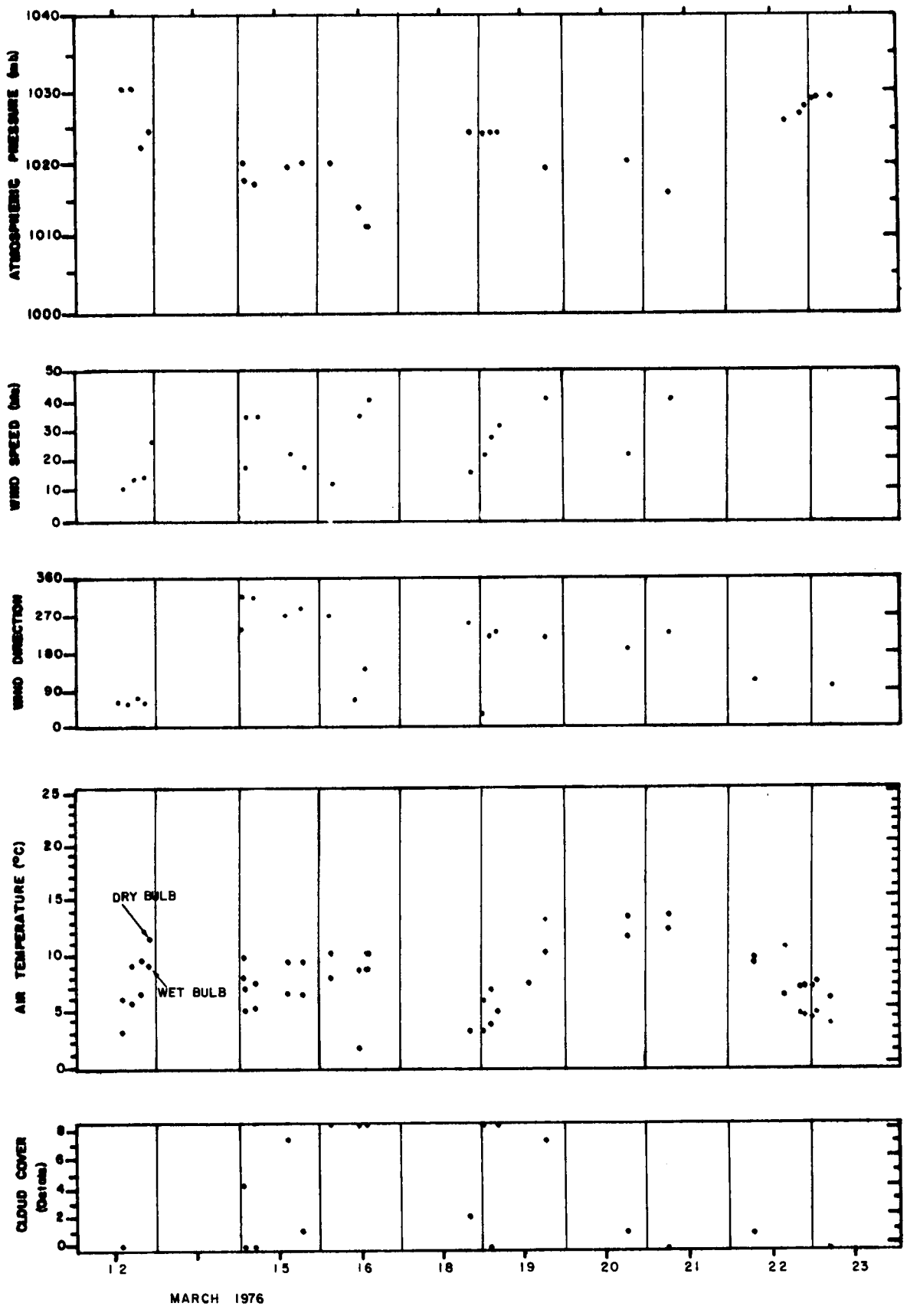

Figure 3-43. (continued) Meteorological data collected during cruise BLM 02B for the period 12-23 March 1976. Note omission of 13, 14 and 17 March. Anemometer lost on 21 March.

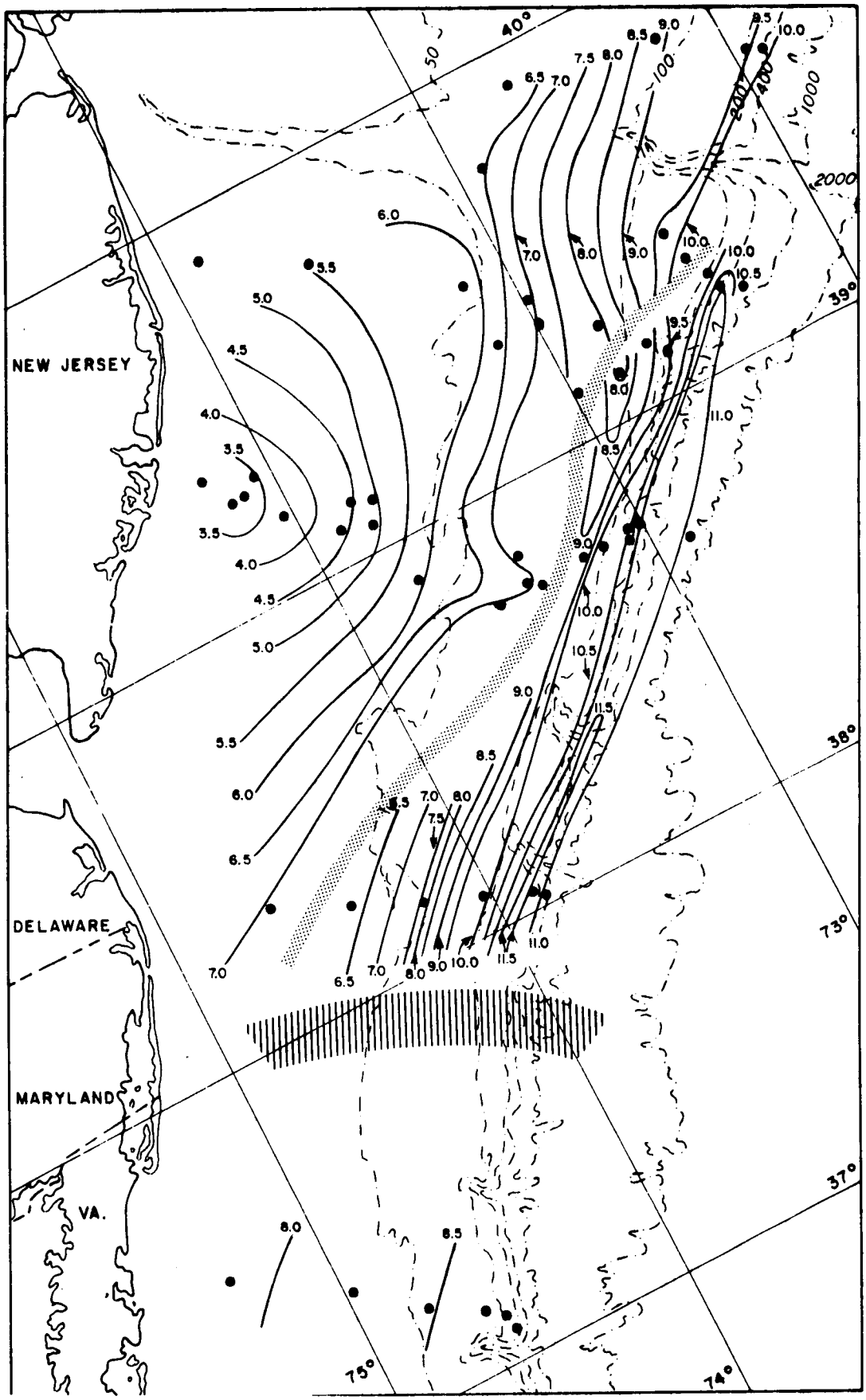

Figure 3-44. Surface temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

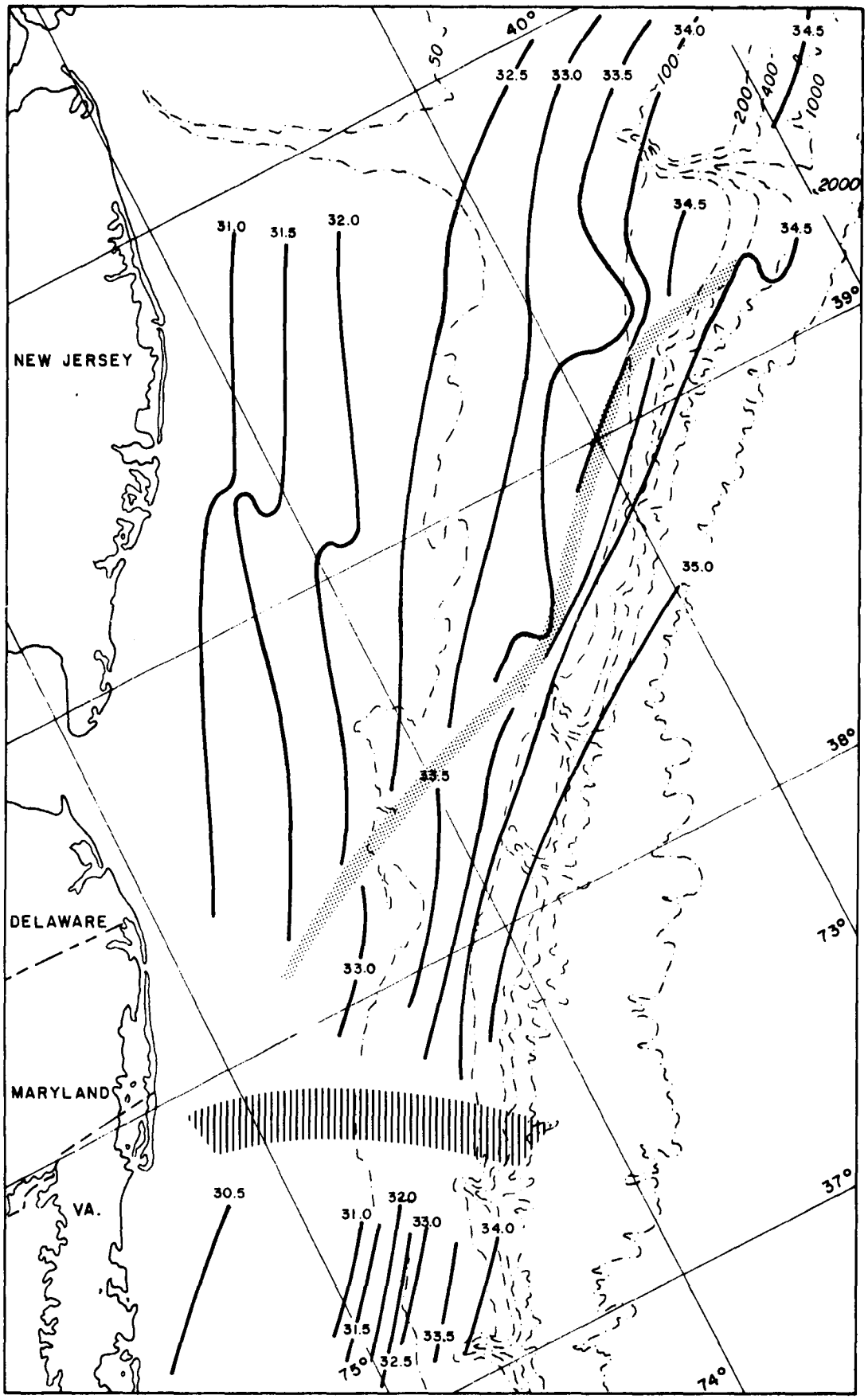

Figure 3-45. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

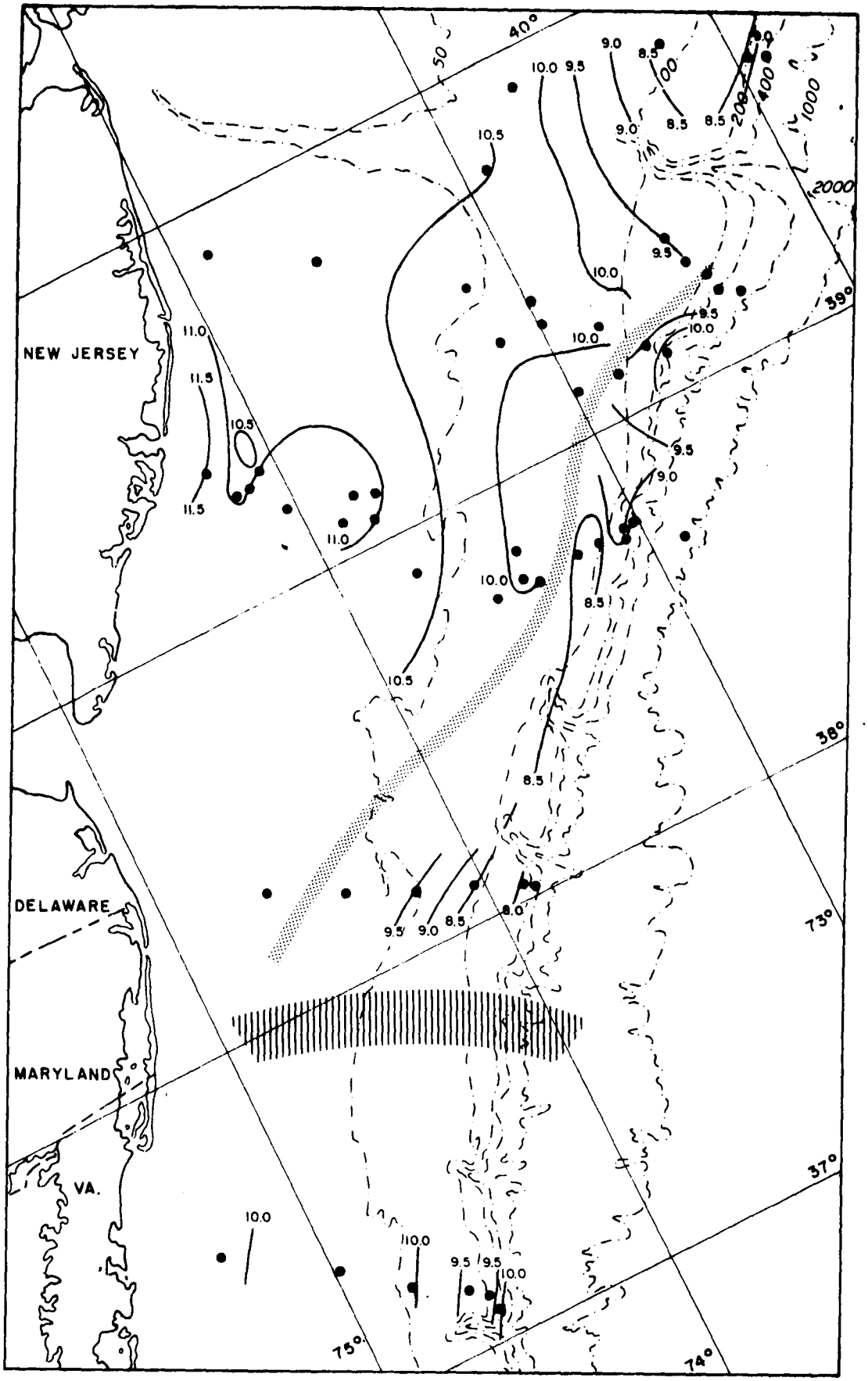

Figure 3-46. Surface dissolved oxygen (mg/1) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

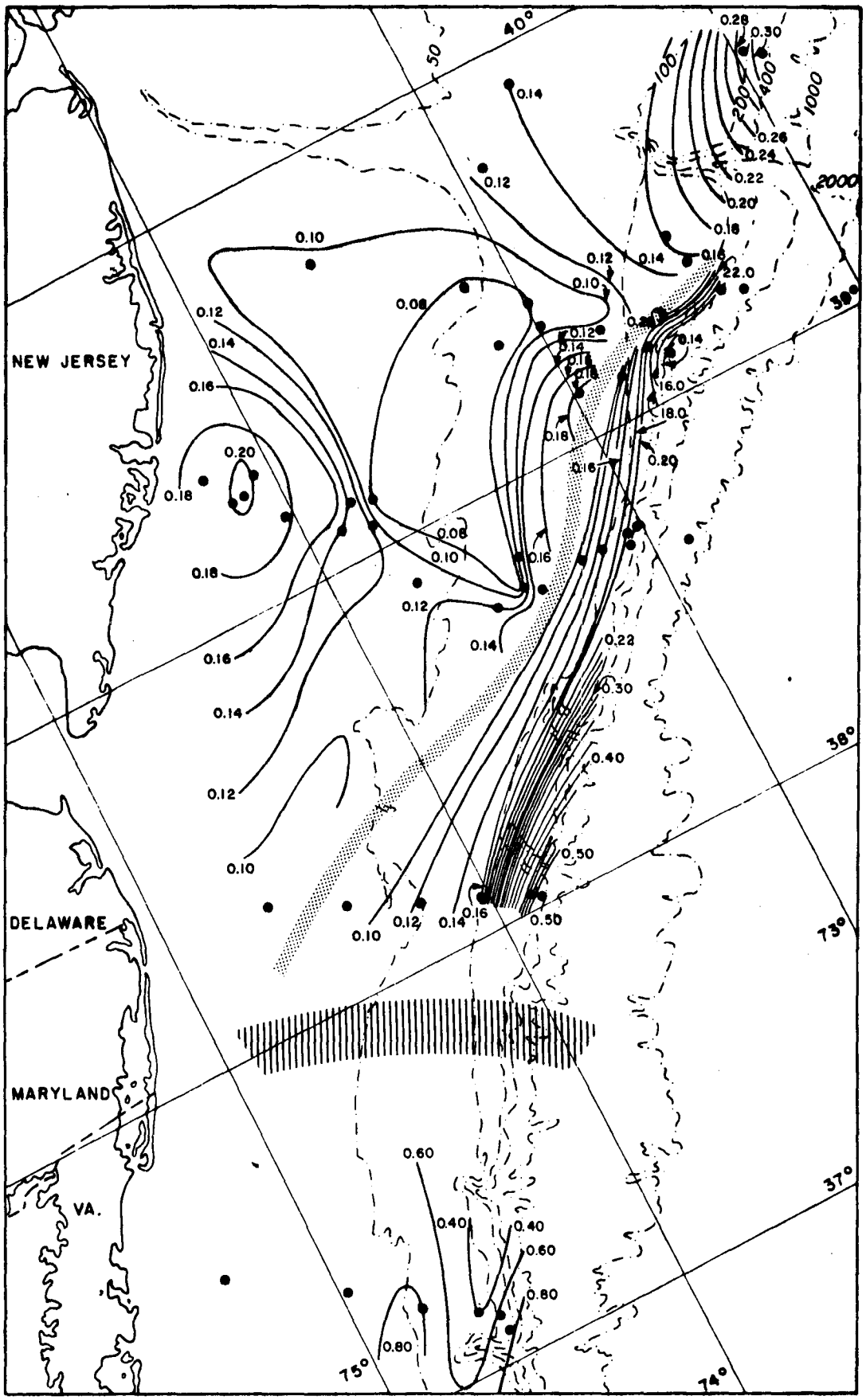

Figure 3-47. Surface NO_2 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

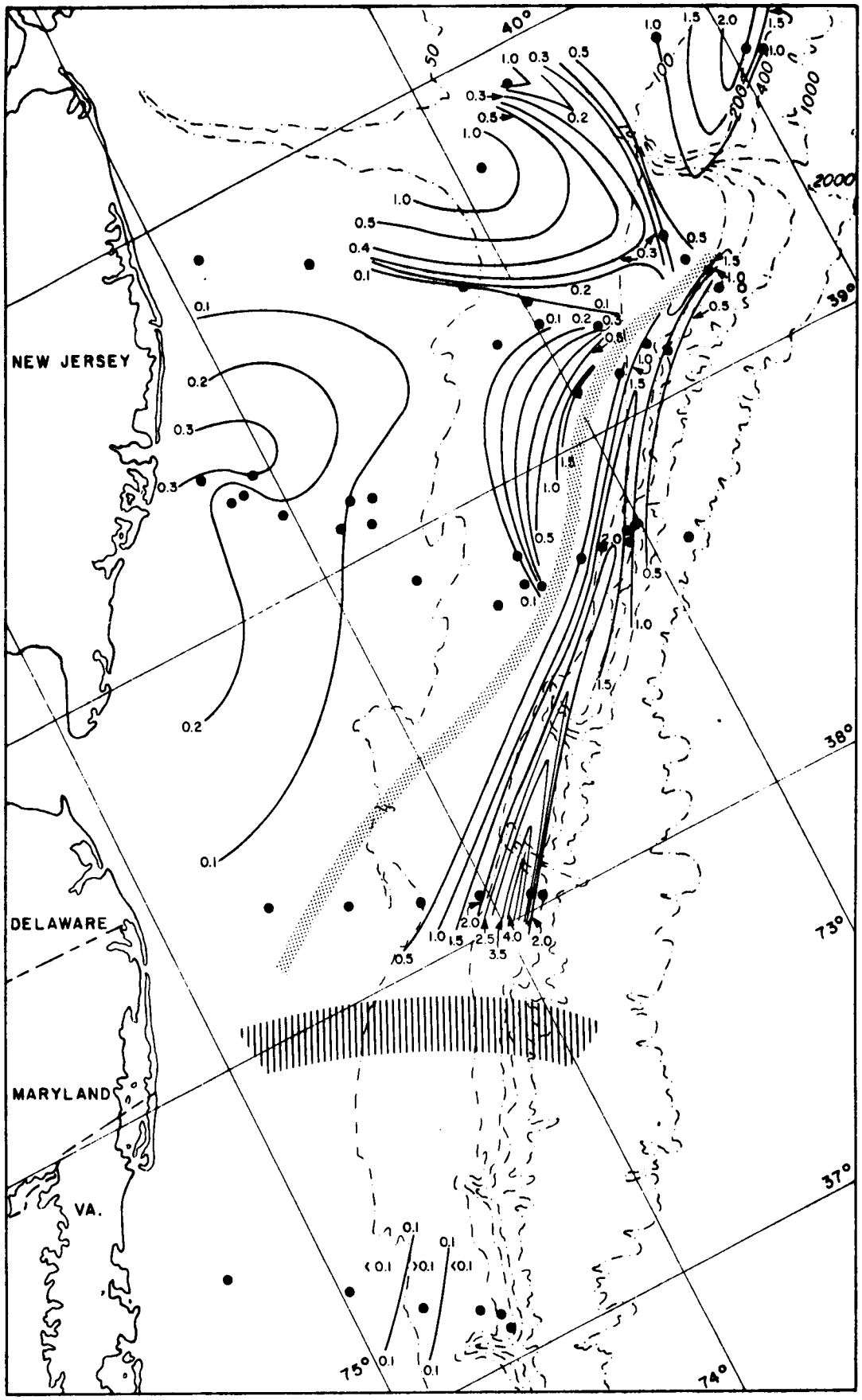

Figure 3-48. Surface NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

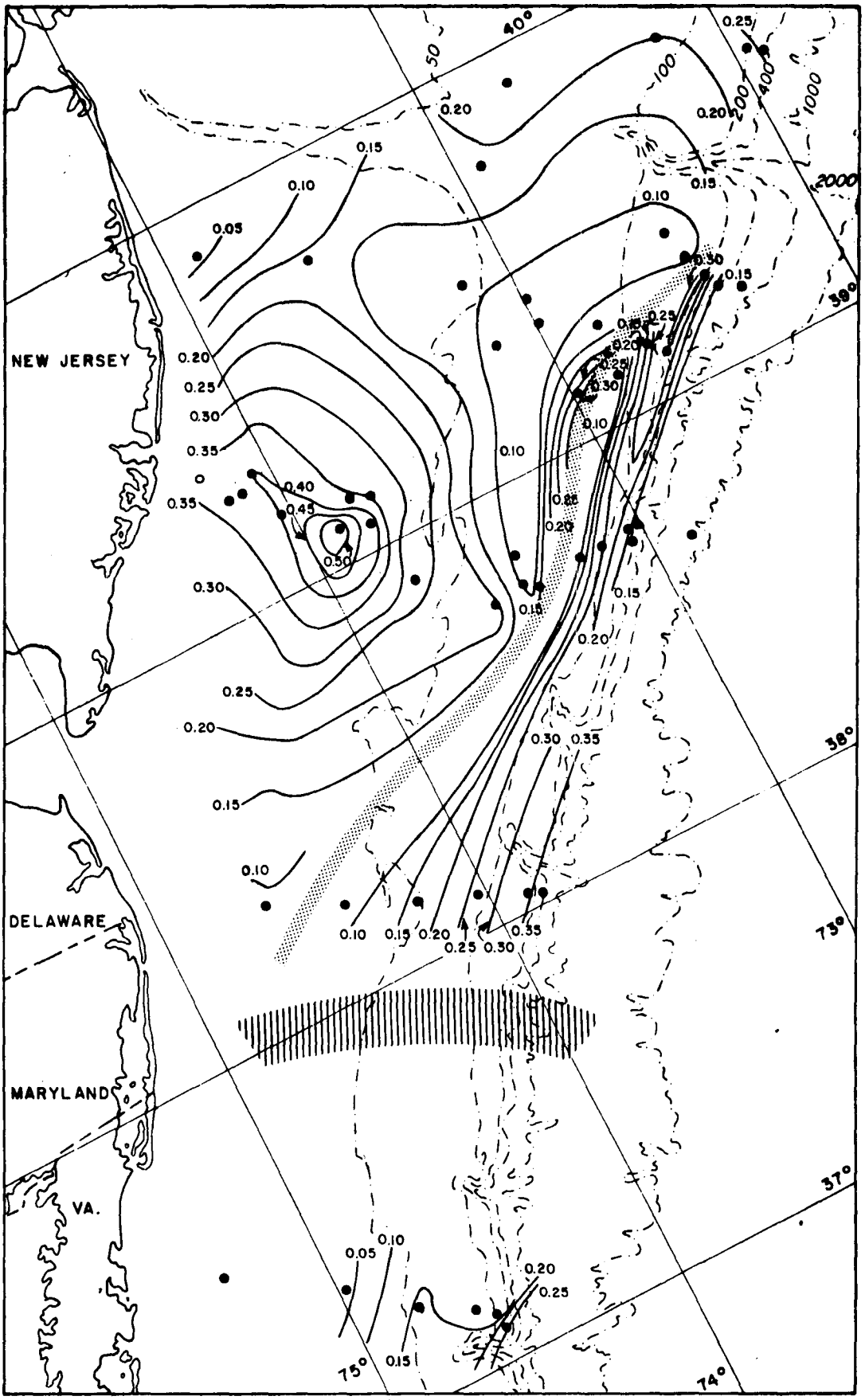

Figure 3-49. Surface O-PO_4 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B). Shaded and hatched areas indicate discontinuity in data caused by 1) break in sampling between 10 and 15 March 1976, and 2) wind event (southwest winds in excess of 60 knots), respectively.

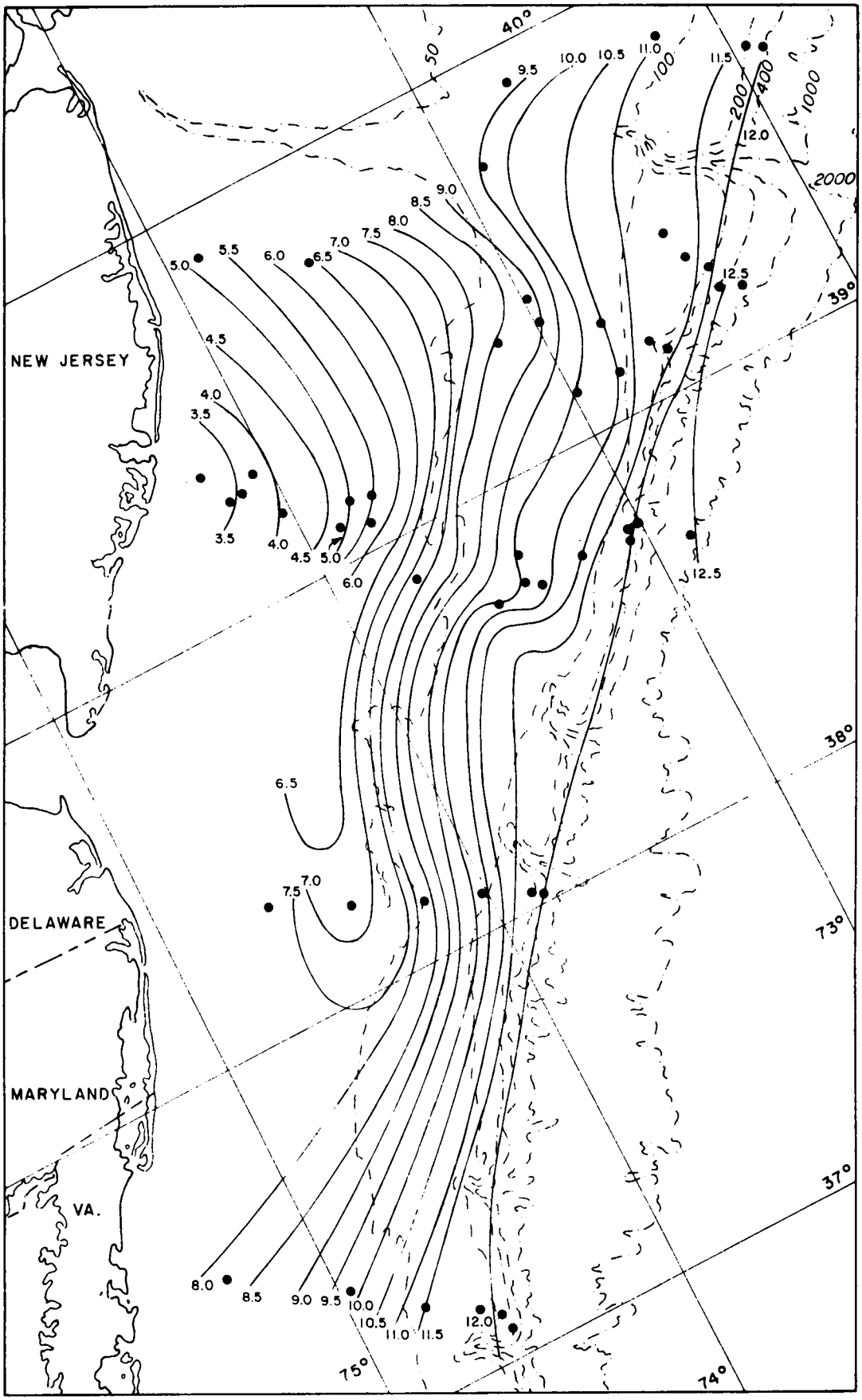

Figure 3-50 Bottom temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

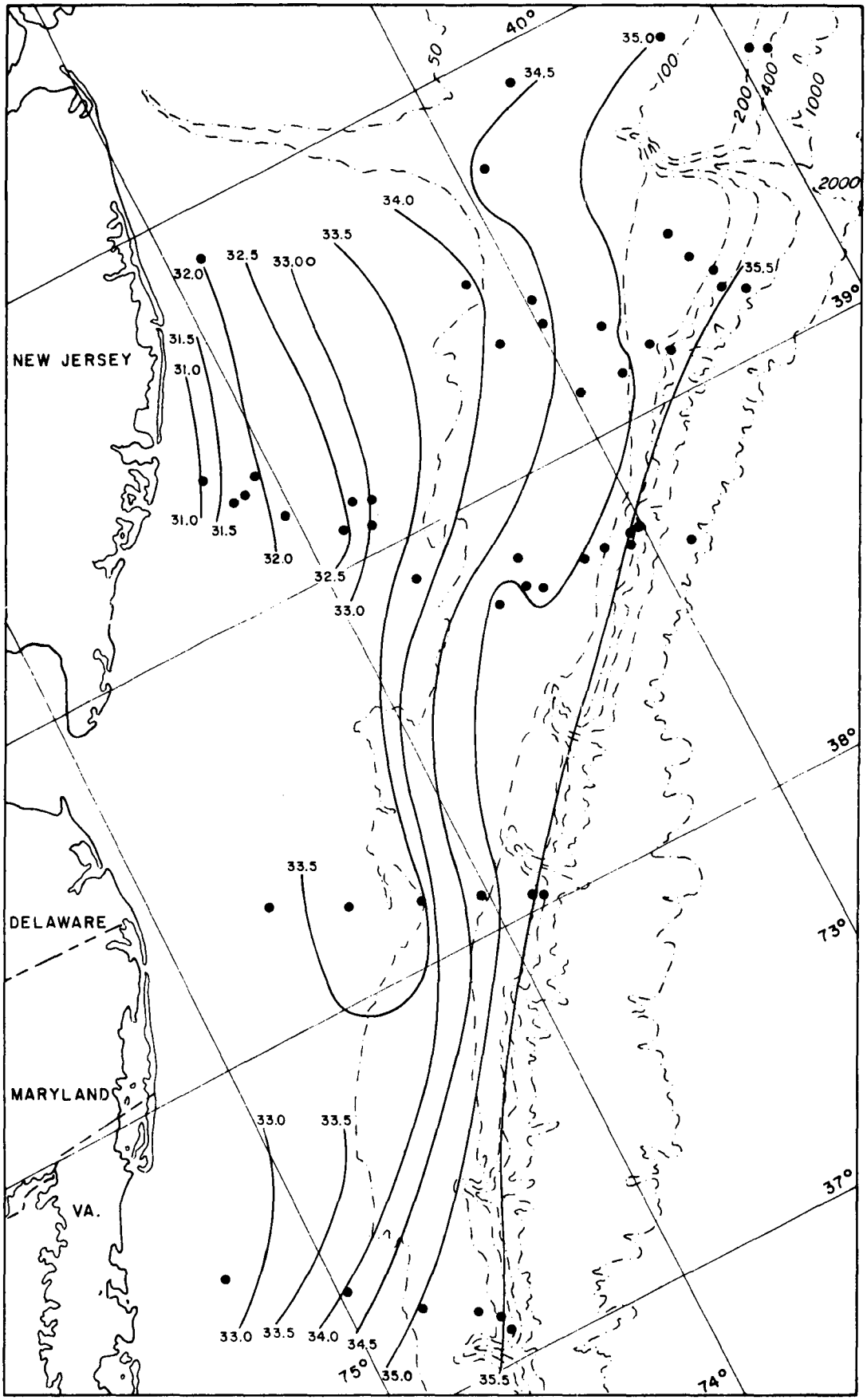

Figure 3-51. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

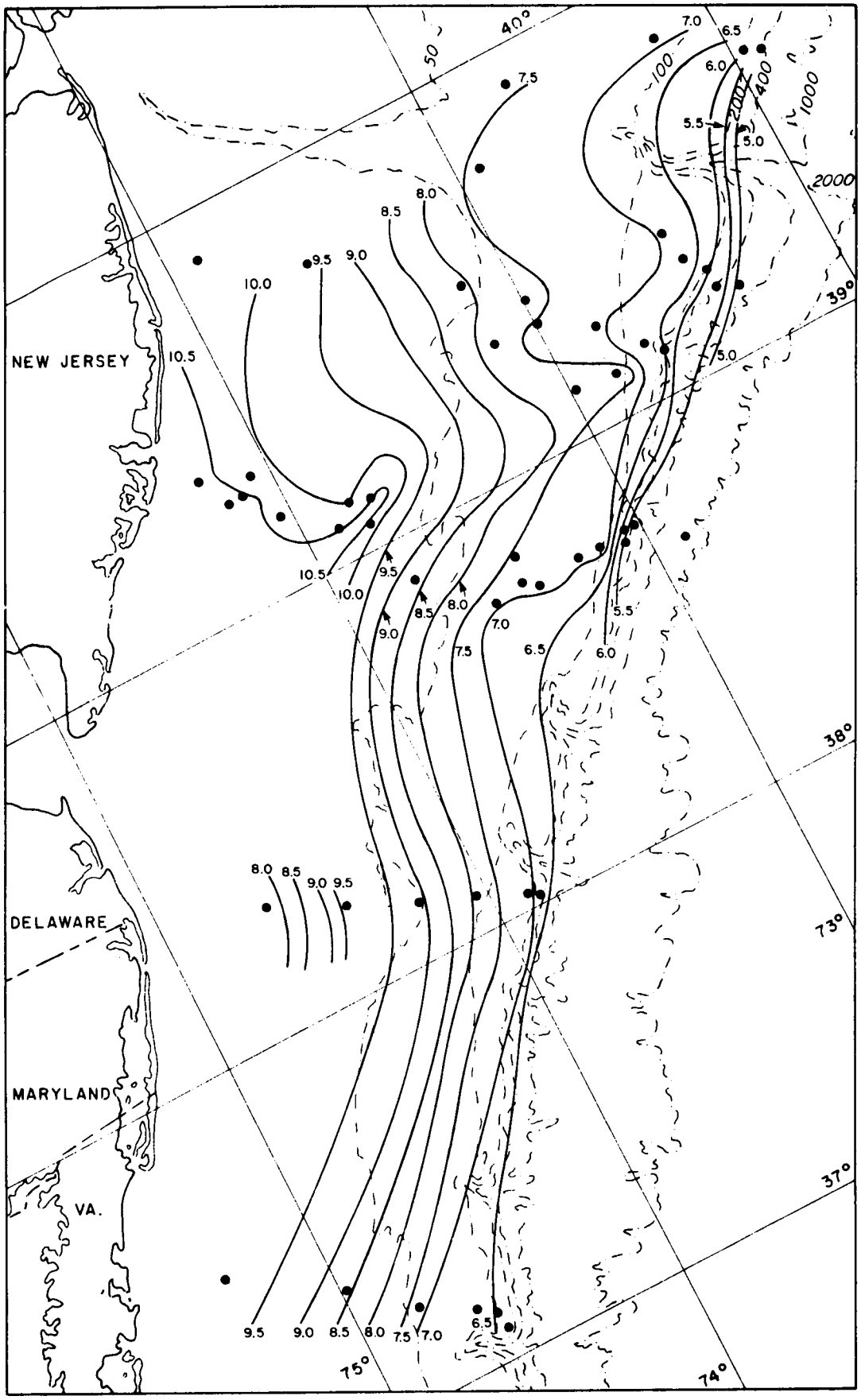

Figure 3-52. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

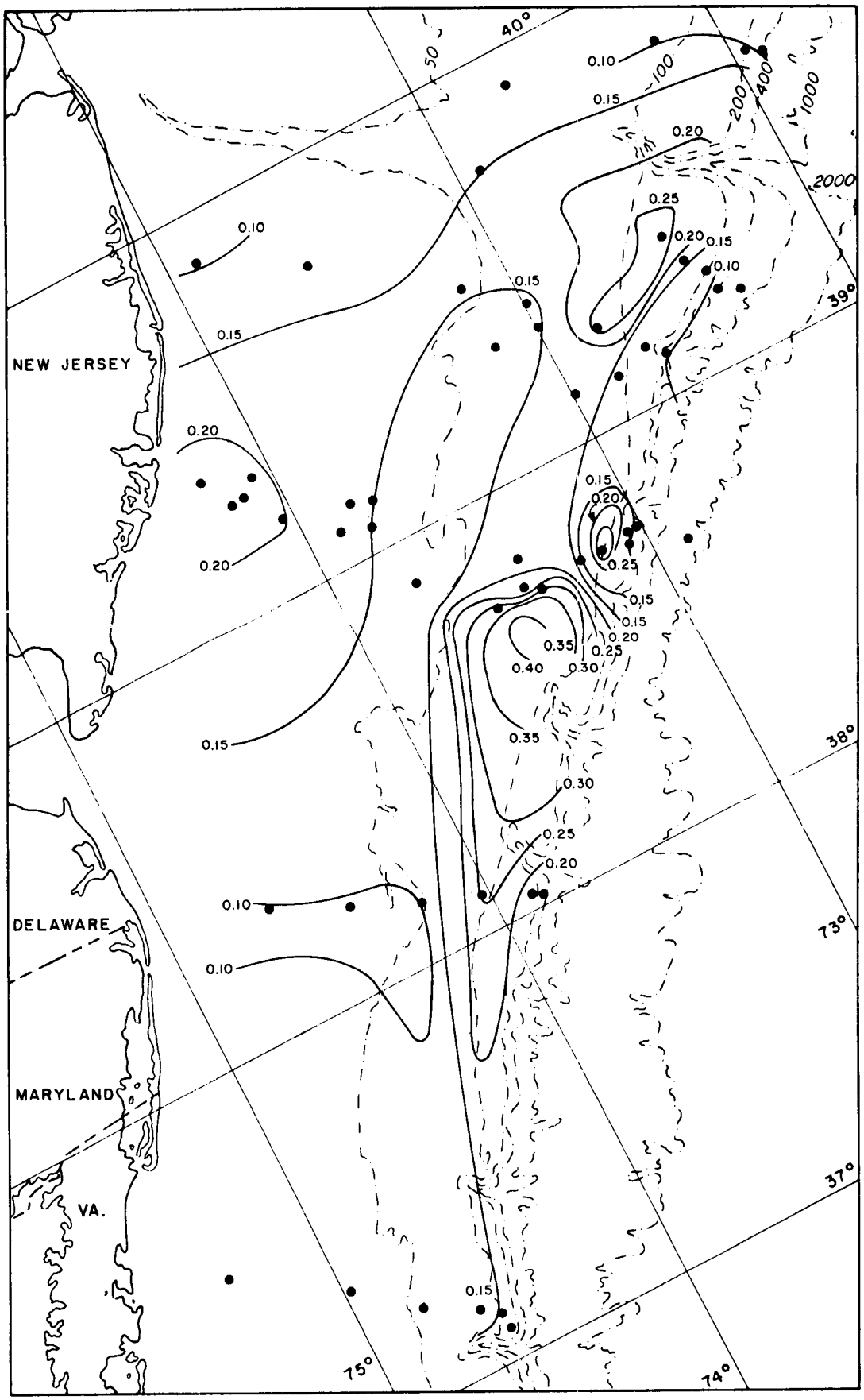

Figure 3-53. Bottom NO_2 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

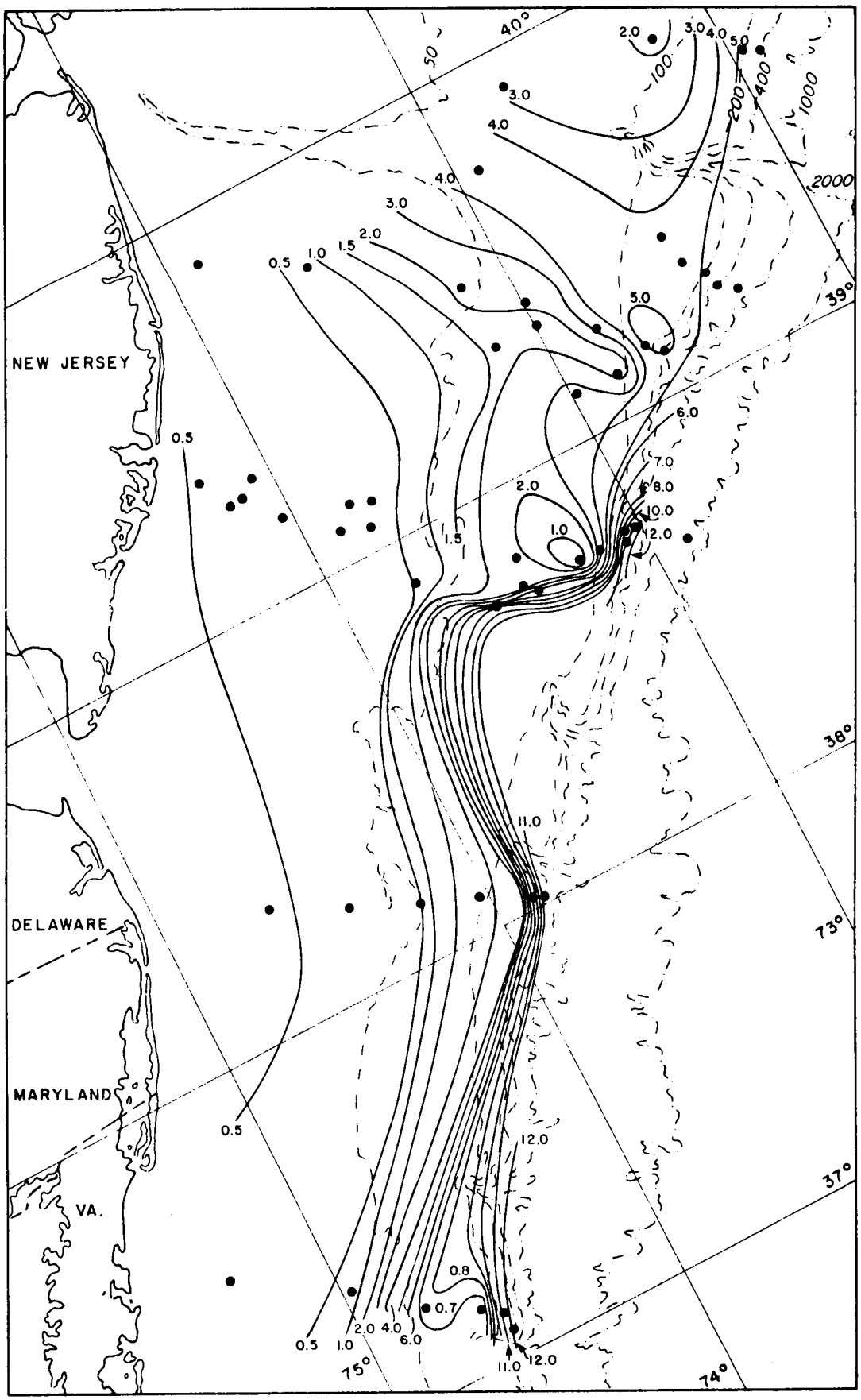

Figure 3-54. Bottom NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

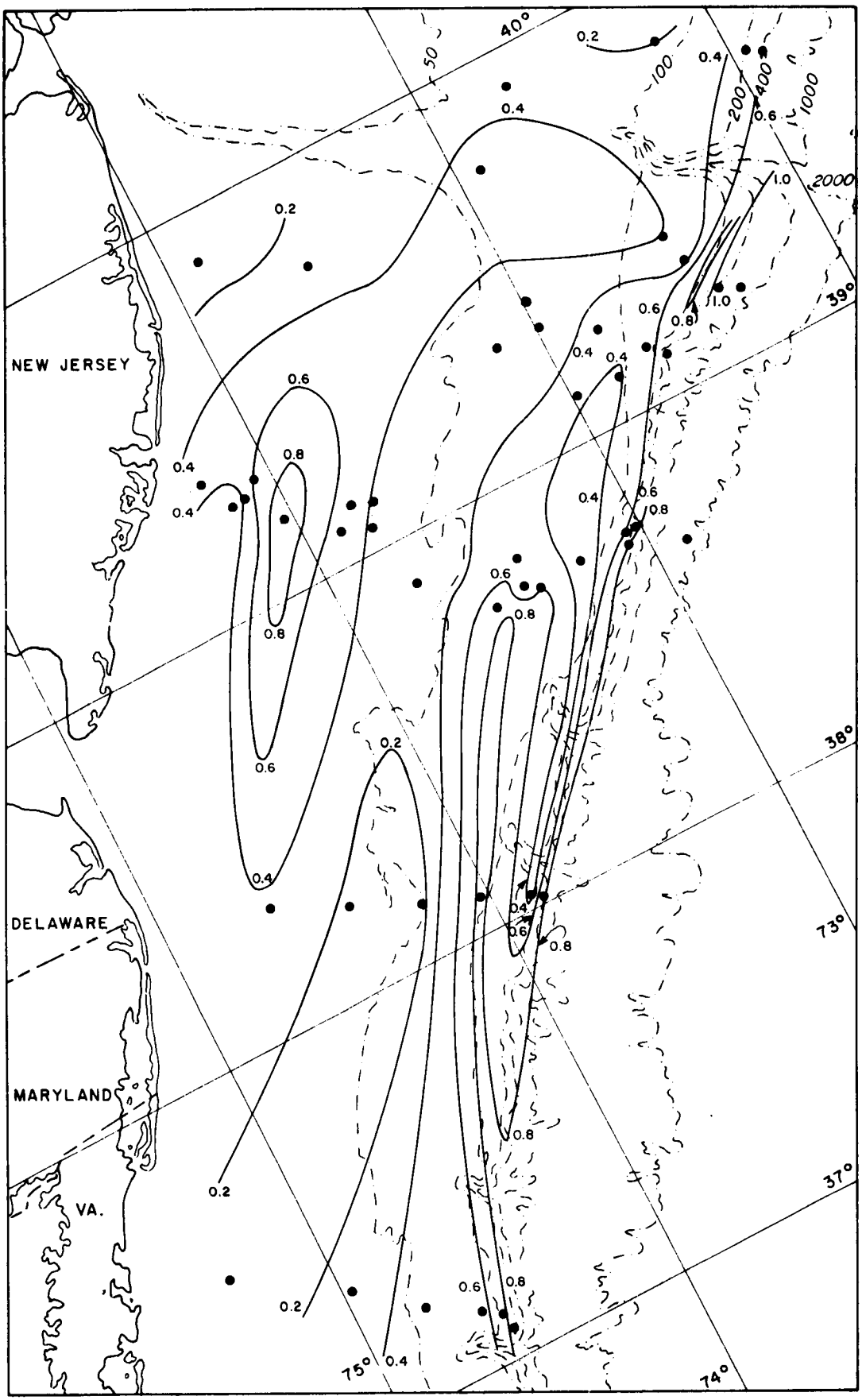

Figure 3-55. Bottom O-PO_4 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 19 February to 23 March 1976 (Cruise BLMØ2B)

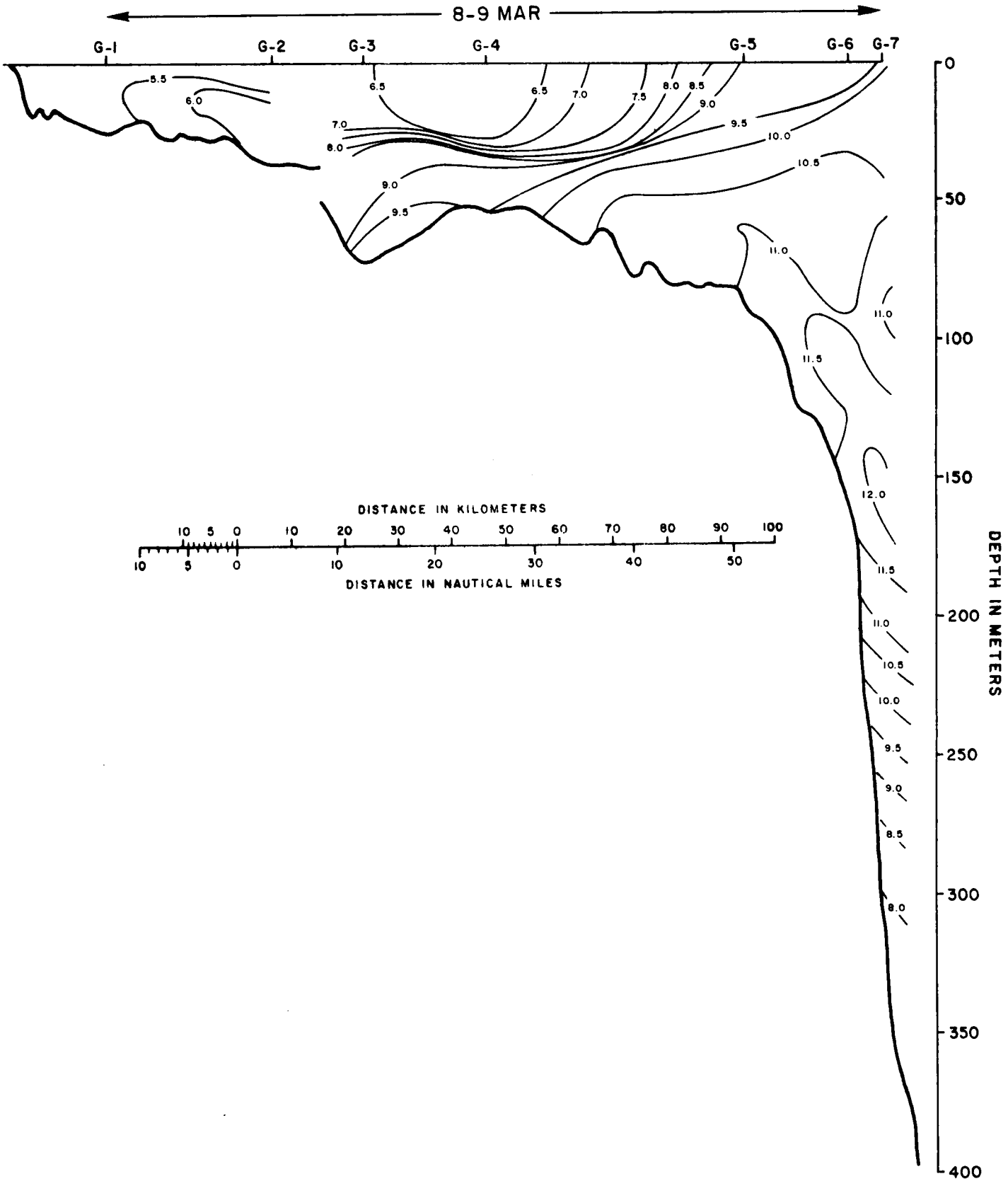

Figure 3-56. Temperature (^{o}C) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

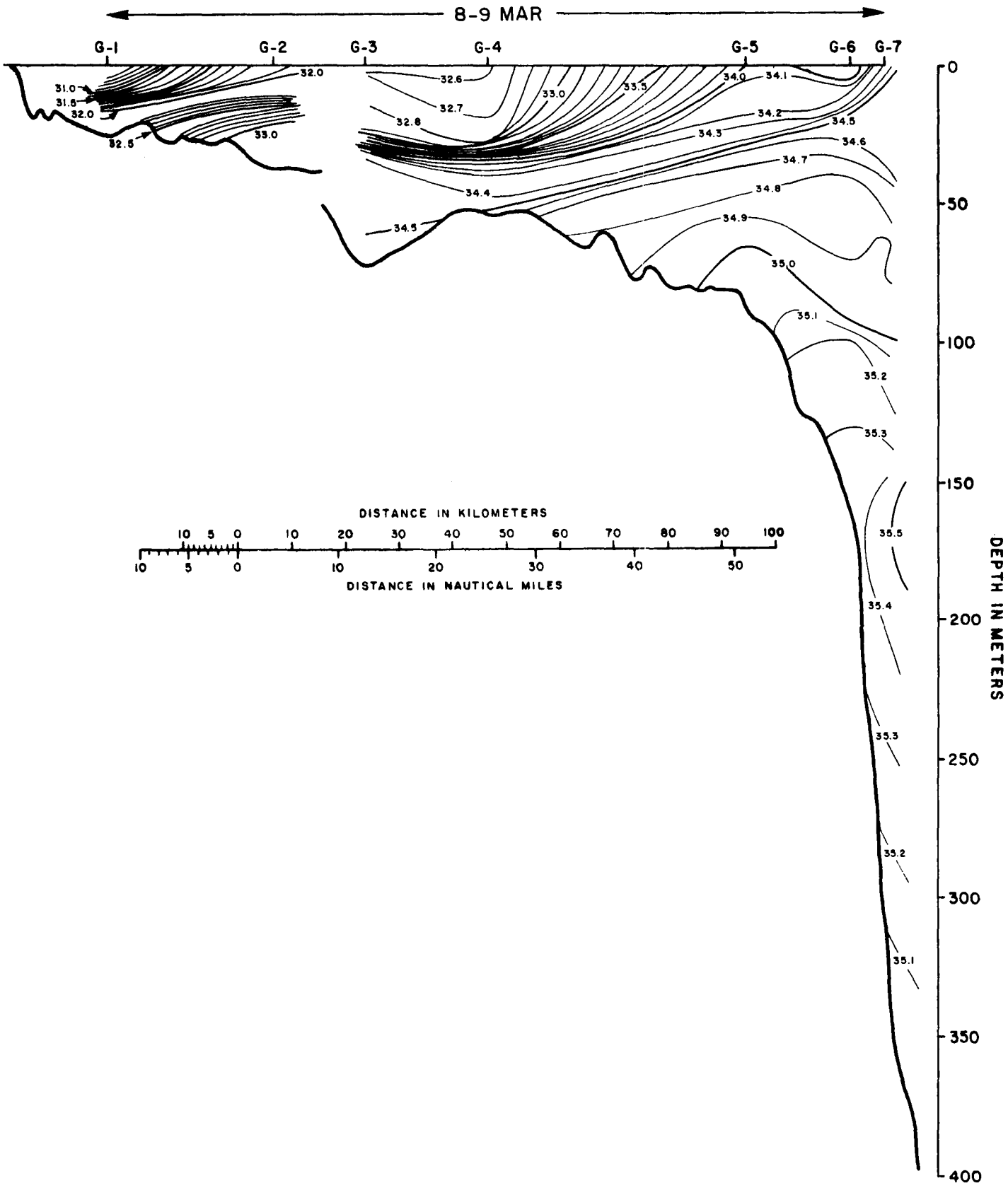

Figure 3-57. Salinity (ppt) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

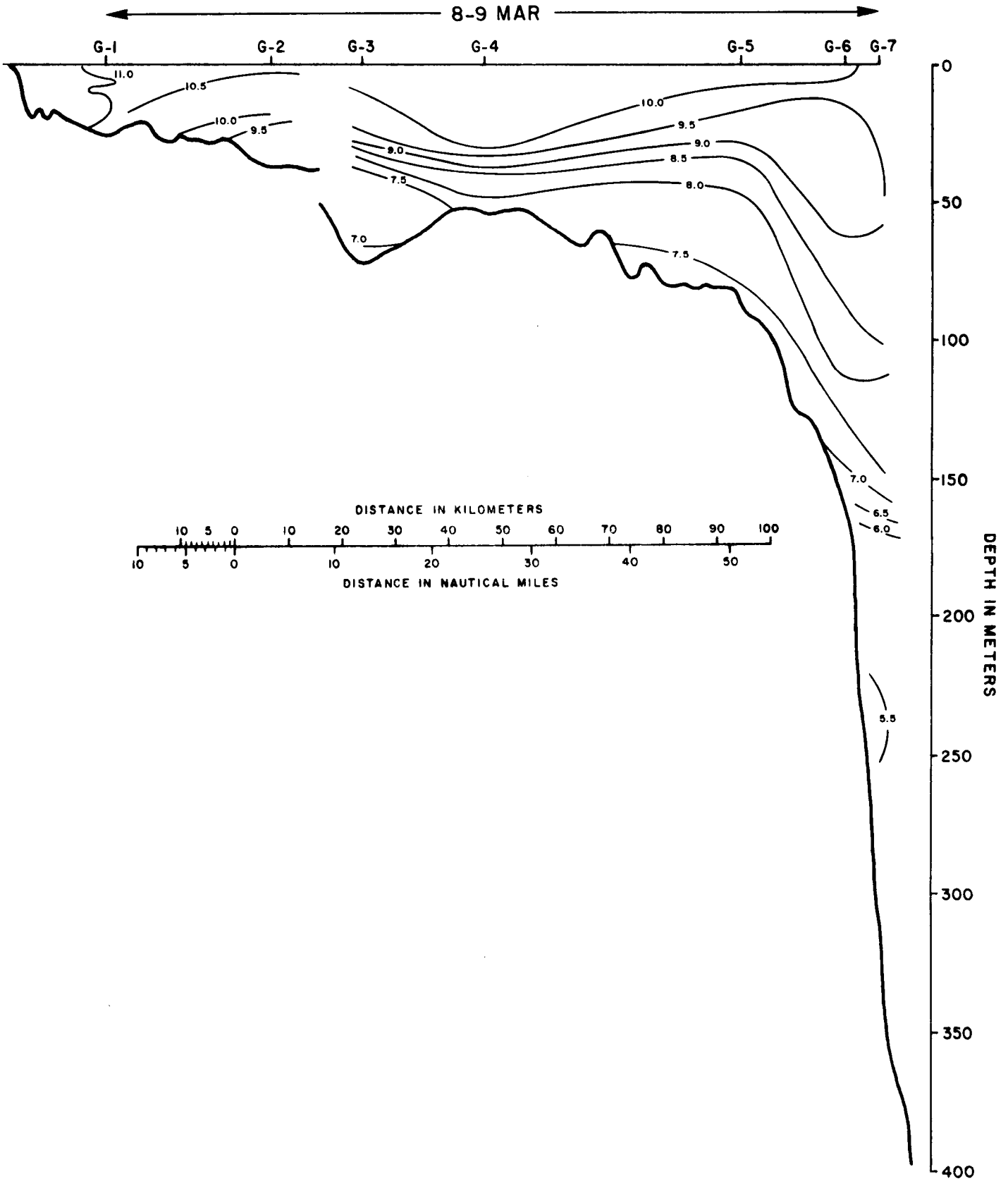

Figure 3-58. Dissolved oxygen (mg/l) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

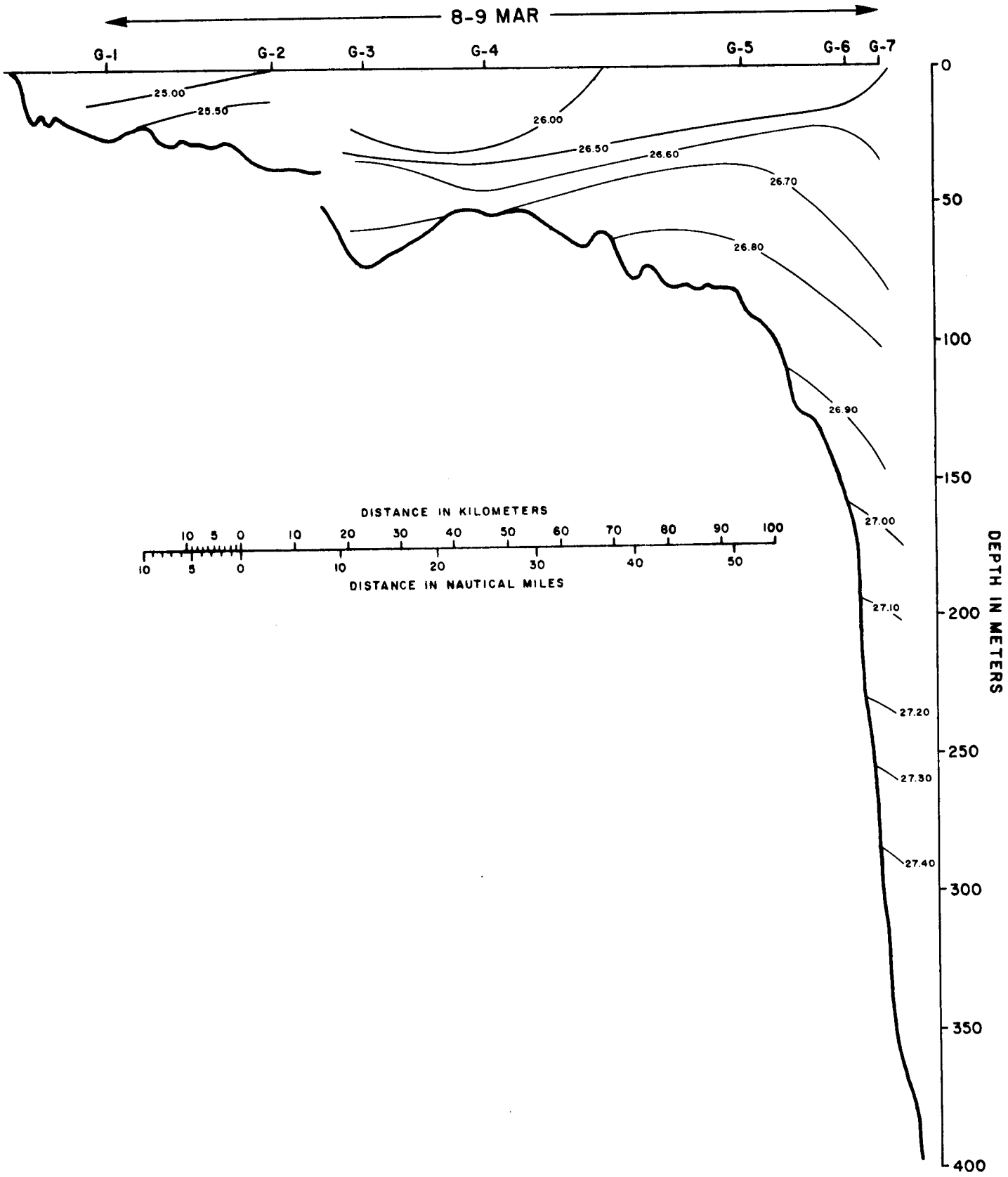

Figure 3-59 . Density (σ_t units) along Section I (Stations G1 to G7, 8-9 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

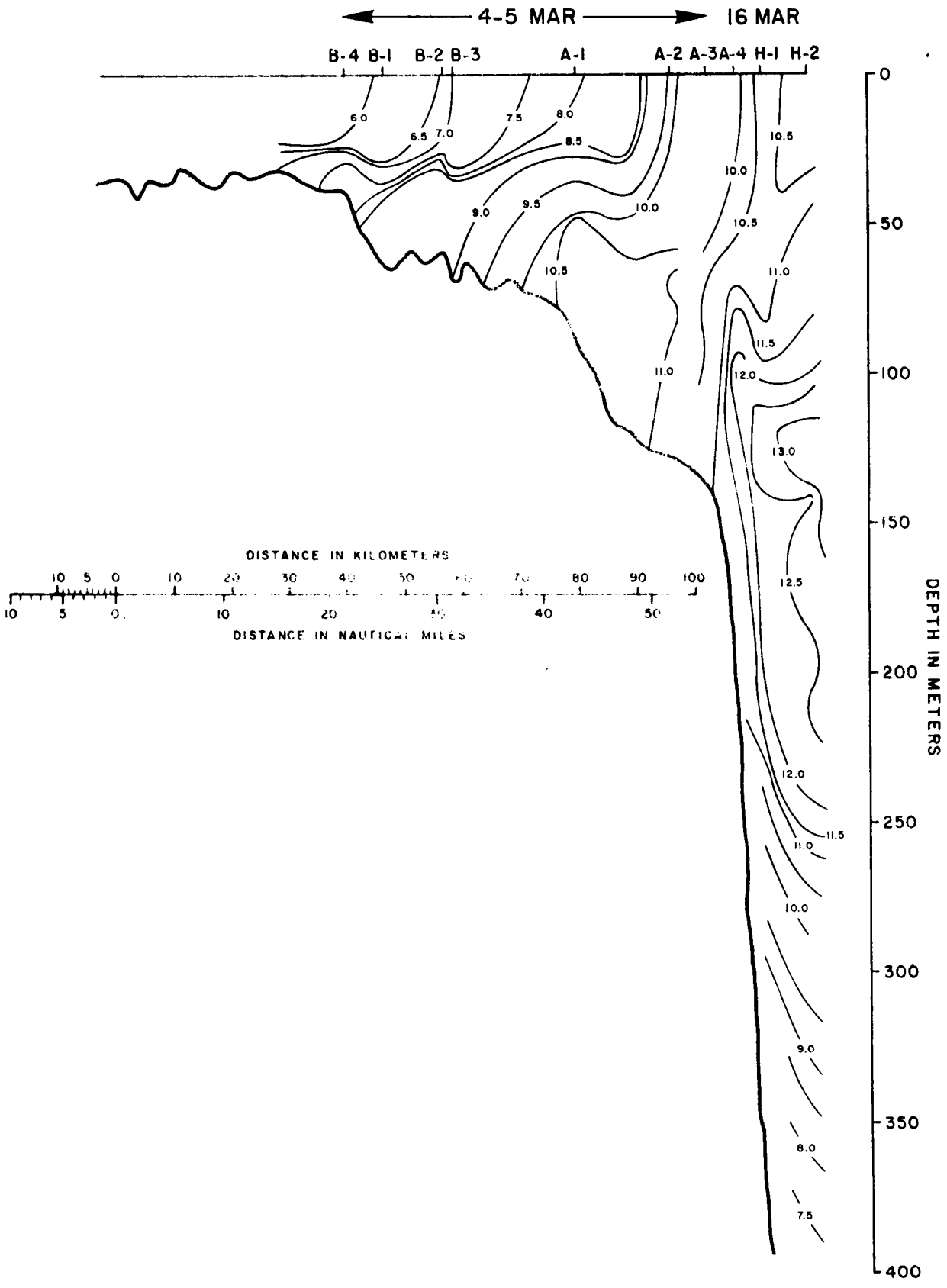

Figure 3-60 . Temperature (^{o}C) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

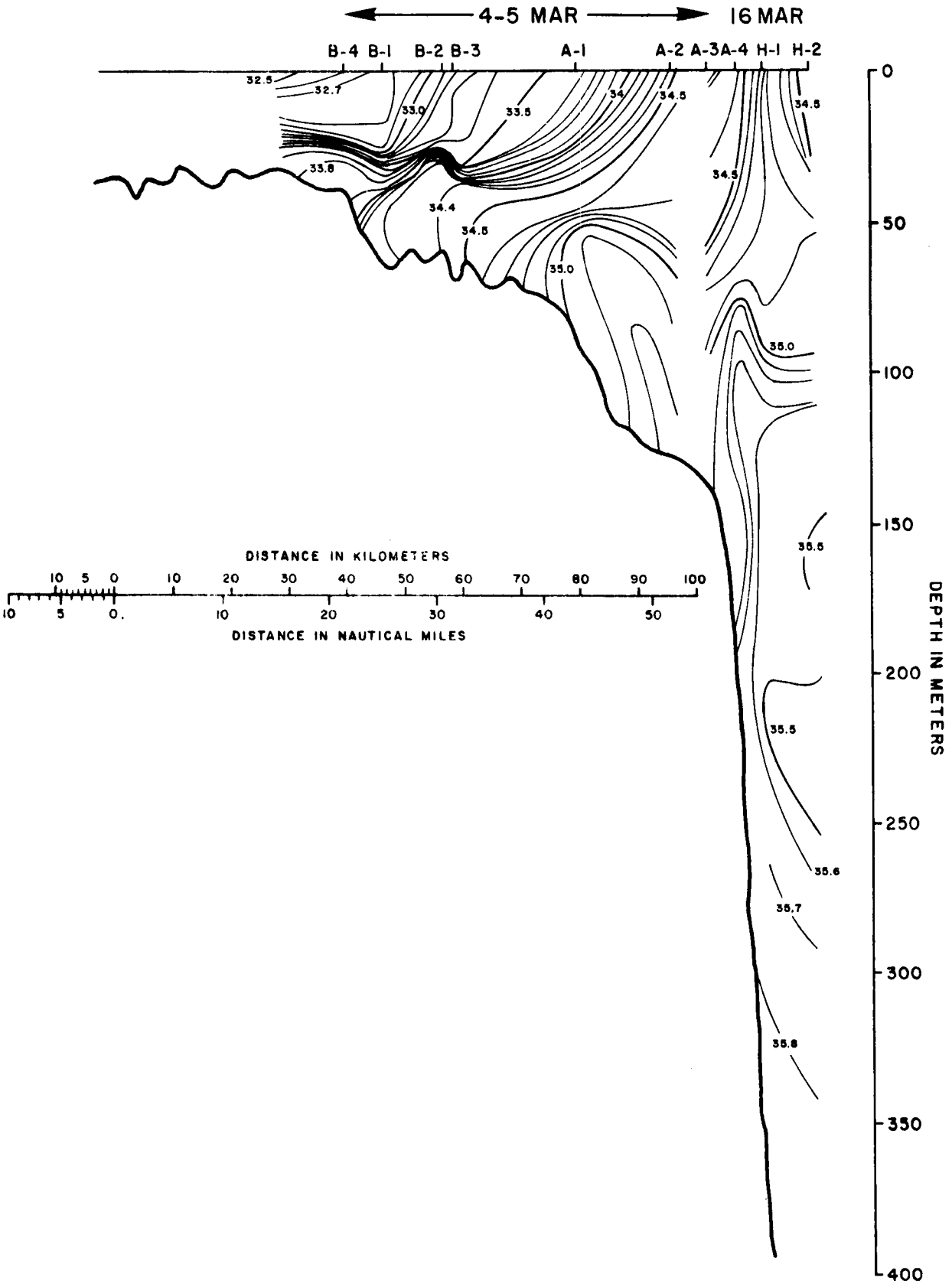

Figure 3-61 . Salinity (ppt) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

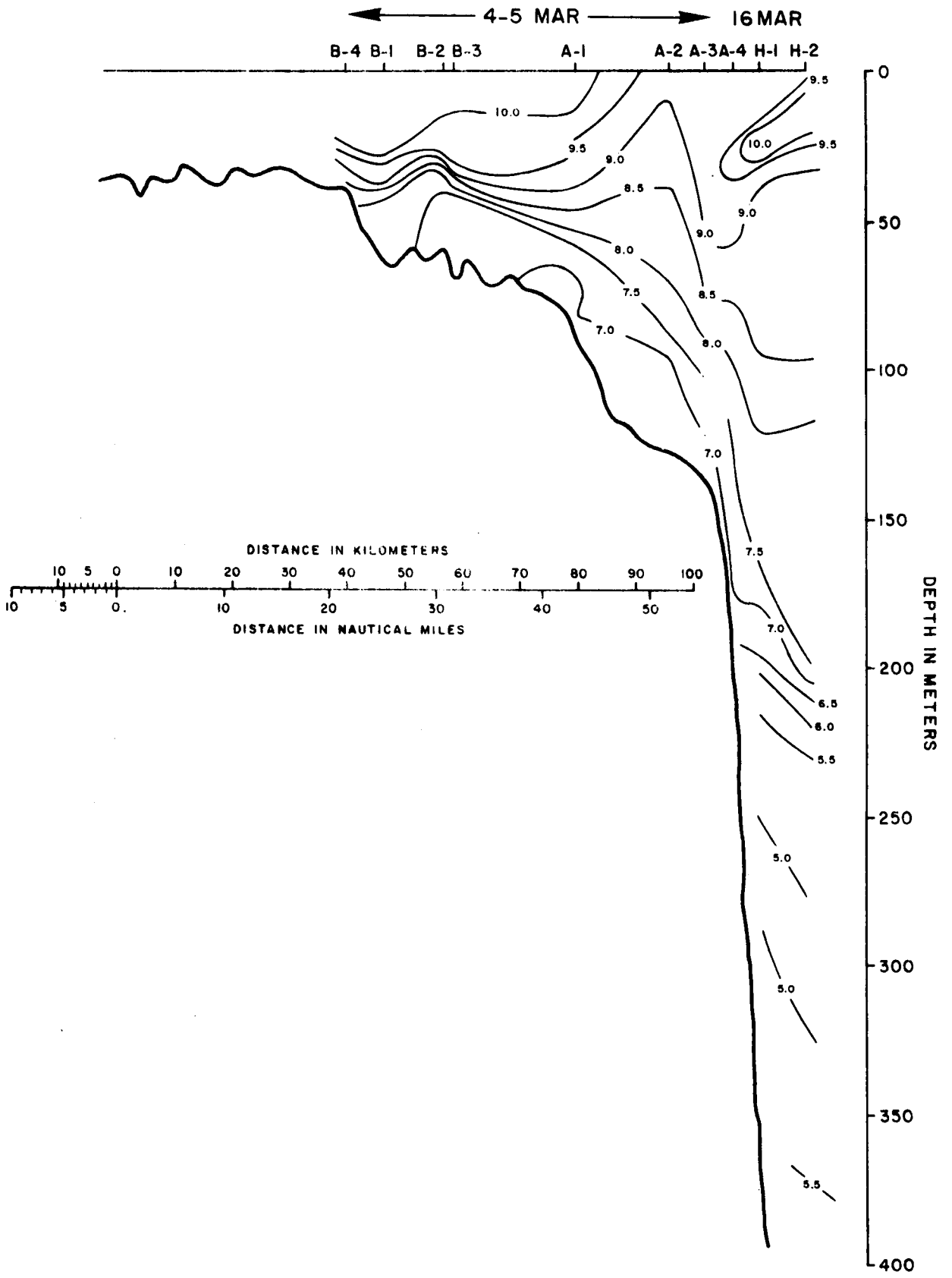

Figure 3-62 . Dissolved oxygen (mg/1) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

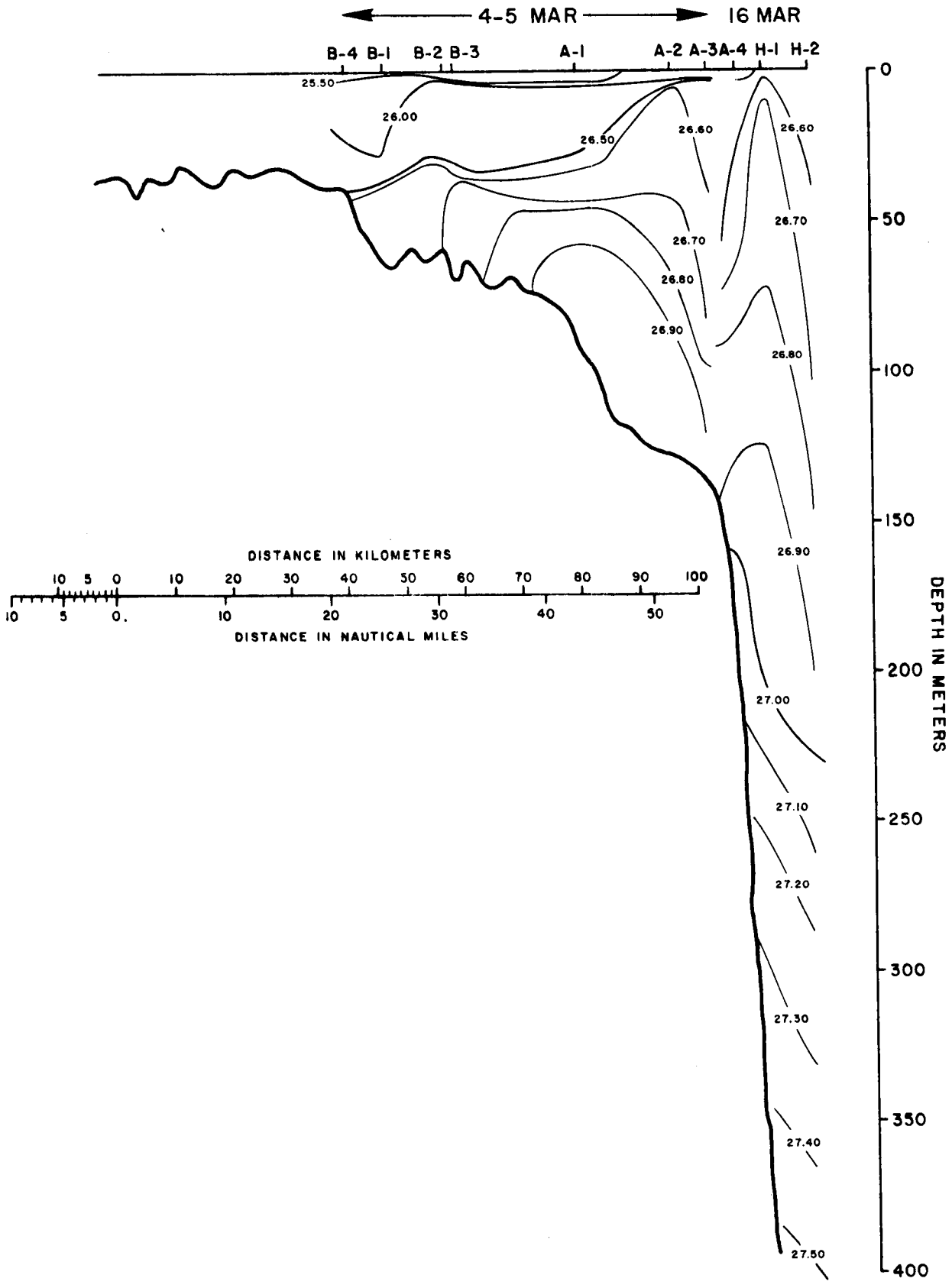

Figure 3-63 . Density (σ_t units) along Section II (Stations B4 to H2, 4-16 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

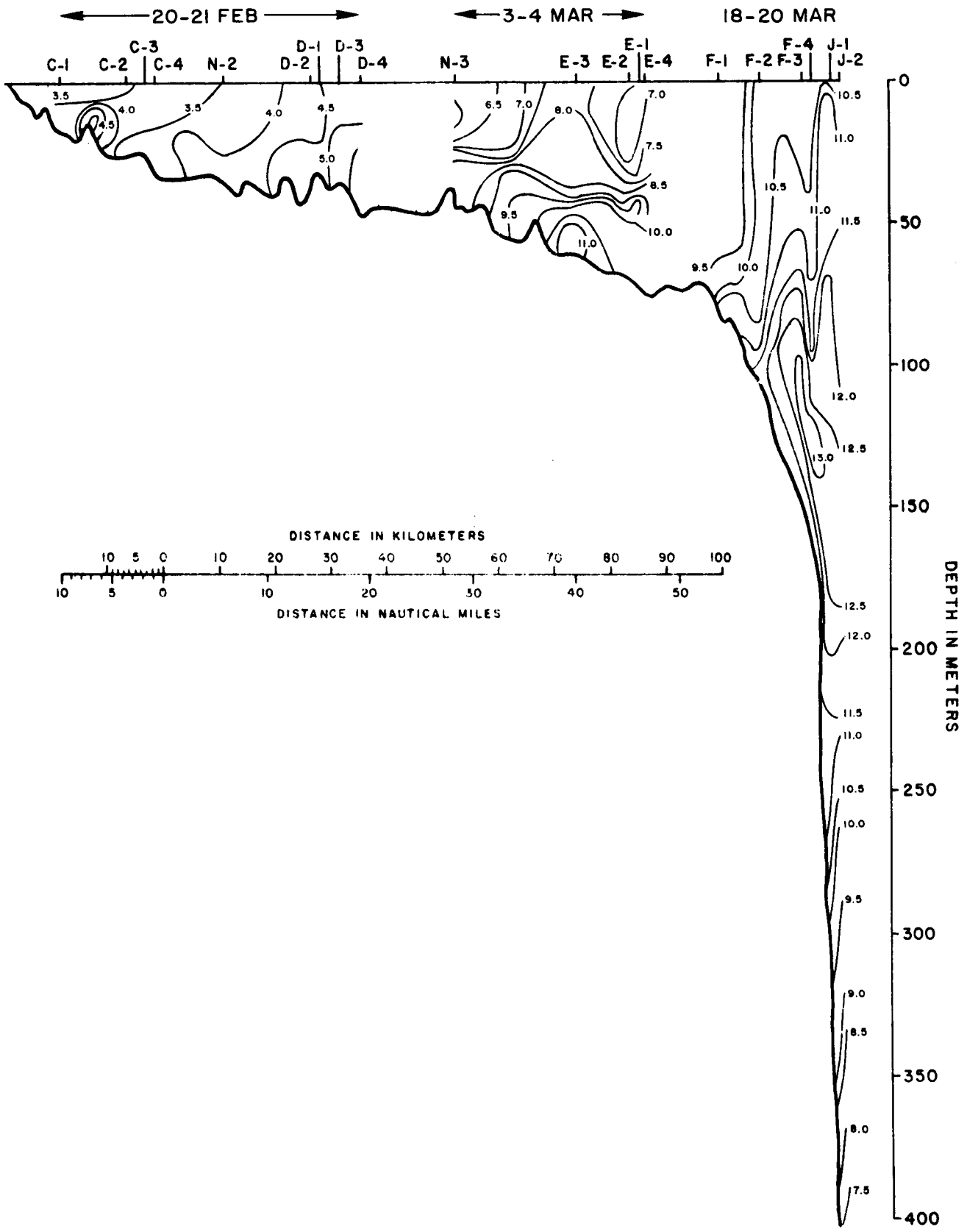

Figure 3-64 . Temperature (^{o}C) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

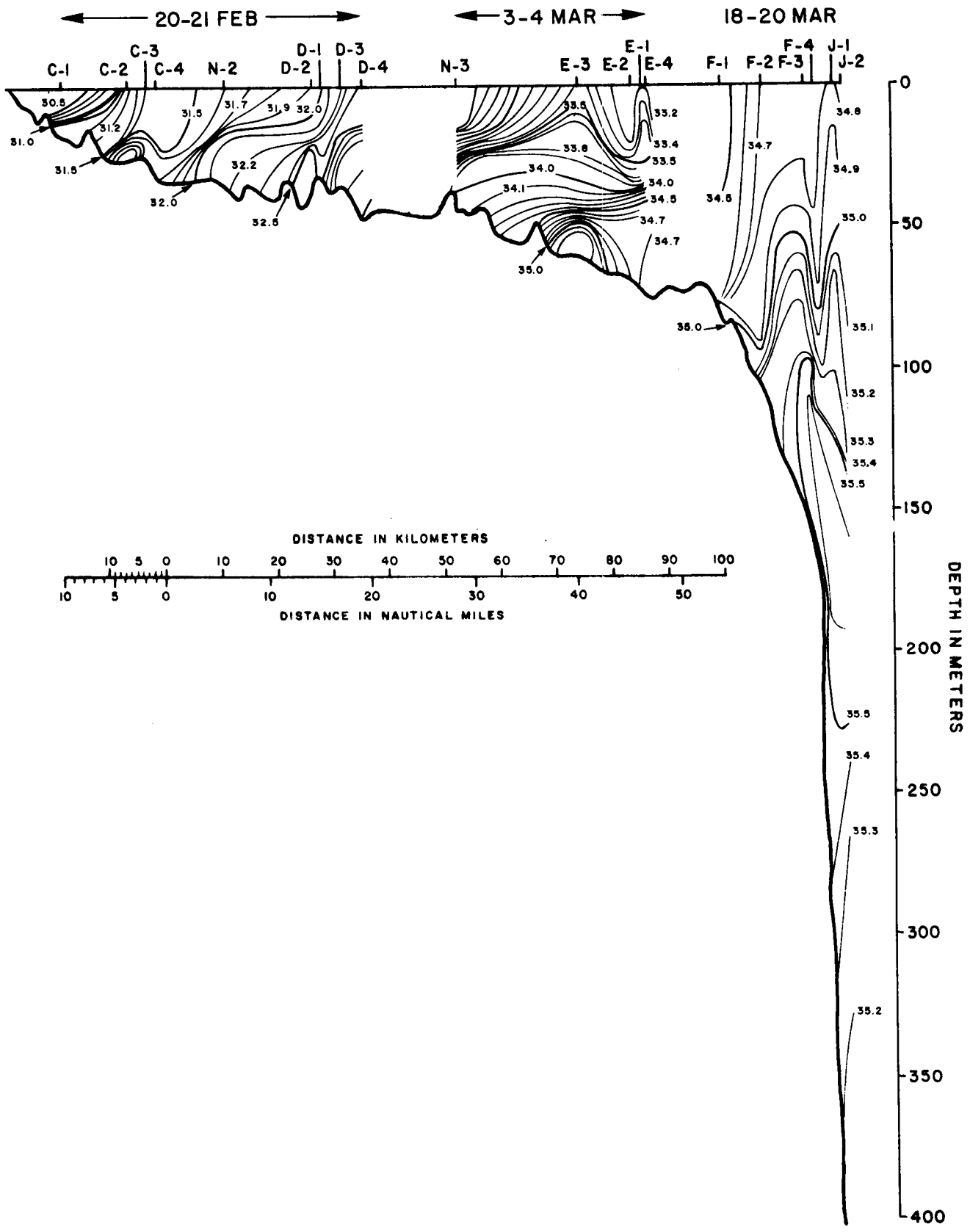

Figure 3-65. Salinity (ppt) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

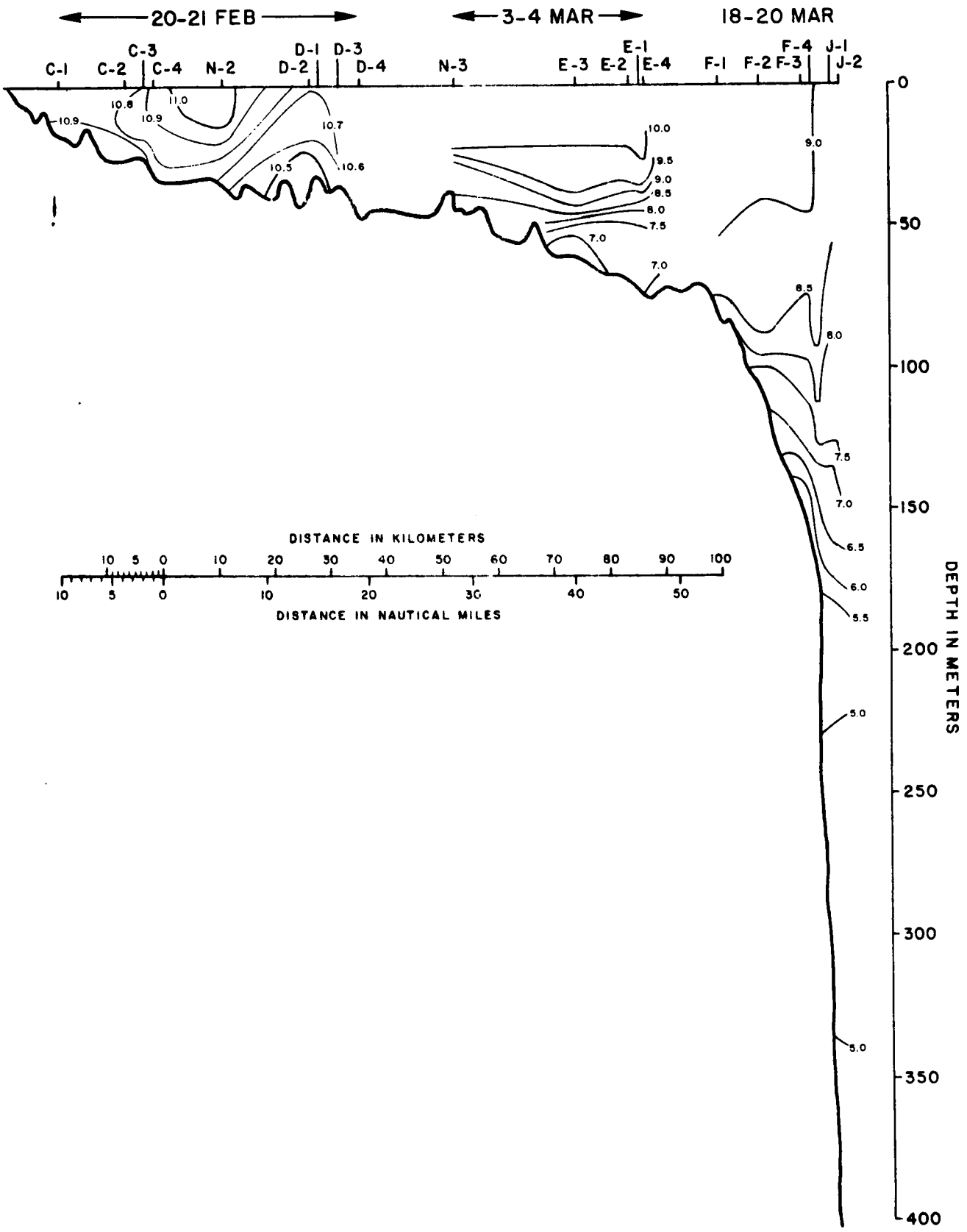

Figure 3-66. Dissolved oxygen (mg/l) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

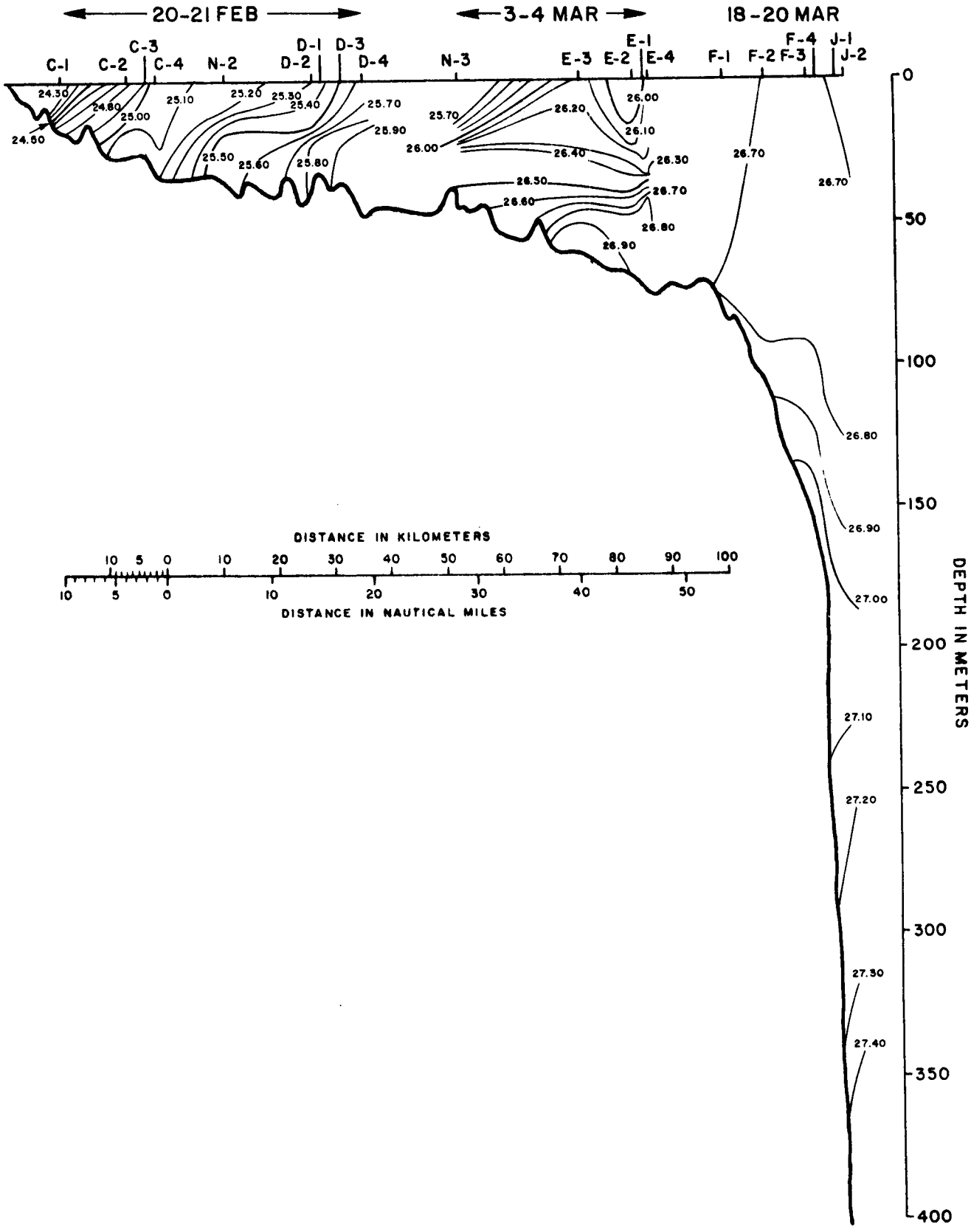

Figure 3-67. Density (σ_t units) along Section III (Stations C1 to J2, 20 February - 20 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

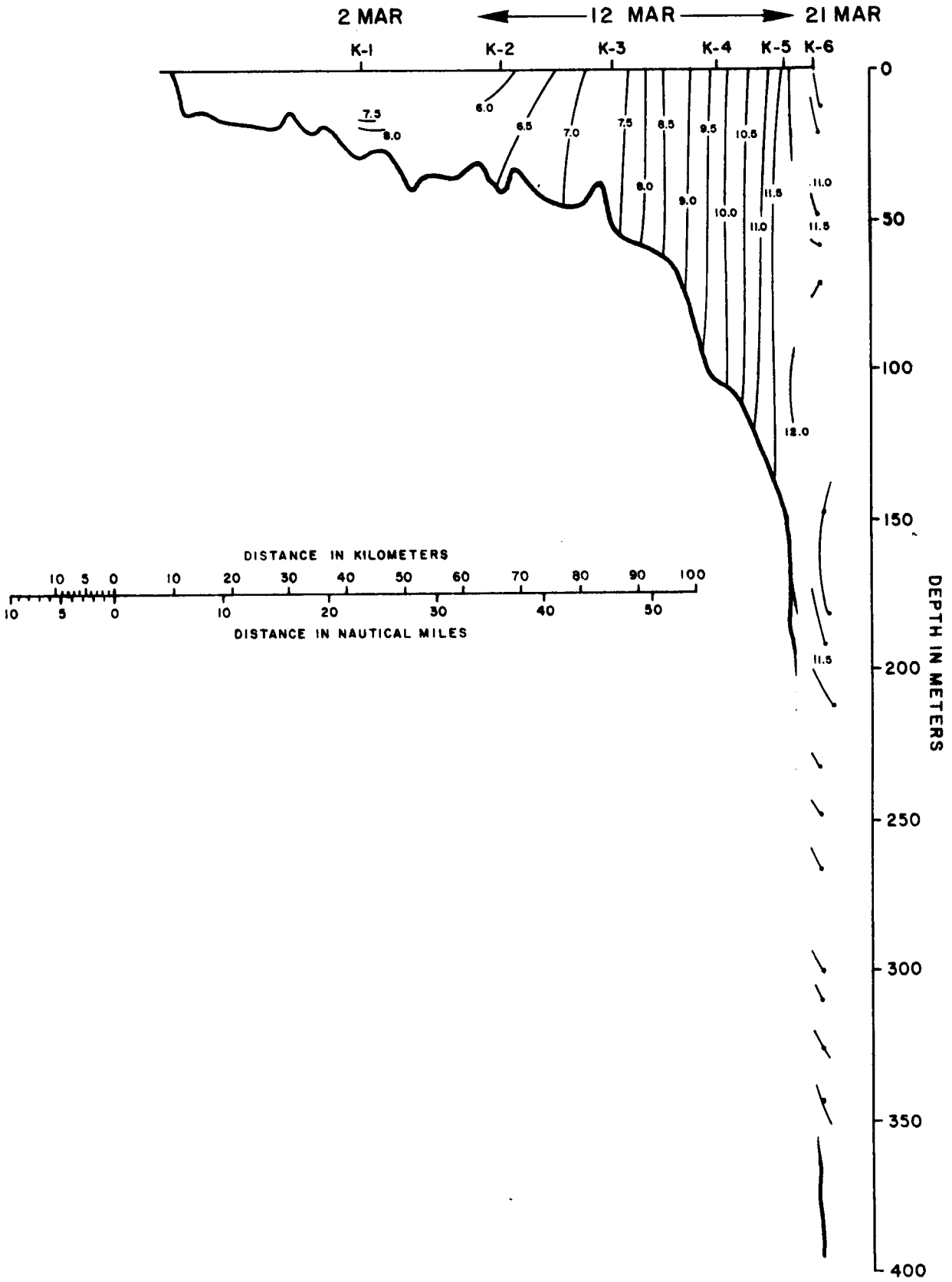

Figure 3-68. Temperature (^{o}C) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

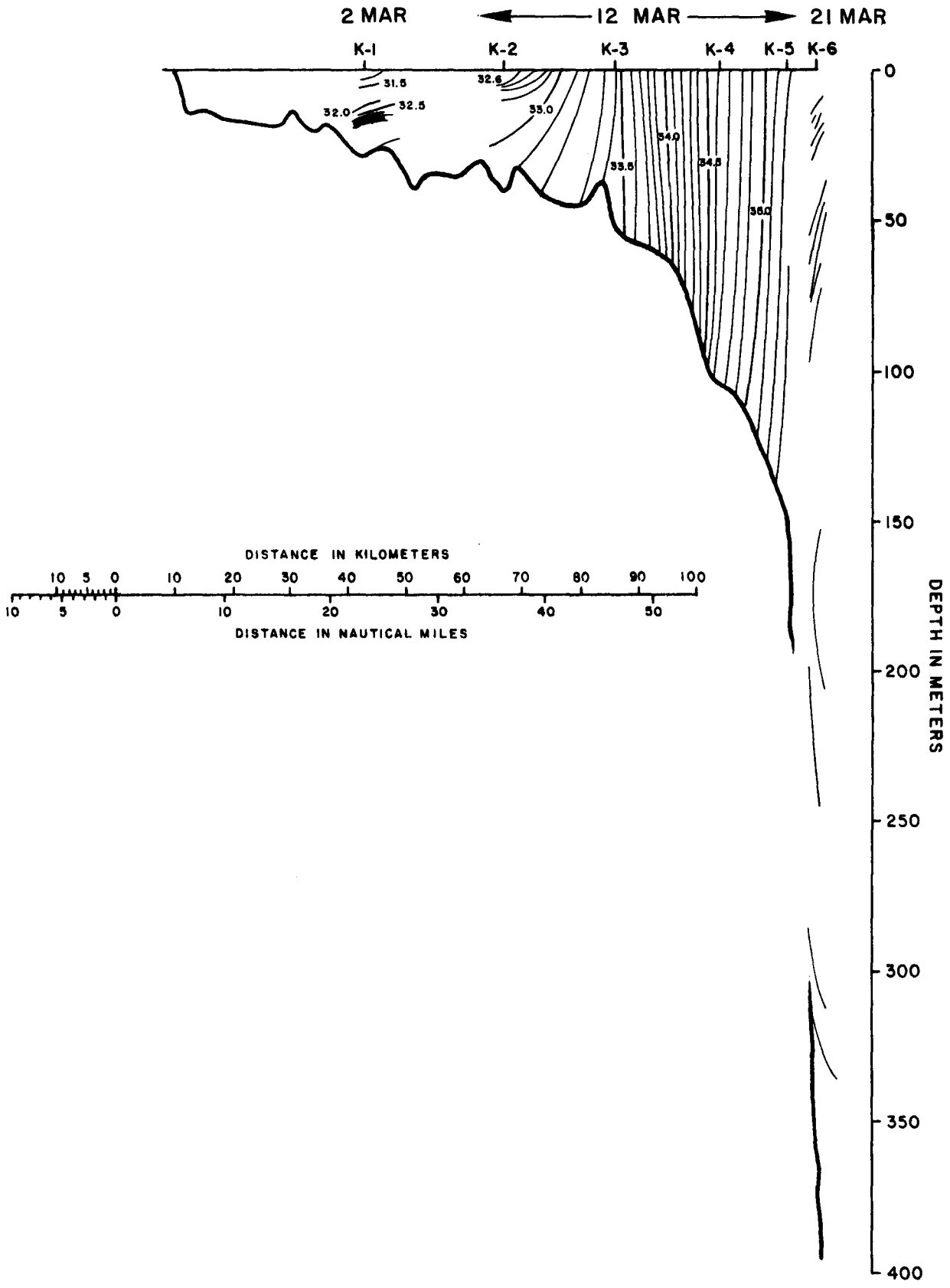

Figure 3-69. Salinity (ppt) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-1Ø. Breaks in isopleths signify temporal breaks in sampling continuity.

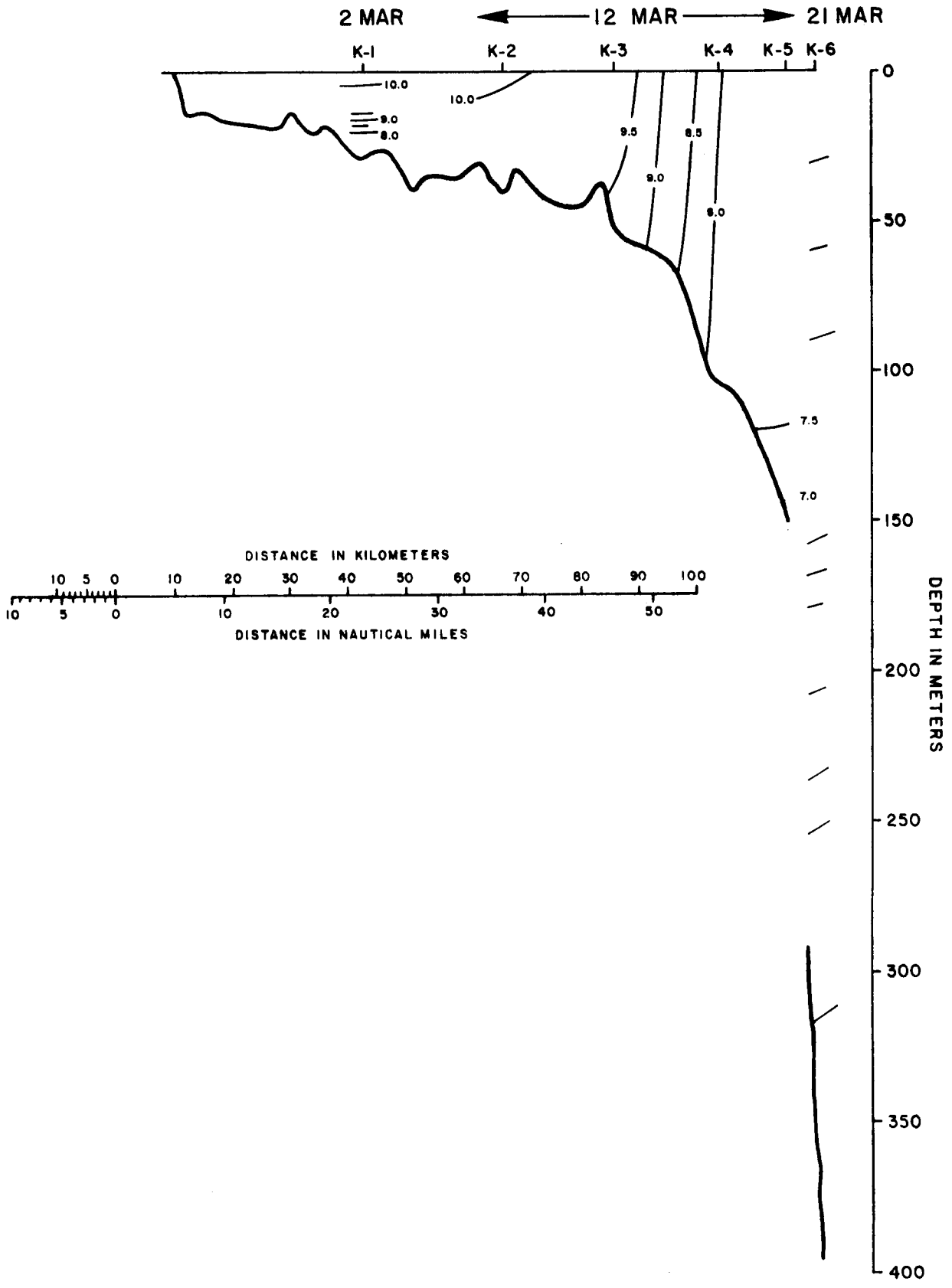

Figure 3-70. Dissolved oxygen (mg/l) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

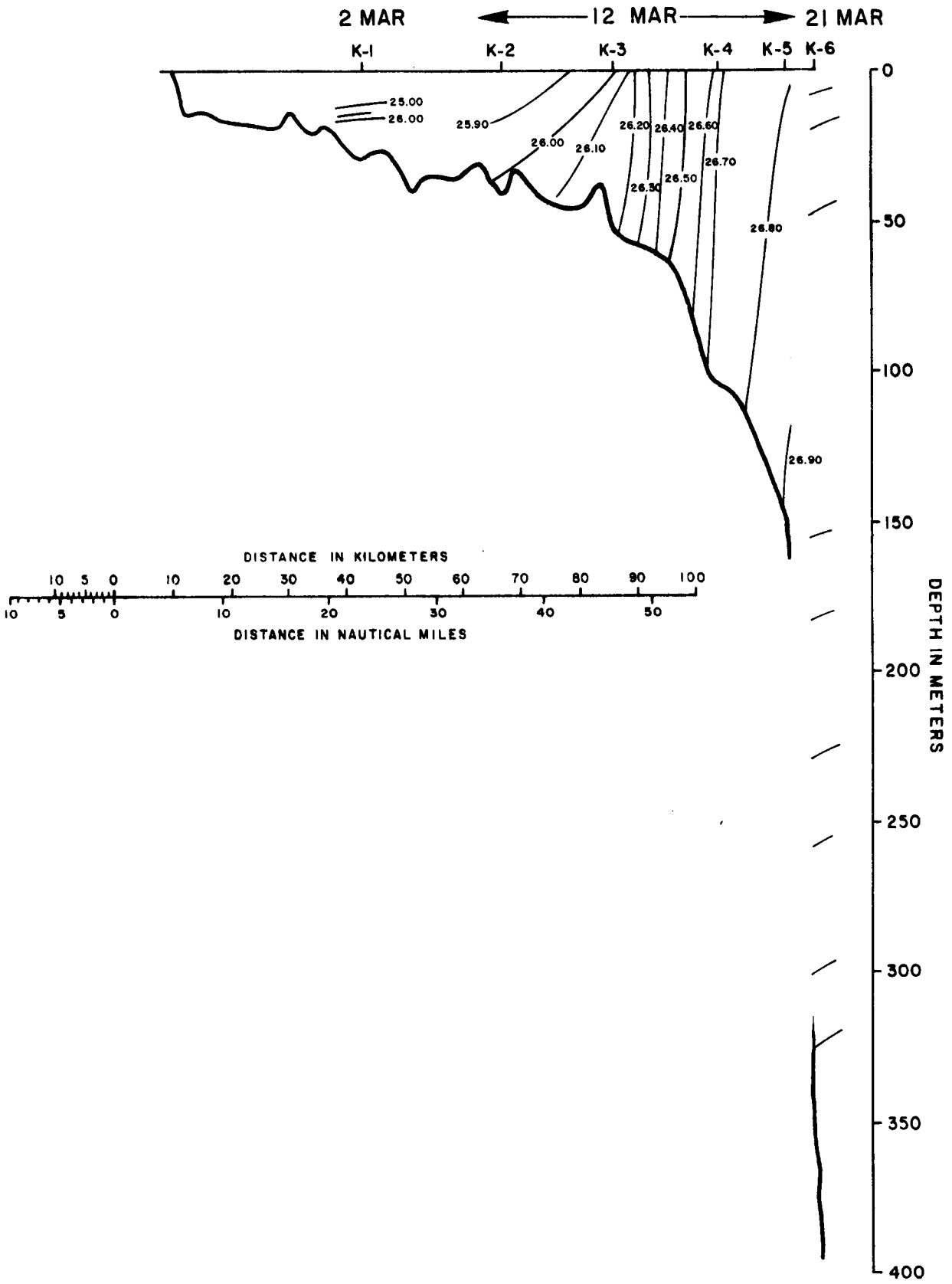

Figure 3-71. Density (σ_t units) along Section IV (Stations K1 to K6, 2-21 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10. Breaks in isopleths signify temporal breaks in sampling continuity.

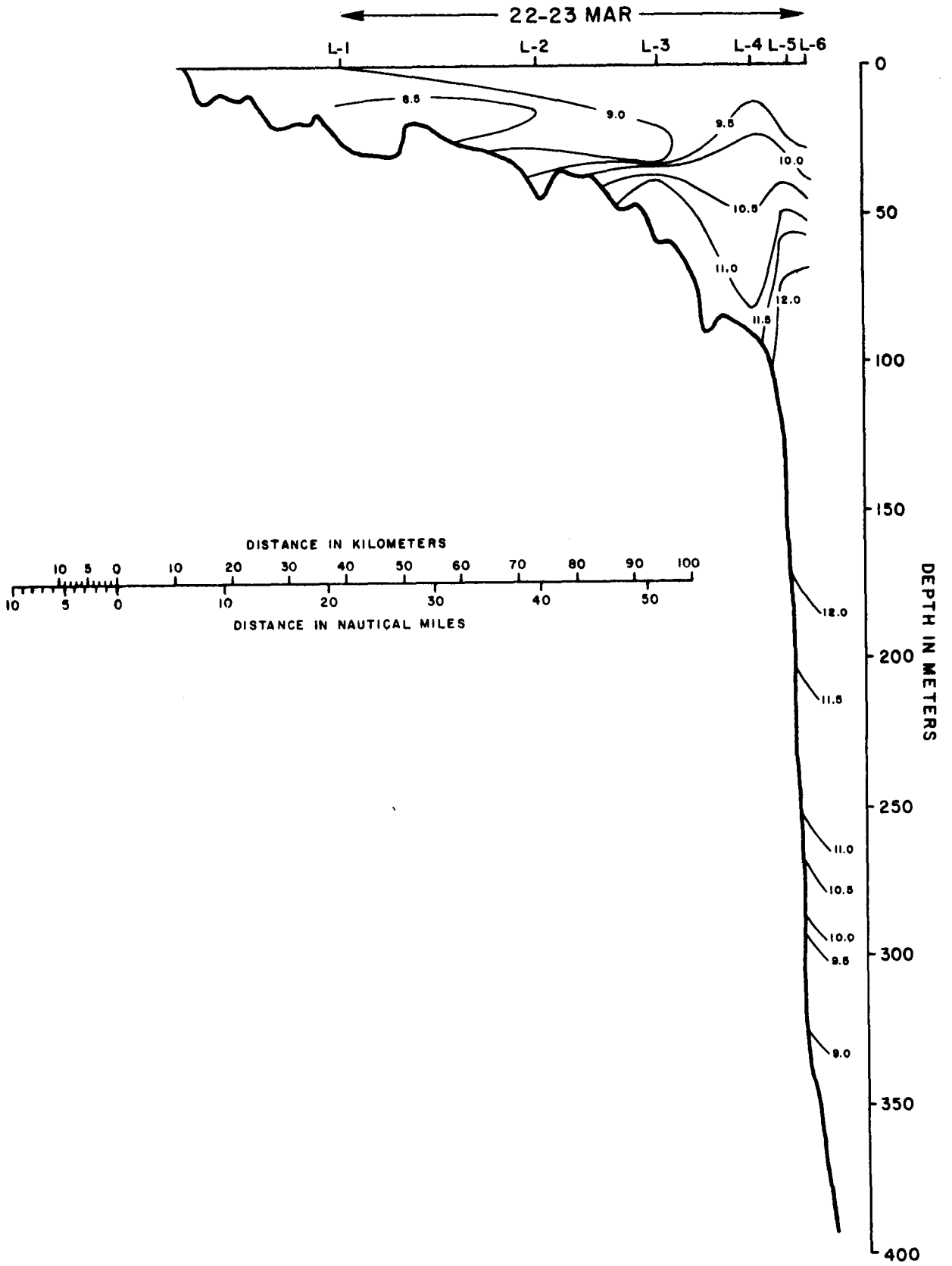

Figure 3-72. Temperature (^{o}C) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

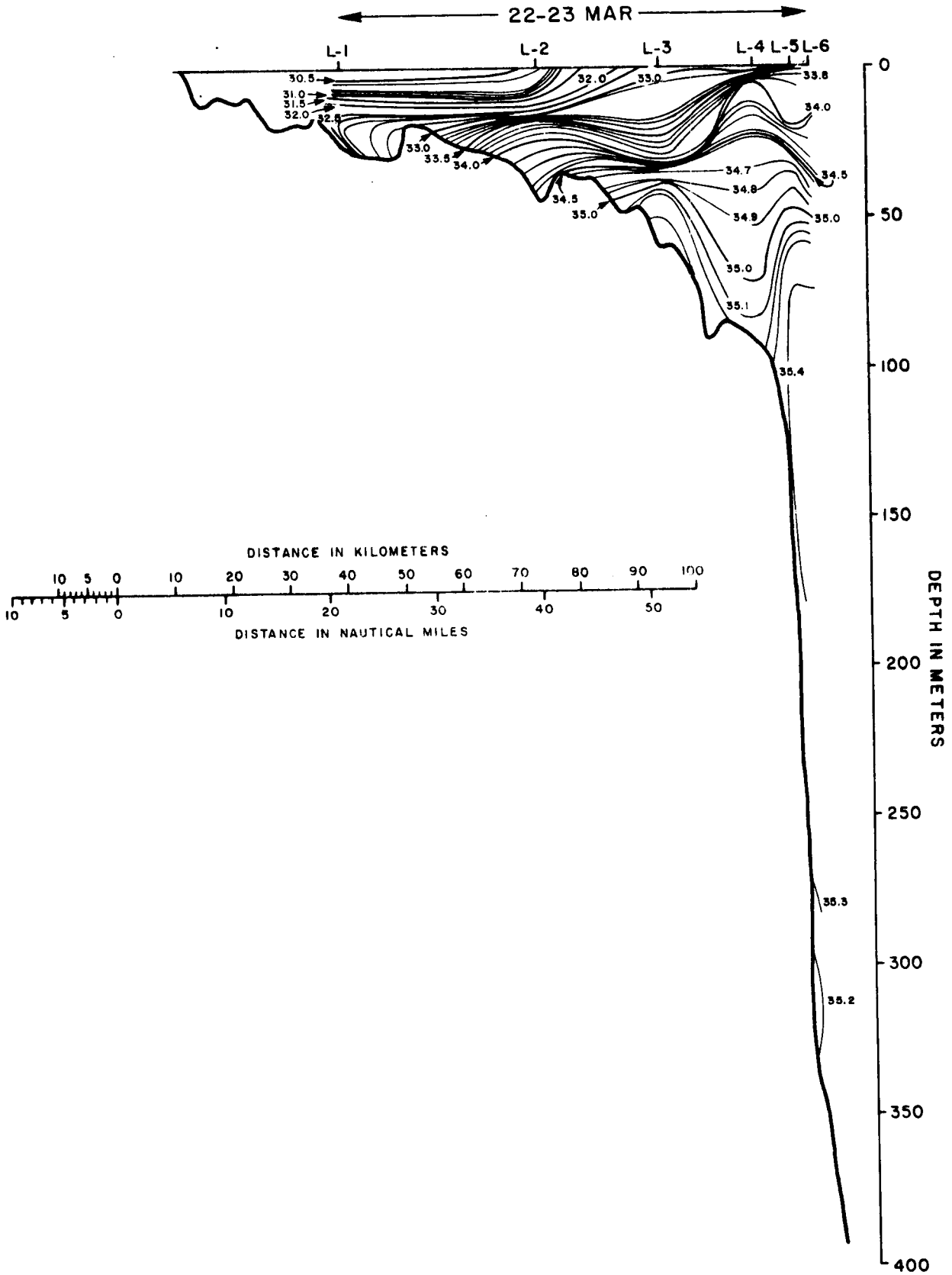

Figure 3-73. Salinity (ppt) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

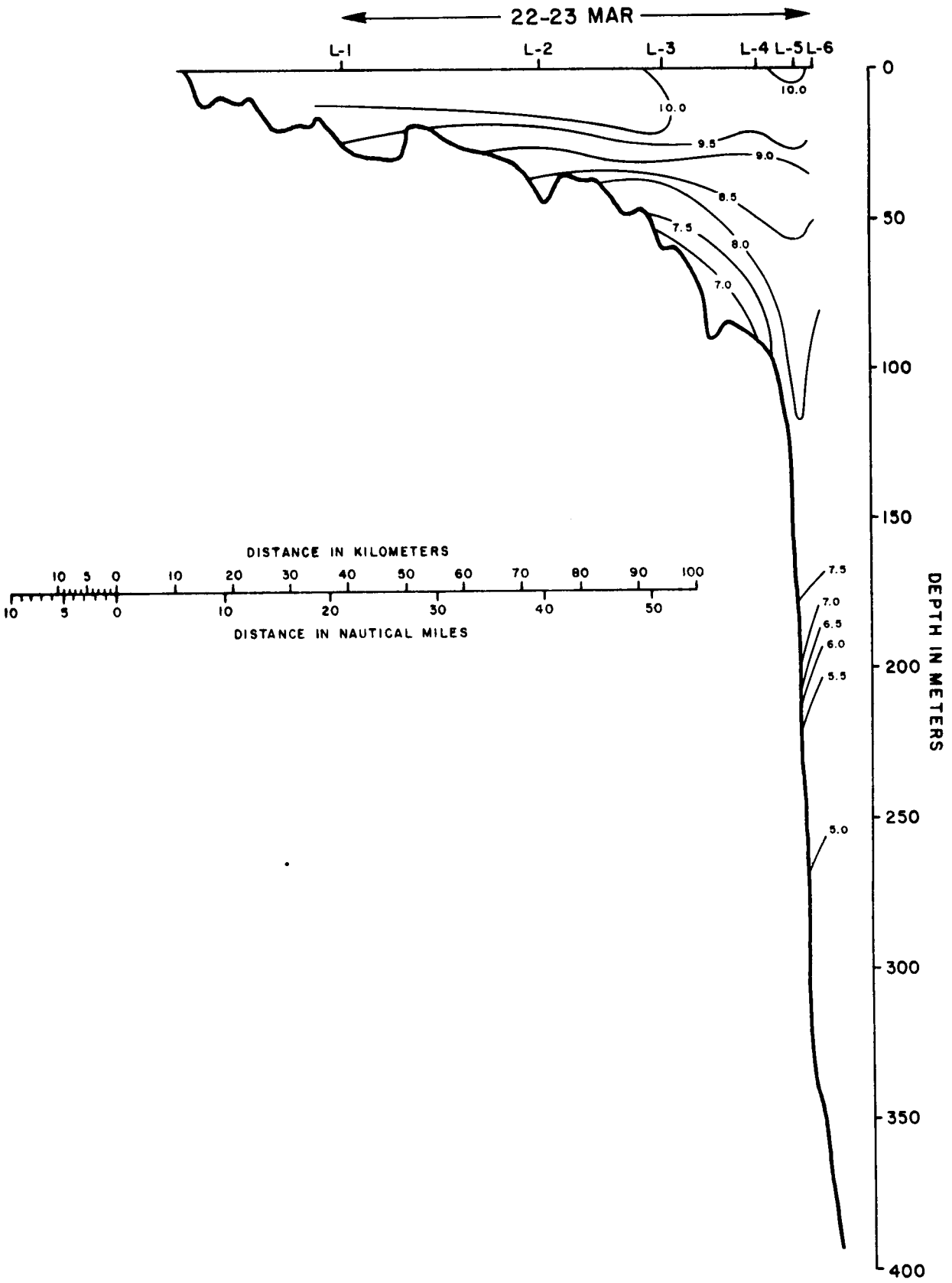

Figure 3-74. Dissolved oxygen (mg/l) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLMØ2B. Section location is shown in Figure 3-10.

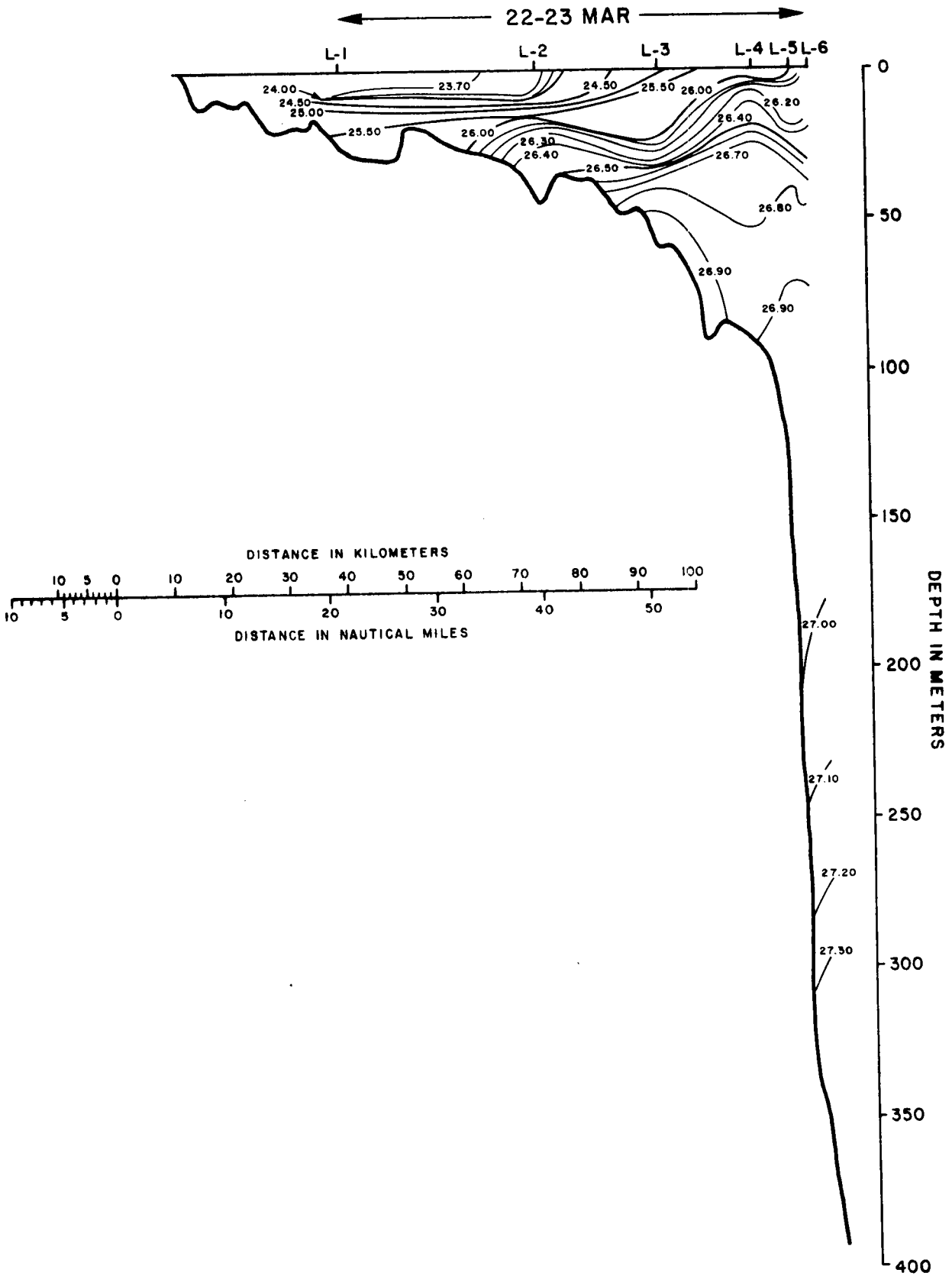

Figure 3-75. Density (σ_t units) along Section V (Stations L1 to L6, 22-23 March 1976) during cruise BLM02B. Section location is shown in Figure 3-10.

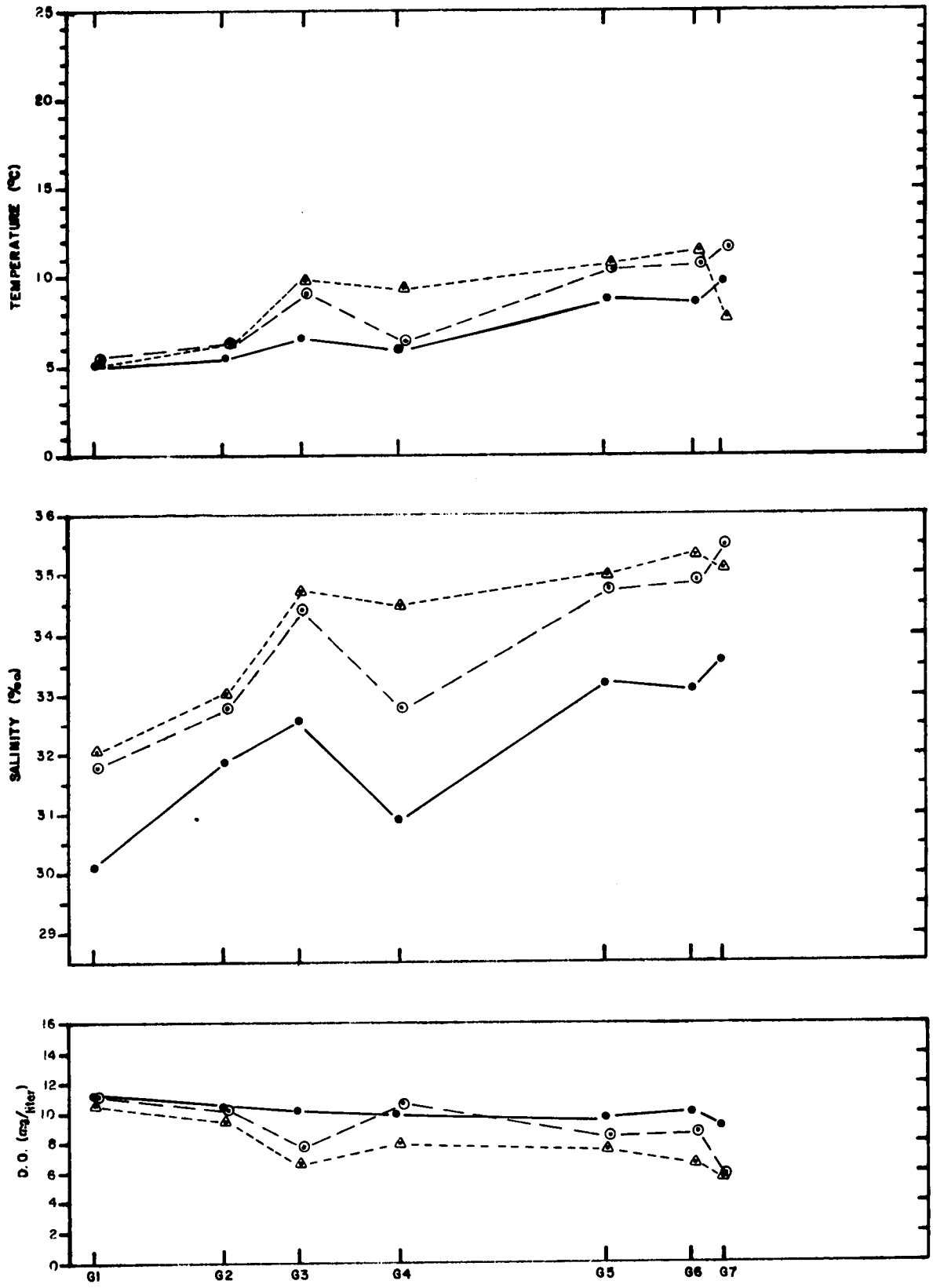

Figure 3-76. Surface (•), mid-depth (0) and bottom (Δ) values of temperature, salinity and DO measured along Section I on cruise BLM Ø2B.

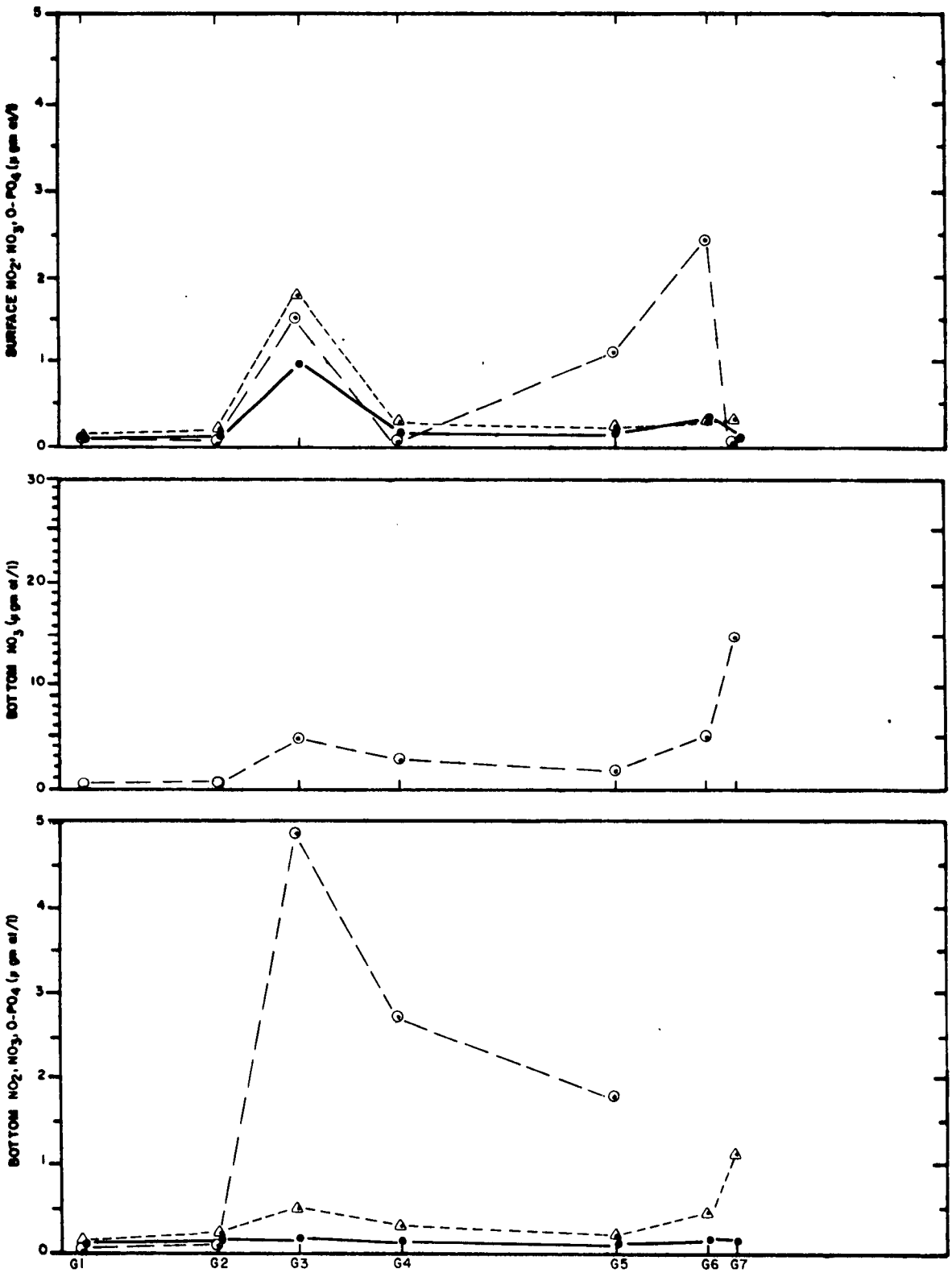

Figure 3-77 . Concentrations of dissolved NO_2 (•), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Section I during Cruise BLM Ø2B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

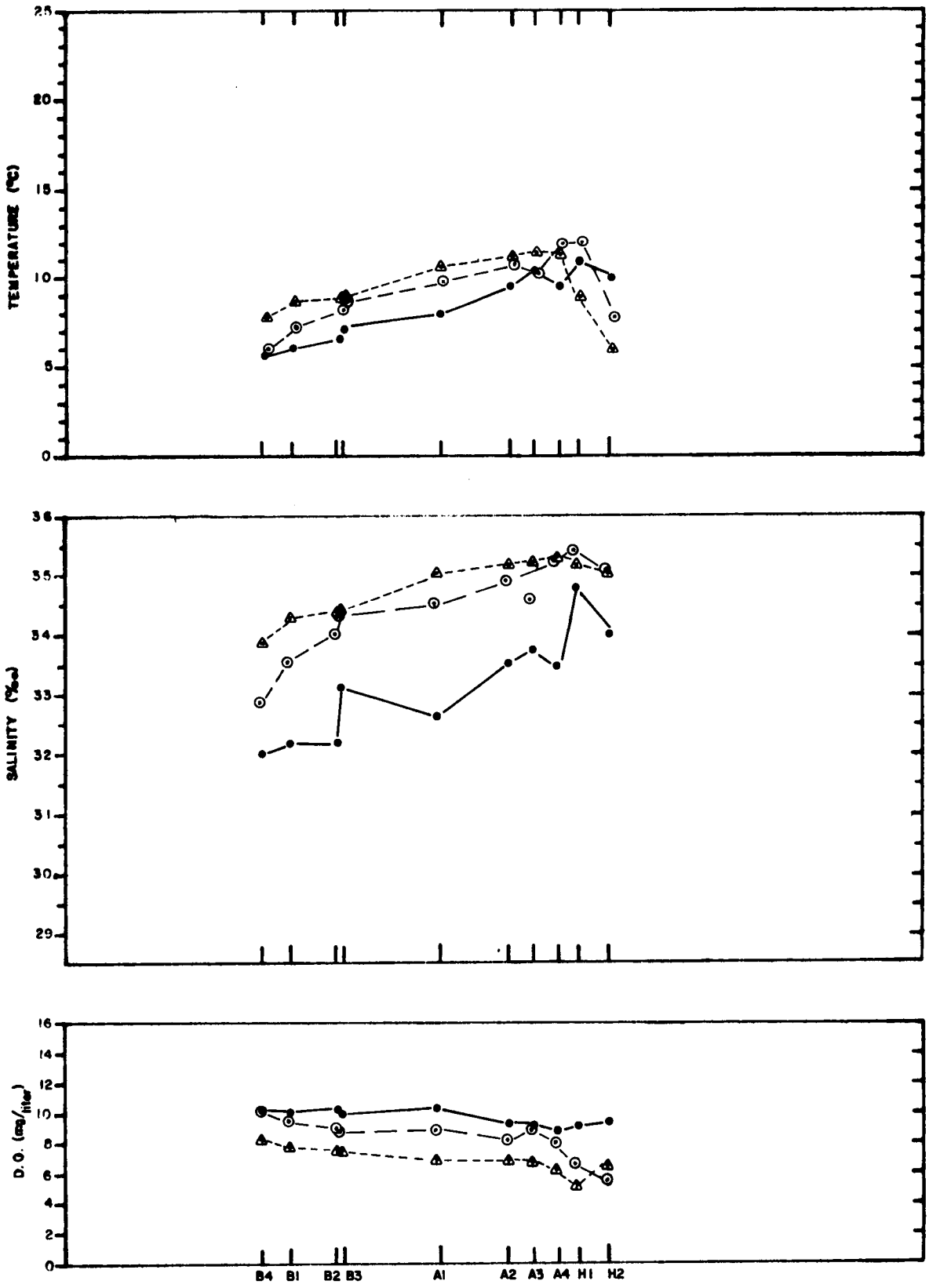

Figure 3-78. Surface (•), mid-depth (0) and bottom (Δ) values of temperature, salinity and DO measured along Section II on cruise BLM Ø2B.

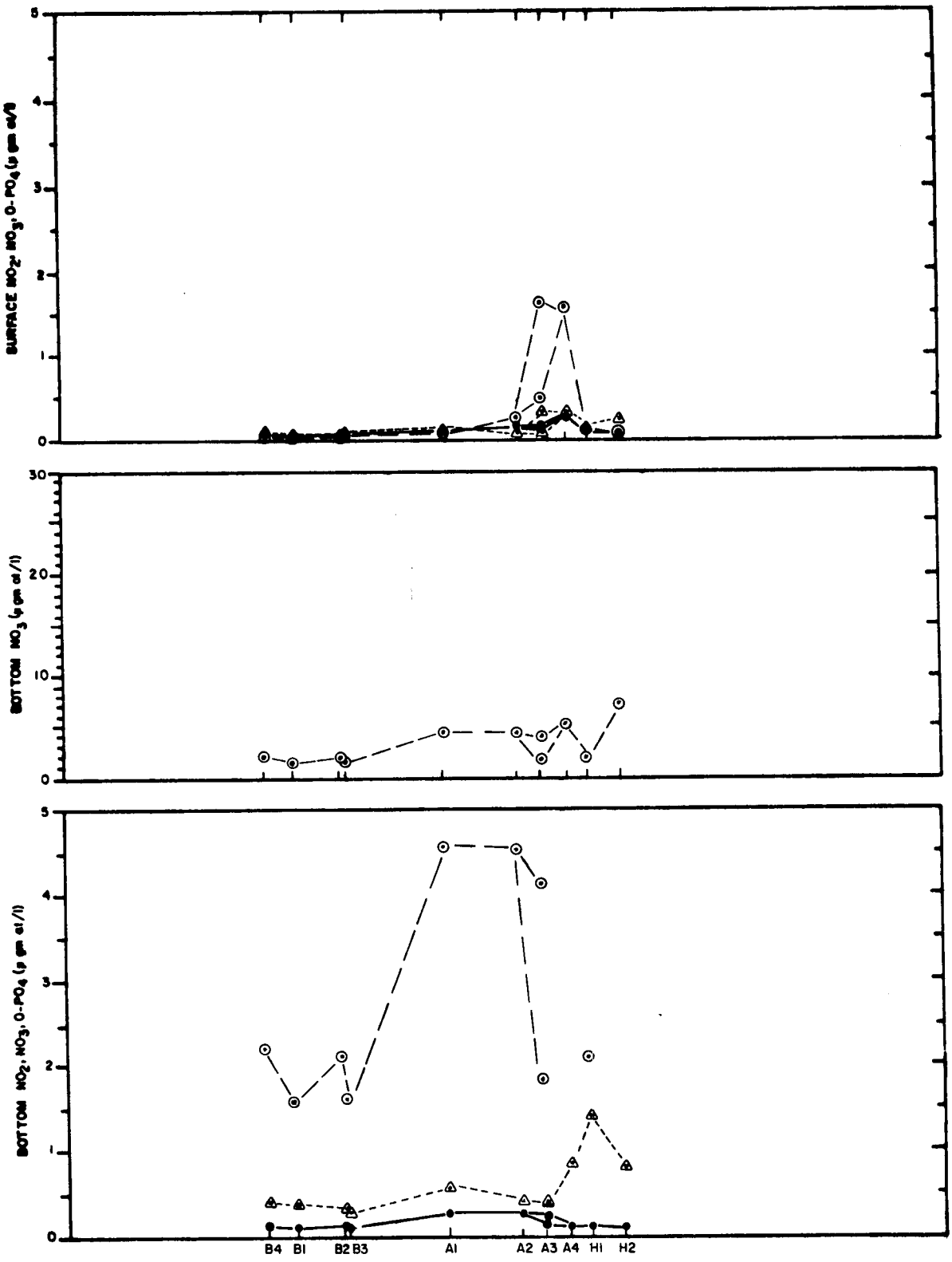

Figure 3-79 . Concentrations of dissolved NO_2 (♦), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section II during Cruise BLM ∅2B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

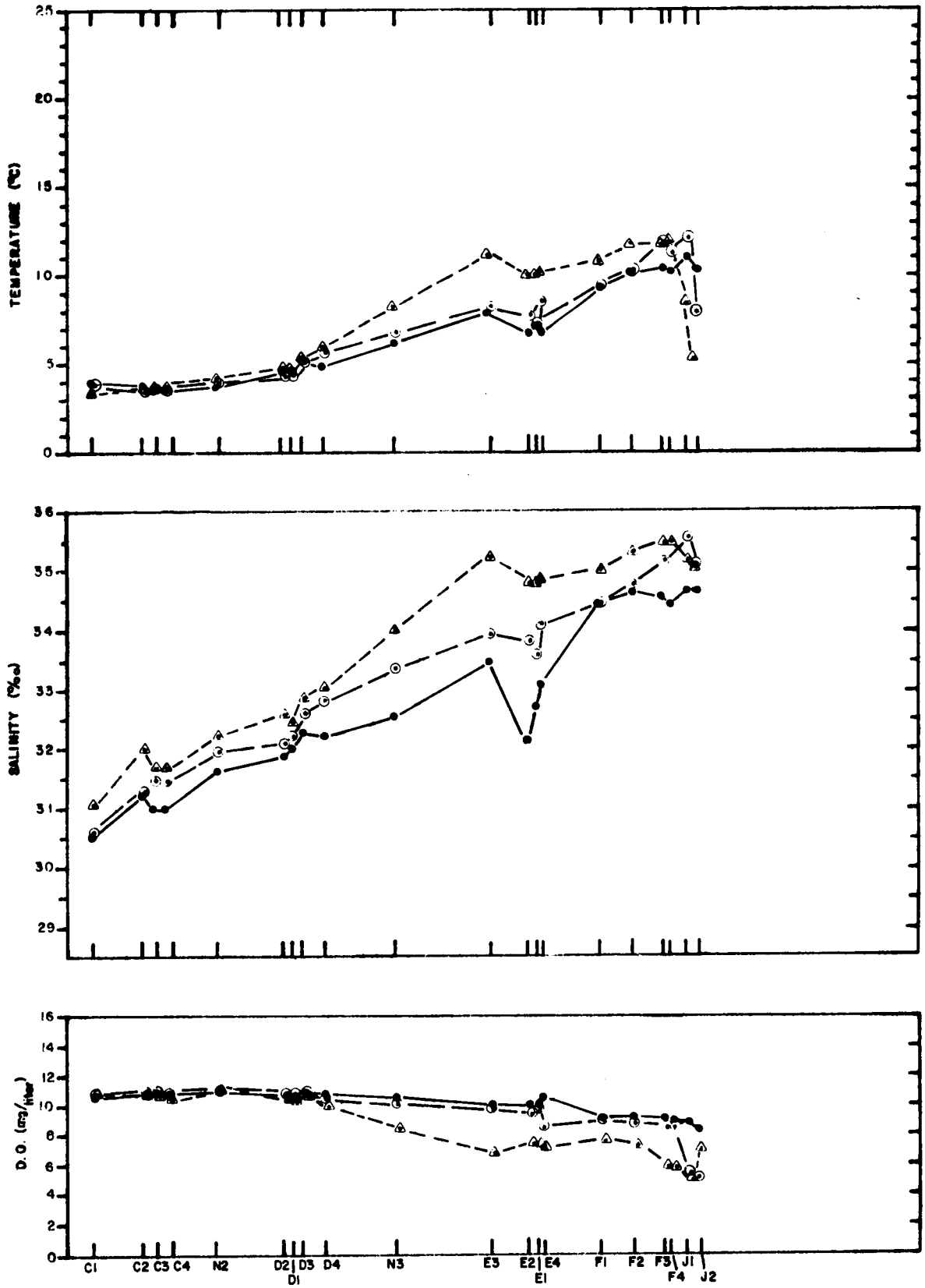

Figure 3-80. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Section III on cruise BLM Ø2B.

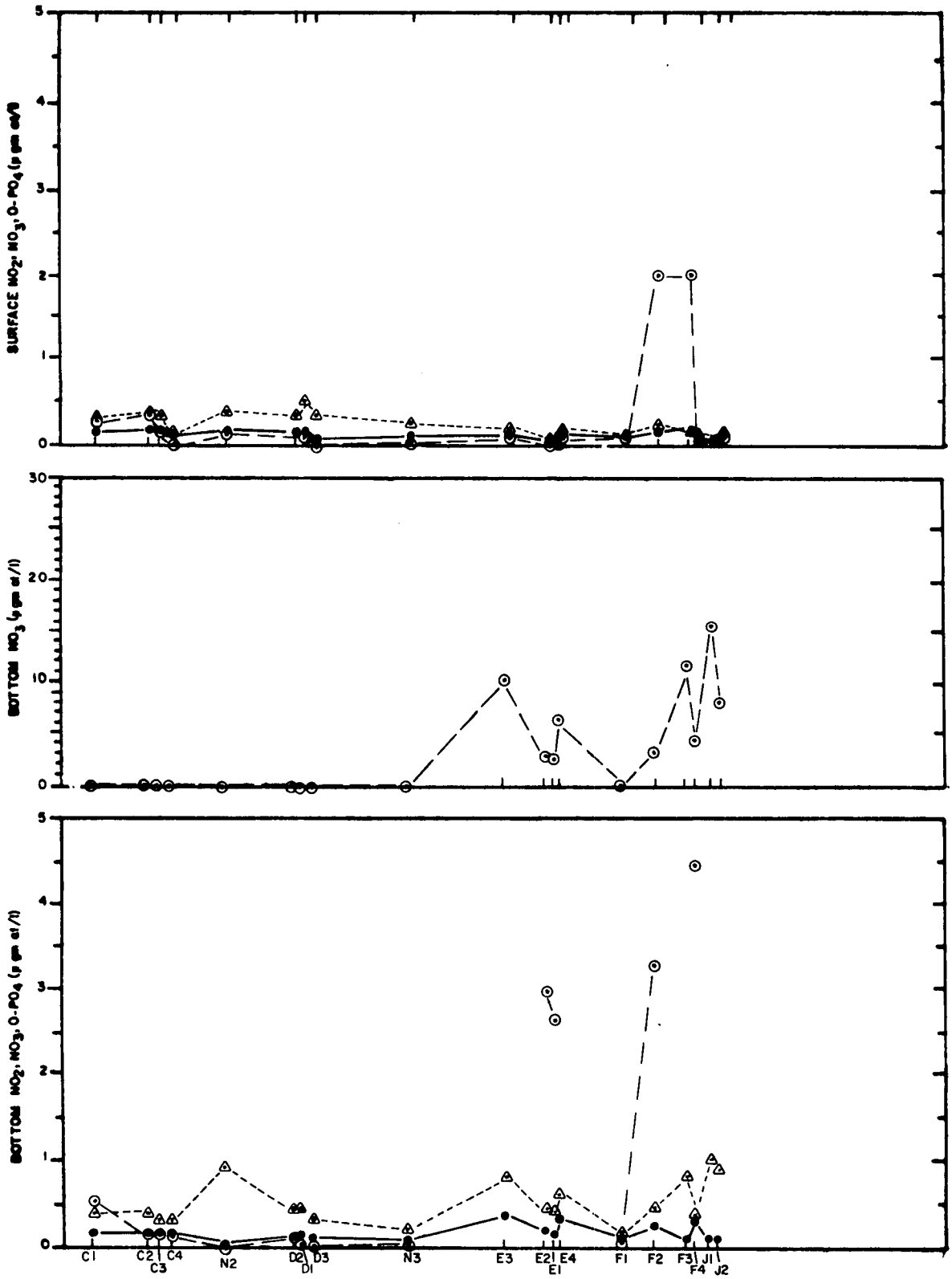

Figure 3-81 . Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM Ø2B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

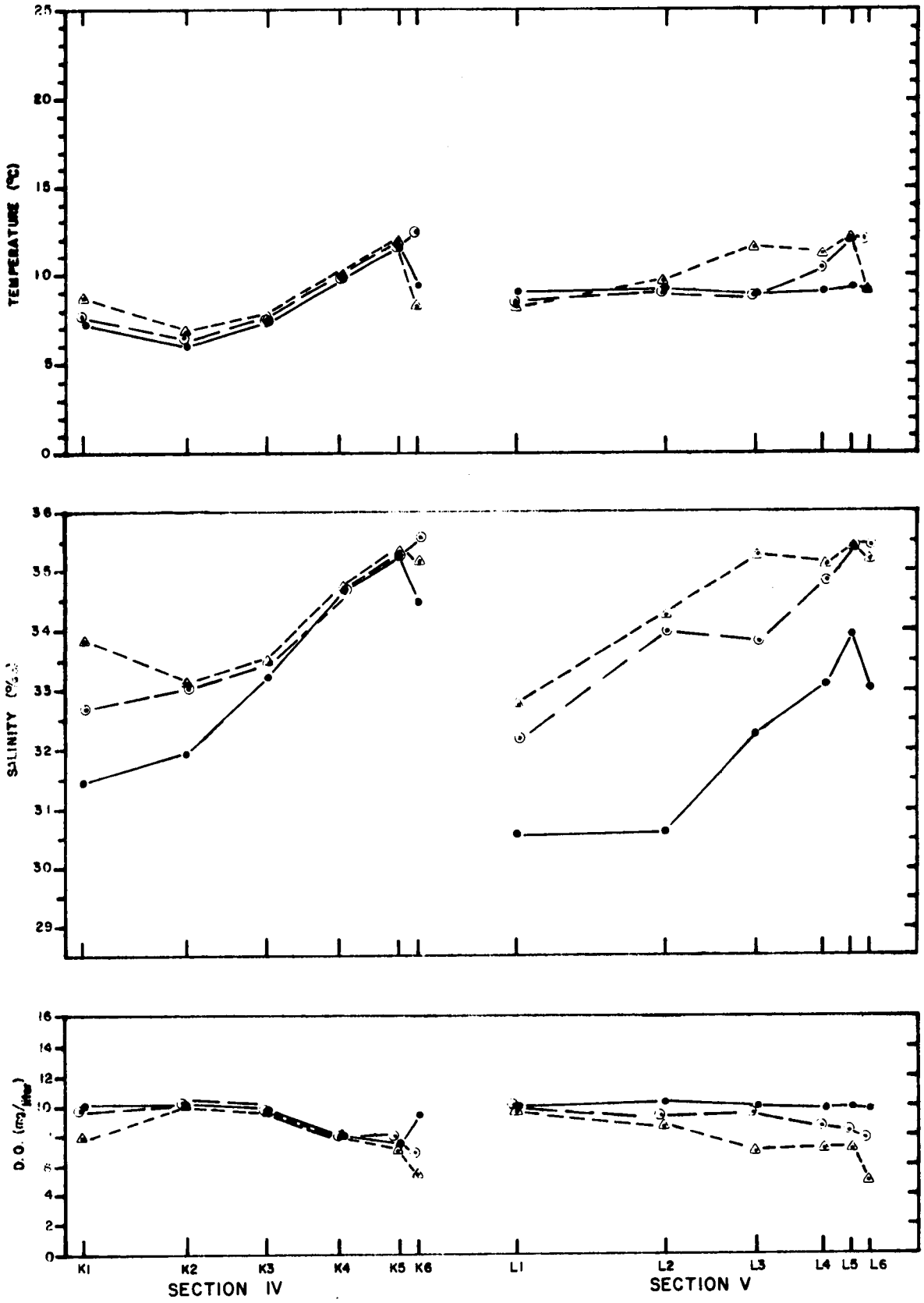

Figure 3-82. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Sections IV and V on cruise BLM Ø2B.

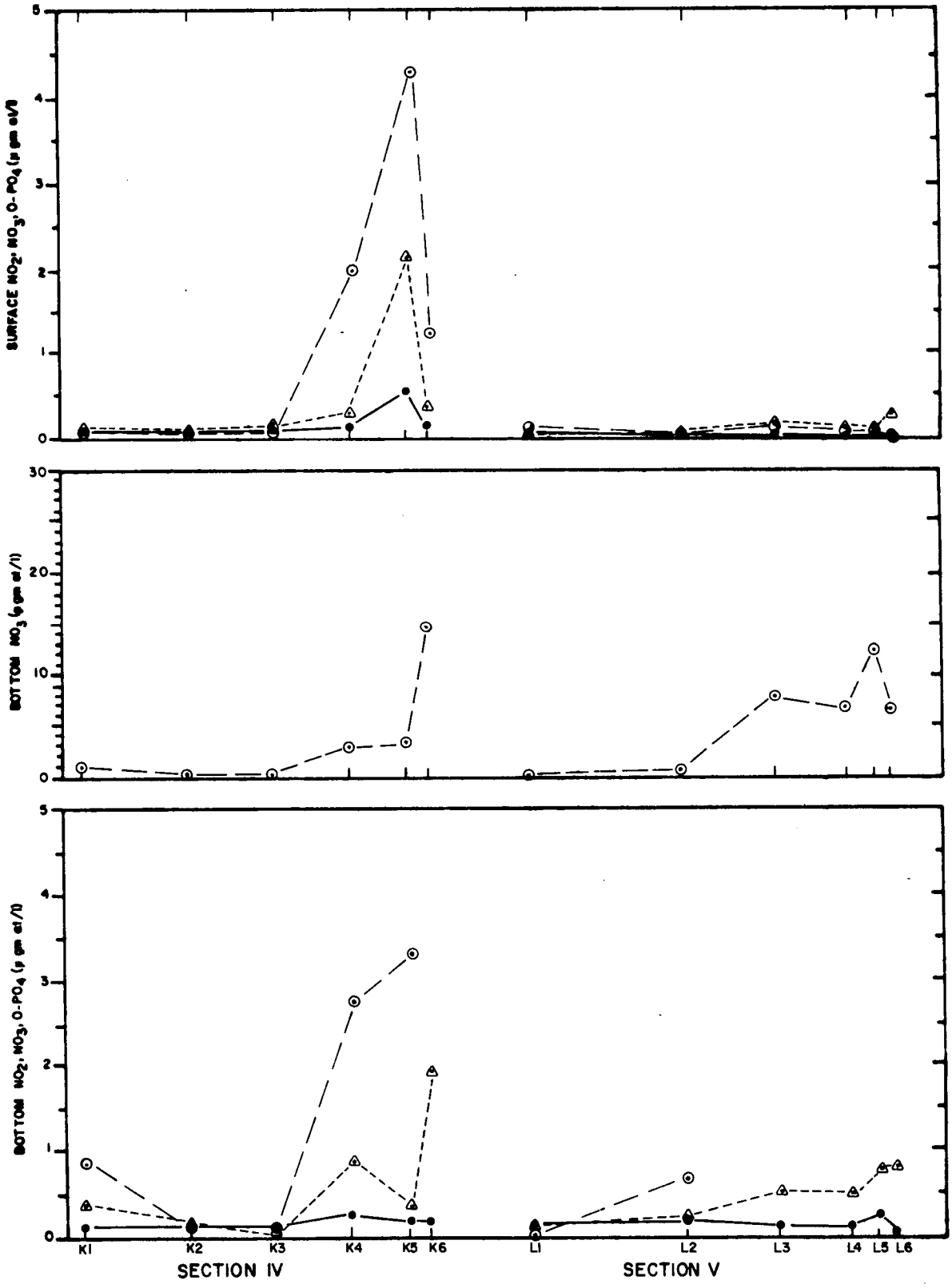

Figure 3-83 . Concentrations of dissolved NO_2 (•), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Sections IV & V during Cruise BLM Ø2B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ2W

Winter 1976

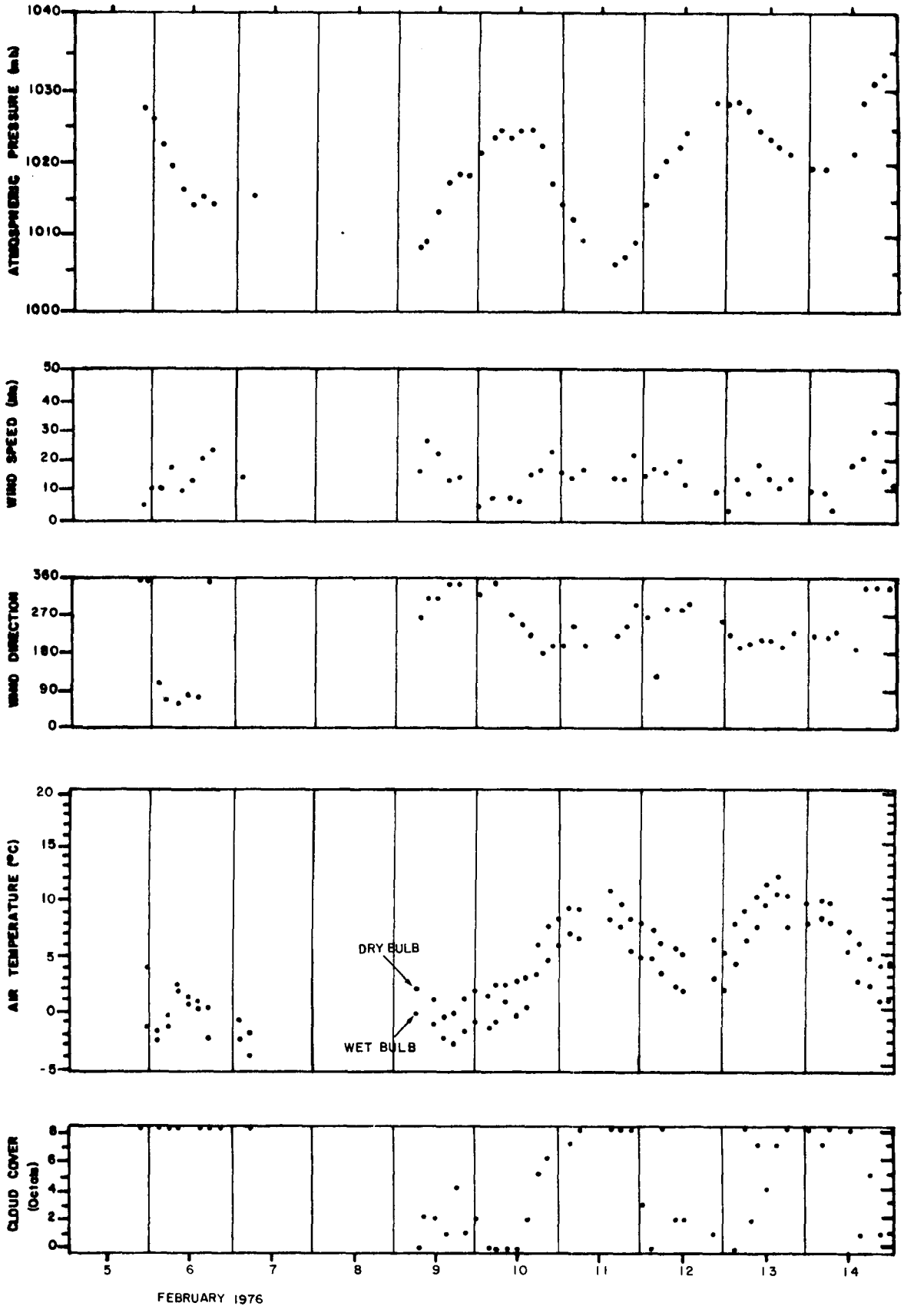

Figure 3-84. Meteorological data collected during cruise BLM Ø2W 5-14 February 1976.

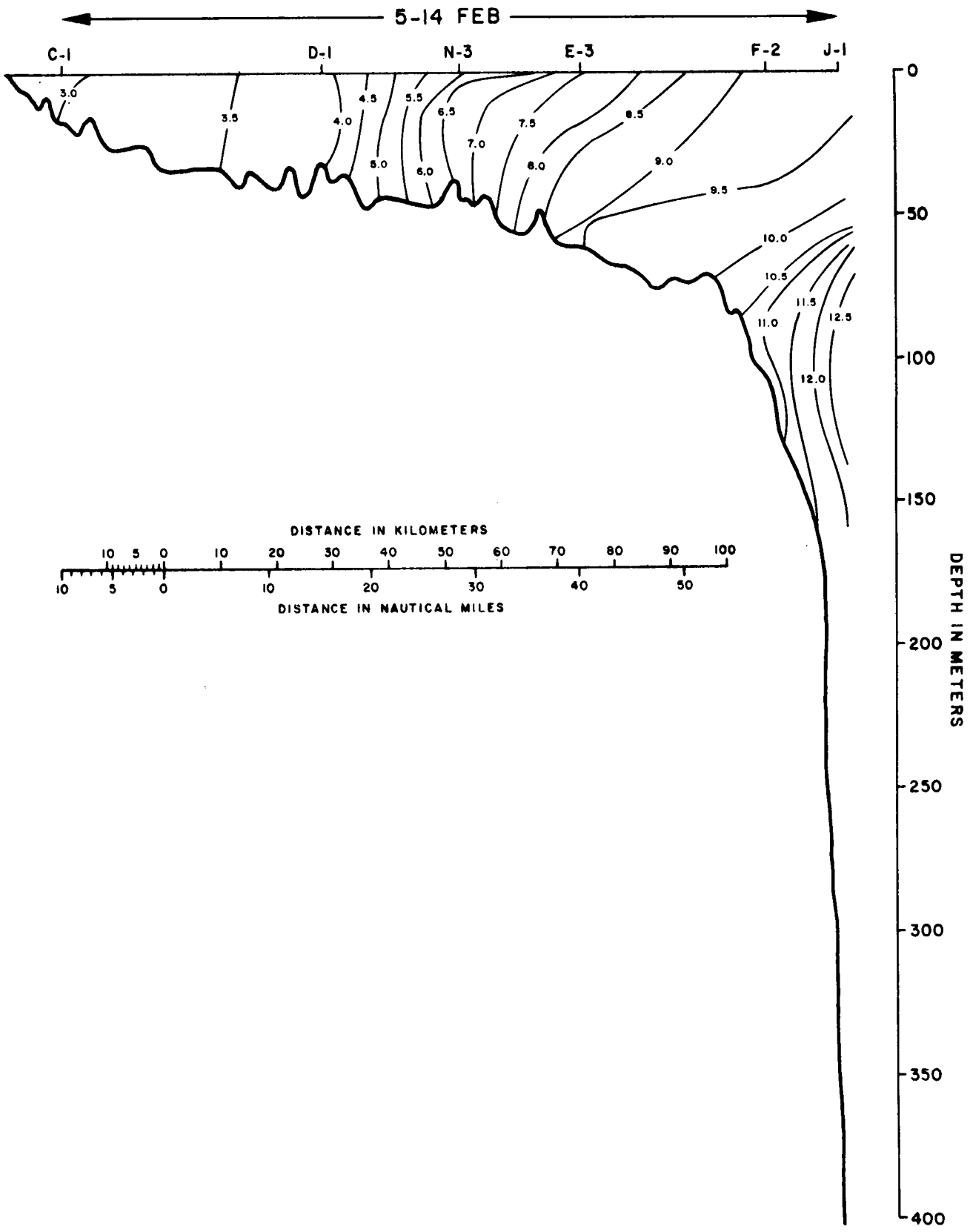

Figure 3-85. Temperature (^{o}C) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLMØ2W. Section location is shown in Figure 3-10.

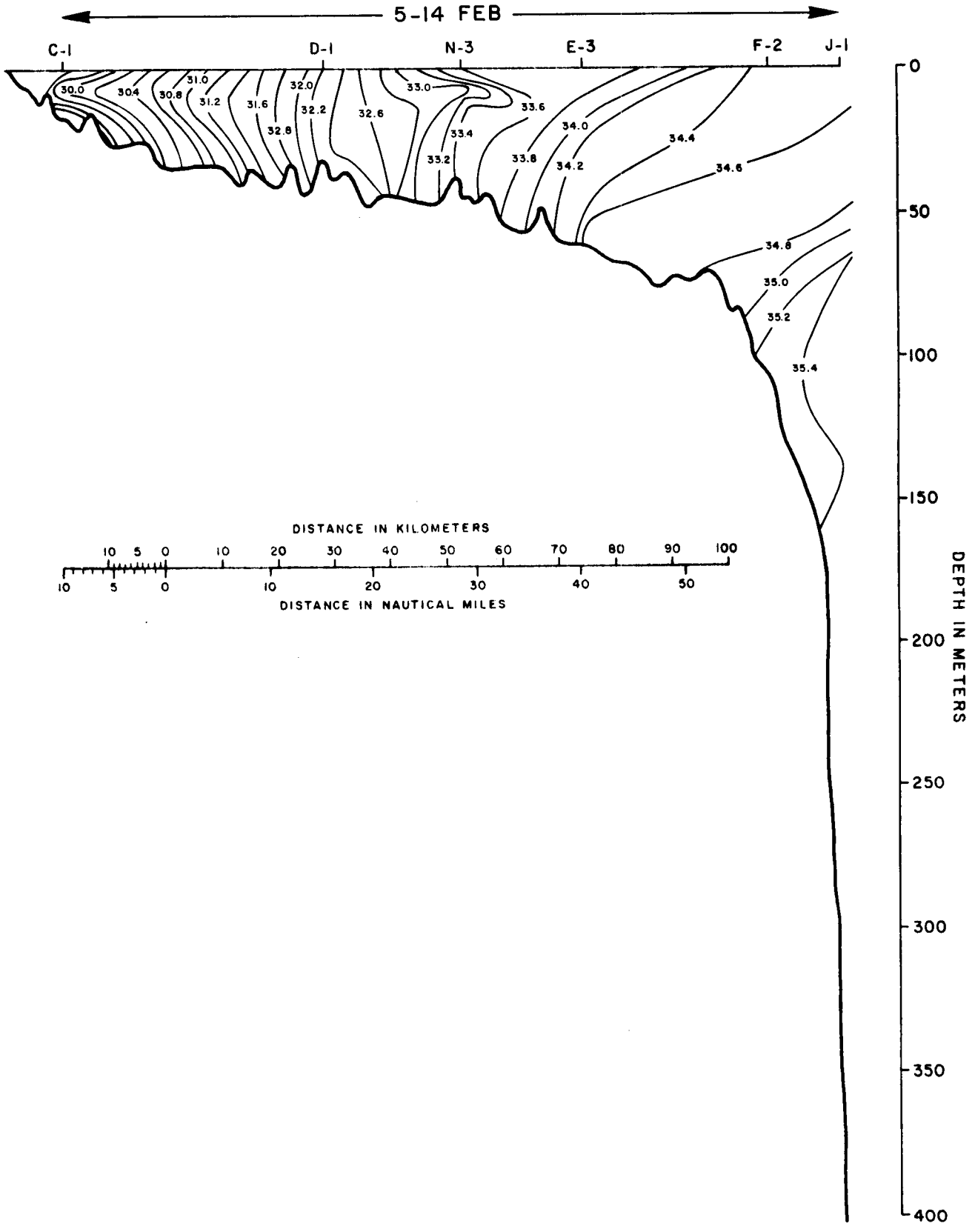

Figure 3-86. Salinity (ppt) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLMØ2W. Section location is shown in Figure 3-10.

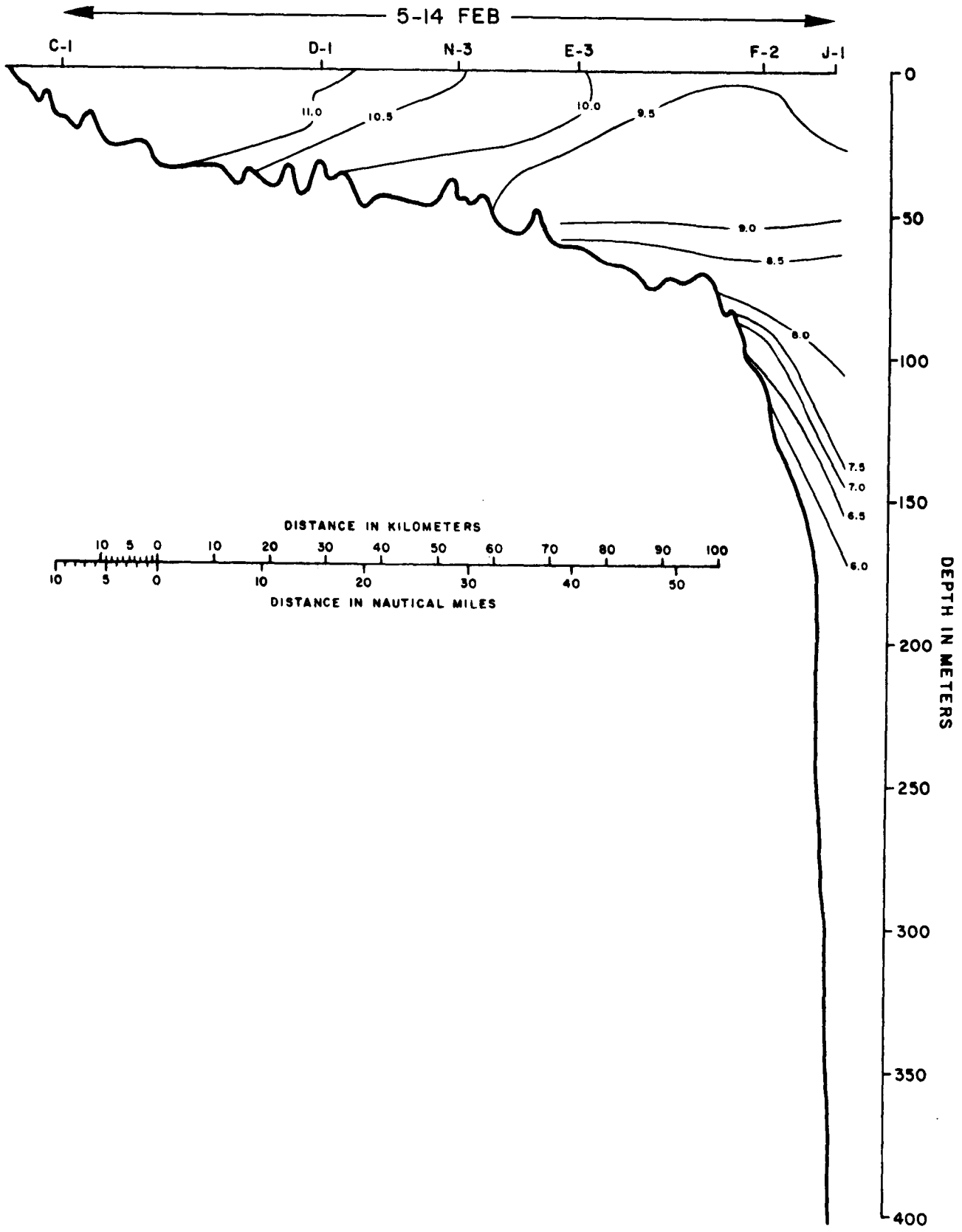

Figure 3-87. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLMØ2W. Section location is shown in Figure 3-10.

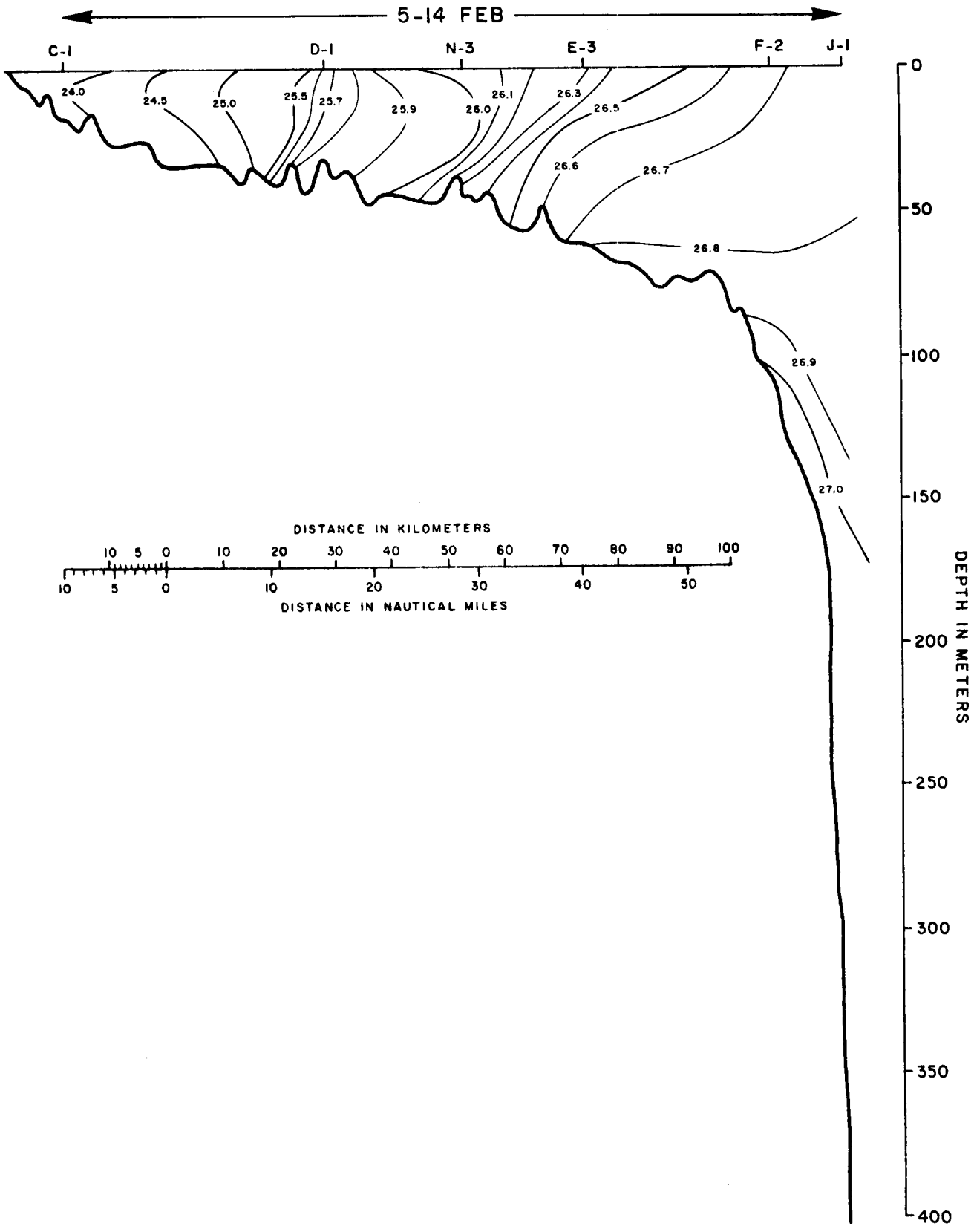

Figure 3-88. Density (σ_t units) along Section III (Stations C1 to J1, 5-14 February 1976) during cruise BLM02W. Section location is shown in Figure 3-10.

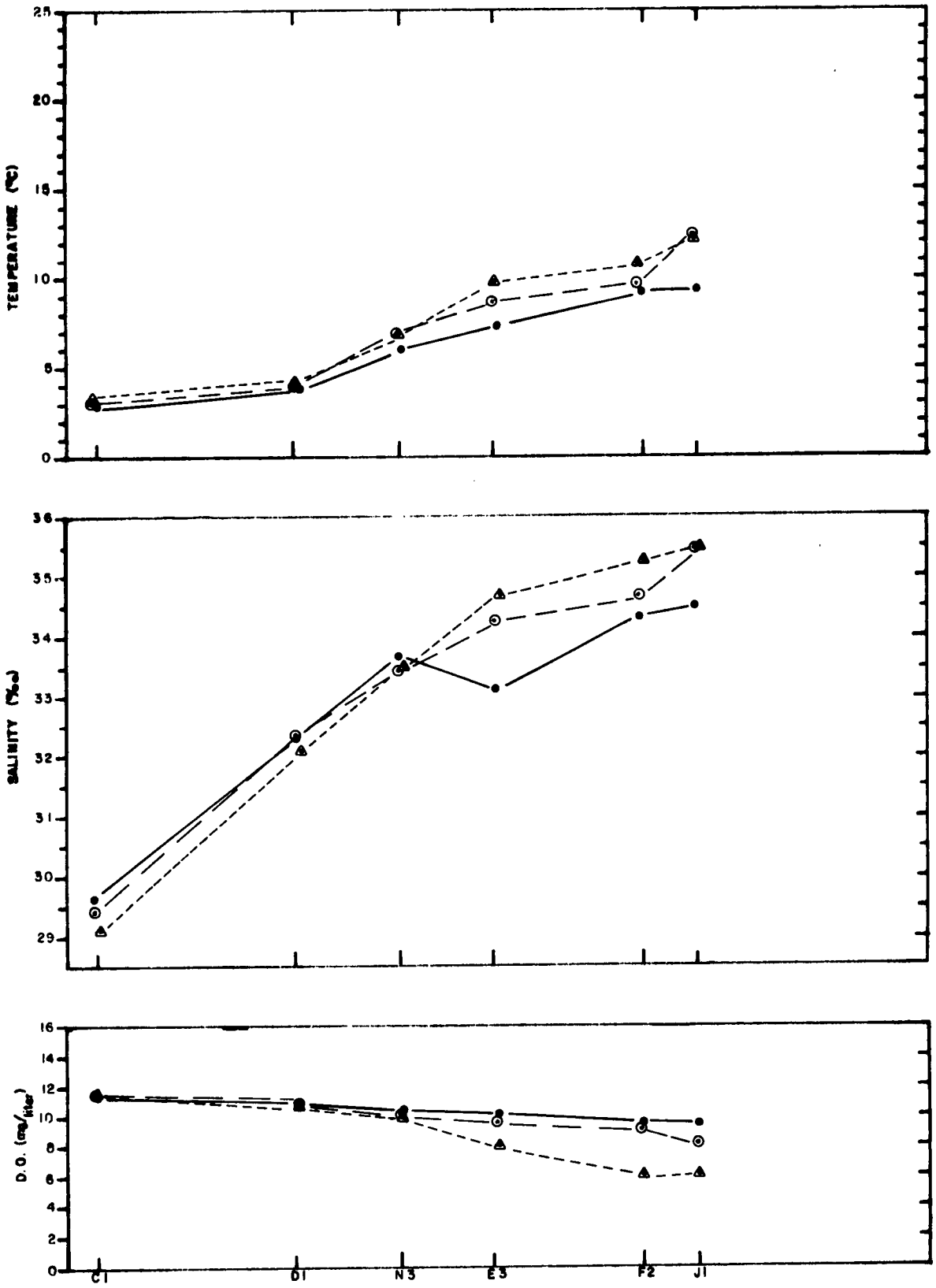

Figure 3-89. Surface (•), mid-depth (⊖) and bottom (▲) values of temperature, salinity and DO measured along Section III on cruise BLM Ø2W.

Cruise BLMØ3B

Spring 1976

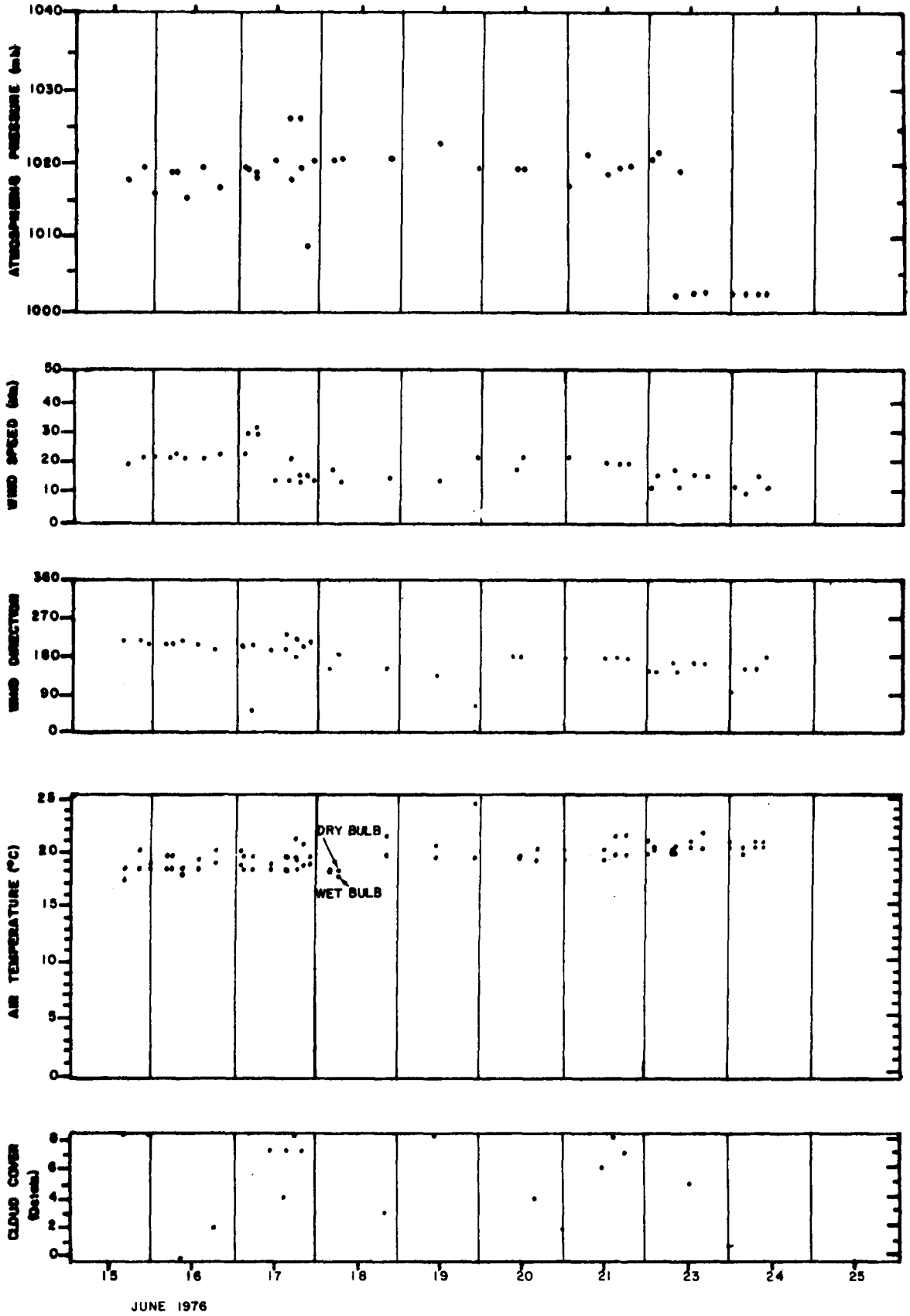

Figure 3-90. Meteorological data collected during cruise BLM 83B 15 to 25 June 1976.

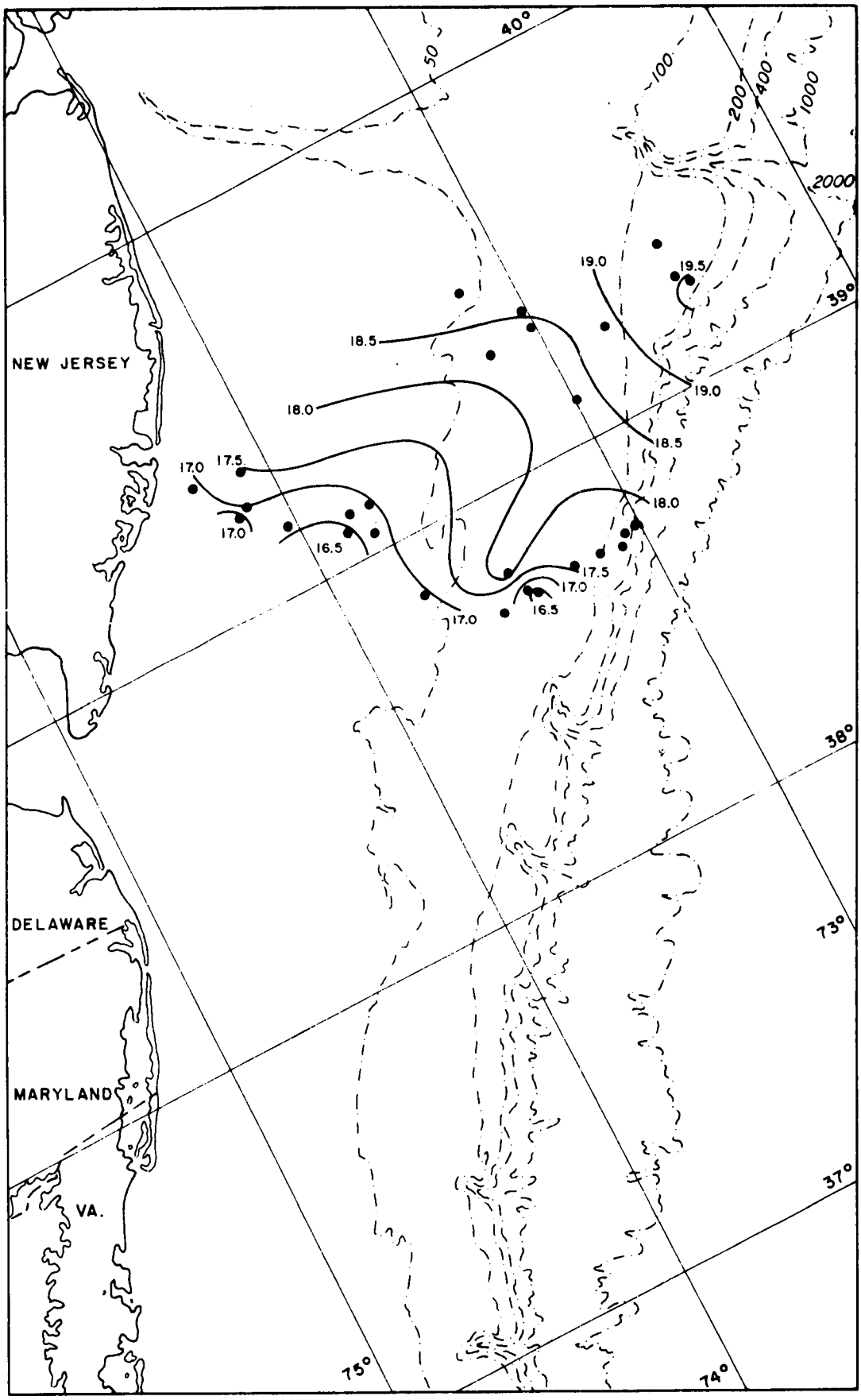

Figure 3-91. Surface temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

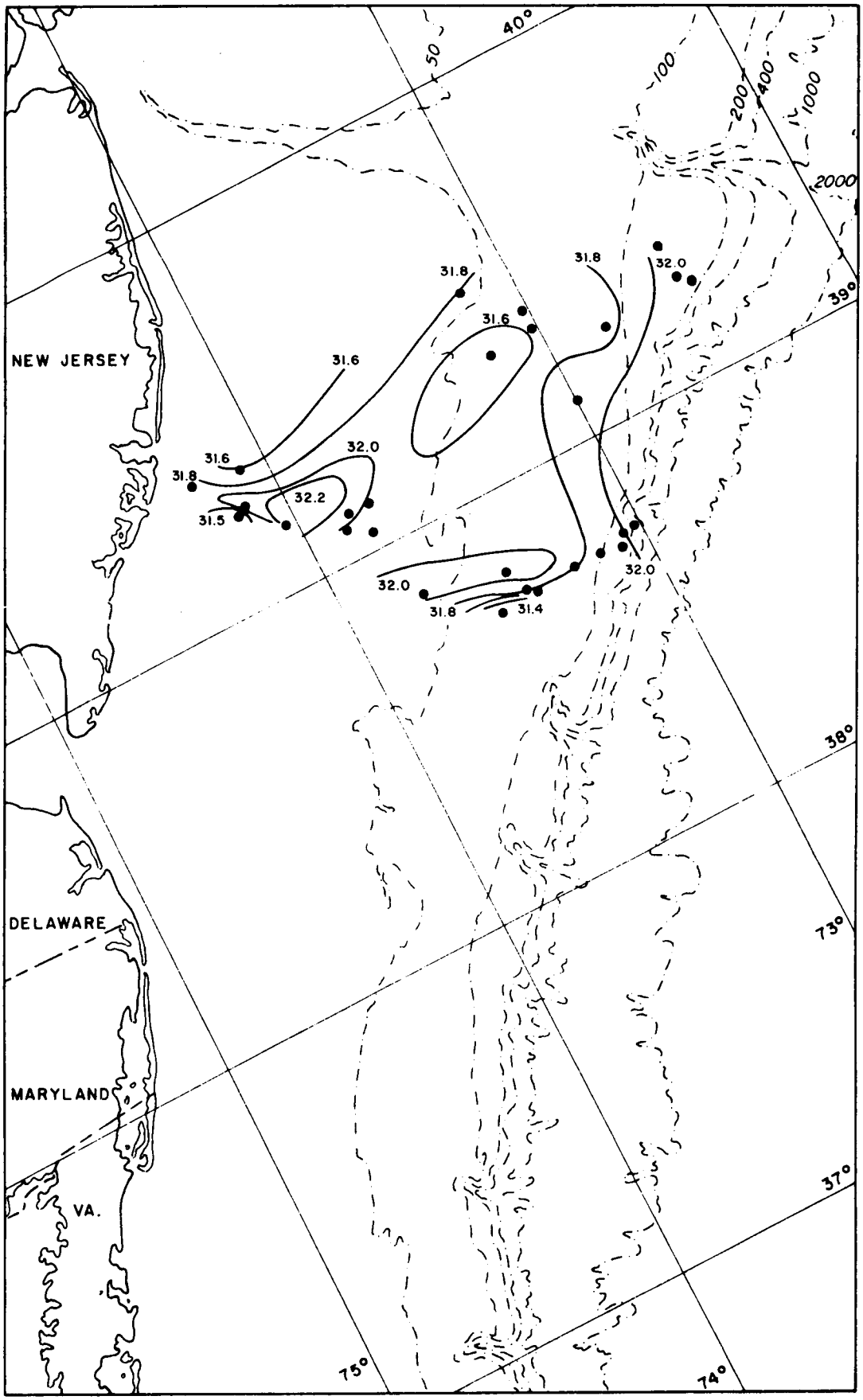

Figure 3-92. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

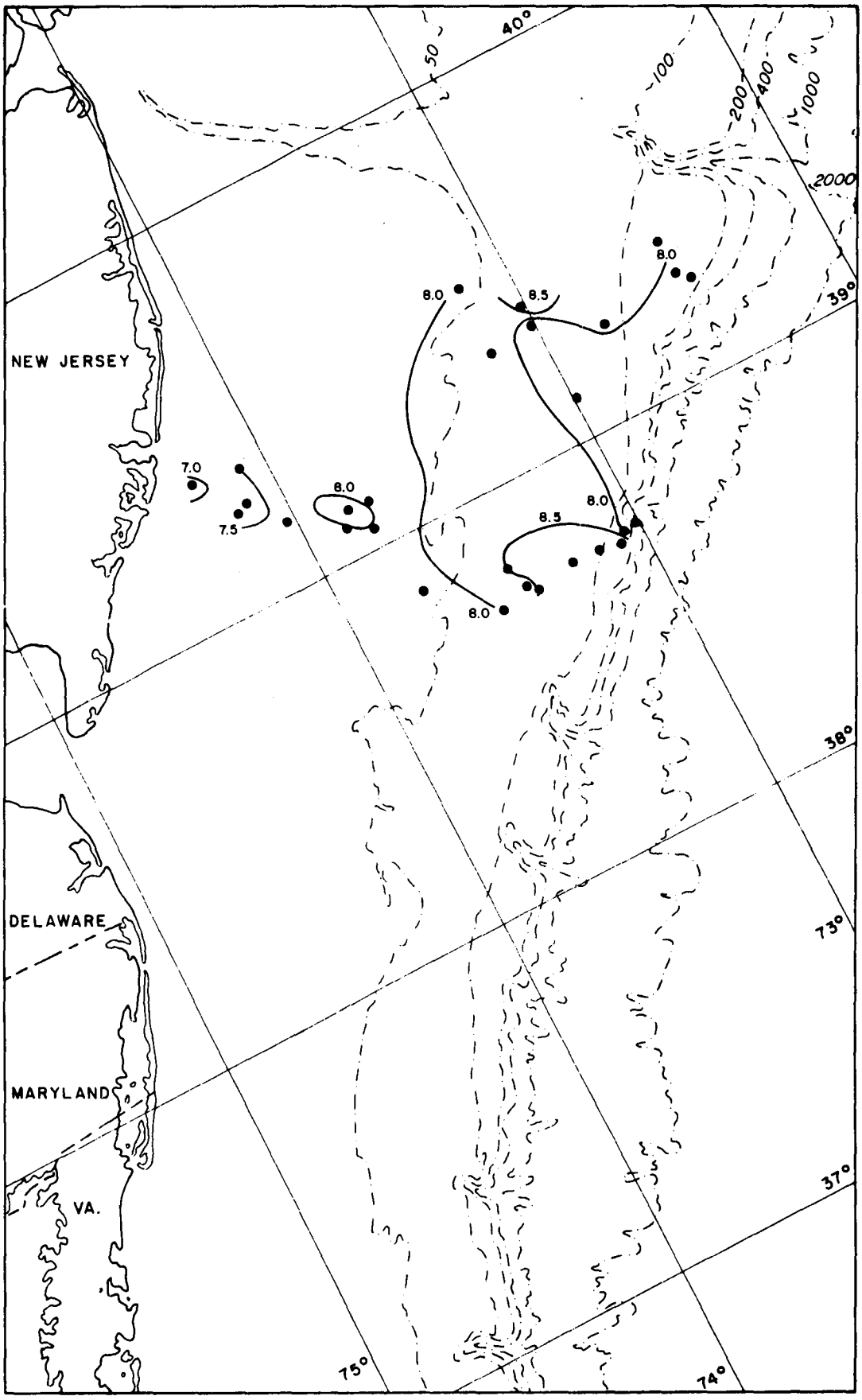

Figure 3-93. Surface dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

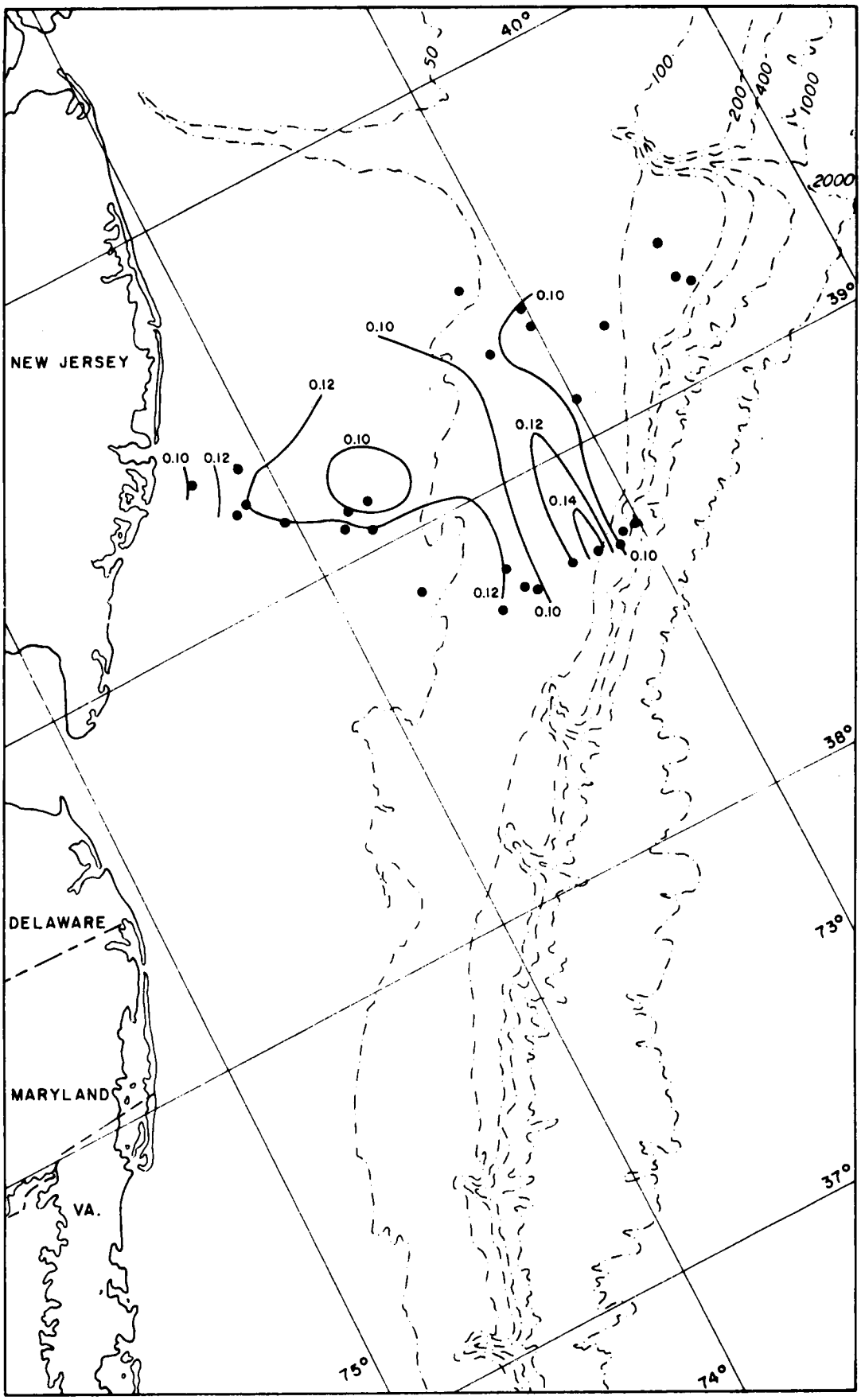

Figure 3-94. Surface NO_2 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

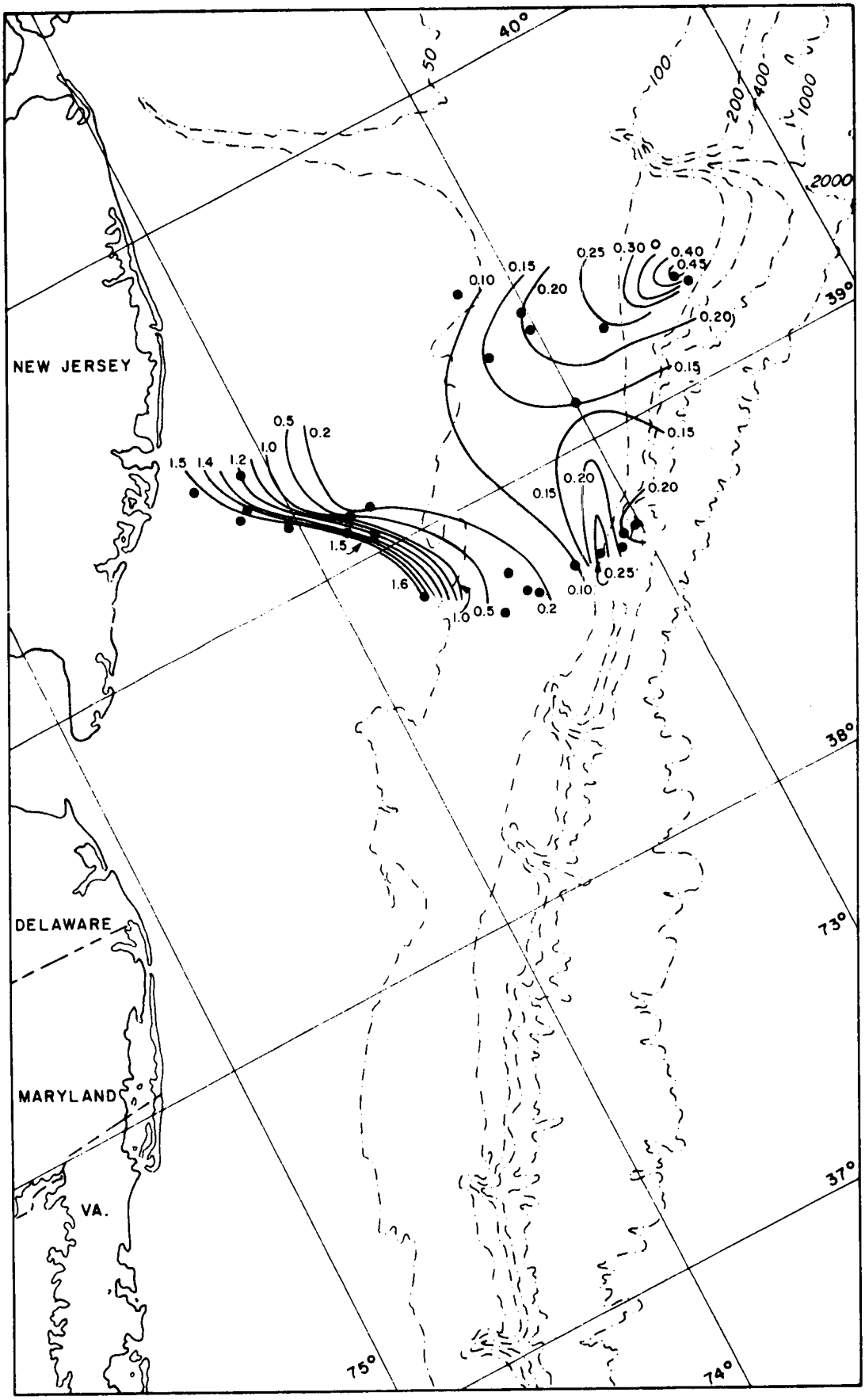

Figure 3-95. Surface NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

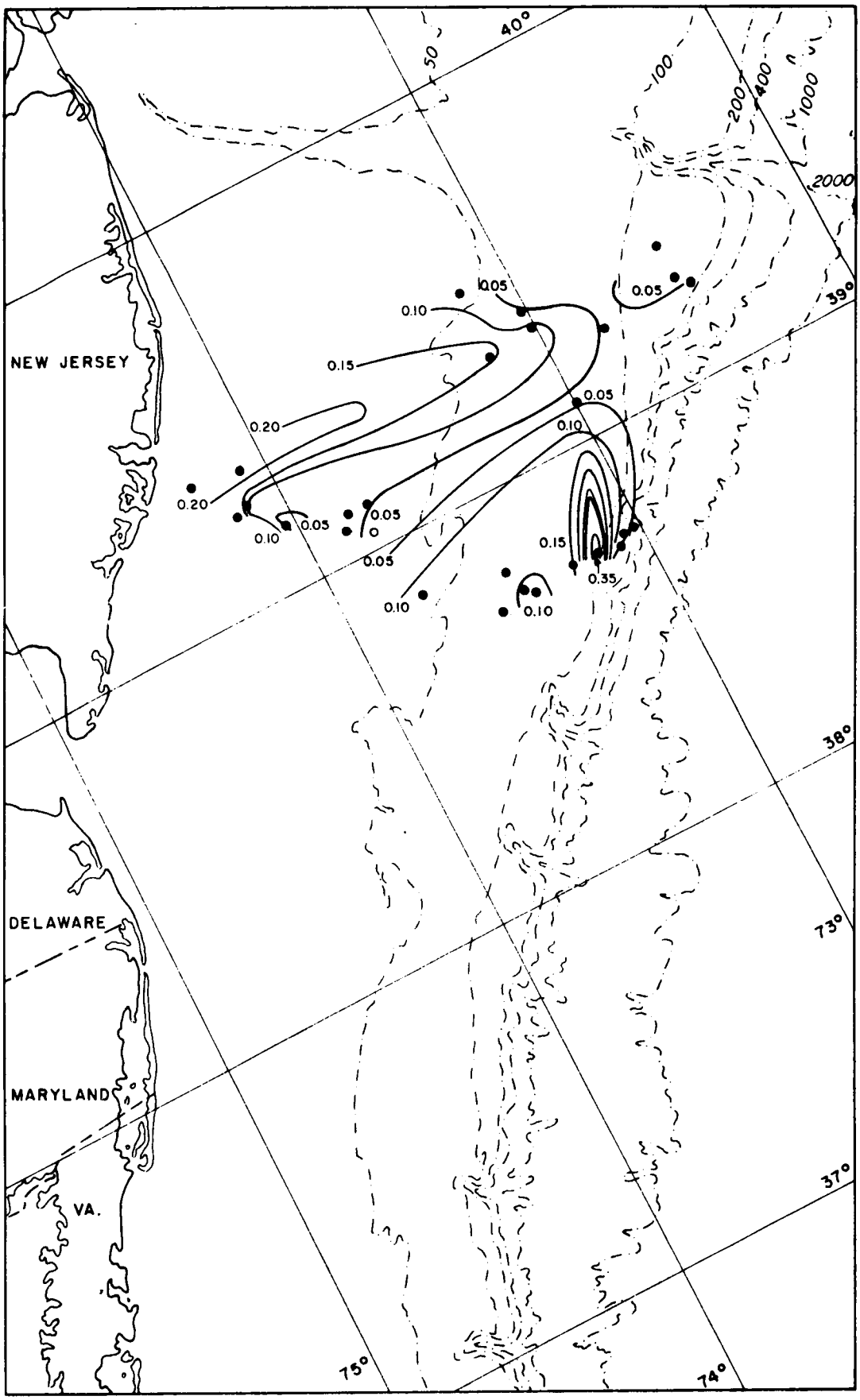

Figure 3-96. Surface O-PO_4 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

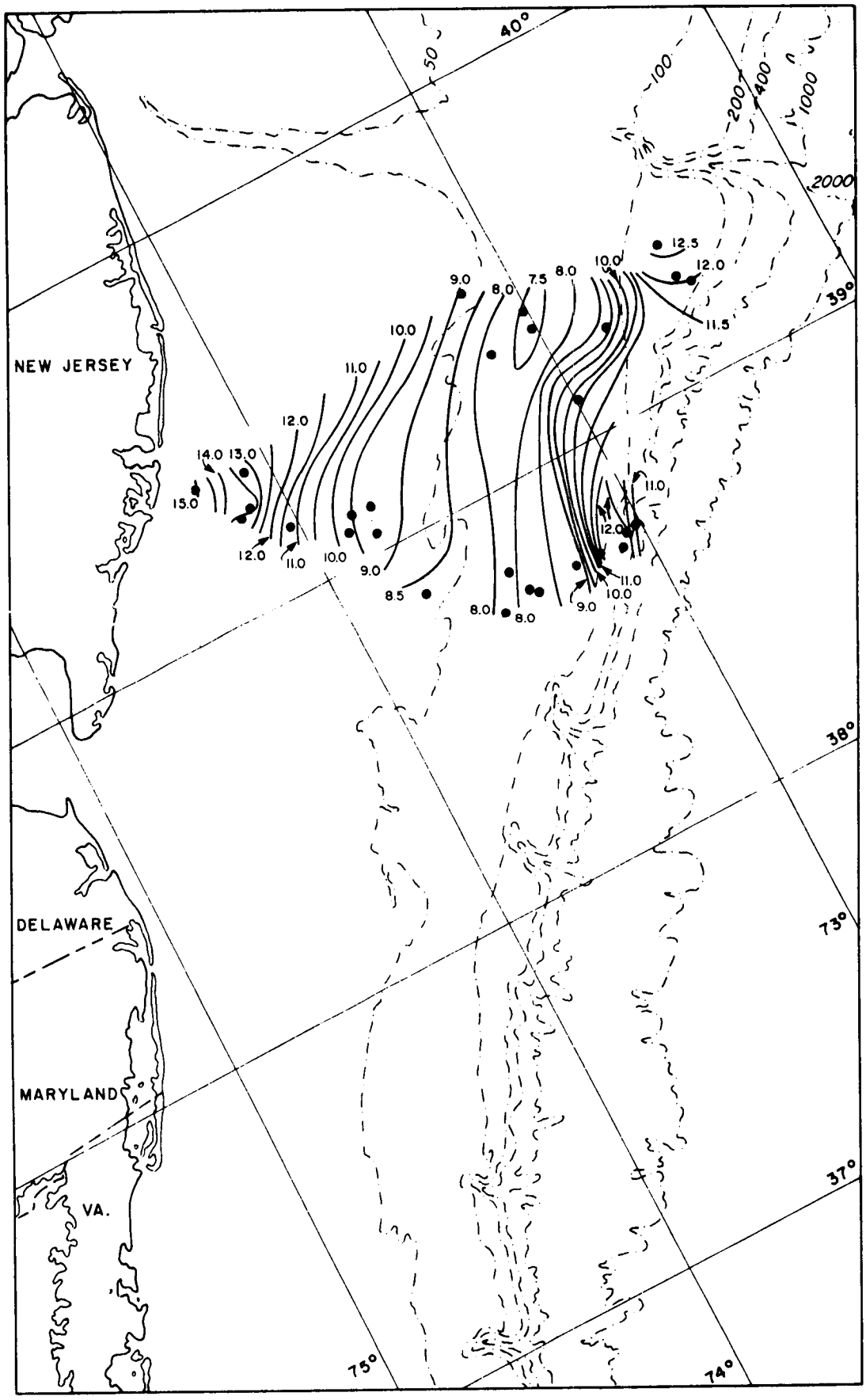

Figure 3-97. Bottom temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

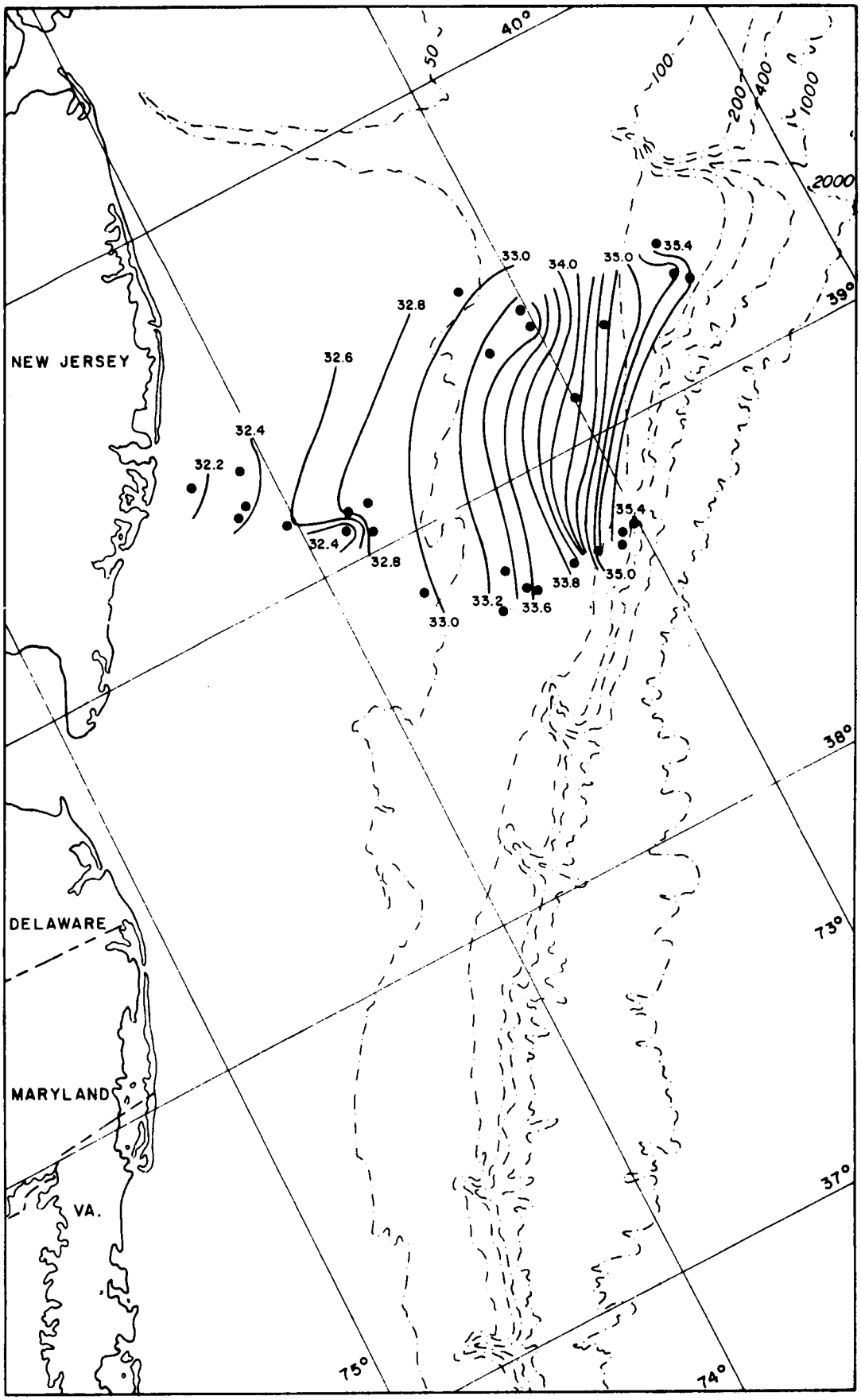

Figure 3-98 Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

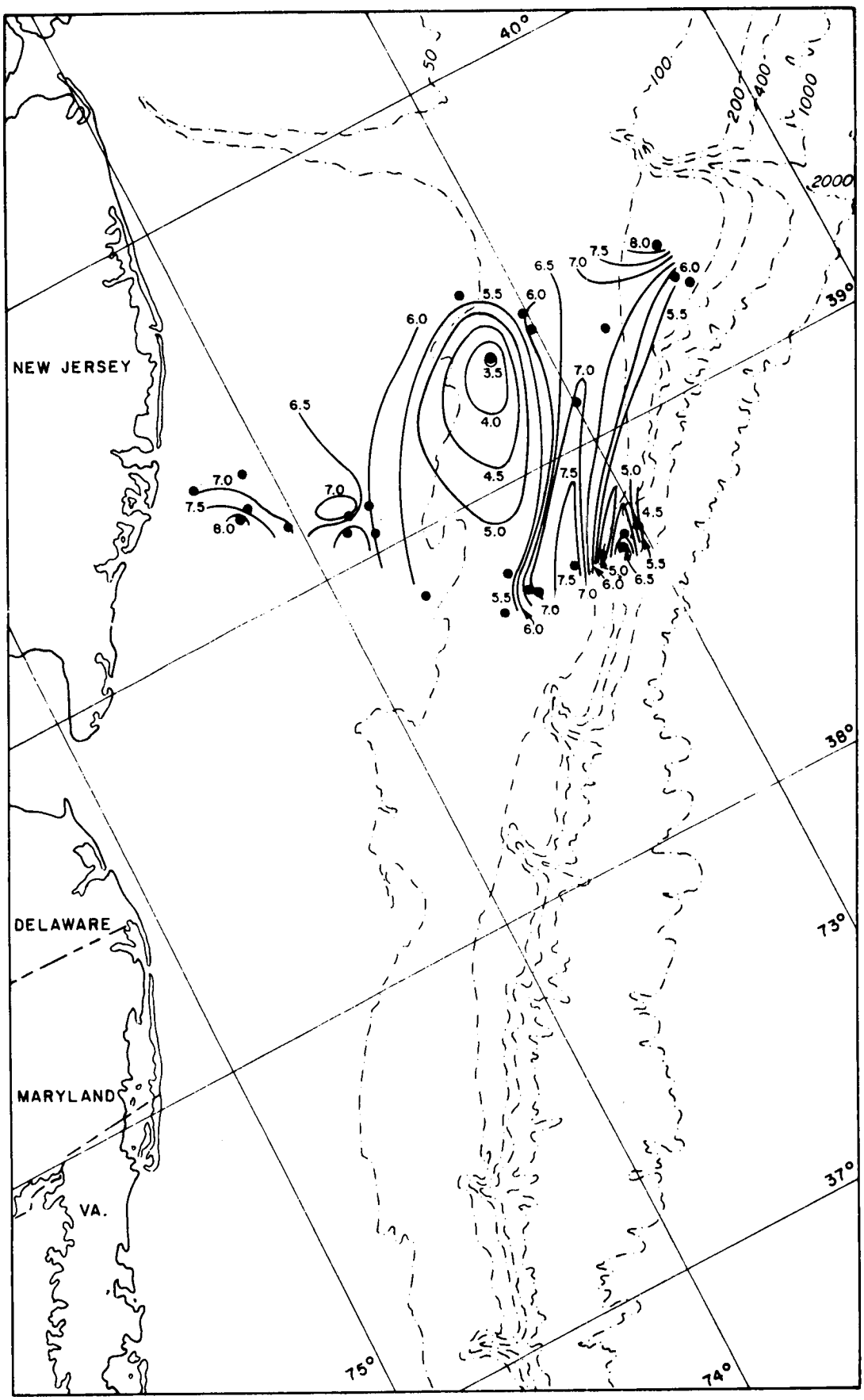

Figure 3-99. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

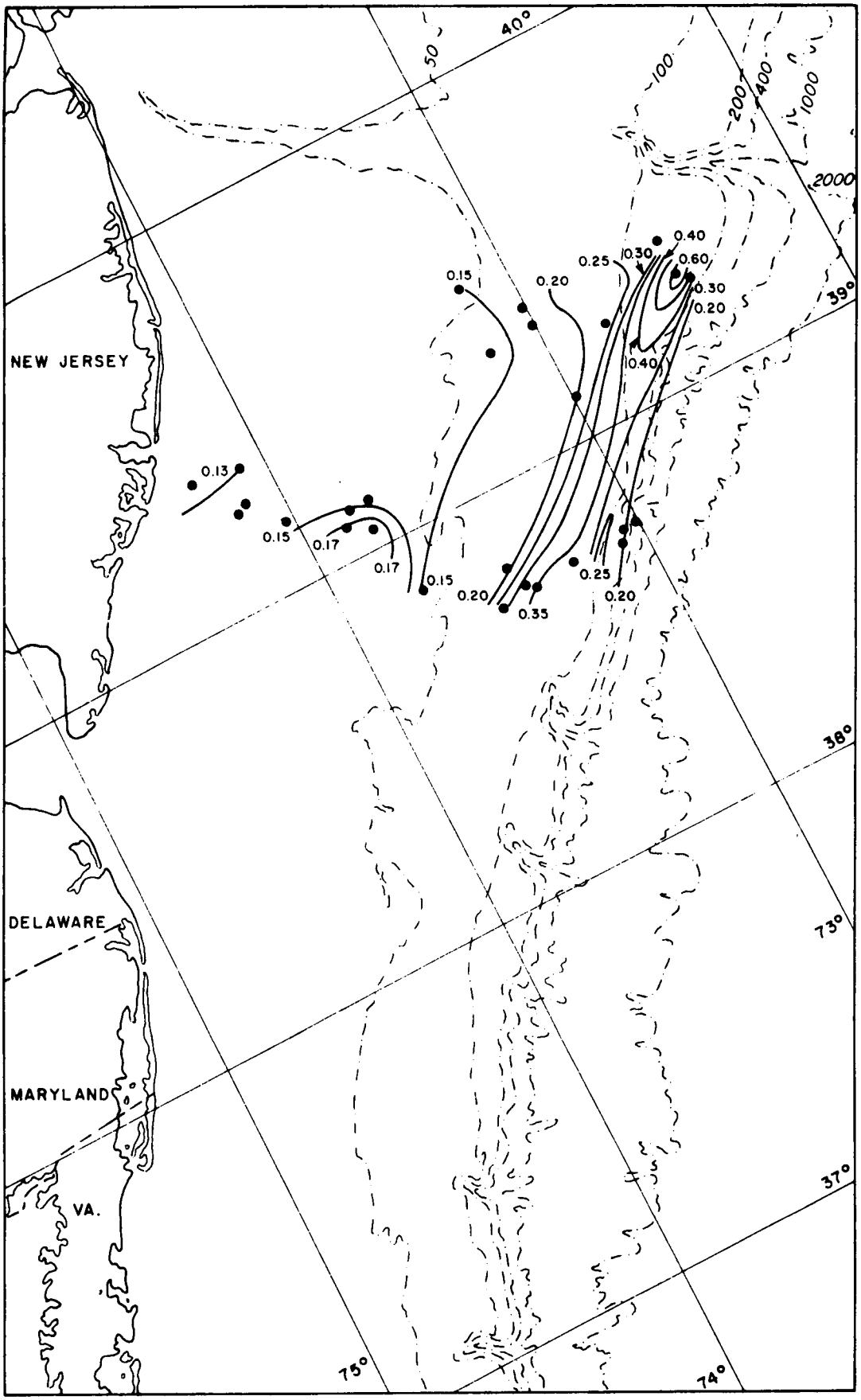

Figure 3-100. Bottom NO_2 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

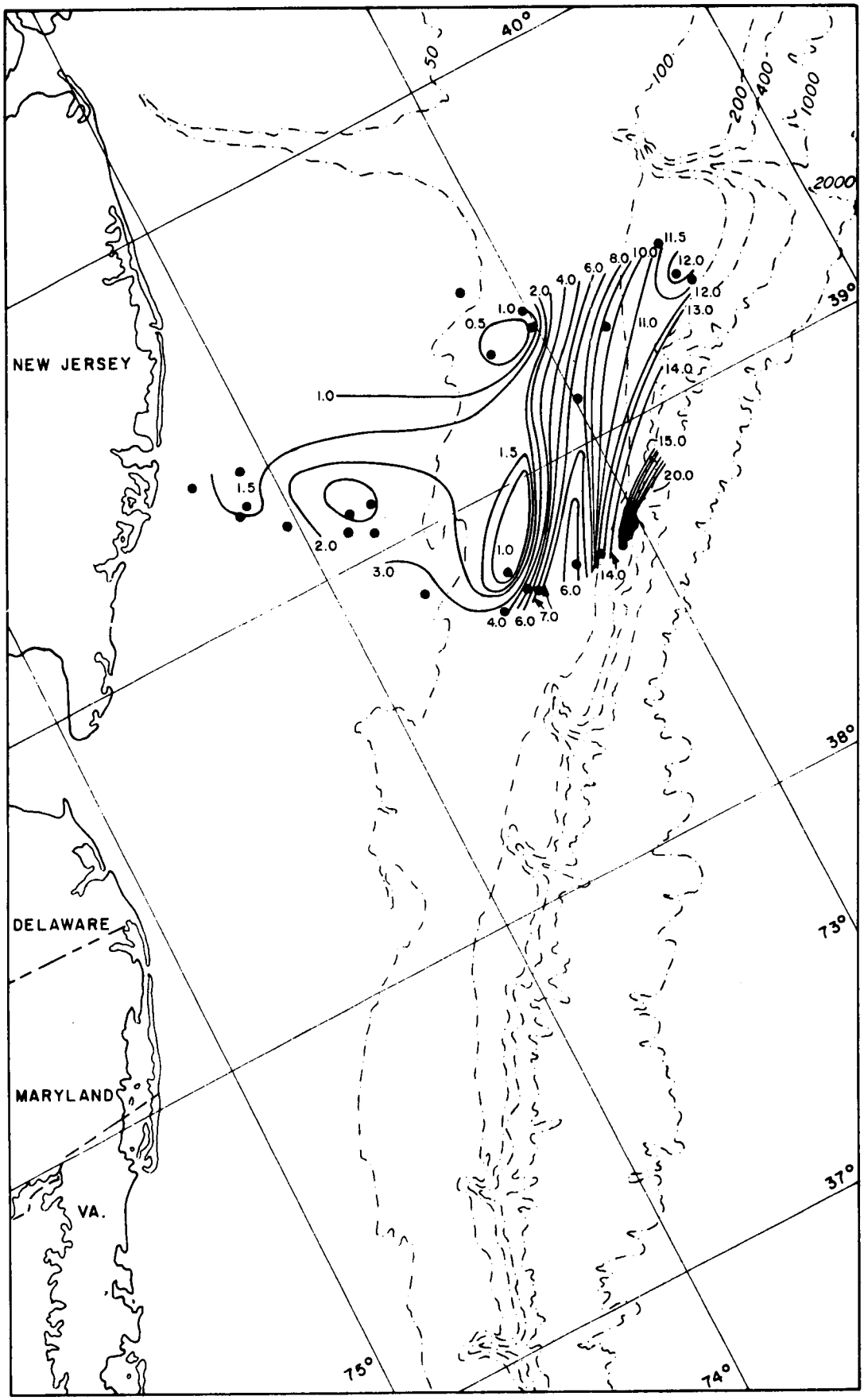

Figure 3-101. Bottom NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

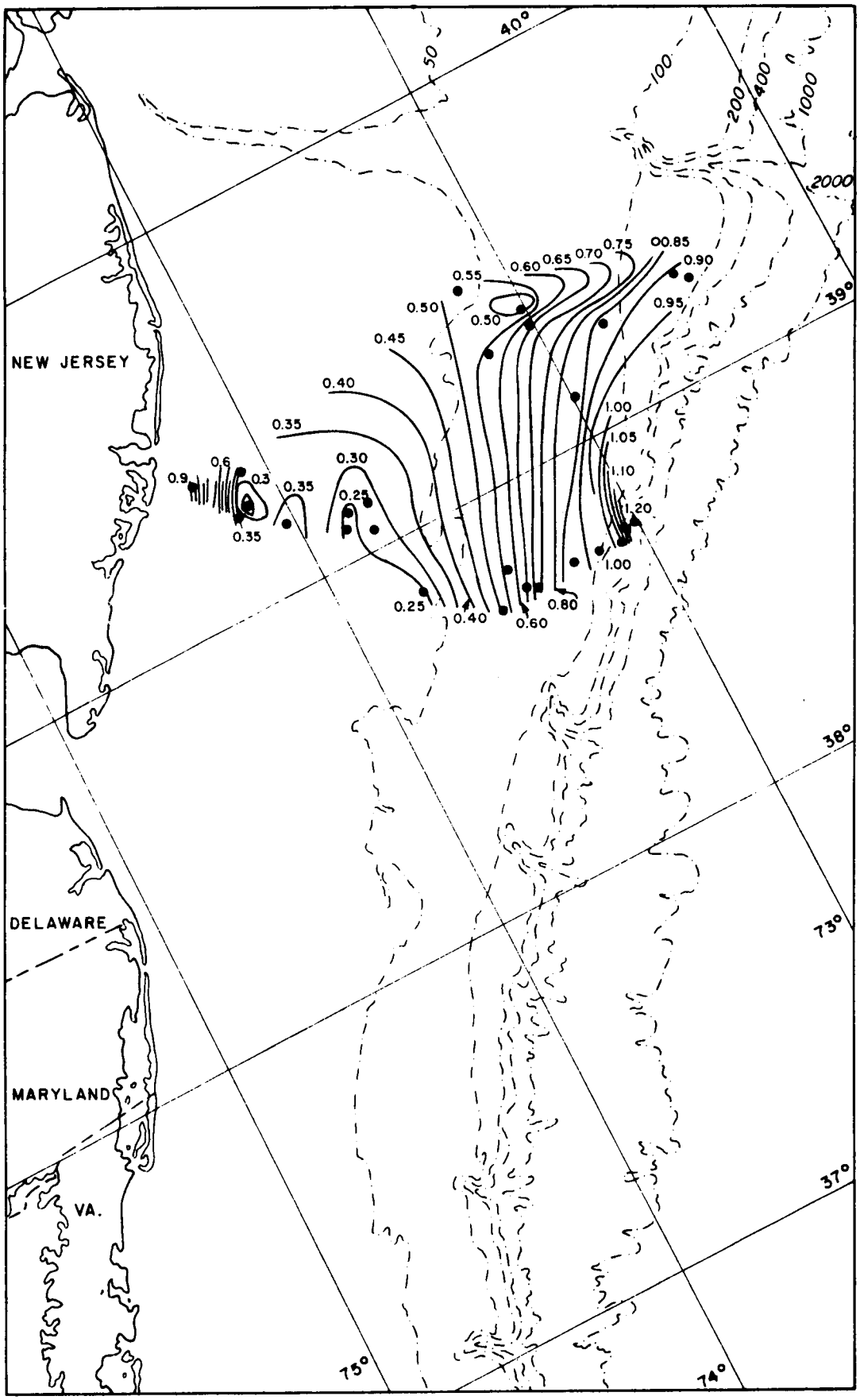

Figure 3-102. Bottom O-PO_4 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 15 to 23 June 1976 (Cruise BLMØ3B)

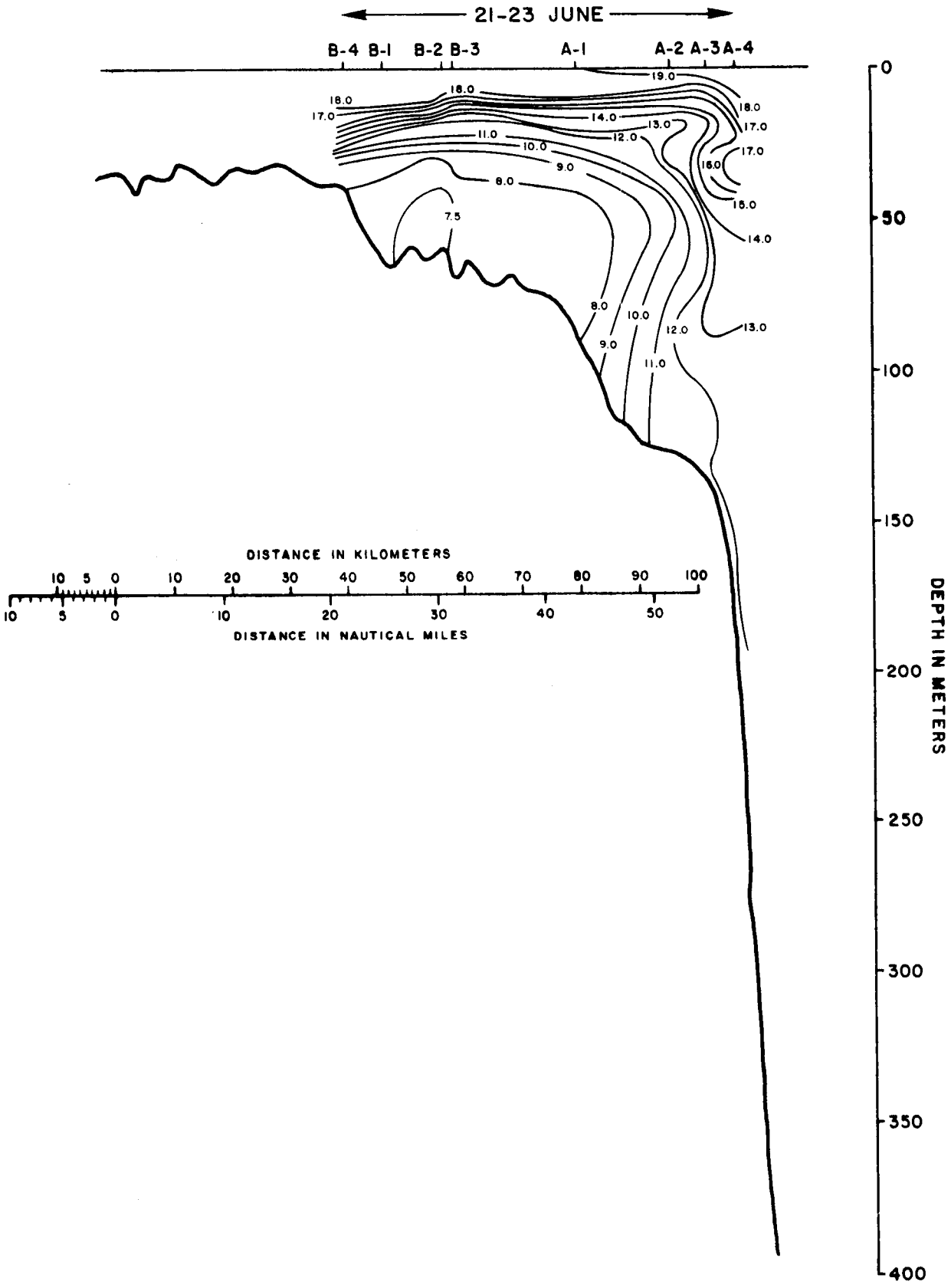

Figure 3-103. Temperature (^{o}C) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

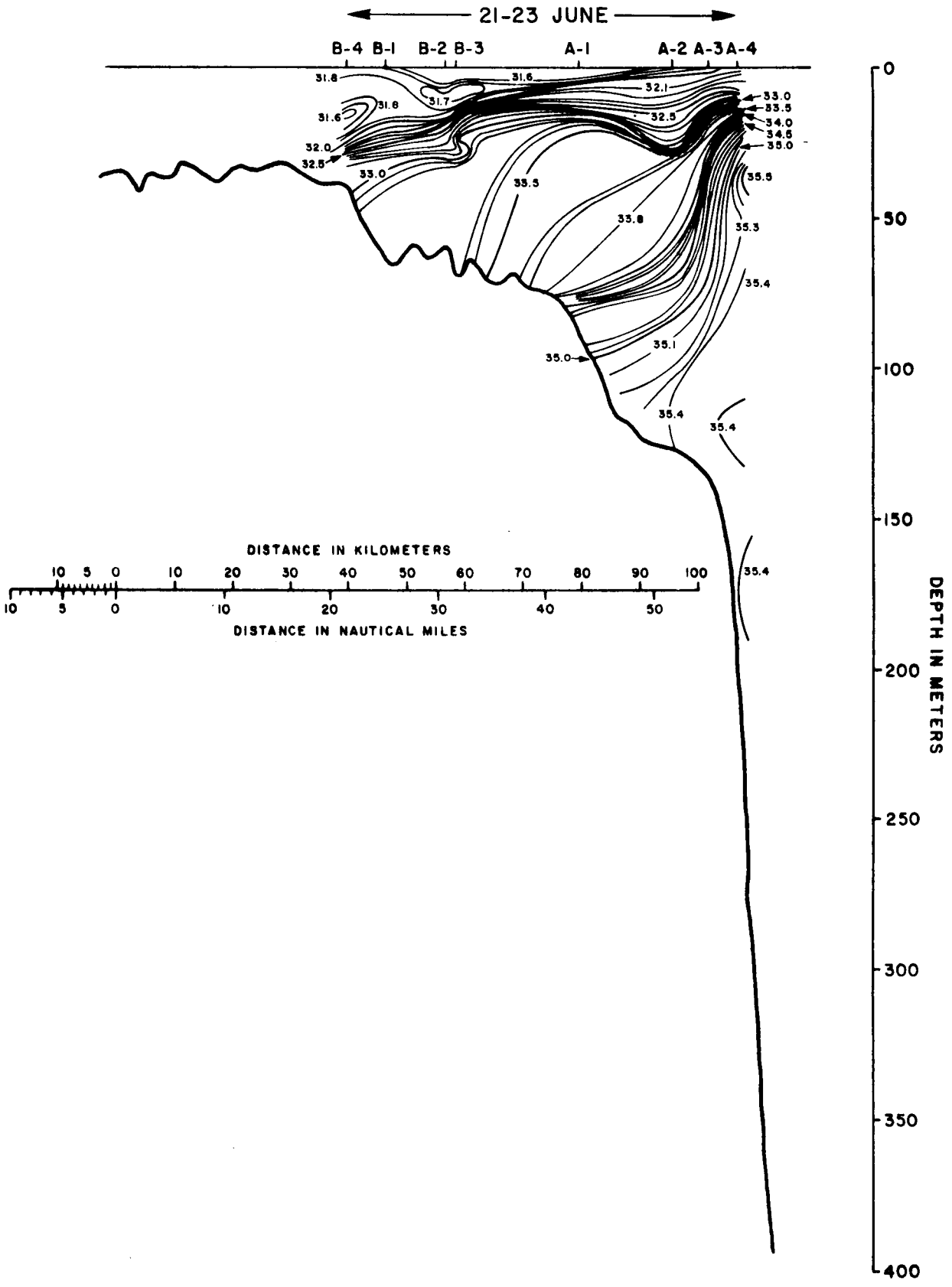

Figure 3-104. Salinity (ppt) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

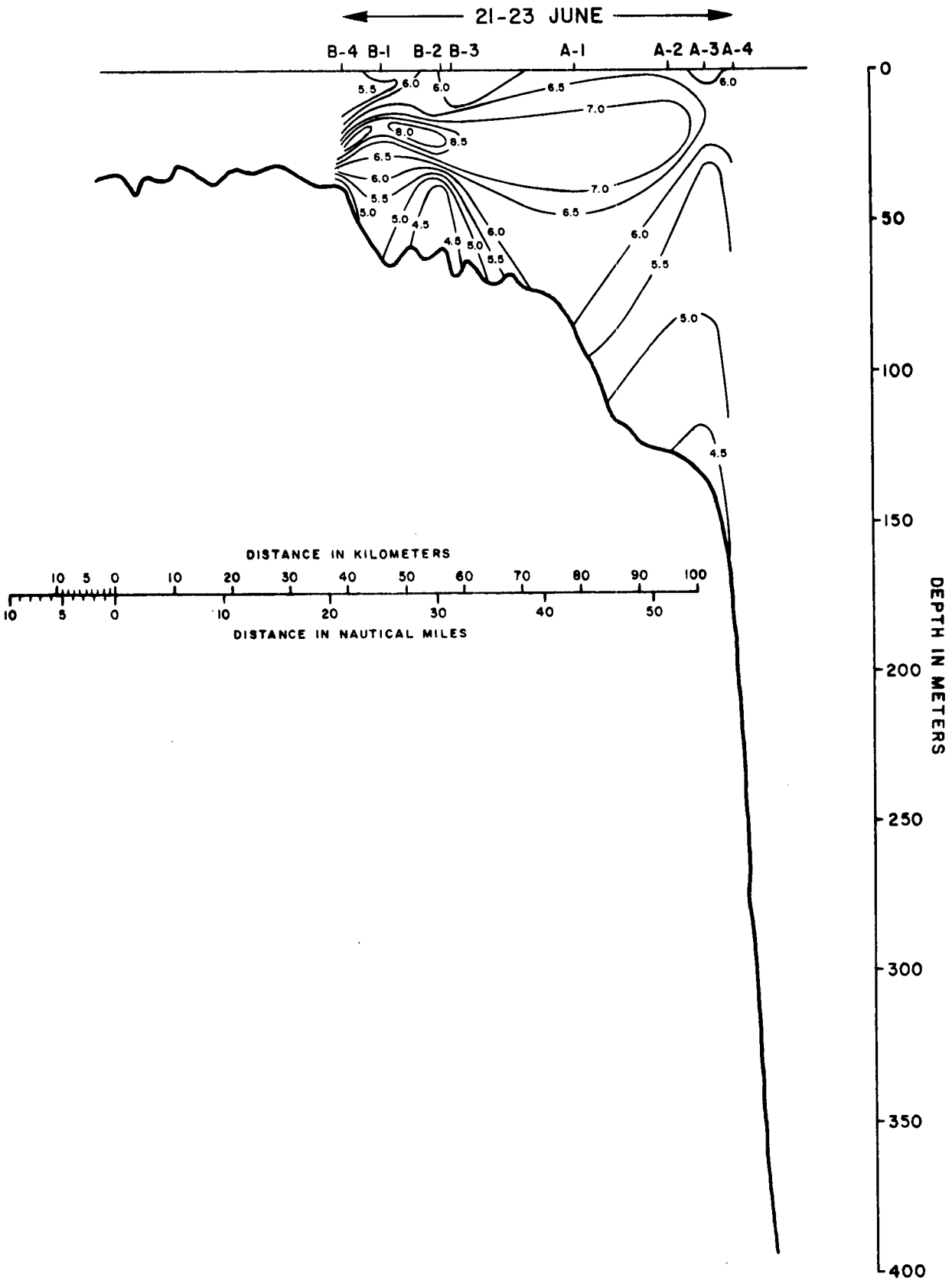

Figure 3-105. Dissolved oxygen (mg/l) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

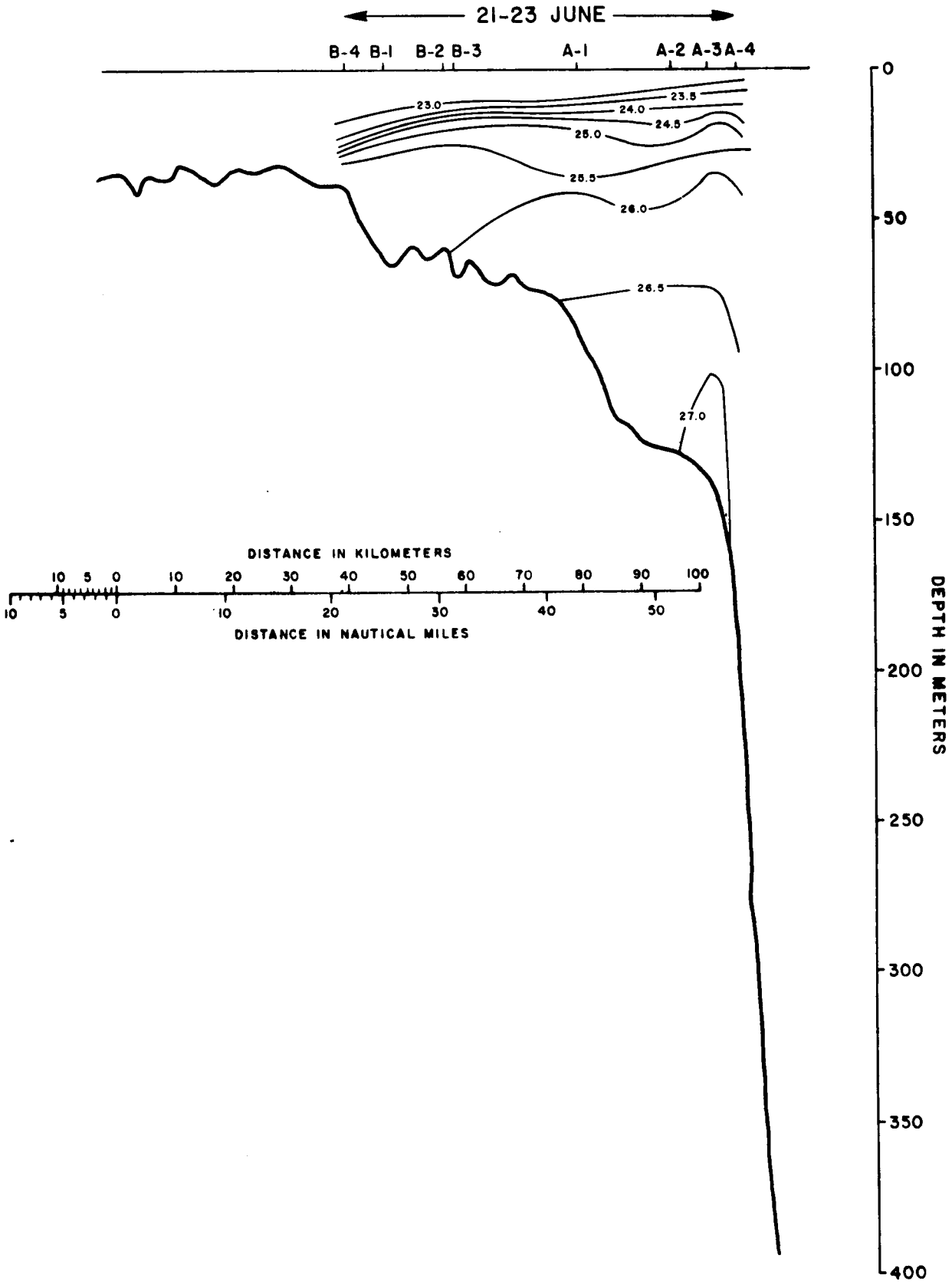

Figure 3-106. Density (σ_t units) along Section II (Stations B4 to A4, 21-23 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

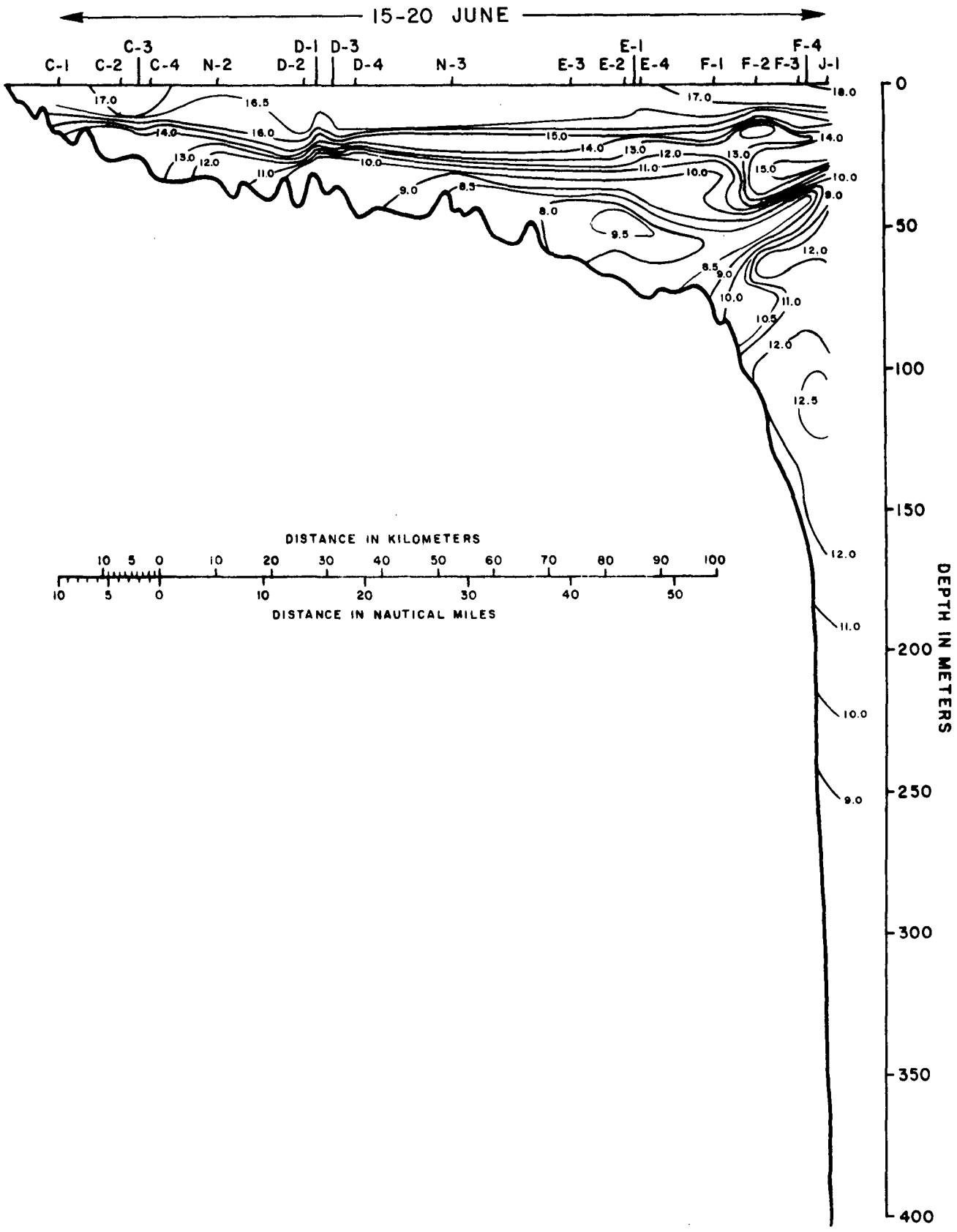

Figure 3-107. Temperature (^{o}C) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

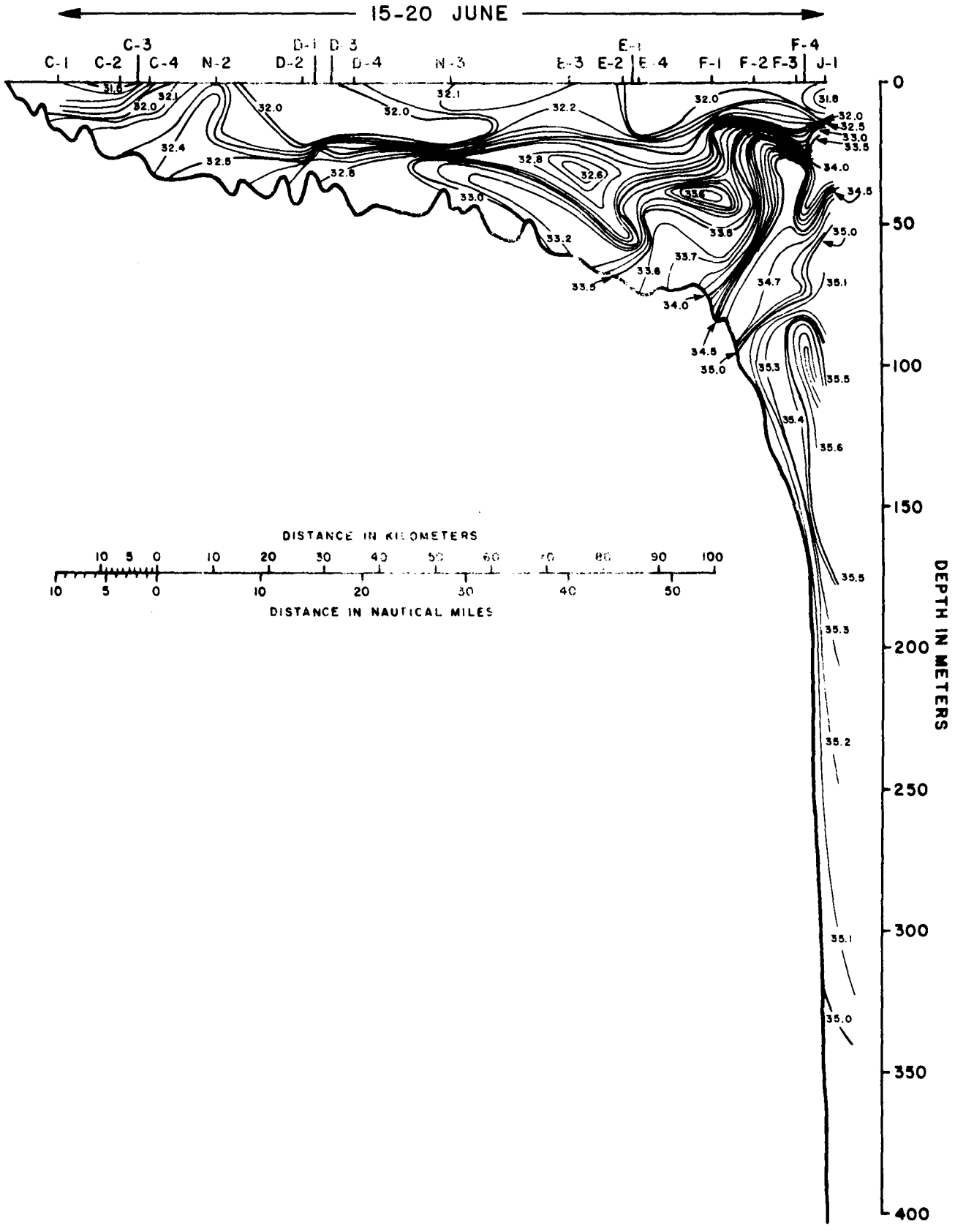

Figure 3-108. Salinity (ppt) along Section III (Stations C1 to J1, 15- 20 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

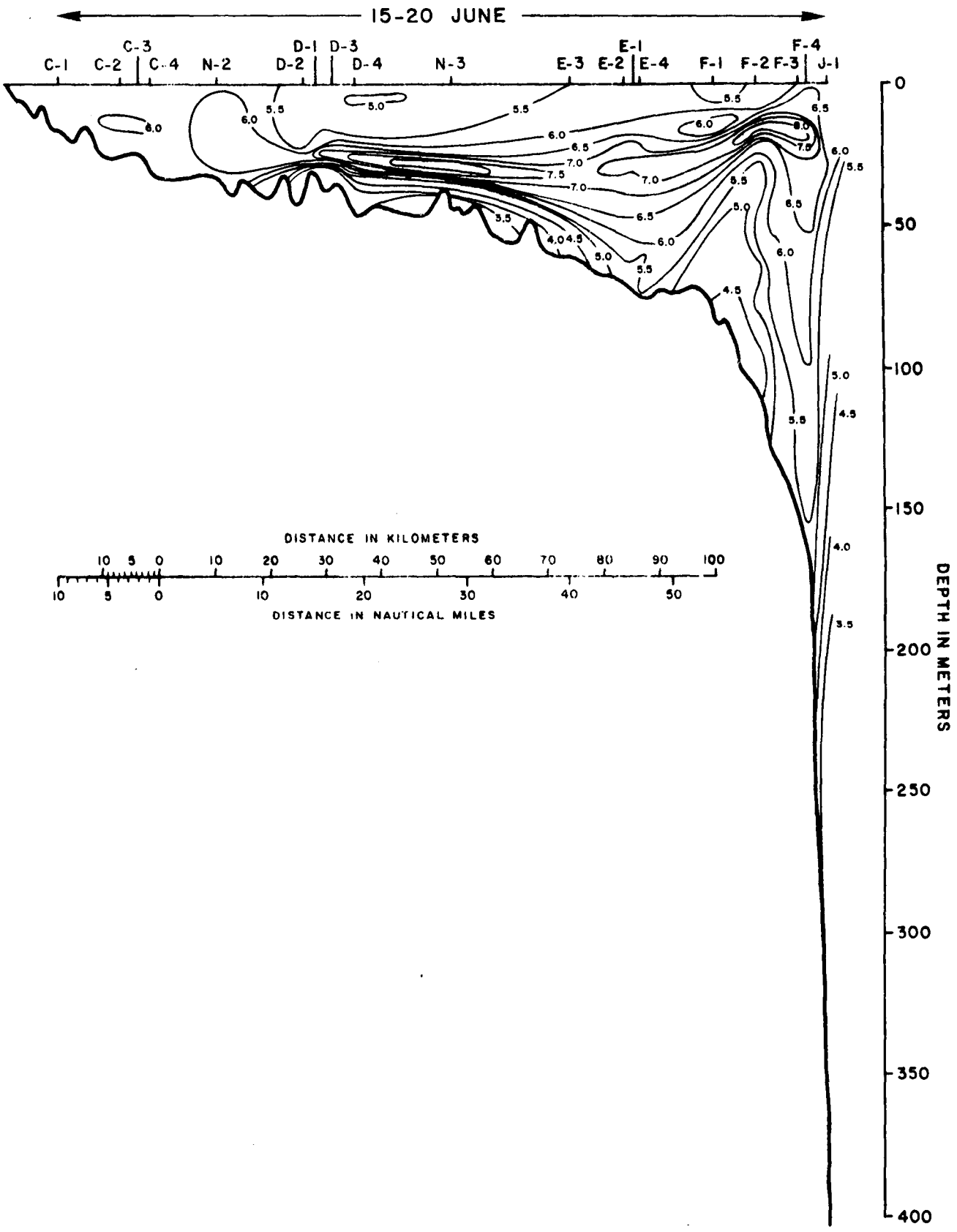

Figure 3-109. Dissolved oxygen (mg/1) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

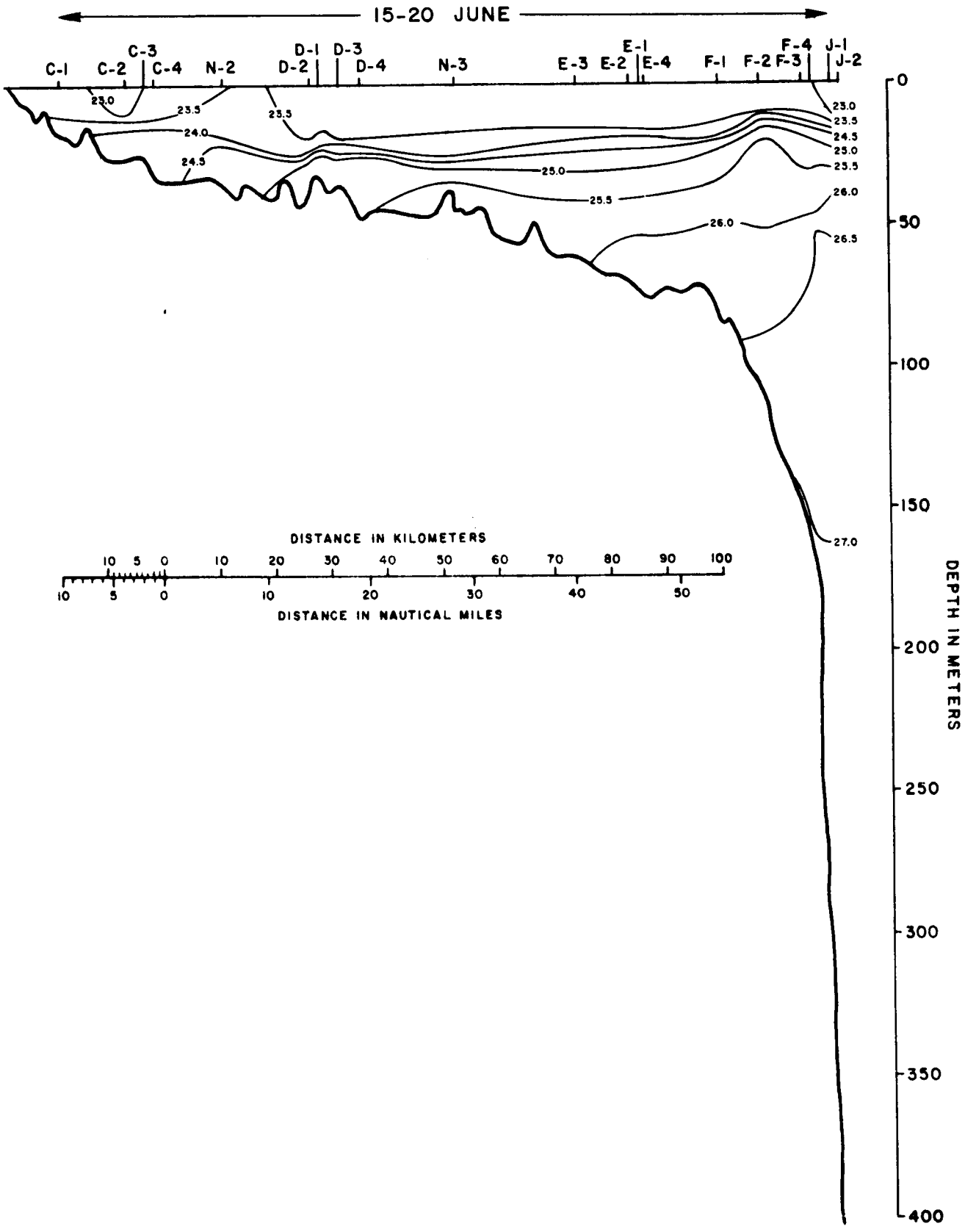

Figure 3-110. Density (σ_t units) along Section III (Stations C1 to J1, 15-20 June 1976) during cruise BLMØ3B. Section location is shown in Figure 3-10.

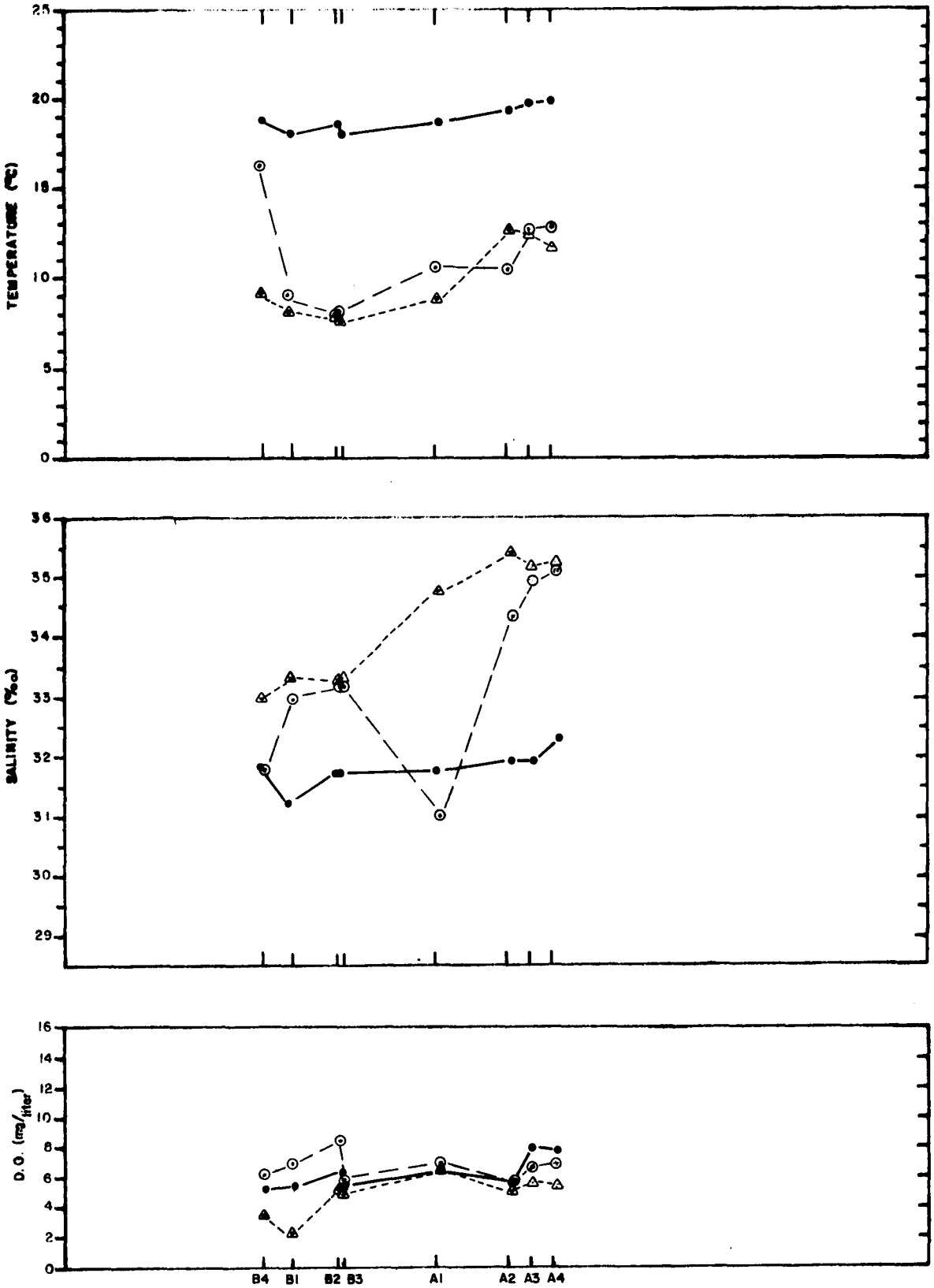

Figure 3-111. Surface (•), mid-depth (⊙) and bottom (△) values of temperature, salinity and DO measured along Section II on cruise BLM Ø3B.

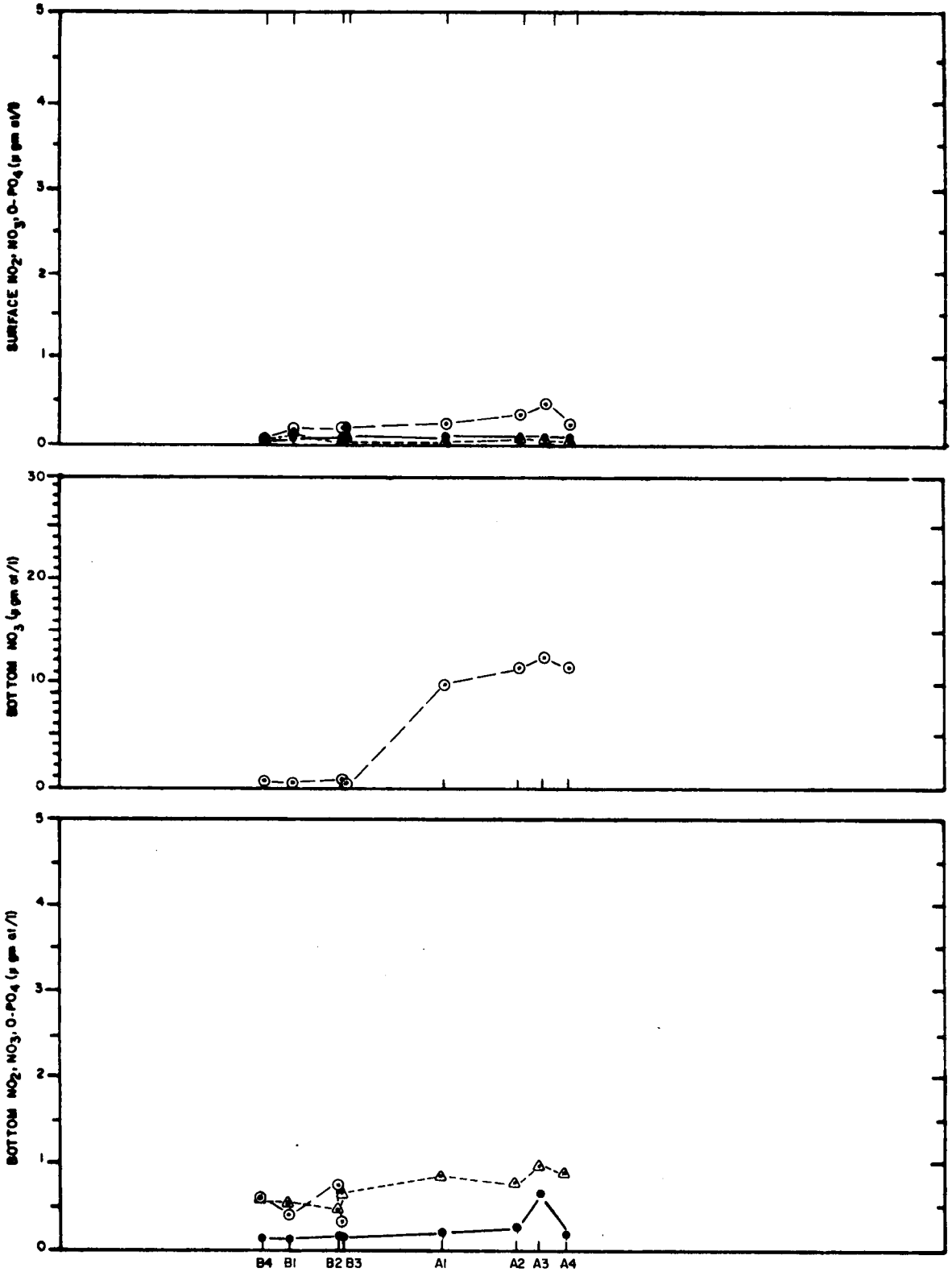

Figure 3-112. Concentrations of dissolved NO_2 (•), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Section II during Cruise BLM Ø3B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

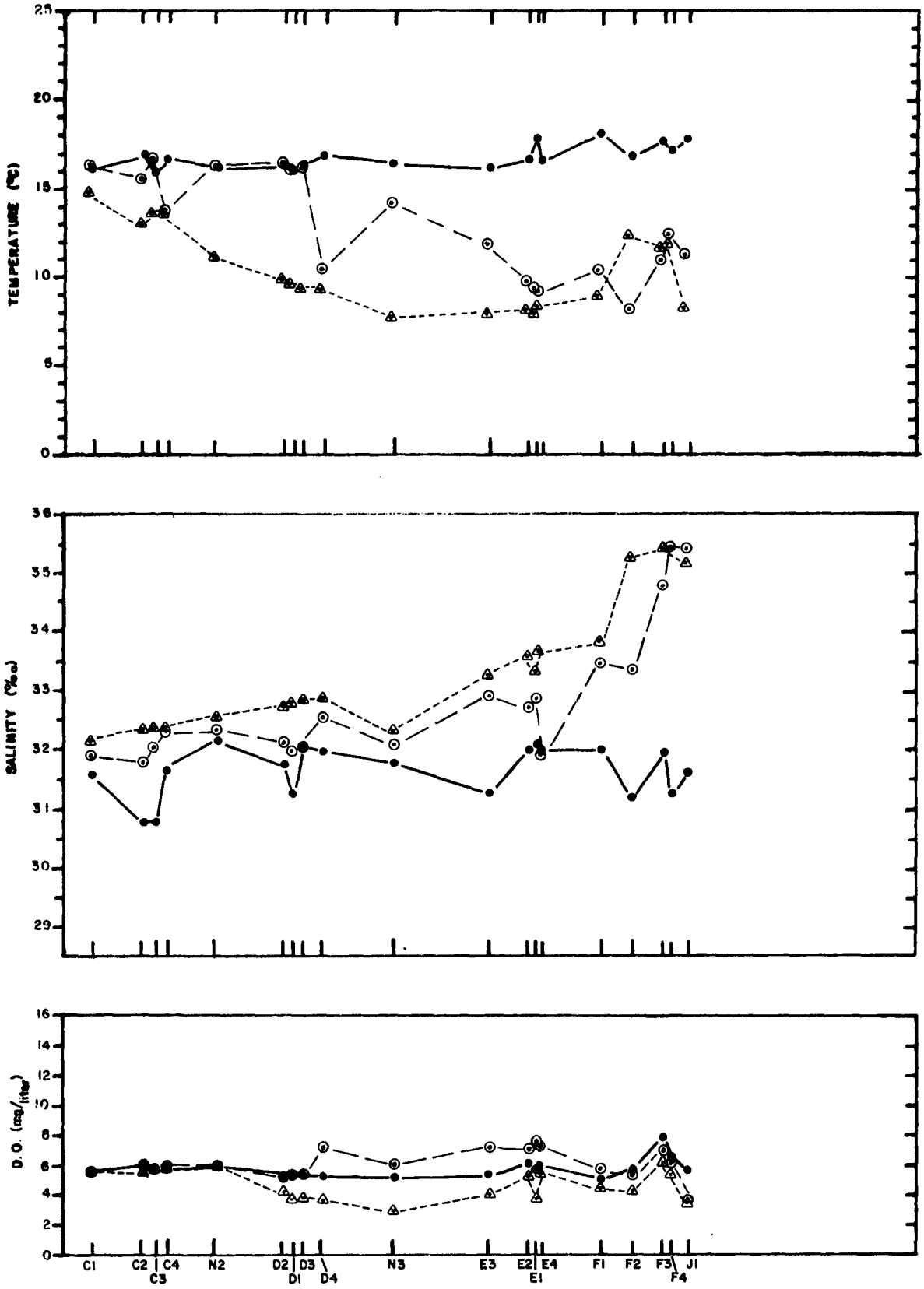

Figure 3-113. Surface (•), mid-depth (⊙) and bottom (△) values of temperature, salinity and DO measured along Section III on cruise BLM Ø3B.

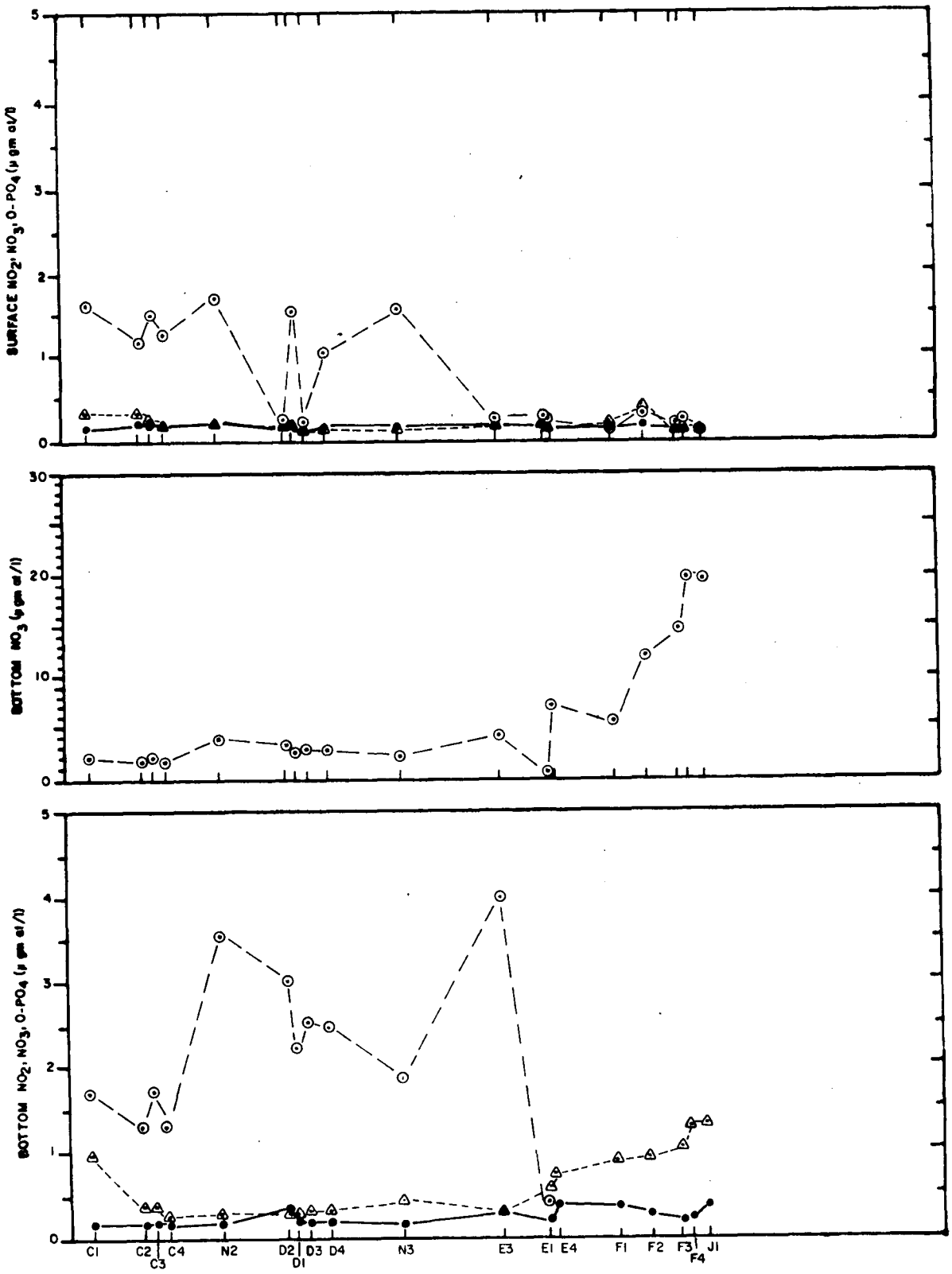

Figure 3-114. Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM ϕ3B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ3W

Spring 1976

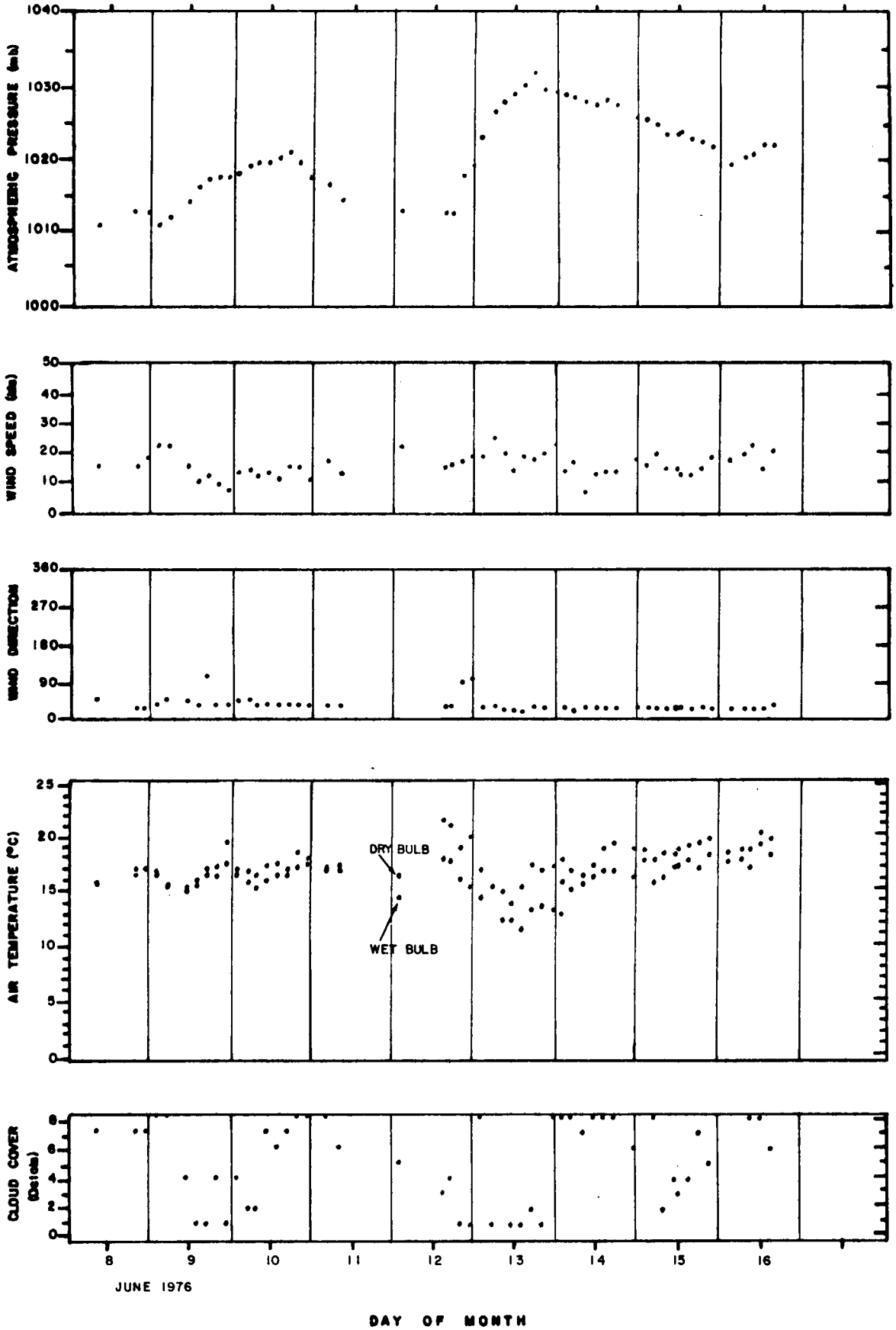

Figure 3-115. Meteorological data collected during cruise BLM Ø3W 8 to 16 June 1976.

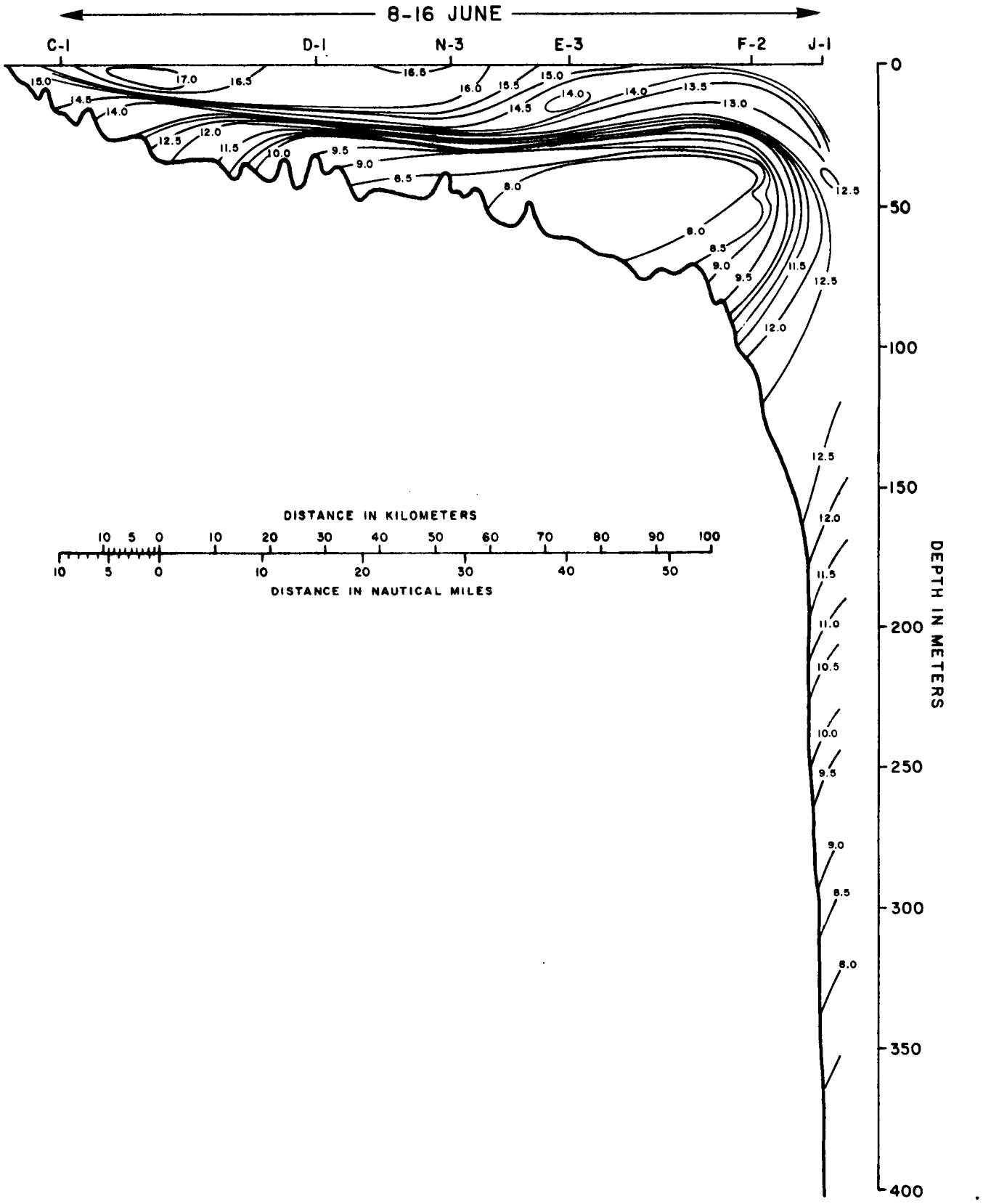

Figure 3-116. Temperature (^{o}C) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

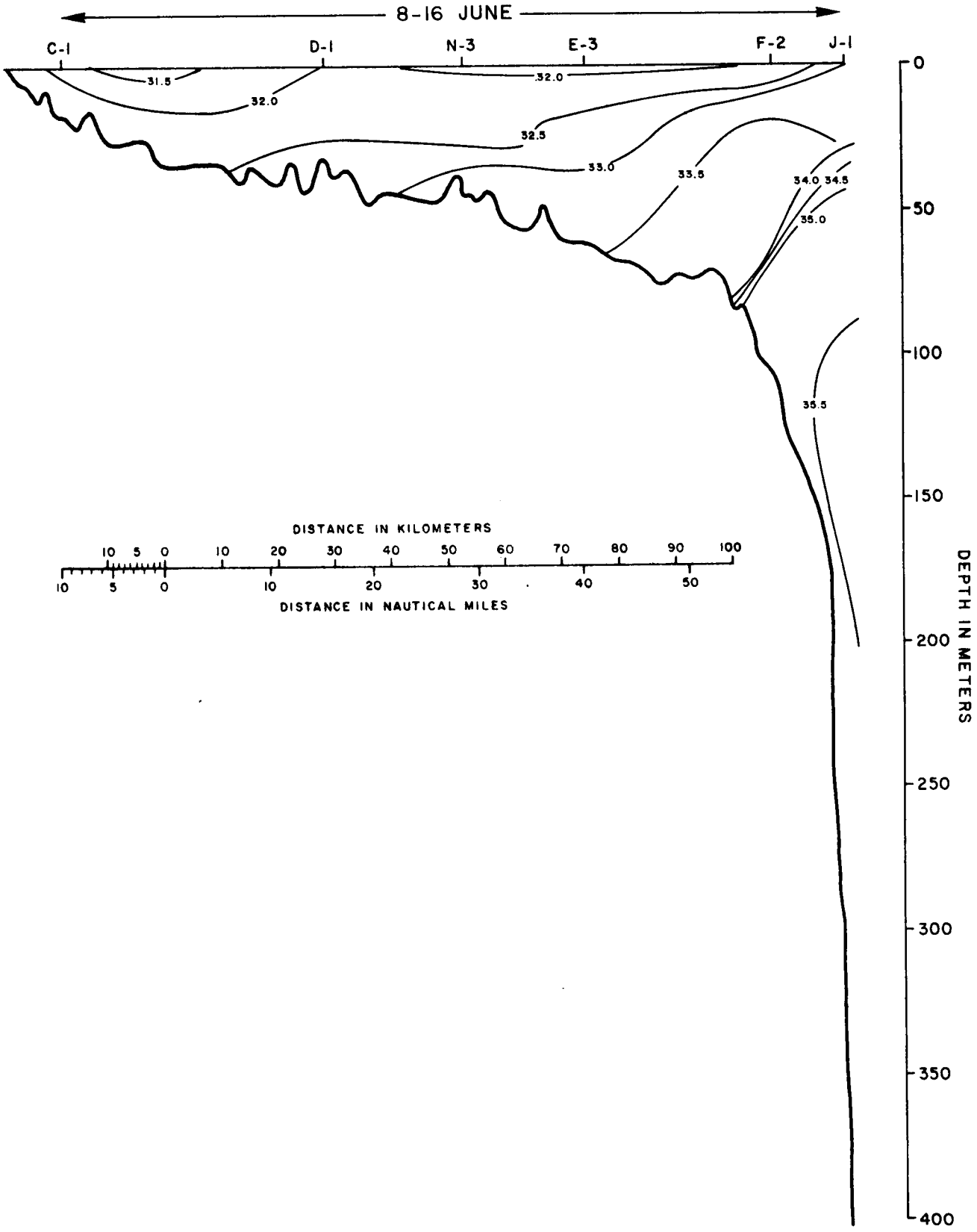

Figure 3-117. Salinity (ppt) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLMØ3W. Section location is shown in Figure 3-10.

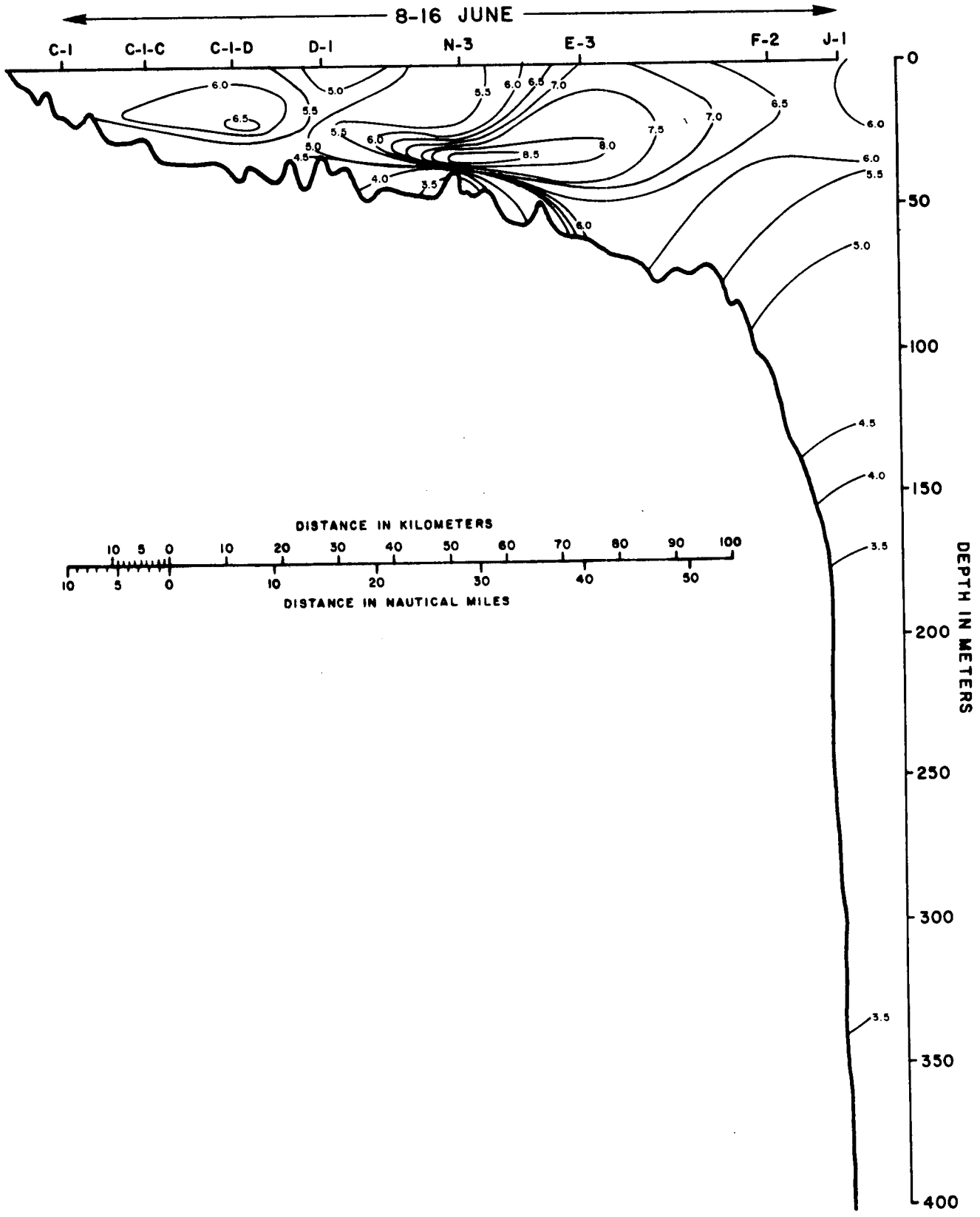

Figure 3-118. Dissolved oxygen (mg/l) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

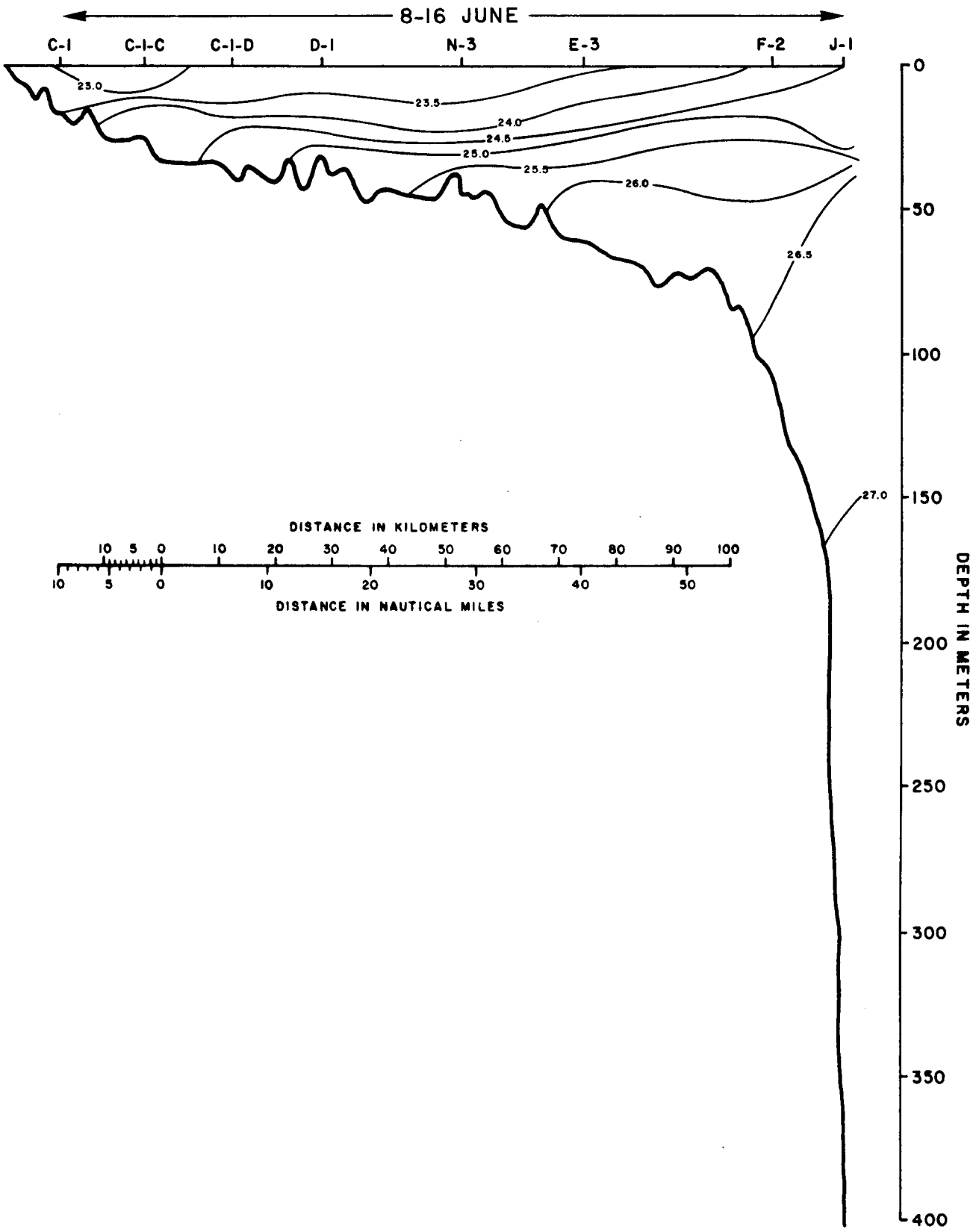

Figure 3-119. Density (σ_t units) along Section III (Stations C1 to J1, 8-16 June 1976) during cruise BLM03W. Section location is shown in Figure 3-10.

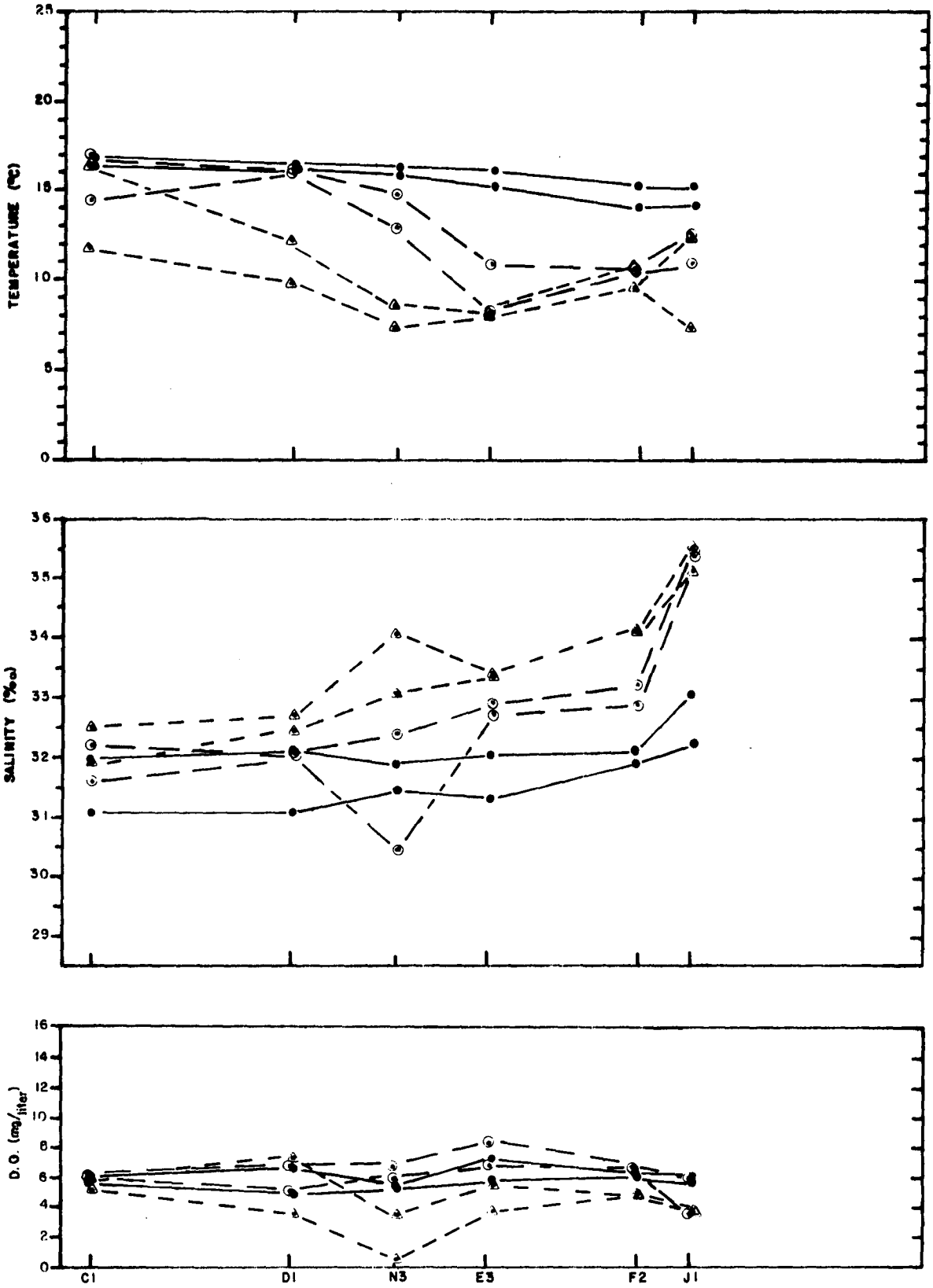

Figure 3-120 Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Section III during cruise BLM Ø3W. Maximum and minimum values measured from four casts are shown at each station.

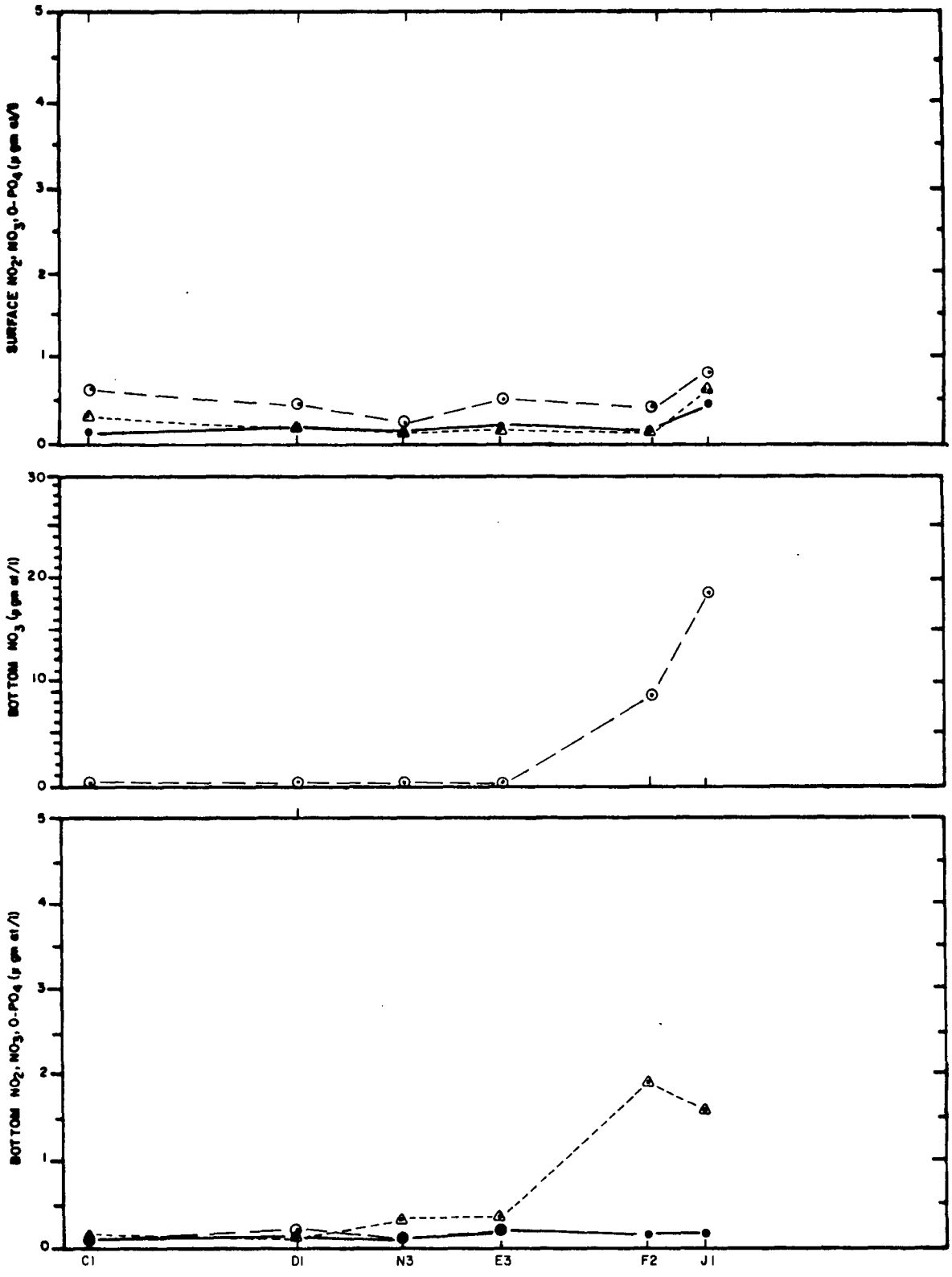

Figure 3-121. Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM Ø3W. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ4B

Summer 1976

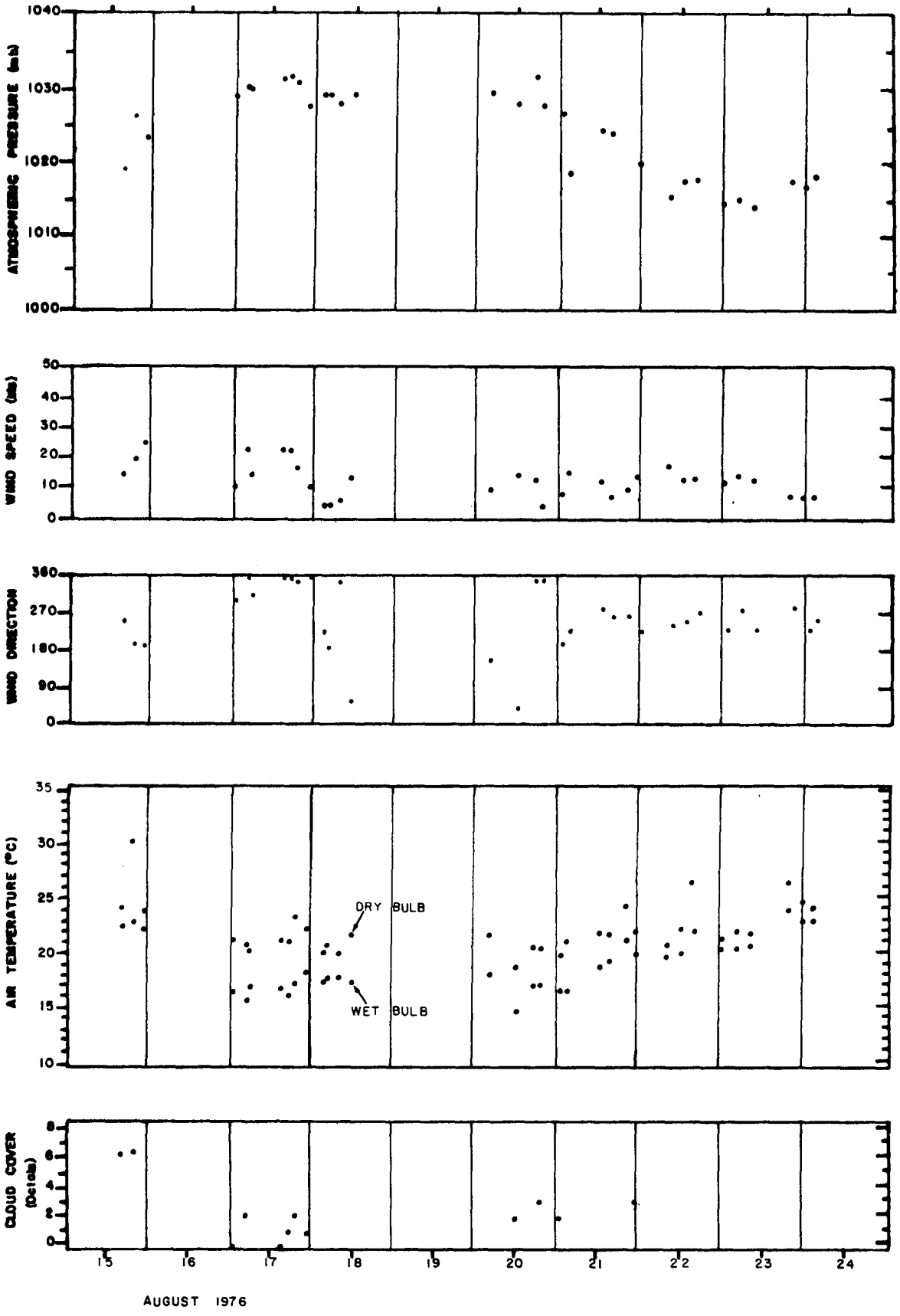

Figure 3-122. Meteorological data collected during cruise BLM 04B 15 to 24 August 1976.

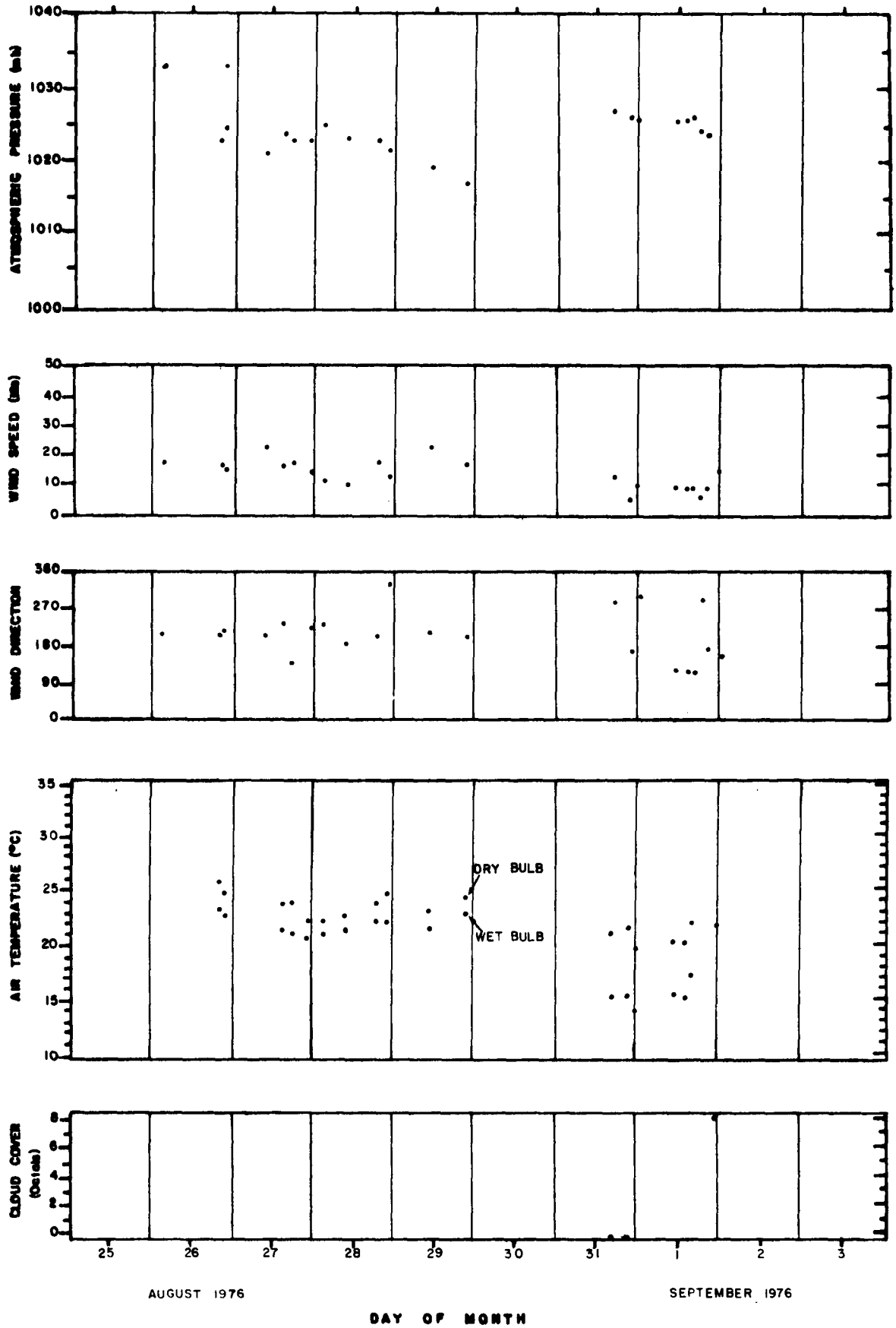

Figure 3-122. (continued) Meteorological data collected during cruise BLM Ø4B 25 August to 1 September 1976.

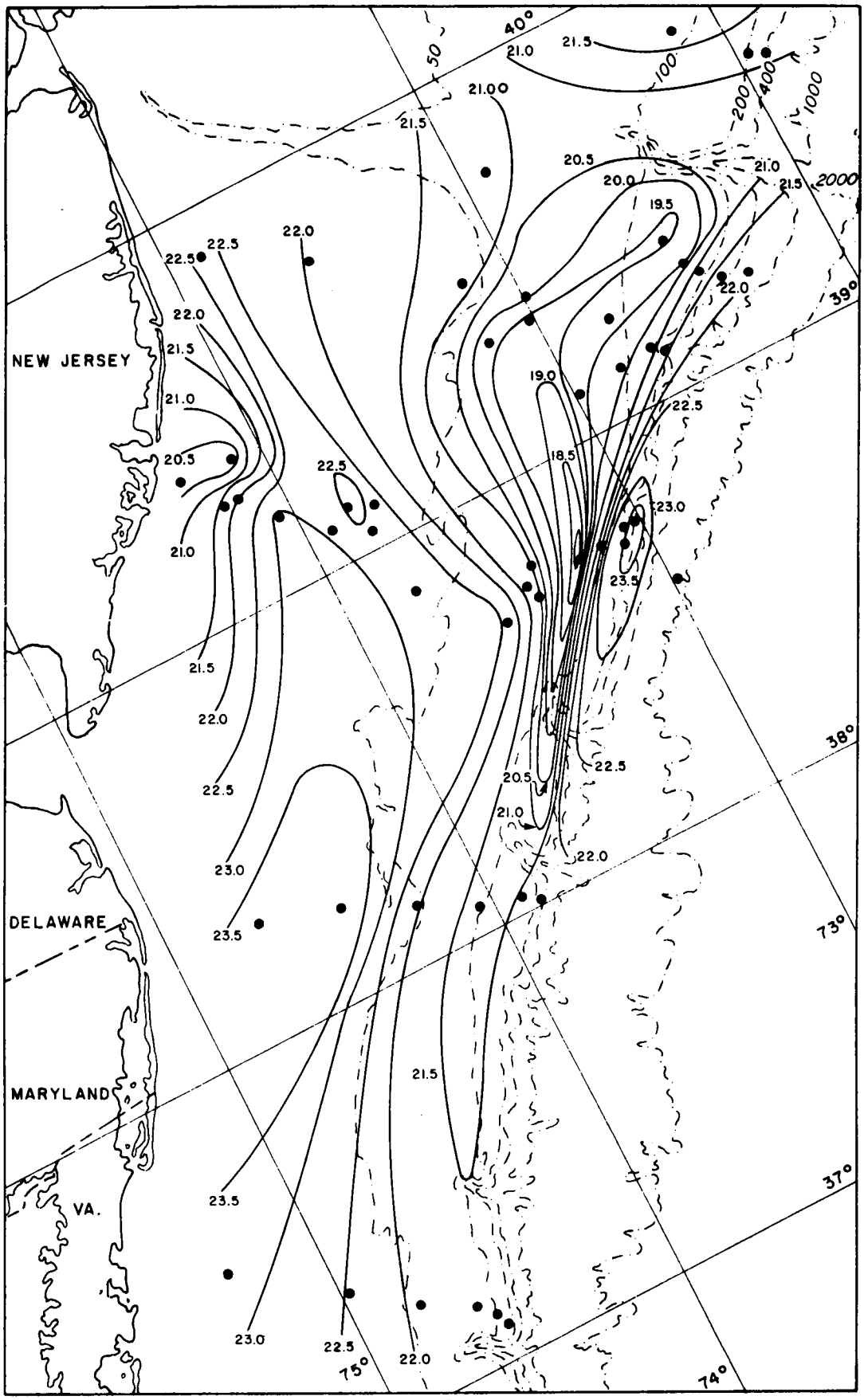

Figure 3-123. Surface temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

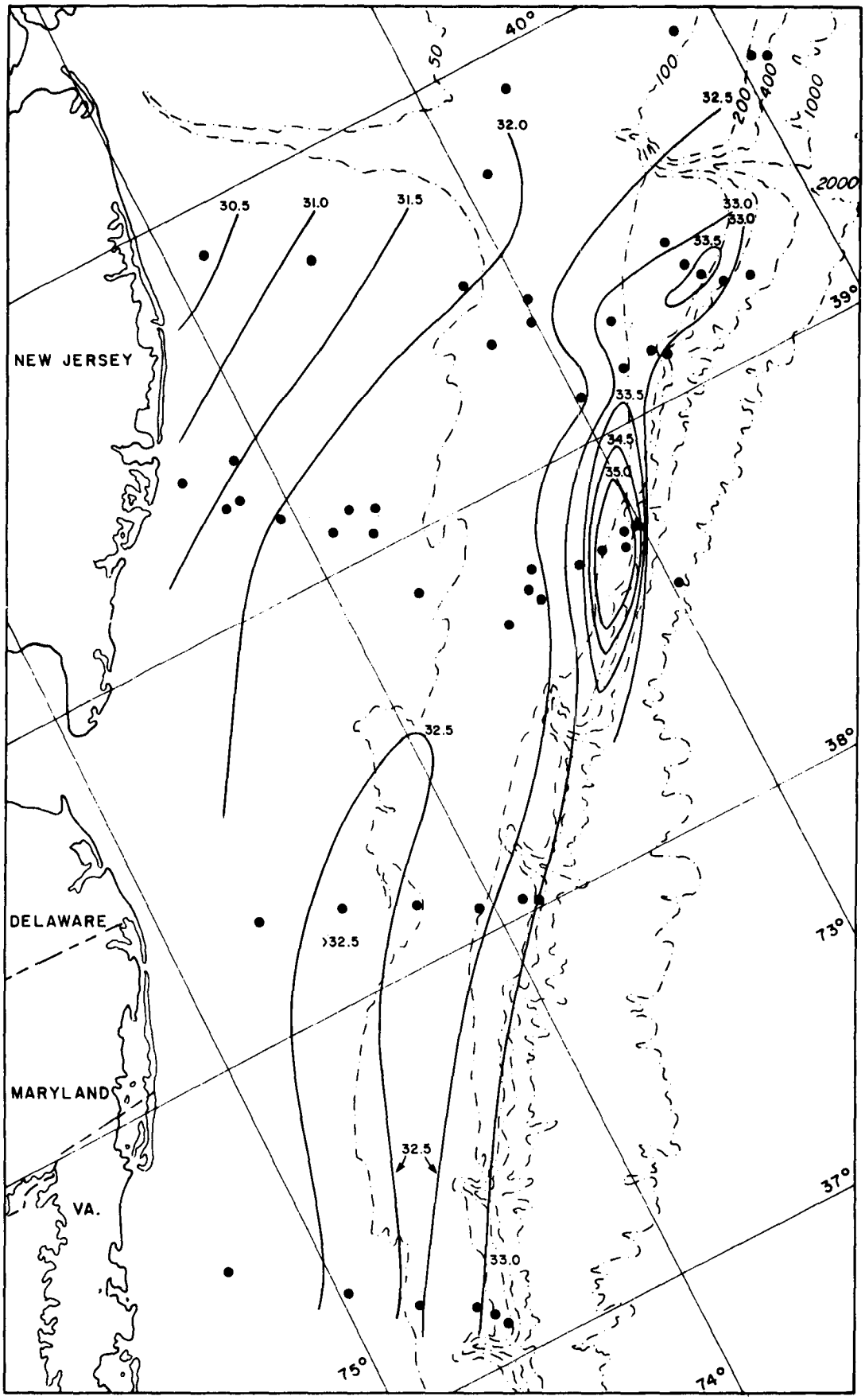

Figure 3-124. Surface salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

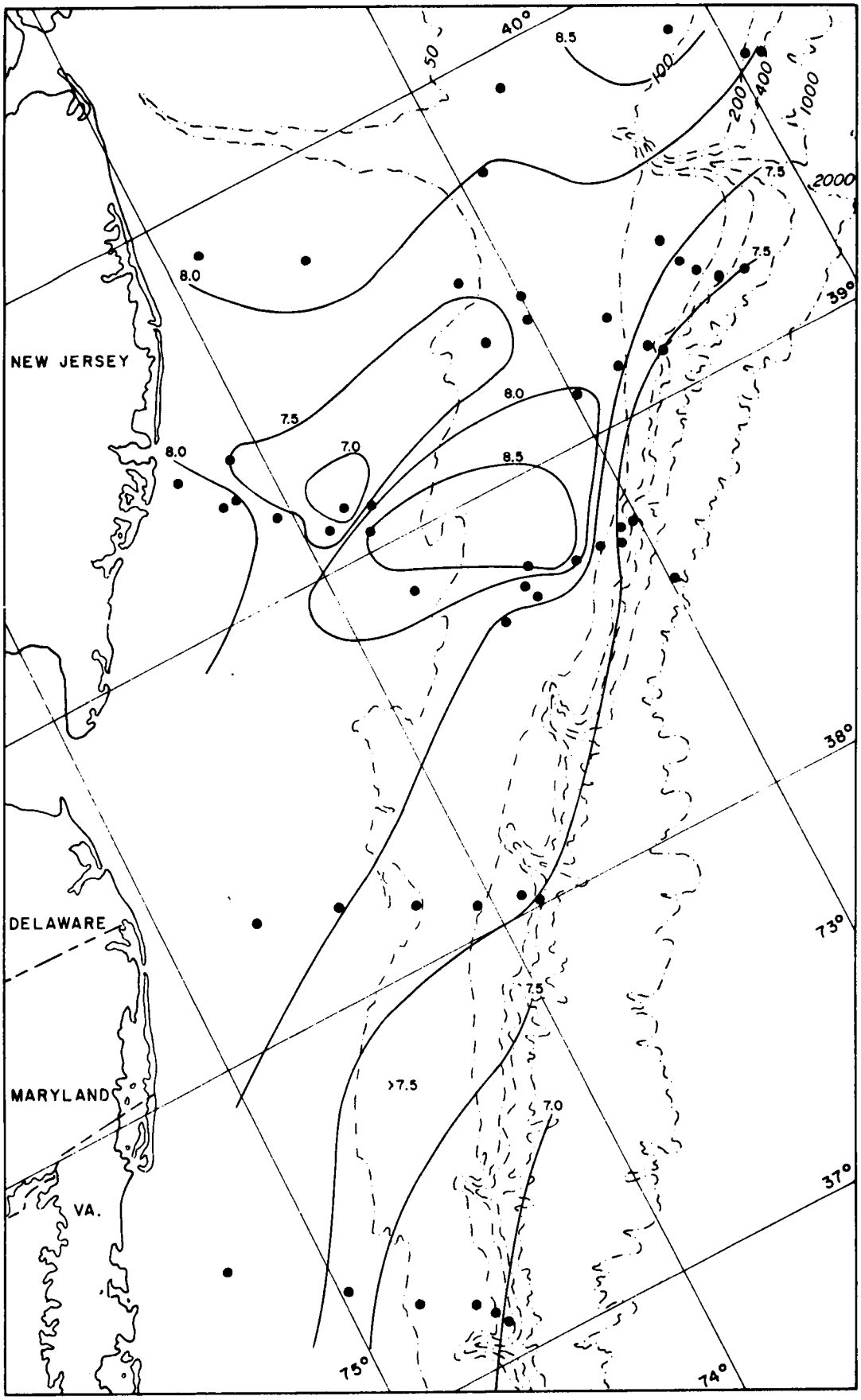

Figure 3-125. Surface dissolved oxygen (mg/1) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

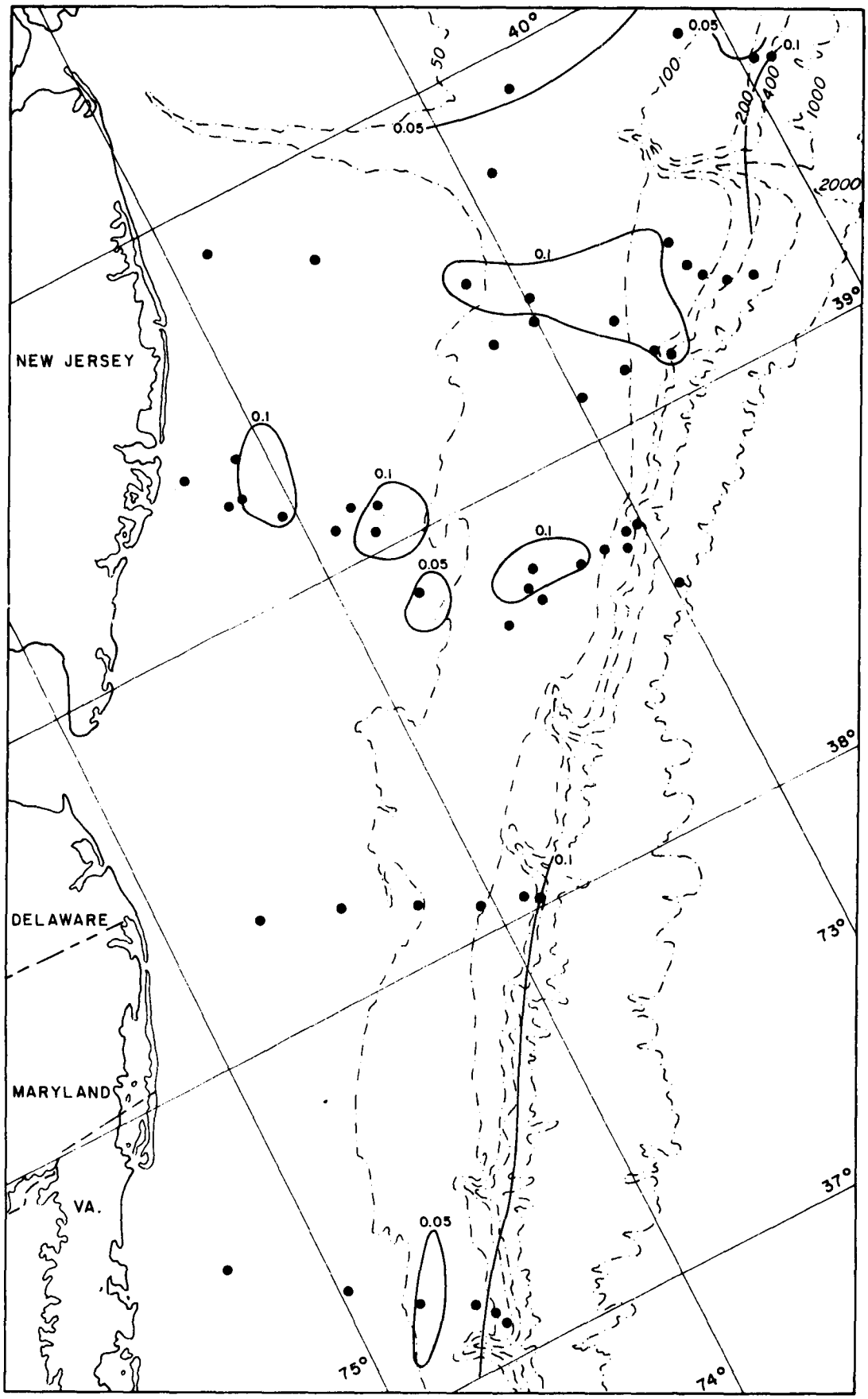

Figure 3-126. Surface NO_2 (µgm atoms/1) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

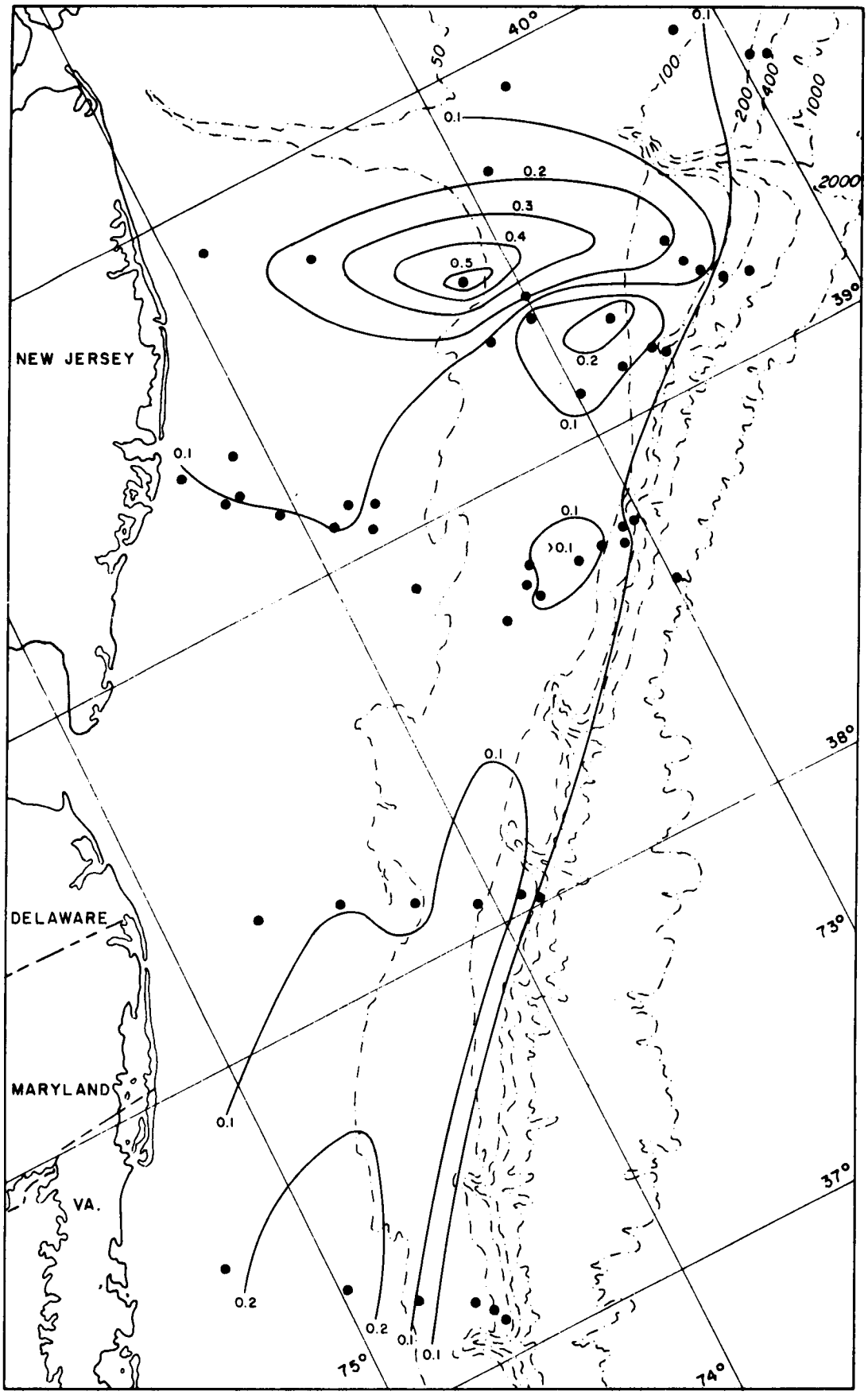

Figure 3-127. Surface NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

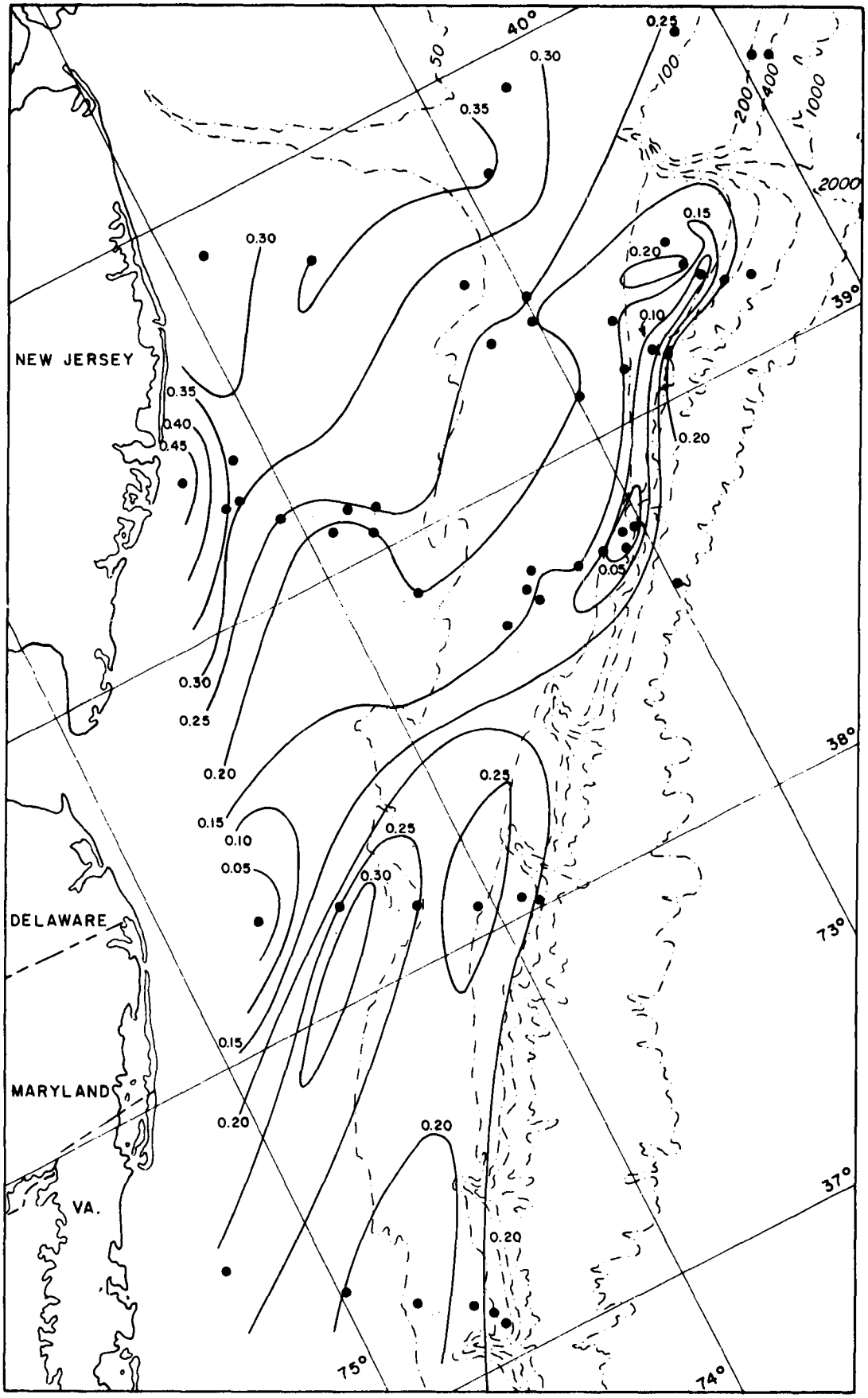

Figure 3-128. Surface O-PO_4 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

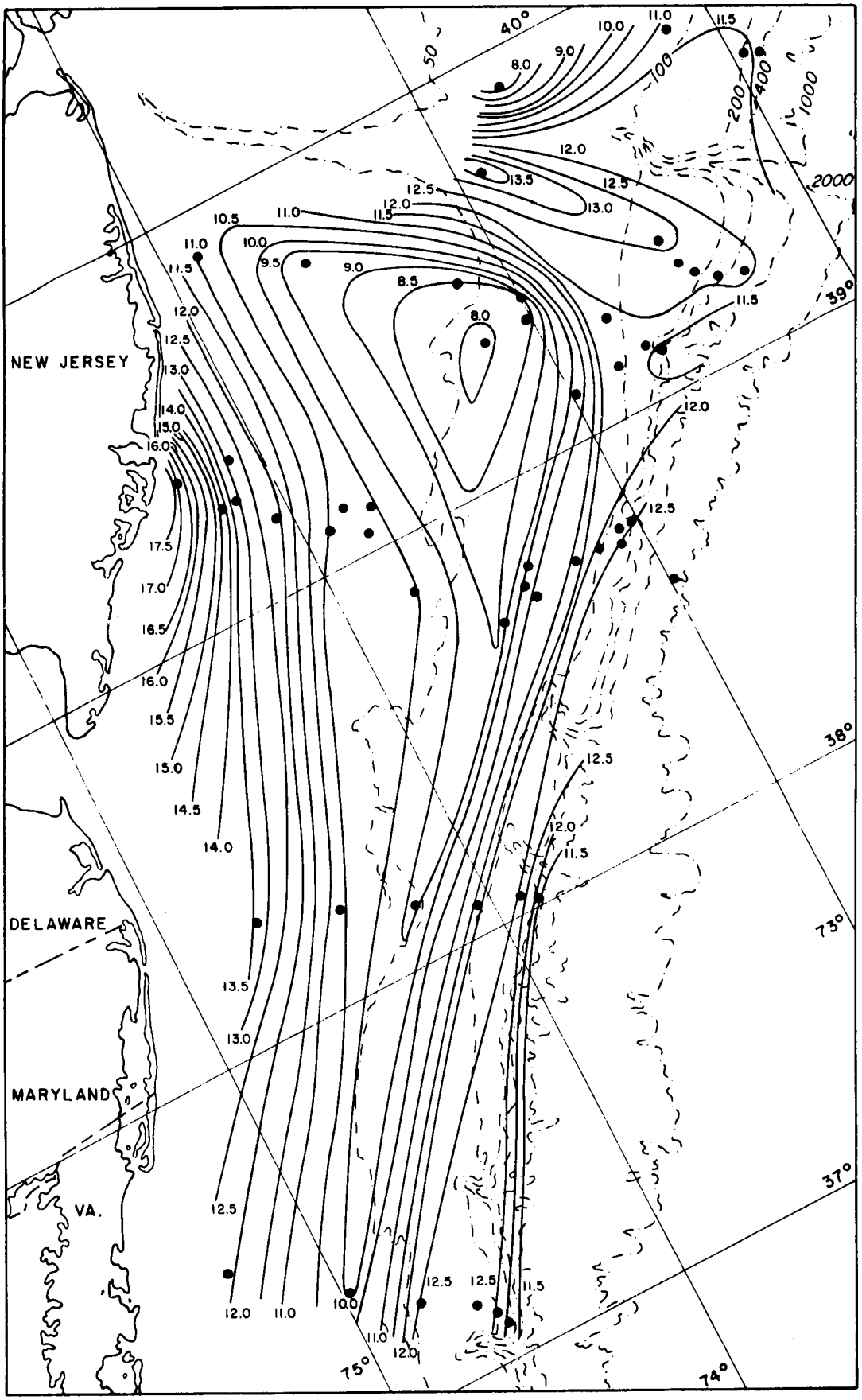

Figure 3-129. Bottom temperature (^{o}C) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

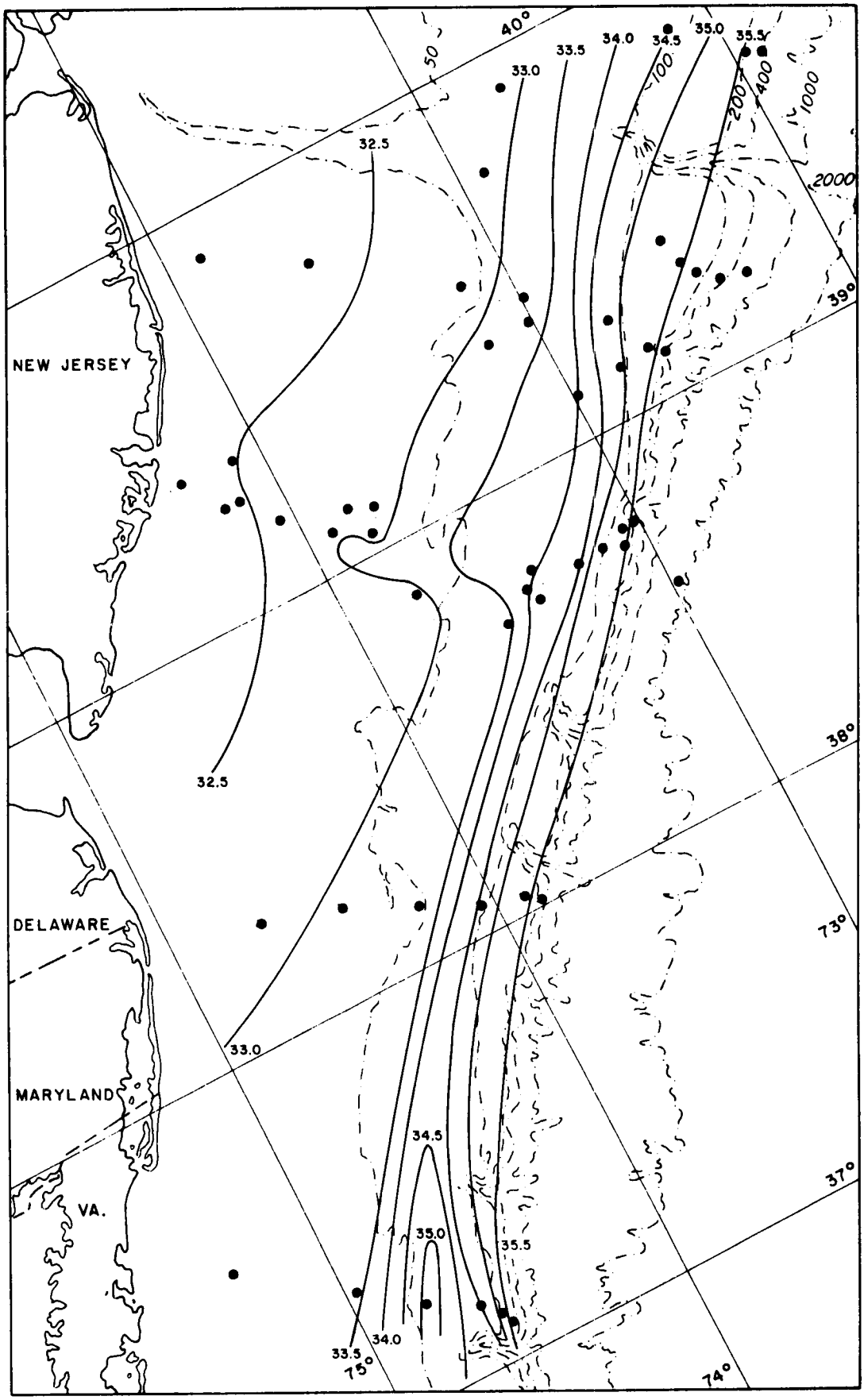

Figure 3-130. Bottom salinity (ppt) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

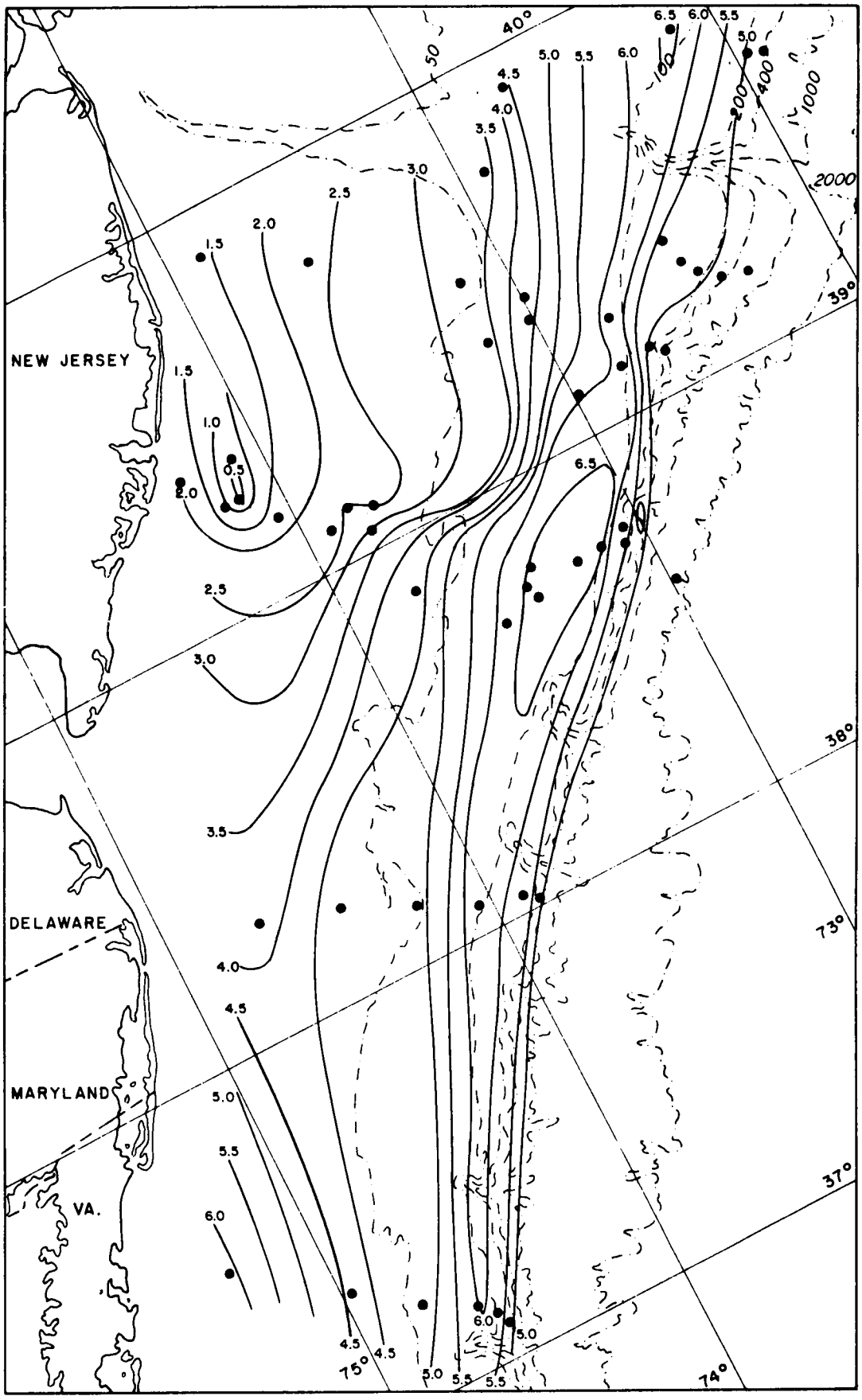

Figure 3-131. Bottom dissolved oxygen (mg/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

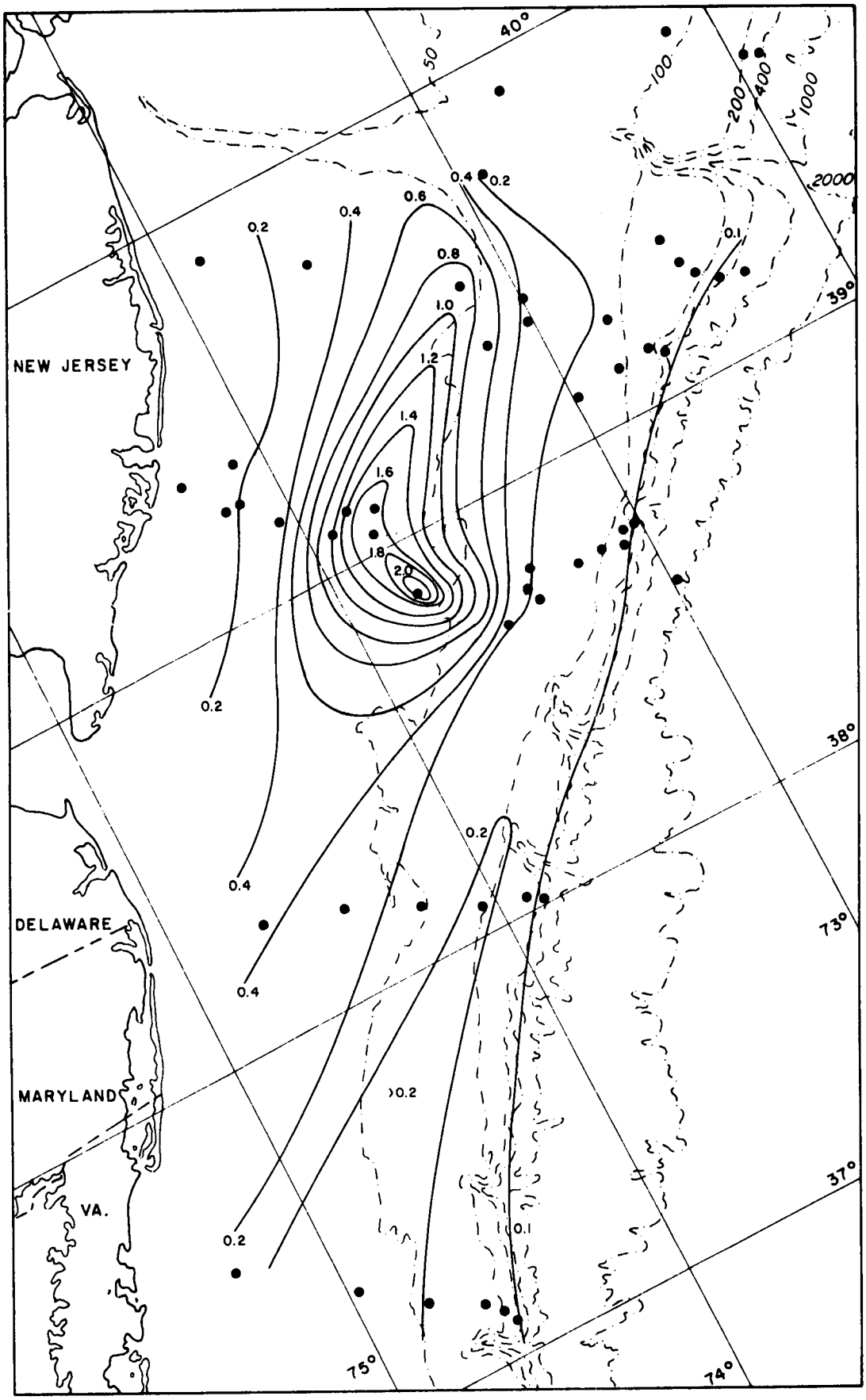

Figure 3-132. Bottom NO_2 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

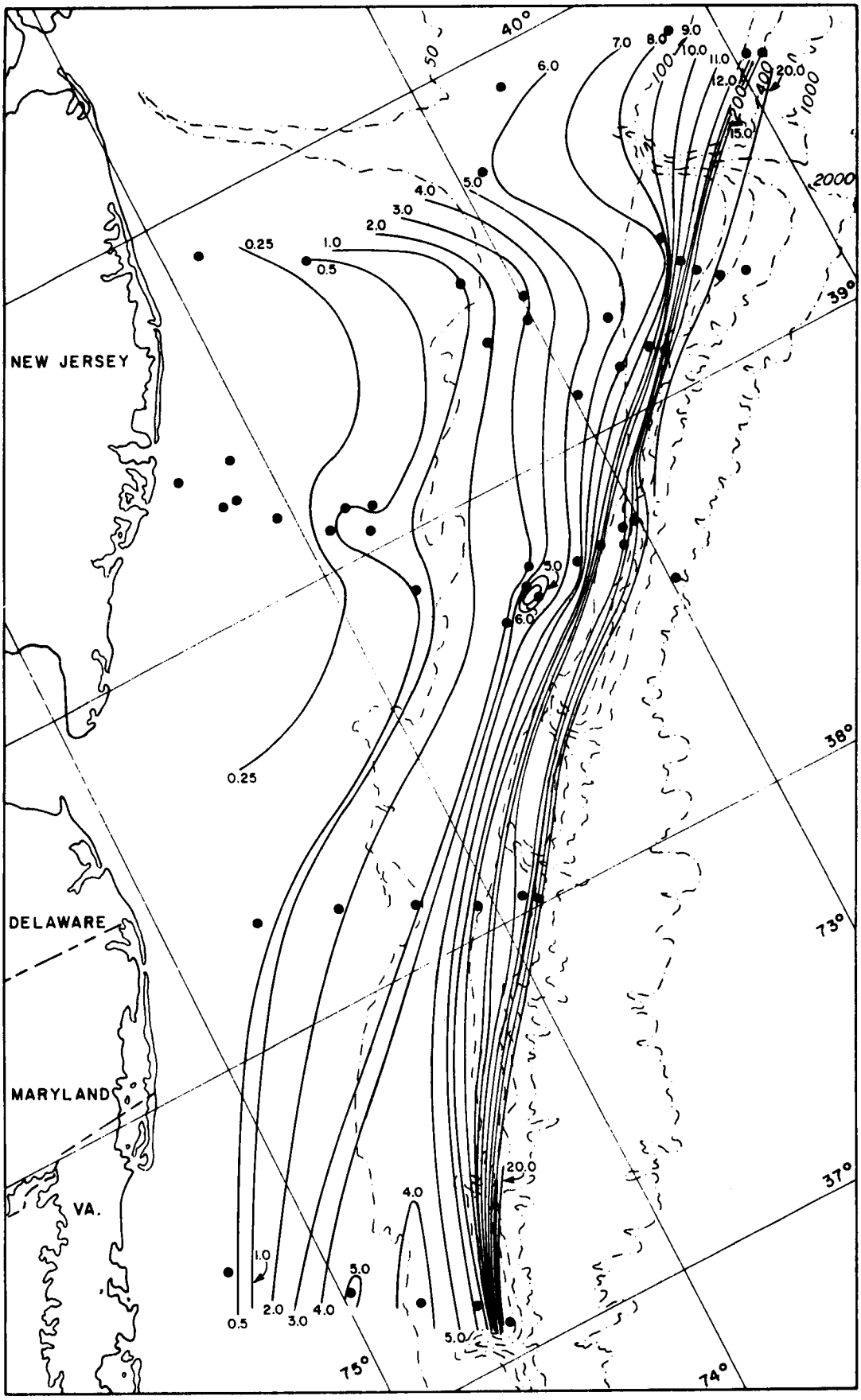

Figure 3-133. Bottom NO_3 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

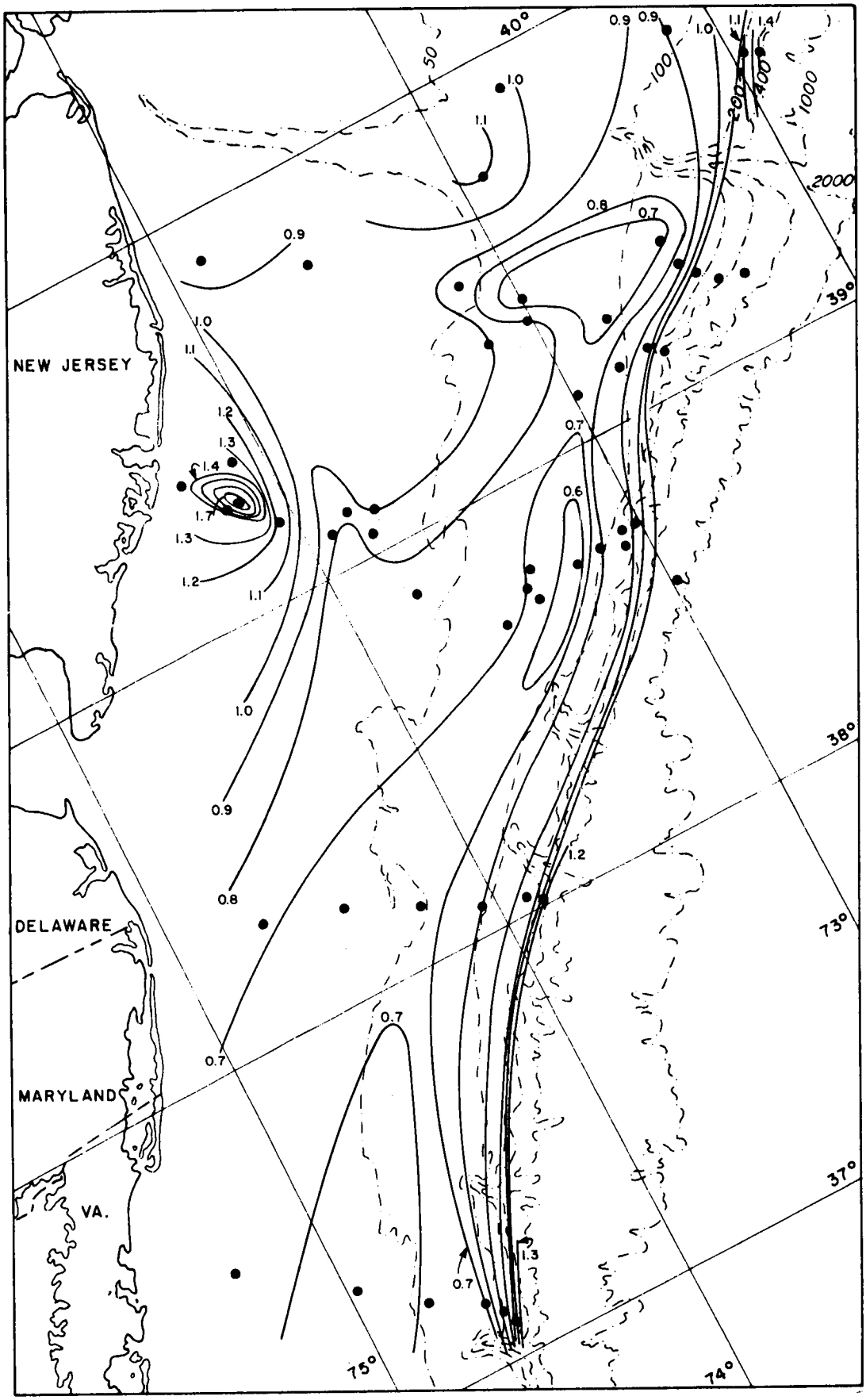

Figure 3-134. Bottom O-PO_4 (µgm atoms/l) distribution in the northern portions of the Middle Atlantic Bight during the period 15 August to 1 September 1976 (Cruise BLMØ4B)

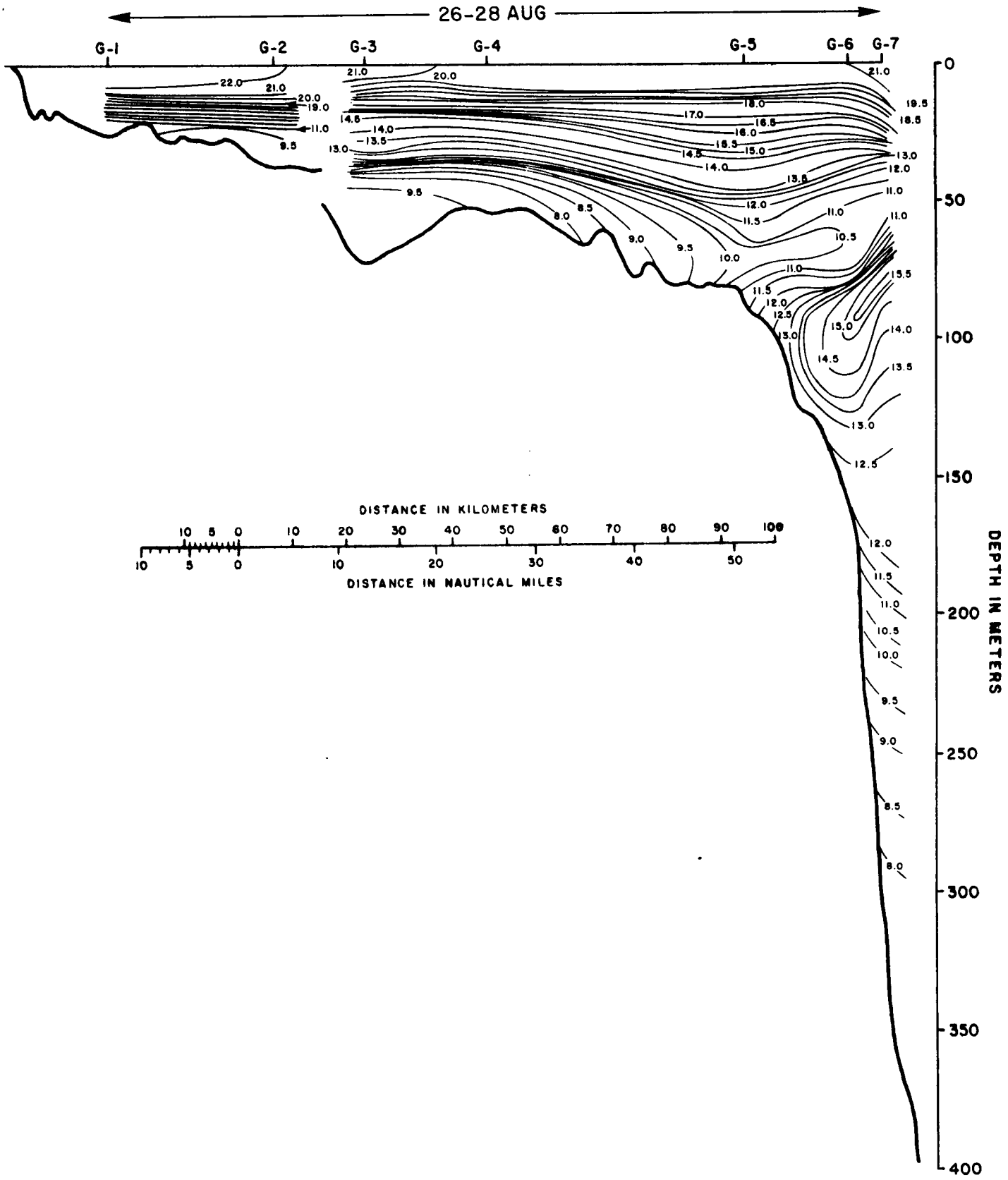

Figure 3-135. Temperature (^{o}C) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLMØ4B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

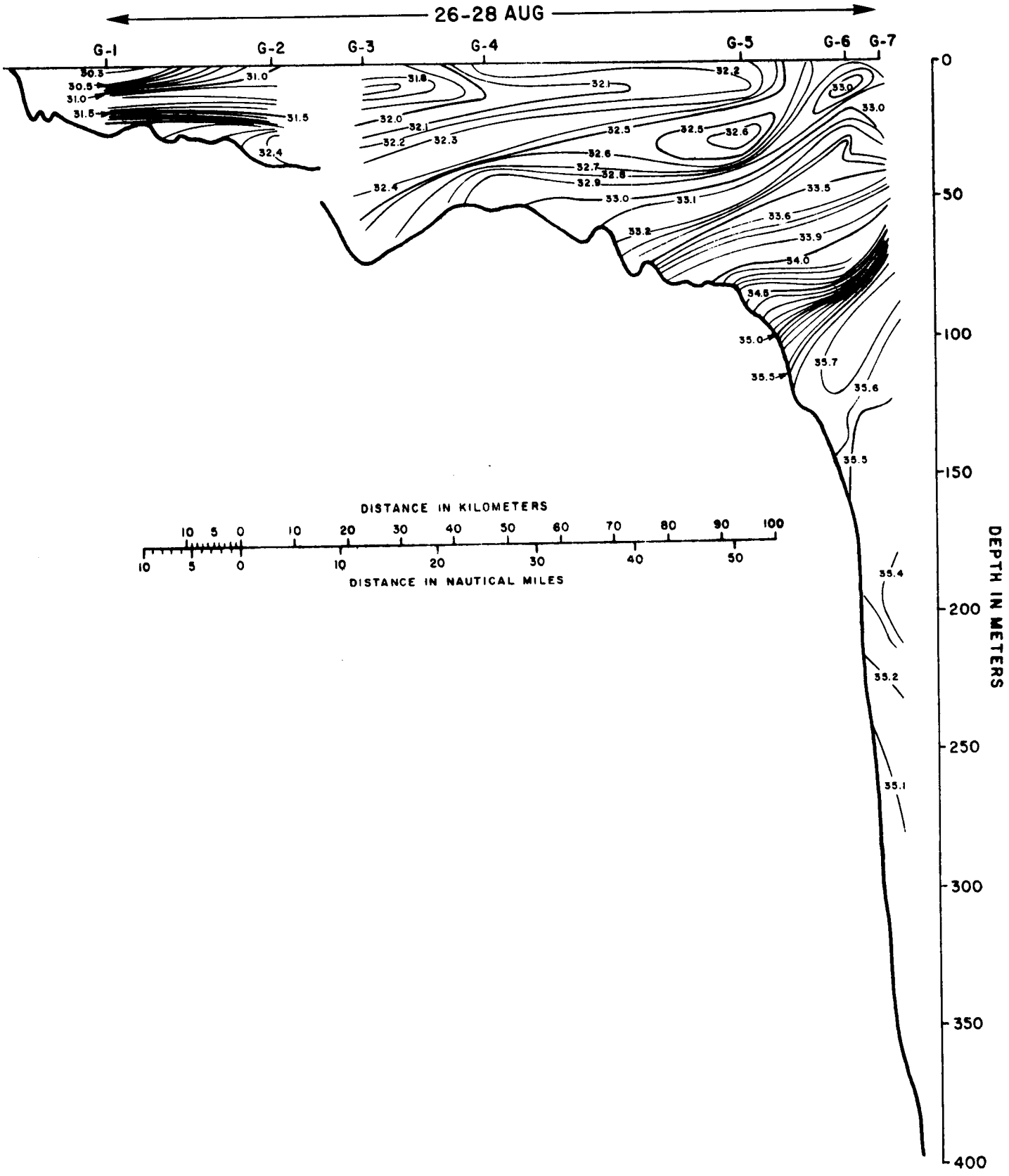

Figure 3-136. Salinity (ppt) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

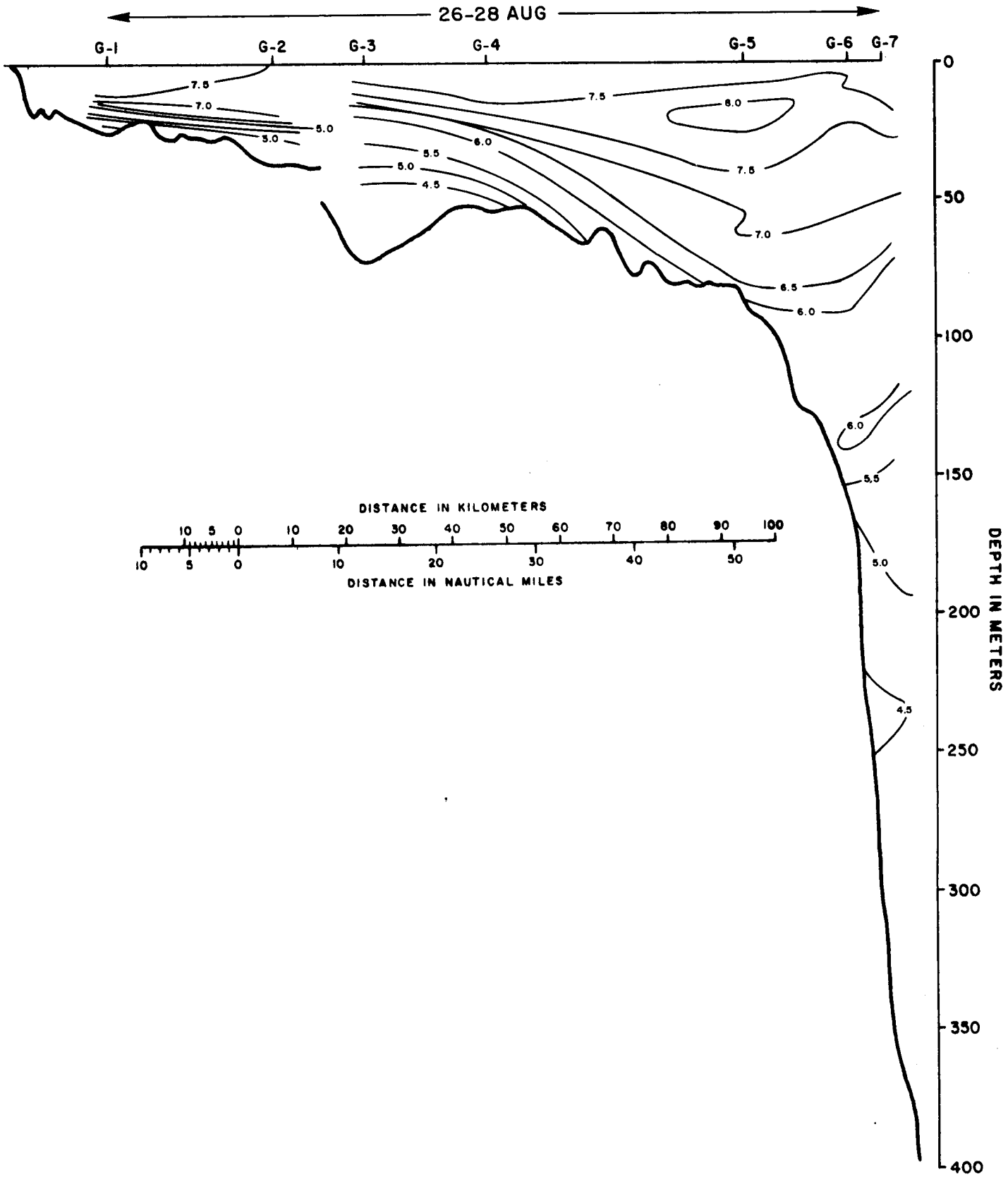

Figure 3-137. Dissolved oxygen (mg/l) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLMØ4B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

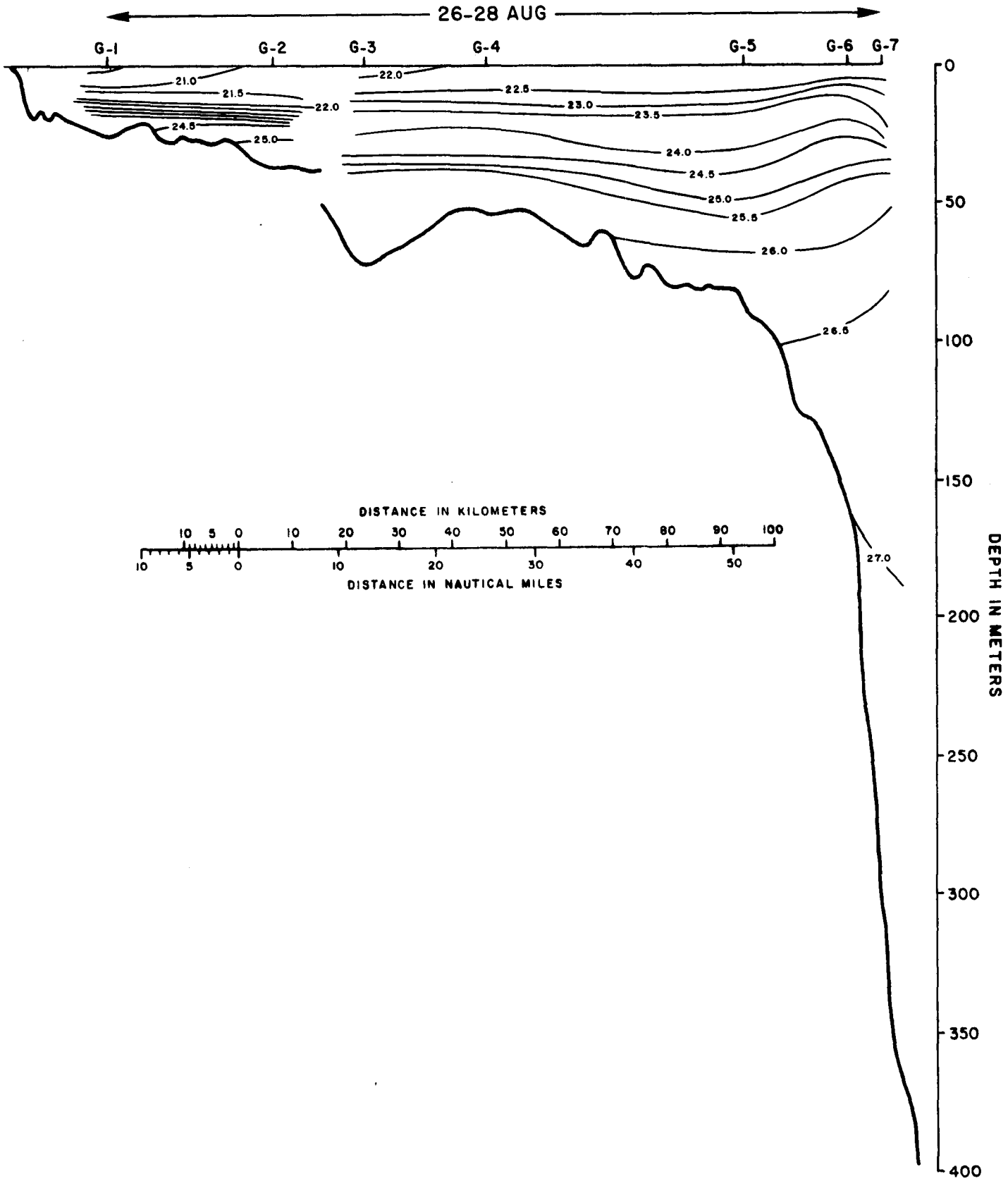

Figure 3-138. Density (σ_t units) along Section I (Stations G1 to G7, 26-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10. Breaks in isopleths signify spatial breaks in sampling continuity.

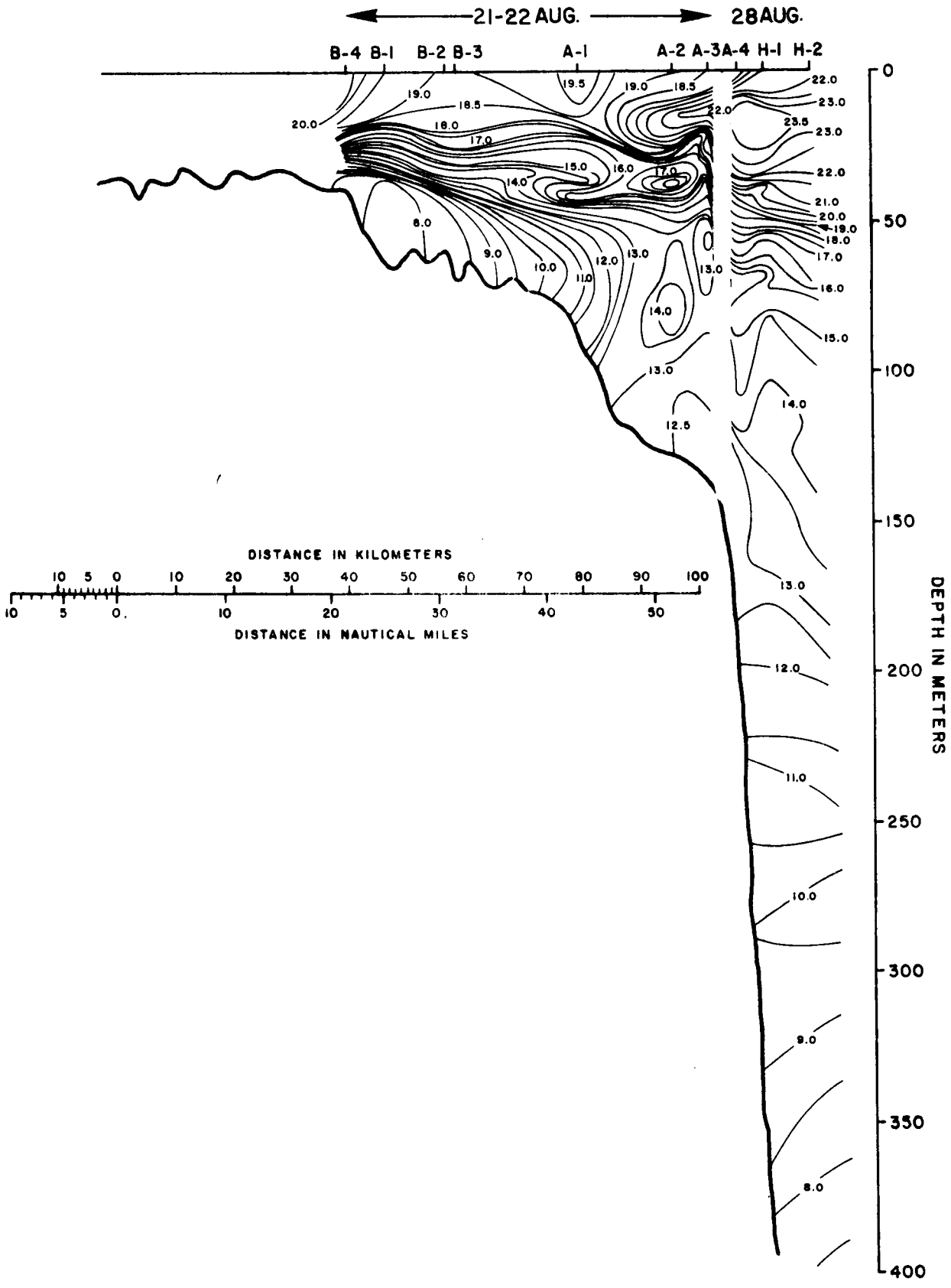

Figure 3-139. Temperature (^{o}C) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

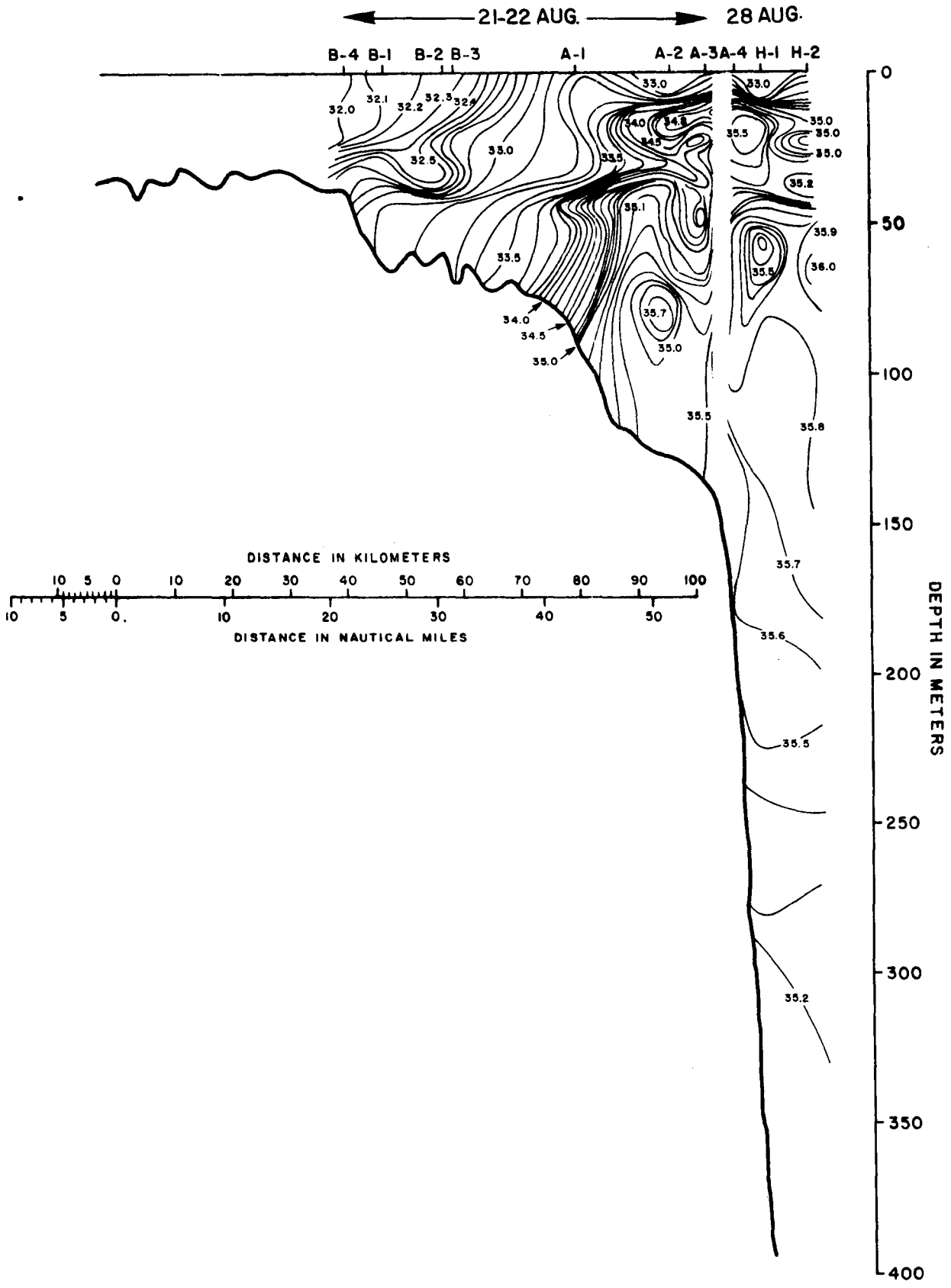

Figure 3-140. Salinity (ppt) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

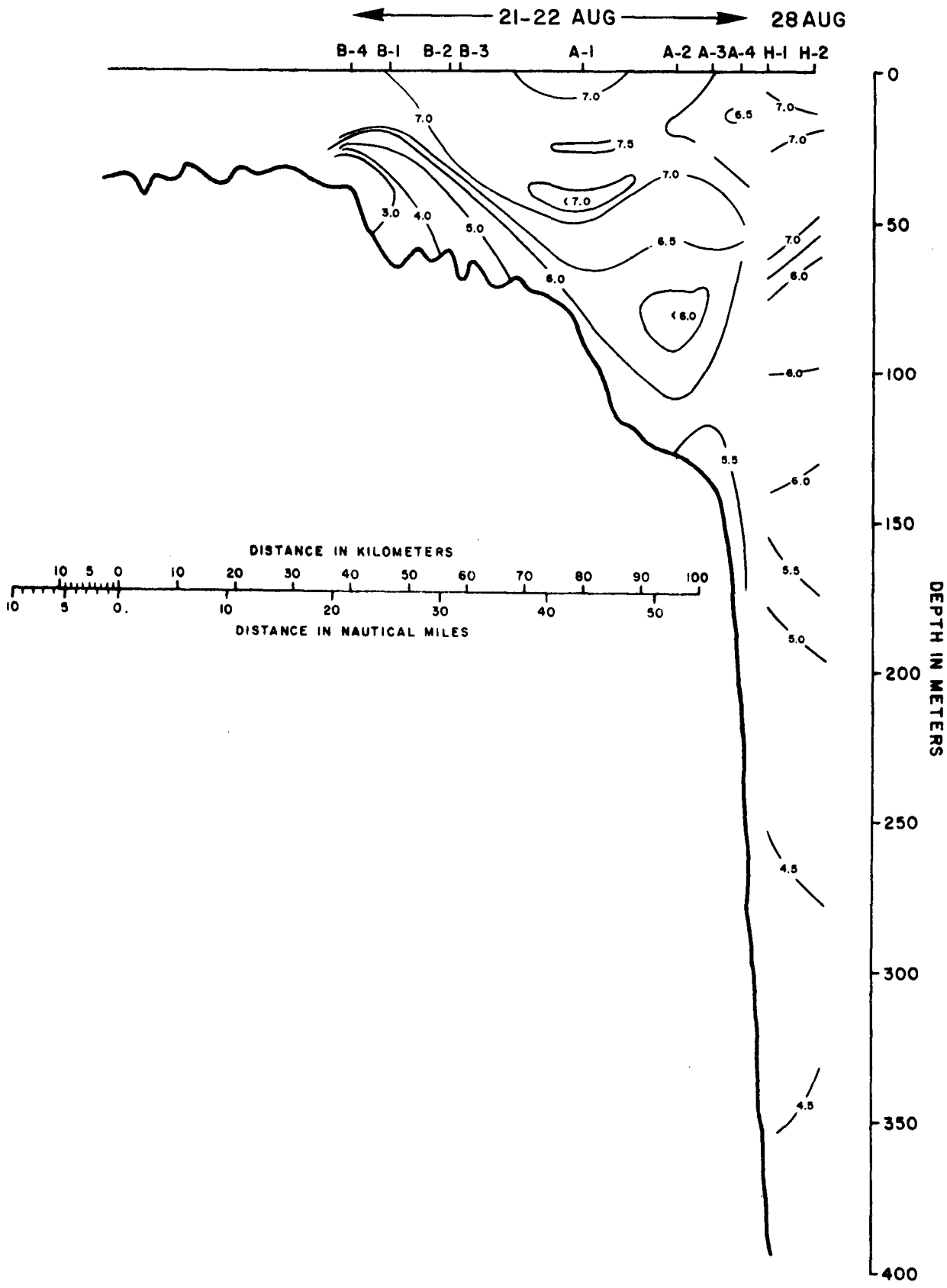

Figure 3-141. Dissolved oxygen (mg/l) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

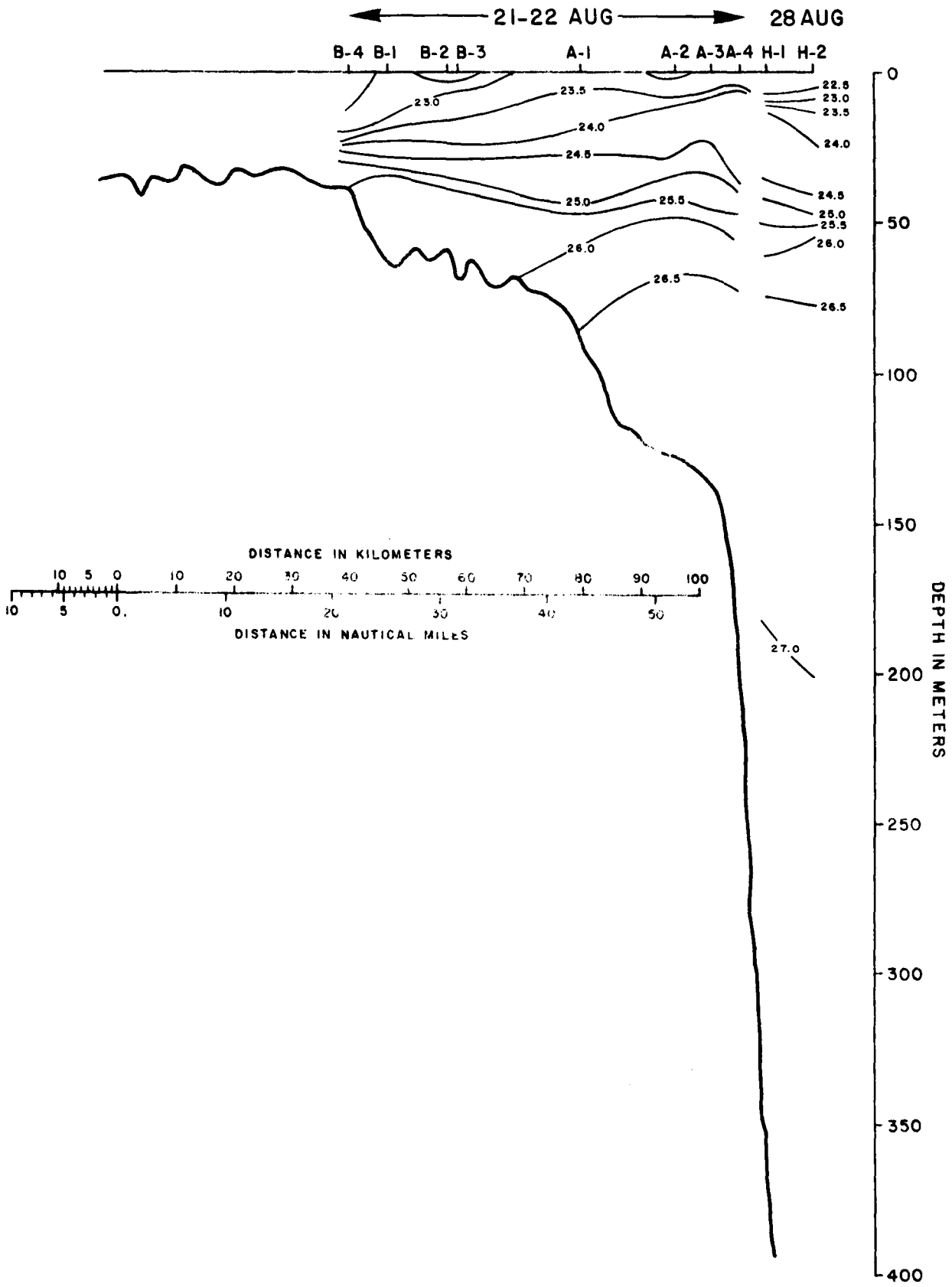

Figure 3-142. Density (σ_t units) along Section II (Stations B4 to H2, 21-28 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

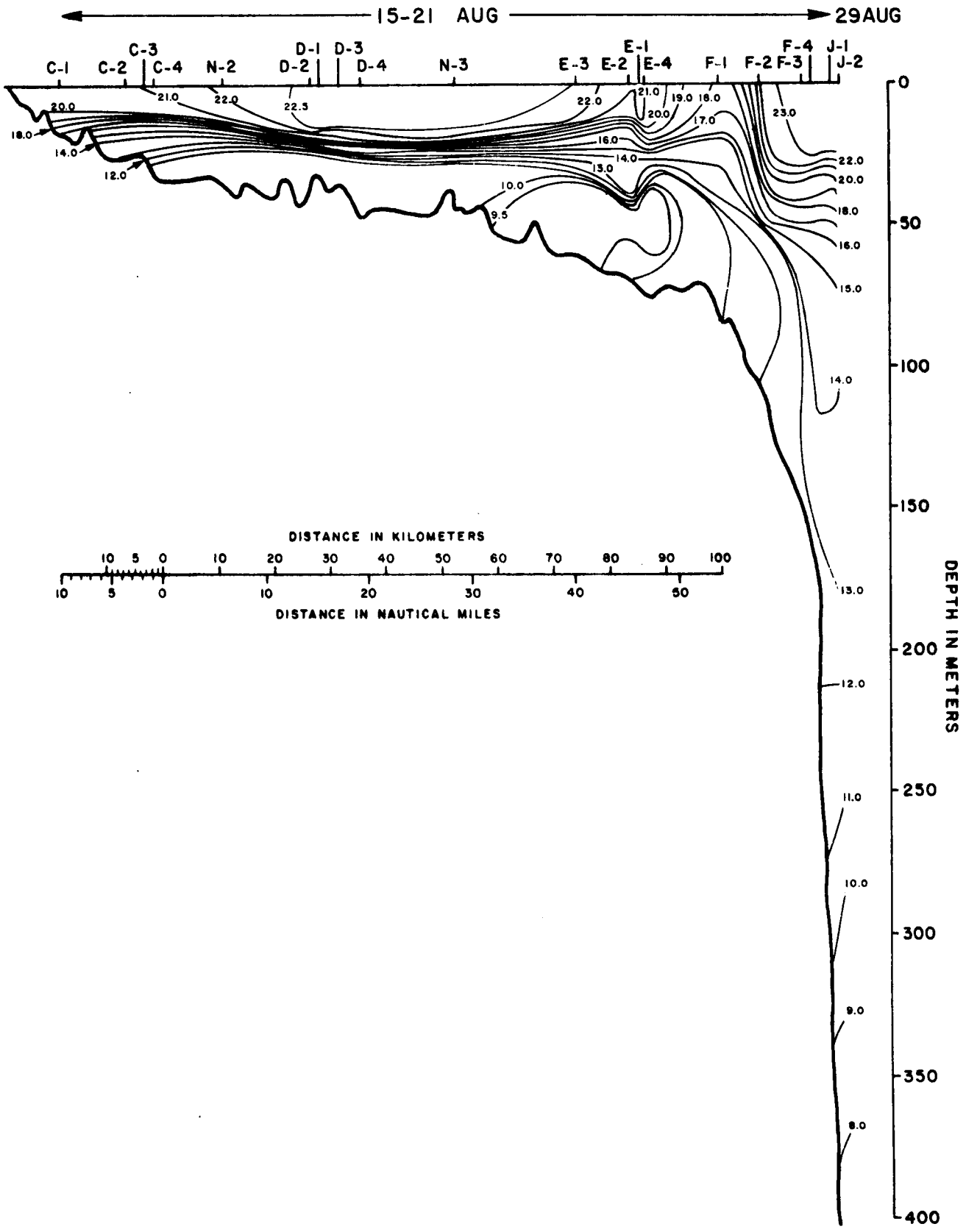

Figure 3-143. Temperature (^{o}C) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLMϕ4B. Section location is shown in Figure 3-10.

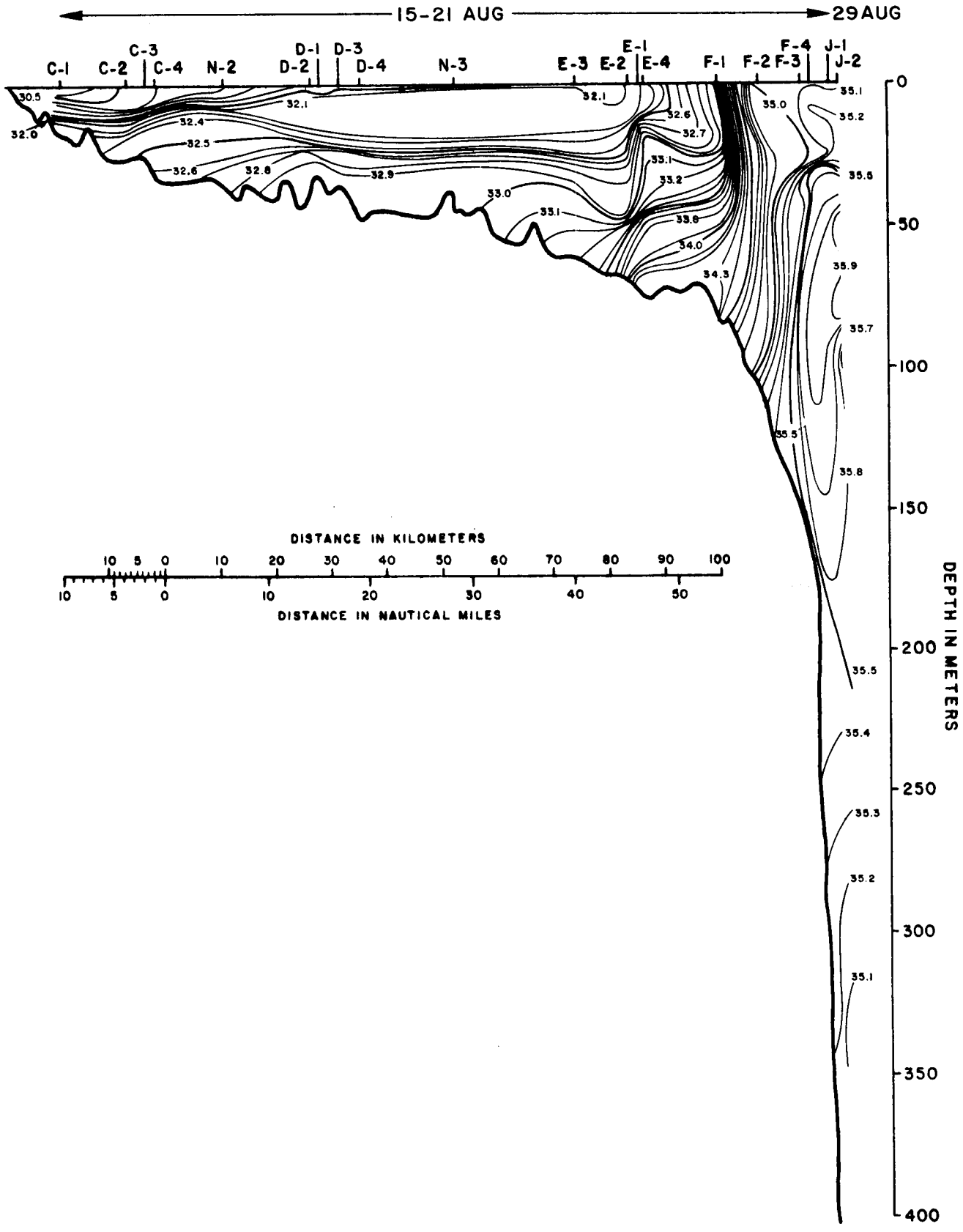

Figure 3-144. Salinity (ppt) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

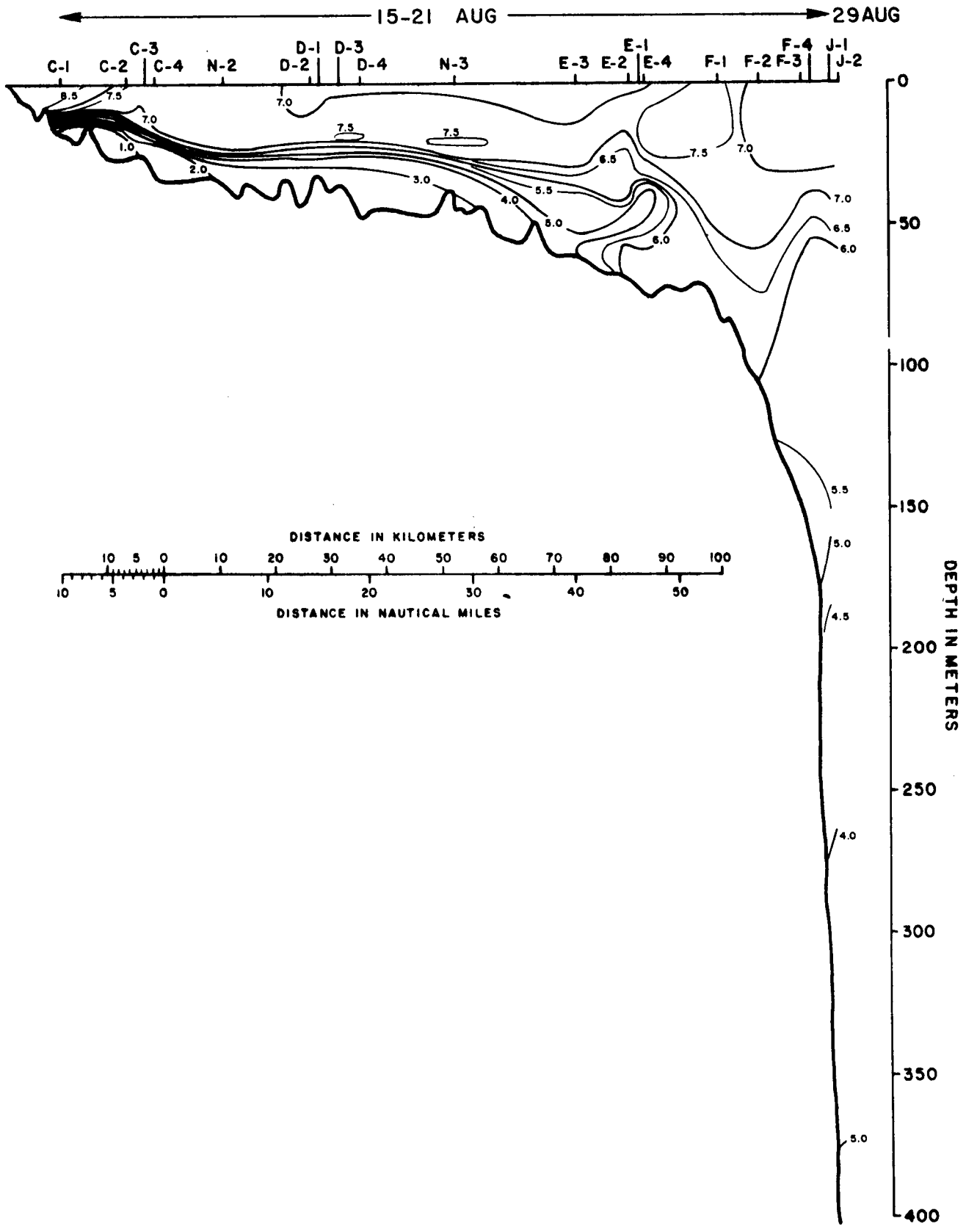

Figure 3-145. Dissolved oxygen (mg/1) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

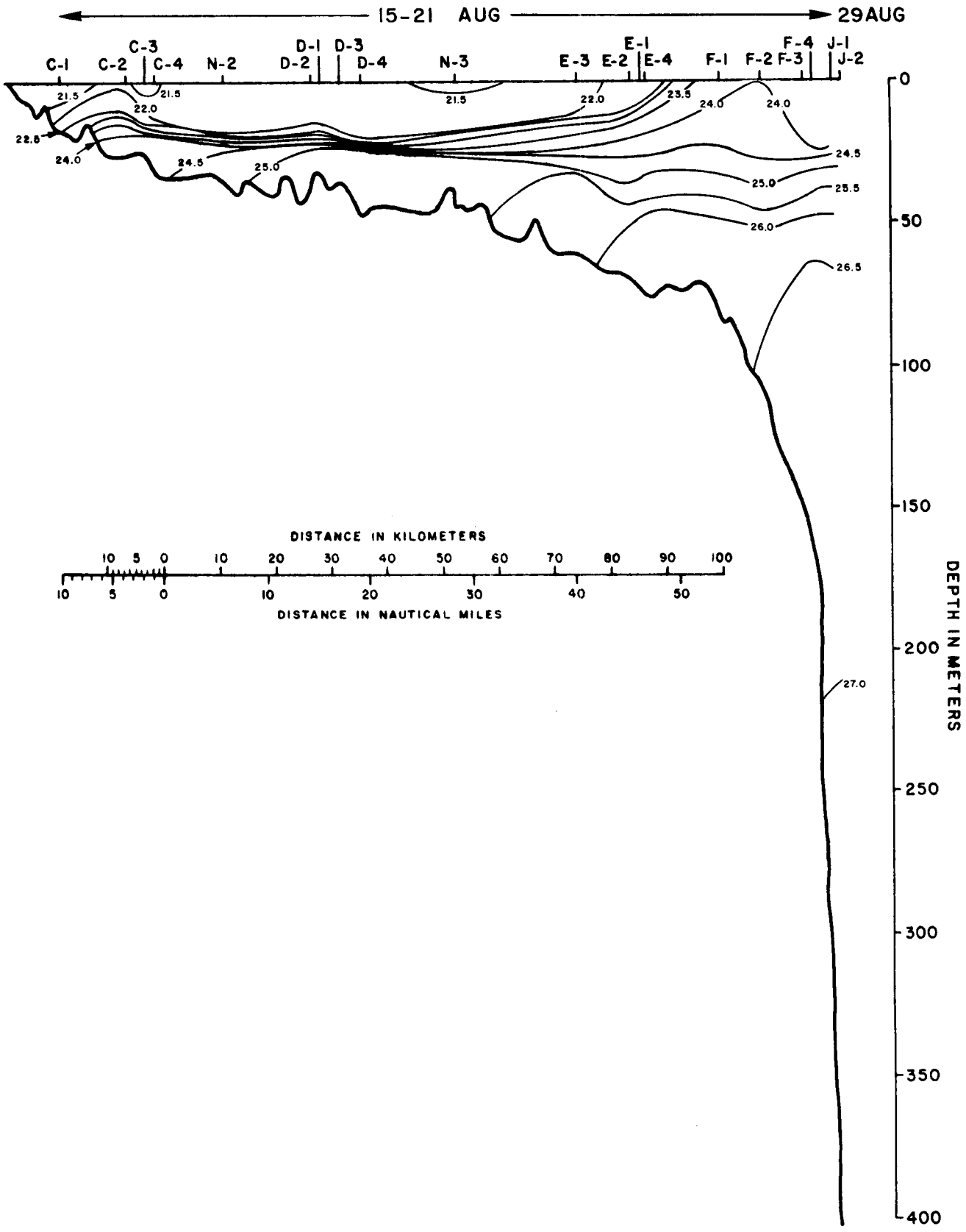

Figure 3-146. Density (σ_t units) along Section III (Stations C1 to J2, 15-29 August 1976) during cruise BLMØ4B. Section location is whosn in Figure 3-10.

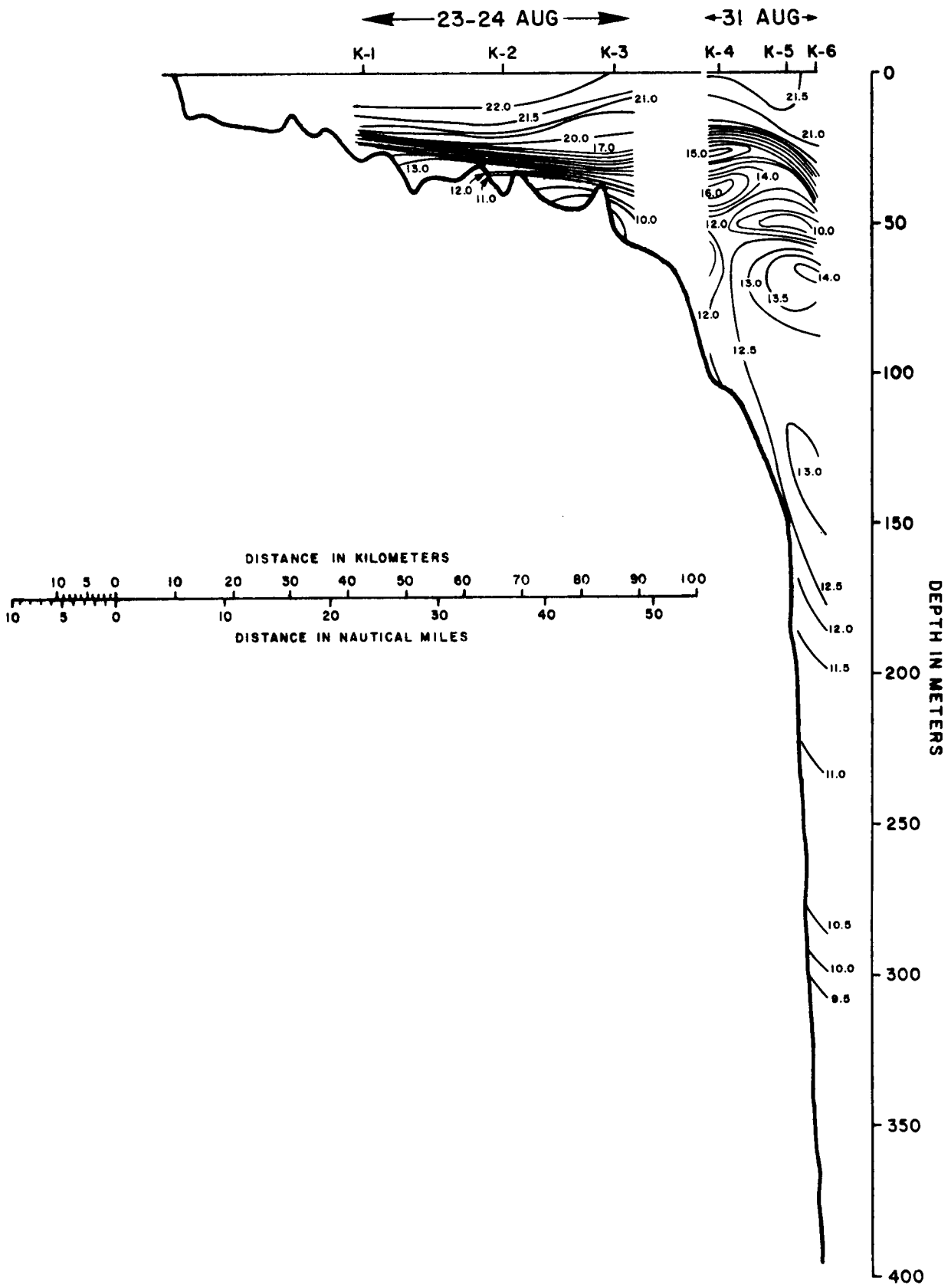

Figure 3-147. Temperature (^{o}C) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLMØ4B. Section location is shown in Figure 3-10.

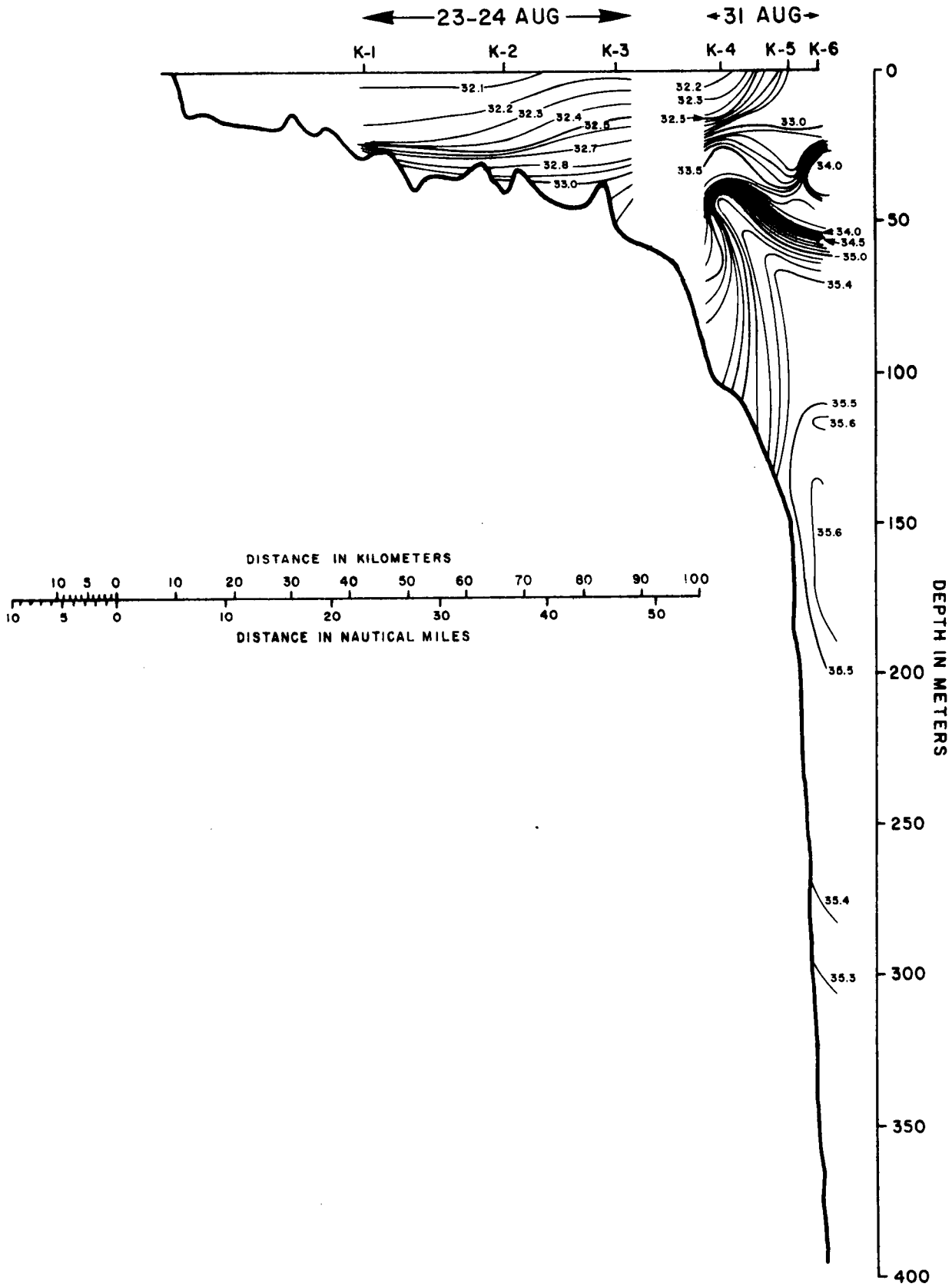

Figure 3-148. Salinity (ppt) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLMØ4B. Section location is shown in Figure 3-10.

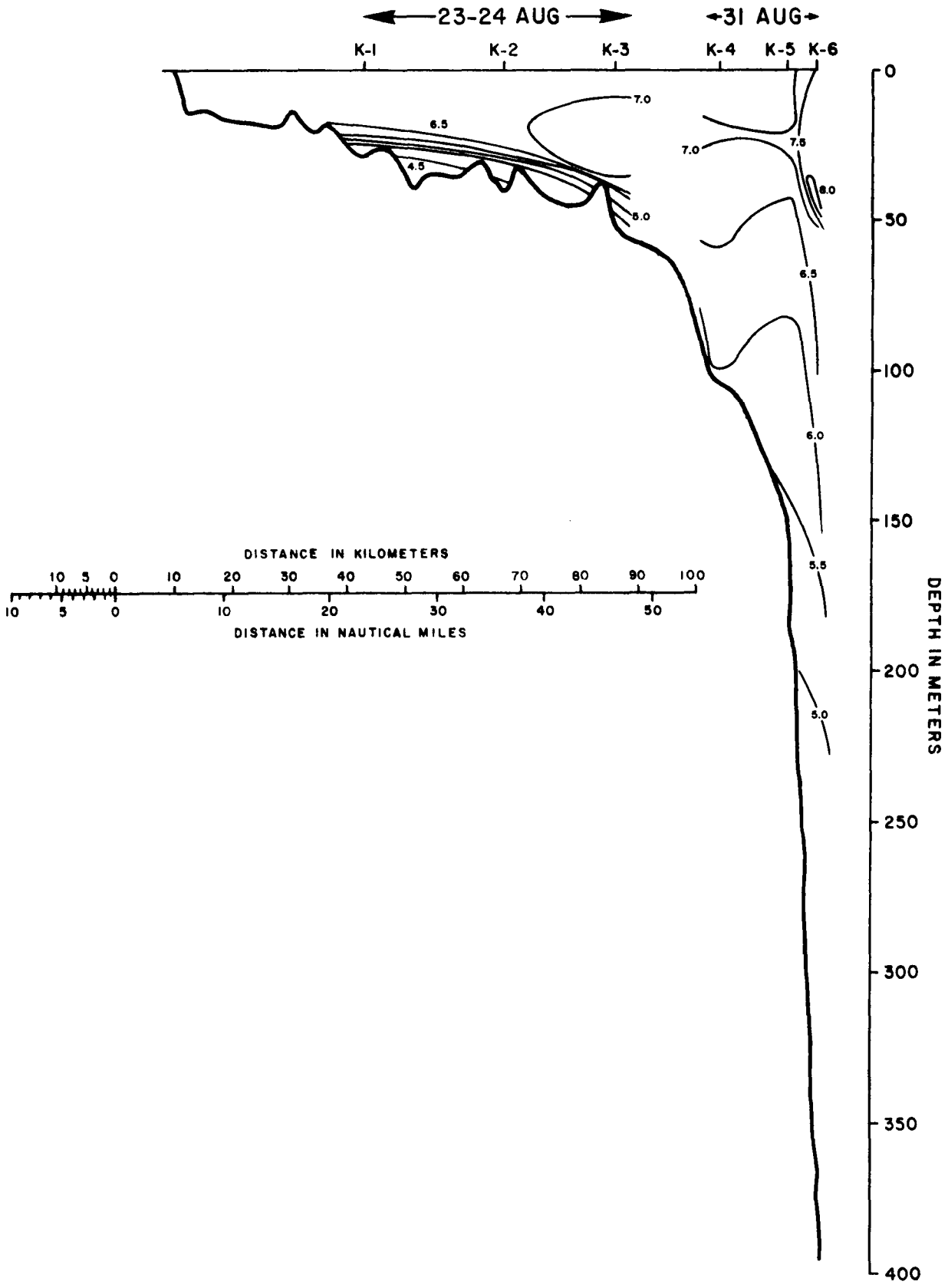

Figure 3-149. Dissolved oxygen (mg/l) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

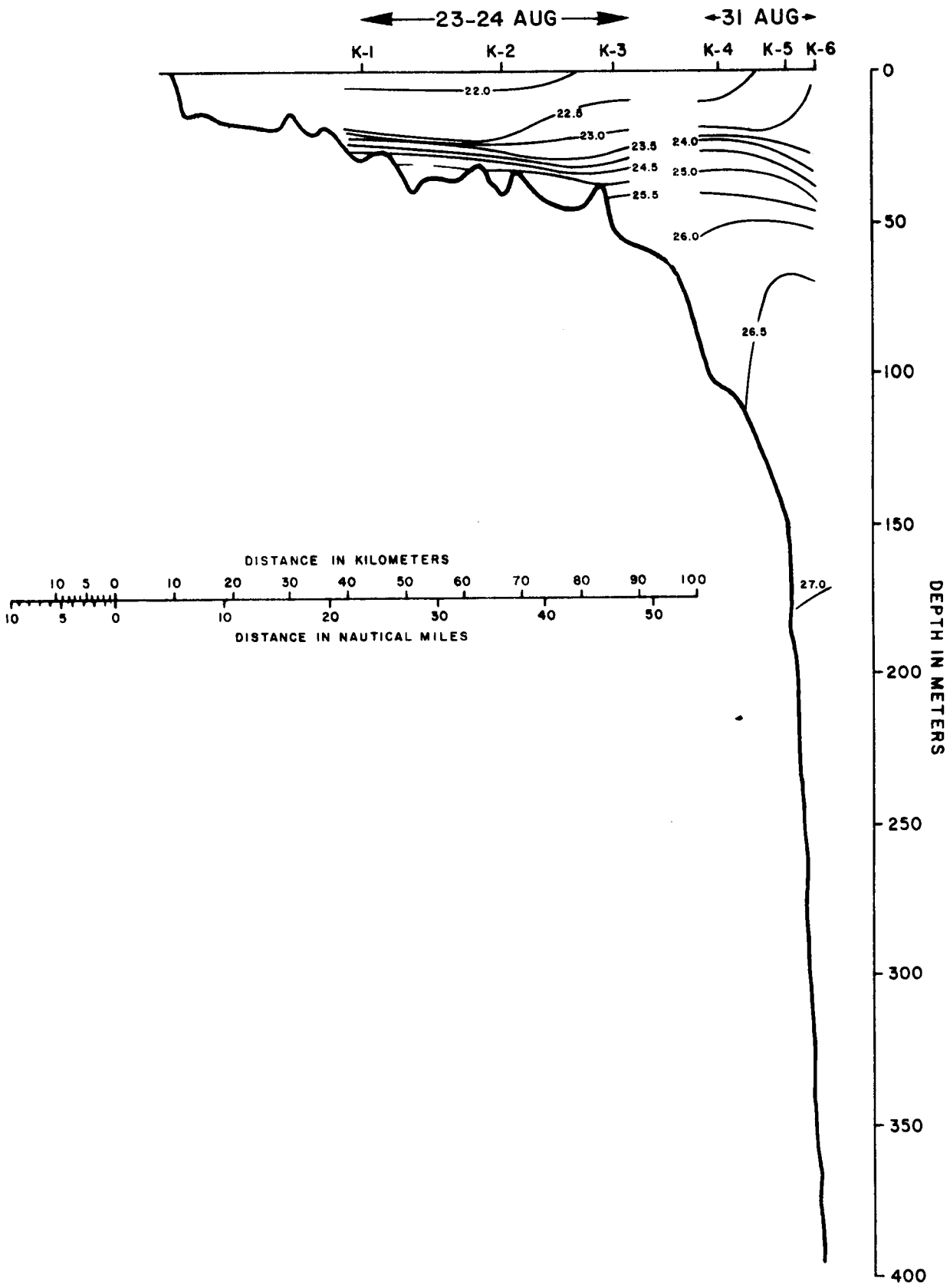

Figure 3-150. Density (σ_t units) along Section IV (Stations K1 to K6, 23-31 August 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

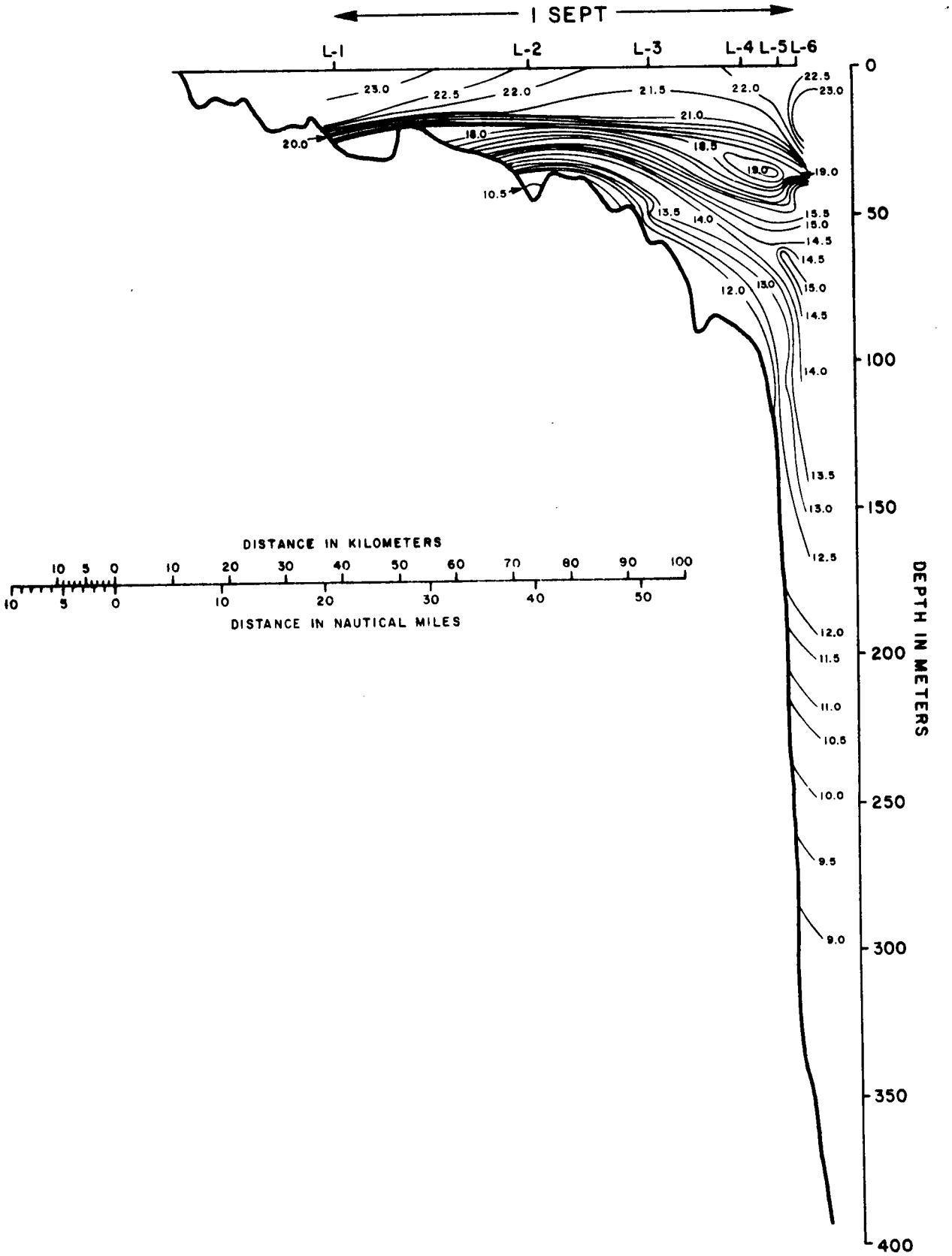

Figure 3-151. Temperature (^{o}C) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

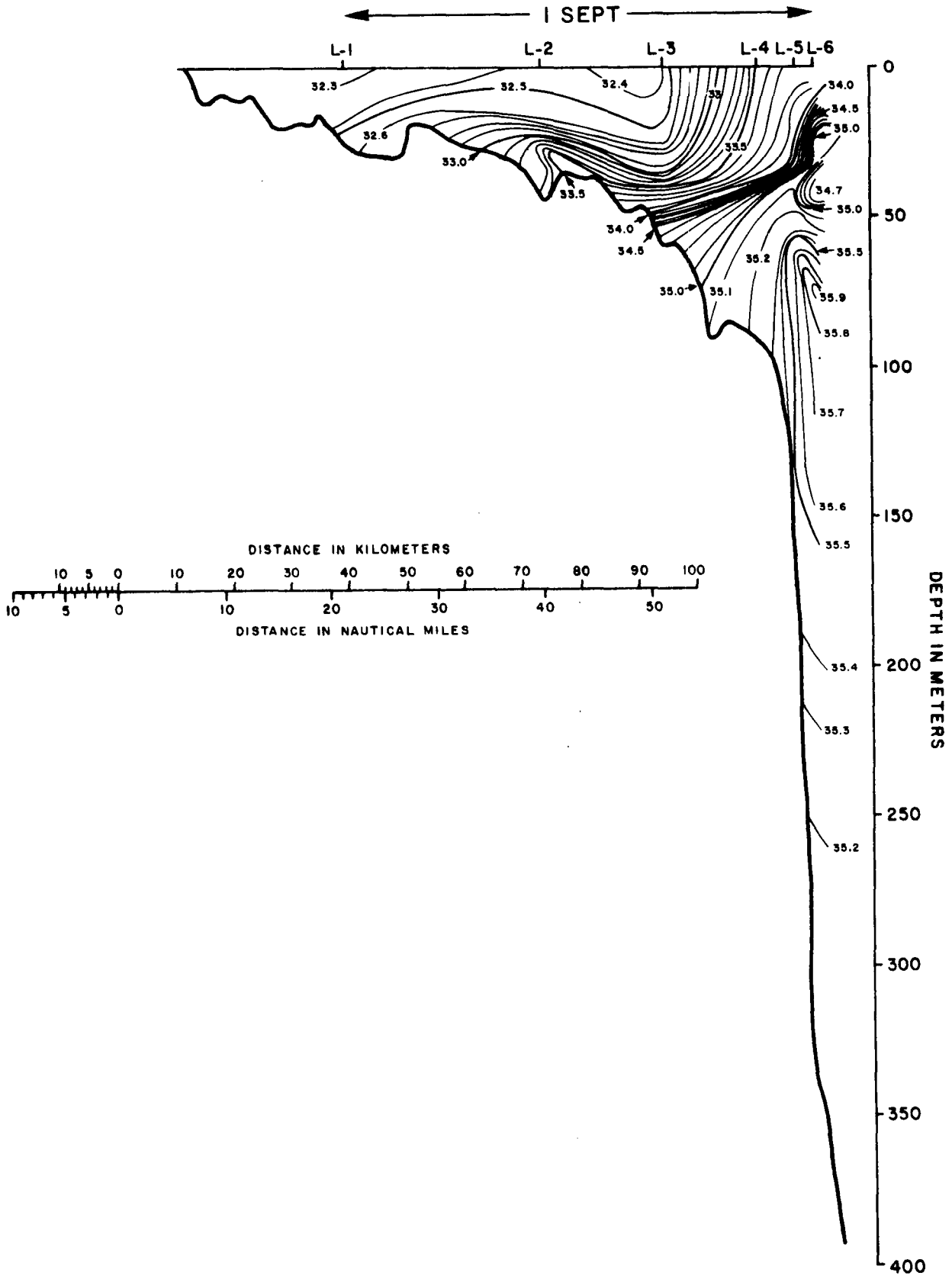

Figure 3-152. Salinity (ppt) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

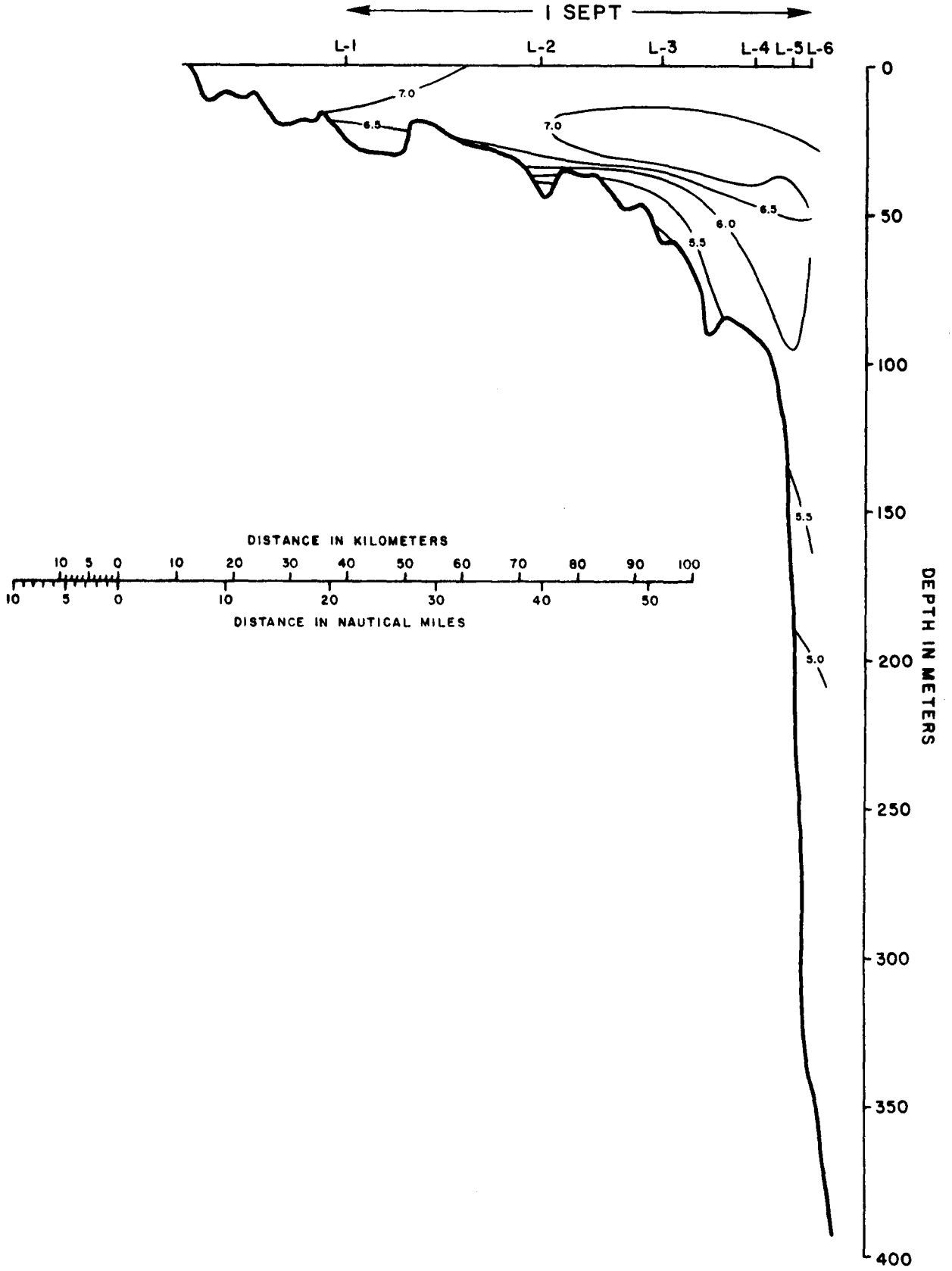

Figure 3-153. Dissolved oxygen (mg/l) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLM04B. Section location is shown in Figure 3-10.

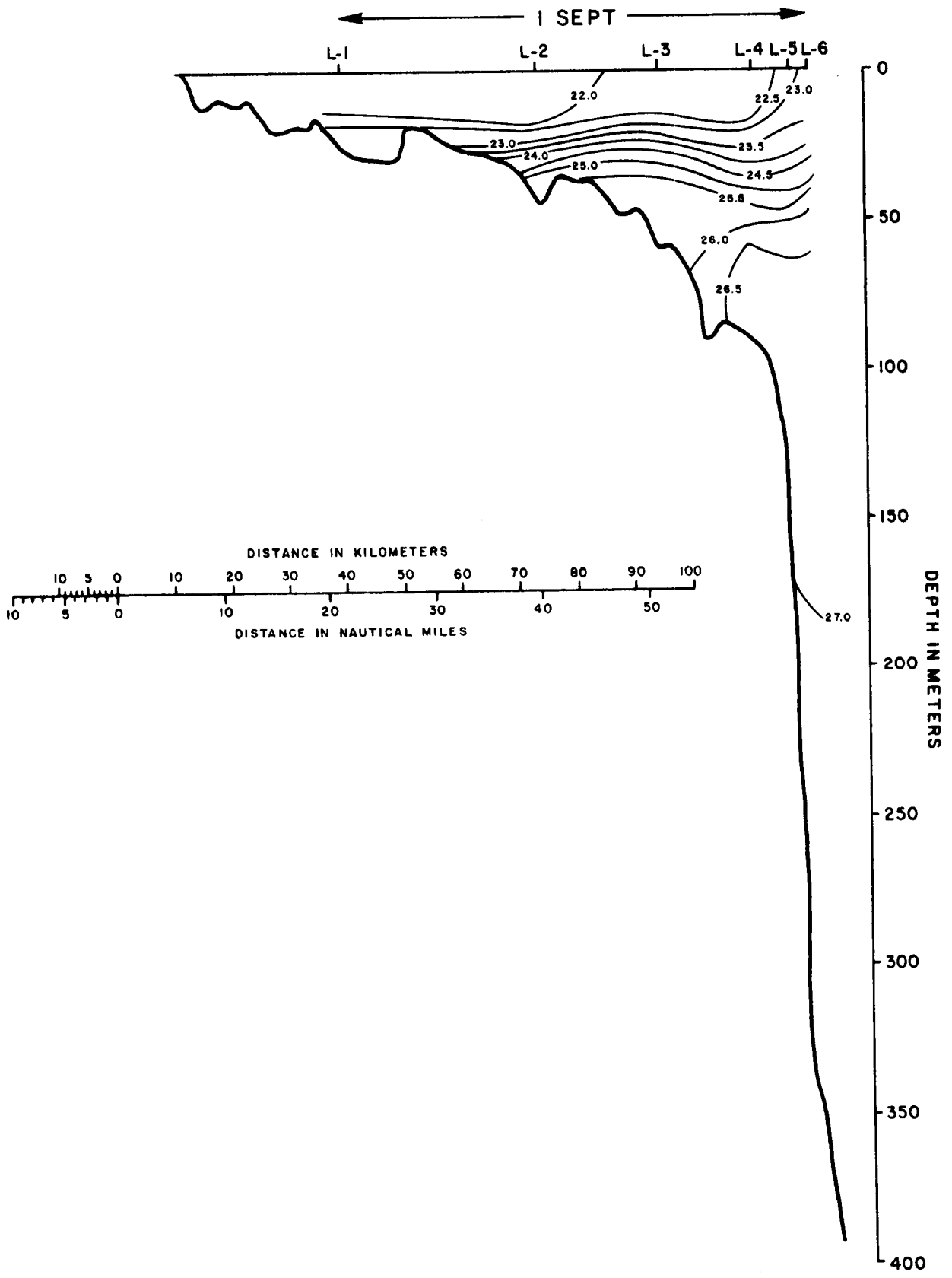

Figure 3-154 . Density (σ_t units) along Section V (Stations L1 to L6, 1 September 1976) during cruise BLMØ4B. Section location is shown in Figure 3-10.

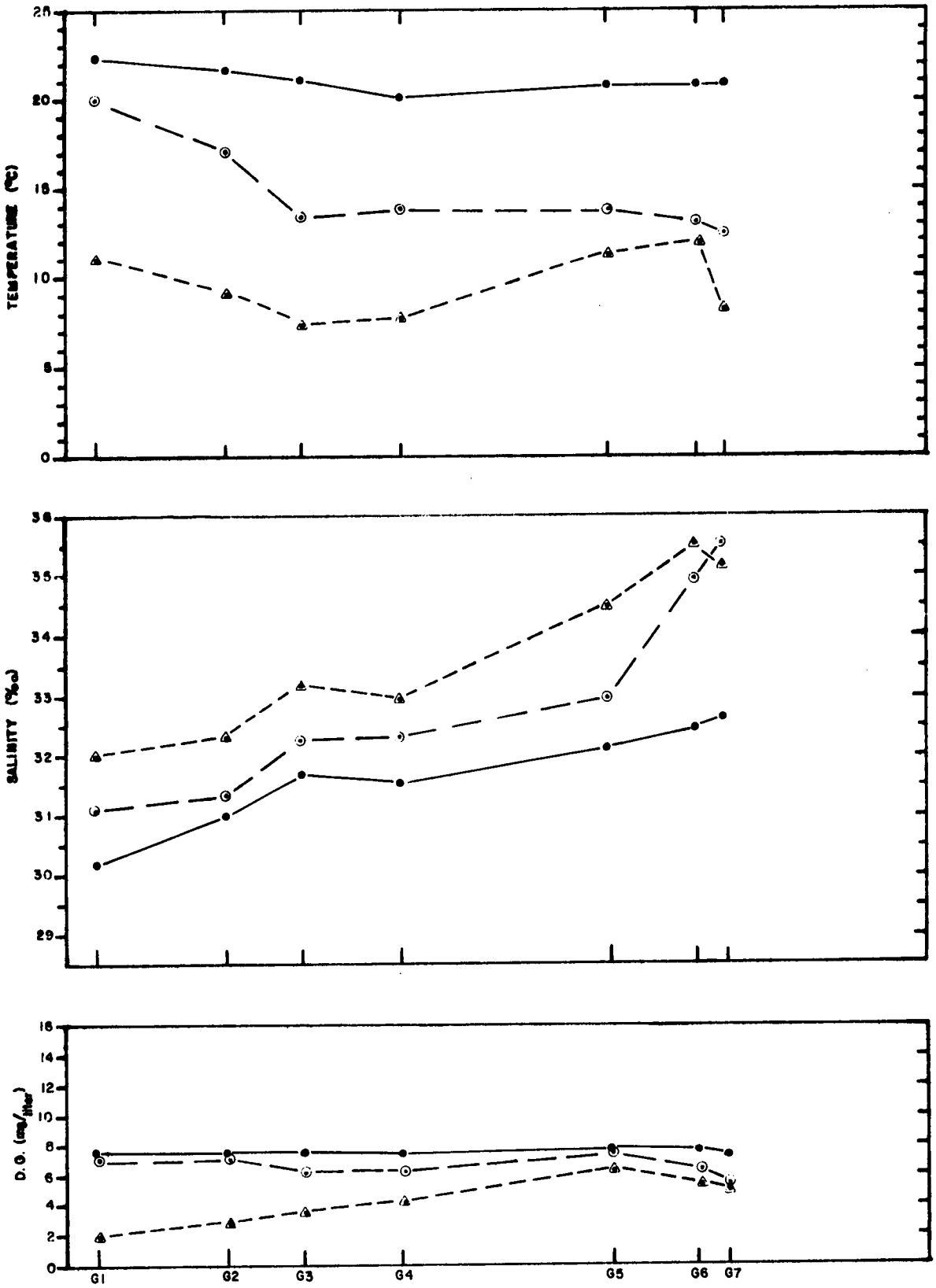

Figure 3-155. Surface (•), mid-depth (Θ) and bottom (▲) values of temperature, salinity and DO measured along Section I on cruise BLM Ø4B.

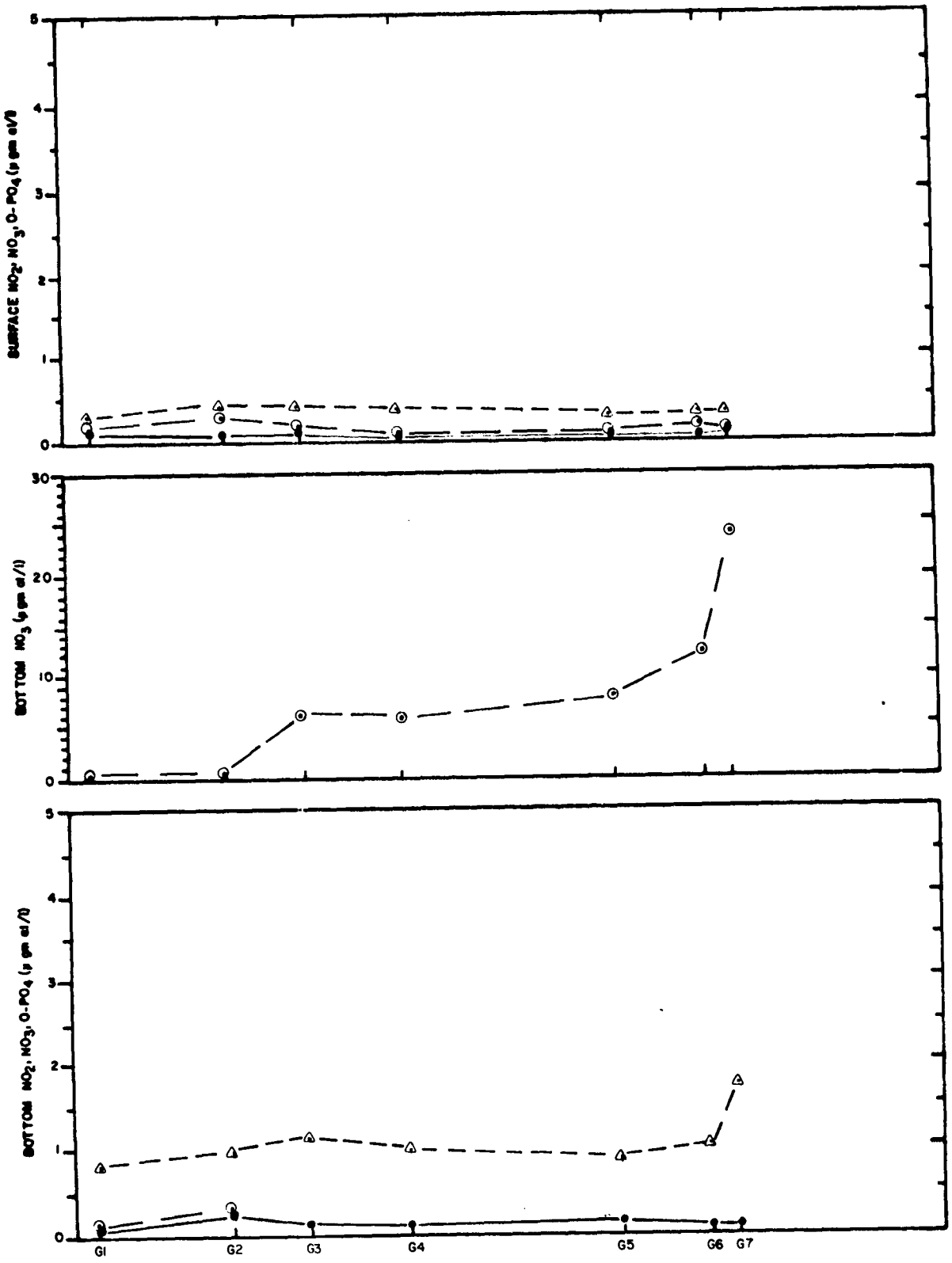

Figure 3-156. Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section I during Cruise BLM 04B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

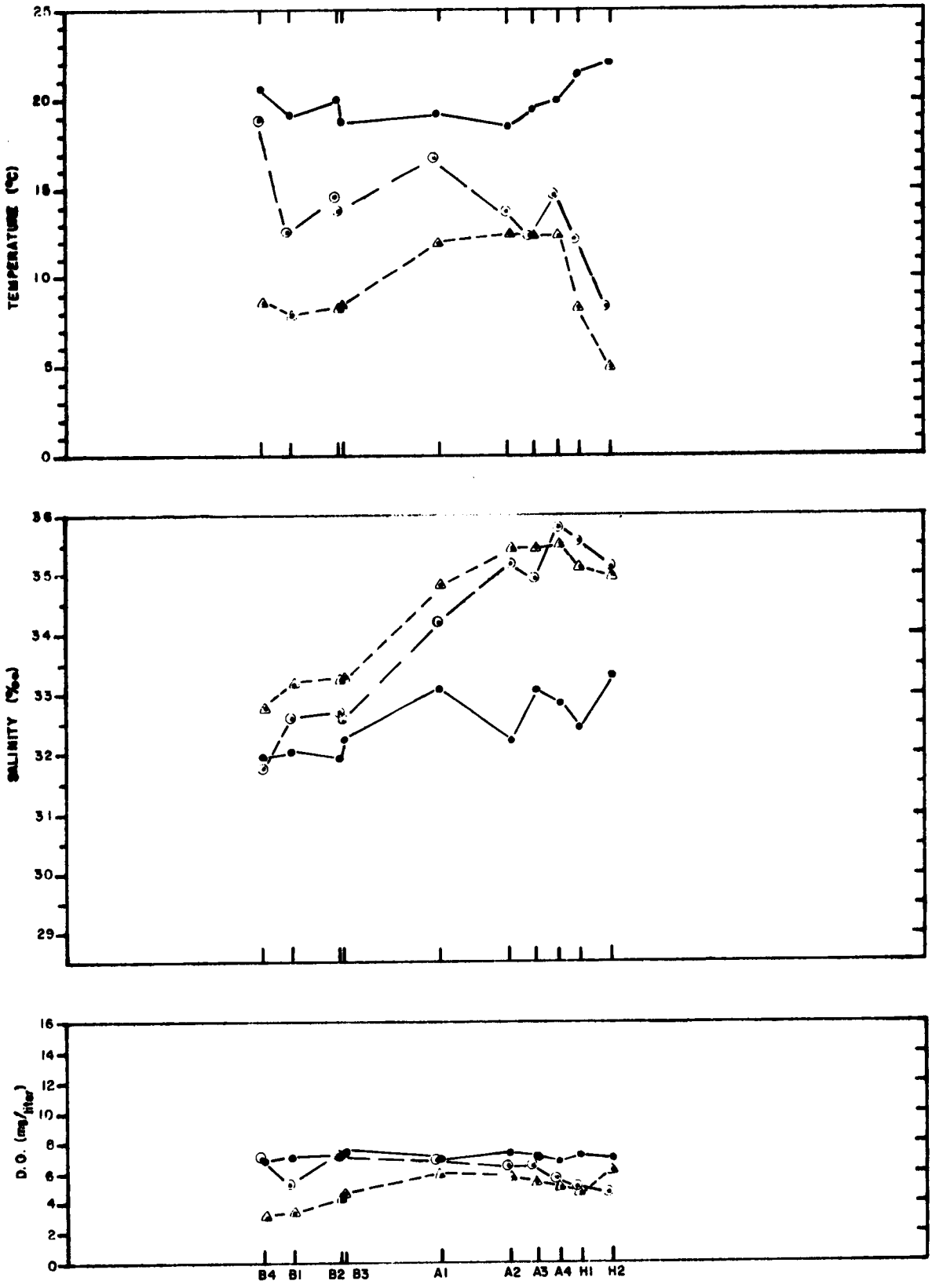

Figure 3-157. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Section II on cruise BLM Ø4B.

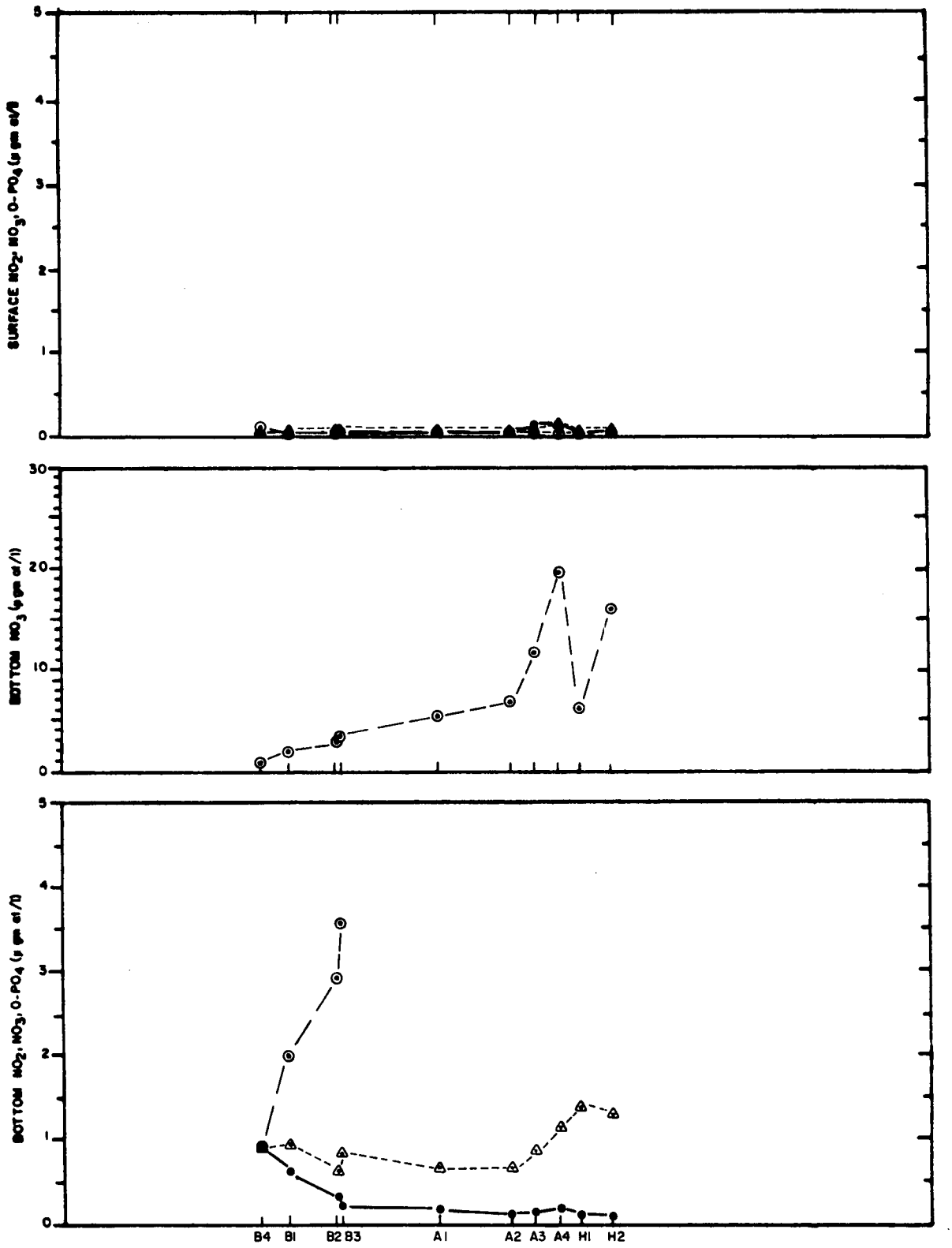

Figure 3-158. Concentrations of dissolved NO_2 (•), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Section II during Cruise BLM 04B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

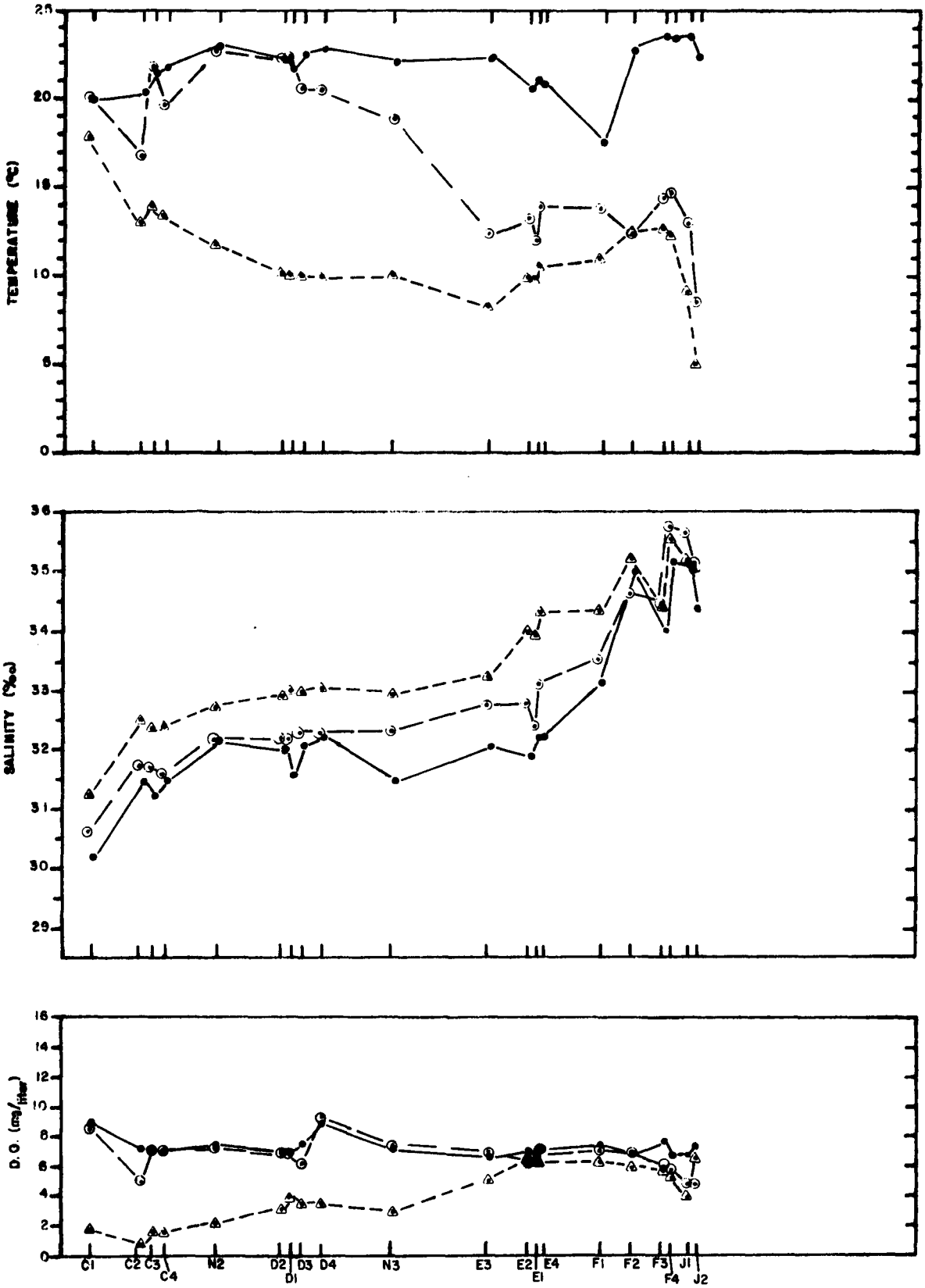

Figure 3-159. Surface (•), mid-depth (0) and bottom (▲) values of temperature, salinity and DO measured along Section III on cruise BLM Ø4B.

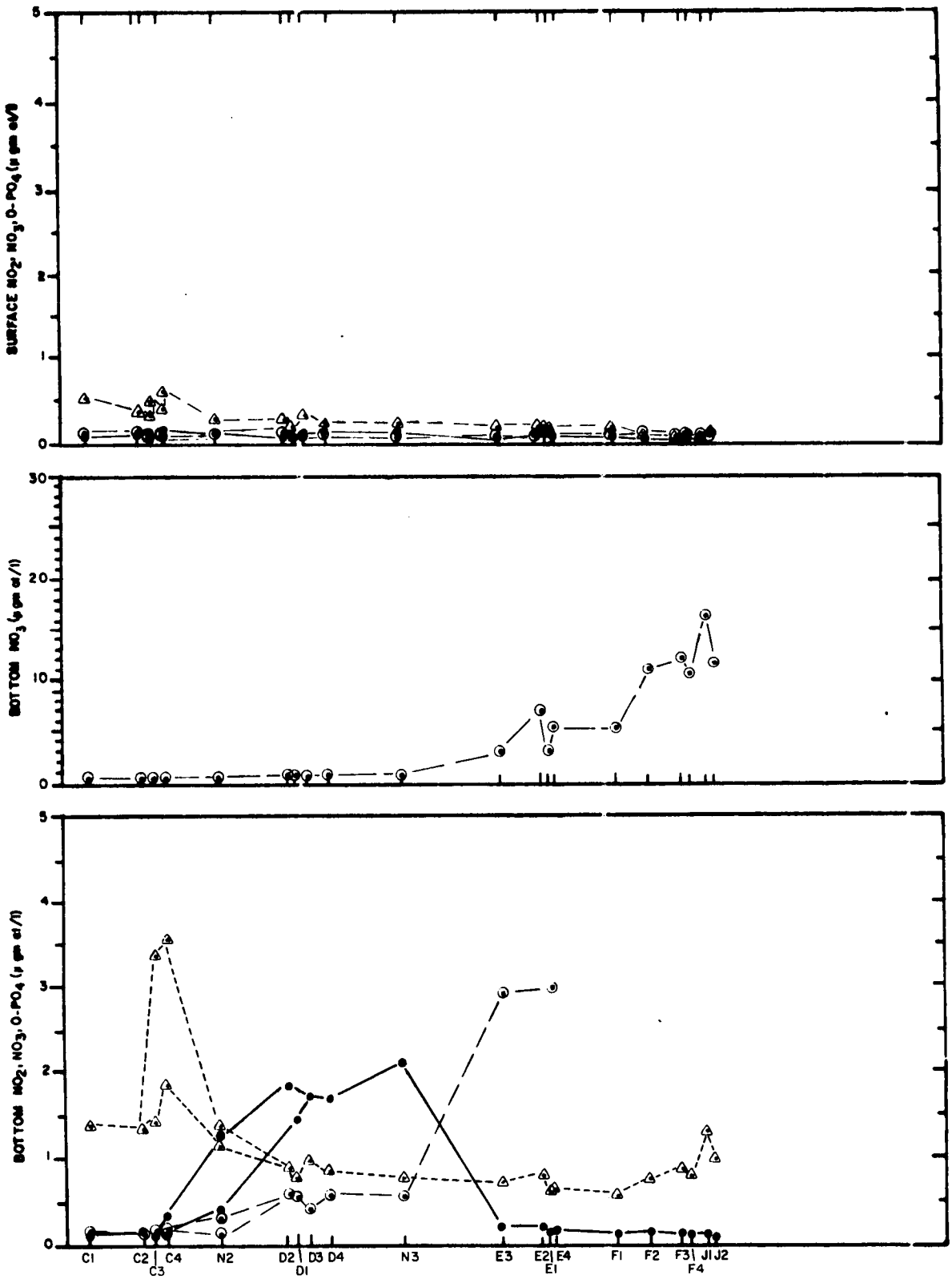

Figure 3-160. Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Section III during Cruise BLM ϕ4B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

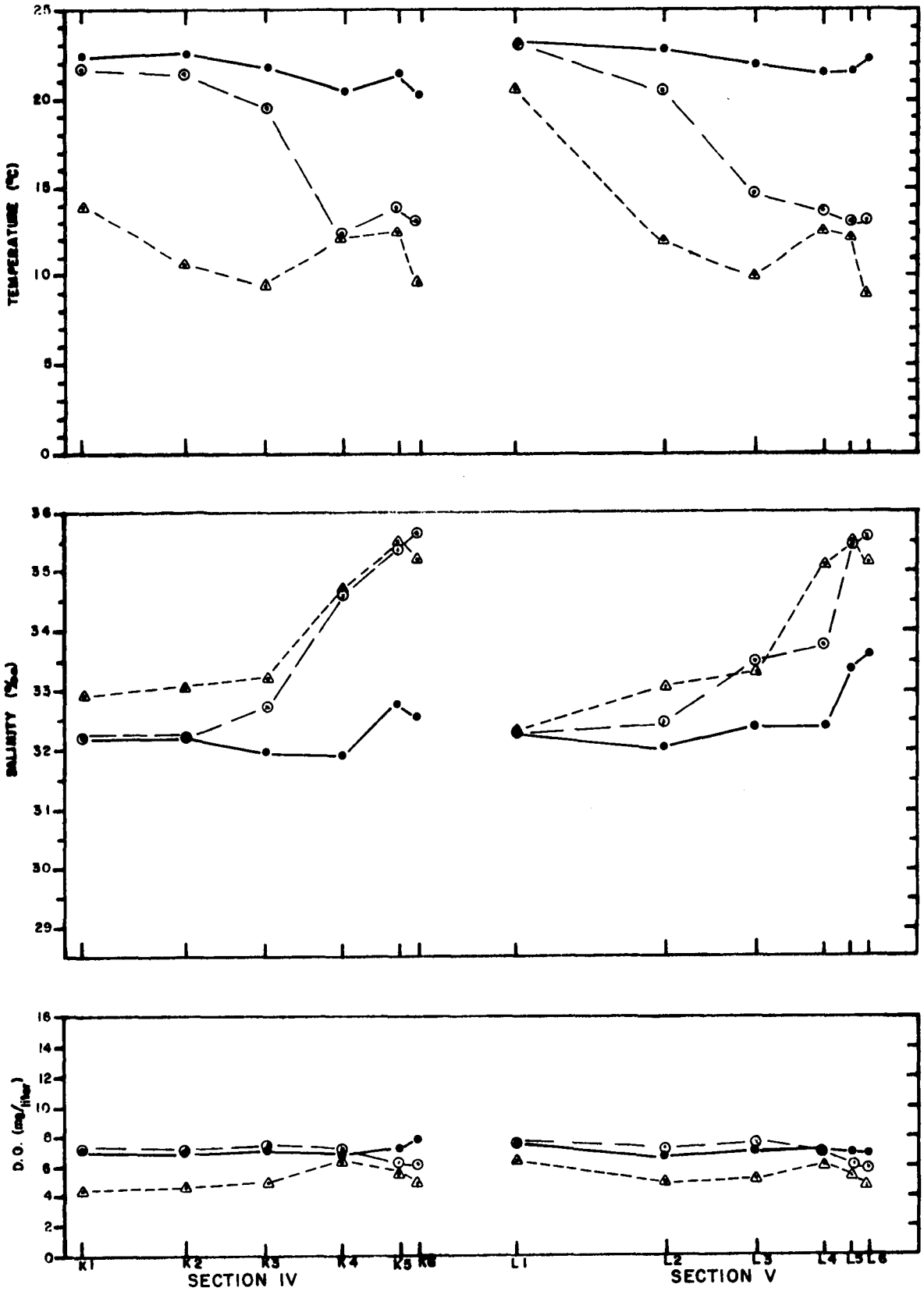

Figure 3-161. Surface (•), mid-depth (⊙) and bottom (△) values of temperature, salinity and DO measured along Sections IV and V during cruise BLM Ø4B.

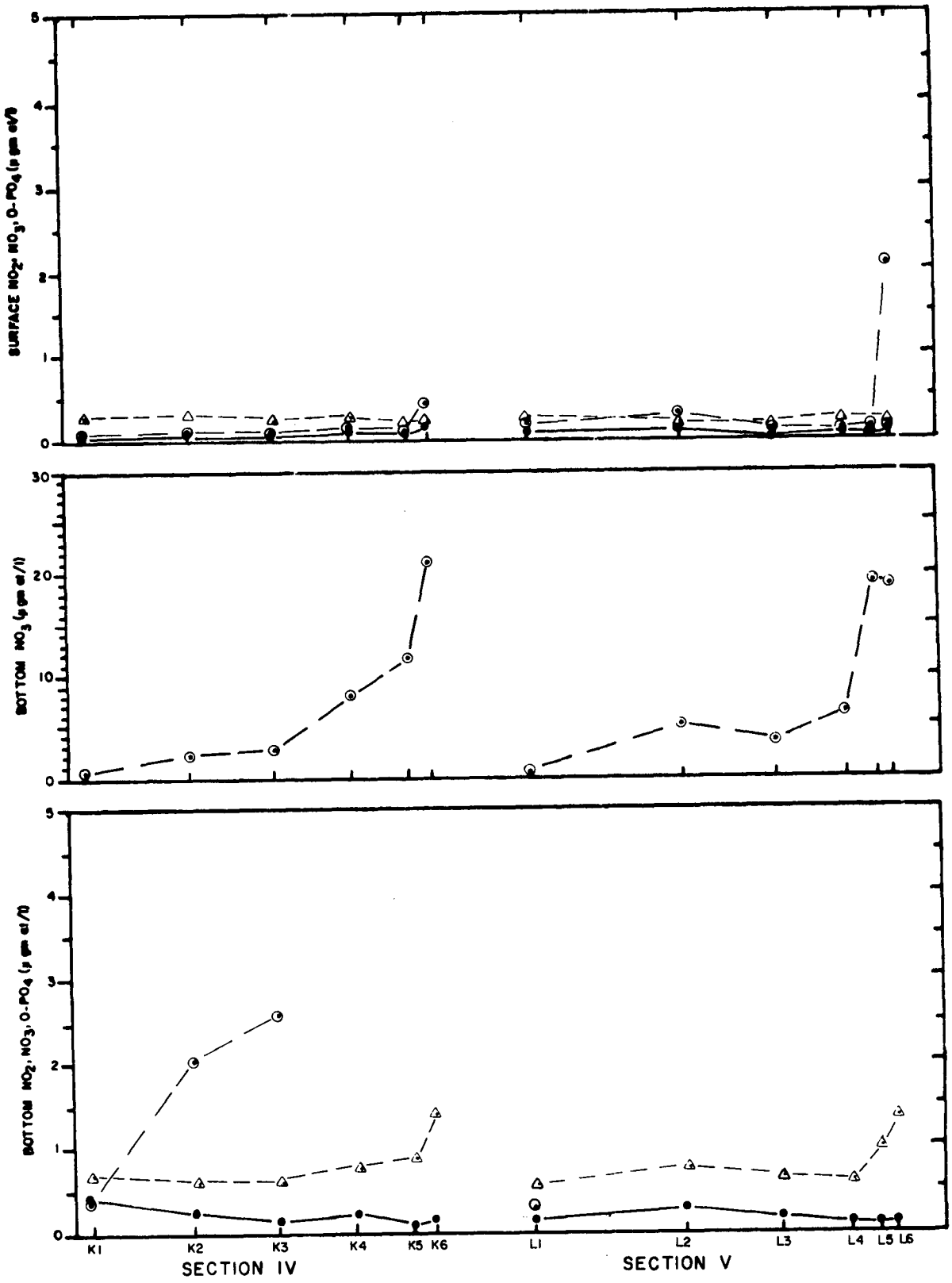

Figure 3-162. Concentrations of dissolved NO_2 (•), NO_3 (θ), and O-PO_4 (Δ) in near surface and near bottom waters along Sections IV & V during Cruise BLM Ø4B. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLM∅4W

Summer 1976

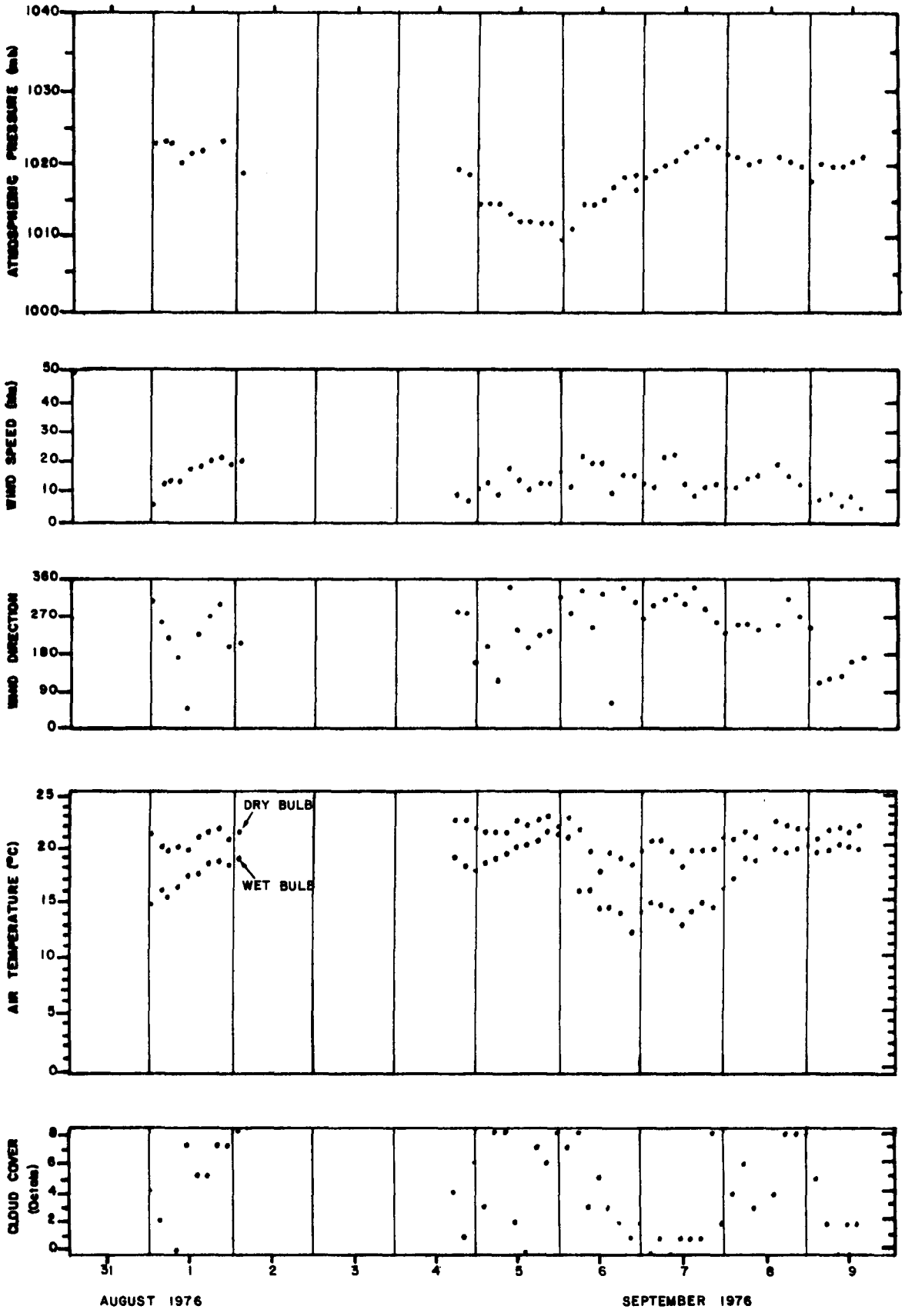

Figure 3-163. Meteorological data collected during cruise BLM Ø4W 31 August to 9 September 1976.

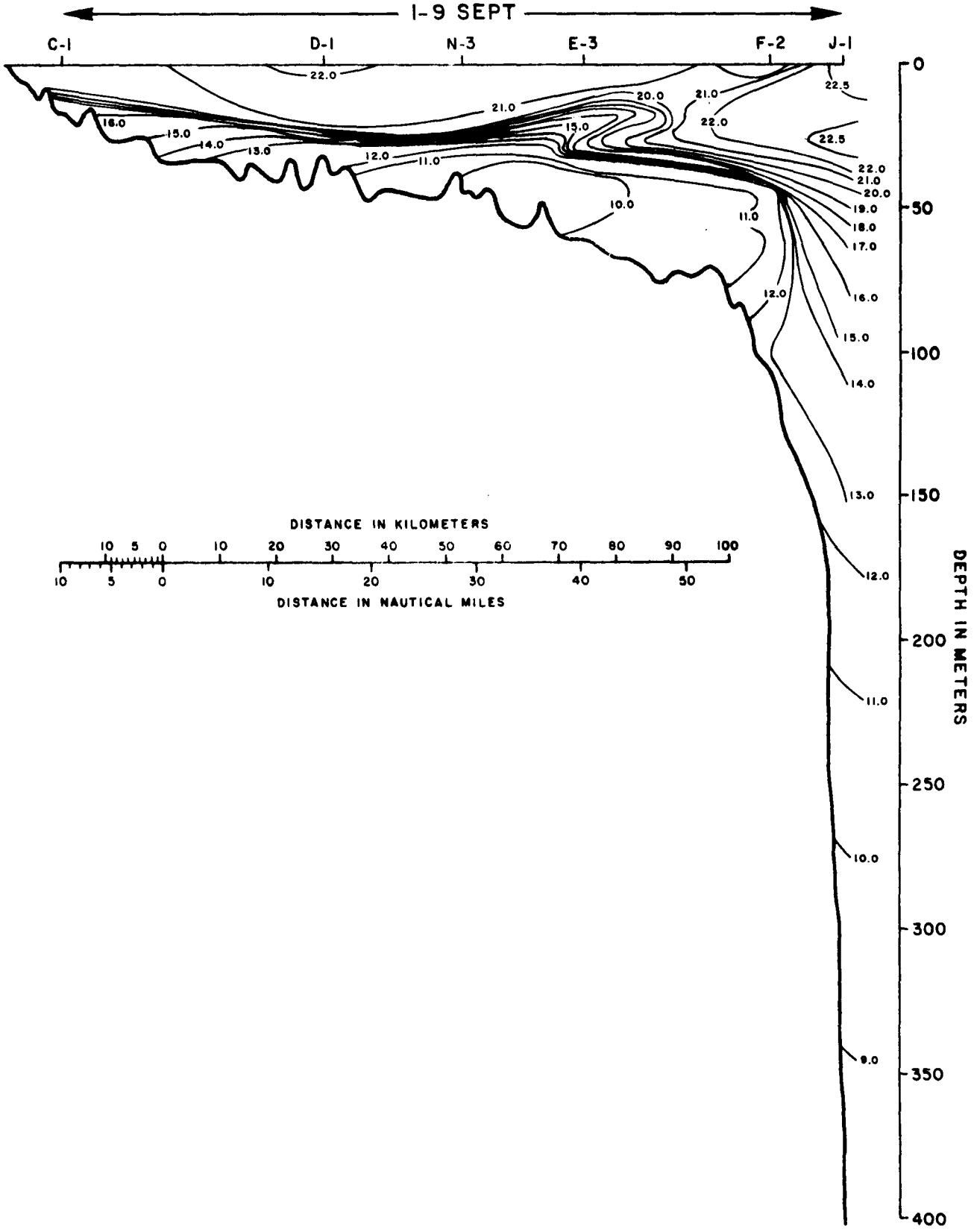

Figure 3-164. Temperature (^{o}C) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLMØ4W. Section location is shown in Figure 3-10.

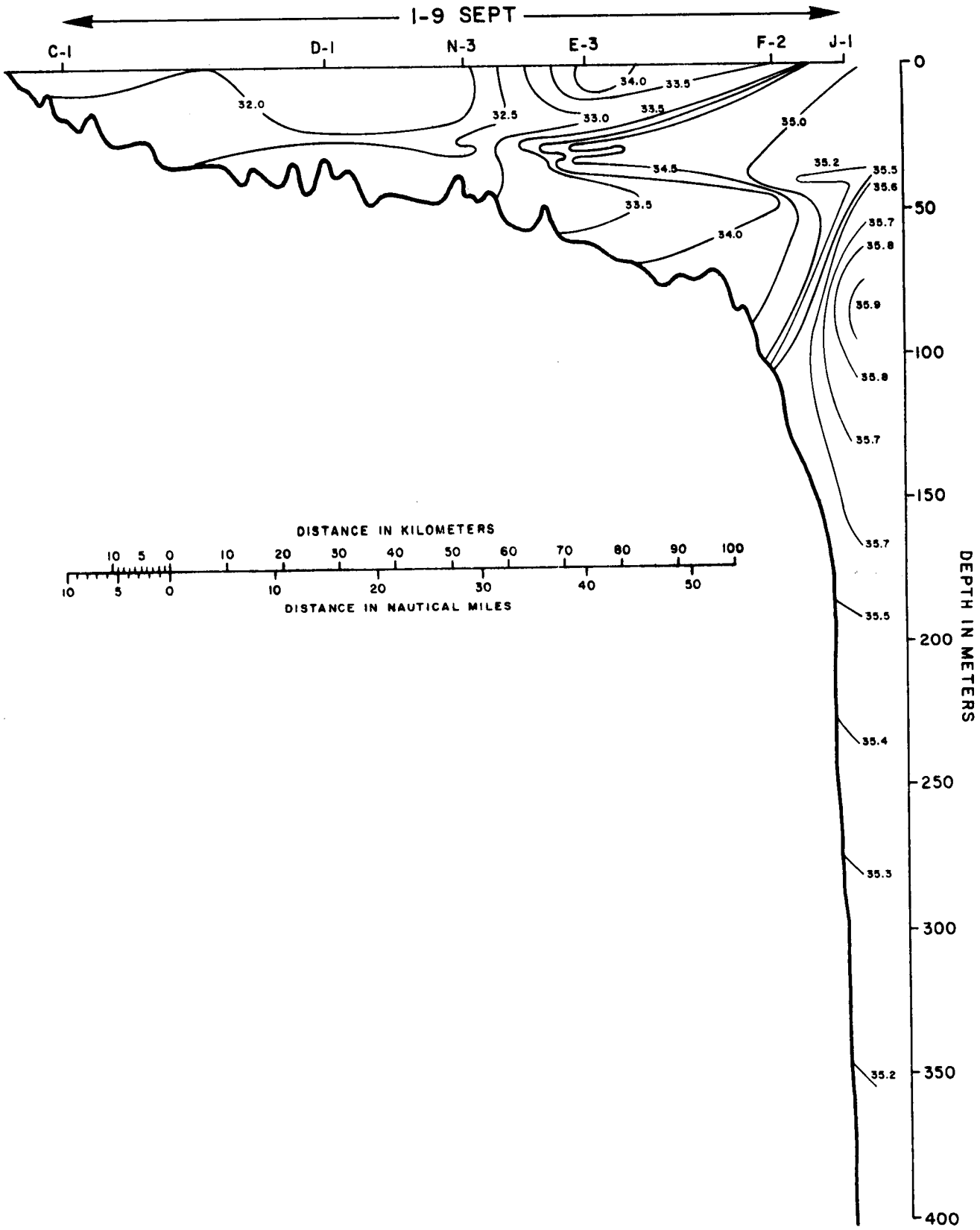

Figure 3-165. Salinity (ppt) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLM04W. Section location is shown in Figure 3-10.

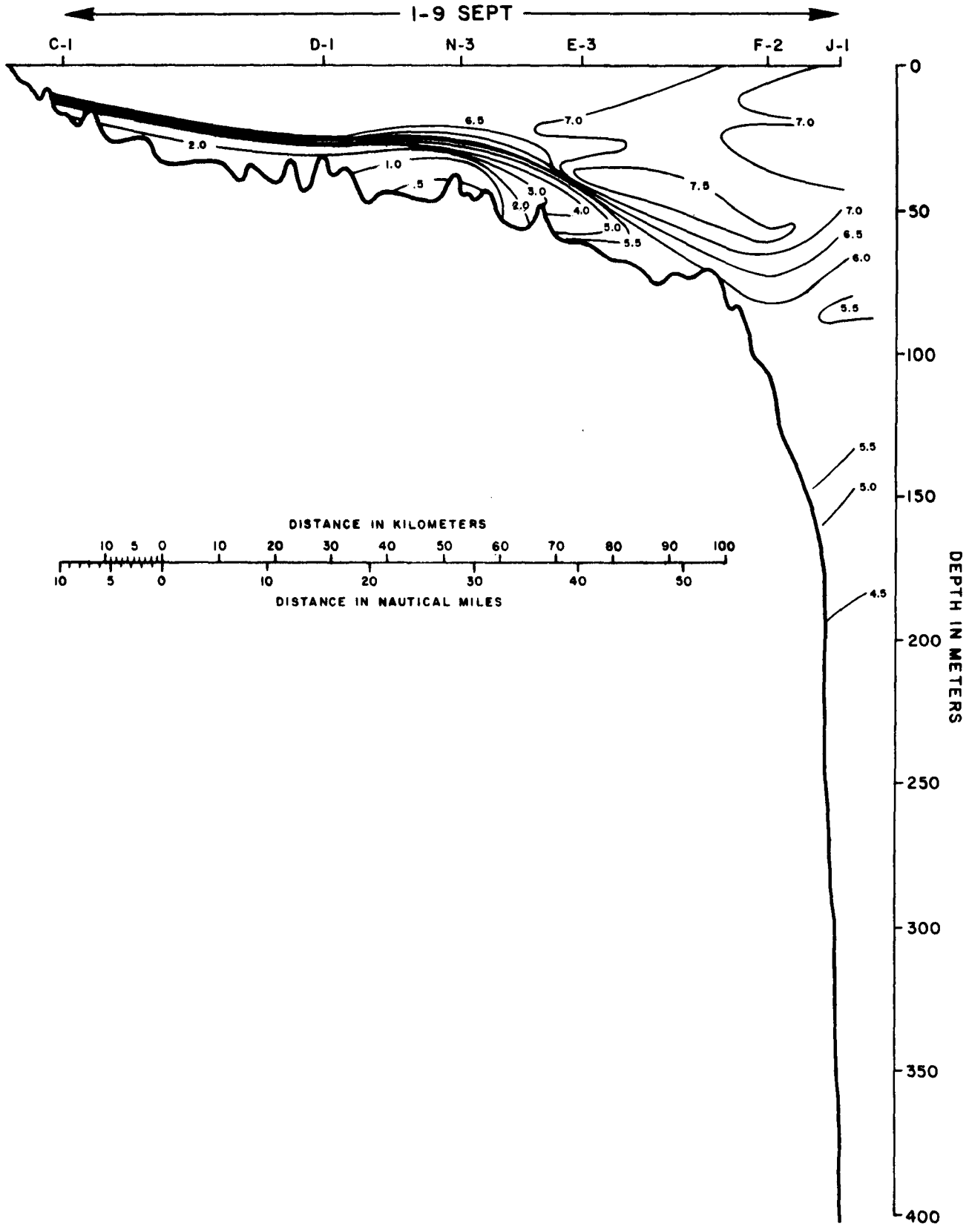

Figure 3-166. Dissolved oxygen (mg/1) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLMØ4W. Section location is shown in Figure 3-10.

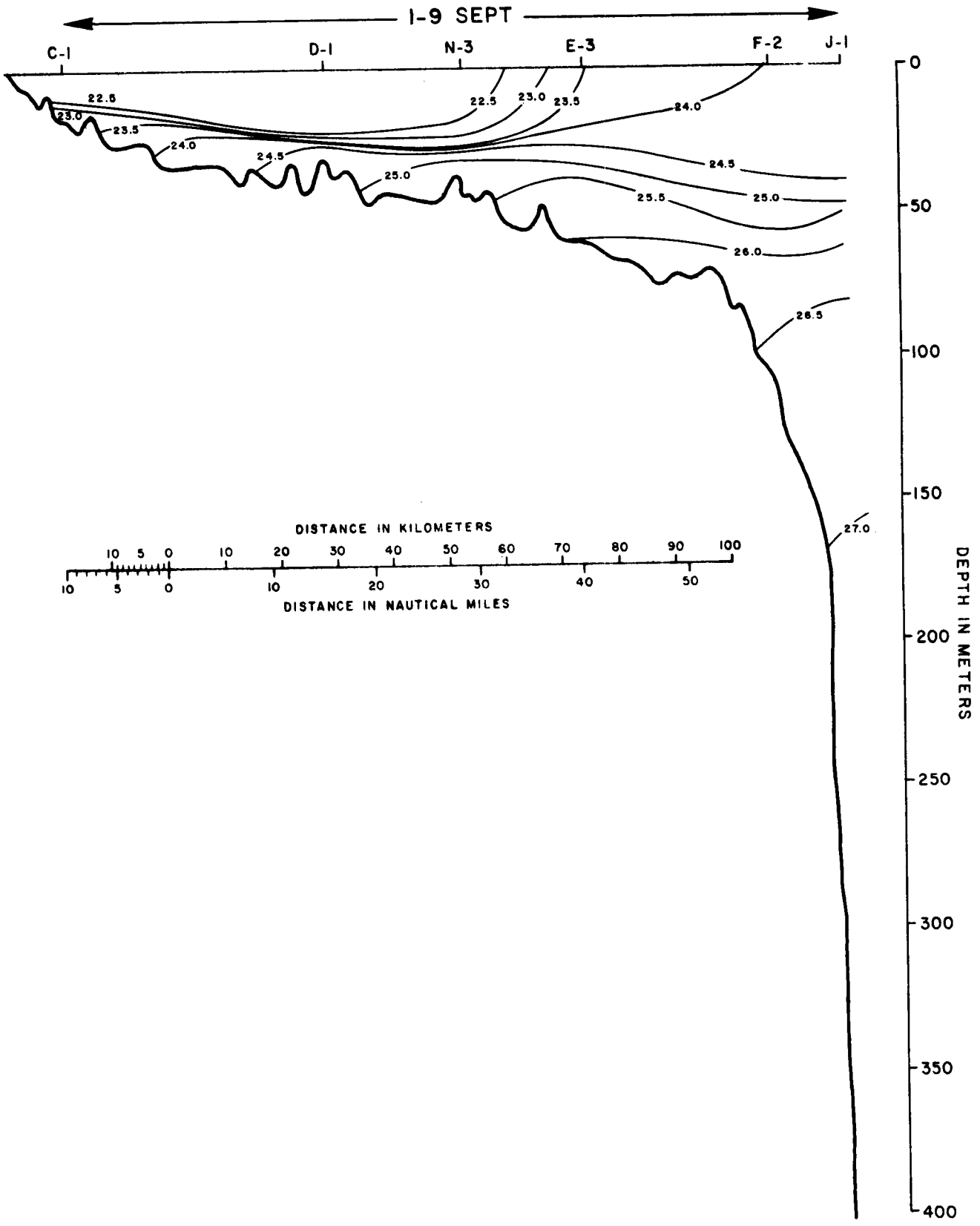

Figure 3-167. Density (σ_t units) along Section III (Stations C1 to J1, 1-9 September 1976) during cruise BLMØ4W. Section location is shown in Figure 3-10.

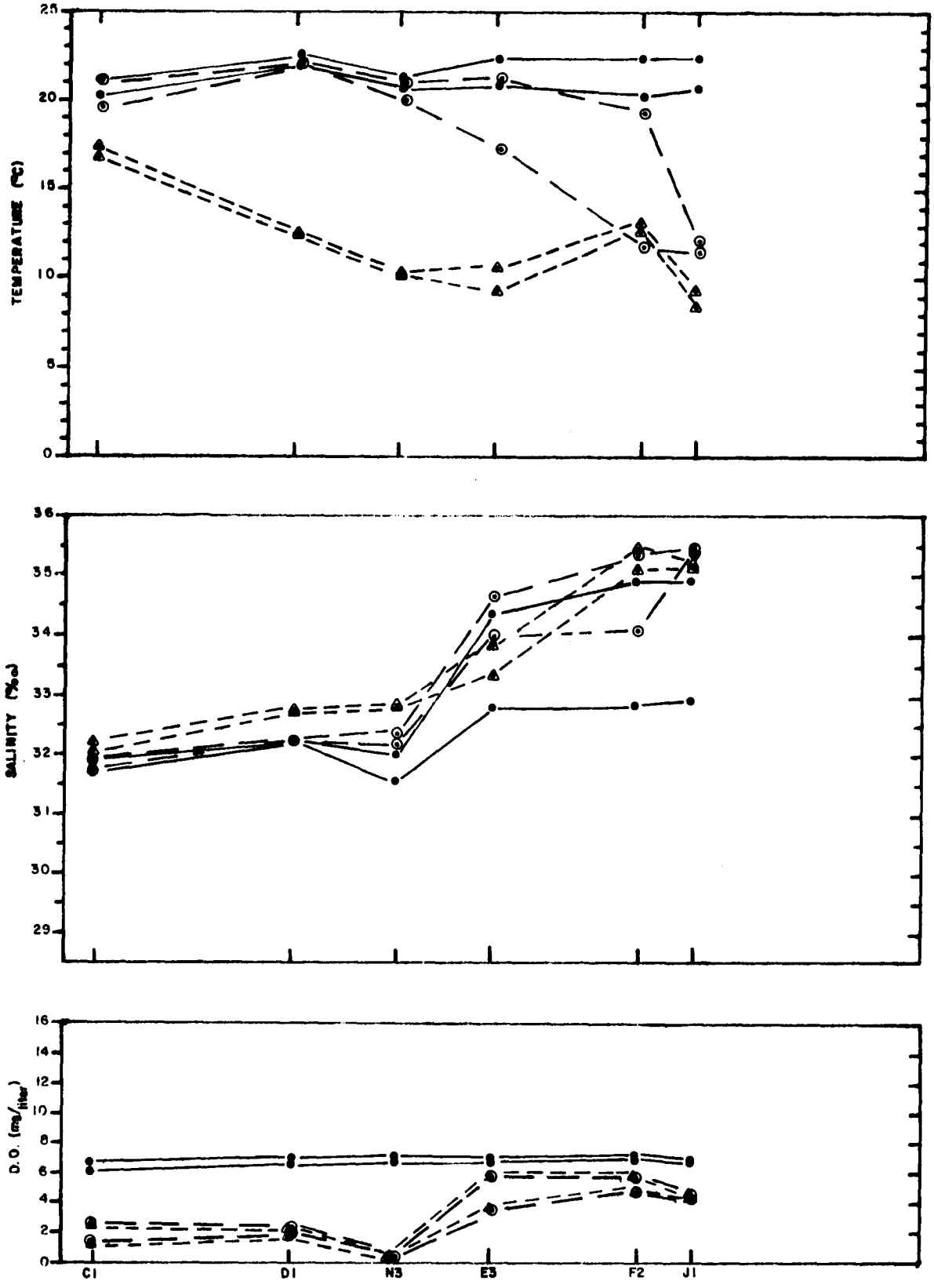

Figure 3-168. Surface (•), mid-depth (θ) and bottom (▲) values of temperature, salinity and DO measured along Section III during cruise BLM Ø4W. Maximum and minimum values measured from four casts are shown at each station.

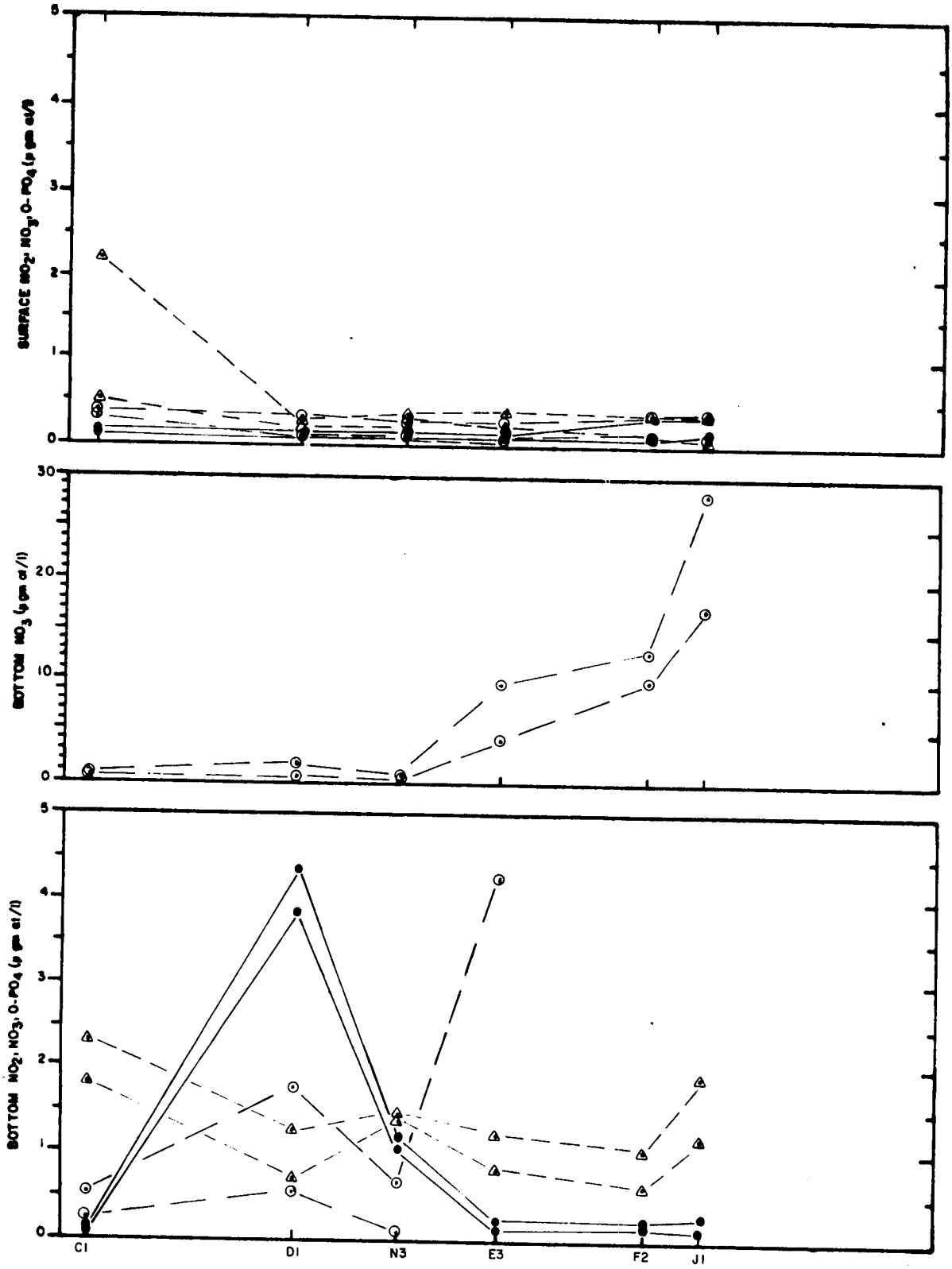

Figure 3-169. Concentrations of dissolved NO_2 (•), NO_3 (θ), and $O\text{-}PO_4$ (Δ) in near surface and near bottom waters along Section III during Cruise BLM 04W. Bottom concentrations of dissolved NO_3 were substantially greater than those of other micronutrients hence the center plot.

Cruise BLMØ4T

Summer 1976

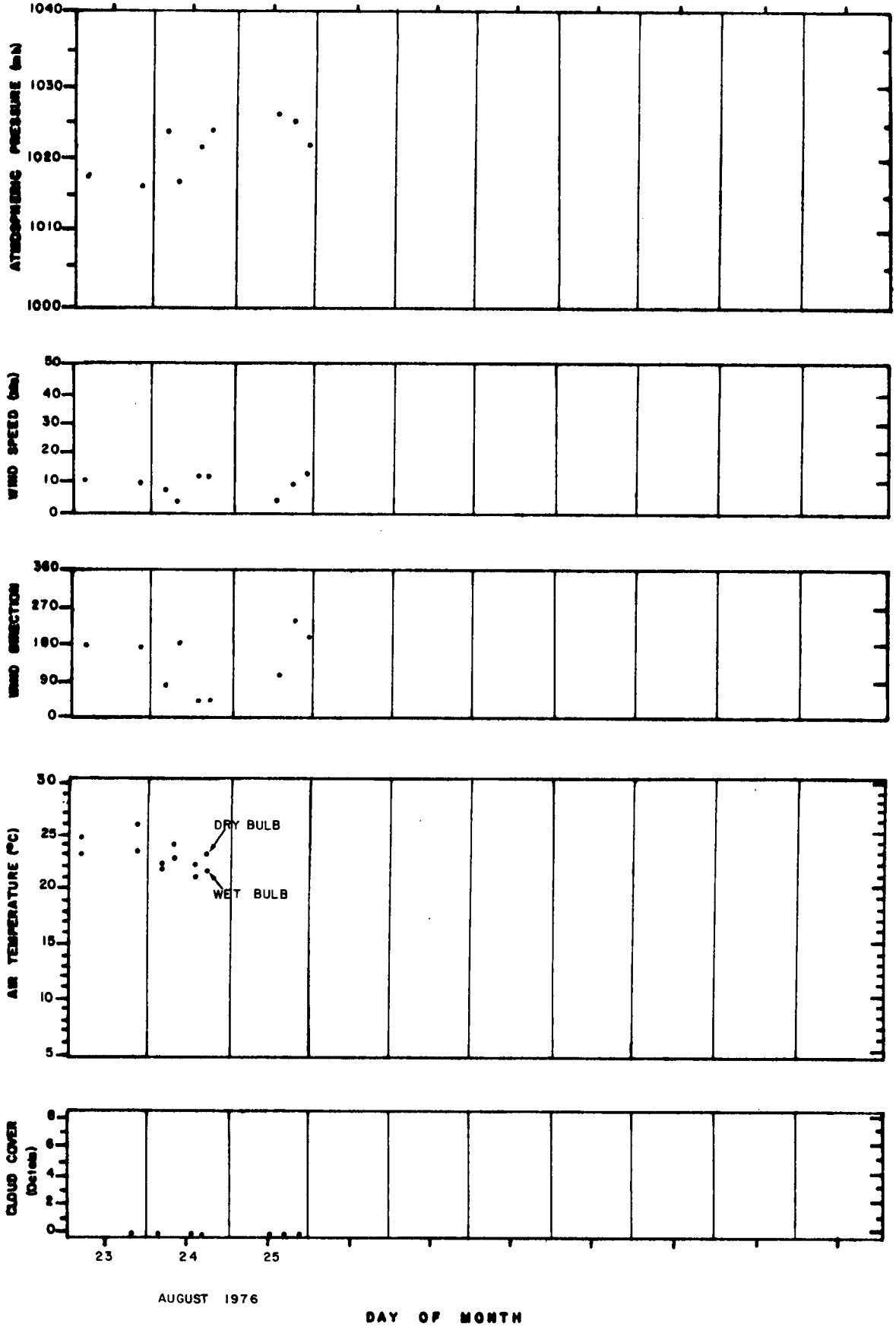

Figure 3-170. Meteorological data collected during cruise BLM ϕ4T 23-25 August 1976.

DISCUSSION

Autumn Conditions (October - November 1975)

Temperature, Salinity, and Density

Vertical mixing of the water column was proceeding from inshore to offshore while cruises BLM 01B and BLM 01W were in progress. Cruise BLM 01W was confined to the region represented by Section III in Figure 3-10 and took place between 23 and 29 October. Figures 3-37, 3-38, and 3-40 show substantial vertical mixing out to station D1 with high thermal stratification between 25 and 30 meters seaward of station E3. Salinity stratification for this cruise changed from horizontal to vertical between stations N3 and E3 (Figure 3-38) was reflected in the more horizontal arrangement of isopycnals beginning in the same region (Figure 3-40). The seaward progression of this stratification was most evident when σ_t vs. depth plots for stations D1, N3, and E3 are compared. They are presented here as Figures 3-171, 3-172, and 3-173. A thermal front was encountered between stations F2 and J1 and appeared as a near surface (down to 20 meters) intrusion of relatively warm (>20°C), salty (>34.5 ppt) water. This is illustrated in plots of temperature and salinity vs. depth at Station J1 (Figures 3-174 and 3-175). A pool of cold, relatively fresher water (11.5°C, 33 ppt) was evident at the bottom between stations N3 and E3. This same region was sampled one week later during cruise BLM01B with results shown in Figures 3-28, 3-29, and 3-31 for temperature, salinity, and σ_t, respectively. During this one week period, vertical mixing extended some 15 km further seaward with horizontal stratification redeveloping near shore in the vicinity of the C stations. The "cold pool" retained a thermal signature (Figure 3-38) and was evident as a seaward bulge of the 33.5 ppt isohaline centered around 50 meters (Figure 3-29). The thermal front was evident between stations F1 and F2 and descended from a depth of 40 meters at Station F2 (Figure 3-176) to 72 meters at J1 (Figure 3-177). Isohalines (Figure 3-29) and isopycnals (Figure 3-31) indicated a shoreward intrusion of slope water along the bottom. The "cold pool" was also evident along Section II in the vicinity of the B stations (Figures 3-24 and 3-25). Extensive interleaving of shelf and slope water was evident in the vicinity of the A stations with an indication of "calving" (Cresswell 1959) of shelf water into the slope regions. However, sampling did not extend sufficiently seaward to verify this. The "cold pool" was also evident in horizontal distributions of temperature and salinity (Figures 3-18 and 3-19) for this season and seemed to be (thermally) most intent in the vicinity of the E stations.

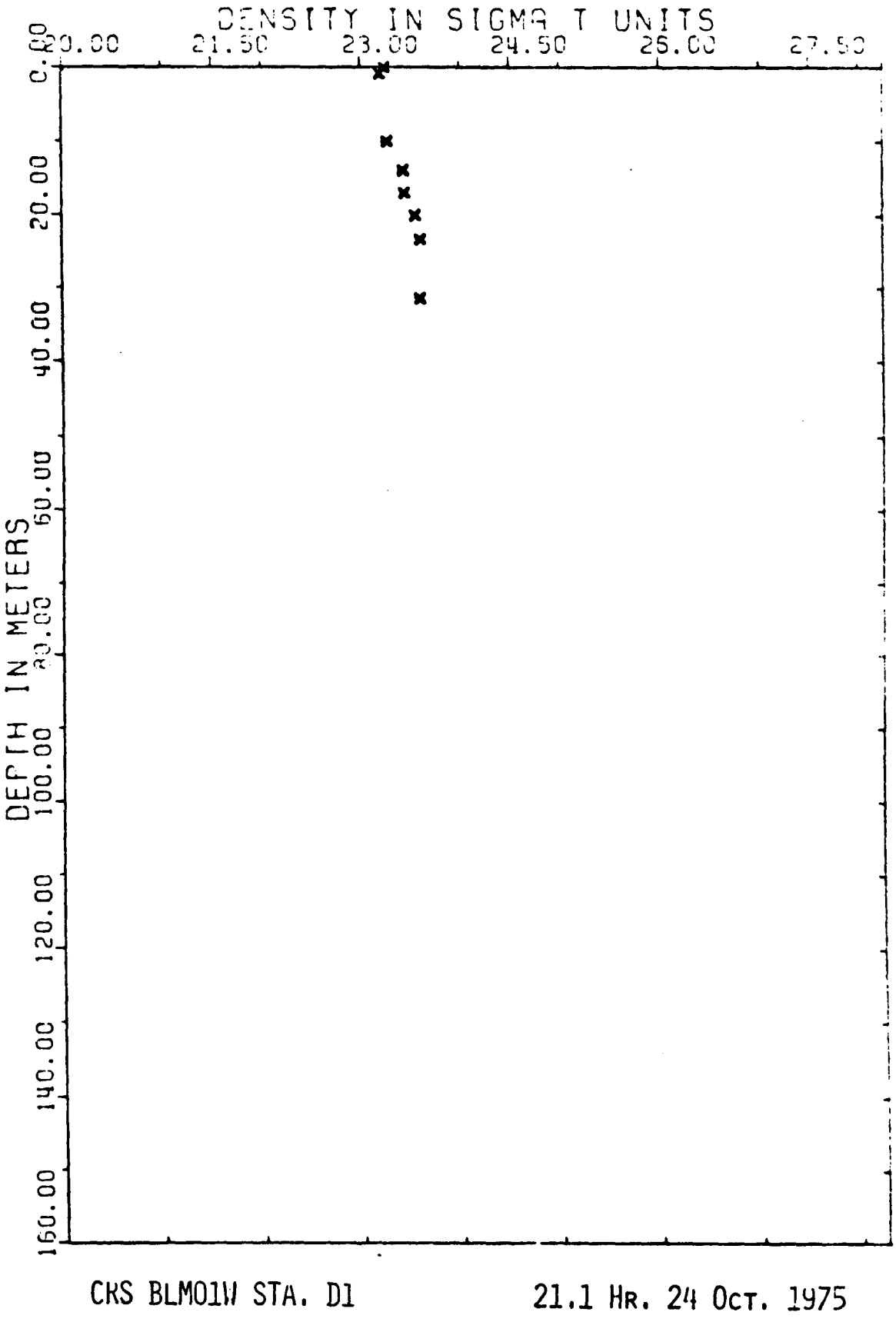

Figure 3-171. Density as a function of depth at Station D1 during cruise BLM 01W.

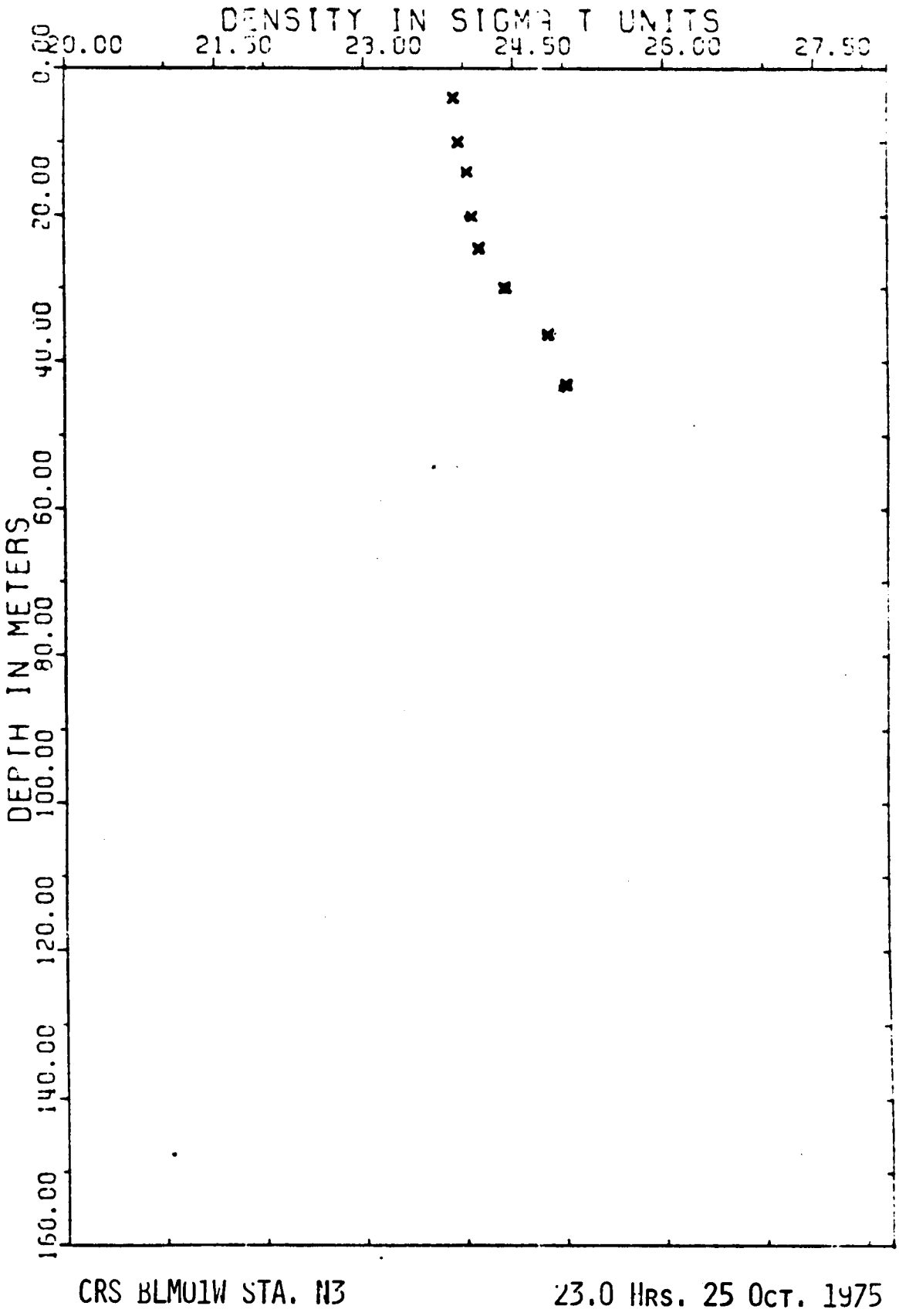

Figure 3-172. Density as a function of depth at Station N3 during cruise BLM 01W.

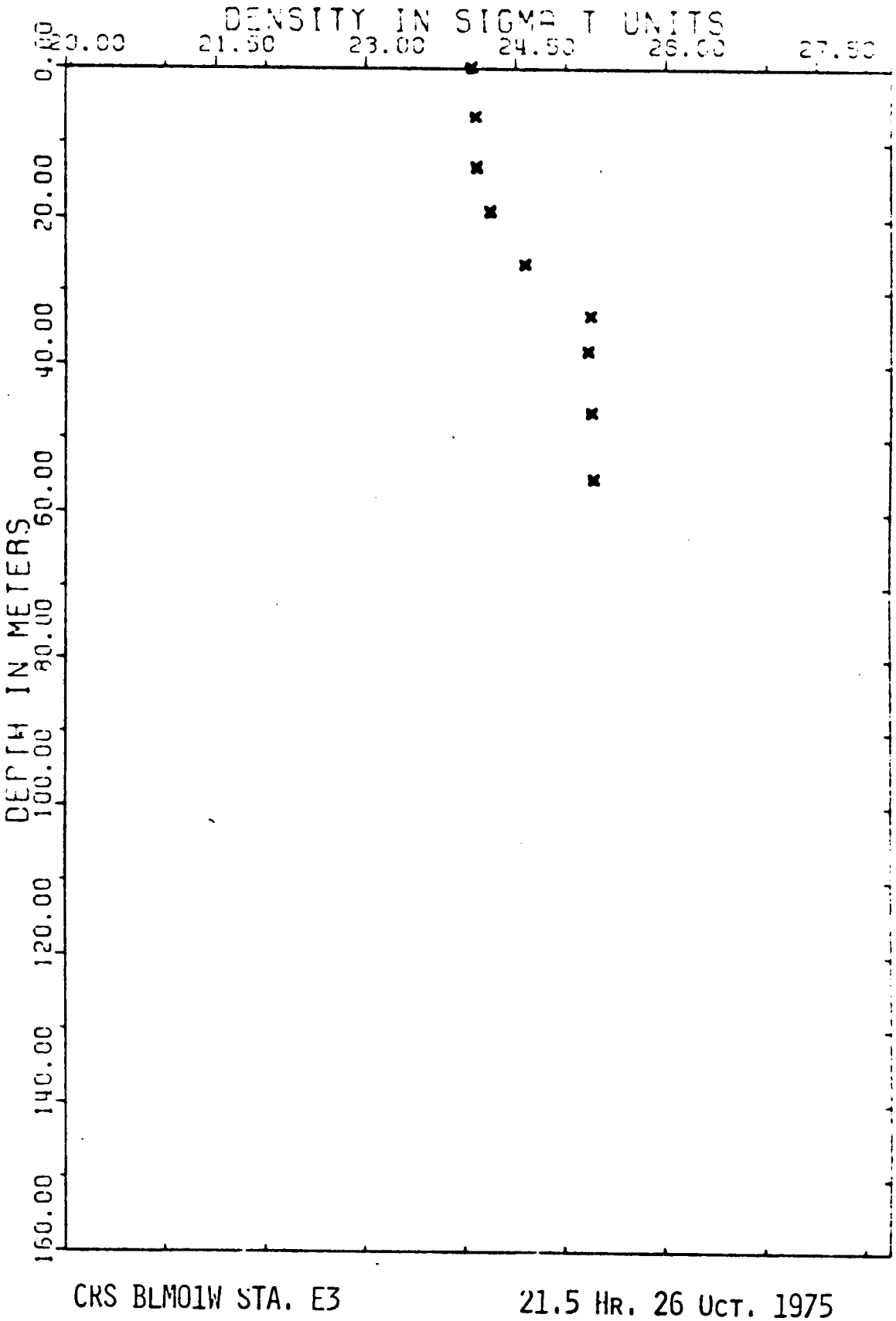

Figure 3-173. Density as a function of depth at Station E3 during cruise BLM ∅1W.

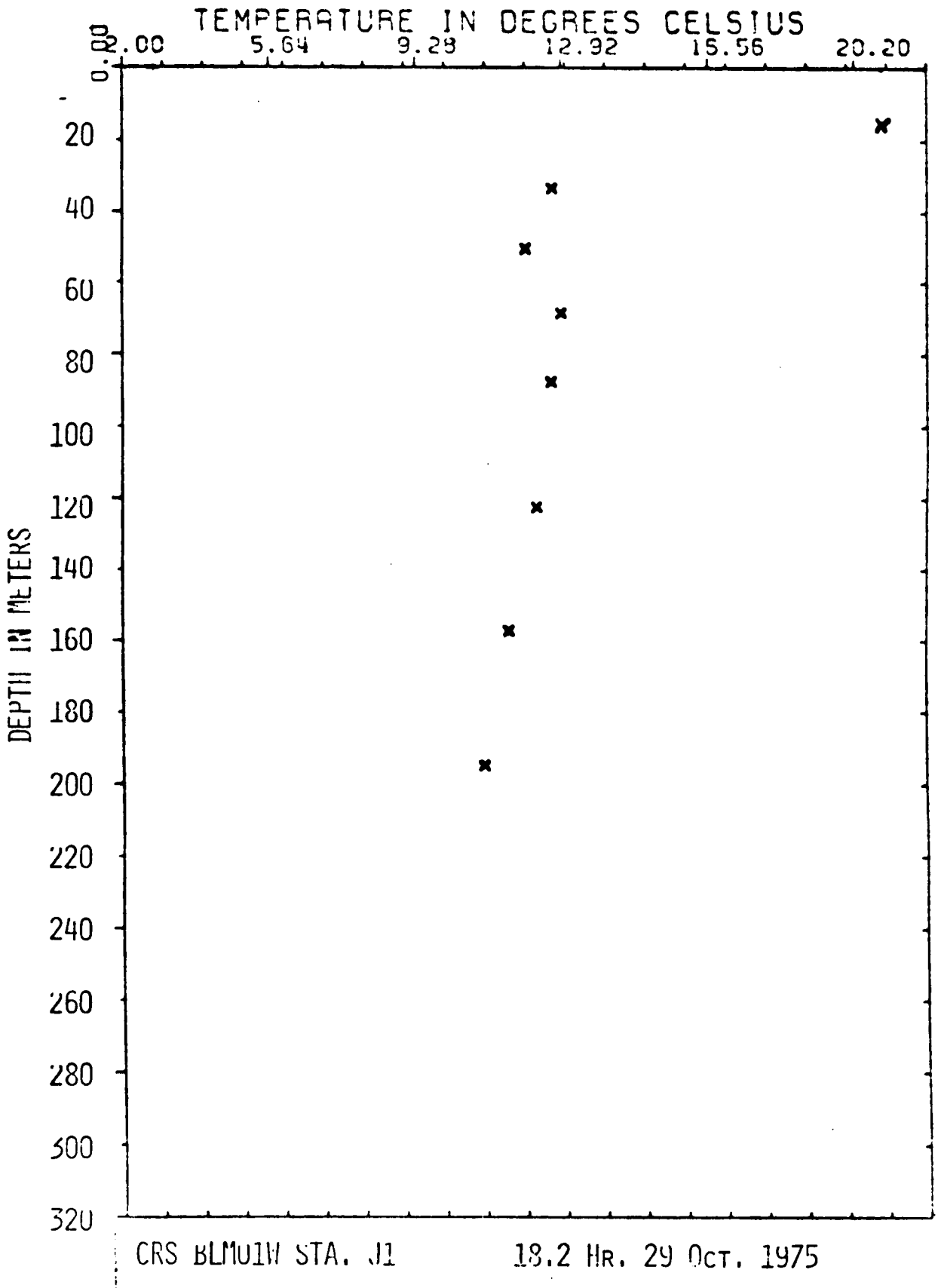

Figure 3-174. Temperature as a function of depth at Station J1 during cruise BLM 01W.

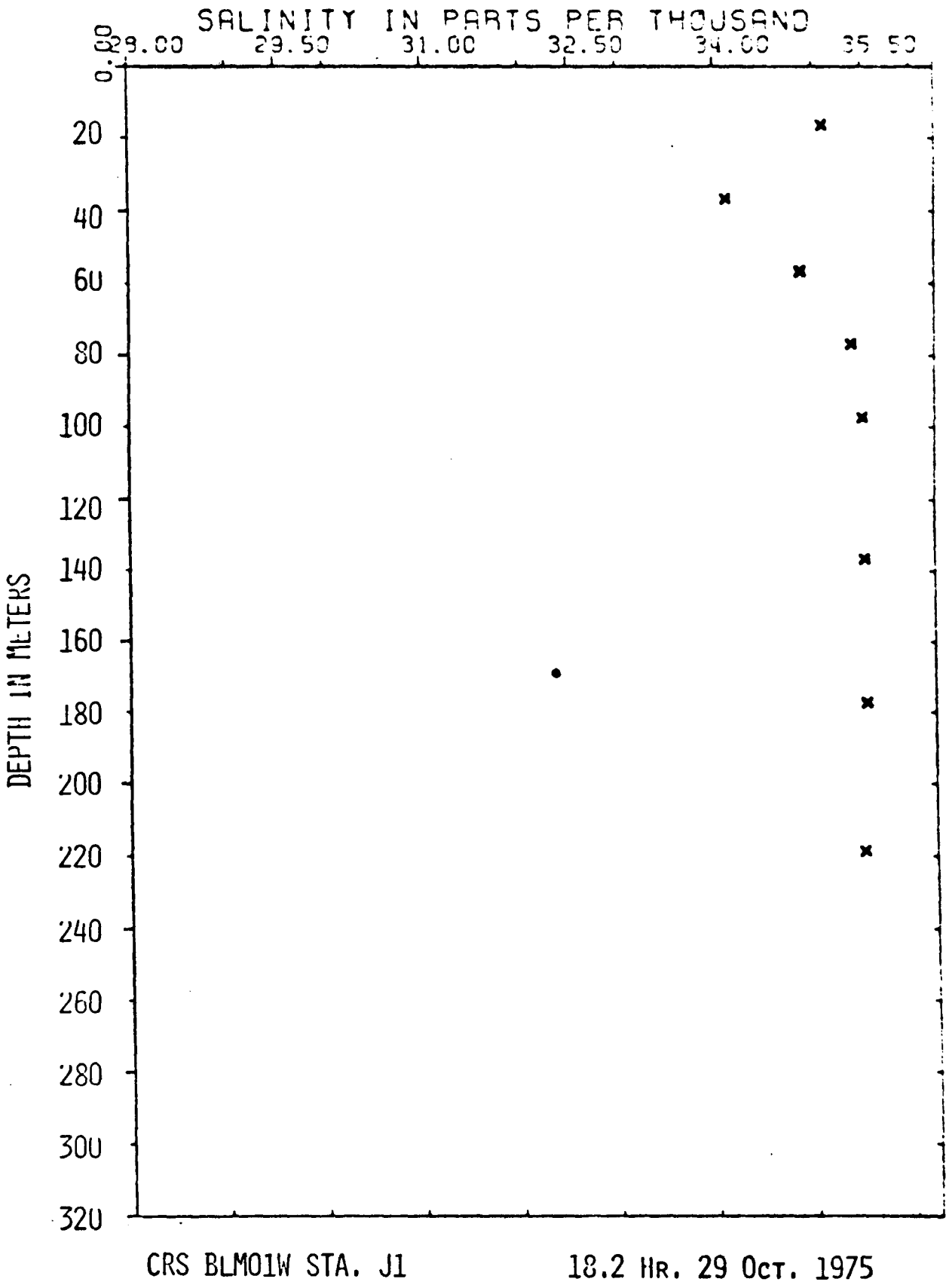

Figure 3-175. Salinity as a function of depth at Station J1 during cruise BLM ϕ1W.

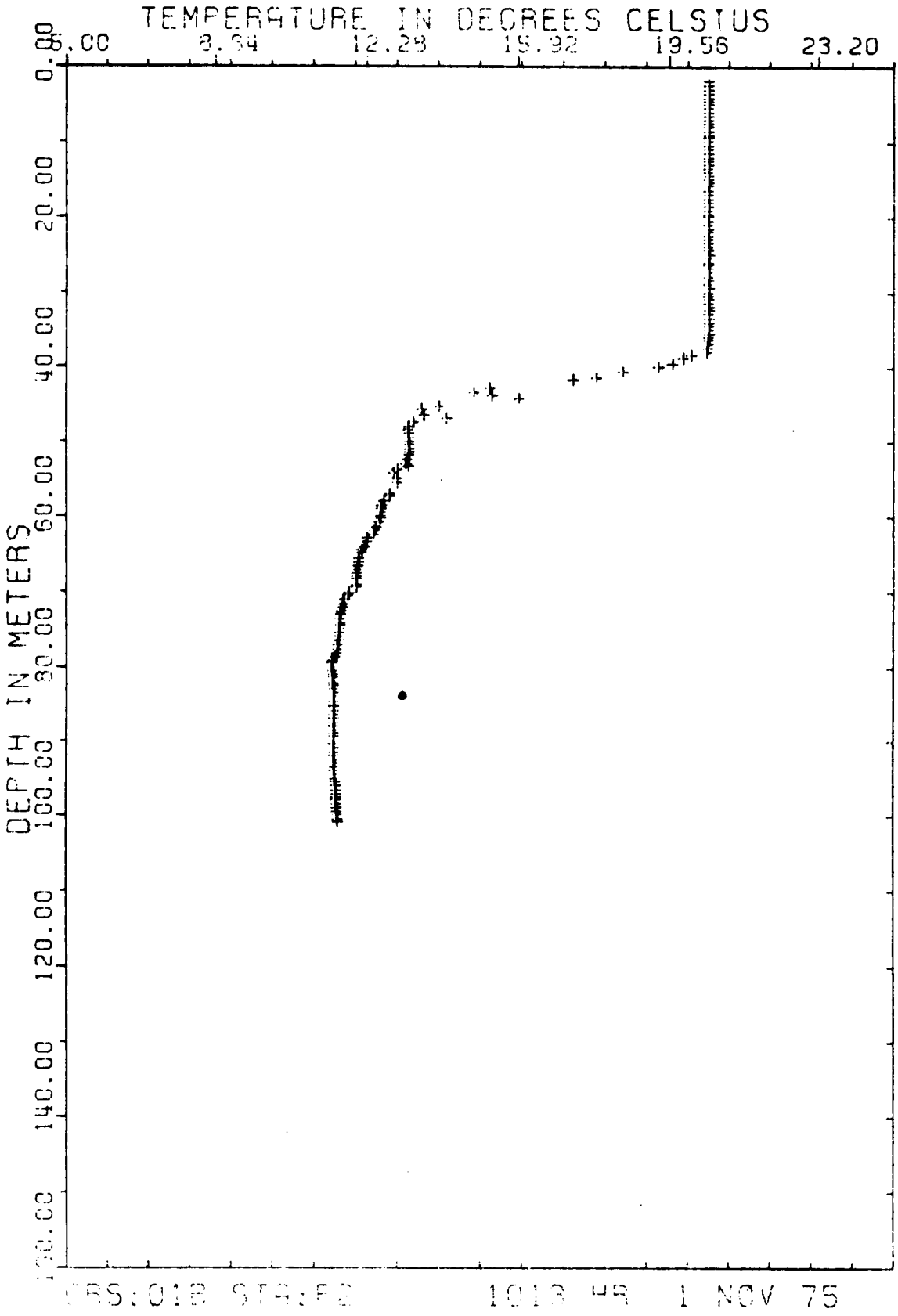

Figure 3-176. Temperature as a function of depth at Station F2 during cruise BLM ϕ1B.

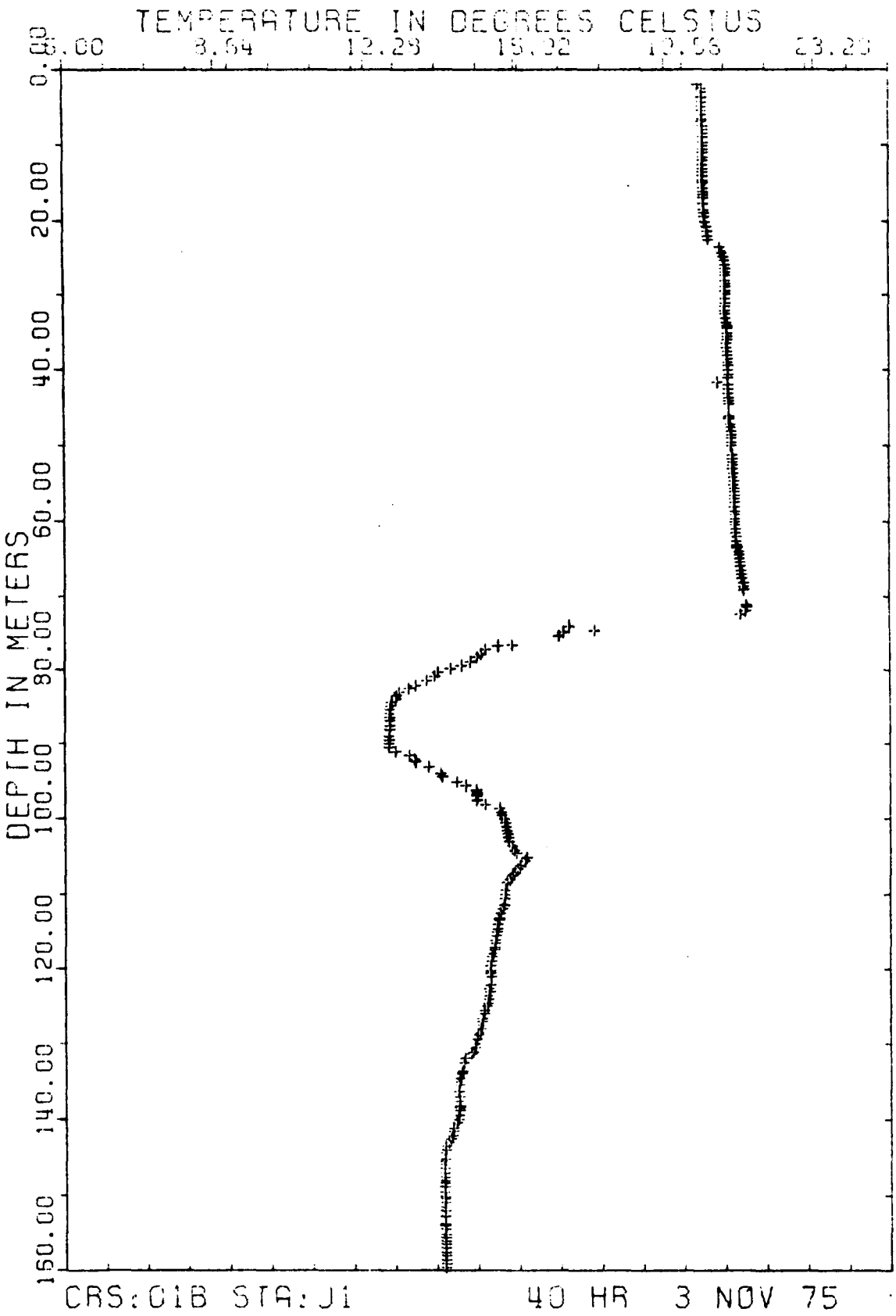

Figure 3-177. Temperature as a function of depth at Station J1 during cruise BLM Ø1B.

Dissolved Oxygen and Micronutrients

Dissolved oxygen values ranged from 5.5 to 10 mg/liter throughout the area during this season. Two exceptions were stations N3 and J1 during cruise BLM 01W where bottom DO values were in the 5 mg/liter range (Figures 3-32, 3-34, and 3-41).

Of the dissolved micronutrients analyzed, NO_2 and $O\text{-}PO_4$ quantities were less than 1 µgm atm per liter in both near surface and near bottom waters (Figures 3-15, 3-17, 3-21, and 3-23). Highest values of $O\text{-}PO_4$ were found near the bottom on the outer shelf at depths between 100 and 150 meters. Nitrates were highest at the bottom (in many cases, an order of magnitude higher than nitrites) (Figures 3-33, 3-35, and 3-42), with highest values found to the south of Hudson Canyon (Figure 3-22).

Winter Conditions (February - March 1976)

Temperature, Salinity, and Density

Normal wintertime inverted thermal conditions were found at all except the outermost stations as shown in Figures 3-76, 3-78, 3-80, and 3-89. Significant changes in hydrographic conditions were evident, however, when results of cruise BLM 02W were compared with those of BLM 02B. The former cruise occupied stations along Section III between 5 and 14 February, while the latter cruise covered the same region in three sections: the inner portion (C to D stations) on 20 and 21 February; the central portion (N3 to E4 stations) on 3 and 4 March; and the outer portion (F1 to J2 stations) from 18 to 20 March. During the water column cruise general vertical homogeniety persisted out to Station D1. Seaward of this station, thermal and salt stratification developed with cooler freshened water overlying warmer saltier water. This structure persisted along with general conditions of warming and increased salt content in the seaward direction. These conditions are illustrated in Figures 3-85 and 3-86 as well as temperature-depth, salinity-depth, and T-S plots for stations D1 (Figures 3-178 to 3-180), E3 (Figures 3-181 to 3-183) and J1 (Figures 3-184 to 3-186). During the temporally segmented sampling of this section on the benthic cruise (BLM 02B), conditions at Station D1 remained essentially the same twelve days later while those at Station E3 (sampled over twenty days later) showed an increase in both temperature and salt content of bottom waters (Figures 3-187 and 3-188) indicating an intrusion of slope water. Comparison of Figures 3-85 and 3-86 with Figures 3-64 and 3-65 further illustrates how conditions along this section changed during the winter sampling period.

The seaward portion of Section IV appears to be anomalous in the winter benthic sampling sequence. Vertical homogeneity persists for temperature, salinity, DO, and density in this region as illustrated in Figures 3-68 to 3-71. All other sections show colder, relatively fresh water overlying warmer ($>10.5^{o}C$) saltier (>34.5 ppt) water intruding from the slope region up onto the shelf to depths of less than 75 meters (Figures 3-56, 3-57, 3-60, 3-61, 3-64, 3-65, 3-72, and 3-73). These sections (I, II, III, and V) also illustrate a horizontal density stratification that is weak but persistent with no well developed pycnocline.

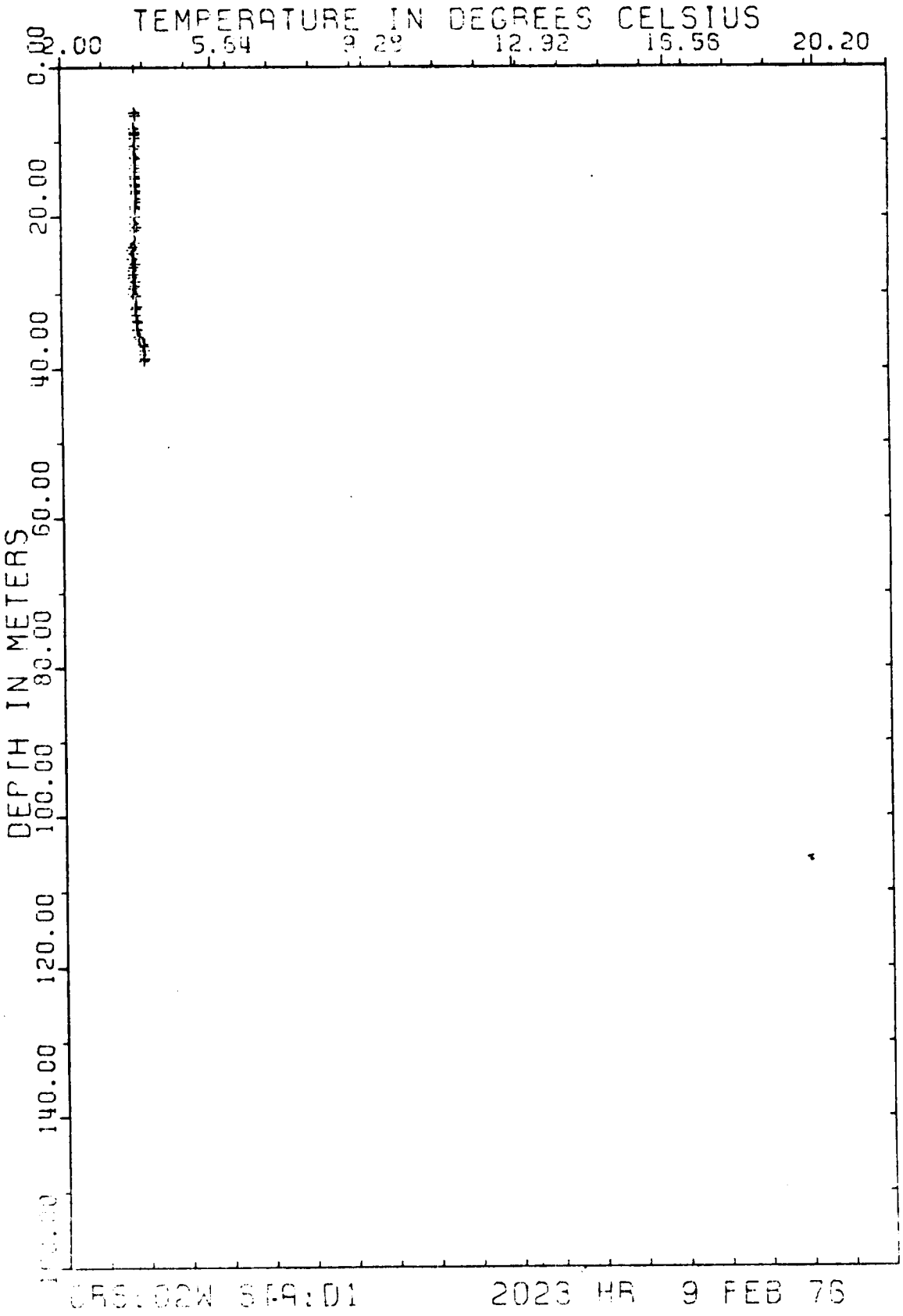

Figure 3-178. Temperature as a function of depth at Station D1 during cruise BLM ∅2W.

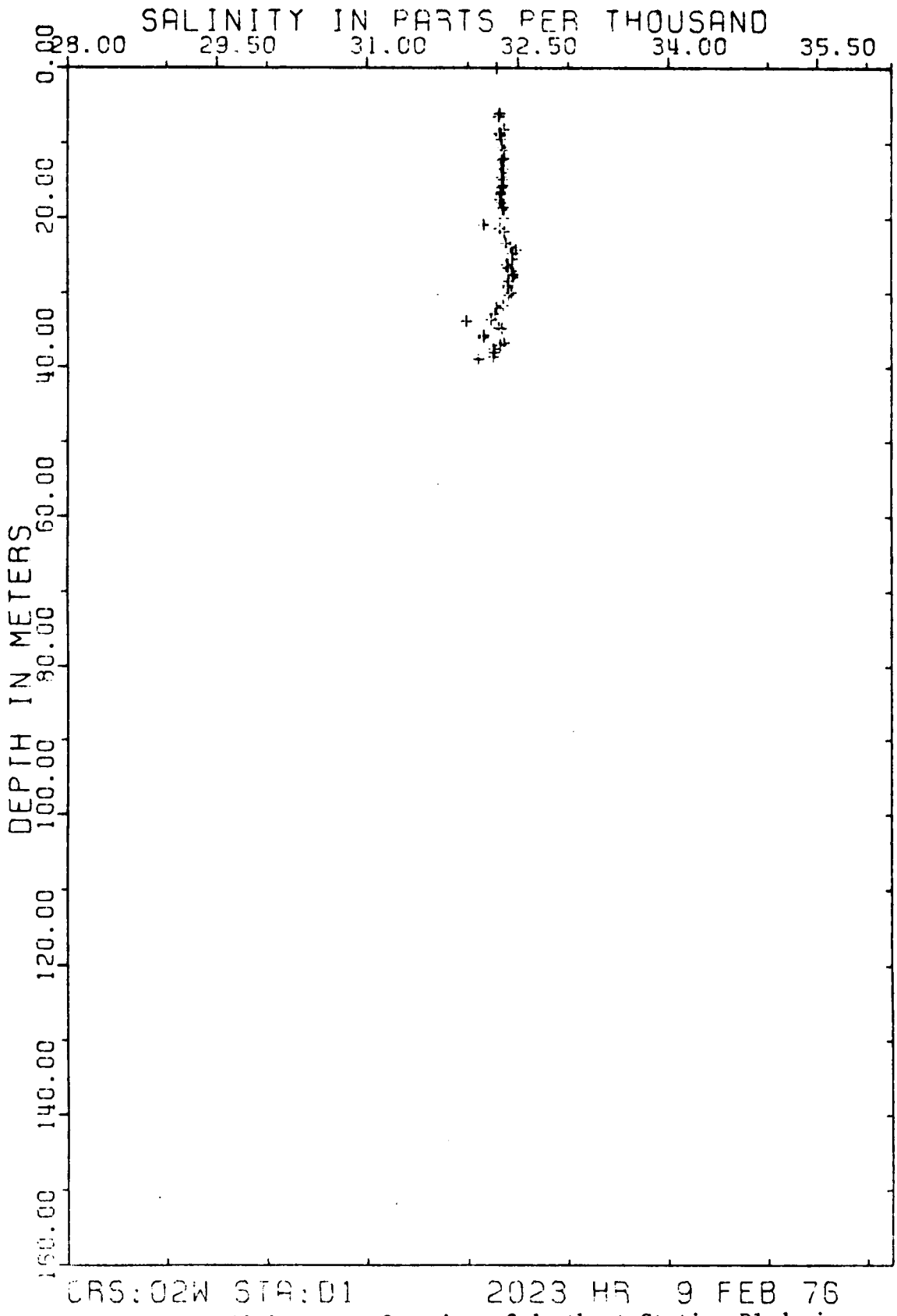

Figure 3-179. Salinity as a function of depth at Station D1 during cruise BLM Ø2W.

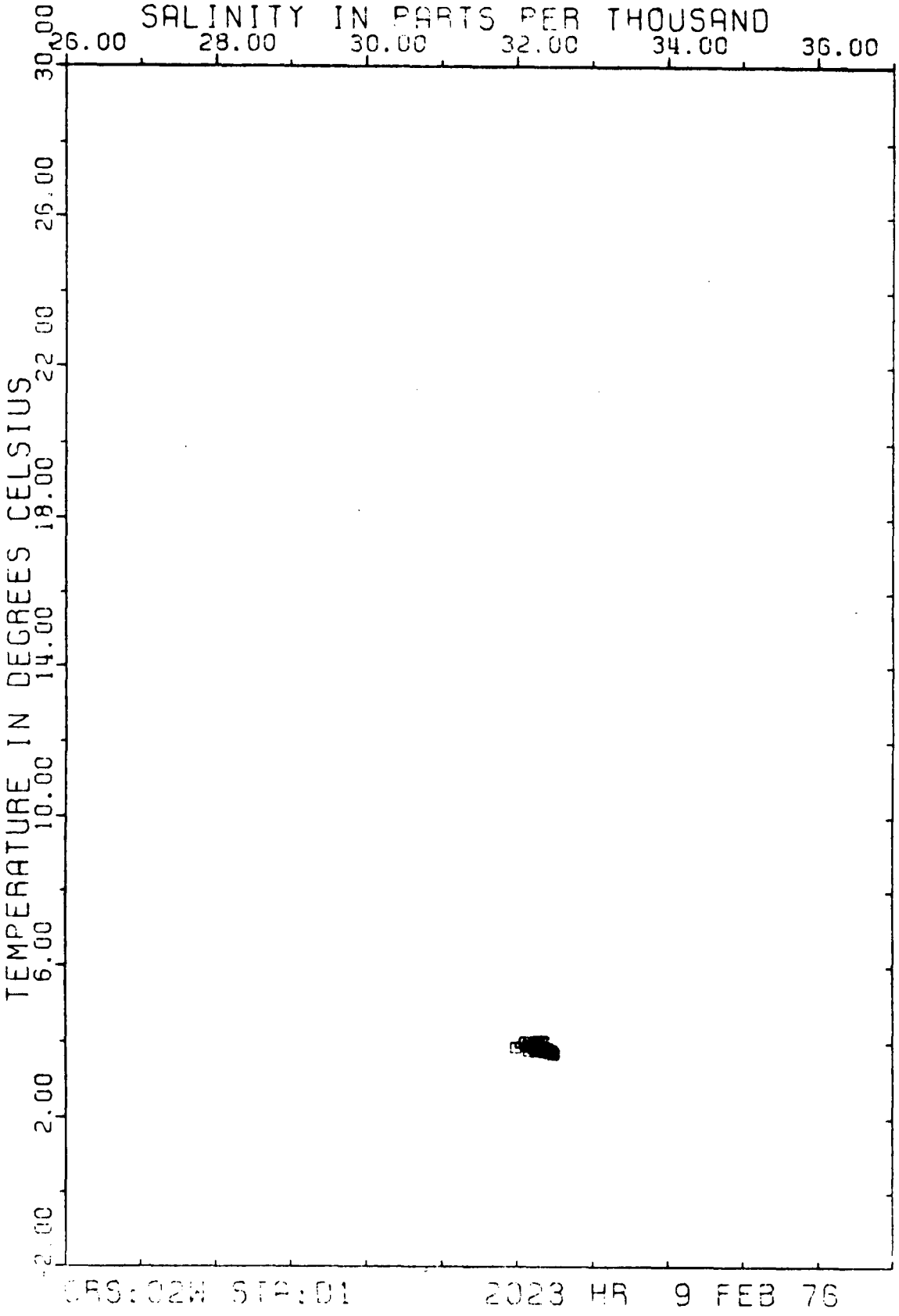

Figure 3-180. T-S diagram for Station D1 during cruise BLM Ø2W.

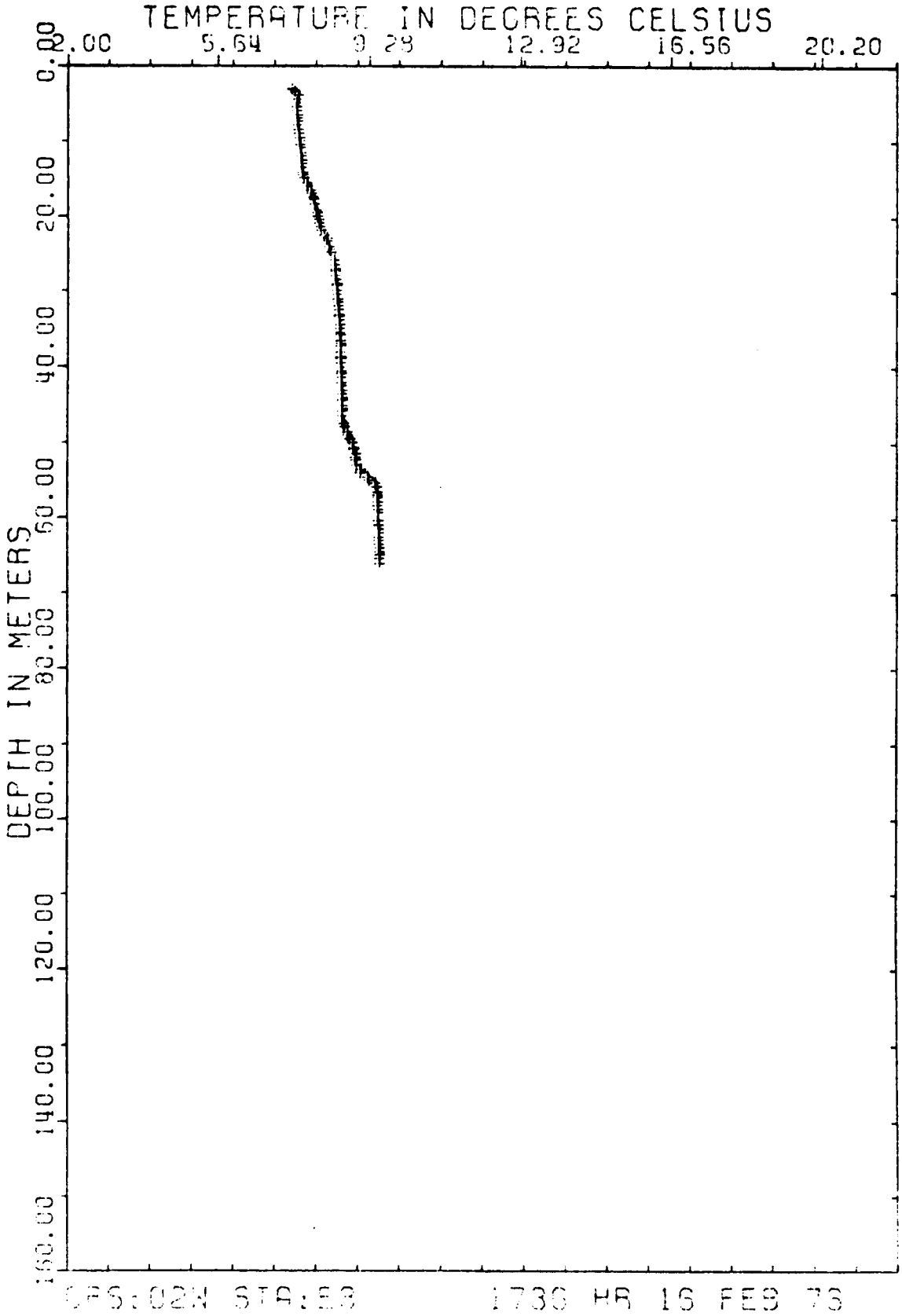

Figure 3-181. Temperature as a function of depth at Station E3 during cruise BLM Ø2W.

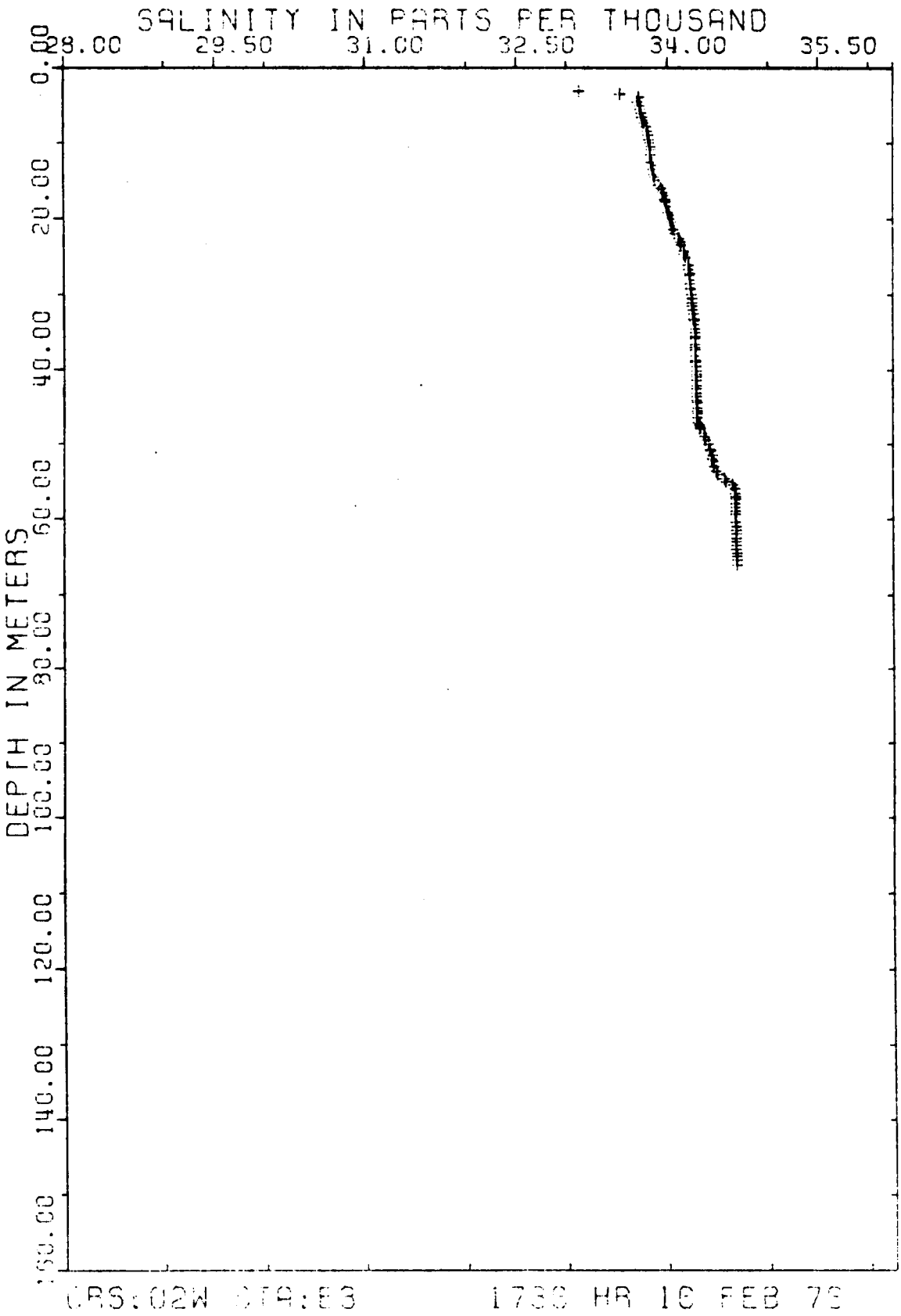

Figure 3-182. Salinity as a function of depth at Station E3 during cruise BLM Ø2W.

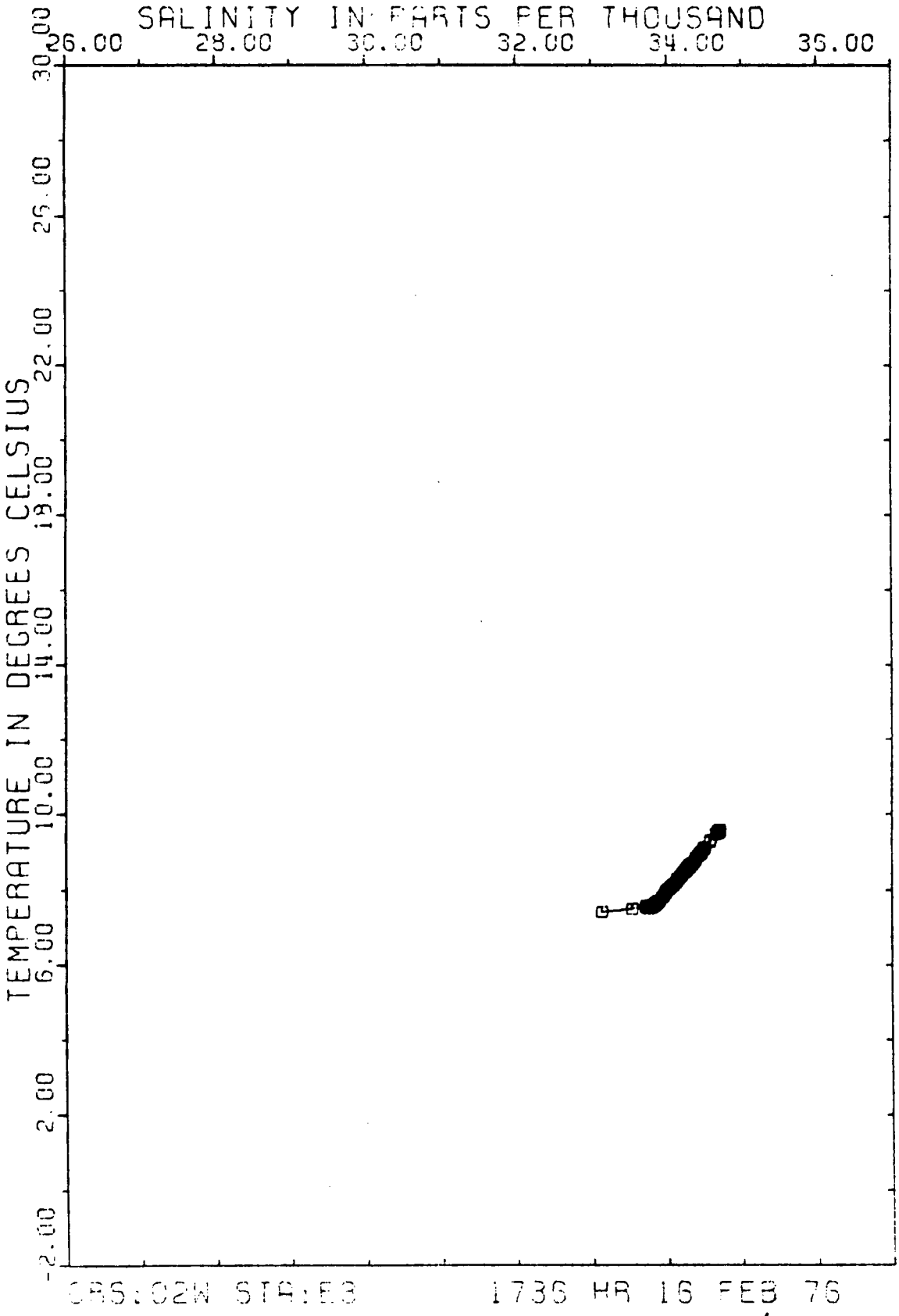

Figure 3-183. T-S diagram for station E3 during cruise BLM Ø2W.

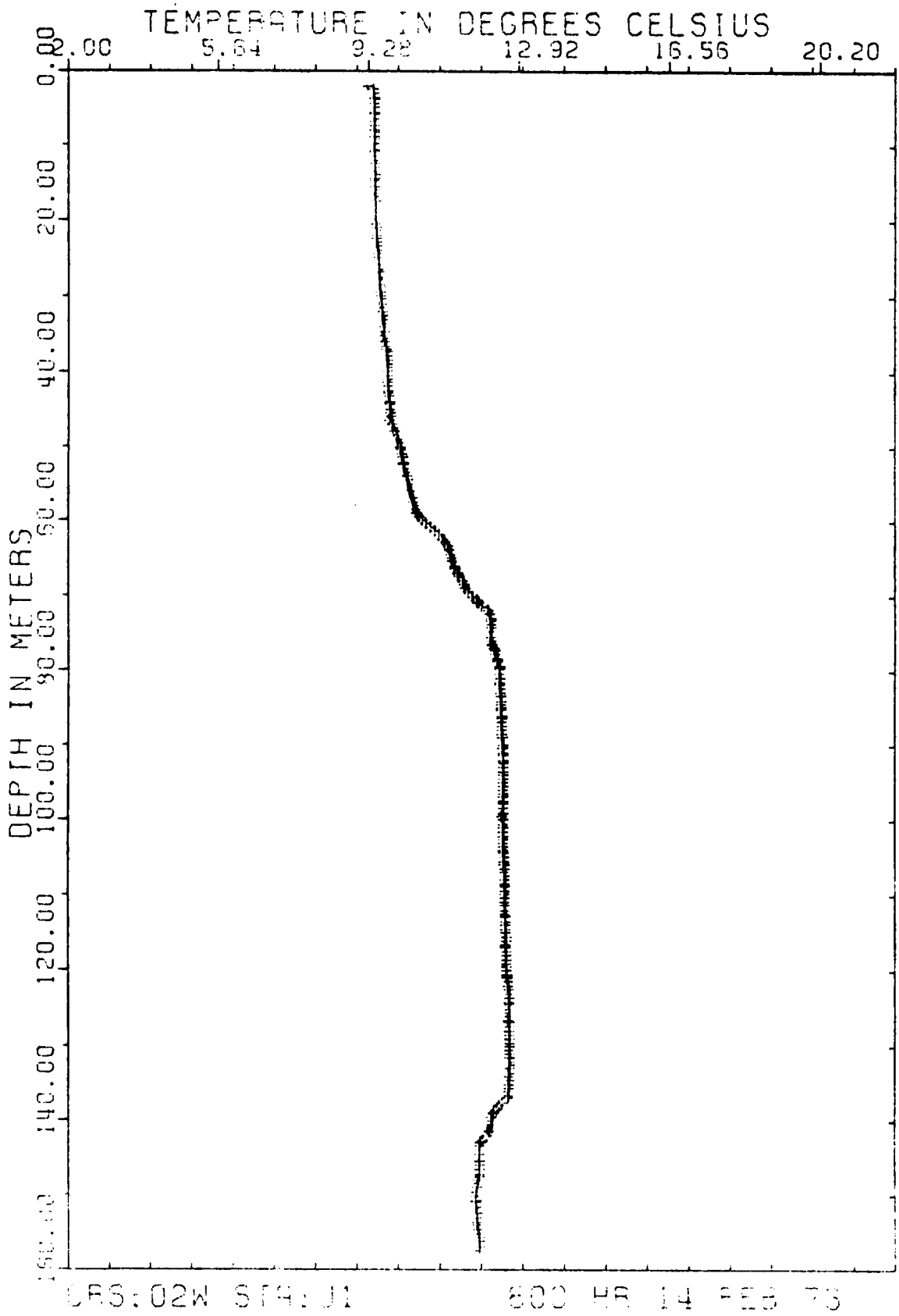

Figure 3-184. Temperature as a function of depth at Station J1 during cruise BLM Ø2W.

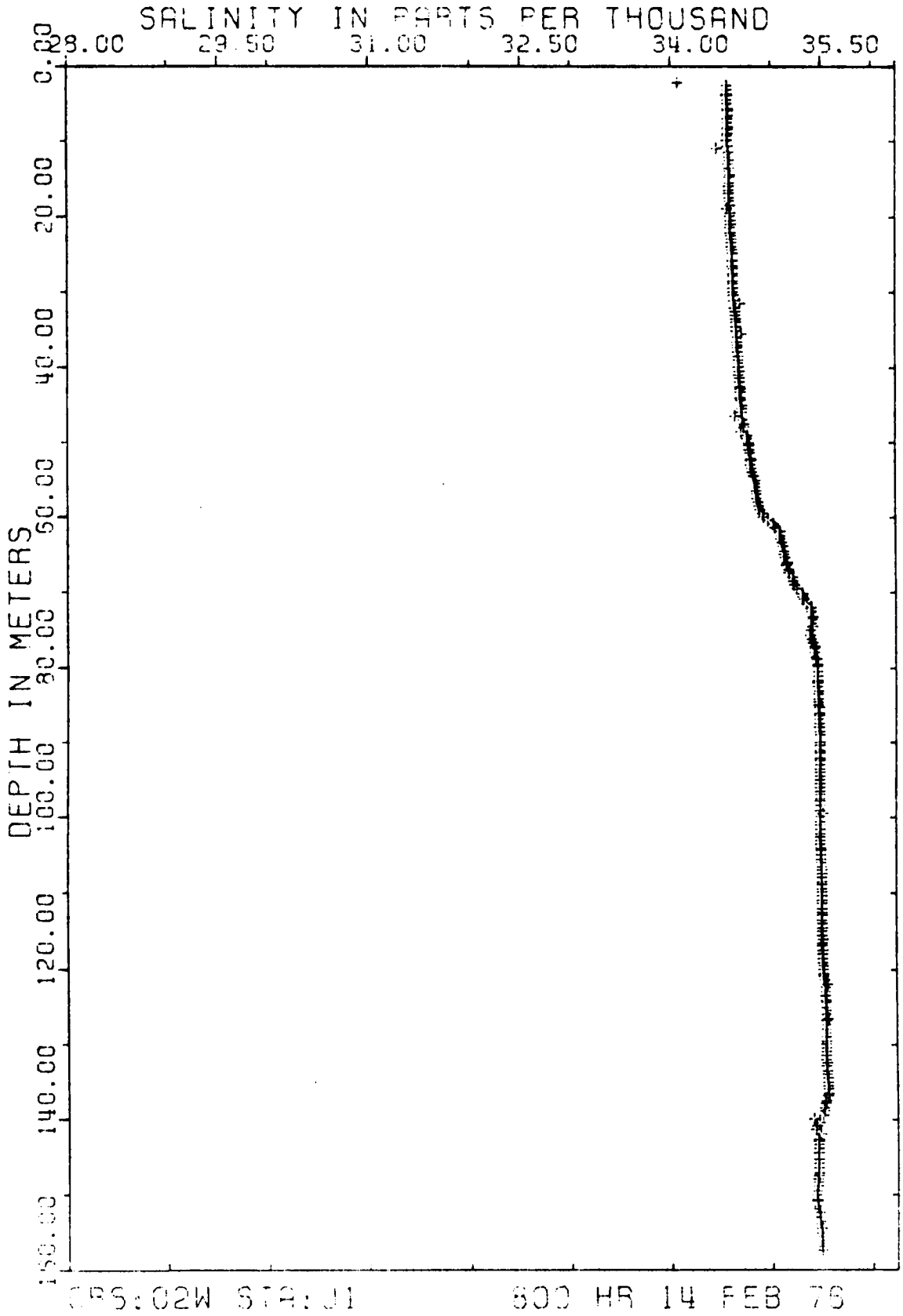

Figure 3-185. Salinity as a function of depth at Station J1 during cruise BLM Ø2W.

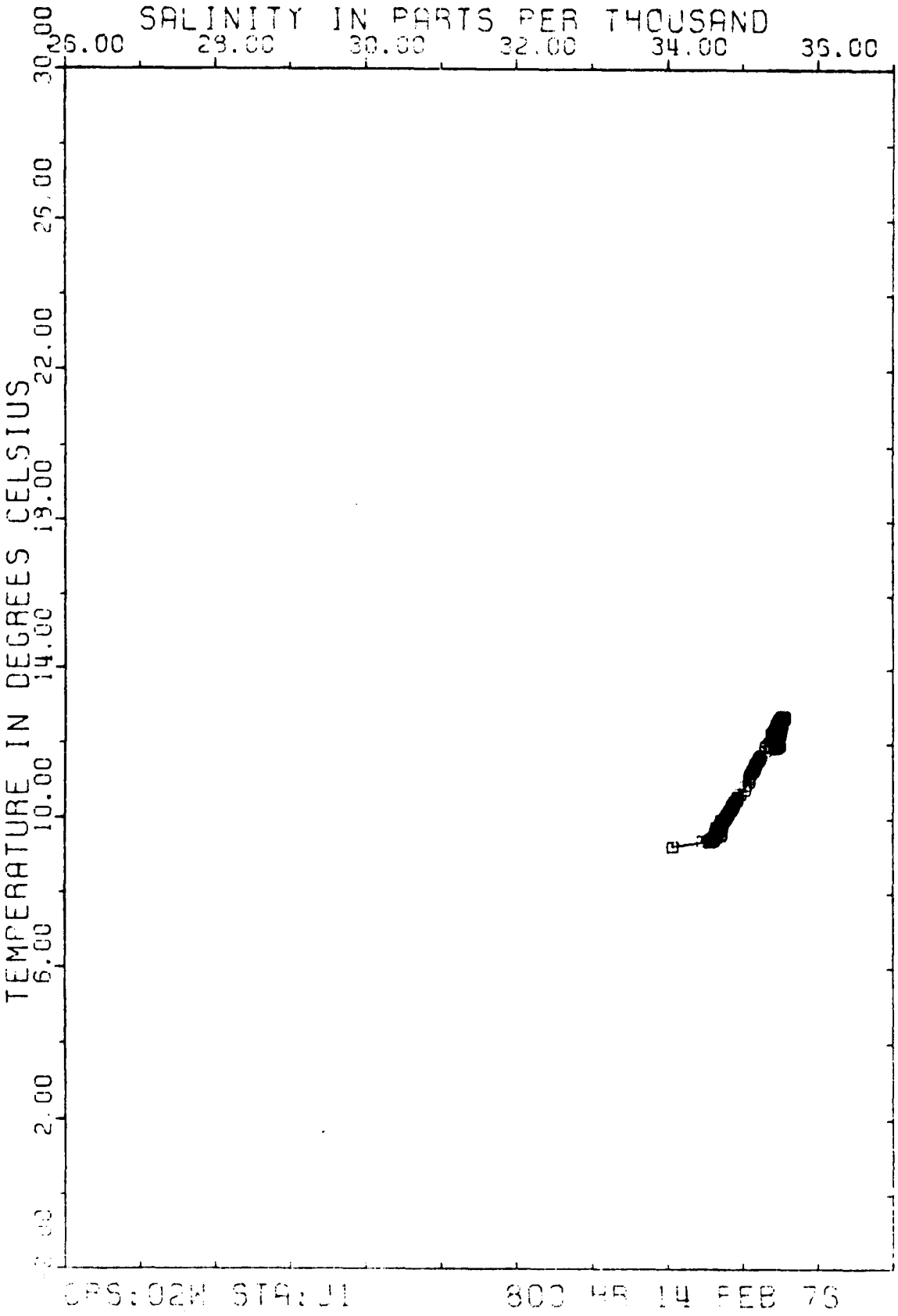

Figure 3-186. T-S diagram for Station J1 during cruise BLM Ø2W.

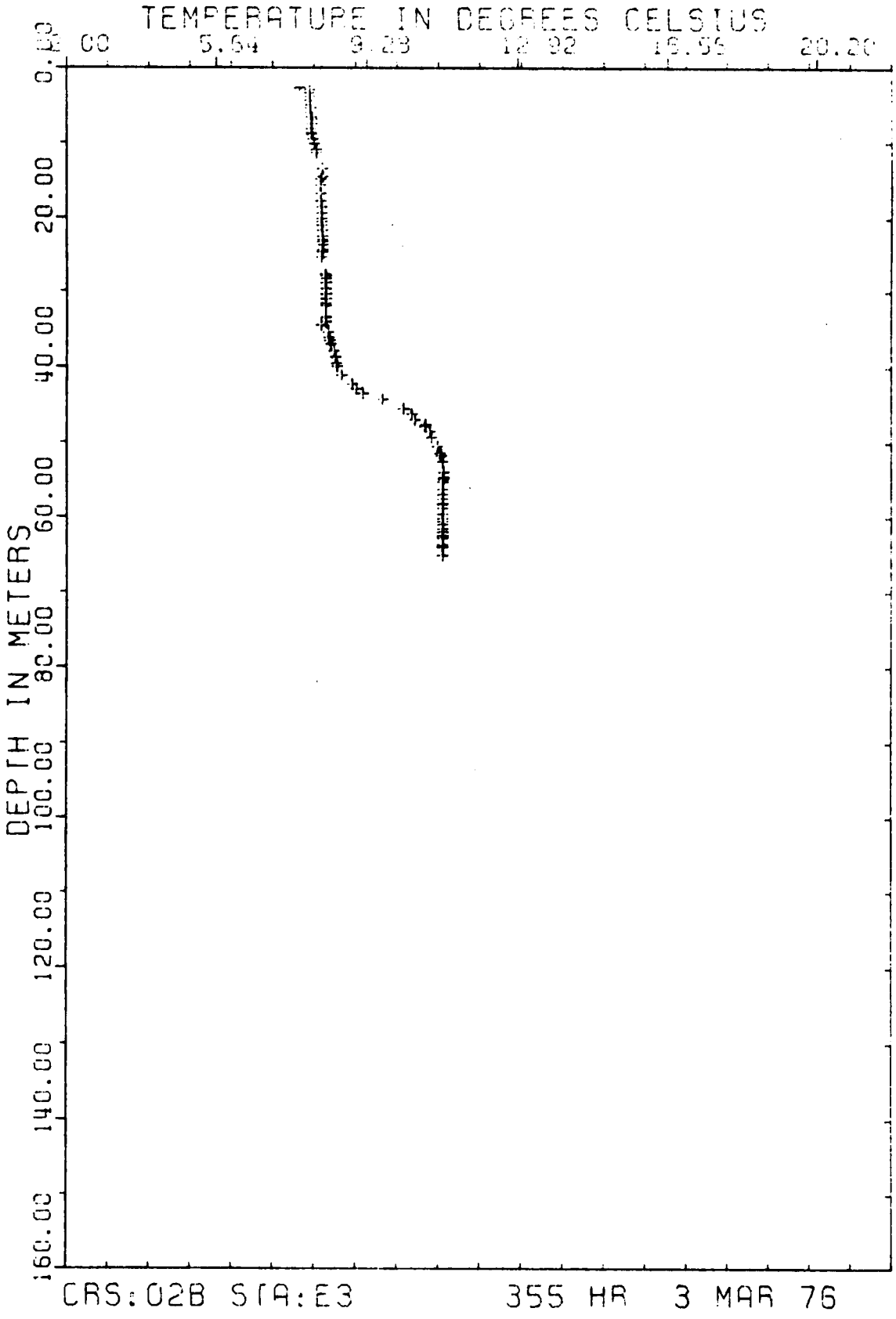

Figure 3-187. Temperature as a function of depth at Station E3 during cruise BLM Ø2W.

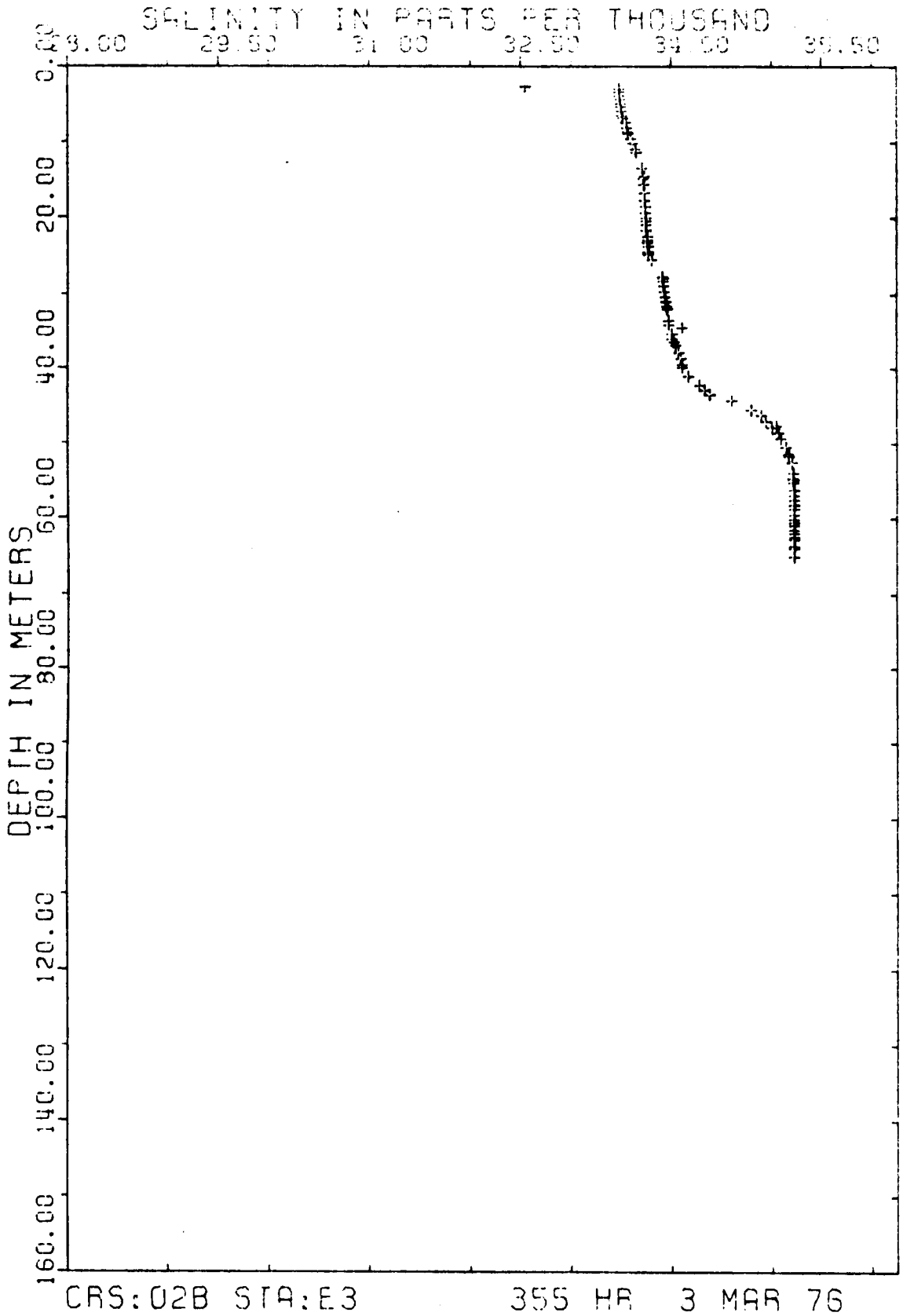

Figure 3-188. Salinity as a function of depth at station E3 during cruise BLM Ø2B.

Dissolved Oxygen and Micronutrients

Dissolved oxygen content of shelf waters during the winter sampling period ranged from 6 to 10 mg/liter for all regions except mid depths and bottom at deeper stations.

Dissolved micronutrient distributions were similar to those of the previous season in that, with the exception of NO_3 at the bottom on the outer shelf, concentrations were generally less than 1 µgm atm per liter.

Spring Conditions (June 1976)

Temperature, Salinity, and Density

Conditions encountered during the spring cruise indicated substantial freshening in the lower layers. Figures 3-104, 3-108, and 3-117 show the preponderance of shelf waters to have salinities less than 33.5 ppt. The strong intrusion of 34.5 ppt slope water along the bottom, which was encountered during the previous winter, was absent. Vernal warming extended to a depth of 18 to 20 meters across the shelf and produced a thin mixed layer. The thermocline region thickened in the offshore direction and covered depths ranging from 3 meters thick near shore to 27 meters thick near the shelf break. These conditions are most evident in Figures 3-189 to 3-192 which are plots of temperature as a function of depth for stations C1, D1, N3, and E2 respectively. Salinities in this mixed layer were in the 32 ppt region and increased to 33.5 ppt at the bottom at Station E2. The resulting pycnocline was strong, generally coincident with the thermocline, and progressed through 2.5 σ_t units at Station E2.

Persistence of the "cold pool" was evident with strongest signatures in the vicinity of the B and E stations as evidenced from Figures 3-97, 3-103, 3-107, and 3-116. Seaward of the E stations, intrusions of slope waters were evident at depths below 25 meters.

Dissolved Oxygen and Micronutrients

Bottom dissolved oxygen values were lowest in the vicinity of the 50 to 75 meter isobaths as evidenced in Figures 3-99, 3-105, 3-109, and 3-118. These low DO's went down to less than 3.5 mg/liter and were invariably overlain with highly oxygenated water which was found in the vicinity of the thermocline-pycnocline. This condition is most dramatically illustrated in Figures 3-193 to 3-195 for stations B1, N3A, and D4. Low bottom DO values were undoubtedly due to consumption and lack of deep mixing during the period between the winter and spring cruises. High DO values in the vicinity of the thermocline-pycnocline are most likely due to phytoplankton activity in this region (Jerlov 1970).

Micronutrients again show low values (< 1 µgm atm per liter) except for NO_3 which appeared in substantially higher concentrations in near surface as well as bottom waters (Figures 3-112, 3-114, and 3-121).

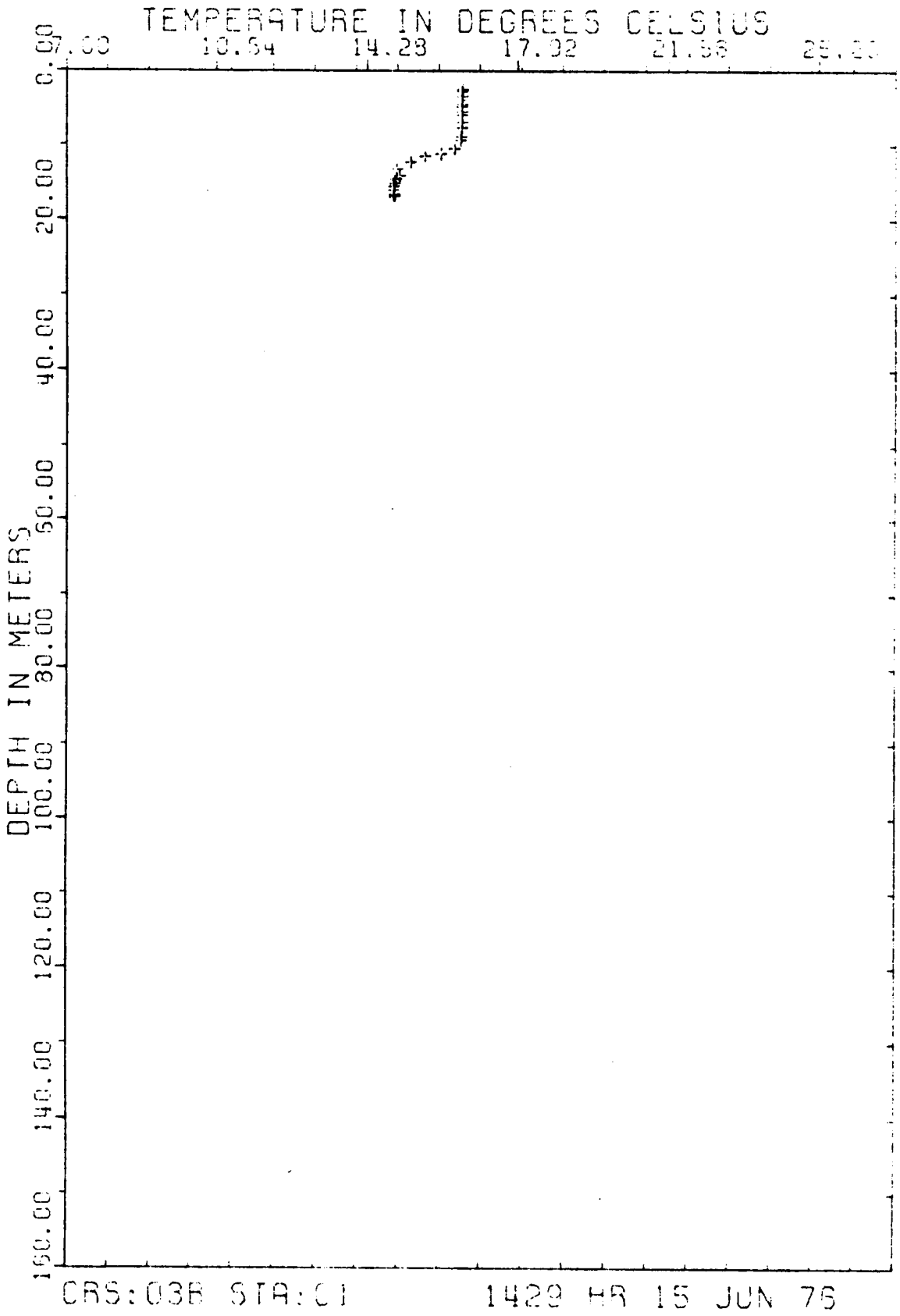

Figure 3-189. Temperature as a function of depth at Station C1 during cruise BLM Ø3B.

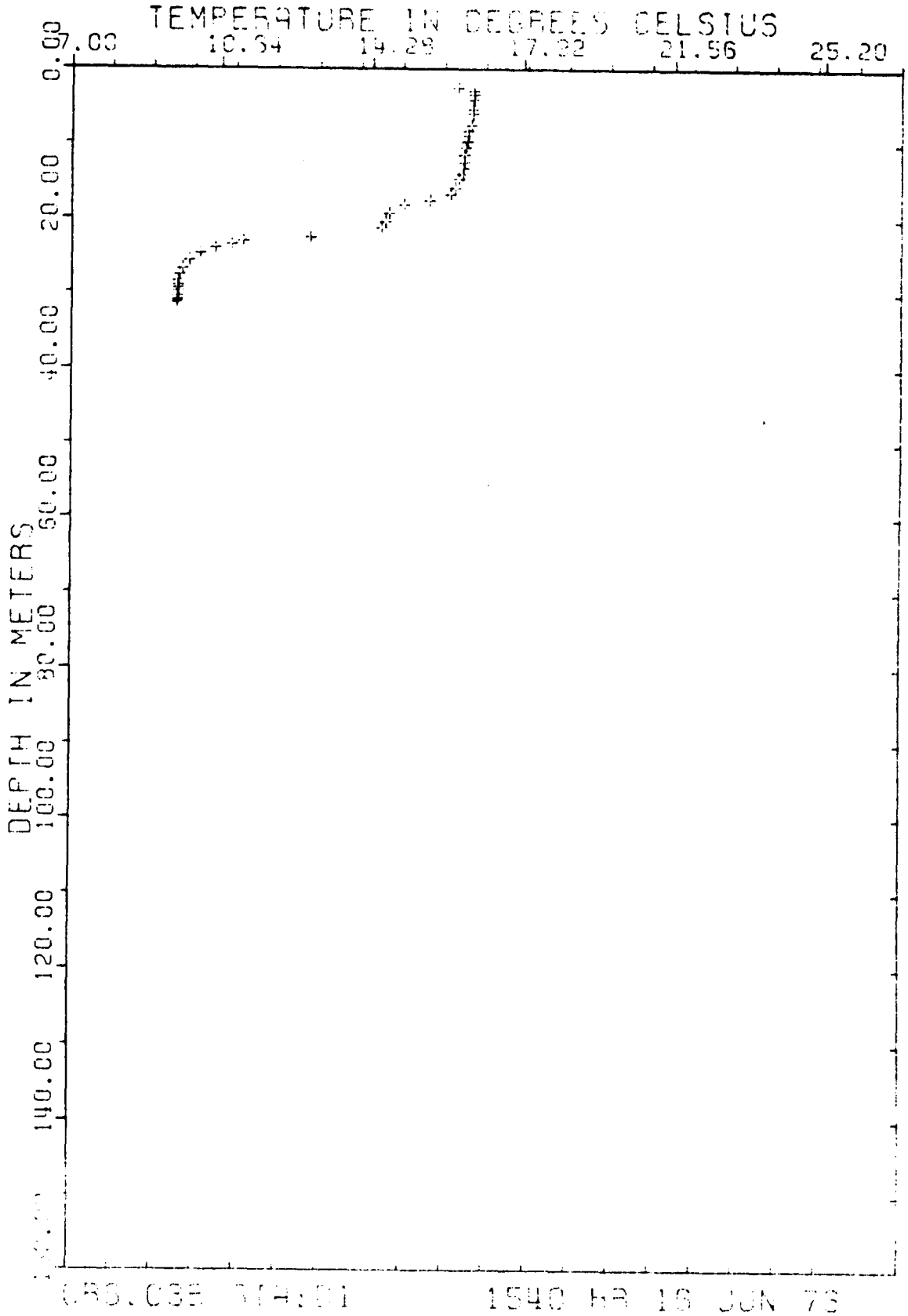

Figure 3-190. Temperature as a function of depth at Station D1 during cruise BLM Ø3B.

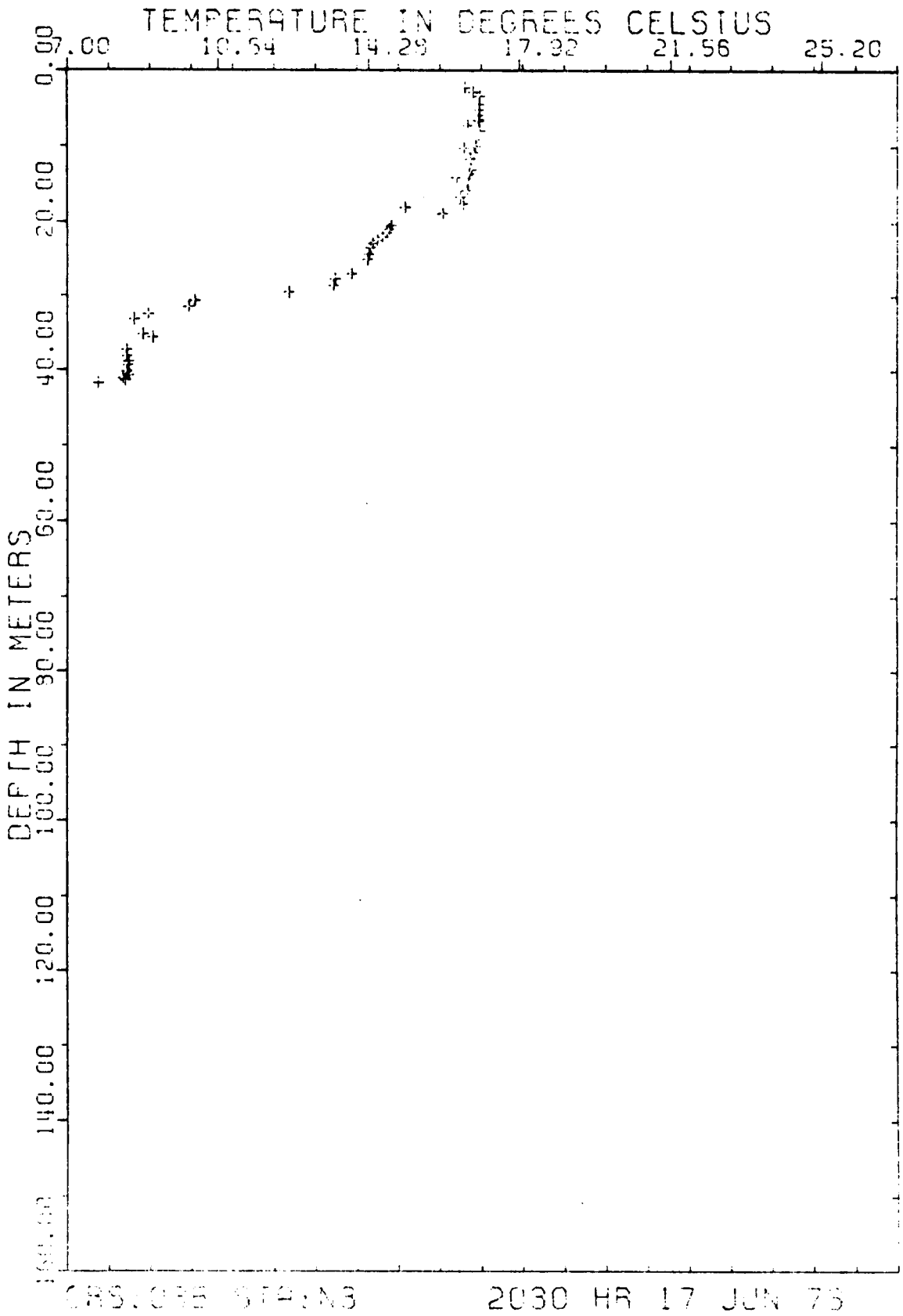

Figure 3-191. Temperature as a function of depth at Station N3 during cruise BLM Ø3B.

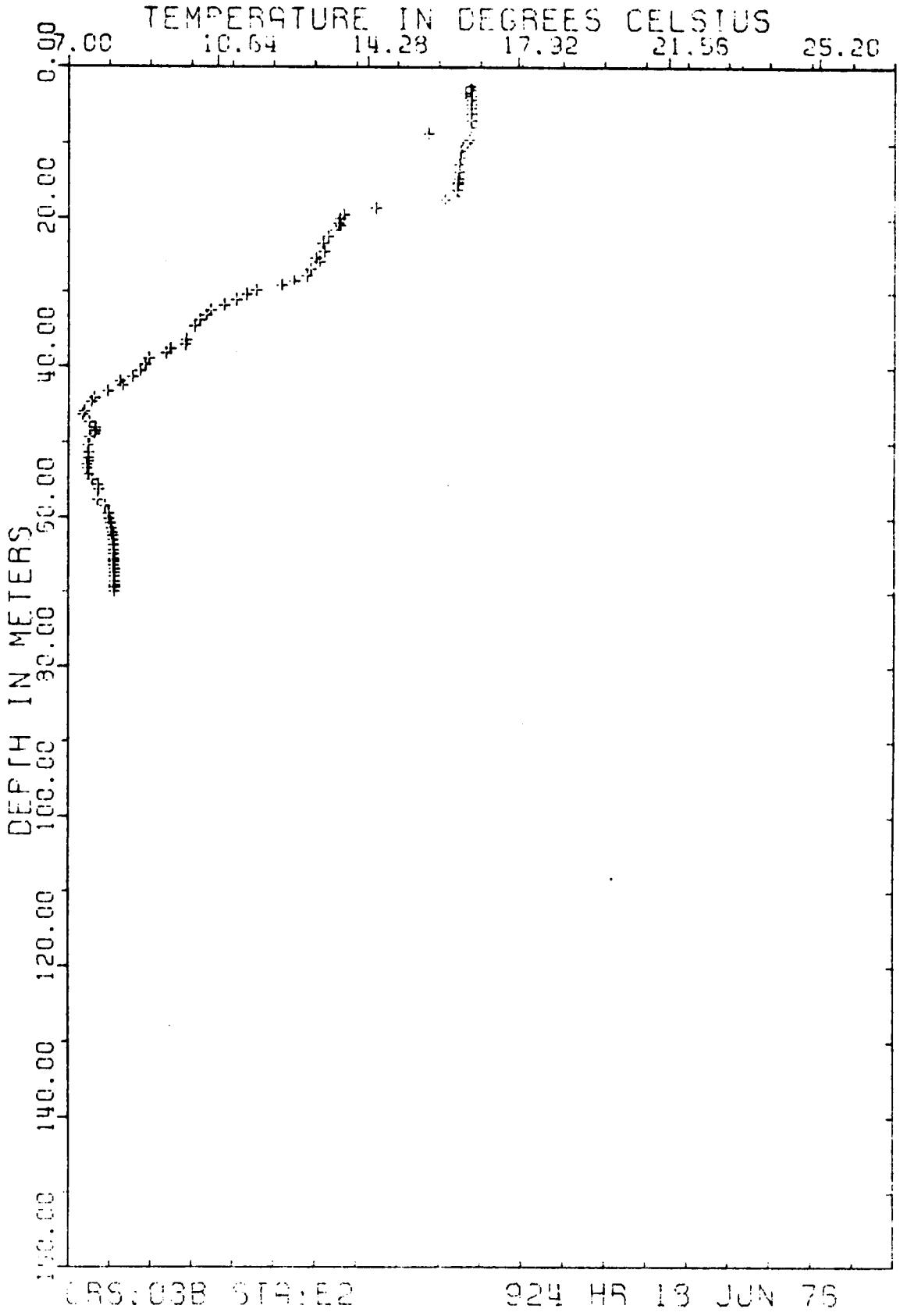

Figure 3-192. Temperature as a function of depth at Station E2 during cruise BLM 03B.

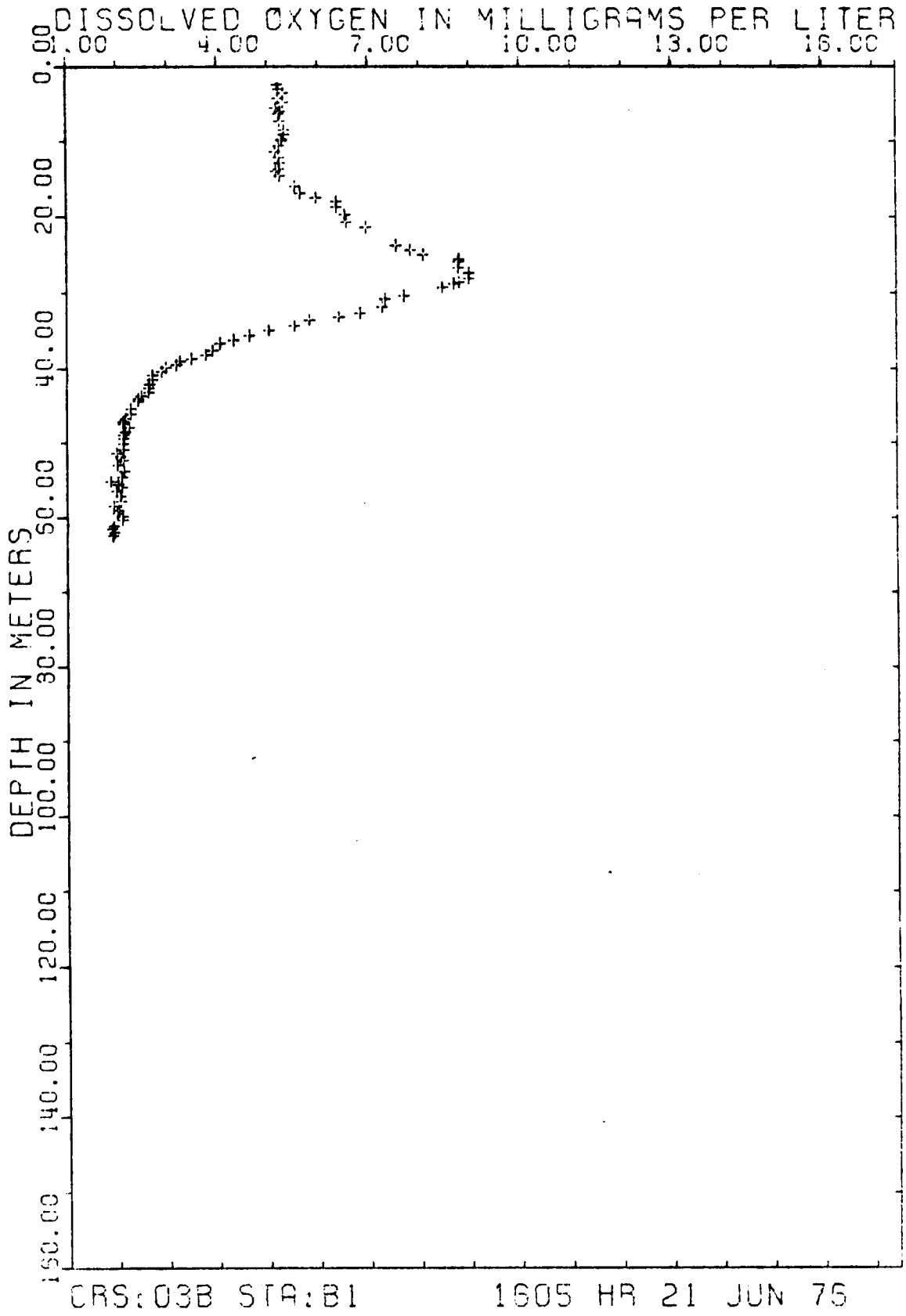

Figure 3-193. Dissolved oxygen as a function of depth at Station B1 during cruise BLM Ø3B.

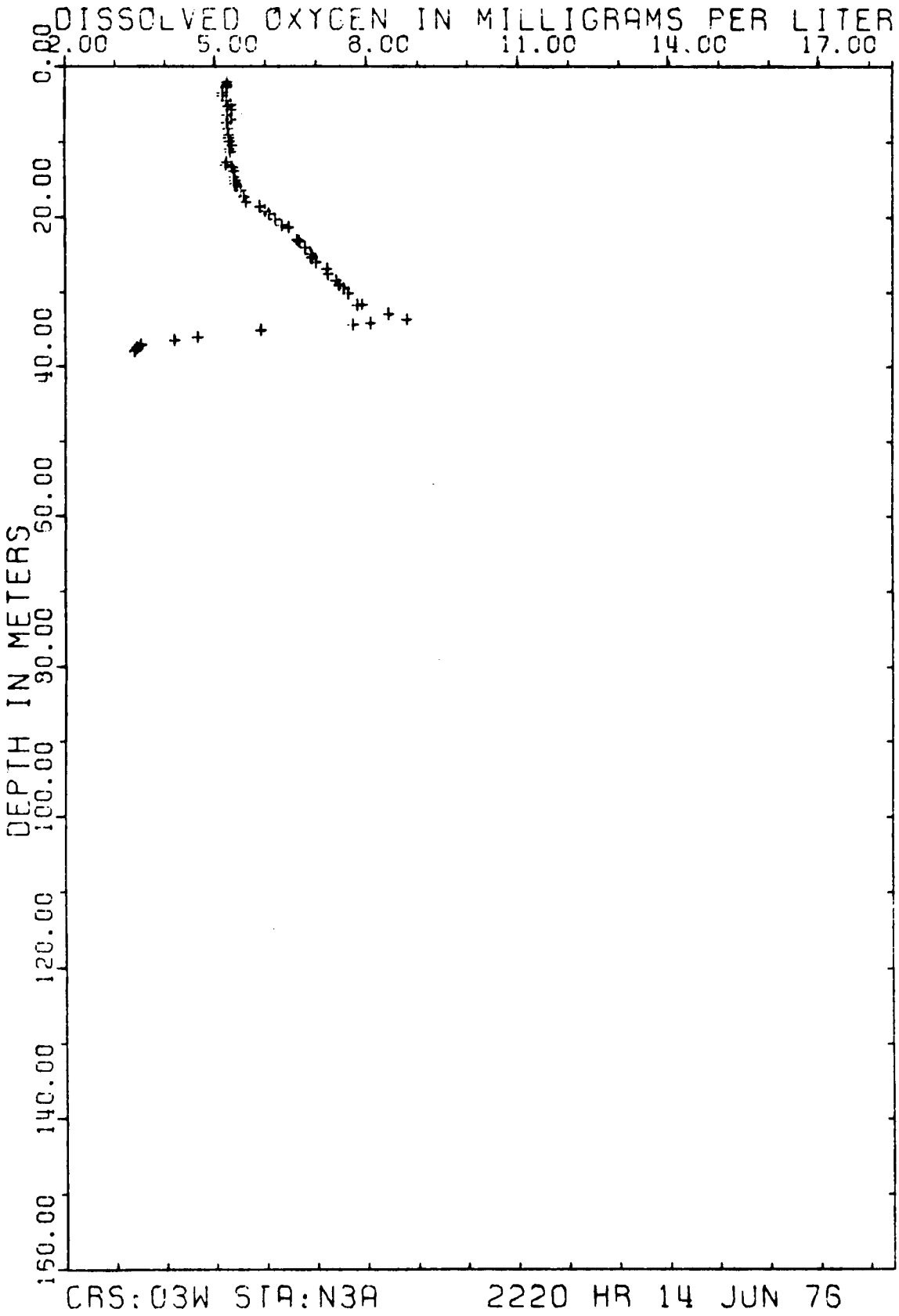

Figure 3-194. Dissolved oxygen as a function of depth at Station N3A during cruise BLM ϕ3W.

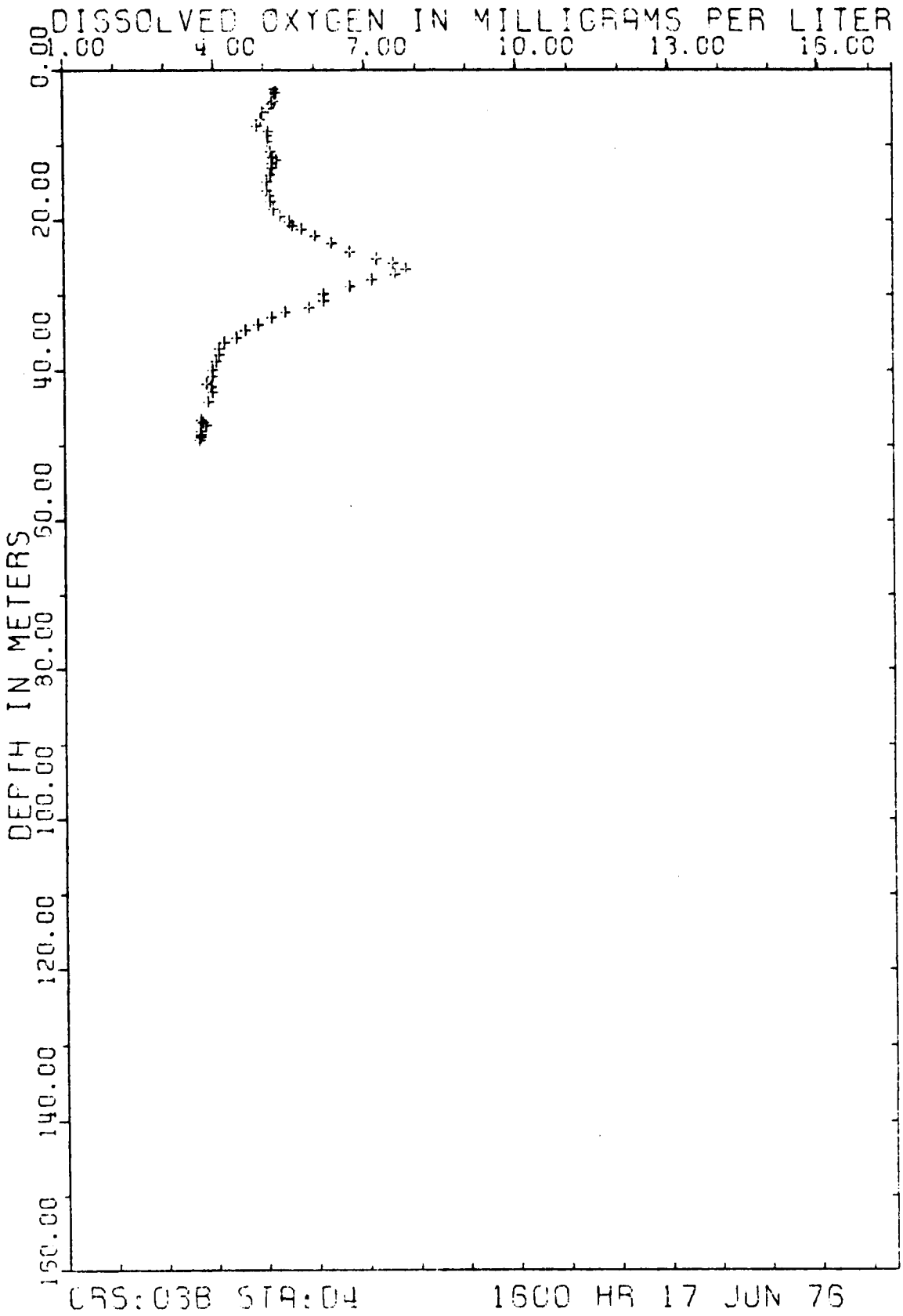

Figure 3-195. Dissolved oxygen as a function of depth at Station D4 during cruise BLM 03B.

Summer Conditions (August - September 1976)

Temperature, Salinity, and Density

The thermohaline structure of shelf waters found during the summer cruises showed strong vertical stratifications with nearly horizontal isopycnals extending offshore to where water depths were between 75 and 100 m. In the outer shelf region, mixing with slope water was evident with strong intrusions of slope water along the bottom as indicated by the positions of the 34.5 ppt isohaline in Figures 3-140, 3-144, 3-148, and 3-152. The mixed layer gradually thickened from 15 to 20 meters in its offshore extension as evidenced by temperature vs. depth trace for stations C1, D1, N3, and E2. (Figures 3-196, 3-197, 3-198, and 3-199). Persistence of the "cold pool" is evident along Sections II and III where water depths are between 50 and 75 meters. Figures 3-139 and 3-200 show this pool to be approximately 20 meters thick along Section II while along Section III it appears to be 25 meters thick and 0.5°C warmer (Figures 3-143 and 3-201). In both cases, salinity of the pool water is 33.1 to 33.2 ppt. The general shape and extent of this "cold pool" can be seen in Figure 3-129.

A region of apparent upwelling was encountered in the vicinity of Station F1 on Section III. Isotherms show a definite bend toward the surface (Figure 3-143); however, there is no similar bending of the isohalines (Figure 3-144). In fact, a salinity frontal system appears in this region. Upward bending of isopycnals does occur, except that this feature is found seaward of the regions of "thermal" upwelling (Figure 3-146).

Dissolved Oxygen and Micronutrients

The summer cruise occurred during the time anoxic water plagued the inner shelf regions near the New Jersey coast. Figure 3-131 shows the extent of bottom anoxic conditions encountered. Further seaward, bottom DO values increased but an oxygen minimum layer became detached from the bottom and extended seaward over intruding slope waters as seen by comparing Figures 3-144 and 3-145. This oxygen minimum layer is further illustrated in Figures 3-202 and 3-203 which show DO as a function of depth at stations E2 and E1 respectively.

Two significant changes in the surface and bottom distributions of micronutrients were encountered when compared to previous seasons. Bottom values of nitrites were elevated immediately seaward of regions of strong anoxia (Figures 3-158, 3-160, and 3-132), and the region of thermal upwelling showed a depletion of surface O-PO_4 (Figure 3-128).

Water Mass and Type Analysis

The water type progression observed during the first full year of cruises (BLM 01 to BLM 04) is, in many general respects, similar to that described by Beardsley and Flagg (1975) and Voorhis, Webb, and Millard (1976) over the shelf and slope south of New England. Some of the differences that are evident are due to the more onshore and southern extent of the present study when compared to those cited above. In all of these cases, the use of a profiling CTD unit allowed interpretations to be made with data which, had only discrete bottle samples been used, would remain obscure.

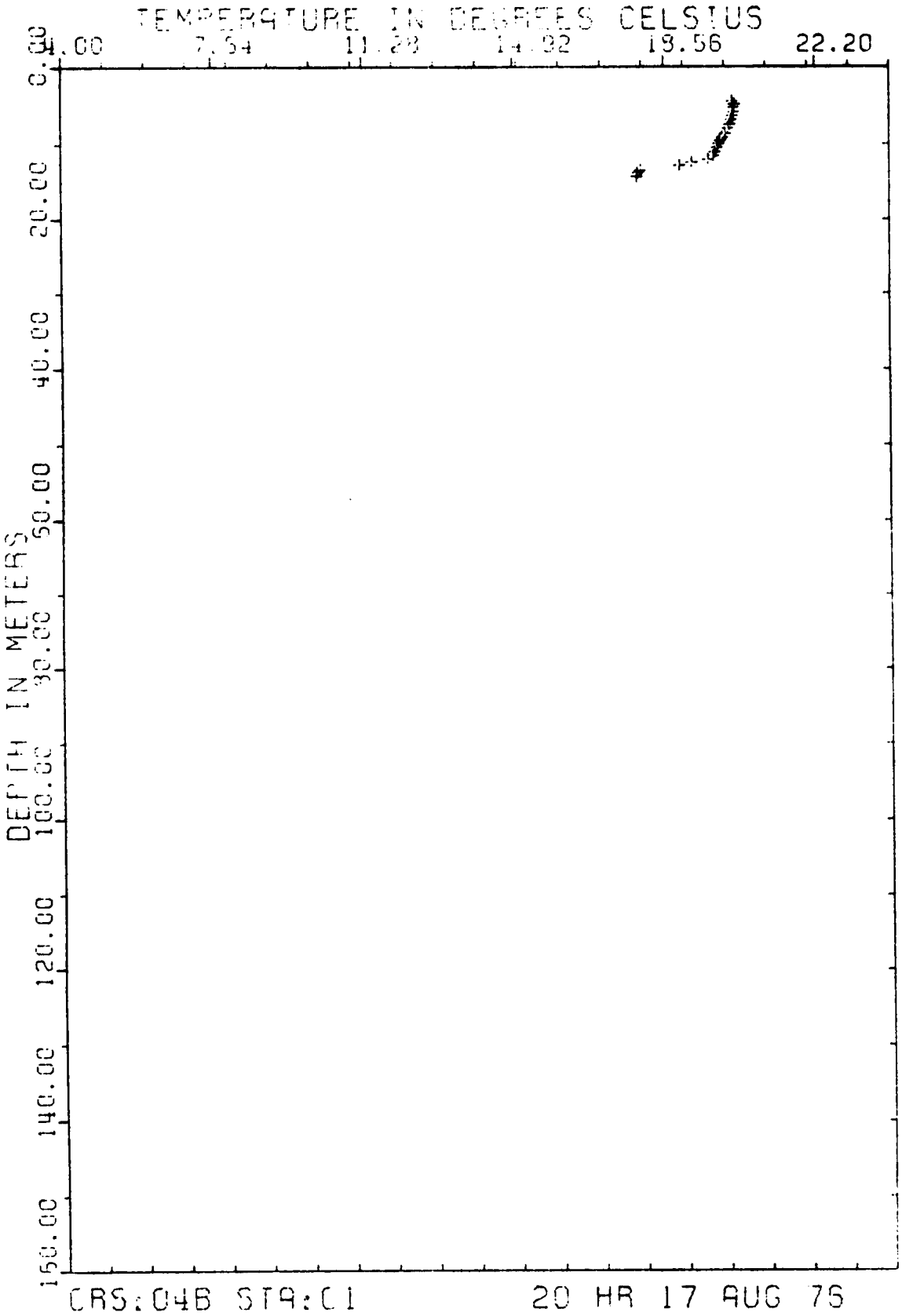

Figure 3-196. Temperature as a function of depth at Station C1 during cruise BLM Ø4B.

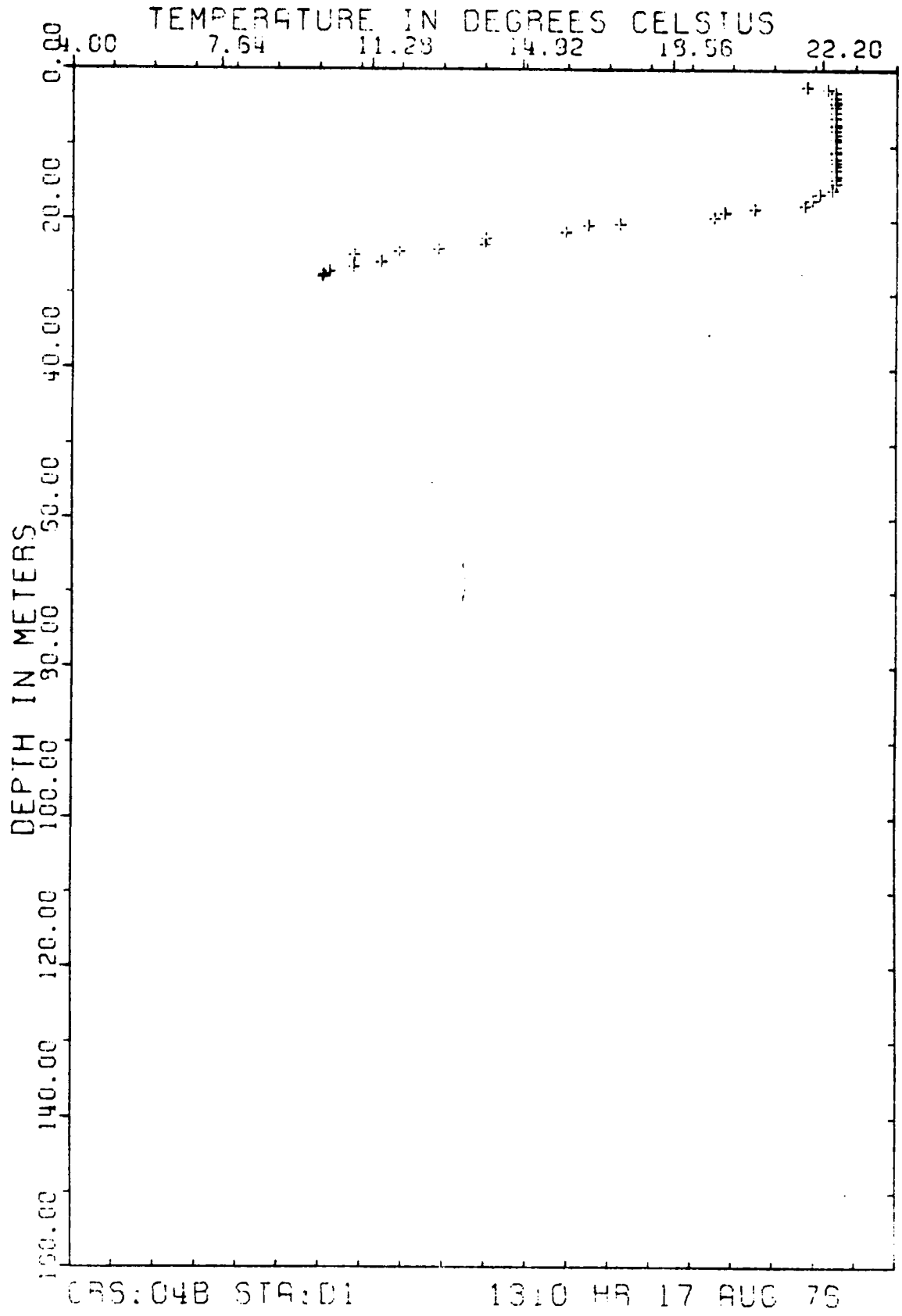

Figure 3-197. Temperature as a function of depth at Station D1 during cruise BLM ϕ4B.

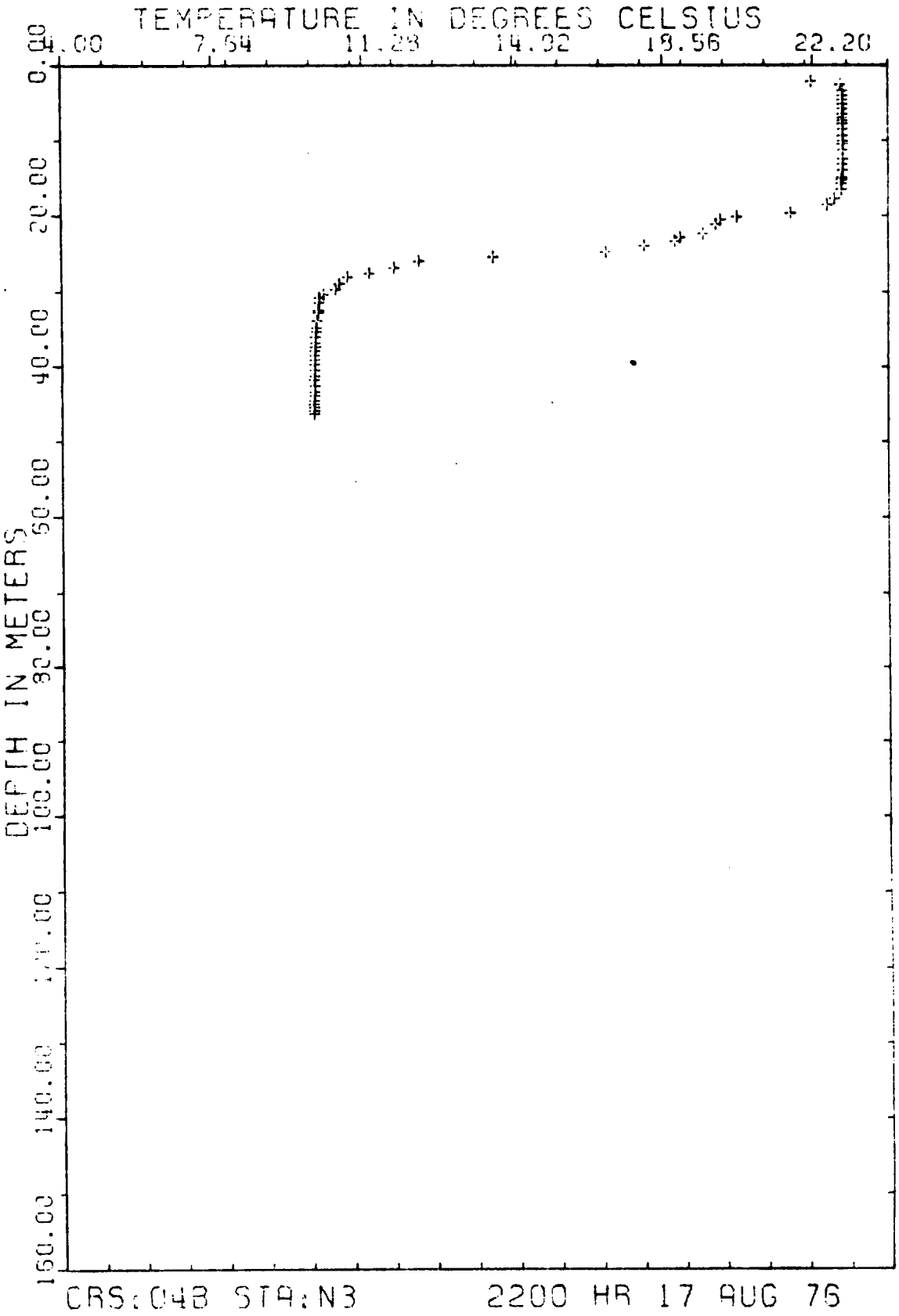

Figure 3-198. Temperature as a function of depth at Station N3 during cruise BLM Ø4B.

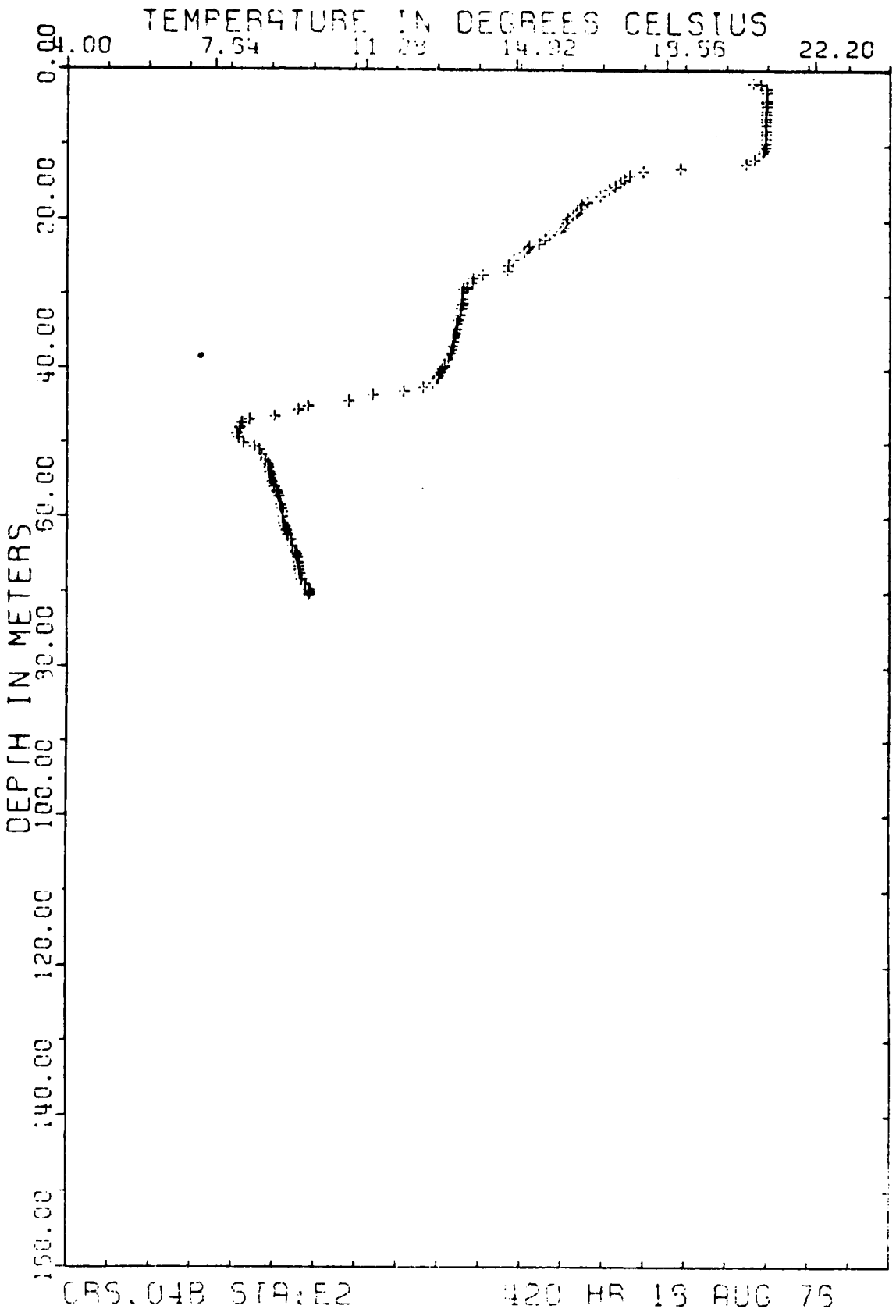

Figure 3-199. Temperature as a function of depth at Station E2 during cruise BLM Ø4B.

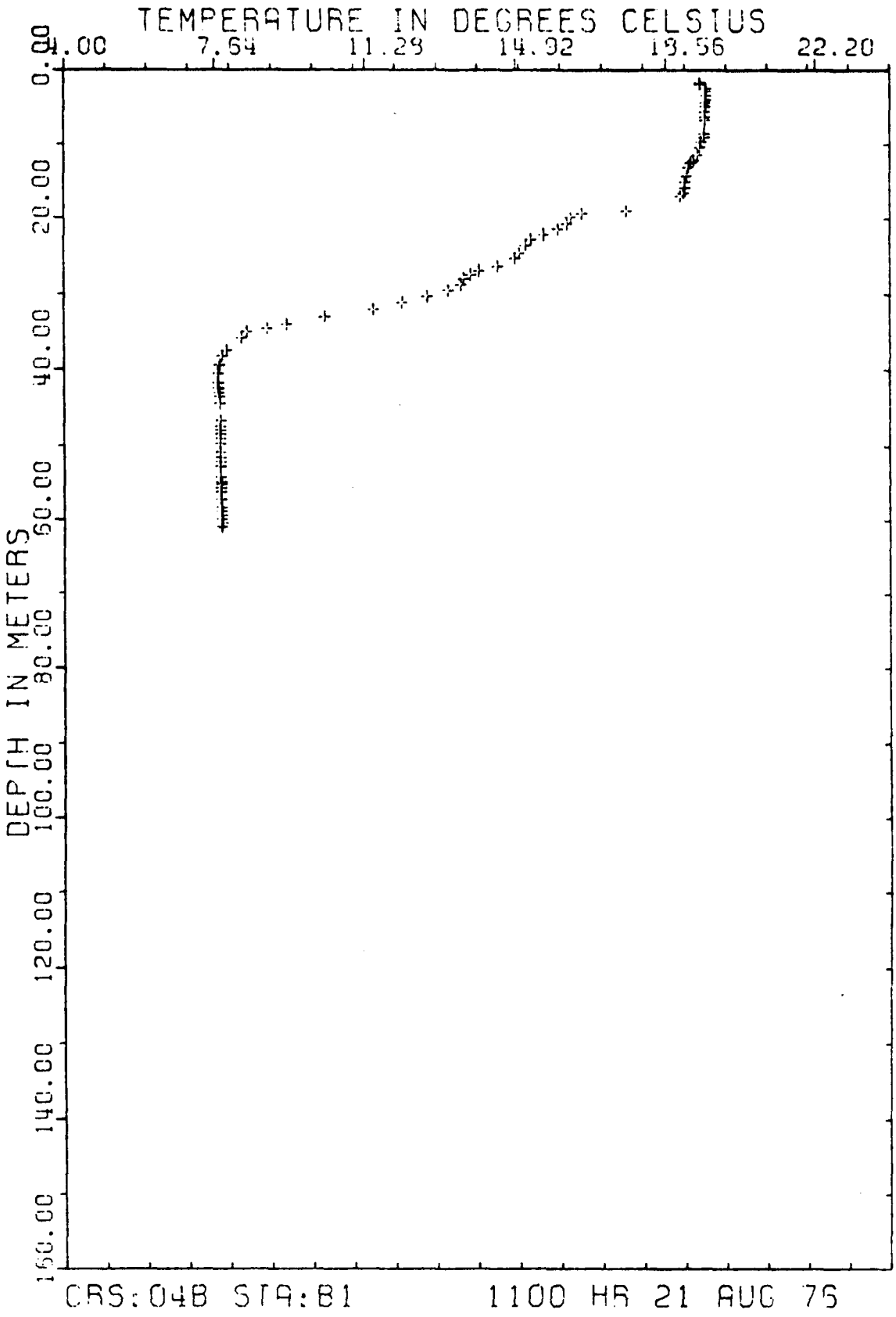

Figure 3-200. Temperature as a function of depth at Station B1 during cruise BLM Ø4B.

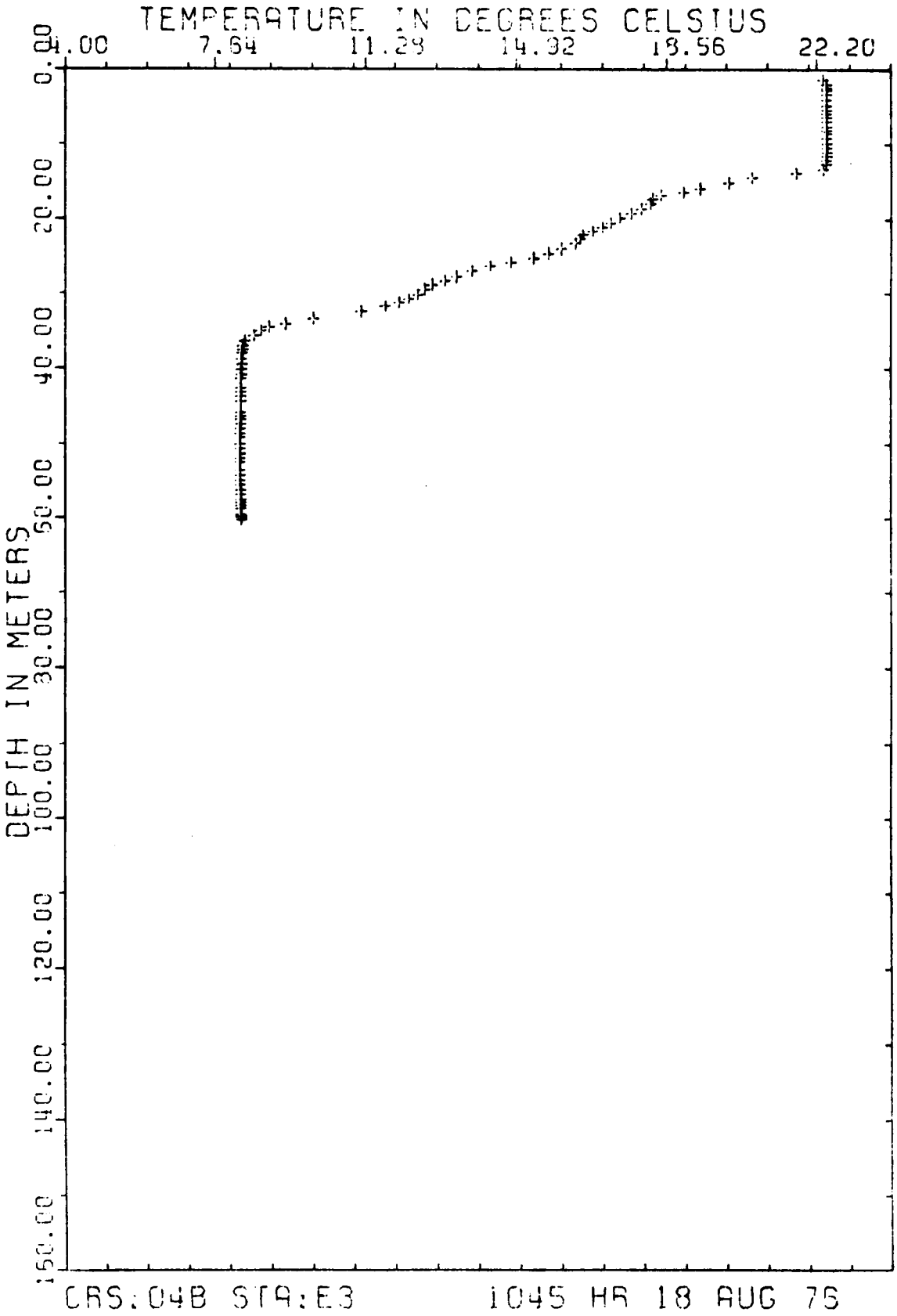

Figure 3-201. Temperature as a function of depth at Station E3 during cruise BLM Ø4B.

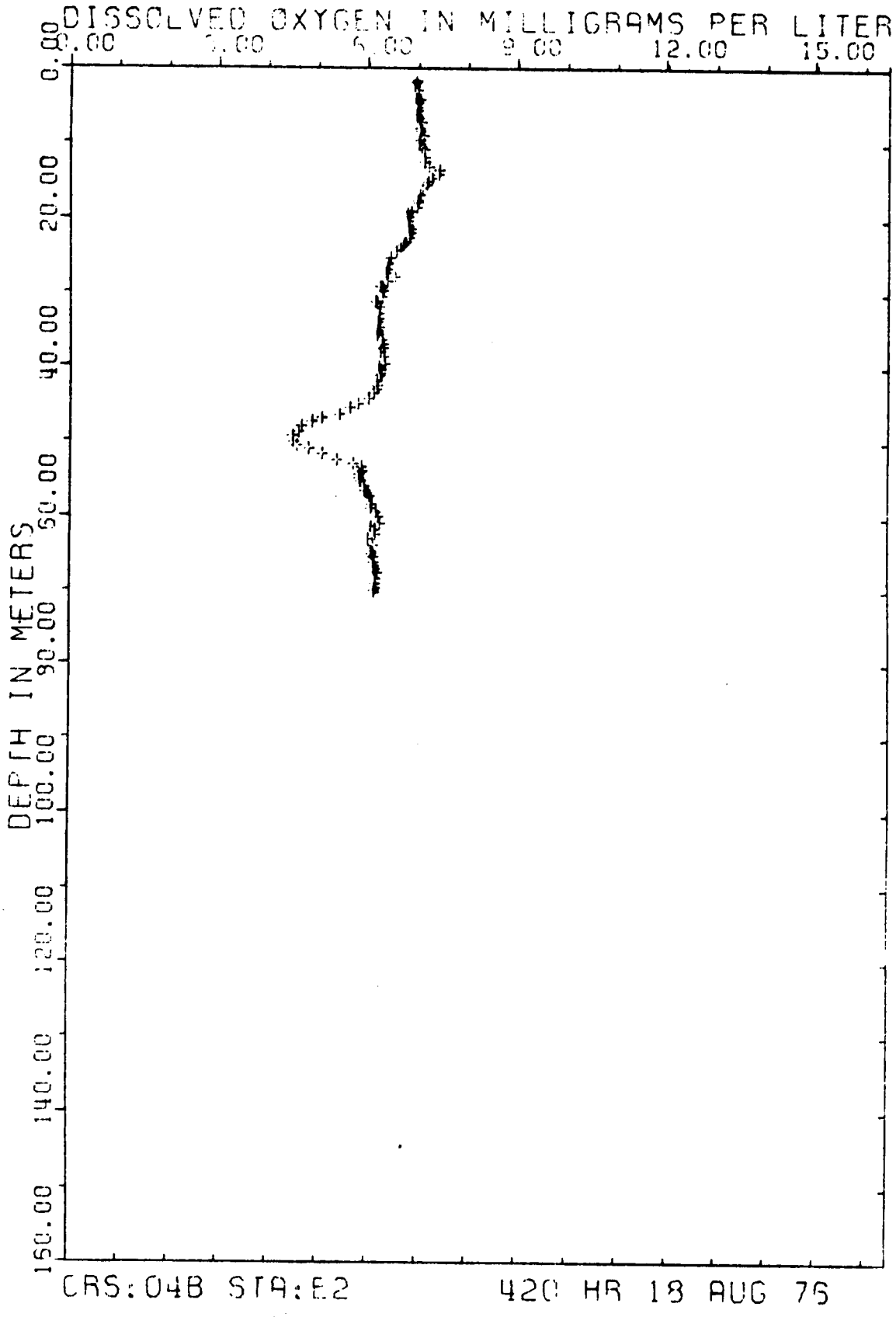

Figure 3-202. Dissolved oxygen as a function of depth at Station E2 during cruise BLM Ø4B.

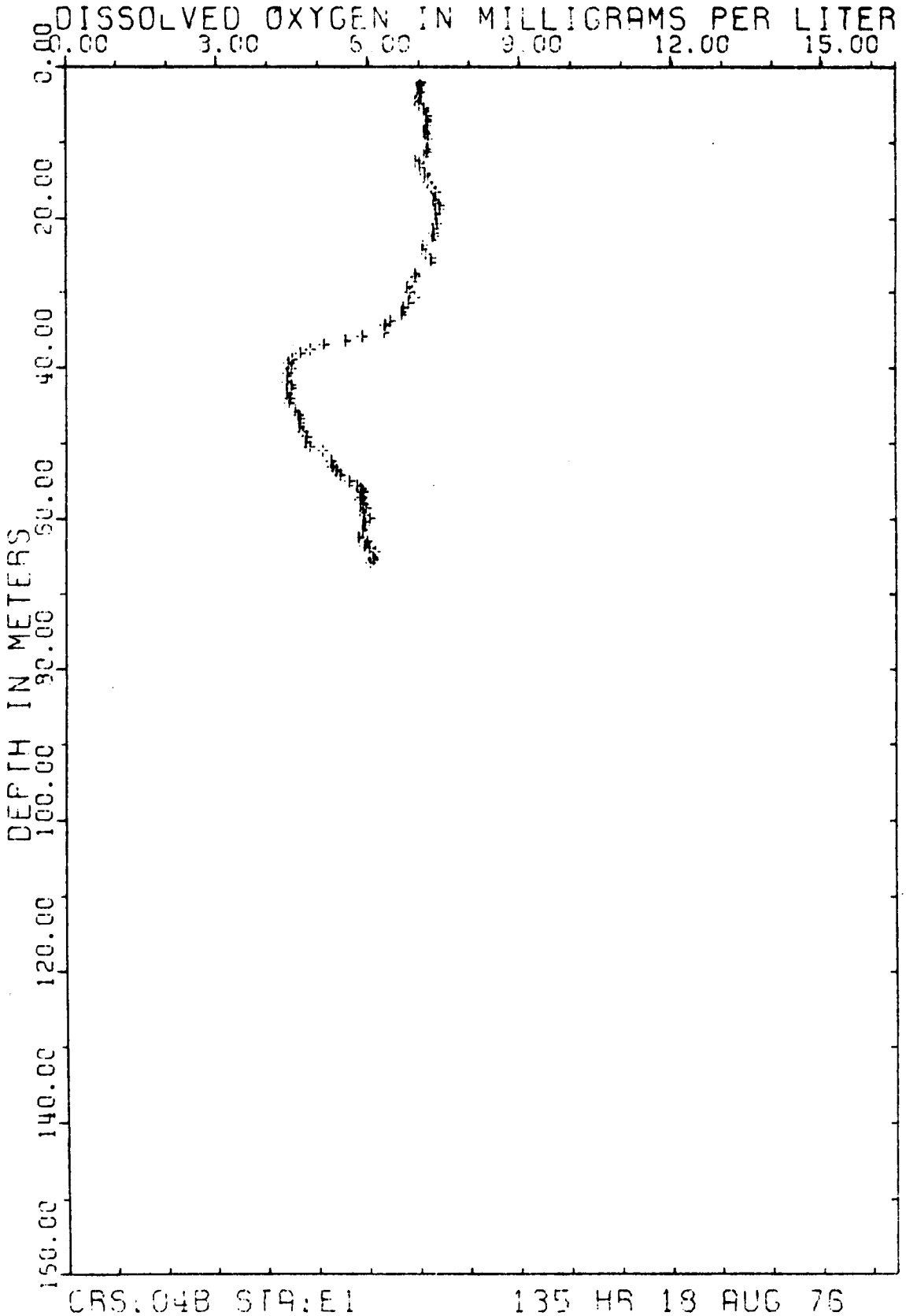

Figure 3-203. Dissolved oxygen as a function of depth at Station E1 during cruise BLM Ø4B.

Before examining these results in some detail, some features of the individual cast Temperature vs. Salinity curves will be noted. In the simplest case, for example Station D2 on cruise BLM 01B (Figure 3-204a-c), the intensity of the fall mixing creates a truly homogeneous water column which appears in the T-S correlation as a single point. In the example, a 27 meter long water column has been stirred to the point that it has a single value of temperature and salinity. In this case, the water is a 16.2°C and 32.4 ppt. Although the entire column is represented by a single water type, it is not likely to be a stable one, as it is certainly in the midst of being cooled, and hence "migrating" vertically down the T-S plane, as it is being observed. The next simplest case is well represented by Station B3 on cruise BLM 02B (Figure 3-205a-c), 4 March 1976. This case is that of some mixing between two well defined water types. In this instance, the interpretation is slightly complicated by the freshening of the water adjacent to the free surface. Such a freshening is consistent with about 3 cm of recent precipitation. The slight asymmetry in the population of water types in the narrow mixing region indicates that the turbulent mixing intensity is greater in the lower water type than in the upper one. A feature of this T-S curve which will be important in later analysis is that an agglomeration of points marks the two primary water types. As a slight contrast to this case, that of Station B1 in the same cruise (Figure 3-206a-c) shows nearly the same T-S correlation line, but an agglomeration region is evident nearly midway between the two end points on the mixing curve. In this case, there are three water types evident in the water column, which again shows freshening in the uppermost region. Such a correlation is consistent with a series of events which includes strong wind mixing, perhaps nearshore, of two water types resulting in the formation of a "daughter" water type which, under the cessation of the mixing driving, intrudes between the "parent" water types. A more general case of mixing in pairs between three water types is shown by Station E4 of cruise BLM 01B (Figure 3-207a-c). This curve exhibits an "L" shape, with agglomerations at the two ends and the corner of the "L". In this case, the intermediate water type bears no apparent relation to the types between which it is found. A still more complex signature is found on the outer part of the shelf, particularly during the summer. This pattern, represented well by Station I1 of cruise BLM 03B (Figure 3-208a-c) is found when the shelf-slope front breaks down into interleaving layers or intrusions. As the thin layers erode between the thicker layers, they lose their characteristic temperature and salinity, and the sharp points of their "L"s become rounded off. The remaining well defined water types are associated with the sharp corners remaining on the correlation curve. The resulting pattern is reminiscent of a telegraph wire strung between poles, so it is suggested that a "telegraph wire signature" be assigned as a name to this particular signature. A similar example is given by Voohris et al. (1976) in their Figure 13. The final illustrative example is given by Station J1 of cruise BLM 01B (Figure 3-209a-c), November 1975. The lower right part of this correlation diagram consists of what appears to be an entire agglomerated line. This line represents the slope water, and it is a stable feature found during all seasons of the year in the deep (greater than 200 meter) stations. Its T-S characteristic is within the range of North Atlantic Central Water. The slope water represents a true water mass, as distinct from the water types discussed above.

A great variety of T-S correlation signatures was observed during the year's survey of the continental shelf, in contrast to the apparent stability

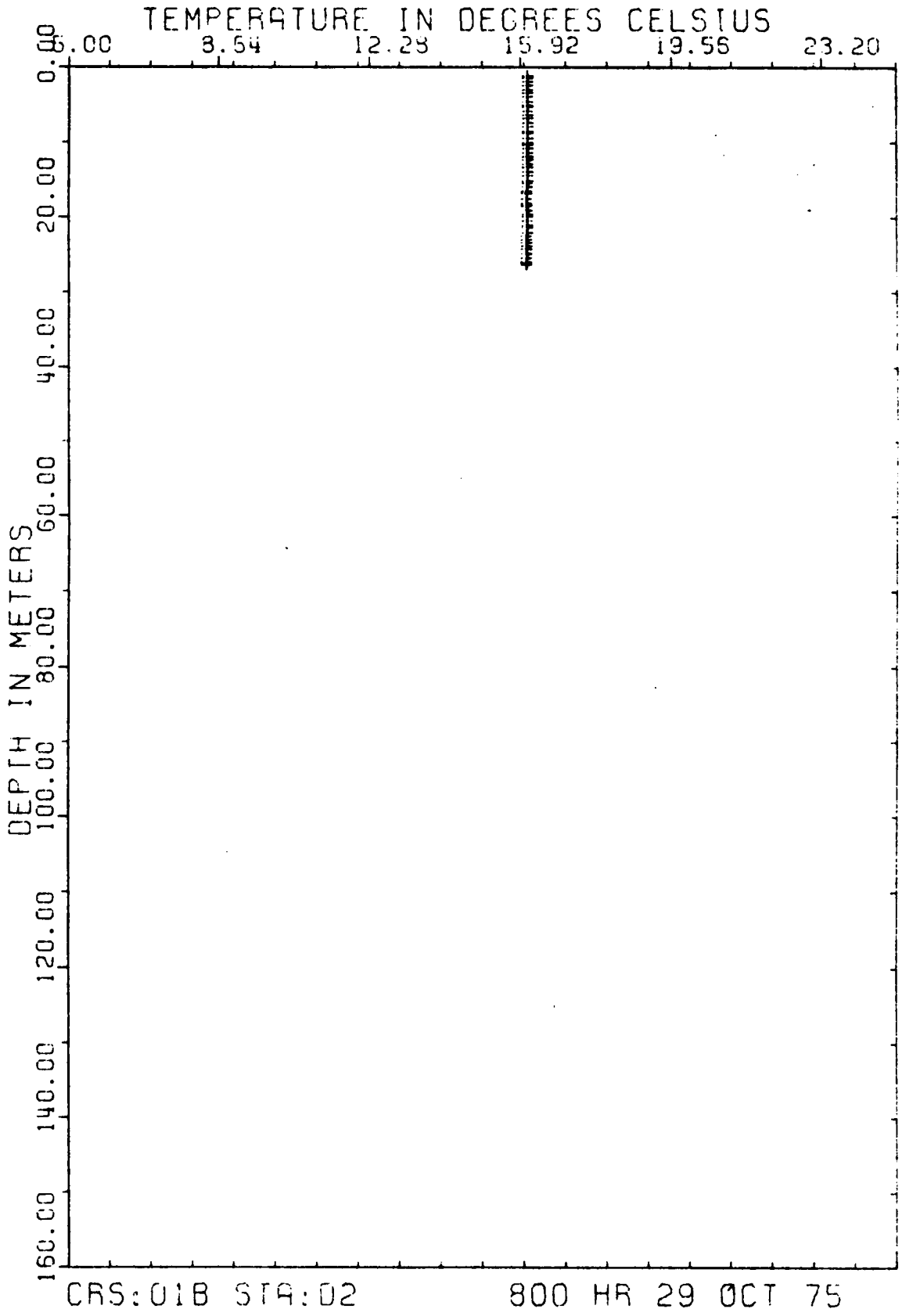

Figure 3-204a. Temperature as a function of depth at Station D2 during cruise BLM Ø1B.

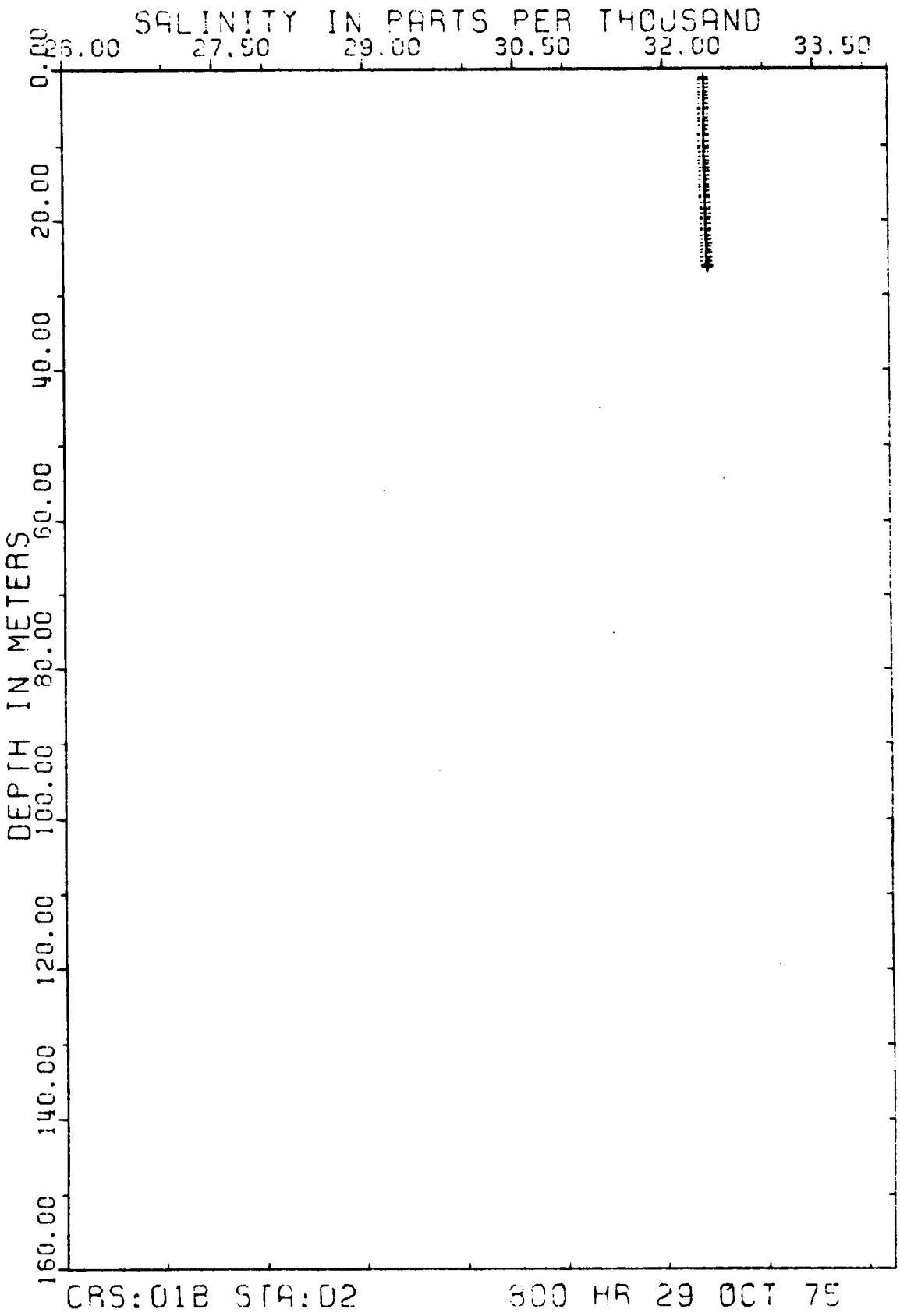

Figure 3-204b. Salinity as a function of depth at Station D2 during cruise BLM ∅1B.

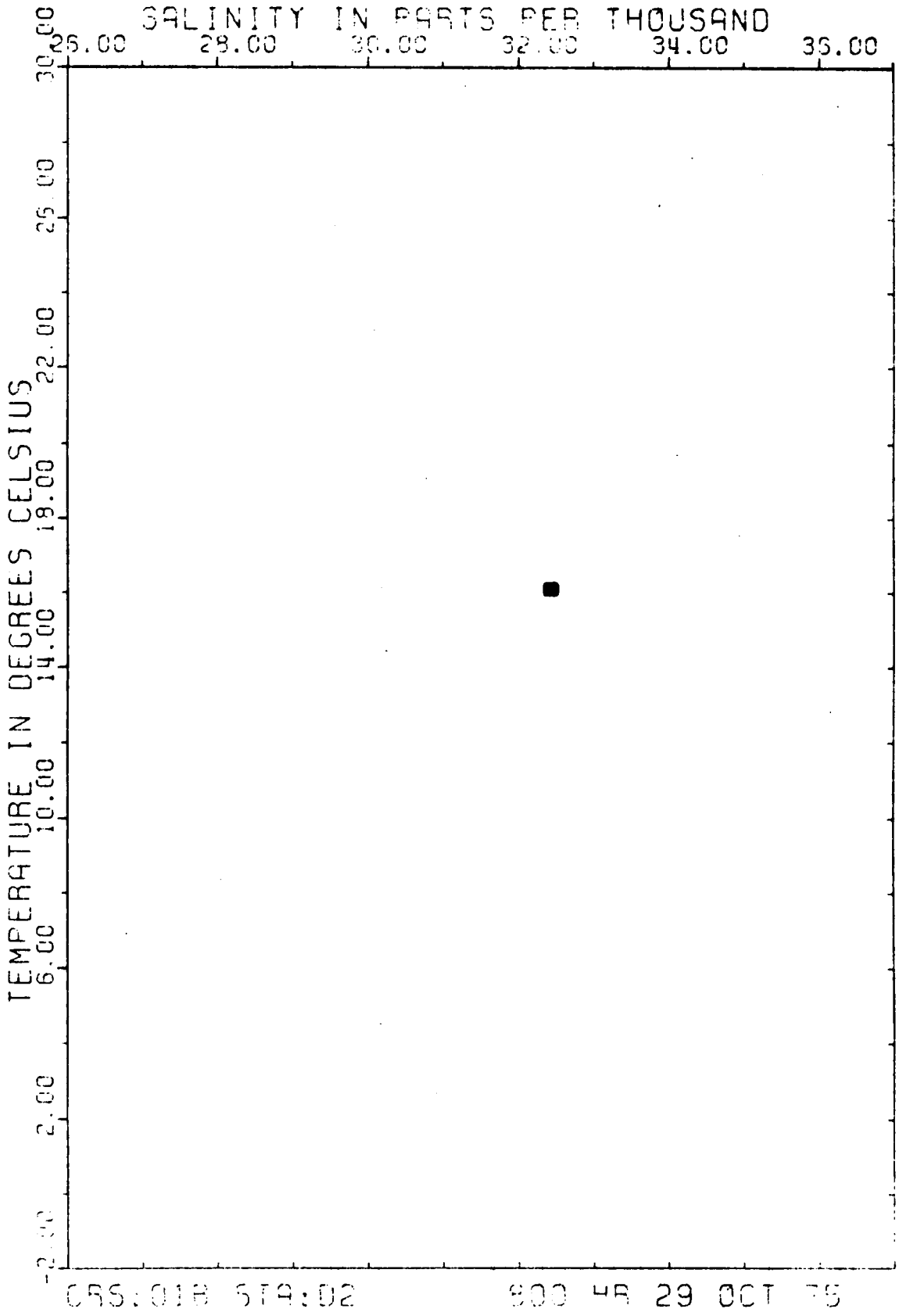

Figure 3-204c. T-S diagram for Station D2 on cruise BLM Ø1B.

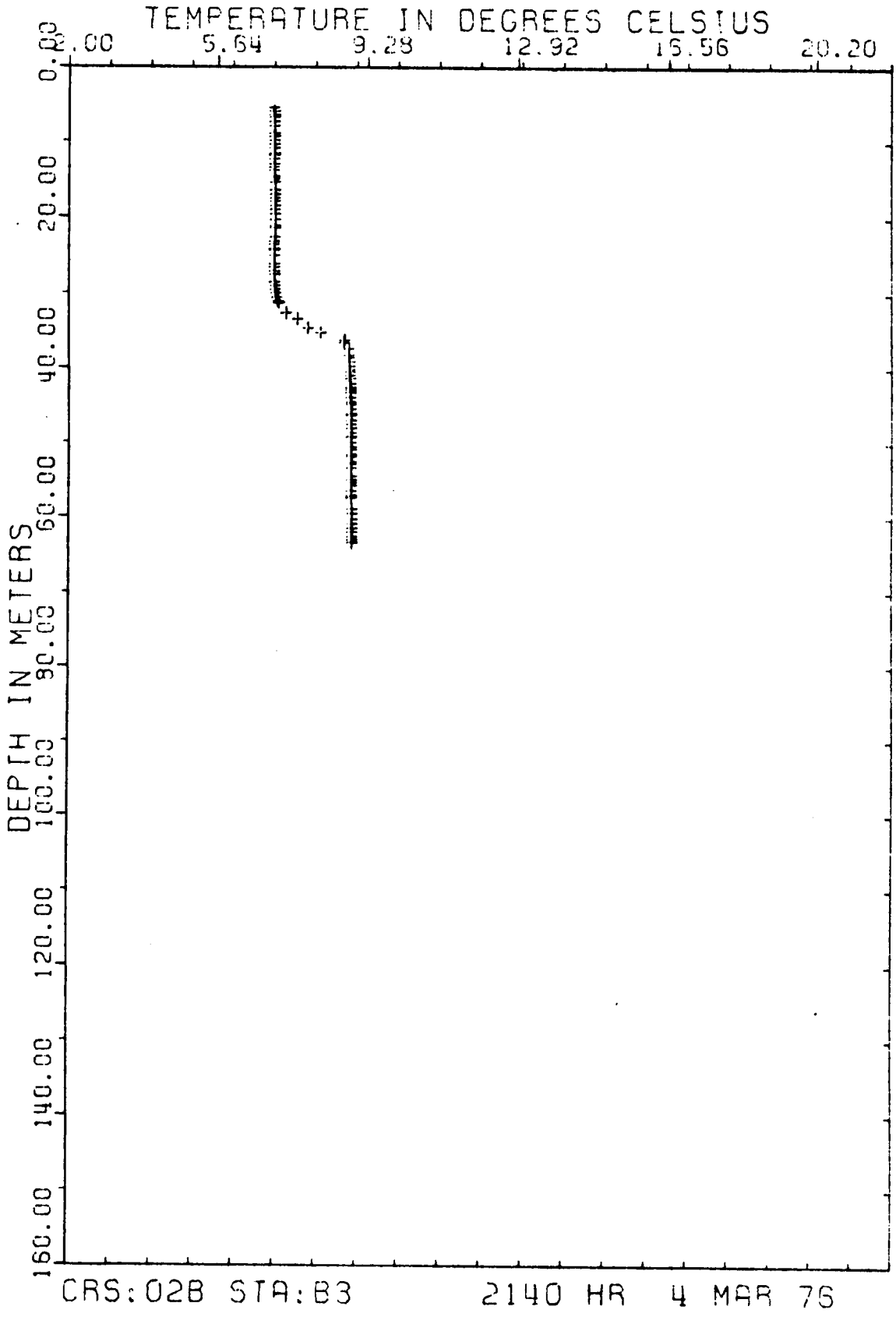

Figure 3-205a. Temperature as a function of depth at Station B3 during cruise BLM Ø2B.

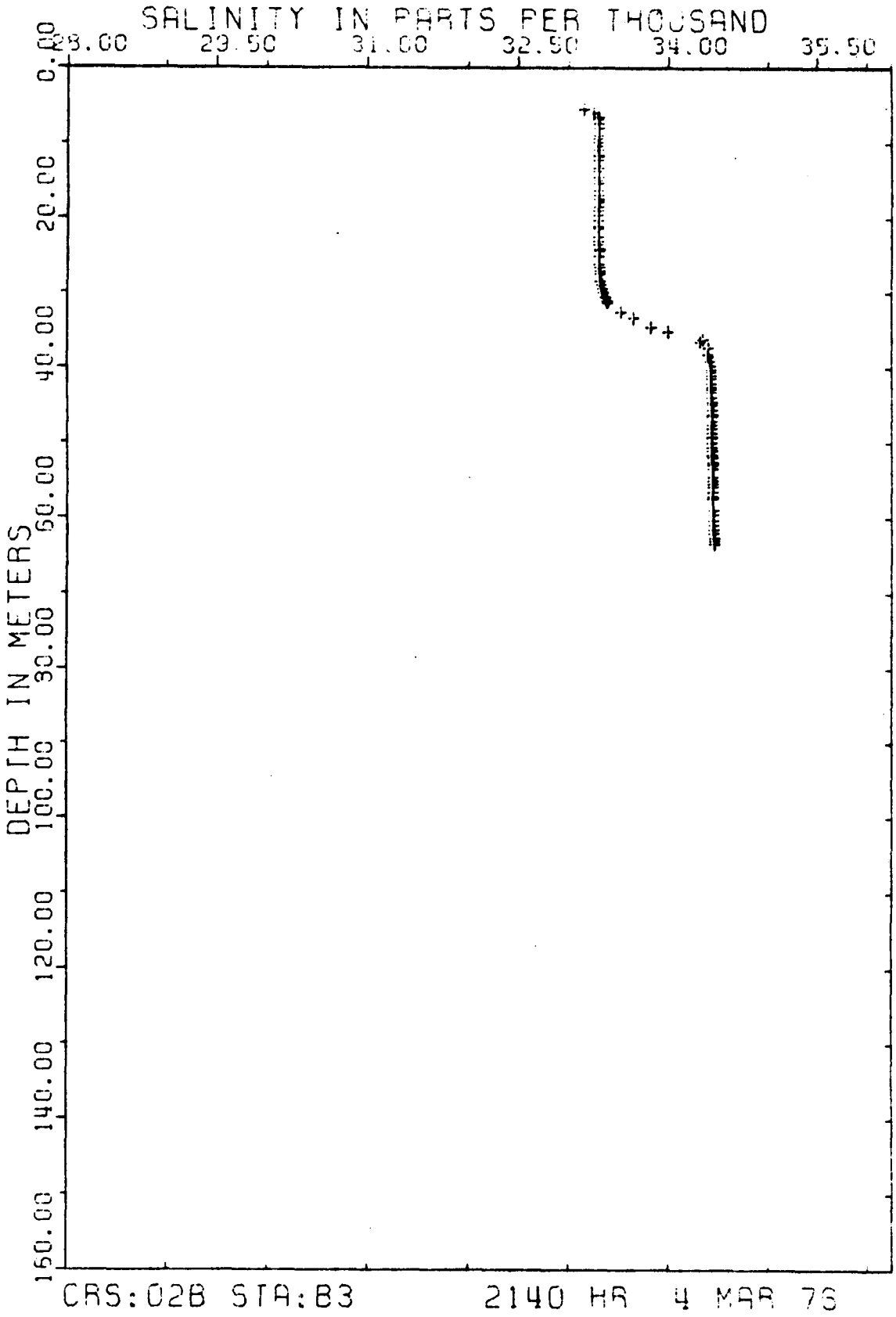

Figure 3-205b. Salinity as a function of depth at Station B3 during cruise BLM Ø2B.

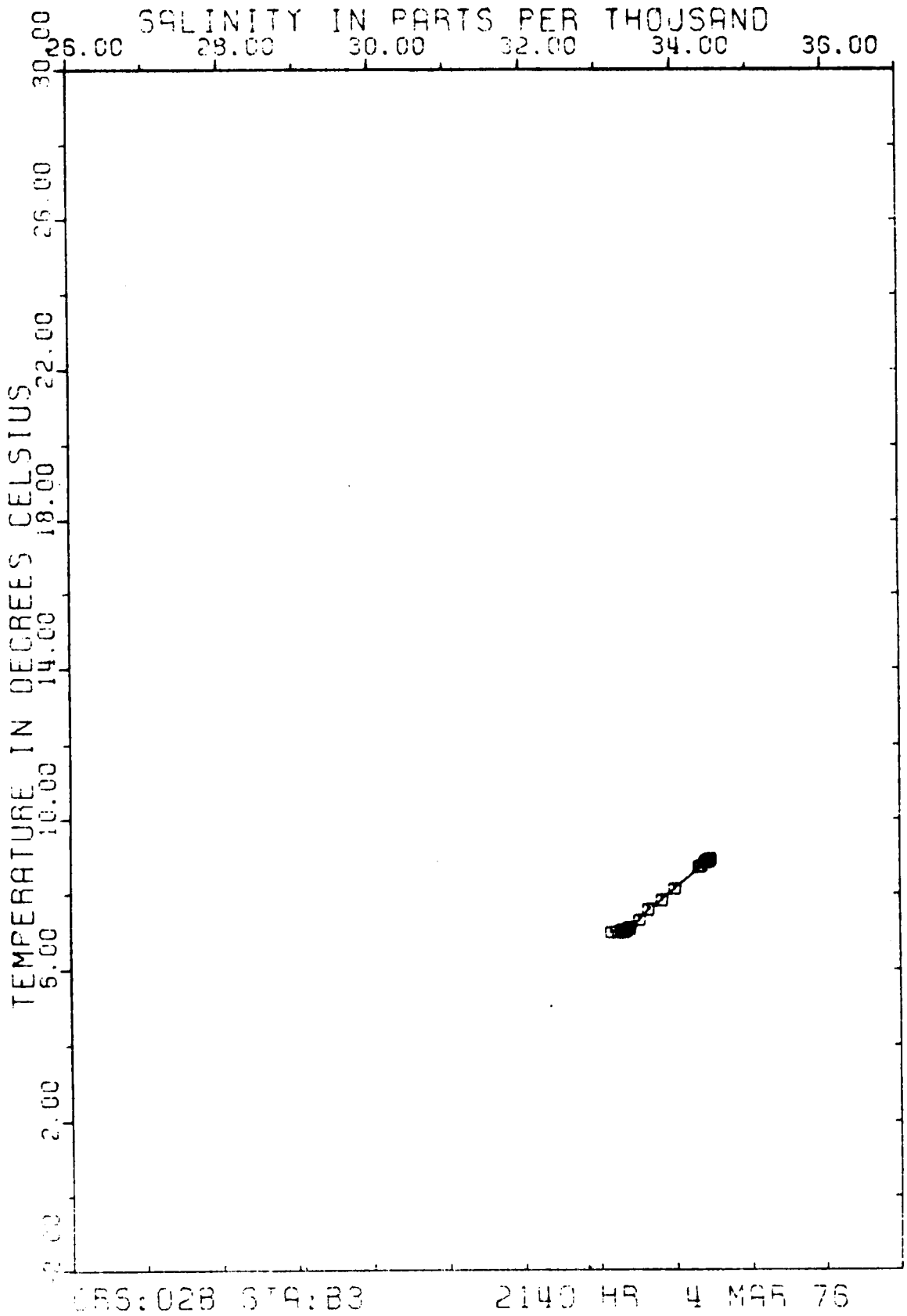

Figure 3-205c. T-S diagram for Station B3 on cruise BLM Ø2B.

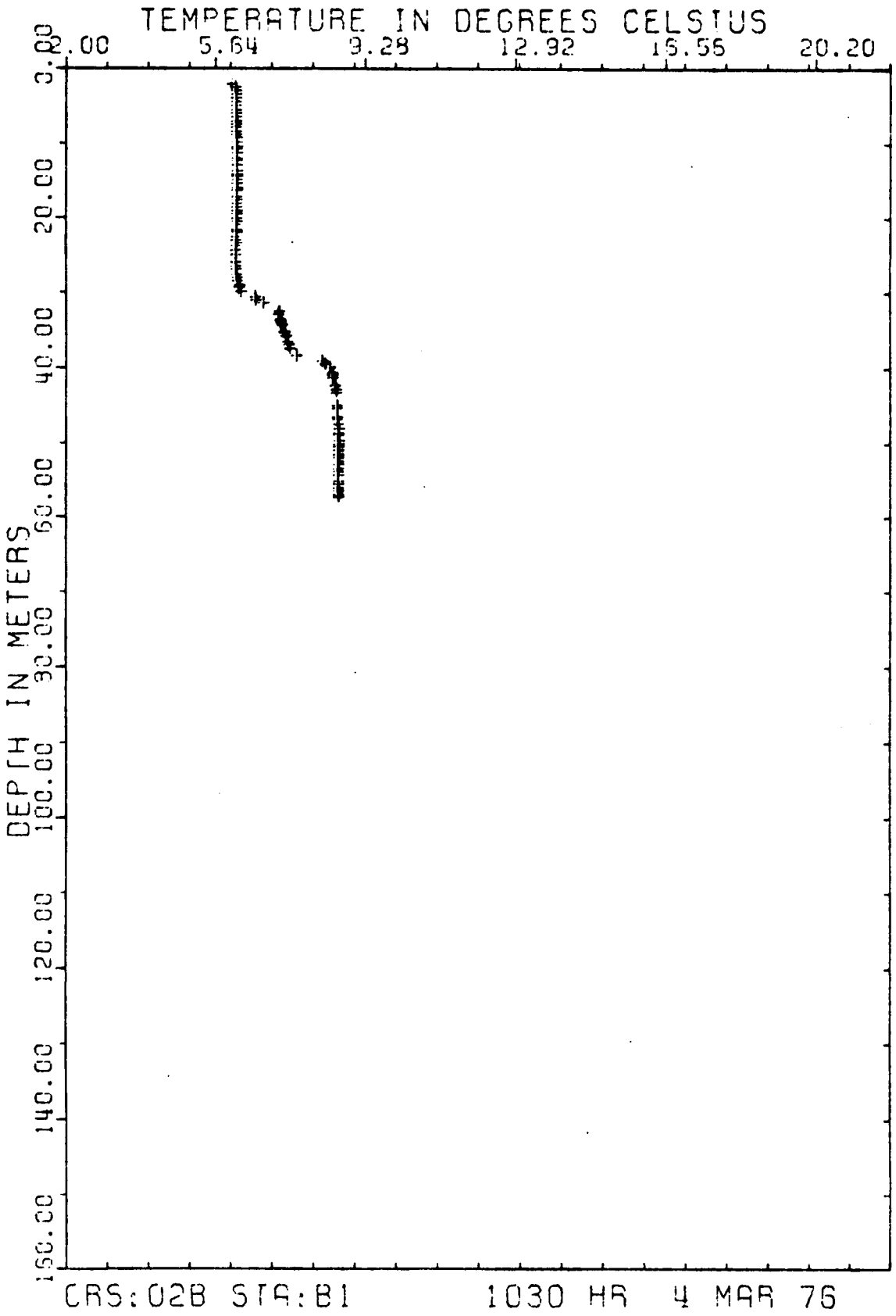

Figure 3-206a. Temperature as a function of depth at Station B1 during cruise BLM ∅2B.

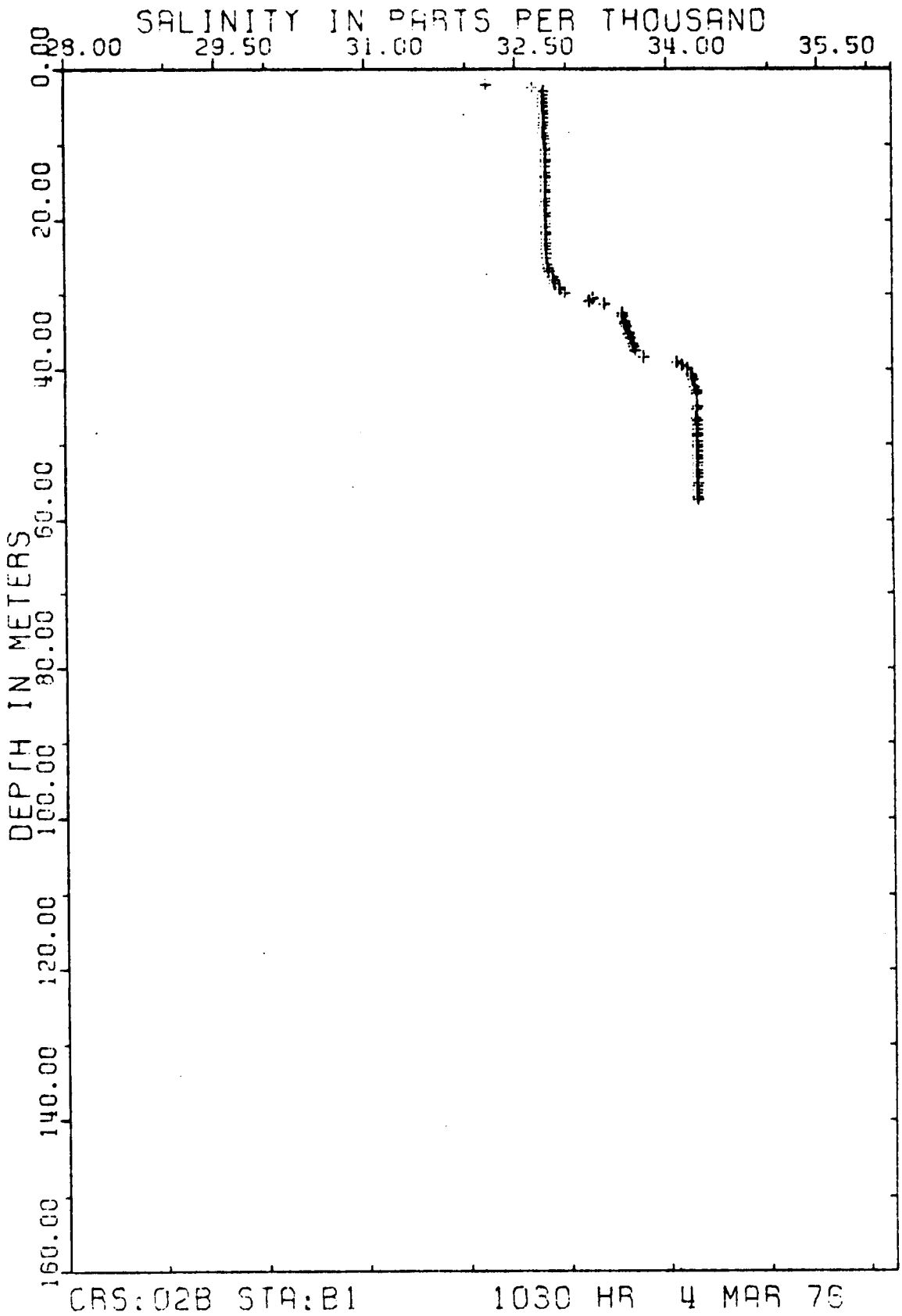

Figure 3-206b. Salinity as a function of depth at Station B1 during cruise BLM 02B.

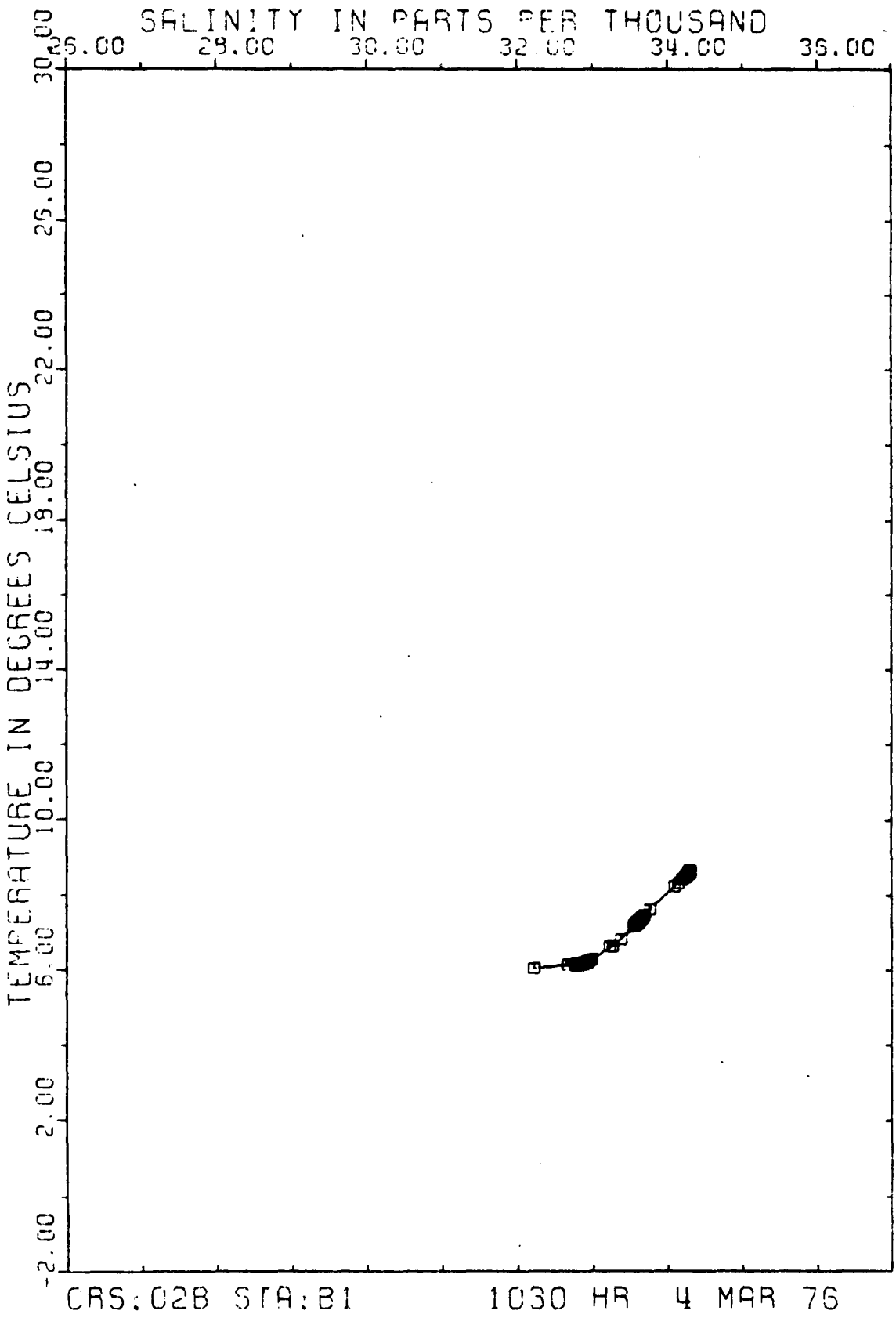

Figure 3-206c. T-S diagram for Station B1 on cruise BLM Ø2B.

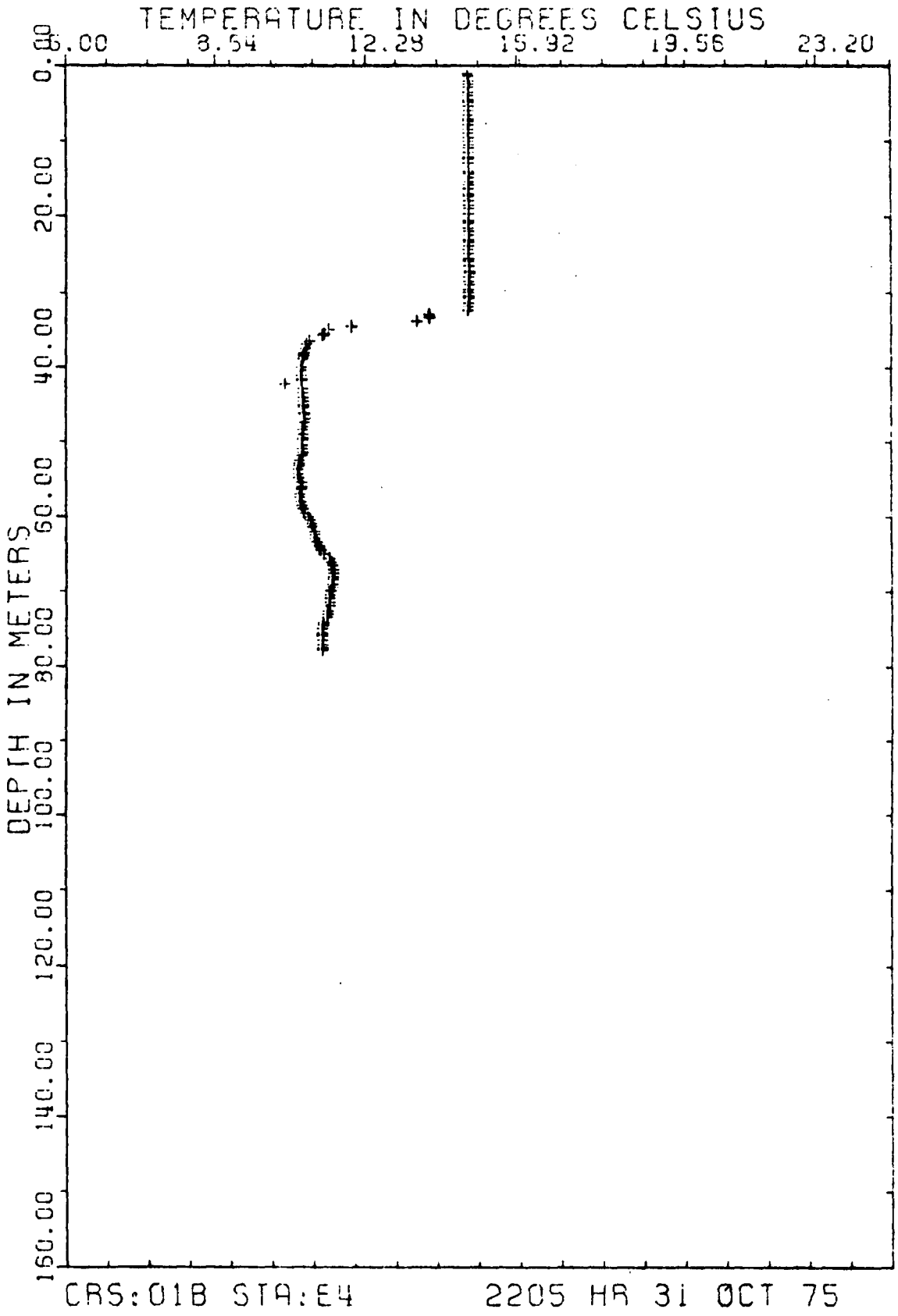

Figure 3-207a. Temperature as a function of depth at Station E4 during cruise BLM Ø1B.

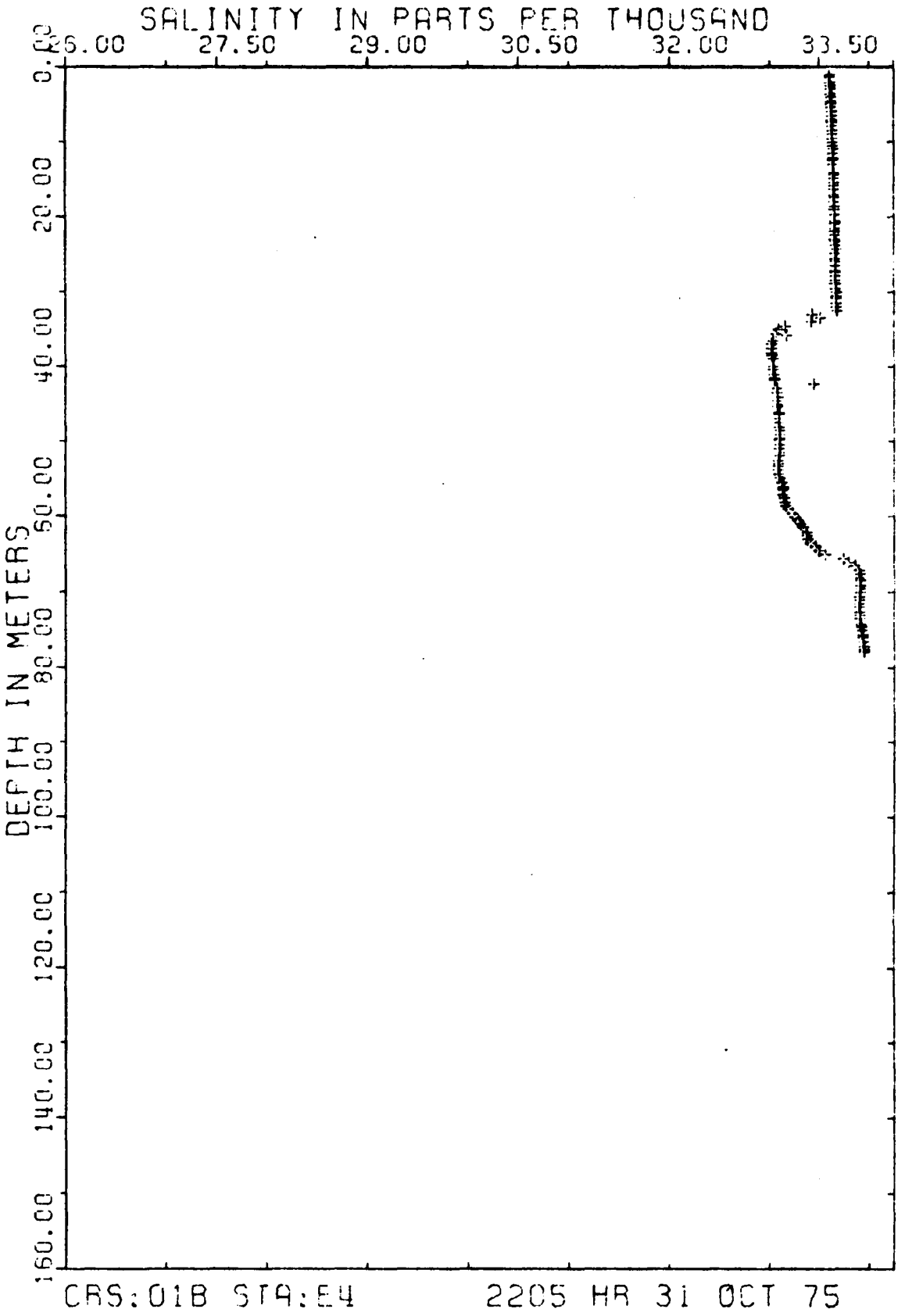

Figure 3-207b. Salinity as a function of depth at Station E4 during cruise BLM Ø1B.

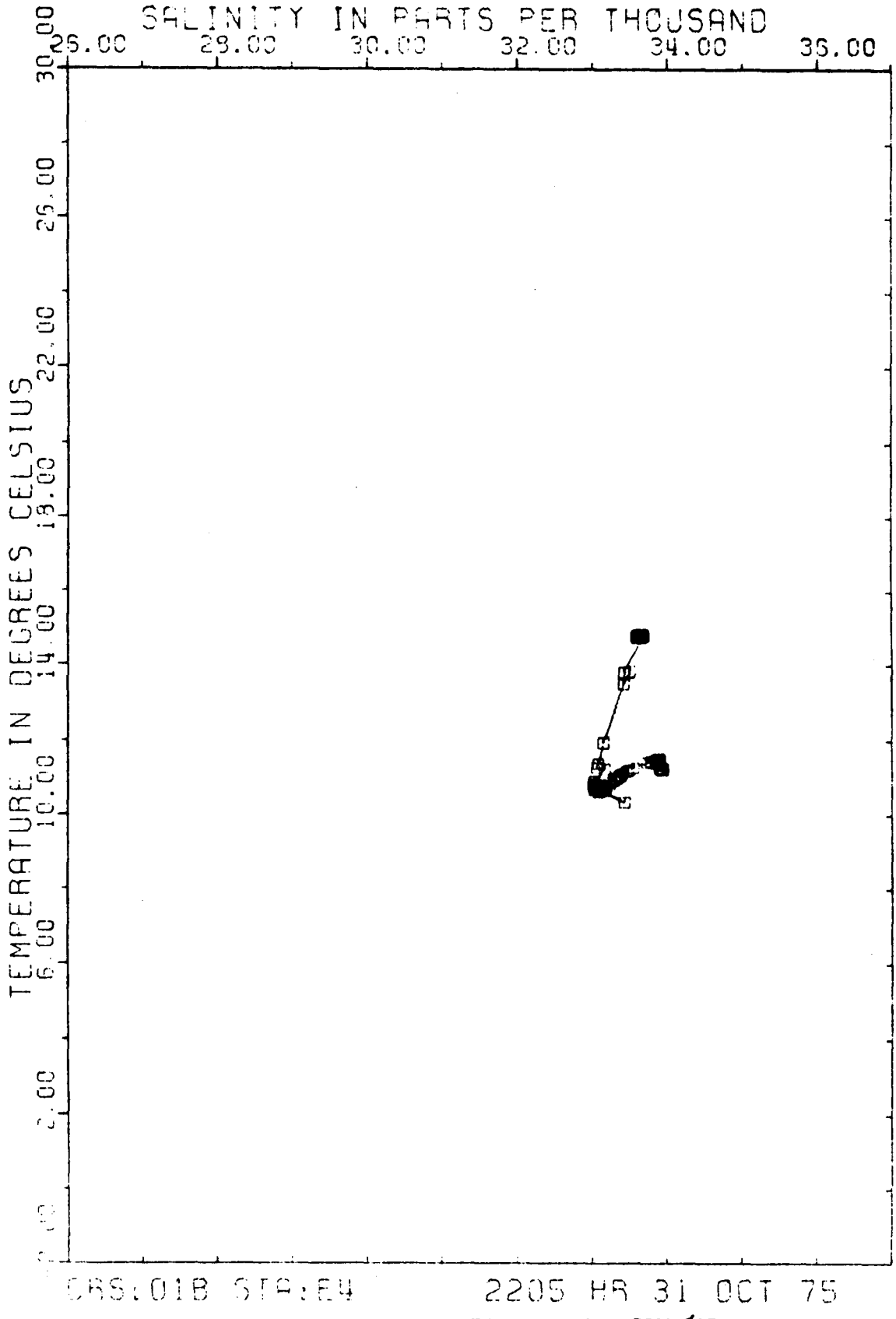

Figure 3-207c. T-S diagram for Station E4 on cruise BLM Ø1B.

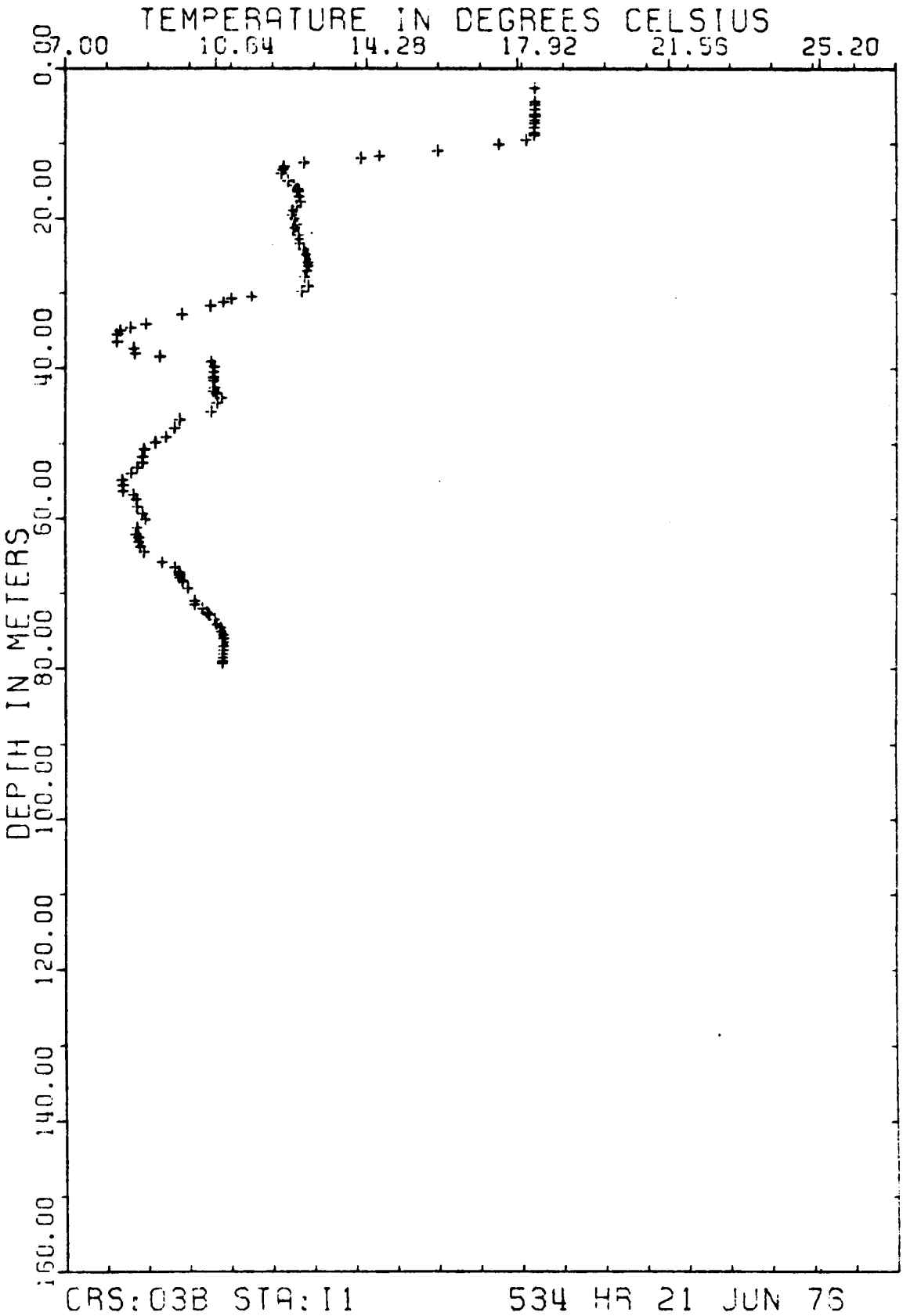

Figure 3-208a. Temperature as a function of depth at Station I1 during cruise BLM 03B.

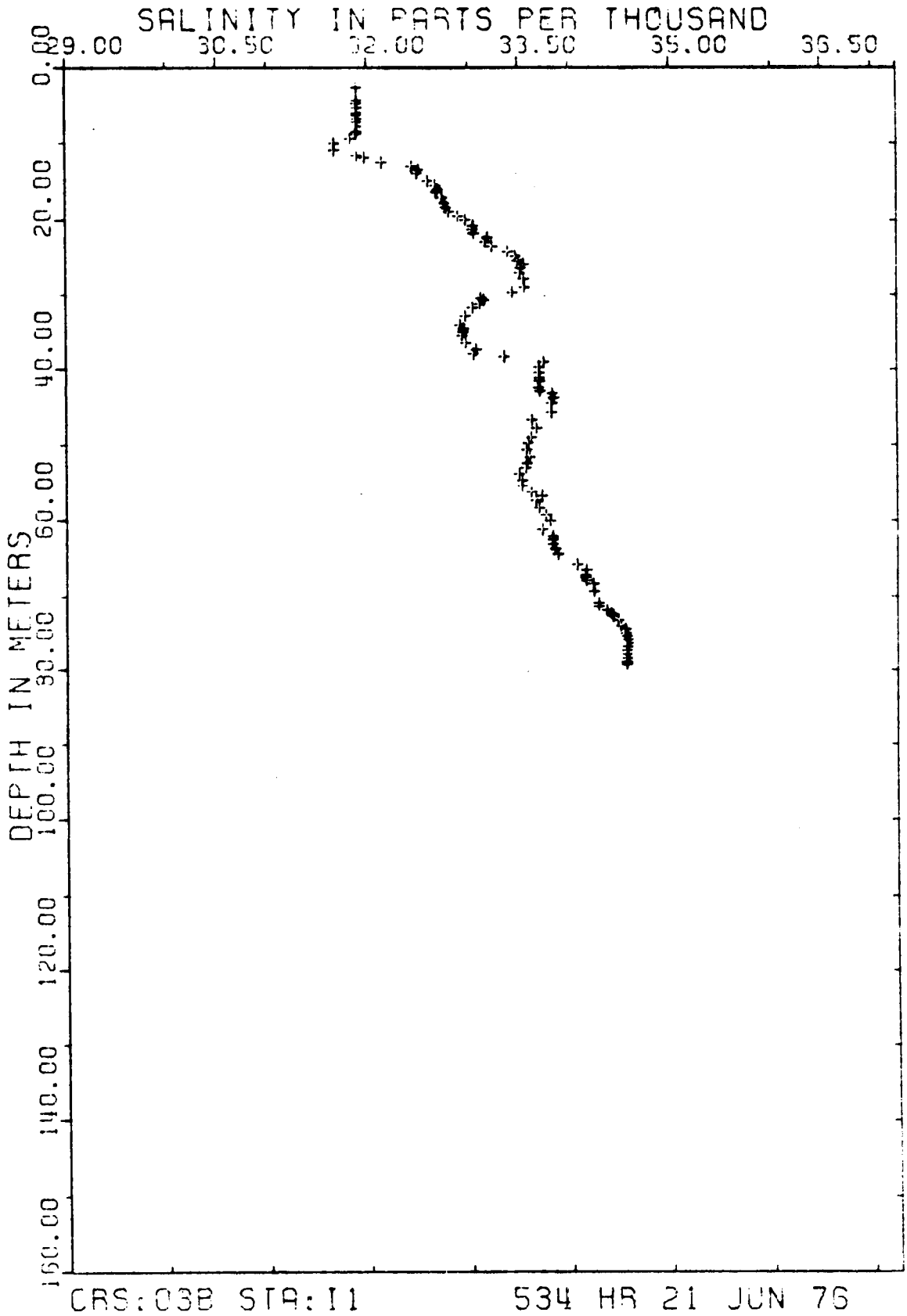

Figure 3-208b. Salinity as a function of depth at Station I1 during cruise BLM ϕ3B.

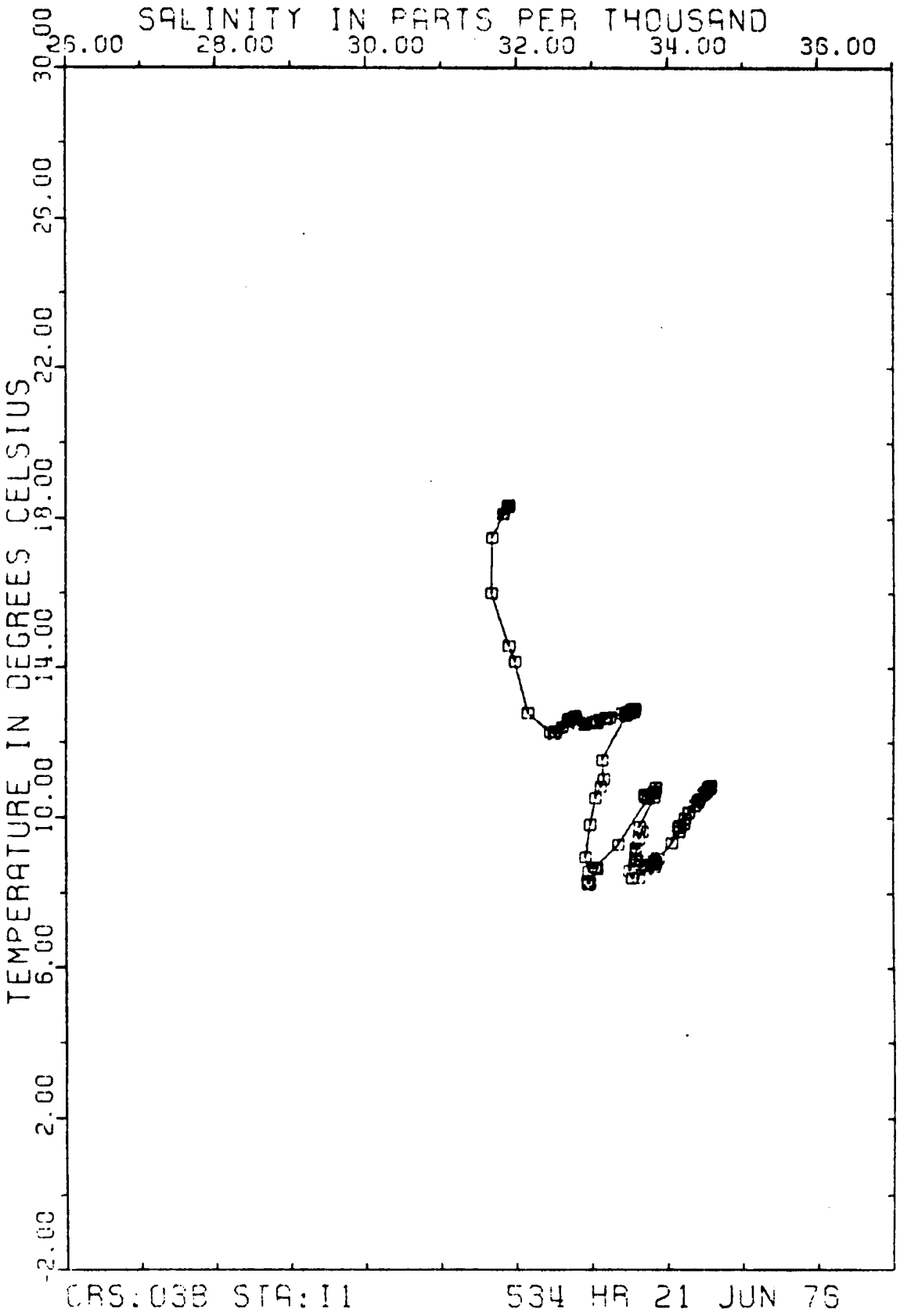

Figure 3-208c. T-S diagram for Station I1 on cruise BLM ∅3B.

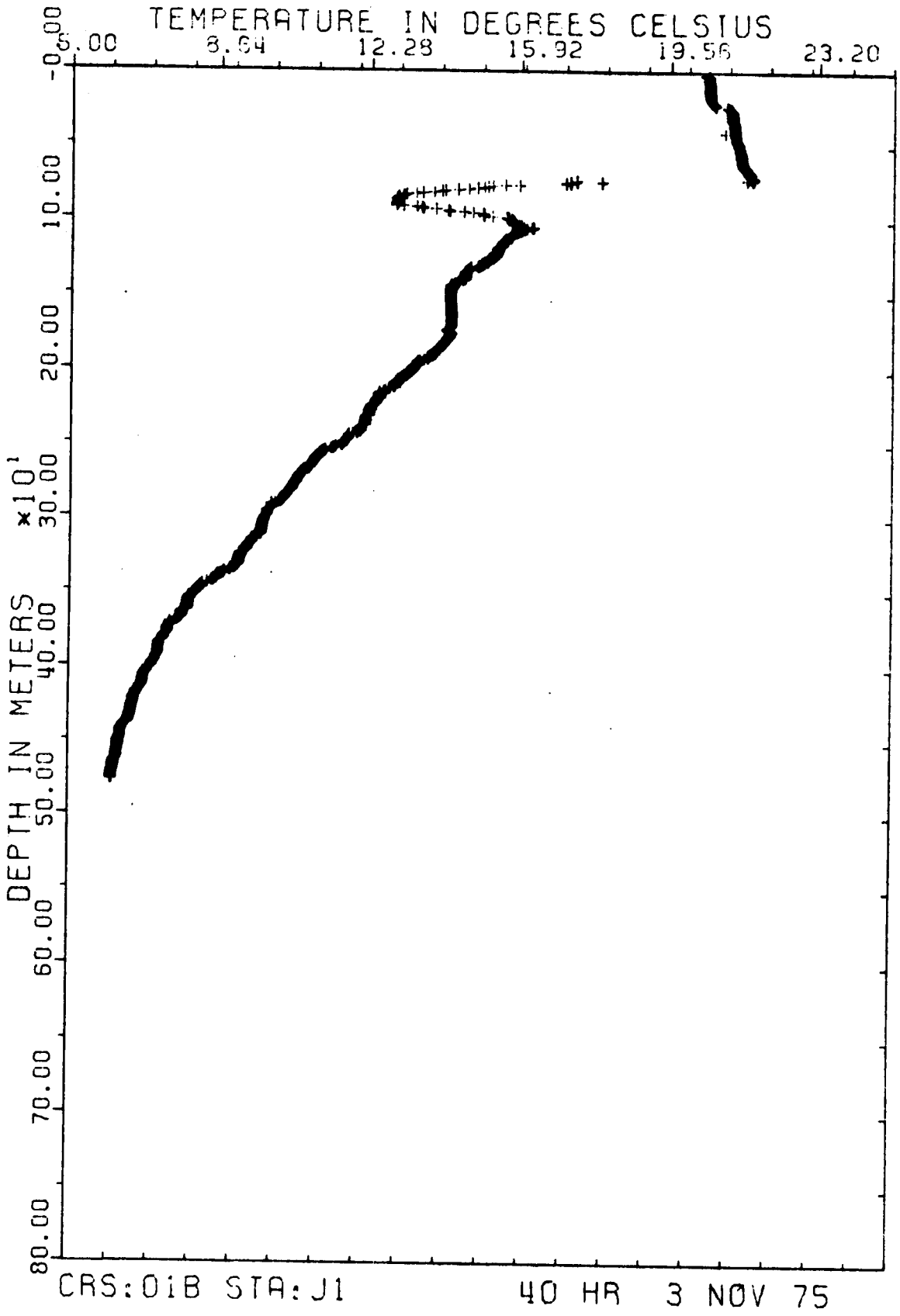

Figure 3-209a. Temperature as a function of depth at Station J1 during cruise BLM ϕ1B.

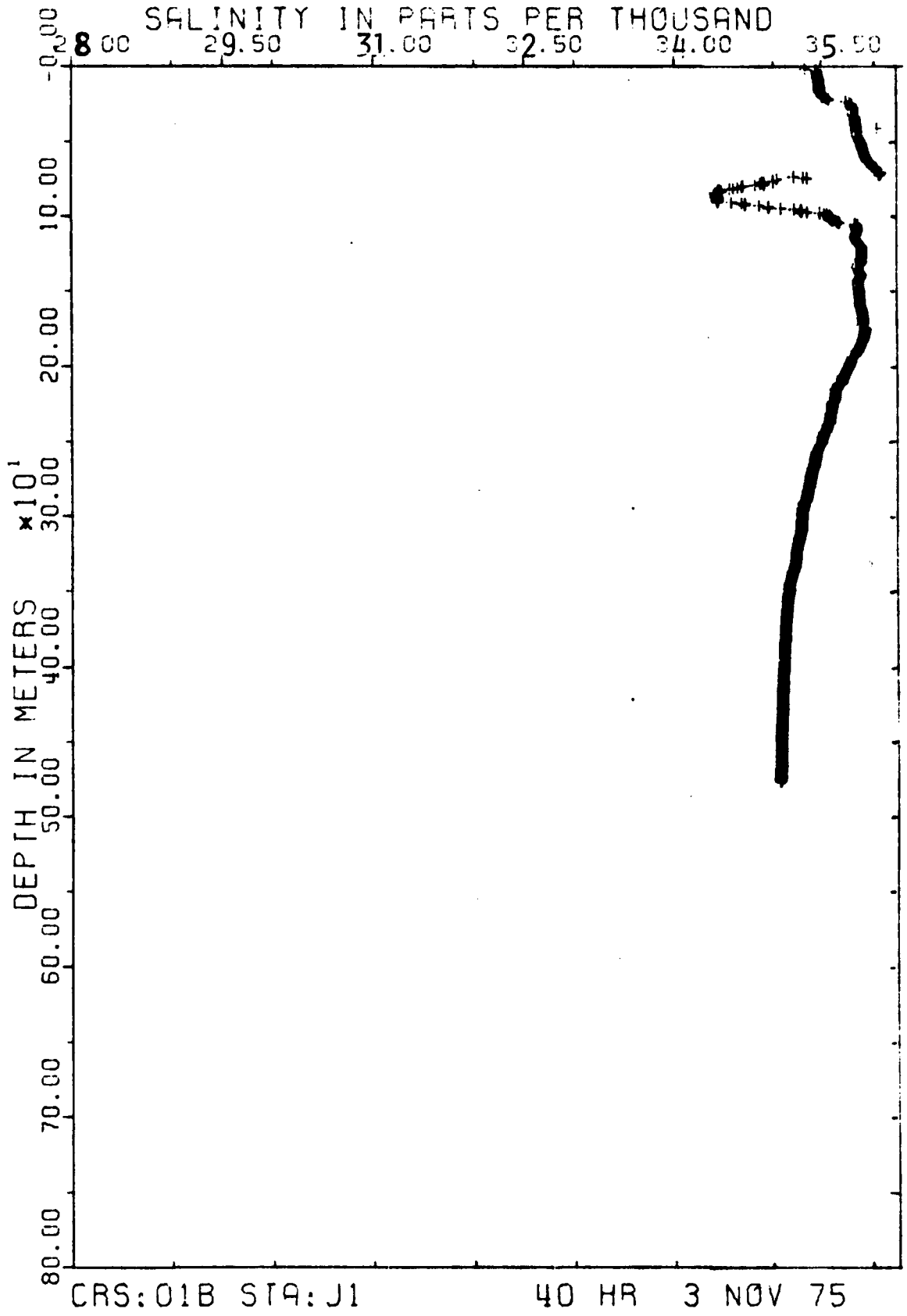

Figure 3-209b. Salinity as a function of depth at Station J1 during cruise BLM ϕ1B.

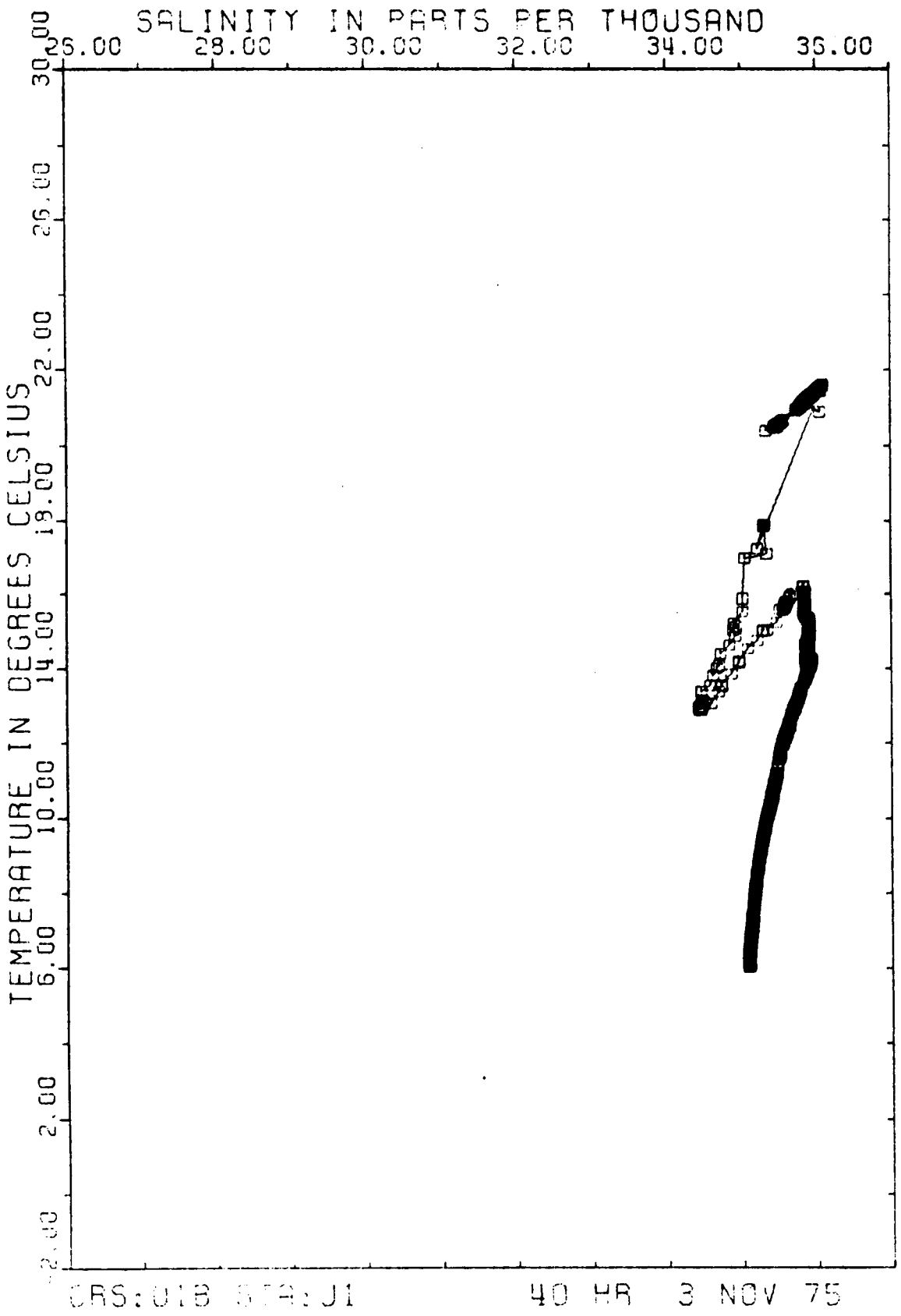

Figure 3-209c. T-S diagram for Station J1 on cruise BLM 01B.

of the T-S correlation of the slope water. This contrast is the reason that, from an oceanic point of view, shelf hydrography seems confusing, complex, and highly variable. However, with the aid of a modern, high resolution CTD system, we arrive at the same impression as did Beardsley and Flagg (1975) when they state,

"...Our data indicates that, contrary to the historical conception, the shelf exhibits a well defined temperature-salinity correlation and moreover this correlation remained approximately constant over the duration of the one-month experiment which occurred during the period of the seasonal extreme....."

The longer temporal and greater spatial extent of our sampling grid has allowed us to amplify somewhat on this impression and construct a series of diagrams which illustrate the progression of water types in the area of study during the first field year. As the T-S correlations for the year 1976 are qualitatively similar to those reported for other years (Beardsley and Flagg 1976; Voorhis et al. 1976) there is some basis for the interpretation that the described seasonal cycle is representative of the seasonal cycle in general, even though some features of the study year (for instance, the oxygen depletion event during the summer) were unusual.

In order to examine the progression of water types over the shelf from T-S correlation data, without undue emphasis being placed on transition zones which actually represent a very small volume of the water, an analysis was performed by identifying the agglomeration points from each of the individual cast correlations and displaying them on a single T-S plot for an entire cruise. Since the data for the water column cruises is similar to that of the benthic cruises, only the analyses for the benthic cruises are presented here as Figures 3-210a-d.

The seasonal pattern of summer is destroyed during the early and middle autumn, leaving a certain amount of confusion in the correlation plots. Recall that the example for the single point T-S correlation curve is taken from the autumn cruise and that the water type so defined is not stable, but is "migrating" towards lower temperatures under the influence of autumnal cooling. During this time, the slope water signature, shown in Figure 3-210a, extends to its lowest value of σ_t encountered during the year. As the winter progresses, the cooling and migration of the points on the T-S correlation curve reaches a winter pattern consisting of the slope water signature for σ_t less than 27 (Figure 3-210b). The curve extends nearly straight to the inshore stations, where σ_t is equal to 25 for this year. The straightness of this line indicates that winter mixing is controlled, over the shelf region and seasonal cycle, by some turbulent exchange process triggered in part by deviations of density from this line of reorganization. Voorhis et al. (1976) show a similar curve in their Figure 5. They term the water mass defined by this line "winter transition water" south of New England. The present study, extending to the shore, carries the description of this water mass all the way to the shore and σ_t's of 25, while the Voorhis et al. description, focused on the shelf break, only defines this line to σ_t of 26. If the repetition of the line from one year to another is an indication of general case, we may speculate that the turbulent exchange process controlling winter mixing can draw on slope water as a reservoir of

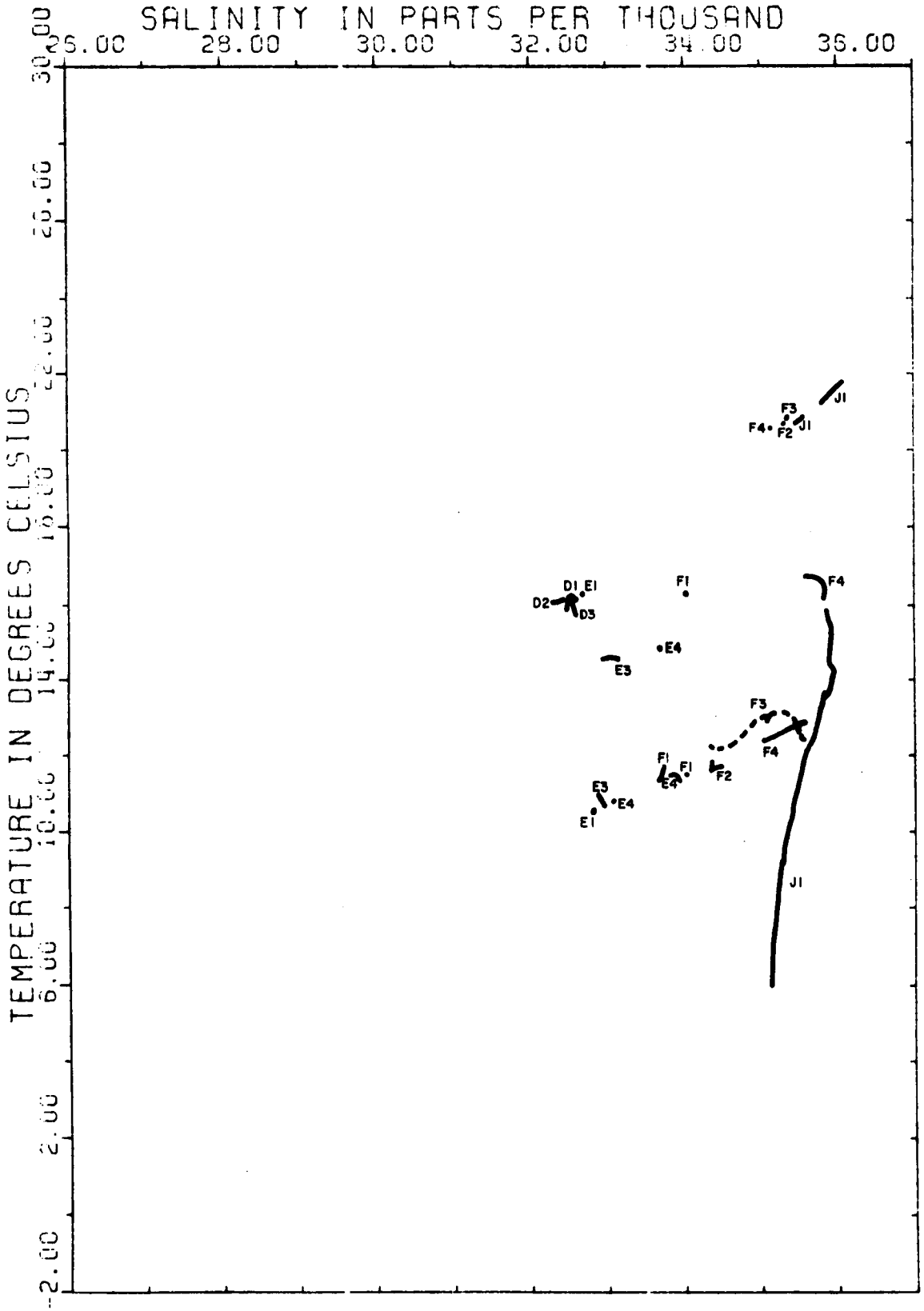

Figure 3-210a. Agglomeration diagram showing water types present at stations during cruise BLM Ø1B. Early winter conditions are shown.

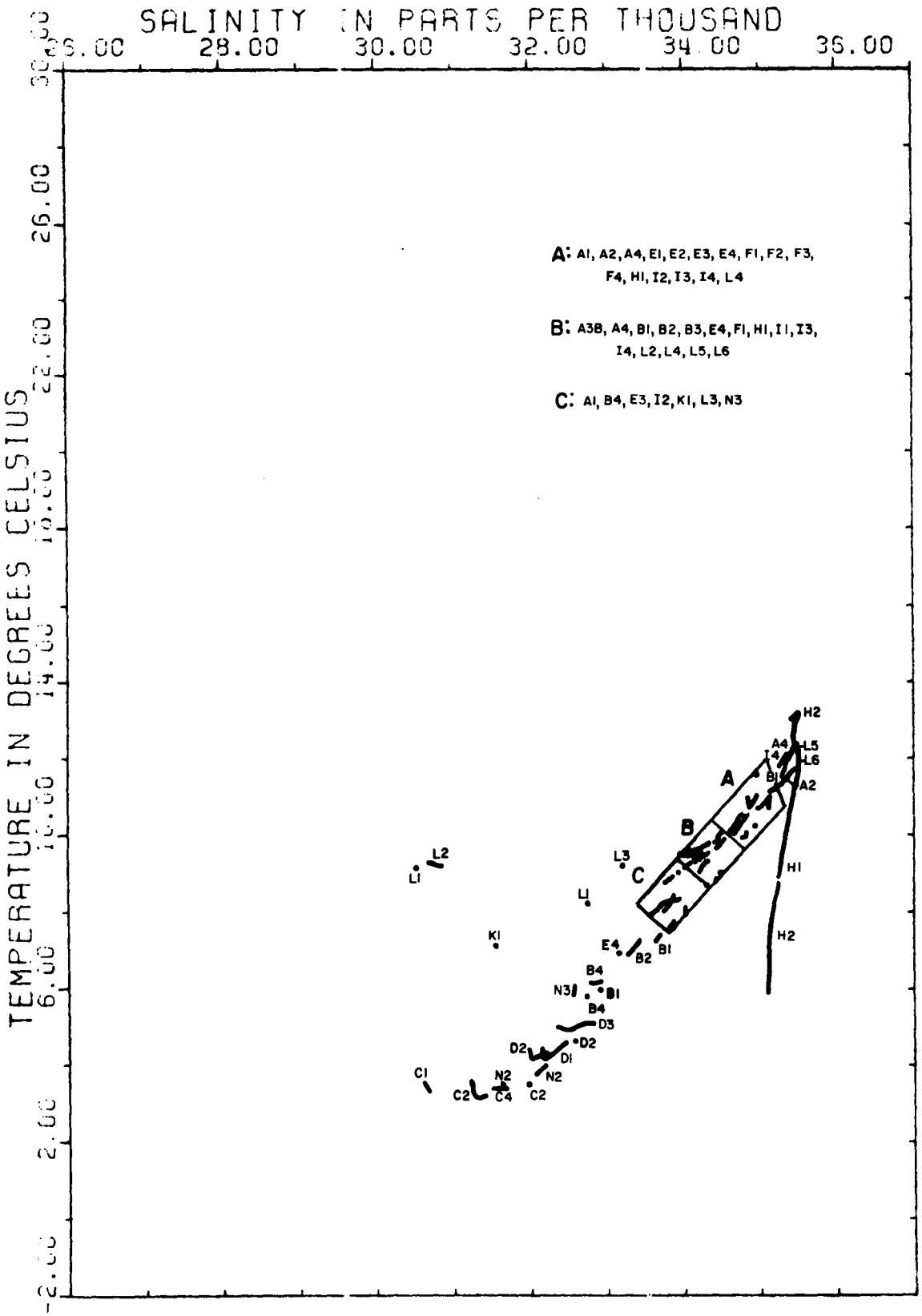

Figure 3-210b. Agglomeration diagram showing water types present at stations during cruise BLM Ø2B. Populous clusters of water types are enclosed in labelled boxes, with the appropriate stations for each box listed above.

cooling which occurs during the winter. In the data for this study, some anomalous points are recorded which deviate markedly from the otherwise well established straight line. These are located primarily at the L stations along Section V. As noted in the analysis of surface patterns elsewhere in this report, Section V was occupied subsequent to a wind event which included winds of more than 60 knots from the southwest, an unusual event for the winter season. The anomalous water types are all associated with water near the surface. A source of fresh water consistent with these observations is the outflow from Chesapeake Bay, which normally flows towards the south, but may have been driven to the northeast by the strong southwest winds. The lower parts of stations along Section V are well within the grouping of points associated with the "winter transition water" line of reorganization. As spring warming starts, the winter transition water mass is truncated at the σ_t 26 level, and a new water mass, termed "spring-warmed shelf water" is formed over the inner and middle shelf, extending later out to the outer shelf. The spring warming is accompanied by the yearly maximum of runoff from the tributaries, so the newly forming water mass tends to extend towards smaller values of salinity as it reaches higher temperatures. This signature is illustrated by Figure 3-210c from the present study. The new corner of the correlation curve is associated with the "cold pool" which is such a characteristic feature of the regional shelf summer hydrography. The majority of the winter transition water disappears from the T-S correlation at this time, and the shelf water and slope water appear juxtaposed with a frontal structure between them. This front, as noted by Bumpus (1974), has been an observed feature of the shelf for many years. It is frequently broken down into an interleaving structure which results in the "calving" of "bubbles" of water of markedly different temperature and salinity but nearly the same density as the water in which they are embedded. The stations which have water types between the shelf and slope types are all near the edge of the shelf in Figure 3-210c. This calving process near the shelf-slope front is the major process of cross shelf mixing during the summer months. Its action erodes the "cold pool" during the summer as well as the general shelf water mass. A later stage in this process is shown in Figure 3-210d, where a spreading out of the T-S correlation of the shelf water indicates that the shelf is acting more as a series of independent systems and less as an entity during the summer. Additional warming is also evident in this figure. The freshening of the inshore stations during the late summer is evidence that the cross-shelf mixing is greatly reduced in the summer. The T-S correlation is, at this time, fully developed and ready for the reorganization imposed by the autumnal cooling.

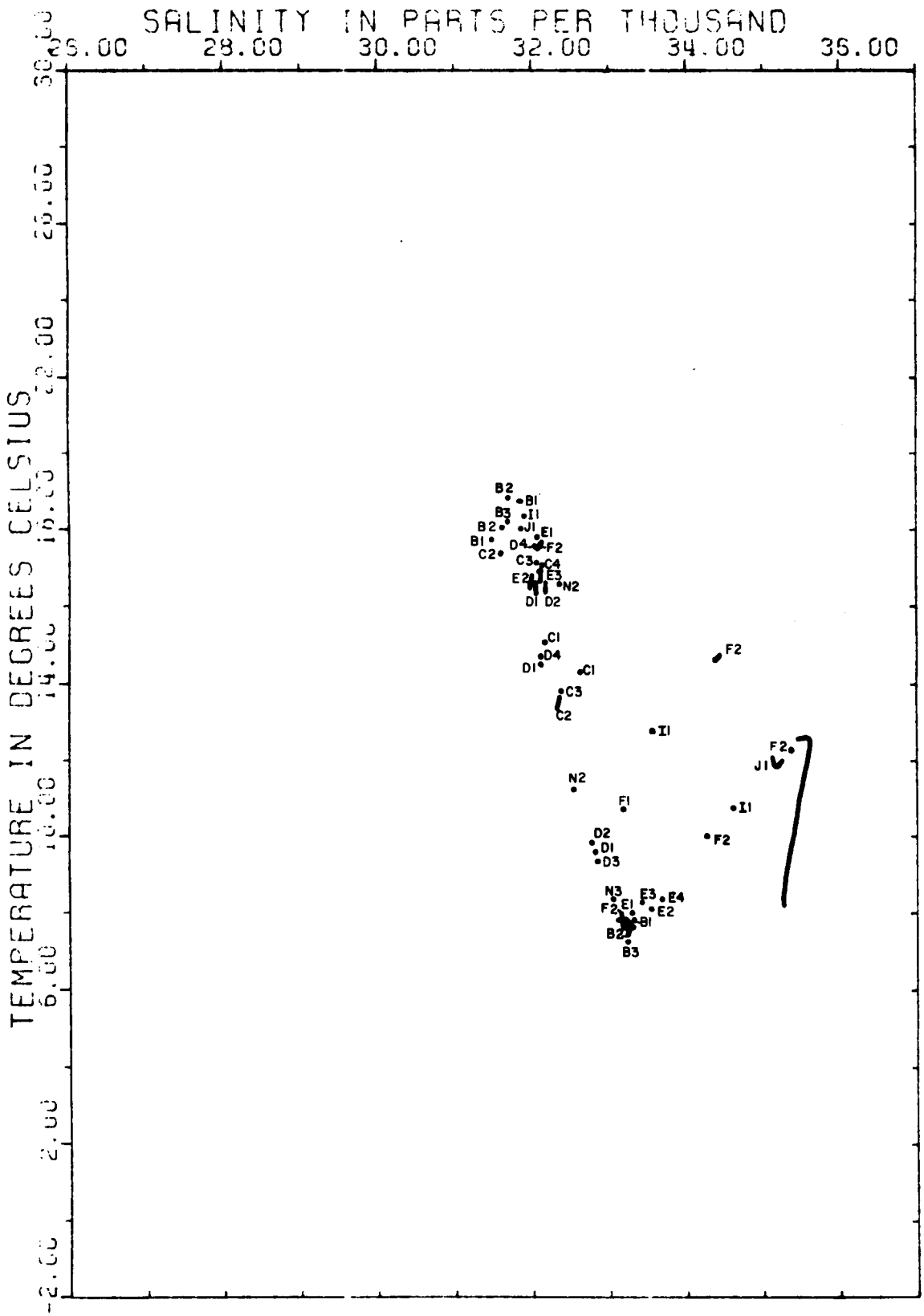

Figure 3-210c. Agglomeration diagram showing water types present at stations during cruise BLM 83B. Spring conditions are shown particularly to the left of the curve.

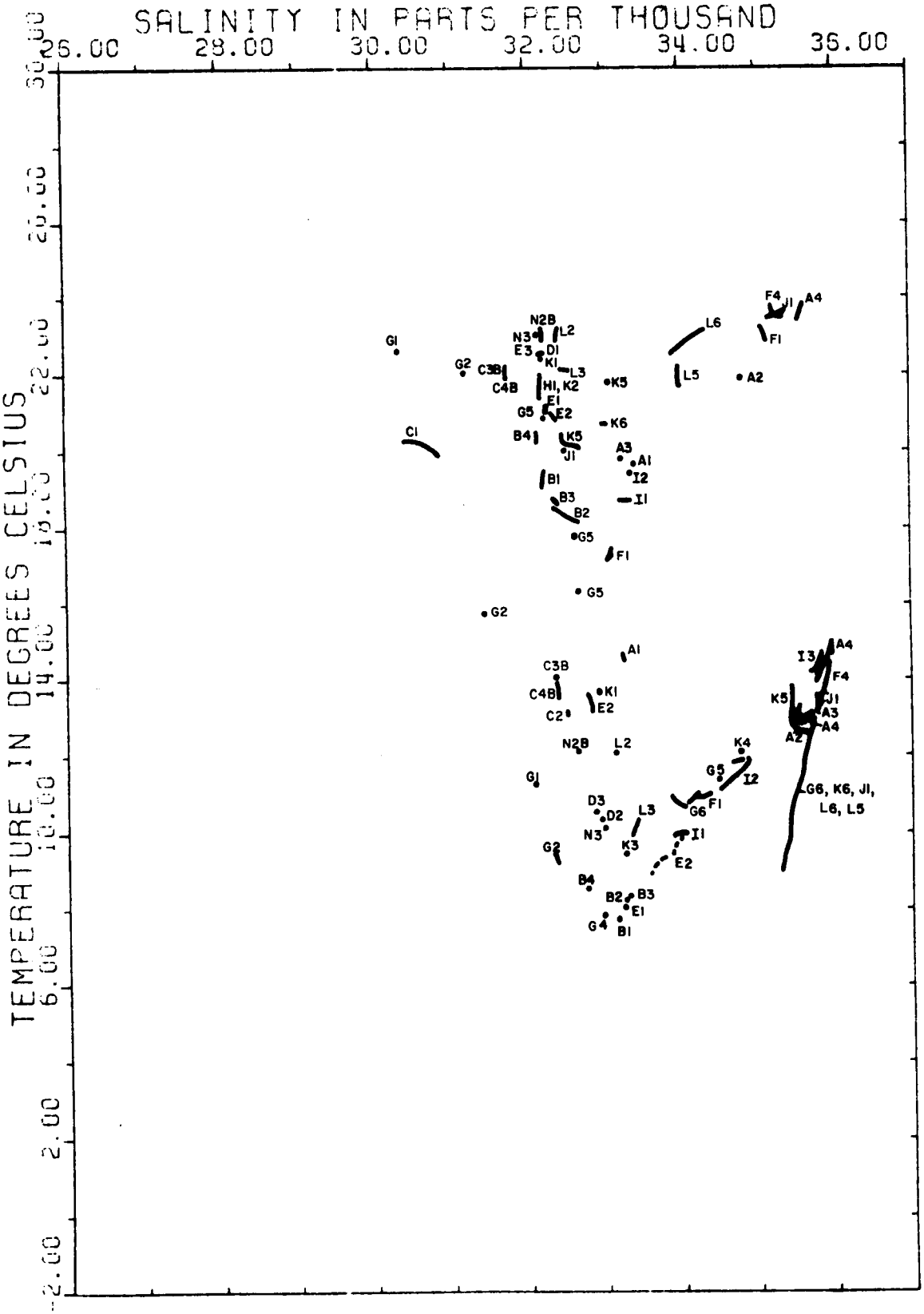

Figure 3-210d. Agglomeration diagram showing water types present at stations during cruise BLM ϕ4B. Late summer conditions are indicated.

Summary of Significant Findings

1. The major effort of this portion of the study was to obtain values of several parameters over a year's time. The parameters measured or calculated include: temperature, salinity, dissolved oxygen, density, nitrite, nitrate, and ortho-phosphate. These are presented as surface and bottom charts as well as sections. The figures are found between pages 3-34 and 3-207. This set of analyses is the single most significant result of the first year's physical study for it presents a set of observations which can be used as a baseline for future work and comparisons. Several features of shelf hydrography during the year invite further comment.

2. The winter period is generally presumed to be well mixed resulting in nearly vertical isopycnals. This is illustrated in Figure 3-71 between stations K3 and K5 which were sampled on 12 March 1976. In contrast to this is the vertical stratification found a week earlier, approximately 170 km to the north between stations B2 and A3 (Figure 3-63). The earlier situation (stations B2 to Z3) follows a period of unusual southerly and easterly winds while the later sampling follows a winter storm (see Figure 3-43). Southerly winds will result in offshore Ekman transport with compensatory onshore flow at depth. This is illustrated by the isohaline configuration in Figure 3-61. Thus, the concept that stratification on the shelf is a dynamic response of hydrographic structure to applied stresses rather than a thermally induced stratification due to local warming is supported.

3. During the early summer of 1976, anoxious conditions developed in bottom waters near the New Jersey coast. The general extent of these conditions during the latter half of August can be seen in Figure 3-131 which shows bottom DO values for the period 15 August to 1 September. Comparison of the results of the summer benthic cruise with those of the summer water column cruise along section III (Figures 3-145 and 3-166) shows that the center of anoxious water moved from a region approximately 10 km off shore during the last two weeks in August to approximately 78 km off shore during the first week of September. Examination of temperature and salinity sections for the same region and period (Figures 3-143, 3-144 and 3-164, 3-165) shows that the anoxious condition moved off shore with no zonal motion of the water (T-S structure of bottom water changed little at stations C1 and N3). The lowest value of oxygen is seen to have moved from close to shore to about 65 km out to sea during this period of time.

4. In addition to these event descriptions, several processes are evident in the data. a. A mid-level dissolved oxygen maximum is indicated in Figures 3-193 to 3-195. These maxima are common summer features and are indicative of biological oxygen production. b. The existence of agglomeration points in T-S correlation curves as shown in Figure 3-207c and plotted in Figures 3-210a-d indicate that much of the mixing on the shelf is caused by events which homogenize a certain amount of water in a short time. c. The "cold pool", a commonly observed feature, is evident in Figure 3-116, which shows temperature along section III during mid-June. d. The shelf edge front is usually observed in salinity sections such as Figure 3-144. This feature frequently has a compensating temperature distribution, with a resulting smoother pattern of density (Figure 3-146) implying some adjustment process having taken place.

ACKNOWLEDGEMENTS

Many people assisted in various phases of this project. We thank them all. Specific thanks are due to our field assistants: Scott Fenstermacher, Jim Cumbee, Ken Worrell, Benji Hahn and Steve Snyder; the technical staff who assisted in preparing drafts of many of the figures: Ms. Shirley Crossley, Ms. Terrell Markle and Ms. Trish Smith; and the data processing staff, Ms. Ginny Shaw, Ms. Shirley Robbins and Ms. Glenda Owens who spent many hours processing CTD tapes and preparing computer graphics.

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APPENDIX 3-A

PROGRAM DESCRIPTION OF CTDRAV

Name: CTDRAV

Type: Main Program

Language: FORTRAN F on VIMS IBM 370/115

Purpose: To generate a 9-track, 800 bpi FORTRAN magnetic tape of depth-sorted oceanographic measured and derived variables, from a binary input tape of raw Neil Brown CTD/DO data.

Description:

Generates averages of measured variables in engineering units for each record of raw binary data. From those averages, salinity and depth are calculated. Separate averages for 1.024 second data periods are kept to generate partial pressure and dissolved concentration of oxygen. Time averaged values of depth, pressure, temperature, conductivity, oxygen probe current, oxygen probe temperature, salinity, elapsed time by data rate, partial O_2 pressure, and dissolved O_2 concentration are sorted and averaged into 0.5 meter depth slots. The depth averages give equal weights to individual samples. They are written on an EBCDIC output tape with indicators for cast direction, CTD unit number, output variable minima and maxima, and number of samples per slot. When the binary input tape is finished, the output file is marked with an End-Of-File (EOF), rewound, and listed.

Input Terminals: Card reader
9-track tape unit, SYS016

Output Terminals: 9-track tape unit, SYS011, FORTRAN unit number 14
Line printer

Usage:

1. Job Control Language:

```
*b$$bJOBbJNM=CTDRAV,USER=(no.)/(name), CLASS=N
//bJOBbCTDRAVb(no.)/(name)
//bLOG
//bOPTIONbLINK
//bEXECbFFORTRAN
//bFTCbLINECNT=55
  Fortran main program (if not binary deck)
  Fortran BLOCK DATA
  Fortran subprograms and functions
/*
bbbINCLUDE
  Binary (main program +) subprograms
```

```
/*
//bEXECbLNKEDT
//bPAUSE,bPLEASEbMOUNTbCTDXXXbONb281,bREADbONLY
//bASSGNbSYSØ16,X'281',X'C8'
//bPAUSE,bMOUNTbVCMXXXbONb280,bREAD/WRITE
//bASSGN SYSØ11,X'28Ø',X'C8'
//bTLBLbIJSYS11
//bEXEC
   data cards
/*
/&
*b$$bEOJ
```

2. Input Tapes, CTDØØ1 through CTD999:
Raw binary CTD data on 800 bpi, 9-track magnetic tape. Records of less than 500 words in integral multiples of frame lengths. Downcasts are terminated by a single EOF mark, upcasts by two EOF marks, and the end of the tape by three EOF marks. The first record of every downcast is data taken before the CTD enters the water and after a 15-minute turn-on and warm-up period. The rest of the downcast starts with the CTD in the water, after the oxygen probe temperature is within $1^{o}C$ of the water temperature. The downcast finishes just before or just after the bottom rosette sample. The upcast starts before the bottom rosetts sample and ends after the CTD leaves the water.

3. Output Tapes, VIMS labeled:
EBCDIC, 800 bpi, 9-track magnetic tape in 12F10.4 format.
The twelve output variables are as follows:
    Code word - negative for downcast, positive for upcase, + 10.0 for pressure sorted data, $\pm$ 20.0 for minima and maxima, $\pm$ 0.N added for CTD unit no. N.
    Pressure (d bar)
    Temperature (^{o}C)
    Conductivity (mmho/cm)
    O_2 probe current (μA)
    O_2 probe temperature (^{o}C)
    Salinity (ppt)
    Time, from cast start by data rate (sec)
    Partial pressure O_2 (atm)
    Dissolved concentration O_2 (ml/l)
    Number of samples/code word - number of samples (frames) per depth sort, repeated code word for minima or maxima.

Each downcast or upcast is recorded with the pressure sorted data in order, followed by one record of the minima of the middle ten output variables and one record of the maxima of the same variables. The ten minima and maxima are each bracketed by code words.

4. Input Cards:
For each station cast (downcast and upcast) an input card in
FORMAT(3A2,2I3,I4,I2)
gives the following header information:
NAME(1),NAME(2),NAME(3)=six letter alphanumeric station code
LATD=degress of latitude
LATM=minutes of latitude
SERIAL=serial number of CTD used, 1295 or 1495
SKP=file number of first cast to be used on the input tape

5. Line Printer:
The first two averaged records in each down- or upcast are printed out in the following manner:
KTIME in FORMAT(1HØ,11H**RECORDb=b,I3)
KTIME,KL,KLO,KDO,FS,UN,FTO in FORMAT(1HØ,4I5,3F1Ø.4)
(AV(I),I=1,11) in FORMAT(1Hb,11F1Ø.4)
At every range limit exception of input oxygen probe current, the printout is:
KTIME,KUIO,D,P in
FORMAT(1HØ,31H**POSSIBLEbBOTTLEbTRIPbKTIMEb=b,I6,9HbbKUIOb=b,
I3,2F1Ø.4)
When the sorting storage has been filled and when the sorting routine is commanded to finish, the next line is a comment in:
FORMAT(16HØ**SORTEDbOUTPUT)
followed by the same data written on the output tape in:
FORMAT(1Hb,12F1Ø.4)
At the end of a downcast, the minima of the sample values of the output variables, excluding samples in the first two records, are written out as:
(XM(I,1),I=1,1Ø) in
FORMAT(1ØHØMINIMA:bb,1ØF1Ø.4)
followed by the maxima:
(XM(I,2),I=1,1Ø) in
FORMAT(1ØHØMAXIMA:bb,1ØF1Ø.4)
The last comment before the output of the next cast is:
FORMAT(1HØ,17H**ENDbOFbDOWNCAST)
The end of an upcast includes the same type of information and comment as the downcast, followed by:
FORMAT(1HØ,17(1HX),15HbbENDbOFbUPCAST)
The end of the tape output includes the above followed by:
FORMAT(1HØ,32(1HX),13HbbENDbOFbTAPE)
After this the output tape is unwound and listed, beginning each down- and upcast sorted output with a new page.

Variable List:

1. COMMON/BLK1/
IOB=(not used)
KEOF=number of consecutive EOF marks read from input tape
KETM=KEOF+1 if KEOF>0 (not used)
FT=time of data sample from start of cast, based on data rate
FIV=integer array for storing equivalent values of 8-bit binary data from an input record
EU=(not used)
IFIV=current beginning of sample frame in FIV

JFIV=current end of sample frame in FIV
IEU=(not used)
IFL=length of input binary sample frame (8-bit words)
IRL=length of input binary record (8-bit words)
FR=frame rate (31.25/sec)
DU=array of engineering unit oceanographic variables, converted from a sample frame in FIV:
DU(1)=frame syn (15 or 240)
DU(2)=pressure (d bar)
DU(3)=temperature (^{o}C)
DU(4)=conductivity (mmho/cm)
DU(5)=O_2 probe current (μA)
DU(6)=O_2 probe temperature (^{o}C)
DU(7)=CTD unit number
DU(8)=frame time from start of cast (sec)
KUIO=number of O_2 probe current boundary limit exceptions per input record
UIO=upper limit allowed for O_2 probe current (μA)
KDO=counter flag to force completion and reinitialization of the oxygen variable calculations with the present input record
KUN=CTD unit number by data card input
KTIME=Number of input records, from the start of the cast, accepted for processing and output
UN=CTD unit number by sample frame
XM=minima and maxima oceanographic variables (by frame for measured variables and by record for calculated variables) for each upcast or downcast, excluding the first two records. The variables (XM(I,1),I=1,10) are the minima and (XM(I,2),I=1,10) are the maxima.
The variable designations for the I indices correspond to those of the DU array except for:
XM(1,J)=depth (m)
XM(7,J)=salinity (ppt)
XM(9,J)=calcualted O_2 partial pressure (atm)
XM(10,J)=calculated O_2 dissolved concentration (ml/l)

2. COMMON/BLK2/
AV=present record average array. Variables correspond to those in the XM array except for:
AV(11)=number of frames used in this record
NAV=number of frames used in present record
KL=number of rate limit exceptions for pressure, temperature, and conductivity in present record
AVL=last record average array
KLO=number of rate limit exceptions for O_2 probe current and temperature in present record

3. COMMON/LIM1/
   DPM=maximum allowed rate for pressure (d bar/sec)
   DTM=maximum allowed rate for temperature (^{o}C/sec)
   DCM=maximum allowed rate for conductivity (mmho/cm/sec)
   DIOM=rate limit for O_2 probe current (μA/sec)
   DTOM=rate limit for O_2 probe temperature (^{o}C/sec)

4. COMMON/OXY1/
   FTO=average frame time of current oxygen calculation variable
   OX=period average array for oxygen calculations. (Corresponds to AV array in COMMON/BLK2/.)
   NO=number of samples in current oxygen calculation

5. COMMON/SORT1/
   YO=sorting and output array. Second index is by depth step, DY. First indices are:
      YO(1,J) through YO(10,J)=depth sorted variables corresponding to AV array in COMMON/BLK2/, weighting each sample equally
      YO(11,J)=number of input samples averaged into the Jth depth slot
      YO(12,J)=number of input records averaged into the Jth depth slot
   BS=starting point of downcast depth sorting (m)
   BC=current starting point of YO array (m)
   DY=slot size of depth sorting (m)
   MX=1, AV array index for depth
   NY=number of depth slots in YO not empty

6. COMMON/HDR/LATD,LATM,NAME,SERIAL,SKIP
   See part 4 of Usage

7. OTHER VARIABLES
   KIOL=value of KUIO for last record
   SL=value of salinity for last record
   CAST=indicator for downcast, upcast, and unit number status
   DO=dissolved O_2 concentration (ml/l)
   PO=partial O_2 pressure (atm)
   D=depth (m)
   KM=flag to force initialization of XM array

Restrictions: Determined by subroutines.

Subprograms Required:

```
SUBROUTINE PSORT (X,I)
SUBROUTINE RECAV
FUNCTION SGN(X)
```

SUBROUTINE SALIN (P,T,C,S,SL)
SUBROUTINE MINMAX (X,XM,KM)

Programmer: Donald L. Baker, Department of Physical Oceanography, Virginia Institute of Marine Science, December 1976. Modified by Dr. Christopher S. Welch, Dept. Physical Oceanog., VIMS, January 1977.

Originator: Donald L. Baker

Date: December 1976

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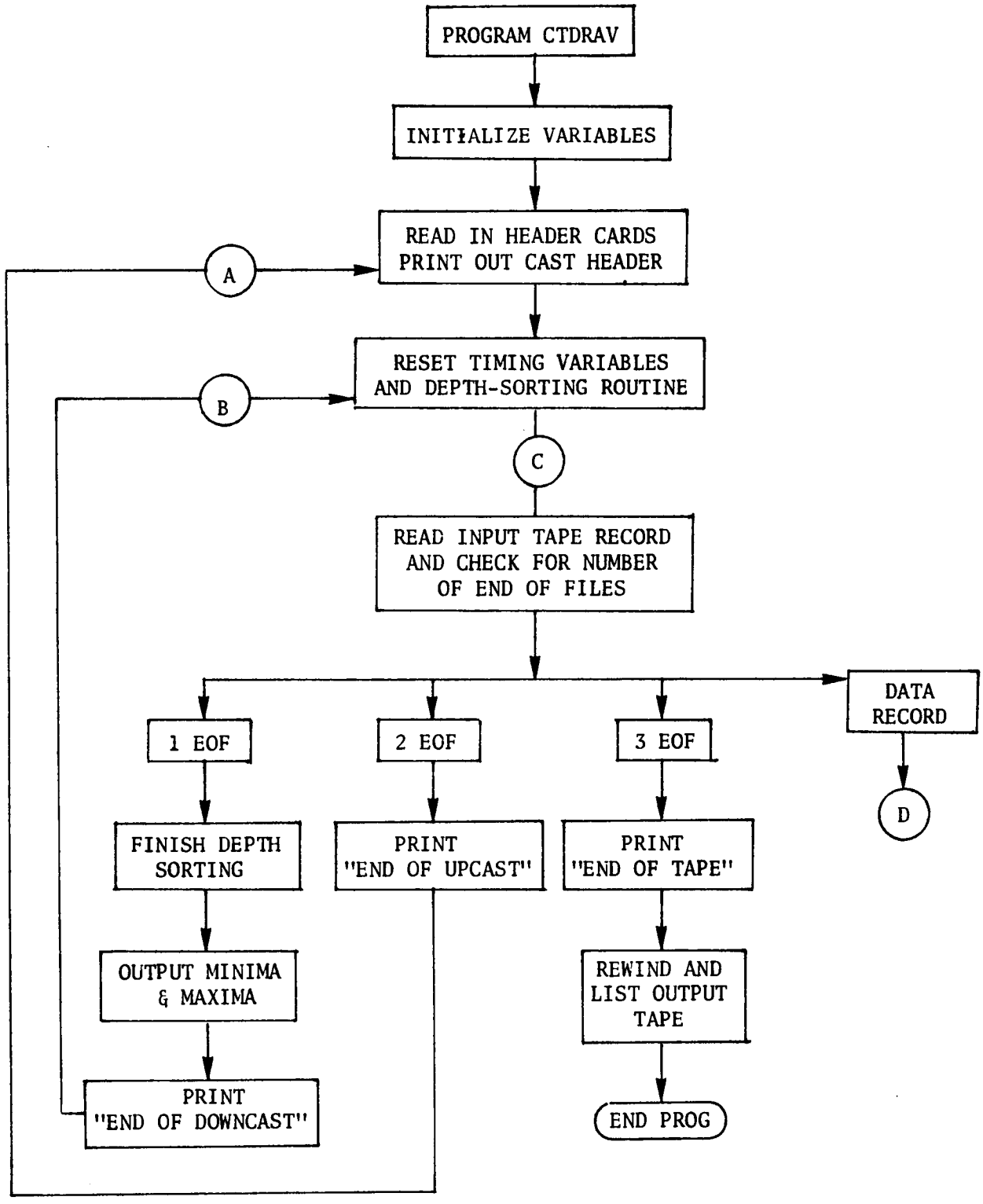
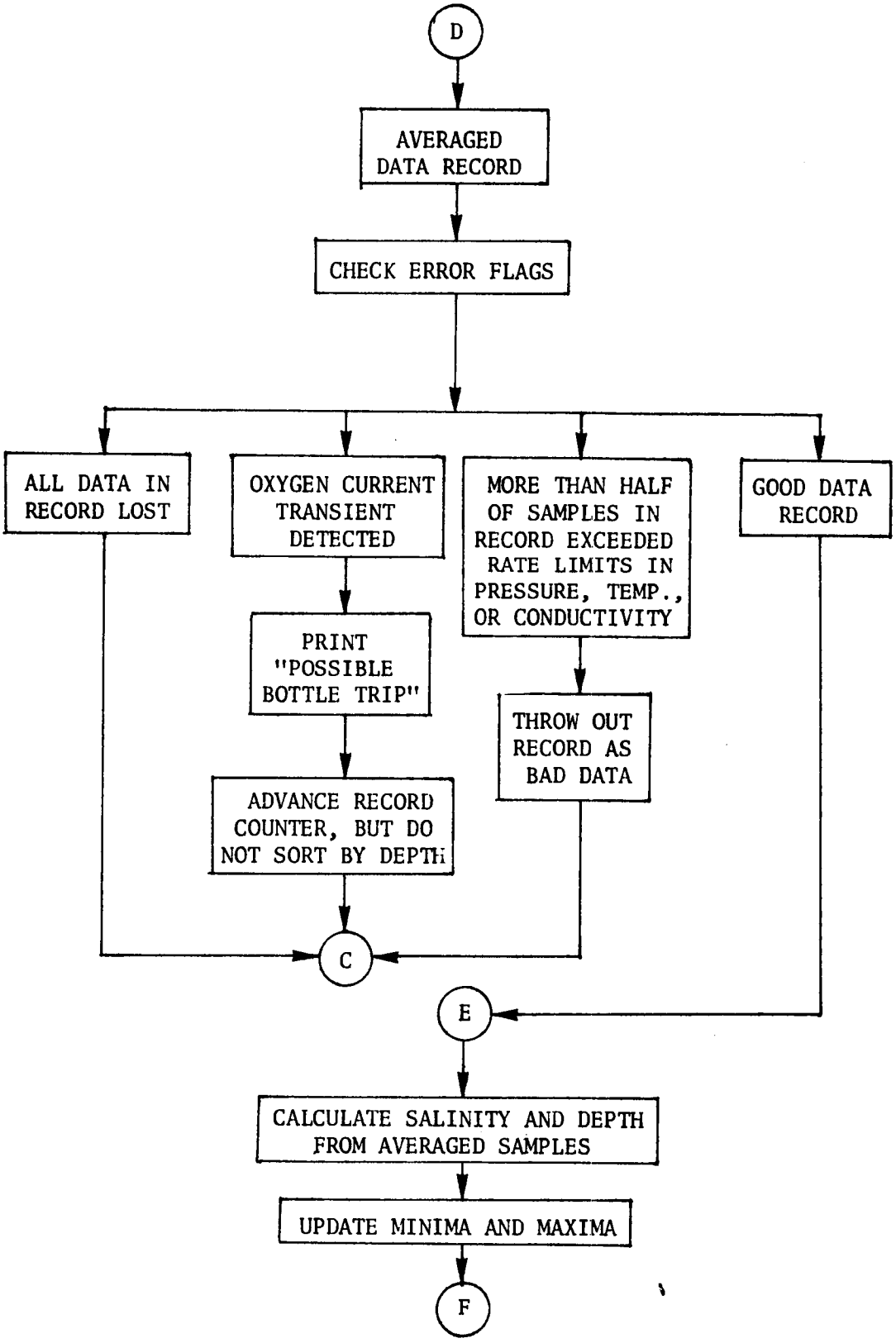
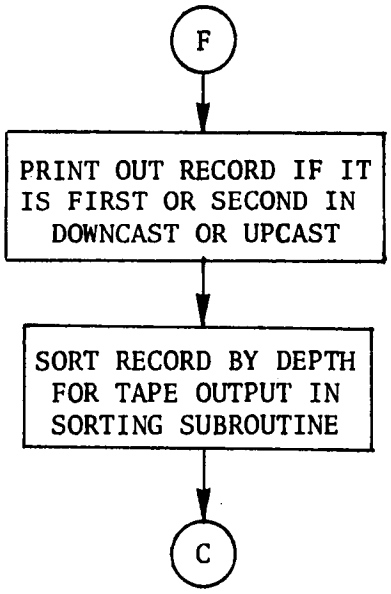

PROGRAM CTDRAV
INITIALIZE VARIABLES
READ IN HEADER CARDS
PRINT OUT CAST HEADER
A
RESET TIMING VARIABLES
AND DEPTH-SORTING ROUTINE
B
C
READ INPUT TAPE RECORD
AND CHECK FOR NUMBER
OF END OF FILES
DATA
RECORD
D
1 EOF
2 EOF
3 EOF
FINISH DEPTH
SORTING
PRINT
"END OF UPCAST"
PRINT
"END OF TAPE"
OUTPUT MINIMA
& MAXIMA
REWIND AND
LIST OUTPUT
TAPE
PRINT
"END OF DOWNCAST"
END PROG


D
AVERAGED DATA RECORD
CHECK ERROR FLAGS
ALL DATA IN RECORD LOST
OXYGEN CURRENT TRANSIENT DETECTED
MORE THAN HALF OF SAMPLES IN RECORD EXCEEDED RATE LIMITS IN PRESSURE, TEMP., OR CONDUCTIVITY
GOOD DATA RECORD
PRINT "POSSIBLE BOTTLE TRIP"
THROW OUT RECORD AS BAD DATA
ADVANCE RECORD COUNTER, BUT DO NOT SORT BY DEPTH
C
E
CALCULATE SALINITY AND DEPTH FROM AVERAGED SAMPLES
UPDATE MINIMA AND MAXIMA
F


F
PRINT OUT RECORD IF IT IS FIRST OR SECOND IN DOWNCAST OR UPCAST
SORT RECORD BY DEPTH FOR TAPE OUTPUT IN SORTING SUBROUTINE
C

CHAPTER 4

ZOOPLANKTON OF THE WATER COLUMN AND NEUSTON

G. C. Grant

CHAPTER 4

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CHAPTER 4

ZOOPLANKTON OF THE WATER COLUMN AND NEUSTON

G. C. Grant

INTRODUCTION

The zooplankton of continental shelf waters are of particular interest in any environmental assessment because, in addition to their critical role of transforming phytoplankton to protein usable by higher members of the marine food chain, they include the reproductive stages of diverse species from the benthos and nekton. This importance is magnified by the limitation of most oceanic food production to the continents' edges. Nearly all species of present day commercial value (including molluscs, decapod crustaceans, and fishes) spend at least a part of their life cycle in the plankton.

There is a general lack of published information on Middle Atlantic Bight zooplankton. The best sources of information on these important communities remain the dated but classic study of Bigelow and Sears (1939), that of Grice and Hart (1962), and a summary of available information by Jeffries and Johnson (1973). The bulk of information on zooplankton of the Middle Atlantic Bight, mostly produced by laboratories lacking ocean-going vessels, is limited to fringing bays and sounds. Most published studies are of either limited areal coverage or of single taxonomic groups, or both. Many important taxonomic groups of zooplankton have never been adequately described in the Middle Atlantic Bight.

Interest in the marine neuston, or plankton of the surface layer, is quite recent. The importance of the surface layer in the economy of the sea was first stressed by Zaitsev (1970) in his monograph on the subject, based largely on studies in the Black Sea. Subsequent studies in the northwest Atlantic (Morris 1975) and Gulf of Mexico (Berkowitz 1976) were located over deep ocean depths, and showed the neuston layer to be an impoverished one, compared with subsurface layers. The composition of neuston in Middle Atlantic Bight waters is unknown, but was suspected by the present investigator to be of considerably greater importance than open ocean neuston, partly because of the large number of shelf fishes with pelagic eggs and larvae, and partly because of the findings of Zaitsev (1970) for families and genera of neuston-abundant organisms common to Russian and American waters.

METHODS AND MATERIALS

Sampling Locations

Details on selection and the rationale for selection of stations are provided under Chapter 2, Benchmark Sampling. Six stations were occupied

each quarter for sampling of water column zooplankton and neustonic zooplankton, shown in Figure 4-1. These stations extended seaward from the nearshore station C1 to Station J1 just off the edge of the continental shelf.

Shipboard Procedure

Water Column Zooplankton

Double-oblique tows were made at each station with 60 cm opening-closing bongo systems (McGowan and Brown 1966), first with paired 202 µm mesh nets, then with 505 µm nets. The track of tows assumed the slope of a broad arc, except in heavy seas, when waves were quartered. To minimize contamination of samples with metals and grease from cable, all tows were taken with a plastic-coated cable. To avoid surface contaminants, samplers were lowered in closed position while underway, opened below the surface, lowered to near-bottom, then raised again to just below the surface. Nets were closed before the sampler was retrieved through the surface layer. Flowmeters (General Oceanics, Inc.) were employed only in the net used for taxonomy collections. The unmetered net collection was reserved for analyses of hydrocarbons and trace metals.

Precautions against contaminations of collections for chemical analysis also included minimizing contact between ship surfaces and nets. This was aided by use of a bongo rigging stand (Ocean Instruments, Inc.) and sail-bags to contain nets not in active use. Samples for chemical analysis were transferred from the net to stainless steel buckets before net wash down to avoid contamination with the ship's seawater system. Chemistry samples were concentrated on 110 µm netting, split into two portions (one for hydrocarbons and one for trace metals), and transferred by teflon-coated utensils into acid washed jars equipped with teflon cap-liners, then immediately frozen.

The sample for taxonomy in the metered net was washed down with the ship's seawater system into a receiving bucket. The sample was concentrated on 110 µm netting, then transferred to glass jars containing buffered formaldehyde in seawater (concentration 5-8 percent). Deck log forms and pre-printed labels (Time Tape) for jars are shown in Appendix I.

For quality control, one station was randomly selected each cruise. Each bongo collection for chemistry (one each 202 µm and 505 µm) at this selected station was doubly split to provide an extra sample to be analyzed at a BLM-designated laboratory for quality control purposes.

Neuston

Neuston samples were obtained every three hours over a 24-hour period at each station, using a sampler developed at Woods Hole Oceanographic Institution (Bartlett and Haedrich 1968; Craddock 1969). This sampler consists of two hydrodynamically shaped foam-filled floats connected by an endless fiberglass band (available from Fiberglass Specialties, Inc., Rochester, Mass.). It accommodates a standard one-meter net which is lashed to it through holes drilled into the band and by bolts attached to the floats. The net opening is 1 meter wide, and the unit samples the

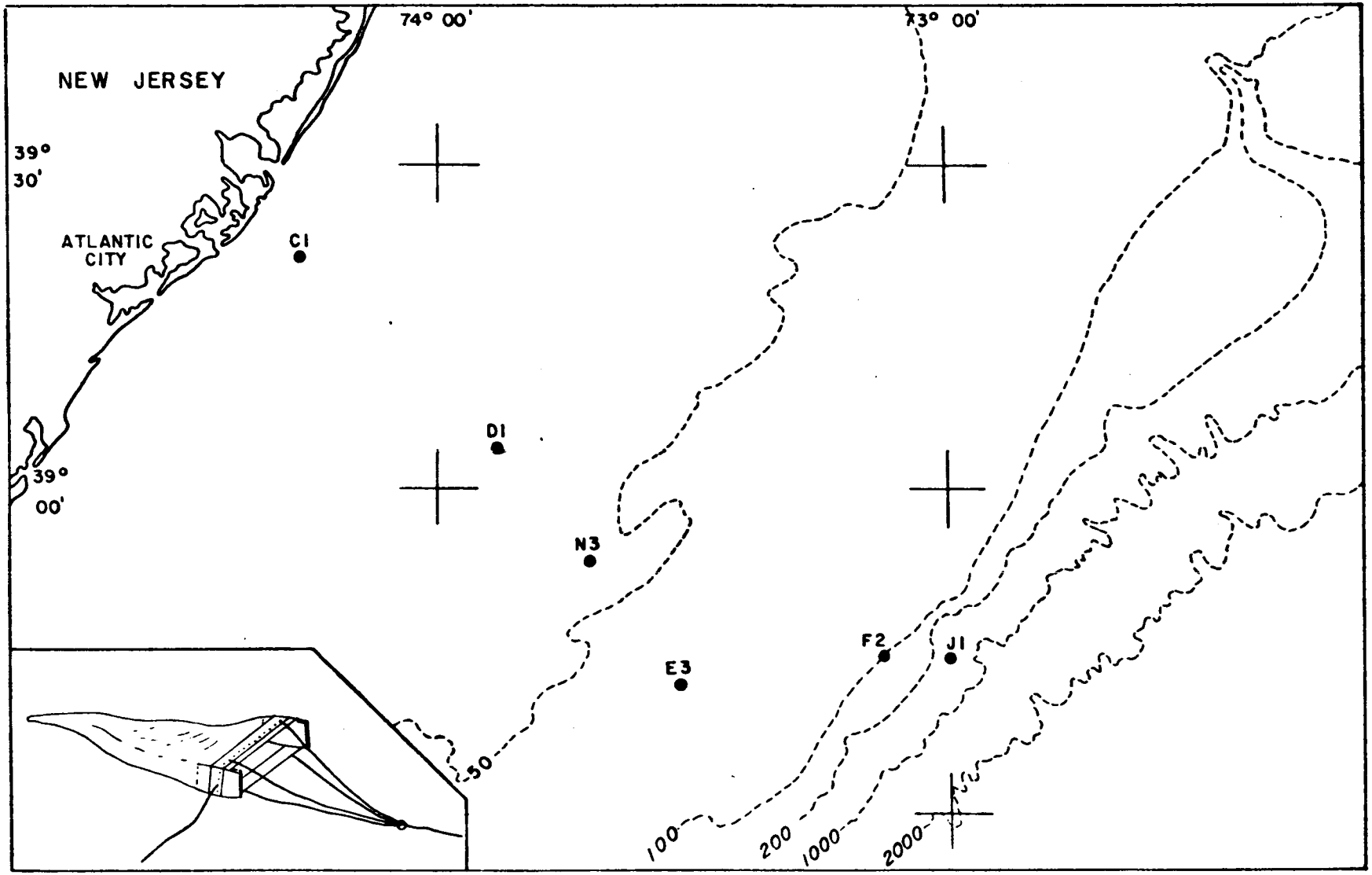

Figure 4-1. BLM 1st year regular water column stations sampled for zooplankton and neuston. Depths in meters. Inset shows neuston sampler.

upper 12 cm of sea surface, approximately. All neuston tows used a 505 μm net and were of 20 minutes duration, except at Station C1 in summer, when tows had to be abbreviated because of overabundance of neuston. Tows were made from an extended boom with the ship proceeding in a wide circular track at 2 knots. The boom and circular track were employed to keep the net away from the ship's wake.

Collected samples were washed into buckets and inspected for tarballs and large removable species. Tarballs, if present, were removed with teflon-coated forceps, placed in labelled plastic zip-bags and frozen. Large species, if present, were removed and individually placed into acid-washed jars with teflon cap-liners and frozen for hydrocarbon and trace metal analyses. A maximum of two species was selected at each station, and specimens were accumulated for a given station through the eight neuston tows. Numbers and the identity of removed specimens and the occurrence of tarballs were noted on deck log sheets (See Appendix I).

Laboratory Procedure

Frozen Samples

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

Preserved Samples

Whole samples were inspected and sorted for large and rare taxa. The sample was then split into successively smaller aliquots for the progressively smaller and more numerous taxa, using a VIMS splitter (Burrell, Van Engel, and Hummel 1974). This method allowed a more complete discovery and enumeration of contained taxa than does the more usual examination of a final, small aliquot. Where samples were large, especially the bongo collections, one-half of the first split was archived. Taxa were sorted and enumerated in the above manner (see example of sorting log) into relatively major categories, such as copepods, fish larvae, decapod larvae, etc., and preserved in individual vials.

Vials of sorted major taxa were then distributed among specialists for identification and counts of species, where possible, or higher taxa in the case of poorly known or undescribed forms. Resulting identifications and counts were entered on identification log sheets (see example, Appendix II) under the column reserved for the proper aliquot size. Representatives of identified species were archived for later reference.

Principal Taxonomic References

The best single source of information on Middle Atlantic Bight fauna that is presently available is the guide produced by Gosner (1971). Its usefulness in identifying taxa to species varies widely, however, among the various groups of importance in the plankton. It is most helpful

in identification of coelenterates, molluscs, barnacles, cumaceans, chaetognaths, and pelagic tunicates. Important planktonic groups such as polychaete larvae, ostracods, copepods, hyperiid amphipods, euphausiids, and decapod larvae require other identification aids.

Specialists in the various groups usually must refer to a diverse literature for species identifications. Only the most common useful references are listed here:

Siphonophores: Sears 1953; Totton 1965.

Pelagic molluscs: Abbott1974; Dales 1957; Gosner 1971; Morton 1957; Naef 1923; Roper, Young, and Voss 1969; Spoel 1972; Thiriot-Quievreaux 1973; and Voss 1956.

Chaetognaths: Fraser 1957; Gosner 1971; and Ritter-Zahony 1911.

Ostracods: Poulsen 1969a, 1969b, 1973; Skogsberg 1920.

Copepods: Owre and Foyo 1967; Wilson 1932; and Rose 1933.

Mysids: Richardson 1905; Tattersall 1951; and Tattersall and Tattersall 1951.

Amphipods: Bowman 1973; Bowman and Gruner 1973; Dick 1970; Harbison and Madin 1976; and Pillai 1966.

Euphausiids: Boden, Johnson, and Brinton 1955; Einarsson 1945; and Mauchline and Fisher 1969.

Decapod Larvae: Bourdillon-Casanova 1960; Gurney 1942; Kurata 1975; Lebour 1928; Lough 1975; Sandifer 1972; Williams 1965, 1974; Williamson 1957.

Fish Eggs and Larvae: Bigelow and Schroeder 1953; Colton and Marak 1969; Gibbs et al. 1971; Hildebrand and Schroeder 1928; Mansueti and Hardy 1967; and Miller and Jorgensen 1973.

Data Analysis

Data Cards and Storage

Two basic data card types were used for the storage, reduction, and manipulation of data. The first, a station/sample card, was prepared for each sample, and contained sample number, position of station, date, time, surface temperature and salinity, depth of station, number of species, number of individuals, sample type, type of sampling gear, net mesh size, type of tow, maximum depth of tow, duration of tow, and volume of water filtered.

The second card type, a species card, was punched for each species (or higher taxa) occurrence. Included on these cards were sample number, species code number (expanded from 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 on the size of aliquot examined. References to "rank of abundance" in this report all were based on simple summation of total sample catches.

Diversity Measurements

Three principal 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 or species richness index ($S-1/\log_e N$). Computer programs for their calculation are included in Appendix III. All diversity measures were based on total number of species and individuals in each sample.

Cluster Analyses

The principal method of analysis used in this study is a cluster analysis, both normal and inverse, based on a matrix of Bray and Curtis (1957) similarity coefficients (Boesch 1976). The normal analysis provides a clustering of samples according to their similarity in species composition, the inverse analysis a clustering of species according to similarity in sample distribution. Other outputs of the program used (see Appendix III) included the frequency of occurrence for species and a listing of species occurrences by sample. A fuller description of the clustering strategy is included in Chapter 6.

A modification of the basic clustering program permitted the use of standardized catches (numbers per $100m^3$) and was employed in all comparisons of bongo samples. No reduction to number per cubic meter filtered was employed in neuston data, since meters were not allowed, by contract, within neuston nets. These tows were, however, standardized to 20 minutes.

RESULTS

Fall 1975 Cruise No. BLM01W

Summary of Collections

The six designated water column stations (C1, D1, Ne, E3, F2, and J1) were sampled for zooplankton and neuston between 23 October and 29 October 1975.

Bongo samplers were fished obliquely twice at each station, once each with 202 µm and 505 µm mesh nets. Resulting collections included 12 preserved samples, 12 trace metal samples, 12 hydrocarbon samples, and material from Station J1 reserved for quality control.

Neuston collections (505 µm nets) were obtained at each station at 3-hr intervals over a 24-hr period and resulted in 48 preserved collections, 5 hydrocarbon samples, 7 trace metal samples, and 35 samples of tarballs. Species selected for chemical analysis included *Velella velella* (hydrozoan), *Pelagia noctiluca* (scyphozoan), *Beroe ovata* (ctenophore), *Parathemisto gaudichaudii* (amphipod), *Idotea metallica* (Isopod), and a filefish (Balistidae).

Faunal Description

A total of 204 taxa were identified from fall 1975 zooplankton and neuston collections and are listed in Table 4-1. Particularly diverse groups included the copepods, amphipods, decapods, and fishes. Dominant taxa are listed in Table 4-2.

Station C1. At the shallowest station, copepods were the numerically dominant group in all 8 neuston tows and in both the oblique bongo tows (202 µm and 505 µm nets). Dominant copepods in the neuston tows (Figure 4-2) and in the bongo 505 included *Labidocera aestiva, Pontella meadii,* and *Centropages typicus.* The bongo 202 collection was dominated by *Acartia tonsa,* too small to be efficiently retained by the 505 µm meshes. Second in abundance in all neuston tows were fish eggs. Decapod larvae, *Beroe ovata,* and *Idotea metallica* were subdominant taxa in the neuston tows. Mysids, cladocerans, and chaetognaths were numerically more important among the subdominants in bongo tows than in neuston tows. *Labidocera aestiva* showed a strong migration to the surface layer at night.

Station D1. Only one-half of the neuston tows were dominated by copepods, including *Centropages typicus, Calanus finmarchicus,* and *Anomalocera patersonii* (see Pennell 1976 for a recent redescription as *A. opalus* of this western Atlantic pontellid). The hyperiid amphipod, *Parathemisto gaudichaudii,* was dominant in three neuston tows and in the bongo 505. The neustonic isopod *Idotea metallica* was dominant in one neuston tow and a small copepod, *Paracalanus* sp., in the bongo 202. Subdominants in night neuston tows also included *Cancer* sp. larvae and the chaetognath, *Sagitta tasmanica.* Chaetognaths and the thecosome, *Spiratella (Limacina) retroversa,* were relatively more abundant in bongo tows. *Centropages typicus* and *Calanus finmarchicus* increased in numbers at night in the surface layer (Figure 4-3).

Station N3. As in Station D1, one-half the neuston tows were dominated by copepods, either *Anomalocera patersonii* or *Calanus finmarchicus. Parathemisto gaudichaudii* was dominant in two tows, fish eggs in one, and *Pelagia noctiluca* in the eighth tow. Other important neustonic taxa included *Sagitta tasmanica, S. elegans,* and *Centropages typicus.* The bongo 505's most abundant taxon was *Sagitta tasmanica,* whereas the companion bongo 202 was dominated by *Paracalanus* sp. Diel changes in abundance of dominant surface layer copepods (Figure 4-4) were similar to those observed at Station D1.

Station E3. Copepods were numerically dominant in six of the eight neuston tows and in both bongo collections. *Centropages typicus* was the dominant copepod in neuston tows from late afternoon to early morning, *Anomalocera patersonii* in midday. Two neuston collections were dominated by *Parathemisto gaudichaudii.* Other important taxa in neuston collections included *Metridia lucens* (a night migrant, Figure 4-5), *Idotea metallica,* and *Sagitta elegans.*

Calanus finmarchicus was dominant in the bongo 505 collection, whereas the small *Paracalanus* sp. was most abundant in the bongo 202. Euphausiids and the thecosomes were of more importance in subsurface tows (bongos) than in surface collections.

Table 4-1. Check list of zooplankton identified from neuston and bongo collections, BLM01W.

CNIDARIA
- unid. hydrozoans
- *Bougainvillea* sp.
- *Nemopsis bachei*
- unid. siphonophores
- *Muggiaea kochei*
- *Forskalia edwardsii*
- *Physophora hydrostatica*
- *Velella velella*
- *Physalia physalis*
- unid. medusae
- *Pelagia noctiluca*
- *Cyanea capillata*
- *Aurelia aurita*

CTENOPHORA
- *Beroe ovata*

PLATYHELMINTHES
- *Hoploplana grubei*
- *Gnesioceros sargassicola*

CHAETOGNATHA
- *Sagitta elegans*
- *Sagitta enflata*
- *Sagitta tasmanica*
- *Sagitta bipunctata*
- *Sagitta helenae*
- *Sagitta hexaptera*
- *Sagitta minima*
- *Pterosagitta draco*

MOLLUSCA
- unid. gastropod larvae
- unid. bivalve larvae
- *Spiratella retroversa*
- *Paedoclione doliiformis*
- unid. aeolidiids
- *Octopus vulgaris*
- unid. squid

ANNELIDA
- unid. polychaete larvae
- *Tomopteris helgolandica*
- *Aphrodita* sp.
- *Autolytus* sp.
- *Platynereis dumerilii*
- *Nereis diversicolor*
- *Tharyx* sp.
- *Chaetozone setosa*
- *Paranaitus speciosa*

PYCNOGONIDA
- unid. pycnogonids
- *Endeis spinosa*

CRUSTACEA
- Cladocera
  - *Penilia avirostris*
- Ostracoda
  - *Halocypris brevirostris*
  - *Conchoecia* sp.
  - *Conchoecia curta*
  - *Euconchoecia chierchiae*
- Copepoda
  - unid. copepodids
  - *Calanus finmarchicus*
  - *Nannocalanus minor*
  - *Undinula vulgaris*
  - *Eucalanus* sp.
  - *Eucalanus attenuatus*
  - *Rhincalanus nasutus*
  - *Mecynocera clausi*
  - *Paracalanus* sp.
  - *Paracalanus crassirostris*
  - *Euchirella amoena*
  - *Undeuchaeta plumosa*
  - unid. euchaetids
  - *Pareuchaeta norvegica*
  - *Scottocalanus securifrons*
  - *Scolecithrix danae*
  - *Centropages typicus*

Table 4-1. (continued)

Copepoda (continued)
- *Centropages violaceus*
- *Metridia lucens*
- *Pleuromamma gracilis*
- *Pleuromamma abdominalis*
- *Pleuromamma robusta*
- *Candacia armata*
- *Anomalocera ornata*
- *Anomalocera patersonii*
- *Labidocera aestiva*
- *Labidocera acutifrons*
- *Pontella atlantica*
- *Pontella meadii*
- *Pontella securifer*
- *Pontella spinipes*
- *Pontellina plumata*
- *Pontellopsis regalis*
- *Pontellopsis villosa*
- *Acartia danae*
- *Acartia tonsa*
- unid. harpacticoids
- *Macrosetella gracilis*
- *Alteutha depressa*
- unid. cyclopoids
- *Oncaea* sp.
- *Oithona* sp.
- *Caligus* sp.

Cirripedia
- unid. cypris larvae
- *Lepas* sp. cypris larvae
- *Lepas pectinata*

Stomatopoda
- unid. stomatopod larvae

Cumacea
- *Oxyurostylis smithi*

Isopoda
- *Idotea baltica*
- *Idotea metallica*
- *Chiridotea tuftsii*
- *Bagatus minutus*
- unid. dajids

Amphipoda
- *Phronima sedentaria*
- *Phronima atlantica*
- *Anchylomera blossevillii*
- *Parathemisto gaudichaudii*
- *Lestrigonus bengalensis*
- *Lestrigonus latissimus*
- *Lestrigonus crucipes*
- *Lestrigonus shoemakeri*
- *Lestrigonus schizogeneois*

Amphipoda (continued)
- *Hyperia* sp.
- *Hypereitta rosseleri*
- *Hypereitta stephenseni*
- *Tetrathyrus forcipatus*
- *Streetia steenstrupi*
- *Primno macropa*
- *Phronimella elongata*
- *Thyropus sphaeroma*
- *Brachyscelus crusculum*
- *Lycaea boralli*
- *Paratyphis* sp.
- unid. hyperiids
- unid. phoxocephalid
- *Cerapus tubularis*
- *Orchestia* sp.
- unid. gammarids

Mysidacea
- *Neomysis americana*
- *Mysidopsis bigelowi*
- *Siriella thompsoni*

Euphausiacea
- *Meganyctiphanes norvegica*
- *Euphausia krohnii*
- *Thysanoessa inermis*
- *Thysanoessa raschi*
- *Thysanoessa gregaria*
- *Thysanoessa longicaudata*
- *Nematoscelis atlantica*
- *Nematoscelis megalops*
- *Thysanopoda tricuspidata*
- *Nyctiphanes couchi?*
- *Stylocheiron abbreviatum*

Decapoda
- *Solenocera* sp.
- *Lucifer faxoni*
- *Leptochela bermudensis*
- *Leptochela* sp.
- *Leander tenuicornis*
- *Hippoloytes pleuracantha*
- *Latreutes fucorum*
- *Crangon septemspinosa*
- *Pontophilus* sp.
- unid. caridean larvae
- unid. phyllosome larvae
- *Galathea* sp.
- unid. pagurids
- *Emerita talpoida*
- *Ethusia microphthalma*
- unid. majids
- *Cancer* sp.

Table 4-1 (concluded)

Decapoda (continued)
Portunus sayi
Oralipes ocellatus
Callinectes similis
Hexapanopeus angustifrons
unid. brachyuran zoea
unid. megalopae
UROCHORDATA
Doliolum nationalis
Thalia democratica
Oikopleura sp.
unid. salps and doliolids
CHORDATA
Pisces
unid. leptocephali
Nemichthys scolopaceus
Clupea harengus
Brevoortia tyrannus
unid. clupeids
Anchoa mitchilli
unid. engraulids
Synodus foetens
synodontid larvae
paralepidid larvae
Myctophum affine
Myctophum nitidulum
Myctophum punctatum
Myctophum obtusirostre
Gonichthys cocco
Symbolophorus veranyi
Ceratoscopelus maderensis
unid. myctophid larvae
Urophycis chuss
Urophycis regius
Urophycis sp.
Merluccius sp.
Syngnathus fuscus
Hippocampus erectus
scorpaenid larvae
Gobionellus sp.
unid. serranid
Centropristis striata
Decapterus punctatus
Coryphaena sp.
Callionymus sp.
scombrid larvae
Scophthalmus aquosus
Bothus ocellatus
Etropus microstomus
Syacium
unid. balistids
Sphoeroides trichocephalus

Table 4-2. Numerically dominant zooplankters in fall 1975 collections (BLM01W). Drawn from the three most abundant taxa in each tow (D = day, N = night).

Station C1

Bongo 202 (N)	Bongo 505 (N)	Neuston 505
Acartia tonsa	*Labidocera aestiva*	*L. aestiva* (4N,2D)
Centropages typicus	*A. tonsa*	*C. typicus* (4N,2D)
Paracalanus sp.	*C. typicus*	*Pontella meadii* (1N,4D)
		A. tonsa (3N)
		Beroe ovata (2D)
		Scophthalmus-type fish eggs (2D)

Station D1

Bongo 202 (N)	Bongo 505 (N)	Neuston 505
Paracalanus sp.	*Parathemisto gaudichaudii*	*P. gaudichaudii* (4N,4D)
C. typicus	*C. typicus*	*C. typicus* (4N,1D)
Spiratella retroversa	*Sagitta tasmanica*	*Idotea metallica* (4D)
		Anomalocera patersonii (1N,2D)
		Cancer sp. (1N)
		S. tasmanica (1N)
		Calanus finmarchicus (1N)

Station N3

Bongo 202 (D)	Bongo 505 (D)	Neuston 505
Paracalanus sp.	*S. tasmanica*	*A. patersonii* (4N,3D)
Oithona sp.	*C. finmarchicus*	*P. gaudichaudii* (2N,3D)
S. tasmanica	*Nannocalanus minor*	*Scophthalmus*-type eggs (1N,4D)
		Urophycis-type eggs (1N,2D)
		Pelagia noctiluca (1N)
		S. tasmanica (1N)
		C. typicus (1N)
		Sagitta elegans (1N)

Table 4-2 (concluded)

Station E3

Bongo 202 (D)	Bongo 505 (D)	Neuston 505
Paracalanus sp.	*C. finmarchicus*	*C. typicus* (4N,4D)
C. typicus	*C. typicus*	*A. patersonii* (2N,4D)
Oithona sp.	*Metridia lucens*	*M. lucens* (4N)
		P. gaudichaudii (3D)
		I. metallica (1N,1D)
		S. elegans (1N)

Station F2

Bongo 202 (D)	Bongo 505 (D)	Neuston 505
S. retroversa	*C. finmarchicus*	*M. lucens* (4N,4D)
C. finmarchicus	*Thysanoessa gregaria*	*P. gracilis* (4N)
Thysanoessa inermis	*P. gaudichaudii*	*Velella velella* (2D)
		Lucifer faxoni (1N, 1D)
		I. metallica (2D)
		P. gaudichaudii (1N, 1D)
		Urophycis-type eggs (1D)
		unid. megalopae (1N)
		unid. medusae (1N)
		Bagatus minutus (1D)

Station J1

Bongo 202 (D)	Bongo 505 (D)	Neuston 505
Paracalanus sp.	*Sagitta enflata*	*P. gaudichaudii* (1N,4D)
S. retroversa	*N. minor*	*P. gracilis* (3N,1D)
Mecynocera clausi	*Nematoscelis megalops*	*M. lucens* (3N)
		S. enflata (1N, 2D)
Bongo 202 (N)	**Bongo 505 (N)**	*L. faxoni* (2D)
		Euphausia krohni (1N,1D)
Paracalanus sp.	*E. krohni*	*T. democratica* (1N,1D)
P. gracilis	*M. lucens*	*Labidocera acutifrons* (1N)
M. lucens	*P. gracilis*	*Pontellopsis villosa* (1D)

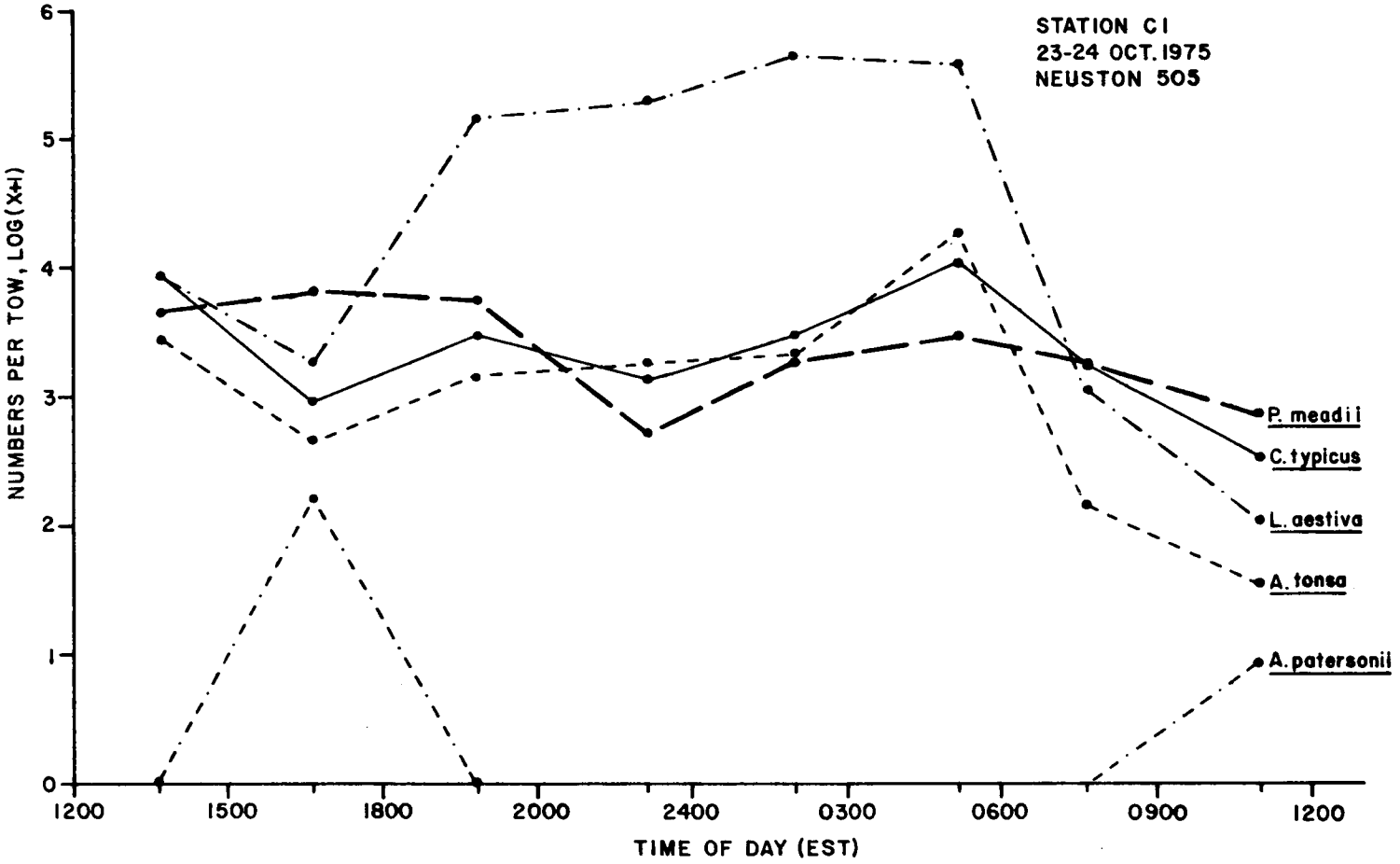

Figure 4-2. Diel cycle of abundance of dominant copepods in the surface layer of Station C1, BLM01W.

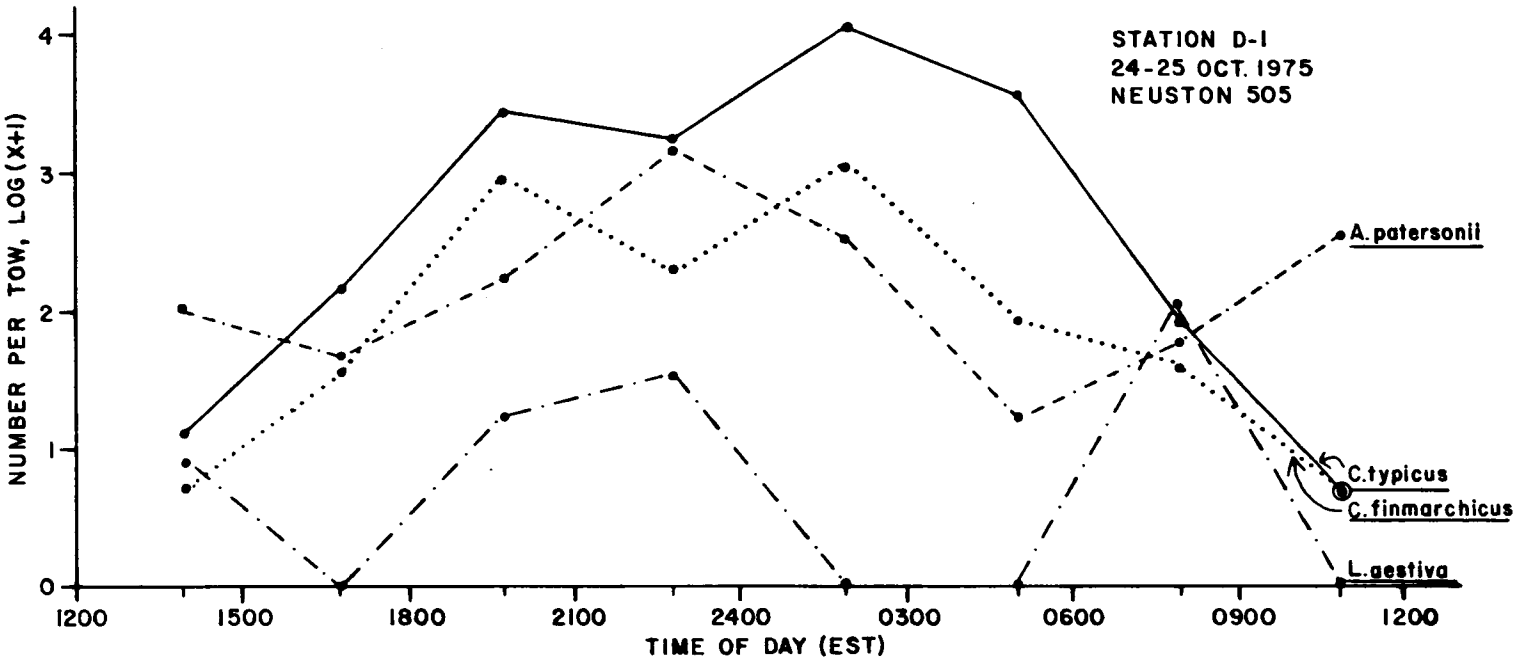

Figure 4-3. Diel cycle of abundance of dominant copepods in the surface layer of Station D1, BLM01W.

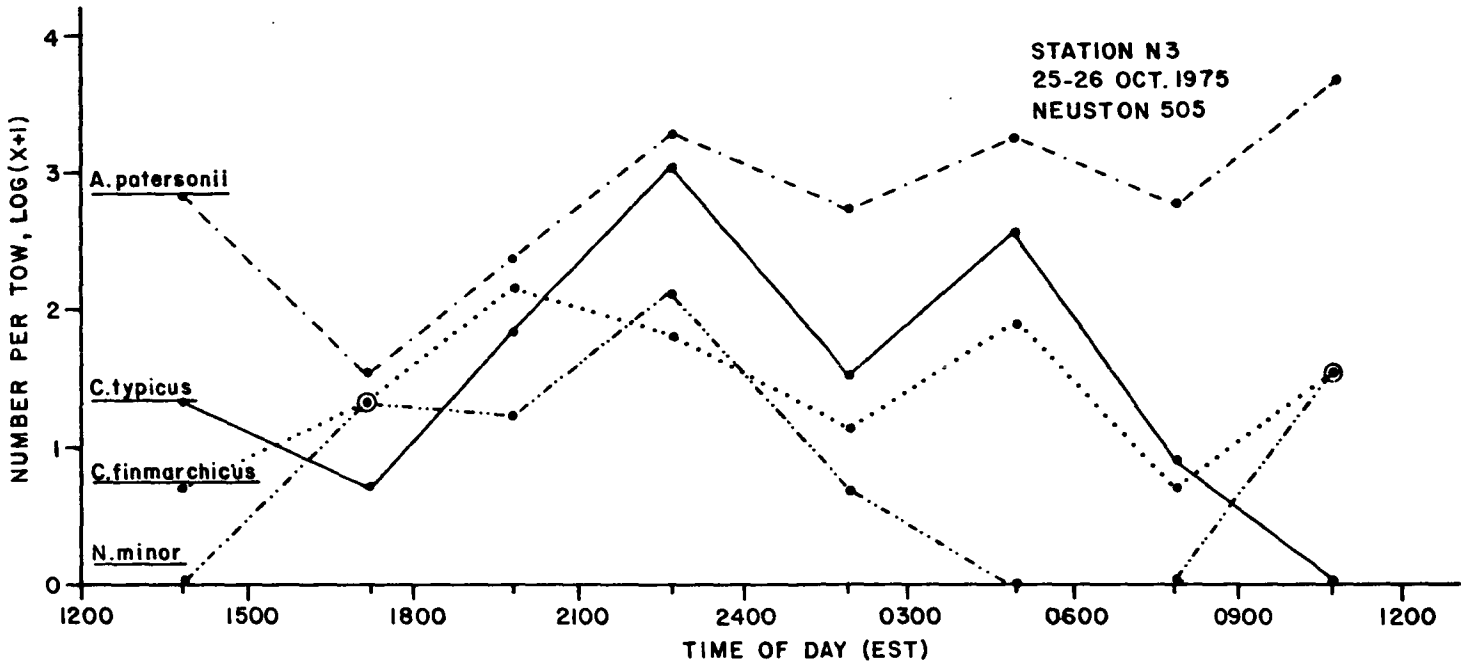

Figure 4-4. Diel cycle of abundance of dominant copepods in the surface layer of Station N3, BLM01W.

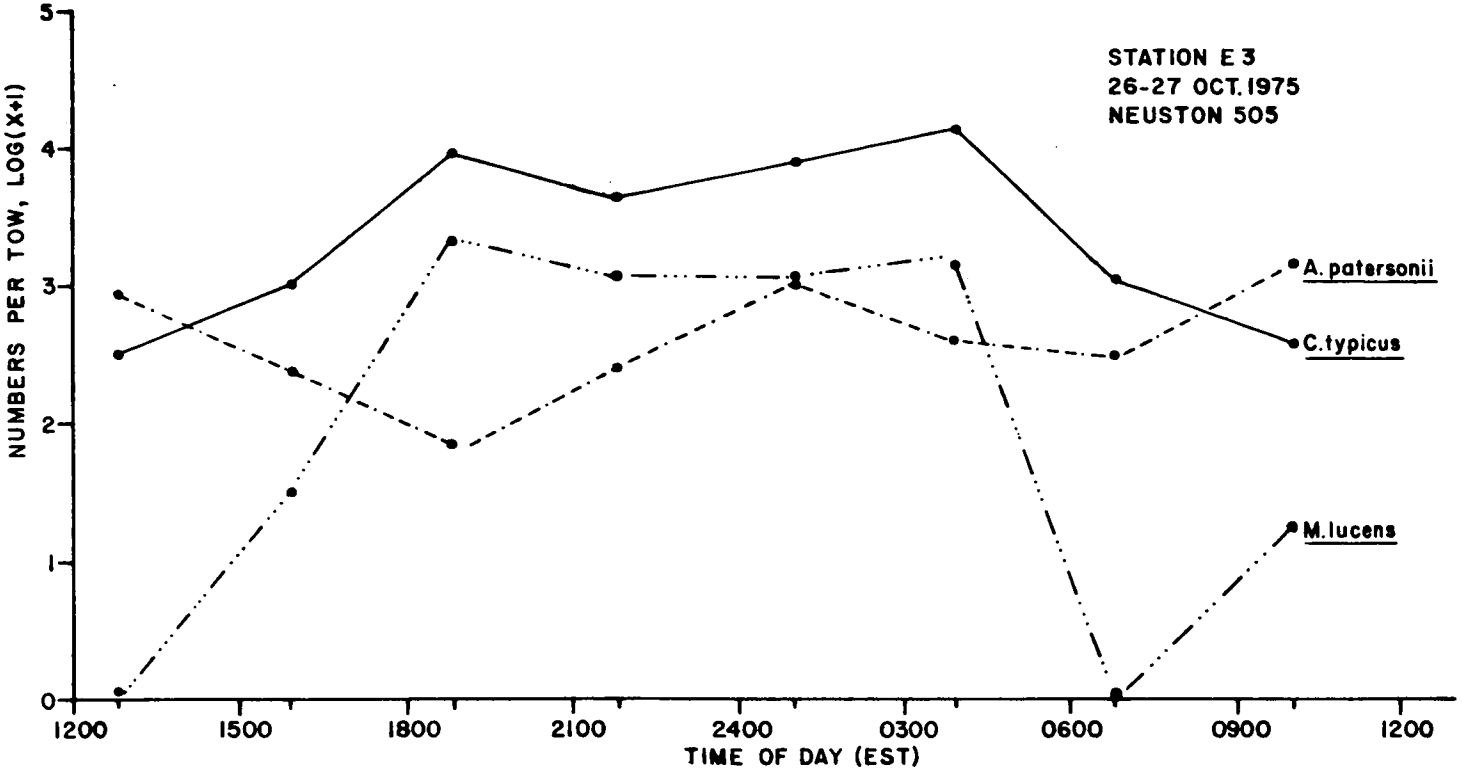

Figure 4-5. Diel cycle of abundance of dominant copepods in surface layer of Station E3, BLM01W.

Station F2. Copepods were the dominants in all eight neuston tows and in the bongo 505 collection. *Metridia lucens* was dominant in dawn-to-dusk neuston tows, replaced at night by *Pleuromamma gracilis* (Figure 4-6). *Calanus finmarchicus* was the dominant copepod in both the bongo 505 and 202 collections, but in the latter was outnumbered by *Spiratella retroversa*, a thecosome. Numbers of copepod species doubled at this stations compared with the previous neritic and mid-shelf stations (15 vs. 6-8 species).

Other important taxa in the neuston included *Velella velella*, *Lucifer faxoni*, *Idotea metallica*, *Parathemisto gaudichaudii*, and fish eggs. *Sargassum* fauna including *Velella velella*, *Bagatus minutus*, *Latreutes fucorum*, and *Portunus sayi*, was also evident. Euphausiids and chaetognaths were of greater relative importance in bongo tows.

Station J1. The diversity of copepods increased to 20 species at this slope station. However, copepods were dominant in only half the neuston tows, specifically those from dusk and night tows. The dominant species at night, as in Station F2, was *Pleuromamma gracilis* (Figure 4-7). Dominant copepods in dawn and daytime collections were the pontellids, *Labidocera acutifrons* and *Pontellopsis villosa*. Ten of the 20 copepod species were pontellids. *Parathemisto gaudichaudii* was dominant in two daytime neuston collections; the remaining two collections were dominated by *Thalia democratica* and *Lucifer faxoni*. Other important taxa in the neuston were *Sagitta enflata* and *Euphausia krohnii*.

An extra two bongo tows were made at this station, one each with 202 µm and 505 µm mesh nets, for a total of four bongo tows. One bongo 505 was dominated by *S. enflata*, the other by *Euphausia krohnii*. *Paracalanus* sp. was the dominant copepod in both bongo 202 collections, but completely absent from bongo 505 and neuston collections. Ostracods, thecosomes, euphausiids, and chaetognaths were more abundant in bongo tows than in the neuston.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent and abundant species from bongo collections are listed in Table 4-3, and those from neuston collections in Table 4-4. Comparison of these two lists, even after discounting the smaller species obtained in 202 µm bongo nets (*Paracalanus* sp., *Oithona* spp., *Acartia danae*, and *Mecynocera clausi*), demonstrates the uniqueness of the surface layer fauna. Half of the ten most frequent representatives of neuston collections do not occur on the tabulated list of bongo species, and two of these are developmental stages of fish (*Urophycis* sp. larvae) and decapods (*Cancer* sp. zoea and megalopae). Other unique species include euneustonic pontellid copepods and the ever-present isopod *Idotea metallica*.

In both lists, the most abundant taxon was a narrowly-distributed near-shore copepod: *Acartia tonsa* in bongos and *Labidocera aestiva* in neuston collections.

Diversity. Three measurements of diversity are listed for each collection in Table 4-5. There was little consistency in results, when values are compared by mesh size in the case of bongo tows, or by time of day in neuston collections. Shannon indices ranged from 0.0437 to 3.4531. The high index was from a bongo 202 tow at Station J1, containing 33

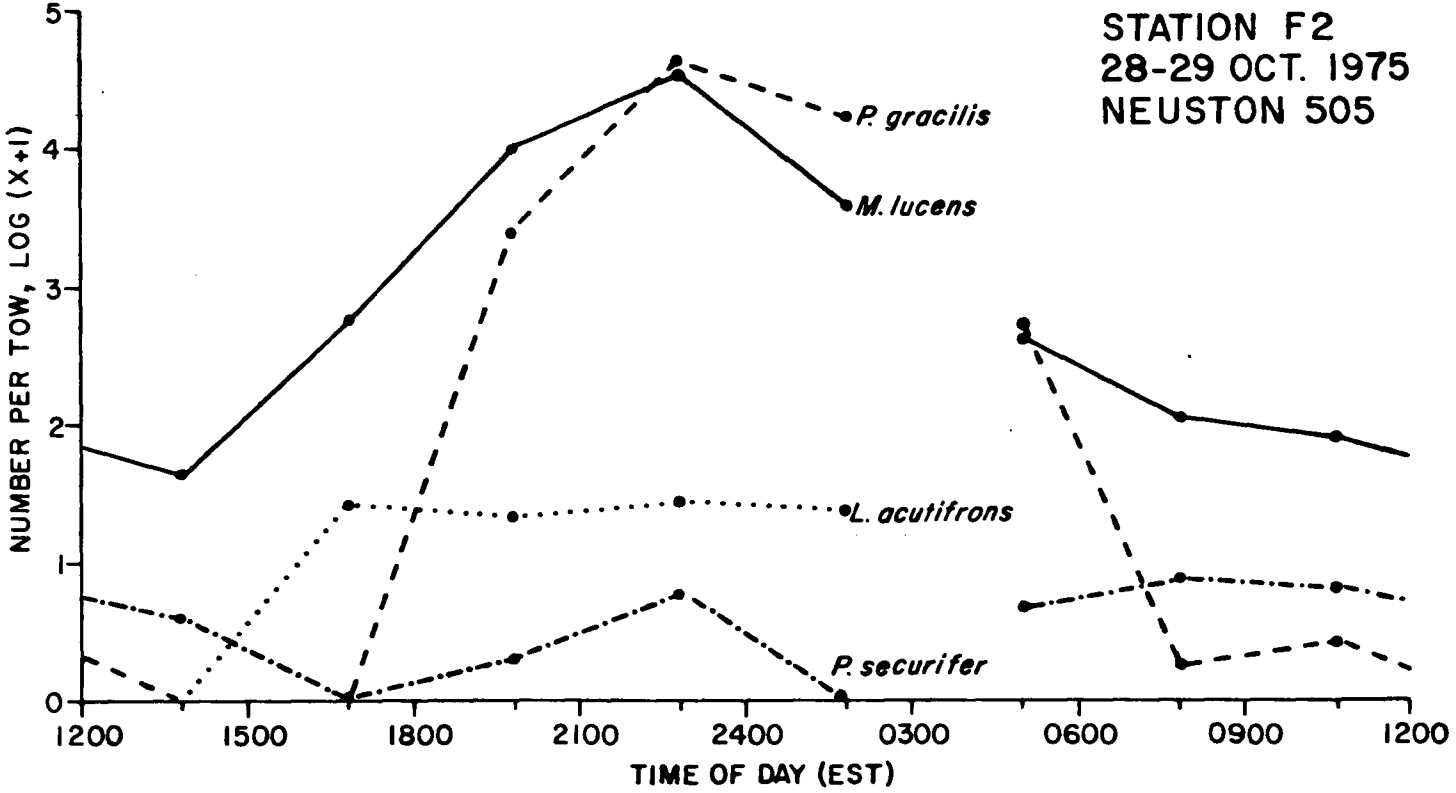

Figure 4-6. Diel cycle of abundance of dominant copepods in surface layer of Station F2, BLM01W.

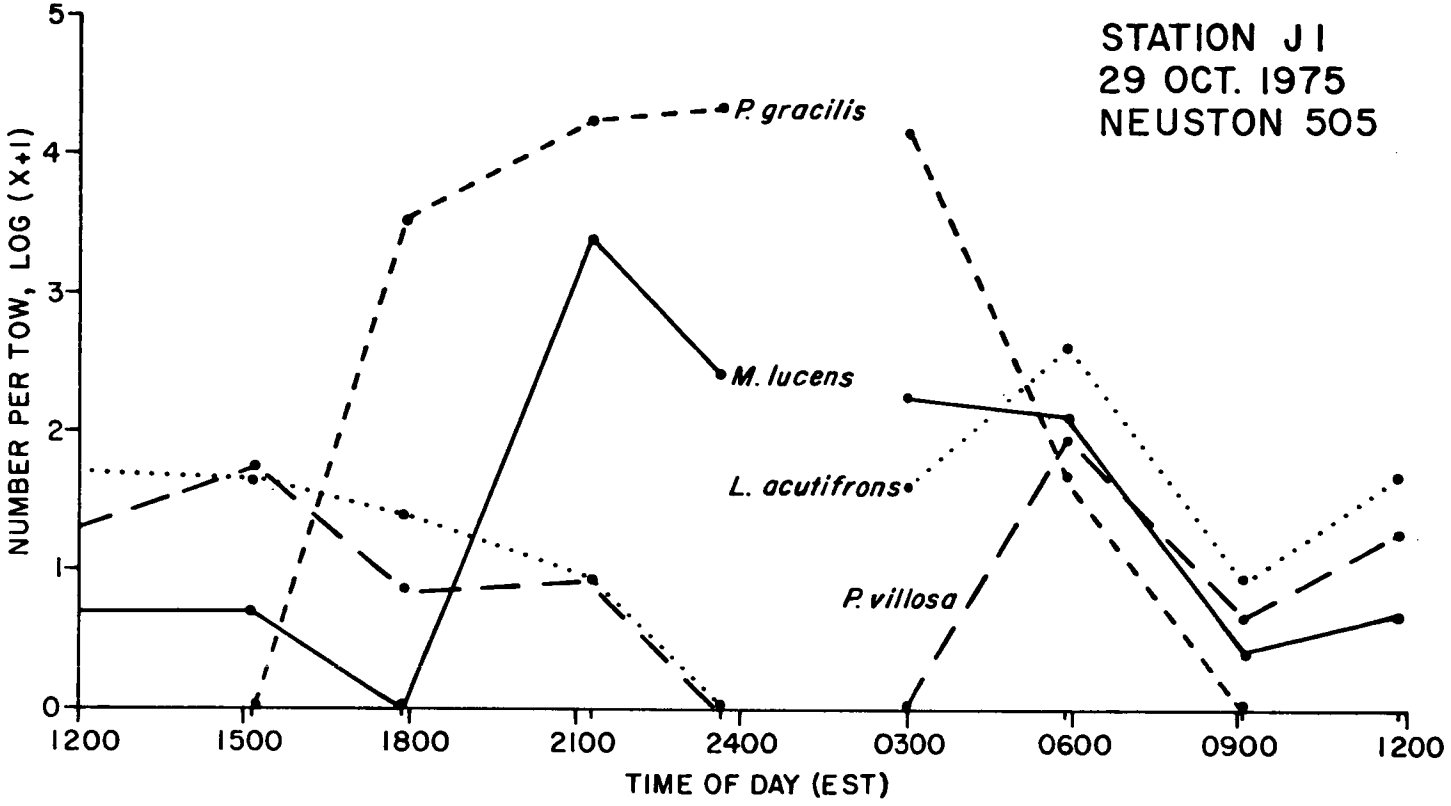

Figure 4-7. Diel cycle of abundance of dominant copepods in surface layer of Station J1, BLM01W.

Table 4-3. Frequency of occurrence and rank of abundance of common species in bongo collections, BLM01W.

Species	Percent Occurrence	Rank Abundance	Maximum Number per $100m^3$
Sagitta tasmanica	93	7	7,008
Parathemisto gaudichaudii	79	10	6,742
Sagitta elegans	79	12	3,378
Eucalanus sp.	71	15	1,451
Centropages typicus	64	3	124,780
Candacia armata	64	16	1,398
Paracalanus	57	2	181,862
Oithona sp.	57	4	27,852
Calanus finmarchicus	57	8	9,769
Nannocalanus minor	57	20	765
Thysanoessa inermis	57	25	30
Bothus ocellatus	50	-	< 1
Acartia danae	43	17	1,638
Thysanoessa sp.	43	24	91
Spiratella retroversa	36	9	8,695
Metridia lucens	36	11	2,662
Euphausia krohni	29	13	983
Mecynocera clausi	29	19	422
Acartia tonsa	21	1	461,270
Labidocera aestiva	21	5	15,597
Thysanoessa gregaria	21	14	2,509
Pleuromamma gracilis	14	6	9,108

Table 4-4. Frequency of occurrence and rank of abundance of common species in neuston collections, BLM01W.

Species	Percent Occurrence	Rank Abundance
Idotea metallica	98	8
Parathemisto gaudichaudii	83	2
Urophycis sp. larvae	75	20
Centropages typicus	71	4
Anomalocera patersonii	69	7
Calanus finmarchicus	50	10
Sagitta tasmanica	50	11
Metridia lucens	48	-
Cancer sp. larvae	42	14
Pontella meadii	40	6
Sagitta elegans	35	12
Lucifer faxoni	33	17
Labidocera aestiva	27	1
Labidocera acutifrons	27	16
Nannocalanus minor	27	19
Pleuromamma gracilis	23	3
Spiratella retroversa	23	15
Acartia tonsa	19	5
Sagitta enflata	19	18
Pelagia noctiluca	15	13
Beroe ovata	10	9

Table 4-5. Diversity of zooplankton and neuston collections, BLM01W. 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
C1	Z75-272	Ns, D	2.1385	0.5474	1.3795
	-273	Ns, D	1.6737	0.4838	1.0856
	-274	Ns, N	0.4807	0.1132	1.5054
	-275	B202, N	1.2673	0.2842	1.3875
	-276	B505, N	1.6508	0.4127	1.2800
	-277	Ns, N	0.1651	0.0460	0.8985
	-278	Ns, N	0.1521	0.0411	0.9249
	-279	Ns, N	0.5352	0.1547	0.7728
	-280	Ns, D	2.2042	0.6635	1.0308
	-281	Ns, D	0.0542	0.5938	1.3429
D1	Z75-282	Ns, D	1.6478	0.5869	1.0014
	-283	Ns, D	0.0437	0.0169	0.4281
	-284	B202, N	2.0953	0.5126	1.2004
	-285	B505, N	2.0183	0.5630	1.0596
	-286	Ns, N	2.4594	0.6149	1.6895
	-287	Ns, N	1.9637	0.5477	1.2539
	-288	Ns, N	1.3537	0.3658	1.1312
	-289	Ns, N	0.7531	0.2177	1.1998
	-290	Ns, D	0.6399	0.1926	0.9836
	-291	Ns, D	1.9111	0.6370	1.0522
N3	Z75-293	Ns, D	0.9561	0.2764	1.4916
	-294	Ns, D	0.0878	0.0237	1.1789
	-295	Ns, N	3.2337	0.7911	2.2265
	-296	Ns, N	2.7282	0.6820	1.7445
	-297	Ns, N	1.4190	0.4476	1.0359
	-298	Ns, N	1.8652	0.5041	1.5004
	-299	Ns, D	0.1928	0.0581	0.8723
	-300	B505, D	1.8177	0.4359	1.6428
	-301	B202, D	1.9949	0.4880	1.2196
	-302	Ns, D	1.3263	0.4724	0.6627
E3	Z75-303	Ns, D	1.2999	0.4333	0.9786
	-304	Ns, D	0.1416	0.0548	0.4438
	-305	Ns, N	1.1751	0.2675	2.1252
	-306	Ns, N	1.5032	0.3539	2.0484
	-307	Ns, N	1.3384	0.3210	1.8315
	-308	Ns, N	0.9090	0.2457	1.2421
	-309	Ns, D	1.7320	0.5773	0.9083
	-310	B505, D	2.1015	0.5379	1.2279
	-311	B202, D	1.4640	0.3511	1.2050
	-312	Ns, D	0.6101	0.1649	1.2226

Table 4-5 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
F2	Z75-313	Ns, N	1.5577	0.4345	1.5749
	-314	Ns, D	2.2108	0.5302	3.2807
	-315	B505, D	0.6018	0.1370	2.2206
	-316	B202, D	2.9746	0.6488	3.0759
	-317	Ns, D	2.7336	0.6325	3.0447
	-319	Ns, D	1.7672	0.6295	1.3985
	-320	Ns, D	2.1079	0.5157	2.2859
	-321	Ns, N	0.9452	0.2483	1.3188
	-323	Ns, N	1.0411	0.2547	1.4201
	-324	Ns, N	0.7641	0.1910	1.5035
J1	Z75-325	Ns, N	0.3295	0.0685	2.7686
	-326	Ns, N	1.1175	0.2114	4.2334
	-327	Ns, D	2.6337	0.6200	3.0743
	-328	Ns, D	3.0454	0.7169	3.1290
	-329	B505, D	2.9833	0.5914	4.3821
	-330	Ns, D	1.8988	0.3764	4.5065
	-331	B202, D	3.4531	0.6845	3.8485
	-332	Ns, D	0.8167	0.1619	3.8695
	-333	B202, N	1.8705	0.3677	2.5649
	-334	B505, N	2.3123	0.4625	2.8834
	-335	Ns, N	0.9076	0.2006	2.2055
	-336	Ns, N	0.4378	0.0840	3.5883

species, but only 4084 individuals. The low index was from a neuston tow at Station D1, heavily dominated by *Parathemisto gaudichaudii*. Evenness (J') values ranged from a low of 0.0237 from a Station N3 daytime neuston tow to 0.7911 from a night neuston tow at the same station.

Species richness generally increased with distance offshore, as shown in Figure 4-8 for neuston collections. Daytime tows tended to be richer in species than night tows inshore at Station C1 and offshore at stations F2 and J1, but the opposite occurred at mid-shelf stations. Either case can be explained by diurnal migration. Night collections may be enriched in species by the addition of vertical migrators; richness may be decreased if one or a few of these migrators strongly dominate the surface population at night.

Cluster Analyses. Clustering of zooplankton and neuston data was performed separately for the two classes of collections. Results are presented first for bongo and then for neuston collections. In both cases, a 9% occurrence cutoff was employed, i.e. species occurring in less than 2 bongo collections or 5 neuston tows were dropped from the analysis.

I. Bongo tows.

A. Sample clusters. Clustering of the 14 bongo samples from BLM01W is shown in Figure 4-9. Companion 202 µm and 505 µm collections from a given station were in most cases more similar to each other than to collections taken with a given mesh size at adjacent stations. The exception occurred at stations N3 and E3, where the bongo 202 collections were closer in composition and abundance of contained taxa than were companion 202 and 505 collections.

At least three major clusters are evident: the neritic station C1, the central shelf stations D1, N3 and E3, and the shelf break and slope stations F2 and J1. Station C1 collections clustered with mid-shelf collections at a low level of similarity.

B. Species clusters. Sixty-three taxa occurred in at least two of the bongo collections; the inverse clustering of these species is shown in Figure 4-10, with a listing of clusters and species in Table 4-6. As in bongo sample clustering, three main clusters resulted: neritic, mid-shelf, and outer shelf and slope. Except for a cluster of fish species occurring in the offshore group, species within major taxa appear to be well distributed among the clusters.

II. Neuston tows.

A. Sample clusters. Samples from the surface layer are shown in Figure 4-11, where three basic clusters are evident: neritic station C1, mid-shelf stations D1, N3, and E3, and shelf-edge and slope stations F2 and J1. The offshore samples are most distinct in this analysis; mid-shelf and

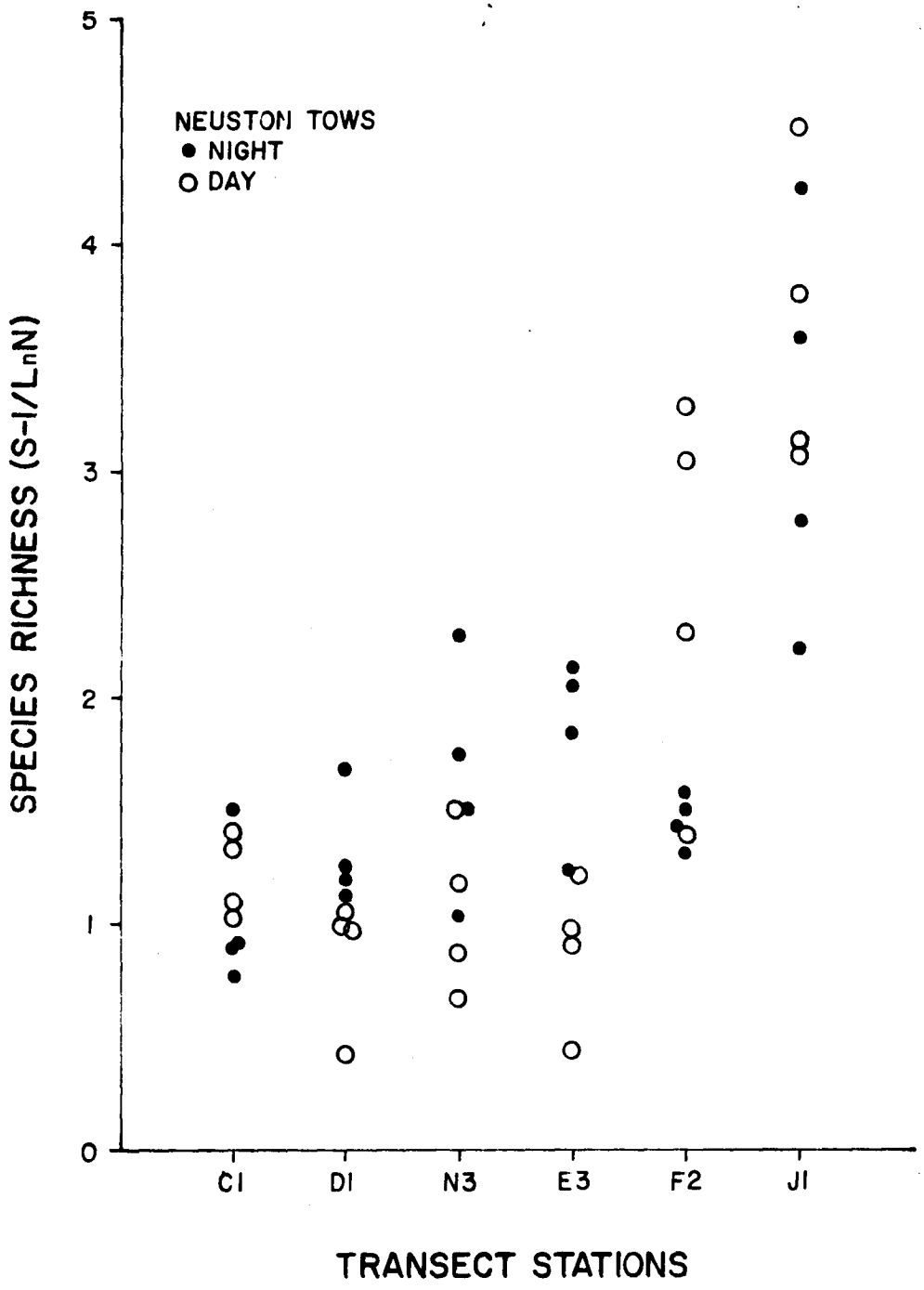

Figure 4-8. Species richness in neuston collections from the fall 1975 cruise, BLM01W. Stations (x-axis) arranged from inshore to offshore.

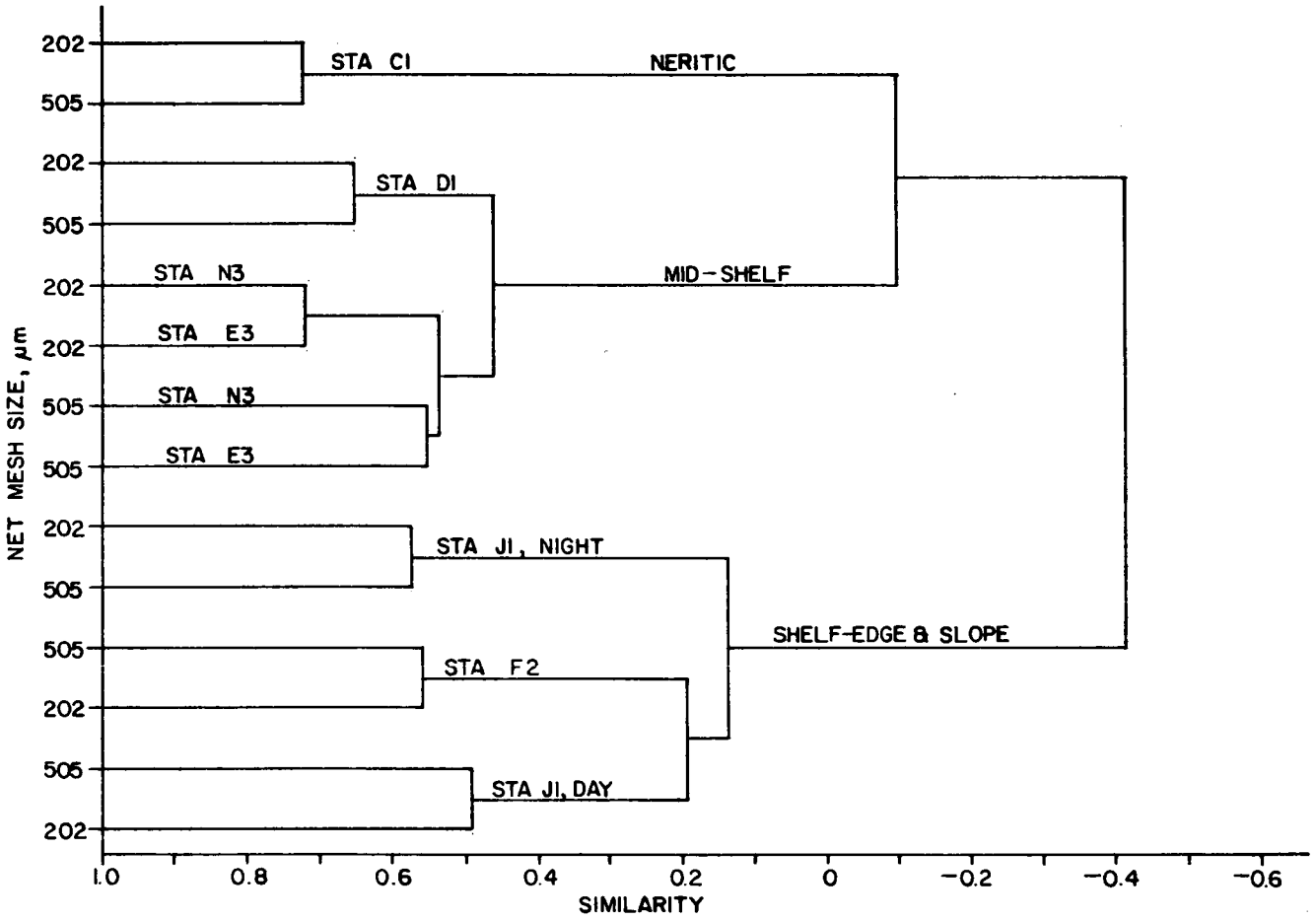

Figure 4-9. Bongo sample clusters, BLM01W, based on the Bray-Curtis coefficient of similarity, all identified species occurring in more than one bongo sample, and catch data standardized to numbers per 100 m^3.

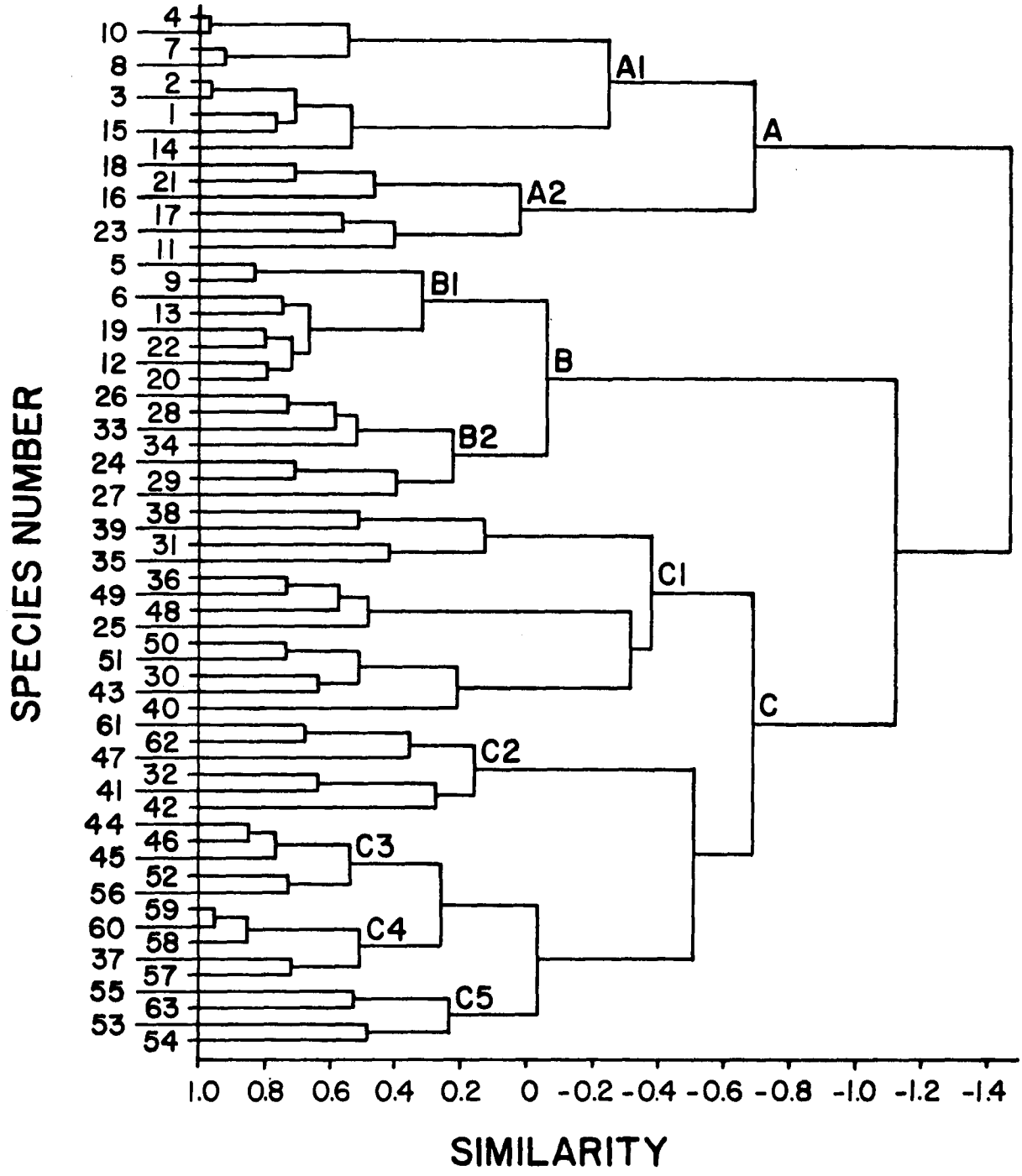

Figure 4-10. Inverse species clusters, bongo tows, BLM01W. See Table 4-6 for identification of species and clusters.

Table 4-6. Identification of species and clusters shown in Figure 4-10, bongo tows, BLM01W.

Cluster	Species No.	Species
A - Neritic Species		
A_1 - restricted to Station C1	4	*Penilia avirostris*
	10	*Neomysis americana*
	7	*Labidocera aestiva*
	8	*Acartia tonsa*
	2	*Beroe ovata*
	3	*Tharyx* sp.
	1	*Bougainvillea*
	15	*Scophthalmus aquosus*
	14	*Anchoa mitchilli*
A_2 - rare at D1 only or mid-shelf species with maximum at D1	18	unid. cephalopods
	21	*Chiridotea tuftsii*
	16	*Idotea metallica*
	17	*Spiratella retroversa*
	23	*Cancer* sp.
	11	*Crangon septemspinosa*
B - Mid-shelf Species		
B_1 - abundant species centered over mid-shelf, often rare or absent at Station C1 & J1	5	*Paracalanus* sp.
	9	*Oithona* sp.
	6	*Centropages typicus*
	13	*Sagitta tasmanica*
	19	*Calanus finmarchicus*
	22	*Parathemisto gaudichaudii*
	12	*Sagitta elegans*
	20	*Candacia armata*
B_2 - less abundant, more offshore than B_1 usually absent at both Station C1 & D1	26	*Eucalanus* sp.
	28	*Acartia danae*
	33	*Mecynocera clausi*
	34	*Thysanoessa inermis*
	24	*Nannocalanus minor*
	29	*Thysanoessa* sp.
	27	*Centropages violaceus*
C - Outer Shelf and Slope Species		
C_1 - mostly rare offshore species but with occurrences over mid-shelf	38	*Thysanoessa gregaria*
	39	galatheid larvae
	31	*Urophycis* sp.
	35	*Merluccius* sp.
	36	*Rhincalanus nasutus*
	49	*Euconchoecia chierchiae*
	48	*Conchoecia curta*
	25	unid. copepodites
	50	*Phronima sedentaria*
	51	*Phrosina semilunata*
	30	*Sagitta hexaptera*
	43	unid. fish larvae
	40	*Ethusa microphthalma*

Table 4-6 (concluded)

Cluster	Species No.	Species
C_2 - larval fishes largely restricted to Station F2 & J1	61	*Nemichthys scolopaceus*
	62	unid. gobioid
	47	*Syacium* sp.
	32	*Bothus ocellatus*
	41	myctophid larvae
	42	paralepidid larvae
C_3 - restricted to F2 & J1	44	*Scolecithrix danae*
	46	*Lucifer faxoni*
	45	*Meganyctiphanes norvegica*
	52	*Euphausia krohnii*
	56	*Sagitta enflata*
C_4 - most abundant in, or restricted to, night tows at J1	59	unid. euchaetid
	60	*Nematoscelis atlantica*
	58	*Pleuromamma robusta*
	37	*Metridia lucens*
	57	*Pleuromamma gracilis*
C_5 - rare spp. at J1 only	55	*Solenocera muelleri*
	63	*Ceratocopelus maderensis*
	53	*Nematoscelis megalops*
	54	*Stylocheiron* sp.

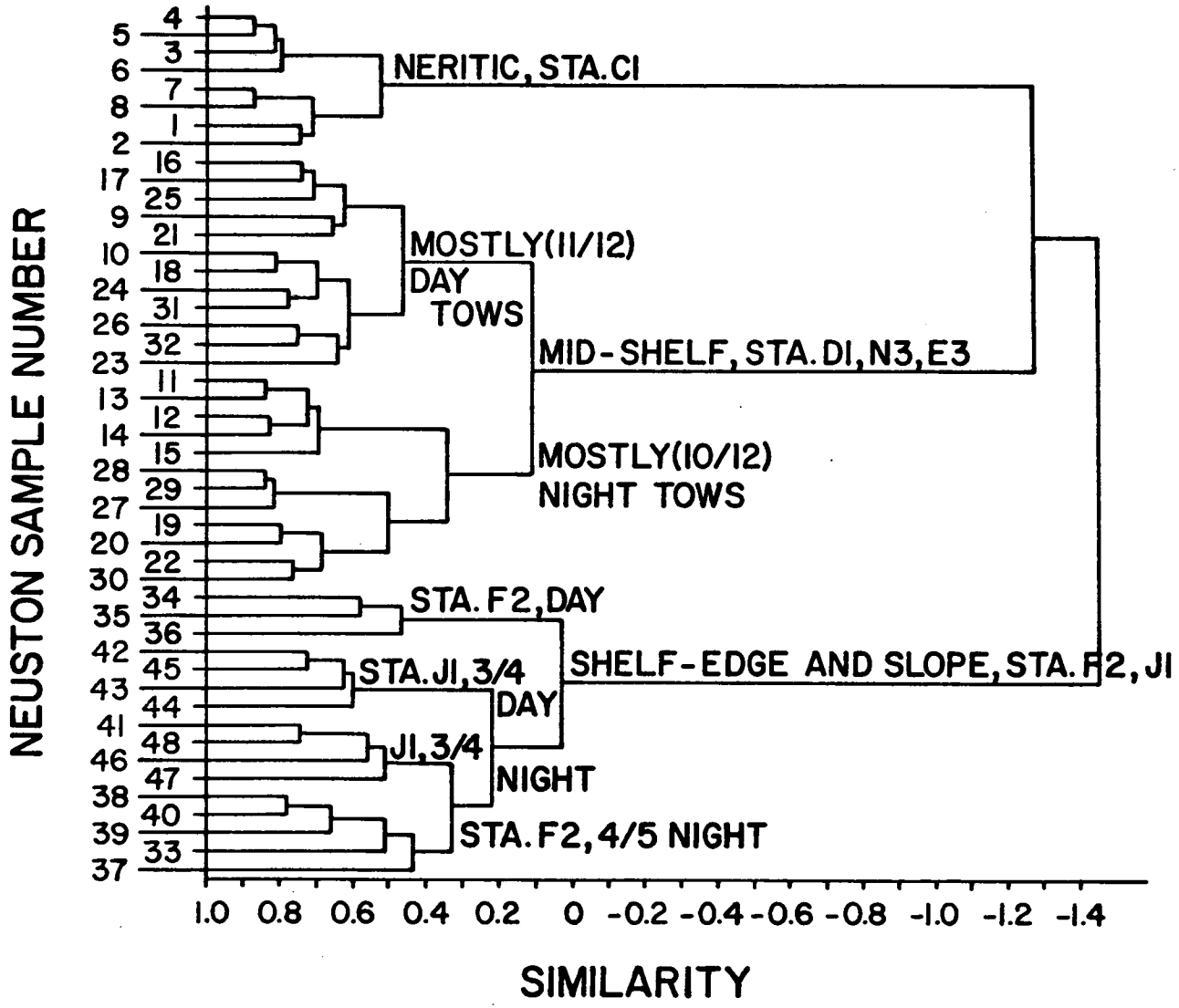

Figure 4-11. Neuston sample clusters, BLM01W, based on the Bray-Curtis coefficient of similarity and all identified species occurring in more than four neuston collections.

neritic samples cluster at a low level of similarity. Except at the shallow station C1, there is a fairly low separation within main clusters of night and day collections.

This analysis is essentially identical to results obtained with bongo samples, with its three principal clusters of neritic, mid-shelf, and offshore samples.

B. Species clusters. Forty-three taxa occurred in at least five of the 48 neuston collections. These were included in the inverse analysis depicted in Figure 4-12. Identification of species within clusters is provided in Table 4-7. Three main clusters of species were found and in patterns similar to species clusters from bongo collections. A notable qualitative difference in offshore bongo and neuston species is the preponderance of pontellid copepods and species associated with *Sargassum* weed in the neuston collections.

Winter 1976 Cruise No. BLM02W

Summary of Collections

The designated water column stations C1, D1, N3, E3, F2, and J1 were sampled for zooplankton and neuston between 5 February and 16 February 1976.

Bongo samplers (60 cm) were fished obliquely twice at each station, one each with 202 µm and 505 µm nets. Resulting collections included 12 preserved collections, 14 hydrocarbon samples (2 for quality control at Station J1), and 14 trace metal samples (also including 2 quality control samples from J1).

Neuston collections (505 µm nets) resulted in a total of 48 preserved collections, one hydrocarbon sample (insufficient material at all but Station E3), 5 trace metal samples, and 5 samples of tarballs. Species selected for chemical analysis included *Idotea metallica* (isopod), *Crangon septemspinosa* (decapod), *Petromyzon marinus* (sea lamprey), and the Atlantic silverside, *Menidia menidia*.

Faunal Description

A total of 132 taxa were identified from winter 1976 zooplankton and neuston collections, a considerable reduction in diversity from the previous fall. Identified taxa are listed in Table 4-8. The length of the list is particularly shortened for the meroplanktonic larvae of decapods and fishes. Also absent from the winter list are the many offshore species and *Sargassum*-associated species found in abundance in fall collections. The dominant taxa found in collections from each of the stations are listed in Table 4-9. Except for the nearshore station C1, where *Temora longicornis* had replaced *Acartia tonsa* and *Labidocera aestiva* as the dominant neritic form, the collections were predominated by *Centropages typicus*.

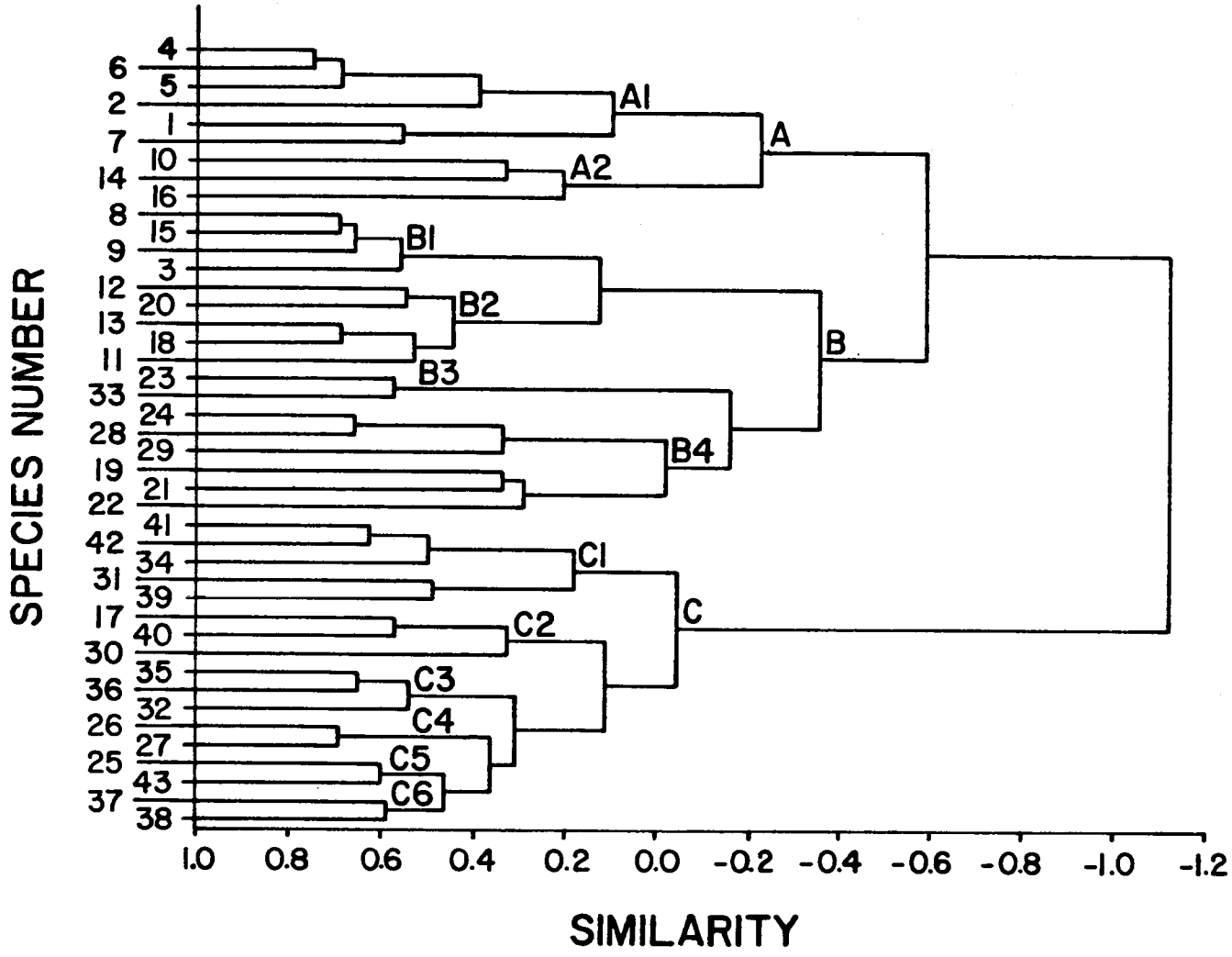

Figure 4-12. Inverse species clusters, neuston tows, BLM01W. See Table 4-7 for identification of species and clusters.

Table 4-7. Identification of species and clusters shown in Figure 4-12, neuston tows, BLM01W.

Cluster	Species No.	Species
A - Neritic Species		
A_1 - mostly restricted to Station C1	4	*Labidocera aestiva*
	6	*Acartia tonsa*
	5	*Pontella meadii*
	2	*Beroe ovata*
	1	*Bougainvillea*
	7	*Penilia avirostris*
A_2 - most abundant at Station C1	10	*Crangon septemspinosa*
	14	*Urophycis* sp.
	16	*Brevoortia tyrannus*
B - Mid-shelf Species		
B_1 - ubiquitous, but thinning offshore	8	*Idotea metallica*
	15	*Anomalocera patersonii*
	9	*Parathemisto gaudichaudii*
	3	*Centropages typicus*
B_2 - abundant mid-shelf, rare or absent at both ends of transect	12	*Sagitta elegans*
	20	*Spiratella retroversa*
	13	*Sagitta tasmanica*
	18	*Calanus finmarchicus*
	11	*Cancer* sp.
B_3 - night dominants, mid-shelf to slope	23	*Metridia lucens*
	33	*Pleuromamma gracilis*
B_4 - mostly night tows, Station D1-E3, rarer offshore	24	*Thysanoessa* sp.
	28	*Centropages violaceus*
	29	*Leptochela* sp.
	19	*Nannocalanus minor*
	21	*Candacia armata*
	22	*Pelagia noctiluca*
C - Offshore Species		
C_1 - pontellids and Sargassum species	41	*Leander tenuicornis*
	42	unid. balistids
	34	*Siriella thompsoni*
	31	*Pontella atlantica*
	39	*Pontella spinipes*
C_2 - Sargassum fauna	17	*Portunus sayi*
	40	*Lepas* sp. larvae
	30	*Velella velella*
C_3 - shelf-edge pontellids	35	*Anomalocera ornata*
	36	*Pontellopsis villosa*
	32	*Pontella securifer*
C_4 - offshore spp. distributed onto mid-shelf	26	*Labidocera acutifrons*
	27	*Lucifer faxoni*
C_5 - mostly offshore, rare on mid-shelf	25	*Sagitta enflata*
	43	*Euphausia krohni*
C_6 - Sargassum fauna	37	*Bagatus minutus*
	38	*Latreutes fucorum*

Table 4-8. Check list of zooplankton species identified from neuston and bongo collections, BLM02W.

PROTOZOA
- unid. foraminiferans

CNIDARIA
- *Obelia* sp.
- *Physophora hydrostatica*
- *Chelophyes appendiculata*
- *Eudoxides spiralis*
- *Lensia subtilis*
- *Abyla* sp.
- *Abylopsis* sp.
- unid. abylids
- unid. siphonophores

RHYNCHOCOELA
- unid. nemerteans

CHAETOGNATHA
- *Sagitta elegans*
- *Sagitta enflata*
- *Sagitta hexaptera*
- *Sagitta lyra*
- *Sagitta minima*
- *Sagitta tasmanica*
- *Eukrohnia hamata*
- *Pterosagitta draco*

PHORONIDA
- *Phoronis psammophilus*

MOLLUSCA
- unid. gastropod larvae
- unid. bivalve larvae
- *Spiratella retroversa*
- *Paedoclione doliiformis*
- unid. gymnosomes
- *?Gemma* sp.
- *Octopus vulgaris*
- unid. cephalopods

ANNELIDA
- *Tomopteris helgolandica*
- unid. polychaete larvae

CRUSTACEA

Cladocera
- *Evadne nordmanni*

Ostracoda
- *Halocypris brevirostris*
- *Conchoecia* sp.
- unid. ostracods

Copepoda
- unid. copepodites
- *Calanus finmarchicus*
- *Eucalanus pileatus*
- *Eucalanus attenuatus*
- *Eucalanus* sp.
- *Rhincalanus nasutus*
- *Rhincalanus cornutus*
- *Nannocalanus minor*
- *Paracalanus crassirostris*
- *Paracalanus* sp.
- *Pseudocalanus* sp.
- *Temora longicornis*
- *Centropages hamatus*
- *Centropages typicus*
- *Centropages violaceus*
- *Candacia armata*
- *Candacia elongata*
- *Metridia lucens*
- *Pleuromamma abdominalis*
- *Pleuromamma gracilis*
- *Pleuromamma xiphias*
- *Scolecithrix danae*
- *Scolecithricella ovata*
- *?Euchaeta* sp.
- *Pareuchaeta norvegica*
- *Undeuchaeta major*
- *Euchirella rostrata*
- *Gaetanus minor*
- *Euaetideus giesbrechti*
- unid. aetideid
- *Heterorhabdus spinifrons*
- unid. augaptilid
- *Labidocera nerii*
- *Anomalocera patersonii*
- *Acartia tonsa*
- *Tortanus discaudatus*
- *Alteutha depressa*
- *Oithona* sp.
- *Farranula* sp.
- *Oncaea venusta*
- *Caligus* sp.

Table 4-8 (concluded)

Cirripedia
- *Balanus* sp. larvae
- *Lepas* sp. larvae

Cumacea
- *Leptocuma minor*
- *Cyclaspis varian*
- *?Campylaspis* sp.
- *Diastylis polita*
- *Diastylis sculpta*
- *Oxyurostylis smithi*

Isopoda
- *Edotea triloba*
- *Idotea metallica*

Amphipoda
- *Parathemisto gaudichaudii*
- *Phronima sedentaria*
- *Paraphronima gracilis*
- *Paraphronima* sp.
- *Primno latreillei*
- *Anonyx debruyni*
- *Anonyx sarsi*
- *Batea catharinensis*
- *Bathyporeia guoddyensis*
- *Argissa hamatipes*
- *Cerapus tubularis*
- *Hippomedon serratus*
- *Monoculodes norvegica*
- *Orchomenella pinguis*
- *Unciola inermis*

Mysidacea
- *Neomysis americana*
- *Mysidopsis bigelowi*

Euphausiacea
- *Euphausia krohnii*
- *Euphausia* sp.
- *Meganyctiphanes norvegica*
- *Thysanoessa gregaria*
- *Thysanoessa longicaudata*
- *Thysanoessa* sp.
- *Thysanopoda acutifrons*
- *Nematoscelis megalops*

Decapoda
- Pandalidae zoea
- *Crangon septemspinosa*
- *Pontophilus brevirostris*
- *Pontophilus* sp.
- Paguridae zoea
- *Bathynectes superba*
- *Cancer* sp.

PISCES
- *Petromyzon marinus*
- *Anguilla rostrata*
- *Ceratoscopelus maderensis*
- *Gonichthys cocco*
- unid. paralepidid
- *Gadus morhua*
- *Pollachius virens*
- *Urophycis* sp.
- *Enchelyopus cimbrius*
- *Menidia menidia*
- *Syngnathus fuscus*
- *Mugil curema*
- unid. goboid
- *Ammodytes* sp.
- *Scophthalmus aquosus*

Table 4-9. Numerically dominant zooplankters in winter 1976 collections (BLM02W). Drawn from the three most abundant taxa in each tow. (D = day, N = night).

Station C1

Bongo 202	Bongo 505	Neuston 505
Oithona sp.	*Temora longicornis*	*T. longicornis* (4N,4D)
Pseudocalanus	*Ammodytes* sp.	*Ammodytes* sp. (4N,3D)
Acartia tonsa	*Sagitta elegans*	*Pseudocalanus* sp. (3N,3D)
		Neomysis americana (1N,1D)
		A. tonsa (1D)

Station D1

Bongo 202	Bongo 505	Neuston 505
Pseudocalanus sp.	*C. typicus*	*C. typicus* (4N,4D)
Oithona sp.	*Pseudocalanus* sp.	*S. elegans* (3N,4D)
Centropages typicus	*Spiratella retroversa*	*N. americana* (2N)
		T. longicornis (1N,1D)
		Calanus finmarchicus (1N,1D)
		Parathemisto gaudichaudii (2D)
		Pseudocalanus sp. (1N)

Station N3

Bongo 202	Bongo 505	Neuston 505
Pseudocalanus sp.	*C. typicus*	*C. typicus* (4N,4D)
Oithona sp.	*S. retroversa*	*S. elegans* (3N,3D)
C. typicus	*S. elegans*	*Metridia lucens* (4N)
		P. gaudichaudii (3D)
		C. finmarchicus (1D)
		Ammodytes sp. (1D)
		S. retroversa (1N)

Table 4-9 (concluded)

Station E3

Bongo 202	Bongo 505	Neuston 505
Oithona sp.	*C. typicus*	*C. typicus* (4N,4D)
Pseudocalanus sp.	*M. lucens*	*P. gaudichaudii* (4D)
S. retroversa	*S. retoversa*	*M. lucens* (4N)
		Ammodytes sp. (3D)
		S. retroversa (2N)
		Pleuromamma gracilis (2N)
		C. finmarchicus (1D)

Station F2

Bongo 202	Bongo 505	Neuston 505
Oithona sp.	*C. typicus*	*C. typicus* (4N,4D)
"Paracalanus" sp.	*S. retroversa*	*M. lucens* (4N)
C. typicus	*M. lucens*	*P. gaudichaudii* (3D)
		S. retroversa (2N,1D)
		P. gracilis (2N)
		Anomalocera patersonii (1D)
		"Paracalanus" sp. (1D)
		C. finmarchicus (1D)
		Ammodytes sp. (1D)

Station J1

Bongo 202	Bongo 505	Neuston 505
"Paracalanus" sp.	*C. typicus*	*C. typicus* (4N,4D)
Oithona sp.	*M. lucens*	*S. retroversa* (4N,3D)
C. typicus	*P. gracilis*	*P. gaudichaudii* (2D)
		C. finmarchicus (2D)
		A. patersonii (1N,1D)
		"Paracalanus" sp. (1N)
		M. lucens (1N)
		P. gracilis (1N)

Station C1. All eight neuston tows and both bongo tows were dominated numerically by copepods. In all collections except the bongo 202, *Temora longicornis* was the most abundant species. Other copepods, in decreasing order of relative abundance, were *Pseudocalanus* sp., *Acartia tonsa, Centropages typicus, C. hamatus, Tortanus discaudatus, Eucalanus pileatus, Calanus finmarchicus, Acartia clausi, Paracalanus crassirostris,* and *Oithona* sp. The last-named was dominant in the small-meshed bongo 202. No strongly-migrating copepods were evident in neuston collections (Figure 4-13), due to the absence of *Labidocera aestiva.* Also important in neuston collections were *Neomysis americana* and larvae of *Ammodytes* sp. Other groups represented in the neuston collections included chaetognaths, barnacle larvae, polychaetes, and decapod larvae. Cumaceans, cladocerans, isopods, and molluscs were relatively more important in bongo tows.

Station D1. Copepods were dominant in five of the eight neuston tows and in both bongo tows. *Centropages typicus* was the most abundant copepod in all tows except the bongo 202, which was dominated by *Pseudocalanus* sp. and *Oithona* sp. Other abundant copepods in neuston collections were *Temora longicornis, Calanus finmarchicus,* and *Pseudocalanus* sp. None were strong vertical migrators (Figure 4-14). Two neuston tows were dominated by the chaetognath *Sagitta elegans* and one by the hyperiid amphipod *Parathemisto gaudichaudii.* The mysid *Neomysis americana* was also of some importance in night neuston collections. Thecosomes, medusae, and cumaceans were of greater relative importance in bongo tows.

Station N3. Copepods were dominant in only three of the eight neuston tows, all of these at night, but were dominant in both bongo tows. *Centropages typicus* and *Metridia lucens* were dominant species in neuston tows. *C. typicus* was the dominant form in the bongo 505, *Pseudocalanus* sp. in the bongo 202. Strong vertical migrators among the copepods (Figure 4-15) included *M. lucens* and *Nannocalanus minor.* Three of the neuston tows were dominated by *Sagitta elegans* and the remaining two by *Parathemisto gaudichaudii.* Occasionally important in the surface layer were *Calanus finmarchicus, Ammodytes* larvae, and *Spiratella retroversa.* Thecosomes, ostracods, and euphausiids were of greater relative importance in bongo tows.

Station E3. Copepods were dominant in five of the eight neuston collections, the amphipod *Parathemisto gaudichaudii* in the other three. Copepods dominated both bongo tows. *Centropages typicus* was the most abundant copepod in all eight neuston tows and in the bongo 505. *Oithona* sp. predominanted in the bongo 202. The first appearance in this seasonal survey of a typically neustonic pontellid copepod occurred at this station, where *Anomalocera patersonii* was found in five neuston tows. Other copepods in the neuston included *Metridia lucens,* abundant at night (Figure 4-16), *Pleuromamma gracilis,* and *Calanus finmarchicus. M. lucens* and *P. gracilis* were both strong migrators. Larvae of *Ammodytes* sp. and the thecosome *Spiratella retroversa* were also found in abundance at times in the surface layer. Polychaetes and cumaceans were relatively more important in bongo collections.

Station F2. Copepods (Figure 4-17) were dominant in all but one neuston tow, the latter a collection in which *Parathemisto gaudichaudii* predominated, and in both bongo tows. *Centropages typicus* dominated most

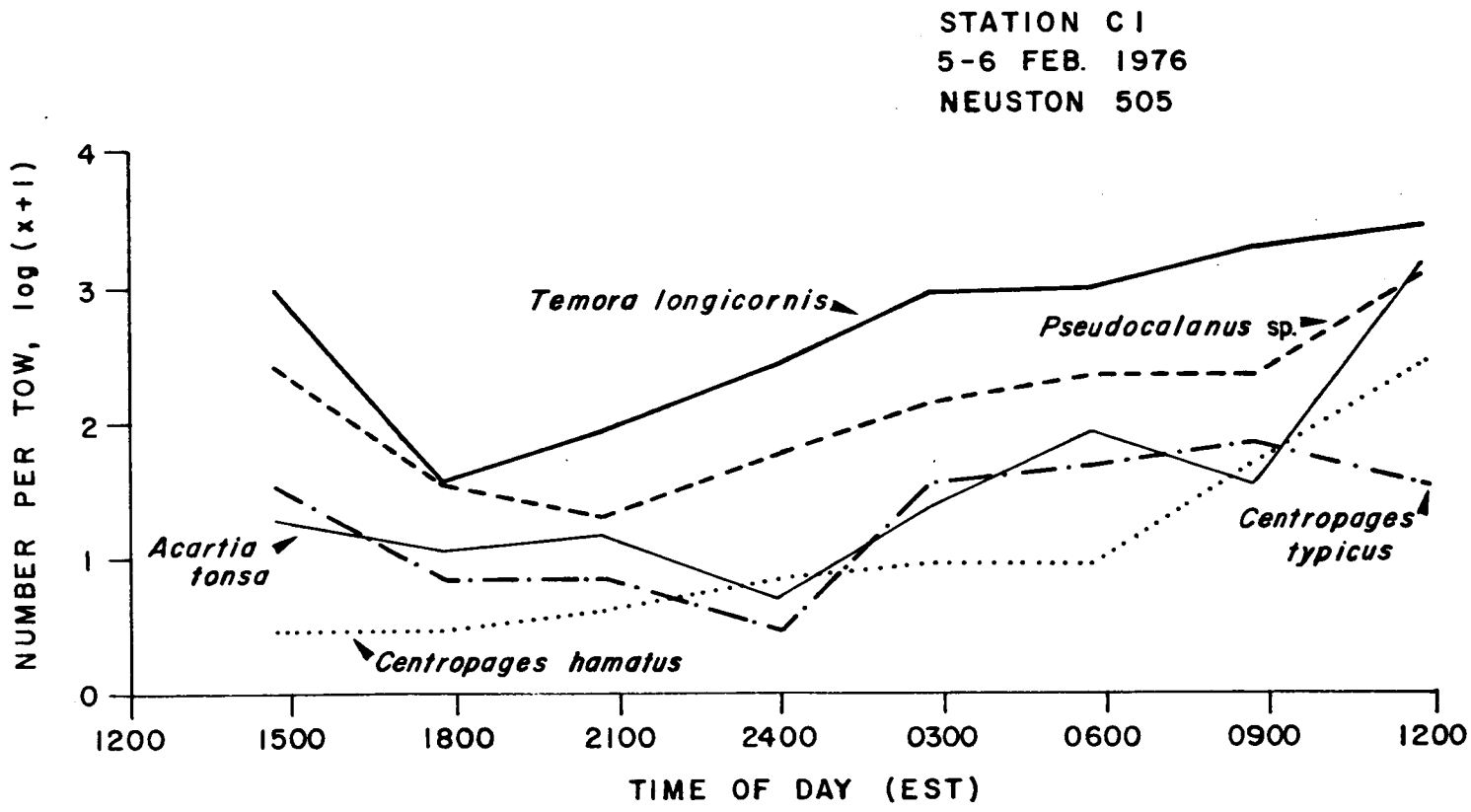

Figure 4-13. Diel cycle of abundance of dominant copepods in the surface layer of Station C1, BLM02W.

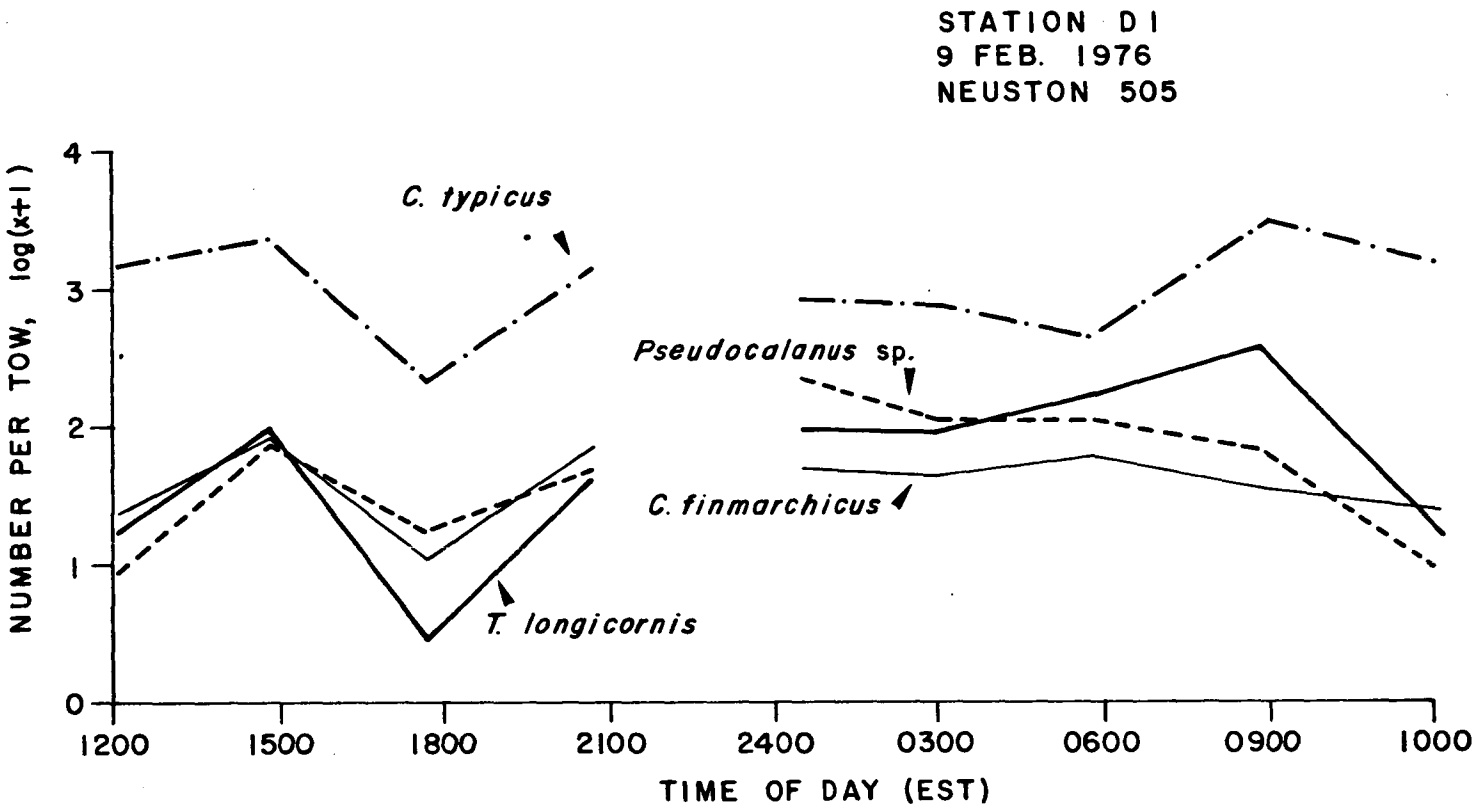

Figure 4-14. Diel cycle of abundance of dominant copepods in the surface layer of Station D1, BLM02W.

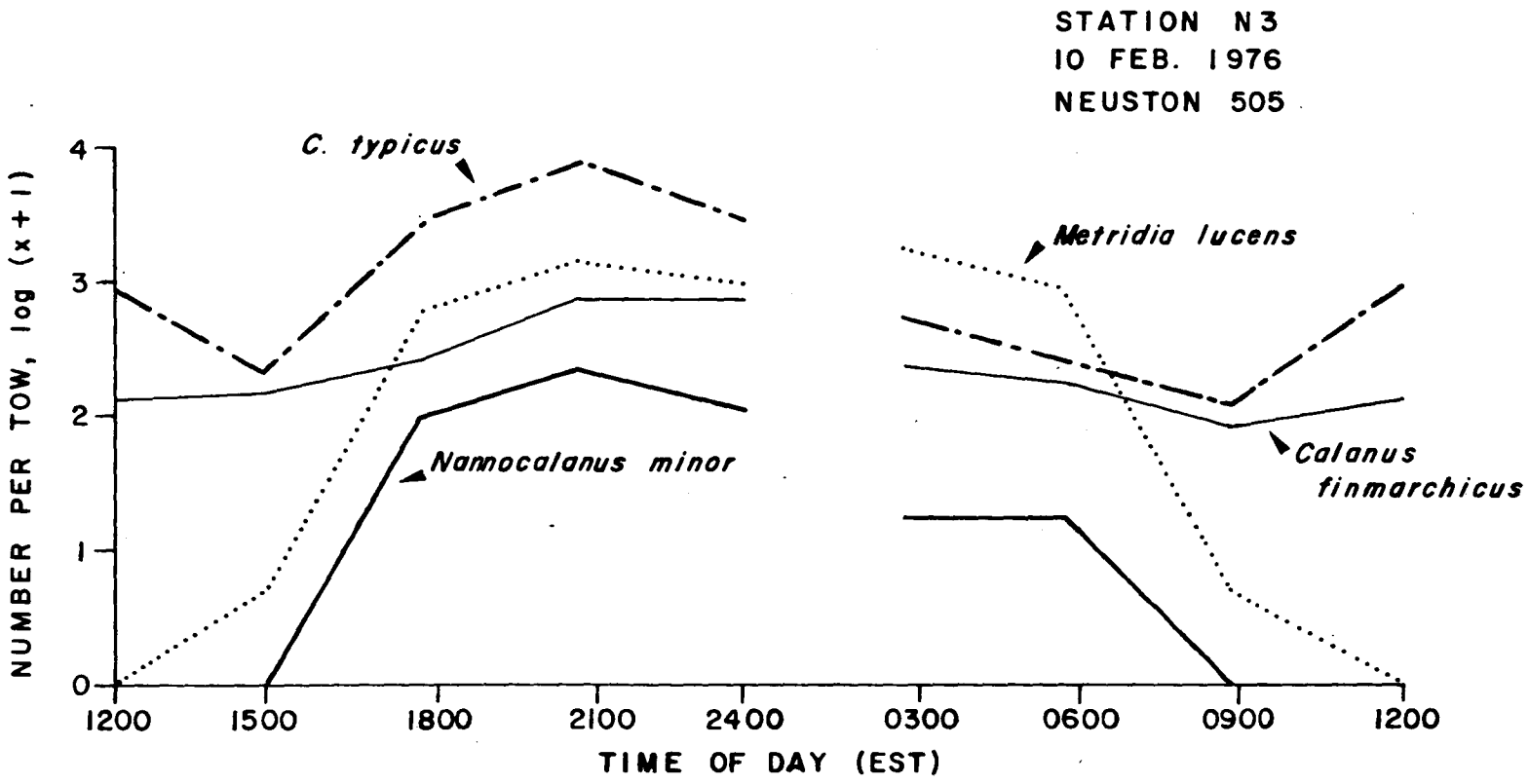

Figure 4-15. Diel cycle of abundance of dominant copepods in the surface layer of Station N3, BOM02W.

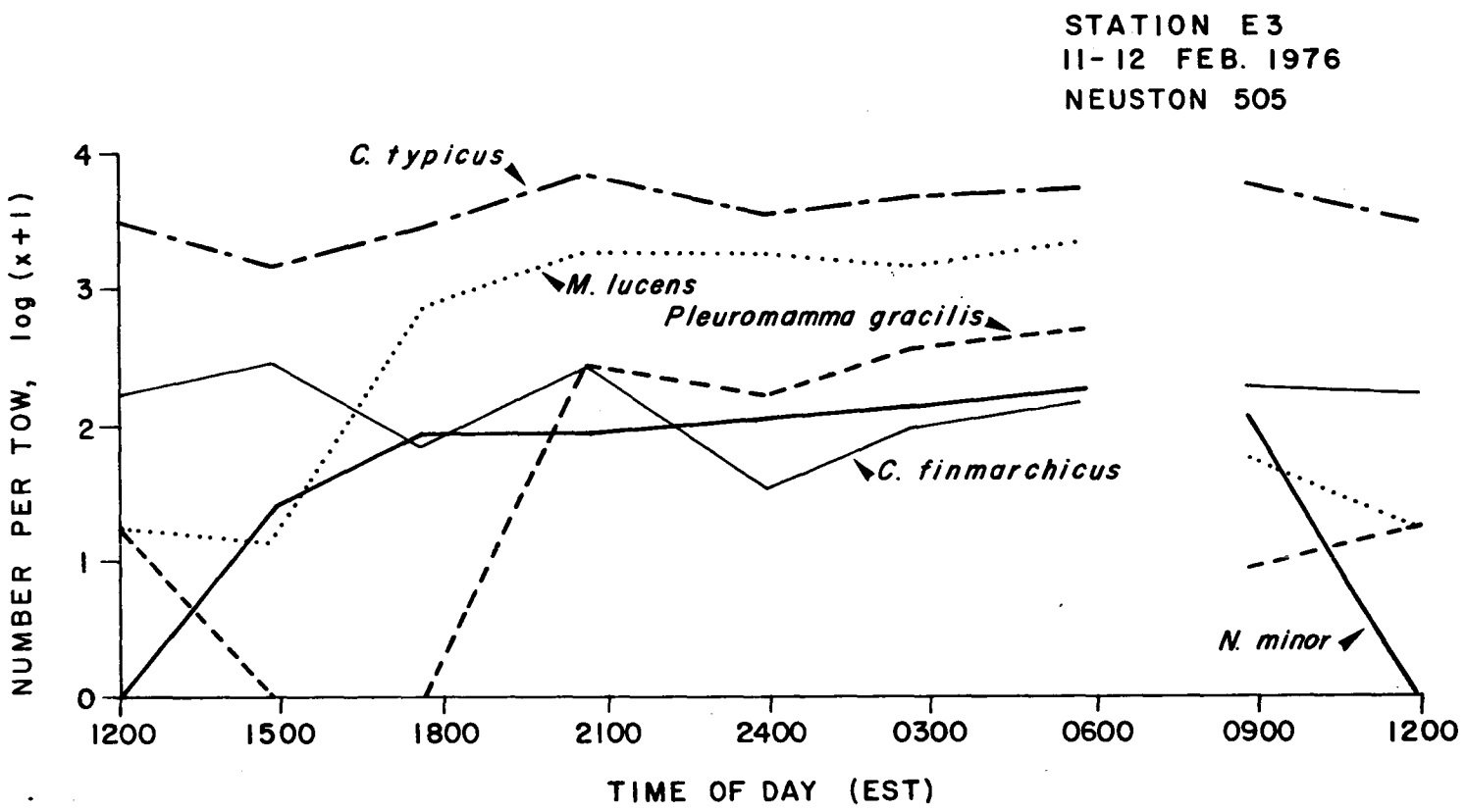

Figure 4-16. Diel cycle of abundance of dominant copepods in the surface layer of Station E3, BLM02W.

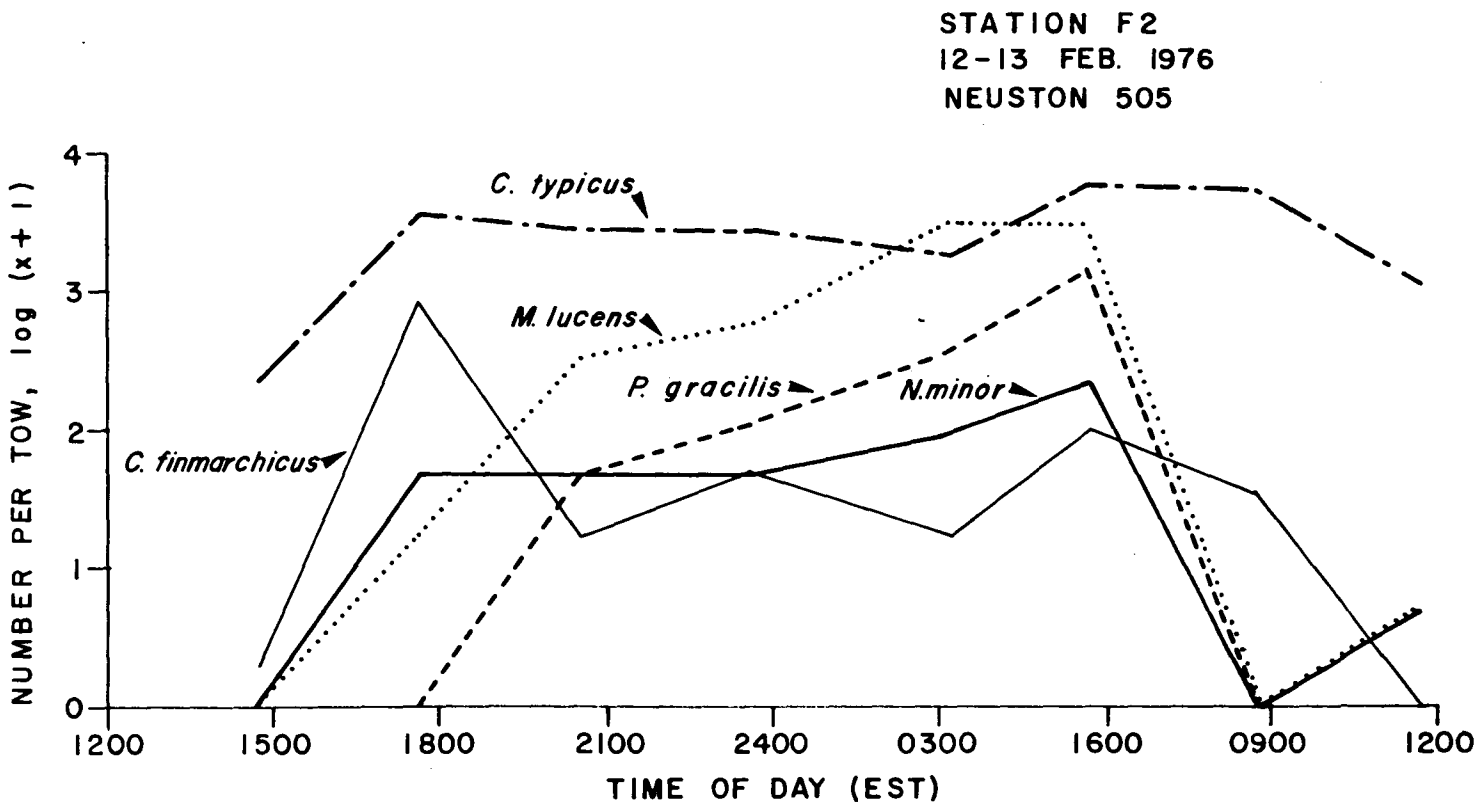

Figure 4-17. Diel cycle of abundance of dominant copepods in the surface layer of Station F2, BLM02W.

neuston tows (exceeded slightly in numbers by *Metridia lucens* in one night collection) and the bongo 505. *Oithona* sp. again was predominant in the fine meshed bongo 202. Other important taxa in the neuston included the copepods, *Pleuromamma gracilis*, *Anomalocera patersonii*, and *Calanus finmarchicus*, the thecosome *Spiratella retroversa*, and larvae of *Ammodytes* sp. Euphausiids and ostracods were somewhat more abundant in subsurface plankton than in neuston collections.

Station J1. Copepods were the most abundant group in six of the eight neuston tows, and in both bongo tows. The thecosome *Spiratella retroversa* predominated in two neuston collections. *Centropages typicus* was the dominant copepod in all 505 μm mesh net collections (neuston and bongo). *Paracalanus* sp. predominated in the bongo 202. Other abundant taxa in the neuston included the copepods *Calanus finmarchiucs*, *Anomalocera patersonii*, *"Paracalanus"* sp., *Metridia lucens*, and *Pleuromamma gracilis* (Figure 4-18). Euphausiids and chaetognaths were somewhat more predominant in subsurface collections.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent and abundant species from bongo and neuston collections are listed in Tables 4-10 and 4-11. A comparison of the two lists shows the importance of *Centropages typicus* in this winter season. It heads both lists, having been found in all collections regardless of mesh size or location, and is outranked in abundance only by *Oithona* sp. and *Pseudocalanus* sp., which were abundantly caught only in bongo 202 nets. *Sagitta elegans* and *Ammodytes* sp. larvae occupy identical second and third positions, respectively, in the two lists. All of the 11 most frequent taxa on the neuston list are also found in the list of common bongo species. Obviously, the winter neuston fauna was much more similar to subsurface zooplankton than was the case during the fall survey. Except for the less frequently occurring pandalid larvae (most likely *Dichelopandalus leptoceras*), *Anomalocera patersonii*, and *Idotea metallica*, the unique fauna characteristic of the neuston is missing.

Diversity. Three measurements of diversity are listed for each collection in the winter cruise in Table 4-12. Shannon indices for winter collections were less variable than in fall collections, but still ranged widely (0.5269-3.1565). The high value occurred with a late afternoon neuston tow at the inshore station C1, the low with an early morning neuston tow at Station F2 that was heavily dominated by *Centropages typicus*. The high index resulted from the occurrence of 14 species among only 158 individuals. Evenness (J') values ranged from a low of 0.1384 in the collection with the previously mentioned low H', to a high of 0.8291, also matching the collection with high H'.

The increase in species richness with distance offshore that was so evident in fall collections had disappeared by winter (Figure 4-19). Night neuston tows were quite consistently richer in species than were day tows at all stations, but the total range of values at each station was similar all along the transect.

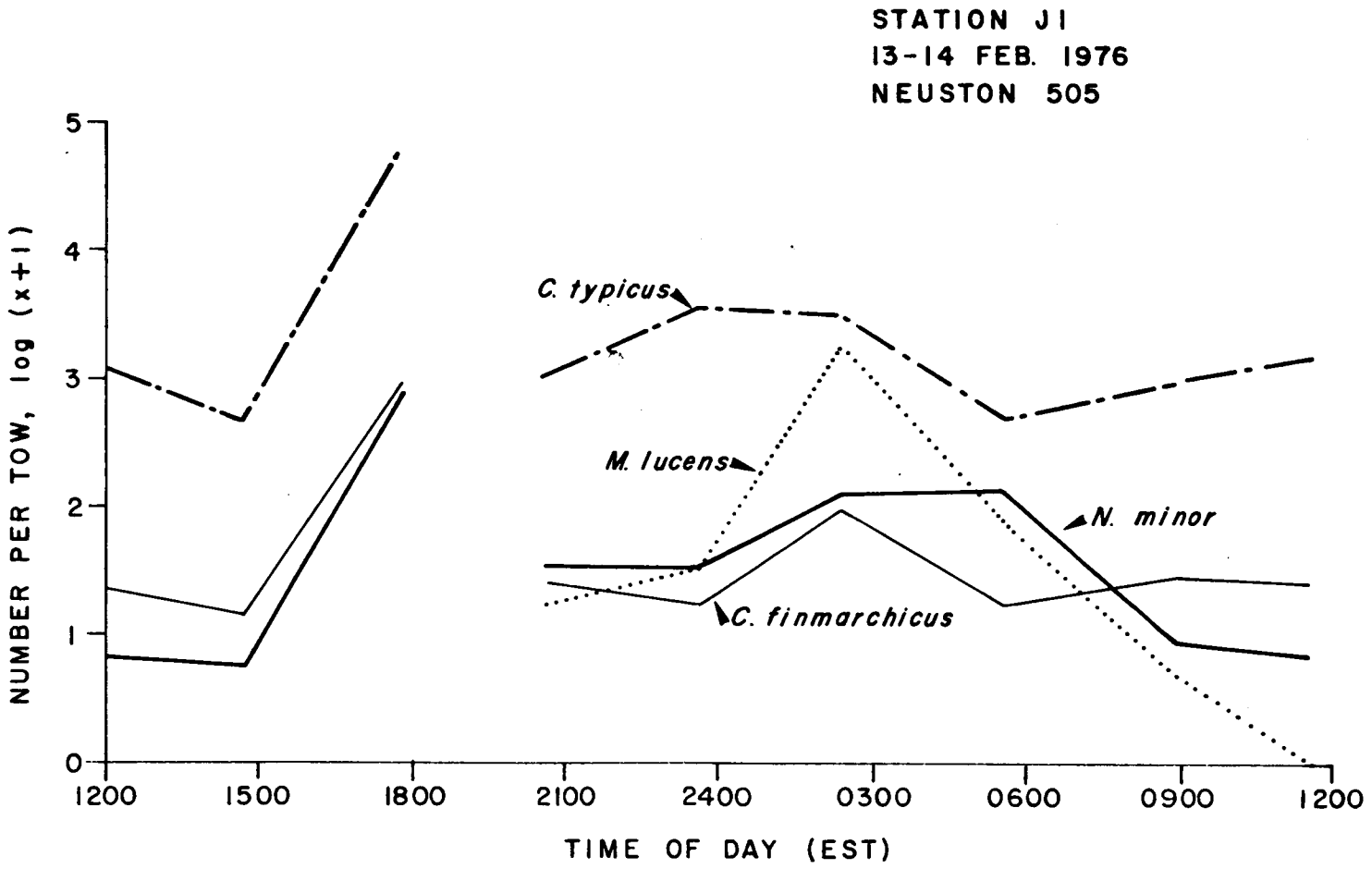

Figure 4-18. Diel cycle of abundance of dominant copepods in the surface layer of Station J1, BLM02W.

Table 4-10. Frequency of occurrence and rank of abundance of common species in bongo collections, BLM02W.

Species	Percent Occurrence	Rank Abundance	Maximum Number per $100m^3$
Centropages typicus	100	3	110,097
Sagitta elegans	92	10	16,556
Ammodytes sp. larvae	92	14	3,082
Spiratella retroversa	83	4	99,337
Metridia lucens	83	9	17,591
Calanus finmarchicus	83	12	7,243
Sagitta tasmanica	75	13	3,477
Eucalanus sp.	75	15	3,311
Parathemisto gaudichaudii	75	18	3,001
Tomopterus helgolandica	75	-	51
Nannocalanus minor	67	17	853
Cancer sp. larvae	67	-	13
Oithona sp.	58	1	355,206
Pseudocalanus sp.	58	2	225,165
unid. calanoids	42	5	34,348
Temora longicornis	42	7	22,829
Pleuromamma gracilis	42	19	523
Paracalanus sp.	33	6	35,593
unid. bivalve larvae	33	11	5,811
Acartia tonsa	25	8	24,074
Paracalanus crassirostris	17	16	2,490
Tortanus discaudatus	17	20	4,967

Table 4-11. Frequency of occurrence and rank of abundance of common species in neuston collections, BLM02W.

Species	Percent Occurrence	Rank Abundance
Centropages typicus	100	1
Sagitta elegans	88	5
Ammodytes sp. larvae	85	6
Calanus finmarchicus	85	8
Parathemisto gaudichaudii	75	2
Spiratella retroversa	65	3
Metridia lucens	60	4
Eucalanus sp.	56	18
Nannocalanus minor	54	11
Pseudocalanus sp.	50	10
Sagitta tasmanica	44	15
Pandalid larvae	40	16
Anomalocera patersonii	40	17
Idotea metallica	40	-
Temora longicornis	38	7
Centropages violaceus	38	19
Cancer sp. larvae	38	-
Neomysis americana	35	13
Pleuromamma gracilis	27	9
Acartia tonsa	23	14
Centropages hamatus	21	20
Paracalanus sp.	10	12

Table 4-12. Diversity of zooplankton and neuston collections, BLM02W. 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
C1	Z76-089	Ns, D	1.3684	0.4119	1.2516
	-090	Ns, D	3.1565	0.8291	2.5679
	-091	Ns, N	3.1367	0.7674	2.8656
	-092	B505, N	1.4663	0.3018	2.8344
	-093	B202, N	2.7058	0.5690	1.8475
	-094	Ns, N	2.2394	0.5479	2.6257
	-095	Ns, N	1.6247	0.4062	2.1184
	-096	Ns, N	1.9871	0.4862	2.1570
	-097	Ns, D	1.6663	0.4265	1.7831
	-098	Ns, D	2.2248	0.6431	1.1042
D1	Z76-099	Ns, N	2.4778	0.6342	1.8664
	-100	Ns, N	2.2811	0.5581	2.0488
	-101	Ns, N	1.7656	0.4771	1.5100
	-102	Ns, D	1.6061	0.4340	1.1492
	-103	Ns, D	0.6893	0.1992	1.3480
	-104	Ns, D	1.6850	0.4426	1.5807
	-105	Ns, D	1.9385	0.4649	2.5190
	-106	Ns, N	2.6489	0.5940	2.6544
	-107	B505, N	2.5190	0.5038	2.7410
	-108	B202, N	2.0121	0.4581	1.5325
N3	Z76-109	Ns, N	2.0744	0.4723	2.3412
	-110	Ns, N	1.6141	0.3735	2.2504
	-111	Ns, D	1.4479	0.4826	0.8843
	-112	Ns, D	1.6990	0.4462	1.6297
	-113	Ns, D	2.1905	0.5607	1.9633
	-114	Ns, D	1.6356	0.4562	1.1402
	-115	Ns, N	2.2566	0.5221	1.9740
	-116	Ns, N	2.6280	0.6570	1.6688
	-147	B202, D	2.4548	0.5286	1.7611
	-148	B505, D	2.4093	0.6328	1.1267
E3	Z76-117	Ns, D	1.2884	0.3090	1.6958
	-118	Ns, D	1.0225	0.2763	1.2406
	-119	Ns, D	1.6200	0.4146	1.8084
	-120	Ns, D	1.2281	0.3004	1.6201
	-121	Ns, N	1.7546	0.3690	2.7945
	-122	B202, N	1.9142	0.3864	2.0939
	-123	B505, N	1.8778	0.4095	1.9624
	-124	Ns, N	1.7674	0.4419	1.7159
	-125	Ns, N	1.6013	0.3770	2.0250
	-126	Ns, N	1.6940	0.3857	2.2028

Table 4-12 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
F2	Z76-127	Ns, D	1.1815	0.3296	1.5703
	-128	Ns, D	2.1399	0.5350	1.6936
	-129	Ns, N	1.6435	0.3633	2.5872
	-130	B202, N	2.5730	0.5688	1.6919
	-131	B505, N	1.9260	0.3965	2.4284
	-132	Ns, N	1.4931	0.3653	1.9355
	-133	Ns, N	1.6574	0.4242	1.6172
	-134	Ns, N	1.9609	0.4702	1.8133
	-135	Ns, D	0.5269	0.1384	1.5035
	-136	Ns, D	1.4772	0.3880	1.6937
J1	Z76-137	Ns, N	1.9470	0.4763	2.1391
	-138	B202, N	2.6032	0.4997	3.1931
	-139	B505, N	2.7451	0.5269	3.4499
	-140	Ns, N	0.8267	0.1739	2.5426
	-141	Ns, N	1.2066	0.2747	1.9627
	-142	Ns, N	2.4592	0.5897	2.3502
	-143	Ns, D	1.6490	0.3882	2.4842
	-144	Ns, D	0.5878	0.1699	1.3521
	-145	Ns, D	1.4986	0.3936	2.0062
	-146	Ns, D	0.6500	0.1664	1.2469

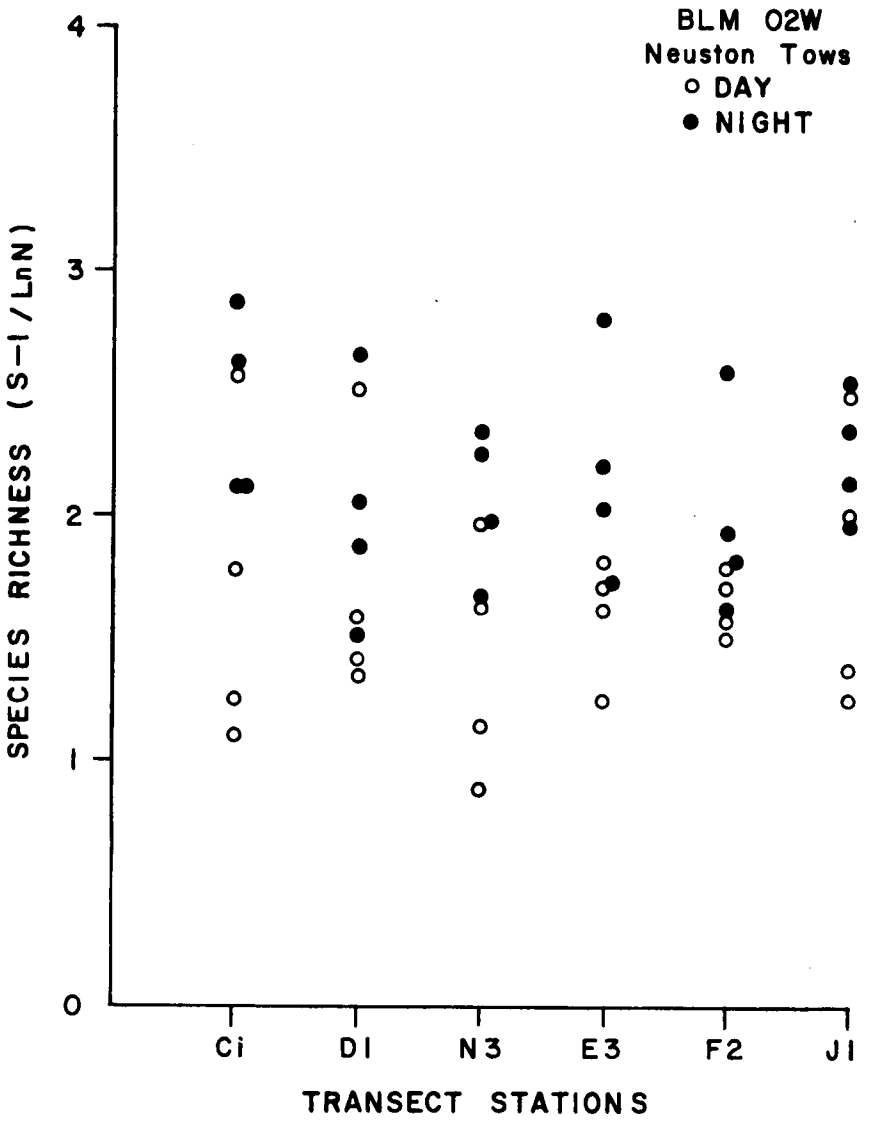

Figure 4-19. Species richness in neuston collections from the winter 1976 cruise, BLM02W. Stations (x-axis) arranged from inshore to offshore.

Cluster Analyses. Clustering of zooplankton and neuston data was performed as for fall collections, i.e. separately for the two types of collections and using a cutoff of 9% occurrence for inclusion of species in the analysis.

I. Bongo tows.

A. Sample clusters. Clustering of the 12 bongo samples from BLM02W is shown in Figure 4-20. Companion 202 µm and 505 µm bongo collections at inner shelf stations and at Station J1 clustered before linkage of either mesh size at adjacent stations. However, the bongo 505 collections at outer shelf stations E3 and F2 were more similar to each other than to their companion 202 collections at the respective stations.

The three major clusters seen in fall bongo collections have been reduced to two: the outer shelf and slope (stations E3, F2, and J1), and the inner shelf (stations N3, D1, and C1). Station C1 links with the inner shelf stations at a relatively low level of similarity.

B. Species clusters. Fifty-eight taxa occurred in at least two bongo collections, a slight reduction from the 63 in fall collections. The inverse cluster analysis of these species is shown in Figure 4-21, with a listing of clusters and species in Table 4-13. Two of the three basic clusters of species are easily matched with those of bongo sample clusters, i.e. the neritic and inner shelf and the outer shelf and slope clusters. The middle cluster (B) contains most of the abundant species, many of them widely distributed over the shelf. It includes species distributed from stations D1 to J1, species found over the whole transect, and two inner shelf species, *Temora longicornis* and *Neomysis americana*.

II. Neuston tows.

A. Sample clusters. Results from the cluster analysis of surface layer winter collections are shown in Figure 4-22. Clusters are very similar to those obtained for bongo samples, with a cluster of samples from outer shelf and slope stations E3, F2, and J1 and a second cluster of samples from neritic station C1 and inner shelf stations D1 and N3. Again, Station C1 links with D1 and N3 at a relatively low level of similarity. Samples from all stations other than C1 were subclustered into day and night samples.

B. Species clusters. Forty-two taxa occurred in at least five of the 48 neuston collections and were included in the inverse analysis shown in Figure 4-23. Identification of species within clusters is provided in Table 4-14. Results were similar to those for bongo collections, with three principal clusters: widespread species, mid-shelf to slope species, and inner shelf species. Three subclusters of widespread species included widespread neritic types, ubiquitous species most abundant at mid-shelf, and a group of species distributed from mid-shelf to the slope. Species in this cluster were, with

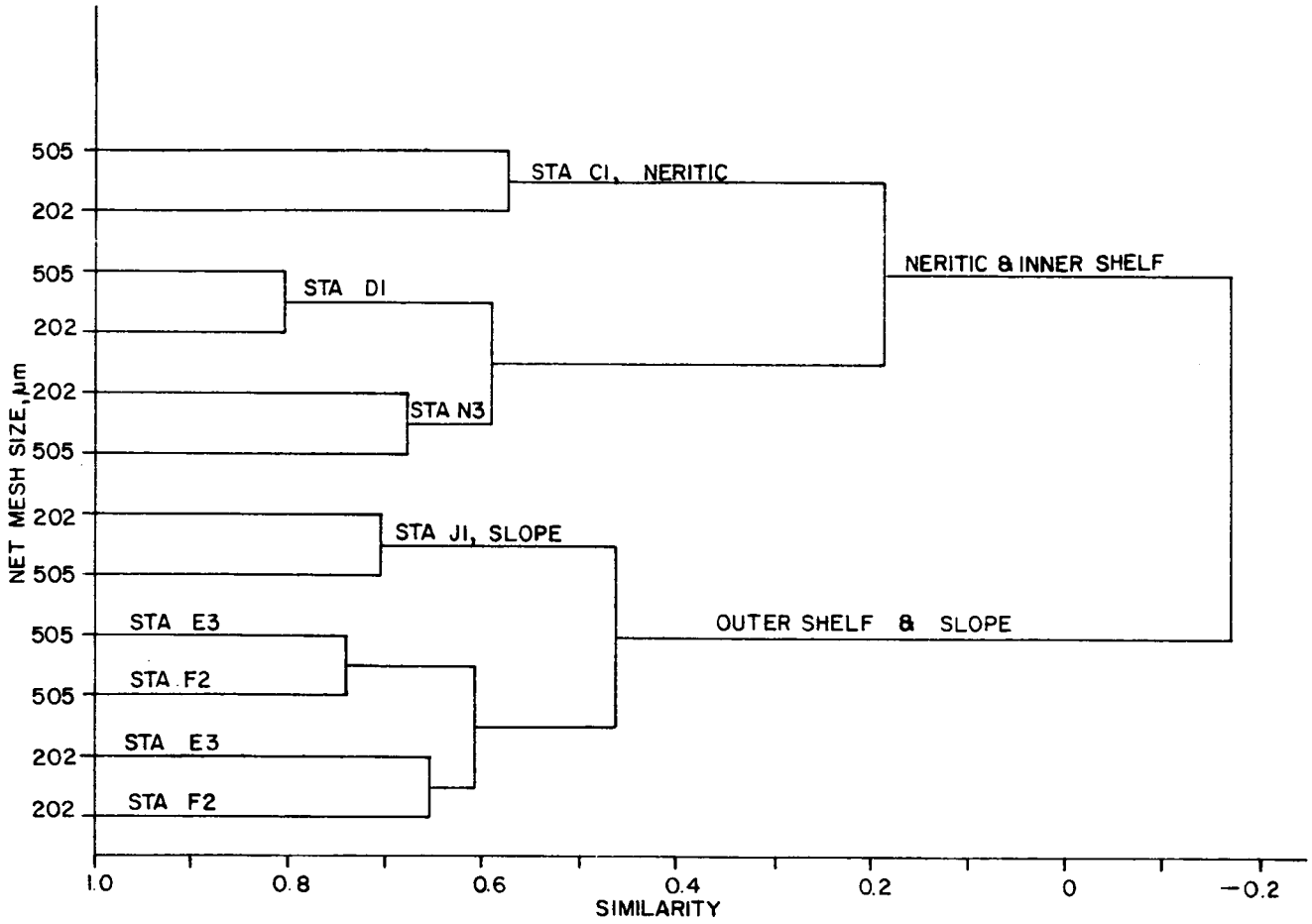

Figure 4-20. Bongo sample clusters, BLM02W, based on the Bray-Curtis coefficient of similarity, all identified species occurring in more than one bongo sample, and catch data standardized to numbers per 100 m^3.

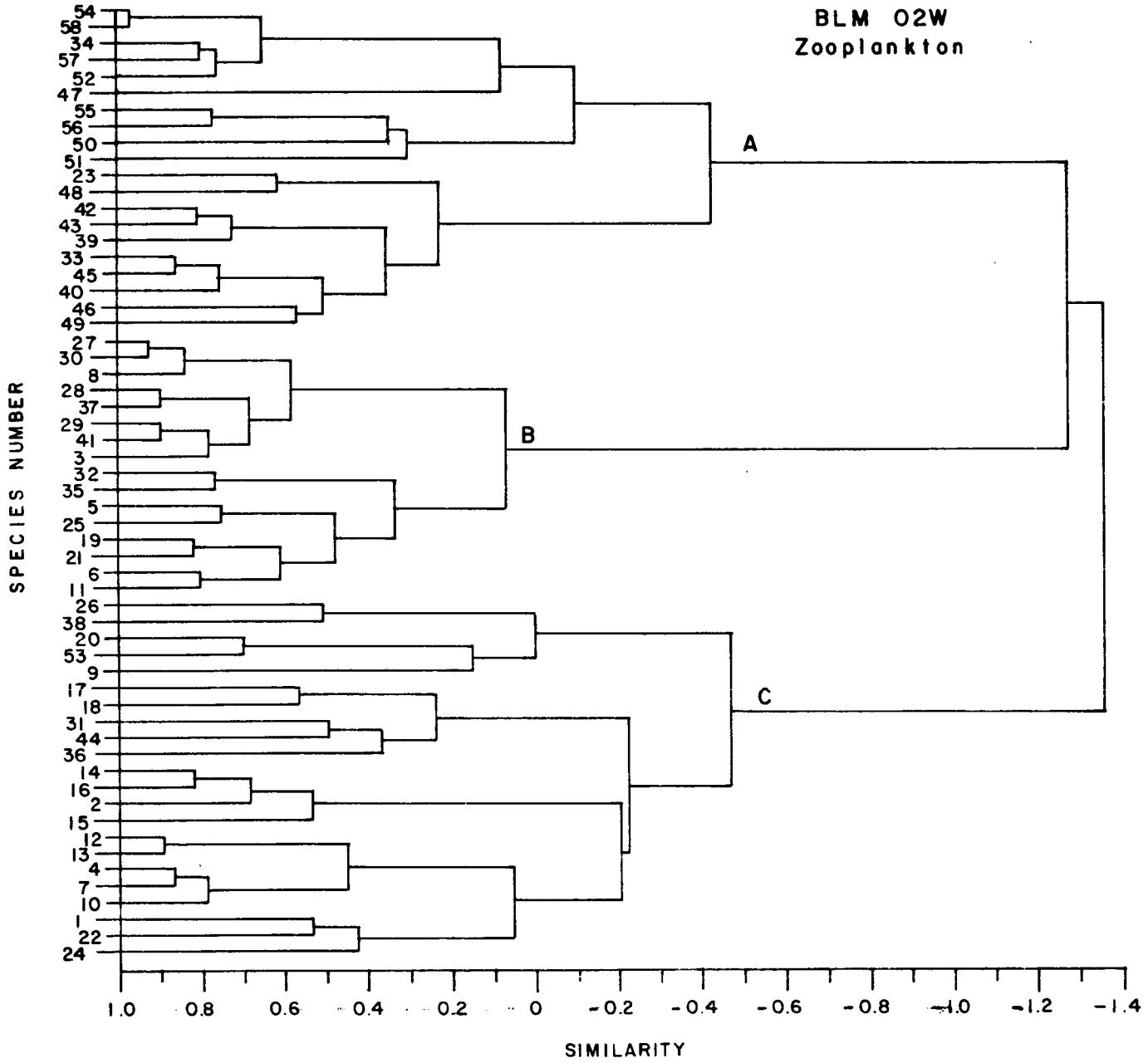

Figure 4-21. Inverse species clusters, bongo tows, BLM02W. See Table 4-13 for identification of species and clusters.

Table 4-13. Identification of species and clusters shown in Figure 4-21, bongo tows, BLM02W.

Clusters	Species No.	Species
A - Outer shelf species from Stations E3, F2 & J1	54	*Pleuromamma robusta*
	58	*Nematoscelis megalops*
	34	*Thysanoessa longicaudata*
	57	*Meganyctiphanes norvegica*
	52	unid. siphonophores
	47	*Rhincalanus cornutus*
	55	*Pareuchaeta norvegica*
	56	*Uneuchaeta major*
	50	unid. fish larvae
	51	*Paralepidid* sp.
	23	unid. calanoids
	48	*Paracalanus* sp.
	42	*Pleuromamma gracilis*
	43	*Euchirella* sp.
	39	*Rhincalanus nasutus*
	33	*Thysanoessa* sp.
	45	*T. gregaria*
	40	*Centropages violaceus*
	46	*Sagitta minima*
	49	*S. hexaptera*
B - Mid-shelf and widely distributed species	27	*Spiratella retroversa*
	30	*Metridia lucens*
	8	*Centropages typicus*
	28	*Eucalanus* sp.
	37	*Sagitta tasmanica*
	29	*Nannocalanus minor*
	3	*Calanus finmarchicus*
	32	*Parathemisto gaudichaudii*
	35	*Pandalidae* larvae
	5	*Pseudocalanus* sp.
	25	*Oithona* sp.
	19	*Sagitta elegans*
	21	*Ammodytes* larvae
	6	*Temora longicornis*
	11	*Neomysis americana*
C - Neritic and inner shelf species	26	unid. nemerteans
	38	*Gadus morhua*
	20	*Anguilla rostrata*
	53	*Phronima sedentaria*
	9	*Tortanus discaudatus*
	17	*Crangon septemspinosa*
	18	*Cancer* sp.
	31	*Diastylis polita*
	44	*D. sculpta*
	36	*Paguridae* larvae

Table 4-13 (concluded)

Clusters	Species No.	Species
C - Neritic and inner shelf species (continued)	14	*Unicola inermis*
	16	*Monoculodes norvegica*
	2	*Evadne nordmanni*
	15	*Hippomedon serratus*
	12	*Mysidopsis bigelowi*
	13	*Leptocuma minor*
	4	*Paracalanus crassirostris*
	7	*Centropages hamatus*
	10	*Balanus* sp. larvae
	1	*Tomopterus helgolandica*
	22	unid. bivalve larvae
	24	*Acartia tonsa*

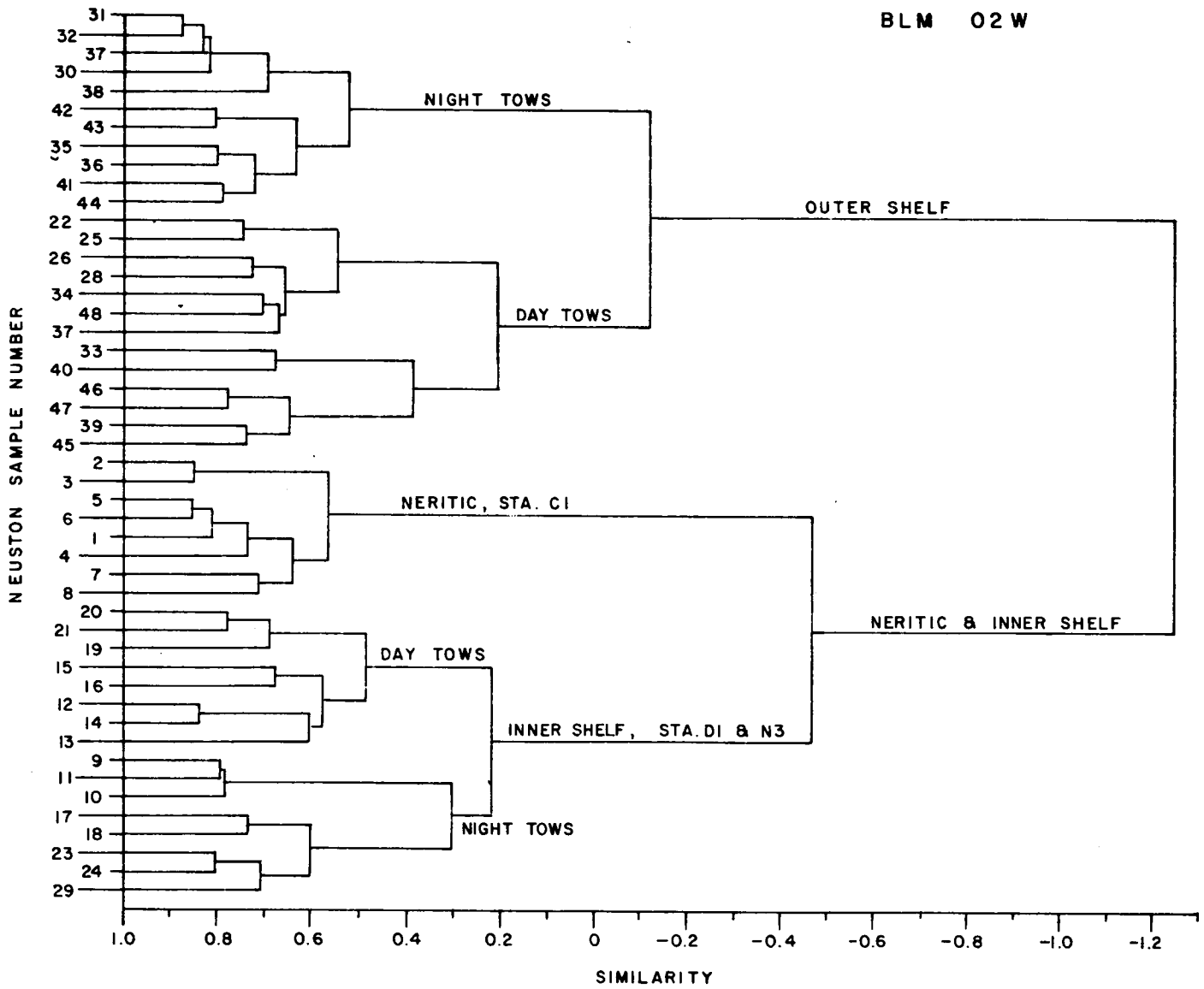

Figure 4-22. Neuston sample clusters, BLM02W, based on the Bray-Curtis coefficient of similarity and all identified species occurring in more than four neuston collections.

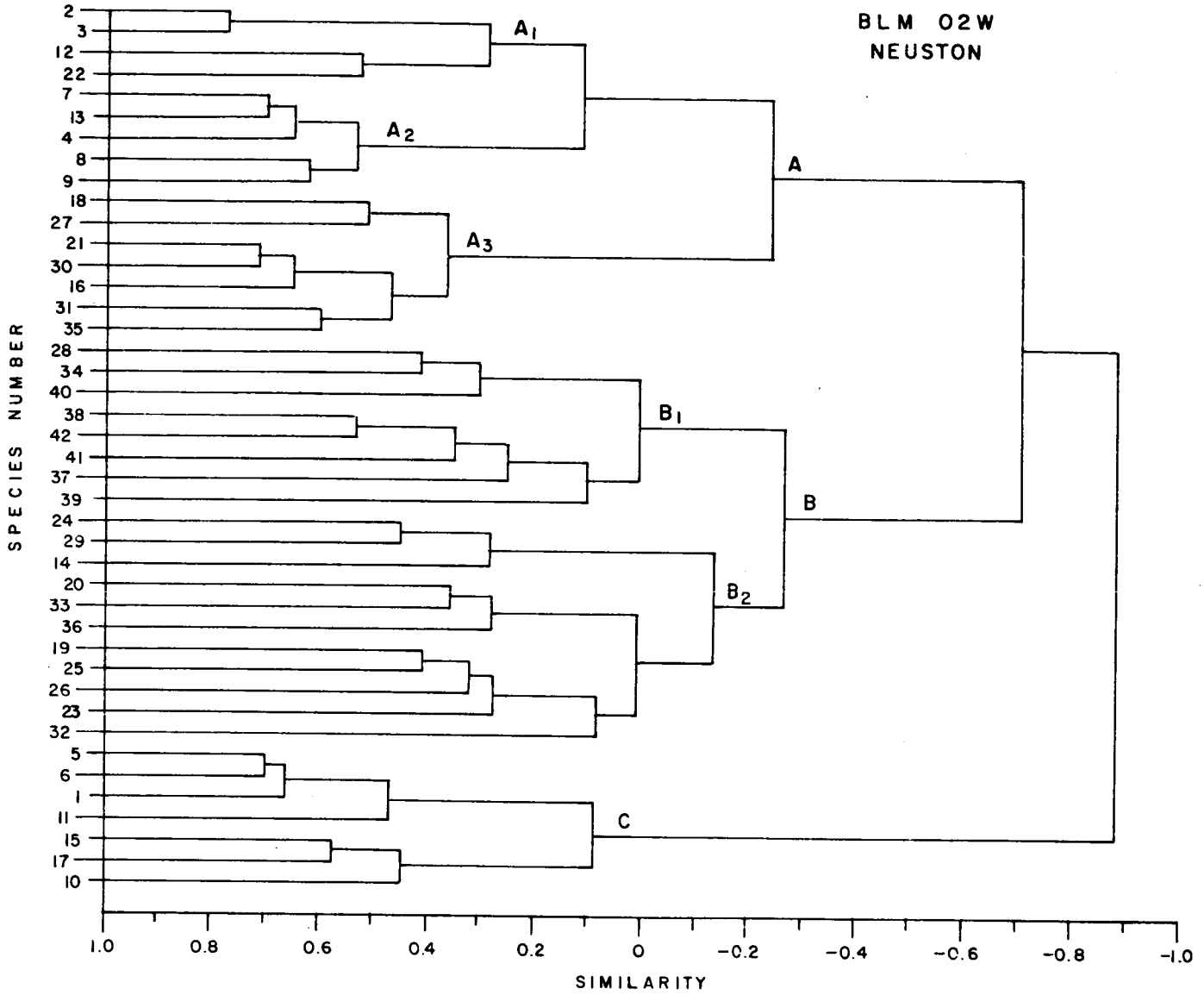

Figure 4-23. Inverse species clusters, neuston tows, BLM02W. See Table 4-14 for identification of species and clusters.

Table 4-14. Identification of species and clusters shown in Figure 4-23, neuston tows, BLM02W.

Cluster	Species No.	Species
A - Widespread species		
A_1 - neritic	2	*Pseudocalanus* sp.
	3	*Temora longicornis*
	12	*Neomysis americana*
	22	*Pandalid* larvae
A_2 - mid-shelf centered	7	*Parathemisto gaudichaudii*
	13	*Calanus finmarchicus*
	4	*Centropages typicus*
	8	*Sagitta elegans*
	9	*Ammodytes* sp.
A_3 - offshore	18	*Eucalanus* sp.
	27	*Sagitta tasmanica*
	21	*Metridia lucens*
	30	*Nannocalanus minor*
	16	*Spiratella retroversa*
	31	*Centropages violaceus*
	35	*Pleuromamma gracilis*
B - Mid-shelf and outer shelf distribution		
B_1 - offshore	28	*Urophycis* sp.
	34	*Anomalocera patersonii*
	40	*Paracalanus* sp.
	38	*Sagitta minima*
	42	*Eudoxides spiralis*
	41	unid. siphonophores
	37	*Euchirella* sp.
	39	*Sagitta hexaptera*
B_2 - mid-shelf centered	24	*Gadus morhua*
	29	*Enchelyopus cimbrius*
	14	*Oithona* sp.
	20	*Rhincalanus nasutus*
	33	*R. cornutus*
	36	*Farranula gracilis*
	19	*Cancer* sp. larvae
	25	*Candacia armata*
	26	*Idotea metallica*
	23	*Tomopterus helgolandica*
	32	*Mugil curema*
C - Neritic and inner shelf species	5	*Acartia tonsa*
	6	*Balanus* sp. larvae
	1	*Centropages hamatus*
	11	*Tortanus discaudatus*
	15	*Crangon septemspinosa*
	17	*Mysidopsis bigelowi*
	10	*Eucalanus pileatus*

few exceptions, the same as those in cluster B (mid-shelf and widely distributed species) of the bongo inverse analysis. Inner shelf species (cluster C) were also common to both neuston and bongo collections. Cluster C in the bongo inverse analysis, however, was extended with various amphipods, decapods, cumaceans, and assorted taxa not frequently found in neuston tows.

The greatest difference in the two lists occurs in clusters of offshore species. Although some species are found in common, the bongo cluster includes several euphausiids and deep-living copepods not taken in neuston tows. Neuston species, on the other hand, include larvae of several fishes (*Urophycis* sp., *Enchelyopus cimbrius*, and *Mugil curema*) and the euneustonic copepod *Anomalocera patersonii* and isopod *Idotea metallica* not common in bongo tows. Differences between neuston and subsurface zooplankton are most pronounced at the deeper stations.

Spring 1976 Cruise No. BLM03W

Summary of Collections

The designated water column stations C1, D1, N3, E3, F2, and J1 were sampled for zooplankton and neuston between 8 June and 16 June 1976. Sampling was initiated at the outermost station (J1) and continued through F2 and E3. At the latter station, impending weather and shortages of fuel and water combined to stop sampling midway through the 24-hr period. Station E3 was reoccupied at the end of the cruise to provide neuston tows over an unbroken 24-hr period. The four neuston samples previously obtained at E3 were processed for comparison with the final eight.

Bongo samplers (60 cm) were fished obliquely twice at each station, once each with 202 μm and 505 μm nets. Resulting collections included 14 preserved samples (extras at stations C1 and N3), 14 hydrocarbon, and 14 trace metal samples (the latter two sample types including 2 each for quality control at Station F2).

Neuston collections, obtained at 3-hr intervals at each 24-hr station, and including extra tows at Station E3, totaled 52 preserved samples, 3 hydrocarbon samples, 8 trace metal samples, and 11 samples of tarballs. Species selected for chemical analysis included *Stomolophus megaleris* (cnidarian), *Idotea metallica* (isopod), *Cancer* sp. megalopae (decapod), and the fish *Scomberesox saurus*.

Faunal Description

A total of 177 taxa were identified from spring 1976 zooplankton and neuston collections and are listed in Table 4-15. Amphipods and fishes were particularly diverse.

The dominant taxa at each of the stations are given in Table 4-16, where the continued importance of *Centropages typicus* at shelf stations

Table 4-15. Check list of zooplankton species identified from neuston and bongo collections, BLM03W.

CNIDARIA
- *Leuckartiara octona*
- *Aglantha conica*
- *Rhopalonema clavigerum*
- *Agalma elegans*
- *Chelophyes appendiculata*
- *Lensia conoidea*
- *Diphyes dispar*
- *Abyla trigona*
- *Abylopsis tetragona*
- *Pelagia noctiluca*
- *Stomolophus meleagris*

TURBELLARIA
- unid. flatworms

RHYNCHOCOELA
- unid. nemerteans

ANNELIDA
- *Tomopteris helgolandica*
- *Tomopteris planctonis*
- unid. polychaetes

MOLLUSCA
- unid. gastropod larvae
- *Spiratella retroversa*
- *Spiratella trochiformis*
- *Spiratella helicina*
- *Paedoclione doliiformis*
- *Clione limacina*
- *Notobranchaea macdonaldi*
- unid. bivalve larvae
- *Mercenaria mercenaria*
- *Spisula solidissima*
- *Aequipecten glyptus*
- *Loligo pealii*
- *Illex illecebrosus*
- *Rossia tenera*

CRUSTACEA

Cladocera
- *Podon intermedius*
- *Podon leuckarti*
- *Evadne nordmanni*
- *Evadne spinifera*

Ostracoda
- unid. ostracods

Copepoda
- unid. calanoids
- *Calanus finmarchicus*
- *Eucalanus* sp.
- *Eucalanus pileatus*
- *Mecynocera clausi*
- *Rhincalanus nasutus*
- *Nannocalanus minor*
- *Neocalanus robustior*
- *Paracalanus* sp.
- *Paracalanus crassirostris*
- *Pseudocalanus* sp.
- *Temora longicornis*
- *Centropages hamatus*
- *Centropages typicus*
- *Centropages violaceus*
- *Candacia armata*
- *Labidocera aestiva*
- *Pontella meadii*
- *Anomalocera ornata*
- *Anomalocera patersonii*
- *Acartia longiremis*
- *Acartia tonsa*
- *Tortanus discaudatus*
- *Metridia lucens*
- *Pleuromamma gracilis*
- *Pleuromamma abdominalis*
- *Pleuromamma robusta*
- *Scolecithrix danae*
- *Pareuchaeta norvegica*
- *Euchirella rostrata*
- *Aetideus armatus*
- *Oithona* sp.
- *Microsetella norvegica*
- unid. harpacticoids
- *Caligus* sp.

Cirripedia
- unid. barnacle larvae
- *Lepas fascicularis*

Nebaliacea
- *Nebalia bipes*

Table 4-15 (continued)

CRUSTACEA (continued)

Mysidacea
Neomysis americana
Mysidopsis bigelowi

Cumacea
unid. cumaceans
Diastylis sp.
Diastylis quadrispinosa
Campylaspis sp.

Isopoda
Cirolana polita
Chiridotea caeca
Idotea baltica
Idotea metallica
Edotea triloba

Amphipoda
unid. gammarids
Ampelisca agassizi
Ampelisca abdita
Byblis serrata
Ampithoe longimanna
Erichthonius rubricornis
Calliopus leaviusculus
Unciola sp.
Unciola inermis
Unciola irrorata
Corophium sp.
Corophium acherusicum
Microprotopus raneyi
Jassa sp.
Pontogenia inermis
Rhachotropis inflata
Hippomedon serratus
Melphidippida sp.
Trichophoxus epistomus
Monoculodes sp.
Monoculodes edwardsi
Monoculodes norvegica
Monoculodes packardi
Parathemisto gaudichaudii
Scina damasii
Scina curvidactyla
Scina borealis
Scina stebbingi
Pseudoaeginella antiquae

Euphausiacea
Euphausia krohnii
Euphausia hemigibba
Euphausia mutica
Meganyctiphanes norvegica
Nematoseelis megalops
Thysanoessa sp.
Thysanoessa gregaria
Thysanoessa inermis
Thysanoessa longicaudata

Decapoda
unid. decapod larvae
Palaemonetes sp.
Pandalid zoea
Dichelopandalus leptoceras
Crangon septemspinosa
Pontophilus sp.
Pontophilus brevirostris
Homarus americanus
Hippolytid zoea
Pagurid zoea
Ovalipes sp.
Carcinus maenas
Cancer sp.
Geryon quinquidens
Hyas sp.
Libinia sp.

CHAETOGNATHA
Sagitta elegans
Sagitta enflata
Sagitta tasmanica
Sagitta hexaptera
Sagitta minima
Sagitta maxima
Eukrohnia hamata
Pterosagitta draco

TUNICATA
unid. oikopleurids

CHORDATA
unid. fish larvae
unid. fish eggs
unid. engraulids
Anchoa sp.
unid. myctophids
Benthosema glaciale
Ceratoscopelus maderensis

Table 4-15 (concluded)

CHORDATA (continued)
unid. paralepidids
Lophius americanus
Urophycis chuss
Merluccius sp.
Enchelyopus cimbrius
Scomberesox saurus
Gasterosteus aculeatus
Hippocampus erectus
Syngnathus fuscus
Pomatomus saltatrix
Mugil curema
Cynoscion regalis
Tautoga onitis
Tautogolabrus adspersus
unid. blenniids
Peprilus triacanthus
Scomber scombrus
unid. pleuronectiforms
Scophthalmus aquosus
Limanda ferruginea
Glyptocephalus cynoglossus
Symphurus sp.
Sphoeroides sp.

Table 4-16. Numerically dominant zooplankters in spring 1976 collections (BLM03W). Drawn from the three most abundant taxa in each tow. (D = Day, N = Night)

Station C1

Bongo 202 (D)	Bongo 505 (D)	Neuston 505
Centropages typicus	*C. typicus*	unid. fish eggs (4D,4N)
Temora longicornis	*Ovalipes* sp. zoea	*Cancer* sp. megalopae (4N)
Oithona sp.	unid. fish eggs	*C. typicus* (2D,2N)
		Tortanus discaudatus (2D,1N)
	Bongo 505 (D)	*Anchoa mitchilli* eggs (2D)
		Urophycis sp. eggs (2D)
	C. typicus	*Ovalipes* sp. zoea (1N)
	Ovalipes sp. zoea	
	Pagurid zoea	

Station D1

Bongo 202 (N)	Bongo 505 (N)	Neuston 505
C. typicus	*C. typicus*	*C. typicus* (3D,4N)
Temora longicornis	*Spiratella retroversa*	unid. fish eggs (4D,1N)
Pseudocalanus sp.	*Sagitta elegans*	*Anomalocera patersonii* (3D,1N)
		S. retroversa (2D,2N)
		Cancer sp. zoea (3N)
		Cancer sp. megalopae (1N)

Station N3

Bongo 202 (N)	Bongo 505 (N)	Neuston 505
C. typicus	*S. retroversa*	*C. typicus* (4D,4N)
S. retroversa	*C. typicus*	unid. fish eggs (4D,1N)
Pseudocalanus sp.	unid. fish eggs	*S. retroversa* (2D,3N)
		Cancer sp. zoea (3N)
	Bongo 505 (N)	*S. elegans* (1D)
		A. patersonii (1D)
	S. retroversa	*Parathemisto gaudichaudii* (1N)
	C. typicus	
	S. elegans	

Table 4-16 (concluded)

Station E3

Bongo 202 (N)	Bongo 505 (N)	Neuston 505
unid. copepodites	*Calanus finmarchicus*	*C. typicus* (3D,7N)
Oithona sp.	*S. elegans*	unid. fish eggs (5D,3N)
C. typicus	*C. typicus*	*Cancer* sp. zoea (6N)
		S. retroversa (2D,2N)
		A. patersonii (3D)
		P. gaudichaudii (2N)
		S. elegans (1D)
		unid. oikopleurids (1D)
		Metridia lucens (1N)

Station F2

Bongo 202 (N)	Bongo 505	Neuston 505
unid. copepodites	*S. retroversa*	unid. fish eggs (4D,1N)
S. retroversa	*Spiratella trochiformis*	*C. typicus* (4D,3N)
C. finmarchicus	*M. lucens*	*S. retroversa* (3D,2N)
		Cancer sp. zoea (2N)
		S. elegans (2N)
		C. finmarchicus (1D,1N)
		M. lucens (1N)

Station J1

Bongo 202 (D)	Bongo 505 (N)	Neuston 505
unid. copepodites	*M. lucens*	*S. retroversa* (1D,4N)
Oithona sp.	*P. gracilis*	*Lepas fascicularis* (3D)
Pleuromamma gracilis	*S. retroversa*	unid. barnacle cypris (2D)
		unid. fish eggs (2D)
		A. patersonii (1D,1N)
		Idotea metallica (2D)
		P. gaudichaudii (2N)
		C. typicus (2N)
		C. finmarchicus (1D)
		Meganyctiphanes norvegica (1D)
		P. gracilis (1N)
		Nannocalanus minor (1N)

is evident. Of more significance, however, is the dominance of fish eggs and the larvae of *Cancer* sp. crabs in neuston collections. Fish eggs were numerically dominant in 46.2% of the neuston tows, decapod larvae in 25.0%. Copepods, dominant in most subsurface bongo collections (a few dominated by *Spiratella retroversa*), were of greatest importance in only 15.4% of the neuston tows.

Station C1. Fish eggs were dominant in five of the eight neuston tows, with megalopae of *Cancer* sp. predominant in the other three tows. Three bongo tows (two 505 and one 202 μm) were taken at this station. All were dominated by copepods, whereas copepods ranked only second or third in abundance in neuston collections. *Centropages typicus* was the dominant in all three bongo tows, and was the most abundant copepod in five neuston tows, outranked by *Tortanus discaudatus* in the other three. Also important in the neuston were the zoeal stages of *Ovalipes* sp. The 24-hr cycle of copepods from Station C1 neuston is shown in Figure 4-24.

In addition to copepods, zooplankters that were found to be more important in bongo collections included euphausiids, cumaceans, and cladocerans.

Station D1. Fish eggs were most abundant in four of the eight neuston tows, *Cancer* sp. larvae in three tows, and copepods in the remaining tow. Among the copepods, *Centropages typicus* was most abundant in five neuston tows and both bongo tows. *Anomalocera patersonii* was predominant in the other three neuston tows (Figure 4-25). The thecosome *Spiratella retroversa* was another important neustont[1] at this station. This species, along with chaetognaths, mysids, and amphipods, were more important in bongo collections, both of which were dominated by the copepod *Centropages typicus*.

Station N3. Fish eggs were dominant in half the neuston tows, *Cancer* sp. zoea in two tows, and *Spiratella retroversa* in the remaining two. Three bongo collections were made at this station, with *Centropages typicus* predominating the 202 μm collection and the thecosome *S. retroversa* dominating both 505 μm tows. *C. typicus*, *Anomalocera patersonii* (Figure 4-26), *Sagitta elegans*, and *Parathemisto gaudichaudii* also assumed importance in neuston collections. *Metridia lucens* and *Pseudocalanus* sp. were night migrants into the neuston layer. Polychaetes and bivalve larvae were more evident in subsurface collections.

Station E3. Four extra neuston tows were made at this station, for a total of 12. Five were dominated by zoeal stages of *Cancer* sp., four by fish eggs, and three by *Centropages typicus*. Both bongo tows were numerically dominated by copepods. Dominant copepods included *C. typicus* (9 neuston tows), *Anomalocera patersonii* (3 neuston tows), *Calanus finmarchicus* in the bongo 505, and small, unidentified copepodites in the bongo 202.

The truncated series of neuston collections and the full series are included in Figure 4-27 and 4-28 for copepods. The similarity in numbers of dominant species and time of peak abundance between sampling dates five

[1] "Neustont" is a term coined by Zaitsev (1968) to denote a component of the neuston, analogous to "planktont" or "plankter".

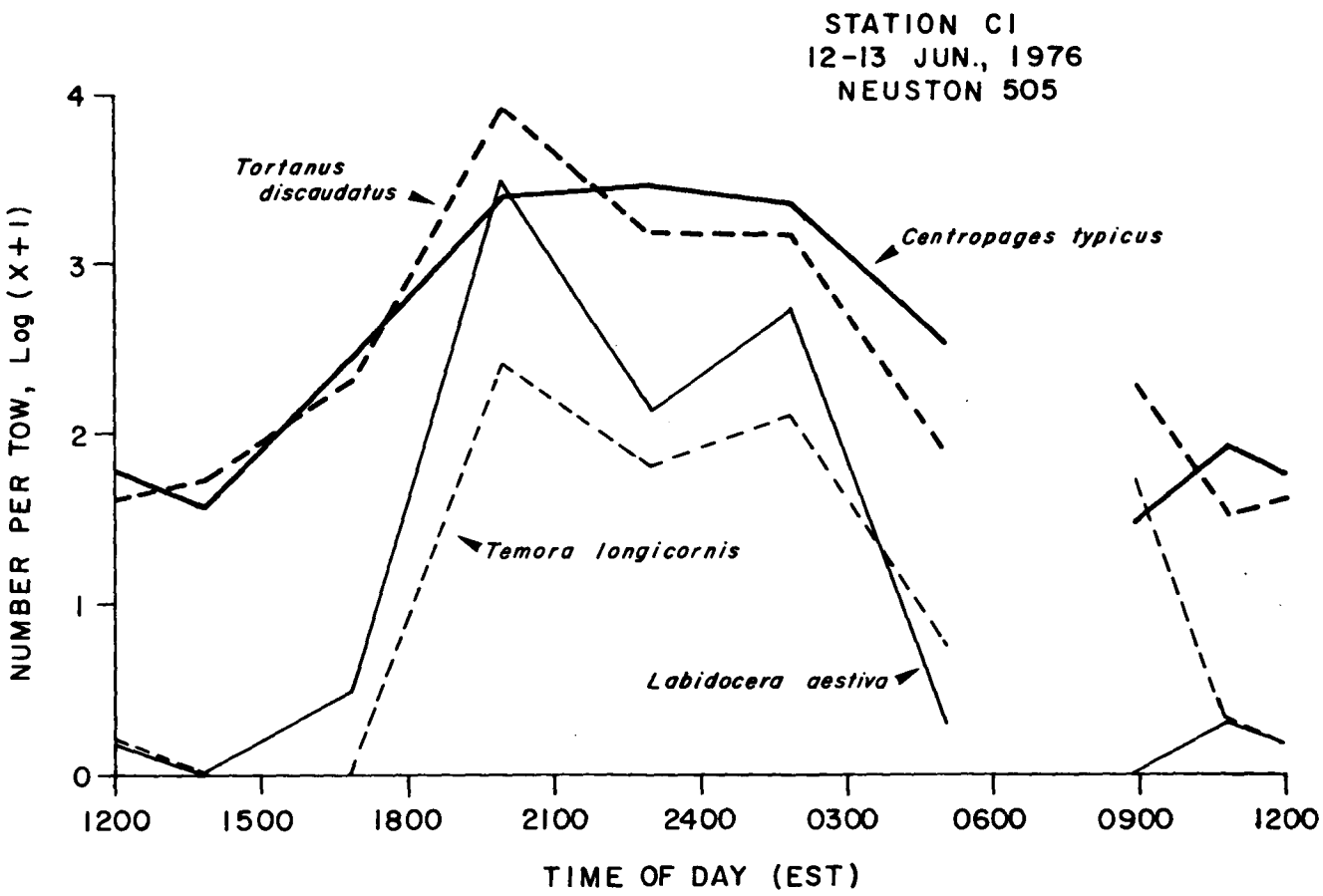

Figure 4-24. Diel cycle of abundance of dominant copepods in the surface layer of Station C1, BLM03W.

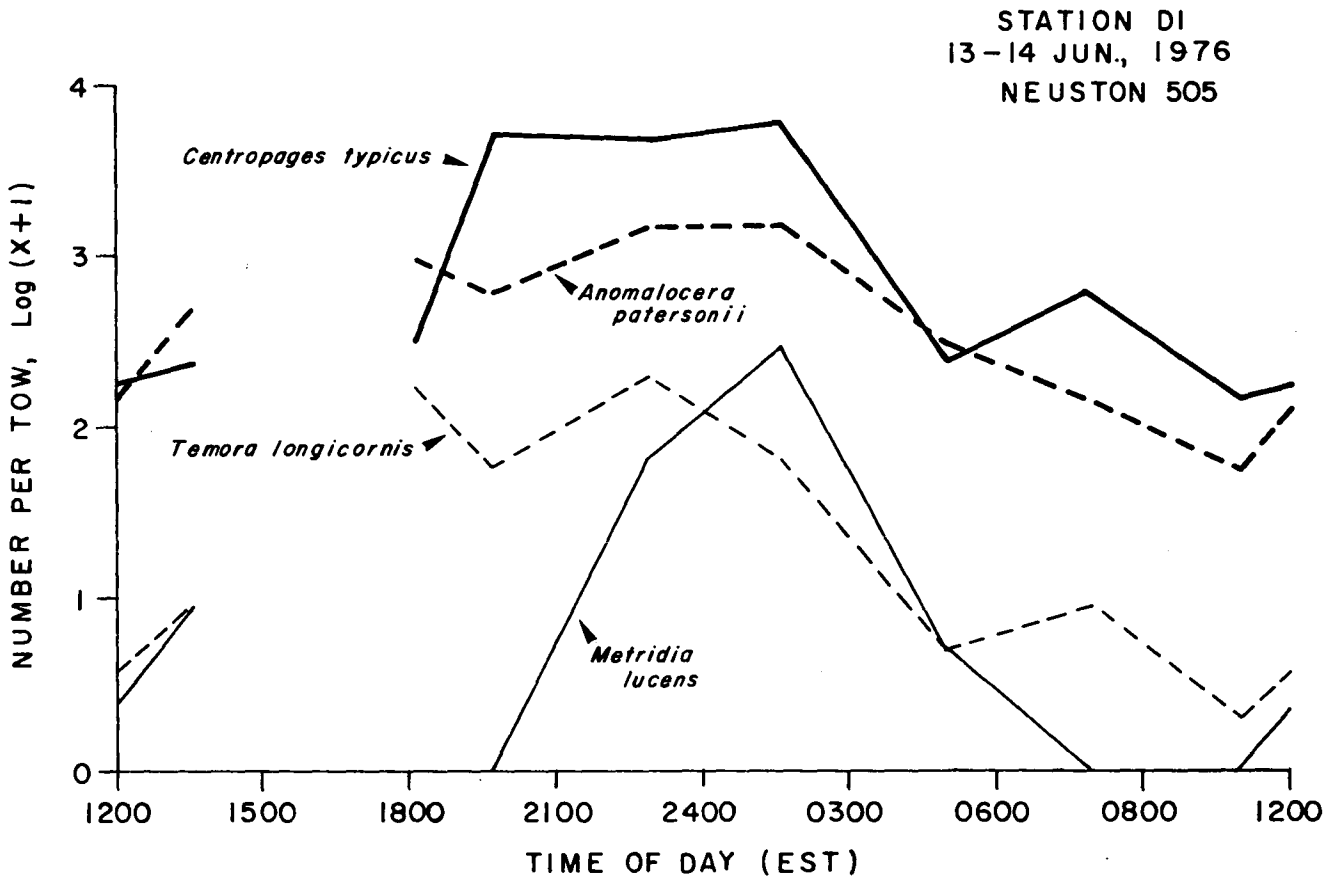

Figure 4-25. Diel cycle of abundance of dominant copepods in the surface layer of Station D1, BLM03W.

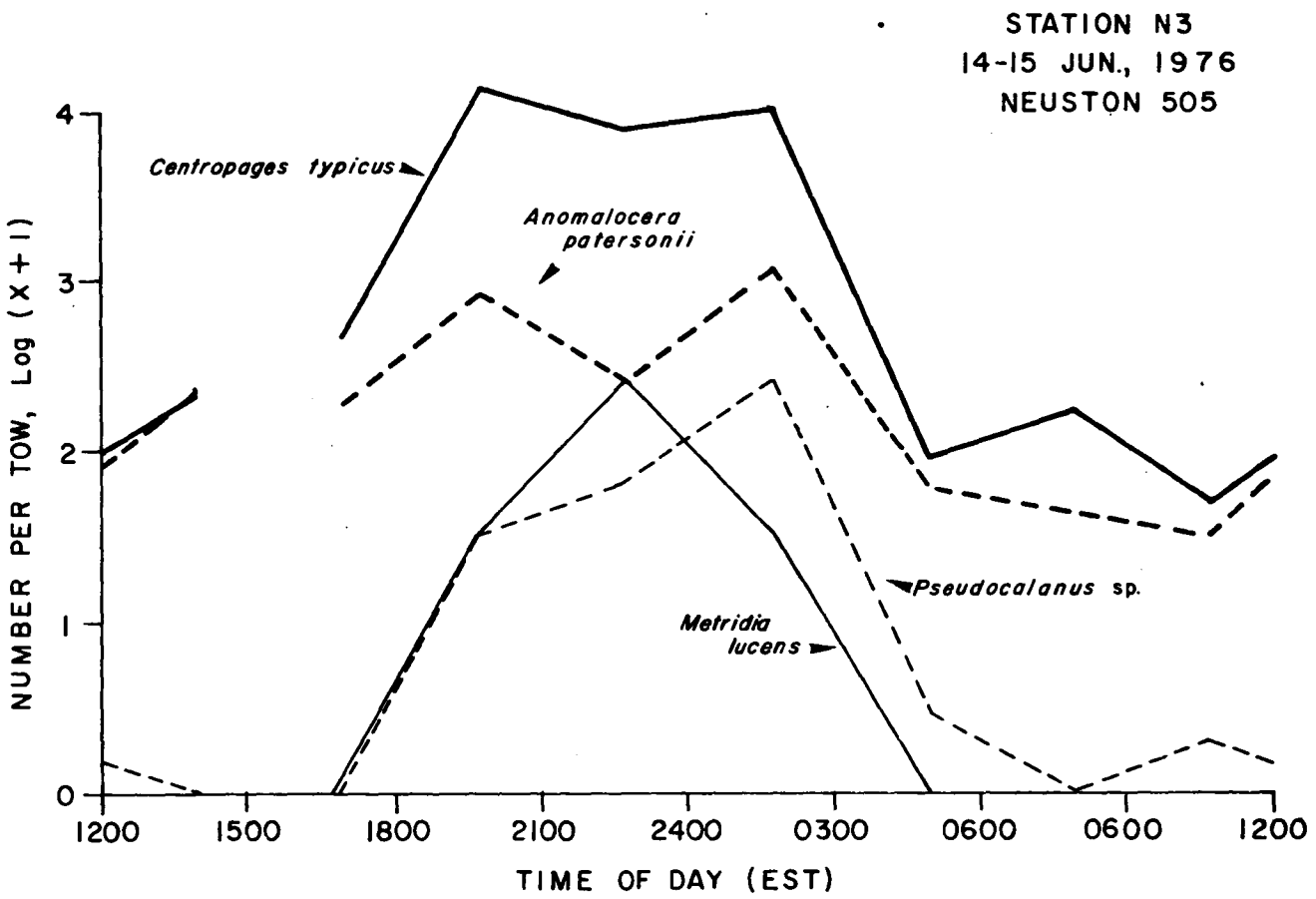

Figure 4-26. Diel cycle of abundance of dominant copepods in the surface layer of Station N3, BLM03W.

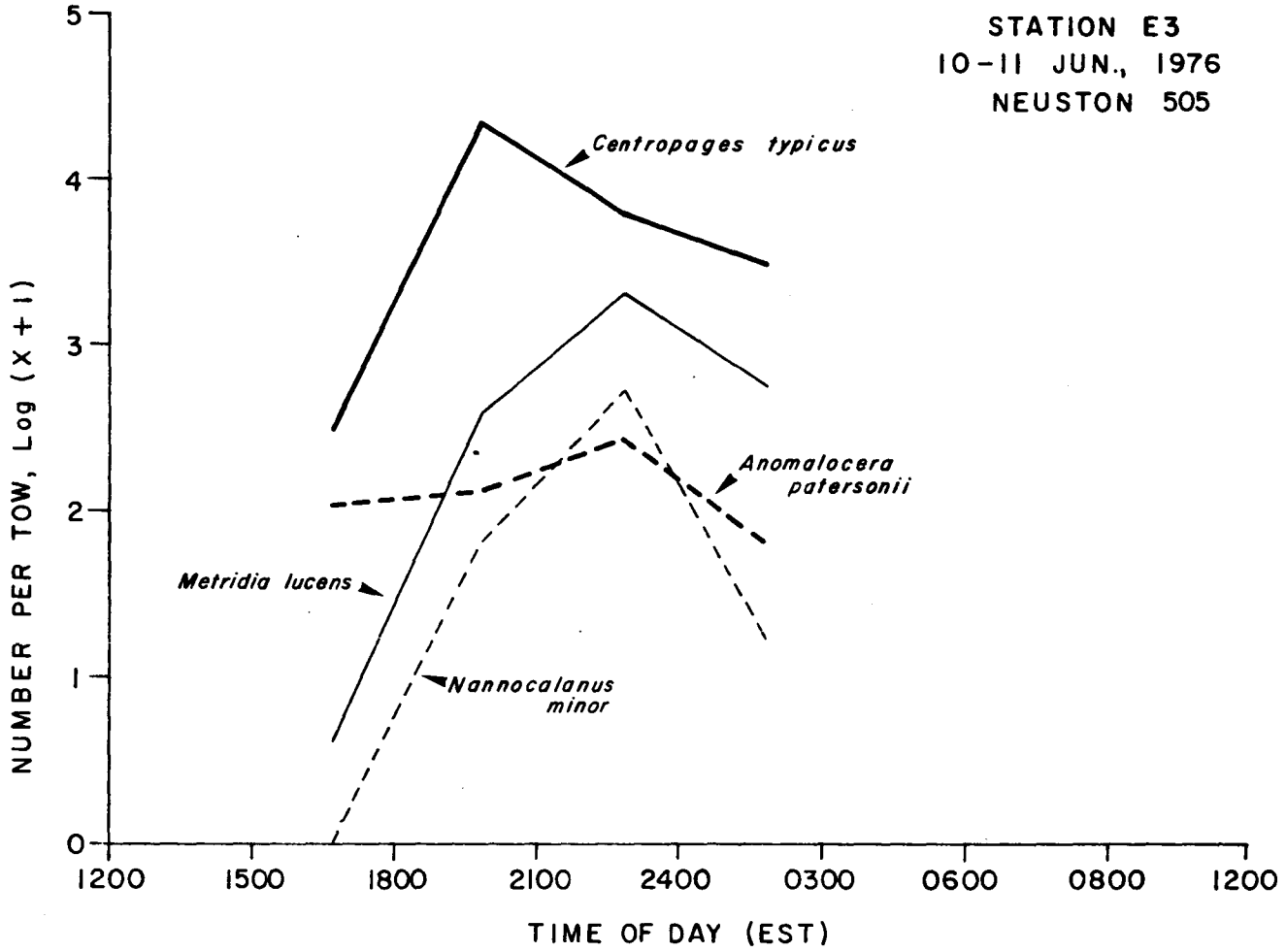

Figure 4-27. Abbreviated diel cycle of abundance of dominant copepods in the surface layer of Station E3, 10-11 June 1976.

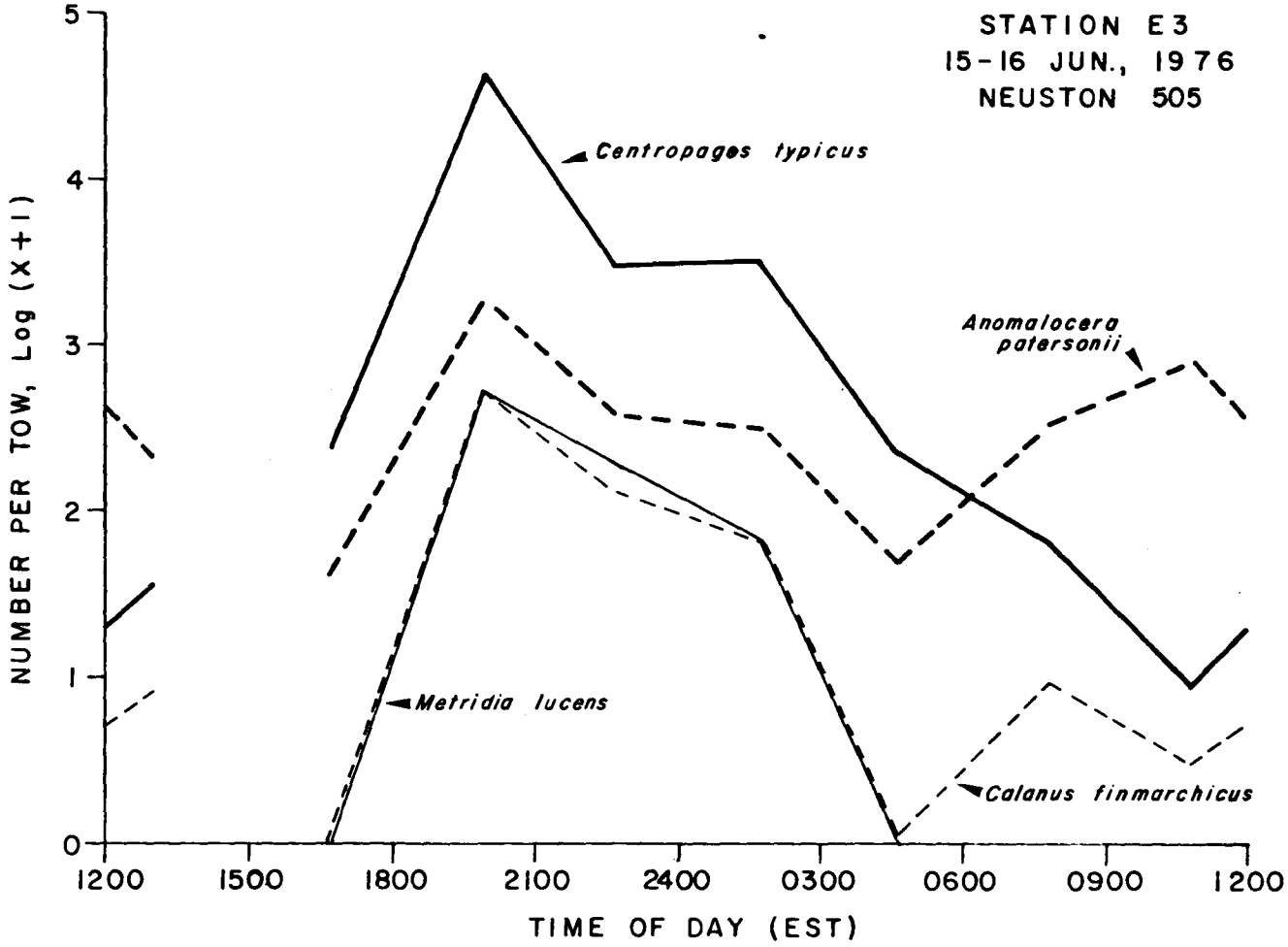

Figure 4-28. Second diel cycle of abundance of dominant copepods in the surface layer of Station E3, 15-16 June 1976.

days apart is noteworthy.

Other neustonts of importance were *Spiratella retroversa, Parathemisto gaudichaudii, Sagitta elegans, Metridia lucens,* and *Oikopleura* sp. Cumaceans and appendiculariens were more evident in bongo tows.

Station F2. Fish eggs were numerically dominant in five of the eight neuston tows, *Spiratella retroversa* in two tows and *Centropages typicus* in the eighth tow. The bongo 202 collection was dominated by the same unidentified copepodite seen at Station E3, the bongo 505 by *S. retorversa.* Dominant copepods in neuston tows included *C. typicus* (6 tows), *Metridia lucens* in one tow, and the above-mentioned unidentified copepodite in one tow (see Figure 4-29). Also important in the neuston at night were *Cancer* sp. zoea, *Sagitta elegans, Calanus finmarchicus,* and *Metridia lucens.*

Station J1. Copepods were dominant in three of the eight neuston tows and in both bongo tows. Two neuston tows were dominated by fish eggs, and one each by *Meganyctiphanes norvegica, Spiratella retroversa,* and *Parathemisto gaudichaudii. Centropages typicus* was the most abundant copepod in two neuston tows, *Anomalocera patersonii* in three tows, and *Pleuromamma gracilis* and *Calanus finmarchicus* in one tow apiece. All of the more abundant copepods in neuston collections were strong vertical migrators (Figure 4-30). Other important neustonts included *Lepas fascicularis,* barnacle cypris larvae, *Idotea metallica,* and *Nannocalanus minor.*

The bongo 505 was dominated by *Metridia lucens* and the bongo 202 by unidentified copepodites.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent and abundant species from bongo collections are listed in Table 4-17, and those from neuston collections in Table 4-18. Three of the five most frequent species in neuston collections do not appear on the list of common bongo species, although the two most important species, *Centropages typicus* and *Sagitta elegans,* are identical in the two lists. Unique neuston species include *Anomalocera patersonii, Idotea metallica, Enchelyopus cimbrius,* and farther down the list the American lobster, *Homarus americanus.* Young stages of the latter important species were never very abundant but occurred in 42% of the 52 neuston collections. After capture, they were observed to remain suspended just below the water surface of the collection bucket, where they continued to feed on floating material.

Omitted from the list of important neuston species are the abundant but unidentified fish eggs. Many of these would rank high in the list if included. The larvae of rock crabs (*Cancer* spp.) outranked all other neuston taxa in abundance, although occurring in a smaller percentage of tows than other highly ranked species.

Diversity. Three indices of diversity are listed for each spring collection in Table 4-19. Shannon indices ranged from 0.2559 at Station N3 to 3.0292 at Station J1, both occurring in night neuston collections.

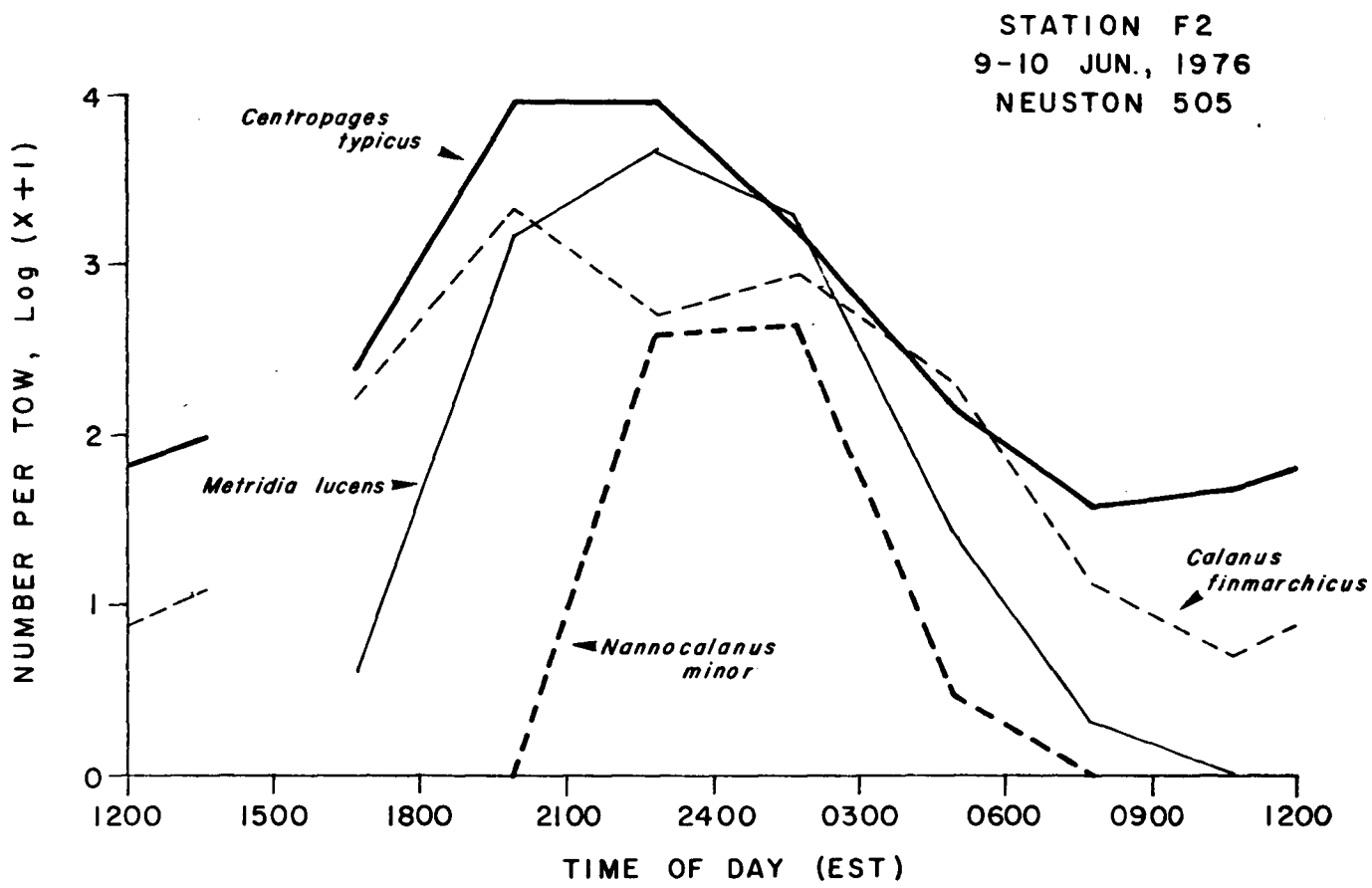

Figure 4-29. Diel cycle of abundance of dominant copepods in the surface layer of Station F2, BLM03W.

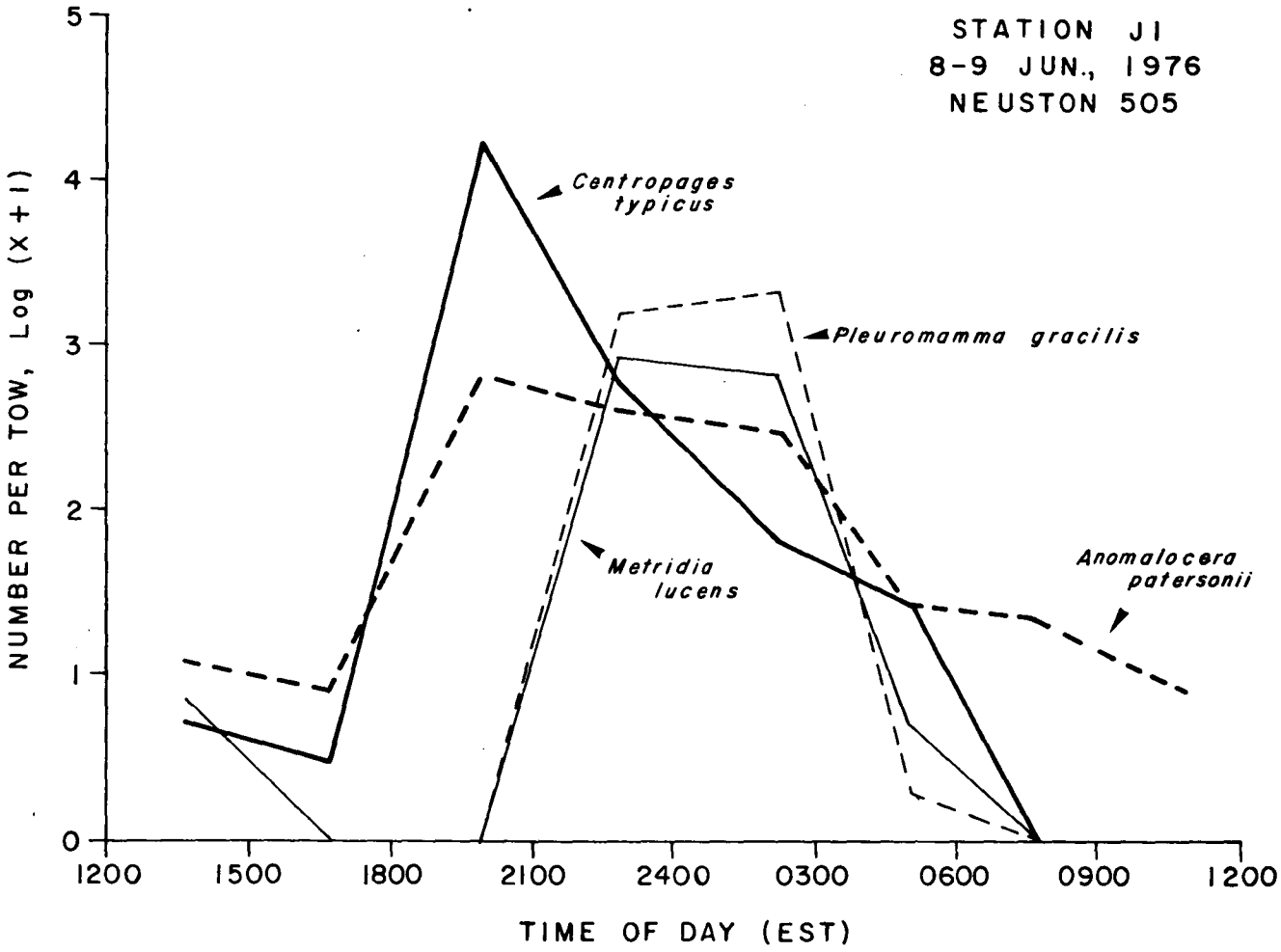

Figure 4-30. Diel cycle of abundance of dominant copepods in the surface layer of Station J1, BLM03W.

Table 4-17. Frequency of occurrence and rank of abundance of common species in bongo collections, BLM03W.

Species	Percent Occurrence	Rank Abundance	Maximum Number per $100m^3$
Centropages typicus	100	1	676,640
Sagitta elegans	100	9	7,824
Cancer sp.	100	14	4,194
Spiratella retroversa	93	4	133,620
Calanus finmarchicus	79	8	44,236
Sagitta tasmanica	79	18	1,014
Parathemisto gaudichaudii	79	23	451
Meganyctiphanes norvegica	79	24	320
Temora longicornis	71	3	414,520
Crangon septemspinosa	64	19	1,477
Paedoclione doliiformis	64	-	158
Pseudocalanus sp.	57	6	77,255
Paguridae zoea	57	17	3,352
Scomber scombrus	57	-	4
Oithona sp.	50	5	193,332
Metridia lucens	50	11	16,589
Spiratella trochiformis	50	13	5,734
Thysanoessa longicaudata	50	-	179
Neomysis americana	43	20	1,428
Nannocalanus minor	43	21	1,229
unid. copepodites	29	2	884,559
Centropages hamatus	29	10	26,214
Ovalipes sp.	29	12	6,861
Evadne nordmanni	29	22	819
Pleuromamma gracilis	21	16	2,351
Paracalanus sp.	14	7	54,068
Spiratella helicina	14	15	5,208

Table 4-18. Frequency of occurrence and rank of abundance of common species in neuston collections, BLM03W.

Species	Percent Occurrence	Rank Abundance
Centropages typicus	96	2
Sagitta elegans	90	5
Anomalocera patersonii	90	7
Idotea metallica	88	23
Enchelyopus cimbrius	77	25
Spiratella retroversa	75	3
Cancer sp.	73	1
Calanus finmarchicus	69	11
Temora longicornis	60	20
Paedoclione doliiformis	54	21
Parathemisto gaudichaudii	52	4
Metridia lucens	48	8
Sagitta tasmanica	48	16
Homarus americanus	42	--
Meganyctiphanes norvegica	38	6
Scomber scombrus	38	--
Barnacle cypris larvae	37	--
Evadne nordmanni	35	19
Nannocalanus minor	31	18
Tortanus discaudatus	23	9
Crangon septemspinosa	23	15
Paguridae zoea	23	17
Pseudocalanus sp.	19	24
Ovalipes sp.	13	10
Labodocera aestiva	13	12
Pleuromamma gracilis	12	14
Neomysis americana	10	13
Spiratella trochiformis	10	22

Table 4-19. Diversity of zooplankton and neuston collections, BLM03W. 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
C1	Z76-173	Ns, D	2.7151	0.6643	2.6489
	-174	Ns, D	2.2262	0.6435	1.9494
	-175	Ns, D	2.2972	0.6915	1.8609
	-176	Ns, D	2.5250	0.6463	2.1284
	-177	Ns, N	2.9587	0.6453	2.2041
	-178	Ns, N	2.2641	0.4710	2.7170
	-179	Ns, N	2.5389	0.5281	2.8399
	-180	Ns, N	1.2502	0.3284	1.6347
	-181	B505, D	2.1553	0.4987	1.7428
	-182	B505, D	2.2524	0.4636	2.4873
	-183	B202, D	1.9153	0.3943	1.8578
D1	Z76-184	Ns, D	2.1424	0.5043	2.4292
	-185	Ns, N	0.7218	0.1804	1.3714
	-186	B505, N	2.0050	0.4010	2.6575
	-187	B202, N	2.6451	0.5290	2.1905
	-188	Ns, N	2.0860	0.4211	2.9649
	-189	Ns, N	1.9974	0.4479	2.1252
	-190	Ns, N	1.9234	0.5365	1.7053
	-191	Ns, D	1.6232	0.4058	2.2162
	-192	Ns, D	1.9158	0.5032	2.1514
	-193	Ns, D	2.1570	0.5392	2.0968
N3	Z76-194	Ns, D	1.6821	0.4692	1.4917
	-195	Ns, N	1.7043	0.3626	2.2737
	-196	B202, N	2.4041	0.6154	1.0933
	-197	B505, N	0.9538	0.1845	2.7458
	-198	B505, N	1.1339	0.2334	2.3133
	-199	Ns, N	2.3222	0.4830	2.6821
	-200	Ns, N	1.7413	0.3662	2.4363
	-201	Ns, N	0.2559	0.0692	1.3578
	-202	Ns, D	1.8797	0.4937	2.1195
	-203	Ns, D	2.4426	0.6813	2.1418
	-204	Ns, D	2.2246	0.7924	0.9118
E3	Z76-167	Ns, D	2.2353	0.5588	2.2686
	-168	Ns, N	0.9305	0.2118	1.5746
	-169	B202, N	1.3667	0.2843	1.8470
	-170	B505, N	2.7201	0.5787	2.2841
	-171	Ns, N	1.8496	0.3667	3.0200
	-172	Ns, N	1.9048	0.4407	2.1025
	-205	Ns, D	1.7177	0.4965	1.4946
	-206	Ns, N	1.5750	0.3708	1.5208

Table 4-19 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
E3(cont.)	Z76-207	Ns, N	1.9933	0.4612	2.0622
	-208	Ns, N	2.3813	0.5711	1.8824
	-209	Ns, N	1.5623	0.4358	1.6134
	-210	Ns, D	1.8797	0.4937	2.1195
	-211	Ns, D	2.4426	0.6813	2.1418
	-212	Ns, D	2.2246	0.7924	0.9118
F2	Z76-157	Ns, D	2.0505	0.4472	3.2973
	-158	Ns, N	2.3542	0.5885	1.3044
	-159	B202, N	2.3485	0.4413	2.8471
	-160	B505, N	0.4259	0.1003	1.4100
	-161	Ns, N	2.1846	0.4899	1.8937
	-162	Ns, N	2.7388	0.6701	1.7803
	-163	Ns, N	2.1817	0.6086	1.7835
	-164	Ns, D	2.1739	0.5875	2.4390
	-165	Ns, D	2.0525	0.5933	2.2886
	-166	Ns, D	1.1414	0.3601	1.6710
J1	Z76-947	Ns, D	2.9764	0.8043	2.7385
	-948	Ns, D	2.6470	0.7652	2.4136
	-149	Ns, N	1.4722	0.3132	2.3649
	-150	B505, N	2.7177	0.5040	3.8179
	-151	Ns, N	2.3702	0.5042	2.4491
	-152	Ns, N	2.4035	0.4947	3.1304
	-153	Ns, N	3.0292	0.7573	3.2231
	-154	Ns, D	2.0708	0.6903	1.8498
	-155	B202, D	2.3171	0.4555	2.9602
	-156	Ns, D	2.4777	0.6911	2.1493

A predictable relationship between diversity and net mesh size is absent, with indices from bongo 202 collections sometimes higher, sometimes lower than companion bongo 505 collections. Evenness (J') values ranged from 0.0692 in the sample with low H' estimate to 0.8043 at Station J1 in a daytime neuston collection.

Species richness showed the beginning of a return to the pattern evident in fall collections, i.e. an increase in this index with distance offshore (Figure 4-31). Indices ranged from 0.9118 in one daytime neuston collection each from stations N3 and E3 to a high of 3.8179 in the bongo 505 collection at Station J1. The highest estimate from neuston tows was 3.2973 in a daytime collection at Station F2.

Cluster Analyses. Bongo and neuston collection data were analyzed separately, using a 9% frequency of occurrence cutoff for inclusion of species. As in previous cruises, those species occurring in less than two bongo collections or five neuston collections were dropped from the analysis.

I. Bongo tows.

A. Sample clusters. Clustering of the 14 bongo samples, based on all identified species, is shown in Figure 4-32. Companion bongo 202 and 505 collections from one station only (J1) were more similar than samples from a given mesh size at adjacent stations, a departure from results in previous cruises. Station J1 samples were linked to those from mid- to outer shelf stations D1 (bongo 505), N3 (replicate bongo 505's), E3, and F2 at a low level of similarity. The second major cluster linked replicate bongo 505 collections at Station C1 with inner shelf bongo 202 samples (stations C1, D1, and N3).

B. Species clusters. Seventy-three taxa occurred in at least two of the bongo collections and were included in the cluster analysis. Results of the inverse analysis are shown in the species clusters of Figure 4-33, with a listing of species within clusters in Table 4-20. The three main clusters are (1) 23 taxa found at the neritic station C1 and at other inner shelf stations, (2) 15 species from inner shelf stations but absent at the innermost station C1, and (3) a large number of species wither widely distributed and abundant (subcluster C_1) or restricted to the outer shelf and slope stations F2 and J1 (subcluster C_2).

II. Neuston tows.

A. Sample clusters. The normal analysis of the 52 spring neuston samples is shown in Figure 4-34. Samples from Station C1 linked with night tows from all other stations at a low level of similarity. The other major cluster consisted of daytime and predawn tows at all stations other than C1. Day tows at Station J1 provided a distinct subcluster within the latter group of samples.

The first division in the cluster of night tows separated

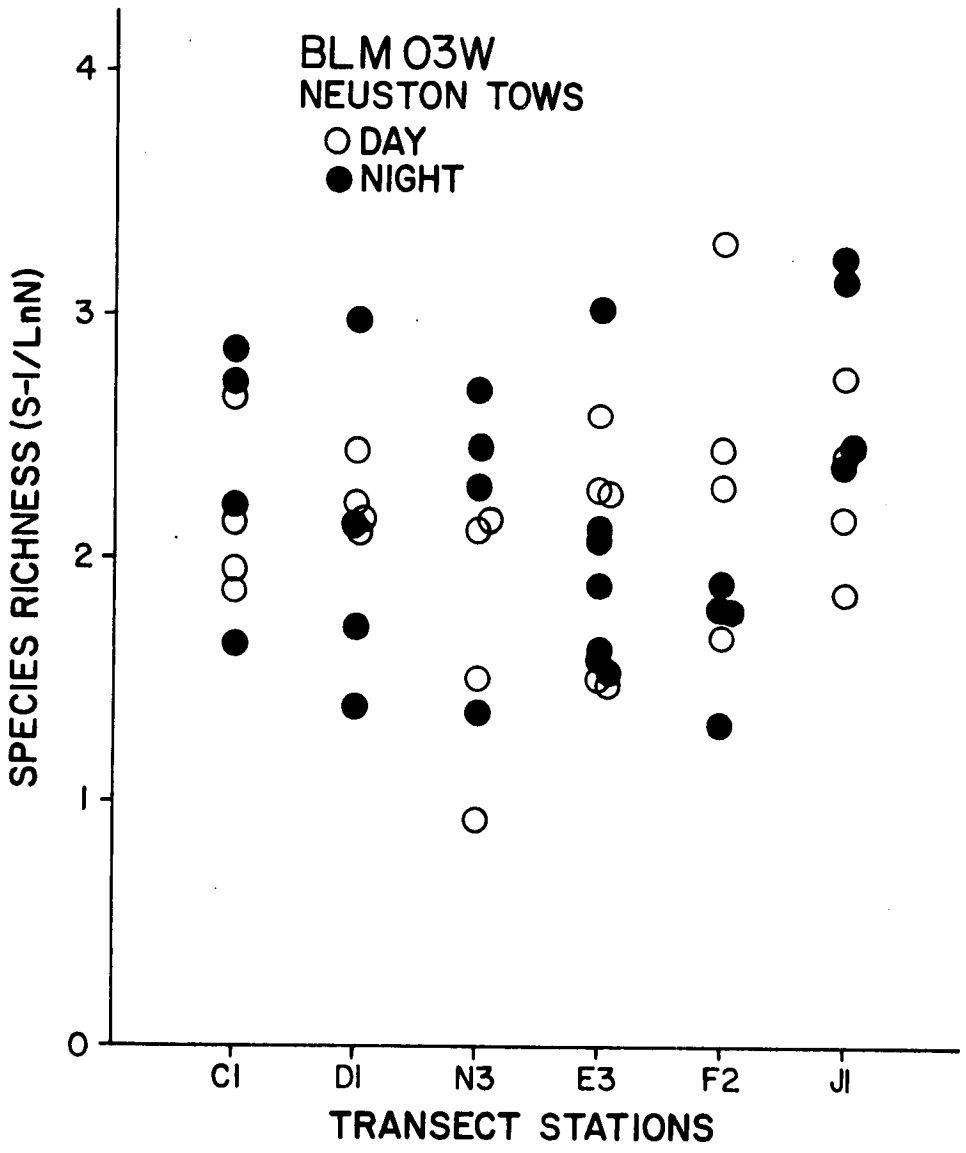

Figure 4-31. Species richness in neuston collections from the spring 1976 cruise, BLM03W. Stations (x-axis) arranged from inshore to offshore.

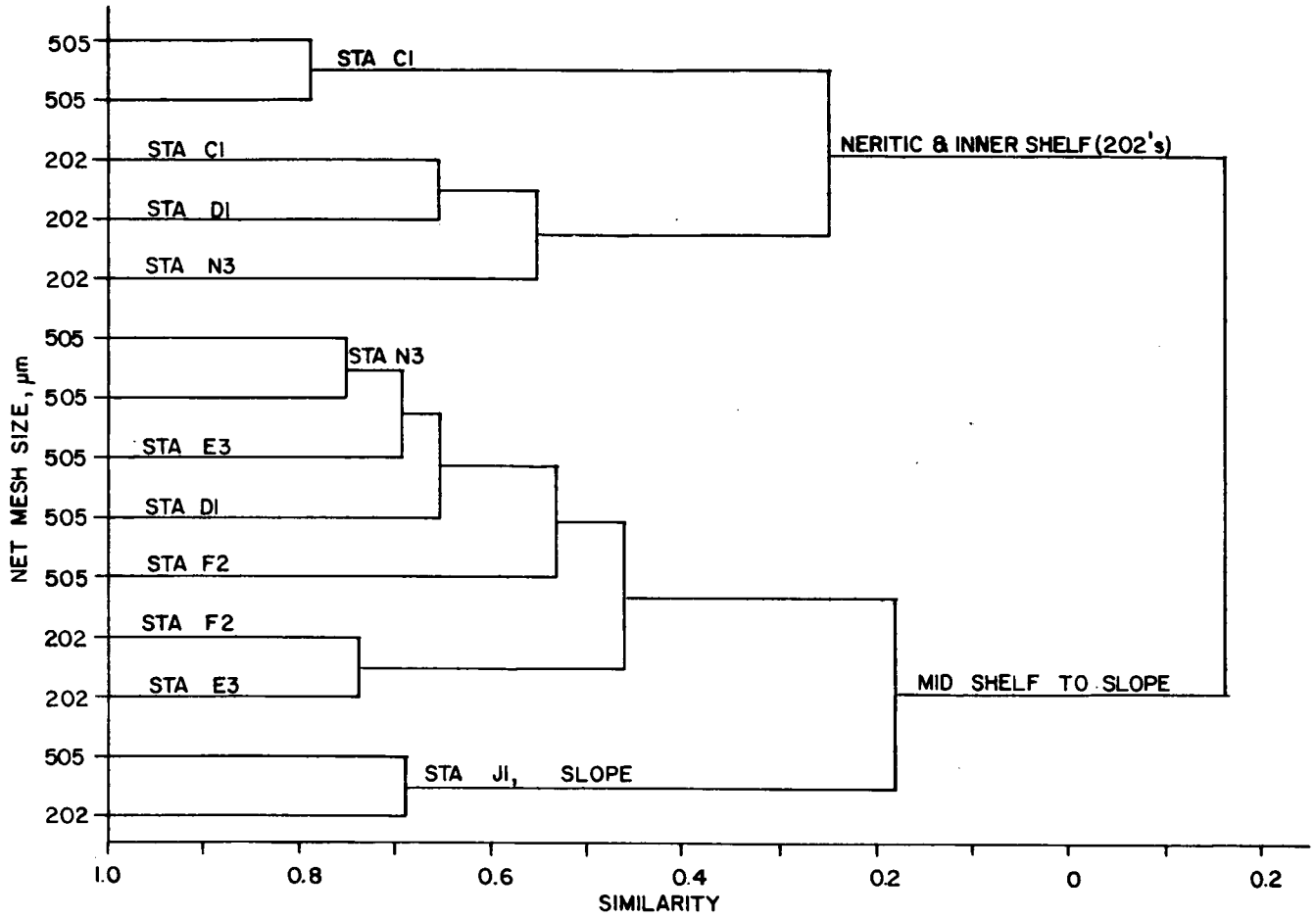

Figure 4-32. Bongo sample clusters, BLM03W, based on the Bray-Curtis coefficient of similarity, all identified species occurring in more than one bongo sample, and catch data standardized to numbers per 100 m^3.

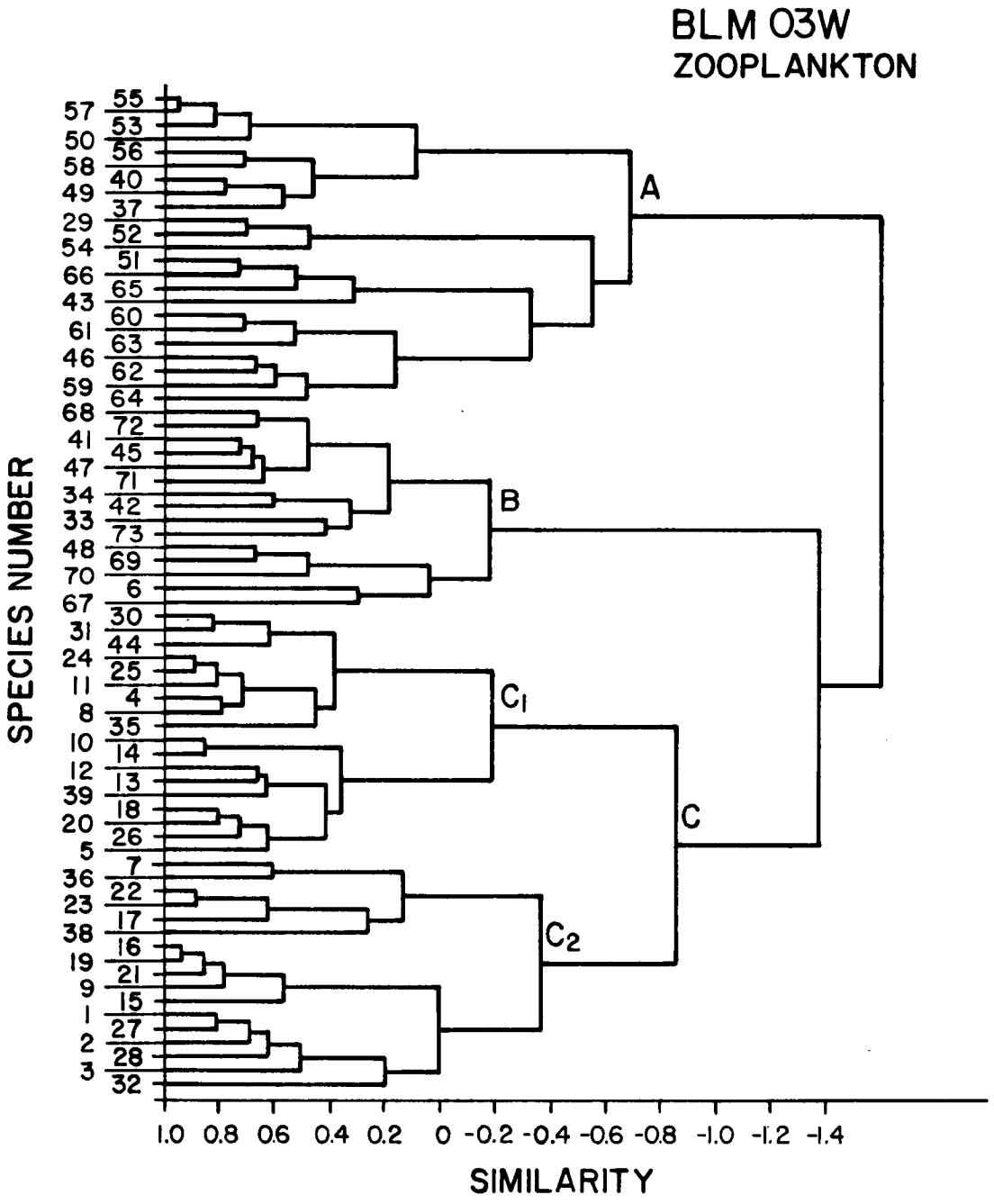

Figure 4-33. Inverse species clusters, bongo tows, BLM03W. See Table 4-20 for identification of species and clusters.

Table 4-20. Identification of species and clusters shown in Figure 4-33, bongo tows, BLM03W.

Cluster	Species No.	Species
A - Neritic and Inner Shelf Species	55	*Palaemonetes* sp.
	57	*Carcinus maenas*
	53	*Tortanus discaudatus*
	50	unid. gastropod larvae
	56	*Ovalipes* sp.
	58	*Libinia* sp.
	40	*Pagurid* zoea
	49	*Crangon septemspinosa*
	37	*Neomysis americana*
	29	unid. bivalve larvae
	52	*Labidocera aestiva*
	54	*Idotea metallica*
	51	*Centropages hamatus*
	66	*Paracalanus* sp.
	65	*Evadne nordmanni*
	43	*Monoculodes* sp.
	60	*Syngnathus fuscus*
	61	*Anchoa* sp.
	63	*Tautoga onitis*
	46	unid. fish larvae
	62	*Scophthalmus aquosus*
	59	*Tautogolabrus adspersus*
	64	*Lophius americanus*
B - Mostly Inner Shelf, but always absent at Station C1	68	*Byblis serrata*
	72	*Limanda ferruginea*
	41	*Merluccius* sp.
	45	*Dichelopandalus leptoceras*
	47	*Enchelyopus cimbrius*
	71	*Pandalid* zoea
	34	*Tomopteris helgolandica*
	42	*Scomber scombrus*
	33	unid. oikopleurids
	73	*Monoculodes norvegica*
	48	*Aglantha conica*
	69	*Unciola inermis*
	70	*Pontogenia inermis*
	6	*Clione limacina*
	67	unid. nemerteans

Table 4-20 (concluded)

Cluster	Species No.	Species
C - Widely distributed and offshore species	30	*Pseudocalanus* sp.
C_1 - widely distributed and abundant species, occasionally absent from either end of transect	31	*Oithona* sp.
	44	*Temora longicornis*
	24	*Cancer* sp.
	25	*Sagitta elegans*
	11	*Centropages typicus*
	4	*Spiratella retroversa*
	8	*Calanus finmarchicus*
	35	*Spiratella trochiformis*
	10	*Nannocalanus minor*
	14	*Metridia lucens*
	12	*Centropages violaceus*
	13	*Candacia armata*
	39	*Thysanoessa longicaudata*
	18	*Parathemisto gaudichaudii*
	20	*Meganyctiphanes norvegica*
	26	*Sagitta tasmanica*
	5	*Paedoclione doliiformis*
C_2 - largely restricted to outer shelf and slope stations F2 and J1	7	unid. calanoid copepods
	36	*Spiratella helicina*
	22	*Thysanoessa* sp.
	23	*Thysanoessa gregaria*
	17	*Aetideus armatus*
	38	*Thysanoessa inermis*
	16	*Pleuromamma abdominalis*
	19	*Euphausia krohni*
	21	*Nematoscelis megalops*
	9	*Rhincalanus nasutus*
	15	*Pleuromamma gracilis*
	1	*Lensia conoidea*
	27	*Eukrohnia hamata*
	2	*Abylopsis tetragona*
	28	unid. myctophids
	3	*Tomopteris planctonis*
	32	*Sagitta hexaptera*

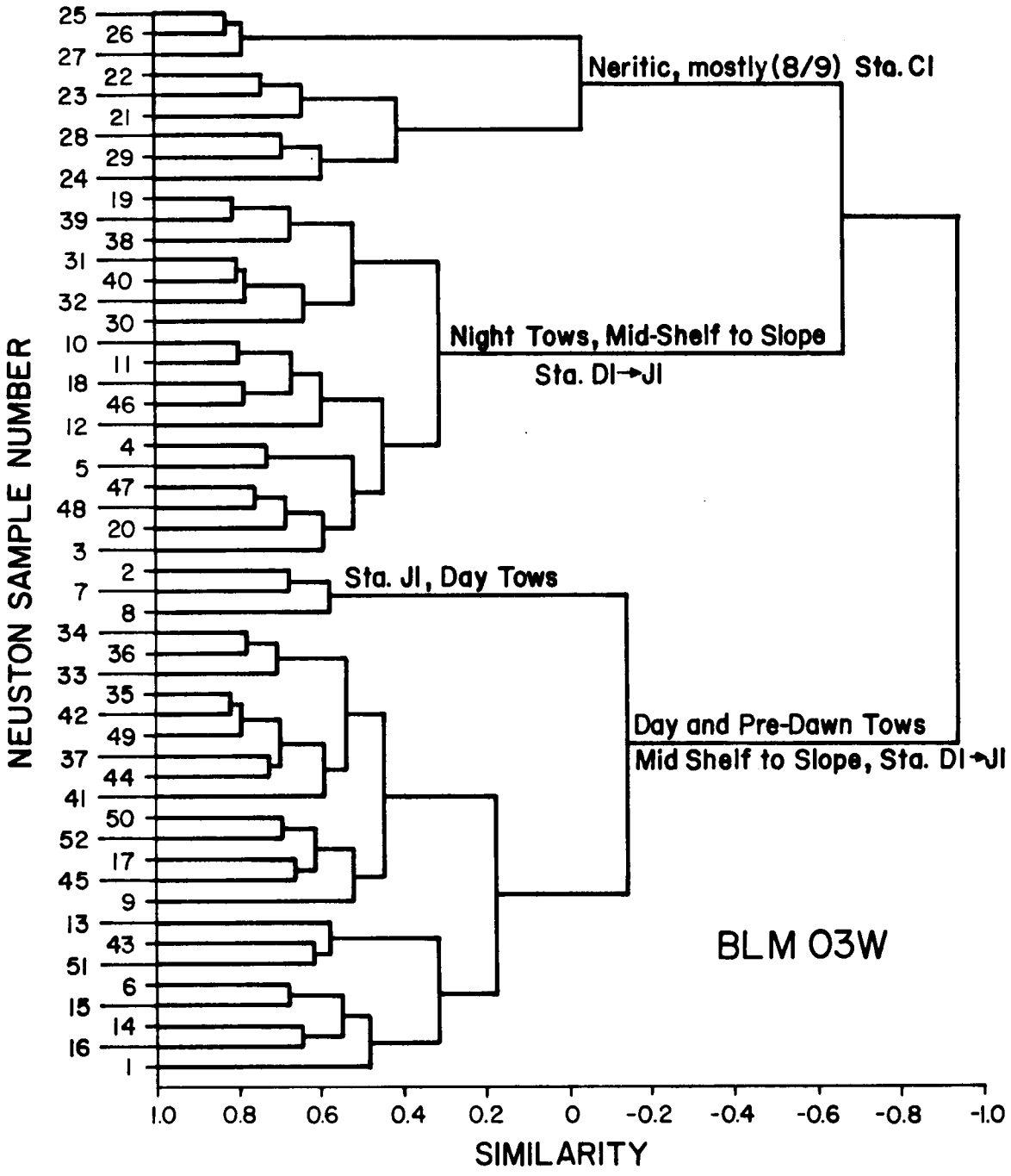

Figure 4-34. Neuston sample clusters, BLM03W, based on the Bray-Curtis coefficient of similarity and all identified species occurring in more than four neuston samples.

samples into those from stations D1 and N3, plus one from E3 (upper subcluster in Figure 4-34), and those from stations E3, F2, and J1 (lower subcluster of 11 samples). A similar division of day tows was not so clearly defined.

B. Species clusters. Results of the inverse analysis of neuston collections are shown in Figure 4-35, with a listing of species and clusters provided in Table 4-21. As in all previous species cluster analyses, a group of close-inshore neritic species was distinguished. It includes four taxa of decapod larvae, the mysid *Neomysis americana*, and several copepods (among them the pontellids *Labidocera aestiva*, *Pontella meadii*, and *Anomalocera ornata*). This group was linked at a low level to a group of less abundant shelf and slope species (cluster B). Subclusters of this group included those shelf species absent at the slope station J1 (important species were *Scomber scombrus* and *Homarus americanus*), and taxa from the outer shelf and slope (barnacles, copepods, thecosomes, tunicates, and the fishes *Urophycis chuss* and *Mugil curema*).

The remaining cluster grouped the widespread and most abundant species, with subclusters of (1) species absent at Station C1 and (2) ubiquitous species. The latter subcluster included the more dominant taxa (*Centropages typicus*, *Cancer* sp., *Sagitta elegans*) as well as the common neustonts *Anomalocera patersonii* and *Idotea metallica*.

Summer 1976 Cruise No. BLM04W

Summary of Collections

The six water column stations C1, D1, K3, E3, F2, and J1 were sampled for zooplankton and neuston between 31 August and 9 September 1976. The effects of anoxia at inshore stations that were so evident in benthic sampling (see Chapter 6 of this report) were not reflected in subsurface zooplankton and neuston collections. The great abundance of plankton at the surface, in fact, necessitated shortening of neuston tows at Station C1 to ten minutes.

Collections obtained with 60 cm bongo samplers, towed obliquely at least twice at each station (once each with 202 µm and 505 µm nets), included 13 preserved collections (an extra bongo 505 at Station F2), 14 trace metal samples, and 14 hydrocarbon samples. The 14 samples for each of the chemical analyses included two (one each mesh size) for quality control obtained at Station C1.

Neuston collections (505 µm nets) resulted in a total of 48 preserved samples, 7 trace metal samples, and 3 hydrocarbon samples. No tarballs were obtained on this cruise. Species selected for chemical analysis included *Aequorea aequorea* (cnidarian), *Beroe ovata* (ctenophore) and *Idotea metallica* (isopod).

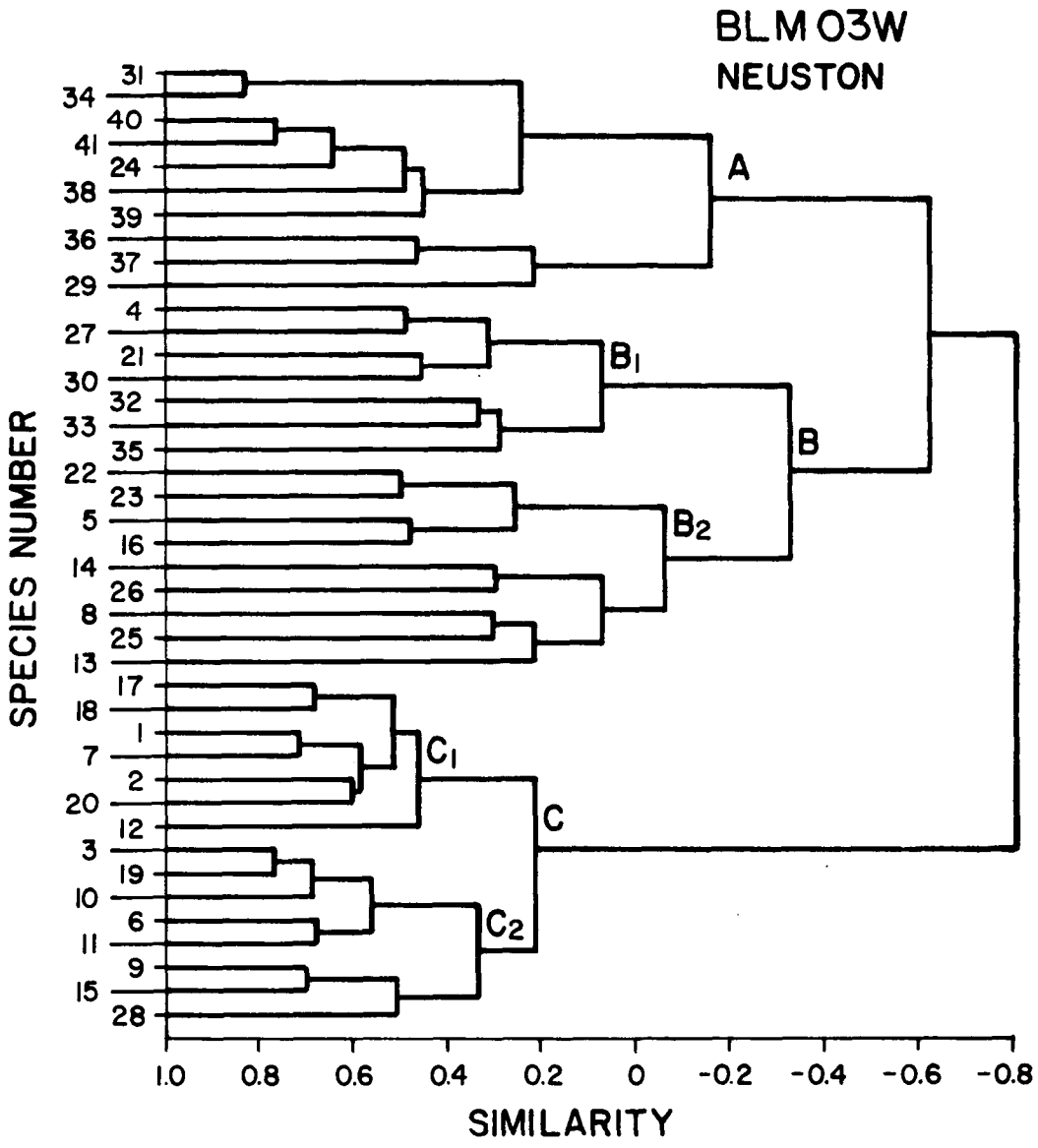

Figure 4-35. Inverse species clusters, neuston tows, BLM03W. See Table 4-21 for identification of species and clusters.

Table 4-21. Identification of species and clusters shown in Figure 4-34, neuston tows, BLM03W.

Cluster	Species No.	Species
A- Neritic Species, some extending over Inner Shelf	31	*Crangon septemspinosa*
	34	*Pagurid* zoea
	40	*Labidocera aestiva*
	41	*Ovalipes* zoea
	24	*Neomysis americana*
	38	*Tortanus discaudatus*
	39	*Palaemonetes* sp.
	36	*Pontella meadii*
	37	*Anomalocera ornata*
	29	*Centropages hamatus*
B - Less abundant shelf and slope species	4	*Evadne nordmanni*
B_1 - shelf species, absent at slope station	27	*Pseudocalanus* sp.
	21	*Scomber scombrus*
	30	*Homarus americanus*
	32	*Tomopteris helgolandica*
	33	*Loligo pealii*
	35	*Merluccius* sp.
B_2 - outer shelf and slope species	22	*Centropages violaceus*
	23	*Pleuromamma gracilis*
	5	*Candacia armata*
	16	*Spiratella trochiformis*
	14	*Urophycis chuss*
	26	*Mugil curema*
	8	unid. barnacle larvae
	25	unid. oikopleurids
	13	*Lepas fascicularis*
C - Widespread Species		
C_1 - shelf and slope, most abundant at outer shelf and at night, generally absent at most inshore station	17	*Parathemisto gaudichaudii*
	18	*Meganyctiphanes norvegica*
	1	*Calanus finmarchicus*
	7	*Metridia lucens*
	2	*Nannocalanus minor*
	20	*Sagitta tasmanica*
	12	*Paedoclione doliiformis*
C_2 - mostly ubiquitous species, often abundant at night	3	*Centropages typicus*
	19	*Cancer* sp.
	10	*Sagitta elegans*
	6	*Anomalocera patersonii*
	11	*Spiratella retroversa*
	9	*Idotea metallica*
	15	*Enchelyopus cimbrius*
	28	*Temora longicornis*

Faunal Description

A total of 331 taxa were identified from summer 1976 zooplankton and neuston collections, nearly double the list found in spring sampling. Identified taxa are listed in Table 4-22. Especially diverse were the molluscs (40 taxa), copepods (52), amphipods (67), decapods (36, mostly larvae), and fishes (53, also mostly larvae).

The dominant taxa found in collections from each of the stations are listed in Table 4-23. Although *Centropages typicus* was still of considerable importance across the shelf, a clear dominance by this species was limited to inner shelf collections. At Station C1, *Labidocera aestiva* had resumed the importance as near-shore dominant seen in fall collections (BLM01W). Species other than *C. typicus* were also most often dominant in outer shelf and slope collections.

Station C1. At the shallowest station, copepods were the numerically dominant group in all eight neuston and both bongo collections. In every collection, the dominant species was *Labidocera aestiva*. Other abundant copepods in the samples included *Centropages typicus* and *Acartia tonsa* (Figure 4-36). Decapod larvae (*Uca* sp., *Callinectes* sp., *Ovalipes* sp.) were of secondary importance in the night neuston, as were cladocerans (*Evadne tergestina* and *Penilia avirostris*) in daytime collections and in the bongo 505. The tunicate *Doliolum nationalis* was also among the dominant neustonts at this station.

Station D1. Seven of the eight neuston tows and both bongo tows were dominated by copepods, the remaining neuston tow by *Penilia avirostris*. The dominant copepod in five neuston tows was *Labidocera aestiva;* the other three were numerically dominated by *Pontella meadii*. In subsurface bongo collections (202 µm and 505 µm), *Centropages typicus* was most abundant. Other important species in the neuston included *Centropages furcatus* (Figure 4-37), unidentified fish eggs, the amphipod *Lestrigonus bengalensis*, the siphonophore *Diphyes dispar*, and the chaetognath *Sagitta enflata*. Chaetognaths were relatively more abundant in subsurface collections than in the neuston.

Station N3. All collections, neuston and bongo, were numerically dominated by copepods, although the bongo 505 (Table 4-23) contained more *Oikopleura* sp. than any individual species of copepod. Dominant copepods (Figure 4-38) included *Labidocera aestiva* (4 neuston tows), *Pontella meadii* (2 neuston tows), and *Centropages typicus* (2 neuston and 2 bongo tows). Other important neustonts were *Callinectes* sp., larvae of *Urophycis* sp., and the bluefish, *Pomatomus saltatrix*, and the tunicate *Doliolum nationalis*. Chaetognaths were again relatively more abundant in bongo tows at this station.

Station E3. Copepods were outnumbered by fish larvae (*Urophycis* sp.) in two of the eight neuston collections. In counts of individual species, *Thalia democratica* (salp) outnumbered any of the copepods in the bongo 505. Dominant copepods (Figure 4-39) were *Pontella meadii* (3 daytime neuston tows), *Centropages typicus* (3 neuston tows), *Nannocalanus minor* (1 neuston tow), *Labidocera aestiva* (1 neuston tow), *Candacia armata* in the bongo 505, and the small *Paracalanus parvus* in the bongo 202. Other important species in the neuston included *Thalia democratica*, *Penilia avirostris*,

Table 4-22. Checklist of species identified from bongo and neuston collections, BLM04W.

CNIDARIA
- unid. cnidarians
- *Bougainvillea* sp.
- *Aequorea aequorea*
- *Liriope tetraphylla*
- *Agalma elegans*
- *Muggiaea kochei*
- *Eudoxides spiralis*
- *Eudoxides mitra*
- *Chelophyes appendirulata*
- *Lensia conoidea*
- *Lensia cossack*
- *Diphyes dispar*
- *Diphyes bojani*
- *Sulculeolaria quadrivalvia*
- *Abylopsis tetragona*
- *Abylopsis eschscholtzii*
- *Bassia bassensis*
- *Pleurobrachia pileus*
- *Beroe ovata*

ANNELIDA
- unid. polychaete larvae
- *Tomopteris* sp.
- *Tomopteris helgolandica*

MOLLUSCA
- unid. gastropod larvae
- *Atlanta peroni*
- *Atlanta fusca*
- *Atlanta gaudichaudii*
- *Atlanta inflata*
- *Atlanta inclinata*
- *Polinices duplicatus*
- *Natica* sp.
- *Phalium granulatum*
- *Buccinum tottenii*
- *Firoloida leseurii*
- *Litiopa melanostoma*
- *Spiratella retroversa*
- *Spiratella trochiformis*
- *Spiratella leseuri*
- *Spiratella bulimoides*
- *Spiratella inflata*
- *Cavolina* sp.
- *Cavolina longirostris*
- *Cavolina uncinata*
- *Cavolina inflexa*
- *Cavolina quadridentata*

MOLLUSCA (continued)
- *Creseis acicula*
- *Creseis virgula*
- *Diacria trispinosa*
- *Paedoclione doliiformis*
- *Clione limacina*
- *Melampus bidentatus*
- unid. bivalve larvae
- *Mytilus* sp.
- *Modiolus* sp.
- *Lima tenera*
- *Dosinia discus*
- *Loligo peali*
- *Rossia tenera*
- *Illex illecebrosus*
- *Onykia caribaea*
- *Abralia veranyi*
- unid. octopodid
- *Argonauta argo*

MEROSTOMATA
- *Limulus polyphemus*

CRUSTACEA
- Cladocera
  - *Penilia avirostris*
  - *Evadne spinifera*
  - *Evadne tergestina*
- Ostracoda
  - unid. ostracods
- Copepoda
  - unid. copepods
  - *Calanus finmarchicus*
  - *Eucalanus* sp.
  - *Eucalanus pileatus*
  - *Eucalanus crassus*
  - *Mecynocera clausi*
  - *Rhincalanus nasutus*
  - *Undinula vulgaris*
  - *Nannocalanus minor*
  - *Neocalanus robustior*
  - *Neocalanus gracilis*
  - *Paracalanus* sp.
  - *Paracalanus parvus*
  - *Pseudocalanus* sp.
  - *Temora stylifera*
  - *Centropages furcatus*

Table 4-22. (continued)

Copepoda (continued)
- *Centropages typicus*
- *Centropages violaceus*
- *Candacia armata*
- *Labidocera aestiva*
- *Labidocera acutifrons*
- *Pontella meadii*
- *Pontella securifer*
- *Pontella spinipes*
- *Anomalocera patersonii*
- *Pontellopsis regalis*
- *Pontellopsis villosa*
- *Pontellina plumata*
- *Acartia longiremis*
- *Acartia tonsa*
- *Acartia danae*
- *Tortanus discaudatus*
- *Metridia lucens*
- *Pleuromamma gracilis*
- *Pleuromamma abdominalis*
- *Pleuromamma robusta*
- *Scolecithrix danae*
- *Euchaeta marina*
- *Calocalanus pavo*
- *Lucicutia flavicornis*
- *Euterpina acutifrons*
- *Macrosetella gracilis*
- *Clytemnestra scutellata*
- *Oithona* sp.
- *Oncaea* sp.
- *Pachos punctatum*
- *Corycaeus speciosus*
- *Farranula gracilis*
- *Sapphirina nigromaculata*
- *Sapphirina ovatolanceolata*
- *Copilia mirabilis*
- *Caligus* sp.

Cirripedia
- unid. barnacle cypris larvae
- *Lepas* sp.
- *Lepas fascicularis*

Stomatopoda
- unid. stomatopod larvae

Mysidacea
- unid. mysids
- *Neomysis americana*
- *Mysidopsis bigelowi*
- *Heteromysis formosa*
- *Siriella thompsoni*
- *Pseudomma* sp.

Cumacea
- unid. cumaceans
- *Diastylis quadrispinosa*
- *Diastylis sculpta*
- *Campylaspis rubicunda*

Isopoda
- *Idotea baltica*
- *Idotea metallica*
- *Cirolana polita*
- *Cirolana impressa*
- unid. isopods

Amphipoda
- unid. gammarid
- unid. hyperiid
- *Hyperia* sp.
- *Hyperia leptura*
- *Hyperia medusarum*
- *Hyperoche mediterranea*
- *Hyperoche capunicus*
- *Hyperoche martinezii*
- *Parathemisto gaudichaudii*
- *Hypereitta* sp.
- *Hypereitta vosseleri*
- *Hyperitta stephenseni*
- *Lestrigonus* sp.
- *Lestrigonus bengalensis*
- *Lestrigonus crucipes*
- *Lestrigonus latissimus*
- *Lestrigonus schizogeneosis*
- *Phronima atlantica*
- *Phronima colletti*
- *Phronima pacifica*
- *Phronimella elongata*
- *Phrosina semilunata*
- *Anchylomera blossevilli*

Table 4-22. (continued)

Amphipoda (continued)
Primno sp.
Primno rectumenus
unid. parascelid
Thyropus sp.
Thyropus sphaeroma
Parascelus sp.
Parascelus edwardsi
Lycaea pulex
Brachyscelus sp.
Brachyscelus crusculum
Brachyscelus rapacoides
Brachyscelus macrocephalus
Tryphana malmi
unid. platyscelid
Paratyphis parrus
Tetrathyrus foreipatus
Platyscelus serratulus
Hemityphis rapax
Amphithyrus sp.
Streetsia steenstrupi
Streetsia porcella
Streetsia mindanaonis
Oxycephalus sp.
Oxycephalus clausi
Oxycephalus piscator
Rhabdosoma armatum
Rhabdosoma whitei
Calamorhynchus pellucidus
Cranocephalus sp.
Leptocotis tenuirostris
Tullbergella cuspidata
Glossocephalus milne-edwardsi
Paraphronima gracilis
Lycaeopsis sp.
Lycaeopsis themistoides
Lycaeopsis zamboangae
Lycaeopsis neglecta
unid. pronoid
Eupronoe sp.
Eupronoe armata
Eupronoe minuta
Sympronoe parva
Paralycaea sp.
Vibilia sp.

Euphausiacea
unid. euphausiids
Euphausia sp.
Euphausia krohnii
Euphausia mutica
Euphausia brevis
Euphausia tenera
Euphausia americana
Meganyctiphanes norvegica
Nematoscelis sp.
Nematoscelis megalops
Nematoscelis microps
Thysanoessa sp.
Thysanoessa gregaria
Thysanoessa longicaudata
Thysanopoda obtusifrons
Stylocheiron carinatum
Stylocherion suhmii

Decapoda
Solenocera sp.
Lucifer faxoni
Lucifer typus
Leptochela bermudensis
Leptochela papulata
Leander tenuicornis
Palaemonetes sp.
Brachycarpus biunguicalatus
Hippolyte sp.
Hippolyte coerulescens
Latreutes fucorum
Eualus pusiolus
Crangon septemspinosa
Pontophilus brevirostris
Upogebia affinis
Naushonia crangonoides
unid. axiid
Munida sp.
unid. pagurids
Emerita sp.
Dromidia antillensis
Homola barbata
unid. leucosiid
Arenaeus cribrarius
Bathynectes superba

Table 4-22. (continued)

Decapoda (continued)
Callinectes sp.
Ovalipes sp.
Portunus sayi
Carcinus maenus
Cancer sp.
Eurypanopeus depressus
Hexapanopeus angustifrons
Neopanope sp.
Geryon quinquidens
Uca sp.
Libinia sp.

CHAETOGNATHA
Sagitta sp.
Sagitta elegans
Sagitta enflata
Sagitta hispida
Sagitta tenuis
Sagitta tasmanica
Sagitta decipiens
Sagitta helenae
Sagitta hexaptera
Sagitta minima
Sagitta serratodentata
Eukrohnia hamata
Krohnitta subtilis
Pterosagitta draco

TUNICATA
unid. doliolids
Doliolum nationalis
Thalia democratica
Salpa fusiformis
Oikopleura sp.

PISCES
unid. fishes
Elops saurus
unid. leptocephalus
Pisodonophis cruentifer
unid. engraulids
Anchoa sp.
Anchoa hepsetus
Anchoa mitchilli
unid. stomiatoid
Vinciguerria sp.

PISCES (continued)
unid. synodontid
Trachinocephalus myops
unid. myctophids
Ceratoscopelus maderensis
Myctophum punctatum
Lophius americanus
unid. antennariid
Urophycis sp.
Merluccius sp.
unid. ophidiids
unid. carapid
Hirundichthys affinis
Ablennes hians
Hippocampus sp.
Syngnathus sp.
Syngnathus fuscus
Syngnathus pelagicus
Prionotus sp.
Centropristis striata
Pomatomus saltatrix
unid. carangid
Seriola sp.
Decapterus sp.
Coryphaena sp.
Coryphaena hippurus
Cynoscion regalis
Hemipteronotus sp.
Astroscopus guttatus
Hypsoblennius hentzi
Callionymus bairdi
unid. gobiid
unid. scombrid
Sarda sarda
Peprilus triacanthus
unid. bothid
Etropus microstomus
Syacium sp.
Citharichthys arctifrons
Bothus sp.
Hippoglossina oblonga
Glyptocephalus cynoglossus
Symphurus plagiusa
unid. ostraciid

Table 4-23. Numerically dominant zooplankters in summer 1976 collections (BLM04W) (D = day, N = night).

Station C1

Bongo 202	Bongo 505	Neuston 505
Labidocera aestiva	*L. aestiva*	*L. aestiva* (4N,4D)
Acartia tonsa	*Evadne tergestina*	*E. tergestina* (2N,2D)
Centropages typicus	*C. typicus*	*C. typicus* (1N,3D)
		Uca sp. (2N)
		Callinectes sp. (2D)
		Penilia avirostris (1N,1D)
		Ovalipes sp. (1N)
		Doliolum nationalis (1N)

Station D1

Bongo 202	Bongo 505	Neuston 505
C. typicus	*C. typicus*	*L. aestiva* (4N,1D)
Oncaea sp.	*Sagitta enflata*	*Pontella meadii* (4D)
Paracalanus parvus	*Eucalanus pileatus*	*P. avirostris* (3N,1D)
		unid. fish eggs (3D)
		Lestrigonus bengalensis (3N)
		Diphyes dispar (2D)
		C. typicus (1N)
		Centropages furcatus (1N)
		Sagitta enflata (1D)

Station N3

Bongo 202	Bongo 505	Neuston 505
C. typicus	*Oikopleura* sp.	*C. typicus* (3N,2D)
Oikopleura sp.	*C. typicus*	*L. aestiva* (4N)
Parathemisto gaudichaudii	*Doliolum nationalis*	*Callinectes* sp. (3N)
		P. meadii (3D)
		Urophycis sp. (2D)
		D. nationalis (1N,1D)
		Pomatomus saltatrix (1D)
		Lucifer faxoni (1D)
		P. gaudichaudii (1D)
		P. avirostris (1D)

Table 4-23 (concluded)

Station E3

Bongo 202	Bongo 505	Neuston 505
P. parvus	*Thalia democratica*	*Urophycis* sp. (1N,4D)
Metridia lucens	*Candacia armata*	*C. typicus* (2N,1D)
C. typicus	*C. typicus*	*P. meadii* (3D)
		T. democratica (2N,1D)
		P. avirostris (2N,1D)
		unid. fish eggs (2D)
		L. aestiva (2N)
		Nannocalanus minor (1N)
		C. armata (1N)
		Atlanta peroni (1N)

Station F2

Bongo 202	Bongo 505	Neuston 505
P. parvus	*C. finmarchicus*	*P. meadii* (3N,4D)
C. typicus	*Pleuromamma gracilis*	unid. fish eggs (3D)
Calanus finmarchicus	*M. lucens*	*C. typicus* (3N)
		Urophycis sp. (2D)
	Bongo 505 (2nd tow)	*Idotea metallica* (2D)
		L. aestiva (2N)
	C. finmarchicus	*L. faxoni* (1D)
	N. minor	*N. minor* (1N)
	M. lucens	*P. gracilis* (1N)
		P. gaudichaudii (1N)
		Labidocera acutifrons (1N)

Station J1

Bongo 202	Bongo 505	Neuston 505
P. parvus	*N. minor*	*P. meadii* (4D)
C. typicus	*C. typicus*	*I. metallica* (3D,1N)
Acartia danae	*Sagitta tasmanica*	unid. fish eggs (1N,2D)
		C. typicus (2N,1D)
		Urophycis sp. (1N,2D)
		N. minor (2N)
		L. faxoni (2N)
		Paedoclione doliiformes (1N)
		L. aestiva (1N)

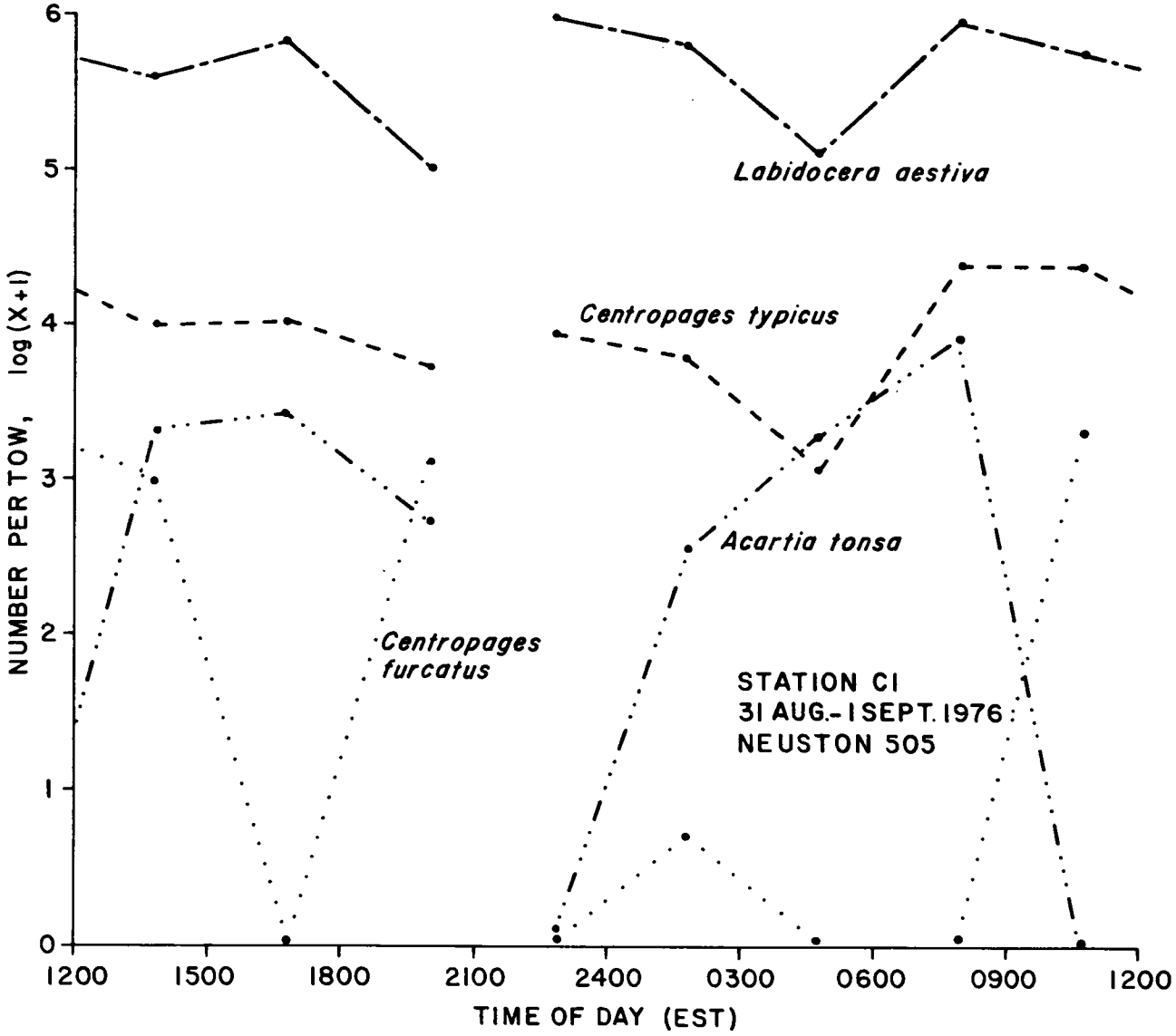

Figure 4-36. Diel cycle of abundance of dominant copepods in the surface layer of Station C1, BLM04W.

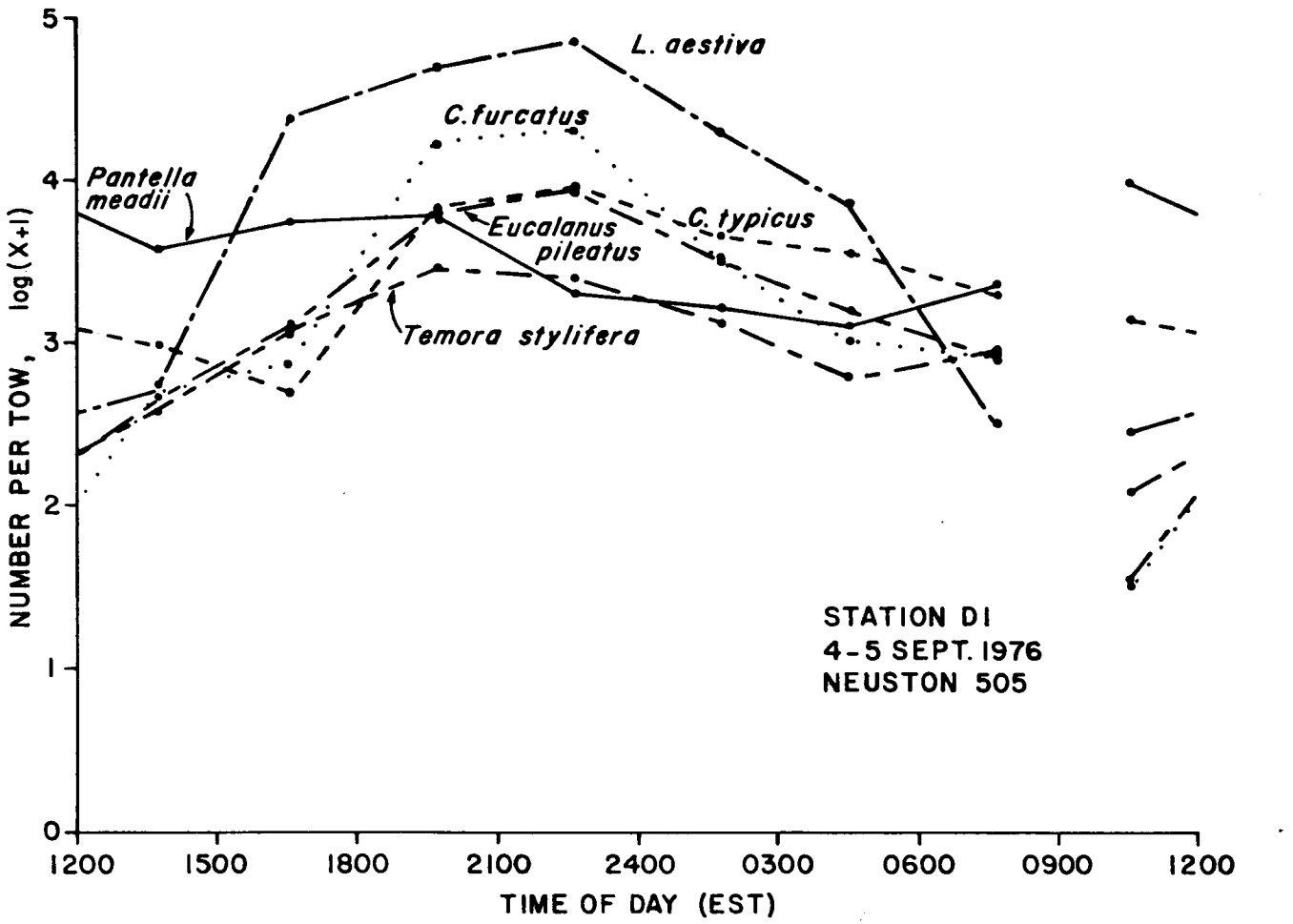

Figure 4-37. Diel cycle of abundance of dominant copepods in the surface layer of Station D1, BLM04W.

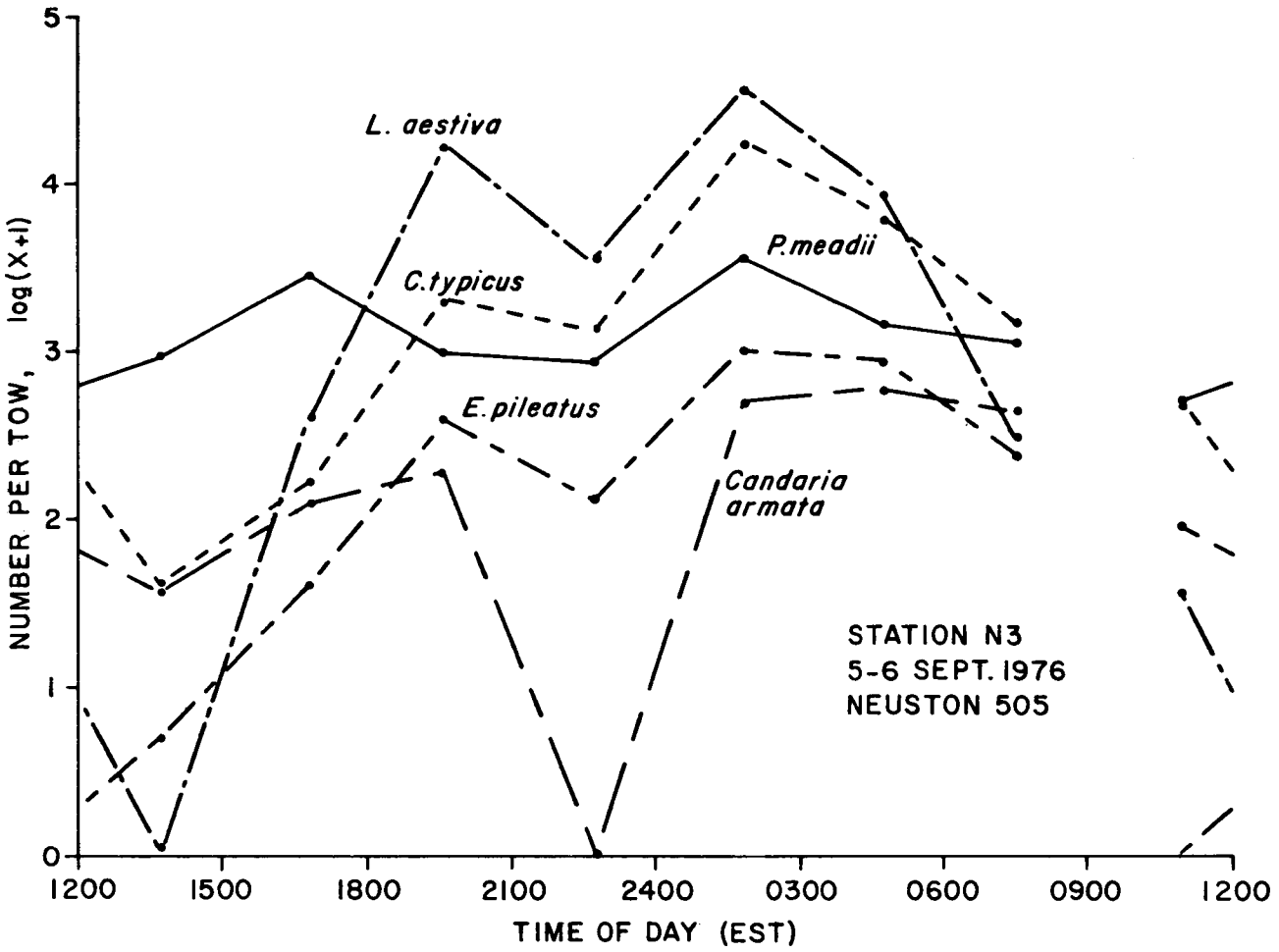

Figure 4-38. Diel cycle of abundance of dominant copepods in the surface layer of Station N3, BLM04W.

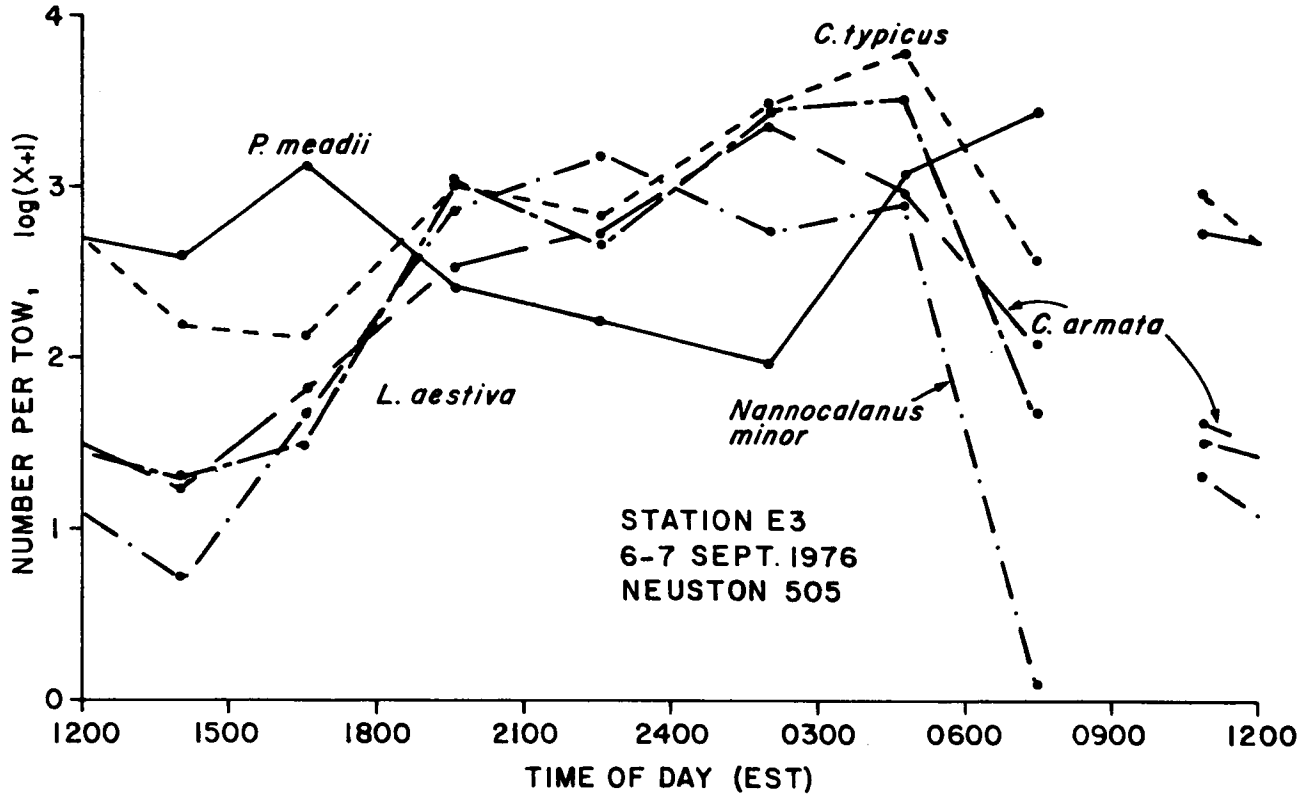

Figure 4-39. Diel cycle of abundance of dominant copepods in the surface layer of Station E3, BLM04W.

and unidentified fish eggs. Chaetognaths and euphausiids were relatively more important in subsurface collections.

Station F2. Copepods dominated six of the eight neuston collections and all three bongo collections. One neuston tow was dominated by fish eggs and one by the sergestid decapod *Lucifer faxoni*. Dominant copepods in neuston collections (Figure 4-40) included *Pontella meadii* (5 tows, pre-dawn and daytime), *Nannocalanus minor*, *Pleuromamma gracilis*, and *Centropages typicus*. Other important neustonts included larvae of *Urophycis* sp. and the isopod *Idotea metallica*. The bongo 202 collection, as at the previous station, was dominated by *Paracalanus parvus*, while both bongo 505 collections were dominated by *Calanus finmarchicus*. Chaetognaths, amphipods, and euphausiids were generally more important in bongo collections.

Station J1. At the slope station, copepods were dominant in all collections. Important species included *Pontella meadii* (dominant in 3 neuston tows), *Centropages typicus* (3 neuston tows), *Labidocera aestiva* (1 neuston tow), *Nannocalanus minor* (1 neuston tow and the bongo 505), and *Paracalanus parvus* (bongo 202). Diel cycles of selected copepods from the surface layer are shown in Figure 4-41. Other important neustonts included *Idotea metallica*, unidentified fish eggs, larvae of *Urophycis* sp., and *Lucifer faxoni*. Euphausiids, chaetognaths, and ostracods were relatively more abundant in subsurface collections.

Community Analysis

Frequency of Occurrence and Abundance. The most frequent and abundant species from summer bongo collections are listed in Table 4-24, those from neuston collections in Table 4-25. Six of the 19 taxa occurring in 50% or more of the neuston collections are absent from the list of subsurface species. These are the euneustonic *Pontella meadii* and *Idotea metallica*, the larval stages of commercially important blue crabs, *Callinectes* sp., and bluefish, *Pomatomus saltatrix*, and the pelagic molluscs *Paedoclione doliiformis* and *Atlanta peroni*. The most abundant species in both lists is *Labidocera aestiva*, a vertically migrating pontellid copepod, which occurred in 90% of the neuston collections, but only 54% of the bongo tows. *Centropages typicus*, probably the most important copepod in the Middle Atlantic Bight, occurred in all neuston and bongo collections, ranking second and third in abundance, respectively. *Acartia tonsa* ranked second in abundance in bongo collections (mostly 202 nets), and the cladoceran *Evadne tergestina* ranked fourth in both lists. Another cladoceran, *Penilia avirostris*, was third in abundance in surface layer collections. Hakes (*Urophycis* sp.) and the sergestid *Lucifer faxoni* were frequent in both types of collections, but abundant only in the neuston.

Diversity. Three measurements of diversity for each summer collection are given in Table 4-26. Shannon indices ranged from 0.3425 from a daytime neuston tow at Station C1 to 4.1128 from a bongo 505 at Station D1. Diversity was generally somewhat higher in subsurface collections than in neuston collections. Exceptions occurred at the offshore stations F2 and J1 where a few night neuston tows had higher H' estimates.

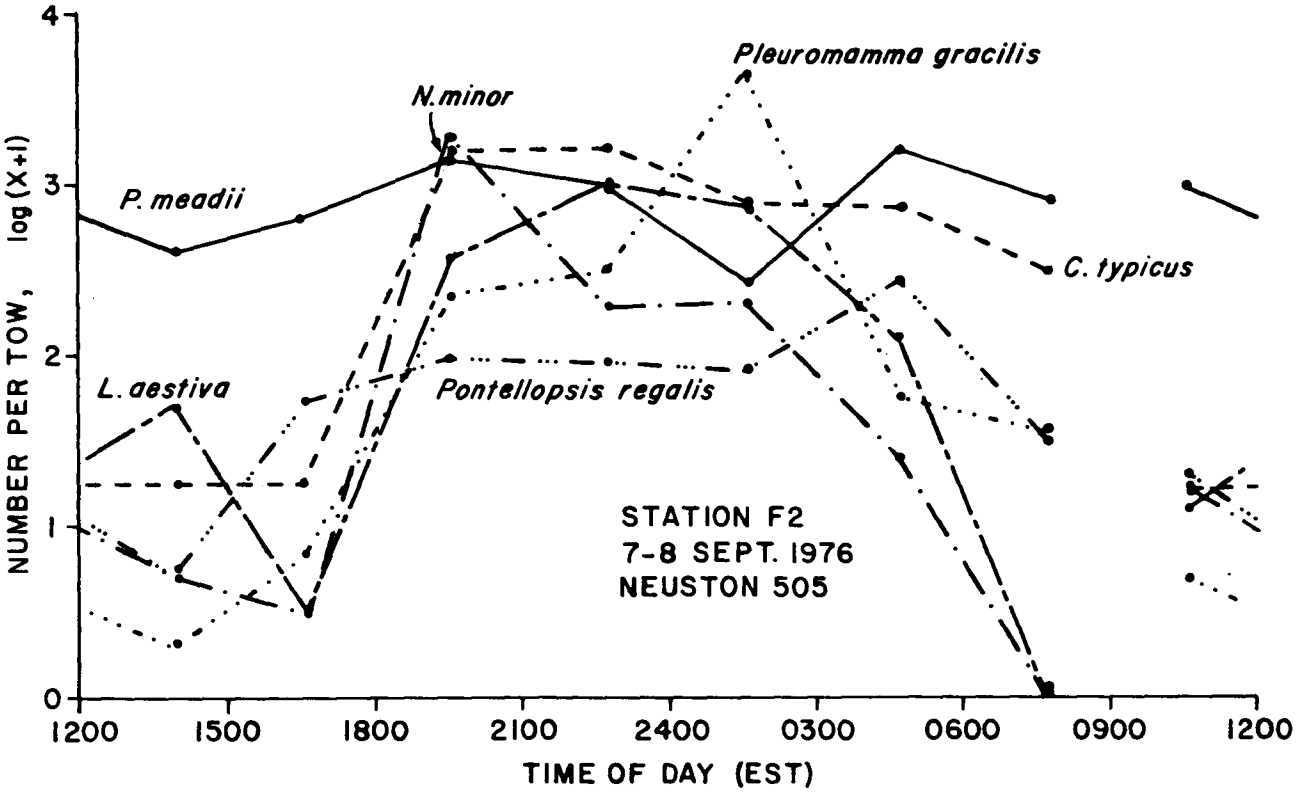

Figure 4-40. Diel cycle of abundance of dominant copepods in the surface layer of Station F2, BLM04W.

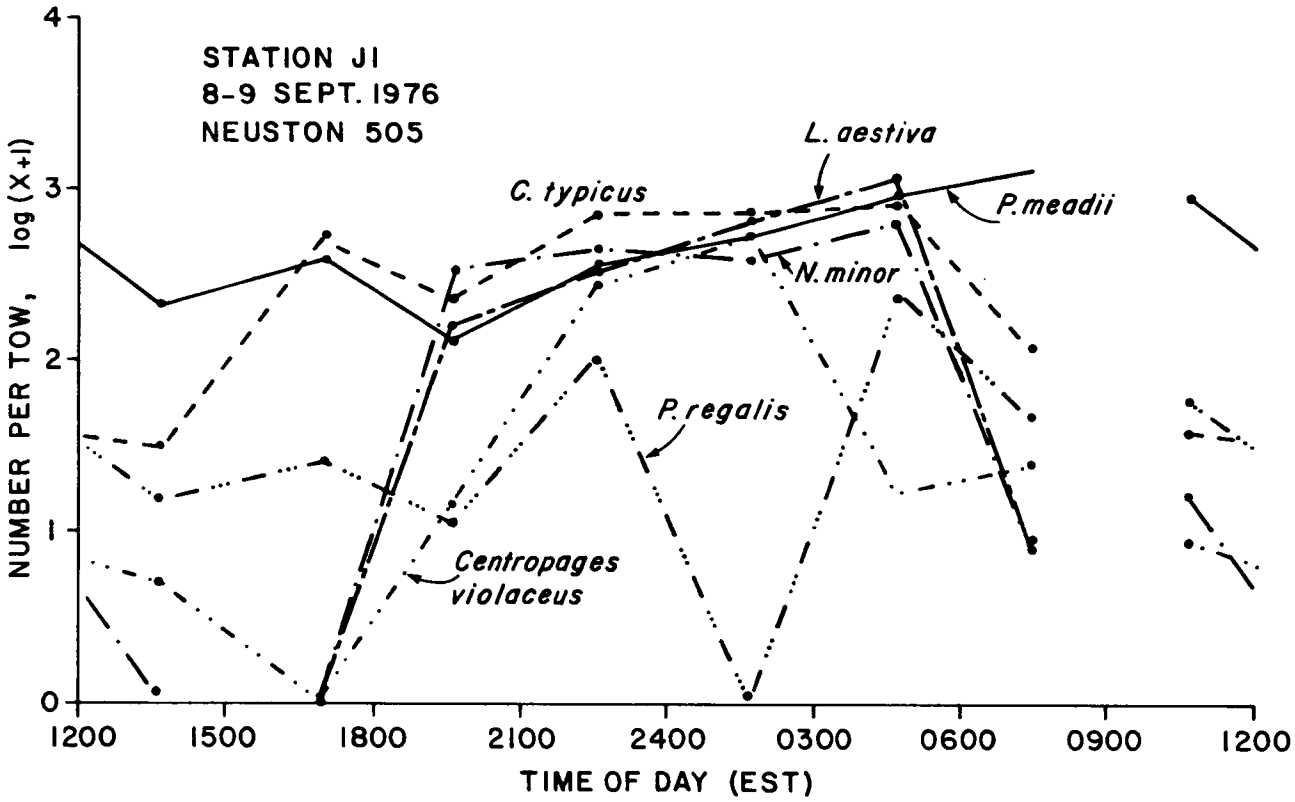

Figure 4-41. Diel cycle of abundance of dominant copepods in the surface layer of Station J1, BLM04W.

Table 4-24. Frequency of occurrence and rank of abundance of common species in bongo collections, summer 1976.

Species	Percent Occurrence	Rank Abundance	Maximum Number per $100m^3$
Centropages typicus	100	3	244,894
Lucifer faxoni	100	-	483
Nannocalanus minor	92	6	9,603
Sagitta enflata	92	14	3,909
Urophycis sp.	92	-	262
unid. ophidiid	92	-	53
Candacia armata	85	10	2,168
Parathemisto gaudichaudii	85	19	2,423
Sagitta tasmanica	85	29	462
Lestrigonus bengalensis	85	-	1,004
Cancer sp.	85	-	157
Stomatopod larvae	85	-	154
Citharichthys arctifrons	85	-	369
Oikopleura sp.	62	7	7,641
Calanus finmarchicus	62	8	3,660
Sagitta elegans	62	21	1,695
Labidocera aestiva	54	1	561,817
Paracalanus parvus	54	5	11,195
Metridia lucens	54	12	2,153
Thalia democratica	54	17	2,231
Centropages violaceus	54	30	470
Doliolum nationalis	46	18	6.678
Penilia avirostris	46	24	1,534
Acartia danae	38	9	2,552
Centropages furcatus	38	15	4,802
Eucalanus pileatus	38	23	4,802
Evadne tergestina	31	4	136,852
Oithona sp.	31	11	2,551
Temora stylifera	31	25	2,446
Undinula vulgaris	31	28	4,802
Mecynocera clausi	23	20	1,679
Calocalanus pavo	23	22	1,342
Acartia tonsa	15	2	436,969
Oncaea sp.	15	13	10,830
Eucalanus sp.	15	27	1,141
Paracalanus sp.	8	16	14,406

Table 4-25. Frequency of occurrence and rank of abundance of common species in neuston collections, summer 1976.

Species	Percent Occurrence	Rank Abundance
Centropages typicus	100	2
Urophycis sp.	96	11
Lucifer faxoni	96	13
Pontella meadii	92	9
Labidocera aestiva	90	1
Lestrigonus bengalensis	85	8
Callinectes sp.	83	6
Idotea metallica	81	25
Sagitta enflata	79	24
Stomatopod larvae	77	--
Candacia armata	75	22
Paedoclione doliiformis	69	--
Nannocalanus minor	67	17
Atlanta peroni	65	23
Eucalanus pileatus	54	12
Cancer sp.	54	--
Parathemisto gaudichaudii	50	21
Oikopleura sp.	50	27
Pomatomus saltatrix	50	--
Thalia democratica	48	29
Centropages violaceus	48	--
Centropages furcatus	46	10
Doliolum nationalis	46	15
Temora stylifera	46	19
Diphyes dispar	40	20
Penilia avirostris	38	3
Uca sp.	31	5
Ovalipes sp.	27	7
Pleuromamma gracilis	25	28
Evadne tergestina	21	4
Palaemonetes sp.	21	16
Emerita sp.	21	26
unid. pagurids	15	30
Acartia tonsa	13	14
Libinia sp.	13	18

Table 4-26. Diversity of zooplankton and neuston collections, BLM04W. 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
C1	Z76-213	B505, N	1.6912	0.3414	2.7596
	-214	B202, N	2.1185	0.3699	3.5346
	-215	Ns, N	0.6636	0.1488	1.5157
	-216	Ns, N	1.5362	0.2867	3.0670
	-217	Ns, N	1.6374	0.3098	3.1140
	-218	Ns, D	0.5543	0.1166	1.8808
	-219	Ns, D	0.4266	0.0832	2.5453
	-220	Ns, D	0.5688	0.1210	1.9320
	-221	Ns, D	0.3425	0.0792	1.2734
	-222	Ns, N	1.5481	0.2890	3.3728
D1	Z76-223	Ns, D	1.7632	0.3668	2.7982
	-224	Ns, D	2.9857	0.5869	3.4893
	-225	Ns, D	2.0245	0.4049	2.9254
	-226	Ns, N	2.8581	0.5370	3.3458
	-227	B505, N	4.1128	0.6448	5.8301
	-228	B202, N	3.6010	0.4529	3.8951
	-229	Ns, N	2.7079	0.4990	3.4534
	-230	Ns, N	2.9980	0.5428	4.0872
	-231	Ns, N	3.6670	0.6845	3.8113
	-232	Ns, D	3.1370	0.5817	4.1304
N3	Z76-233	Ns, D	2.8846	0.5938	3.7394
	-234	Ns, D	2.7820	0.5851	3.3411
	-235	Ns, D	2.7977	0.5647	3.4022
	-236	Ns, N	2.0430	0.4124	2.9465
	-237	B202, N	2.5428	0.4529	4.2113
	-238	B505, N	3.5966	0.5972	6.0003
	-239	Ns, N	2.9489	0.5435	4.4344
	-240	Ns, N	2.3629	0.4607	3.0108
	-241	Ns, N	2.8683	0.5136	4.4012
	-242	Ns, D	3.1399	0.6531	2.9795
E3	Z76-243	Ns, D	2.6280	0.5210	3.9438
	-244	Ns, D	2.7056	0.5569	3.5931
	-245	Ns, D	2.3692	0.4928	3.1462
	-246	Ns, N	3.0753	0.5344	5.7826
	-247	B505, N	3.1384	0.4871	7.7206
	-248	B202, N	4.0711	0.6837	5.4185
	-249	Ns, N	3.5691	0.6619	4.6453
	-250	Ns, N	3.0205	0.5438	4.8282
	-950	Ns, N	3.2536	0.5708	5.0096
	-251	Ns, D	2.1773	0.4211	3.9451

Table 4-26 (concluded)

Station	Collection Number	Type of Tow Day or Night	H'	J'	Richness
F2	Z76-252	Ns, D	1.7518	0.3873	2.9868
	-253	Ns, D	2.6861	0.5784	3.5707
	-254	Ns, D	2.8017	0.4964	5.9732
	-255	Ns, N	3.2232	0.5682	5.6220
	-256	B202, N	3.0209	0.4689	6.7444
	-257	B505, N	3.3546	0.5530	6.8596
	-258	Ns, N	3.2810	0.5784	5.7742
	-259	Ns, N	2.2370	0.4203	4.3582
	-260	Ns, N	3.5822	0.6040	6.4133
	-261	Ns, D	2.8873	0.6072	3.3438
	-262	B505, D	2.0109	0.3545	5.9761
J1	Z76-263	Ns, D	2.1534	0.4433	3.8429
	-264	Ns, D	2.9379	0.5987	4.6287
	-265	Ns, D	2.8548	0.6147	3.2726
	-266	Ns, N	3.7906	0.6618	6.9668
	-267	B505, N	3.2686	0.5264	7.5128
	-268	B202, N	3.4412	0.5275	7.5476
	-269	Ns, N	3.6805	0.6005	8.3804
	-270	Ns, N	3.5514	0.6088	6.5287
	-271	Ns, N	3.3928	0.5767	5.7573
	-272	Ns, N	2.2968	0.4728	3.5124

Evenness varied from 0.0792 at the Station C1 tow with low H' to 0.6845 from a night neuston tow at Station D1. These estimates are directly correlated with those of the Shannon index, so that information resulting from their calculation is somewhat redundant.

Species richness varied from 1.2734 to 8.3804 (Figure 4-42). The low estimate was from the same Station C1 collection yielding low H' and J' indices, a collection of 20 species, and over 3 million individuals, heavily dominated by *Labidocera aestiva*. The high index was also the high for the year and occurred in a night neuston collection from Station J1 containing 70 species and 3765 individuals.

Cluster Analyses. The large number of species encountered in summer collections exceeded the fixed limitations of our computer program for clustering and forced (1) the removal by hand of cards for species occurring in less than 9% of tows and (2) the omission of all species occurring in less than 18% of bongo tows. The usual cutoff of 9% was used for neuston collections.

I. Bongo tows.

A. Sample clusters. Similarity of the 13 bongo collections from BLM04W is shown in Figure 4-43. Companion 202 and 505 μm net collections at inner stations C1, D1, N3, and E3 were more similar than collections with a given mesh size at adjacent stations. At offshore stations F2 and J1, collections with equal mesh sizes linked first. The second bongo 505 at Station F2, a daytime tow, was most dissimilar within this cluster. Major clusters included one of inner shelf stations C1, D1, and N3 samples and a second that included samples from outer shelf and slope stations E3, F2, and J1. The nearshore station C1 samples were linked to inner shelf samples at a low level of similarity.

B. Species clusters. One hundred and sixteen taxa occurred in at least three of the 13 bongo collections and were included in the analysis. The inverse clustering of these taxa is shown in Figure 4-44, with a listing of clusters and species in Table 4-27. Last to be linked (most dissimilar) were mid- to outer shelf and slope species in clusters A and B to those in clusters C, D, and E, containing neritic species, widespread species, and species distributed over the inner and mid-shelf. Cluster C, containing species limited to the inner shelf, was most distinct from clusters D and E.

II. Neuston tows.

A. Sample clusters. Surface layer neuston samples are shown in Figure 4-45. The most distinct cluster in neuston samples was that consisting of Station C1 samples, followed by daytime neuston from outer stations F2 and J1. The third major division is between outer shelf and slope night tows and mid-shelf tows (these in turn divided into day and night tows).

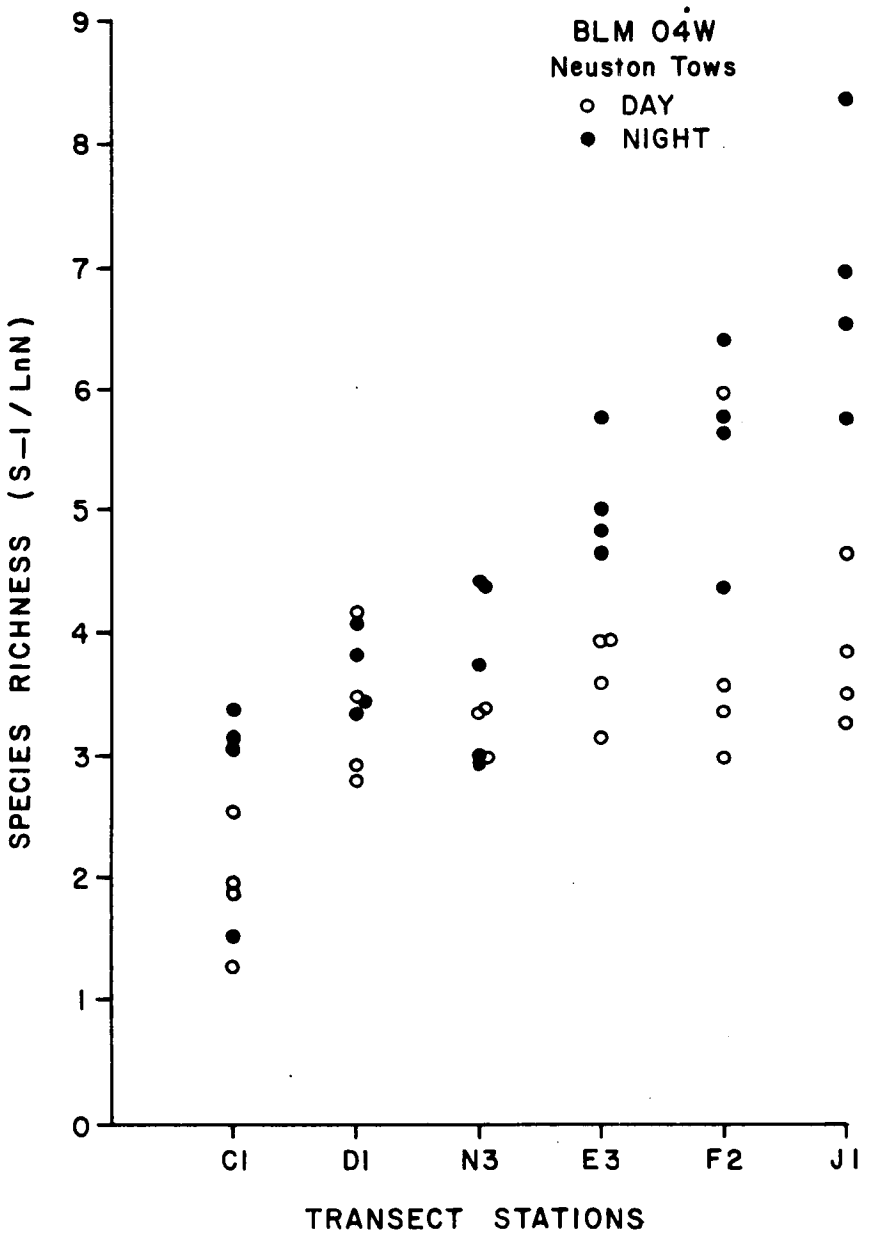

Figure 4-42. Species richness in neuston collections from the summer 1976 cruise, BLM04W. Stations (x-axis) arranged from inshore to offshore.

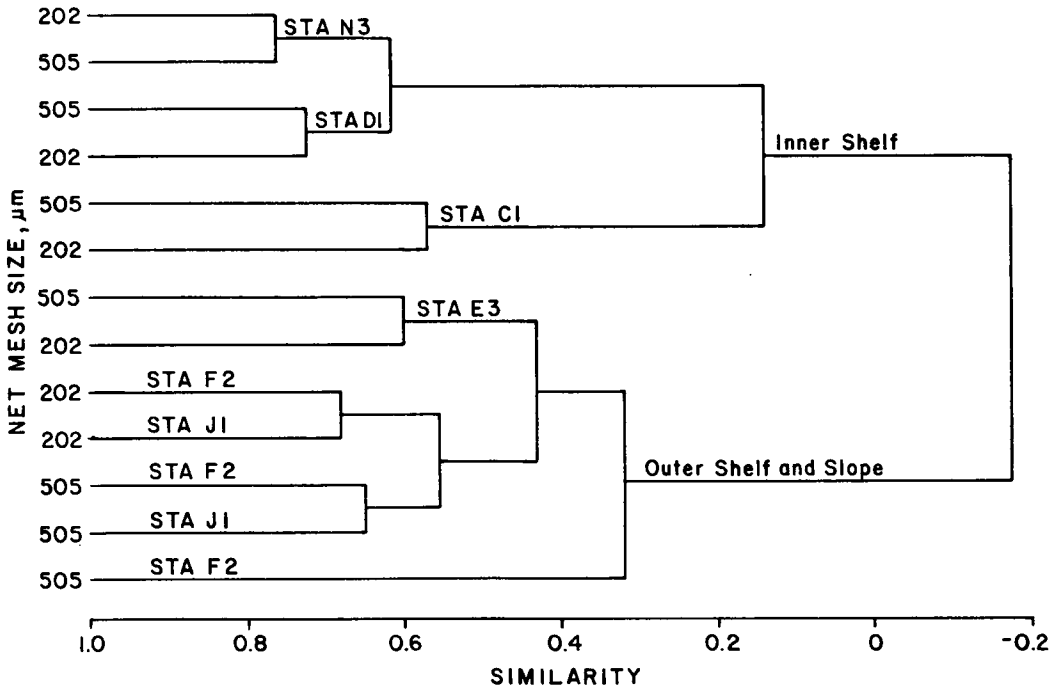

Figure 4-43. Bongo sample clusters, BLM04W, based on the Bray-Curtis coefficient of similarity, all identified species occurring in more than two samples, and catch data standardized to numbers per 100 m^3.

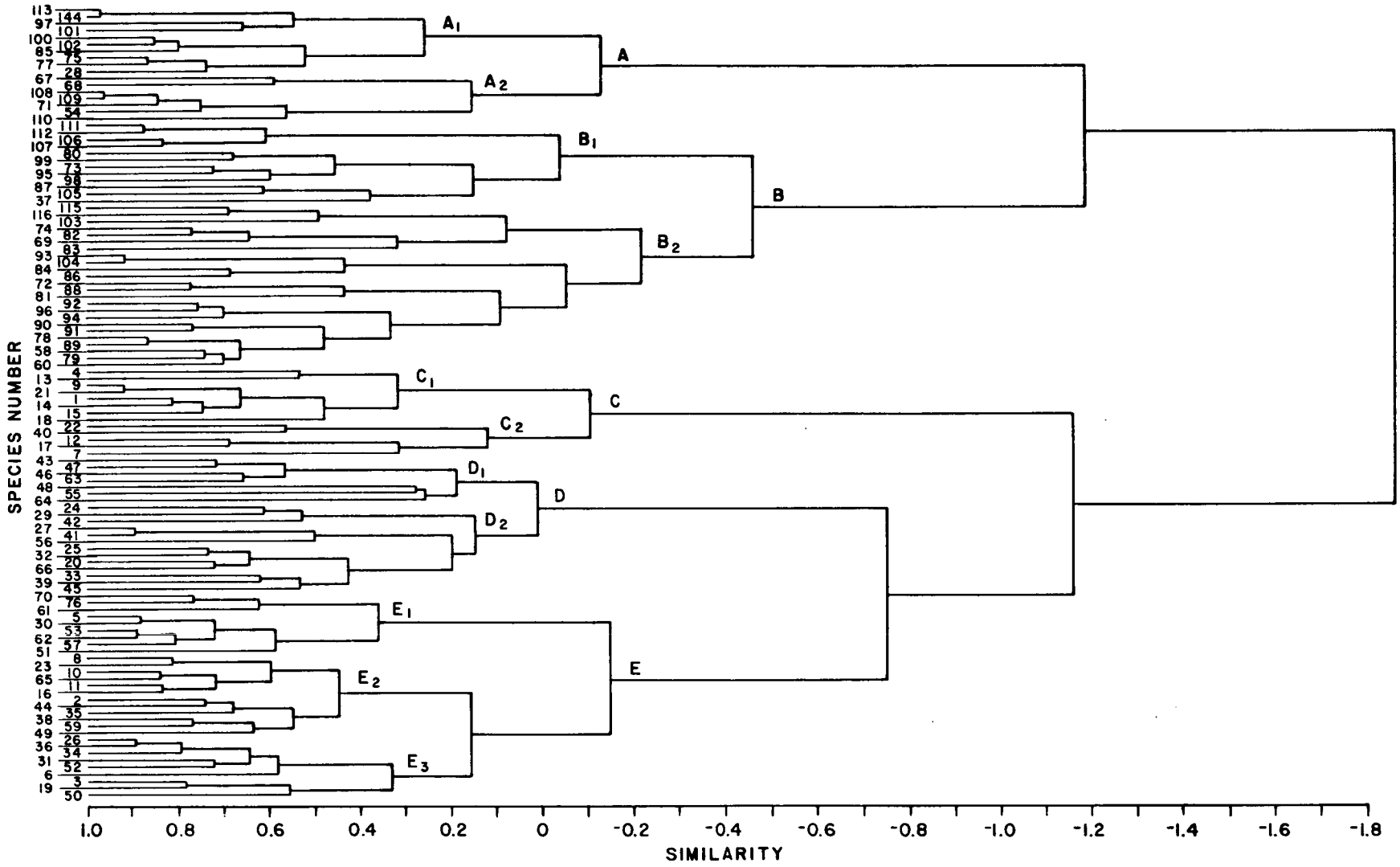

Figure 4-44. Inverse species clusters, bongo tows, BLM04W. See Table 4-27 for identification of species and clusters.

Table 4-27. Identification of species and clusters shown in Figure 4-44, bongo tows, BLM04W.

Cluster	Species No.	Species
A - Outer shelf and slope		
A_1 - larger species, taken in both 202 & 505 nets	113	*Thysanoessa* sp.
	114	*T. gregaria*
	97	*Euphausia krohnii*
	101	*Sagitta hexaptera*
	100	*Munida* sp.
	102	*Thalia democratica*
	85	*Metridia lucens*
	75	*Centropages violaceus*
	77	*Scolecithrix danae*
	28	*Rhincalanus nasutus*
A_2 - small species, taken mostly in 202 nets	67	*Spiratella inflata*
	68	*Clytemnestra scutellata*
	108	*Mecynocera clausi*
	109	*Calocalanus pavo*
	71	*Oithona* spp.
	54	*Acartia danae*
	110	*Corycaeus speciosus*
B - Mid-to outer shelf and slope		
B_1 - outer shelf and slope, few in number	111	unid. bivalve larvae
	112	*Euphausia tenera*
	106	*Diphyes bojani*
	107	*Abylopsis tetragona*
	80	*Thysanoessa inermis*
	99	*Pontophilus brevirostris*
	73	*Platyscelus sinatulus*
	95	*Eupronoe armata*
	98	*Lucifer typus*
	87	*Idotea metallica*
	105	*Chelophyes appendiculata*
	37	unid. fish larvae
B_2 - mid-to outer shelf and slope, mostly rare species	115	*Lepas* sp.
	116	*Brachyscelus crusculum*
	103	unid. myctophids
	74	*Hemipteronotus* sp.
	82	*Merluccius* sp.
	69	*Bothus* sp.
	83	unid. gobiids
	93	*Lycaeopsis zamboangae*
	104	unid. antennariids
	84	*Onykia caribaea*
	86	*Siriella thompsoni*
	72	*Primno rectumenus*
	88	*Phronima pacifica*
	81	*Stylocheiron suhmii*

Table 4-27 (continued)

Cluster	Species No.	Species
	92	*Hemityphis rapax*
	96	*Eupronoe minuta*
	94	*Lycaeopsis neglecta*
	90	*Anchylomera blossevilli*
	91	*Paratyphis parvus*
	78	*Phronima atlantica*
	89	*Phrosina semilunata*
	58	*Tetrathyrus forcipatus*
	79	*Phronimella elongata*
	60	*Styloceiron carinatum*
C - Neritic and Inner Shelf		
C_1 - abundant species*	4	*Evadne tergestina*
	13	unid. pagurids
	9	*Neomysis americana*
	21	*Prionotus* sp.
	1	*Beroe ovata*
	14	*Emerita* sp.
	15	*Uca* sp.
	18	*Sagitta tenuis*
C_2 - less abundant	22	*Pomatomus saltatrix*
	40	*Peprilus triacanthus*
	12	*Palaemonetes* sp.
	17	*Sagitta hispida*
	7	*Caligus* sp.
D - Scattered distribution,		
or neritic and inner shelf	43	*Tomopteris helgolandica*
D_1 - absent from Sta. C1,	47	*Cavolina uncinata*
extending to slope	46	*Spiratella trochiformis*
	63	*Sagitta minima*
	48	*Cavolina inflexa*
	55	*Euchaeta marina*
	64	unid. engraulids
D_2 - neritic, inner to	24	*Muggiaea kochei*
mid-shelf	29	*Undinula vulgaris*
	42	*Bassia bassensis*
	27	*Eucalanus crassus*
	41	*Diphyes dispar*
	56	*Copilia mirabilis*
	25	*Creseis acicula*
	32	*Sapphirina nigromaculata*
	20	unid. ophidiid
	66	*Hippoglossina oblonga*

**Acartia tonsa* and *Libinia* sp. were dropped from cluster analyses (13% occurrence).

Table 4-27 (concluded)

Cluster	Species No.	Species
	33	*Crangon septemspinosa*
	39	*Centropristis striata*
	45	*Firoloida leseurii*
E - Abundant species		
E_1 - mid-to outer shelf or ubiquitous	70	*Calanus finmarchicus*
	76	*Pleuromamma gracilis*
	61	*Sagitta elegans*
	5	*Centropages typicus*
	30	*Nannocalanus minor*
	53	*Candacia armata*
	62	*Sagitta tasmanica*
	57	*Parathemisto gaudichaudii*
	51	*Paracalanus parvus*
E_2 - ubiquitous species	8	stomatopod larvae
	23	*Etropus microstomus*
	10	*Lestrigonus bengalensis*
	65	*Citharichthys arctifrons*
	11	*Lucifer faxoni*
	16	*Sagitta enflata*
	2	gastropod larvae
	44	*Atlanta peroni*
	35	*Cancer* sp.
	38	*Urophycis* sp.
	59	unid. euphausiids
	49	*Paedoclione doliiformis*
E_3 - neritic and mid-shelf	26	*Eucalanus pileatus*
	36	*Doliolum nationalis*
	34	*Callinectes* sp.
	31	*Centropages furcatus*
	52	*Temora stylifera*
	6	*Labidocera aestiva*
	3	*Penilia avirostris*
	19	*Oikopleura* sp.
	50	*Evadne spinifera*

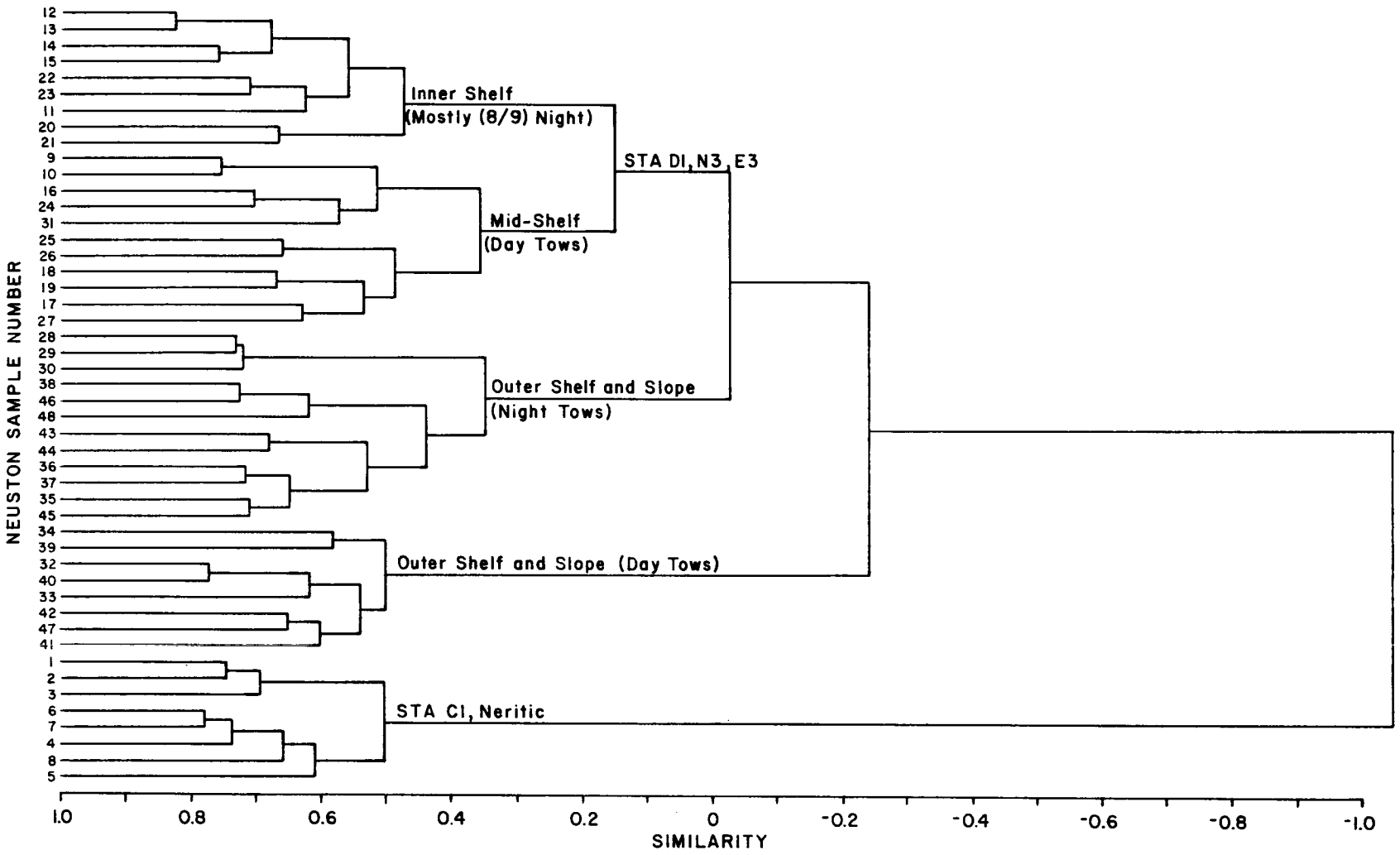

Figure 4-45. Neuston sample clusters, BLM04W, based on the Bray-Curtis coefficient of similarity and all identified species occurring in more than four neuston collections.

B. Species clusters. A total of 108 taxa occurred in five or more neuston collections and were included in the analysis. The inverse clustering of these species is shown in Figure 4-46, with a listing of clusters and contained species in Table 4-28. A group (cluster C) of ubiquitous dominants and inner shelf species was most distinct from the remainder of the species. Almost as distinct was a cluster (A) of neritic and inner shelf subdominants. The remaining and less abundant species (cluster B) were roughly divided into inner shelf and outer shelf and slope taxa.

DISCUSSION

Seasonal Succession of Zooplankton Communities

Throughout most of the year zooplankton communities of the shelf and slope, as evidenced by cluster analyses of bongo collections, fall into two types: 1) an inner shelf community that includes a fairly distinct near shore group of species and 2) a community of outer shelf and slope species. The only significant departure from this general pattern occurred in the fall of 1975 cruise when three distinct communities were evident: nearshore, mid-shelf, and a shelf-edge and slope community, the latter showing Gulf Stream influence. Neuston collections revealed similar distributions of communities, but cluster analyses showed a considerable difference between day and night collections. Subclusters of day and night collections within major clusters (communities) occurred regularly at all stations except the nearshore station C1.

Subsurface Copepods

Combining data from all cruises would be desirable to show similarity of samples between and maong seasons. However, the large number of species would require a very long, expensive computer run. Comparisons of data from all four cruises showed that cluster analyses of copepods along produced essentially the same results obtained in analyses incorporating all zooplankton species (a representative comparison is shown in Figure 4-47). Although some shuffling of individual samples occurred, the basic division of samples into major ecological groups was very similar in all comparisons. Therefore, the 53 bongo samples obtained during the first year were clustered, according to copepod distribution and abundance, to show seasonal similarity (Figure 4-48). The expected clean separation into four seasonal clusters of samples did not occur. The first division was between 24 samples, 19 of which were from inner shelf stations C1, D1, and N3, and 29 samples, 22 of which were from outer shelf and slope stations E3, F2, and F1. The inner shelf cluster was subdivided into five summer and fall neritic samples and 19 samples from winter and spring cruises. The outer shelf and slope cluster was first separated into seven tows at stations F2 and J1 from the fall, winter, and spring cruises and the remainder of outer shelf and slope collections. The latter were, in turn, comprised of subclusters characterized by mesh size, i.e. groups of samples primarily from either 202 μm or 505 μm mesh nets.

Using the similarity of bongo collections of copepods as a guide, it appears that 1) the nearshore fauna evident as a distinct community in

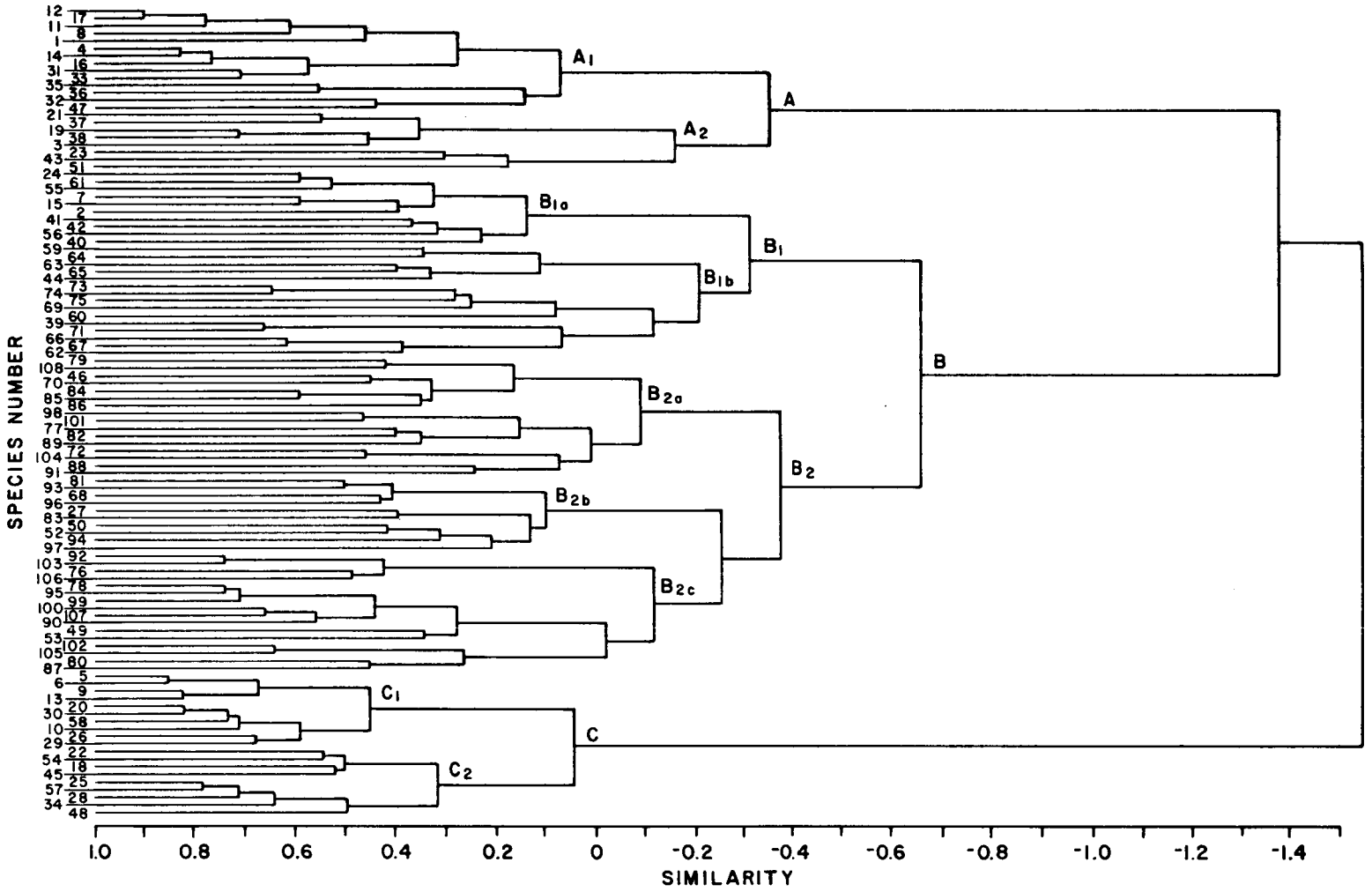

Figure 4-46. Inverse species clusters, neuston tows, BLM04W. See Table 4-28 for identification of clusters and species.

Table 4-28. Identification of species and clusters shown in dendrogram of neuston collections, Figure 4-46.

Cluster	Species No.	Species
A - Subdominant species, neritic and inner shelf		
A_1 - neritic, largely restricted to Sta. C1	12	unid. pagurids
	17	*Libinia* sp.
	11	*Palaemonetes* sp.
	8	*Neomysis americana*
	1	*Beroe ovata*
	4	*Evadne tergestina*
	14	*Ovalipes* sp.
	16	*Uca* sp.
	31	*Acartia tonsa*
	33	*Emerita* sp.
	35	*Sagitta hispida*
	36	*Sagitta tenuis*
	32	*Upogebia affinis*
	47	*Muggiaea kochei*
A_2 - inner shelf	21	*Prionotus* sp.
	37	unid. engraulids
	19	*Anchoa* sp.
	38	unid ophidiids
	3	*Loligo pealeii*
	23	*Aequorea aequorea*
	43	*Idotea baltica*
	51	unid. bivalve larvae
B - Species of lesser abundance		
B_1 - widely distributed and shelf species		
B_{1a} - widely distributed, more abundant at night	24	*Atlanta peroni*
	61	*Spiratella trochiformis*
	55	*Paedoclione doliiformis*
	7	stomatopod larvae
	15	*Cancer* sp.
	2	gastropod larvae
	41	*Creseis acicula*
	42	*Evadne spinifera*
	56	*Undinula vulgaris*
	40	unid. anidarians
B_{1b} - shelf forms (59-44 were more prevalent in day tows)	59	*Tetrathyrus forcipatus*
	64	*Pontellopsis villosa*
	63	*Clione limacina*
	65	*Euchaeta marina*
	44	*Hyperoche mediterranea*
	73	*Leptochela papulata*
	74	unid. fish larvae
	75	*Sapphirina nigromaculata*
	69	*Arenaeus cribrarius*
	60	*Sagitta elegans*
	39	*Etropus microstomus*

Table 4-28 (continued)

Cluster	Species No.	Species
	71	*Citharichthys arctifrons*
	66	*Firoloida leseurii*
	67	*Cavolina uncinata*
	62	*Cavolina longirostris*
B_2 - mid-to outer shelf and slope forms		
B_{2a} - outer shelf and slope, mostly night tows	79	*Acartia danae*
	108	*Spiratella inflata*
	46	*Bothus* sp.
	70	*Pterosagitta draco*
	84	*Metridia lucens*
	85	*Siriella thompsoni*
	86	unid. scombrids
	98	*Sagitta hexaptera*
	101	*Argonauta argo*
	77	*Dromidia antillensis*
	82	*Phronima atlantica*
	89	*Meganyctiphanes norvegica*
	72	*Leptochela bermudensis*
	104	*Phronima pacifica*
	88	*Cavolina inflexa*
	91	*Creseis virgula*
B_{2b} - shelf species, often more prevalent in day tows	81	*Chelophyes appendiculata*
	93	*Abylopsis tetragona*
	68	*Diphyes bojani*
	96	*Pontella securifer*
	27	*Paracalanus parvus*
	83	*Calanus finmarchicus*
	50	unid. euphausiids
	52	barnacle cypus larvae
	94	*Bassia bassensis*
	97	*Sapphirina ovatolanceolata*
B_{2c} - mid-to outer shelf and slope, usually more abundant at night	92	*Lycaeopsis zamboangae*
	103	*Atlanta fusca*
	76	*Corycaeus speciosus*
	106	*Scolecithrix danae*
	78	*Centropages violaceus*
	95	*Labidocera acutifrons*
	99	*Thalia democratica*
	100	*Pontellopsis regalis*
	107	*Pleuromamma gracilis*
	90	*Abylopsis eschscholtzii*
	49	*Parathemisto gaudichaudii*
	53	*Sagitta tasmanica*
	102	*Munida* sp.
	105	*Euphausia krohnii*
	80	*Latreutes fucorum*
	87	*Melampes bidentatus*

Table 4-28 (concluded)

Cluster	Species No.	Species
C - Dominant species		
C_1 - ubiquitous species	5	*Centropages typicus*
	6	*Labidocera aestiva*
	9	*Lestrigonus bengalensis*
	13	*Callinectes* sp.
	20	*Urophycis* sp.
	30	*Pontella meadii*
	58	*Idotea metallica*
	10	*Lucifer faxoni*
	26	*Nannocalanus minor*
	29	*Candacia armata*
C_2 - neritic and inner shelf	22	*Pomatomus saltatrix*
	54	*Diphyes dispar*
	18	*Doliolum nationalis*
	45	*Oikopleura* sp.
	25	*Eucalanus pileatus*
	57	*Temora stylifera*
	28	*Centropages furcatus*
	34	*Sagitta enflata*
	48	*Penilia avirostris*

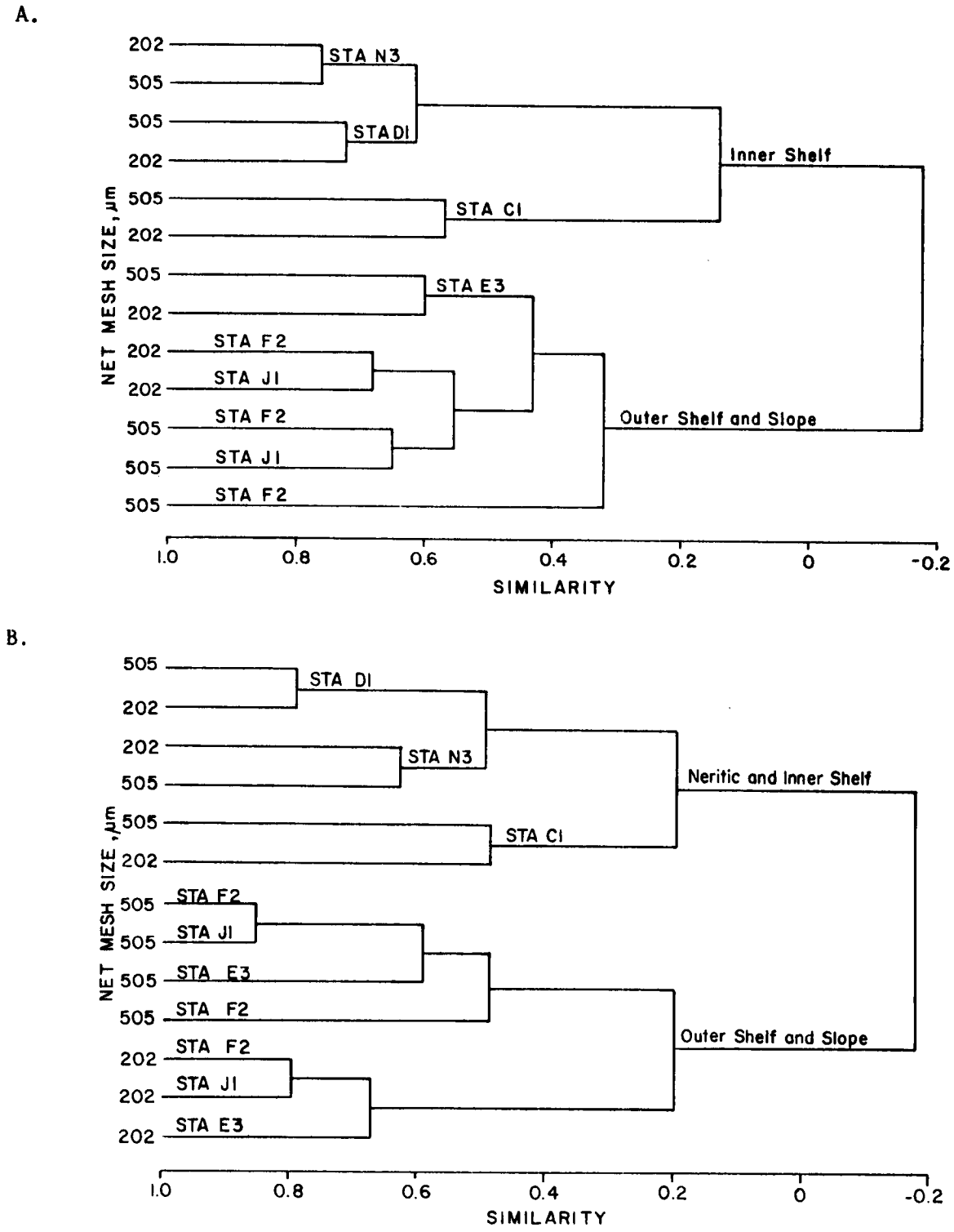

Figure 4-47. Results of cluster analyses of zooplankton data from BLM04W, using (A) all species, and (B) copepods only.

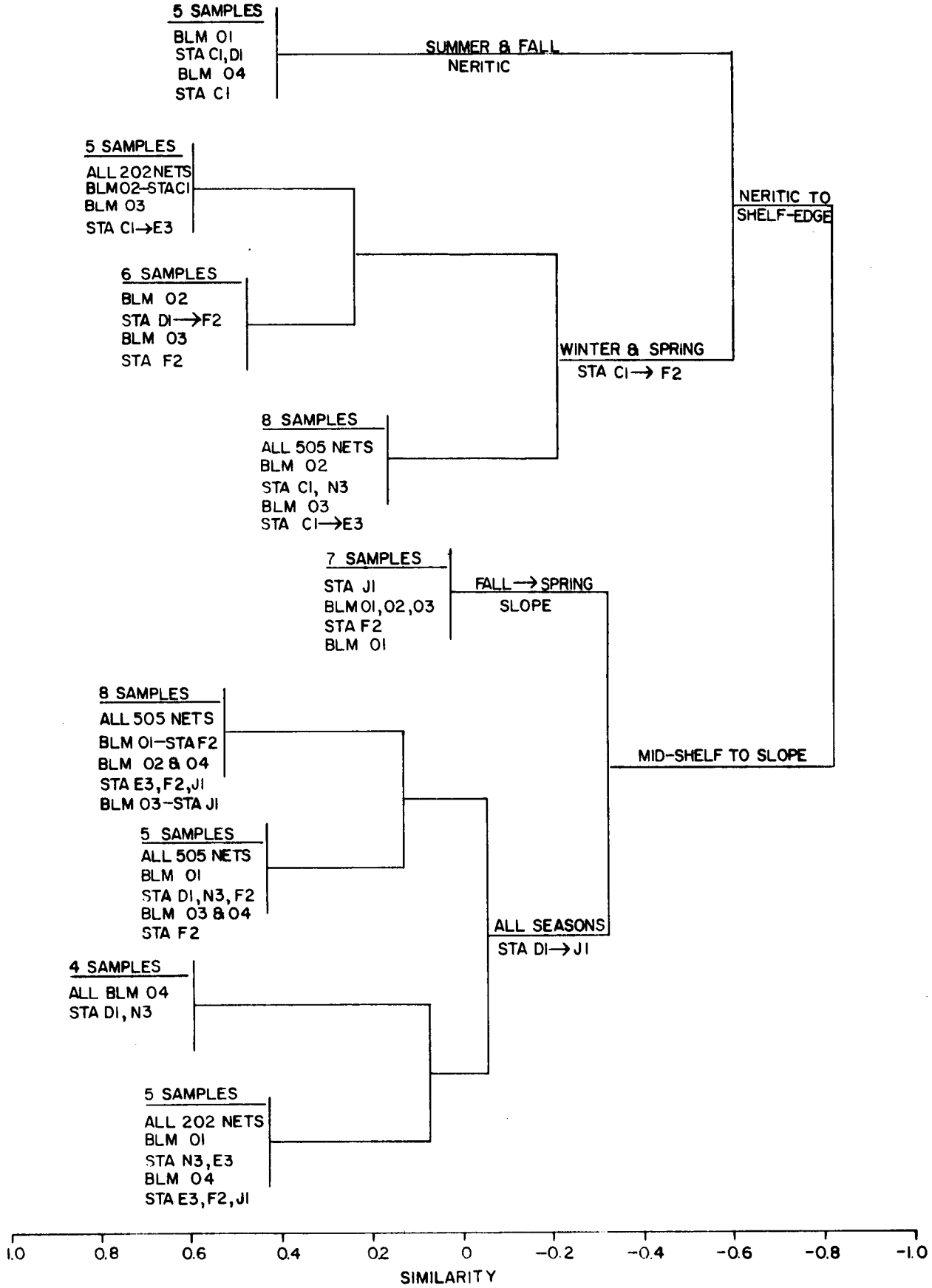

Figure 4-48. Bongo sample clusters, four seasonal cruises combined, based on the Bray-Curtis coefficient of similarity, copepods occurring in five or more samples, and catch data standardized to numbers

summer and fall is replaced by a more widespread inner shelf community in winter and spring, one that extends to Station E3, 2) the mid-shelf community of abundant and widespread species in summer and fall is displaced offshore to the shelf-edge and slope in winter and spring, and 3) the shelf-edge and slope fauna of fall collections was distinct and generally absent in other seasons.

The copepod species occurring in more than four bongo tows during the year and thereby retained in the inverse cluster of species are listed in Table 4-29. The principal division in this cluster analysis was between inner shelf species and a combination of widely-distributed, typical shelf species and outer shelf and slope species. Inner shelf species were split into three subclusters: 1) summer residents over the inner shelf, stations C1 to E3, 2) the coastal species *Acartia tonsa* and *Labidocera aestiva*, the latter extending over the mid-shelf in summer, and 3) a group of cold-water species largely restricted to the winter and spring seasons.

The group of four widely-distributed species are typical of shelf zooplankton collections and are separated in Table 4-29 from the following group of outer shelf species, with which they were linked at a relatively low level of similarity. This group is typified by *Centropages typicus*, present in all seasons and at all stations except F2 and J1 in the fall.

The last major cluster of outer shelf and slope species is divided into two subclusters: 1) a group of outer shelf species usually present year-round, but absent at the more coastal stations, and 2) three species more narrowly restricted to the shelf-edge and slope.

Surface Layer Copepods

A total of 194 neuston samples collected throughout the year were clustered as shown in Figure 4-49, based on the similarity of distribution and abundance of copepods, and standardized tows of 20 minutes. The primary division of samples was between one group of 56, including all summer collections and fall coastal collections, and the remainder of 138, including all winter and spring collections plus those from stations D1 through J1 from the fall cruise.

Four secondary clusters of the first group were 1) summer and fall samples from the coastal station C1, 2) daytime summer tows at stations N3 through J1, 3) summer night tows at stations E3 through J1, and 4) day and night summer tows at central shelf stations D1 through E3. The latter subcluster had a tertiary division into day and night tows.

The first division of the second group separated a distinct, small group of 16 fall samples from shelf break and slope stations F2 and J1 from the remaining 122 fall, winter, and spring samples. These 16 samples were from the offshore water type noted in bongo sampling. Remaining subclusters included 1) night tows from winter stations E3 through J1 and spring stations F2 and J1, 2) night tows from fall mid-shelf stations D1 through E3 combined with mid-shelf winter samples and outer shelf and slope spring samples, 3) mid-shelf, mostly daytime, fall samples, offshore winter samples and inner shelf spring samples, 4) combined mid-shelf fall and mid-shelf

Table 4-29. Seasonal and inshore-offshore distribution of the more common copepods from bongo tows, within clusters of species obtained from an inverse cluster analysis of 53 bongo collections.

Species	Station:	Fall						Winter						Spring						Summer					
		C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1
Inner Shelf Species																									
Eucalanus pileatus																				X	X	X			
Centropages furcatus																				X	X	X	X		
Sapphirina nigromaculata																				X	X	X	X		
Labidocera aestiva		X	X											X		X				X	X	X	X		
Acartia tonsa		X	X					X	X											X					
Pseudocalanus sp.								X	X	X	X			X	X	X	X	X	X		X				
Temora longicornis								X	X	X				X	X	X	X								
Centropages hamatus								X						X	X										
Tortanus discaudatus								X		X				X							X				
Widely-distributed Mid-shelf Species																									
Centropages typicus		X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Calanus finmarchicus			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Oithona sp.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Paracalanus sp.		X	X	X	X	X	X					X	X	X	X					X					
Outer Shelf and Slope Species																									
Candacia armata			X	X	X	X	X			X	X	X	X		X	X	X	X	X		X	X	X	X	X
Nannocalanus minor			X	X	X	X	X		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
Centropages violaceus				X	X	X					X	X	X			X	X	X	X			X	X	X	X
Metridia lucens					X	X			X	X	X	X	X			X	X	X	X				X	X	X
Pleuromamma gracilis							X				X	X	X					X	X			X		X	X
Eucalanus sp.				X	X	X	X		X	X	X	X	X											X	X
Rhincalanus nasutus					X	X	X				X	X	X										X	X	X
Scolecithrix danae						X	X					X											X	X	X
Pleuromamma robusta							X						X						X						X

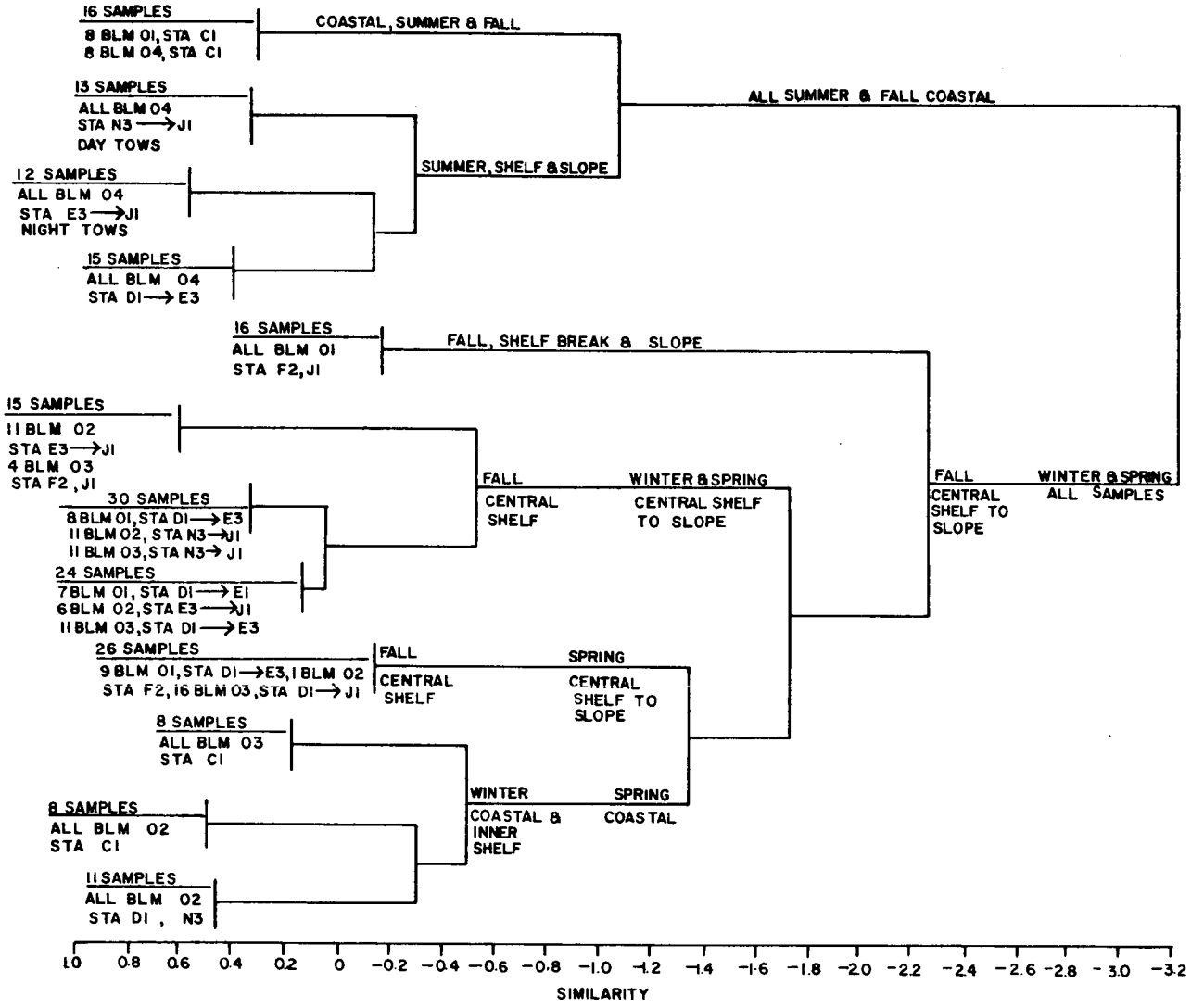

Figure 4-49. Neuston sample clusters, all seasonal cruises combined, based on the Bray-Curtis coefficient of similarity, copepods occurring in more than 9% of the samples, and total catches in standard 20-minute tows.

to slope spring samples, mostly daytime tows, 5) spring samples at the coastal station C1, 6) winter samples at Station C1, and 7) winter samples at inner shelf stations D1 and N3.

Closer inspection of the samples comprising the final clusters diagrammed in Figure 4-49 reveals a suggestion of the following seasonal succession: communities, represented here by copepods that were characteristic of the coastal station C1 in fall were replaced by a distinct cold water fauna that spread over the inner shelf in winter and persisted at Station C1 in spring. The fall coastal community reappeared at Station C1 in summer. Communities of the central shelf in fall were either displaced offshore in winter or disappeared from collections until spring. Summer mid-shelf communities were distinct from those of the rest of the year. The shelf-edge and slope community (stations F2 and J1) of fall collections was a unique one that did not reappear in other seasonal cruises.

Copepod species occuring in more than nine percent of the 194 neuston collections were included in an inverse cluster analysis and are listed in Table 4-30. The first division of species separated a small group of six copepods (those in the first two subclusters listed under Inner Shelf Species in Table 4-30) from the remaining 15 species. These included species associated with coastal water, such as *Acartia tonsa*, others restricted to nearshore except in summer, and two that occurred only in summer.

Among the remaining 15 species in the inverse analysis, the first to be separated were four winter-spring inner shelf copepods, then the three distinctly offshore pontellids that occurred only in summer and fall. The final eight species were evenly divided between widely-distributed shelf species, including *Centropages typicus*, and species characteristic of the outer shelf and slope.

Zooplankton and Hydrography

The Coastal Boundary Layer

Throughout the year, zooplankton at Station C1 was taxonomically distinct from fauna at other, more offshore stations. This station is located within the Coastal Boundary Layer (CBL) known to exist along the New Jersey coast (Csanady 1976). Zooplankton species in the CBL, either from nearshore and estuarine sources or from offshore sources, are restricted to the layer by shore-trapped flow structures. The width of the CBL probably varies seasonally, as evidenced by changes in the degree of similarity between fauna at Station C1 and central shelf stations D1 and N3. Demarcation of the CBL from central shelf waters, unfortunately, is not readily evident in plots of temperature, salinity, dissolved oxygen, or density (see Chapter 3 of this report). Station C1 fauna was most distinct in the fall (Figure 4-9) when, by inference, it may be assumed that the CBL was narrow and limited to waters inshore of Station D1, even though temperature was quite uniform at both stations C1 and D1, salinity and density increased steadily from the coast to the shelf break and dissolved oxygen differed only slightly between stations C1 and D1 (Figures 3-37 through 3-40, Chapter 3). Zooplankton may be the best

Table 4-30. Seasonal and inshore-offshore distribution of the more common copepods from neuston collections, within clusters of species obtained from an inverse cluster analysis of 194 neuston samples.

Species	Station:	Fall						Winter						Spring						Summer					
		C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1	C1	D1	N3	E3	F2	J1
Inner Shelf Species																									
Eucalanus pileatus								X	X					X						X	X	X	X	X	X
Temora stylifera																					X	X	X	X	
Centropages furcatus																				X	X	X	X	X	
Labidocera aestiva		X	X											X	X					X	X	X	X	X	X
Pontella meadii		X				X	X							X	X					X	X	X	X	X	X
Acartia tonsa		X	X					X	X	X				X	X					X					
Pseudocalanus sp.								X	X	X	X			X	X	X			X						
Temora longicornis								X	X	X				X	X	X	X	X	X						
Tortanus discaudatus								X	X	X				X	X		X								
Eucalanus sp.				X			X	X	X	X	X	X	X												
Widely-distributed Shelf Species																									
Calanus finmarchicus			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Metridia lucens				X	X	X	X		X	X	X	X	X	X	X	X	X	X	X				X	X	X	X
Centropages typicus		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Anomalocera patersonii		X	X	X	X	X	X				X	X	X	X	X	X	X	X	X					X		
Outer Shelf Species																									
Nannocalanus minor			X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Centropages violaceus					X		X			X	X	X	X			X	X	X	X			X	X	X	X
Candacia armata			X	X	X		X		X	X	X	X	X			X	X		X	X	X	X	X	X	X
Pleuromamma gracilis						X	X				X	X	X					X	X				X	X	X
Labidocera acutifrons				X		X	X																X	X	X
Pontellopsis regalis							X																X	X	X
Pontella securifer						X	X																X	X	X

indicators of this water type. Important species at Station C1 included *Labidocera aestiva* and *Acartia tonsa* (copepods), *Penilia avirostris* (cladoceran), *Neomysis americana* (mysid), and *Scophthalmus aquosus* and *Anchoa mitchilli* (fishes). In the winter, the primary faunal difference was between stations C1, D1, and N3 and outer stations E3, F2, and J1. Station C1 secondarily differed from central shelf stations D1 and N3, but fauna was more similar than in the fall (Figure 4-20), perhaps indicating a widening of the CBL. Important species were *Acartia tonsa* and *Tortanus discaudatus* (copepods), *Cancer* sp. (decapod larvae), *Tomopteris helgolandica* (polychaete), and unidentified bivalve larvae. Fishes in this inner shelf group included *Gadus morhua* and *Anguilla rostrata*.

In spring the CBL may have narrowed somewhat, judging from faunal similarities, although evidence is mixed. Bongo 505 collections at Station C1 differed distinctly from collections taken elsewhere on the transect, while species caught in the fine-meshed bongo 202 nets at stations C1, D1, and N3 were similar (Figure 4-32). Inshore species in the spring included *Centropages hamatus* and *Tortanus discaudatus* (copepods); unidentified gastropod larvae; larvae of several decapods, including *Ovalipes* sp., *Libinia* sp., pagurids, and *Crangon septemspinosa; Neomysis americana* (mysid), *Evadne nordmanni* (cladoceran), and the fishes *Syngnathus fuscus, Anchoa* sp., *Tautoga onitis, Tautogolabrus adspersus,* and *Lophius americanus*.

In summer, although the primary division of faunal types fell between stations N3 and E3 as in the winter and spring cruises, a secondary and rather sharp difference was evident between species at Station C1 and those at central shelf stations D1 and N3. *Acartia tonsa* and *Libinia* sp. were found only at Station C1. Others primarily from the inner station included *Evadne tergestina,* unidentified pagurid zoea, *Emerita* sp., *Palaemonetes* sp., and *Sagitta hispida*. Other inner shelf species were distributed primarily at stations C1 and D1 or at all three inner shelf stations.

Acartia tonsa was a conspicuous indicator of the CBL in all seasons except spring, when *Centropages hamatus* and *Tortanus discaudatus* were the copepods characteristic of nearshore waters. Density of these species in bongo tows is provided in Table 4-31. *Tortanus discaudatus* is reliable as an indicator only in spring, and then is useful only when caught with *C. hamatus*.

Central Shelf Fauna

Certain species are typical central and outer shelf inhabitants, and include some of the most abundant zooplankters in the survey. They were found in maximum abundance at stations D1, N3, or E3 and were often absent at either end, or both ends of the transect. *Centropages typicus* was the dominant member of this species group. Others included *Calanus finmarchicus, Sagitta elegans, S. tasmanica, Nannocalanus minor,* and *Parathemisto gaudichaudii*. Indicators are listed in Table 4-32.

The Shelf Break or Slope Boundary

A distinct, faunal boundary sometimes exists at the offshore end of

Table 4-31. Density of copepod indicators of the Coastal Boundary Layer off southern New Jersey, calculated from subsurface bongo tows.

Species	Season	Mesh Size	Numbers per $100m^3$ at Station					
			C1	D1	N3	E3	F2	J1
Acartia tonsa	Fall	202	461,000	710	0	0	0	0
		505	2,570	0	0	0	0	0
	Winter	202	24,100	0	0	0	341	0
		505	0	827	0	0	0	0
	Spring	202	0	0	0	0	0	0
		505	0	0	0	0	0	0
	Summer	202	437,000	0	0	0	0	0
		505	306	0	0	0	0	0
Centropages hamatus	Fall	202	0	0	0	0	0	0
		505	0	0	0	0	0	0
	Winter	202	415	0	0	0	0	0
		505	35	0	0	0	0	0
	Spring	202	26,200	1,430	0	0	0	0
		505	19-57 *	0	0	0	0	0
	Summer	202	0	0	0	0	0	0
		505	0	0	0	0	0	0
Tortanus discaudatus	Fall	202	0	0	0	0	0	0
		505	0	0	0	0	0	0
	Winter	202	0	0	4,970	0	0	0
		505	14	0	0	0	0	0
	Spring	202	0	0	0	0	0	0
		505	268-852 *	0	0	0	0	0
	Summer	202	0	699	0	0	0	0
		505	0	0	0	0	0	0

* Indicates values of two replicate tows.

Table 4-32. Density of typical Central Shelf zooplankters off southern New Jersey, calculated from subsurface bongo tows.

Species	Season	Mesh Size	Numbers per 100m³ at Station					
			C1	D1	N3	E3	F2	J1
Centropages typicus	Fall	202	125,000	35,700	3,480	46,500	<1	0
		505	2,150	2,980	73	3,320	0	0
	Winter	202	4,570	19,100	110,000	46,600	32,100	3,490
		505	35	13,000	10,300	24,800	11,000	2,390
	Spring	202	19,100	165,000	69,100	85,300	11,900	78
		505	7,760	21,800	10,200	5,820	722	77
	Summer	202	245,000	14,300	17,400	1,792	9,260	2,950
		505	2,140	3,290	1,400	754	321	542
Calanus finmarchicus	Fall	202	0	400	3,170	205	74	0
		505	0	693	579	9,770	1,030	0
	Winter	202	0	0	7,240	894	683	147
		505	13	561	2,480	427	398	147
	Spring	202	0	715	1,650	17,100	44,200	0
		505	57	683	281	6,660	979	115
	Summer	202	0	0	205	538	3,660	67
		505	0	0	99	0	1,700	86
Sagitta elegans	Fall	202	11	89	3,380	819	<1	0
		505	7	46	86	454	2	1
	Winter	202	564	1,100	16,600	128	16	0
		505	155	1,960	3,270	16	18	5
	Spring	202	589	7,820	4,730	4,810	3,040	20
		505	1,840	4,130	1,370	6,440	535	19
	Summer	202	0	66	58	0	1,700	2
		505	0	56	273	0	493	0

our sampling transect. This is more a function of depth and shelf-edge effects on water masses than the trapping of water seen in the CBL. Figure 4-9 shows that the fauna at Station J1, after eliminating the CBL (Station C1) was most distinct from remaining stations. The shelf-break station, F2, was intermediate. Species in this offshore element included *Pleuromamma gracilis, P. robusta, Metridia lucens,* and *Scolecithrix danae* (copepods); *Meganyctiphanes norvegica, Euphausia krohnii,* and *Nematoscelis atlantica* (euphausiids); *Sagitta enflata* (chaetognath); and a group of offshore fishes, including *Nemichthys scolopaceus,* unidentified myctophids, paralepidids, gobioids, *Syacium* sp. and *Bothus* sp.

This distinctly offshore element was lacking in winter (Figure 4-20), when fauna from outer shelf, shelf break, and slope stations are similar. However, certain of the species noted above for fall collections reoccurred in this group: *Pleuromamma gracilis, P. robusta, Meganyctiphanes norvegica,* and a paralepidid fish larva. *Sagitta enflata* was replaced by *S. hexaptera* and *S. minima.*

Station J1 was more distinct in spring collections (Figure 4-32), with carryovers in offshore species including *Pleuromamma gracilis, Euphausia krohnii,* unidentified myctophids, and *Sagitta hexaptera.* Other species included *Spiratella helicina* (thecosome); *Aetideus armatus, Pleuromamma abdominalis,* and *Rhincalanus nasutus* (copepods); *Thysanoessa gregaria, T. inermis,* and *Nematoscelis megalops* (euphausiids); *Tomopteris planctonis* (polychaete); and *Eukrohnia hamata* (chaetognath).

Shelf break and slope stations F2 and J1 were similar in summer collections, with the outer shelf station (E3) intermediate between offshore and inshore fauna. Reoccurring species included *Metridia lucens, Centropages violaceus, Scolecithrix danae,* and *Rhincalanus nasutus* (copepods); *Euphausia krohnii, Thysanoessa gregaria,* and *T. inermis* (euphausiids); and *Sagitta hexaptera* (chaetognath).

Useful indicators of this offshore water type include *Metridia lucens* and *Pleuromamma gracilis* (copepods), *Euphausia krohnii* and *Meganyctiphanes norvegica* (euphausiids), and *Sagitta hexaptera* (chaetognath). Total subsurface catches of four of these species, by season and station, are listed in Table 4-33. *Metridia lucens* extends over the shelf to central shelf locations in the cooler seasons of winter and spring. *Meganyctiphanes norvegica* also has an extended distribution in spring. These species in other seasons are more restricted to offshore stations. *P. gracilis, E. krohnii,* and *S. hexaptera* were more narrowly restricted to offshore stations throughout the year.

All of the above observations are based on subsurface bongo tows. It should be noted that species selected as indicators of both the CBL and offshore water types were often found, although in reduced numbers, over a much wider range in the surface layer (neuston tows).

Diversity Measurements

Diversity of zooplankton collected in oblique, subsurface bongo tows was usually higher than neuston collections at a given location (with

Table 4-33. Density of offshore indicators off southern New Jersey, calculated from subsurface bongo tows.

Species	Season	Mesh Size	Numbers per 100m³ at Station					
			C1	D1	N5	E3	F2	J1
Metridia lucens	Fall	202	0	0	0	0	<1	2,660
		505	0	0	0	2,150	0	493
	Winter	202	0	268	17,600	6,170	9,560	367
		505	0	89	1,570	6,230	2,080	569
	Spring	202	0	0	0	0	16,600	392
		505	0	0	38	938	1,010	3,070
	Summer	202	0	0	0	1,840	2,150	336
		505	0	0	0	94	607	24
Pleuromamma gracilis	Fall	202	0	0	0	0	0	9,110
		505	0	0	0	0	0	481
	Winter	202	0	0	0	268	0	433
		505	0	0	0	256	228	532
	Spring	202	0	0	0	0	0	2,350
		505	0	0	0	0	26	1,570
	Summer	202	0	0	0	0	1,080	67
		505	0	0	7	0	813	79
Euphausia krohnii	Fall	202	0	0	0	0	0	224
		505	0	0	0	0	0	983
	Winter	202	0	0	0	0	0	0
		505	0	0	0	0	0	<1
	Spring	202	0	0	0	0	0	118
		505	0	0	0	0	0	386
	Summer	202	0	0	0	0	<1	301
		505	0	0	0	<1	0	110
Meganyctiphanes norvegica	Fall	202	0	0	0	0	<1	2
		505	0	0	0	0	0	22
	Winter	202	0	0	0	0	0	5
		505	0	0	0	0	0	14
	Spring	202	0	75	0	117	320	<1
		505	<1	65	169	160	77	46
	Summer	202	0	0	0	0	0	117
		505	0	0	0	0	0	4

exceptions) and increased in an offshore direction. These differences are attributable to the passage of bongo samplers through various layers of water differing in hydrographic character (see profiles in Chapter 3). Physical parameters of the water column at the shelf break and slope stations are particularly complex, and a single oblique bongo tow may capture representatives of several different communities during its passage through the various water types. Discreet sampling of these water types would be required before the communities now lumped in single collections could be sorted out and identified.

Although several measures of diversity were calculated for each collection obtained through the year, Margalef's Index (species richness) appeared most suitable for these zooplankton data. Trends across the shelf evidenced from this index were more consistent than other indices, and were plotted for neuston collections for each of the four cruises (Figures 4-8, 4-19, 4-31, and 4-42). Comparison of these four figures shows a decided seasonal progression, with diversity increasing from winter to summer and from the coast to the slope in the warm seasons.

No consistent differences between collections made with 202 μm and 505 μm bongo nets were evident. Thirteen of 24 paired tows yielded Shannon indices (H') that were higher in 202 μm nets, whereas 15 of these pairs yielded species richness estimates that were higher in 505 μm nets. One-third of the paired comparisons between Shannon indices and species richness disagreed as to whether 202 μm or 505 μm collections were more diverse.

Trace Metals and Zooplankton

Mixed samples from bongo tows and individual species from neuston tows were analyzed for trace metals (see Chapter 8). The nine metals of interest were V, Cr, Fe, Ni, Cu, Zn, Cd, Ba, and Pb. Variability in the trace metal data was very high, a characteristic that must be kept in mind during the following remarks.

Levels of these metals in collections made with nets of different mesh sizes (202 μm and 505 μm) usually overlapped, but were generally higher in the fine-meshed collections. Exceptions incuded Ni, higher in winter; Cu and Zn, higher in spring; Fe, higher in summer; and Pb, higher in 505 samples in fall and summer. Generally higher levels in 202 nets, especially of Pb, Cd, Cu, and Ba could be due to presence of dinoflagellates in the mixed collections; higher Fe levels could suggest the presence of phytoplankton (Martin and Knauer 1973). The only elevated level of cadmium found in a mixed bongo collection occurred at Station J1 in the fall. Other elevated levels (Martin and Braenkow 1975) occurred in the neuston (*Velella velella* and *Idotea metallica*, also at J1).

The neustonic isopod *Idotea metallica* was collected at all seasons for trace metal analysis. Ranges of concentrations of the trace metals are given in Table 4-34. Compared with subsurface mixed-plankton collections obtained with comparable mesh sizes (bongo 505) and at the same stations, concentration levels in *I. metallica* were generally lower for vanadium, zinc, and lead, higher for chromium and cadmium. Whether these differences reflect differences in availability of trace metals between the subsurface and neuston layers

or are species specific is not presently known. Riley and Roth (1971) found no differences in trace metal distributions attributable to classification of 15 species of phytoplankton. Also, phytoplankton appear to have little effect on the concentrations of trace metals in water, with the exception of cadmium, which decreased during peak productivity in Monterey Bay, California (Knauer and Martin 1973). Farther up the food chain, however, the zooplankton may show increasing divergence in ability to concentrate various metals. Species composition of samples was found to be an important factor for Ba, Sr, Ca, Pb, Hg, Cu, Fe, and Zn by Martin and Knauer (1973). Needed are determinations of metal concentrations from a range of neustonic and subsurface zooplankters raised under controlled laboratory conditions.

Table 4-34. Concentration of trace metals (in ppm) in *Idotea metallica* collected from the surface layer of the Middle Atlantic Bight. Cruises BLM01W-BLM04W.

	Fall	Winter	Spring	Summer
Season:	1975	1976	1976	1976
Stations:	C1,D1	E3,F2,J1	C1-J1	D1-J1
Element	Concentration (µg/g)			
Vanadium*	ND	ND	ND	ND
Iron	47-227	174-205	48-106	19-78
Chromium**	0.4-3.6	0.8-13	0.6-3.7	0.4-1.8
Nickel	0.5-1.7	1.1-8.0	0.4-5.4	0.4-2.4
Copper	32-37	46-73	24-59	18-70
Zinc*	30-36	100-152	35-105	28-89
Cadmium**	2.6-5.8	5.5-11	2.8-11	1.6-4.1
Barium	ND	ND-50	ND	ND-18
Lead*	0.9-3.4	3.8-15	1.2-5.0	0.6-4.4

* Concentration generally lower than subsurface mixed plankton, bongo 505
** Concentration generally higher than bongo 505

Neuston and its Importance

Analysis of samples from the first four seasonal cruises has revealed an important qualitative difference between surface layer and subsurface zooplankton. Subsurface zooplankton communities are nearly always dominated by copepods, not only in the present study area, but in other regions as well. Neuston of the Middle Atlantic Bight, on the other hand, is at times dominated by the developmental stages of decapod crustaceans and fishes, many of them of considerable commercial importance. Conventional sampling would not have detected this concentration of eggs, zoea, megalopae, and larvae in the surface layer (Zaitsev 1970). Nearly half of the neuston tows taken in the spring cruise were numerically dominated by fish eggs. Half the remainder of collections was dominated by decapod zoea and megalopae (mostly *Cancer* spp.). In addition to these seasonally-dominant forms (Table 4-35), there is a unique faunal assemblage in the neuston that is almost always undetected by conventional sampling.

Table 4-35. Percent of neuston collections numerically dominated by copepods and other principal taxa in four seasonal cruises, BLM01W-BLM04W, in the Middle Atlantic Bight off southern New Jersey.

Taxa	Number of Tows	Fall 1975 48	Winter 1976 48	Spring 1976 52	Summer 1976 48
Copepods		70.8	70.8	15.4	82.7
Fish Eggs		2.1	0	46.2	2.1
Decapod Larvae		2.1	0	25.0	2.1
Hyperiid Amphipods		18.7	14.6	1.9	0
Chaetognaths		0	10.4	0	0
Other		6.2	4.2	11.5	6.2

Unique Fauna of the Surface Layer

The vertical distribution of certain species of zooplankton is limited to the thin surface layer sampled by our neuston net (upper 12 cm). These are termed "euneuston" or true neuston, and many of them show peculiar adaptations to life in the surface layer (gas-filled floats of siphonophores, ventrally-directed eyes of pontellid copepods, intense pigmentation, etc.). Diversity of surface-restricted species is greatest in open ocean waters, but a large number of euneustonic forms also exist in the Middle Atlantic Bight (Table 4-36). Although many of these were prominent only in fall 1975 collections, when oceanic waters were present at the outer two stations, others occur either year-round as does *Idotea metallica* or during more restricted portions of the year. Euneustonts are fewest in number during the winter. *Anomalocera ornata* was found only offshore in the fall, but was restricted to the coastal boundary layer (CBL) in spring. Other species showed repeated patterns of distribution from one season to another.

Developmental Stages of Benthos and Nekton

So-called "facultative neuston" includes species with a part of their life cycle spent in the surface layer (eggs or larvae or both) and species rising to the surface layer at night in apparent response to decreasing light. Both classes of neuston were evident in Middle Atlantic Bight collections. Planktonic eggs of fishes concentrate in the surface layer and during the primary reproductive season of spring and early summer, attain densities in excess of copepods, usually the dominant taxon. Most of the commercially important Middle Atlantic Bight fishes produce such eggs. Certain larvae also show an affinity for the surface layer. These include *Urophycis* spp., *Mugil curema*, *Enchelyopus cimbrius*, *Merluccius* sp., and *Pomatomus saltatrix*.

Table 4-36. Occurrence of euneustonic species found in four seasonal cruises, Middle Atlantic Bight.

Species	Cruise			
	Fall 1975	Winter 1976	Spring 1976	Summer 1976
Velella velella	X			
Abylopsis eschscholtzii				X
Eudoxides spiralis		X		
Argonauta argo				X
Anomalocera ornata	X		X	
Anomalocera patersonii	X	X	X	
Labidocera acutifrons	X			
Pontella atlantica	X			
Pontella meadii	X		X	X
Pontella securifer	X			X
Pontella spinipes	X			
Pontellopsis regalis	X			X
Pontellopsis villosa	X			
Idotea baltica				X
Idotea metallica	X	X	X	X
Sargassum fauna				
Lepas fascicularis			X	
Lepas sp. larvae	X			
Bagatus minutus	X			
Latreutes fucorum	X			X
Leander tenuicornis	X			
Portunus sayi	X			
balistids	X			

The zoea and megalopae of decapod crustacea, with the important exception of the American lobster, *Homarus americanus*, are strong vertical migrators, rising into the surface layer at night. Lobster larvae, occurring in our spring collections, appeared to be restricted to the surface layer. They occurred in half our 52 neuston collections, but in none of the subsurface bongo collections. The most abundant decapods in our night neuston samples were zoea and megalopae of rock crabs, *Cancer* spp., also of commercial significance. Decapod larvae in the spring 05 1976 numerically dominated 25% of the neuston collections.

Diel Cycles of the Neuston

The six stations occupied quarterly during this survey were each sampled over a 24-hour period for neuston, resulting in 24 observations on diel cycles. Cluster analyses of collections from each cruise reflect the importance of day-night differences within primary divisions of fauna into inshore and offshore community-types. Day and night collections, except at the shallowest stations, tended to cluster together, i.e. day tow with day tow, night with night tow. This is due to the upward migration at night

of species characteristic of subsurface waters in daylight, and a resulting close similarity of night neuston at stations with a common subsurface zooplankton community. Neuston at night often decreased in diversity as one or a few vertically migrating species became more dominant in the surface layer. Euneustonic species tended to remain at the same density throughout a 24-hour period.

Summary of Significant Findings

1. Subsurface zooplankton of the Middle Atlantic Bight off New Jersey occurred in two, or occasionally three, distinct communities, usually an inner shelf assemblage and one from the outer shelf and upper slope. Fall 1975 collections included three communities: coastal, central shelf, and a distinct shelf break and slope community.

2. Surface zooplankton, as represented in neuston collections, was more clearly differentiated by season. Coastal collections in the fall and shelf-wide collections in summer were collectively distinct from the remainder of offshore fall and shelf-wide winter and spring collections. Fall 1975 neuston assemblages at the shelf break and slope stations were distinctly different from other communities, as noted for subsurface communities.

3. Both surface and subsurface zooplankton at the coastal station C1 formed a more or less distinct fauna throughout the year, with a substitution of cold-water species occurring in winter. Indicators of this water type (Coastal Boundary Layer) include *Acartia tonsa*, *Centropages hamatus*, and *Tortanus discaudatus*.

4. Central shelf fauna, overlapping both coastal and slope boundaries, included the most abundant and widespread species. The overwhelming dominant member of this "community" was the copepod *Centropages typicus*.

5. Outer shelf and upper slope zooplankton include the indicators *Metridia lucens*, *Pleuromamma gracilis*, and *Euphausia krohnii*.

6. Margalef's Index of Species Richness was the most useful of several diversity indices calculated for plankton collections. Diversity of both subsurface and surface zooplankton increased from winter to summer and from the coast to the slope in the warmer half of the year (summer and fall).

7. Neuston of the Middle Atlantic Bight contained a distinct assemblage of species, compared with subsurface tows, although night tows were usually dominated by vertically migrated subsurface species. The principal euneustonts ("true" neuston, restricted to the surface layer) included the pontellid copepods and the isopod *Idotea metallica*.

8. Neuston in the active reproductive period for Middle Atlantic Bight benthos and nekton (spring and early summer) was dominated by the young stages of decapods and fishes. Nearly one-half of the neuston tows from the spring 1976 cruise were numerically dominated by fish

eggs; 25 percent were dominated by larvae of *Cancer* sp. Lobster larvae, apparently restricted to the surface, were found in half the collections.

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Identifications not performed by the author included the following:

Siphonophores and amphipods - Russell A. Short
Molluscs - Michael Vecchione
Cladocerans - Burton B. Bryan
Decapods and euphausiids - Peter O. Smyth
Fishes - John E. Olney

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CHAPTER 5

SEDIMENTS AND SEDIMENTARY FRAMEWORK

D. F. Boesch

CHAPTER 5

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SEDIMENTS AND SEDIMENTARY FRAMEWORK

D. F. Boesch

INTRODUCTION

The great emphasis placed on the seabed in these Middle Atlantic OCS Environmental Studies is a reflection of the sedimentary nature of anticipated contaminants resulting from oil and gas development and the predominantly sedentary nature of the benthic biota. Thus, there is greater potential to detect low level contamination of bottom sediments and organisms and resulting effects than in the more transient pelagic realm.

A commonality of all the seabed related studies is their reliance on a good understanding of the physical nature of the bottom sediments of the continental shelf and slope. Furthermore, the processes, both past and present, affecting the composition of bottom sediments must be considered in interpretation of chemical and biological data.

This section reports data on the granulometry and organic carbon and nitrogen concentrations of sediments at stations sampled for benthos, hydrocarbons, and trace metals. Thus, it is supportive of other sections of this report on biological and chemical studies rather than constituting a report on sedimentology per se. However, the results are interpreted in reference to the sedimentary framework of the Middle Atlantic shelf and slope to provide the biological and chemical studies a dynamic prospective of shelf sediments.

SEDIMENTARY FRAMEWORK

The Middle Atlantic continental shelf has been the subject of extensive geological studies making it one of the best known in the world. Several comprehensive reviews emphasizing the Middle Atlantic shelf and slope are available (Emery and Uchupi 1972; Swift et al. 1972a; Milliman 1973; Swift 1976; Southard and Stanley 1976). No attempt will be made here to review all available information, but this serves as an abbreviated perspective to assist in the interpretation of the sediment data presented.

Physiography

The Middle Atlantic continental shelf is a broad, gently sloping platform varying in width from 160 km south of Cape Cod to 140 km off New Jersey and 25 km off Cape Hatteras. The shelf break, that zone where the declivity of the depth gradient changes abruptly, begins at between 100 and 150 m depth along the central Middle Atlantic shelf (Emery and Uchupi 1972; Wear et al. 1974). The continental slope, characterized by steep gradients ($4\text{-}5^0$), ranges from the shelf break to the continental rise at about 2000 m. The continental slope and edge of the shelf are incised by numerous submarine canyons. In the study area,

the major canyons are, from the north, Hudson, Wilmington, Baltimore, Washington, and Norfolk (Wear et al. 1974). The shelf surface is not flat and featureless but is crossed by depressions and covered by an obviously complex topography evidenced by convoluted isobaths. These topographic patterns are largely the result of processes which occurred during the low sea level stand during the last glacial period, roughly 14,000 years B.P., and the subsequent post-glacial retreat of the shoreline with the rise of the sea level (Swift et al. 1972a).

Old river valleys filled mainly by estuarine deposits underlie the principal cross-shelf depressions in the study area, the Hudson, Great Egg, Delaware, and Chesapeake shelf valleys (Figure 5-1). Topographic highs composed of linear shoal fields occur to the north of each shelf valley. These shoal retreat massifs mark the retreat paths of littoral drift depositional centers that occur on the north sides of the mouths of estuaries (Swift et al. 1972a). The shelf valleys often terminate in flat areas on the outer shelf thought to represent former deltas; however, the subsurface structure can be traced to the major submarine canyons at the shelf edge (Twichell et al. 1977). Terraces running parallel to the isobaths can often be traced over large sections of the Middle Atlantic shelf (Milliman 1973). These are evidently erosional features reflecting former shorelines during major sea level stillstands.

Superimposed on these relict large scale features is a whole spectrum of topographic features of smaller scales, which may be more the result of contemporary processes. Of major importance and wide distribution is the so-called ridge and swale topography (Duane et al. 1972; Swift et al. 1972a). The linear sand ridges trend roughly northeast to southwest or slightly oblique to the shoreline. Swift et al. (1972a) examined the size and spacing of ridges and swales on the New Jersey shelf and showed that on the innermost shelf mean ridge spacing (crest to crest) was 1.4 km, and mean relief was 4.7 m, whereas on the central shelf these mean dimensions were 2.5 km and 6 m. Outer shelf ridge spacing averaged 6.1 km and relief of 6.0 m. Furthermore, McKinney et al. (1974) recognized two morphological orders of ridge and swale topography on the central New Jersey shelf in VIMS cluster area D. A first-order system had ridges 14 m high and 2-6 km apart trending north-northeast, and a second-order system had ridges 2-5 m high and 0.5-1.5 km apart trending northeast. The origin and development of the ridge and swale topography have been the subject of much debate, but most current investigators believe the ridges had their genesis at the shoreface, were stranded by transgression, and were modified by hydrodynamic processes on the shelf (Figure 5-2). It will be shown later in this report that the ridge and swale topography found over approximately 75% of the width of the continental shelf of the study area is of major importance in the distribution of sediments, their chemical constituents (Chapters 8 and 9) and benthic organisms (Chapters 6, 7, 11).

Smaller scale topographic features are also found, and they too may be of geochemical and biological importance. Sand waves are known to occur in some regions of the Middle Atlantic continental shelf. Knebel and Folger (1976) describe asymmetrical sand waves having a spacing of 100-650 m and a relief of 2-9 m near the head of Wilmington Canyon. Current lineations of 1.5 m amplitude and less than 100 m spacing have been

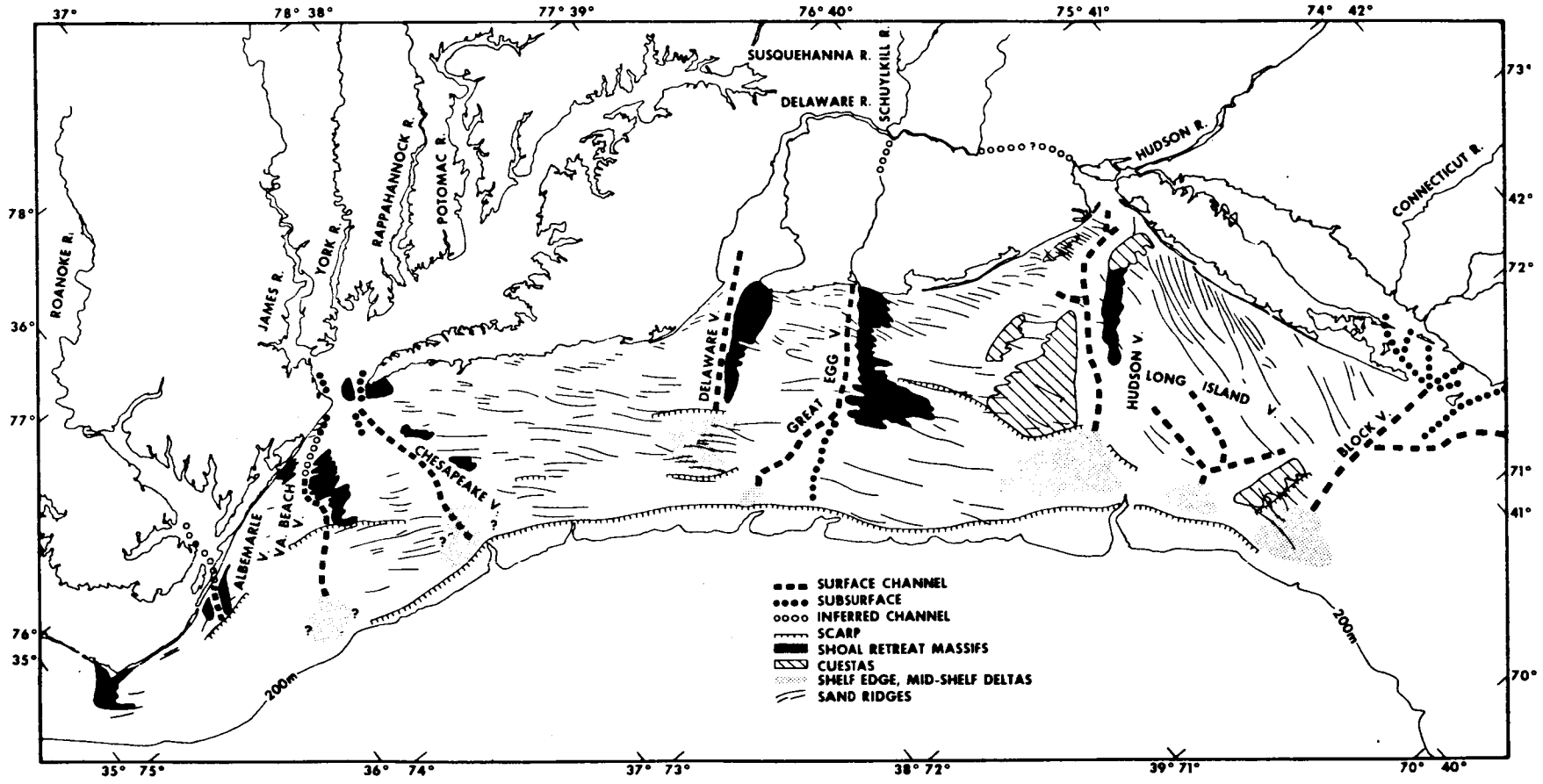


Figure 5-1. Major morphologic elements of the Middle Atlantic Bight (from Swift 1975).

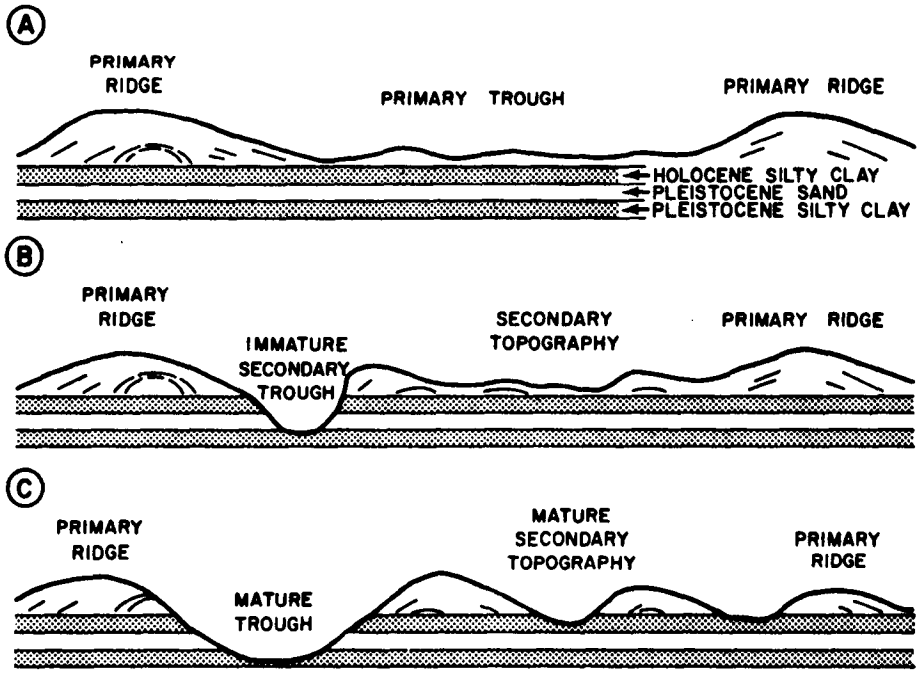


Figure 5-2. Schema for ridge and swale evolution based on observations on the central New Jersey shelf (Stubblefield and Swift 1976). Primary ridges are formed by the detachment of shoreface connected ridges during Holocene transgression. Scouring during storms forms a secondary trough and locally penetrates underlying deposits. Secondary trough erodes laterally and secondary ridges develop from sand eroded upcurrent.

found associated with ridge and swale topography on the central New Jersey shelf (McKinney et al. 1974). Finally, wave and current ripple patterns of a few cm scale are very characteristic of the central and inner continental shelf and may periodically develop in response to storms out to the shelf break.

These topographic patterns introduce considerable heterogeneity in granulometric, chemical, and biological parameters. Sampling and interpretation must take full cognizance of the complexity of the shelf surface.

Sediments

Most of the Middle Atlantic continental shelf is covered by a sheet of sand 0-30 m thick overlying older, finer sediments. The surface sediments are palimpsest (Swift et al. 1972a), meaning they are relict in the sense that they have been eroded from a local, pre-Recent substrate and modern in the sense that they have been redeposited under the present hydraulic regime. Thus, broad scale patterns of distribution of sediments tend to be related to sources of material and historical processes, whereas smaller scale patterns seem to be more related to contemporary processes.

Because of the fairly rapid Holocene transgression and limited input of modern detrital sediments from rivers, shelf sediments contain remarkably little silts and clays. Most sediments can be classified as sand (>75% sand) or gravelly sand to water depths at least as deep as 200 m. The only major exception is the large area of fine sediments on the outer shelf off southern New England, just to the northeast of the present study area.

On the upper continental slope, shelf sands grade quickly into clayey-silts. In the central study area, sediments at 400 m contain roughly 30% silt-clay, whereas deeper than 600 m most sediments are over 90% silts and clays.

Broad scale patterns of grain size distribution within the study area are well known and have been summarized by Milliman (1973) and Johnson (1977). Medium sands predominate over most of the continental shelf. Large patches of coarser sediment (coarse sand or gravel predominating) are found on the inner shelf off central New Jersey and off the mouth of Delaware Bay. Fine and very fine sands predominate on the inner shelf off southern New Jersey and on the inner half of the shelf off the southern Delmarva Peninsula. As mentioned above, silts and clays are rare over the entire continental shelf in this region and do not become predominant until the upper continental slope (Southard and Stanley 1976).

Presentations of broad scale patterns of such grain size parameters as general size classes (Milliman 1972) or central tendency measures such as median grain size (Johnson 1977) tend to convey a misleading sense of homogeneity. More detailed studies of grain size distribution (e.g. Stubblefield et al. 1975; Southard and Stanley 1976) often show

more complicated patterns of potential biological and geochemical importance. Stubblefield et al. (1975) found that in a region of the central New Jersey continental shelf (containing VIMS cluster area D) fine sand and moderate sorting occur on the flanks of ridges, medium to fine sand and moderate sorting occur on the crests, and sediments in the swales were either coarse, poorly sorted sands or very fine, well-sorted sands. Southard and Stanley (1976) similarly showed complex distribution of sediment texture at the shelf break between Wilmington and Norfolk Canyons (Figure 5-3). A narrow band of gravel concentration is continuous on the outer shelf shoreward of the break, and mosaics of texture types characterize the heads of the major submarine canyons. On an even smaller scale, Knebel (1975) examined the significance of sediment textural variables on within-sample, within-station, and between-station bases and found significant within-station variance for several grain size parameters.

In terms of minerology, Middle Atlantic shelf sands are predominantly quartz (subarkosic) with biogenic carbonate locally important, particularly at the shelf break (Milliman 1972). Carbonates of the shelf break consist mainly of tests of planktonic foraminifera, and their light density posed some problems in the analysis of grain size of shelf break and slope sediments (see Methods). Local concentrations of glauconite, an authigenic mineral, are also found in the study area south of the Hudson Shelf Valley and at the shelf break (Milliman 1972).

Sedimentary Processes

Of the various processes affecting granulometric patterns, two are of particular relevance to the interpretation of biological and geochemical benchmark studies. The first concerns the origin and distribution of fines (silt and clay) with which trace metals, hydrocarbons, and biologically important materials (e.g. organic carbon) are often associated. The second concerns the transport of sediment with respect to bathymetry, both in relation to depth and to local topography.

As mentioned above, Middle Atlantic continental shelf sediments are notable for their lack of fines (<63μ) out to slope depths. Since the fine component is of particular biological and chemical importance, it is relevant to consider why fine sediments are not better represented and the origin of the fine sediments present. Although the Middle Atlantic Bight receives the drainage of several large river systems (in particular, the Connecticut, Hudson, Delaware, Susquehanna, Potomac, and James Rivers) and these rivers carry large quantities of suspended sediment (Meade 1969), the major rivers empty into large estuaries rather than directly into the ocean. The basins and wetlands of these estuaries act as traps for fluvial sediments. Furthermore, bottom waters at the estuary mouths, which have greater suspended sediment loads than surface waters, have a net non-tidal flow into the estuary. Surprisingly, this means that large estuaries such as the Chesapeake and Delaware Bays have a net import of sediment from the ocean (Schubel and Carter 1976). Nonetheless, some fluvial sediment does escape the estuary for potential deposition on the continental shelf. However, Schubel and Okubo (1972) demonstrate that sediments originating from the Chesapeake Bay mainly bypass the shelf to be deposited on the continental slope or rise.

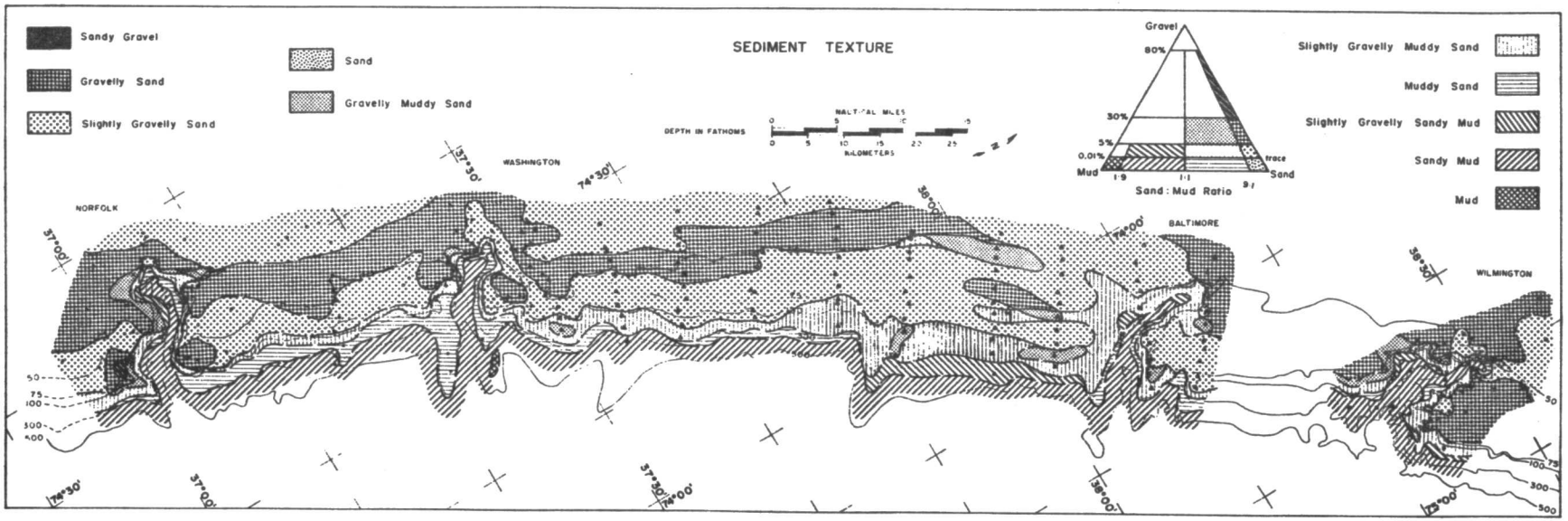


Figure 5-3. Distribution of surface sediments on the outer continental margin between Wilmington and Norfolk canyons (from Southard and Stanley 1976).

Milliman and Bothner (1977) report that seston in the Middle Atlantic Bight is principally biogenic, composed largely of phytoplankton. Since much of this material is degradable or is larger sized skeletal material, the standing seston must not contribute significantly to accumulation of fines in bottom sediments. We, as well as others (Folger 1977), have observed from direct observation and bottom photographs the presence of a thin surface floc of fine sediments over "clean" sands. This material is probably considerably organic and appears to be easily resuspended. Although this mobile floc does not contribute significantly to the surface sediments (Bothner 1977), it may be of considerable biological importance.

Another locally important source of fine sediments on the Middle Atlantic continental shelf is the erosion of relict (Pleistocene or Holocene) fine deposits underlying the surficial sand sheet. These presumably lagoonal deposits are locally eroded, particularly in swales (McKinney et al. 1974). This stiff material is fragmented into lumps, and the fines are further disaggregated by physical (waves and currents) and biological (boring and bioturbation) forces. The importance of the contribution of this source to the fine component of surrounding sediments is unknown. However, clay lumps can evidently be transported over considerable distances as evidenced by their inclusion in barrier island washover deposits (Meza and Paola 1977).

The disturbance of bottom sediments by physical or biological forces is important in redistributing sediments, thus affecting granulometric distributions. Furthermore, sediment movement is of direct ecological importance because benthic organisms must be able to cope with shifting sediments in which they live.

It is apparent from sediment distribution patterns and observations made during these studies that bottom sediment movement is widespread and frequent over much of the Middle Atlantic continental shelf. Bottom currents which potentially cause sediment movement have several causes, outlined in Table 5-1. The sediment textural and morphologic patterns on the Middle Atlantic shelf are largely storm dominated (Swift 1976). Wave induced oscillations are important, setting sediment in motion on the inner half of the shelf, and tidal current may be locally important. Predominant currents during fair-weather conditions are driven by the geostrophic response of the stratified shelf water column to freshwater runoff and to winds. Neither these currents nor tidal currents are strong enough to result in significant transport on the outer continental shelf. Rather, strong currents are generated during winter storms, when air-water coupling is more efficient and northeast winds induce a setup of shelf water against the coast (Swift 1976; Butman et al. 1977). Sediment movement observation and direct current measurements in VIMS Areas B and E (60 - 90 m) by the USGS (Butman et al. 1977) confirm that on the outer shelf, wave oscillations, geostrophic flow, internal waves, and fair-weather winds do not cause significant sediment transport at these depths. However, they show that winter storms cause bottom currents of over 35 cm sec^{-1}, well above the sediment resuspension threshold of 25-30 cm sec^{-1}, causing considerable resuspension and movement of bed forms. Little known, but undoubtedly also important, are the effects on bottom sediments of summer storms resulting from extratropical depressions which are irregular but not uncommon occurrences in the area.

Table 5-1. Bottom currents potentially causing sediment movement (after Southard and Stanley 1976).

Cause	Time Scale
Surface waves	Seconds
Barotropic motions	Diurnal or semidiurnal
Wind-driven	Storm events or seasonal
Differences in atmospheric pressure	Storm events
Thermohaline circulation	Meso-megascale
Internal waves	Hours

At the shelf break, conditions are apparently more quiescent, and bottom sediment transport is less frequent. However, ripples were occasionally observed in bottom photographs of the sea bed down to 200 m. Sediments appear to be more dynamic in the vicinity of submarine canyons (Southard and Stanley 1976; Knebel and Folger 1976) possibly in response to increased velocity of tidal currents or internal waves.

Important local differences exist in bottom sediment transport with respect to ridge and swale topography. These are responsible for sediment textural patterns of profound biological and geochemical importance (Chapters 6 and 8). Stubblefield et al. (1975) developed a model of sediment transport inferred from surface sediment distribution and near-surface structure in the vicinity of VIMS Area D. They hypothesize up-flank rheologic and suspensive transport of medium and fine sand during intense storms and subsequent down-flank winnowing of fine sand during less intense meteorological events. This results in a pattern of slightly coarser sand on the ridges than on the flanks, and finer sands in the swales except in erosional pockets which contain a lag of coarse sand and shell.

METHODS

Sampling

Sediment samples for grain size, organic carbon, and nitrogen analyses were collected at each grab station - 24 cluster stations in fall, winter, spring, and summer and 27 additional stations in winter and summer (see Chapter 2). At each station 12 replicate 0.1 m^2 Smith-McIntyre grab hauls were made except at some deep stations where, because of long haul time, fewer hauls were made. From each of these successful hauls a 3.5 cm inside diameter clear acrylic core was inserted, removed, and capped on both ends for grain size analysis. Length of the core sample varied with depth of penetration of the grab, but generally the cores contained the top 10 cm of sediment. Cores from the grabs taken for trace metal or hydrocarbon samples, usually the first six, were sent to the USGS, Woods Hole, where a single grain size analysis was performed on composited aliquants from the cores and the remaining material returned to VIMS. At VIMS, grain size analyses were performed

on all six sediment samples from the grabs taken for faunal analysis, usually grabs 7-12, and two of the individual samples returned by USGS, usually samples from grabs 1 and 2. The core samples from the biota grabs were kept frozen from the time of collection until the time of analysis, whereas those cores delivered to USGS were not.

Organic carbon and nitrogen samples were collected in a similar fashion but in smaller diameter core tubes (2.2 cm inside diameter). One core sample each was taken only from the six grabs collected for analyses of macrobenthos. Samples were quickly frozen and remained so until analysis.

Granulometry

Goals of the Analysis

The purpose of the grain size analysis was to obtain size distribution parameters which, through correlation with the results of other program components such as benthic ecological studies and sediment chemistry, would explain, at least partially, the spatial variability of those characteristics. The sediment size parameters selected were:

a) the gravel, sand, silt, and clay fraction percentages
b) the median, mean, standard deviation, skewness, and kurtosis. In this study the graphic measures were used (following Folk 1968) wherein:

ϕ Graphic Median; $Md_{\phi} = \phi_{50}$

ϕ Graphic Mean; $M_{\phi} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$

ϕ Graphic Standard Deviation; $\sigma_{G\phi} = \frac{\phi_{84} - \phi_{16}}{2}$

ϕ Graphic Skewness; $Sk_{G\phi} = \frac{\phi_{16} + \phi_{84} - 2(\phi_{50})}{(\phi_{84} - \phi_{16})}$

ϕ Graphic Kurtosis; $K_{G\phi} = \frac{\phi_{95} - \phi_{5}}{2.44\ (\phi_{75} - \phi_{25})}$

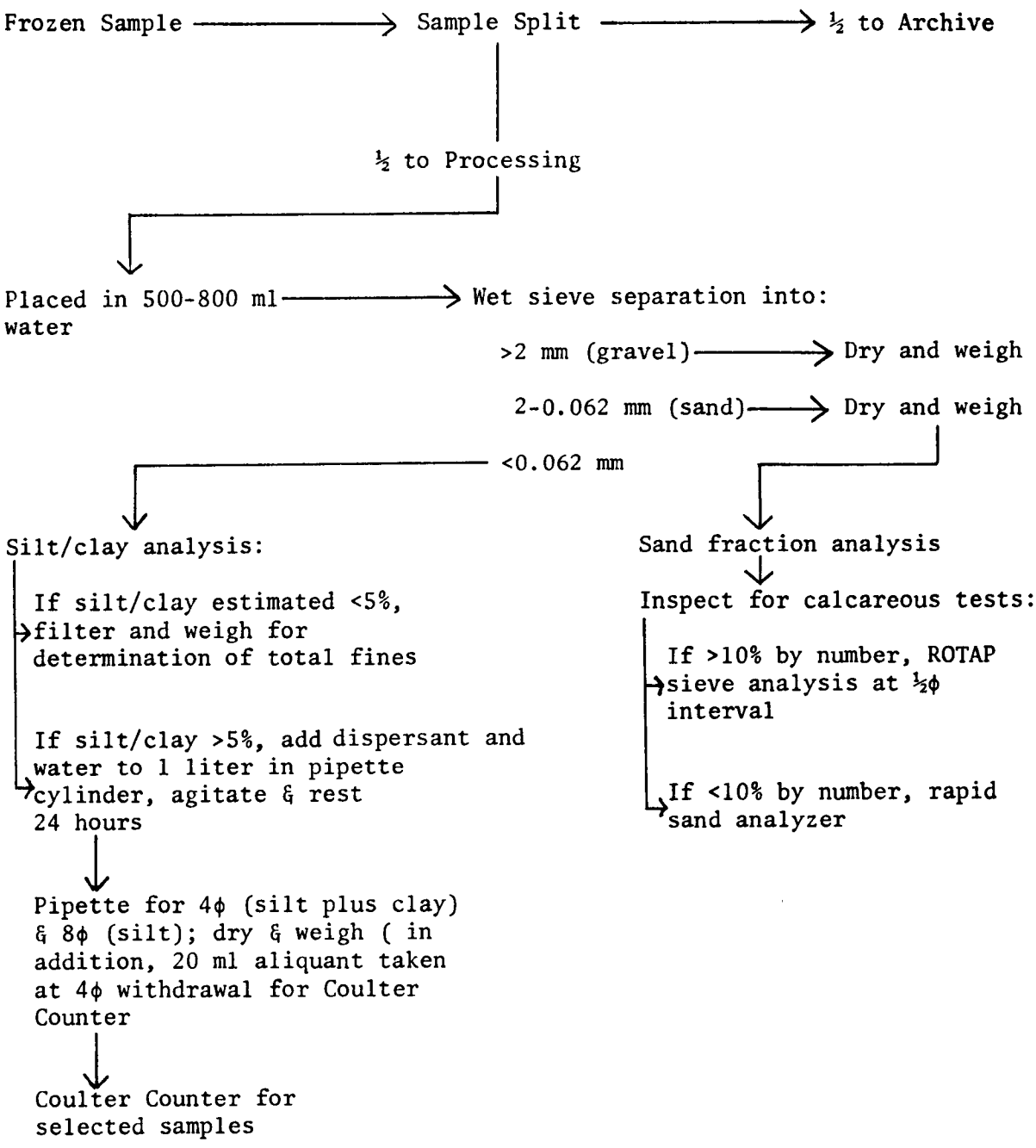
c) a listing of the percent weight in each successive whole ϕ interval.

Laboratory Methods

Since the sediments encountered in the bottom sampling program varied in composition from predominantly sand and gravel to predominantly silt and clay, no single size analysis technique could cover the size range for all samples. Consequently a combined analysis was performed using sieve separation, pipette analysis, rapid sand analyzer, and Coulter electronic particle counter. The analysis followed the flow chart shown in Table 5-2 and is discussed in detail below:

Step 1. The samples were frozen aboard ship and held frozen until treated in the laboratory. The core samples were split longitudinally with a knife, and one part was then repackaged and returned to the freezer as an archive sample.

Table 5-2. Flow chart for sediment analysis.



Step 2. The frozen split retained for analysis was then placed in a jar with 500 to 800 ml of tap water to thaw.

Step 3. After thawing completely, the sediment-water mixture was agitated and wet sieved through a 2.0 mm and 0.062 mm sieve with the passing slurry retained in a large evaporation dish. The material retained on the 2.0 mm sieve (the gravel fraction) was then washed, dried, and weighed. The material on the 0.062 mm sieve (the sand fraction) was similarly treated. If less than an estimated 5% total silts and clays were present, the slurry passing the 0.062 mm sieve was filtered through a No. 3 Whatman filter, and total silts and clays were determined gravimetrically. Otherwise, the slurry was then poured into 1000 ml graduated cylinder, 40 ml of 4% Calgon (sodium hexametaphosphate) added to aid disaggregation, and water was added to fill the cylinders. The column was then agitated and left to stand for 24 hours to complete dispersion of the clays.

Step 4. After dispersion in the pipette column was complete, the column was again agitated and 20 ml aliquots extracted as time and depth intervals corresponding to 4ϕ (total sample) and passage of the silt fraction 8ϕ. Settling times were calculated with compensation for water temperature following Folk (1968). An additional 20 ml aliquot was retrieved at the 4ϕ (silt plus clay) withdrawal time for retention (under refrigeration) for possible Coulter Counter analysis. After drying and weighing, the 4ϕ and 8ϕ subsamples were corrected for the addition of dispersant, and calculation was then made for the total weights of silt and clay. At this point in the analysis, it was possible to state the gravel, sand, silt, and clay content of the sample.

Step 5. The dried sand fractions were then examined under a binocular microscope to estimate the abundance of foraminifera and other calcareous material. Since these tests have very low settling velocity, those samples with a high percentage of tests (<10%) would give misleading results in the rapid sand analyzer, a device which measures the settling velocity of the particles in the sample. Consequently, if a microscopic examination indicated a visual estimate greater than 10% (by number), the samples were segregated for subsequent analysis by conventional sieve analysis at $\frac{1}{2}\phi$ intervals using a ROTAP vibratory system. If the sample contained less than 10% (by number) of calcareous particles, the sample was subjected to analysis in the rapid sand analyzer after reduction in sample weight to about 1 gm using a micro-splitter.

Step 6. After examination of the sand/silt/clay ratios, the decision was made as to which of the samples warranted further detailed analysis of the fine grain fractions with the Coulter Counter (Model TA). The counter sizes and counts particles suspended in an electrolyte as they pass through an aperture with a specific path of current flow. As each particle passes through the aperture, it displaces its own volume of electrolyte with a change in the resistance of the current path. The magnitude of this change is directly proportional to the volumetric size of the particle, and the number of particles in the sample suspension.

In the analyses made in this study, two apertures were used, the

140 μ and the 30 μ, which when combined provides a working a range of 70 μ to 0.6 μ.

Calibration of the Rapid Sand Analyzer

The sand analyzer used, modeled after the design of Zeigler et al. (1960), is a device which measures the terminal settling velocity of the sand grains in the sample ensemble. The sediment is introduced into a water column of 1 meter in length. The fluid drag on the particles transmits the buoyant weight of the falling particles to the fluid below as an apparent increase in fluid density thereby causing an increase in hydrostatic pressure. In those instruments using a differential hydrostatic pressure sensor (DHPS) as the detector, one leg of the DHPS is the active column while another leg, connected to a common upper reservoir, acts as the passive leg. In this mode, the pressure changes solely due to the falling sediment are registered as output signal. The VIMS rapid sand analyzer operates with a 6-inch ID active column in the differential pressure mode with the output signal recorded on a strip chart recorder.

Only in the case of single spherical particles does the instrument measure the unimpeded fall velocity, and only in that case can one associate an unambiguous size characteristic, the sphere diameter, with that fall velocity. In the operational case a diverse assemblage of grains is dropped in the tube wherein the particles are not spherical nor do they fall without mutual interference. In order to minimize the influence of mutual interference, small samples (∿1 gm) are dropped over a large area. The effects of grain shape and differences in grain density must be explicity resolved. The problem of grain shape can be addressed by microscopic examination with the application of shape factors incorporated into the settling velocity (Zeigler and Gill 1959). Another approach is to calibrate the machine within sieved size classes of the material being tested. This was the technique used in this study.

Composite samples of sediments from the study area where treated with HCl to remove calcareous materials and then sieved into ¼φ size class intervals. Five subsamples of each size class were dropped in the analyzer, and the average median fall velocity was associated with the geometric mean of the sieve limits. A curve was then constructed from this information which related the sieve diameter with fall velocity. Templates were then constructed for various water temperatures (Zeigler and Gill 1959) wherein fractional φ units were scribed as a function of the time to fall one meter. In this way the strip chart recorder record could be directly interpreted in φ size intervals.

Calculation of Size Parameters

In order to construct the cumulative frequency curve for a sample, the various subanalyses were recombined in terms of the total sample weight. The total sample weight was determined as the sum of the gravel plus sand plus the weights of silt and clay which were determined by the pipette analysis. The recombination in terms of total weight is necessary since both the rapid sand analyzer and the Coulter Counter

represent their results as fractional percentages of the material introduced into the respective devices. Once the cumulative frequency distribution for the entire sample was constructed, the needed percentile levels were read from the curve, and the desired graphic moments were calculated.

Total Organic Carbon

Sediment samples were oven dried at 100°C, sieved through a 1 mm sieve to remove shell and pebbles, powdered on an analytical mill, and weighed to 0.01 g. The sample was then placed in an ampule; 5 ml of 12% phosphoric acid was added. The ampule was purged of inorganic carbon constituents for 4 to 6 minutes and then sealed in a special apparatus to prevent CO_2 contamination from the sealing flame. Sealed ampules were heated at 125°C for four hours in an autoclave to oxidize the organic carbon to carbon dioxide. The carbon dioxide of each ampule was flushed with a nitrogen stream and measured by an infrared analyzer (Model 524, Oceanography International Carbon Analyzer). Instrument output was recorded on a Hewlett-Packard (Model 724A) potentiometric strip chart recorder equipped with an integrator. Standard carbon dioxide conversion graphs are made by plotting the integrated area versus carbon for standardized sodium carbonate solutions. Triplicate determinations were averaged, and reported as mg/g dry weight of sediment.

Total Nitrogen

Total nitrogen was estimated using the persulfate digestion method of D'Elia et al. (in press) for samples from the fall 1975 cruise.

12.5 ml of oxidizing reagent (3.0 g NaOH + 6.7 g $K_2S_2O_8$/1) was added to a 100 ± 10 mg wet sediment sample in a tared productivity tube. Samples were autoclaved at 100°-110°C for 45 minutes, the optimal temperature for persulfate digestion (Williams 1969), then centrifuged for 5 minutes. After pouring off the supernatant, the sediment was dried in the productivity tube for 24 hours at 55°C to determine the quantity of dry sediment used. 0.75 ml of 0.3 N HCl was added to the supernatant and mixed with a Vortex mixer until any precipitate dissolved (often $Mg(OH)_2$ in seawater samples). Samples were then passed through a Cu-Cd^{++} reduction column and analyzed for NO_2^- on a DU spectrometer at 535 mμ. Blanks consisted of 12.5 ml of oxidizing reagent only.

Because of the unavailability of contaminant-free persulfate, this method could not be employed for the remainder of the samples. Instead a gas chromatographic technique was employed and calibrated by the persulfate digestion method. In the gas chromatographic method, 100 mg ± 10 mg of dried sediment was weighed into tared 5 ml ampules, covered by a constant amount of cupric oxide powder and copper metal, and sealed after purging with helium for 5 minutes. Samples were combusted at 550°C for 1 hour, cooled, and inserted into a newly designed crushing apparatus equipped with Swagelak fittings which allow ampules to be fitted in a helium-purged chamber. When the ampules were broken, combustion gases are drawn through a series of columns designed to remove water, sulfur dioxide, and convert CO to CO_2.

A Fisher gas partitioner (Model 1200) was used to measure combustion

gases. Two chromatographic columns were employed in series, each having its own detector. Column 1 (53.54 cm x 0.635 cm) consisted of 30% HMPA (hexamethyl phosphoramide) on 60 to 80 mesh columpaks. Column 2 (3.35 m x 0.48 cm) consisted of a 60 to 80 mesh activated molecular sieve 13x. The detector system consisted of a thermal conductivity cell containing four thermistor detectors with a separate detector at the end of each column. The output is recorded on a strip chart recorder. Helium is used as the carrier gas with a flow rate of 30 ml min^{-1}. Columns are used at ambient temperature for separation of combustion gases.

RESULTS

Patterns of Sediment Texture

General

Sediment texture is generally described for each station in Table 5-3 with respect to depth and topographic location. Sediments ranged from those on the inner continental shelf (Figure 5-4) composed almost exclusively of medium and coarse sand to continental slope sediments of greater than 90% silt and clay. Sediments at inner and central shelf stations over the entire study area are mainly well-sorted to moderately well-sorted sands with very little silt and clay except in topographic depressions (C4, D4, G3). These sands vary considerably in size, and although medium sand usually predominates, coarse sand is abundant off central and northern New Jersey (B4, C stations, G1, G2), and fine sand predominates off the central Delmarva Peninsula (L1, L2).

On the outer continental shelf (50-100 m), sediments again largely consist of medium sands, frequently with a sizeable coarse sand component. Silt and clay content is slightly higher than inshore and may again be locally greater in depressions (B3, E4). Sediments on the outer shelf in the vicinity of the Hudson Canyon (A1, G5) have a larger silt-clay component of about 10%. In the region of the shelf break (100-200 m), sediments become considerably finer, both in terms of sand-sized particles (shift to finer sands) and in terms of increases silt and clay (5-10% except around Hudson Canyon where 15-30% silt and clay was found). Thus, shelf break sediments are generally less well sorted than those on the shelf due to the lack or infrequency of hydraulic sorting.

On the continental slope, sediments quickly grade to muddy-fine sands (20-40% silt and clay) at 300-350 m and then to clayey-silt (>90% silt and clay) at 700 m.

Cluster Stations

Quarterly sampling in 4 of the 6 cluster station areas (B-E) was aimed at sampling the range of topographic features because of assumed effects of topography on sediments. The results of this study confirm these initial assumptions in that the differences among stations within a cluster area where often greater than those separated by much greater distances. The following is a narrative description of the patterns of sediment texture among the stations in each cluster area for each quarterly

Table 5-3. General description of sediment characteristics at each station. Nomenclature of sediment texure is adapted from Shepard (1954). Description of sorting refers to sorting coefficients range for well ($\leq$ 0.5), moderately well (0.5-0.7), moderate (0.7-1.0), and poor ($\geq$ 1.0) sorting.

Station (Season)	Depth (m)	Topographic Location	Sediment Description	Sorting	Percent Silt and Clay Range
A1	90-91	outer shelf	Medium-fine sand	moderate	6-9
A2	127-132	shelf break	Silty-med.-fine sand	poor	22-25
A3	136-139	hummock	Medium sand	poor	17-21
A4	196-198	shelf break	Medium-fine sand	poor	14-16
B1	63-65	flat	Medium sand	well	1-2
B2	60-61	ridge	Medium sand	mod. well	<1
B3	72-74	swale	Medium-fine sand	mod. well	5-6
B4	40-42	terrace	Medium-coarse sand	mod. well	<1
C1	15-17	ridge	Medium-coarse sand	well	<1
C2	21-26	flank	Medium-coarse sand	mod. well	<1
C3	24-25	flank	Medium-coarse sand	moderate	<1
C4 (F-Su)	34	swale	Clayey-mixed sand	poor	23-38
C4 (W-Sp)	34-36	swale	Medium-fine sand	mod. well	<1-5
D1	31	ridge	Medium sand	well	<1
D1 (W)	39	flank	Fine sand	mod. well	2
D2	33	flank	Medium sand	well	<1
D3	34-39	flat	Medium sand	well	<1
D4	48-51	swale	Fine sand	mod. well	4-6
E1	66-67	ridge	Medium sand	well	4
E1 (Su)	68	flank	Medium-fine sand	well	2
E2	64-73	flank	Medium-fine sand	mod. well	3-7
E3	63-64	flat	Medium sand	mod. well	<1
E4	75-80	swale	Shelly-medium-coarse sand	moderate	3-6

Table 5-3. (Continued)

Station (Season)	Depth (m)	Topographic Location	Sediment Description	Sorting	Percent Silt and Clay Range
F1	84-85	outer shelf	Medium-fine sand	well	1-2
F2	110-113	shelf break	Fine sand	well	4-7
F3	150-153	shelf break	Medium-fine sand	moderate	6-9
F4	183-184	shelf break	Medium-fine sand	moderate	7-1
G1	24-27		Gravelly-coarse sand	moderate	<1
G2	37		Medium-coarse sand	mod. well	<1
G3	73		Mixed sand	poor	8
G4	55		Medium-coarse sand	moderate	<1
G5	90-92		Medium sand	moderate	9-11
G6	167		Medium-fine sand	poor	18-22
G7	310-350		Fine sand	poor	21-29
H1	350-400		Silty-medium-fine sand	poor	28-33
H2	720-750		Clayey-silt	poor	89-92
I1	77-80		Medium-coarse sand	moderate	2-4
I2	93-94		Medium-coarse sand	poor	4-5
I3	176-181		Medium-fine sand	moderate	9-16
I4	460		Sand-silt-clay	poor	46-51
J1	350-410		Silty-fine sand	poor	28-31
J2	680-760		Clayey-silt	poor	94-95
K1	29		Medium-coarse sand	mod. well	<1
K2	41-42		Medium sand	mod. well	<1
K3	53		Medium-coarse sand	mod. well	<1
K4	102-105		Fine sand	mod. well	10
K5	143-152		Medium-fine sand	poor	7-9
K6	339-370		Fine sand	poor	22-24

Table 5-3. (Concluded)

Station (Season)	Depth (m)	Sediment Description	Sorting	Percent Silt and Clay Range
L1	24-26	Fine-very fine sand	mod. well	<1
L2	41-48	Fine-very fine sand	mod. well	1-2
L3	58-66	Medium-fine sand	well	<1
L4	90-94	Medium-coarse sand	moderate	1
L5	180-201	Mixed sand	poor	8
L6	332-350	Sand-silt-clay	poor	36-53

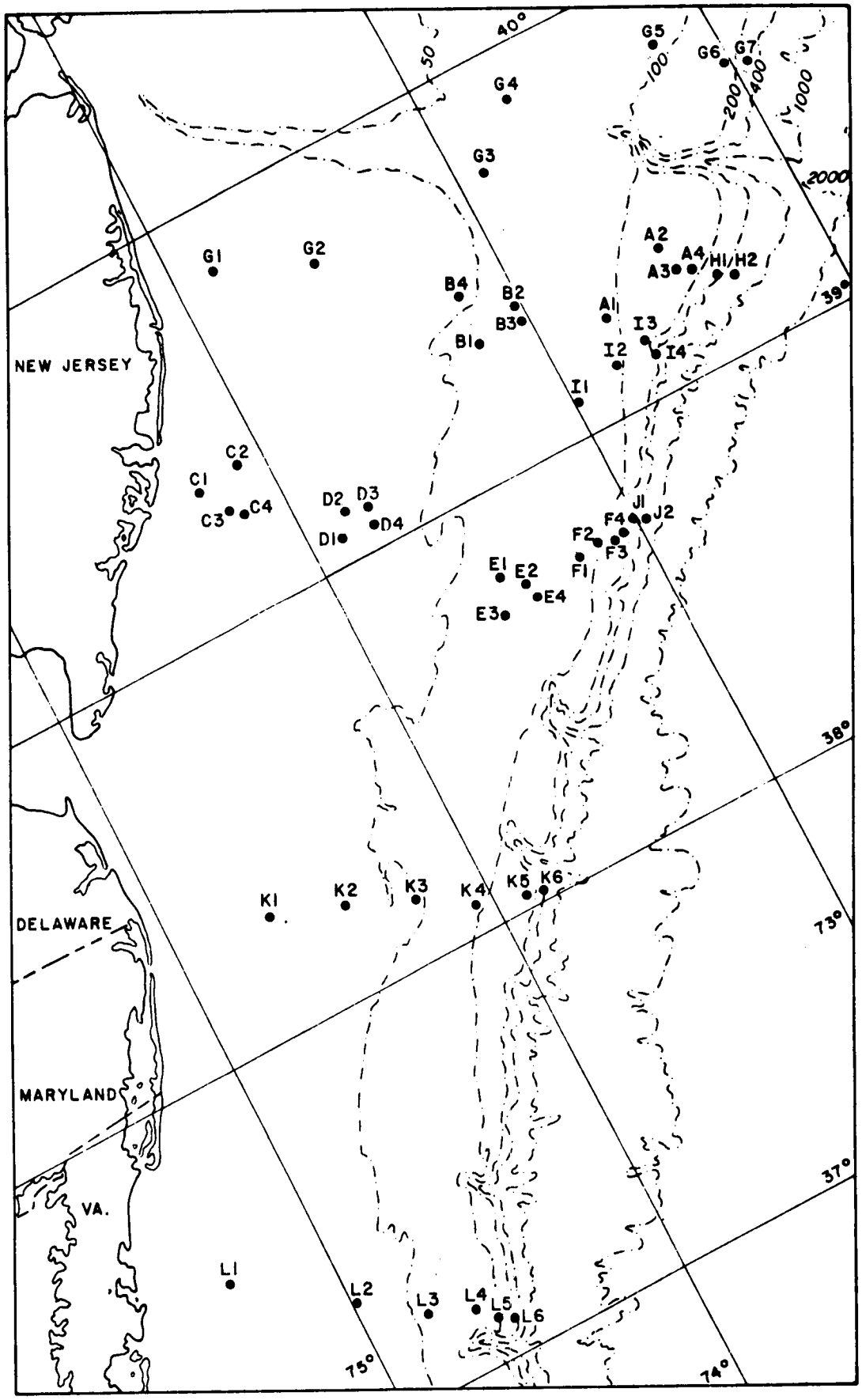


Figure 5-4. Study area showing location of stations from which sediments were analyzed for grain size, organic carbon and nitrogen.

cruise as summarized in Figures 5-5 to 5-8.

Sediments in Area A consist mainly of medium sand in the southwestern corner near A1. Depth increases much more gradually offshore than elsewhere along the shelf break in the Middle Atlantic Bight. Sands become finer, and silt and clay increase with depth and to the northeast in the direction of Hudson Canyon. Thus, stations A4, A3, and particularly A2 are considerably muddier than Station A1.

Within Area B, Station B4 is situated on a portion of a broad terrace above a SW-NE trending scarp (Tiger Scarp). Sediments at B4 were medium and coarse sands with an appreciable gravel component. Very little fine sand was present. Below the scarp, Station B1 lies on a fairly flat bottom, Station B2 sits on a ridge, and Station B3 is in a swale. Sediments at these three stations were very different. At B1 sediments were well sorted medium sands, low in shell and gravel, and with a small silt-clay component. Sediments at B2 were somewhat coarser with more shell and very little silt and clay. At the swale station B3, fine sands were abundant and predominated in some samples. Silt and clay content increased to about 5%. In summary, the 4 stations in Area B represent a continuum of sediment type from the coarser clean sands at B4 and B2 through the medium sands at B1 to the medium-fine, slightly muddy sands at B3.

Sediments at C1, C2, and C3 were very similar despite differences in their depths and topographic position. The sediments generally consisted of about one-half coarse and very coarse sand, with fine sand very poorly represented. However, sediments at the swale station C4 were vastly different. Sediments sampled at C4 during fall 1975 and summer 1976 consisted of medium and coarse sand with a highly variable amount of silt and clay. Replicate samples at this station in the fall ranged from 3.5 to 45% silt and clay and in the summer from 22 to 58%. However, during winter and spring 1976, sediments were quite different, consisting of medium and fine sand containing little silt and clay (maximum for any one replicate was 7%). The sediments at this site were obviously very patchy and probably consisted of slightly muddy fine sands over much of the swale and coarser material combined with clay lumps eroding from the underlying Holocene lagoonal carpet in local erosional windows (McKinney et al. 1974; Stubblefield et al. 1975). Because of the shallow depth of this swale, it is probably subject to alternate deposition and erosion of fine sands depending on hydraulic conditions (Stubblefield et al. 1975). Thus, the silt and clay in the sediments is probably of a predominantly relict origin resulting from erosion of underlying deposits rather than from recent sedimentation.

The distribution of sediments, with respect to topography, has been well characterized in Area D by Stubblefield et al. (1975). Samples taken at the designated ridge station D1, in fall 1975, were well sorted medium sands as reported for "crest" populations by Stubblefield et al. However, due to a Loran navigation error, when this station was sampled in winter 1976, the location was off the target feature and well down a flank. As a consequence, sediments collected were much finer sands with a small silt-clay component. During the spring cruise, the original

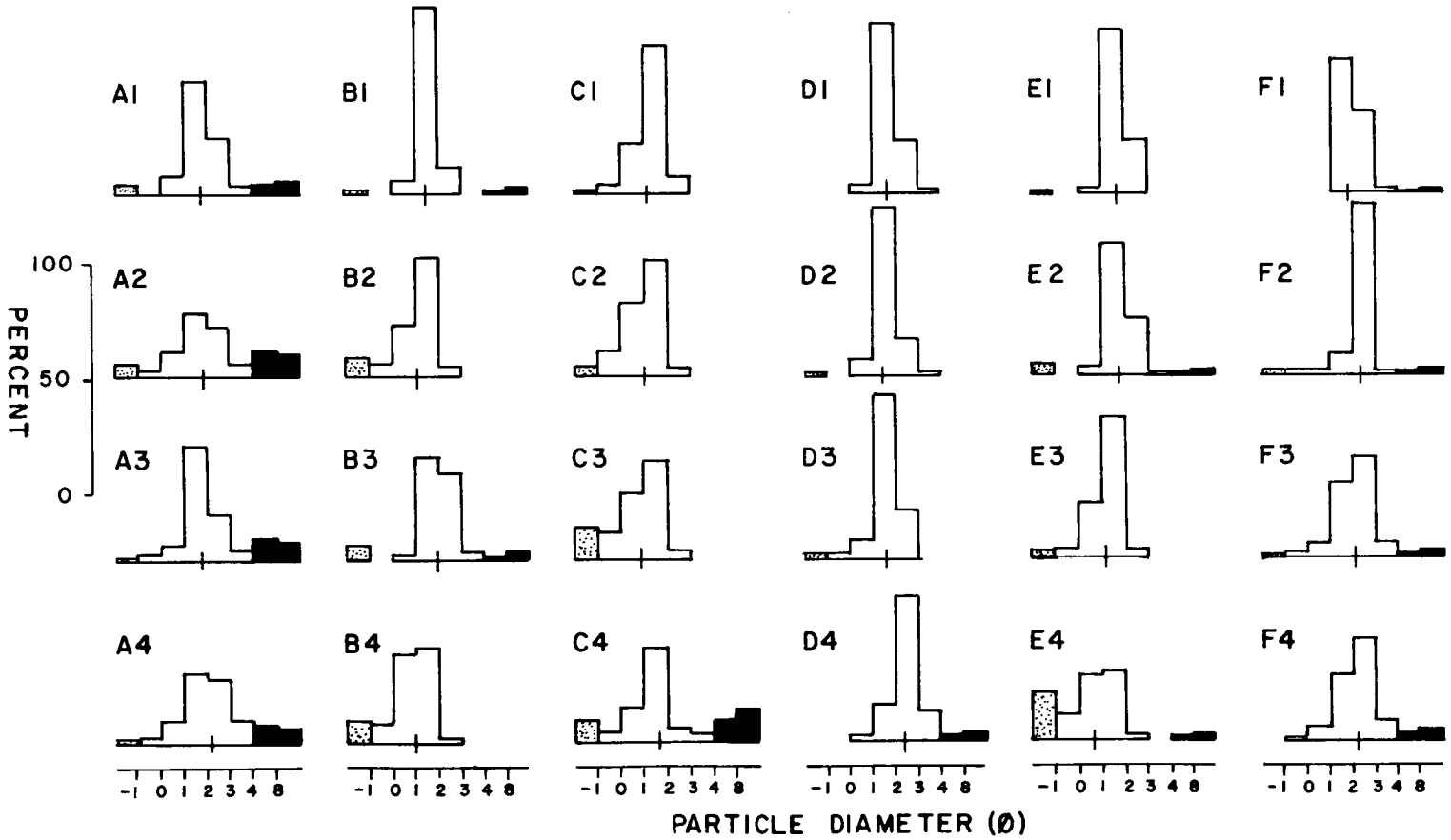


Figure 5-5. Histograms showing average frequency distribution of grain size in percent of mass by whole phi interval for the 24 cluster stations, Fall 1975. Gravel and shell (>2 mm) is shown as stippled and silt and clay as black bars. The median grain size is indicated by vertical line crossing base. Sand size particles are termed very coarse (-1-0ϕ), coarse (0-1ϕ), medium (1-2ϕ), fine (2-3ϕ) and very fine (3-4ϕ). Silt is represented between 4-8ϕ and clay is greater than 8ϕ.

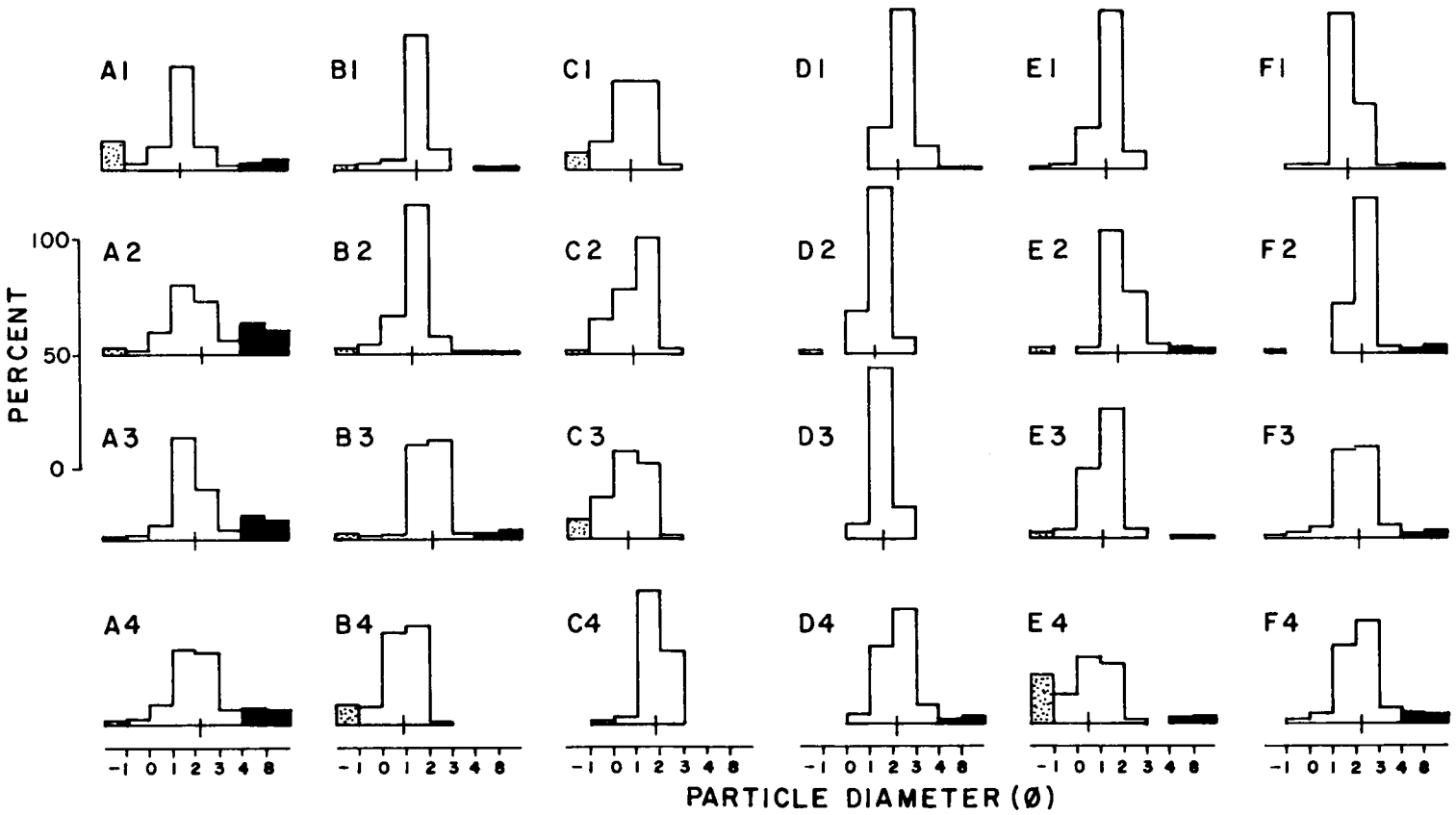


Figure 5-6. Average frequency distribution of grain size at 24 cluster stations, Winter 1976. As in Figure 5-5.

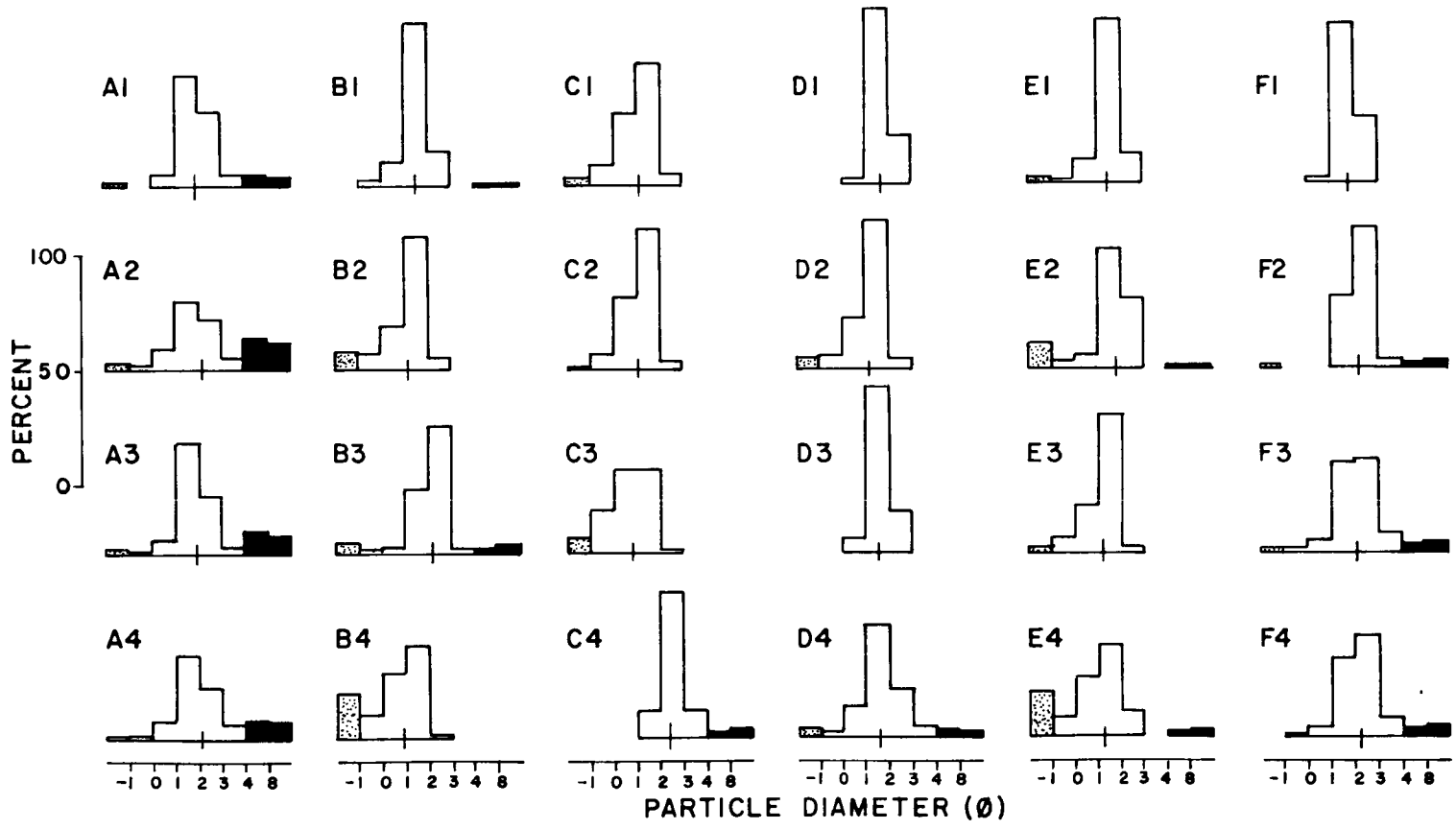


Figure 5-7. Average frequency distribution of grain size at 24 cluster stations, Spring 1976. As in Figure 5-5.

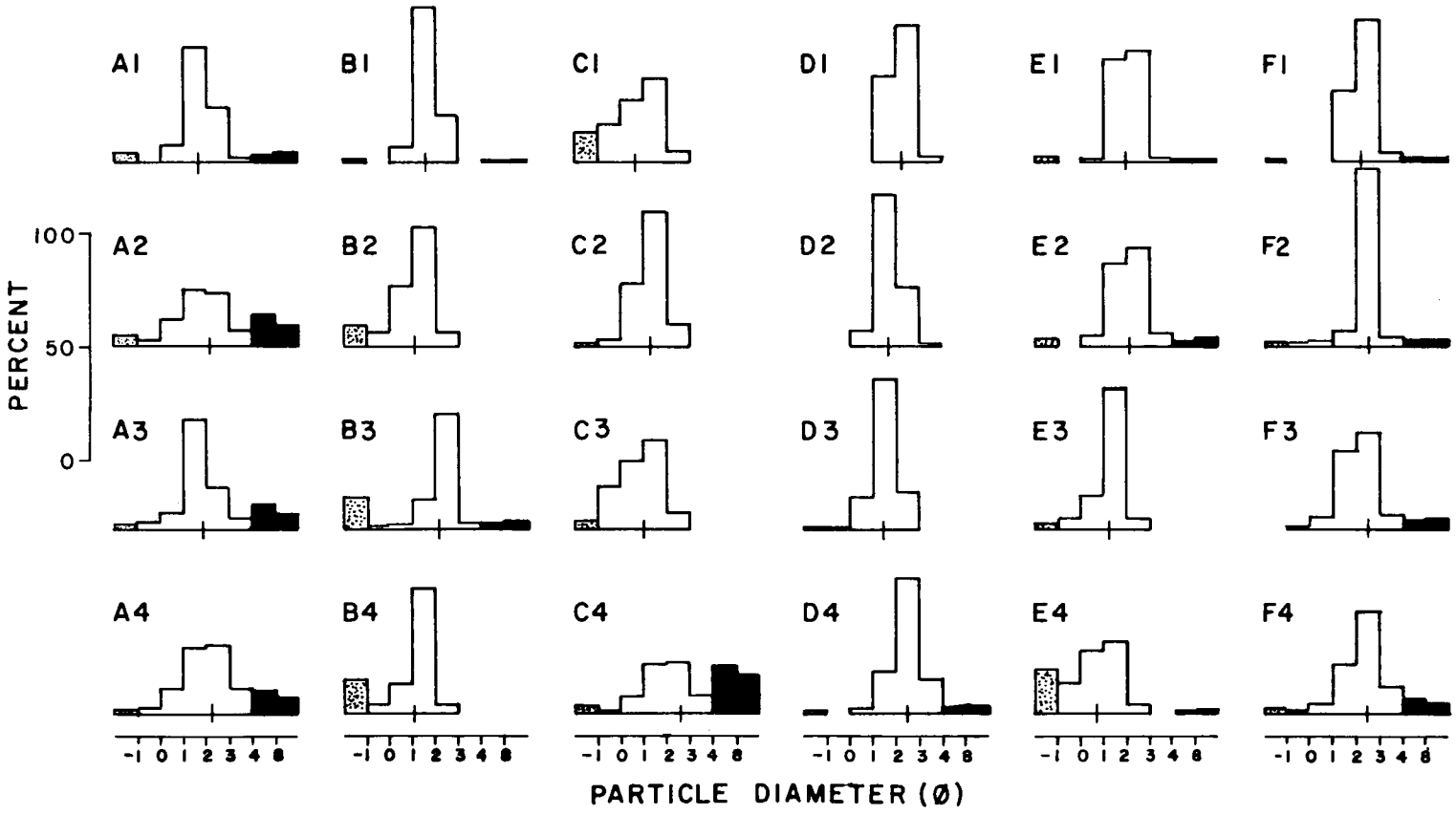


Figure 5-8. Average frequency distribution of grain size at 24 cluster stations, Summer 1976. As in Figure 5-5.

feature could not be located near the assigned position, and another topographic high at 31 m was sampled, again yielding medium "crest" sands. However, in summer 1976 somewhat finer sediments were again collected at the same site.

In contrast, sediments collected at D2 and D3 were similar from cruise to cruise, consisting of about 70% medium sand in each instance. The median grain sizes at these stations are coarser than those reported by Stubblefield et al. (1975) for "flank" sediment populations (ca. 1.6 vs. 2.2 ϕ); however, the sorting coefficients are comparable. Sediments collected at D4, the swale station, again consisted of finer particles than the other stations in the area, typically ca. 60% fine and very fine sand with 4-6% silt and clay. Median diameters were comparable to those reported by Stubblefield et al. (1975) for "trough II" populations. Sediments at D4 during spring 1976 were somewhat coarser and contained more shell/gravel tending toward Stubblefield et al.'s "trough II" sediment type, characteristic of erosional windows within a swale.

Due to navigational difficulties and attempts to rectify them, the location of Station E1 varied more than any other (Chapter 2). Designated as a ridge station, the station was apparently never located on the crest of a ridge during the first 4 cruises but rather on its upper flanks. During the fall, winter, and spring, clean, predominantly medium sands were collected. However, during the summer a site slightly down slope was sampled resulting in the collection of medium-fine, slightly muddy sands, characteristic of a less exposed environment. Station E2 was located well down a flank and was characterized by medium-fine sands with 3-7% silt and clay. Station E3 was located on a flat area and yielded coarser medium sands with little silt-clay. Station E3 was located on a flat area and yielded coarser medium sands with little silt-clay. Sediments at the designated swale station E4 consisted of medium to coarse sand densely littered by shells (chiefly of the bivalve *Cyclocardia borealis*). Silt-clay content averaged 3-6% and may result from the erosion of Holocene lagoonal clay since the coarse sediments indicate active erosion at this site.

Sediments at the F stations were predominantly medium and fine sands. Fine sand was especially important at F2. Silt-clay increased from about 2 to 10% from F1 to F4, and conversely, sorting decreased. Pelagic foraminifera comprised an increasing portion of the sediment along this gradient.

Transect Stations

Grain size distributions at stations located on the cross-shelf transects are summarized in Figures 5-9 and 5-10. Along the inner portion of the G transect, sediments were from predominantly coarse sand inshore (G1) and medium-coarse sand on either side of the Hudson Shelf Valley (G2, G4). Muddy (8%), very poorly sorted sands were found at G3 located in the axis of the Hudson Shelf Valley. On the outer shelf and upper slope, sediments graded from slightly muddy, medium sands at G5 to quite muddy, fine sands at G7.

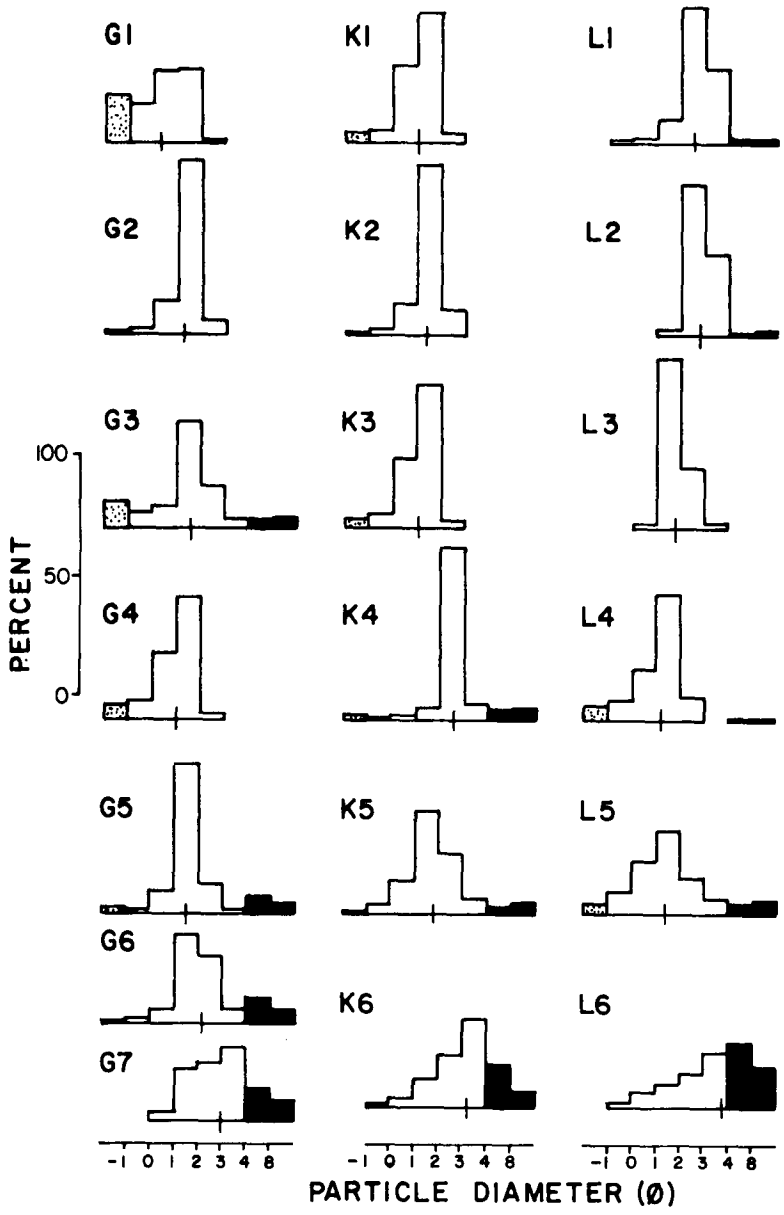


Figure 5-9. Average frequency distribution of grain size at 19 shelf transect stations, Winter 1976. As in Figure 5-5.

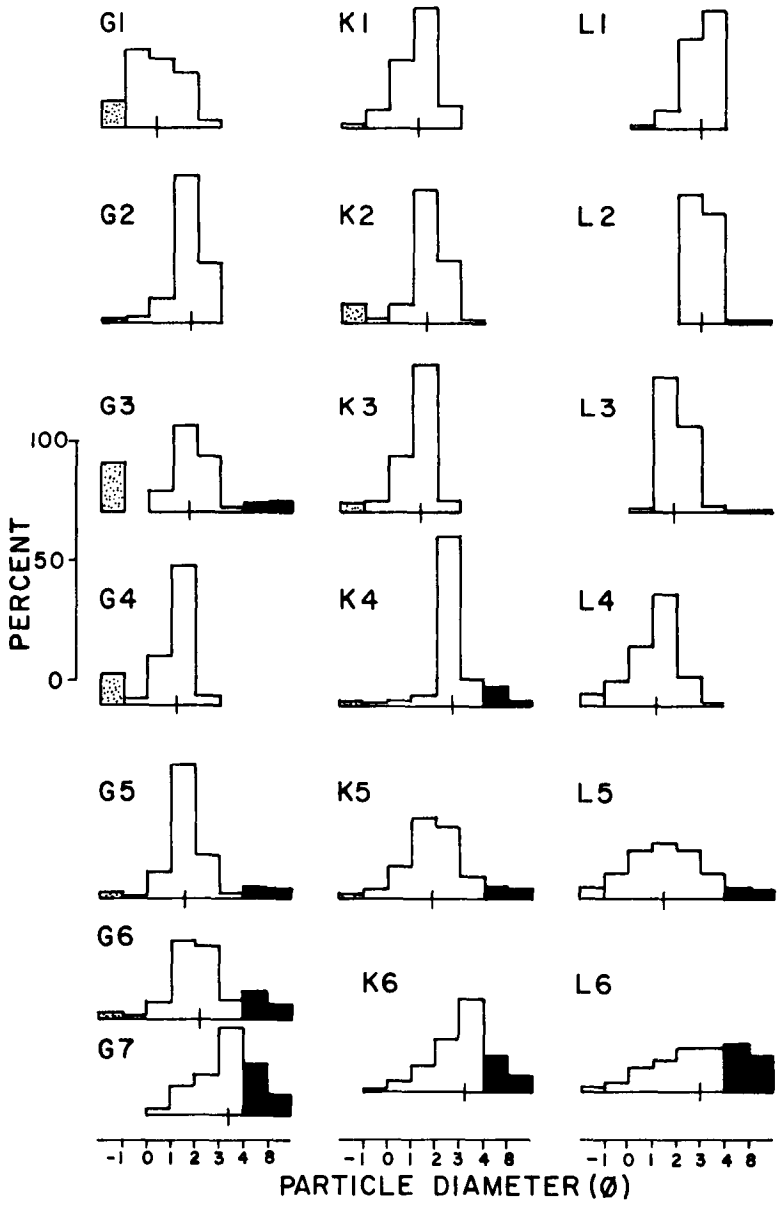


Figure 5-10. Average frequency distribution of grain size at 19 shelf transect stations, Summer 1976. As in Figure 5-5.

Clean medium sand predominated at the inner three stations on the K transect although sands were coarser at K1 and K3 than K2. Fine sands with about 10% silt and clay were found at K4 during both cruises. This station appears to lie in a topographic depression. Muddy, medium-fine sands which are poorly-sorted were found at K5 in the shelf break region, and muddy, fine sands were found at K6 on the upper slope.

Sediments at L1 and L2 were almost exclusively fine and very fine sands. These stations lie in a broad expanse of fine sand extending out over half of the shelf off the southern Delmarva Peninsula (Swift 1976, Figure 24). Swift (1976) suggested that the deposition of fine sands in this area results from the expansion and deceleration of storm flows brought about by the westward shoreline curvature of the southern half of the Delmarva coastal compartment. On the outer shelf, sediments again consisted of medium-fine sands at L3 and medium-coarse sand at L4, reflecting the shelf-edge coarsening (Figure 5-3) reported by Southard and Stanley (1976). At L5, poorly sorted mixed sands containing 8% silt-clay were found, and sand-silt-clay was found at L6 during both cruises.

Canyon Head and Continental Slope Stations

Sediments from I1 and I2 on the outer shelf between the A and F stations were coarser than sediments in either of those two areas (Figures 5-11 and 5-12). Both stations were characterized by much coarse sand and gravel and a small amount (ca. 4%) of silt and clay. Sediments at I3 at the head of Toms Canyon (460 m) consisted of about 50% fine sand and 50% silt and clay. Sediments at the two stations in the canyon head I3 and I4 were not unlike those at stations of similar depth removed from canyons.

Texture of sediments on the upper slope off the A stations (H1 and H2) was similar to that of stations off the F stations (J1 and J2) at comparable depths. At 350-400 m (H1 and J1) sediments consisted of silty-fine sand (ca. 30% silt and clay), although the sand fraction at H1 was somewhat coarser than at J1. Deeper on the slope at 700-750 m (H2, J2), sediments were 90% or more silt and clay.

Inter-Replicate Variability

At most stations 8 individual determinations of grain size distribution were made for each period in which the station was sampled. Only in those cases where fewer than 8 samples were taken were fewer analyses done. Generally, the samples from replicate grabs 1 and 2 were analyzed after return of the samples from USGS. Sediment samples from replicates 7-12 or those grabs taken for macrobenthos analyses were always analyzed. The relevance of the data reported to the interpretation of chemical studies conducted on samples from grabs 1-6 depends on the accuracy and precision of the analysis as well as the natural variability experienced.

For each of the parameters measured or computed, including percent composition by whole phi intervals, means, standard errors, and confidence intervals have been computed and are available in unpublished listings. These data show that sediment parameters can be highly variable from replicate to replicate, although in most cases variability is fairly low.

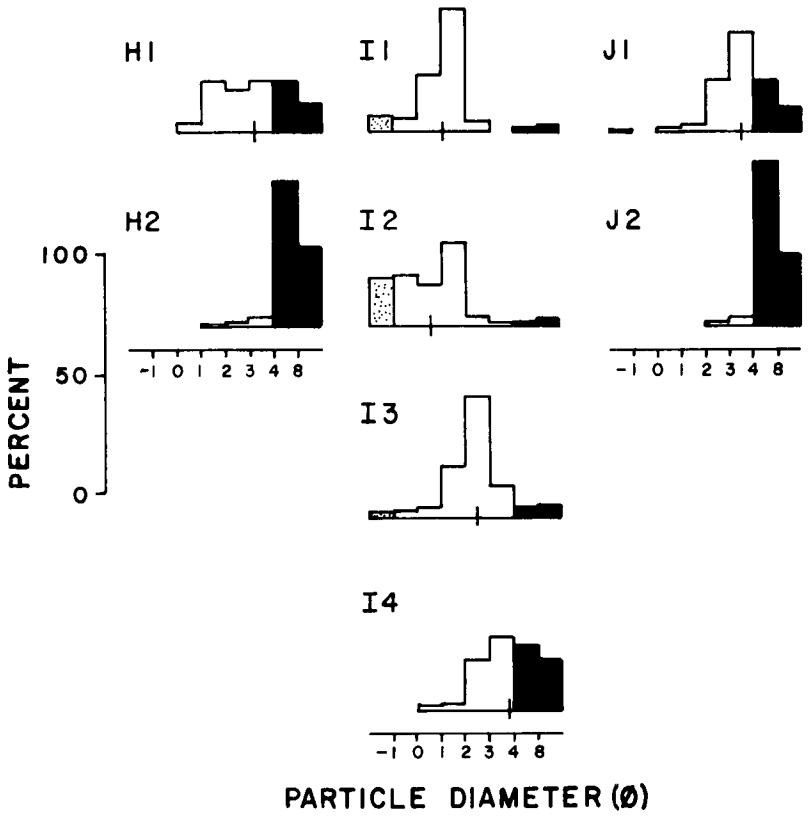


Figure 5-11. Average frequency distribution of grain size at 8 stations on the continental slope (H and J stations) and at the head of Toms Canyon (I stations), Winter 1976. As in Figure 5-5.

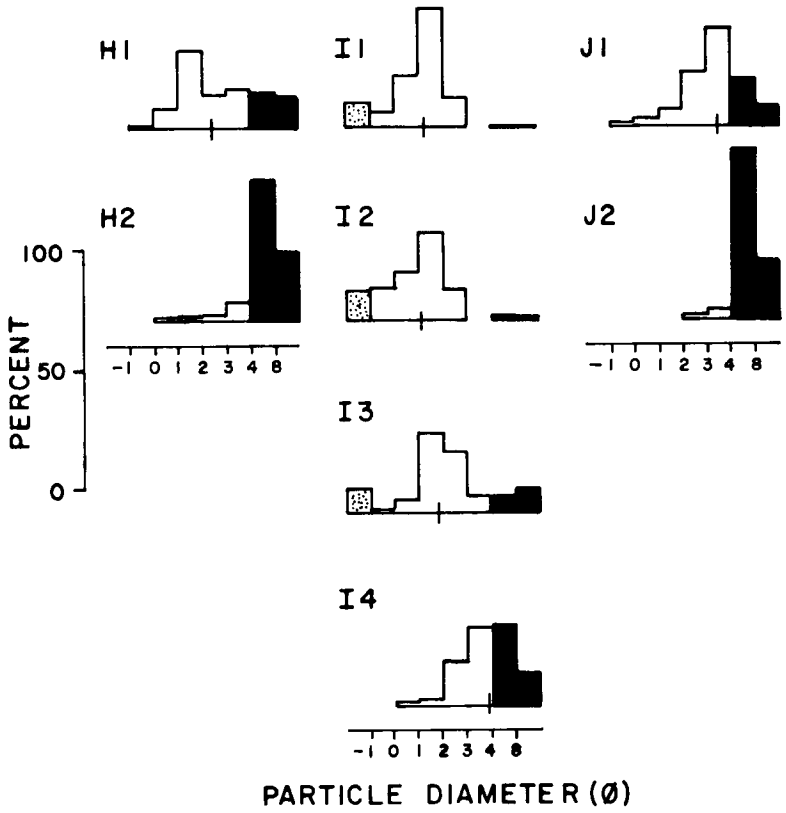


Figure 5-12. Average frequency distribution of grain size at 8 stations on the continental slope (H and J stations) and at the head of Toms Canyon (I stations), Summer 1976. As in Figure 5-5.

Although no extensive experiments were conducted on sample splits, the low variability of some replicate data indicates that the precision of the granulometric analyses was quite high. This was selected for by the extensive replication which provides ample opportunity to detect aberrant values and recompute or reanalyze if necessary. The accuracy of the data depend on assumptions of the method of analysis and on calibration. The principal analytical tool, the rapid sand analyzer (RSA), was calibrated using a blend of continental shelf sand sieved to ¼ϕ size intervals. This approach enhanced accuracy with regard to a relevant standard. Furthermore, these data agree well with those published in the literature from the study area (Hollister 1973; Stubblefield et al. 1975).

Thus, the main source of variation in the data appears to be environmental and not methodological. Variability in grain size parameters among replicate grabs and among replicate cores within grabs is known to be of consequential magnitude within the study area (Knebel 1975). However, the magnitude of variability is by no means constant throughout the study area, and it is important to understand this in order to interpret biological and geochemical data. As an example, cumulative frequency curves are shown for two extreme cases in Figures 5-13 and 5-14. Sediments at C4, a shallow station where position keeping with reference to the bottom should be quite good, were extremely variable because of the presence of clayey patches resulting from erosion of underlying lagoonal deposits. On the other hand, the fine sands at Station F2, located in much deeper water, were extremely homogeneous within the certainly wider range of locations of replicate grabs.

Skewness and Kurtosis

Values of the graphic skewness and kurtosis measures were quite variable among replicate samples and, because of this variability and lack of clear trends among the stations, will not be discussed in detail.

Distributions in most samples tended to be near-symmetrical, and although both fine-skewed and coarse-skewed distributions were found, coarse-skewed distributions were more common. Kurtosis was perhaps more variable, and there was a tendency toward platykurtic distributions.

Although the models of Swift et al. (1972b) suggest that skewness and kurtosis should sensitively reflect hydraulic regimes, in practice it is often difficult to discern interpretable patterns in environmental samples. In addition, the biological and chemical implications of the skewness and kurtosis of grain size distributions are obscure.

Total Organic Carbon

Total organic carbon (TOC) concentrations in sediments ranged from trace amounts in coarse sands to 10.2 mg/g (1%) in muddy slope sediments. As is widely recognized, the grain size parameter most closely correlated with organic carbon concentration is the silt and clay content. The product-moment correlation coefficient between TOC and percent silt and clay was significant at 0.87 ($p < 0.01$) for the cluster stations and 0.83 ($p < 0.01$) overall.

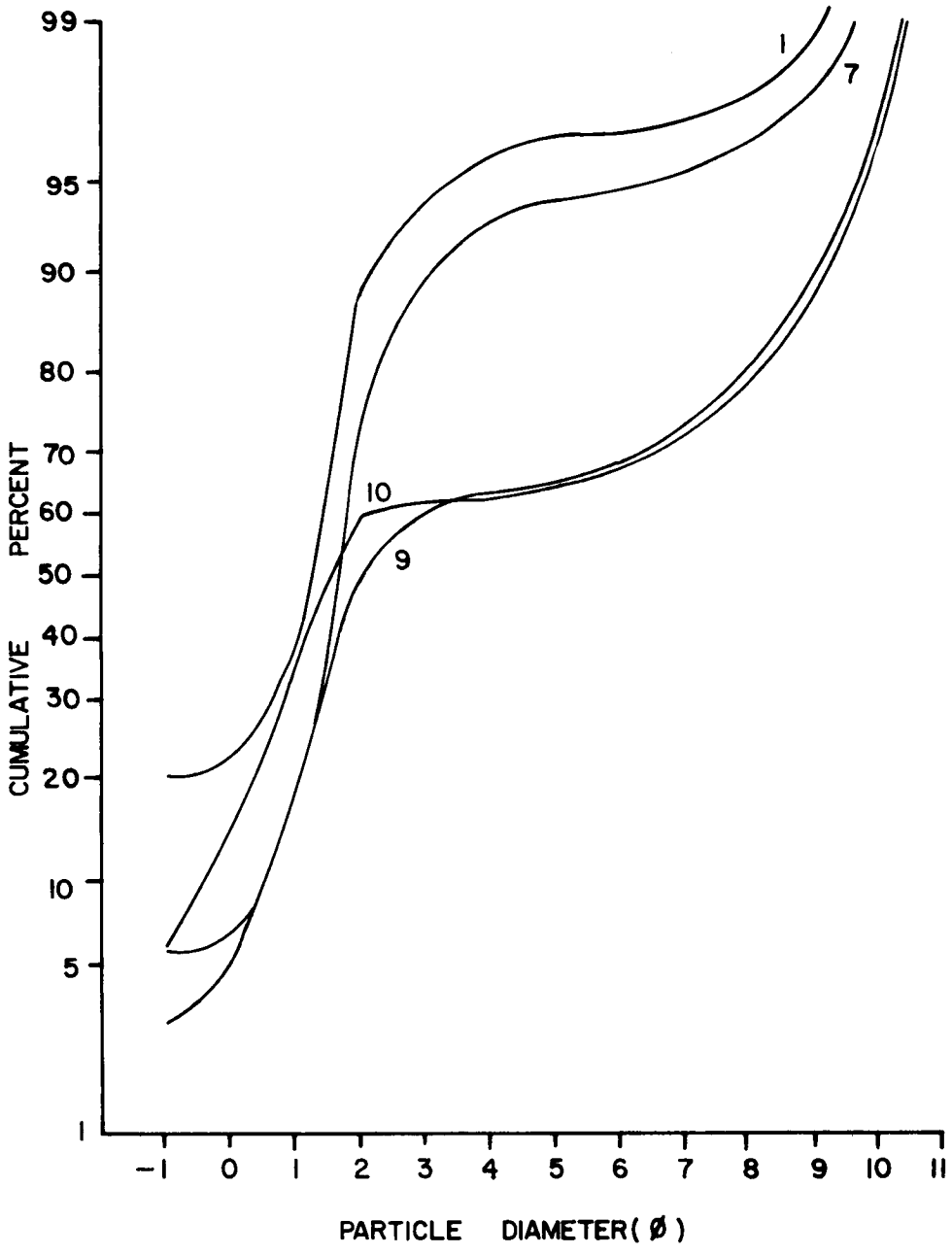


Figure 5-13. Inter-replicate variability demonstrated by the cumulative frequency distributions of 4 samples from Station C4, Fall 1975.

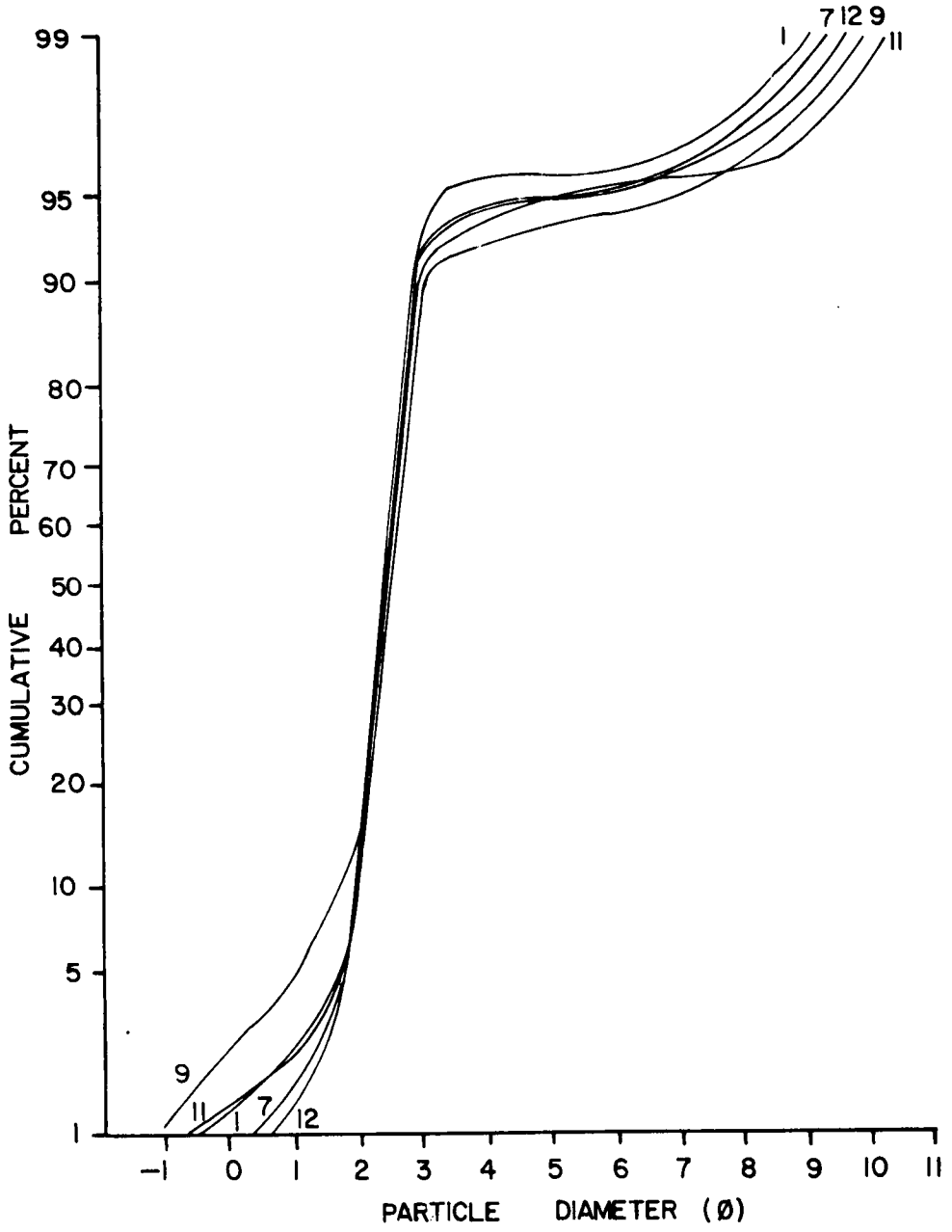


Figure 5-14. Low inter-replicate variability demonstrated by the cumulative frequency distributions of 6 samples from Station F2, Fall 1975.

The carbon data are thus best visualized as scatter plots against percent silt and clay (Figures 15-15 to 15-18). These plots show low TOC (< 1 mg/g) at a large number of shelf stations where silt and clay comprised less than 2% of the sediments. Within the addition of small amounts of silt and clay, organic carbon increased dramatically; sediments containing ca. 10% silt and clay contained > 3 mg/g carbon. The rate of increase of carbon with increasing silt and clay declines, however, such that most continental slope sediments composed of 50% or more silt and clay contain less than 6 mg/g carbon. This is in part due to the fact that, although the sediments are finer, they are further removed from sources of productivity, thus the increase in TOC is not proportional to that of silt and clay.

Shelf break stations had higher silt-clay composition and therefore higher TOC than shelf stations. The swale stations (B3, C4, D4, and E4) and others in depressions (G3) had higher TOC (2-4 mg/g) than elsewhere on the shelf. In many cases the TOC in swale station sediments was higher than would be predicted based on the overall TOC-silt and clay relationship, possibly reflecting greater macrobiological and microbiological activity in swale environments (see Chapters 6 and 11).

Despite the high overall correlation between silt and clay and organic carbon, correlations between these parameters within the replicates at any one station were generally poor. Significant ($p < 0.05$) correlations were found at less than 10% of the stations. Two non-exclusive explanations for this are suggested. First, the variability in sedimentary parameters, including silt-clay percentage and carbon concentration, within a single grab sample, may be as great as that among replicate grab samples. Thus, since two separate cores were taken for granulometric and carbon analyses, their comparability is compromised. Secondly, the relationship between silt and clay and organic carbon may be to some degree indirect. That is, areas of silt-clay deposition may also be sites for organic carbon deposition rather than any direct causal relationship between the two parameters. Biological processes may be more important in determining the localized distribution of organic carbon. Thus, local distribution is controlled by processes other than sedimentation. In reality, both explanations probably pertain.

Total Nitrogen

Total nitrogen concentration of sediments ranged from trace amounts to 11 mg/g. The determined values were much more variable among replicate samples than with either TOC or grain size parameters. Overall, correlations of nitrogen with percent silt and clay or TOC were poor ($p > 0.05$) due to the extreme variability (over 2 orders of magnitude) of the measured nitrogen content in sediments with little silt and clay (Figure 5-19). However, nitrogen values for fall 1975 and summer 1976 were significantly correlated ($p < 0.01$) with both silt and clay and TOC.

Emery and Uchupi (1972) show a strong correlation of Kjeldahl nitrogen concentration with silt and clay and organic carbon in a wide range of sediments from the northwestern Atlantic continental margin. The values of total nitrogen reported here are generally higher than the norm, drawn relative to silt and clay by Emery and Uchupi (Figure 5-19),

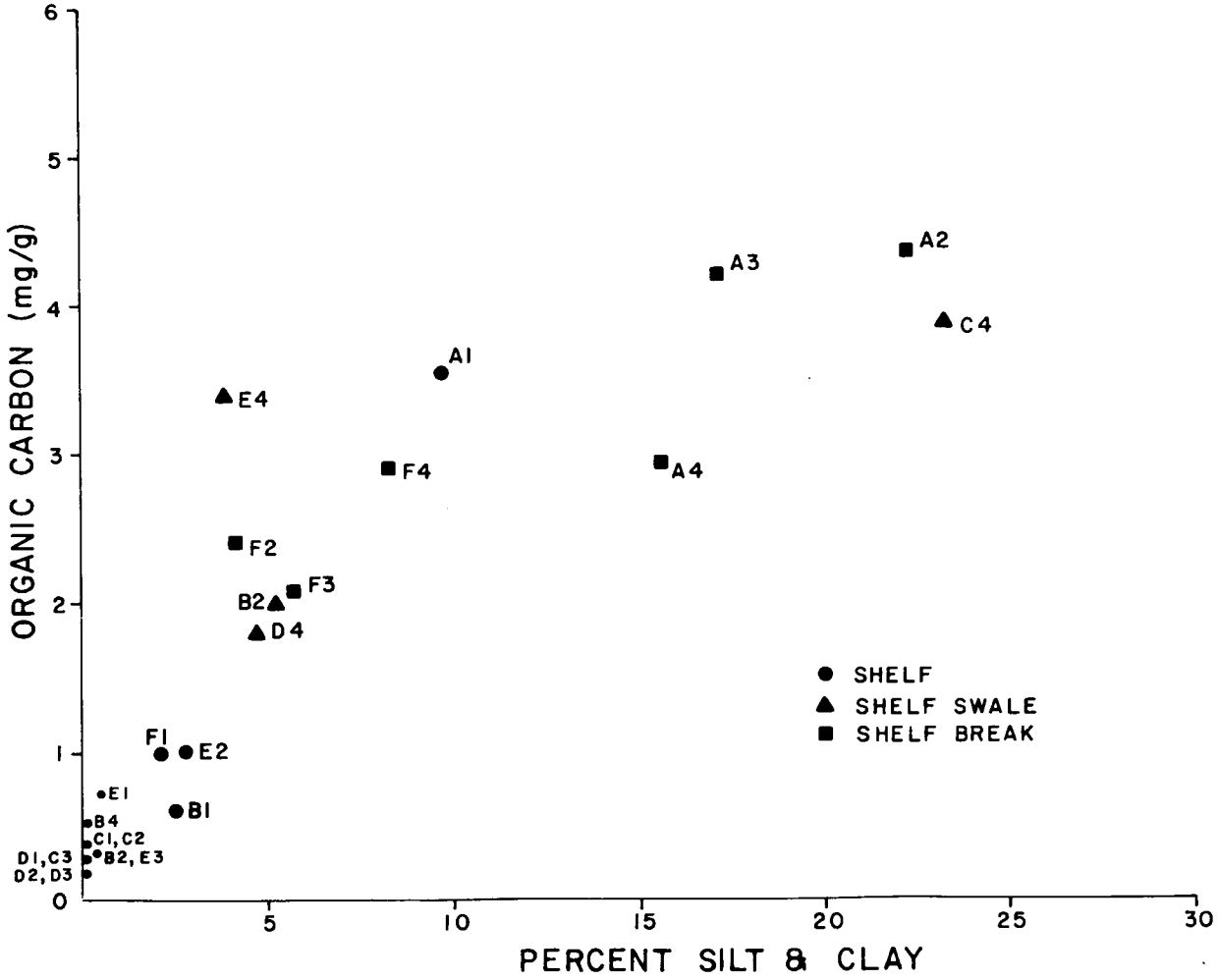


Figure 5-15. Relationship of mean total organic carbon concentration to mean silt and clay percent for stations sampled in Fall 1975.

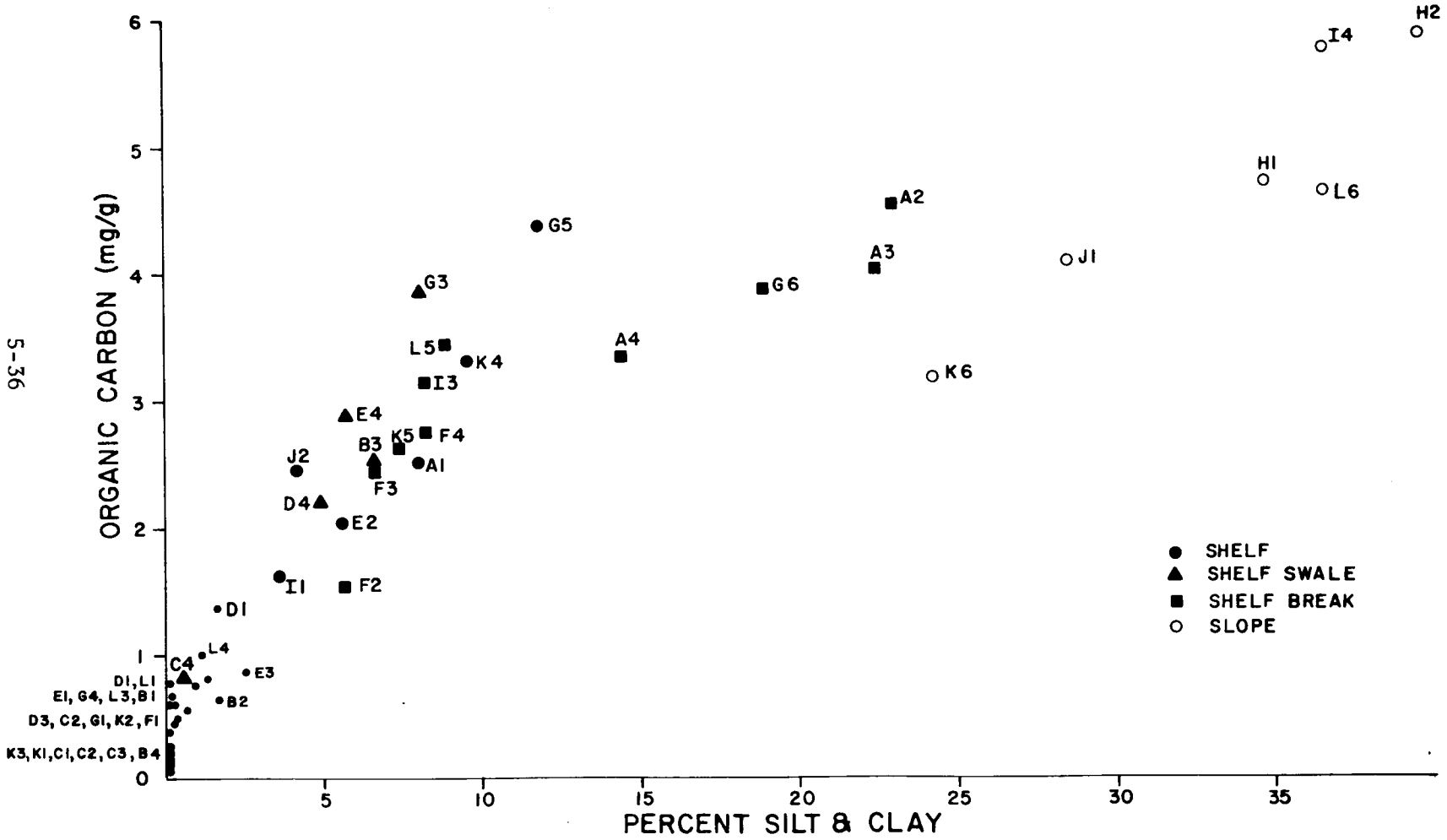


Figure 5-16. Relationship of mean total organic carbon concentration to mean silt and clay percent for stations sampled in Winter 1976.

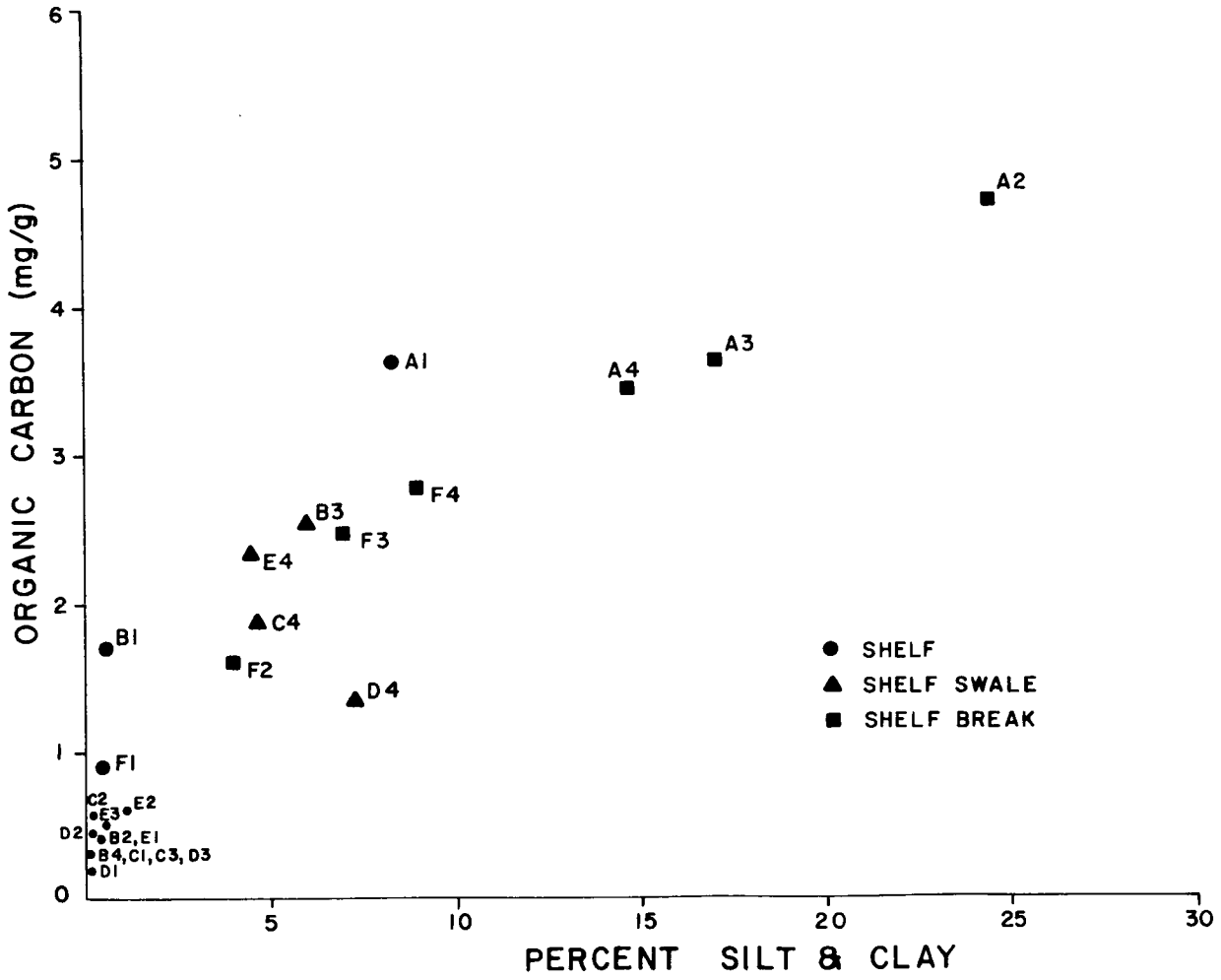


Figure 5-17. Relationship of mean total organic carbon concentration to mean silt and clay percent for stations sampled in Spring 1976.

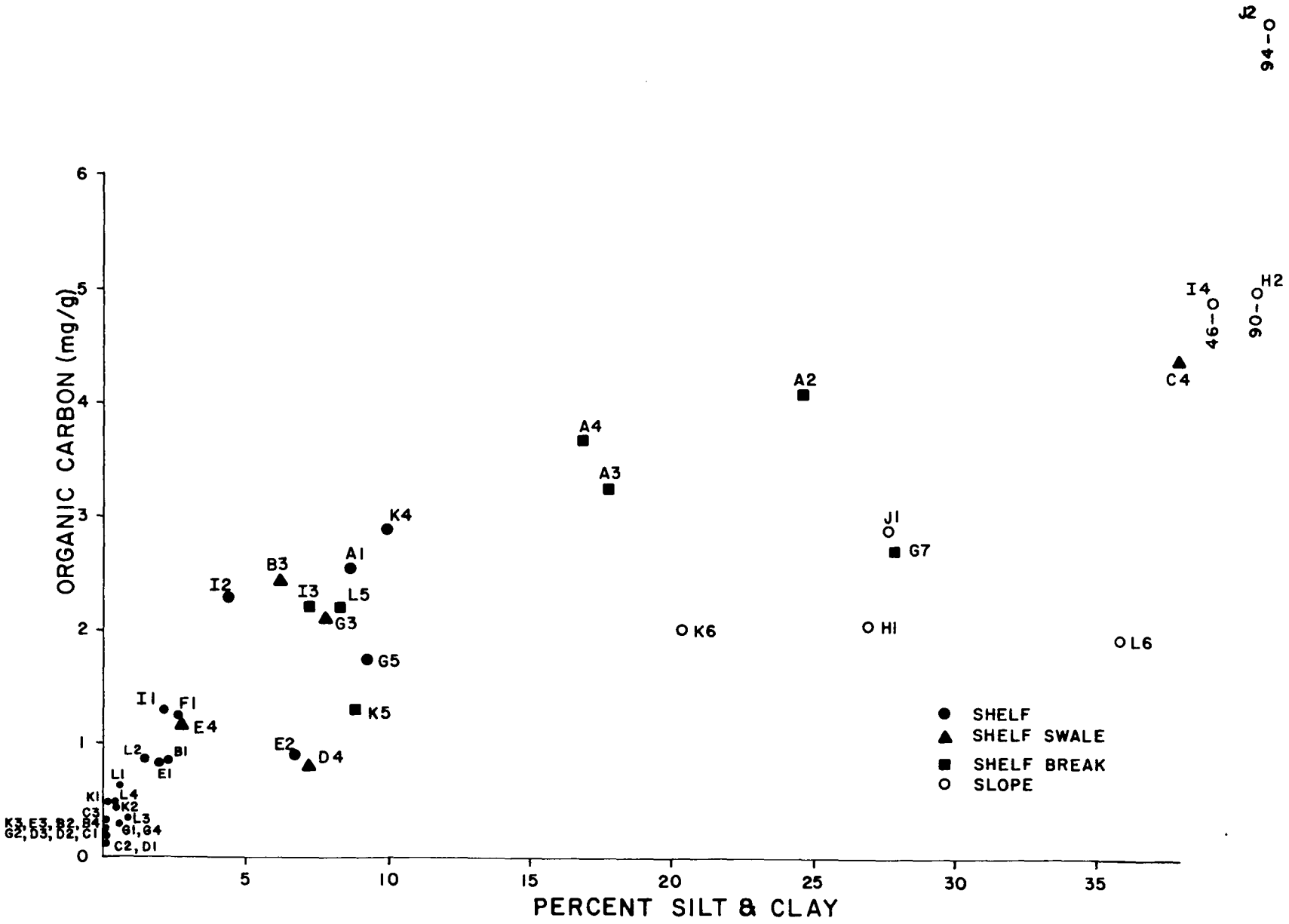


Figure 5-18. Relationship of mean total organic carbon concentration to mean silt and clay percent for stations sampled in Summer 1976.

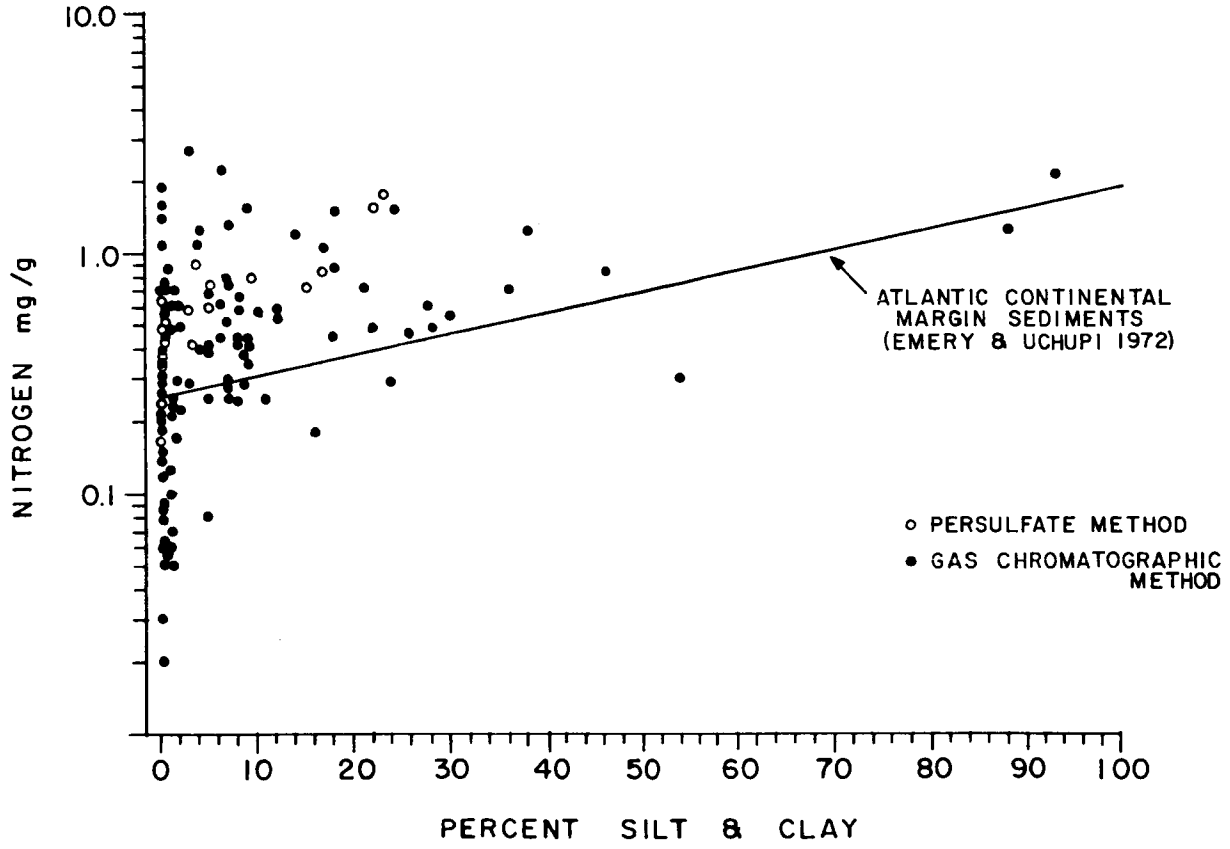


Figure 5-19. Relationship of mean nitrogen concentration to mean silt and clay percentage for stations sampled, Fall 1975 through Summer 1976.

and many values from low silt and clay sediments fall outside this reported range. This is in part due to the fact that the methods used here measure nitrogen in addition to the nitrogen in amines and ammonia measured by the Kjeldahl method.

The great inter-replicate variability in nitrogen determinations, particularly those made by the gas chromatographic technique, and the lack of expected correlation with other sediment parameters for winter and spring 1976 samples suggest that analytical techniques lacked in precision and accuracy. However, the distribution of nitrogen in shelf sediments might naturally be highly variable. In either case, the nitrogen data show no overall systematic relationship with any sedimentary or benthic biological parameters measured in these studies.

Seasonal Variability

The variability in key sediment parameters among seasonal sampling periods is assessed with respect to inter-replicate variability for the quarterly sampled stations in Figures 5-20 to 5-25. Parameters chosen for this analysis were median diameter, percent silt and clay, organic carbon content, and percent fine sand (2-4ϕ). These were selected because of conventional importance, relevance to biological and chemical studies, and for sensitivity.

Sediment parameters at the A stations were quite consistent from season to season. Only the winter samples at A2 showed significant differences from those found in other seasons. The proportion of fine sand in the sediment was less, thus lowering the median diameter. Otherwise, basic size parameters, such as percent silt, clay, and fine sand, were highly diagnostic among stations.

Similarly, key parameters at the B stations (Figure 5-20) showed few significant differences among seasons. Differences in median diameter between fall and summer samples at B1 and B3 were slight and could not be explained by significant differences in fine sediments.

Variability of median diameters at the C stations (Figure 5-22) was greater than at most other stations. At stations C1, C2, and C3 this was due to variations in the distribution of medium and coarse sand. As discussed earlier, sediments at C4 were the most variable of any station due to the great heterogeneity at this swale station. Even with the very wide inter-replicate variability, significant differences in percent silt and clay and fine sand existed between seasonal samples.

The variability in sediments due to station relocation difficulties at D1 have already been discussed. Fall and spring samples were dominated by medium sand and winter and summer samples by fine sand. Among the other D stations, sediments in spring samples at D2 and D4 were somewhat coarser than during other periods.

Sediments in cluster area E are probably the most spatially heterogeneous of any of the study areas (Figure 5-24). This, compounded by station relocation problems (e.g. at Station E1), resulted in the greatest apparent temporal variability witnessed. However, no consistent

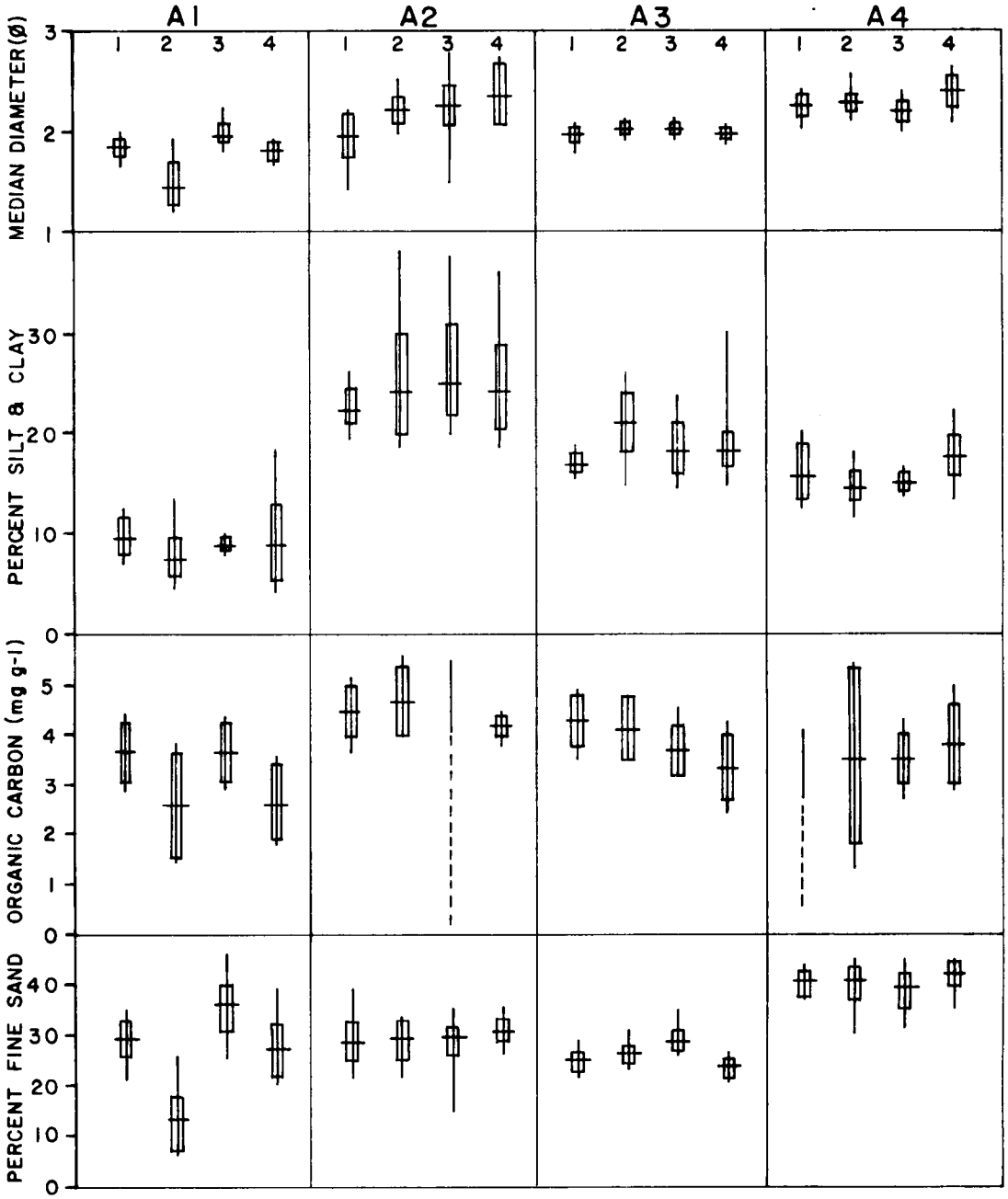


Figure 5-20. Seasonal variation in key sedimentary parameters, cluster area A. Vertical lines represent range represented in samples from replicate grabs, short horizontal lines represent means and vertical bars represent the 95% confidence limits ($\bar{x} \pm s_{\bar{x}}\, t_{.05}$). Numbers refer to sampling period numbers: 1 (Fall 1975), 2 (Winter 1976), 3 (Spring 1976), and 4 (Summer 1976).

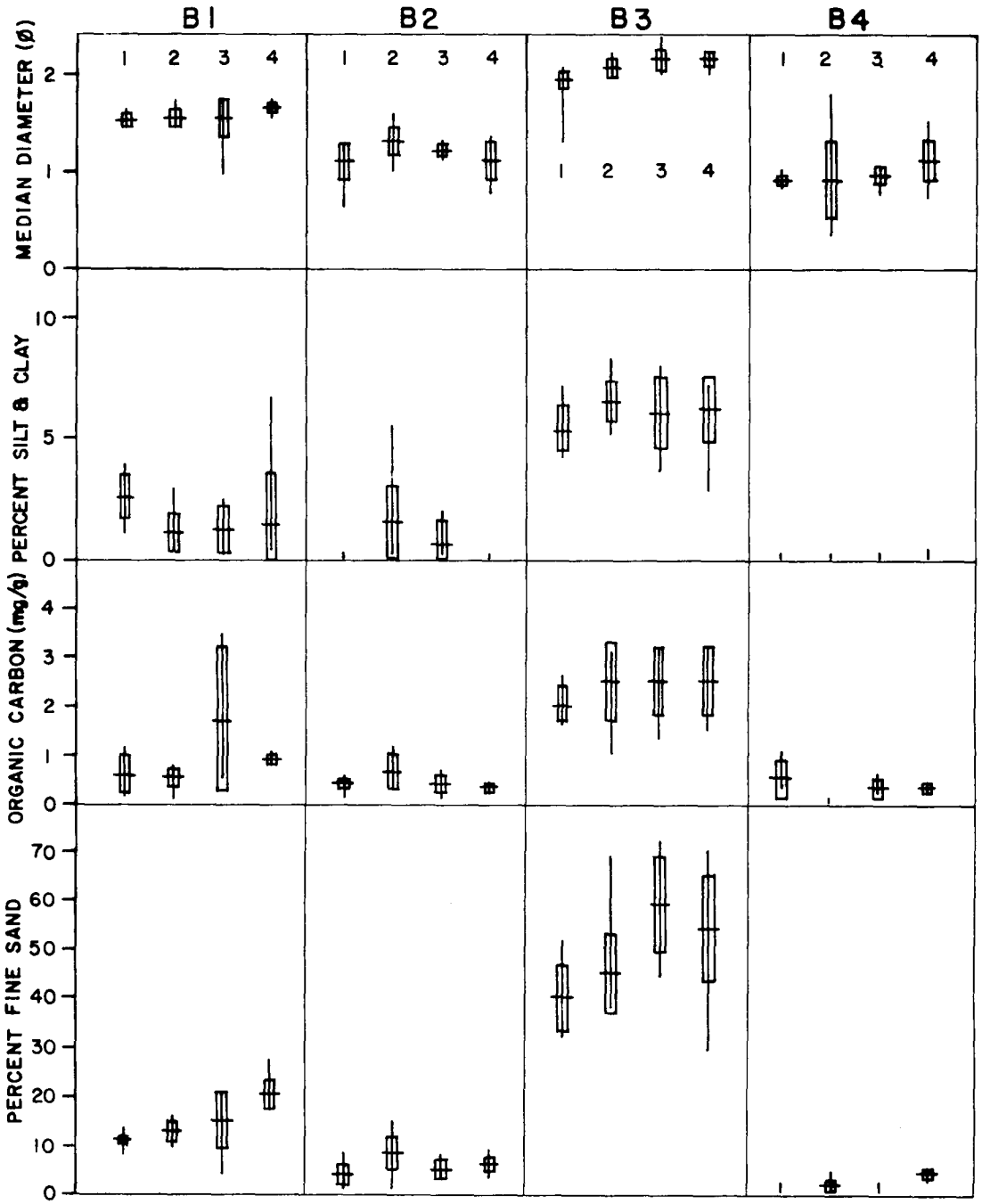


Figure 5-21. Seasonal variation in key sedimentary parameters, cluster area B. Vertical lines represent range represented in samples from replicate grabs, short horizontal lines represent means and vertical bars represent the 95% confidence limits ($\bar{x} \pm s_{\bar{x}} t_{.05}$). Numbers refer to sampling period numbers: 1 (Fall 1975), 2 (Winter 1976), 3 (Spring 1976), and 4 (Summer 1976).

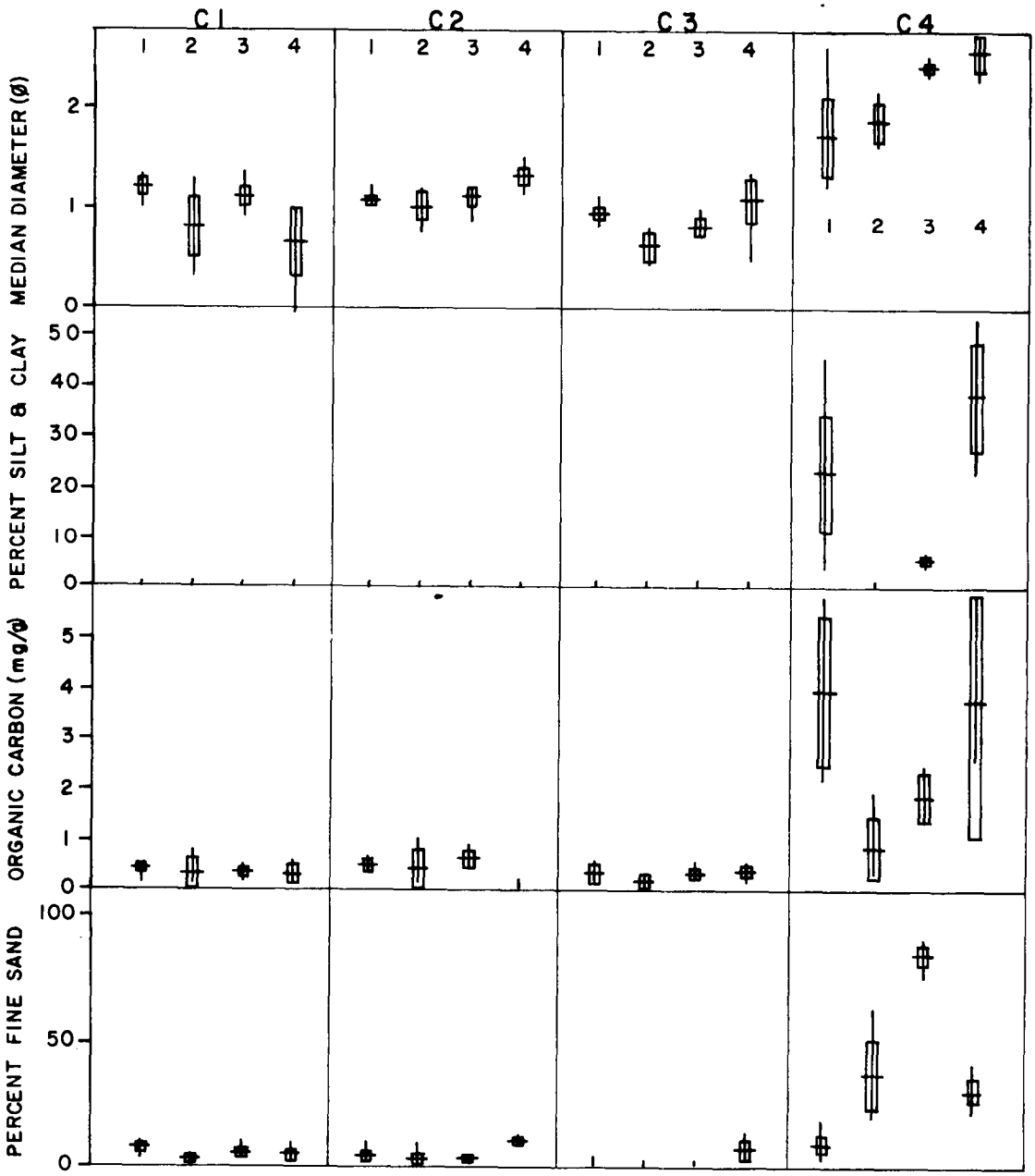


Figure 5-22. Seasonal variation in key sedimentary parameters, cluster area C. As in Figure 5-21.

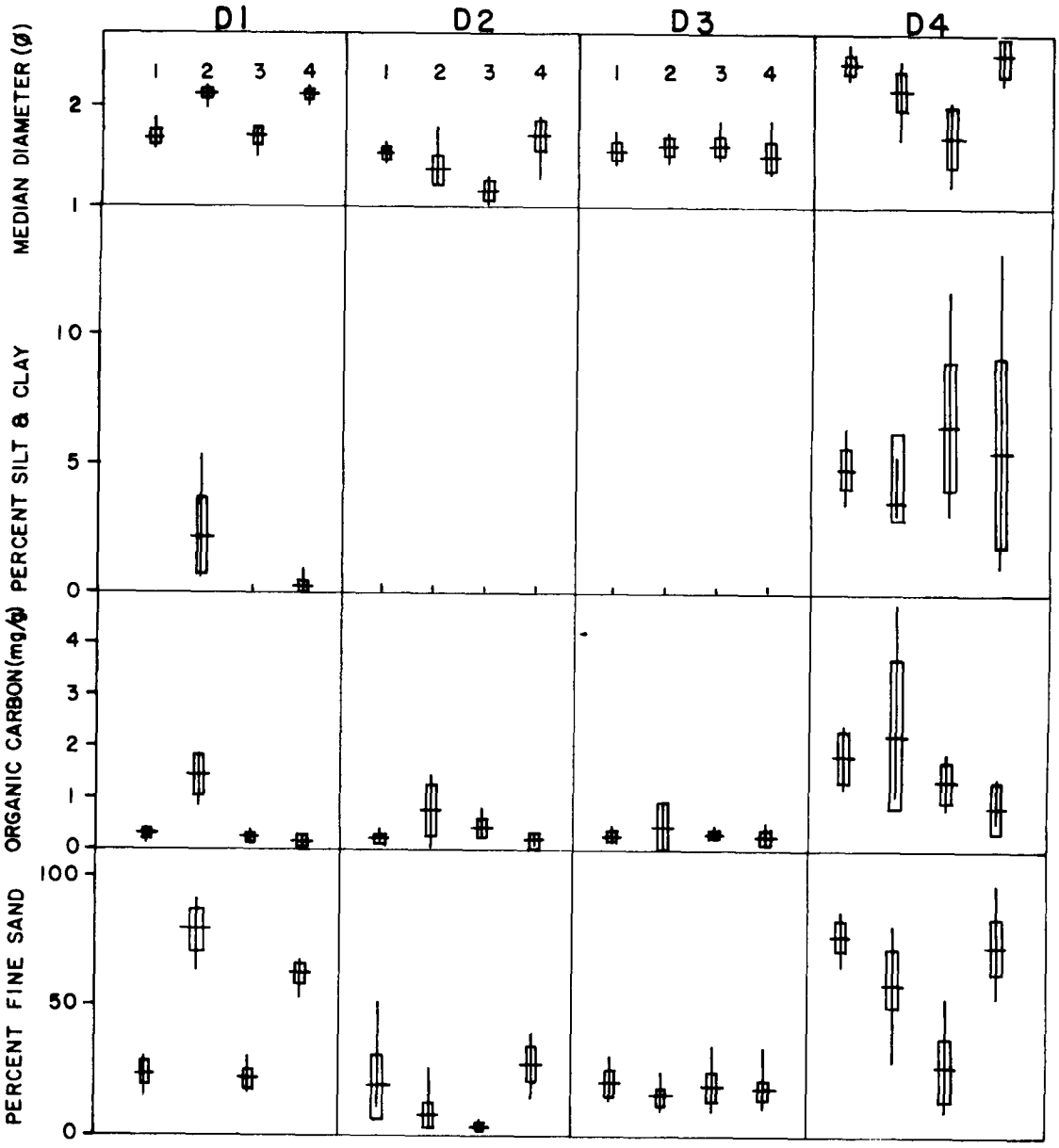


Figure 5-23. Seasonal variation in key sedimentary parameters, cluster area D. As in Figure 5-21.

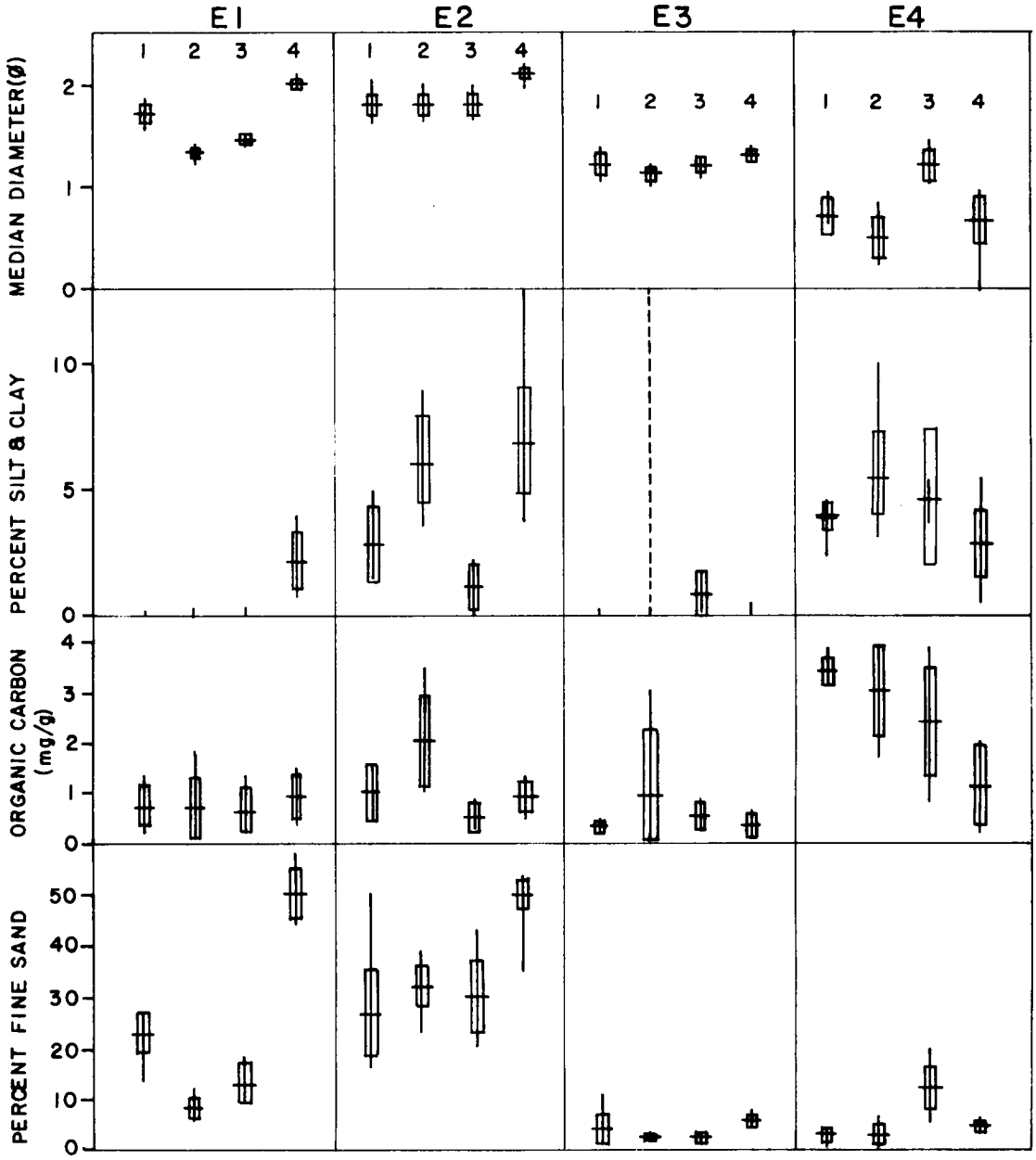


Figure 5-24. Seasonal variation in key sedimentary parameters, cluster area E. As in Figure 5-21.

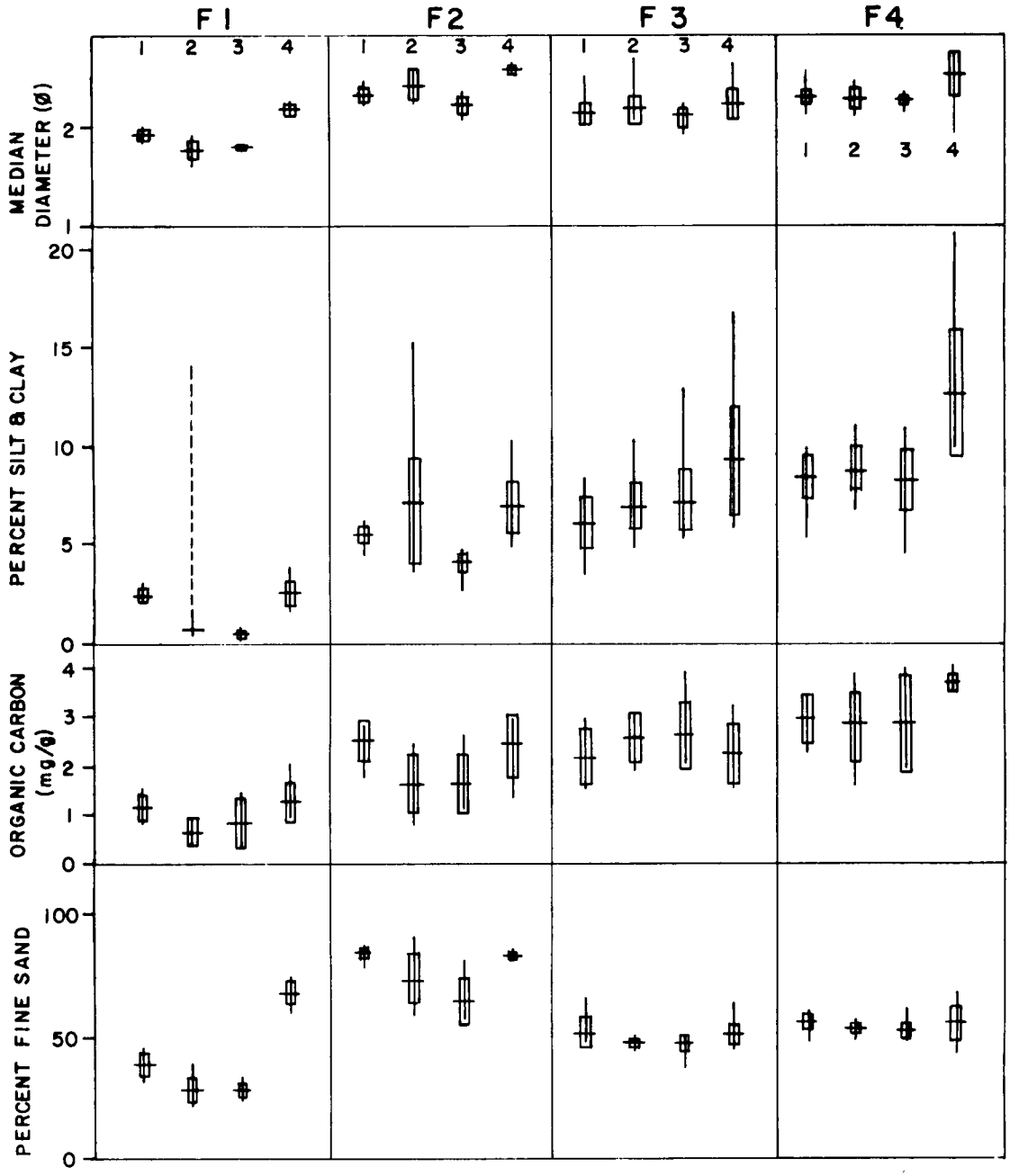


Figure 5-25. Seasonal variation in key sedimentary parameters, cluster area F. As in Figure 5-21.

trends in the sediment patterns exist which could be attributed to widespread seasonal variability in sediments in area E.

Sediment parameters at the F stations again show general consistency from season to season (Figure 5-26). Notable differences exist at F1 in the summer where the sands were finer and at F4 in the summer where the silt and clay content was greater.

Comparison of means and their confidence limits of these sediment parameters, which include those most likely to vary seasonally either because of seasonal patterns of physical disturbance or biological productivity, shows that few differences exist among seasons. Furthermore, only few of the statistically significant differences could not be explained by known patchiness and variation in station location. As a further test of whether there may be some broad, but subtle seasonal trends in sediment parameters, seasonal rankings of mean values of these grain size parameters were tested for concordance, overall and within cluster areas, using Kendall's coefficient of concordance (Siegel 1956).

Significant ($p \leq 0.05$) concordance in seasonal rankings of means over all 24 stations was apparent for median diameter, silt and clay percentage, and fine percent sand. With all three parameters, summer samples showed generally finer sediments (finer median diameter and greater amounts of fine sand and silt and clay) than those from other seasons. Within station areas, concordance in mean rankings was significant ($p < 0.05$) in Areas B and F for median diameter and percent fine sand and Area E for median diameter. In each case, sediments from summer samples were concordantly finer. Concordance in mean rankings of organic carbon was also significant among the D stations where winter means were highest and summer means lowest.

Tests of concordance do not demonstrate statistically significant differences in means but merely reflect the degree to which there is a trend in seasonal means among stations. Combining these findings with tests of mean differences described above suggests that, although there was a clear trend toward finer sediments occurring in the summer in many areas, the differences were largely non-significant in the context of inter-replicate variability.

DISCUSSION

Comparison with Existing Data

The data on grain size and organic carbon conform well with those published in the literature on broad and local scales. A broad picture of Middle Atlantic shelf and slope sediments is available from data collected at stations on an 18 km grid by the Woods Hole Oceanographic Institution - U. S. Geological Survey continental margin program of the 1960's. Much of the resulting data is given in Hathaway (1971) and has been summarized by Emery and Uchupi (1972), Milliman (1972, 1973), Hollister (1973), and Trumbull (1972). From these and other sources,

Johnson (1977) prepared a map of the distribution of median grain size for the continental shelf from northern New Jersey to Cape Charles.

The surficial sediments of the continental shelf of the study area are overwhelmingly sand, and it is only in isolated regions where coarser or finer sediments are found. Increased silt and clay content is found in the Hudson Shelf Valley and near the shelf break, particularly in the broad shelf-slope transition south of Hudson Canyon.

Gross parameters such as percent sand and median grain size lack the specificity needed to relate grain-size to sediment dynamics or to benthic organisms (Chapter 6). Many examples can be found in the data reported here of predominantly sandy sediments with equivalent median diameters but quite different distribution within the sand fractions. Also, small amounts of silt and clay, of little consequence in the context of the entire continental margin, may be of extreme biological and geochemical importance. Because of the topographic and sedimentologic complexity of the Middle Atlantic shelf, the resolution of these broad scale data sets is likewise inadequate for more localized sedimentological, biological, or chemical studies.

More detailed data on sediment distribution are available for several small areas within the study area (Stubblefield et al. 1974, 1975; Freeland et al. 1976; H. Knebel, unpublished data). These show more complicated granulometric distributions reflective of both the erosional source of sediments and the contemporary hydraulic regime. The sediment distribution is particularly related to ridge and swale topography as our data from repetitively-sampled fixed stations clearly indicate. Finer sands with small amounts of silt and clay are found in swales. However erosional windows, often extending into older sediments beneath the surficial sand sheet (Stubblefield and Swift 1976; Knebel and Spiker 1977), locally winnow swale sediments leaving a coarse lag of sand, shell, gravel, and mud lumps. Most of the swale stations sampled here (except E4) were apparently in depositional rather than erosional sections of swales.

Organic carbon concentrations were also similar to those reported in the literature (Hathaway 1971; Emery and Uchupi 1972; Hatcher and Keister 1976). Shelf sediments in the study area contain less than 5 mg/g total organic carbon except in the New York Bight apex and upper end of the Hudson Shelf Valley where concentrations up to 50 mg/g are found (Hatcher and Keister 1976). In those sediments containing less than 1% silt and clay, which includes most of the shelf, very low concentrations of 1 mg/g or less of organic carbon are found. However, where silt and clay become only slightly more important, either in depressions on the shelf or at the shelf break, organic carbon concentration increases dramatically.

Total nitrogen concentrations are not directly comparable with Kjeldahl nitrogen values reported by Emery and Uchupi (1972). In those sediments containing less than 1% silt and clay, Kjeldahl nitrogen is present in concentrations generally less than 0.1 mg/g, and, although it is difficult to characterize total nitrogen concentrations because of the variability of the data, such sediments probably contain much less than 1 mg/g nitrogen. Emery and Uchupi (1972) have shown that as with organic carbon, Kjeldahl nitrogen increases greatly with slightly

increased silt and clay percentage.

Comparison with USGS Data

As described in the Introduction, composite sediment samples from the grab samples taken for chemical analyses were analyzed for grain size distribution by USGS-Woods Hole. An attempt was made to standardize the methodology employed as much as possible, although some exceptions are discussed below. The USGS data and the conclusions drawn on these by Johnson and Wood (1977) are compared here with those from the VIMS analysis of replicate samples.

Values of percentage of gravel, sand by phi-interval, and silt and clay, median and mean diameter, sorting coefficient, skewness, and kurtosis supplied by USGS were compared to the range, mean, and 95% confidence interval of the mean for the same statistics resulting from the VIMS analyses. Instances where USGS values fell outside the range of VIMS values were relatively few, but many values fell outside of the confidence limits of VIMS means. Systematic differences occurred for only two parameters, percent coarse sand and sorting coefficients. USGS data consistently showed sediments contained more coarse sand and less medium sand than those produced by VIMS. Sorting coefficients computed by USGS were consistently higher than those by VIMS.

In several cases where there were considerable differences in grain-size distribution, comparison of both data sets with data from the same stations during other seasons cast doubt on the accuracy of the USGS data. That is, the VIMS data were similar to those (both USGS and VIMS) from other seasons at that station, but USGS values were disparate. For example, 12.5% of silt and clay was reported at D3 in fall, whereas not more than 1% was found in the 35 other VIMS or USGS analyses of sediments at that station. Although such great disparaties were few, they do affect the results of some of Johnson and Wood's (1977) statistical analyses. This speaks for the value of replication, if for no other reason than to allow an internal check for the detection of analytical or computational errors.

Although time did not permit intercomparison of raw data in order to detect causes of discrepancies, comparisons with data from the literature were made in an attempt to resolve differences. Sorting coefficients, one statistic showing systematic differences, reported from continental shelf sediments by Hollister (1973) were mostly between 0.5-1.0 ϕ except for sediments with a median diameter coarser than 1 ϕ. VIMS values of the sorting coefficient from shelf sediments also fall in this range, whereas those computed by USGS frequently fell outside of this range. Sorting coefficients and frequency distributions were also compared with those by Stubblefield et al. (1975) from within Area D. Again, VIMS values of σ for non-swale stations (0.35-0.54 ϕ) were closer to the mean values reported by Stubblefield et al. for crest populations (0.47 ϕ) than those supplied by USGS (0.64-1.97). Similarly, VIMS data are in closer agreement with those of Stubblefield et al. in terms of the percent of coarse sand, generally low in this area, whereas USGS found up to 40% coarse sand in samples from Area D.

Possible causes for the differences in VIMS and USGS grain size data included:

1) USGS samples were composites from generally the first 6 grabs, whereas VIMS usually analyzed samples from grabs 1, 2, 7-12, i.e. not including sediment from grabs 3-6.

2) Sand analysis at USGS utilized a 7.62 cm. diameter tube in the rapid sand analyzer whereas VIMS used a 15.24 cm. tube.

3) VIMS RSA analyses were calibrated using fractionated sand from the study area, whereas USGS used an existing calibration.

4) In samples with appreciable calcareous sediment, VIMS employed sieves for sand analysis, whereas USGS apparently did not.

Some of the discrepancies affect the conclusions of Johnson and Wood (1977) regarding seasonal variability. Johnson and Wood analyzed the significance of temporal variability by an analysis of variance (ANOVA) using estimates of intra-site variance extrapolated from Knebel (1975). Of the 28 instances where significant F values were reported for comparisons of 11 parameters over 24 stations (264 comparisons), at least 10 were judged to be caused by apparent inaccuracies in the USGS data. Almost all of the remainder of the significant comparisons were related to the differences discussed in this chapter as being related to station relocation difficulties (i.e. D1 and E1) or great heterogeneity (i.e. C4).

On the basis of the analysis of variance and some simple rank comparison, Johnson and Wood (1977) concluded that sediments were finer in spring and summer over much of the study area. Comparisons made here suggest that although this conclusion has some merit in terms of concordant trends, most of the seasonal changes witnessed were not significant in the context of inter-replicate variation.

Summary of Significant Findings

1. The continental shelf of the Middle Atlantic Bight is topographically complex and is covered by sandy palimpsest sediments which reflect both ancient sources and contemporary redistribution. Although the scale of spatial variation in sedimentary parameters is essentially continuous, the widespread system of ridges and swales with spacing on the order of one kilometer particularly affects the distribution of sediments. Bottom currents due to surface waves and meteorological forcing are important in resuspending sediment over most of the shelf which disallows the accumulation of the scarce silt and clay.

2. Analyses of sediments from 51 benchmark stations show the predominance of medium and coarse sand over much of the shelf and muddy finer sands in the shelf break region, grading into predominantly silt and clay sediments on the continental slope. Silt and clay were scarce at shelf stations except in topographic depressions and at the shelf break where this component makes up 5-10% of sediments. Higher amounts were found near Hudson Canyon. The sand component of the sediments tended to be finer in topographic depressions, at the shelf break and off the southern Delmarva Peninsula.

3. Organic carbon content was closely related to the distribution

of silt and clay. Thus, organic carbon concentrations were very low (< 1 mg/g) over most of the shelf but higher (1-2 mg/g) in topographic depressions and at the shelf break. Still higher concentrations (to 10 mg/g) were found in muddy slope stations. Nitrogen concentration values were too variable to support coherent conclusions.

4. Variability in grain size distribution and carbon content both among replicate samples and among seasonal samples was low at most stations. Those instances of apparently great seasonal variability could mainly be explained in terms of variability in station location or great patchiness in the local distribution of sediments. Although there was a concordant trend of slightly finer sediments occurring during summer 1976, these changes were mostly non-significant in the context of normal variability at each of the stations.

ACKNOWLEDGEMENTS

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CHAPTER 6

BENTHIC ECOLOGICAL STUDIES : MEGABENTHOS AND MACROBENTHOS

D. Boesch
J. N. Kraeuter
D. K. Serafy

CHAPTER 6

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BENTHIC ECOLOGICAL STUDIES: MEGABENTHOS AND MACROBENTHOS

Donald F. Boesch
John N. Kraeuter
D. Keith Serafy

INTRODUCTION

Studies on benthic macroorganisms are of central importance in the Middle Atlantic Benchmark Studies Program because of the potential for detection of environmental impacts in this biotic component and the relationship of these studies to chemical studies of benthos and bottom sediments. This chapter reports the results of studies of the distribution and community structure of megabenthos, arbitrarily defined as those macroorganisms captured by dredge or trawl of relatively large mesh (4 mm), and the smaller macrobenthos captured in sediment samples sieved through a 0.5 mm mesh screen.

Locations within the study area in which macrobenthos has been quantitatively sampled in previous investigations are indicated in Figure 6-1. It is ironic that the macrobenthos of the Middle Atlantic Bight, off the most populous region of the United States, has been so little studied.

Pratt (1973) reviewed reports published to that date and speculatively proposed a three-tiered zonation scheme for the benthic fauna of the shelf. The sand fauna zone extends from the littoral zone to 30-50 m and is covered by clean, dynamic sands. The central silty-sand fauna zone has sediments of somewhat greater silt and clay and organic matter concentration and includes more tube-building, suspension, and deposit feeders than inshore. The outer shelf beyond a variable "mud line" is populated by a silt-clay fauna dominated by deposit feeding polychaetes, bivalves, and echinoderms.

Extensive samples of macrobenthos were collected on an 18 km grid throughout the study area during the Woods Hole Oceanographic Institution - U. S. Geological Survey Continental margins program. Few results have been published, although recently a compilation of abundance and biomass data by major taxonomic group was produced (Wigley and Theroux 1976). Extensive sampling of macrobenthos has also taken place in the New York Bight apex in the assessment of the effects of solid and chemical waste disposal. Some results have been reported by National Marine Fisheries Service (1972), Pearce (1972), Pearce et al. (1976) and Rowe (1971). Regional studies of the macrobenthos of the nearshore or inner shelf have been conducted off western Long Island (Steimle and Stone 1973), northern New Jersey (Pearce 1974), and northern Virginia (Boesch 1972). Maurer et al. (1976) reported on the composition of the macrobenthos in a number of small samples from the central shelf off Delaware and synthesized the faunistic similarities of the sand fauna of the shelf off the northeastern U. S. Their data suggested large scale temporal variations existed in shelf benthic communities.

Few published reports relate to the benthic fauna of the outer continental shelf, shelf break, and slope areas which are the central focus of this study.

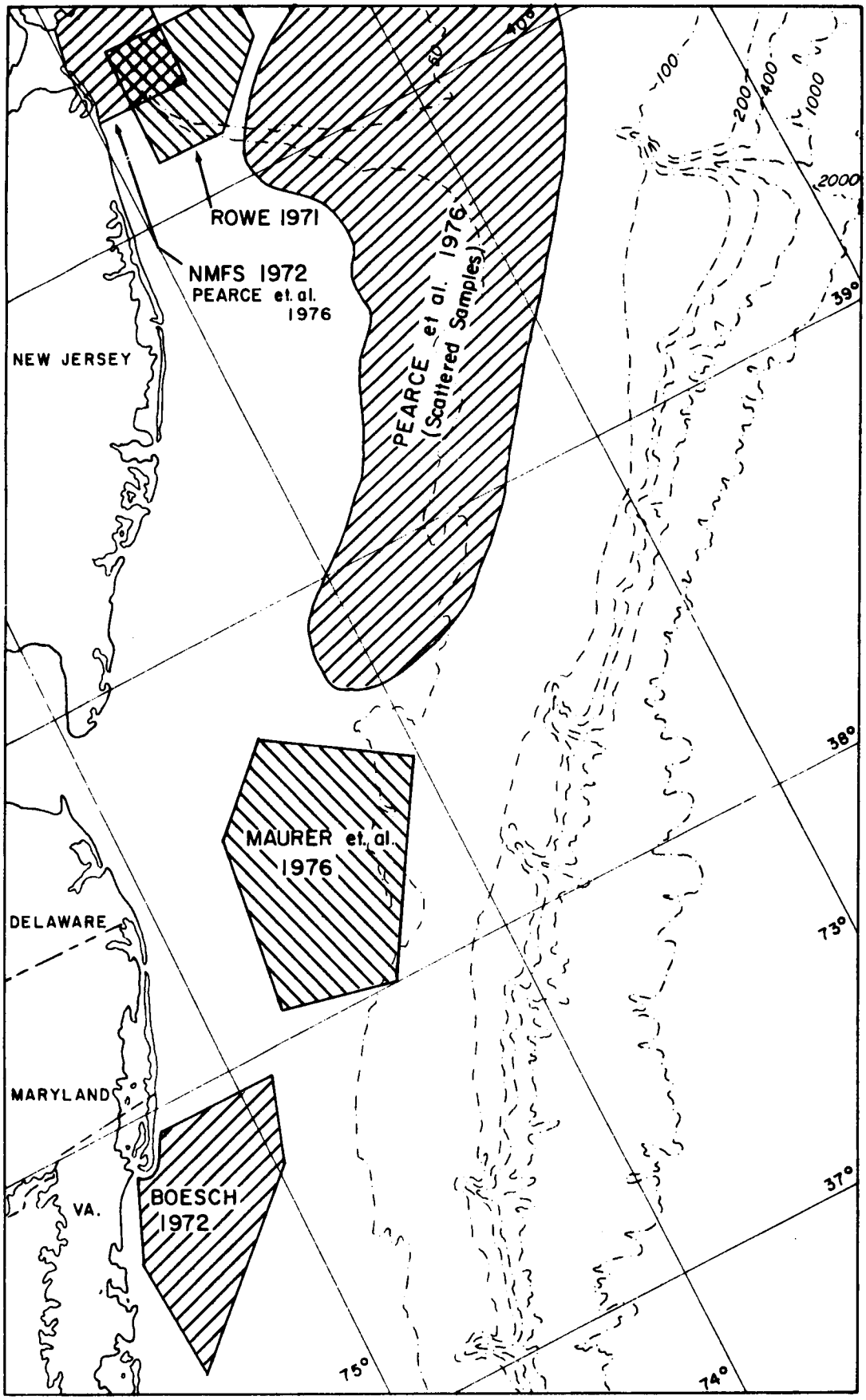


Figure 6-1. Location of previous studies of macrobenthos on the Middle Atlantic continental shelf.

Pearce (1975; Pearce et al. 1976) reports scant data, principally on density and diversity, from stations in 40-70 m of water off New Jersey and Long Island, some included in the area sampled in this study. He concluded that the outer shelf communities were largely similar to those of the New York Bight apex in terms of species composition, diversity, and density. Finally, the zonation of the epibenthic macrofauna, including demersal fishes, on the continental slope south of New England was reported by Haedrich et al. (1975). Their collections were made by otter trawl and include only larger megabenthos (in the sense used here). They concluded that sharp faunal changes took place between the upper (141-285 m) and middle (393-1095 m) continental slope.

The goals of the present study are to describe the distribution of macrobenthic communities on the Middle Atlantic continental shelf and upper slope between New Jersey and Virginia, to determine the seasonality of these communities and to relate them to hydrographic, sedimentologic, and geochemical environmental conditions. Emphasis is placed on multi-species distribution patterns, biomass, species diversity, spatial and temporal variability, animal-sediment relationships, and effects of hydrographic conditions. Interpretation is focused on developing inductive hypotheses on the factors controlling the structure of these communities.

METHODS

Macrobenthos

Shipboard Procedure

Macrobenthos was sampled at the 24 cluster stations quarterly and at 27 transect, continental slope and canyon stations during winter and summer (Figure 6-2). The rationale for selection of stations and general shipboard procedures are described in Chapter 2.

The principal sampling device was a 0.1 m^2 Smith-McIntyre grab (Figure 6-3) of stainless steel construction modified to accommodate a Benthos Edgerton 35 mm camera (Model 371) and flash (Model 381). The camera's shutter was activated by a bottom trip switch when the grab was approximately 1 m off the bottom. Good quality black and white photographs were obtained for about 75 percent of successful grab hauls. Color-positive transparencies were also obtained at many of the stations. Maximum depth of penetration, sediment temperature, and depth and appearance of the redox potential discontinuity (RPD) were measured and recorded for each grab sample. The Smith-McIntyre grab sampled to a sediment depth of 7-18 cm, and generally depth of penetration exceeded 10 cm.

Originally it was intended to regularly use a spade box corer (Bouma 1969), sampling a surface area of 0.05 m^2 and weighing approximately 700 kg, to supplement grab samples by providing data on deeper living infauna. Several box cores exceeding 20 cm were collected; however the box core did not prove feasible for routine sampling, for the following reasons: (1) poor depth of penetration often not exceeding that of grab in the characteristically firm sandy bottom, (2) the loss or winnowing of the sample due to stones and shells caught between the bottom of the box and the spade, (3) difficulty and safety risk of deployment in other than calm seas, and (4) rigging problems caused

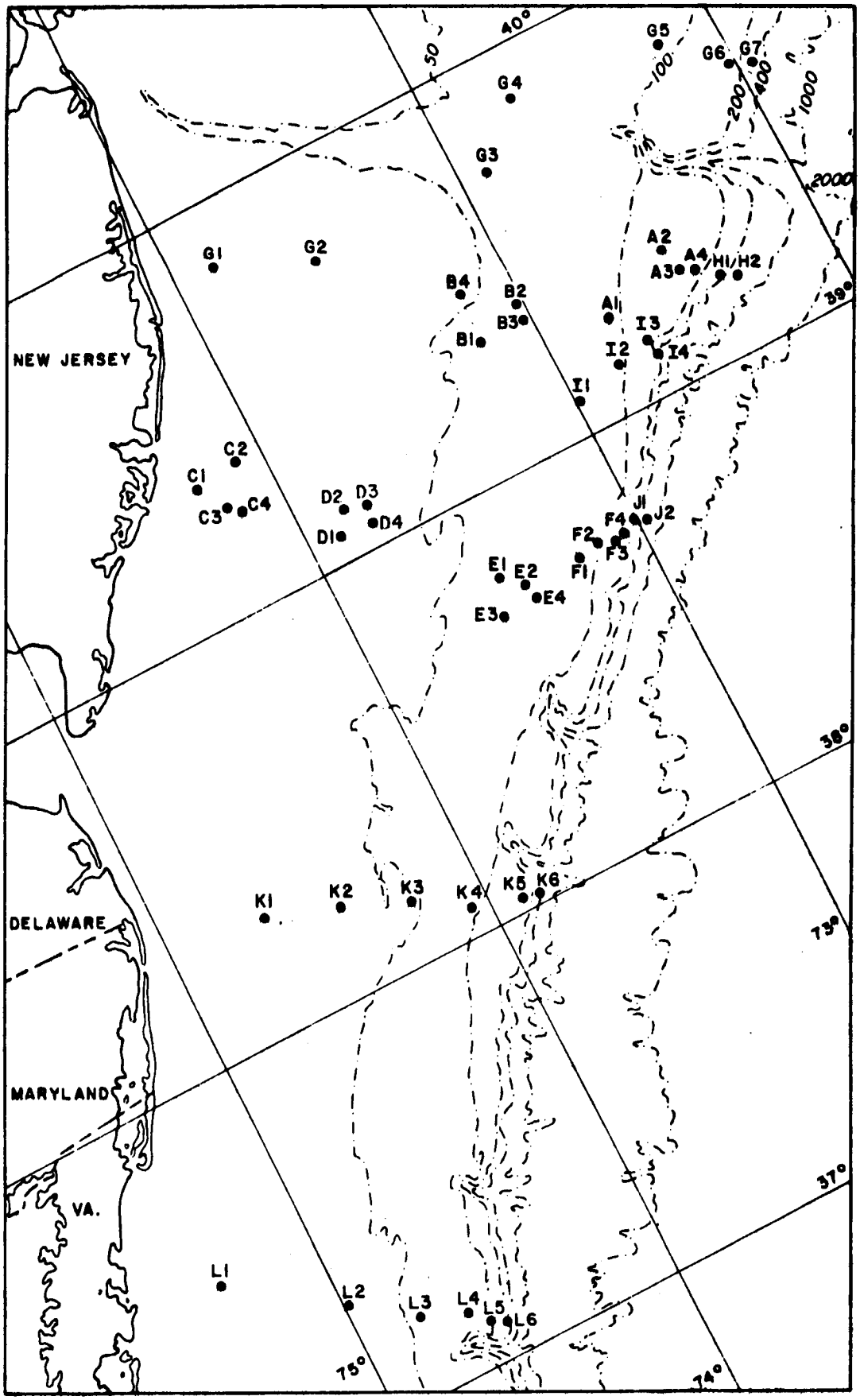


Figure 6-2. Stations sampled for macrobenthos.

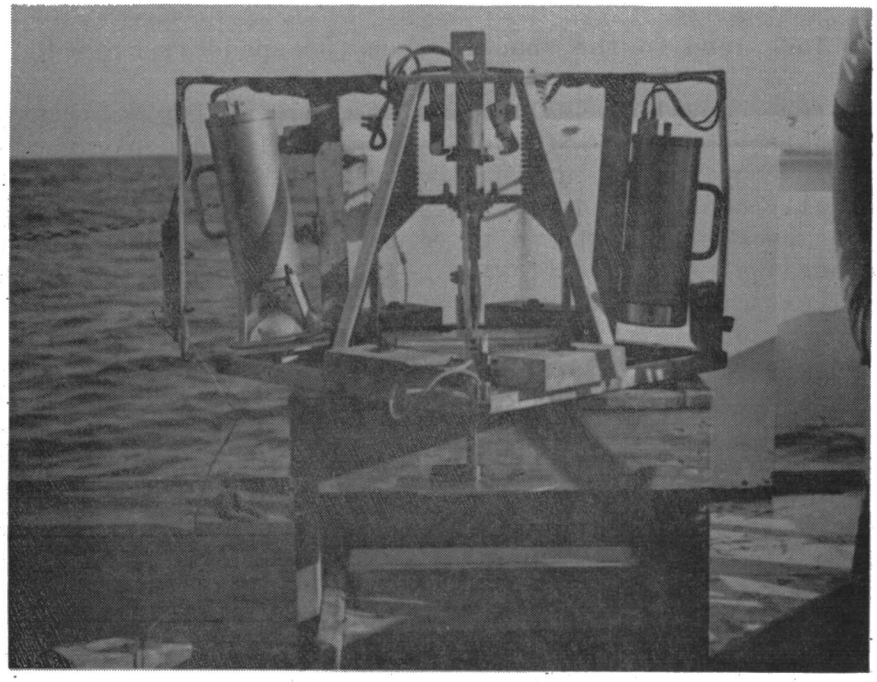


Figure 6-3. Top. Stainless steel Smith-McIntyre grab modified to accommodate a Benthos Edgerton 35 mm camera (right), strobe flash (left), and bottom trip switch (left).
Bottom. Small biology trawl (SBT) or Menzies trawl being retrieved.

by the long lead to the shackle when the spade is closed.

After removal of small cores of sediment for sediment and bacteriological analyses (see Chapters 5 and 11), the remaining contents of the Smith-McIntyre grab were emptied into a 5-gallon galvanized bucket which was then placed on a specially constructed elutriation stand (Figure 6-4). Sea water was run into the bucket and allowed to elutriate light-bodied organisms until no macrofauna was seen overflowing. The overflow was caught on a small 0.5 mm mesh Nitex screen in a frame at the bottom of the elutriator. This screen was then removed with the trapped organisms and debris and placed in a small labeled cloth bag. The remaining sediment and heavy organisms in the bucket were sieved through a similar, but larger surface area, 0.5 mm Nitex screen (Figure 6-4), and the debris placed in a large cloth bag. Because of coarse sediments, a majority of the original sediment collected often remained on this screen after washing. The "light" fraction and "heavy" fraction were anesthetized in isotonic $MgCl_2$ for about 30 minutes, then transferred to separate 30-gallon drums containing 10% buffered formalin with Rose Bengal as a vital stain.

Laboratory Procedure

In the laboratory, samples were first soaked for several hours in fresh water. The "light" fractions were sorted into major taxa by examination with a binocular dissecting microscope. The heavy fractions were processed by placing a small amount of sediment in a metal pan, elutriating and decanting repeatedly through a 0.5 mm Nitex screen. This material was examined as with the "light" fraction, while the remaining sediment was spread out in a pan and examined for the stained organisms with the naked eye. All organisms were sorted in major taxonomic groups, at a minimum, Annelida, Mollusca, Crustacea, Echinodermata, and other taxa, and stored in 70% ethanol.

Wet weight biomass was determined to the nearest 0.1 g on a top loading electric balance for each major group in each replicate grab sample following removal of external fluid by blotting on paper towels. The weights include skeletal material such as shells and tests and, in some cases, tubes and protective encrustations not easily removable.

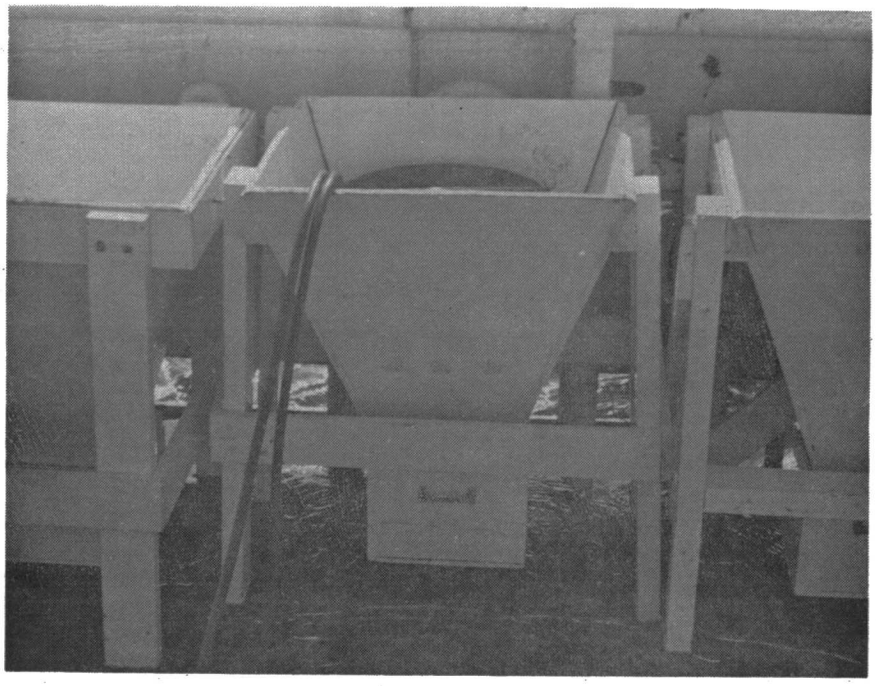
Organisms were identified and counted for each replicate grab sample. Determinations were possible to species with most individuals; however, only genus, family, or higher taxon identifications were possible in some cases. Much of the species level nomenclature is provisional at this time.

Megabenthos

Shipboard Procedure

Megabenthos was sampled at nine stations: A1, B1, C2, D1, E1, F1, I1, J1, and N3 (Figure 6-5). Samples were also collected at D4 during the fall 1975 cruise. Locations and physical characteristics of the stations are summarized in Chapters 2, 3, and 5.

Two pieces of gear were utilized to sample the megabenthic fauna, a small biology (Menzies) trawl (SBT) (Figure 6-3) and a modified anchor dredge. The trawl was patterned after that used by Duke University and was lined with



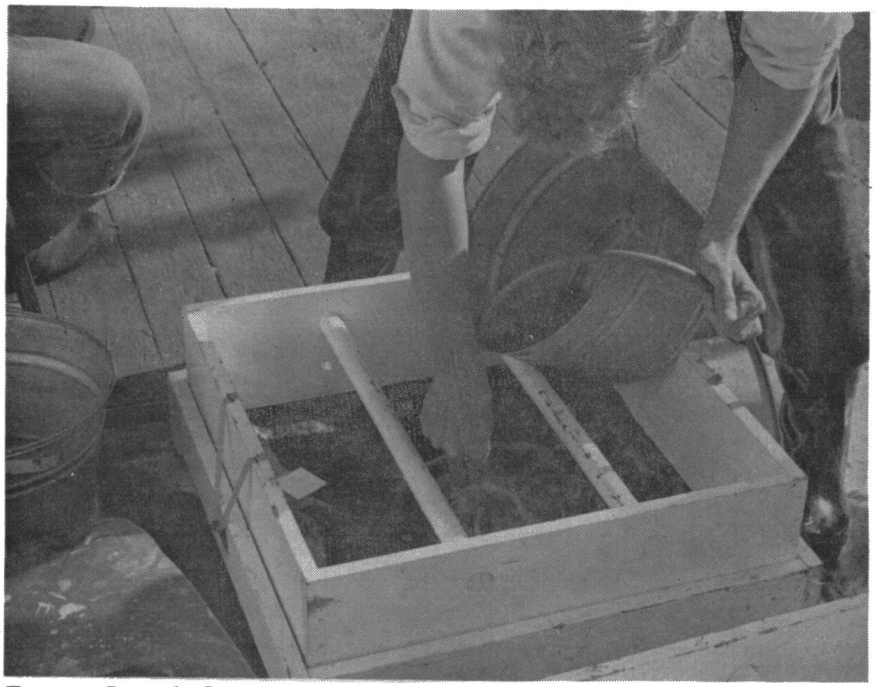


Figure 6-4. Top. Stand for elutriation of macrobenthos samples. Overflow from galvanized bucket falls down through 0.5 mm mesh screen in drawer below.
Bottom. Washing the "heavy" fraction remaining after elutriation through detachable 0.5 mm mesh Nitex screen.

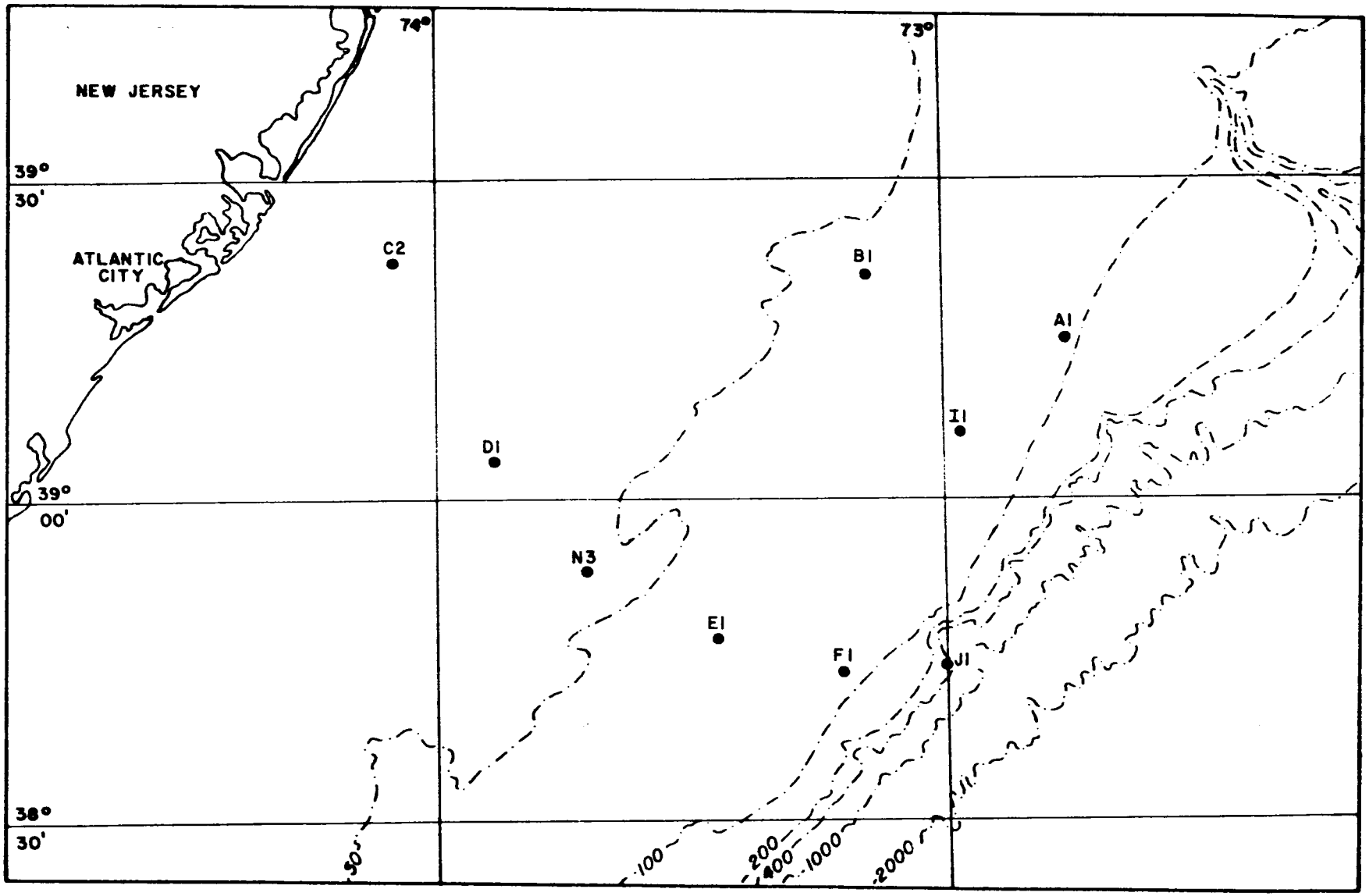


Figure 6-5. Stations sampled quarterly for megabenthos with dredge and trawl.

a 4 mm mesh fishing seine. The trawl (SBT) mouth was 1 m wide and 10.5 cm high. An anchor dredge with a 39.5 cm wide and 10.5 cm high mouth (maximum cutting depth) was modified by attaching a 1.35 m long tail section covered with a 4 mm stainless steel mesh to allow finer materials to winnow through. When additional material was needed for hydrocarbon, heavy metal, or histopathology analysis, a 40-ft. otter trawl was used. Only voucher specimens were kept from the otter trawl catches, and thus no data are presented for ecological interpretation.

The two different samplers were used in order to provide accurate representation of both vagile, surface dwellers as well as the infauna. The SBT skimmed the surface layers and obtained shrimp and other motile forms as well as shallow infaunal species. The anchor dredge dug much deeper and thus sampled infaunal forms more effectively.

Three samples were taken with both the SBT and anchor dredge at each station. The only exceptions were on the first cruise when the anchor dredge was lost, when additional materials were required, or at station J1 where the substrate was not suitable for anchor dredging. Several times additional SBT tows were made, and weather conditions sometimes caused poor sample recovery for one sample from a station.

All SBT samples were three minute tows except at J1 where five minute tows were utilized. Anchor dredges were towed two minutes except where indicated. These tow times provided a sample as uniform as possible without filling the sampler, which greatly diminishes sampling efficiency and produces unknown sampling bias. A series of short tows produced more repeatable and interpretable data.

When the sampler was brought on board, the catch was placed in wooden buckets to prevent contamination. If the sample was large, an estimated proportion was removed for relaxing and preserving. The remainder was utilized for specimens for histopathology and hydrocarbon and trace metal analysis. Small samples were preserved in their entirety except for specimens removed for histopathology and hydrocarbon and trace metal analysis, and those specimens removed were noted on the field sheet. All animals were preserved in 10% buffered formalin.

Laboratory Procedure

In the laboratory the samples were rinsed to remove excess formalin and any remaining sediment. The samples were then spread in pans, the animals picked from the debris and identified. The major groups (molluscs, echinoderms, and decapod Crustacea) and representatives of some minor groups were identified and counted while being sorted. Others were separated, placed in containers, and stored or shipped to an appropriate taxonomic authority. All identifications were to species unless there were taxonomic difficulties. Some of the minor groups have not been identified to species for all cruises. The analyses of distribution and diversity and other data manipulations have taken these discrepancies into account.

Data Analysis

Abundance data for megabenthos and macrobenthos and biomass data for macrobenthos were entered on specially designed coding forms (Appendix III). Taxa were coded using the 10-digit VIMS taxonomic code (Swartz et al. 1972) as amended.

Numerical Classification

Patterns of community similarity and species distribution were assessed using numerical classification techniques (cluster analysis). Numerical classification was selected from among several multivariate techniques, including ordination, because it is usually more efficacious with large data sets than other techniques and requires few assumptions about the data. For a more detailed explanation of numerical classification and the various methods of classification used here the reader is referred to Clifford and Stephenson (1975) and Boesch (1977).

Normal classifications of collections and inverse classifications of species were produced for various data sets of mega- and macrobenthos using the VIMS program COMPAH. Algorithms used include, except where indicated, a combination of log-transformation (log x+1) of species abundance, interentity resemblance expressed by the Bray-Curtis similarity measure, and either group-average or flexible sorting (Clifford and Stephenson 1975; Boesch 1977). Thus, the classifications are polythetic, agglomerative hierarchies based on quantitative data.

The Bray-Curtis similarity measure can be expressed as:

$$S_{jk} = 1 - \frac{\sum_i |x_{ji} - x_{ki}|}{\sum_i (x_{ji} + x_{ki})}$$

where S_{jk} is the similarity between entities j and k; x_{ji} is the abundance of the i-th attribute for entity j; and x_{ki} the abundance of the i-th attribute for entity k. In the case of normal analysis (classification of collections) the collections are the entities and the species are attributes. In inverse analyses (classification of species) the species are the entities with collections as attributes.

The sorting strategy determines how the various entities are hierarchically grouped based on their similarities. The results of hierarchical classification are usually depicted in the form of a dendrogram. Group-average sorting was employed when small numbers of entities were being classified because it has desirable space conserving properties. However, when large numbers of entities are considered, group-average sorting has a tendency to produce undesirable chaining in the hierarchical clustering route. In this case entities are fused to a few nuclear groups one at a time rather than forming new groups. This results in classifications in which many entities are not effectively clustered but must be considered as individuals. Therefore, when large numbers of entities were classified, as in the case of most inverse analyses, the

space-dilating flexible sorting strategy was used to induce more discrete groupings. With this strategy, the intensity of clustering can be varied by varying the cluster intensity coefficient β. In these applications β was set at -0.25 which effects moderately intense clustering.

Data Reduction

For classifications of macrobenthos, because the total number of species in any given data set was too large (>500 species) for practical computation, it was necessary to reduce the data to a subset of $\leq$ 150 species, an arbitrary, practical limit set by computer core size and computation time. Several criteria were used to accomplish this data reduction. First, colonial species which were not enumerated were eliminated as were taxa not separated to species. Secondly, a score for each remaining species in the data set was computed as the sum of the number of stations at which it occurred, the number of replicates in which it occurred divided by six, the number of stations at which it occurred in three or more replicates, and the number of replicates in which its abundance was $\geq$ 10, divided by six. Thus, this score reflects the composite ubiquity, constancy, and abundance of each species. The species were ranked by the score sum, and only data on the top 150 (or fewer in some cases) ranked species were selected from the total data set and written on tape to be read by COMPAH.

Nodal Analysis

Normal and inverse classifications were cross-related in order that the collection groups might be described in terms of their characteristic species and the species groups described in terms of the patterns of occurrence over the collection. Results of these comparisons, termed nodal analysis, were expressed in nodal diagrams (Boesch 1977). Coincidence was expressed in terms of nodal constancy, fidelity, and abundance concentration.

Simply stated, constancy is the degree to which a species is consistently found in a habitat. Highly constant species are found in most or all samples collected within the habitat. However, constancy implies nothing about the abundance of the species. In the context used here, group constancy refers to the average constancy of species in a species group in the collections within a habitat as defined by a site group. Constancy of species in a group within a collection group was computed as:

$$c_{ij} = a_{ij}/(n_i n_j),$$

where a_{ij} is the actual number of occurrences of members of species group i in the collection group j and the n_i and n_j are the numbers of entities in the respective groups. The index will take a value of 1 when all species occurred in all collections in the group and 0 when none of the species occurred in the collection.

Fidelity, a concept long in use in community ecology (Fager 1963; Westhoff and van der Maarel 1973), is the degree to which a species selects or is restricted to a habitat. Species with high fidelity, or faithful species, are found rarely outside of their preferred habitat. As with constancy, fidelity is qualitative and implies nothing about patterns of abundance. Group fidelity

refers to the average fidelity of species in a species group in the collections within a habitat (site group) relative to the collections from all other habitats (site groups) sampled. The fidelity of species group i in collection group j was defined as:

$$F_{ij} = (a_{ij}\Sigma_j n_j)/(n_j\Sigma_j a_{ij})$$

using the same terms as in the constancy index. This index is unity when the constancy of a species group in a site group is equivalent to its overall constancy, greater than 1 when its constancy in that collection group is greater than that overall, and less than 1 when its constancy is less than its overall constancy.

Some species may have high constancy in a range of habitats, and thus low fidelity, but be much more abundant in one habitat than elsewhere. To describe this aspect of distribution, abundance concentration was measured. Abundance concentration is computed for each species for each collection group by dividing the mean abundance of the species in the collection group by its mean abundance overall. These ratios are averaged over all species in the species group.

Species Diversity

Species diversity was measured by the commonly used index of Shannon (Pielou 1975), which expresses the information content per individual. The index denotes the uncertainty in predicting the specific identity of a randomly chosen individual from a multispecies assemblage. The index H' is given by:

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where s = number of species in the sample and p_i = proportion of the i-th species in the sample.

As considered above, species diversity is a composite of two components: species richness (the number of species in a community) and evenness (how evenly the individuals are distributed among the species). Species richness was measured in terms of area (areal richness) simply by the number of species in collections of standard area (0.6 m^2) and also as standardized in terms of numbers of individuals (numerical richness). Numerical richness was expressed using Hurlburt's (1971) modification of Sanders' (1968) rarefaction technique, by which the number of species in a rarefied sample of given size in terms of number of individuals is computed based on known abundance relationships. For a given sample size n the expected number of species is:

$$E_{S(n)} = \sum_{i=1}^{s} \left[1 - \frac{\binom{N-N_i}{n}}{\binom{N}{n}} \right]$$

where N is the number of individuals, s is the number of species in the collection, and N_i is the number of individuals of the i-th species. In this case a sample size of 500 individuals was used since the number of specimens collected exceeded this at almost all of the stations.

Evenness was reflected by the ratio of Pielou (1975) expressed as

$$J = H'/\log_2 s$$

RESULTS

Bottom Photographs

Over 600 bottom photographs were obtained by the grab-mounted camera during regular sampling. At a distance of 1 m off the bottom, the field of view represented in each photograph was approximately 1 x 1.5 m. This allowed resolution of sediment surface features and moderate to large sized epibenthos. Surface dwelling asteroids, echinoids, and decapod crustaceans were readily apparent, and structures as small as ophiuroid arms were frequently visible. Delicate feeding appendages of infauna and small epifauna (e.g. amphipod crustaceans) were not distinguishable at the 1 m focal distance.

The photographs proved especially useful in three regards. First, they allowed estimation of the composition and abundance of the epibenthic community. Secondly, the photographs exhibit features of the sediment surface which indicate sediment movement (e.g. ripple marks), bioturbation, deposition, and the abundance of coarse substrate material, such as shell. Finally, photographs from replicate grab hauls were useful in understanding variations in the biota among replicates.

Several photographs are presented in Figures 6-6 through 6-13 which illustrate the main benthic environments and common epibenthos of the study area. Inner shelf sediments consist of dynamic sands almost always with obvious ripple marks, mainly resulting from oscillatory currents generated by surface waves (Figures 6-6 and 6-7, top). The sand dollar *Echinarachnius parma* is the principal epifaunal species observed in this region as well as on the central shelf. *E. parma* is frequently seen to occur primarily in the troughs of ripple marks (Figure 6-6, bottom) although in deeper waters it may preferentially congregate on the crests of ripples.

At swale stations on the inner and central shelf, the bottom is less well rippled and appears either as relatively featureless fine sand or littered with shell fragments (Figure 6-8, bottom). This conforms with the known distribution of surface sediments in swales (Chapter 5) which are fine except in erosional windows where a coarse lag remains from active winnowing. Demersal fishes are frequently seen in the photographs and seem to be more common at the swale stations, particularly D4 (Figure 6-8, top).

On the outer shelf, sands are again medium textured but the rippling of the surface sediment is much more subdued and often has been partially obliterated by the activities of benthic organisms (Figure 6-8, bottom). These ripple features probably result from infrequent seasonal strong bottom currents

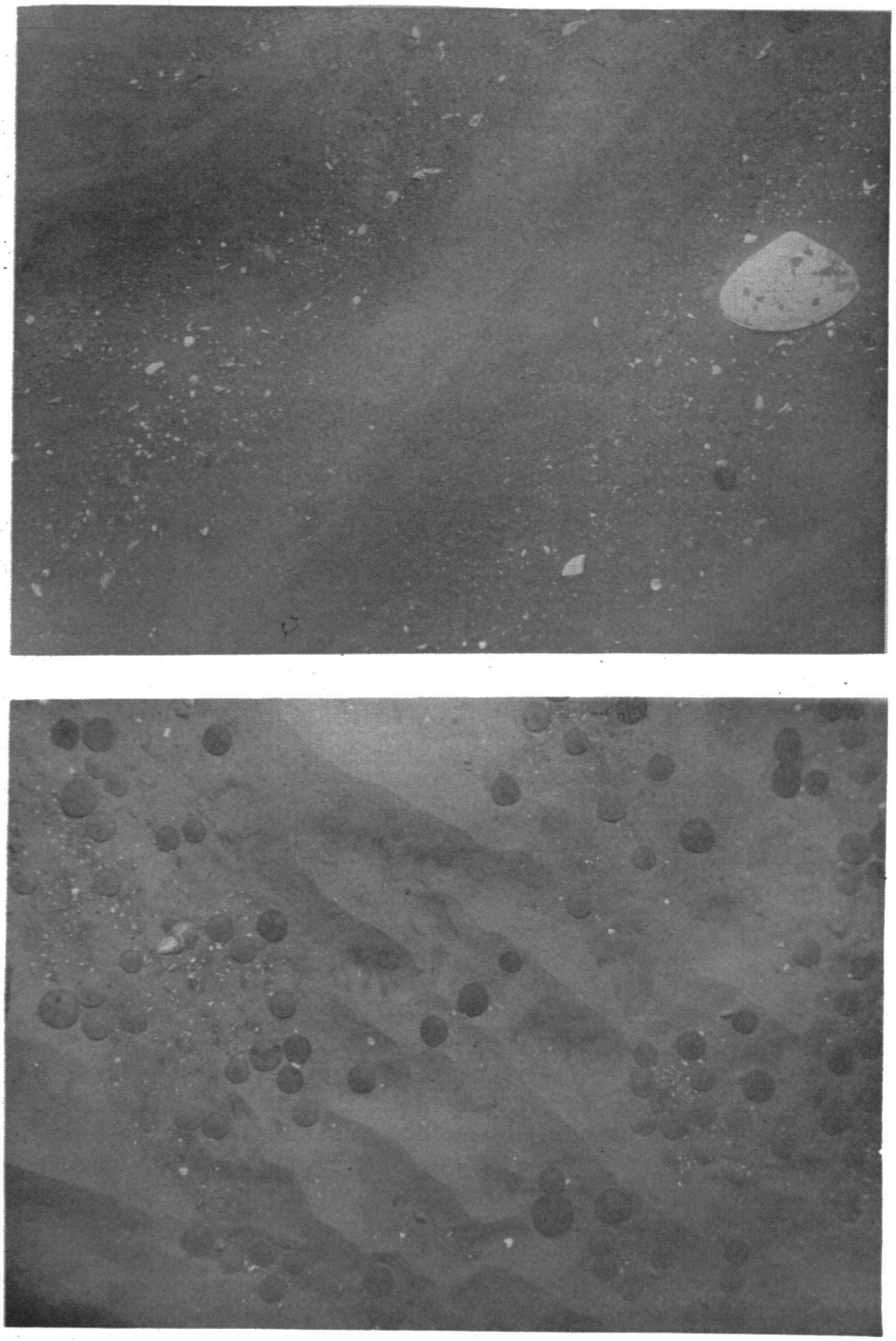


Figure 6-6. Top. Station C3, Winter 1976, 24 m. Note large ripples and paucity of large epifauna.
Bottom. Station D2, Fall 1975, 33 m. Sand dollars, *Echinarachnius parma*, occur preferentially in troughs of rippled medium sand bottom.

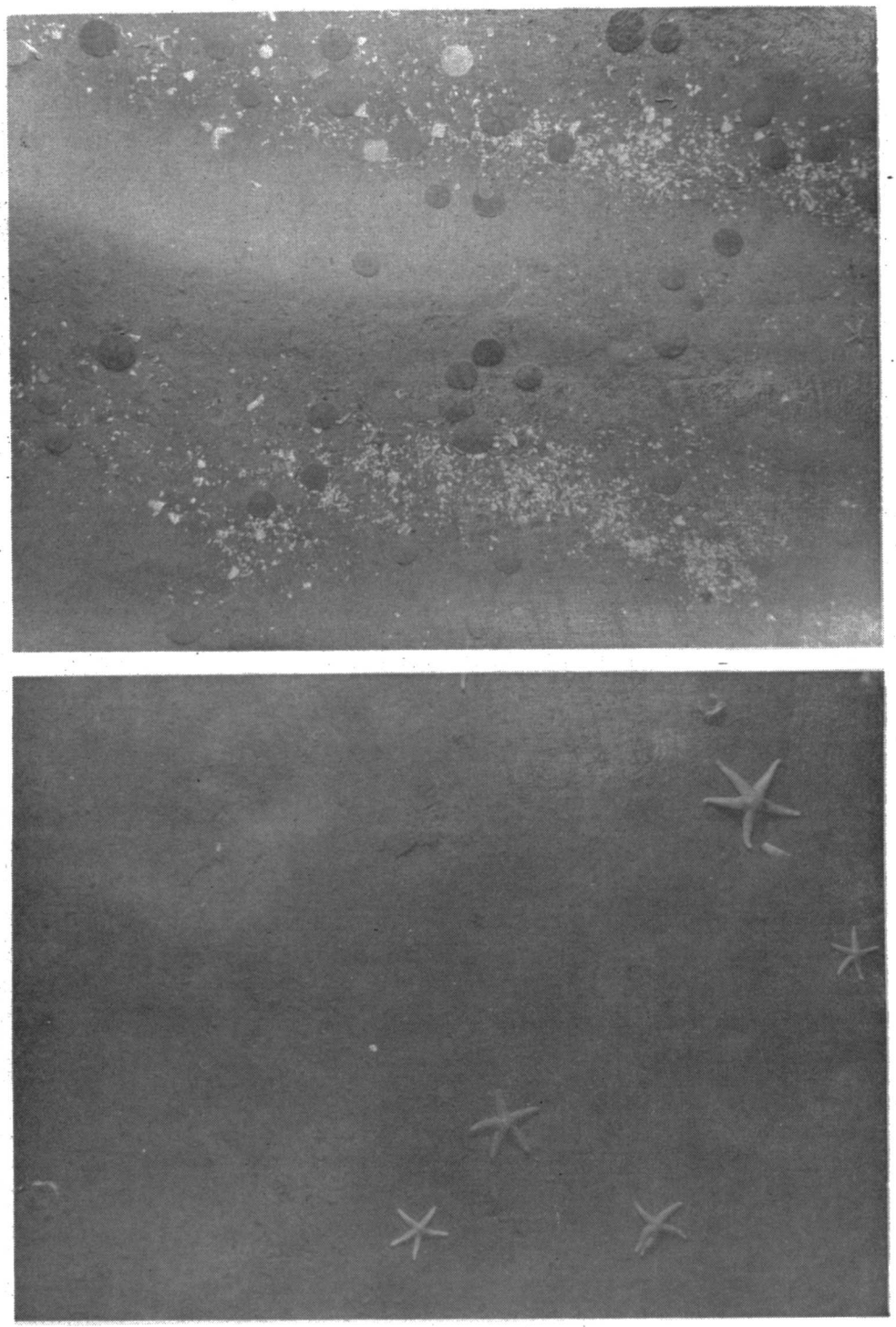


Figure 6-7. Top. Station D2, Winter 1976, 33 m. Very large ripples were present in winter with shell hash in the troughs. *Echinarachnius parma* and small sea stars, *Asterias forbesi*, are evident. Bottom. Station D4, Summer 1976, 49 m. Somewhat muddy-fine sands characterize this swale station. Sea stars, *Asterias forbesi* and *A. vulgaris*, and a small crab, *Cancer irroratus*, are visible.

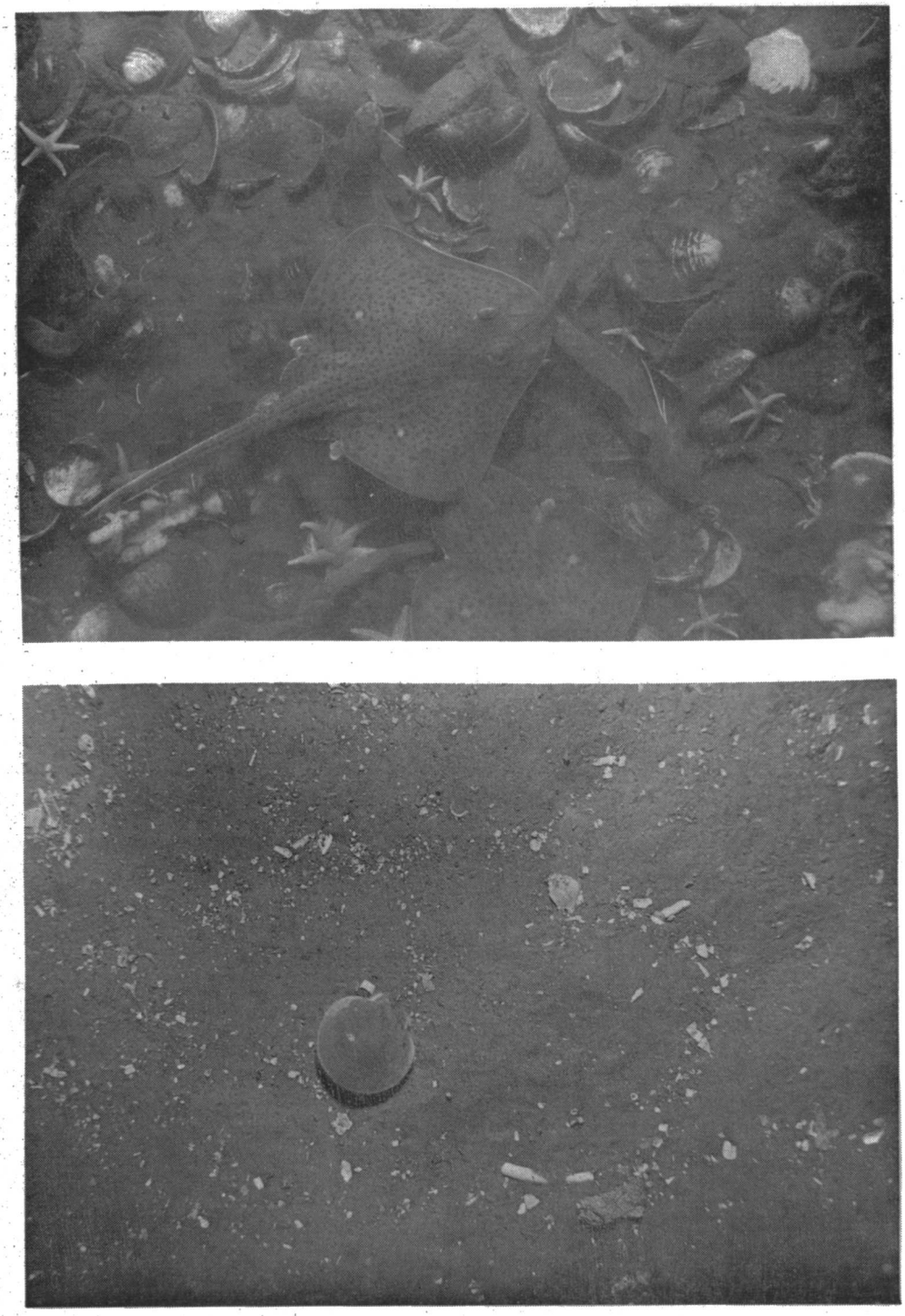


Figure 6-8. Top. Station D4, Summer 1976, 49 m. Photograph from the same station as the previous one but of a localized area of shells of *Arctica islandica*. A dense aggregation of fishes (*Raja erinacea*, *Urophycis chuss*, and *U. regius*) and several *Asterias forbesi* and *A. vulgaris* are evident.
Bottom. Station E3, Fall 1975, 63 m. Medium sand bottom is without obvious ripples. A large scallop, *Placopecten magellanicus*, sits in a depression it has excavated.

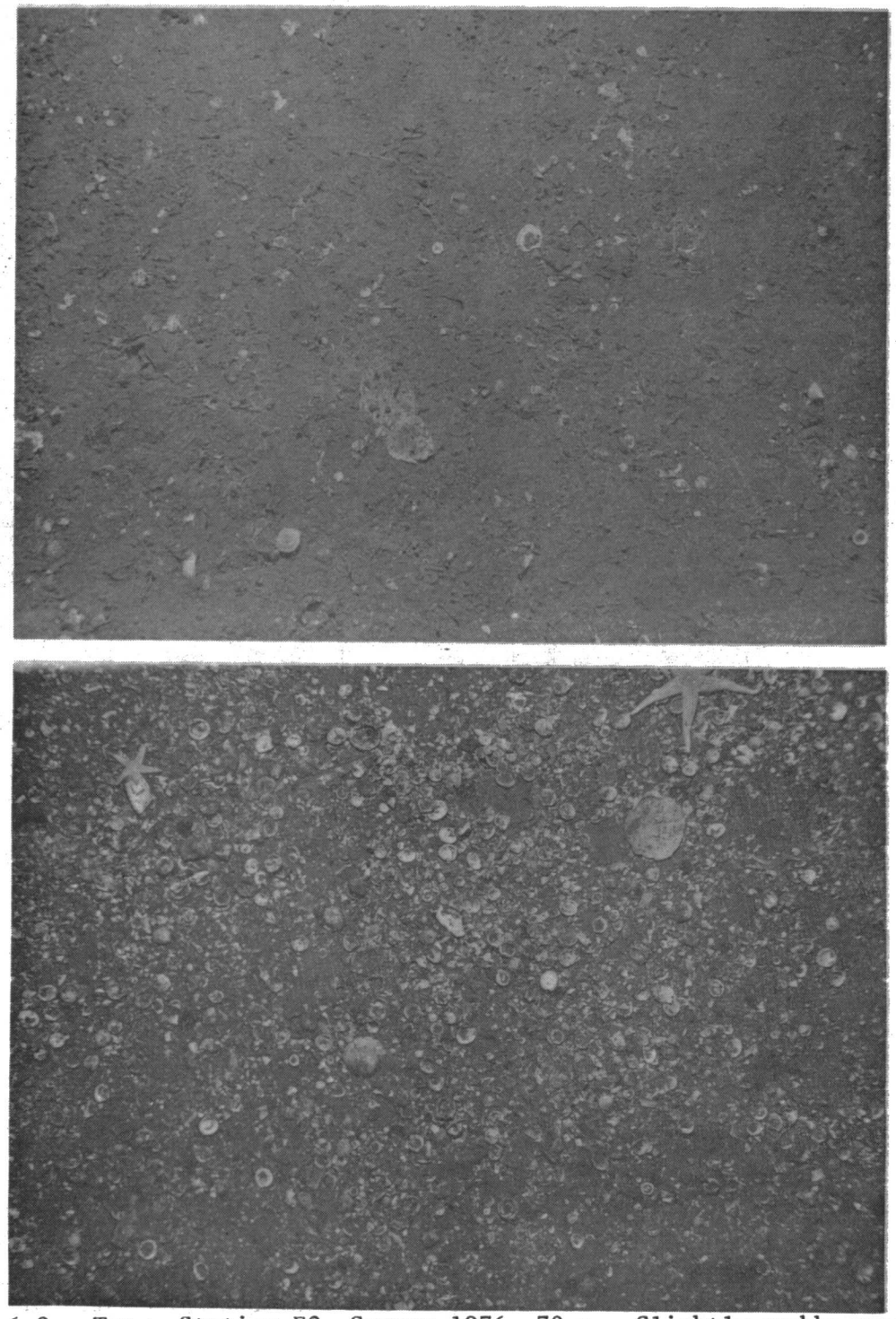


Figure 6-9. Top. Station E2, Summer 1976, 70 m. Slightly muddy sands without obvious rippling were found at this deep flank station. Some clay lumps are visible. Numerous string-like arms of the ophiuroid, *Amphioplus macilentus*, and two gastropods, *Calliostoma bairdi*, are seen.
Bottom. Station E4, Spring 1976, 80 m. The bottom at this trough station was densely strewn with bivalve shells, chiefly of *Cyclocardia borealis*. Sea stars, *Astropecten americanus* (left) and *Asterias vulgaris* (right), are also visible.

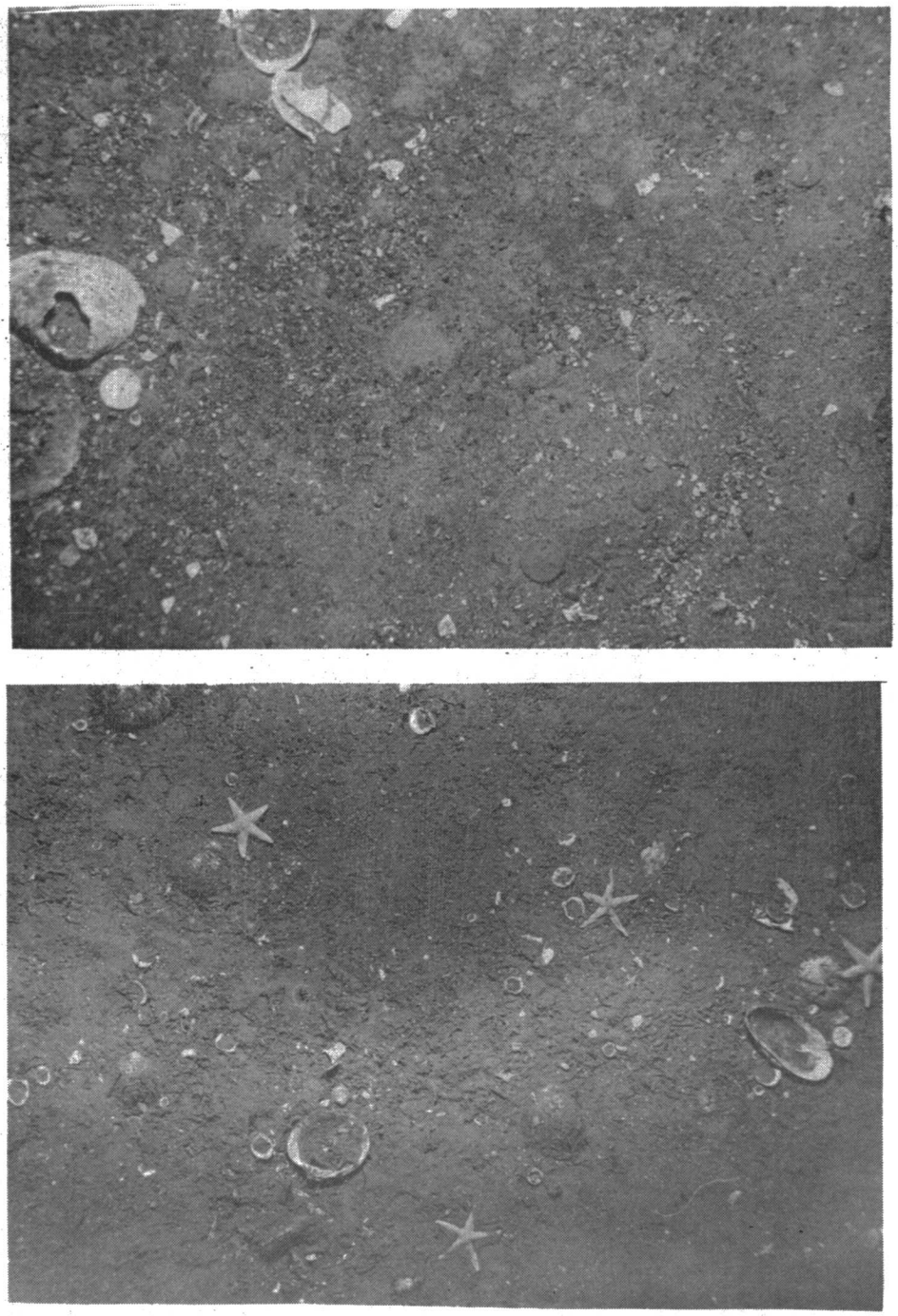


Figure 6-10. Top. Station B4, Spring 1976, 42 m. This station sits on a plateau above a scarp and sediments consisted of medium-coarse sand strewn with shell fragments and gravel. Bioturbation is apparent in lighter colored mounds of reworked sediment.
Bottom. Station B3, Fall 1975, 72 m. Somewhat muddy, fine sands were found at this swale station. Abundant tubes of the amphipod *Ampelisca agassizi* are visible on the sediment surface. The sea stars are *Astropecten americanus*.

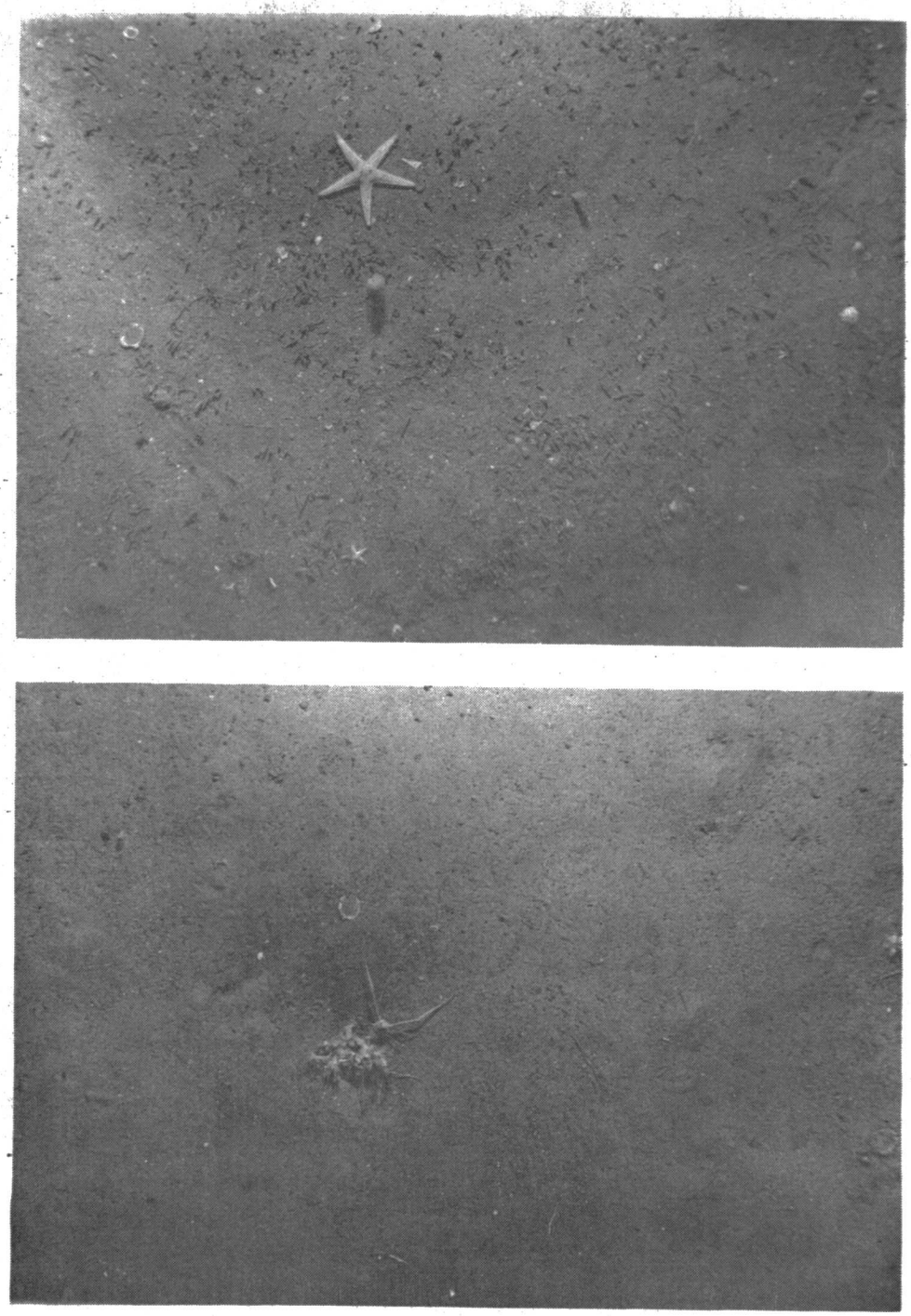


Figure 6-11. Top. Station A1, Fall 1975, 91 m. Visible are abundant tubes of infaunal polychaetes, a pennatulid (center), and *Astropecten americanus*.
Bottom. Station A3, Fall 1975, 136 m. Galatheid crab, *Munida iris*, seeks shelter under debris covered with zoantharian anemones.

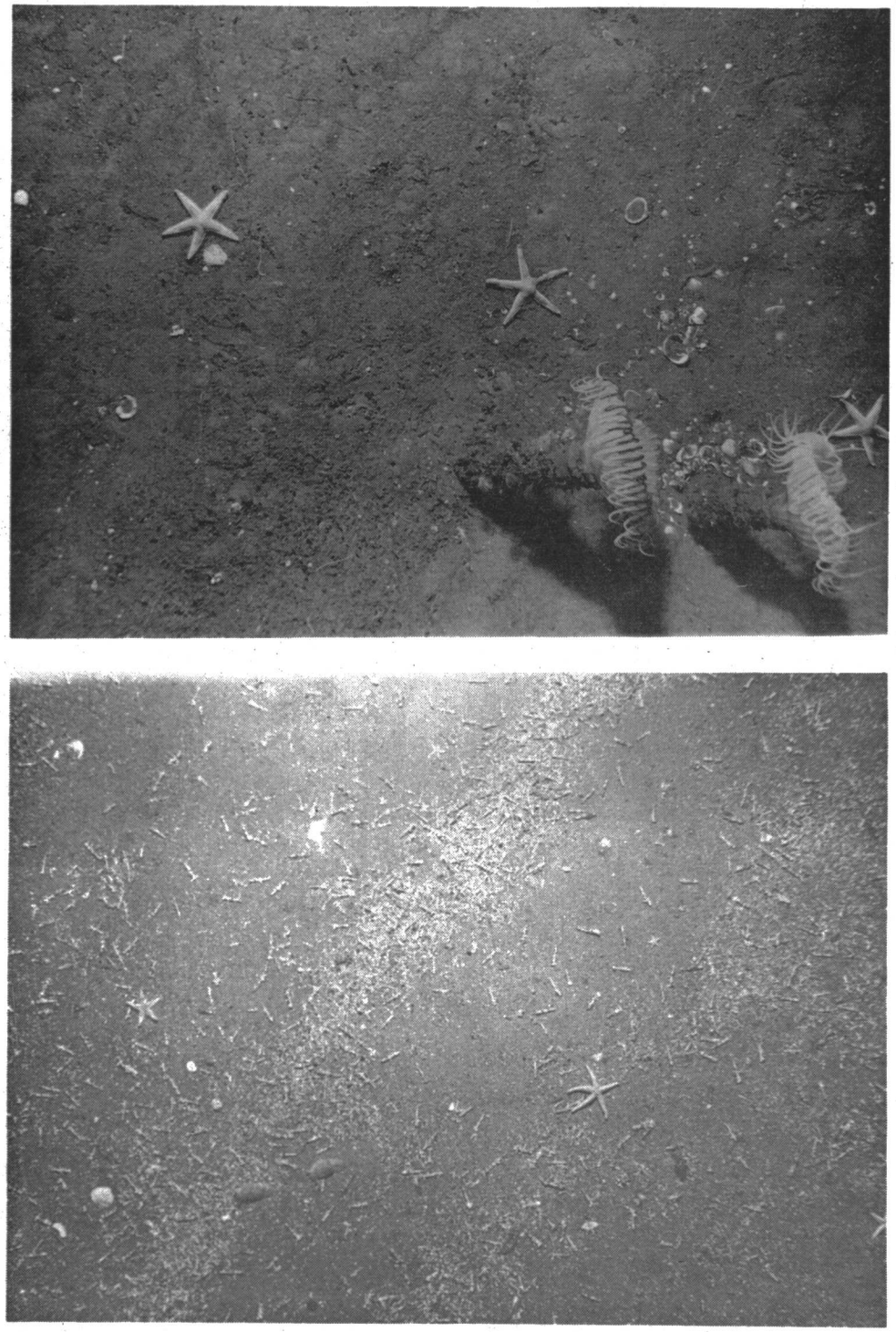


Figure 6-12. Top. Station F1, Summer 1976, 84 m. Two large cerianthid anemones project out of their tubes and lean into the current. *Astropecten americanus* and the arms of the brittle star, *Amphioplus macilentus*, are also visible. Bottom. Station F3, Winter 1976, 150 m. Large, low ripples are apparent. Numerous tubes of the motile polychaete *Nothria conchylega* are obvious. Sea stars include *Astropecten americanus* and *Sclerasterias tanneri*. Two large opistobranch gastropods crawl to the lower left.

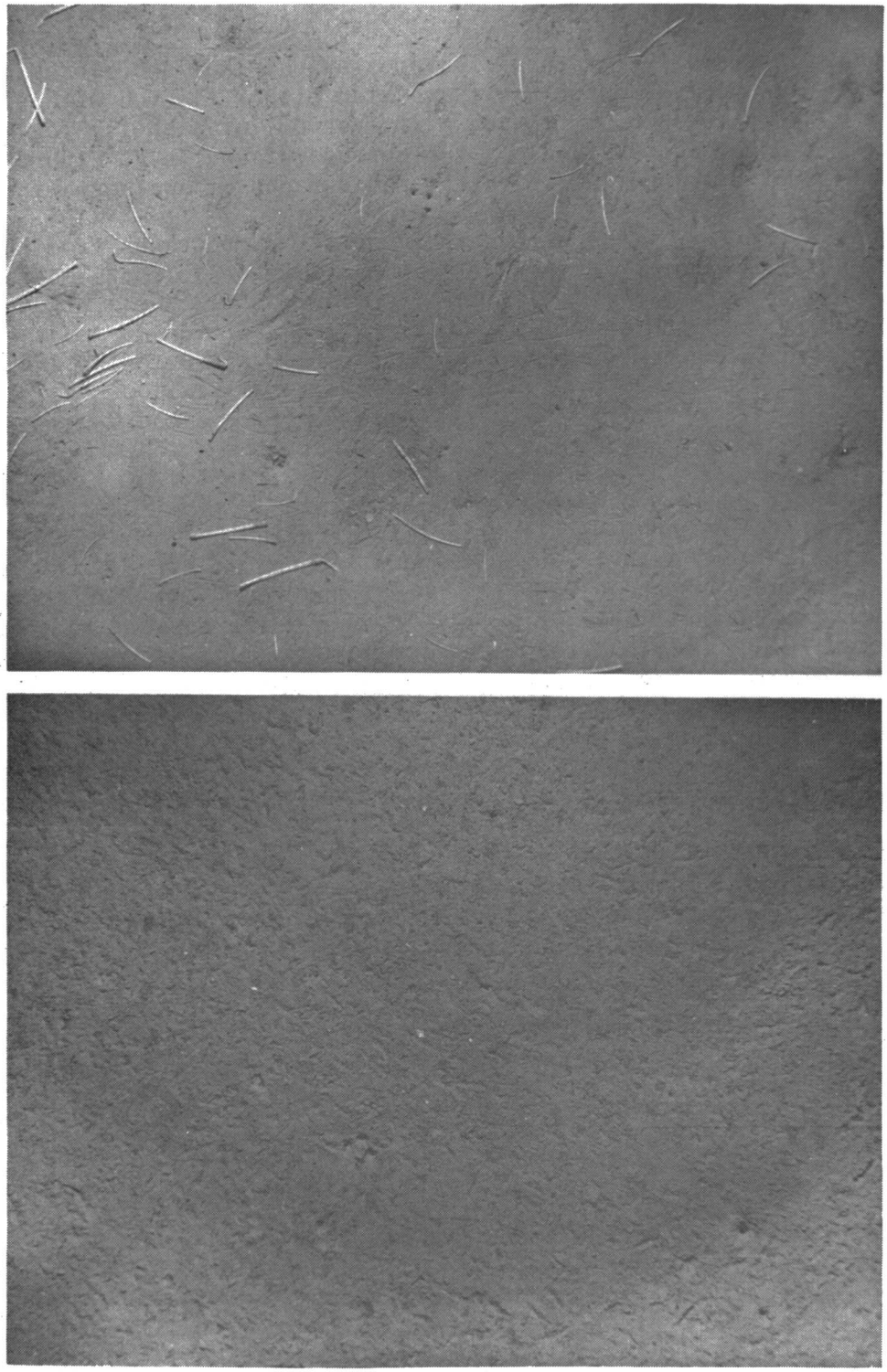


Figure 6-13. Top. Station H1, Winter 1976, 380 m. The substrate is silty sand. Large numbers of the quill worm, *Hyalinoecia artifex*, are present. Various trails, burrows, and fecal casting are visible indicating rather quiescent bottom conditions. Bottom. Station H2, Winter 1976, 730 m. Continental slope muds are characterized by a paucity of epifauna and abundant evidence of trails, burrows, and biogenic sediment reworking.

and subsequent aggradation of these features by physical and biological processes. Swales on the outer shelf are also either floored with slightly muddy fine sand (Figures 6-9, top and 6-10, bottom) or a shelly lag (Figure 6-9, bottom). Dense aggregations of tubicolous infauna (e.g. Figure 6-10, bottom) are sometimes apparent in bottom photographs of swale stations.

Asteroids are very frequently seen in bottom photographs from the central and outer shelf. Inshore, *Asterias forbesi* (Figure 6-7) is the most common starfish, but offshore *Asterias vulgaris* is most conspicuous. At outer shelf swale stations and in the shelf break region the asteroid *Astropecten americanus* is quite commonly seen in bottom photographs (Figures 6-9, 6-10, and 6-11). Also frequently seen on the continental shelf are the scallop *Placopecten magellanicus*, caridean shrimp *Dichelopandalus leptoceras* and *Crangon septemspinosa*, and cancroid crabs *Cancer irroratus* and *C. borealis*.

At the shelf break and on the continental slope, rippling of surface sediments is uncommon and biogenic structures, including mounds of reworked sediments, burrows, and excavations, are more apparent. Large burrowing anemones (mainly cerianthids), pennatulids (sea pens), and zoantharian anemones are quite common at the shelf edge (Figures 6-11 and 6-12, top). Two species of epifaunal tubicolous polychaetes of the family Onuphidae are particularly obvious in photographs from the shelf break and upper continental slope. *Nothria conchylega*, which constructs flat tubes of cemented shell fragments, is particularly abundant on the shelf break (approximately 100 to 200 m) (Figure 6-12, bottom). The larger *Hyalinoecia artifex* secretes a quill-like tube and inhabits the upper slope below 200 m (Figure 6-13, bottom). Ophiuroid arms emanating from their burrows are quite apparent at the shelf edge and on the upper slope. The thin-armed specimens are mainly *Amphioplus macilentus* while the more robust armed specimens are *Amphilimna olivacea* (Figure 6-12, top). Other benthic animals frequently seen at the edge of the shelf include the asteroid *Sclerasterias tanneri* and the galatheid lobster *Munida iris*.

On the continental slope deeper than about 500 m, macrobenthic animals are infrequently seen. However, the fine sediments show extensive evidence of animal activity in the abundance of trails, burrows, and sediment reworking.

Megabenthos

Composition of the Fauna

Specimens collected by the small biology trawl and anchor dredge were dominated in numbers and species by molluscs, decapod crustaceans, and echinoderms. The species identified from collections made during the four seasonal cruises and the stations at which they were collected are listed in Appendix 6-A. Identifications are incomplete for some minor taxonomic groups. In addition to the aforementioned dominant taxa many others, including Foraminifera, Porifera, Hydrozoa, Anthozoa, Polychaeta, Pericaridea, Sipuncula, and Ascidiacea, were collected; however, species in these groups were seldom abundant or richly represented in the collections. These collections represent a considerably different portion of the macrobenthos than that sampled by bottom grab. Although many species captured by dredge or trawl were also taken in grab samples, most were infrequent in grab samples. On the other hand, a large portion of the fauna sampled by grab (0.5 mm mesh), particularly diverse small annelids

and crustaceans, was not represented in dredge and trawl samples (4 mm mesh).

The megabenthic species sampled by the SBT and anchor dredge are surface dwellers or near-surface infauna. Neither sampler penetrated deeply enough into the sediment to reliably collect large bivalves, e.g. *Spisula solidissima* and *Arctica islandica*, and other deep dwelling infauna. Sampling this component would require massive mechanical or hydraulic dredges and much coarser screening of sediments.

Sampling Variability

Tows of trawls and dredges produce notoriously variable catches due to differences in sampling efficiency and area from tow to tow as well as natural patchiness. For this reason, these data are considered semi-quantitative in that the spatial and temporal trends may be deduced from species abundances, but considerable caution must be applied to interpretations. The data collected indicate that tow times and sampler efficiency remained reasonably consistent at least within a cruise and in most cases between cruises. For example, catches of dominant species in SBT hauls during the fall and spring at 3 of the stations are compared in Table 6-1. Still, the variance of the abundance of these species was generally rather large with respect to the mean.

The one exception to the overall sampling consistency was at the continental slope station J1, where because of abrupt bathymetric and faunal change, catches were produced which were quantitatively and, frequently, qualitatively variable from tow to tow and cruise to cruise.

Comparison of Gear

Both SBT and anchor dredge were used in order to sample two components of the biota, epifauna and infauna, respectively. Although there was considerable overlap in the fauna sampled by either device, the anchor dredge usually caught more species of molluscs and fewer echinoderms and decapod crustaceans at all stations than did the SBT (Table 6-2). When catch data are adjusted for differences in mouth width and tow duration, differences in density estimates among abundant species can also be observed. For example, when adjusted abundances of mollusc species at stations C2 and D1 were compared for the two samplers (Tables 6-3), the estimates of deeper dwelling bivalves (e.g. *Ensis*, *Arctica*, and *Astarte*) were high with the anchor dredge. On the other hand epifaunal or shallow infaunal molluscs show minor or inconsistent differences between the SBT and anchor dredge.

Distribution Patterns

Faunal distributions and assemblage similarities were investigated using numerical classification and analysis of the distribution of dominant species. Collections from J1 were not included in the classificatory analyses because of the provisional nature of many identifications of specimens from this continental slope station.

Classification of collections from 8 stations for each season produced station groups similar to the normal analysis with all seasons combined, so only the latter is presented. Only taxa identified for all cruises are included in the analyses.

Table 6-1. Dominant species in replicate SBT tows at Stations A1, E1, and D1 during fall 1975 and spring 1976.

Station	Species	Fall			Spring		
		1	2	3	1	2	3
A1	*Astropecten americanus*	387	429	553	531	318	241
	Pontophilis brevirostris	201	234	128	175	132	123
	Astarte undata	119	153	133	154	100	54
	Pandora inflata	34	73	53	185	167	94
	Cancer borealis	45	70	65	1	1	1
	Euprognatha rastellifera	24	19	60	13	13	16
	Bythocaris nana	13	17	4	24	26	21
	Solerasterias tanneri	9	7	5	16	20	12
	Crangon septemspinosa	39	33	29	0	1	0
	Munida iris	24	19	29	0	4	3
E1	*Echinarachnius parma*	189	241	53	1756	308	1236
	Astrorhiza limnicola	11	7	1	3060	2092	1640
	Crangon septemspinosa	101	32	21	256	56	112
	Astropecten americanus	66	1064	318	48	8	8
	Cancer irroratus	591	434	102	32	24	0
	Dichelopandalus leptoceras	108	57	20	132	44	40
	Asterias vulgaris	79	26	9	108	32	36
	Cyclocardia borealis	0	3	2	4	4	0
	Pagurus acadianus	11	6	1	56	28	12
	Placopecten magellanicus	6	11	2	88	32	36
D1	*Echinarachnius parma*	3100	3014	2754	1677	1120	1850
	Crangon septemspinosa	68	84	64	522	356	244
	Cancer irroratus	250	230	178	9	52	20
	Asterias forbesi	96	50	16	21	40	130
	Asterias vulgaris	46	46	8	25	96	80
	Dichelopandalus leptoceras	0	0	0	54	52	26
	Pagurus acadianus	28	10	20	11	60	0
	Nassarius trivittatus	2	8	10	2	12	0
	Molgula arenata	0	0	0	27	48	64

Table 6-2. Numbers of species collected in SBT and anchor dredge samples by station, season, and major taxon. Some groups are not included in the spring and summer data.

		Small Biological Trawl				Anchor Dredge			
Station	Season	Total	Echino-derms	Deca-pods	Mol-lusks	Total	Echino-derms	Deca-pods	Mol-lusks
C2	Fall	23	4	8	2				
C2	Winter	20	3	4	7	9	2	2	3
C2	Spring	27	4	6	10	14	2	2	6
C2	Summer	12	0	0	9	5	0	0	4
D1	Fall	29	3	4	8				
D1	Winter	26	3	7	6	21	3	3	11
D1	Spring	28	5	4	11	28	3	5	12
D1	Summer	17	3	4	6	22	3	5	11
N3	Fall	22	4	5	6				
N3	Winter	25	5	6	10	26	4	4	10
N3	Spring	32	5	5	10	25	3	3	14
N3	Summer	30	4	7	11	27	3	3	15
E1	Fall	53	8	8	12				
E1	Winter	54	9	8	21	22	3	1	14
E1	Spring	55	10	7	22	20	5	1	10
E1	Summer	39	9	8	12	33	6	3	18
B1	Fall	52	7	7	13				
B1	Winter	53	9	8	18	24	3	2	11
B1	Spring	38	9	7	14	40	5	5	18
B1	Summer	45	9	9	17	39	6	5	19
A1	Fall	53	6	11	13				
A1	Winter	42	7	10	12	15	4	2	9
A1	Spring	52	8	11	14	23	5	2	6
A1	Summer	50	7	12	11	22	4	1	10
F1	Fall	42	4	11	10				
F1	Winter	28	5	10	8	27	3	4	11
F1	Spring	28	4	7	9	20	3	1	10
F1	Summer	31	6	9	9	22	4	4	7
I1	Fall	60	9	13	15				
I1	Winter	46	8	11	12	10	2	0	8
I1	Spring	55	9	9	17	21	3	2	9
I1	Summer	50	10	8	22	26	2	2	13
J1	Fall	52	7	18	13				
J1	Winter	43	6	13	12				
J1	Spring	43	5	11	19				
J1	Summer	46	8	13	16				

Table 6-3. Adjusted abundance of molluscs collected in the SBT and anchor dredge at Stations C2 and D1. Data are the sums of the averages for winter and spring. The anchor dredge data were adjusted relative to the SBT to compensate for difference in mouth width and tow length.

	Station			
	C2		D1	
	SBT	Anchor	SBT	Anchor
Ensis directus	2	15		958
Spisula solidissima	17	15		58
Arctica islandica				203
Cyclocardia borealis			1	7
Astarte castanea	46	254	1	22
Pandora gouldiana	4	7	2	152
Cerastoderma pinnulatum	13	7	14	58
Lyonsia hyalina	4		4	29
Crenella glandula	1			
Placopecten magellanicus			1	15
Lunatra heros	2		8	29
Nassarius trivittatus	95	36	29	275
Colus pygmaeus			7	160
Polenicus immaculata			1	7
Soluvella obscura				22
Pleurobranchaea tarda	66			
Crepidula plana	1		8	

The normal classification of the SBT collections employed group average sorting and resulted in 6 groups of collections (Figure 6-14), each including all collections from one or more sites except that the collection from C2 during summer did not cluster with any of the others. This was an apparent effect of mortalities resulting from anoxia of bottom waters, and this will be discussed in detail later. A pattern of cross-shelf zonation is clearly apparent in the structure of the normal dendrogram, suggesting differences among the inner shelf (C2), central shelf (D1 and N3), outer shelf (B1 and E1) and, most markedly, the shelf break (A1, I1, and F1). Station D4, located in a swale near D1, was only sampled in the fall. This collection grouped with those from the outer shelf (B1 and E1) and not with those from D1.

Species groups were interpretable at the 15 group level of the inverse dendrogram resulting from flexible sorting (Figure 6-14, Table 6-4).

The distribution of these species groups can be interpreted in terms of nodal constancy. Because rare species were not excluded from the analysis, basic subdivisions of the inverse classification reflect common or abundant species (Groups 1-6) and less common species (Groups 7-15). Species in Group 1 were widely distributed on the shelf but were less common at the shelf edge, whereas species in Group 2 were ubiquitous over all 8 sites. Species in Group 3 were especially characteristic of the outer shelf (B1, E1) and species in Groups 4, 5, and 6 occurred on the outer shelf and, preferentially, at the shelf

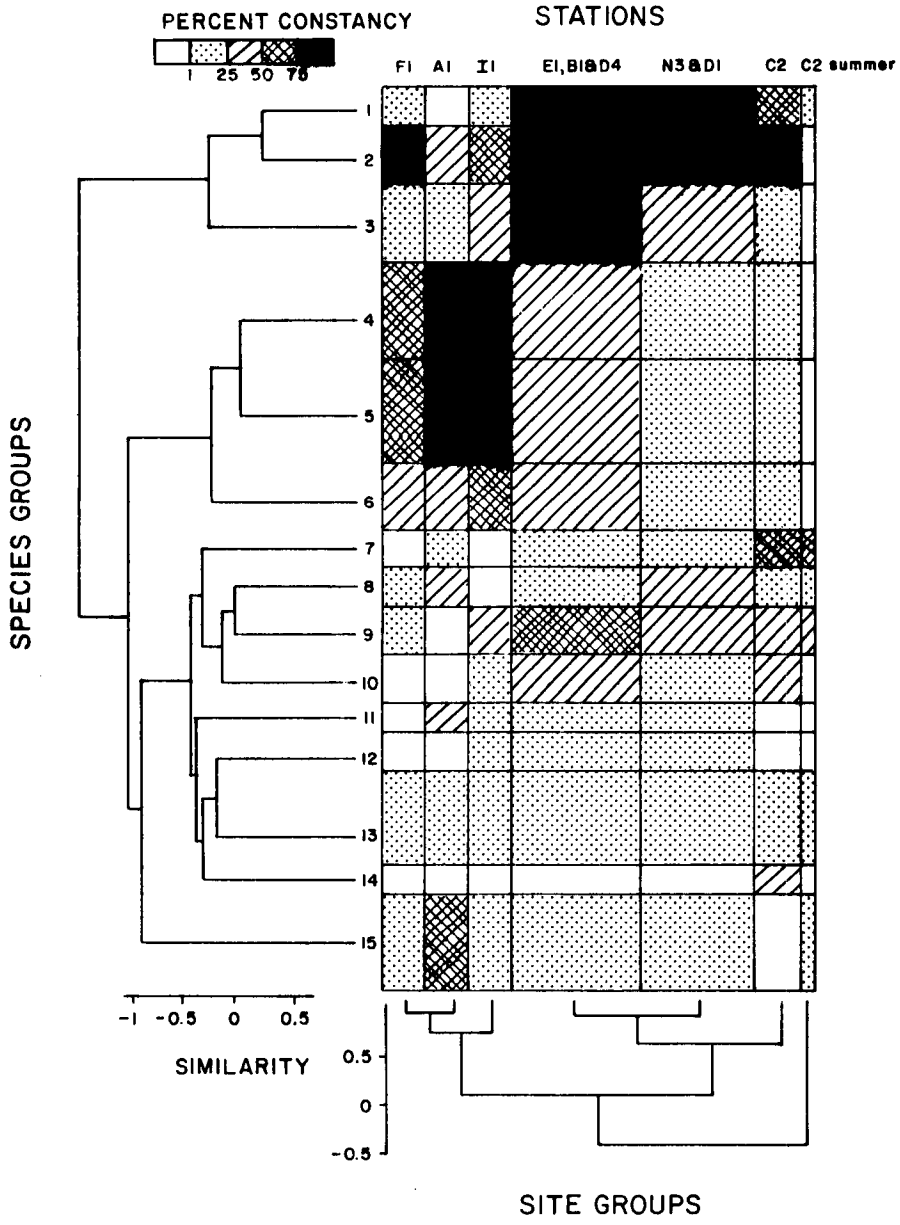


Figure 6-14. Normal and inverse classification hierarchies and nodal constancy for site-species group coincidence based on all small biology trawl collections.

Table 6-4. Species groups resulting from numerical classification of SBT data combined for four seasonal cruises.

Species Group 1

Cerastoderma pinnulatum
Pagurus acadianus
Nassarius trivittatus
Asterias forbesi

Species Group 2

Asterias vulgaris
Dichelopandalus leptoceras
Crangon septemspinosa
Cancer irroratus
Echinarachnius parma
Astrorhiza limicola

Species Group 3

Lyonsia hyalina
Aphrodita hastata
Solariella obscura
Leptasterias tenera
Colus pygmaeus
Crucibulum striatum
Pagurus arcuatus
Placopecten magellanicus

Species Group 4

Astropecten americanus
Pontophilus brevirostris
Molgula arenata
Cancer borealis
Cyclopecten nanus
Nothria conchylega
Astarte undata
Astarte crenata subequilatera
Calliostoma bairdii
Cyclocardia borealis

Species Group 5

Sclerasterias tanneri
Euprognatha rastellifera
Pandora inflata
Bythocaris nana
Amphilimna ovalacea
Munida iris
Henricia sanguinolenta
Diastylis bispinosa
Axiognathus squamata
Rossia tenera
Pleurobranchaea tarda

Species Group 6

Crenella glandula
Ascidia callosa
Modiolus modiolus
Anomia simplex
Anomia squamula
Hyas coarctatus
Ophiopholis aculeata

Species Group 7

Astarte castanea
Spisula solidissima
Edotea triloba
Tellina agilis

Species Group 8

Lunatia heros
Crepidula plana
Dendroda carnea
Eualus pusiolus

Table 6-4. (Concluded)

Species Group 9

Lunatia triseriata
Polinices immaculatus
Edotea montosa
Ensis directus
Pandora gouldiana

Species Group 10

Strongylocentrotus droebachiensis
Arctica islandica
Buccinum undatum
Stereoderma unisemita
Ovalipes stephensoni

Species Group 11

Philine quadrata
Edotea acuta
Havelockia scabra

Species Group 12

Loligo pealeii
Coronaster briareus
Caridion gordoni
Janira alta

Species Group 13

Pitar morrhuana
Scyllarus chacei
Musculus niger
Polinices uberinus
Hyas araneus
Dendronotus frondosus
Cirolana concharum
Bathynectes superba
Solariella infundibulum
Cylichna verrilli

Species Group 14

Dissodactylus mellitae
Pagurus pollicaris
Pagurus longicarpus

Species Group 15

Goneplax hirsuta
Pachycheles rugimanus
Lucinoma filosa
Yoldia sapotilla
Perploma papyratium
Cuspidaria rostrata
Collodes robustus
Epitonium dallianum
Amphioplus macilentus
Cirolana polita

edge. Species Group 7 included those species highly characteristic of the inner shelf, whereas species in Groups 8, 9, 10, and 11 were variably widespread on the shelf. The remaining groups consisted of relatively rare species. One, Group 15, was highly characteristic of Station A1.

The classifications based on anchor dredge data were very similar to those based on SBT collections (Figure 6-15, Table 6-5). The classification of sites was almost identical, except that the summer C2 collection was grouped with the other collections at that station rather than separately. Species in Groups 1-6 were to varing degrees widely distributed over the shelf, whereas those in Groups 7-10 occurred preferentially on the outer shelf and at the shelf break. The remaining species were generally less characteristic of any given shelf zone, and some were widespread over the shelf.

In terms of the numerically dominant species in the SBT and anchor dredge collections (Figures 6-16 to 6-18), the inner shelf (C2) community was dominated by *Echinarachnius parma, Asterias forbesi, Crangon septemspinosa, Astarte castanea, Nassarius trivittatus,* and *Pagurus acadianus.* The central and outer shelf was characterized by *Echinarachnius, Crangon, Cancer irroratus, Asterias vulgaris,* and *P. acadianus. Asterias forbesi* was abundant at D1 on the central shelf but not on the outer shelf, and *Dichelopandalus leptoceras* and *Astrorhiza limicola* were more abundant on the outer shelf (B1, E1). The dominants of the communities at the shelf edge (A1, I1, F1) were very different from those on the shelf and consisted of *Astropecten americanus, Cancer borealis, Euprognatha rastellifera, Pontophilus brevirostris, Astarte undata,* and *Molgula arenata.* Other abundant species, some characteristic of only one of the shelf edge stations, included *Cyclopecten nanus* and *Calliostoma bairdii.*

The megabenthos of the continental slope station J1 was quite different. Although *Astropecten* was abundant as in the shelf-break zone, many of the species collected at J1 were not found on the shelf (Table 6-6). The conspicuous polychaete *Hyalinoecia artifex* was very characteristic of this station as was the asteroid *Stephenasterias albula.* Other dominants have not yet been identified to species including two zoantharian anemones.

Seasonal Variation

Seasonal variations in megabenthos populations were hard to assess because of the semi-quantitative nature of the abundance data. Nonetheless, some seasonal variability can be seen in mean catches of some dominant species at several stations. The two species of the crab *Cancer* demonstrate the most obvious seasonality. At central and outer shelf stations (B1, I1, E1, D1, and N3) *Cancer irroratus* and (at I1) *C. borealis* declined in abundance from fall to spring but increased greatly in abundance during the summer (Figure 6-16 and 6-17). This was apparently the result of recruitment during the spring, as *Cancer* megalopae were abundant in neuston samples during June (Chapter 4). In comparison, another common decapod, *Crangon septemspinosa,* tended to be more abundant during the winter and spring. This cycle is also coupled with the occurrence of *Crangon* larvae primarily during the colder months of the year.

Some apparent seasonal variations were more probably the result of patchy occurrence than true seasonality. For example, the ascidian *Molgula arenata*

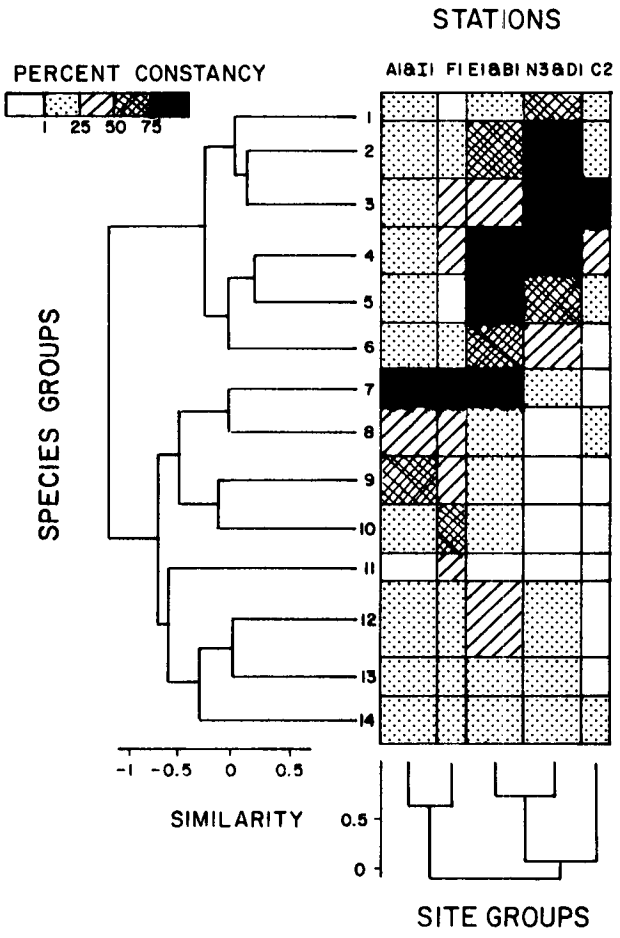


Figure 6-15. Normal and inverse classification hierarchies and nodal constancy for site-species group coincidence based on all anchor dredge collections.

Table 6-5. Species groups resulting from numerical classification of anchor dredge data combined for four seasonal cruises.

Species Group 1

Tellina agilis
Solariella obscura
Lunatia heros

Species Group 2

Pagurus acadianus
Cerastoderma pinnulatum
Asterias vulgaris
Crangon septemspinosa
Pandora gouldiana
Molgula arenata

Species Group 3

Nassarius trivittatus
Asterias forbesi
Spisula solidissima
Astarte castanea
Cirolana polita

Species Group 4

Ensis directus
Cancer irroratus
Arctica islandica
Echinarachnius parma
Astrorhiza limicola

Species Group 5

Lyonsia hyalina
Lunatia triseriata
Colus pygmaeus
Aphrodita hastata
Solariella obscura

Species Group 6

Havelockia scabra
Crucibulum striatum
Pitar morrhuana
Placopecten magellanicus
Polinices immaculatus

Species Group 7

Astarte undata
Astropecten americanus
Astarte crenata subequilatera
Cyclocardia borealis

Species Group 8

Cancer borealis
Diastylis bispinosa
Cyclopecten nanus
Nothria conchylega
Crenella glandula

Species Group 9

Lucinoma filosa
Perploma papyratium
Amphilimna ovalacea
Pontophilus brevirostris
Pandora inflata

Species Group 10

Euprognatha rastellifera
Calliostoma bairdii
Amphioplus macilentus
Rossia tenera
Cylichna verrilli

Species Group 11

Cylichna alba
Sclerasterias tanneri
Yoldia sapotilla

Species Group 12

Buccinum undatum
Dendroda carnea
Stereoderma unisemita
Dichelopandalus leptoceras
Musculus niger
Axiognathus squamata
Anomia simplex
Pagurus arcuatus

Table 6-5. (Concluded)

Species Group 13

Edotea montosa
Modiolus modiolus
Henricia sanguinolenta
Leptasterias tenera

Species Group 14

Edotea triloba
Ovalipes stephensoni
Epitonium dallianum
Perploma leanum
Nuculana

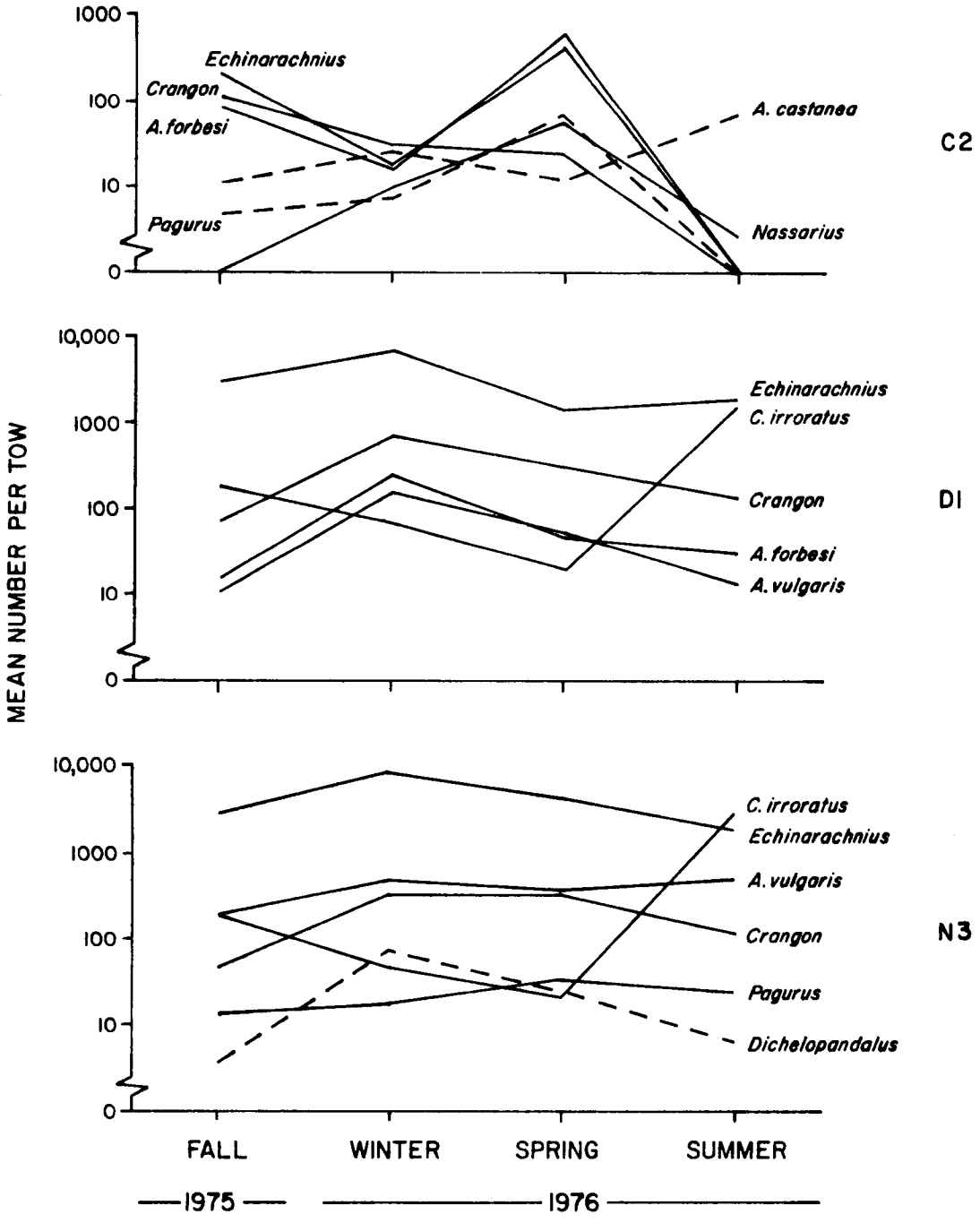


Figure 6-16. Fluctuation in mean catch of dominant species in small biology trawl collections from inner and central shelf stations.

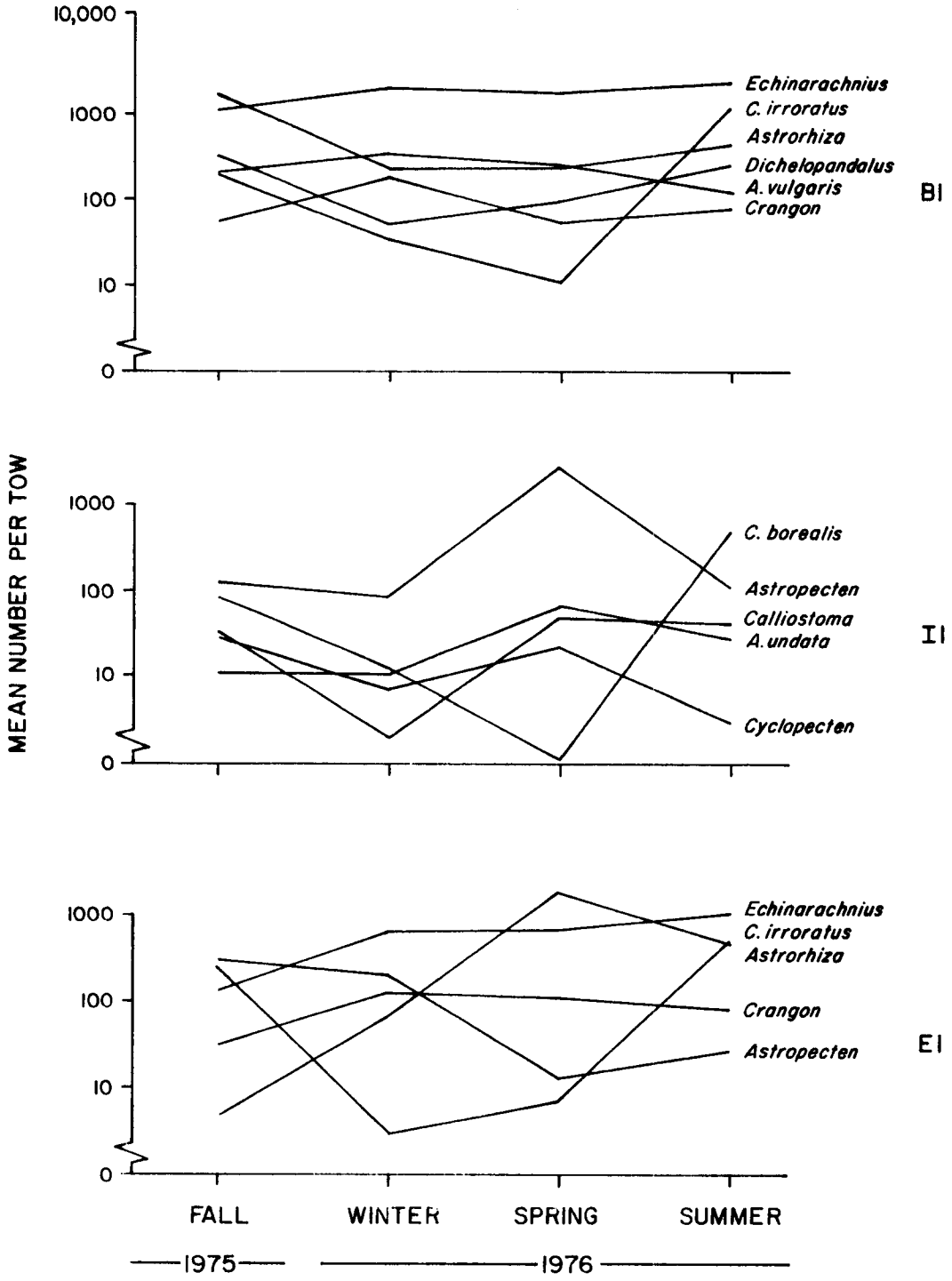


Figure 6-17. Fluctuation in mean catch of dominant species in small biology trawl collections from outer shelf stations.

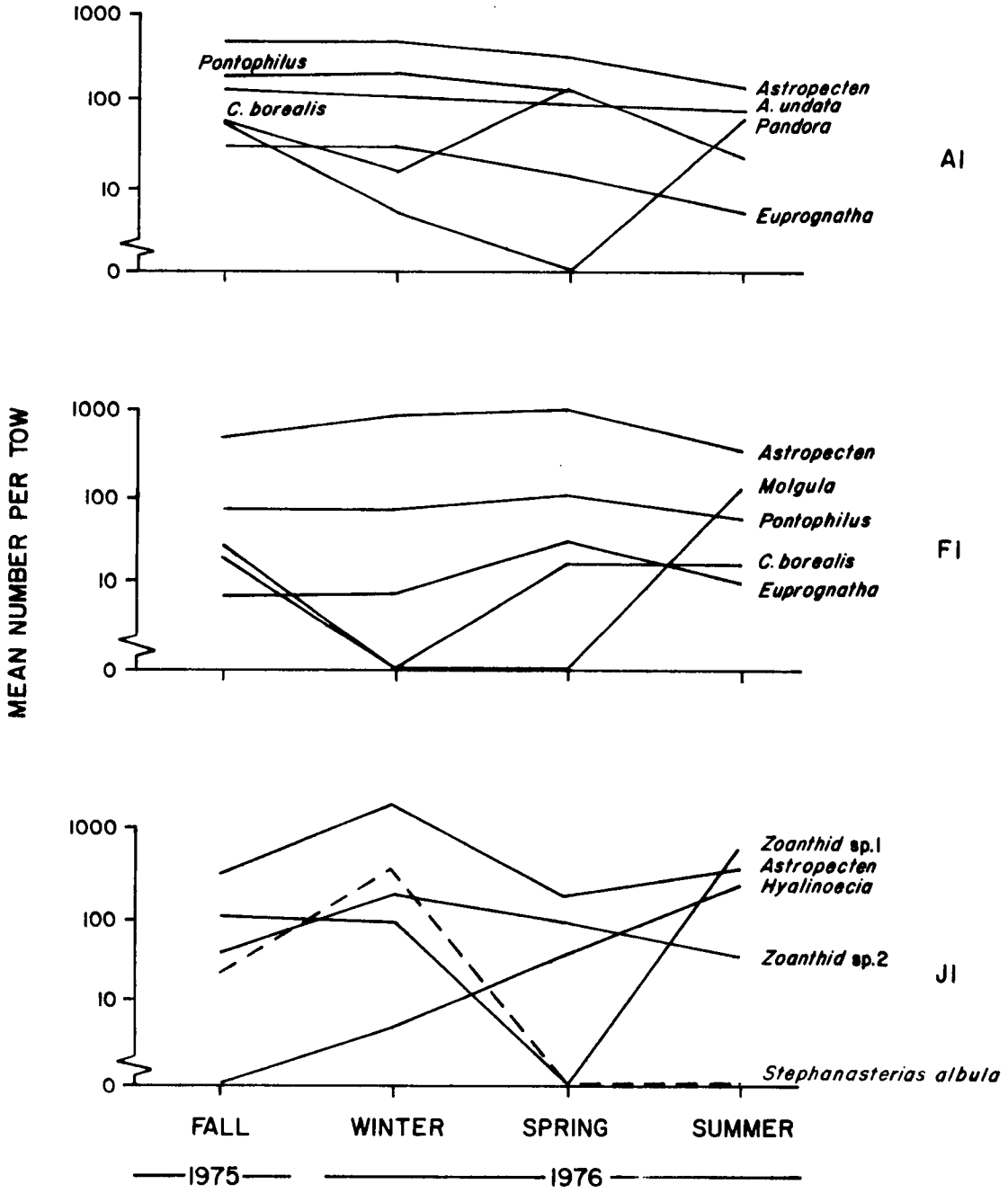


Figure 6-18. Fluctuation in mean catch of dominant species in small biology trawl collections from shelf break and continental slope stations.

Table 6-6. Species of megabenthos taken only at the continental slope station, J1.

Mollusca

Nuculana caudata
Nuculana acuta
Poromya granulatum
Cardiomya perrostrata
Thyasira flexuosa
Bathyarca sp.
Inodrilla sp.
Turbonilla sp.
Colus pubescens
Colus stimpsoni
Eudolium crosseanum
Heliacus borealis
Dentalium occidentale ?
Dentalium meridionale ?
Unid. gastropods 3
Unid. bivalves 2

Decapod Crustacea

Homarus americanus
Geryon quinquedens
Processa tenuipes
Acanthocarpus alexandri
Munida valida
Sergestes arcticus
Palicus cursor
Parapandalus willisi ?
Pagurus politus ?
Parapagurus pilosimanus ?
Catapagurus sharreri
Spirontocaris liljeborgii

Echinodermata

Odontaster setosus
Stephanasterias albula

Other Taxa

Zoantharian anemones 2 sp.
Anemones 2 sp.
Actinauge rugosa ?
Polymastia robusta ?
Hyalinoecia artifex
Laetmonice filicornis
Cirolana impressa
Diastylis cornuifer
Meganyctiphanes norvegicus
Epineria loricata
Anoplodactylus iuleus
Phycis chesteri
Enchelyopus glutinosa
Coelorhynchus carminatus
Glyptocephalus cynoglossus
Myxine glutinosa
Merluccius albidus
Nezumia bairdi

was taken only twice at station F1 but when present was abundant. The large changes in population densities at C2 during the summer resulting from low dissolved oxygen stress are discussed more thoroughly below.

Species Diversity

The number of species collected at each station showed a general pattern of increase across the shelf (Figure 6-19). The average number of species taken in 3 SBT tows ranged from fewer than 20 on the inner and central shelf to 30-40 species at most outer shelf and shelf break stations. On the continental slope 35 to 39 species were taken each season. Generally fewer species were taken in anchor dredge hauls than in SBT samples, and the cross-shelf species richness gradient was not as apparent.

The distribution of H' diversity exhibited a pattern which reflected both the species richness pattern and the evenness of constituent populations (Figure 6-20). Higher H' values of ca. 3 bits/individual were found at the outer shelf and shelf break stations, particularly I1 and A1. Lowest values of ca. 1 bit/individual for collections on the central shelf where heavy dominance by *Echinarachnius parma* reduced evenness (Figure 6-21). Collections from the inner shelf station (C2) were more even, thus H' was relatively high (ca. 2 bits/individual) even though the species richness was low.

Effects of Hypoxia during Summer 1976

Unusual conditions developed during the summer of 1976 resulting in widespread depletion of dissolved oxygen below the pycnocline on the inner continental shelf off New Jersey (Sharp 1976). Although dissolved oxygen was depressed over a wide portion of the shelf (Figure 6-22, Chapter 3), C2 was the only station sampled for megabenthos which appeared to be affected during the summer. This station was in one of the most severely affected areas where dissolved oxygen concentrations were very near zero for a prolonged period and a build-up of H_2S was observed.

The anoxic or hypoxic conditions heavily impacted the megabenthos at C2 (Figure 6-23); however the effect varied with species. Abundant molluscs (e.g. *Astarte castanea* and *Nassarius trivittatus*) did not appear to suffer significant mortalities. The opisthobranch mollusc *Pleurobranchea tarda* was not found in August 1976, but was also absent the previous February. Decapod crustaceans and echinoderms suffered complete extirpation at this site. No live specimens of the previously dominant *Crangon*, *Cancer*, *Asterias*, or *Echinarachnius* were collected in SBT, anchor dredge, or other trawl hauls.

In addition to the elimination of most dominant species, less abundant species were also affected, resulting in a reduction of the total number of species taken to 10 in the SBT and 5 in the anchor dredge. SBT tows and, in particular, otter trawl tows collected much decaying flesh of the surf clam *Spisula solidissima* and dead or moribund specimens of some species previously infrequent. These included several representatives of the deep dwelling infauna (the polychaetes *Glycera dibranchiata* and *Sigalion arenicola*, the sipunculan *Phascolopsis gouldi*, the stomatopod *Platysquilla enodis*, and unidentified edwardsiid anemones) which had apparently migrated to the sediment surface in response to hypoxic stress.

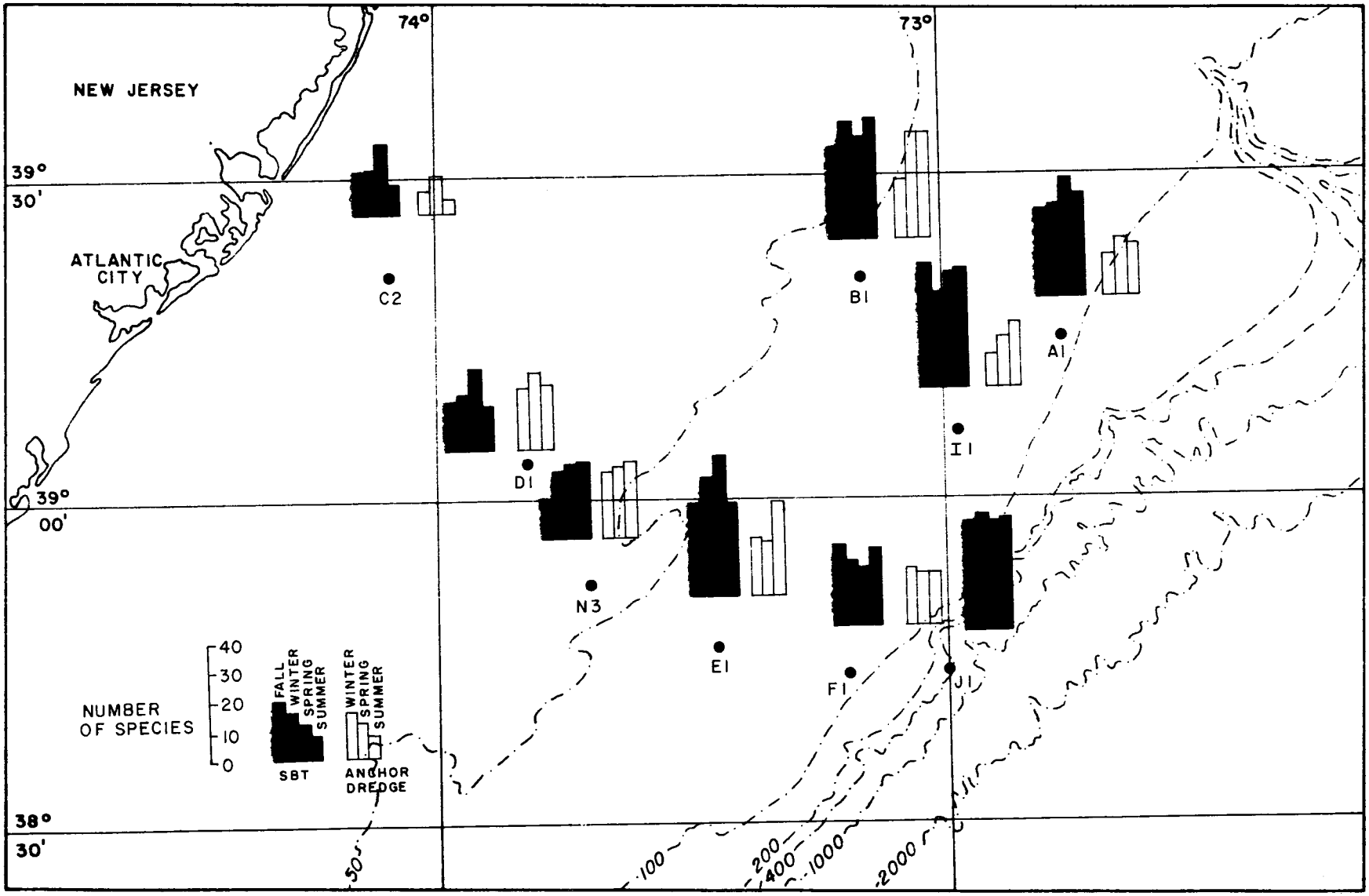


Figure 6-19. Total number of species collected by small biology trawl and anchor dredge at each station for each season. Includes only those taxa identified for all seasons. Numerical values are listed in Appendix 6-D.

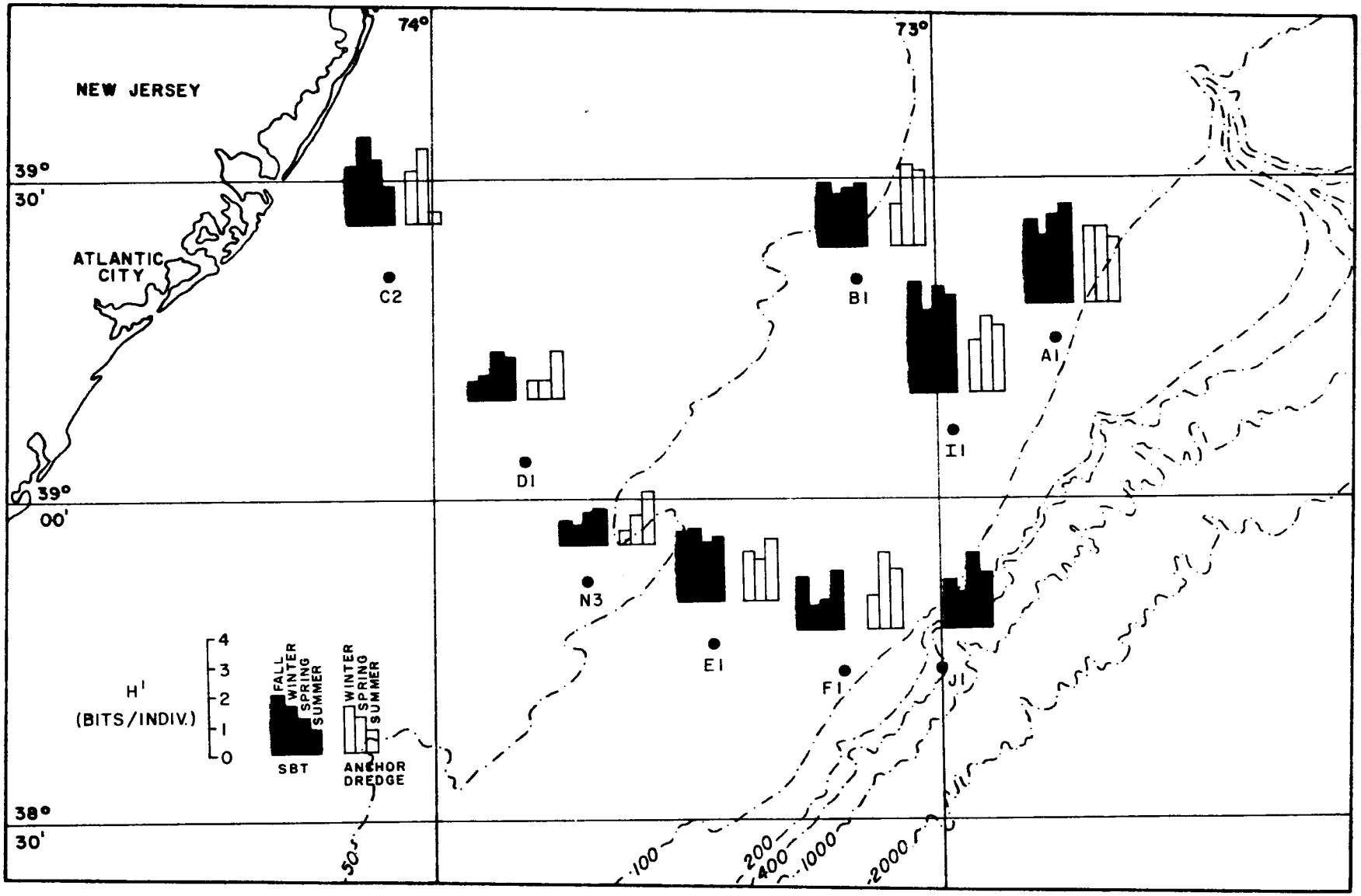


Figure 6-20. Shannon diversity (H') for small biology trawl and anchor dredge collections at each station for each season. Includes only those taxa identified for all seasons. Numerical values are listed in Appendix 6-D.

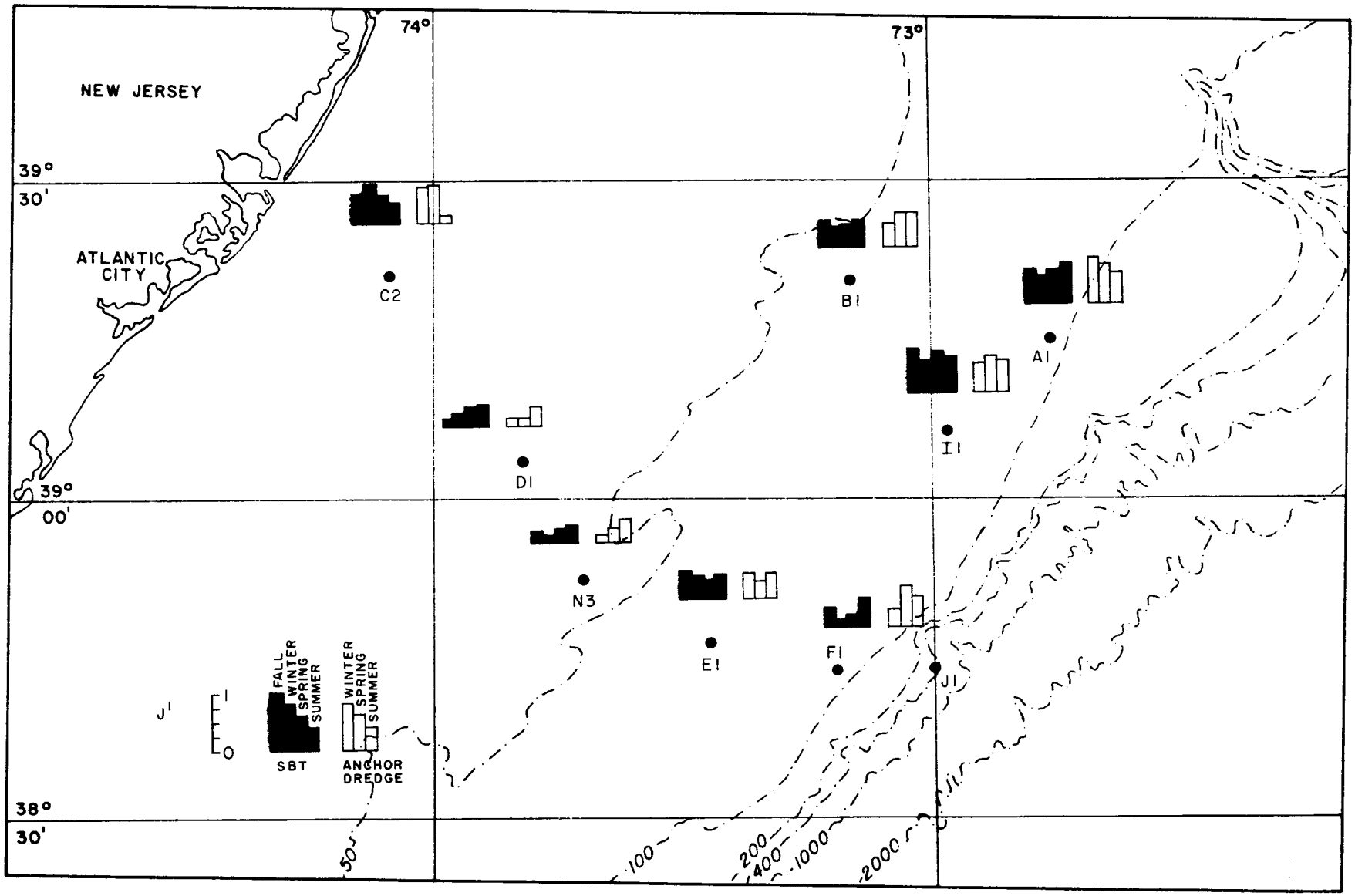


Figure 6-21. Evenness (J') for small biology trawl and anchor dredge collections at each station for each season. Includes only those taxa identified for all seasons. Numerical values are listed in Appendix 6-D.

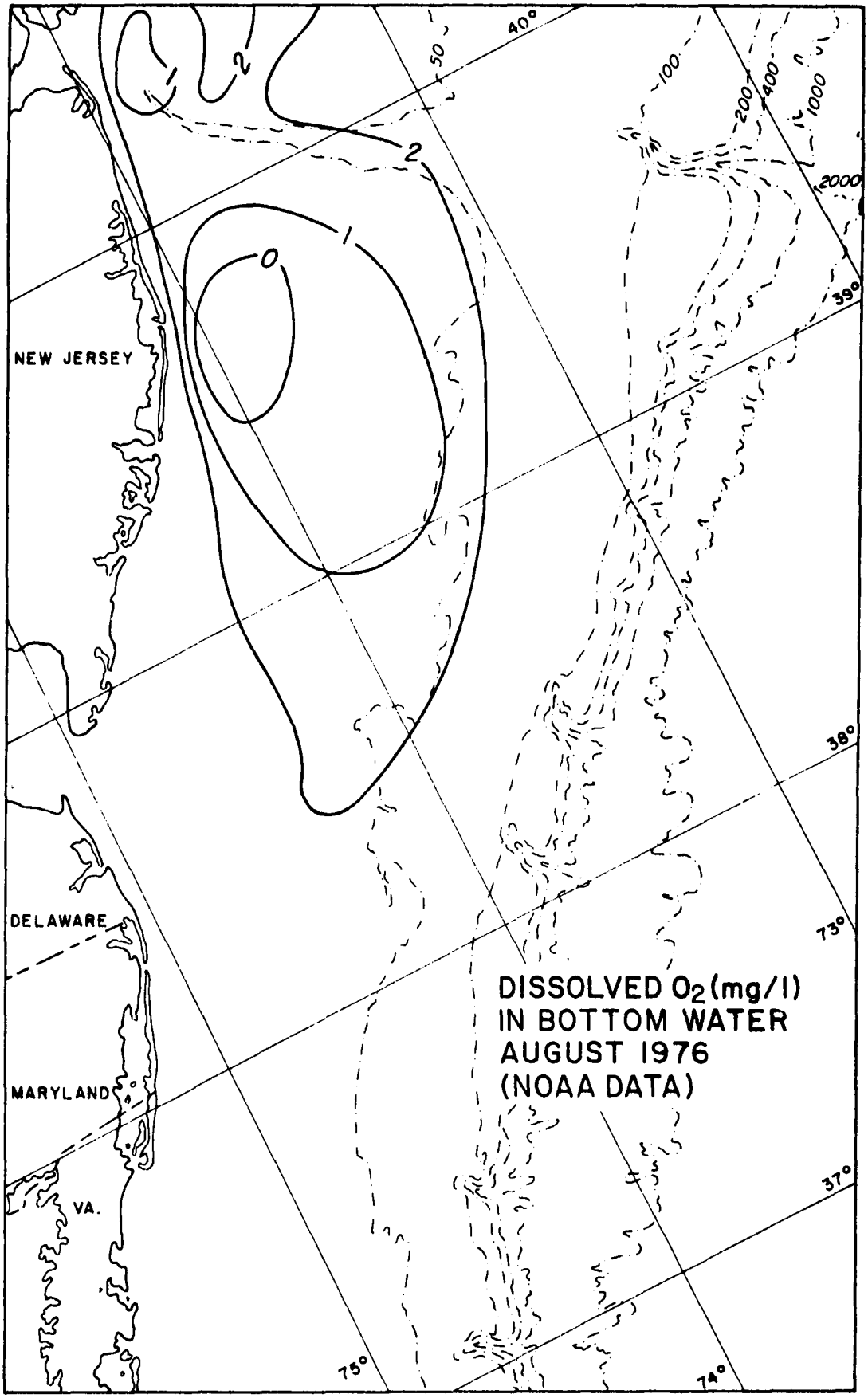


Figure 6-22. Distribution of dissolved oxygen in bottom waters on the continental shelf off New Jersey during August 1976, based on NOAA data (Sharp 1976).

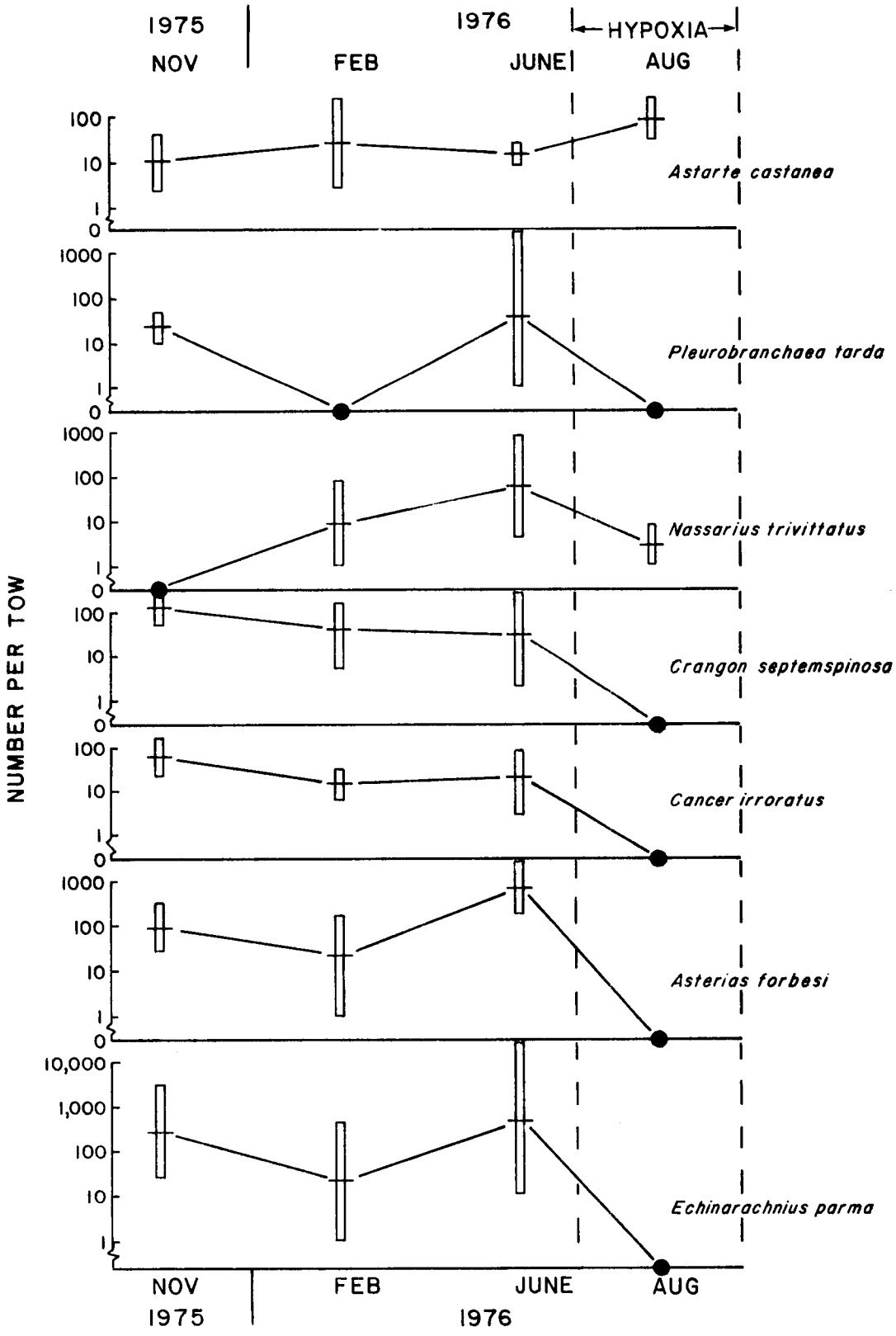


Figure 6-23. Fluctuations of catches of dominant megabenthos taken by small biology trawl at Station C2, Fall 1975 to Summer 1976. Black dots indicate absence, vertical bars are 95% confidence limits ($\bar{x} \pm s_{\bar{x}}\, t_{.05}$) computed on log-transformed abundance.

Collections made during the fall 1976 and winter 1977 cruises during the second year of study indicate relatively little recovery of the megabenthos at C2, except for some recruitment of *Crangon*. Furthermore, similar effects, including severe reduction of *Echinarachnius* populations, were apparent at N3 (but not D1) during the fall 1976 cruise. This apparently resulted from offshore movement of low-oxygen water during September or October.

Macrobenthos

Composition of the Fauna

Over 640 species of macrobenthic invertebrates were identified from the grab samples taken at the 51 stations from fall 1975 through summer 1976 (Appendix 6-B). Numerous other species were collected but have not yet been separated to species. Only a few organisms have not yet been identified to at least the family level. However, species in several important taxa, in particular cirratulid, syllid, and ampharetid polychaetes, have not yet been completely separated.

Polychaetous annelids numerically dominated the collections at most stations, usually comprising 40 to 60% and occasionally up to 90% of the individuals. Over 250 polychaetes were identified, and this number continues to increase as taxonomic specialists differentiate some of the more difficult taxa. It is estimated that about 29 polychaete species are new to science.

The second most abundant group was the peracaridean crustaceans which included 137 species and whose major component was the Amphipoda. A total of 96 amphipod species was identified, and at least 6 are believed to be new to science. Peracarideans generally comprised 10 to 30% of the individuals in collections but were occasionally dominant (>70%).

Molluscs were the third most abundant and diverse group with a total of 115 species identified to date. They generally accounted for less than 10% but up to 50% of the individuals in a collection.

The fourth most abundant group was the echinoderms. A total of 27 species were collected with most of the individuals being amphiurid ophiuroids. Although echinoderms accounted for generally less than 5% of the individuals at a station, as many as 50% of the total was found at some stations.

Other groups which occasionally accounted for a significant portion of the individuals in a collection were ostracod and tanaidacean crustaceans. The remaining taxa were almost never present in large numbers.

It is clear from even casual comparison of species lists (Appendices 6-A and 6-B) that dredge and trawl sampling and grab sampling captured vastly different components of the macrobenthic biota. The dredge and trawl sampling, because of the larger mesh size (4 mm), selected for larger asteroids and echinoids, decapod crustaceans, and molluscs, while the grab sampling (0.5 mm mesh) recovered the abundant but smaller annelids, peracarideans, and ophiuroids. The two approaches used in combination gave a good representation of the macroinvertebrate communities at any given site.

Sampling Variability

Variability of faunal parameters affects the detection and description of spatial and temporal distribution patterns. An understanding of the scale of natural sampling variation is thus critical to the use of biological data in baseline or environmental impact studies. There are a number of approaches one can follow in the assessment of sampling variation in communities. The most fundamental is the assessment of dispersion of constituent species. Computation of sample means and variances of replicate estimates is a standard part of the data listing routines used in this study. Thus, an enormous amount of information on species dispersion is available, and the whole spectrum of patterns is in evidence, from quite uniform abundance to extreme contagion.

These data defy simple summary, but one particularly relevant question which can be posed concerns the adequacy of replication for population estimation. Replication is a prime determinant of effort; thus it is cost effective to keep replication at a minimum, consistent with stated interests in statistical accuracy. We have examined the adequacy of replication using techniques similar to those of Saila et al. (1976). The necessary level of replication to detect significant changes in population density depends on (1) population statistics (mean and variance) and (2) the degree of change one wishes to detect. If we argue that it is sufficient to be able to detect with 90% confidence a reduction in population mean density of 50%, then the number of replicates required, n, is:

$$n \geq \frac{2t^2_{.10}\, s^2}{(\bar{x} - \bar{x}/2)^2}$$

where t is the appropriate value of the t statistic, s^2 is the variance, and $\bar{x}$ the population mean. Such estimates were made using log-transformed abundance values for a representative range of dominant species at 6 stations sampled in fall 1975. The results are summarized in Figure 6-24. It is obvious that the answer to the statistical question varies greatly among species. Species which are randomly or uniformly distributed need only to be sampled with 2 or 3 replicates, whereas those very contagiously distributed may require many more than the current 6 replicate samples. However, if one looks for the point of diminishing returns, it appears from Figure 6-24 to be about 5 or 6 replicates. Further replicates each add only a small fraction of the species considered, producing a gradually levelling curve. Thus, for the purposes of detecting differences in population levels of dominant or characteristic species, the current level of replication is about right: reduction of replication rapidly reduces the number of species for which a 50% population reduction could be discerned, and increasing replication adds only few species to such statistical consideration. Using the same arguments, summary biotic statistics, such as total macrofaunal density, areal richness, and species diversity indices, can generally be accurately assessed with fewer (ca. 3) replicate samples.

Biomass and Abundance

Wet weight biomass is not directly comparable among the various macrobenthic taxa because of the inclusion of skeletal material, tubes, and gut contents.

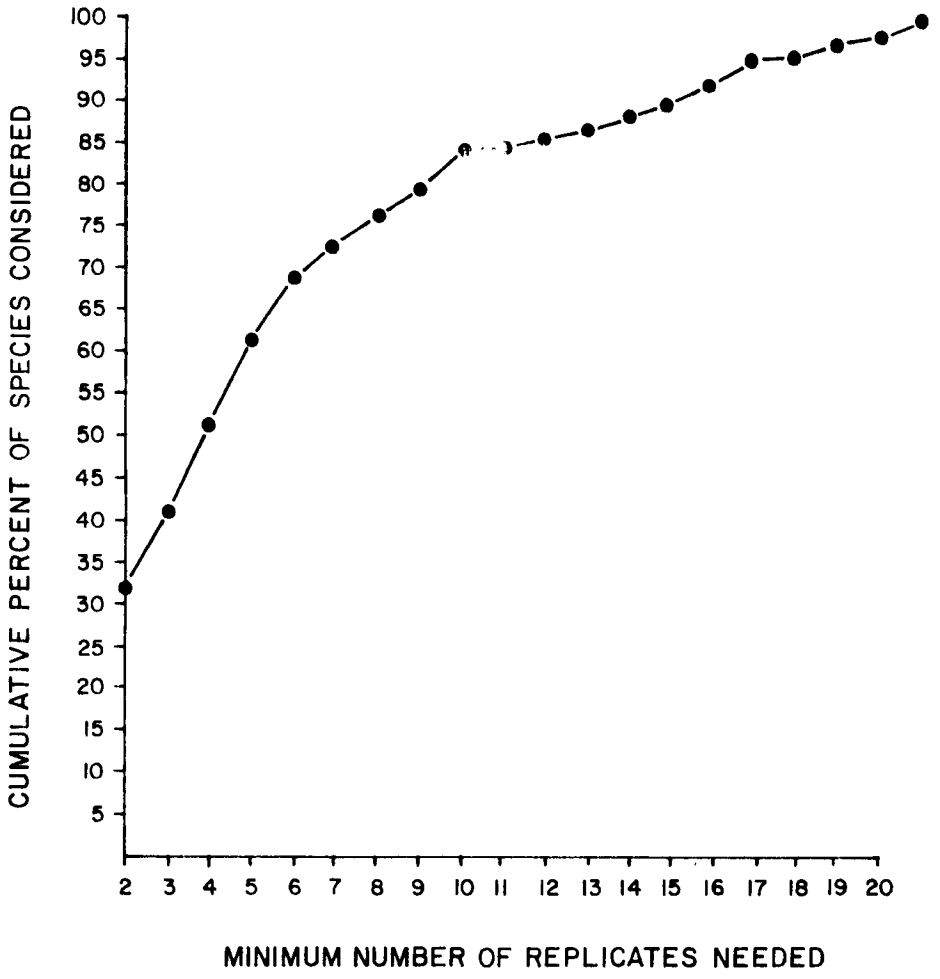


Figure 6-24. Cumulative percent of dominant species at Stations B1, B2, D1, D4, F1, and F4 (Fall 1975) requiring given minimum number of replicate samples to detect a 50% reduction in mean population density at the 90% confidence level.

Such data are, however, much more comparable within a taxon, e.g. Annelida, Echinodermata, etc., which tends to have a relatively similar living matter to total bulk relationship. Thus, the biomass data are here treated separately by major taxon with no attempts to combine biomass over all taxa.

Biomass data are summarized in Figures 6-25 to 6-32 and in Appendix 6-E in terms of geometric means of six replicate samples. Geometric means are employed to reduce the effect on mean comparisons of the typically great variability in biomass.

Annelid biomass was the least variable from replicate to replicate because many individuals are usually the main biomass contributors rather than a few large ones. Wet weight biomass was generally highest in the muddy fine sands of topographic lows, including swales (B3, C4, and D4) and the Hudson Shelf Valley (G3). Although geometric mean biomass ranged as high as 100 g/m^2, most estimates for shelf stations ranged 10-30 g/m^2. Annelid biomass was lowest in dynamic sand bottoms on the inner and central shelf and on the continental slope where 1-5 g/m^2 were found. No consistent seasonal trends were apparent, and at those stations where there was great variability among seasons (e.g. C4, D1, and E1) it was principally caused by station relocation difficulties or patchiness (Chapter 5).

Mollusc wet weight biomass estimates were highly variable due to the occasional capture of large bivalves. Greatest geometric mean biomass (up to 588 g/m^2 but more typically 50-100 g/m^2) was found in swales and on the outer shelf. The highest mollusc biomass for a single 0.1 m^2 grab sample was 223 g. The chief contributor to high molluscan biomass in swales and on the outer shelf was the bivalve *Arctica islandica*, but *Astarte* spp. and *Cyclocardia borealis* were also important. As with the Annelida, lowest biomass was observed in dynamic sands of the inner and central shelf, the continental slope and at the shelf break (approximate range 1-10 g/m^2), and no obvious seasonal variations were discovered.

Biomass of Crustacea was less than 10 g/m^2 over most of the shelf. Biomass of crustaceans from the shelf depressions (B3, G3) was higher (up to 50 g/m^2) due mainly to aggregations of ampeliscid amphipods. Crustacean biomass at the shelf break and on the upper slope was much lower (1-4 g/m^2) than on the shelf.

Wet weight biomass of echinoderms was extremely variable. This variability reflects the inclusion of the sand dollar *Echinarachnius parma* and the asteroid *Astropecten americanus* in the samples. Biomass was generally highest (50-300 g/m^2) on the central and inner shelf where *Echinarachnius* was most abundant and low at swale stations where annelid, mollusc, and crustacean biomass was high. Echinoderm biomass was near zero at continental slope stations and at certain stations on the southern K and L transects.

The combined wet weight biomass of remaining taxa was generally less than 2 g/m^2, although occasionally the inclusion of cerianthid or zoanthid anemones or nemerteans raised this value to 5-10 g/m^2.

Data on total macrofaunal abundance are summarized in Figures 6-33 and 6-34. Total density ranged two orders of magnitude from 37,835 individuals/m^2 at E2 in fall to 393 individuals/m^2 at C3 in summer. Density was highest on the outer continental shelf, intermediate on the inner and central shelf

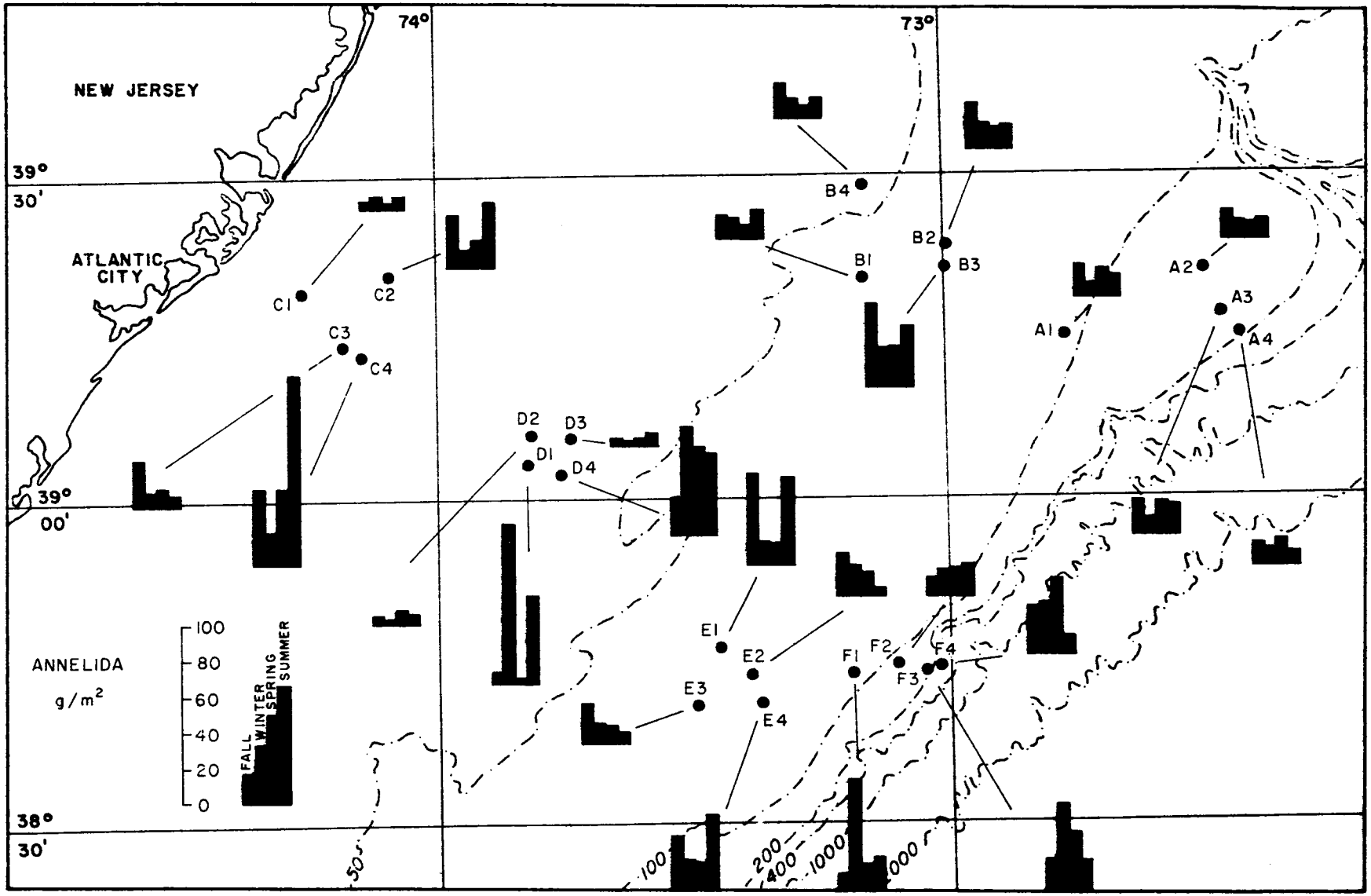


Figure 6-25. Wet weight biomass of Annelida at the quarterly sampled cluster stations.

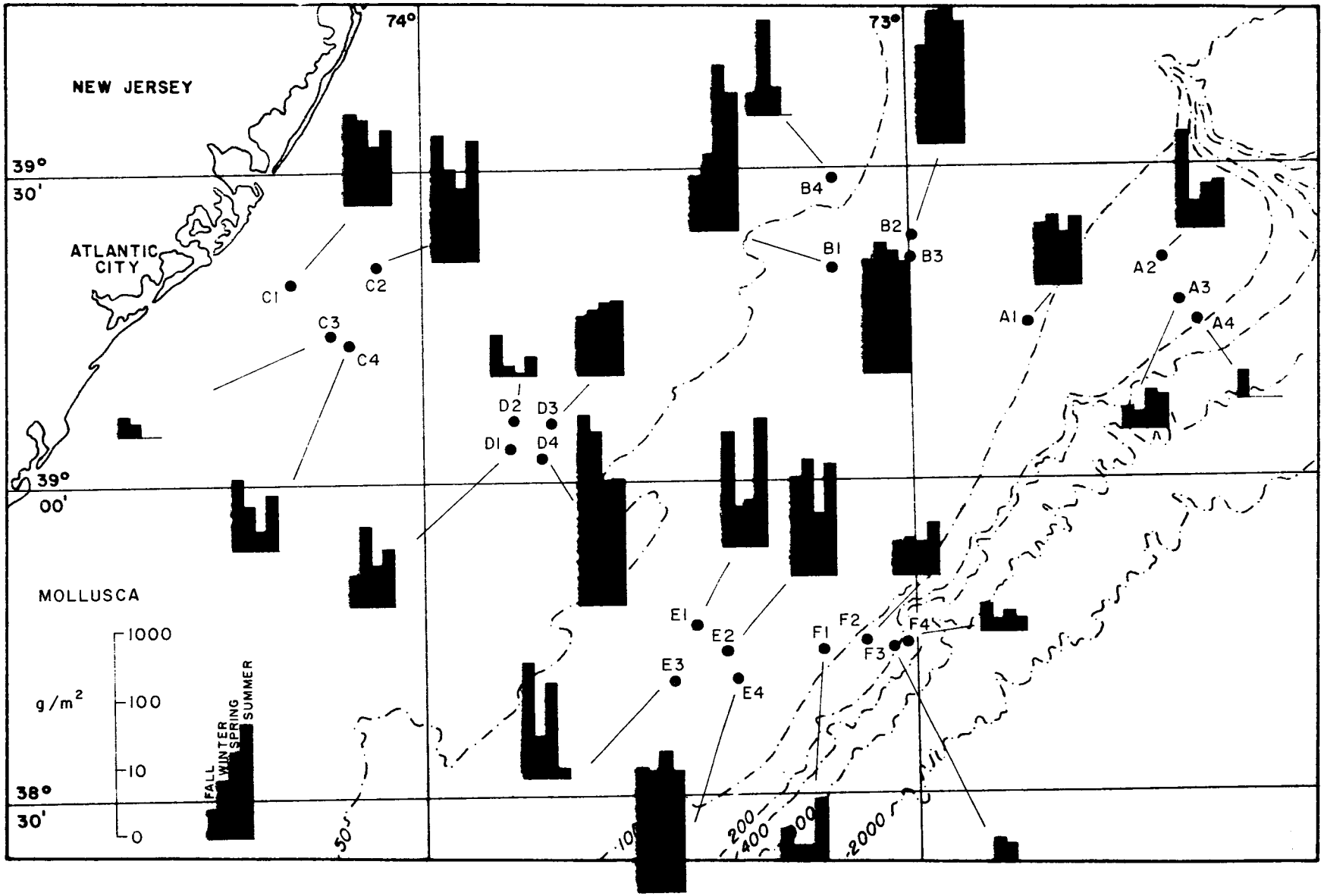


Figure 6-26. Wet weight biomass of Mollusca at the quarterly sampled cluster stations.

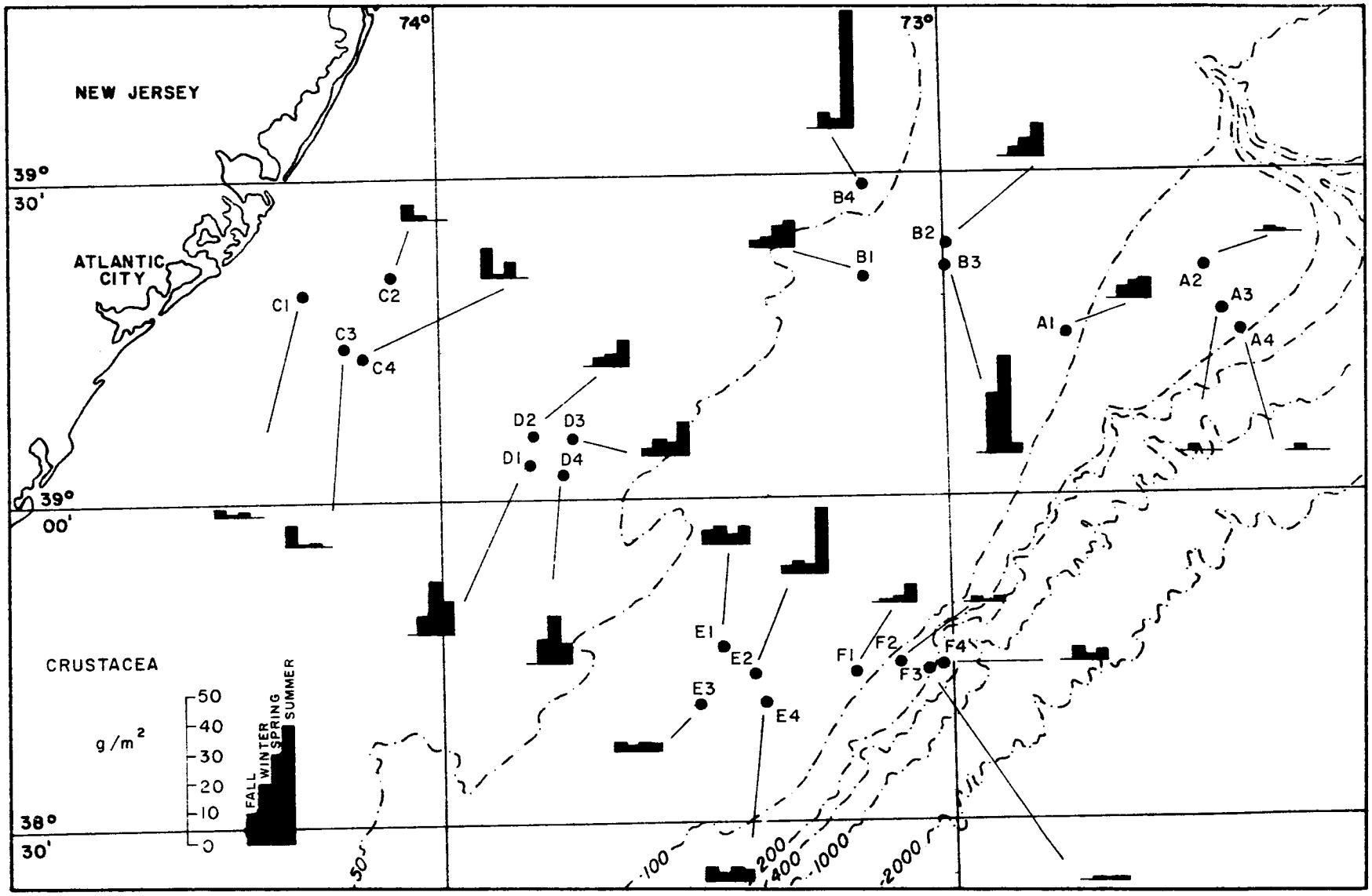


Figure 6-27. Wet weight biomass of Crustacea at the quarterly sampled cluster stations.

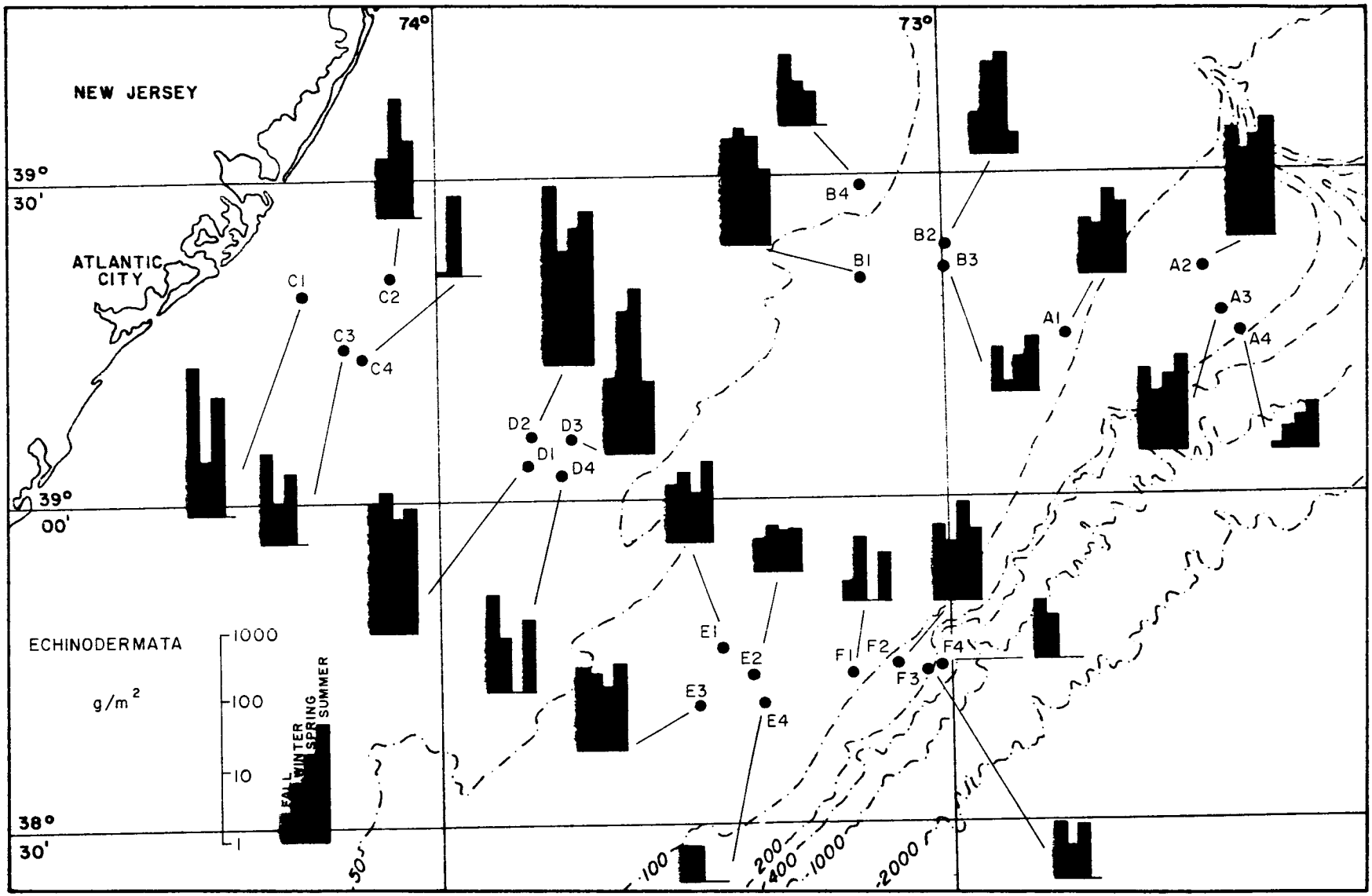


Figure 6-28. Wet weight biomass of Echinodermata at the quarterly sampled cluster stations.

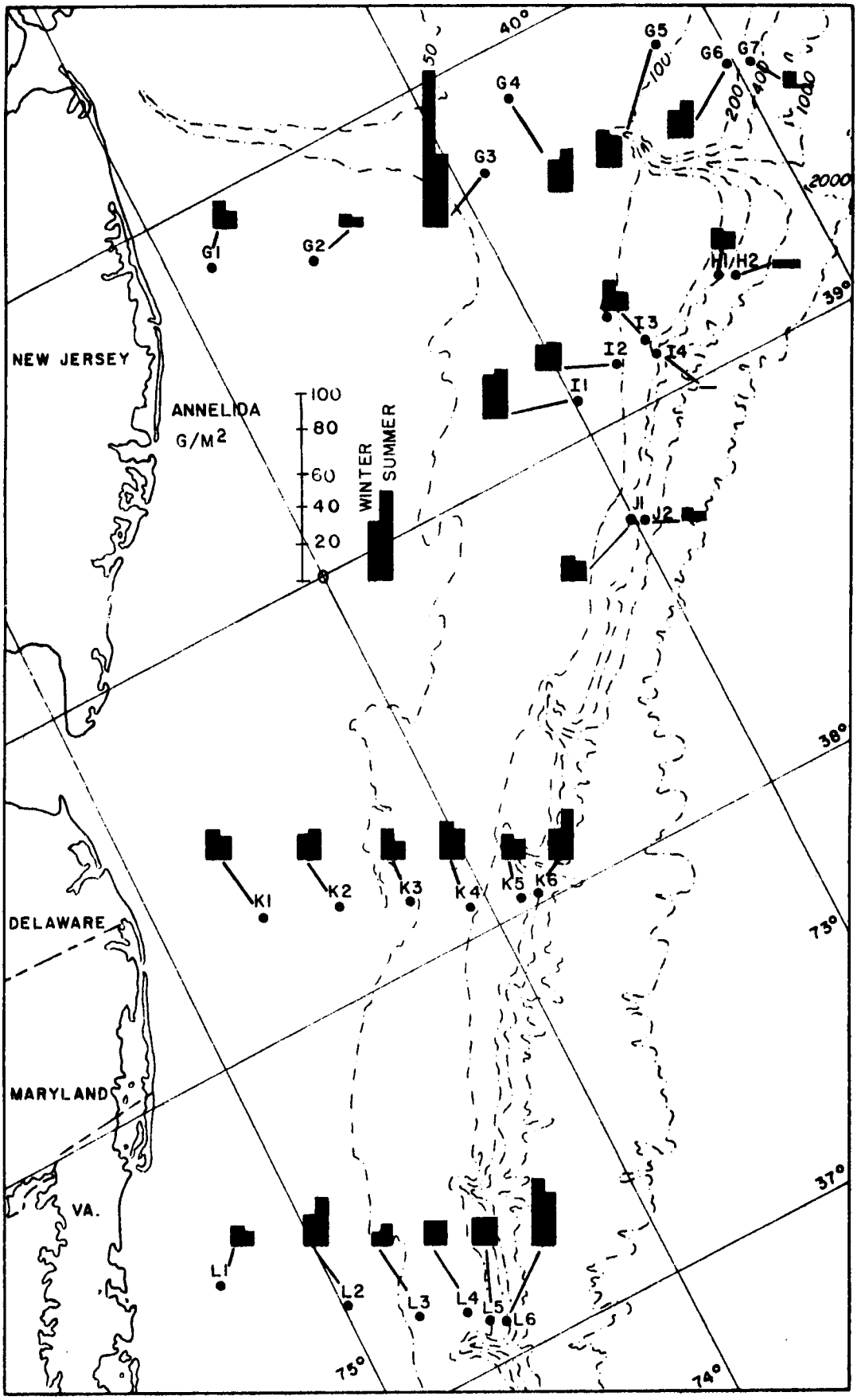


Figure 6-29. Wet weight biomass of Annelida at the semi-annually sampled transect, continental slope and canyon stations.

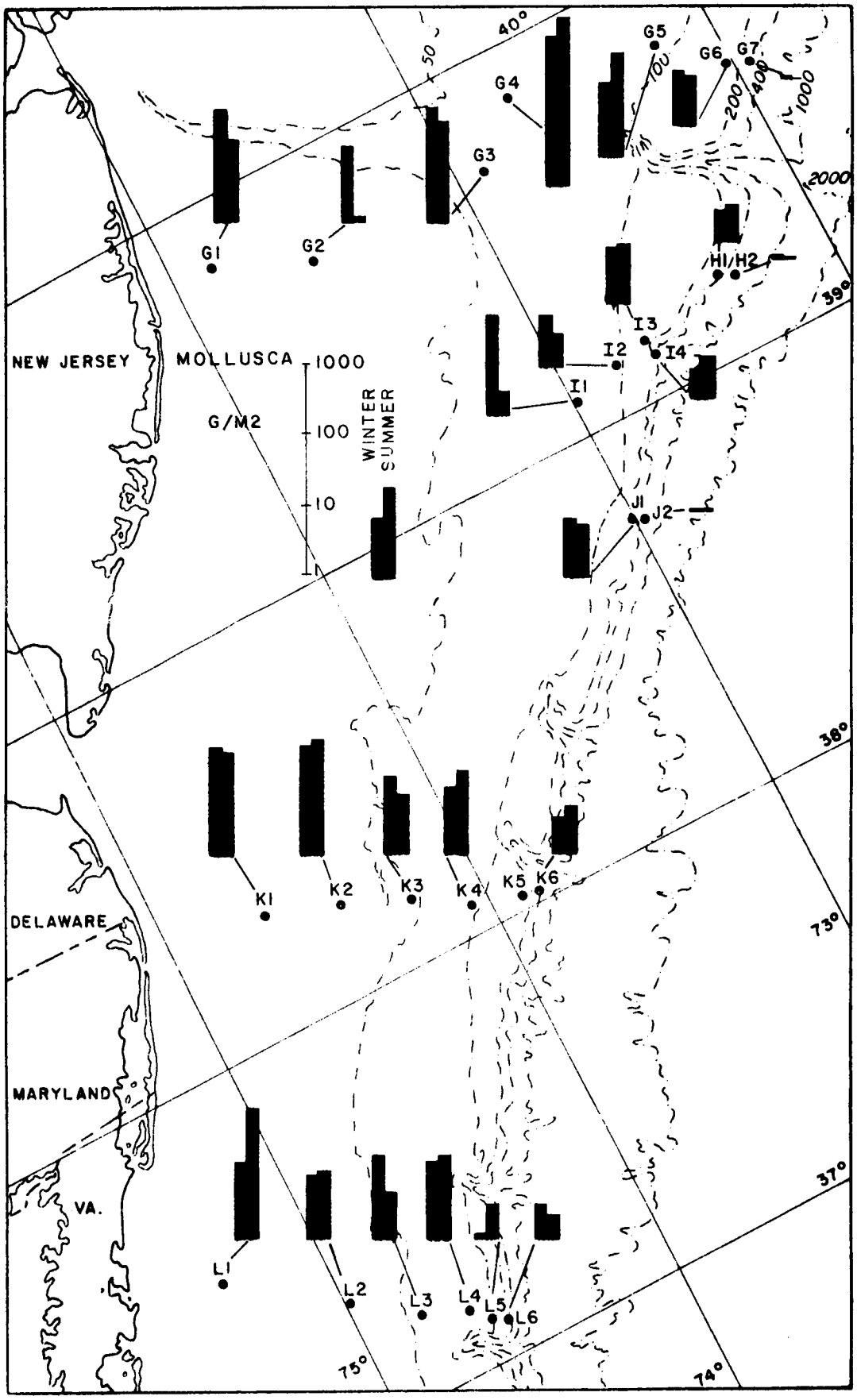


Figure 6-30. Wet weight biomass of Mollusca at the semi-annually sampled transect, continental slope and canyon stations.

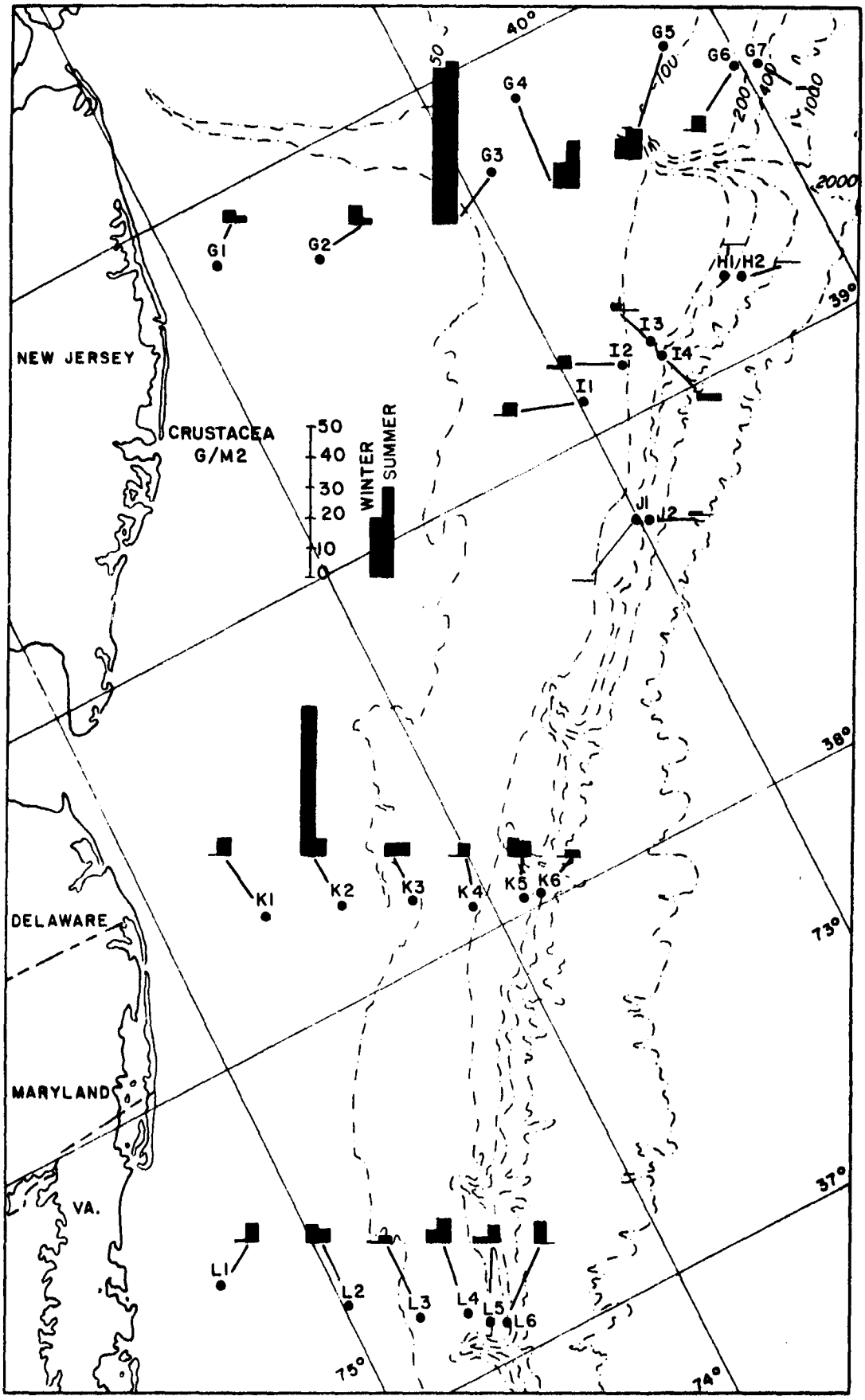


Figure 6-31. Wet weight biomass of Crustacea at the semi-annually sampled transect, continental slope and canyon stations.

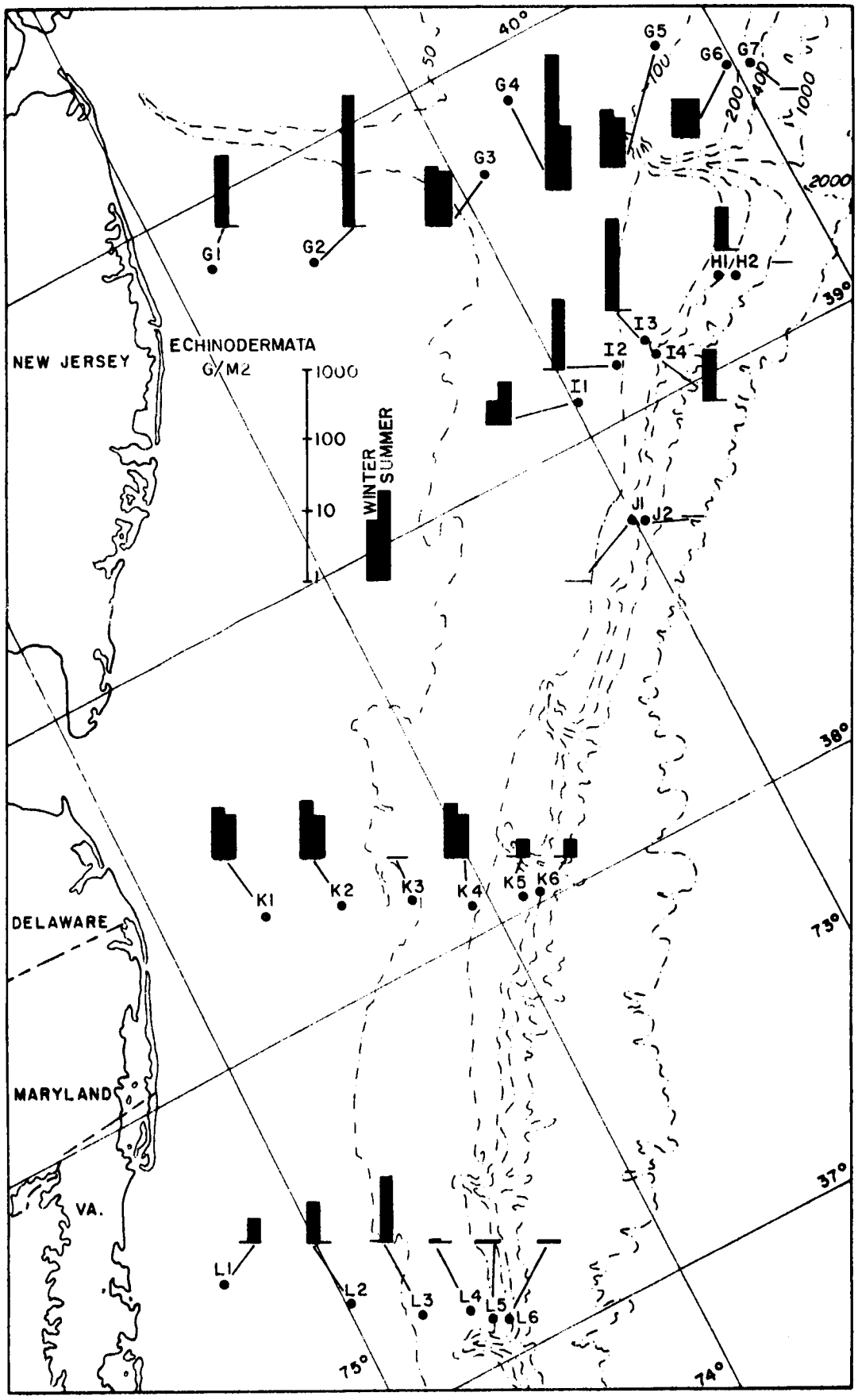


Figure 6-32. Wet weight biomass of Echinodermata at the semi-annually sampled transect, continental slope and canyon stations.

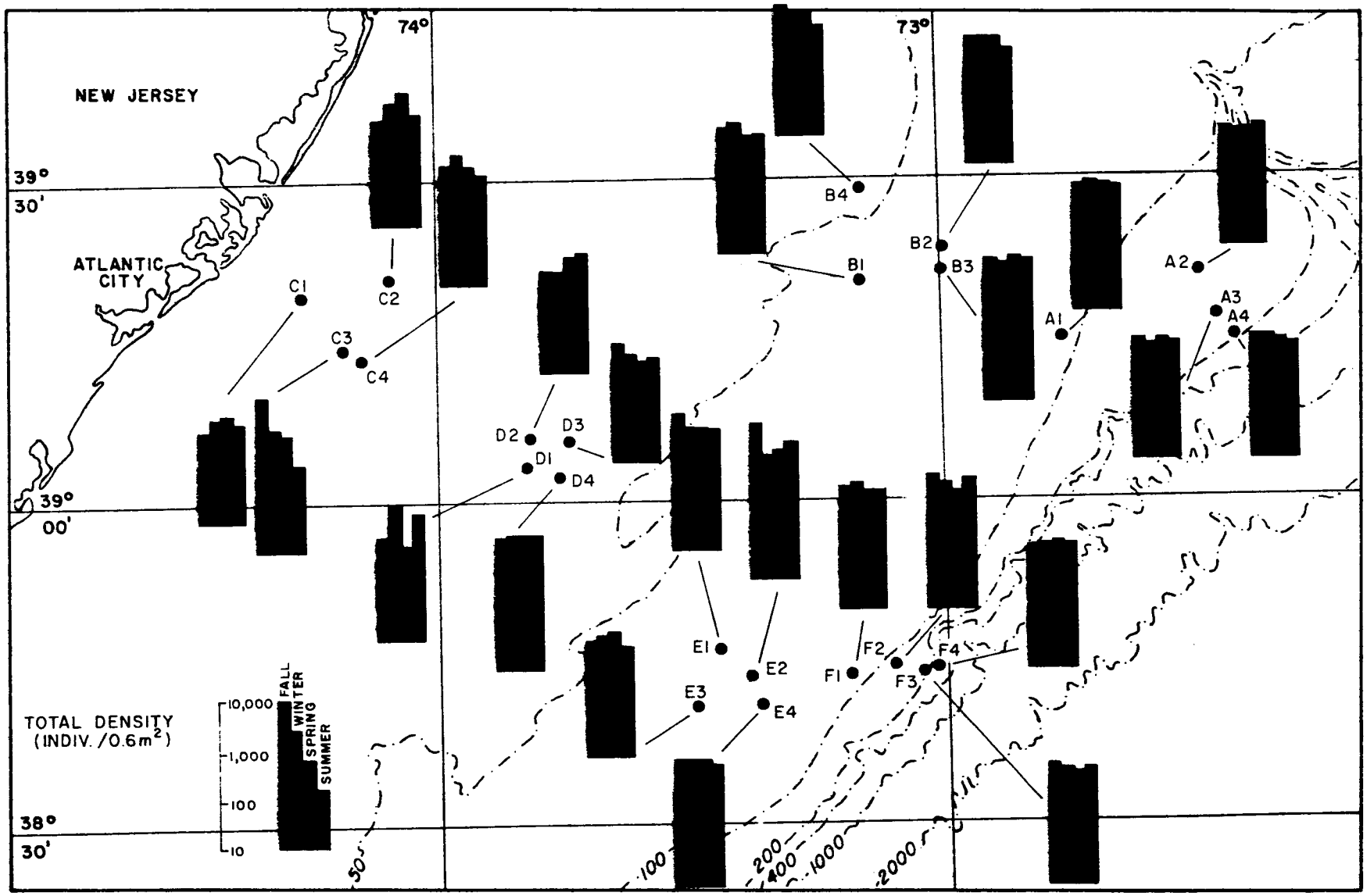


Figure 6-33. Total density of macrobenthos at the quarterly sampled cluster stations. Numerical values are listed in Appendix 6-F.

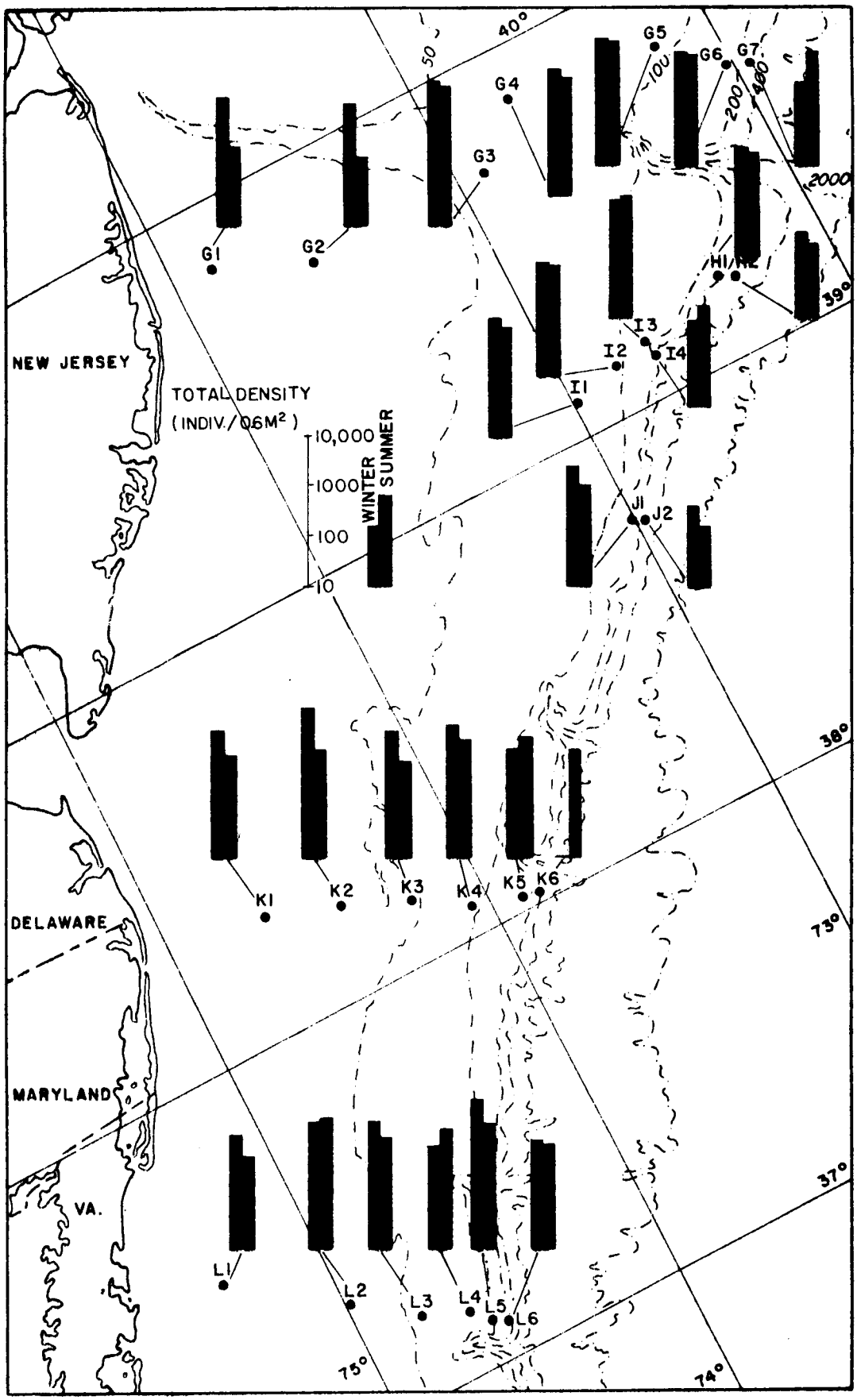


Figure 6-34. Total density of macrobenthos at the semi-annually sampled transect, continental slope and canyon stations. Numerical values are listed in Appendix 6-F.

and shelf break, and lowest on the continental slope. Densities were on the average much higher (2 to 5 times higher) at swale stations than at nearby stations. At continental shelf stations densities tended to be higher in fall 1975 and declined into the summer. At shelf break stations, however, densities remained seasonally more constant.

Patterns of Distribution

The description of patterns of distribution of the macrobenthos of the study area is made difficult by the bewilderingly large data set produced by this study. As a consequence, numerical classification was heavily relied on to discern and summarize the patterns of distribution witnessed in the data set. Because the entire 150 station data set could not be practically analyzed by existing programs and computing facilities, analysis focused on 1) data from 51 stations during the winter 1976 cruise in order to describe broad trends in the study area and 2) data from the 24 cluster stations for each of four seasons in order to discern finer spatial and temporal patterns. Summer data for the 51 stations were not finalized at the time of analysis, but subsequent analysis has shown the results based on the winter data to be representative. In each case, the data set was reduced to the 150 most "important" species using the criteria described in the Methods section. Flexible sorting was used in each of the analyses.

Winter 1976 Distribution. The 51 stations were classified into 13 site groups as indicated in Table 6-7 and the inverse analysis of 149 species was interpreted at the 24 group level (Table 6-8). The fusion hierarchies of these groups are given on Figures 6-35 through 6-37.

Table 6-7. Site groups selected from numerical classification of macrobenthos from 51 stations sampled during winter 1976.

Site Group	Stations Included	Distribution
A	C1, C2, G1, C3	inner shelf
B	D2, D3, G2, K3, K1, B4	central shelf
C	C4, L1	inner shelf, fine sand
D	L2, L3, D1, D4	central shelf, fine sand
E	B2, G4, E3, E1, B1, K2	outer shelf
F	B3, G3	outer shelf, depressions
G	E2, E4, I1, I2, A1	outer shelf-shelf break
H	L4	outer shelf
I	G5, K4, F1, F2	outer shelf-shelf break
J	F3, F4, G6, K5, L5	shelf break
K	A2, A3, A4, I3	shelf break, muddy
L	L6, K6, J1, I4, H1, G7	upper slope
M	J2, H2	middle slope

Table 6-8. Species groups selected from numerical classification of macrobenthos at 51 stations sampled during winter 1976.

Species Group 1

Hemipodus roseus
Nephtys picta
Spisula solidissima
Tellina agilis
Pseudoleptocuma minor
Nephtys bucera
Chiridotea arenicola
Sigalion arenicola
Pseudunciola obliquua
Protohaustorius wigleyi

Species Group 2

Synchelidium americanum
Pandora inflata
Edotea triloba
Clymenella zonalis

Species Group 3

Nemertea sp. 2
Ampharete arctica

Species Group 4

Cytheretta edwardsi
Pitar morrhuana
Sarsiella zostericola
Nucula proxima

Species Group 5

Corophium crassicorne
Photis sp. 5
Clymenella torquata

Species Group 6

Goniadella gracilis
Lumbrinerides acuta
Tanaissus liljeborgi
Polygordius sp. 1
Aricidea suecica
Aricidea cerrutii
Praxillella sp. A
Cirolana polita

Species Group 7

Byblis serrata
Spiophanes bombyx
Enchinarachnius parma
Trichophoxus epistomus
Aglaophamus circinata
Ampelisca vadorum
Unciola irrorata

Species Group 8

Edotea montosa
Ensis directus
Aricidea wassi
Lumbrineris fragilis
Lyonsia hyalina

Species Group 9

Schistomeringos caeca
Solariella obscura
Cancer irroratus

Table 6-8. (continued)

Species Group 10

Scalibregma inflatum
Euchone sp. A
Phoxocephalus holbolli
Phascolion strombi
Ptilanthura tricarina
Glycera dibranchiata
Arctica islandica
Cerastoderma pinnulatum
Diastylis sculpta
Phyllodoce mucosa

Species Group 11

Sthenelais limicola
Crenella glandula
Astarte undata
Cyclopecten nanus
Nereis grayi
Drilonereis longa
Polycirrus eximius
Leptocheirus pinguis
Photis dentata
Eudorella pusilla
Erichthonius rubricornis
Diastylis bispinosa

Species Group 12

Ampelisca agassizi
Lumbrineris impatiens
Chone infundibuliformis
Axiognathus squamata
Notomastus latericeus

Species Group 13

Stenopleustes inermis
Pholoe minuta
Euchone incolor
Prionospio steenstrupi

Species Group 14

Turbonilla interrupta
Chaetopleura apiculata
Janira alta
Leptochelia filum
Melita dentata
Cyclocardia borealis
Cirrophorus lyriformis
Nucula delphinodonta
Crenella decussata

Species Group 15

Harmothoe extenuata
Nicolea venustula
Philine quadrata
Campylaspis rubicunda
Synasterope sp.1
Melinna cristata

Species Group 16

Ampharete acutifrons
Scoloplos acmeceps
Marphysa bellii

Species Group 17

Lumbrineris cruzensis
Thyasira flexuosa
Spiophanes wigleyi
Onuphis pallidula
Aricidea neosuecica
Amphioplus macilentus

Species Group 18

Eriopisa elongata
Ophelina acuminata
Harbansus bowenae
Harbansus dayi
Macrocyprina sp. 1
Macrocypris sapeloensis
Echinocythereis echinata
Lucinoma filosa
Asychis carolinae

Table 6-8. (concluded)

Species Group 19

Tanaidacean sp. 3
Harpinia n. sp. A
Nothria conchylega
Eunice antennata
Limatula subauriculata
Corbula sp.
Nemertea sp. 5

Species Group 20

Paradoneis lyra
Myrtea lens
Paralacydonia paradoxa
Amphilimna ovalacea
Onchnesoma steenstrupi
Lasaea rubra
Cossura longocirrata

Species Group 21

Alvania pelagica
Astropecten americanus
Laonice cirrata
Abra lioica
Golfingia minuta
Periploma fragilis
Stenopleustes gracilis
Cocculina sp. 1

Species Group 22

Nephtys incisa
Ninoe nigripes
Thyasira trisinuata

Species Group 23

Terebellides stroemi
Paraonis gracilis
Harpinia sp. 2
Lumbrineris albidentata
Lumbrineris tenuis

Species Group 24

Orbinia swani
Onuphis atlantisa
Myriochele heeri
Portlandia inconspicua
Havelockia scabra
Nucula tenuis
Paramphinome pulchella

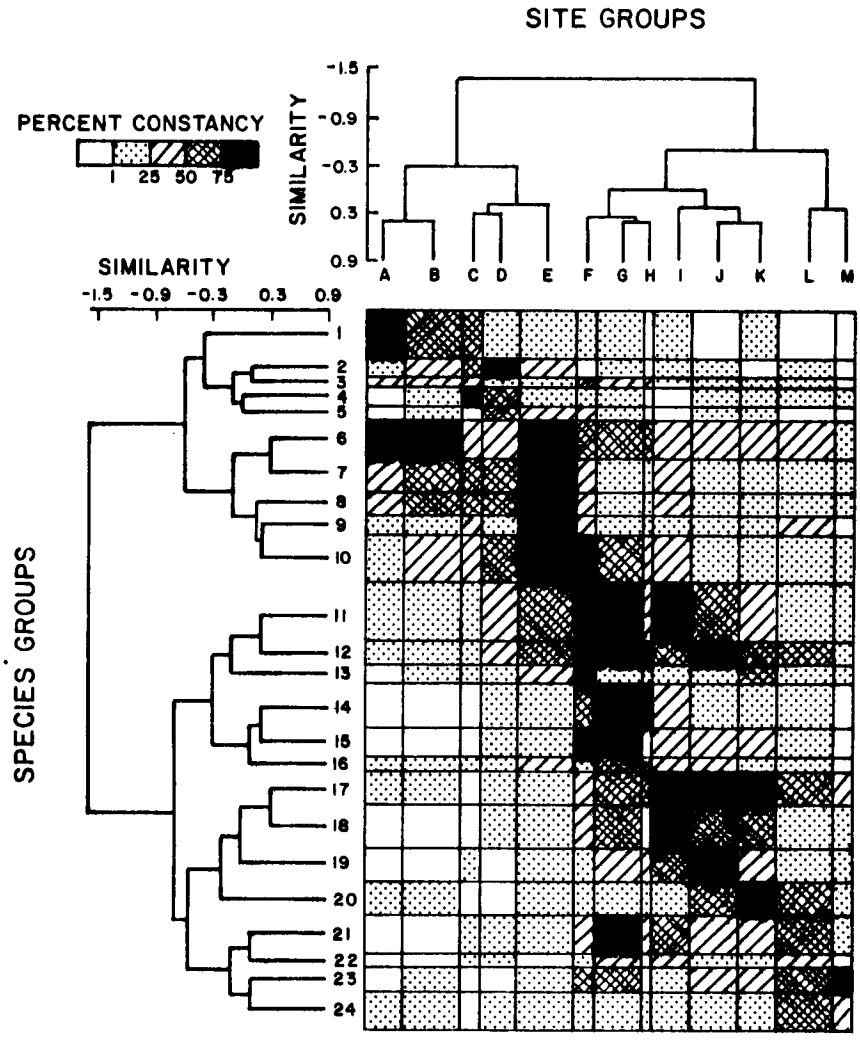


Figure 6-35. Normal and inverse classification hierarchies and nodal constancy for site-species group coincidence based on collections at 51 stations during Winter 1976.

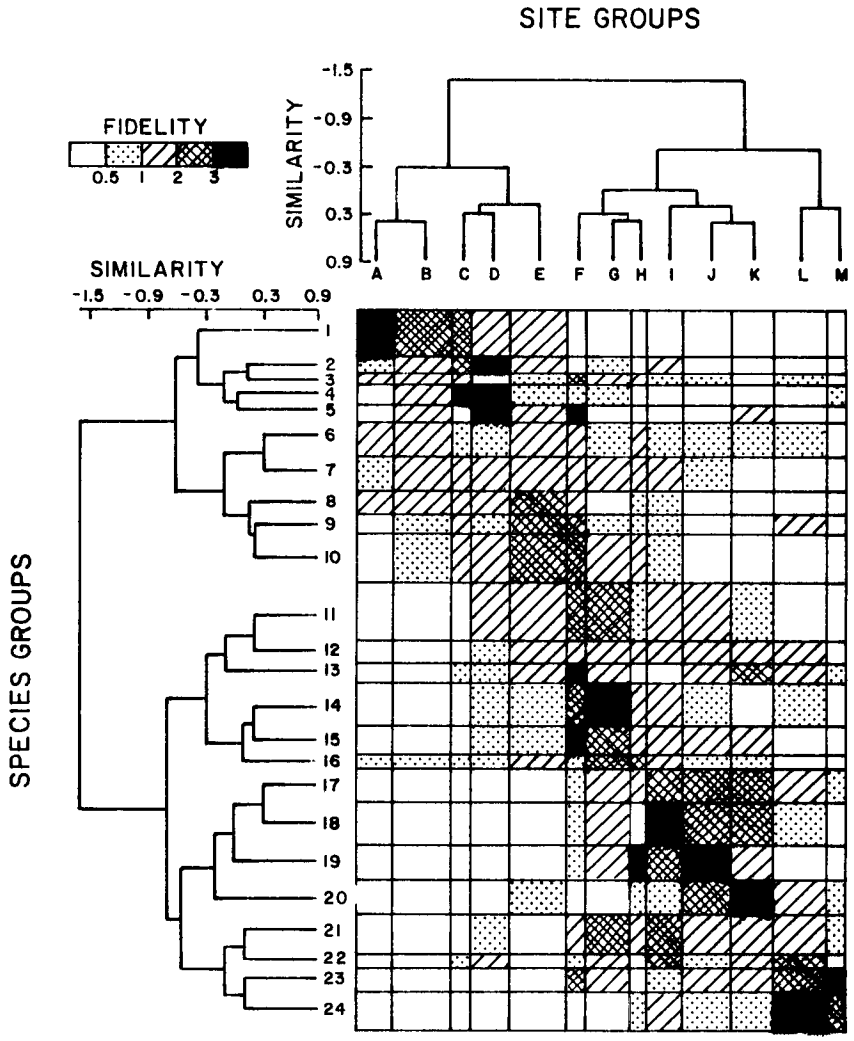


Figure 6-36. Nodal fidelity for classifications of Winter 1976 collections, as in Figure 6-35.

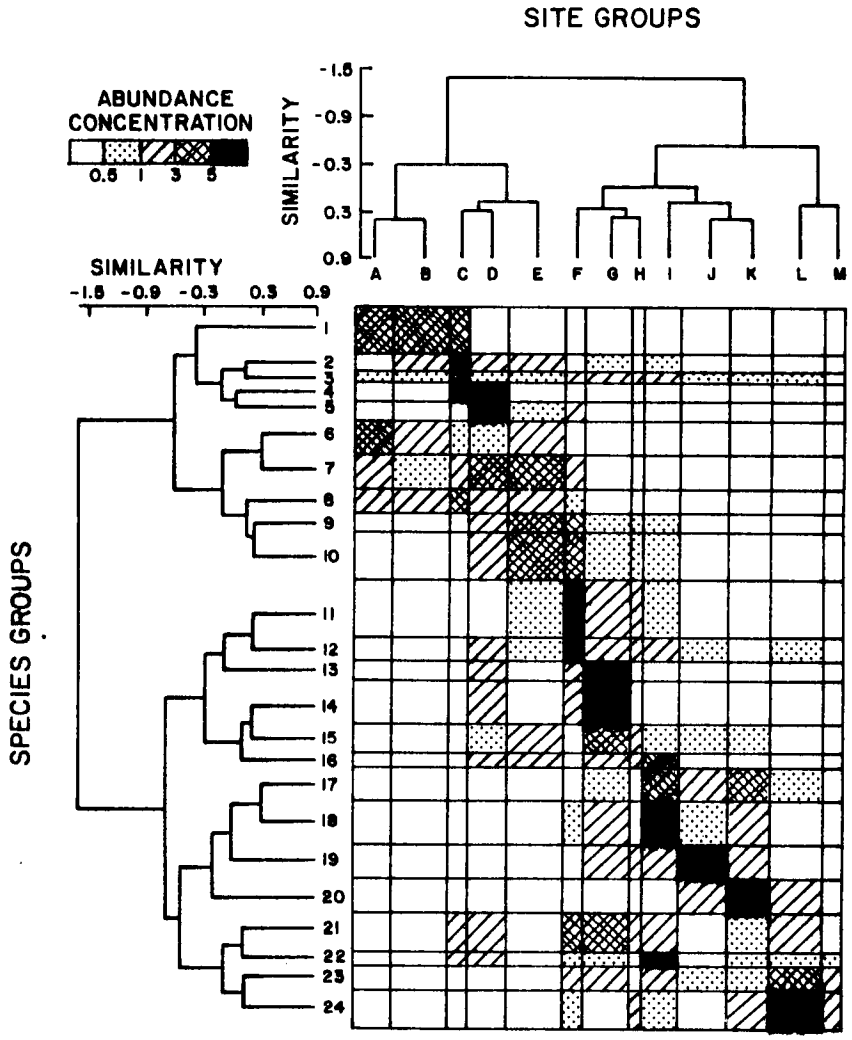


Figure 6-37. Nodal abundance concentration for classifications of Winter 1976 collections, as in Figure 6-35.

Stations were clearly grouped in accordance with bathymetric and topographic position (Figure 6-38). The four main branches of the dendrogram represent: inner and central shelf stations (A, B), inner and central shelf swales or other fine sand stations and outer shelf stations (C-E), outer shelf swale and shelf break stations (F-K), and slope stations (L, M). There was particularly strong similarity of stations within a given depth range in the shelf break region and on the continental slope over the entire study area. Stations in swales were generally more similar to stations in deeper bathymetric strata than to surrounding stations.

The distribution of species within the 24 species groups was investigated in nodal analyses in which these groups are directly related to the site groups in terms of constancy (Figure 6-35), fidelity (Figure 6-36), and abundance concentration (Figure 6-37). Species in Group 1 were very constant and faithful at inner shelf coarse-medium sand stations and rare or absent past the central shelf. These species are restricted to nearshore, dynamic sand bottoms. Species in Group 2 occurred broadly over the inner and central shelf but were more constant and abundant in finer sands present in swales or the finer sand area off the Delmarva Peninsula. Species in Group 3 also occurred over the inner and central shelf but were not constant or abundant in any site group. Species in Group 4 were very constant and faithful at stations in Groups C and D (except L3) which had predominantly fine sands. They were very uncommon elsewhere. Species in Group 5 were uncommon except on finer sand and were particularly abundant at D1 and D4, on a deep flank and swale on the central shelf. Species in Group 6 include species widespread and abundant in coarse to medium sands from the inner to the outer shelf. Many of these species are among the dominant macrobenthos on the inner and central shelf, but because of their ubiquity they are not faithful to any site group. Species in Group 7 were likewise widespread over the shelf, but except for *Echinarachnius parma*, were infrequent at inner shelf stations. These species were generally more abundant at outer shelf stations (Group E) and fine sand stations on the central shelf (Group D). They were also among the most ubiquitous; all occurred at a minimum of 50% of the stations and one, *Unciola irrorata*, occurred at as many stations as any other species (75%). Species in Group 8 were also distributed over the entire shelf but were more common and abundant at fine sandy sites (Groups C and D) and on the outer shelf (Group E). Species in Groups 9 and 10 were rare on the inner and central shelf and most frequent on the outer shelf. Those in Group 9 were relatively uncommon and seldom abundant, whereas those in Group 10 were common and frequently abundant at outer shelf sites.

Although some were fairly ubiquitous, species in Group 11 were very characteristic of outer shelf stations. *Cyclopecten nanus* was particularly characteristic of the outer shelf-shelf break transition region (Group G). The five peracarideans listed last in the group were much more abundant in topographic depressions (Group F) than elsewhere. Species in Group 12 were widespread on the outer shelf and in the shelf break region. All of these species were especially abundant in topographic depressions (B3, G3), but they were also abundant elsewhere. As with species in Group 7 these species were very ubiquitous, occurring at 45-69% of the stations. Species in Group 13 were highly faithful to topographic depressions (G3, B3, and D4).

Group 14 species were particularly constant and faithful at stations in the outer shelf-shelf break transition (Group G). Species in Groups 15 and 16

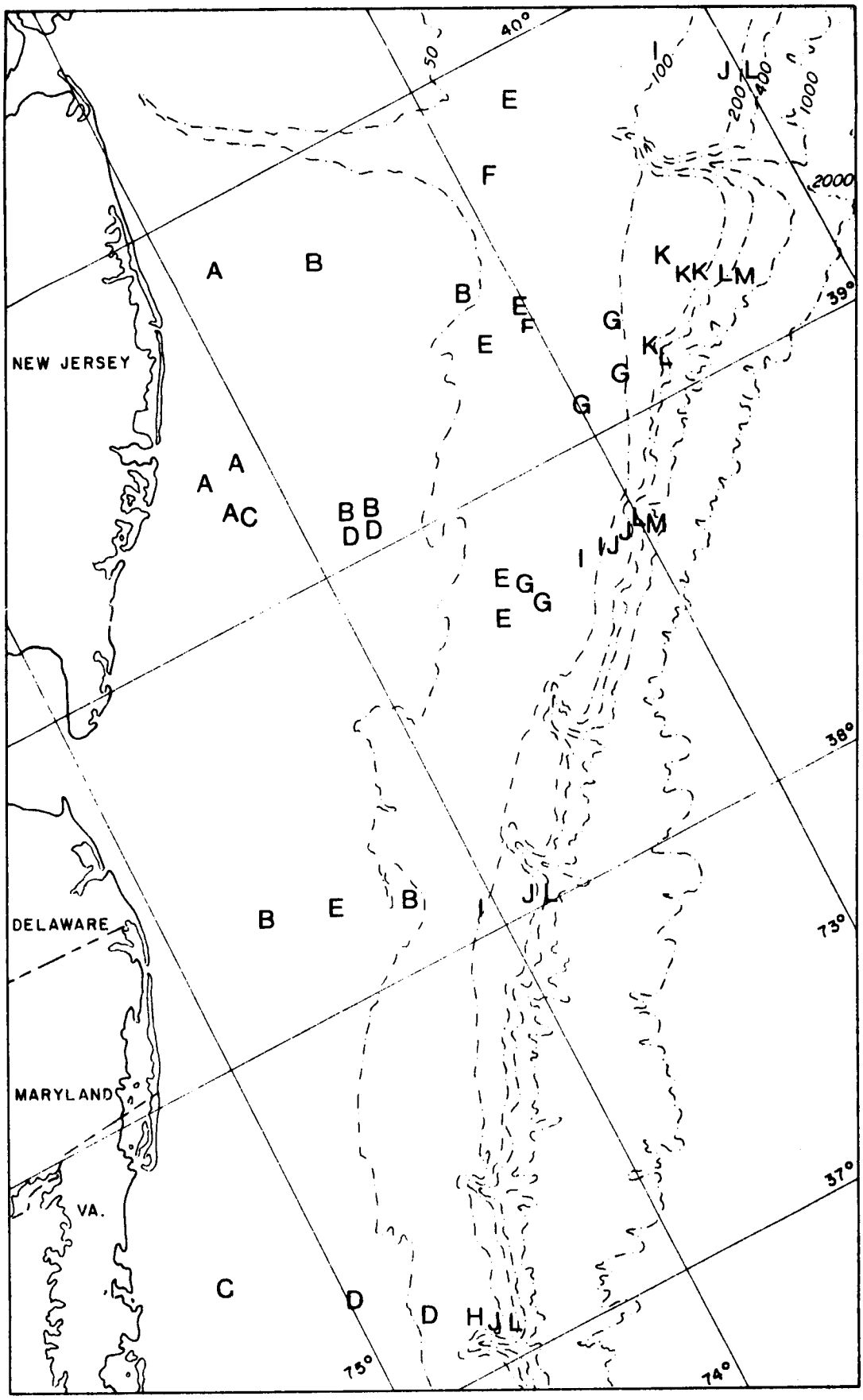


Figure 6-38. Distribution of stations in each site group resulting from numerical classification of Winter 1976 collections.

were seldom abundant but were fairly constant members of the deeper portions of the outer shelf zone.

Most species in Groups 17, 18, 19, and 20 are not distributed much shoreward of the shelf break and their inclusion effects a major discontinuity in the bathymetric distribution of communities at the shelf break. Although most members of Groups 17, 18, and 19 are present in the outer shelf-shelf break transition zone (Group G), their frequency and abundance are low except at shelf-break stations. Members of Groups 18 and 19 were distributed throughout the shelf break zone, and some (e.g. *Lumbrineris cruzensis* and *Thyasira flexuosa*) were common on the upper slope as well. The unexplained complete absence of any members of Group 18 at L4 set this station apart from others at its same depth. Species in Group 18 were not as common at deeper stations within the shelf break zone (Group J stations) as those in Group 17. Species in Group 19 were mostly confined to the deeper portion of the shelf break (Group J) but were relatively uncommon in the muddy area south of Hudson Canyon (Group K). The bathymetric range of members of Group 20 was similarly confined except that they were common in the muddy area. *Onchnesoma steenstrupi*, *Lasaea rubra*, and *Cossura longocirrata* were also common at upper continental slope stations. Surprisingly one species in Group 20, *Paradoneis lyra*, was also found on the inner shelf.

Most species in Group 21 were eurybathic from the outer shelf to continental slope depths, although one, *Stenopleustes gracilis*, was essentially restricted to the shelf. These species were relatively uncommon and seldom abundant. Species in Group 22 were likewise widespread from the outer shelf to the upper slope but were even more uncommon. Species in Group 23 also had the same overall distribution but were most frequent and abundant at the continental slope stations (Groups L and M). Members of Group 24 were uncommon on the shelf break but were highly characteristic of the shallow slope stations (Group L).

Seasonal Distribution at Cluster Stations. The quarterly samples at 24 stations (96 collections) were classified into 13 site groups as indicated in Table 6-9, and the inverse classification of 150 species is interpreted at the 23 group level (Table 6-10). The fusion hierarchies of these classifications are given on Figures 6-39 through 6-41).

The classification of collections generally agreed with the patterns apparent from the analysis of the synoptic winter data, in that the prime factors correlating with the patterns are bathymetry, topography, and sediments. The grouping together of the seasonal samples from most stations suggests that seasonality is of relatively little importance in the overall patterns of biotic similarity. Rather, it appears that the quantitative composition of the community was remarkably persistent. Except for the summer collections at C1, C2, and C3 when dissolved oxygen deficiency substantially affected the communities, those few cases where collections from a station did not cluster closely together could be explained by station relocation differences (D1, E1, and E2, see Chapters 2 and 5).

Major agglomerations in the normal classifications represented the inner and central shelf stations (Groups A-G), the outer shelf stations (Groups H-J), and the shelf break stations (Groups K-M). This compares well with the general

Table 6-9. Site groups selected from numerical classification of seasonal collections of macrobenthos at the 24 cluster stations.

Site Group A		Site Group E		Site Group I		Site Group L	
C1	summer	D3	fall	B1	fall	F4	summer
C3	summer	D2	summer	B1	spring	F4	spring
C2	summer	D1	fall	B1	summer	F4	winter
		D1	summer	B1	winter	F3	spring
Site Group B		D1	winter	E2	fall	F3	summer
				E1	fall	F3	winter
C1	winter	Site Group F		E1	summer	F4	fall
C1	spring			E2	spring	F3	fall
C1	fall	C4	fall				
C3	fall	C4	spring	Site Group J		Site Group M	
C3	spring	C4	winter				
C2	winter	C4	summer	B3	summer	A2	winter
C3	winter			B3	winter	A2	spring
C2	fall	Site Group G		B3	spring	A2	summer
C2	spring			B3	fall	A2	fall
		D4	winter	E2	summer	A3	fall
Site Group C		D4	fall	E2	winter	A3	winter
		D4	summer	E4	spring	A3	spring
D1	spring	D4	spring	E4	summer	A3	summer
D3	spring			E4	winter	A4	fall
D3	winter	Site Group H		E4	fall	A4	winter
D2	fall					A4	spring
D2	spring	B2	spring	Site Group K		A4	summer
D3	summer	B2	summer				
D2	winter	B2	winter	F1	fall		
		B2	fall	F1	winter		
Site Group D		E3	fall	F1	spring		
		E3	spring	F1	summer		
B4	fall	E3	summer	F2	fall		
B4	winter	E3	winter	F2	winter		
B4	spring	E1	spring	F2	spring		
B4	summer	E1	winter	F2	summer		
				A1	winter		
				A1	fall		
				A1	spring		
				A1	summer		

Table 6-10. Species groups selected from numerical classification of seasonal collections of macrobenthos at 24 cluster stations.

Species Group 1

Spisula solidissima
Sigalion arenicola
Hemipodus roseus
Astarte castanea
Nephtys picta
Bathyporeia quoddyensis

Species Group 2

Pseudunciola obliquua
Tellina agilis
Nephtys bucera
Protohaustorius wigleyi
Cirolana polita
Aricidea wassi

Species Group 3

Goniadella gracilis
Lumbrinerides acuta
Tanaissus liljeborgi
Echinarachnius parma
Polygordius sp. 1

Species Group 4

Protodorvillea kefersteini
Chiridotea arenicola

Species Group 5

Cancer irroratus
Hippomedon serratus
Crangon septemspinosa
Drilonereis magna
Edotea acuta
Lunatia triseriata

Species Group 6

Corophium crassicorne
Photis macrocoxa
Monoculodes sp. A
Pandora inflata

Species Group 7

Clymenella zonalis
Aricidea cerrutii
Ensis directus
Schistomeringos caeca
Diastylis sculpta
Cirrophorus lyriformis
Lyonsia hyalina

Species Group 8

Cytheretta edwardsi
Pitar morrhuana
Sarsiella zostericola
Nucula proxima

Species Group 9

Lumbrineris fragilis
Glycera dibranchiata
Cerastoderma pinnulatum
Harmothoe extenuata
Euchone sp. A
Phoxocephalus holbolli
Trichophoxus epistomus
Spiophanes bombyx
Byblis serrata
Praxillella sp. A

Species Group 10

Unciola irrorata
Aricidea suecica
Ampelisca agassizi
Notomastus latericeus
Axiognathus squamata
Chone infundibuliformis

Species Group 11

Aglaophamus circinata
Scalibregma inflatum
Ampelisca vadorum
Lumbrineris impatiens
Ptilanthura tricarina
Phascolion strombi
Diastylis bispinosa
Erichthonius rubricornis

Table 6-10. (Continued)

Species Group 12

Drilonereis longa
Nereis grayi
Sthenelais limicola
Phyllodoce mucosa
Polycirrus eximius
Euchone incolor

Species Group 13

Photis dentata
Eudorella pusilla
Leptocheirus pinguis
Prionospio steenstrupi
Clymenella torquata

Species Group 14

Stenopleustes gracilis
Philine quadrata
Stenopleustes inermis
Arctica islandica
Pholoe minuta
Ninoe nigripes
Cancer borealis
Pherusa affinis

Species Group 15

Nemertea sp. 5
Gammaropsis sp. 1
Limatula subauriculata
Tanaidacean sp. 3
Amphilochoides odontonyx
Lucinoma filosa
Astropecten americanus
Synasterope sp. 1
Campylaspis rubicunda
Paraonis gracilis
Photis reinhardi

Species Group 16

Harpinia sp. 2
Lumbrineris albidentata
Terebellides stroemi
Eriopisa elongata
Laonice cirrata
Nicolea venustula

Species Group 17

Melita dentata
Janira alta
Crenella decussata
Chaetopleura apiculata
Leptochelia filum
Golfingia minuta
Cyclocardia borealis
Goniada brunnea

Species Group 18

Marphysa bellii
Scoloplos acmeceps
Nucula delphinodonta
Echinocythereis planisbalis
Abra lioica
Turbonilla interrupta
Cyclopecten nanus
Astarte undata
Crenella glandula
Ophelina acuminata
Periploma fragilis

Species Group 19

Lumbrineris cruzensis
Thyasira flexuosa
Harbansus dayi
Onuphis pallidula
Spiophanes wigleyi
Harbansus bowenae
Aricidea neosuecica
Amphioplus macilentus

Species Group 20

Cossura longocirrata
Myrtea lens
Onchnesoma steenstrupi
Lasaea rubra
Amphilimna ovalacea
Nepthys squamosa
Onuphis atlantisa
Paradoneis lyra

Table 6-10. (Concluded)

Species Group 21

Cardiomya perrostrata
Paralacydonia paradoxa
Nuculana acuta
Tanaidacean sp. 2

Species Group 22

Platyishnopus sp. 1
Harpinia n. sp. A
Macrocypris sapeloensis
Echinocythereis echinata
Macrocyprina sp. 1
Asychis carolinae
Dacrydium vitreum

Species Group 23

Nothria conchylega
Eunice pennata
Parametopella sp. A

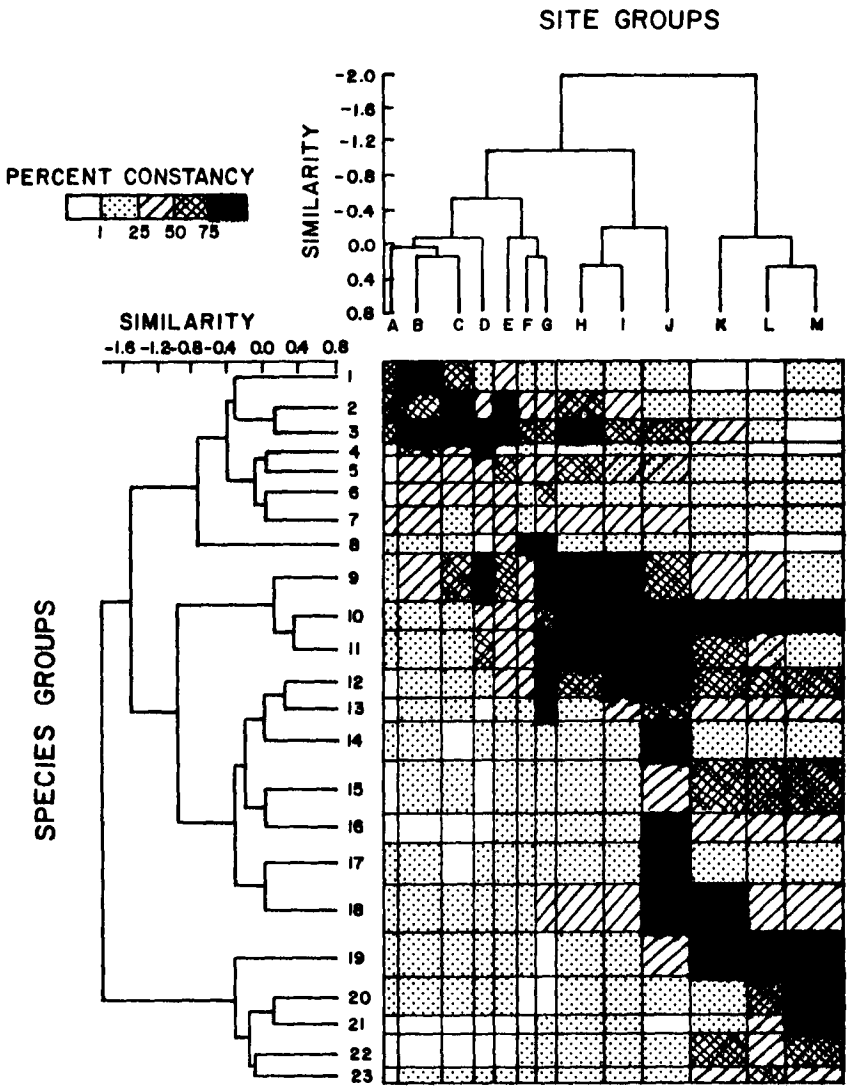


Figure 6-39. Normal and inverse classification hierarchies and nodal constancy for site-species group coincidence based on quarterly collections at the 24 cluster stations, Fall 1975 to Summer 1976.

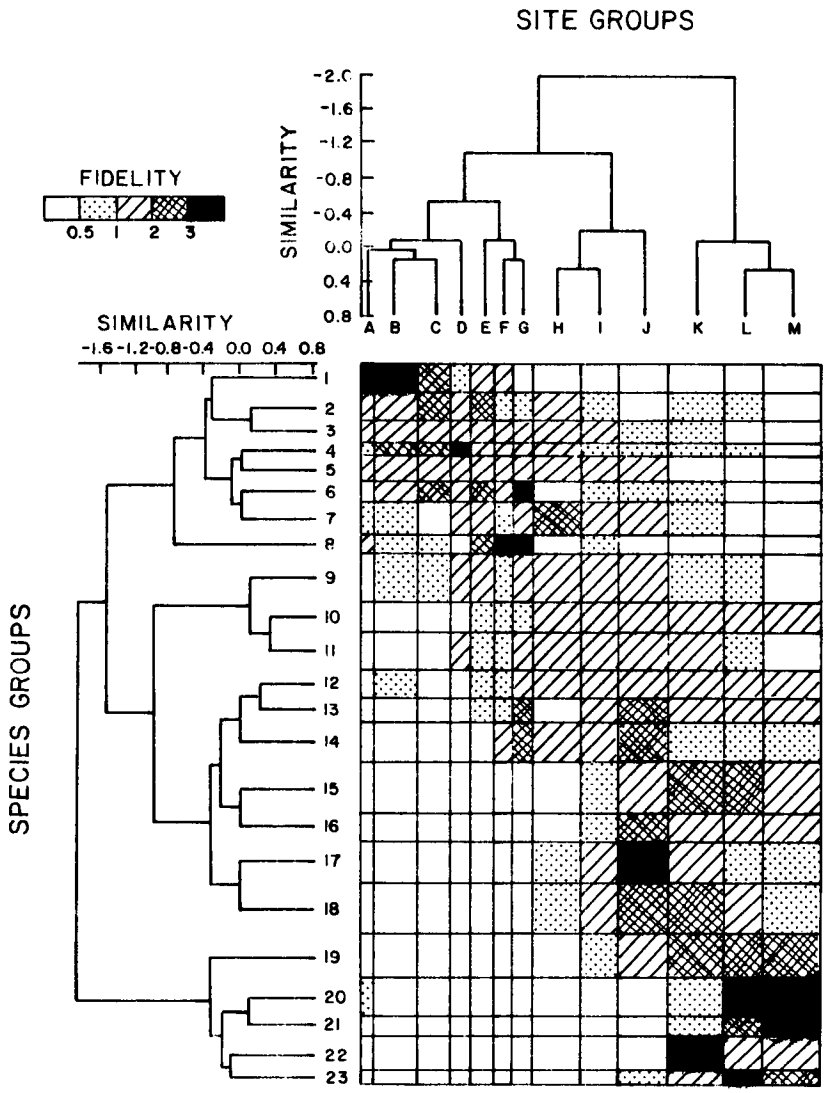


Figure 6-40. Nodal fidelity for classifications of cluster station collections, as in Figure 6-39.

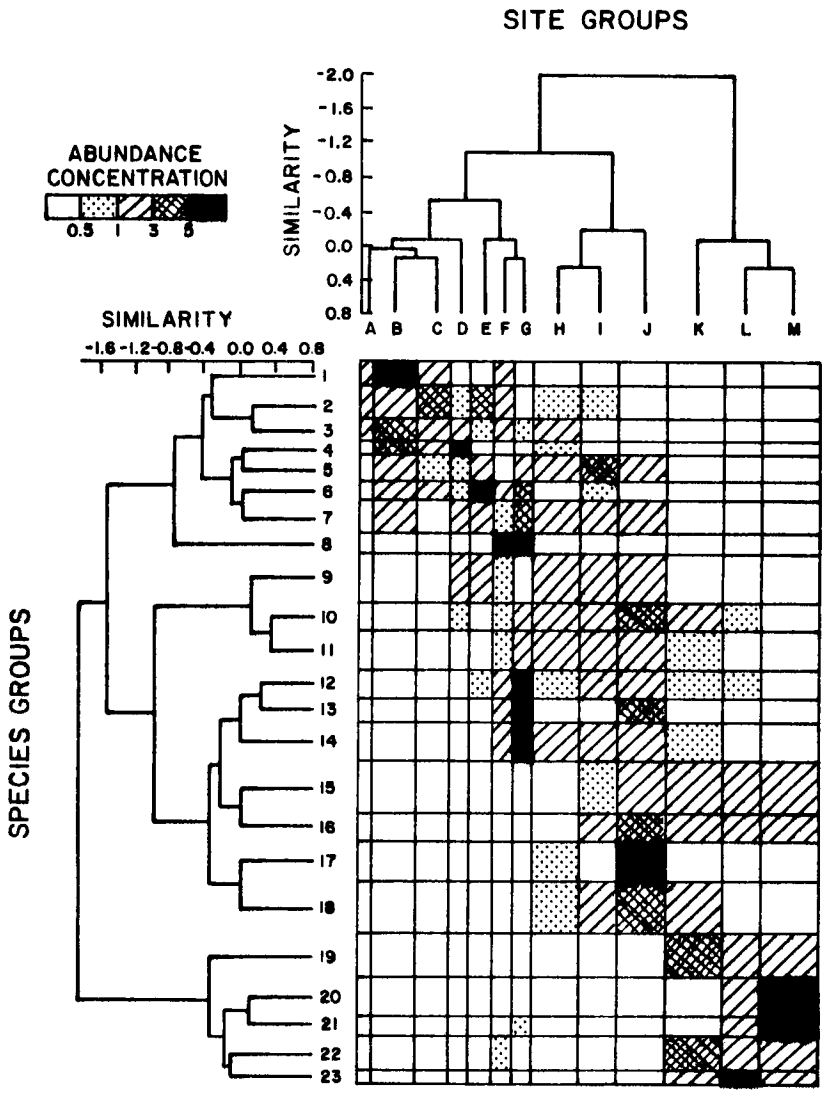


Figure 6-41. Nodal abundance concentration for classifications of cluster station collections, as in Figure 6-39.

cross-shelf zonation displayed by the megabenthos (Figures 6-14 and 6-15). In addition to the separate group of summer collections, the C stations were exclusively in two groups, one representing the collections from C1, C2, and C3 and the other from the swale station C4. This reflects the strong faunal differences between the swale communities and those surrounding. The D stations present a more confused picture. Three groups contained D stations exclusively, one containing the 4 collections from the swale station D4 and two containing various collections from D1, D2, and D3 (Groups C and E). These groupings closely reflect the granulometry (Chapter 5) in that sediments in Group E collections were made up of finer sand than those in Group C collections. This is probably more the result of station relocation inaccuracies (Chapters 2 and 5) than truly seasonal changes. Similarly, groupings of collections from E1 and E2 reflect sedimentologic differences in the positions sampled. Winter and spring collections at E1 are grouped with collections from more dynamic outer shelf bottoms (Group H) than those from fall and summer (Group I). Winter and summer collections at E2 show finer sands with more silt and clay (Chapter 5), thus they are grouped with collections from outer shelf swales (Group J).

Groupings of collections from the outer shelf areas B and E into the 3 groups is a clear reflection of the ecological importance of subtle sedimentologic differences related to topography and the fact that they transcend regional differences (i.e. similar B and E collections are grouped). As in the analysis of the winter data the classification of collections from the shelf break zone conforms to three subdivisions representing shallow (Group K) and deep (Group L) portions and the muddy sand area south of Hudson Canyon (Group M).

Except for the exclusion of slope species, the results of the inverse classification of 150 species (Table 6-10) agree very well with the species groupings resulting from classification of the winter cruise data. Therefore, interpretation of the nodal analyses (Figures 6-39 through 6-41) will not be as extensive as for the winter data. Because of the inclusion of more samples from a restricted area, these results allow a finer resolution of distributional patterns among the fauna. There is a similar pattern of groups of species found primarily over the inner and central shelf (Groups 1-8), those of species found largely on the outer shelf (Groups 9-18) and those of species found mostly in the shelf break zone (Groups 19-23). However, there is considerable overlap such that some inner and central shelf species are found on more dynamic bottoms on the outer shelf (e.g. Group 3), some outer shelf species are common in inner and central shelf swales (e.g. Groups 9, 11, and 12), some shelf break species are common in outer shelf swales (e.g. Group 18), and some species are ubiquitous (e.g. members of Group 10, which is nearly identical with Group 12 of the winter cruise analysis, are found across the outer shelf and shelf break zone).

Dominant Species

The ten most abundant species at each station for each of the four seasons are listed in Appendix 6-C. This presentation is striking in the often remarkable concordance in ranking of dominants from season to season, especially on the outer continental shelf and in the shelf break region. This concordance suggests that the communities are well "structured" in terms of abundance relationships.

The patterns of dominant species over the major habitats conform well with the results of the classification analyses. There are clear differences in the characteristically dominant species between the bathymetric habitats. Inner shelf stations were numerically dominated by the archiannelid *Polygordius* sp.; the polychaetes *Goniadella gracilis, Lumbrinerides acuta,* and *Aricidea suecica* and syllids; the peracarideans *Tanaissus liljeborgi* and *Pseudunciola obliquua;* the bivalve *Tellina agilis;* and the echinoid *Echinarachnius parma.*

Central shelf stations had as dominants the polychaetes *Spiophanes bombyx, Aricidea suecica, A. wassi,* and syllids (mainly *Exogone* and *Parapionosyllis*); the peracarideans *Trichophoxus epistomus, Pseudunciola, Tanaissus* and *Protohaustorius wigleyi*; and *Echinarachnius.* Where sands were coarser on the central shelf, *Goniadella, Lumbrinerides,* and *Polygordius* were also abundant. Dominants in central and inner shelf swales included some of these species plus others generally not found elsewhere in those regions. These include the polychaetes *Tharyx* sp., *Clymenella torquata, Lumbrineris impatiens,* and *Pherusa affinis* (C4); the bivalve *Nucula proxima* (C4) and the amphipod *Ampelisca vadorum* (D4).

Numerical dominants at outer shelf stations were more variable but generally included the polychaetes *Lumbrineris impatiens, Spiophanes bombyx, Scalibregma inflatum, Tharyx* sp., and *Chone infundibuliformis,* and syllids (mainly *Exogone*) and the peracarideans *Ampelisca vadorum, Byblis serrata, Unciola irrorata, Trichophoxus epistomus,* and *Diastylis bispinosa.* Where sediments were evidently more dynamic such as at B2 and E3 (see Chapter 5), the characteristic *Goniadella* and *Lumbrinerides* were also present. At outer shelf swale stations the dominants were supplemented by the polychaetes *Notomastus latericeus* and *Typosyllis tegula* (E4), the bivalve *Cyclocardia borealis* (E4), and the peracarideans *Ampelisca agassizi, Photis dentata, Leptocheirus pinguis* (B3), and *Eudorella pusilla.*

Whereas the changes in dominant species from the inner to the outer shelf were more-or-less gradual, sharp changes in the characteristic dominants existed at the shelf break. The dominant species at the shelf break stations were highly congruent from north of Hudson Canyon to Norfolk Canyon. They include the polychaetes *Onuphis pallidula, Aricidea neosuecia, Tharyx* sp., *Spiophanes wigleyi,* and *Lumbrineris cruzensis*; the bivalve *Thyasira flexuosa;* the ostracods *Harbansus bowenae* and *H. dayi*; the amphipod *Ampelisca agassizi*; and the ophiuroid *Amphioplus macilentus.*

The dominants at continental slope stations have been less well characterized because of taxonomic difficulties. They include some species abundant in the shelf break zone, *Lumbrineris cruzensis, Notomastus latericeus, Tharyx* sp., and *Thyasira flexuosa,* as well as the polychaetes *Lumbrineris tenuis, Paramphinome pulchella, Samytha sexcirrata,* and other ampharetids, and the molluscs *Cadulus* sp., *Lasaea rubra,* and *Nucula tenuis.*

Distribution with Respect to Topography

The results of the classificatory analyses clearly indicate that the assemblages in topographic depressions in the Middle Atlantic continental shelf are qualitatively and quantitatively different from those at nearby sites not located in such depressions. These faunal distribution patterns

coincide with the important sedimentologic differences related to ridge and swale topography as described in Chapter 5. Sediments on ridges generally are coarser, and contain very little silt and clay (<1%) and organic carbon (<1 mg/g), whereas those in swales are generally finer and contain about 5% silt and clay and more organic carbon (1-2 mg/g). This sediment distribution reflects the hydraulic regime in which movement of sediment by bottom currents is more frequent on the ridges and exposed flanks.

Important differences between swale assemblages and those from outside swales existed in each of the relevant cluster areas, B, C, D, and E. Distribution patterns among the B stations were, however, the most striking because station relocation was good, and the four stations presented a clear spectrum of sediment type and mobility. Furthermore, Area B encompasses the tracts of current prime interest for oil and gas development in the Middle Atlantic OCS. Therefore, we will present results from the B stations in some detail. Station B4 was located on a relatively shallow terrace (40 m) west of Tiger Scarp and had medium-coarse sand sediments poor in fines and organics. Bedforms observed in bottom photographs indicated that bottom sediments were more frequently disturbed than other B stations. Station B2 was located near the crest of a ridge offshore of the scarp at 60 m and had moderately dynamic medium-coarse sand. Station B1 was located on a fairly flat area at a depth of 64 m. Sediments there were well sorted medium sands with a small amount (1-2%) of silt and clay, and ripple marks usually appeared worn or "aged", suggesting infrequent physical disturbance of the seabed. The swale station, B3 (72 m), had medium-fine sand sediments with about 5% silt and clay. Ripple marks were not in evidence at B3, and most bedforms appeared biogenic, i.e. tubes, burrows, excavations, and fecal casting.

Seasonal abundances of several dominant species at the four B stations are presented in Figures 6-42 through 6-45 to illustrate the great differences in the macrobenthic communities over this topographic and sedimentologic continuum. The species presented in Figure 6-42 and *Clymenella torquata* (Figure 6-45) were absent from the shallow terrace station and only abundant at the swale station. *Notomastus* and *Clymenella* live in deep burrows or tubes and feed on subsurface deposits. *Ampelisca*, *Leptocheirus*, and *Chone* construct fragile tubes at the sediment surface and feed on surface deposits or seston. The dense population of *A. agassizi*, persistently about 10,000/m^2, created mats of tubes, visible even in the bottom photographs, which undoubtedly bound fine sediments and diversified habitat space.

The species included in Figure 6-43, although rare at B4, and generally more abundant at B3, were not restricted to the swale station but occurred as well as B2 and B1. These four species also probably feed on deposits. Considerable seasonality is evident in *Diastylis bispinosa* and *Axiognathus squamata* populations. At B3 *Diastylis* declined continuously from fall to summer, a pattern repeated by several other species. *Axiognathus* showed a similar decline at B2 and B1, but apparent recruitment is witnessed between winter and spring at B3.

The species included in Figure 6-44 as well as *Lumbrinerides acuta* and *Clymenella zonalis* (Figure 6-45) appear to be variously restricted to coarser and more dynamic sediments. They are among those species described in the presentation of results of classifications as characteristic of the inner and

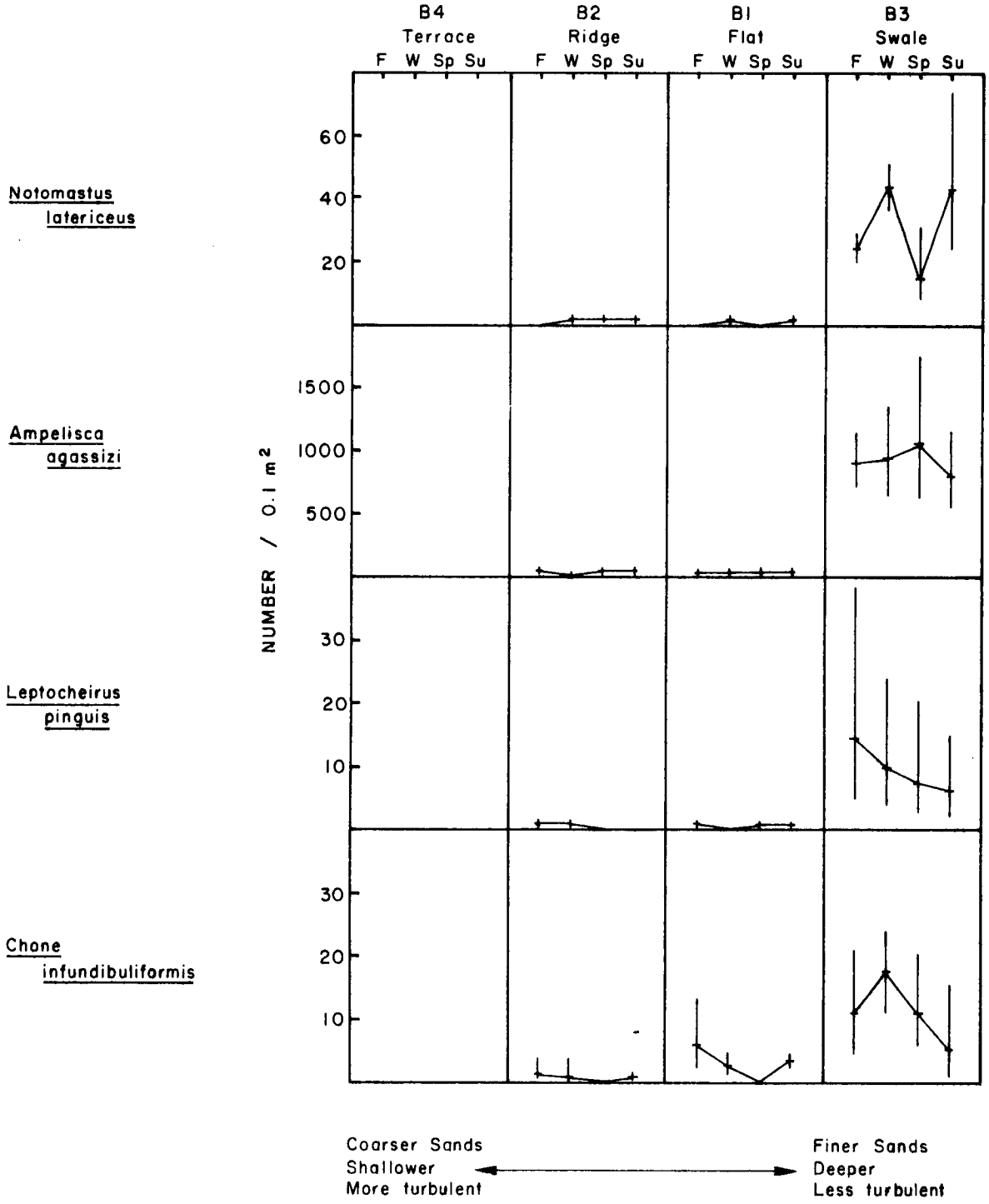


Figure 6-42. Spatial and temporal abundance patterns for abundant macrobenthic species at stations in area B. Lines connect seasonal geometric means; vertical lines represent 95% confidence intervals ($x \pm s_{\bar{x}}\, t_{.05}$) about the means.

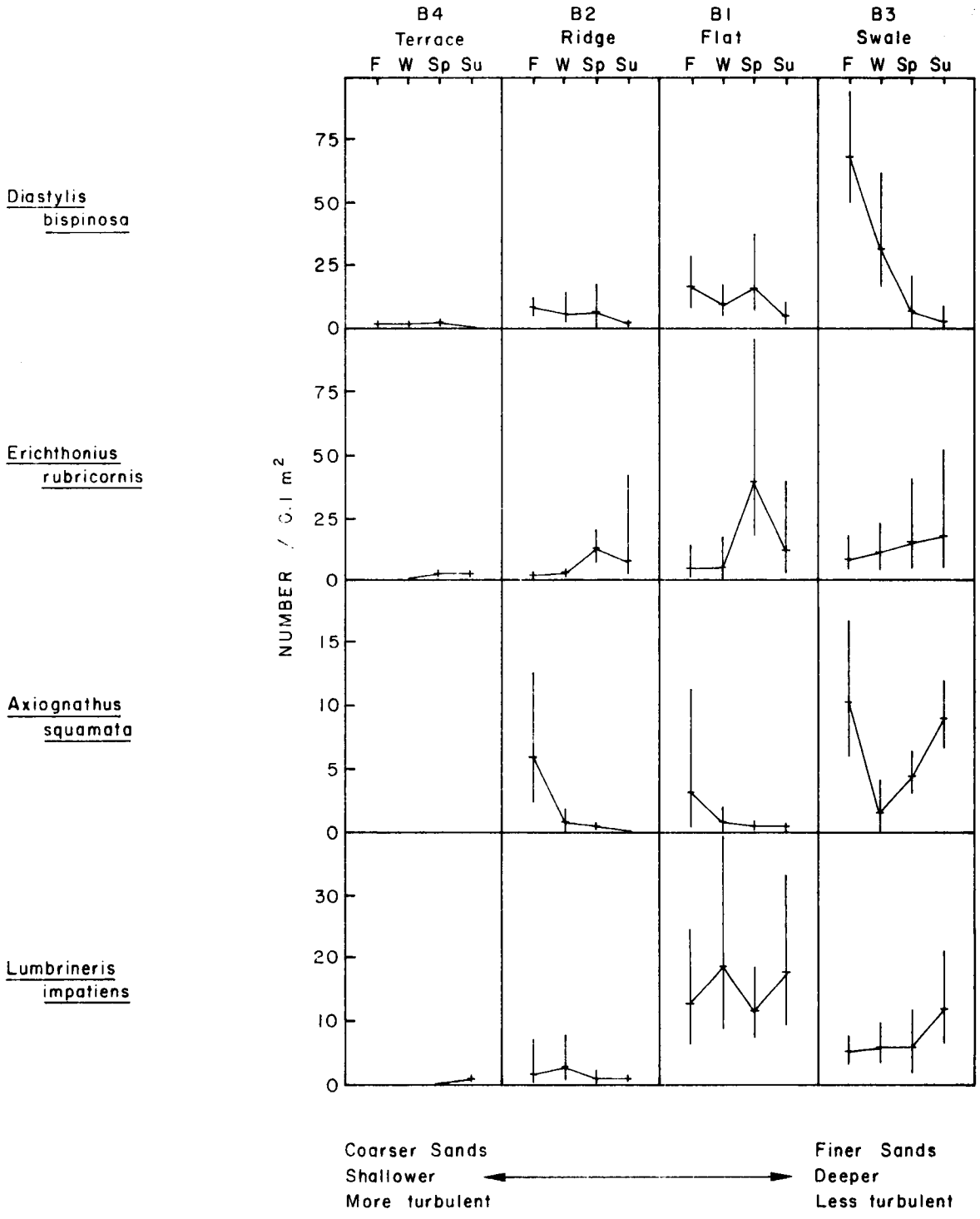


Figure 6-43. Spatial and temporal abundance patterns for abundant macrobenthic species at stations in area B. Lines connect seasonal geometric means; vertical lines represent 95% confidence intervals ($\bar{x} \pm s_{\bar{x}} t_{.05}$) about the means.

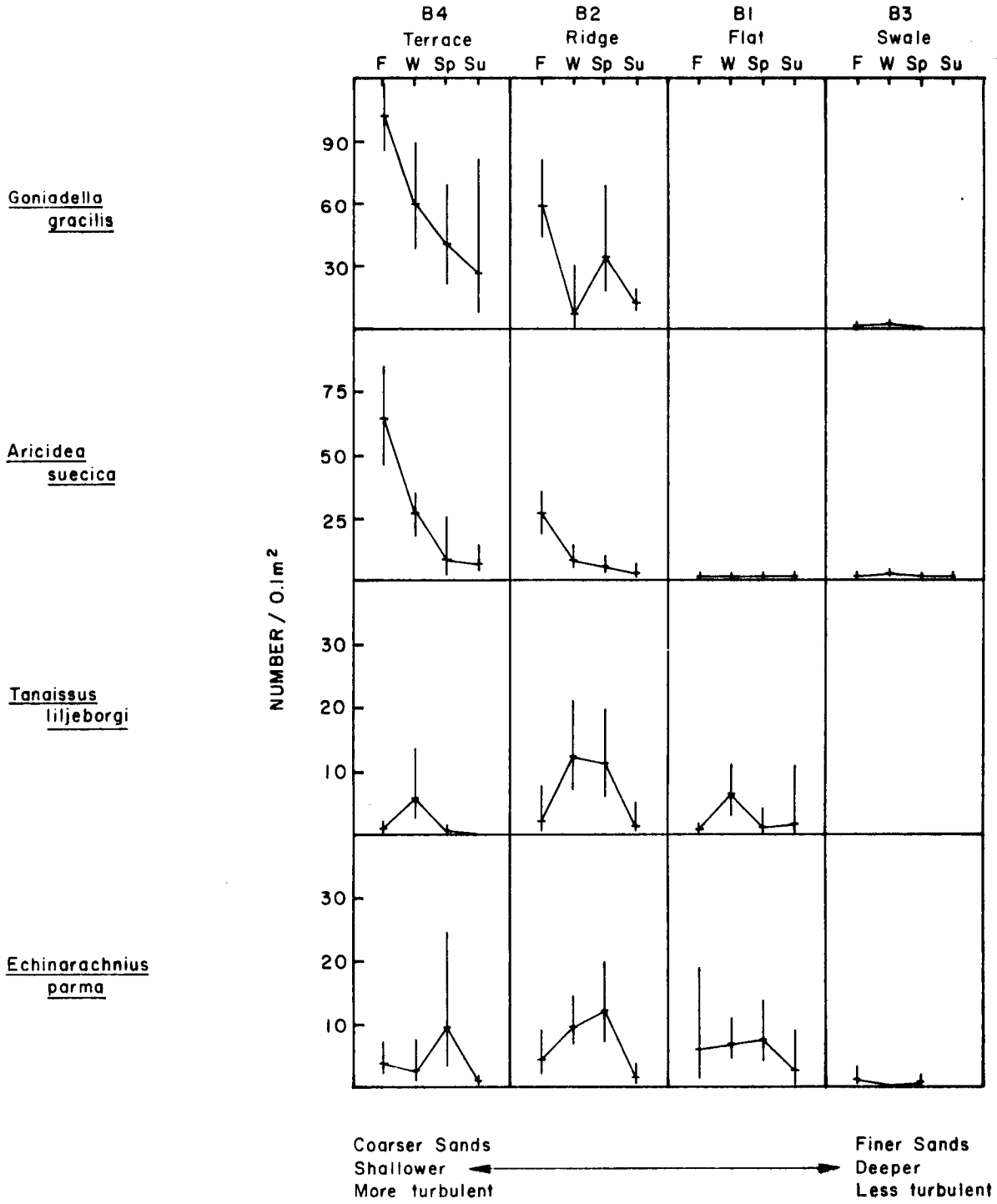


Figure 6-44. Spatial and temporal abundance patterns for abundant macrobenthic species at stations in area B. Lines connect seasonal geometric means; vertical lines represent 95% confidence intervals ($\bar{x} \pm s_{\bar{x}} t_{.05}$) about the means.

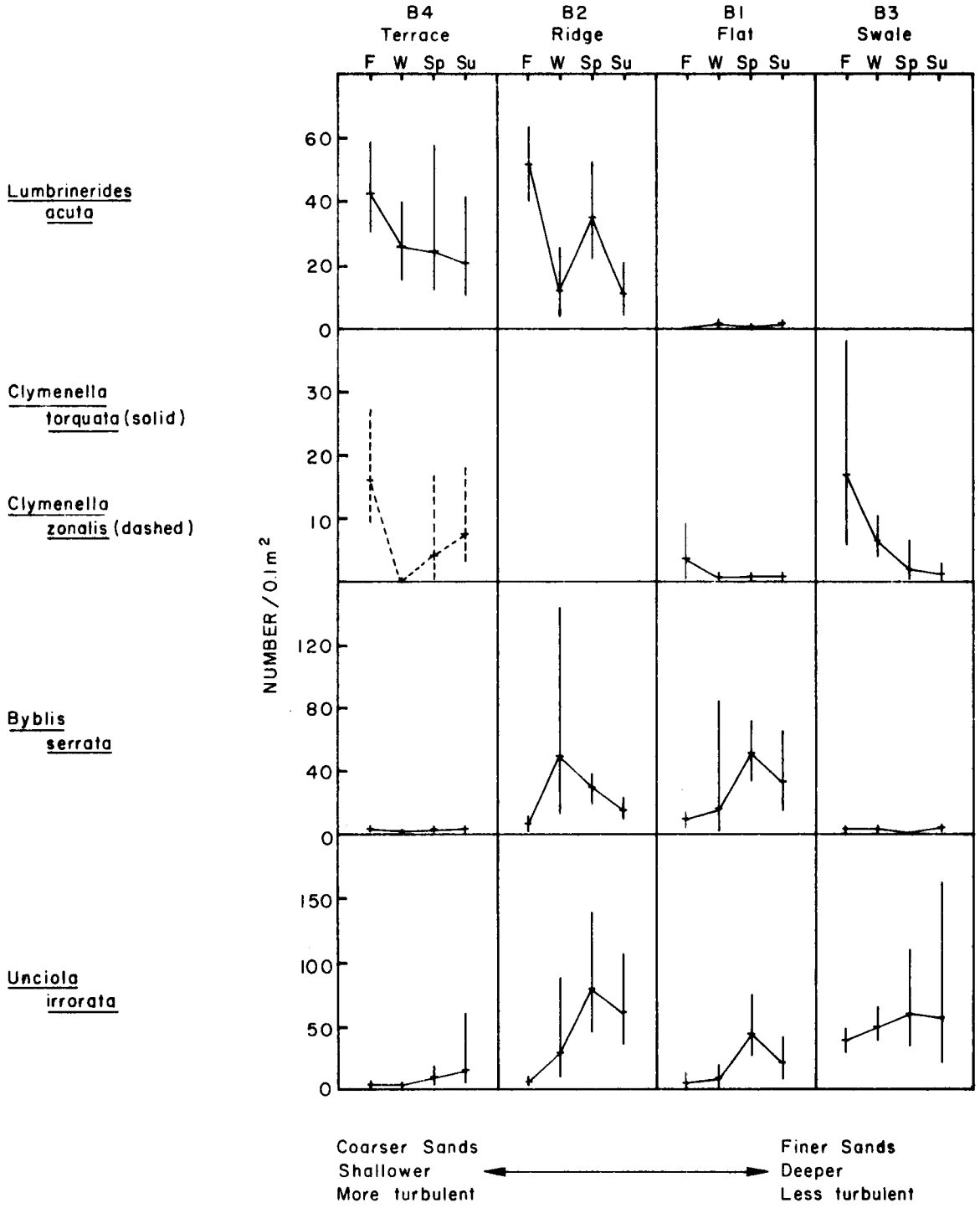


Figure 6-45. Spatial and temporal abundance patterns for abundant macrobenthic species at stations in area B. Lines connect seasonal geometric means; vertical lines represent 95% confidence intervals ($\bar{x} \pm s_{\bar{x}}\, t_{.05}$) about the means.

central shelf. The polychaetes *Goniadella* and *Lumbrinerides* and the tanaidacean *Tanaissus* are very thin animals, and the polychaetes have a pointed (and in life, actively inquiring) prostomium. They are apparently adapted to the basically interstitial habitat afforded in the coarser sediments. Both polychaetes are equipped with powerful jaws and may prey on meiofauna or small macrofauna living in the sediment interstices. *Aricidea suecica* is also a thread-like polychaete, but its habits are not well known. *Clymenella zonalis* is, as is its congener *C. torquata*, a tubicolous deposit feeder. It is known to occupy sandier, more dynamic sediments than *C. torquata* (Mangum 1964). The sand dollar *Echinarachnius parma* tends to occur on dynamic, clean sand sediments and seldom on muddy sands. Those few specimens collected at B3 in fall and spring were small, recently metamorphosed individuals which apparently do not survive in the swales.

Other species are more eurytopic in their preferences, and some avoid either extreme of shallow terrace or swale. The amphipod *Unciola irrorata* was common at each of the stations and was found across the shelf and shelf break. Another amphipod, *Byblis serrata*, was only common at the ridge (B2) and deep-flat (B1) stations in Area B, probably excluded from B4 by sediment conditions and from B3 by sediment conditions or competition with the other abundant ampeliscid *A. agassizi*.

In summary, the differences between the macrobenthic communities of dynamic, coarser sediments on ridges and more stable, fine sediments in swales were expressions of selection for certain purchase and feeding types. The more dynamic sediments support thin, active species which are adapted for recovery from physical disturbance and dependent on interstitial resources. The stable muddy sands support large burrowers and surface tube builders maladapted for frequent physical disturbance of the substrate and utilizing surface and subsurface deposits for food.

Seasonal Variation

This report covers data resulting from the first year of sampling at benchmark stations, most of which are being sampled for a second year. Thus, it is premature to draw specific conclusions regarding seasonality until it is seen whether population variations witnessed the first year are repeated. Nonetheless, several general observations seem in order.

As discussed earlier, total macrofaunal densities tended to decline from fall 1975 to summer 1976 at many stations. This is a reflection of similar declines in the populations of constituent dominant species. This trend suggests a probable yearly cycle of heavy recruitment during the summer and subsequent mortalities. However, this interpretation based on total densities would be an oversimplification. Although juveniles of many species were most abundant in the fall, the presence of juveniles, gravid or brooding adults, and other signs of reproductive activity indicates recruitment processes go on during all seasons depending on the species involved.

While there was a clearly concordant trend over several stations of considerable seasonal fluctuation for some species (e.g. Figure 6-44), the persistence of others is surprising in light of station relocation difficulties and patchiness of distribution. For example, the near constancy of mean abundance of *Ampelisca agassizi* at B3 (Appendix 6-C, Figure 6-42) is truly remarkable.

Species Diversity

Species diversity parameters including areal richness (number of species), Shannon diversity, numerical richness, and species evenness for all collections are presented in Figures 6-46 through 6-53.

Areal richness showed a clear increase across the shelf similar to that displayed by the megabenthos. Except in swales or other fine sand locations, generally fewer than 60 species were taken in 6 replicate 0.1 m^2 grab samples from inner or central shelf stations. At the inner shelf swale station (C4), 74-80 species were taken except in summer when hypoxic stress reduced this number to 39 (see next section). At the central shelf swale site (D4) 80-108 species were taken.

At outer shelf stations (50-100 m) more than 80 species were almost always collected in 6 grabs. Over 100 (and up to 141) species were collected on each sampling occasion in outer shelf swales. Collections at shelf break stations (100-200 m) were about as rich as those from the outer shelf (range 74-128 species). The areal richness of continental slope stations declined markedly from about 100 species in 0.6 m^2 at ca. 350 m to 56 or fewer at ca. 700 m. This corresponded with a similar drastic decline in total macrofaunal density.

The overall distribution of Shannon diversity followed the pattern described for areal richness, namely an increase from lower values (< 4 bits/individual) on the inner and central shelf to higher values (> 4) on the outer shelf and shelf break. Diversity values for continental slope collections were even higher at about 5. This pattern is locally and seasonally affected by low evenness (Figure 6-49 and 6-53), reflecting strong dominance where population densities are great. This frequently occurs at swale stations, where dense aggregations of one or two species, e.g. *Ampelisca agassizi*, lowers evenness but may also reflect seasonally explosive population increases. The H' diversity of megabenthos collections also showed a general increase across the shelf.

Rarefaction techniques allow for comparison of the species richness of samples of disparate sizes by estimating the number of species that would be taken in samples smaller than the one at hand. For simplicity, estimations for a fixed numerical sample size are presented rather than entire rarefaction projections (Sanders 1968). A sample size of 500 individuals was used because this allowed for good differentiation of differences among collections. At some stations the collection did not yield 500 individuals, but interpretation can be based on consulting rarefaction estimations for fewer than 500 individuals.

The pattern of distribution of numerical richness as measured by $E_{S(500)}$ was intermediate between that of areal richness and Shannon diversity (Figures 6-48 and 6-52). Numerical richness was lowest at inner shelf stations (ca. 30-40 species/500 individuals) intermediate at central shelf stations and reached highest values on the outer shelf, shelf edge, and upper slope (50-80 species/500 individuals). Like H' it was sensitive to lowered evenness caused by dense populations of certain species. Thus, numerical richness at swale stations is lower than would be expected based on areal richness.

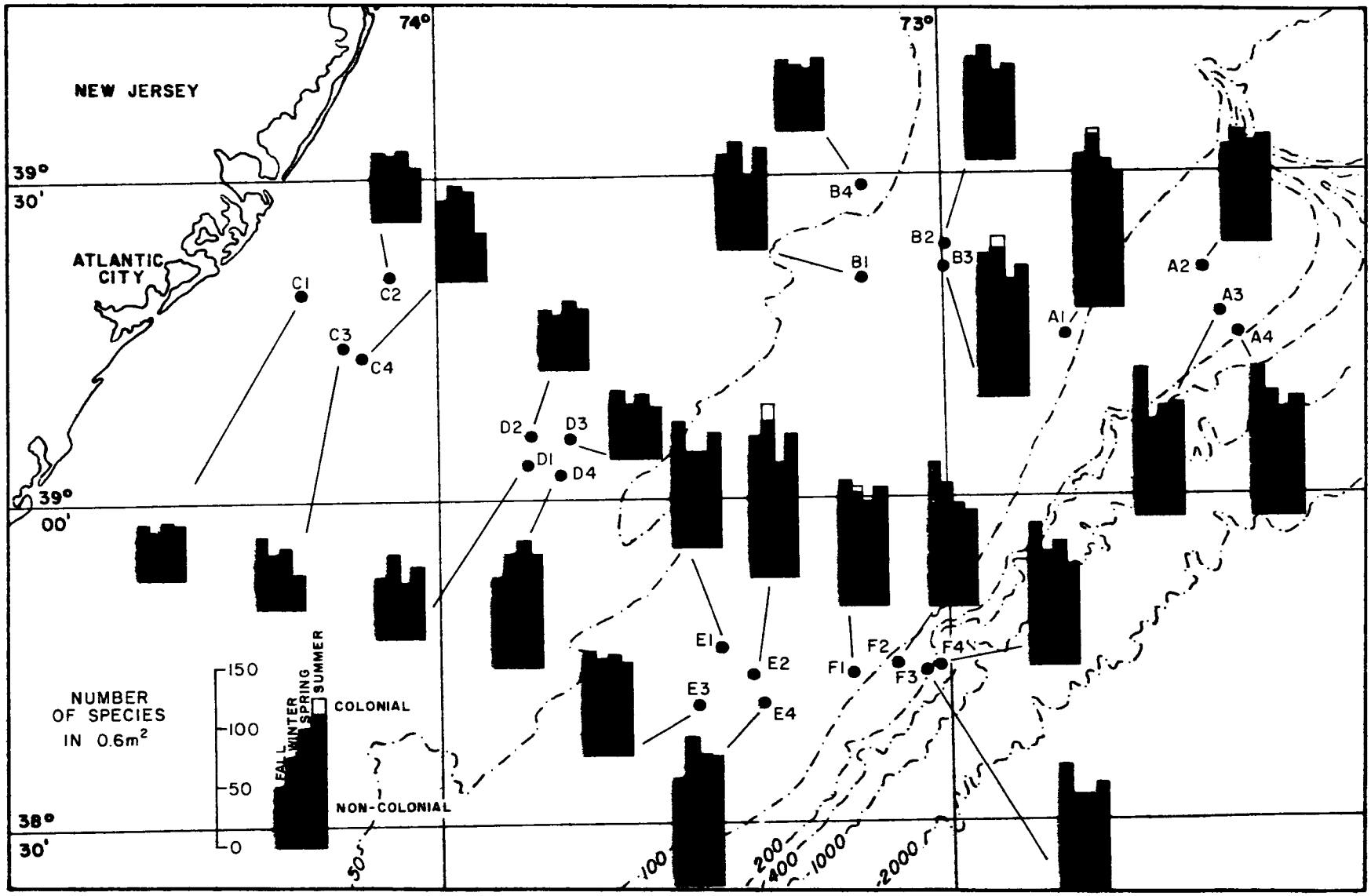


Figure 6-46. Total number of species of macrobenthos collected in 0.6 m^2 at each quarterly station for each season.

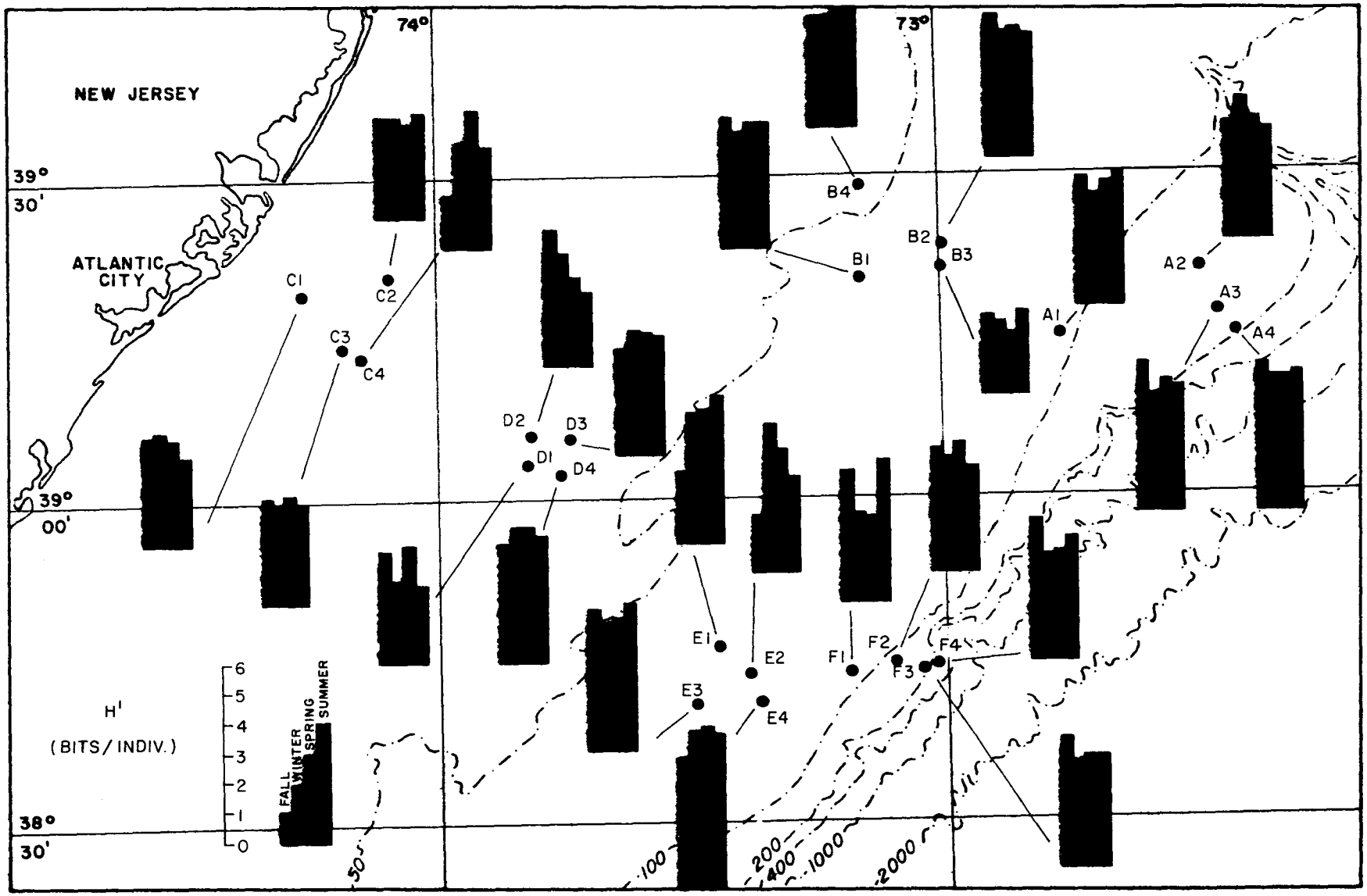


Figure 6-47. Shannon diversity (H') for collections of macrobenthos at each quarterly station for each season.

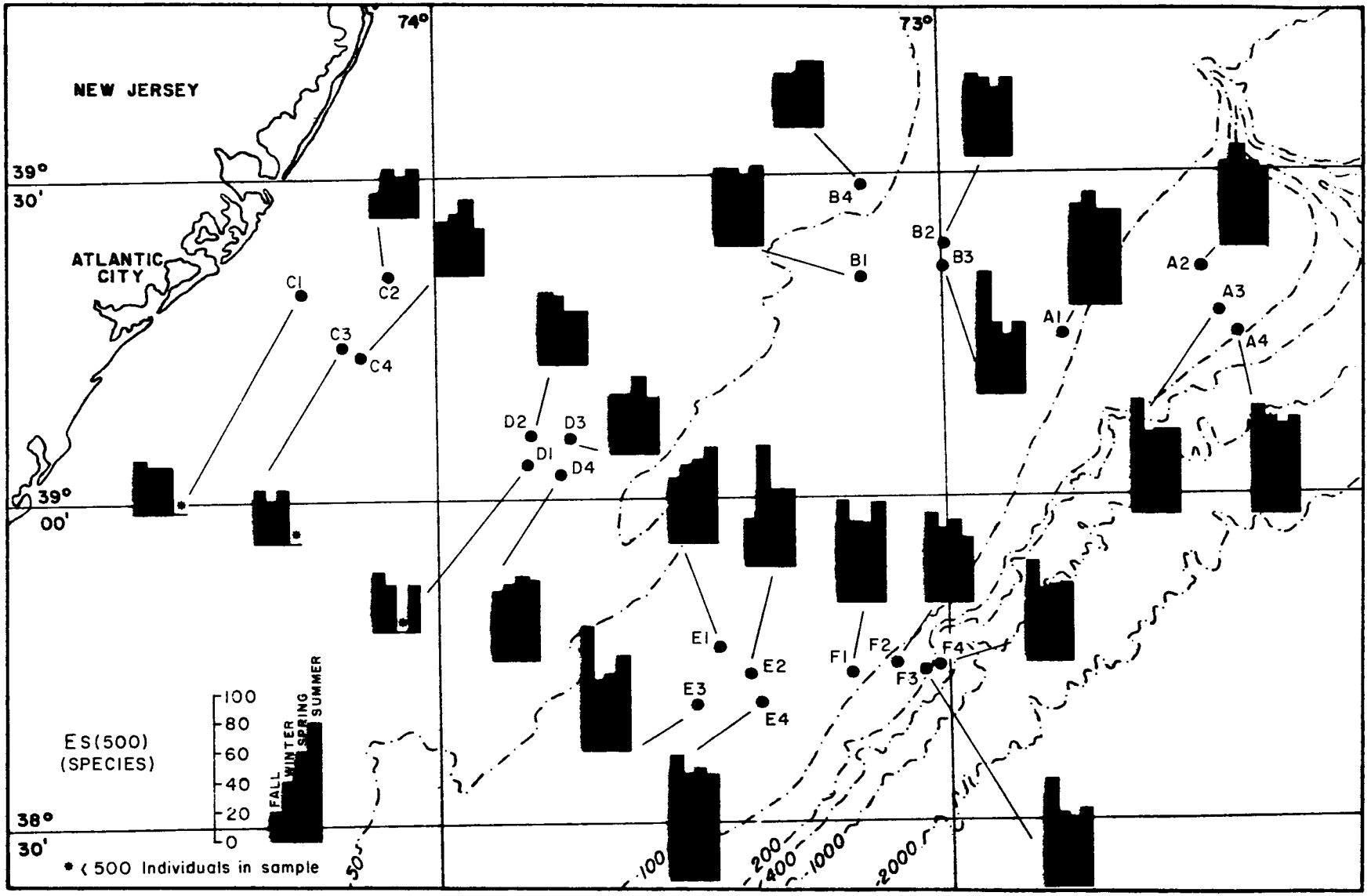


Figure 6-48. Expected number of species in a sample of 500 individuals ($E_{S(500)}$) as predicted by Hurlburt's rarefaction technique for collections of macrobenthos at each quarterly station for each season.

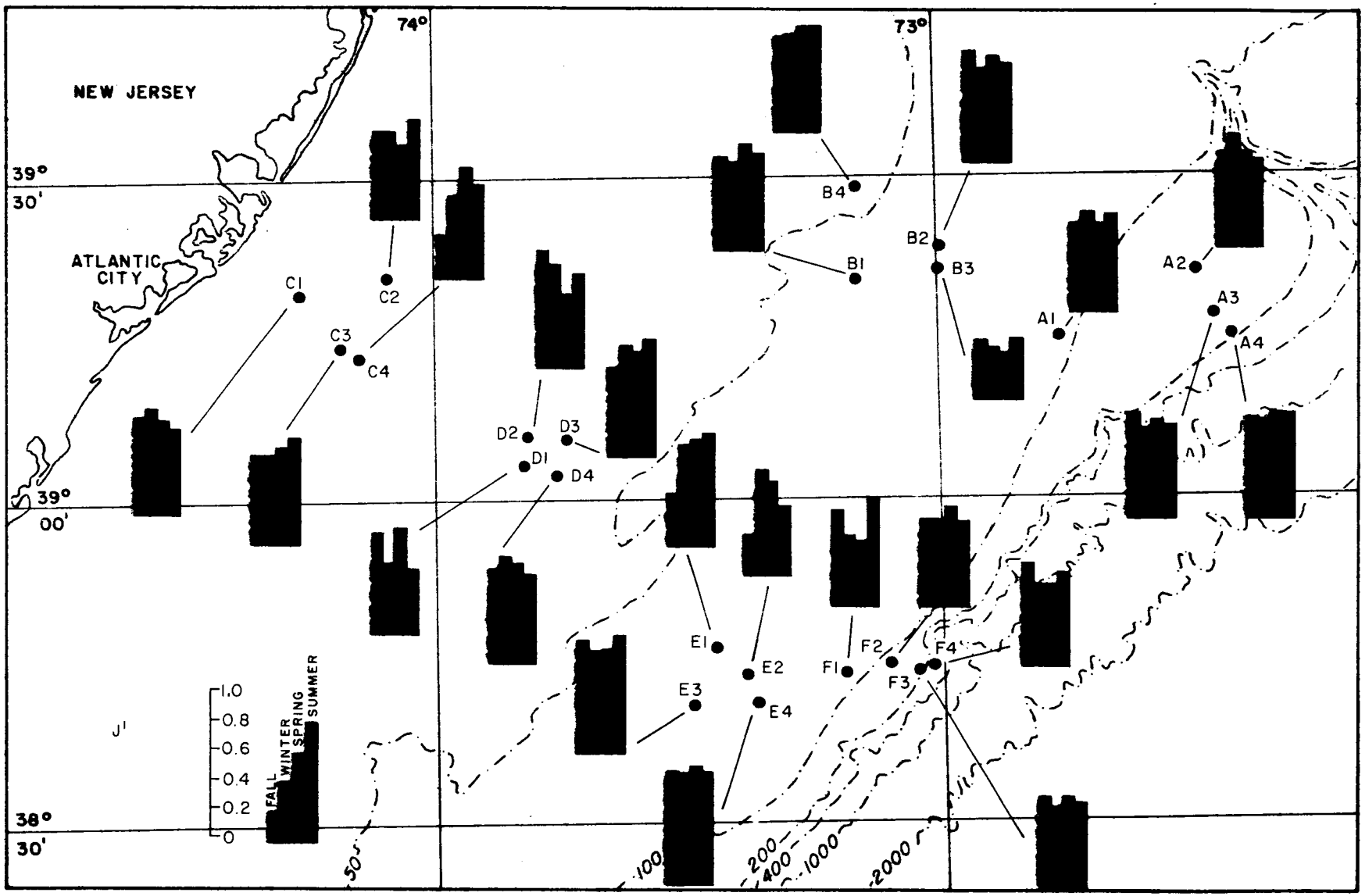


Figure 6-49. Evenness (J') for collections of macrobenthos at each quarterly station for each season.

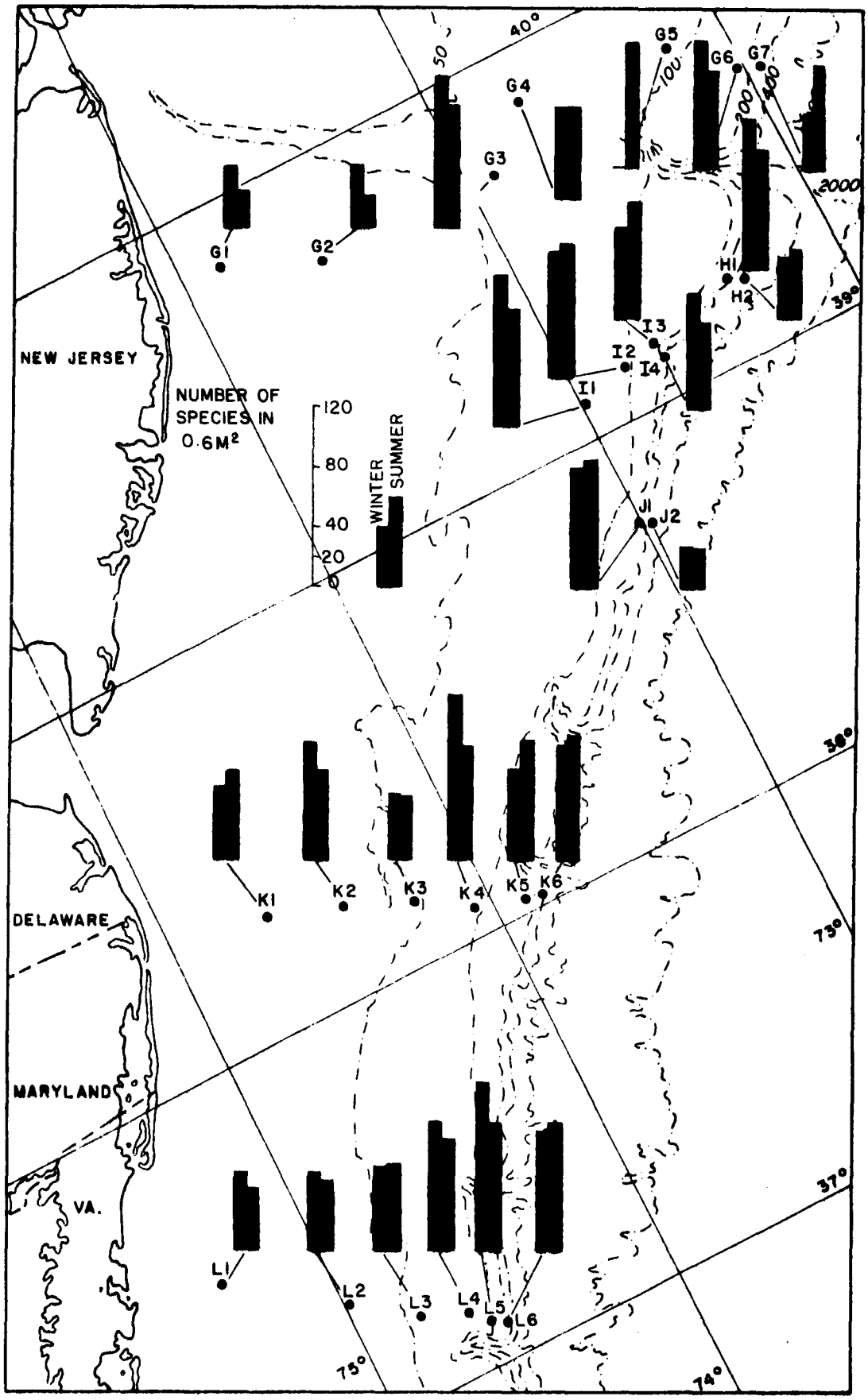


Figure 6-50. Total number of species of macrobenthos collected in 0.6 m^2 at each semiannual station for Winter and Summer 1976.

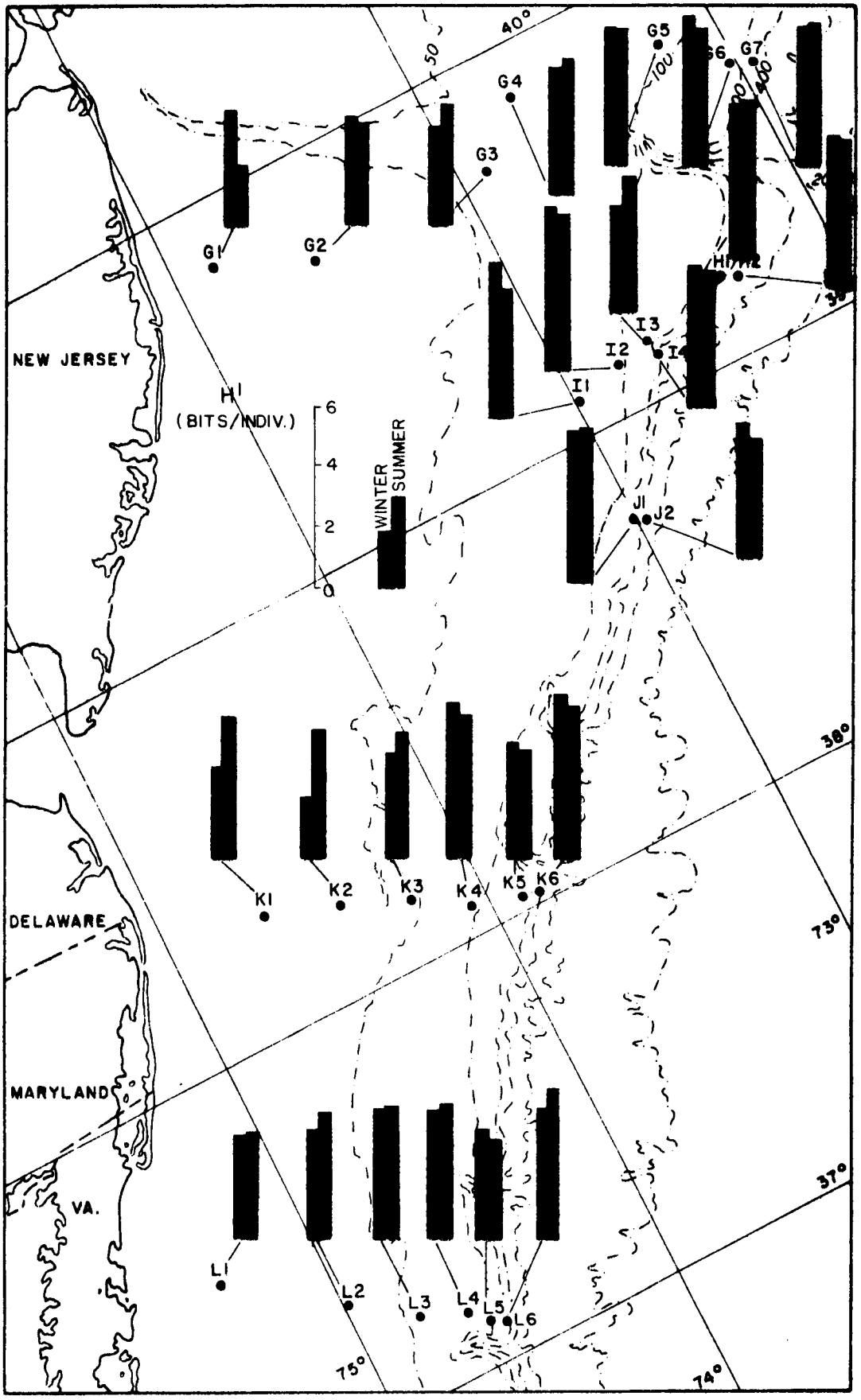


Figure 6-51. Shannon diversity (H') for collections of macrobenthos at each semiannual station for Winter and Summer 1976.

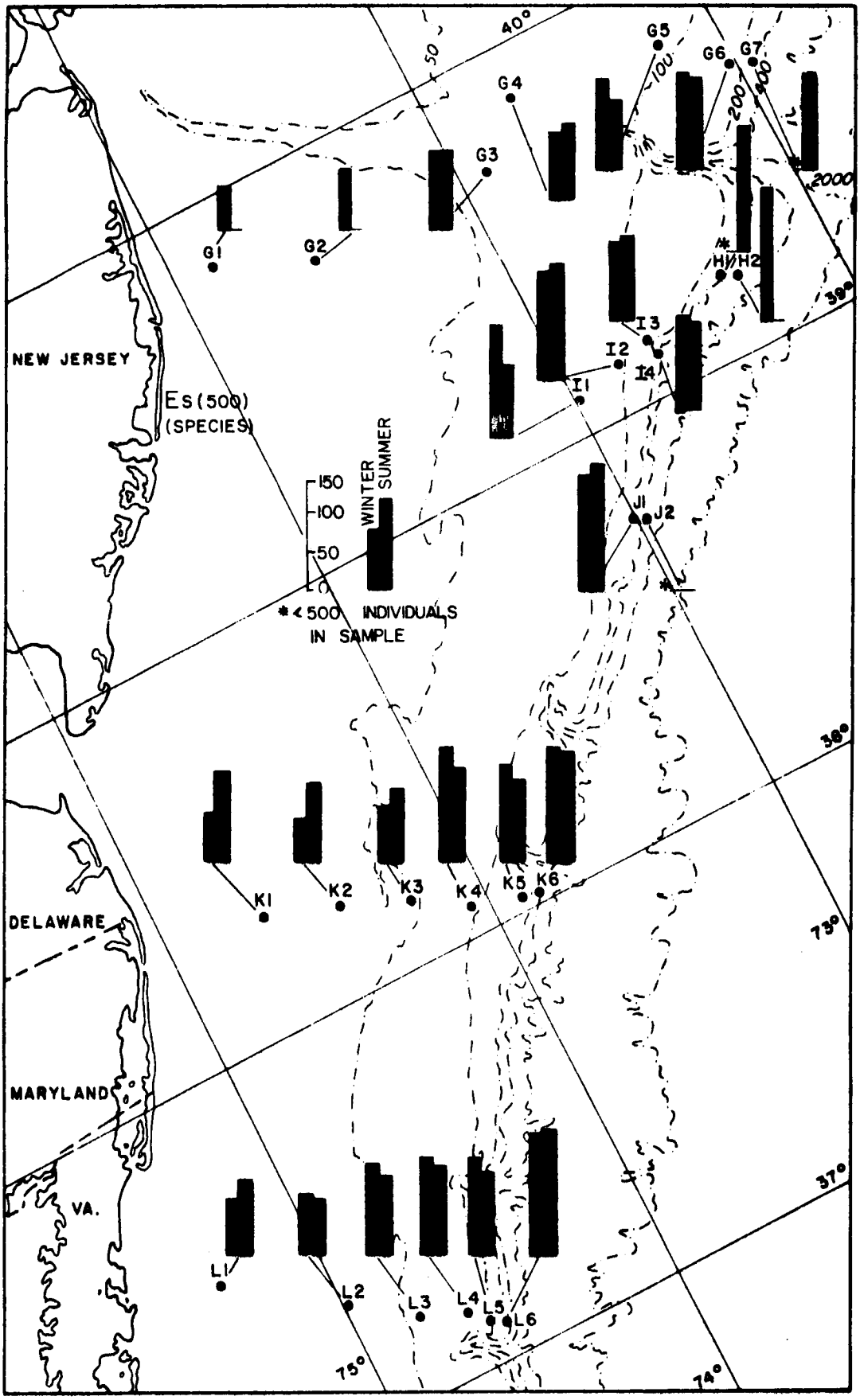


Figure 6-52. Expected number of species in a sample of 500 individuals ($E_{S(500)}$) as predicted by Hurlburt's rarefaction technique for collections of macrobenthos at each station for Winter and Summer 1976.

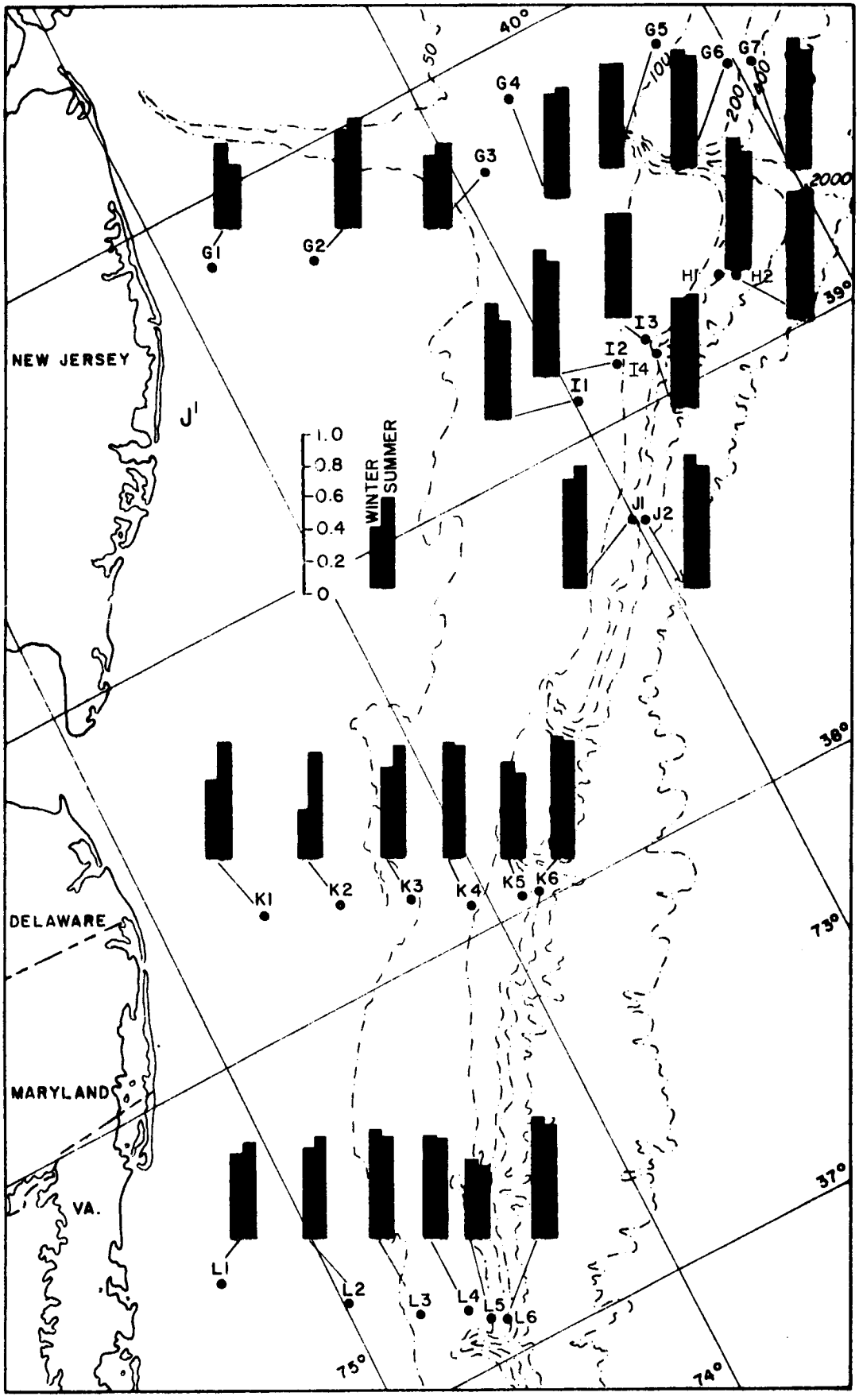


Figure 6-53. Evenness (J') for collections of macrobenthos at each semi-annual station for Winter and Summer 1976.

Effects of Hypoxia during Summer 1976

Anoxic or seriously oxygen-deficient conditions occurred in bottom waters over the inner one-third of the continental shelf off central and northern New Jersey (Figure 6-22) (Sharp 1976). Analysis of collections of macrobenthos show evidence of community alterations due to these conditions only at C1, C2, C3, C4, G1, and possibly G2, although the hypoxic conditions could have caused effects over a wider area after the August 1976 sampling. The stations affected probably experienced nearly complete anoxia for considerable periods of time during July-September 1976 and may have also experienced free H_2S in bottom water (Sharp 1976). The effects on the macrobenthos were similar among the non-swale stations (all except C4) that were affected. This discussion will focus on the effects on the community at C2 because it is the site of megabenthos sampling and continuing macrobenthos sampling.

Fluctuation in the abundance of several dominant species at C2 are presented in Figures 6-54 and 6-55. The archiannelid *Polygordius* sp. was a temporally variable but abundant member of the community prior to the summer when only a very few specimens were found. A similar trend at other affected stations coupled with its continued abundance at unaffected stations suggest *Polygordius* was strongly reduced by hypoxia. Conversely, most other dominant annelids, including *Goniadella gracilis* and *Lumbrinerides acuta*, remained abundant during the incident. Similarly, the bivalve *Tellina agilis* showed no significant mortality due to oxygen stress. Juvenile *Spisula solidissima* were absent in August and the populations may have suffered some losses although they were sparse in June. Large mortalities of adult *Spisula* were observed at this site in dredge and trawl samples.

In contrast to the lack of apparent effects on dominant polychaetes and bivalves, effects on dominant crustaceans and echinoderms were catastrophic (Figure 6-55). Megabenthic crustaceans and echinoderms were also the most severely affected by oxygen depletion. *Tanaissus liljeborgi* was the most abundant organism during fall and spring at this site, but only a few specimens were found in August. Although *Tanaissus* populations generally declined at unaffected stations during the summer, its virtual elimination at C2 and other affected stations is certainly due to the anoxic condition. Similarly, *Protohaustorius wigleyi* is a consistent member of the inner shelf dynamic sand community but was eliminated at those stations experiencing anoxia. *Pseudunciola obliquua* was extremely abundant in winter and spring but was much reduced in August. *Echinarachnius parma* was completely eliminated at C2 because none at all were taken in grab, dredge, or trawl samples.

The effects at C4, another station where sampling is continuing, are difficult to assess because of the great variability in sediments from cruise to cruise (Chapter 5). However, there appears to have been a great reduction in *Polygordius* and crustaceans while polychaetes and bivalves persisted. At all of the affected stations areal species richness declined in summer 1976 in response to the elimination of species, including less abundant forms (Figure 6-46).

The effects of the 1976 hypoxia incident on macrobenthos will be better understood after analysis of subsequent samples and assessment of recovery

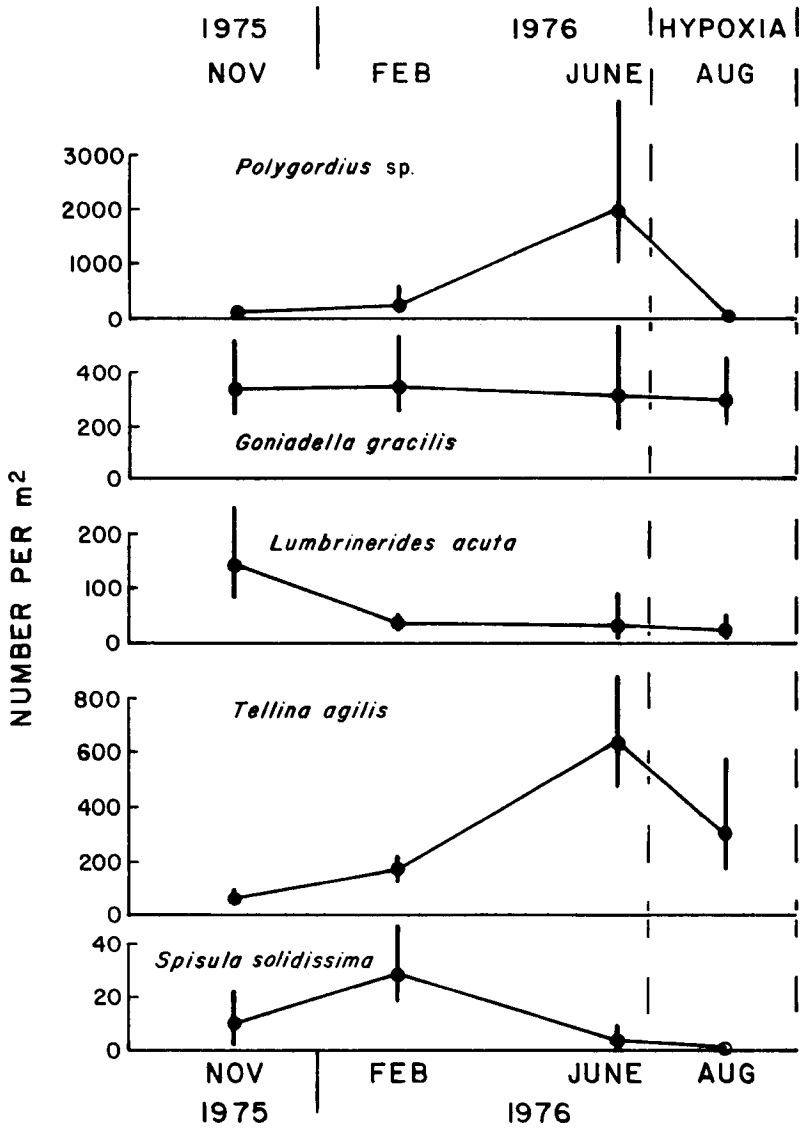


Figure 6-54. Fluctuations in the abundance of dominant annelids and molluscs at Station C2, November 1975 to August 1976. Lines connect geometric means, vertical lines are 95% confidence limits ($x \pm s_{\bar{x}}\ t_{.05}$) of sample means.

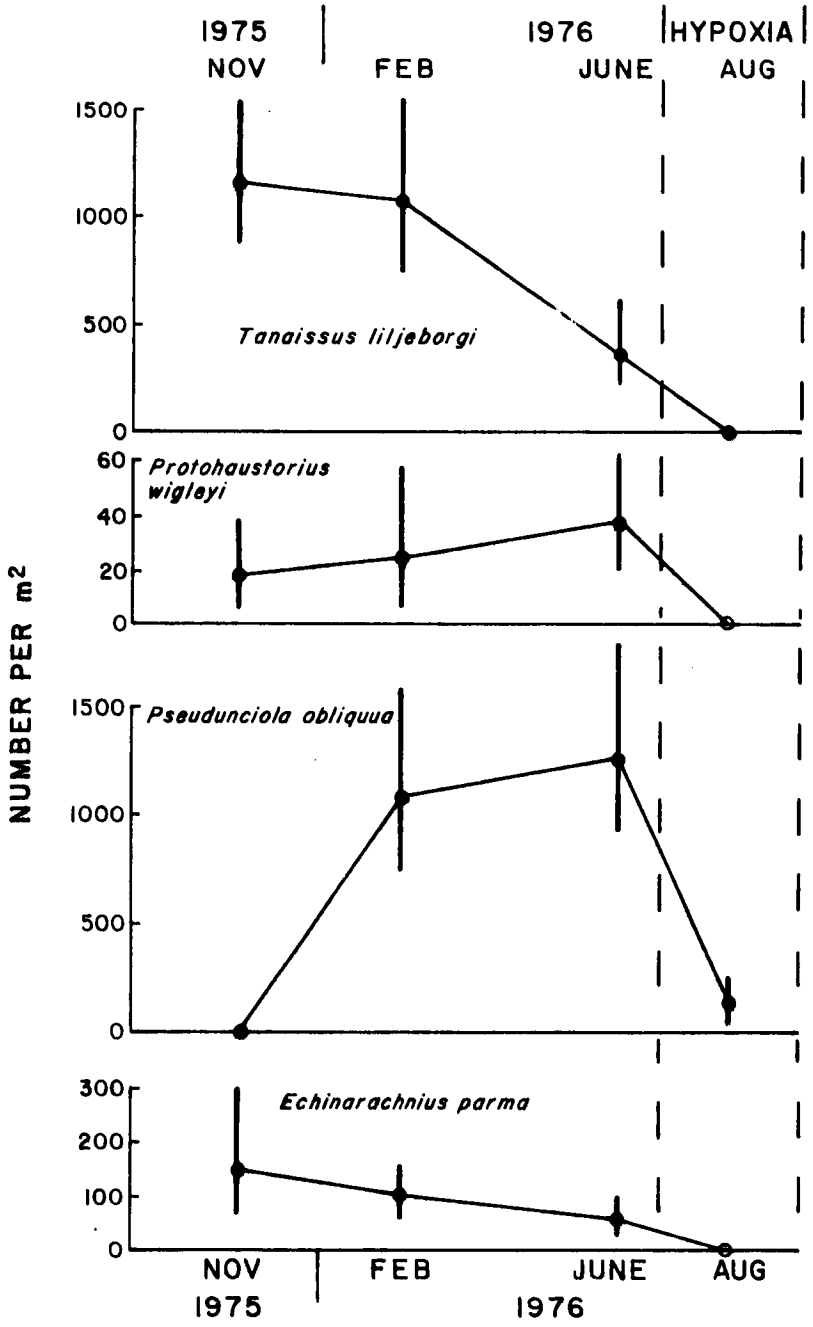


Figure 6-55. Fluctuation in the abundance of dominant crustaceans and echinoderms at C2, November 1975 to August 1976. Lines connect geometric means, vertical lines are 95% confidence limits ($x \pm s_{\bar{x}}\, t_{.05}$) of sample means.

processes. These early data suggest that effects on epifauna and certain active infauna, such as the peracarideans and *Polygordius*, were devastating due to their physiological intolerance of such low oxygen (or high H_2S) conditions. The infauna, in particular polychaetes and certain bivalves, largely survived the conditions at least until August due to physiological adaptations which allow them to live within frequently oxygen-deficient sediments.

DISCUSSION

Characterization of Benthic Communities of the Middle Atlantic Bight

Abundance and Diversity of Macrobenthos

Comparable studies of megabenthos have not been conducted in the Middle Atlantic Bight, thus discussion of our results in relation to existing information is necessarily limited. Furthermore, the semi-quantitative nature of data resulting from dredges and small trawls also restricts comparisons.

Several quantitative investigations of macrobenthos of the Middle Atlantic Bight have been conducted using grab sampling techniques more or less similar to those used here (Figure 6-1), but even so, comparable data on the density, biomass, and diversity of macrobenthos are scant. Wigley and Theroux (1976) report on densities and biomass of macrobenthos by major taxonomic group based on a broad scale survey of the continental margin from Cape Cod to Cape Hatteras. They found patterns of decreased density and biomass from shallow to deep water, from north to south within the Bight, from coarse-grained to fine-grained sediments, and from areas with wide to areas with narrow temperature range.

It is difficult to evaluate Wigley and Theroux's conclusions with respect to the present results because their study covered much broader latitudinal and bathymetric ranges. However, comparisons can be made between the data sets using Wigley and Theroux's (1976, Tables 8 and 16) summary data for comparable bathymetric classes within the subregion they define as the New York Bight (Montauk Point to Cape May). Mean densities reported by Wigley and Theroux are only 10-20% of the estimates based on this study (Table 6-11). The differences were particularly striking for the deeper bathymetric strata, corresponding to the shelf break and continental slope. These great differences are mainly attributable to the different sieve sizes used (1.0 versus 0.5 mm in this study) and, perhaps, to the greater than traditional care in sample sorting exercised during this study (i.e. microscope sorting). An examination of the densities of major taxa reported by Wigley and Theroux indicates that the density differences are primarily due to the much greater number of small annelids and crustaceans collected in the present study. Although we found a clear diminution in density down the continental slope which has been widely reported (Wigley and McIntyre 1964; Sanders et al. 1965), there was no decrease in density of macrobenthos with depth on the shelf. In fact, highest mean densities were found on the outer shelf where bottom temperatures are quite constant. There was also no trend toward higher densities in the coarsest substrates. Although low densities characterized the muddy continental slope sediments, highest densities on the continental shelf were found in stable medium-fine sands, and densities were reduced in coarse sand.

Table 6-11. Mean number of individuals of macrobenthos by bathymetric stratum compared with values given in Wigley and Theroux (1976) for the New York Bight region.

Bathymetric Stratum (m)	BLM Benchmark Studies Mean No. Individuals/m^2 (0.5 mm sieve)					Wigley & Theroux Mean No. Indiv/m^2 (1.0 mm sieve)
	Fall	Winter	Spring	Summer	Overall	
25-49						
Quarterly Stations	6640	4219	3464	2644	4242	752
Semiannual Stations	--	6849	--	1787	4318	
50-99						
Quarterly Stations	9746	5826	5710	5103	6596	1390
Semiannual Stations	--	5100	--	3685	4393	
100-199						
Quarterly Stations	4435	3608	3530	3889	3915	442
Semiannual Stations	--	2910	--	3528	3219	
200-1000						
Semiannual Stations	--	1740	--	1606	1673	230

Densities of macrobenthos reported here are similarly higher than those reported in other studies, including Steimle and Stone (1973) and Pearce et al. (1976), both of which employed a 1.0 mm sieve. Extremely high densities (over 100,000/m^2) have occasionally been reported from the New York Bight apex (Rowe 1971; National Marine Fisheries Service 1972; Pearce et al 1976).

Biomass data from this study are more directly comparable to those of Wigley and Theroux (1976) because animals retained by their 1.0 mm sieve should comprise almost all of the biomass. Strangely though, overall mean biomass of annelids found in this study is twice or more than reported by Wigley and Theroux for each bathymetric stratum (Table 6-12). Greatest differences were between estimates for the shelf break (100-199 m). Wigley and Theroux's estimates of mean mollusc biomass are, however, generally higher than ours. The distribution of mollusc biomass in grab samples is highly skewed. Wigley and Theroux's values are arithmetic means which are biased by inclusion of a few samples containing large molluscs. This probably accounts for the discrepancies between their data and ours based on the geometric mean of 6 sample estimates. Geometric means tend to reduce the influence of a very large value obtained when a single large mollusc is collected. Mean biomass estimates for Crustacea and Echinodermata in each bathymetric stratum are very similar to those reported by Wigley and Theroux (1976).

Table 6-12. Mean wet weight biomass of macrobenthos by bathymetric stratum and major taxonomic group compared with values given in Wigley and Theroux (1976) for the New York Bight region.

Bathymetric Stratum (m)	BLM Benchmark Studies Biomass (g/m^2)					Wigley & Theroux Biomass (g/m^2)
	Fall	Winter	Spring	Summer	Overall	
Annelida						
25-49	17.7	16.9	11.6	22.1	17.7	8.0
50-99	28.0	24.7	17.9	19.9	22.5	11.3
100-199	17.6	18.9	23.2	15.5	18.3	3.9
200-1000	--	14.7	--	12.6	13.5	6.8
Mollusca						
25-49	16.2	15.6	3.7	18.0	14.3	41.1
50-99	87.0	57.6	65.9	40.9	59.0	131.0
100-199	5.5	2.7	2.5	3.9	3.5	2.7
200-1000	--	2.7	--	2.3	2.5	1.6
Crustacea						
25-49	3.4	6.0	4.1	3.8	4.5	5.7
50-99	1.9	5.6	8.4	10.2	6.9	5.7
100-199	0.1	2.0	0.9	2.4	1.6	1.2
200-1000	--	0.7	--	0.9	0.8	0.1
Echinodermata						
25-49	93.4	29.3	54.1	16.9	41.5	66.2
50-99	9.8	7.6	10.1	7.0	8.2	8.4
100-199	13.0	6.3	12.4	10.1	9.8	19.4
200-1000	--	1.5	--	1.0	1.2	2.6

As with total densities of macrobenthos, the biomass of each major taxon declines greatly on the continental slope. For all taxa except Echinodermata, biomass is highest on the outer shelf. Biomass of molluscs and crustaceans is lower at the shelf break than on the shelf. Excluding the continental slope, no other trend toward reduction of biomass across the shelf is apparent. Highest biomass was found in stable, medium-fine sands rather than in the coarsest substrates.

There were no clear latitudinal trends in total density of macrobenthos (Figures 6-33 and 6-34) or in the biomass of major taxa (Figures 6-25 through 6-32) within the study area. Wigley and Theroux (1976) found strong latitudinal trends in density and biomass, but this was based on comparisons over the whole Middle Atlantic Bight, from Cape Cod to Cape Hatteras.

Comparisons of the observed patterns of species diversity with previous results are confounded by varying sample sizes and forms of analysis. Wigley and Theroux (1976) present no data on species diversity or richness, but conclude that portions of the Middle Atlantic Bight experiencing marked seasonal changes in bottom temperature supported "diverse forms", whereas areas with uniform temperatures throughout the year (bathyal habitats) support only "a moderate variety of species". Their characterization of bottom temperature variability is based on long-term extremes and not seasonal variation within a year, as in this study. Zones described as varying in bottom temperature from 12-16°C varied only 2-3°C during this study year.

Day et al. (1971) sampled macrobenthos on a cross-shelf transect off Cape Lookout, North Carolina, and reported greatest numerical species richness in the 20-120 m zone, but reduced richness at 160 and 200 m stations.

By comparison, our data generally indicate increased species richness and diversity with reduced seasonal variation in bottom water temperature and increased depth. Areal richness declined from the shelf break to the continental slope (Figure 6-50) due to the reduced densities of macrobenthos, but numerical richness (Figure 6-52) and Shannon diversity (Figure 6-51) did not. Thus, our results agree with those of Hessler and Sanders (1967) who found increasing diversity from the outer continental shelf, across the shelf break, and down the slope off southern New England.

Pearce et al. (1976) describe the distribution of Shannon diversity (H') from collection of macrobenthos from the central and outer continental shelf in the New York Bight. Their values (<3) are generally much below those reported here, although the units employed (base logarithms) are not stated. Their collections were made on a 1 mm sieve and were not replicated, thus their values are probably underestimates of the true (asymptotic) diversity of the 1 mm sieve populations. Boesch (1972) reported values of H' for macrobenthos (1 mm sieve) from the inner shelf off the Delmarva Peninsula and the shelf break of the Virginia-North Carolina shelf which are within the range of those values reported for these respective environments in this study.

In summary, our data indicate that Wigley and Theroux's (1976) conclusions regarding decreased density and biomass (1) from shallow to deep water, (2) from north to south within the Middle Atlantic Bight, (3) from coarse-grained to fine-grained sediments, and (4) from areas with wide to areas with narrow temperature range are not applicable within the study area (continental shelf and upper slope). Furthermore, the patterns of species richness are in agreement with the predictions of Sanders' (1968) stability-time hypothesis. That is, higher richness was found in more temperature constant, less dynamic benthic habitats.

Patterns of Distribution

Bathymetric Distribution. A clear bathymetric gradient in distribution was apparent for both megabenthos and macrobenthos. Even though the analyses performed were, because of necessary simplicity, designed to dissect this gradient it should be conceptualized as a coenocline, or community continuum, rather than as discrete faunal zones. Reasonable classification of the distribution of even the more common species shows a pattern of overlapping distributions across the continental shelf and slope. Thus, the bounds of the

artificial zones should coincide with somewhat sharper biotic change across the continuum.

In terms of assemblage similarity, the sharpest changes occurred at or near the shelf break. Change on the upper slope and the outer shelf was more gradual, and the degree of change between the central and outer shelf was intermediate. Thus, the apparently optimal subdivisions of the bathymetric coenocline conform well to the geographic subdivisions: inner shelf (to ca. 30 m), central shelf (30 - 50 m), and outer shelf (50 - 100 m), shelf break (100 - ca. 200 m), and continental slope (>200 m).

Latitudinal Distribution. The study area is usually described as part of the Virginian biogeographic province which extends from Cape Cod to Cape Hatteras and is thought to be inhabited mainly by eurythermal warm temperate species (Ekman 1953; Briggs 1974). Few tropical species, most of which extend no further north than Cape Hatteras, and few arctic or boreal species, most of which extend no further south than Cape Cod, presumably occur in the region. However, this characterization is based primarily on epifaunal echinoderms, decapods, crustaceans, molluscs, and fishes and primarily on littoral or shallow water biota. Some of the dominant infaunal taxa, in particular polychaetes and peracarideans, demonstrate less clear-cut biogeographic patterns. Polychaetes, for example, tend to have notoriously wide latitudinal and bathymetric ranges. Furthermore, the biogeography of outer shelf, shelf break, and continental slope regions is not well known, but often does not bear much resemblance to that of the littoral biota.

The latitudinal distribution of macrobenthos within the study area is overwhelmed by strong bathymetric trends such that there are no apparent faunal differences from north to south. Communities seem to be qualitatively and quantitatively similar within a given depth zone over the 3^{o} latitude studied. This is in part due to the dominant along-shelf flow of shelf currents and the lack of direct influence of oceanic circulation (e.g. the Gulf Stream) on shelf waters. As a consequence, bottom temperatures within a depth zone are fairly uniform (Chapter 3) and are dominated by the advection of relatively cold water from the north. Because of this and strong seasonal stratification, bottom temperatures on the outer shelf remain cold throughout the year and apparently support many boreal species previously thought limited north of Cape Cod (Table 6-13).

The bottom in the shelf break region is bathed by slope water of rather constant temperature (11-12^{o}C) along the Middle Atlantic Bight and is populated by stenothermal species which probably have broad latitudinal ranges along the shelf break and continental slope.

Relationships with Substrate and Topography. As is usual, the distribution of macrobenthic animals is strongly related to substrate characteristics (Gray 1974). In this case, however, the substrate characteristics were related to the water depth (or more specifically to bottom turbulence), and thus the effects of sediment type are included in the shelf complex-gradient along with those of temperature, etc. Where sediments varied within a depth zone (e.g. within a cluster area), the effects of substrate are more separable and, thus, most striking. For example, the community at the fine sand station L1 is clearly different than the others on the inner shelf and the muddier sediments at A2,

Table 6-13. Examples of boreal species of polychaetes, crustaceans, and echinoderms presumed to be at their southern distributional limits on the outer Middle Atlantic continental shelf.

Polychaeta	Echinodermata
Austrolaenilla mollis	Holothuroidea
Euphrosine armadillo	*Havelockia scabra*
Ceratocephale loveni	*Stereoderma unisemita*
Cistena hyperborea	*Caudina arenata*
Orbinia swani	*Leptosynapta tenuis*
	Ophuroidea
Crustacea	*Ophiopholis aculeata*
Tanaidacea	Asteroidea
Leptochelia filum	*Asterias vulgaris*
Cumacea	Echinoidea
Eudorella pusilla	*Briaster fragilis*
Isopoda	*Strongylocentrotus droebachiensis*
Pleurogonium rubricundum	
Pleurogonium spinosissum	
Amphipoda	
Eriopisa elongata	
Melita dentata	
Phoxocephalus holbolli	
Harpinia truncata	
Decapoda	
Eualus pusiolus	
Spirontocaris lilljeborgii	
Axius serratus	
Hyas areneus	

A3, and A4 support a somewhat different community than elsewhere in the shelf break region.

More widespread, though, are the local effects of substrate related to topographic features, in particular to the ridge and swale topography. These may produce differences in the communities greater than those witnessed across considerable depth or latitudinal ranges. Communities in swales tend to be more like those further offshore than those outside of swales within the same bathymetric zone. This introduces further complexity to the general depth zonation scheme described above.

Overall Distribution. A generalized distribution scheme of shelf benthic biotopes is given in Figure 6-56. This is based on data collected during the study and extrapolations from sediment distribution in areas not sampled. Because of the scale, the detailed influence of ridge and swale topography could

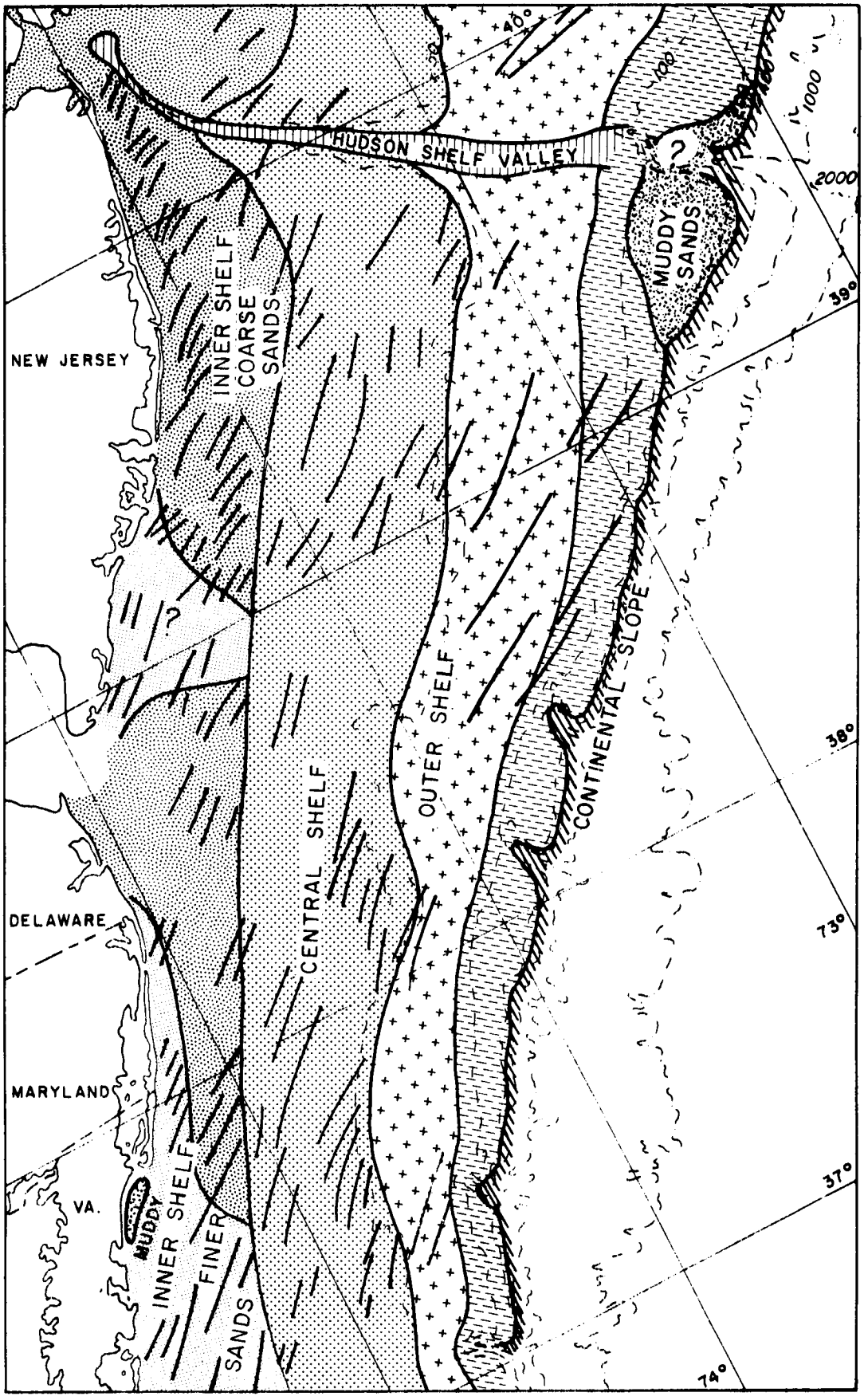


Figure 6-56. Schematic zonation of macrobenthic biotopes in the middle portion of the Middle Atlantic Bight. Major ridge fields are indicated.

not be included in this figure, but it should be kept in mind that local topography can effect biological differences as great as those of the depth zones.

The data on which to base such biotope characterizations have heretofore been scant, and conclusions were thus speculative (see Introduction). Pratt's (1973) conception of latitudinally homogeneous bathymetric zone bears some relationship to the observed distribution of benthos in this study, although the relationship of his zonation scheme to sediment type was somewhat misconceived. Changes in benthic communities occur on the outer shelf even if sediments are not silty. Also, although sediments do have somewhat higher silt and clay content at the shelf break, the great faunal changes found there are probably more the result of temperature differences than the existence of a "mud line". Pearce (1975, Pearce et al. 1976) emphasized the homogeneity in the distribution of macrobenthos across the Middle Atlantic continental shelf by referring to species found widely across the shelf. Our results demonstrate that the composition and structure of the benthic communities are, in fact, greatly different from the inner to the outer shelf. Although there are several notable ubiquitous species, there are large numbers of species restricted to the inner or outer shelf.

Maurer et al. (1976) listed characteristic sand fauna species on the inner and central shelf of the Middle Atlantic Bight based on their studies and others. Although they recognized the effect of local sediment differences on the benthic communities off the mouth of Delaware Bay and the possible influence of microtopography, their qualitative characterization leaves the impression of greater homogeneity than observed in this study. The species listed by them are in fact characteristic of much of the inner and central shelf; however, their patterns of distribution and abundance are strongly influenced by bottom topography and subtle differences in sand size distribution.

Factors Controlling Community Composition and Structure

The bathymetric coenocline is controlled by several environmental factors acting across the bathymetric complex-gradient (sensu Whittaker 1971). The principal cause of the biotic change is not the effect of depth (pressure) itself but rather the complex effects of hydrography and sediment characteristics.

Hydrographic Factors

Temperature is the principal hydrographic factor affecting macrobenthic distribution. Not only the absolute extremes, but also the temperature range, are certainly important. The temperature regime on the inner shelf is influenced by the continental climate and bottom water in Area C experienced a 12-14°C range during the year of sampling (Chapter 3). Coldest temperatures were 3.5°C in winter and warmest were about 17°C in summer. On the central shelf, bottom temperature was only slightly less variable (10-12°C) with the warmest temperatures in fall 1975 (16°C) and the coldest in the following winter (5°C). Bottom temperatures on the outer shelf are, however, much more constant with a range during the sampling period of only 3-4°C. The temperatures were warmest in the fall (ca. 11°C), following vertical mixing concomitant with the break up of the thermocline, and coldest during spring and summer (8-9°C). During the spring and summer the outer shelf is covered by the "cold pool" of southward traveling water formed off New England during the winter

(Beardsley et al. 1976). This creates the unusual condition whereby the bottom temperatures in the shelf break region are warmer than those on the outer shelf during most of the year. At the shelf break bottom temperatures were extremely constant, varying $1^{o}C$ or less over the year and continuously 11-$12^{o}C$.

The variable temperature conditions of the inner and central shelf no doubt restrict some cold stenothermal species found on the outer shelf. Moreover, the constantly cool conditions on the outer shelf coupled with a predominantly southwesterly flow of water masses carrying larval drift from off New England allow the existence of boreal species farther south than previously expected. The shelf break assemblages probably contain warm stenothermal species which have broad latitudinal distributions. Thus, differences in temperature regime are probably the prime cause of the sharper faunal change at the outer shelf-shelf break transition than elsewhere.

Salinity and other hydrographic factors are thought to have an insignificant effect on the distribution of macrobenthos in the study area. Although lowered dissolved oxygen levels during the summer of 1976 altered distribution patterns, dissolved oxygen is not thought to be a limiting factor under usual conditions.

Sedimentologic Factors

Our results suggest that not only are the static properties of grain-size and organic carbon content important in affecting the distribution of macrobenthos, but the dynamic property of sediment mobility must also be important. Relative sediment mobility can be inferred from observations of bedforms in bottom photographs and from submersible observations (Folger 1977), direct observations of movement such as those made during the USGS studies in the area (Butman et al. 1977), and theoretical considerations based on water depth and bottom topography (e.g. Chapter 12 and Stubblefield et al. 1975).

Disturbance on the inner and central shelf is frequent and is due primarily to oscillatory bottom currents created by surface waves. Sediments in swales in the region are less affected by surface waves but may be occasionally resuspended by meteorologically-forced bottom currents moving down the swales (Stubblefield et al 1975). Surface waves are less effective in moving bottom sediments on the outer shelf, and sediments at many of the sites sampled apparently undergo long periods of quiescence (Chapter 5). Major disturbances occur here during winter storms and apparently little resuspension takes place during the remainder of the year (Butman et al. 1977). Although bedforms in evidence of physical disturbance are visible in photographs of bottoms deeper than 100 m, sediments in the shelf break region must be much less dynamic than on the shelf.

Major changes in the frequency of sediment mobility seem to take place in the same portions of the shelf gradient as the biological and temperature range changes, namely between the central and outer shelf and outer shelf and shelf break region. Thus, it is difficult to determine the relative importance of sediment size and mobility and the temperature regime to the distribution of benthos. The detailed analysis of distribution patterns in Area B sheds some light on this subject because there were only minor temperature differences

among the four stations. Apparent differences in sediment mobility and relatively minor differences in sediment characteristics coincided with major changes in community composition and trophic structure. This suggests that sedimentologic factors are more important than temperature regime over much of the shelf. However, at the deeper shelf break stations, sediment characteristics appear less important than on the shelf. For example, the muddy stations in area A have a slightly different fauna than the much less muddy stations in area F. However, these differences are less than would be expected from such different sediment characteristics on the shelf. This suggests that the effect of temperature is preeminent at the shelf break and continental slope.

Biotic Factors

Although this sampling study did not permit direct determination of biotic factors affecting community composition and structure, observations lead to several preliminary hypotheses regarding the importance of biotic interactions. The abundance of epibenthic predators, including mega-invertebrates and demersal fishes, is great over most of the study area. Bottom photographs and direct submersible observations indicate higher densities of predaceous asteroids, crabs (*Cancer* spp.) and bottom feeding fishes (e.g. flat fishes, hakes and skates) than would be inferred from grab samples or dredge and trawl hauls. Their effects on infaunal communities include direct mortality due to predation, which selects for species which can avoid predation, and mortality or non-lethal disturbance due to foraging activities, which selects for species which can recover from sediment disturbance (Virnstein 1977).

Interspecific competition within benthic communities does not seem to produce dramatic effects of exclusion or monopolization of resources. In fact, in those instances of extreme abundance of one species, for example at B3 which was dominated by the amphipod *Ampelisca agassizi*, the diversity and abundance is also high, probably as a result of increased habitat heterogeneity caused by tubes, etc. Although there were many instances of habitat segregation by congeners, for example *Clymenella torquata* and *C. zonalis* (Figure 6-45), this is more probably the evolutionary end product of habitat selection rather than the result of contemporary competitive exclusion. Interference competition may, however, be important within the communities as a result of sediment disturbance by animal activity.

Benthos and Impact Assessment

Benthic Resources

Several members of the benthos of the study area are (or may be) commercially exploited. These include the surf clam, *Spisula solidissima*, the ocean quahog, *Arctica islandica*, the deep-sea scallop, *Placopecten magellanicus*, the American lobster, *Homarus americanus*, the rock and Jonah crabs, *Cancer irroratus* and *C. borealis*, and the red crab, *Geryon quinquidens*. All of these species except the American lobster were collected regularly in the present study; however, the sampling gear employed was not designed to collect these larger commercial species efficiently. Sampling results indicate the distribution of these species on the continental shelf and slope, but not their abundance. The distributions found coincide well with known distributions for the species (Saila and Pratt 1973). *Spisula* was found on the inner and

central shelf, *Arctica* on the central and outer shelf, and *Placopecten* on the outer shelf to the shelf break. The *Cancer* species broadly overlapped, with *C. irroratus* occurring on the inner to outer shelf and *C. borealis* occurring on the outer shelf and shelf-break zone. *Geryon* was found only on the continental slope.

Commercially valuable species of demersal fishes and squid also occur in the study area and were occasionally captured in trawl (SBT) hauls.

The benthic environment of the Middle Atlantic Bight harbors important living resources, both in terms of benthic species of direct importance and in terms of trophic support of demersal fisheries. Many of the species of macrobenthos discussed in this report are important prey items of a number of exploited fishes (Maurer and Bowman 1975). Because of the high resource value of the benthic environment and the sedimentary nature of contaminants which may result from oil and gas development, impact studies should concentrate on effects on benthic organisms and resources.

Important or Sensitive Communities

The benthic communities of the outer continental shelf and shelf break areas which are planned for future development are diverse and dense. In particular, they contain large populations of crustaceans and near surface dwelling polychaetes known to be important food items for demersal fishes (Maurer and Bowman 1975; McEachran et al. 1976). Swale habitats appear to be more biologically productive of benthos and of inordinate importance for living resources. Furthermore, the selective deposition of fine sediments in swales would allow greater chance of contamination of the sediments and organisms by toxic materials resulting from development activities. For these reasons of biological importance and vulnerability, it is recommended that special precaution be taken in managing developments which might impact swale habitats. It appears that swale habitats can be fairly well identified and delineated, although with somewhat arbitrary boundaries, based on the detailed bathymetric charts which are available.

Relationship to Contaminants

There has been no evidence that toxic materials are having an effect on the benthos at the locations sampled. Concentrations of trace metals (Chapter 8) and petroleum hydrocarbons (Chapter 9) in megabenthic organisms were generally very low. Bioaccumulation of anthropogenic trace metals and possible effects of these and other toxic materials on the benthos have been demonstrated near the New York Bight apex dump sites (Pearce 1972) and the Philadelphia dump site off Delaware Bay (Lear et al. 1974). However, the central study area was too far away from those sources to experience detectable elevation above "background" concentrations.

The concentration of trace metals in megabenthic species appeared to be related to the sediments on/in which the animals were living. Specimens from stations with higher silt and clay content of sediments had higher metals concentrations, reflective of the higher concentrations of trace metals in those sediments (Chapter 8).

Temporal Variations in the Benthos

A major difficlty in establishing biological "baseline" conditions is the determination of temporal patterns of variability against which changes can be measured. Highly variable and dynamic communities present a particular problem, because it often becomes impossible to determine if changes witnessed in impact investigations are due to effects of man's activities or natural variations.

Four seasons of sampling have shown the benthic communities of the Middle Atlantic Bight have persistent integrity. That is to say, at any given station, if adequately relocated, collections from one season to another are very similar as evidenced in the numerical classifications of macro- and megabenthos. This was apparent even though population estimates of individual species were variable among replicates and seasons. Preliminary conclusions drawn on this first year's data are that the dynamics of individual populations are more persistent than reported for other temperate continental shelf and coastal communities (Boesch et al. 1976; Frankenberg and Leiper 1977).

If this persistence is shown to continue over longer periods of time, confidence in projections from "baseline" conditions would improve. The observed persistence also indicates that monitoring of long-term community dynamics need not be continued for several years over all stations in order to establish a reliable baseline. Rather, more efficient long-term (more than two years) studies should be limited to a smaller subset of stations, in this case those for which seasonal rather than semiannual sampling has been accomplished.

The magnitude of future environmental contamination resulting from oil and gas development is, of course, unknown. Furthermore, virtually nothing is known regarding the sensitivity of the benthic biota of the outer continental shelf. However, the macrobenthic communities of the potentially more susceptible swale environments in areas of imminent development contain abundant populations of peracaridean crustaceans which have been shown to be among the more sensitive members of the benthos to oil pollution (Sanders et al. 1972). Thus, the feasibility of detection of biologically significant impacts of oil and gas development on the macrobenthos should be relatively good.

Summary of Significant Findings

1. The megabenthos and macrobenthos demonstrated similar distribution patterns across the shelf. Faunal changes were mainly continuous rather than abrupt, but five faunal zones could be distinguished: inner shelf (to 30 m), central shelf (30-50 m), outer shelf (50-100 m), shelf break (100-200 m), and continental slope (> 200 m). Inner and central shelf assemblages were relatively similar, and outer shelf assemblages contained both inshore and offshore species overlapping in distribution, but shelf break and continental slope assemblages were more discrete.

2. Although difficult to fully assess on the basis of one year's data, the megabenthos and macrobenthos of the Middle Atlantic continental shelf and slope display remarkably little seasonality. Although there was evidence for seasonal change in density and age structure

of some populations, populations generally did not fluctuate as widely as is usual for temperate benthos. Assemblages at specific stations generally retained qualitative similarity and constancy of dominant species from season to season.

3. Biomass of macrobenthos was similar to that reported in other studies in the Middle Atlantic Bight. Numerical density, however, was much greater owing in part to the finer sieve mesh size used in this study. Biomass distribution patterns varied among the higher taxa. Biomass of annelids and molluscs was highest on the outer shelf and in topographic depressions, whereas echinoderm biomass, dominated by the sand dollar *Echinarachnius parma*, was highest on the inner and central shelf. Total density of macrobenthos was also highest on the outer shelf. Macrobenthic density on the continental slope was one-third or less than typical on the continental shelf.

4. Species diversity of megabenthos and macrobenthos generally increased with depth. Highest Shannon diversity and numerical species richness of macrobenthos was found on the shelf break and continental slope and lowest was found on the inner shelf. Species richness in topographic depressions was also high, but Shannon diversity was not because of typically heavy dominance. Species diversity on the outer shelf and shelf break was higher than previously reported.

5. Major faunal differences occur over small distances in relation to ridge and swale topography. Swales have finer sediments with more organic carbon than ridges and flanks. The benthos of swales is more abundant and has a greater biomass and species richness. Because their benthic biota is richer and potentially contaminated fine sediments may be deposited there, swale environments must be regarded as relatively more valuable and susceptible shelf habitats.

6. Anoxic or hypoxic conditions developed in bottom waters over a broad area of the inner and central shelf off New Jersey during the summer of 1976. The oxygen stress resulted in mass mortalities of many megabenthic and macrobenthic species. Crustaceans and echinoderms were particularly affected; however, some species of molluscs and annelids demonstrated no reduction in population density.

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Appendix 6-A. Megabenthic taxa collected and the stations at which each occurred. Collection by small biology trawl (S) or anchor dredge (A) and stations at which taxon was numerically dominant (italicized) are indicated.

Taxon	SBT Anchor	Station(s)
PROTOZOA		
Sarcodina		
Astrorhizidae		
Astrorhiza limicola	SA	*B1*,C2,D1,D4,*E1*,F1,I1,N3
PORIFERA		
Calcarea		
Heterocoelidae		
Scypha ciliata	S	I1
Desmospongiae		
Suberitidae		
Polymastia robusta	S	J1
Suberites ficus		
Myxillidae	S	C2,D4
Mixilla fimbriata	SA	A1,I1
Mixilla incrustans	S	A1
Halichondridae		
Halichondria sp.	S	E1,I1,J1
CNIDARIA		
Hydrozoa		
Tubulariidae		
Tubularia sp.	S	I1
Corymorpha pendula	S	A1,F1
Bougainvilliidae		
Garveia sp.	S	D1
Eudendriidae		
Eudendrium ramosum	S	A1,F1,I1
Haleciidae		
Halecium sp.	S	A1,B1,D1,I1
Campanulariidae		
Clytia sp.	S	B1,C2,D1
Clytia hemisphaerica	S	A1,B1,I1
Clytia paulensis	S	I1
Obelia longissima	SA	A1,B1,C2,D1,D4,E1,I1,N3,J1
Obelia geniculata	S	D1,D4
Campanularia verticillata	SA	B1,D1,D4,I1,N3
Sertulariidae		
Sertularia cupressina	SA	A1,B1,C2,D1,D4,E1,F1,I1,N3
Sertularia polyzonias	S	D4
Plumularidae		
Cladocarpus flexilis	SA	A1,I1
Nemertesia antennina	SA	B1,E1,I1
Campanuliidae		
Cuspidella grandis	S	I1
Stegopoma fastigatum	S	A1,F1,I1

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Lafoeidae		
Lafoea dumosa	S	A1,I1
Anthozoa		
Alcyoniidae		
Alcyonium digitatum	SA	A1,I1
Edwardsiidae		
Edwardsia elegans	S	C2
Halcampidae		
Actinauge rugosa	S	J1
Zoanthidae		
Virgularia sp.	SA	A1,F1,J1
ENTOPROCTA		
Pedicellinida		
Pedicellinidae		
Pedicellina sp.	S	I1
ANNELIDA - (POLYCHAETA)		
Phyllodocida		
Aphroditidae		
Aphrodita hastata	SA	A1,B1,D1,D4,E1,I1,N3
Laetmonice filicornis	S	J1
Eunicida		
Onuphidae		
Hyalinoecia artifex	SA	*J1*
Nothria conchylega	SA	A1,F1,I1,J1
MOLLUSCA		
Scaphopoda		
Dentaliidae		
Dentalium occidentale	S	J1
Siphonodentaliidae		
Cadulus agassizi	S	I1,J1
Cadulus pandionis	S	J1
Gastropoda		
Trochidae		
Solariella obscure	SA	B1,D1,D4,E1,N3,J1
Calliostoma bairdii	SA	A1,E1,F1,I1,J1
Architectonicidae		
Heliacus borealis	S	J1
Epitoniidae		
Epitonium dallianum	SA	A1,I1
Calptraeidae		
Crepidula plana	S	C2,D1
Crucibulum striatum	SA	B1,D4,E1,N3
Naticidae		
Polinices immaculatus	SA	B1,D1,D4,E1,F1,I1,N3
Polinices uberinus	S	B1
Lunatia heros	SA	A1,B1,C2,D1,E1,N3
Lunatia triseriata	SA	B1,D4,E1,N3

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Tonnidae		
Eudolium crosseanum	S	J1
Columbellidae		
Buccinidae		
Astyris diaphana	S	I1,J1
Buccinum undatum	SA	B1,N3
Colus pygmaeus	SA	B1,D1,E1,J1,N3
Colus pubescens	S	J1
Colus stimpsoni	S	J1
Nassariidae		
Nassarius trivittatus	SA	B1,*C2*,D1,D4,E1,N3
Turridae		
Enlimella smithi	S	E1
Inodrilla dalli	S	J1
Propebela harpularia	S	J1
Scaphandridae		
Cylichna alba	SA	F1,J1
Cylichna verrilli	SA	F1
Philinidae		
Philine quadrata	S	A1,D1,E1,J1
Pyramidellidae		
Turbonilla interrupta	SA	B1,E1,F1,I1,J1
Pleurobranchidae		
Pleurobranchaea tarda	S	A1,B1,C2,D1,E1,F1,J1,N3
Dendronotidae		
Dendronotus frondosus	S	F1
Pelecypoda		
Nuculanidae		
Yoldia sapotilla	SA	A1,F1,J1
Nuculana acuta	S	J1
Nuculana caudata	S	J1
Arcidae		
Bathyarca pectunculoides	S	J1
Mytilidae		
Modiolus modiolus	SA	A1,E1,F1,I1
Musculus niger	SA	B1,D4,I1,N3
Crenella glandula	SA	A1,B1,C2,F1,I1
Pectinidae		
Placopecten magellanicus	SA	A1,B1,D1,D4,E1,F1,I1,N3
Cyclopecten nanus	SA	A1,E1,F1,*I1*
Anomiidae		
Anomia simplex	SA	B1,E1,I1
Anomia squamula	S	B1,E1,I1,N3
Astartidae		
Astarte castanea	SA	B1,C2,D1,D4,E1,F1,I1,N3
Astarte undata	SA	*A1*,*B1*,D4,E1,*F1*,*I1*,J1
Astarte crenata subequilatera	SA	A1,B1,E1,F1,*I1*,J1,N3

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Carditidae		
Cyclocardia borealis	SA	A1,*B1*,D1,D4,*E1*,F1,*I1*,N3
Arcticidae		
Arctica islandica	SA	A1,*B1*,D1,E1,F1,I1,*N3*
Lucinidae		
Lucinoma filosa	SA	A1,J1
Myrtaea lens	S	J1
Cardiidae		
Cerastoderma pinnulatum	SA	B1,C2,D1,D4,E1,I1,N3
Veneridae		
Pitar morrhuana	SA	A1,B1,C2,D1,D4,E1,N3
Tellinidae		
Tellina agilis	SA	C2,D1,N3
Semelidae		
Abra liocia	S	J1
Solenidae		
Ensis directus	SA	*B1*,C2,*D1*,D4,*E1*,I1,*N3*
Mactridae		
Spisula solidissima	SA	*C2*,*D1*,D4,N3
Lyonsiidae		
Lyonsia hyalina	SA	B1,C2,D1,D4,E1,N3
Pandoridae		
Pandora gouldiana	SA	B1,C2,*D1*,D4,E1,F1,I1,*N3*
Pandora inflata	SA	*A1*,F1,I1
Periplomatidae		
Periploma fragile	SA	A1,C2,F1,J1
Periploma leanum	A	F1,I1
Poromyidae		
Poromya granulata	S	J1
Cuspidariidae		
Cardiomya perrostrata	S	J1
Cuspidaria rostrata	S	A1,F1,J1
Thyasiridae		
Thyasira flexuosa	S	A1,J1
Cephalopoda		
Loliginidae		
Loligo pealeii	S	I1
Sepiolidae		
Rossia tenera	SA	A1,B1,D4,E1,F1,I1,J1,N3
PYCNOGONIDA		
Phoxichiliidae		
Anoplodactylus lentus	S	F1
Anoplodactylus petiolatus	S	A1,F1,I1,J1
Anoplodactylus iuleus	S	J1
Ammotheidae		
Ascorhynchus pyrginospinum	S	A1
Nymphonidae		
Nymphon grossipes	S	D4,J1

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
CRUSTACEA		
Stomatopoda		
Lysidsquillidae		
Platysquilla enodis	S	C2
Cumacea		
Diastylidae		
Diastylis bispinosa	SA	A1,B1,E1,F1,I1,J1
Diastylis cornuifer	S	J1
Isopoda		
Idoteidae		
Edotea triloba	SA	A1,B1,C2,D1,N3
Edotea acuta	S	E1
Edotea montosa	SA	B1,D1,D4,E1,F1,I1,N3
Cirolanidae		
Cirolana polita	SA	A1,B1,C2,D1,E1,F1,I1,J1,N3
Cirolana concharum	S	C2
Cirolana impressa	SA	J1
Janiridae		
Janira alta	S	I1
Amphipoda		
Ampeliscidae		
Ampelisca vadorum	SA	A1,B1,D1,D4,E1,F1,I1
Ampelisca verrilli	S	A1,D4
Ampelisca macrocephala	S	B1
Ampelisca agassizi	S	A1,B1,E1,F1,J1
Byblis serrata	SA	B1,D4,N3
Aoridae		
Leptocheirus pinguis	SA	A1,B1,D1,D4
Corophiidae		
Erichthonius brasiliensis	S	B1
Erichthonius rubricornis	S	B1,E1,I1,J1,N3
Unciola irrorata	SA	A1,B1,D1,E1,F1,I1,N3
Unciola spicata	SA	A1,D4,F1,I1,J1
Unciola dissimilis	S	D4,E1
Siphonoecetes colletti	S	D1
Siphonoecetes new sp.	S	B1,D1,I1
Gammaridae		
Melita dentata	SA	B1,D1,D4,E1,I1
Casco bigelowi	S	D4,E1
Haustoriidae		
Protohaustorius wigleyi	S	N3
Isaeidae		
Photis dentata	SA	E1,F1,J1
Gammaropsis nitida	S	N3
Lysianassidae		
Hippimedon serratus	S	B1
Anonyx sarsi	SA	C2,N3

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Paramphithoidae		
Epimeria loricata	S	J1
Epimeria new sp.	S	F1,J1
Caprellidae		
Aeginina longicornis	S	B1,D1,D4,E1,I1,N3
Caprella unica	S	B1
Euphausiacea		
Euphausiidae		
Meganyctiphanes norvegica	S	J1
Decapoda		
Sergestidae		
Sergestes arcticus	S	J1
Hippolytidae		
Caridion gordoni	S	E1,I1
Eualus pusiolus	S	A1,D1,D4,F1,I1,J1
Spirontocaris lilljeborgii	S	J1
Bythocaris nana	S	A1,F1,I1,J1
Processidae		
Processa profunda	S	J1
Pandalidae		
Dichelopandalus leptoceras	SA	A1,*B1*,C2,D1,D4,E1,F1,I1,J1,*N3*
Parapandalus willisi	S	J1
Crangonidae		
Crangon septemspinosa	SA	A1,*B1*,*C2*,*D1*,D4,*E1*,F1,I1,*N3*
Pontophilus brevirostris	SA	*A1*,B1,*F1*,I1,J1
Homaridae		
Homarus americanus	S	J1
Scyllaridae		
Scyllarus chacei	S	A1
Galatheidae		
Munida iris	S	A1,E1,F1,I1,J1
Munida valida	S	J1
Paguridae		
Catapagurus sharreri	S	A1,J1
Pagurus acadianus	SA	B1,*C2*,D1,D4,E1,I1,*N3*
Pagurus longicarpus	S	C2
Pagurus politus	S	J1
Pagurus pollicaris	S	C2
Pagurus arcuatus	SA	A1,B1,C2,D1,D4,E1,F1,I1,N3
Parapagurus arcuatus	S	J1
Calappidae		
Acanthocarpus alexandri	S	J1
Portunidae		
Bathynectes superbus	S	F1,J1
Ovalipes ocellatus	S	C2
Ovalipes stephensoni	A	D1
Ovalipes sp.	S	B1

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Cancridae		
Cancer borealis	SA	*A1*,B1,D1,D4,E1,*F1*,*I1*,J1,N3
Cancer irroratus	SA	A1,*B1*,C2,*D1*,D4,*E1*,F1,I1,*N3*
Goneplacidae		
Geryon quinquedens	S	J1
Goneplax hirsuta	S	A1
Pinnotheridae		
Dissodactylus mellitae	S	C2
Palicidae		
Cymopolia cursor	S	J1
Majidae		
Collodes robustus	S	A1,F1,I1
Euprognatha rastellifera	SA	*A1*,*F1*,I1,J1
Hyas coarctatus	S	A1,B1,E1,I1,J1,N3
Hyas araneus	S	B1,N3
Parthenopidae		
Parthenope pourtalesi	S	A1
SIPUNCULIDA		
Phascolopsis gouldii	S	C2
ECHINODERMATA		
Asteroidea		
Astropectinidae		
Astropecten americanus	SA	*A1*,B1,C2,D1,*E1*,*F1*,*I1*,*J1*,N3
Odontasteridae		
Odontaster setosus	S	J1
Echinasteridae		
Henricia sanguinolenta	SA	A1,B1,E1,F1,I1,N3
Asteriidae		
Asterias forbesi	SA	B1,*C2*,*D1*,E1,F1,N3
Asterias vulgaris	SA	A1,*B1*,C2,*D1*,D4,E1,F1,I1,*N3*
Sclerasterias tanneri	SA	B1,D1,E1,I1,N3
Leptasterias tenera	SA	A1,E1,F1,I1,J1
Coronaster briareus	S	I1,J1
Stephanasterias albula	S	*J1*
Echinoidea		
Strongylocentrotidae		
Strongylocentrotus droebachiensis	S	B1,E1,I1,N3
Echinarachiniidae		
Echinarachnius parma	SA	A1,*B1*,*C2*,*D1*,D4,*E1*,F1,I1,*N3*
Ophiuroidea		
Amphiuridae		
Amphioplus macilentus	SA	A1,E1,F1,I1
Axiognathus squamata	SA	A1,B1,E1,F1,I1,J1
Ophiactidae		
Ophiopholis aculeata	S	D1,E1,I1
Ophiacanthidae		
Amphilimna ovalacea	SA	A1,E1,F1,I1,J1

Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Holothuroidea		
Cucumariidae		
Stereoderma unisemita	SA	A1,B1,C2,E1
Phyllophoridae		
Havelockia scabra	SA	A1,B1,E1,I1,J1
UROCHORDATA		
Ascidiacea		
Molgulidae		
Molgula arenata	SA	A1,B1,C2,D1,E1,*F1*,I1,J1,N3
Styelidae		
Dendroda carnea	SA	A1,B1,D1,D4,E1,I1,N3
Ascidiidae		
Ascidia callosa	S	A1,I1
CYCLOSTOMATA		
Myxiniformes		
Myxinidae		
Myxine glutinosa	S	J1
ELASMOBRANCHII		
Rajiformes		
Rajidae		
Raja erinacea	SA	B1,C2,D1,D4,E1,I1
TELEOSTEI		
Anguilliformes		
Ophichthidae		
Pisodonophis cruentifer	SA	A1,B1,E1,*F1*,I1,J1,N3
Lophiiformes		
Lophiidae		
Lophius americanus	S	A1,I1
Gadiformes		
Gadidae		
Phycis chesteri	S	J1
Urophycis chuss	SA	B1,C2,D1,D4,E1,I1,J1,N3
Urophycis regius	SA	D1,I1,J1,N3
Enchelyopus glutinosus	S	J1
Merlucciidae		
Merluccius albidus	S	J1
Ophidiidae		
Lepophidium cervinum	S	A1,B1,E1,F1
Macruridae		
Nezumia bairdii	S	J1
Coelorhynchus coelorhynchus carminatus	S	J1
Zoarcidae		
Macrozoarces americanus	S	E1

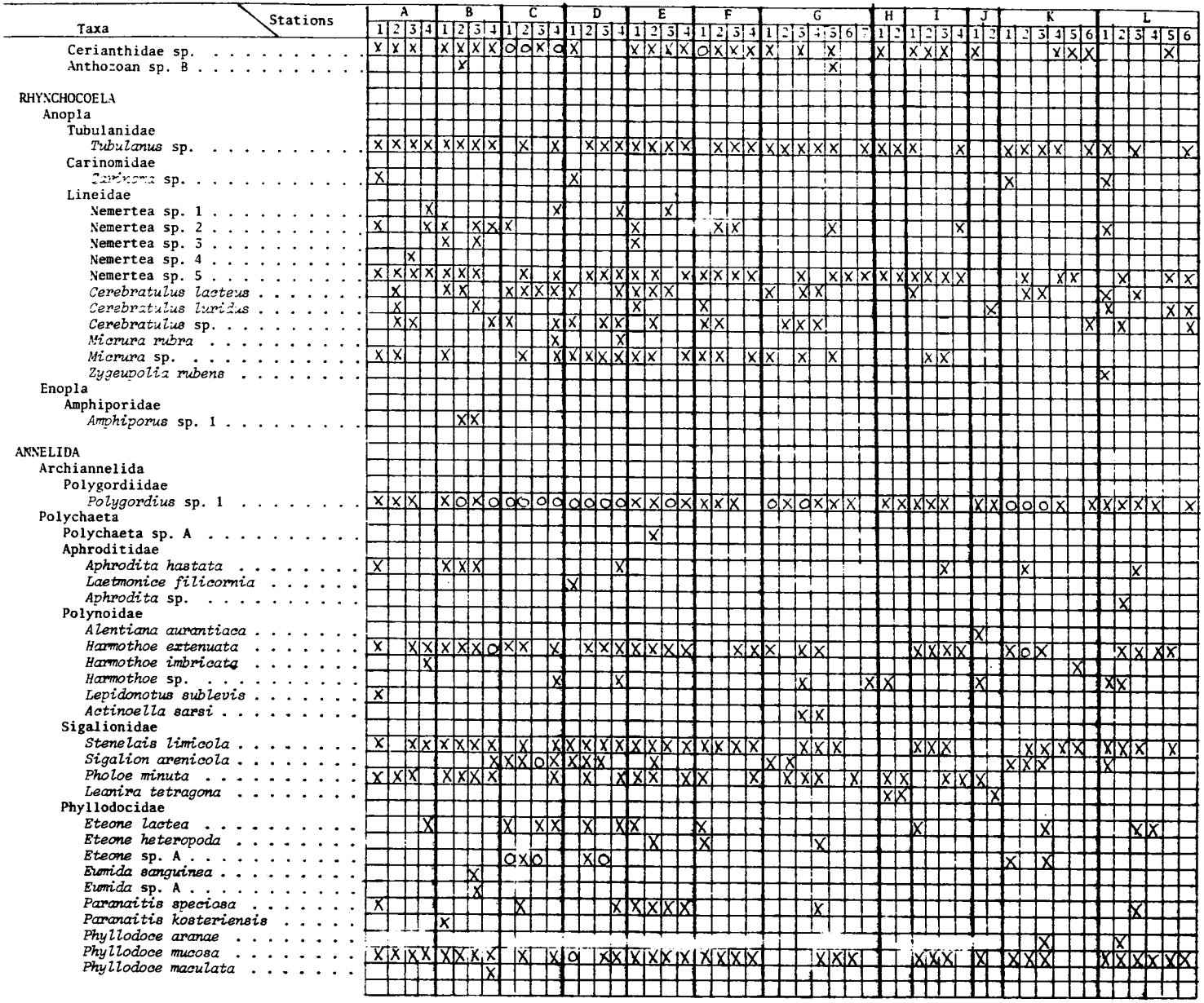
Appendix 6-A (continued).

Taxon	SBT Anchor	Station(s)
Gasterosteiformes		
Syngnathidae		
Hippocampus erectus	S	C2,D4
Sygnathus sp.	S	C2,D1
Scorpaeniformes		
Triglidae		
Prionotus carolinus	S	C2
Prionotus evolans	S	A1
Cyclopteridae		
Liparis enquilinus	SA	B1,D1,E1,N3
Percoidei		
Serranidae		
Centropristis striata	S	D1,I1
Labroidei		
Labridae		
Tautogolabrus adspersus	S	D1
Blennioidei		
Pholididae		
Pholis gunnellus	S	B1,D1
Ammodytoidei		
Ammodytidae		
Ammodytes americanus	SA	C2,D1,E1,N3
Gobioidei		
Gobiidae		
Gobiosoma ginsburgi	S	C2,D1
Pleuronectiformes		
Bothidae		
Citharichthys arctifroms	SA	A1,B1,C2,D1,D4,E1,F1,I1,N3
Hippoglossina oblonga	S	B1,I1,J1
Pleuronectidae		
Glyptocephalus cynoglossus	S	J1

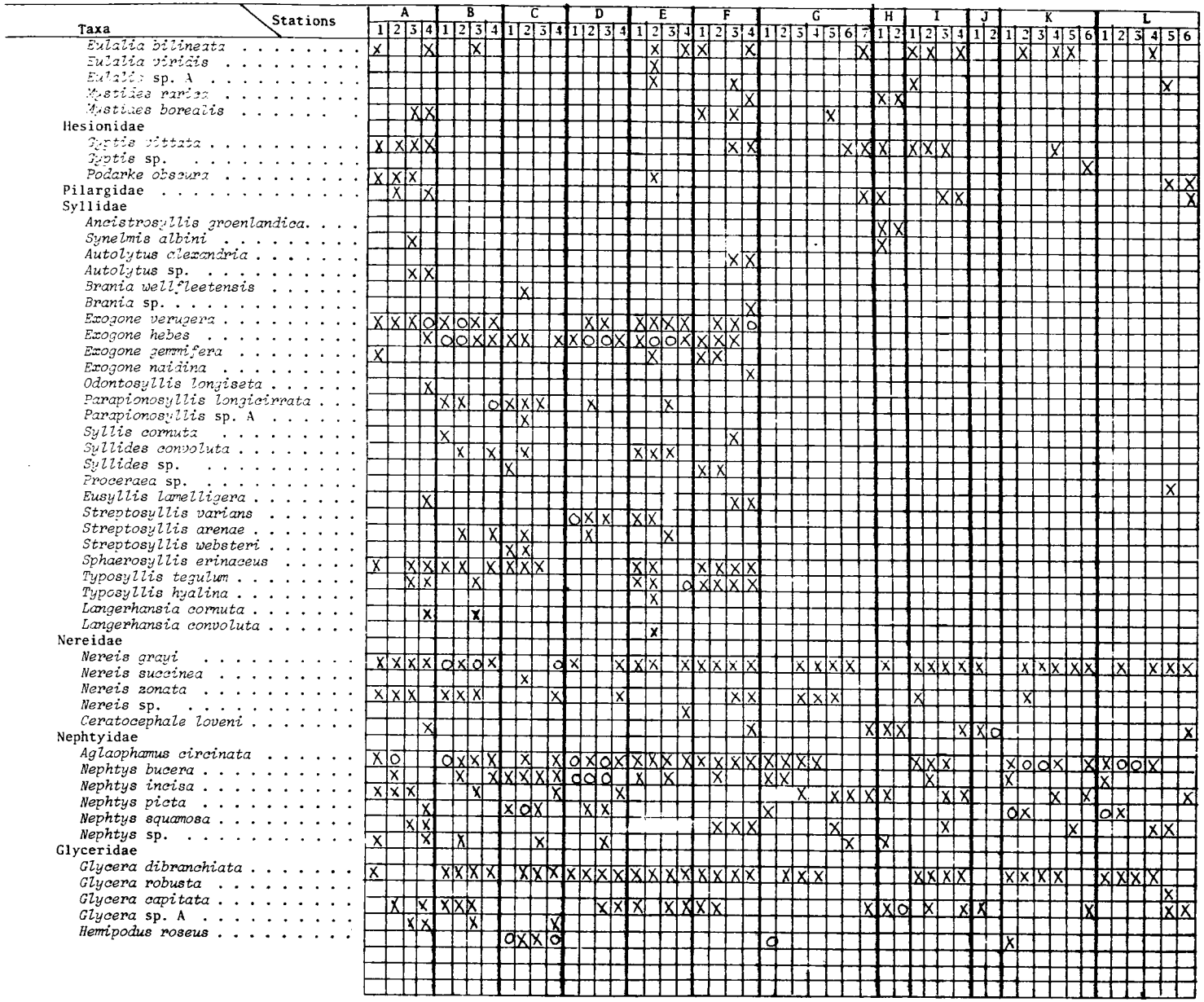
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. X = present; 0 = one of 10 most abundant species.

Taxa	Stations	A				B				C				D				E				F				G							H		I				J		K					L					
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	5	6
PORIFERA																																																				
Porifera sp. 1																									X																					X					
Porifera sp. 2																																									X										
Porifera sp. 3																										X				X															X					
Calcarea																																																			
Heterocoelidae																																																		
Scypha sp.																			X	X															X	X										X					
Desmospongiae																																																			
Haliclonidae																																																			
Haliclona permollis										X																																								
Microcionidae																																																			
Eurypon clavata																																				X															
CNIDARIA																																																			
Hydrozoa																																																			
Tubulariidae																																																			
Tubularia larynx											X																																							
Haleciidae																																																			
Halecium halecium															X																																				
Halecium articulosum							X																																											
Campanulariidae																																																			
Clytia hemisphaerica					X		X												X								X																								
Clytia paulensis							X																																											
Obelia longissima							X	X							X		X			X			X				X	X		X					X		X					X										
Gonothyraea loveni								X																																										
Campanularia verticillata						X										X											X								X															
Lovenellidae																																																			
Lovenella grandis										X	X	X																																						
Sertulariidae																																																			
Sertularia cupressina					X	X	X	X		X		X		X		X		X	X	X						X	X	X	X						X		X					X					X				
Sertularia latiuscula					X													X																																	
Plumularidae																																																			
Cladocarpus flexilis		X		X														X																	X															
Incertae sedis																																																		
Eulaomedea gelatinosa															X																																			
Campanuliidae																		X																																	
Stegopoma fastigatum																																																		
Lafoeidae																																																		
Lafoea dumosa		X																																																
Hydractiniidae																																																		
Hydractinia echinata															X					X																															
Anthozoa																																																		
Pennatulidae																																																		
Pennatulidae sp. 1		X		X	X	X				X					X							X	X		X			X																						
Edwardsiidae																																																		
Edwardsia sp.		X	X	X	X	X	X	X	X			X	X	X					X	X	X	X	X	X	X	X		X		X	X	X	0	0	X		X	0	0	X			X	X	X	X		X	X	X	X
Metridiidae																																																		
Metridium senile		X				X		X				X	X					X	X	X						X		X	X						X					X						X				
Halicampoididae																																																		
Eloactis sp. 1				X																																													
Eloactis producta		X		X																					X		X																						
Halcampidae																																																		
Bicidium sp. 1		X		X														X		X																														
Trochosmiliidae																																				X									X	X				X	
Caryophylliidae																																																	X		
Zoanthidae																																																		
Parazoanthus sp.		X					X																																											
Isozoanthus sp.			X	X	X															X	X												X					X	X	X			X	X			X	X		
Epizoanthus incrustatus			X	X	X												X	X		X	X								X					X	X	X	X	X	X			X	X	X			X	X		

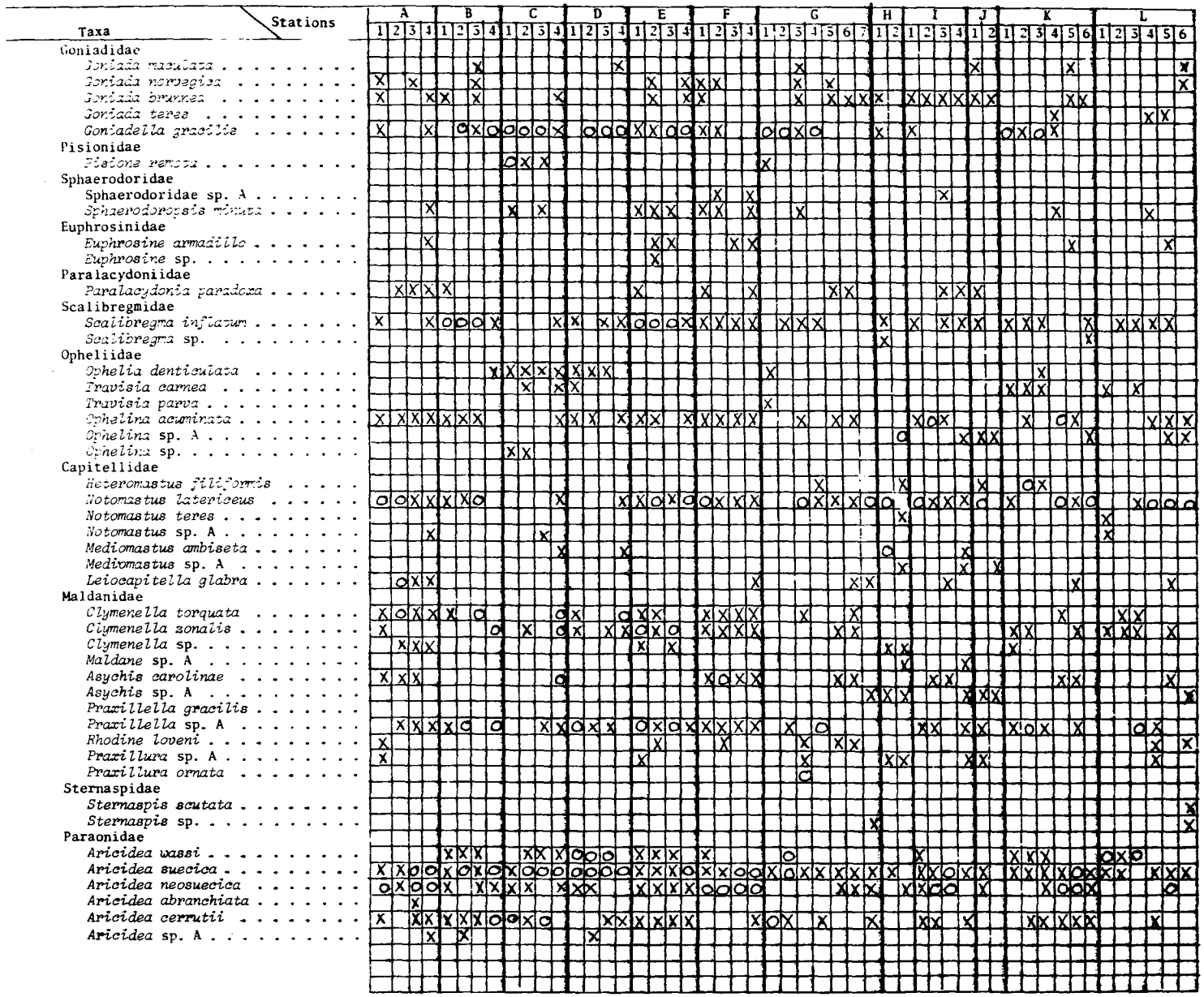
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



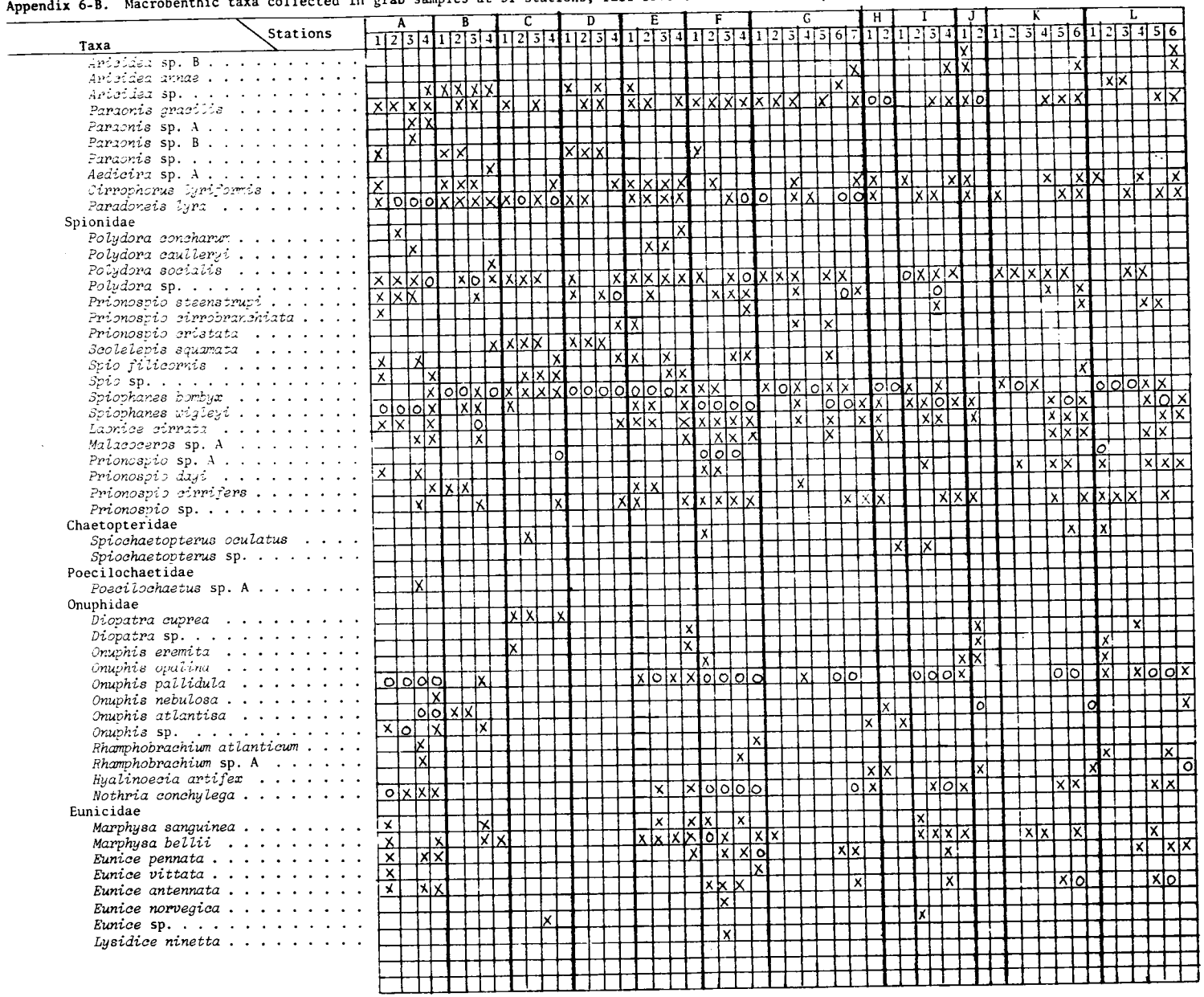
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



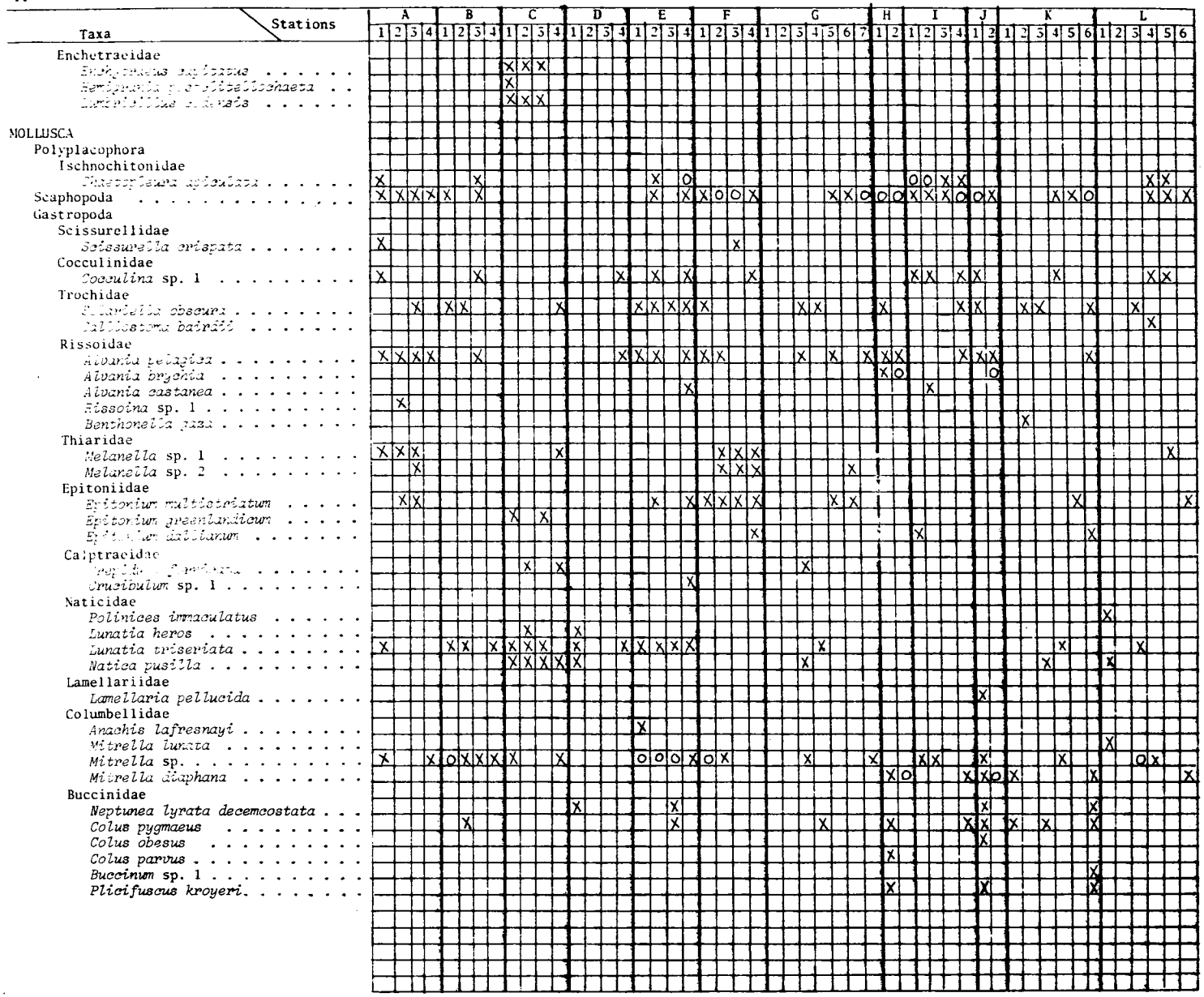
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).

Taxa \ Stations	A				B				C				D				E				F				G							H		I			J		K						L					
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	5	6
Lumbrineridae																																																		
Lumbrineris tenuis						X															X											o	X			o	o	o											
Lumbrineris fragilis	X	X	X	X	X	X	X	X	X	o	o	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X			X	X		X	o	o	X	X	X	X	o	X	X	X	X	X
Lumbrineris latreilli																																o										X	X					X	
Lumbrineris cruzensis	o	o	o	o			X		X									X		X	o	o	o	o				o	o			o	X	X		o	o	o				o	o	X			X	o	o
Lumbrineris impatiens	X	X	X	X	o	X	o	X		X	o	X	X		o	o	o	X	o	o			o		X		o			X		X	o	o	o	o	o	X			X			o	o	o			X
Lumbrineris albidentata	X	X	X															X		X	X	X		X				X				X	X	X				X				X	X	X				X	X
Lumbrineris sp.				X	X						X						X	X	X			X							X														X					
Ninoe nigripes	X	X		X	X		X			X	X					X		X	X	X	X		X			X			X	X	X			X				X							X			X	X
Ninoe brevipes		X																																																
Lumbrinerides acuta	X				X	o		o	X	o	o	X	X	o	X	X	X		o	X		X		X	o	X	o	X	o		X							X	o	o	X		X							
Lumbrineriopsis paradoxa			X				X		X		X								o				X																											
Arabellidae																																																		
Arabella iricolor					X								X	X	X	X	X					X													X									X						
Arabella mutans							X				X																X											X											
Drilonereis longa	X	X	X		X	X	X	X		X		O		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X
Drilonereis magna	X	X		X	X	X	X	X		X		X		X	X		X	X	X		X		X	X	X	X	X	X		X				X			X	X				X	X	X	X			
Drilonereis cuvieri																		X				X						X																						
Notocirrus spiniferus									X		X			X							X																		X		X									
Dorvilleidae																																																		
Protodorvillea gaspeensis						X				X							X	X	X	X																														
Protodorvillea kefersteini	X					X		O			O	X		X	X		X	X	X	X	X	X												X		X	X			X									
Schistomeringos caeca					X	X	X	X	X	X	O	X	X			X	X	X	X	X	X	X				X	X	X	X			X	X		X			X		X	X	X	X		X				X	X
Meiodorvillea minuta																			X	X			X						X																				
Amphinomidae																																																		
Paramphinome pulchella																				X												X	o	X			o	o	o									X	o
Magelonidae																																																		
Magelona sp.		X	X	X						X	X	X	X						X		X		X	X							X					X		X	X		X		X	X				X	X
Orbiniidae																																																		
Orbinia ornata																				X																														
Orbinia swani						X								X				X				X						X	X					X	X				X			X	X			X	X	X		X
Orbinia michaelseni	X																	X	X				X	X						X		X		X		X	X						X	X					X
Scoloplos fragilis						X	X					X								X																														
Scoloplos robustus												X																												X							X	X		
Scoloplos armiger																		X																														X		
Scoloplos acmeceps					X	X											o	o	X	X	o	X	X	X		X		X		X				o	X	X	X		X	X	X	X		X	X	X	X	o		
Scoloplos foliosus										X	X				X		X																					X								X				
Scoloplos sp.																																X															X			X
Naineris sp.																		X																																
Cirratulidae																																																		
Cirratulidae sp. A																																X																	
Tharyx sp.	o	o	o	o	o	o	o	o				o		X	X	o	o	o	X			X	X	o	o																				X	X		
Dodecaceria sp.																																																X		
Caulleriella sp.					o	o		X					X	o	X	X		X																													o		o	X	
Chaetozone sp.					o	X							X											X																											
Cossuridae																																																		
Cossura longocirrata	X	X	o	X																			X	X					X	X	o	X	o			X	X	o	o			X	X					X	X
Oweniidae																																																		
Myriochele heeri	X	X		X		X													X	X	X	X					X	X	X	X		X				X	X	X	X				X	X			X	X	X
Myriowenia sp. A																		X									X					X	X	X			X							X				
Owenia fusiformis																																																X		

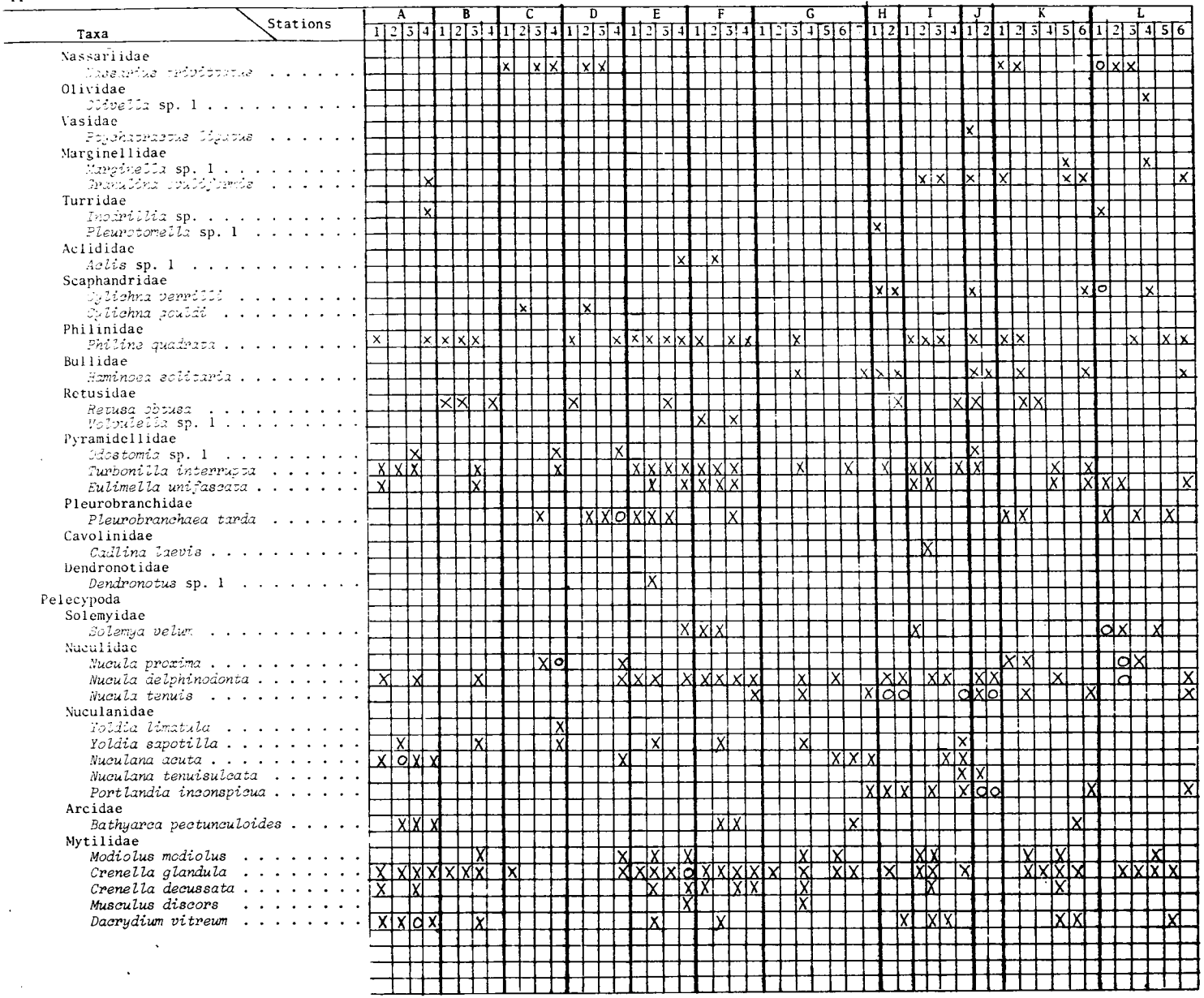
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).

Taxa \ Stations	A				B				C				D				E				F				G							H		I				J	K					L					
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	5	6
Amphictenidae																																																	
Cistena gouldii									X																																								
Cistena hyperborea																																															X		
Ampharetidae																																																	
Asabellides oculata																					X																									O			
Melinna cristata	X	X	X	X			X											X		X			X	X		X		X			X																	
Ampharete acutifrons			X														X	X	X	X	X	X	X	X	X	X																						
Ampharete arctica	X			X	X	X	X	X		X	X	X	X	X	X		X	X			X	X	X			X			X		O													X				
Ampharete sp. A							X	X		X			X				X		X	X					X		X	X																				
Amage auricula																	X	X										X	X																			
Amage tumida	X			X	X													X		X	O	X	X	X																							
Amage sp.				X																																												
Auchenoplax crinita																															O														X			
Samytha sexcirrata																															O																	
Amphicteis sp.																	X	X		X																													
Terebellidae																																																	
Lysilla alba	X			X		X		X						X										X										X	X												
Polycirrus medusa																		O	X																													
Polycirrus eximius	X	X	X	X	X	X	X	X					X			X	X	X	X	X	X	X	X	X		X	X	X	X					X	X		X		X	X	X			X	X				
Polycirrus phosphoreus	X																																															
Polycirrus sp.		X	X	X	X		X	X			X						X			X	X											X		X		X						X		X	X		
Nicolea venustula	X			X	O	X	X				X						X	X	X	X			X	X		X		X						X	X	X								X	X		
Amaeana trilobata	X	X	X	X													X		X		O	X	X	X			X																		X	X		
Artacama sp. A																											X				X	X				X											
Streblosoma spiralis							X							X				X	X	X																X	X											
Trichobranchidae																																																
Terebellides stroemi	X	O	X	X	X		X										X	X		X		X		X		X		X			X	X	X	X	X	O	X	X		X	X	X			X	X	
Flabelligeridae																																																
Flabelligeridae sp. A																																																
Pherusa affinis					X		X				O	X		X	X	X		X			X			X		X												X		X								
Pherusa inflata							X																					X											X					X				
Brada villosa		X	X	X			X							X		X			X				X		X			X	X	X		X	X	X							X					
Brada granosa																										X																					O	
Brada sp.																																	X			X												
Fauveliopsis sp. A		X	X	X																						X	X	X				X				X	X				X					X	
Sabellidae																																																
Fabricia sabella																					X		X																								
Potamilla reniformis	X						X							X	X				X							X	X											X									
Chone sp.																																X																
Euchone incolor		X	X	X	X	X	X							O	O	X	X	X					X		X	O	X	X	X	X	X		X		X			X				X					
Euchone sp. A	X		X	X	O	X	X	X					X		X	X	O	X	X				X			X	O																				X
Euchone sp.																						X																									
Chone infundibuliformis	X		X	X	X	X	O			X			X	X		O	O	O	O	X	X	O	X	O	X			X	X	X		X				O	O	O	O	X			X	X	X		O	X	
Jasmineira filiformis																															X								X									X
Megalomma bioculatum		X	X																	X																											
Serpulidae																																																
Serpulidae sp. A																															X																	
Hydroides protulicola	X						X																				X												X								
Hydroides sp.																	X			X																											
Filograma implexa																																															X	
Oligochaeta	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tubificidae																																																
Peloscolex dukei																																																
Smithsonidrilus marinus																					X	X																								X		
Clitello arenarius											X																																					
Naididae									X	X	X																																					

Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



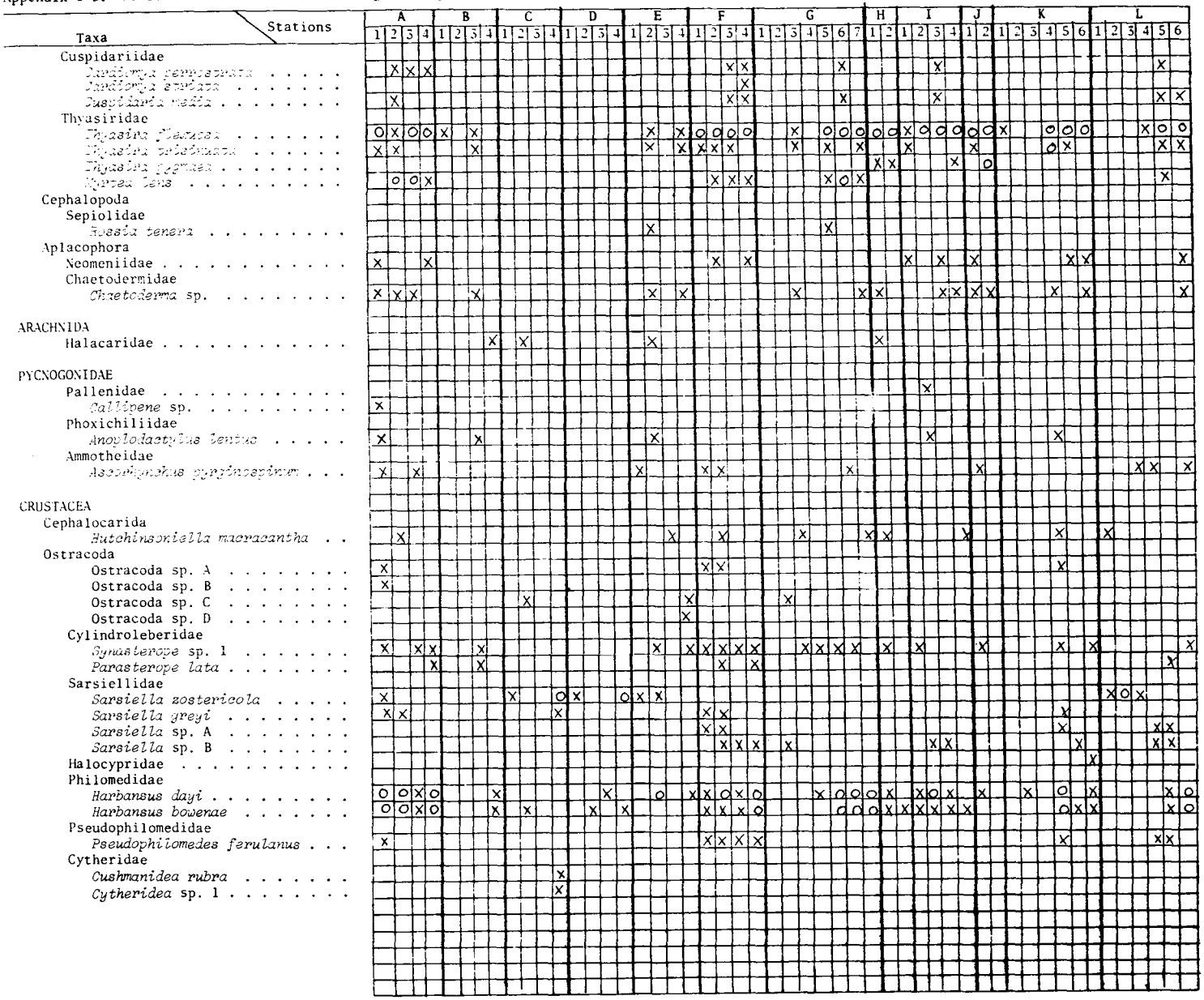
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



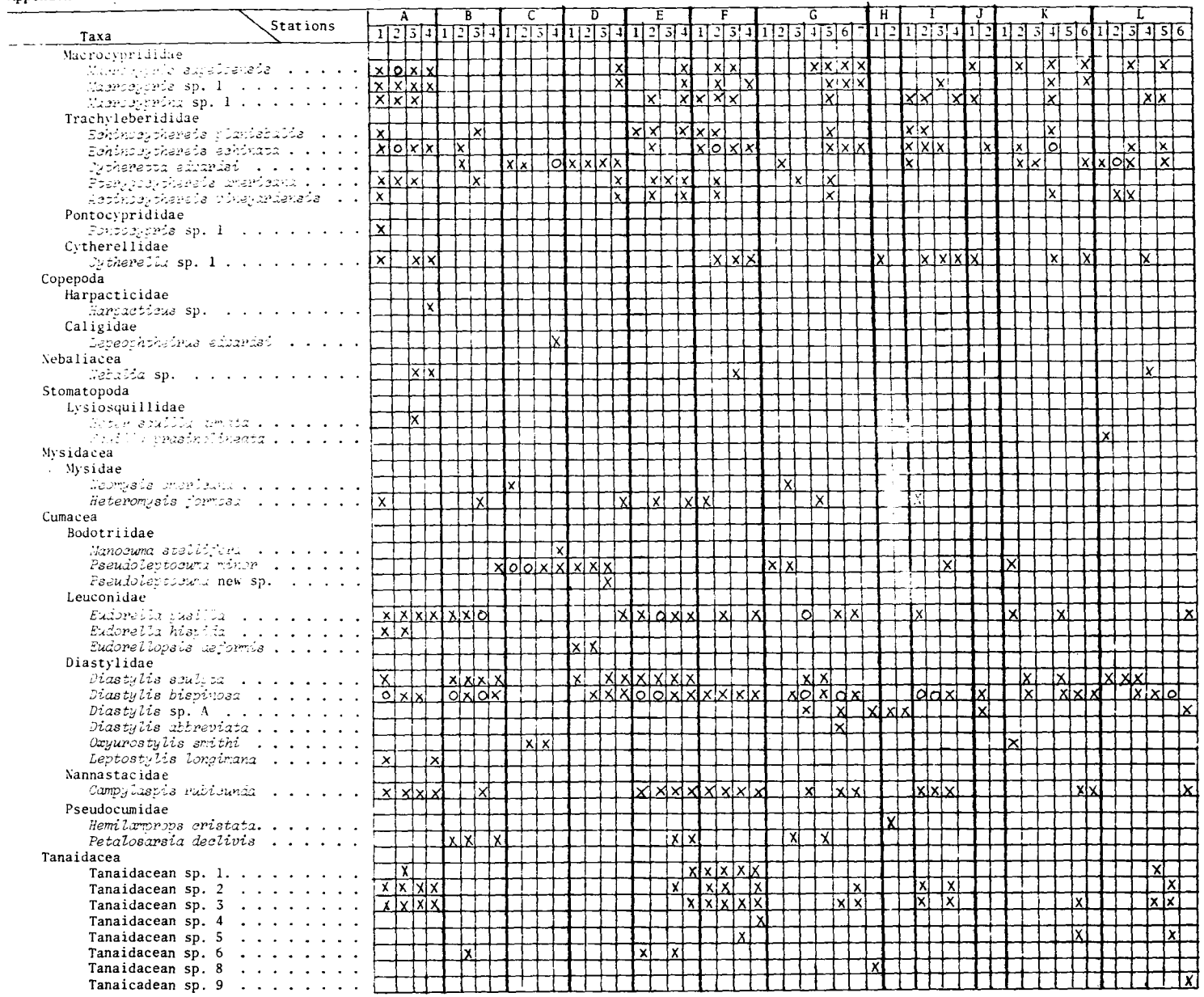
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).

Taxa \ Stations	A				B				C				D				E				F				G							H		I				J		K						L					
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	1	2	1	2	3	4	1	2	1	2	3	4	5	6	1	2	3	4	5	6
Pectinidae																																																		
Plagioctenium magellanicus						X													X				X																											
Cyclopecten nanus	O	X	X	X			X										X	X	X	X	X	X	X			X		X	X				X	O	X	X			X		X			X	X	X			
Limidae																																																		
Limatula subauriculata	X	X	X	X														X	X	X	X	X	X	X					X				X		X														
Anomiidae																																																		
Anomia simplex																X				X																														
Anomia squarula																		X																																
Astartidae																																																		
Astarte castanea						X		X	X	X	O	X		X	X				X						O			X												X	X	X				X				
Astarte undata	X	X	X	X	X	X	X		X		X					X	X	X	O	X	O	X	X	X		O		X	X	X	X	X		X	X	X	X	X			X	X	X	X		X	X	X	X	X
Astarte crenata subequilatera						X												X	X	X			X			X				X			X	X	X						X							X
Carditidae																																																		
Cyclocardia borealis	X				X	X	X			X	X				X	X	O	X		O	X					X		X						X						X		X			X	X	X	X	
Arcticidae																																																		
Arctica islandica		X			X	X	X		X		X	X	X	X	X	X	X	X	X	X	X					X	X	X						X						X	X	X			X	X	X	X	
Lucinidae																																																		
Lucinoma filosa	X	X	X	X			X											X		X	X	O	X	X			X	X	X	X			X		X					X	X	X			X	X	X		
Leptonidae																																																		
Kellia suborbicularis																													X																				
Montacutidae																																																		
Mysella ovata			X	X		O												X	X	X						X			X		X																	
Cardiidae																																																		
Cardiidae sp. 1																																																		
Cerastoderma pinnulatum	X	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X			X			X	X	X						X	X	X				X	O	X	X		X	O	X	X	
Veneridae																																																		
Pitar morrhuana										X	X	O	X			X	X									X	X					X						X	X	X				X	X				
Liocyma fluctuosa																															X																		
Petricolidae																																																		
Petricola pholadiformis																																																		
Tellinidae																																																		
Tellina agilis					X	X			O	O	O	O	O	O	O	X			X						O	X										X					O	X								
Semelidae																																																		
Abra lioica	X	X	X			X											X	X	X	X	X	X	X	X				X				X	X	X	X	X	X	X	X			X	X	X				
Lasaeidae																																																		
Lasaea rubra	X	X	O	O													X			X		X	O					X	O	O	X				X	X														
Solenidae																																																		
Ensis directus					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X		X					X				X	X	X				X	X	X				
Siliqua costata																																																		
Mactridae																																																		
Spisula solidissima					X		X	O	X	O	X	X	O	O	X										X	X	X														O	X	X							
Corbulidae																																																		
Corbula sp.																X			X	X	X	X												X															
Varicorbula operculata																																																		
Lyonsiidae																																																		
Lyonsia hyalina	X				X	X			X	X	X	X	X		X	X	X		X						X	X	X	X						X	X	X				X	X								
Lyonsia sp. 1																				X	X											X					X	X	X											
Pandoridae																																																		
Pandora gouldiana													X																																					
Pandora inflata	X	X			X		X	X	X	X	X	X	X	X			X		X	X							X	X										X	X	X	X			X	X	X				
Thraciidae																																																		
Thracia sp.																																																		
Periplomatidae																																																		
Periploma fragilis	X	X	X	X	X		X		X			X	X			X	X	X	X	X	X	X	X	X		X	X	X	X	X					X	X	X	X				X	X	X	X	X	X	X	X	X
Periploma leanum																					X																													
Poromyidae																																																		
Poromya granulata																																																		

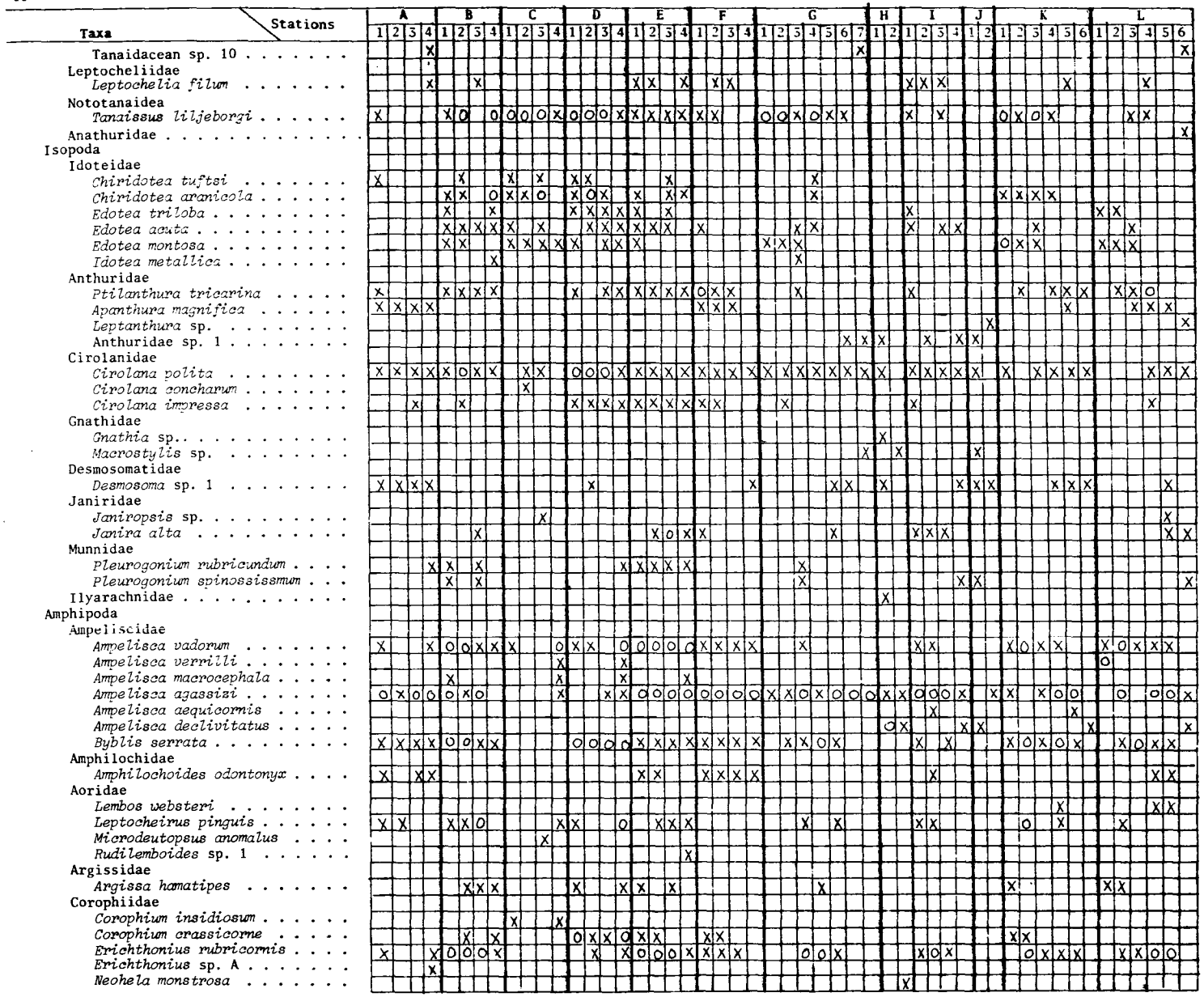
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



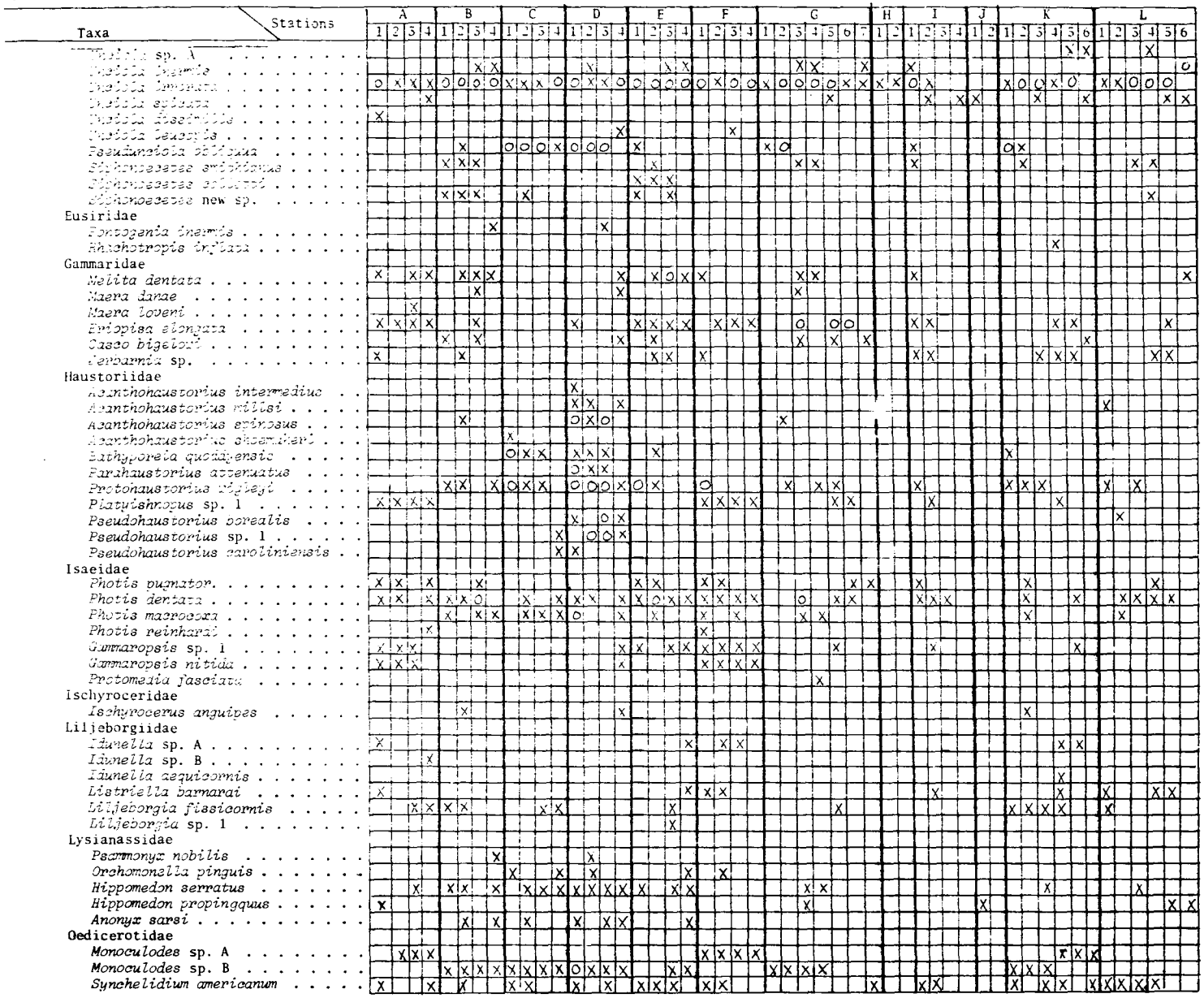
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



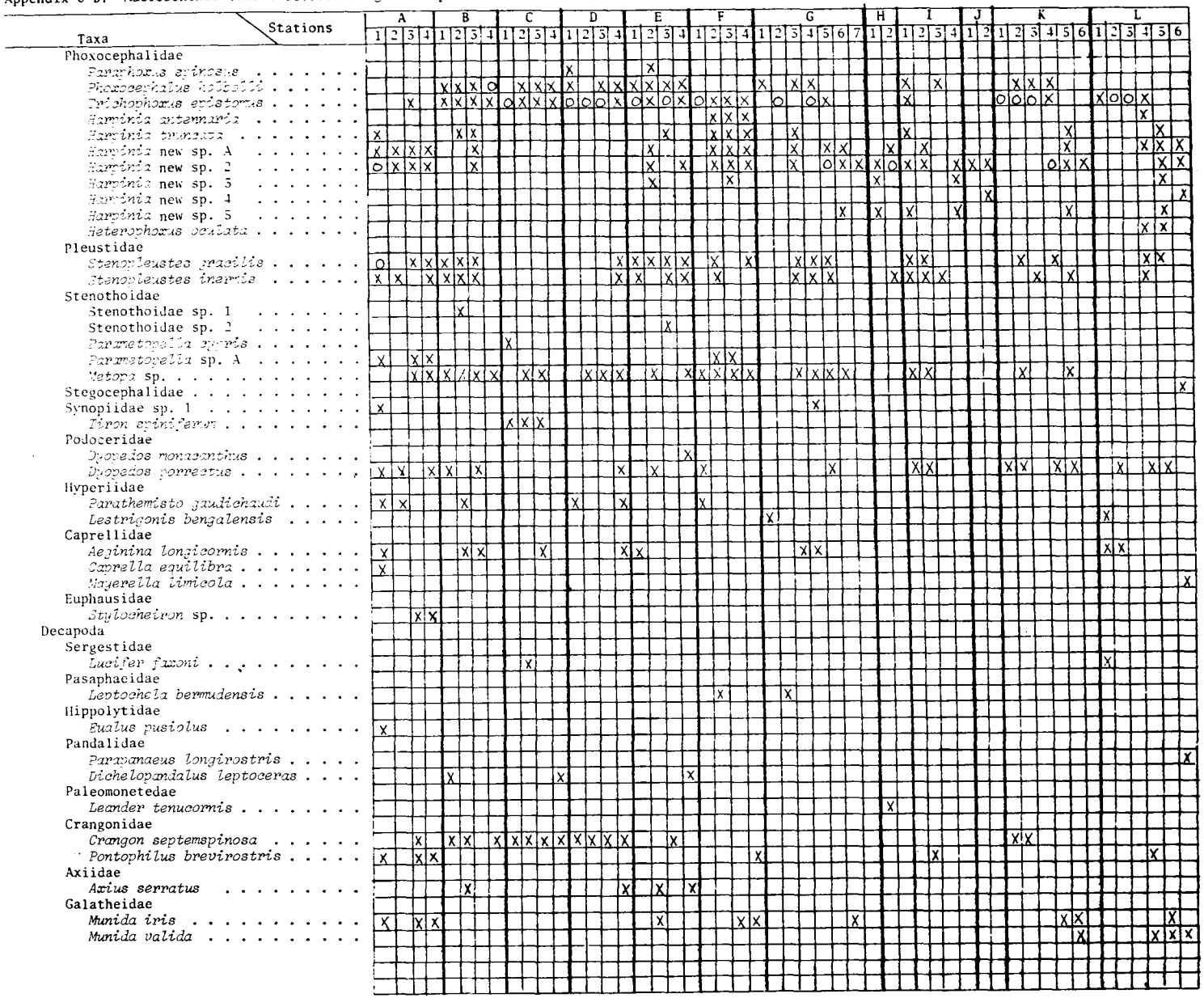
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



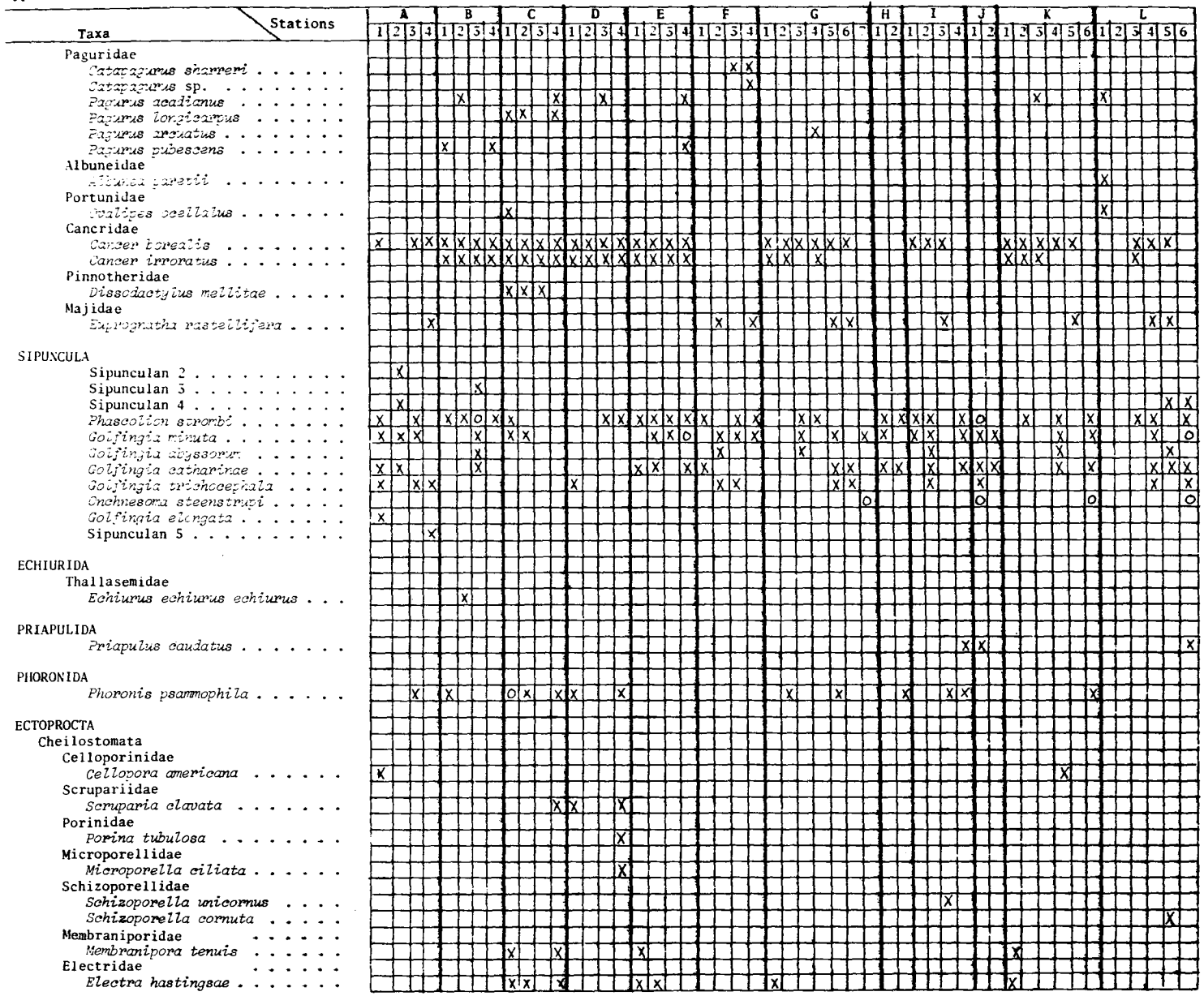
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



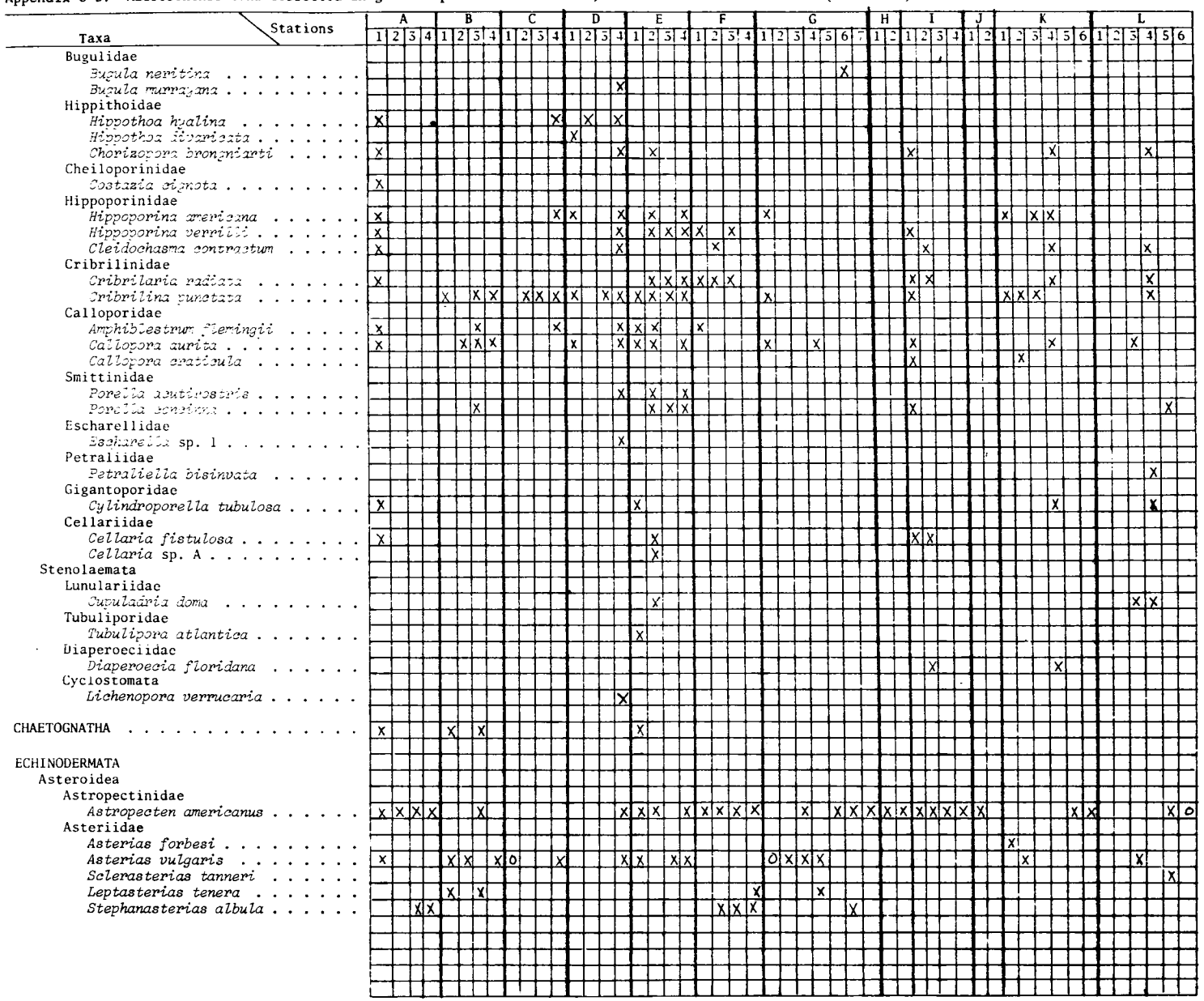
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



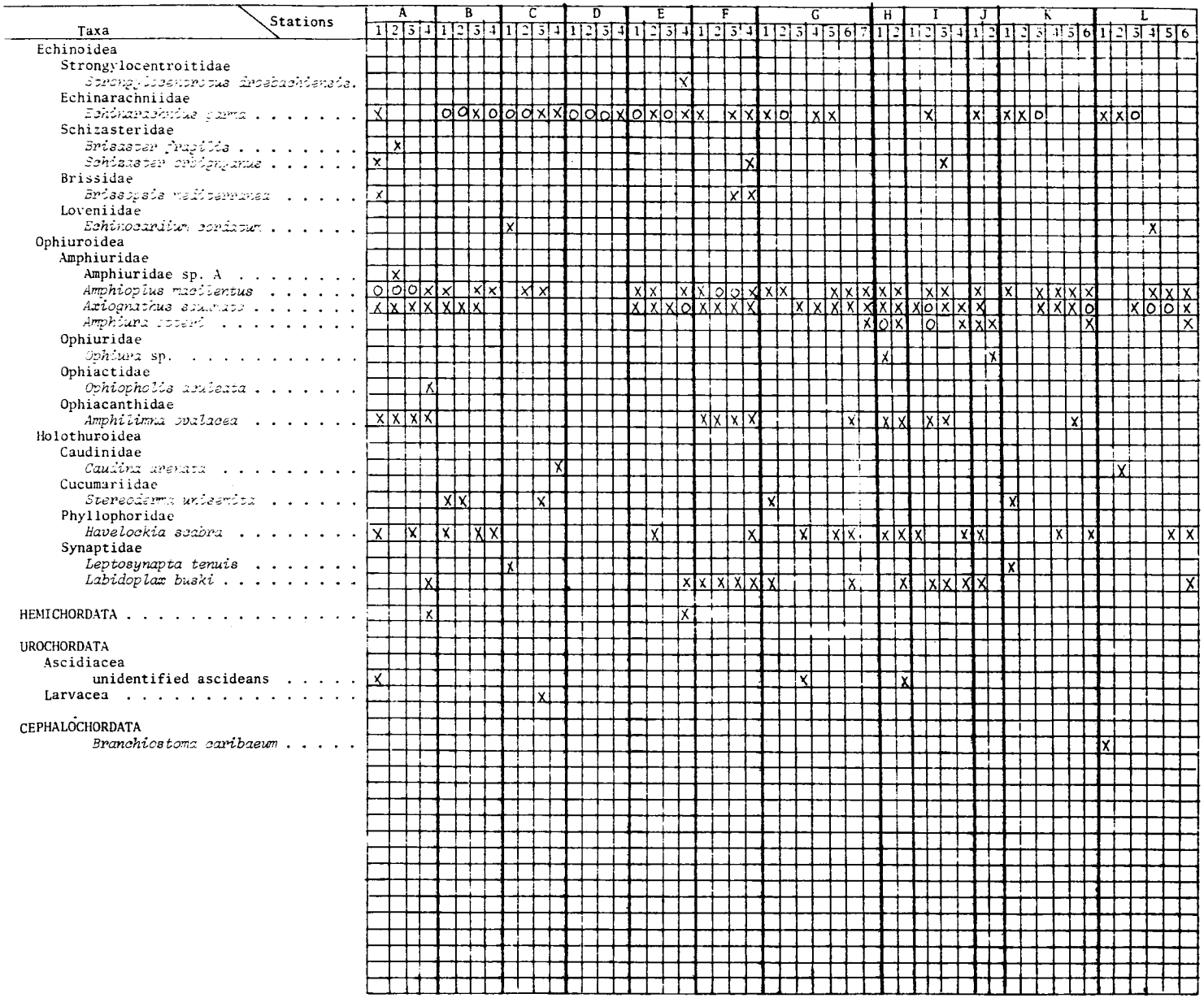
Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



Appendix 6-B. Macrobenthic taxa collected in grab samples at 51 stations, fall 1975 to summer 1976. (continued).



Appendix 6-C. Ten most numerically abundant species at each station during each collection period. (A, Am-Amphipoda; An-Anthozoa; Ar-Archiannelida; As-Asteroidea; B-Bivalvia; C-Cumacea; G-Gastropoda; E-Echinoidea; I-Isopoda; Op-Ophiuroidea; Os-Ostracoda; P-Polychaeta; Pp-Polyplacophora; Sc-Scaphopoda; Si-Sipuncula; T-Tanaidacea).

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
A1	1	*Ampelisca agassizi* (Am)	1733	*Ampelisca agassizi* (Am)	1330
	2	*Tharyx* sp. (P)	571	Cirratulidae (*Tharyx*) (P)	703
	3	*Lumbrineris cruzensis* (P)	303	*Cyclopecten ranus* (B)	406
	4	*Thyasira flexuosa* (B)	283	*Lumbrineris cruzensis* (P)	313
	5	*Spiophanes wigleyi* (P)	185	*Notomastus latericeus* (P)	175
	6	*Amphioplus macilentus* (Op)	150	*Harbansus dayi* (Os)	137
	7	*Diastylis bispinosa* (C)	147	*Unciola irrorata* (Am)	120
	8	*Harbansus bowenae* (Os)	140	*Stenopleustes gracilis* (Am)	113
	9	*Nothria conchylega* (P)	133	*Harbansus bowenae* (Os)	105
	10	*Harpinia* sp. 2 (Am)	90	*Onuphis pallidula* (P)	100
		SPRING 1976		SUMMER 1976	
A1	1	*Ampelisca agassizi* (A)	2108	*Ampelisca agassizi* (A)	1359
	2	Cirratulidae (P)	546	*Harbansus bowenae* (Os)	633
	3	*Thyasira flexuosa* (B)	336	*Lumbrineris cruzensis* (P)	343
	4	*Lumbrineris cruzensis* (P)	286	*Onuphis pallidula* (P)	271
	5	*Amphioplus macilentus* (Op)	231	*Diastylis bispinosa* (C)	263
	6	*Harbansus bowenae* (Os)	203	Cirratulidae (P)	263
	7	*Spiophanes wigleyi* (P)	167	*Thyasira flexuosa* (B)	260
	8	*Onuphis pallidula* (P)	165	*Unciola irrorata* (A)	168
	9	*Unciola irrorata* (A)	160	*Aricidea neosuecica* (P)	133
	10	Syllidae (P)	155	Syllidae (P)	118

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
A2	1	*Amphioplus macilentus* (Op)	1539	*Amphioplus macilentus* (Op)	681
	2	*Paradoneis lyra* (P)	295	*Paradoneis lyra* (P)	270
	3	*Terebellides stroemi* (P)	145	Cirratulidae (*Tharyx*) (P)	250
	4	*Tharyx* sp. (P)	143	*Onuphis* sp. (P)	150
	5	*Onuphis pallidula* (P)	118	*Onuphis pallidula* (P)	102
	6	*Harbansus bowenae* (Os)	102	*Macrocypris sapeloensis* (Os)	98
	7	*Notomastus latericeus* (P)	97	*Notomastus latericeus* (P)	88
	8	*Echinocythereis echinata* (Os)	95	*Spiophanes wigleyi* (P)	83
	9	*Lumbrineris cruzensis* (P)	88	*Harbansus dayi* (Os)	82
	10	*Spiophanes wigleyi* (P)	77	*Harbansus bowenae* (Os)	77
		SPRING 1976		SUMMER 1976	
A2	1	*Amphioplus macilentus* (Op)	1505	*Amphioplus macilentus* (Op)	2184
	2	*Paradoneis lyra* (P)	231	*Harbansus bowenae* (Os)	258
	3	*Onuphis pallidula* (P)	212	*Onuphis pallidula* (P)	253
	4	Cirratulidae (P)	208	*Paradoneis lyra* (P)	193
	5	*Harbansus bowenae* (Os)	155	Cirratulidae (P)	165
	6	*Spiophanes wigleyi* (P)	107	*Lumbrineris cruzensis* (P)	93
	7	*Nuculana acuta* (B)	87	*Aglaophamus circinata* (P)	62
	8	*Clymenella torquata* (P)	68	*Leiocapitella glabra* (P)	57
	9	*Aglaoplamus circinata* (P)	62	*Axinopsida orbiculata* (B)	55
	10	*Leiocapitella glabra* (P)	52	*Spiophanes wigleyi* (P)	53

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
A3	1	*Aricidea neosuecica* (P)	366	Cirratulidae (*Tharyx*) (P)	373
	2	*Amphioplus macilentus* (Op)	325	*Onuphis pallidula* (P)	320
	3	*Tharyx* sp. (P)	303	*Amphioplus macilentus* (Op)	233
	4	*Onuphis pallidula* (P)	278	*Aricidea neosuecica* (P)	102
	5	*Spiophanes wigleyi* (P)	180	*Paradoneis lyra* (P)	67
	6	*Lumbrineris cruzensis* (P)	113	*Cossura longocirrata* (P)	53
	7	*Paradoneis lyra* (P)	103	*Ampelisca agassizi* (Am)	48
	8	*Thyasira flexuosa* (B)	85	*Lumbrineris cruzensis* (P)	47
	9	Maldanidae (P)	83	*Aricidea suecica* (P)	38
	10	*Ampelisca agassizi* (A)	80	*Lasaea rubra* (B)	35
		SPRING 1976		SUMMER 1976	
A3	1	Cirratulidae (P)	661	*Aricidea neosuecica* (P)	560
	2	*Aricidea neosuecica* (P)	448	Cirratulidae (P)	438
	3	*Amphioplus macilentus* (Op)	351	*Amphioplus macilentus* (Op)	386
	4	*Onuphis pallidula* (P)	323	*Onuphis atlantisa* (P)	373
	5	*Onuphis atlantisa* (P)	290	*Onuphis pallidula* (P)	185
	6	*Ampelisca agassizi* (A)	123	*Spiophanes wigleyi* (P)	93
	7	*Spiophanes wigleyi* (P)	100	*Ampelisca agassizi* (A)	70
	8	*Lumbrineris cruzensis* (P)	88	*Lumbrineris cruzensis* (P)	65
	9	*Thyasira flexuosa* (B)	80	*Axinopsida orbiculata* (B)	37
	10	*Dacrydium vitreum* (B)	80	*Cossura longocirrata* (P)	37

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
A4	1	*Harbansus bowenae* (Os)	736	*Polydora* sp. (P)	569
	2	*Tharyx* sp. (P)	370	*Ampelisca agassizi* (Am)	438
	3	*Exogone verrugera* (P)	353	Syllidae (P)	395
	4	*Polydora* sp. (P)	346	Cirratulidae *(Tharyx)*	330
	5	*Thyasira flexuosa* (B)	271	*Paradoneis lyra* (P)	228
	6	*Harbansus dayi* (Os)	218	*Lasaea rubra* (B)	168
	7	*Ampelisca agassizi* (A)	197	*Aricidea neosurcica* (P)	163
	8	*Lasaea rubra* (B)	175	*Onuphis atlantisa* (P)	133
	9	*Paradoneis lyra* (P)	152	*Thyasira flexuosa* (B)	132
	10	*Onuphis pallidula* (P)	130	*Aricidea suecica* (P)	120
		SPRING 1976		SUMMER 1976	
A4	1	*Ampelisca agassizi* (A)	401	*Harbansus bowenae* (Os)	325
	2	*Polydora* sp. (P)	325	Cirratulidae (P)	308
	3	Cirratulidae (P)	265	Syllidae (P)	283
	4	*Thyasira flexuosa* (B)	207	*Polydora* sp. (P)	270
	5	*Aricidea neosuecica* (P)	193	*Onuphis atlantisa* (P)	193
	6	Syllidae (P)	187	*Thyasira flexuosa* (B)	177
	7	*Onuphis atlantisa* (P)	185	*Lasaea rubra* (B)	112
	8	*Lasaea rubra* (B)	177	*Ampelisca agassizi* (A)	102
	9	*Harbansus bowenae* (Os)	117	*Lumbrineris cruzensis* (P)	93
	10	*Onuphis pallidula* (P)	92	*Harbansus dayi* (Os)	85

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B1	1	*Tharyx* sp. (P)	1412	Cirratulidae (*Tharyx*) (P)	1820
	2	*Scalibregma inflatum* (P)	498	*Byblis serrata* (Am)	291
	3	*Chaetozone setosa* (P)	217	*Spiophanes bombyx* (P)	283
	4	*Spiophanes bombyx* (P)	187	*Scalibregma inflatum* (P)	226
	5	*Caulleriella* sp. (P)	173	*Lumbrineris impatiens* (P)	222
	6	*Diastylis bispinosa* (C)	170	Syllidae (P)	142
	7	*Exogone hebes* (P)	167	*Unciola irrorata* (Am)	123
	8	*Euchone* sp. A (P)	158	*Euchone* sp. A (P)	118
	9	*Lumbrineris impatiens* (P)	145	*Diastylis bispinosa* (C)	95
	10	*Nicolea venustula* (P)	130	*Erichthonius rubricornis* (Am)	87
		SPRING 1976		SUMMER 1976	
B1	1	*Byblis serrata* (A)	535	Cirratulidae (P)	1066
	2	*Erichthonius rubricornis* (A)	511	*Byblis serrata* (A)	375
	3	*Unciola irrorata* (A)	495	*Unciola irrorata* (A)	223
	4	*Diastylis bispinosa* (C)	202	*Spiophanes bombyx* (P)	223
	5	Cirratulidae (P)	163	*Lumbrineris impatiens* (P)	198
	6	*Lumbrineris impatiens* (P)	127	*Erichthonius rubricornis* (A)	182
	7	*Ampelisca agassizi* (A)	103	*Scalibregma inflatum* (P)	92
	8	*Mitrella* sp. (G)	102	Syllidae (P)	90
	9	*Echinarachnius parma* (E)	87	*Aglaophamus circinata* (P)	87
	10	*Ampelisca vadorum* (A)	85	*Nereis grayi* (P)	85

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B2	1	*Goniadella gracilis* (P)	608	*Ampelisca vadorum* (Am)	1092
	2	*Lumbrinerdes acuta* (P)	513	Syllidae (P)	896
	3	*Exogone hebes* (P)	418	*Byblis serrata* (Am)	866
	4	*Exogone verugera* (P)	305	Cirratulidae (P)	768
	5	*Polygordius* sp. 1 (Ar)	296	*Unciola irrorata*	500
	6	*Aricidea suecica* (P)	270	*Scalibregma inflatum* (P)	281
	7	*Caulleriella* sp. (P)	230	*Spiophanes bombyx* (P)	231
	8	*Scalibregma inflatum* (P)	222	*Polygordius* sp. 1 (Ar)	143
	9	*Tharyx* sp. (P)	200	*Tanaissus liljeborgi* (T)	138
	10	*Praxillella* sp. A. (P)	193	*Lumbrinerides acuta* (P)	137
		SPRING 1976		SUMMER 1976	
B2	1	*Unciola irrorata* (A)	912	*Unciola irrorata* (A)	666
	2	Syllidae (P)	443	Cirratulidae (P)	200
	3	*Goniadella gracilis* (P)	401	*Cirolana polita* (I)	175
	4	*Lumbrinerides acuta* (P)	373	*Erichthonius rubricornis* (A)	167
	5	*Ampelisca vadorum* (A)	346	*Byblis serrata* (A)	160
	6	*Byblis serrata* (A)	316	*Ampelisca vadorum* (A)	152
	7	Cirratulidae (P)	263	*Goniadella gracilis* (P)	128
	8	*Scalibregma inflatum* (P)	143	*Lumbrinerides acuta* (P)	127
	9	*Erichthonius rubricornis* (A)	140	Syllidae (P)	100
	10	*Echinarachnius parma* (E)	130	*Scalibregma inflatum* (P)	78

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B3	1	*Ampelisca agassizi* (Am)	9273	*Ampelisca agassizi* (Am)	9839
	2	*Diastylis bispinosa* (C)	704	*Unciola irrorata* (Am)	523
	3	*Unciola irrorata* (Am)	381	*Notomastus latericeus* (P)	443
	4	*Photis dentata* (Am)	313	*Diastylis bispinosa* (C)	368
	5	*Leptocheirus pinguis* (Am)	248	*Photis dentata* (Am)	336
	6	*Clymenella torquata* (P)	245	Syllidae (P)	311
	7	*Notomastus latericeus* (P)	235	*Eudorella pusilla* (C)	208
	8	*Scalibregma inflatum* (P)	210	*Chone infundibuliformis* (P)	188
	9	*Eudorella pusilla* (C)	182	*Erichthonius rubricornis* (A)	142
	10	*Laonice cirrata* (P)	163	Cirratulidae (*Tharyx*) (P)	133
		SPRING 1976		SUMMER 1976	
B3	1	*Ampelisca agassizi* (A)	11,685	*Ampelisca agassizi* (A)	8355
	2	*Unciola irrorata* (A)	706	*Unciola irrorata* (A)	813
	3	*Photis dentata* (A)	288	*Photis dentata* (A)	649
	4	*Phascolion strombi* (Si)	268	*Notomastus latericeus* (P)	466
	5	*Mysella ovata* (B)	261	*Erichtonius rubricornis* (A)	256
	6	*Erichthonius rubricornis* (A)	228	*Nereis grayi* (P)	250
	7	*Notomastus latericeus* (P)	175	*Polydora* sp. (P)	248
	8	*Eudorella pusilla* (C)	150	*Scalibregma inflatum* (P)	225
	9	Syllidae (P)	135	*Eudorella pusilla* (C)	135
	10	*Chone infundibuliformis* (P)	127	*Lumbrineris impatiens* (P)	132

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B4	1	*Goniadella gracilis* (P)	1039	*Goniadella gracilis* (P)	636
	2	*Praxillella* sp. A (P)	793	*Praxillella* sp. A (P)	508
	3	*Aricidea suecica* (P)	666	Syllidae (P)	345
	4	*Lumbrinerides acuta* (P)	436	*Aricidea suecica* (P)	281
	5	*Parapionosyllis longicirrata* (P)	331	*Lumbrinerides acuta* (P)	276
	6	*Tharyx* sp. (P)	218	*Aricidea cerrutii* (P)	207
	7	*Polygordius* sp.1 (Ar)	188	*Polygordius* sp. 1 (Ar)	147
	8	*Clymenella zonalis* (P)	173	*Tanaissus liljeborgi* (T)	73
	9	Syllidae	155	Cirratulidae (P)	73
	10	*Protodorvillea kefersteini*	118	Oligochaeta	62
		SPRING 1976		SUMMER 1976	
B4	1	*Goniadella gracilis* (P)	445	*Goniadella gracilis* (P)	388
	2	*Lumbrinerides acuta* (P)	315	*Lumbrinerides acuta* (P)	236
	3	*Aricidea suecica* (P)	112	*Unciola irrorata* (A)	213
	4	*Praxillella* sp. A. (P)	112	*Aricidea cerrutii* (P)	177
	5	*Unciola irrorata* (A)	110	*Spiophanes bombyx* (P)	127
	6	*Harmothoe extenuata* (P)	110	*Praxillella* sp. A. (P)	123
	7	*Clymenella zonalis* (P)	75	*Clymenella zonalis* (P)	100
	8	*Phoxocephalus holbolli* (A)	73	*Aricidea suecica* (P)	85
	9	*Chiridotea arenicola* (I)	53	Cirratulidae (P)	50
	10	*Echinarachnius parma* (E)	47	*Harmothoe extenuata* (P)	45

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
C1	1	*Tanaissus liljeborgi* (T)	543	*Goniadella gracilis* (P)	240
	2	*Tellina agilis* (B)	328	*Tanaissus liljeborgi* (T)	193
	3	*Goniadella gracilis* (P)	203	*Polygordius* sp. (Ar)	173
	4	Oligochaeta	178	*Tellina agilis* (B)	165
	5	*Polygordius* sp. (Ar)	118	*Echinarachnius parma* (E)	147
	6	*Echinarachnius parma* (E)	108	Oligochaeta	97
	7	*Spisula solidissima* (B)	102	*Aricidea cerrutii* (P)	78
	8	*Bathyporeia quoddyensis* (Am)	82	*Hemipodus roseus* (P)	77
	9	Cirratulidae (P)	45	Syllidae (P)	58
	10	*Trichophoxus epistomus* (Am)	28	*Pisione remota* (P)	30
		SPRING 1976		SUMMER 1976	
C1	1	*Goniadella gracilis* (P)	563	*Goniadella gracilis* (P)	390
	2	*Tellina agilis* (B)	376	Oligochaeta	117
	3	*Tanaissus liljeborgi* (T)	335	Syllidae (P)	50
	4	Syllidae (P)	133	Cerianthidae (An)	48
	5	*Polygordius* sp.1 (Ar)	133	Phoronida	27
	6	*Echinarachnius parma* (E)	118	Cirratulidae (P)	20
	7	*Pseudounciola obliquua* (A)	85	*Aricidea cerrutii* (P)	17
	8	*Protohaustorius wigleyi* (A)	73	*Asterias vulgaris* (As)	15
	9	*Pseudoleptocuma minor* (C)	62	*Tanaissus liljeborgi* (T)	15
	10	*Eteone* sp. A (P)	57	*Polygordius* sp.1 (Ar)	12

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
C2	1	*Tanaissus liljeborgi* (T)	1219	*Tanaissus liljeborgi* (T)	1161
	2	*Goniadella gracilis* (P)	383	*Pseudunciola obliquua* (Am)	838
	3	*Echinarachnius parma* (E)	195	*Goniadella gracilis* (P)	381
	4	*Aricidea suecica* (P)	188	*Polygordius* sp.1 (Ar)	375
	5	*Lumbrinerides acuta* (P)	165	Syllidae (P)	321
	6	Cirratulidae (P)	115	Cirratulidae (P)	230
	7	Oligochaeta	107	*Tellina agilis* (B)	185
	8	*Polygordius* sp. (Ar)	98	*Echinarachnius parma* (E)	125
	9	*Astarte castanea* (B)	75	*Nephtys picta* (P)	73
	10	*Tellina agilis* (B)	70	*Paradoneis lyra* (P)	45
		SPRING 1976		SUMMER 1976	
C2	1	*Polygordius* sp.1 (Ar)	2626	*Tellina agilis* (B)	391
	2	*Pseudunciola obliquua* (A)	1399	*Goniadella gracilis* (P)	335
	3	Syllidae (P)	1245	Syllidae (P)	320
	4	*Tellina agilis* (B)	689	*Pseudunciola obliquua* (A)	130
	5	*Tanaissus liljeborgi* (T)	415	Cirratulidae (P)	120
	6	*Goniadella gracilis* (P)	386	Hyperiidae (Am)	105
	7	*Nephtys picta* (P)	147	*Aricidea suecica* (P)	82
	8	*Aricidea suecica* (P)	120	*Lumbrineris fragilis* (P)	43
	9	Cirratulidae (P)	113	Cerianthidae (An)	38
	10	*Pseudoleptocuma minor* (C)	105	Oligochaeta	35

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
C3	1	*Goniadella gracilis* (P)	771	*Polygordius* sp. (Ar)	1324
	2	Cirratulidae (P)	586	*Goniadella gracilis* (P)	646
	3	*Polygordius* sp.1(Ar)	520	*Tanaissus liljeborgi* (T)	358
	4	*Tanaissus liljeborgi* (T)	445	*Protodorvillea* sp. (P)	313
	5	*Spisula solidissma (B)*	360	Oligochaeta	218
	6	*Lumbrinerides acuta* (P)	283	*Lumbrinerides acuta* (P)	172
	7	Oligochaeta	261	Cirratulidae (P)	120
	8	*Schistomeringos caeca* (P)	55	*Aricidea cerruti* (P)	105
	9	Phyllodocidae (P)	45	Syllidae (P)	102
	10	*Aricidea cerrutii* (P)	42	*Tellina agilis* (B)	87
		SPRING 1976		SUMMER 1976	
C3	1	*Goniadella gracilis* (P)	829	*Goniadella gracilis* (P)	107
	2	*Tanaissus liljeborgi* (T)	400	*Lumbrinerides acuta*(P)	67
	3	*Lumbrinerides acuta* (P)	333	*Pseudunciola obliquua* (A)	50
	4	Syllidae (P)	197	Cirratulidae (P)	50
	5	*Polygordius* sp.1(Ar)	193	Syllidae (P)	30
	6	*Protodorvillea kefersteini* (P)	160	*Tanaissus liljeborgi* (T)	10
	7	Oligochaeta	150	*Lumbrineris fragilis* (P)	8
	8	*Eteone* sp. A. (P)	70	*Aricidea suecica* (P)	8
	9	*Chiridotea arenicola* (I)	58	*Sigalion arenicola* (P)	8
	10	*Aricidea cerrutii* (P)	53	Oligochaeta	7

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
C4	1	*Tharyx* sp. (P)	2937	*Tellina agilis* (B)	2326
	2	*Paradoneis lyra* (P)	1595	*Polygordius* sp.1(Ar)	846
	3	*Polygordius* sp.1(Ar)	1280	Cirratulidae (P)	624
	4	*Tellina agilis* (B)	828	*Pitar morrhuana* (B)	518
	5	*Nucula proxima* (B)	208	*Cytheretta edwardsi* (Os)	486
	6	Oligochaeta	195	*Nucula proxima* (B)	158
	7	*Lumbrineris impatiens*	162	*Aricidea suecica* (P)	157
	8	*Prionospio* sp. A (P)	57	*Hemipodus roseus* (P)	117
	9	*Nereis grayi* (P)	43	*Sarsiella zostericola* (Os)	113
	10	*Unciola irrorata* (Am)	42	*Clymenella zonalis* (P)	113
		SPRING 1976		SUMMER 1976	
C4	1	*Polygordius* sp.1(Ar)	468	*Clymenella torquata* (P)	505
	2	*Aricidea suecica* (P)	345	*Lumbrineris impatiens* (P)	430
	3	*Nucula proxima* (B)	338	Cirratulidae (P)	187
	4	*Unciola irrorata* (A)	315	Cerianthidae (An)	97
	5	*Ampelisca vadorum* (A)	276	*Drilonereis longa* (P)	68
	6	Cirratulidae (P)	243	*Aricidea suecica* (P)	68
	7	*Tellina agilis* (B)	183	*Asychis carolinae* (P)	57
	8	*Pitar morrhuana* (B)	142	Syllidae (P)	55
	9	*Lumbrineris impatiens* (P)	140	*Nucula proxima* (B)	50
	10	*Clymenella torquata* (P)	127	*Pherusa affinis* (P)	27

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
D1	1	*Pseudunciola obliquua* (Am)	478	*Spiophanes bombyx* (P)	4772
	2	*Trichophoxus epistomus* (Am)	147	*Corophium crassicorne* (Am)	936
	3	*Protohaustorius wigleyi* (Am)	103	*Trichophoxus epistomus* (Am)	699
	4	*Echinarachnius parma* (E)	90	*Byblis serrata* (Am)	545
	5	*Tanaissus liljeborgi* (T)	90	*Echinarachnius parma* (E)	381
	6	*Polygordius* sp.1 (Ar)	68	*Aglaophamus circinata* (P)	245
	7	*Aricidea suecica* (P)	53	*Pseudunciola obliquua* (Am)	213
	8	*Tellina agilis* (B)	50	*Unciola irrorata* (Am)	188
	9	*Streptosyllis varians* (P)	50	*Photis macrocoxa* (A)	172
	10	*Praxillella* sp. A. (P)	35	*Tellina agilis* (B)	113
		SPRING 1976		SUMMER 1976	
D1	1	*Cirolana polita* (J)	138	*Spiophanes bombyx* (P)	2033
	2	*Protohaustorius wigleyi* (A)	105	*Corophium crassicorne* (A)	1400
	3	*Monoculodes* sp. B (A)	88	*Pseudunciola obliquua* (A)	263
	4	*Aricidea wassi* (P)	52	*Trichophoxus epistomus* (A)	158
	5	*Acanthohaustorius spinosus* (A)	48	*Protohaustorius wigleyi* (A)	150
	6	*Trichophoxus epistomus* (A)	36	*Unciola irrorata* (A)	95
	7	*Tanaissus liljeborgi* (T)	28	*Tanaissus liljeborgi* (T)	65
	8	*Corophium crassicorne* (A)	23	*Phyllodoce mucosa* (P)	62
	9	*Parahaustorius attenuatus* (A)	20	*Nephtys bucera* (D)	52
	10	*Echinarachnius parma* (E)	13	*Echinarachnius parma* (E)	45

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
D2	1	*Echinarachnius parma* (E)	162	Syllidae (P)	228
	2	*Protohaustorius wigleyi* (Am)	92	*Tanaissus liljeborgi* (T)	226
	3	*Spiophanes bombyx* (P)	73	*Goniadella gracilis* (P)	100
	4	*Exogone hebes* (P)	65	*Spisula solidissima* (B)	73
	5	*Caulleriella* (P)	57	*Echinarachnius parma* (E)	52
	6	*Spisula solidissima* (B)	52	Oligochaeta	32
	7	*Polygordius* (Ar)	50	*Lumbrinerides acuta* (P)	32
	8	*Trichophoxus epistomus* (Am)	48	*Chiridotea arenicola* (I)	23
	9	*Aricidea wassi* (P)	48	*Pseudohaustorius* sp. 1 (Am)	20
	10	*Nephtys bucera* (P)	43	*Spiophanes bombyx* (P)	17
		SPRING 1976		SUMMER 1976	
D2	1	*Goniadella gracilis* (P)	1139	*Pseudunciola obliquua* (A)	2138
	2	Syllidae (P)	341	*Trichophoxus epistomus* (A)	343
	3	Oligochaeta	266	*Protohaustorius wigleyi* (A)	127
	4	*Lumbrinerides acuta* (P)	220	*Echinarachnius parma* (E)	98
	5	*Chiridotea arenicola* (I)	70	*Polygordius* sp.1 (Ar)	73
	6	*Tanaissus liljeborgi* (T)	63	*Nephtys bucera* (P)	62
	7	*Echinarachnius parma* (E)	35	*Byblis serrata* (A)	58
	8	*Cirolana polita* (I)	35	*Tanaissus liljeborgi* (T)	45
	9	Cirratulidae (P)	32	*Tellina agilis* (B)	32
	10	*Aricidea suecica* (P)	22	*Aricidea suecica* (P)	30

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
D3	1	*Pseudunciola obliquua* (Am)	839	*Pseudunciola obliquua* (Am)	181
	2	*Byblis serrata* (Am)	811	*Trichophoxus epistomus* (Am)	170
	3	*Spiophanes bombyx* (P)	305	*Tanaissus liljeborgi* (T)	155
	4	*Trichophoxus epistomus* (Am)	202	*Protohaustorius wigleyi* (Am)	150
	5	*Aricidea suecica* (P)	105	*Echinarachnius parma* (E)	112
	6	*Exogone hebes* (P)	103	*Aricidea wassi* (P)	75
	7	*Echinarachnius parma* (E)	100	*Polygordius* sp. 1 (Ar)	62
	8	*Polygordius* sp.1 (Ar)	93	Syllidae (P)	57
	9	*Aglaophamus circinata* (P)	78	*Spisula solidissima* (B)	37
	10	*Tellina agilis* (B)	47	*Pseudohaustorius* sp. 1 (Am)	35
		SPRING 1976		SUMMER 1976	
D3	1	*Trichophoxus epistomus* (A)	243	Syllidae (P)	230
	2	*Tanaissus liljeborgi* (T)	120	*Polygordius* sp.1 (Ar)	178
	3	*Protohaustorius wigleyi* (A)	112	*Eteone* sp. A. (P)	103
	4	*Echinarachnius parma* (E)	103	*Goniadella gracilis* (P)	95
	5	*Aricidea wassi* (P)	67	*Tanaissus liljeborgi* (T)	62
	6	*Acanthohaustorius spinosus* (A)	25	*Cirolana polita* (I)	55
	7	*Pseudohaustorius borealis* (A)	23	*Pseudunciola obliquua* (A)	52
	8	*Aricidea suecica* (P)	23	*Protohaustorius wigleyi* (A)	48
	9	*Nephtys bucera* (P)	23	Cirratulidae (P)	38
	10	*Polygordius* sp.1 (Ar)	23	*Nephtys bucera* (P)	37

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
D4	1	*Ampelisca vadorum* (Am)	1061	*Tharyx* sp. (P)	773
	2	*Lumbrineris impatiens* (P)	861	*Chone infundibuliformis* (P)	728
	3	*Spiophanes bombyx* (P)	794	*Polygordius* sp. 1 (Ar)	719
	4	*Clymenella torquata* (P)	579	*Spiophanes bombyx* (P)	623
	5	*Trichophoxus epistomos* (Am)	498	*Clymenella torquata*(P)	594
	6	*Prionospio steenstrupi* (P)	343	*Lumbrineris impatiens* (P)	586
	7	*Aricidea suecica* (P)	217	*Ampelisca vadorum* (Am)	436
	8	*Byblis serrata* (Am)	212	*Prionospio steenstrupi*(P)	385
	9	*Leptocheirus pinguis* (Am)	117	*Aricidea cerruti* (P)	353
	10	*Sarsiella zostericola* (Os)	82	*Byblis serrata* (Am)	315
		SPRING 1976		SUMMER 1976	
D4	1	*Euchone incolor* (P)	1698	Cirratulidae (P)	2999
	2	*Lumbrineris impatiens* (P)	894	*Spiophanes bombyx* (P)	793
	3	*Polygordius* sp.1(Ar)	515	*Lumbrineris impatiens* (P)	446
	4	*Clymenella torquata* (P)	501	*Clymenella torquata* (P)	320
	5	*Corophium crassicorne* (A)	438	*Euchone incolor* (P)	306
	6	*Unciola irrorata* (A)	378	*Polygordius* sp.1(Ar)	291
	7	Cirratulidae (P)	371	*Aricidea suecica* (P)	290
	8	*Goniadella gracilis* (P)	326	*Unciola irrorata* (A)	187
	9	*Spiophanes bombyx* (P)	310	*Sarsiella zostericola* (Os)	148
	10	*Ampelisca vadorum* (A)	281	*Pleurobranchaea tarda* (G)	147

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
E1	1	*Spiophanes bombyx* (P)	6664	*Ampelisca vadorum* (Am)	856
	2	*Lumbrineris impatiens* (P)	353	*Spiophanes bombyx* (P)	654
	3	*Mitrella* sp. (G)	207	*Chone infundibuliformis* (P)	301
	4	*Trichophoxos epistomus* (Am)	200	Syllidae (P)	228
	5	*Tharyx* sp. (P)	193	Cirratulidae *(Tharyx)* (P)	217
	6	*Scalibregma inflatum* (P)	182	*Clymenella zonalis* (P)	153
	7	*Ampelisca vadorum* (Am)	162	*Euchone* sp. A. (P)	150
	8	*Echinarachnius parma* (E)	152	*Unciola irrorata* (Am)	143
	9	Sabellidae (P)	125	*Trichophoxus epistomus* (Am)	130
	10	*Scoloplos acmeceps* (P)	107	*Praxillella* sp. A. (P)	115
		SPRING 1976		SUMMER 1976	
E1	1	*Spiophanes bombyx* (P)	779	*Lumbrineris impatiens* (P)	471
	2	*Ampelisca vadorum* (A)	466	*Ampelisca agassizi* (A)	283
	3	*Unciola irrorata* (A)	300	*Spiophanes bombyx* (P)	223
	4	*Chone infundibuliformis* (P)	296	*Cyclocardia borealis* (B)	215
	5	Cirratulidae (P)	172	*Scoloplos acmeceps* (P)	193
	6	*Diastylis bispinosa* (C)	165	*Erichthonius rubricornis* (A)	182
	7	*Trichophoxus epistomus* (A)	137	*Aricidea wassi* (P)	150
	8	*Aricidea wassi* (P)	97	*Ampelisca vadorum* (A)	130
	9	*Echinarachnius parma* (E)	93	*Scalibregma inflatum* (P)	120
	10	*Mitrella* sp. (G)	78	*Euchone incolor* (P)	117

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
E2	1	*Spiophanes bombyx* (Am)	904	*Ampelisca agassizi* (Am)	986
	2	*Exogone hebes* (P)	385	Syllidae *(Exogone)* (P)	361
	3	*Lumbrineris impatiens* (P)	323	Cirratulidae *(Tharyx)* (P)	245
	4	*Polycirrus eximius* (P)	260	*Lumbrineris impatiens* (P)	220
	5	*Chone infundibuliformis* (P)	255	*Notomastus latericeus* (P)	192
	6	*Mitrella* sp. (G)	173	*Ampelisca vadorum* (Am)	177
	7	*Notomastus latericeus* (P)	145	*Chone infundibuliformis* (P)	138
	8	*Scalibregma inflatum* (P)	133	*Eudurella pusilla* (C)	130
	9	*Ampelisca agassizi* (A)	97	*Astarte undata* (B)	120
	10	*Tharyx* sp. (P)	90	*Diastylis bispinosa* (C)	88
		SPRING 1976		SUMMER 1976	
E2	1	*Chone infundibuliformis* (P)	2058	*Ampelisca agassizi* (A)	4957
	2	*Spiophanes bombyx* (P)	430	Syllidae (P)	463
	3	*Lumbrineris impatiens* (P)	301	*Unciola irrorata* (A)	306
	4	*Ampelisca agassizi* (A)	291	*Notomastus latericeus* (P)	300
	5	*Ampelisca vadorum* (A)	233	*Photis dentata* (A)	243
	6	Syllidae (P)	215	*Erichthonius rubricornis* (A)	192
	7	*Unciola irrorata (A)*	195	*Harbansus dayi* (Os)	183
	8	*Notomastus latericeus* (P)	183	*Onuphis pallidula* (P)	177
	9	*Scoloplos acmeceps* (P)	158	*Eudorella pusilla* (C)	148
	10	Cirratulidae (P)	138	*Lumbrineris impatiens* (P)	133

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
E3	1	*Goniadella graciles* (P)	288	Syllidae *(Exogone)*	758
	2	*Spiophanes bombyx* (P)	253	*Goniadella gracilis* (P)	435
	3	Cirratulidae (P)	236	Cirratulidae (P)	283
	4	*Praxillella* sp. A. (P)	233	*Polygordius* sp.1 (Ar)	197
	5	*Echinarachnius parma* (E)	122	*Praxillella* sp. A. (P)	193
	6	*Trichophoxos epistomus* (Am)	103	*Ampelisca vadorum* (Am)	185
	7	*Exogone hebes* (P)	90	*Echinarachinius parma* (E)	130
	8	*Lumbrinerides acuta* (P)	85	*Clymenella zonalis* (P)	117
	9	*Scalibregma inflatum* (P)	75	*Lumbrinerides acuta* (P)	102
	10	*Mitrella* sp. (G)	70	*Trichophoxus epistomus* (Am)	85
		SPRING 1976		SUMMER 1976	
E3	1	*Ampelisca agassizi* (A)	1176	*Goniadella gracilis* (P)	218
	2	*Goniadella gracilis* (P)	571	*Ampelisca vadorum* (A)	145
	3	Syllidae (P)	251	*Unciola irrorata* (A)	140
	4	*Unciola irrorata* (A)	210	*Echinarachnius parma* (E)	100
	5	Cirratulidae (P)	180	Syllidae (P)	93
	6	*Erichthonius rubricornis* (A)	163	*Praxillella* sp. A. (P)	90
	7	*Janira alta* (I)	153	*Trichophoxus epistomus* (A)	72
	8	*Lumbrinerides acuta* (P)	147	*Spiophanes bombyx* (P)	63
	9	*Ampelisca vadorum* (A)	145	Cirratulidae (P)	62
	10	*Melita dentata* (A)	140	*Lumbrinerides acuta* (P)	57

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
E4	1	*Cyclocardia borealis* (B)	403	Syllidae (P)	644
	2	Cirratulidae (P)	375	Cirratulidae (P)	403
	3	*Astarte undata* (B)	315	*Ampelisca vadorum* (Am)	341
	4	*Typosyllis tegulum* (P)	280	*Cyclocardia borealis* (B)	298
	5	*Crenella glandula* (B)	261	*Ampelisca agassizi* (Am)	271
	6	*Chaetopleura apiculata* (P_p)	236	*Astarte undata* (B)	225
	7	*Axiognathus squamata* (O_p)	235	*Unciola irrorata* (Am)	185
	8	*Notomastus latericeus* (P)	215	*Lumbrineris impatiens* (P)	180
	9	*Lumbrineriopsis paradoxa* (P)	163	*Notomastus latericeus* (P)	155
	10	*Unciola irrorata* (Am)	142	*Crenella glandula* (B)	148
		SPRING 1976		SUMMER 1976	
E4	1	Syllidae (P)	533	Syllidae (P)	333
	2	Cirratulidae (P)	381	*Notomastus latericius* (P)	305
	3	*Ampelisca vadorum* (A)	290	*Ampelisca agassizi* (A)	301
	4	*Golfingia minuta* (Si)	231	*Golfingia minuta* (Si)	278
	5	*Notomastus latericeus* (P)	207	Cirratulidae (P)	246
	6	*Cyclocardia borealis* (B)	203	*Cyclocardia borealis* (B)	202
	7	*Crenella glandula* (B)	190	*Unciola irrorata* (A)	200
	8	*Axiognathus squamata* (Op)	173	*Astarte undata* (B)	195
	9	*Unciola irrorata* (A)	143	*Axiognathus squamata* (Op)	103
	10	*Astarte undata* (B)	128	*Goniadella gracilis* (P)	100

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
F1	1	*Chone infundibuliformis* (P)	1325	*Chone infundibuliformis* (P)	3094
	2	*Trichophoxus epistomus* (Am)	205	*Notomastus latericæus* (P)	160
	3	*Ampelisca agassizi* (Am)	192	*Onuphis pallidula* (P)	135
	4	*Lumbrineris cruzensis* (P)	158	*Ampelisca agassizi* (Am)	133
	5	*Nothria conchylega* (P)	112	*Scoloplos acmeceps* (P)	117
	6	*Amage tumida* (P)	108	*Lumbrineris cruzensis* (P)	112
	7	*Prionospio* sp. A (P)	108	*Trichophoxus epistomus* (Am)	107
	8	*Ameana trilobata* (P)	105	*Lumbrineris impatiens* (P)	97
	9	Cerianthidae	105	*Mitrella* sp. (G)	67
	10	*Scoloplos acmeceps* (P)	93	Syllidae (P)	67
		SPRING 1976		Summer 1976	
F1	1	*Chone infundibuliformis* (P)	1940	*Onuphis pallidula* (P)	488
	2	*Lumbrineris cruzensis* (P)	105	*Notomastus latericius* (P)	310
	3	*Ampelisca agassizi* (A)	90	*Lumbrineris cruzensis* (P)	308
	4	*Trichophoxus epistomus* (A)	75	*Ampelisca agassizi* (A)	212
	5	*Unciola irrorata* (A)	67	*Aricidea neosuecica* (P)	205
	6	*Onuphis pallidula* (P)	52	*Thyasira flexuosa* (B)	163
	7	*Mitrella* sp. (G)	45	*Trichophoxus epistomus* (A)	105
	8	*Protohanstorius wigleyi* (A)	35	Cirratulidae (P)	90
	9	*Ptilanthura tricarina*	32	Syllidae (P)	62
	10	*Marphysa bellii* (P)	32	*Scoloplos acmeceps* (P)	58

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
F2	1	*Amphioplus macilentus* (Op)	2000	*Aricidea neosuecica* (P)	1592
	2	*Aricidea neosuecica* (P)	1495	*Amphioplus macilentus* (Op)	629
	3	*Lumbrineris cruzen* (P)	609	*Lumbrineris cruzensis* (P)	436
	4	*Ampelisca agassizi* (Am)	371	*Onuphis pallidula* (P)	335
	5	*Echinocythereis echinata* (Os)	333	*Thyasira fluxuosa* (B)	283
	6	*Thyasira flexuosa* (B)	230	*Echinocythereis echinata* (Os)	220
	7	*Nothria conchylega* (P)	213	*Ampelisca agassizi* (Am)	183
	8	*Spiophanes wigleyi* (P)	195	Scaphopoda	140
	9	*Lucinoma filosa* (B)	153	*Harbansus dayi* (Os)	98
	10	*Harbansus dayi* (Os)	132	*Spiophanes wigleyi* (P)	87
		SPRING 1976		SUMMER 1976	
F2	1	*Aricidea neosuecica* (P)	699	*Aricidea neosuecica* (P)	2163
	2	*Amphioplus macilentus* (Op)	488	*Amphioplus macilentus* (Op)	1338
	3	*Onuphis pallidula* (P)	418	*Lumbrineris cruzensis* (P)	411
	4	*Lumbrineris cruzensis* (P)	271	*Onuphis pallidula* (P)	390
	5	*Thyasira flexuosa* (B)	202	*Ampelisca agassizi* (A)	301
	6	*Ampelisca agassizi* (A)	152	*Thyasira flexuosa* (B)	213
	7	*Harbansus dayi* (Os)	152	*Spiophanes wigleyi* (P)	168
	8	Scaphopoda	95	Cirratulidae (P)	145
	9	*Asychis carolinae* (P)	90	*Lucinoma filosa* (B)	120
	10	*Lucinoma filosa* (B)	83	*Prionospio* sp. A (P)	118

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
F3	1	*Aricidea neosuecica* (P)	977	*Aricidea neosuecica* (P)	1285
	2	*Nothria conchylega* (P)	351	*Nothria conchylega* (P)	415
	3	*Lumbrineris cruzensis* (P)	333	Cirratulidae *(Tharyx)* (P)	265
	4	*Tharyx* sp. (P)	268	*Lumbrineris cruzensis* (P)	260
	5	*Thyasira flexuosa* (B)	250	*Ampelisca agassizi* (Am)	168
	6	Scaphopoda	167	*Thyasira flexuosa* (B)	110
	7	*Ampelisca agassizi* (Am)	123	Scaphopoda	98
	8	*Harbansus dayi* (Os)	107	*Aricidea suecica* (P)	82
	9	*Spiophanes wigleyi* (P)	68	*Spiophanes wigleyi* (P)	73
	10	*Prionospio* sp. A (P)	60	*Onuphis pallidula* (P)	45
		SPRING 1976		SUMMER 1976	
F3	1	*Aricidea neosuecica* (P)	999	*Aricidea neosuecica* (P)	971
	2	*Ampelisca agassizi* (A)	280	*Nothria conchylega* (P)	343
	3	*Nothria conchylega* (P)	207	*Ampelisca agassizi* (A)	265
	4	*Lumbrineris cruzensis* (P)	202	Cirratulidae (P)	203
	5	*Thyasira flexuosa* (B)	140	*Lumbrineris cruzensis* (P)	200
	6	Cirratulidae (P)	125	*Onuphis pallidula* (P)	117
	7	*Harbansus dayi* (Os)	105	*Chone infundibuliformis* (P)	103
	8	*Onuphis pallidula* (P)	98	*Thyasira flexuosa* (B)	80
	9	*Amphioplus macilentus* (Op)	83	*Spiophanes wigleyi* (P)	78
	10	*Unciola irrorata* (A)	53	*Unciola irrorata* (A)	73

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
F4	1	*Aricidea neosuecica* (P)	569	*Aricidea neosuecica* (P)	1712
	2	*Ampelisca agassizi* (Am)	536	*Ampelisca agassizi* (A)	551
	3	*Tharyx* sp. (P)	415	Cirratulidae (P)	331
	4	*Thyasira flexuosa* (B)	350	*Nothria conchylega* (P)	295
	5	*Lumbrineris cruzensis* (P)	208	*Lumbrineris cruzensis* (P)	273
	6	*Harbansus bowenae* (Os)	167	*Thyasira flexuosa* (B)	127
	7	*Nothria conchylega* (P)	148	*Aricidea suecica* (P)	102
	8	*Exogone verugera* (P)	142	*Onuphis pallidula* (P)	88
	9	*Lasaea rubra* (B)	107	*Spiophanes wigleyi* (P)	70
	10	*Paradoneis lyra* (P)	90	*Eunice pennata* (P)	68
		SPRING 1976		SUMMER 1976	
F4	1	*Aricidea neosuecica* (P)	2035	*Aricidea neosuecica* (P)	806
	2	*Ampelisca agassizi* (A)	726	*Ampelisca agassizi* (A)	776
	3	*Nothria conchylega* (P)	281	*Polydora* sp. (P)	466
	4	Cirratulidae (P)	275	*Harbansus bowenae* (Os)	273
	5	*Lumbrineris cruzensis* (P)	270	Cirratulidae (P)	235
	6	*Harbansus dayi* (Os)	172	*Lumbrineris cruzensis* (P)	225
	7	*Thyasira flexuosa* (B)	158	*Onuphis pallidula* (P)	200
	8	*Onuphis pallidula* (P)	130	*Nothria conchylega* (P)	145
	9	*Aricidea suecica* (P)	122	*Thyasira flexuosa* (B)	120
	10	*Unciola irrorata* (A)	80	*Aricidea suecica* (P)	118

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
G1	1	*Polygordius* sp.1 (Ar)	1545	*Goniadella gracilis* (P)	375
	2	*Goniadella gracilis* (P)	1179	*Lumbrinerides acuta* (P)	72
	3	*Cirratulidae* (P)	806	*Asterias vulgaris* (As)	28
	4	*Tanaissus liljeborgi* (T)	761	*Astarte castanea* (B)	13
	5	*Lumbrinerides acuta* (P)	503	No other species abundant	
	6	*Hemipodus roseus* (P)	441		
	7	Syllidae (P)	167		
	8	*Tellina agilis* (B)	87		
	9	*Aricidea cerrutii* (P)	67		
	10	*Paraonides lyra* (P)	60		
		WINTER 1976		SUMMER 1976	
G2	1	*Pseudunciola obliquua* (A)	1024	Syllidae (P)	112
	2	Syllidae (P)	538	*Goniadella gracilis* (P)	72
	3	*Tanaissus liljeborgi* (T)	371	*Aricidea wassi* (P)	40
	4	Cirratulidae (P)	158	*Spiophanes bombyx* (P)	28
	5	*Trichophoxus epistomus* (A)	130	*Aricidea suecica* (P)	23
	6	*Unciola irrorata* (A)	90	Cirratulidae (P)	22
	7	*Aricidea suecica* (P)	83		
	8	*Goniadella gracilis* (P)	80	No other species abundant	
	9	*Polygordius* sp.1 (Ar)	80		
	10	*Echinarachnius parma* (E)	77		

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
G3	1	*Ampelisca agassizi* (A)	8475	*Ampelisca agassizi* (A)	3585
	2	Syllidae (P)	1116	Syllidae (P)	1082
	3	*Unciola* sp. (A)	1076	*Unciola irrorata* (A)	774
	4	*Unciola irrorata* (A)	1072	*Erichthonius rubricornis* (A)	556
	5	*Diastylis bispinosa* (C)	1046	*Lumbrineris impatiens* (P)	271
	6	*Euchone incolor* (P)	796	*Diastylis bispinosa* (C)	233
	7	*Praxillura ornata* (P)	316	*Unciola inermis* (A)	220
	8	*Unciola inermis* (A)	291	*Eriopisa elongata* (A)	163
	9	*Eudorella pusilla* (C)	253	*Photis dentata* (A)	153
	10	*Astarte undata* (B)	238	*Notomastus latericeus* (P)	150
		WINTER 1976		SUMMER 1976	
G4	1	Syllidae (P)	878	*Unciola irrorata* (A)	608
	2	Cirratulidae (P)	508	*Unciola inermis* (A)	393
	3	*Tanaissus liljeborgi* (T)	240	Syllidae (P)	295
	4	*Unciola* sp. (A)	231	*Erichthonius rubricornis* (A)	215
	5	*Lumbrinerides acuta* (P)	170	*Spiophanes bombyx* (P)	197
	6	*Asterias* sp. (juv.) (As)	155	Cirratulidae (P)	165
	7	*Trichophoxus epistomus* (A)	135	*Lubrinerides acuta* (P)	138
	8	*Euchone* sp. A. (P)	132	*Diastylis bispinosa* (C)	128
	9	*Goniadella gracilis* (P)	132	*Byblis serrata* (A)	115
	10	*Spiophanes bombyx* (P)	130	*Praxillella* sp. A (P)	93

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
G5	1	*Ampelisca agassizi* (P)	1014	*Ampelisca agassizi* (A)	901
	2	*Harbansus dayi* (Os)	563	*Harbansus dayi* (Os)	388
	3	*Thyasira flexuosa* (B)	466	*Harbansus bowenae* (Os)	313
	4	*Harbansus bowenae* (Os)	385	*Onuphis pallidula* (P)	288
	5	*Onuphis pallidula* (P)	325	Cirratulidae (P)	205
	6	Cirratulidae (P)	321	*Unciola irrorata* (A)	198
	7	*Lumbrineris cruzensis* (P)	238	*Lumbrineris cruzensis* (P)	193
	8	*Spiophanes wigleyi* (P)	177	*Thyasira flexuosa* (B)	170
	9	*Harpinia* sp. 2 (Os)	170	*Eriopisa elongata* (A)	145
	10	*Eriopisa elongata* (A)	140	*Diastylis bispinosa* (C)	140
		WINTER 1976		SUMMER 1976	
G6	1	*Onuphis pallidula* (P)	260	*Onuphis pallidula* (P)	463
	2	*Ampelisca agassizi* (A)	236	*Harbansus bowenae* (Os)	343
	3	Cirratulidae (P)	215	*Ampelisca agassizi* (A)	263
	4	*Nothria conchylega* (P)	175	Cirratulidae (P)	152
	5	*Harbansus bowenae* (Os)	120	*Harbansus dayi* (Os)	88
	6	*Paradoneis lyra* (P)	95	*Prionospio steenstrupi* (P)	87
	7	*Prionospio steenstrupi* (P)	85	*Eriopisa elongata* (A)	73
	8	*Spiophanes wigleyi* (P)	83	*Paradoneis lyra* (P)	55
	9	*Axinopsida orbiculata* (B)	82	*Thyasira flexuosa* (B)	53
	10	*Thyasira flexuosa* (B)	80	*Lumbrineris cruzensis* (P)	53

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
G7	1	*Samytha sexcirrata* (P)	210	Ampharetidae (P)	593
	2	*Harbansus bowenae* (Os)	190	*Thyasira flexuosa* (B)	258
	3	*Thyasira flexuosa* (B)	190	*Onchnesoma steenstrupi* (Si)	217
	4	*Onchnesoma steenstrupi* (Si)	160	*Lasaea rubra* (B)	173
	5	*Lasaea rubra (B)*	110	Cirratulidae (P)	172
	6	*Auchenoplax crinita* (P)	90	*Paradoneis lyra* (P)	108
	7	Cirratulidae (P)	70	*Harbansus bowenae* (Os)	107
	8	*Ampelisca agassizi* (A)	60	*Cossura longicirrata* (P)	105
	9	Syllidae (P)	60	*Notomastus latericeus* (P)	82
	10	*Harbansus dayi* (Os)	40	Scaphopoda	62
		WINTER 1976		SUMMER 1976	
H1	1	Cirratulidae (P)	238	Cirratulidae (P)	266
	2	*Lumbrineris cruzensis* (P)	128	*Edwardsia* sp. (An)	137
	3	Scaphopoda	120	*Lumbrineris cruzensis* (P)	105
	4	*Paraonis gracilis* (P)	118	*Paramphinome pulchella* (P)	95
	5	*Thyasira flexuosa* (B)	72	Ampharetidae (P)	88
	6	*Spiophanes bombyx* (P)	62	*Paraonis gracilis* (P)	87
	7	*Mediomastus ambiseta* (P)	45	*Lasaea rubra* (B)	78
	8	*Ampharete arctica* (P)	32	*Notomastus latericeus* (P)	75
	9	Syllidae (P)	32	*Axiognathus squamata* (Op)	58
	10	*Nucula tenuis* (B)	30	*Ampelisca declivitatus* (A)	53

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
H2	1	Cirratulidae (P)	57	Cirratulidae (P)	57
	2	*Lumbrineris tenuis* (P)	42	*Ophelina* sp. A (P)	32
	3	*Paraonis gracilis* (P)	25	*Mitrella diaphana* (G)	32
	4	*Harpinia* sp. 2 (A)	17	*Harpinia* sp. 2 (A)	27
	5	Scaphopoda	17	*Nucula tenuis* (B)	23
	6	*Spiophanes bombyx* (P)	17	*Lumbrineris impatiens* (P)	17
	7	*Lumbrineris latreilli* (P)	12	*Alvania bruchia* (G)	15
	8	*Thyasira flexuosa* (B)	11	*Paraonis gracilis* (P)	15
	9	*Glycera capitata* (P)	10	*Cossura longocirrata* (P)	13
	10	*Edwardsia* sp. (An)	10	*Lumbrineris tenuis* (P)	13
		WINTER 1976		SUMMER 1976	
I1	1	Syllidae (P)	348	*Chone infundibuliformis* (P)	924
	2	Cirratulidae (P)	325	Cirratulidae (P)	263
	3	*Notomastus latericeus* (P)	268	*Lumbrineris impatiens*	167
	4	*Lumbrineris impatiens* (P)	188	*Notomastus latericeus* (P)	150
	5	*Ampelisca agassizi* (A)	163	Syllidae (P)	123
	6	*Chone infundibuliformis* (P)	160	*Diastylis bispinosa* (C)	103
	7	*Polydora* sp. (P)	100	*Ampelisca agassizi* (A)	85
	8	*Chaetopleura apiculata* (Pp)	77	*Scoloplos acmeceps* (P)	75
	9	*Diastylis bispinosa* (C)	62	*Onuphis pallidula* (P)	72
	10	*Onuphis pallidula* (P)	55	*Unciola irrorata* (A)	65

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
I2	1	*Cyclopecten nanus* (B)	215	*Aricidea neosuecica* (P)	285
	2	*Chone infundibuliformis* (P)	130	*Amphioplus macilentus* (Op)	222
	3	*Diastylis bispinosa* (C)	118	*Erichthonius rubricornis* (A)	205
	4	*Lumbrineris impatiens* (P)	115	*Chone infundibuliformis* (P)	177
	5	*Aricidea neosuecica* (P)	105	Cirratulidae (P)	162
	6	Cirratulidae (P)	103	*Lumbrineris impatiens* (P)	150
	7	*Chaetopleura apiculata* (Pp)	85	*Ophelina acuminata* (P)	112
	8	*Harbansus dayi* (Os)	67	*Ampelisca agassizi* (A)	108
	9	*Thyasira flexuosa* (B)	65	*Axiognathus swuamata* (Op)	102
	10	*Onuphis pallidula* (P)	58	*Cyclopecten nanus* (B)	87
		WINTER 1976		SUMMER 1976	
I3	1	*Ampelisca agassizi* (A)	456	*Ampelisca agassizi* (A)	972
	2	*Aricidea neosuecica* (P)	431	*Chone infundibuliformis* (P)	253
	3	Cirratulidae (P)	323	*Spiophanes wigleyi* (P)	218
	4	*Aricidea suecica* (P)	231	*Onuphis pallidula* (P)	215
	5	*Onuphis pallidula* (P)	198	Cirratulidae (P)	195
	6	*Thyasira flexuosa* (B)	135	*Aricidea neosuecica* (P)	150
	7	*Lumbrineris impatiens* (P)	128	*Thyasira flexuosa* (B)	132
	8	*Spiophanes wigleyi* (P)	122	*Nothria conchylega* (P)	118
	9	*Lumbrineris cruzensis* (P)	85	*Lumbrineris cruzensis* (P)	115
	10	*Prionospio steenstrupi* (P)	78	*Prionospio steenstrupi* (P)	113

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
I4	1	*Thyasira flexuosa* (B)	515	Cirratulidae (P)	298
	2	Cirratulidae (P)	485	*Thyasira flexuosa* (B)	132
	3	*Chone infundibuliformis* (P)	275	*Thyasira phynea* (B)	122
	4	*Paramphinome pluchella* (P)	255	Ampharetidae (P)	115
	5	Ampharetidae (P)	215	*Paramphinome pulchella* (P)	90
	6	*Lumbrineris tenuis* (P)	213	*Lumbrineris impatiens* (P)	73
	7	Scaphopoda. (P)	122	*Edwardsia* sp. (An)	63
	8	*Terebellides stroemi* (P)	113	*Nucula tenuis* (B)	55
	9	*Edwardsia* sp. (An)	103	Scaphopoda	53
	10	*Nucula tenuis* (B)	98	*Lumbrineris cruzensis* (P)	48
		WINTER 1976		SUMMER 1976	
J1	1	Scaphopoda (Sc)	726	*Lasaea rubra* (B)	193
	2	Cirratulidae (P)	225	*Notomastus latericeus* (P)	157
	3	*Lasaea rubra* (B)	177	Ampharetidae (P)	155
	4	*Thyasira flexuosa* (B)	157	*Onchnesoma steenstrupi* (Si)	137
	5	*Portlandia inconspicua* (B)	142	Scaphopoda (Sc)	87
	6	*Paramphinome pulchella* (P)	133	*Thyasira flexuosa* (B)	67
	7	*Lumbrineris tenuis* (P)	83	*Onuphis atlantisa* (P)	65
	8	*Phascolion strombi* (Si)	80	Cirratulidae (P)	60
	9	*Cossura longocirrata* (P)	75	*Lumbrineris cruzensis* (P)	55
	10	*Onchnesoma steenstrupi* (Si)	68	*Periploma fragilis* (B)	50

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
J2	1	*Ceratocephale loveni* (P)	40	*Ceratocephale loveni* (P)	58
	2	*Paraonis gracilis* (P)	38	Cirratulidae (P)	32
	3	*Nucula tenuis* (B)	23	*Lumbrineris tenuis* (P)	27
	4	*Lumbrineris tenuis* (P)	23	*Paramphinome pulchella* (P)	22
	5	*Mitrella diaphana* (G)	13	*Thyasira pygmea* (B)	13
	6	*Alvania pelagica* (C)	13	Phoxocephalidae (A)	8
	7	Cirratulidae (P)	12	*Nucula tenuis* (B)	8
	8	*Thyasira flexuosa* (B)	10	*Alvania pelagica* (G)	8
	9	*Portlandia inconspicua* (B)	10	*Cossura longocirrata* (P)	7
	10	*Lumbrineris cruzensis* (P)	8.3		
		WINTER 1976		SUMMER 1976	
K1	1	Syllidae (P)	1792	*Spiophanes bombyx* (P)	241
	2	*Polygordius* sp.1(Ar)	1292	Syllidae (P)	205
	3	*Tanaissus liljeborgi* (T)	318	*Tanaissus liljeborgi* (T)	115
	4	*Tellina agilis* (B)	168	*Nephtys picta* (P)	107
	5	Cirratulidae (P)	123	*Trichophoxus epistomus* (A)	93
	6	Oligochaeta	112	*Pseudunciola irrorata* (A)	93
	7	*Goniadella gracilis* (P)	108	*Tellina agilis* (B)	87
	8	*Trichophoxus epistomus* (A)	80	*Polygordius* sp. (Ar)	70
	9	*Nephtys picta* (P)	70	*Edotea montosa* (I)	53
	10	*Spisula solidissima* (B)	63	Cirratulidae (P)	50

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
K2	1	*Ampelisca vadorum* (A)	2821	*Erichthonius rubricornis* (A)	525
	2	*Byblis serrata* (A)	2110	*Unciola irrorata* (A)	228
	3	*Unicola irrorata* (A)	994	*Ampelisca vadorum* (A)	217
	4	*Cerastoderma pinnulatum* (B)	263	*Aglaophamus circinata* (P)	183
	5	*Praxillella* sp. A. (P)	222	*Byblis serrata* (A)	115
	6	Cirratulidae (P)	162	*Heteromastus filiformis* (P)	107
	7	*Polygordius* sp. (Ar)	162	*Harmothoe extenuata* (P)	105
	8	*Leptocheirus pinguis* (A)	145	*Trichophoxus epistomus* (A)	60
	9	*Trichophoxus epistomus* (A)	143	*Lumbrinerides acuta* (P)	53
	10	*Erichthonius rubricornis* (A)	113	*Lumbrineris fragilis* (P)	48
		WINTER 1976		SUMMER 1976	
K3	1	*Goniadella gracilis* (P)	1037	*Goniadella gracilis* (P)	251
	2	*Polygordius* sp. (Ar)	886	*Unciola irrorata* (A)	133
	3	Syllidae (P)	614	*Lumbrinerides acuta* (P)	92
	4	*Spiophanes bombyx* (P)	386	*Aglaophamus circinata* (P)	78
	5	*Lumbrinerides acuta* (P)	152	*Lumbrineris fragilis* (P)	73
	6	*Trichophoxus epistomus* (A)	143	*Spiophanes bombyx* (P)	63
	7	*Lumbrineris fragilis* (P)	103	*Polygordius* sp.1(Ar)	62
	8	*Tanaissus liljeborgi* (T)	97	*Trichophoxus epistomus* (A)	60
	9	Cirratulidae (P)	72	*Tanaissus liljeborgi* (T)	47
	10	*Echinarachnius parma* (E)	68	Cirratulidae (P)	47

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
K4	1	*Thyasira flexuosa* (B)	814	*Ampelisca agassizi* (A)	376
	2	*Ampelisca agassizi* (A)	351	*Thyasira flexuosa* (B)	356
	3	*Lumbrineris cruzensis* (P)	318	*Onuphis pallidula* (P)	310
	4	*Harbansus bowenae* (Os)	306	*Lumbrineris cruzensis* (P)	288
	5	*Onuphis pallidula* (P)	198	*Harbansus bowenae* (Os)	153
	6	*Harbansus dayi* (Os)	173	*Ninoe nigripes* (P)	135
	7	*Harpinia* sp. 2 (A)	157	*Notomastus latericeus* (P)	132
	8	*Notomastus latericeus* (P)	133	*Aricidea neosuecica* (P)	130
	9	*Echinocythereis echinata* (Os)	128	*Ophelina acuminata* (P)	103
	10	*Thyasira trisinuata* (B)	115	*Harpinia* sp. 2 (A)	90
		WINTER 1976		SUMMER 1976	
K5	1	*Ampelisca agassizi* (A)	673	*Ampelisca agassizi* (A)	1151
	2	*Aricidea neosuecica* (P)	626	*Aricidea neosuecica* (P)	1089
	3	*Lumbrineris cruzensis* (P)	210	Cirratulidae (P)	276
	4	Cirratulidae (P)	167	*Lumbrineris cruzensis* (P)	213
	5	*Aricidea suecica* (P)	127	*Onuphis pallidula* (P)	207
	6	*Thyasira flexuosa* (B)	93	*Unciola irrorata* (A)	132
	7	*Onuphis pallidula* (P)	50	*Eunice antennata* (P)	85
	8	*Corbula* sp. (B)	47	*Aricidea suecica* (P)	82
	9	*Spiophanes wigleyi* (P)	47	*Thyasira flexuosa* (B)	52
	10	Oligochaeta	37	*Spiophanes wigleyi* (P)	35

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
K6	1	*Onchnesoma steenstrupi* (Si)	153	*Onchnesoma steenstrupi* (Si)	280
	2	Scaphopoda (Sc)	153	*Lasaea rubra* (B)	217
	3	*Notomastus latericeus* (P)	148	*Notomastus latericeus* (P)	207
	4	Ampharetidae (P)	147	Ampharetidae (P)	197
	5	*Thyasira flexuosa* (B)	125	*Thyasira flexuosa* (B)	147
	6	*Lasaea rubra* (B)	122	Syllidae (P)	95
	7	Cirratulidae (P)	92	Cirratulidae (P)	73
	8	Syllidae (P)	72	*Paramphinome pulchella* (P)	63
	9	*Paramphinome pulchella* (P)	50	*Axiognathus squamata* (Op)	60
	10	*Onuphis atlantisa* (P)	40	*Onuphis atlantisa* (P)	57
		WINTER 1976		SUMMER 1976	
L1	1	*Spiophanes bombyx* (P)	1545	*Tellina agilis* (B)	286
	2	*Magelona papillicornis* (P)	889	Magelonidae (P)	220
	3	*Prionospio* sp. A (P)	316	*Nephtys picta* (P)	162
	4	*Tellina agilis* (B)	310	*Ampelisca verrilli* (A)	127
	5	*Spisula solidissima* (B)	246	*Nassarius trivittatus* (G)	38
	6	*Caulleriella* sp. (P)	167	*Prionospio* sp. A (P)	33
	7	*Asabellides oculata* (P)	155	Cirratulidae (P)	25
	8	*Aricidea wassi* (P)	90	*Solemya velum* (B)	23
	9	Nephtyidae (P)	87	*Lumbrineris fragilis* (P)	15
	10	*Nephtys picta* (P)	77	*Cylichna verrilli* (G)	13

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
L2	1	*Cytheretta edwardsi* (Os)	926	*Spiophanes bombyx* (P)	1167
	2	*Nucula delphinodonta* (B)	824	*Nucula proxima* (B)	664
	3	*Nucula proxima* (B)	799	*Lumbrineris impatiens* (P)	476
	4	*Ampelisca agassizi* (A)	431	*Nucula delphinodonta* (B)	473
	5	*Lumbrineris impatiens* (P)	378	*Ampelisca agassizi* (A)	376
	6	*Trichophoxus epistomus* (A)	270	*Cytheretta edwardsi* (Os)	246
	7	*Spiophanes bombyx* (P)	82	*Trichophoxus epistomus* (A)	241
	8	*Aglaophamus circinata* (P)	72	*Cerastoderma pinnulatum* (B)	197
	9	*Sarsiella zostericola* (Os)	65	*Aglaophamus circinata* (P)	162
	10	*Tellina agilis* (B)	58	*Ampelisca vadorum* (A)	92
		WINTER 1976		SUMMER 1976	
L3	1	*Scolaplos acmecips* (P)	385	*Scoloplos acmeceps* (P)	774
	2	*Caulleriella* sp. (P)	103	*Aglaophamus circinata* (P)	285
	3	*Trichophoxus epistomus* (A)	93	*Spiophanes bombyx* (P)	208
	4	*Aricidea wassi* (P)	92	*Unciola irrorata* (A)	157
	5	*Lumbrineris impatiens* (P)	72	Cirratulidae (P)	135
	6	*Mitrella* sp. (G)	67	*Aricidea wassi* (P)	88
	7	*Echinarachnius parma* (E)	65	Syllidae (P)	87
	8	*Byblis serrata* (A)	65	*Echinarachnius parma* (E)	72
	9	*Aglaophamus circinata* (P)	52	*Praxillella* sp. A (P)	72
	10	Syllidae (P)	38	*Trichophoxus epistomus* (A)	65

Appendix 6-C. (continued)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
L4	1	*Ampelisca agassizi* (A)	1041	*Chone infundibuliformis* (P)	949
	2	*Chone infundibuliformis* (P)	350	*Ampelisca agassizi* (A)	666
	3	*Erichthonius rubricornis* (A)	296	*Erichthonius rubricornis* (A)	518
	4	*Notomastus latericeus* (P)	142	*Unciola irrorata* (A)	230
	5	Oligochaeta	127	*Notomastus latericeus* (P)	215
	6	*Unciola irrorata* (A)	115	Cirratulidae (P)	142
	7	*Axiognathus squamata* (Op)	90	*Onuphis pallidula* (P)	120
	8	*Onuphis pallidula* (P)	68	*Scoloplos acmeceps* (P)	103
	9	*Jasmineira filiformis* (P)	57	*Lumbrineris impatiens* (P)	103
	10	*Ptilanthura tricarina* (I)	55	*Axiognathus squamata* (Op)	97
		WINTER 1976		SUMMER 1976	
L5	1	*Ampelisca agassizi* (A)	1800	*Ampelisca agassizi* (A)	2534
	2	Cirratulidae (P)	160	*Unciola irrorata* (A)	288
	3	*Thyasira flexuosa* (B)	140	*Onuphis pallidula* (P)	193
	4	*Unciola irrorata* (A)	133	*Axiognathus squamata* (Op)	137
	5	*Onuphis pallidula* (P)	113	Cirratulidae (P)	130
	6	*Notomastus latericeus* (P)	103	*Eunice antennata* (P)	118
	7	*Lumbrineris cruzensis* (P)	77	*Thyasira flexuosa* (B)	108
	8	*Aricidea neosuecica* (P)	72	*Lumbrineris cruzensis* (P)	92
	9	*Axiognathus squamata* (Op)	67	*Diastylis bispinosa* (C)	70
	10	*Spiophanes wigleyi* (P)	52	*Erichthonius rubricornis* (A)	50

Appendix 6-C. (concluded)

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		WINTER 1976		SUMMER 1976	
L6	1	Ampharetidae (P)	263	Ampharetidae (P)	453
	2	*Notomastus latericeus* (P)	157	*Notomastus latericeus* (P)	153
	3	*Golfingia minuta* (Si)	110	*Harbansus dayi* (Os)	140
	4	*Paramphinome pulchella* (P)	63	*Onchnesoma steenstrupi* (Si)	90
	5	*Lasaea rubra* (B)	53	*Lasaea rubra* (B)	85
	6	*Brada villosa* (P)	52	*Paramphinome pulchella* (P)	83
	7	*Lumbrineris cruzensis* (P)	48	*Harbansus bowenae* (Os)	65
	8	Maldanidae (P)	47	*Hyalinoecia artifex* (P)	50
	9	Cirratulidae (P)	43	*Thyasira flexuosa* (B)	48
	10	*Astropecten americanus* (As)	42	*Unciola inermis* (A)	33
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

Appendix 6-D. Total number of species captured and diversity measures for SBT and anchor dredge collections of megabenthos at each station during each season.

		Small Biology Trawl			Anchor Dredge		
Station	Season	No. Spp.	H'(bits/indiv)	J'	No. Spp.	H'(bits/indiv)	J'
A1	Fall	40	3.00	0.56	*	*	*
	Winter	33	2.30	0.45	13	2.80	0.75
	Spring	43	3.05	0.56	21	2.78	0.63
	Summer	35	3.42	0.66	18	2.29	0.55
B1	Fall	46	2.45	0.44	*	*	*
	Winter	48	1.97	0.35	22	1.70	0.38
	Spring	37	2.01	0.38	36	2.93	0.56
	Summer	43	2.35	0.43	36	2.79	0.54
C2	Fall	20	2.18	0.50	*	*	*
	Winter	16	2.98	0.74	9	2.08	0.65
	Spring	25	2.29	0.49	13	2.60	0.70
	Summer	14	1.54	0.40	5	0.43	0.18
D1	Fall	23	0.73	0.16	*	*	*
	Winter	27	0.95	0.20	23	0.69	0.15
	Spring	28	1.70	0.35	26	0.75	0.16
	Summer	17	1.51	0.36	22	1.83	0.41
E1	Fall	46	2.67	0.48	*	*	*
	Winter	44	2.52	0.46	21	1.98	0.45
	Spring	49	2.05	0.36	18	1.49	0.35
	Summer	35	2.30	0.44	32	2.13	0.42
F1	Fall	36	2.00	0.38	*	*	*
	Winter	24	0.92	0.20	25	1.51	0.32
	Spring	21	1.10	0.25	18	2.82	0.67
	Summer	27	2.22	0.46	19	2.50	0.59
I1	Fall	53	4.24	0.74	*	*	*
	Winter	35	2.93	0.57	10	1.81	0.54
	Spring	43	3.69	0.68	17	2.76	0.67
	Summer	42	3.54	0.65	23	2.40	0.53
N3	Fall	19	0.83	0.19	*	*	*
	Winter	26	0.72	0.15	23	0.63	0.14
	Spring	29	1.23	0.25	25	1.08	0.23
	Summer	29	1.35	0.27	26	1.93	0.41

* Samples not taken this season

Appendix 6-E. Geometric mean wet-weight biomass (g/m^2) for each major taxon.

Station	Season	Annelida	Mollusca	Crustacea	Echinodermata	Other
A1	Fall	1.78	0.85	0.02	0.57	0.42
	Winter	0.82	1.25	0.39	0.53	0.24
	Spring	1.70	0.65	0.62	1.70	0.12
	Summer	1.48	1.11	0.87	0.99	0.17
A2	Fall	1.50	2.26	0.00	3.42	0.13
	Winter	1.22	0.26	0.08	1.73	0.16
	Spring	1.15	0.46	0.06	2.81	0.15
	Summer	1.19	0.47	0.01	4.70	0.08
A3	Fall	2.10	0.21	0.00	1.64	0.03
	Winter	1.05	0.17	0.08	0.72	0.15
	Spring	2.12	0.39	0.07	1.24	0.23
	Summer	1.80	0.31	0.07	2.24	0.04
A4	Fall	1.30	0.19	0.02	0.20	0.13
	Winter	0.98	0.08	0.11	0.19	0.46
	Spring	1.63	0.08	0.05	0.28	0.14
	Summer	0.94	0.06	0.03	0.44	0.09
B1	Fall	1.45	0.53	0.19	3.05	0.15
	Winter	1.53	1.59	0.26	4.20	0.11
	Spring	0.68	25.56	0.79	3.38	0.42
	Summer	1.90	10.07	0.93	1.16	0.27
B2	Fall	2.72	2.67	0.03	0.44	0.15
	Winter	1.48	8.58	0.32	1.84	0.25
	Spring	1.37	10.25	0.62	2.70	0.17
	Summer	1.54	5.27	1.16	0.19	0.07
B3	Fall	4.85	4.22	0.05	0.43	0.35
	Winter	2.29	9.39	2.00	0.13	0.28
	Spring	2.24	6.05	3.30	0.35	0.43
	Summer	3.48	5.72	3.94	0.66	0.07
B4	Fall	2.05	0.21	0.03	0.98	0.04
	Winter	1.34	2.58	0.49	0.44	0.46
	Spring	0.88	0.25	0.35	0.31	0.10
	Summer	1.34	0.07	0.31	0.10	0.11
C1	Fall	0.48	2.37	0.23	10.63	0.00
	Winter	0.77	1.98	0.08	0.56	0.09
	Spring	0.30	0.63	0.16	4.92	0.00
	Summer	0.89	1.26	0.00	0.00	0.13

Appendix 6-E. (continued)

Station	Season	Annelida	Mollusca	Crustacea	Echinodermata	Other
C2	Fall	3.03	7.85	0.50	5.95	0.00
	Winter	1.02	2.14	0.14	5.09	0.24
	Spring	1.48	1.27	0.12	1.29	0.12
	Summer	3.81	5.75	0.03	0.00	0.67
C3	Fall	2.55	0.20	0.66	1.96	0.00
	Winter	0.89	0.13	0.03	0.41	0.10
	Spring	1.05	0.04	0.17	0.97	0.15
	Summer	0.69	0.09	0.00	0.08	0.08
C4	Fall	4.32	1.02	1.04	0.06	0.25
	Winter	1.96	0.46	0.06	1.59	0.37
	Spring	4.03	0.18	0.53	0.00	1.83
	Summer	10.98	0.68	0.07	0.00	4.04
D1	Fall	0.74	0.27	0.05	6.91	0.05
	Winter	8.98	1.56	0.60	9.58	0.33
	Spring	0.21	0.44	1.18	4.18	0.01
	Summer	5.04	0.68	1.12	5.77	0.12
D2	Fall	0.50	0.34	0.03	35.39	0.00
	Winter	0.29	0.11	0.35	3.93	0.10
	Spring	0.89	0.10	0.39	8.84	0.02
	Summer	0.47	0.19	0.88	15.66	0.10
D3	Fall	0.48	0.69	0.20	12.84	0.68
	Winter	0.35	0.99	0.46	10.20	0.14
	Spring	0.43	0.07	0.38	22.75	0.01
	Summer	0.61	1.35	1.08	1.05	0.03
D4	Fall	2.71	58.75	0.05	2.26	0.39
	Winter	6.28	43.68	0.81	0.63	0.31
	Spring	5.03	6.40	1.59	0.10	0.59
	Summer	4.57	5.98	0.67	0.99	0.27
E1	Fall	5.15	5.09	0.51	0.69	0.25
	Winter	1.33	0.39	0.59	1.03	0.12
	Spring	1.31	0.53	0.31	0.53	0.18
	Summer	1.29	7.42	0.49	1.61	0.14
E2	Fall	2.41	2.72	0.28	0.29	0.61
	Winter	1.74	5.16	0.44	0.47	0.11
	Spring	1.27	0.83	0.26	0.38	0.05
	Summer	2.44	4.12	2.22	0.43	0.17
E3	Fall	2.49	5.02	0.25	1.60	0.64

Appendix 6-E. (continued)

Station	Season	Annelida	Mollusca	Crustacea	Echinodermata	Other
E3	Winter	1.16	0.40	0.15	1.31	0.15
	Spring	1.11	2.41	0.29	0.83	0.26
	Summer	0.89	0.14	0.32	1.72	0.08
E4	Fall	3.32	6.83	0.54	0.32	0.83
	Winter	1.81	6.05	0.32	0.29	0.22
	Spring	1.76	11.49	0.47	0.11	0.05
	Summer	1.48	5.72	0.43	0.00	0.23
F1	Fall	1.09	0.31	0.00	0.20	0.70
	Winter	6.22	0.14	0.14	0.79	0.02
	Spring	1.47	1.69	0.15	0.01	0.10
	Summer	1.93	0.94	0.63	0.47	0.10
F2	Fall	1.01	0.29	0.00	1.22	0.94
	Winter	1.40	0.33	0.14	0.71	0.60
	Spring	1.47	0.31	0.08	2.44	0.09
	Summer	1.84	0.65	0.20	0.97	0.01
F3	Fall	1.82	0.13	0.00	0.64	0.39
	Winter	5.00	0.18	0.12	0.28	0.31
	Spring	3.26	0.04	0.07	0.54	0.08
	Summer	1.17	0.09	0.12	0.07	0.11
F4	Fall	2.81	0.24	0.00	0.69	0.63
	Winter	2.98	0.14	0.46	0.34	0.55
	Spring	4.29	0.21	0.19	0.10	0.41
	Summer	1.79	0.15	0.31	0.15	2.01
G1	Winter	1.40	3.07	0.15	1.15	0.37
	Summer	0.86	1.21	0.03	0.22	2.72
G2	Winter	0.69	1.12	0.43	6.77	0.05
	Summer	0.33	0.08	0.08	0.00	0.08
G3	Winter	9.38	3.97	3.25	0.77	0.45
	Summer	4.15	2.12	3.30	0.80	1.03
G4	Winter	1.49	14.97	0.45	0.79	0.09
	Summer	2.13	19.98	1.41	0.82	0.42
G5	Winter	1.92	1.01	0.26	0.56	0.77
	Summer	1.87	2.43	0.61	0.36	0.17
G6	Winter	1.44	0.54	0.06	0.25	0.19
	Summer	1.77	0.45	0.11	0.62	0.07

Appendix 6-E. (continued)

Station	Season	Annelida	Mollusca	Crustacea	Echinodermata	Other
G7	Summer	0.89	0.09	0.08	0.04	0.01
H1	Winter	1.32	0.19	0.03	0.39	0.06
	Summer	1.08	0.24	0.11	0.34	0.06
H2	Winter	0.17	0.01	0.01	0.00	0.03
	Summer	0.19	0.03	0.02	0.12	0.03
I1	Winter	2.39	2.37	0.12	0.24	0.05
	Summer	2.43	0.18	0.38	0.39	0.00
I2	Winter	1.10	0.47	0.10	0.00	0.96
	Summer	1.17	0.26	0.16	0.85	0.37
I3	Winter	1.78	0.29	0.04	1.99	0.31
	Summer	2.15	0.35	0.34	1.28	0.18
I4	Winter	1.45	0.25	0.00	0.48	0.39
	Summer	0.77	0.32	0.07	0.00	0.49
J1	Winter	1.30	0.72	0.00	0.00	0.76
	Summer	1.03	0.48	0.08	0.10	0.28
J2	Winter	0.64	0.07	0.00	0.00	0.02
	Summer	0.56	0.02	0.00	0.00	0.00
K1	Winter	1.94	2.77	0.07	0.53	0.16
	Summer	1.22	2.49	0.50	0.37	0.08
K2	Winter	1.36	2.94	5.04	0.57	0.21
	Summer	1.61	3.16	0.59	0.40	0.10
K3	Winter	1.85	1.63	0.14	0.03	0.09
	Summer	0.81	0.58	0.28	0.03	0.00
K4	Winter	2.11	0.84	0.13	0.59	3.63
	Summer	1.63	1.30	0.26	0.37	1.48
K5	Winter	1.33	0.05	0.75	0.08	1.01
	Summer	1.40	0.12	0.45	0.17	0.51
K6	Winter	1.64	0.37	0.03	0.08	0.13
	Summer	2.74	0.43	0.24	0.18	0.59
L1	Winter	1.06	1.15	0.14	0.00	0.07
	Summer	0.80	7.31	0.32	0.18	0.06

Appendix 6-E. (concluded)

Station	Season	Annelida	Mollusca	Crustacea	Echinodermata	Other
L2	Winter	1.61	0.82	0.40	0.23	0.08
	Summer	2.35	0.91	0.28	0.00	0.09
L3	Winter	0.49	1.42	0.08	0.09	0.14
	Summer	1.12	0.46	0.11	0.81	0.36
L4	Winter	1.18	1.26	0.25	0.05	0.54
	Summer	1.20	1.15	0.41	0.00	0.30
L5	Winter	1.50	0.10	0.28	0.05	0.60
	Summer	1.40	0.32	0.72	0.09	0.51
L6	Winter	3.76	0.31	0.40	0.08	0.02
	Summer	2.78	0.22	0.09	0.03	0.03

Appendix 6-F. Density and diversity measures for collections of macrobenthos for each station during each season.

Station	Season	Density (indiv/ 0.6 m^2)	Areal Richness (spp/ 0.6 m^2)	Species Diversity (H'-bits/ indiv)	Numerical Richness (spp/500 indiv)	Species Evenness (J')
A1	Fall	3176	136	4.43	67.6	0.63
	Winter	3250	149	4.82	77.3	0.67
	Spring	3426	124	4.17	64.1	0.59
	Summer	3191	117	4.50	62.9	0.65
A2	Fall	2118	88	4.23	54.2	0.65
	Winter	1758	97	5.03	67.2	0.76
	Spring	2122	86	4.29	56.8	0.66
	Summer	2493	90	3.85	52.2	0.59
A3	Fall	2260	128	5.01	75.4	0.71
	Winter	1576	80	3.93	53.7	0.62
	Spring	2031	93	4.46	55.8	0.68
	Summer	1708	93	4.27	57.3	0.65
A4	Fall	2620	130	4.95	72.5	0.70
	Winter	2173	110	4.63	64.5	0.68
	Spring	1726	91	4.59	59.3	0.70
	Summer	1682	100	4.77	64.6	0.71
B1	Fall	2841	83	4.36	52.8	0.68
	Winter	2698	91	3.91	52.8	0.60
	Spring	1904	63	4.23	46.6	0.70
	Summer	2112	85	4.22	54.2	0.65
B2	Fall	2973	86	4.83	55.9	0.75
	Winter	3929	97	4.25	50.9	0.64
	Spring	2898	75	4.42	46.0	0.71
	Summer	1516	78	4.22	50.7	0.67
B3	Fall	8508	123	2.74	49.9	0.39
	Winter	8645	133	2.52	46.6	0.36
	Spring	9385	99	2.07	40.2	0.31
	Summer	8131	108	2.86	47.7	0.42
B4	Fall	2918	65	3.85	37.3	0.64
	Winter	1866	59	3.85	35.5	0.66
	Spring	1129	52	4.10	43.4	0.71
	Summer	1167	58	4.14	43.4	0.70
C1	Fall	1204	50	3.67	35.3	0.65
	Winter	870	41	3.82	32.4	0.72
	Spring	1335	47	3.59	31.6	0.64
	Summer	487	38	3.04	***	0.58

Appendix 6-F. (continued)

Station	Season	Density (indiv/ 0.6 m^2)	Areal Richness (spp/ 0.6 m^2)	Species Diversity (H'-bits/ indiv)	Numerical Richness (spp/500 indiv)	Species Evenness (J')
C2	Fall	1828	60	3.47	38.2	0.59
	Winter	2478	57	3.43	32.7	0.59
	Spring	4739	60	3.19	29.2	0.54
	Summer	1112	44	3.64	32.7	0.66
C3	Fall	2260	63	3.60	35.0	0.61
	Winter	2331	45	3.36	28.8	0.61
	Spring	1720	50	3.70	36.3	0.65
	Summer	236	27	3.41	***	0.71
C4	Fall	20741	77	1.87	14.6	0.30
	Winter	3898	80	3.57	38.9	0.56
	Spring	2301	74	4.73	52.9	0.76
	Summer	1047	39	3.36	31.3	0.63
D1	Fall	868	49	3.86	41.6	0.68
	Winter	5366	74	2.82	33.3	0.46
	Spring	406	44	4.00	***	0.73
	Summer	2779	59	2.61	30.8	0.44
D2	Fall	620	51	4.62	47.6	0.81
	Winter	594	46	3.82	46.0	0.69
	Spring	1472	58	2.95	36.2	0.50
	Summer	2021	52	2.48	35.8	0.43
D3	Fall	1912	58	3.62	40.2	0.61
	Winter	787	46	4.15	40.5	0.75
	Spring	601	53	4.14	53.0	0.72
	Summer	751	42	4.27	38.1	0.79
D4	Fall	3504	80	4.09	46.8	0.65
	Winter	4593	103	4.63	52.8	0.70
	Spring	5001	108	4.65	57.8	0.68
	Summer	4676	94	3.98	53.7	0.60
E1	Fall	5814	107	2.49	43.1	0.37
	Winter	2460	84	4.41	52.4	0.69
	Spring	2214	81	4.54	56.6	0.71
	Summer	2125	96	5.05	64.3	0.76
E2	Fall	22701	124	2.00	34.8	0.29
	Winter	2613	144	5.10	81.8	0.72
	Spring	3423	97	4.16	56.9	0.63
	Summer	5371	119	3.34	55.2	0.48

Appendix 6-F. (continued)

Station	Season	Density (indiv/ 0.6 m^2)	Areal Richness (spp/ 0.6 m^2)	Species Diversity (H'-bits/ indiv)	Numerical Richness (spp/500 indiv)	Species Evenness (J')
E3	Fall	1436	89	4.88	63.3	0.75
	Winter	2030	84	4.34	49.1	0.68
	Spring	2802	82	4.48	53.5	0.70
	Summer	1021	77	4.97	63.7	0.79
E4	Fall	2889	149	5.46	82.4	0.76
	Winter	2780	124	5.13	72.1	0.74
	Spring	2957	111	5.44	74.7	0.80
	Summer	2255	112	5.22	72.6	0.76
F1	Fall	2289	106	4.51	67.7	0.67
	Winter	3054	100	3.06	53.8	0.46
	Spring	1823	87	2.88	54.1	0.44
	Summer	1832	101	4.86	66.2	0.73
F2	Fall	4390	121	4.16	58.8	0.60
	Winter	2906	103	3.95	50.3	0.59
	Spring	2069	86	4.43	55.7	0.69
	Summer	3736	80	3.68	42.2	0.58
F3	Fall	2201	115	4.44	65.8	0.65
	Winter	1975	91	3.60	50.0	0.55
	Spring	1666	84	3.85	52.1	0.60
	Summer	1781	85	3.89	51.3	0.60
F4	Fall	2378	122	4.77	67.7	0.69
	Winter	2603	96	3.63	50.3	0.55
	Spring	3094	102	3.70	51.4	0.55
	Summer	2600	93	4.26	51.0	0.65
G1	Winter	3611	59	3.23	27.6	0.56
	Summer	332	27	1.98	**	0.41
G2	Winter	1926	55	3.65	38.8	0.63
	Summer	227	25	3.37	**	0.72
G3	Winter	10845	132	3.32	47.7	0.47
	Summer	5522	105	3.83	53.3	0.57
G4	Winter	2483	75	4.23	42.5	0.68
	Summer	2000	78	4.50	50.5	0.71
G5	Winter	3147	111	4.62	61.4	0.68
	Summer	2447	102	4.57	59.3	0.68

Appendix 6-F. (continued)

Station	Season	Density (indiv/ 0.6 m^2)	Areal Richness (spp/ 0.6 m^2)	Species Diversity (H'-bits/ indiv)	Numerical Richness (spp/500 indiv)	Species Evenness (J')
G6	Winter	1402	93	4.98	63.9	0.76
	Summer	1428	79	4.60	60.4	0.73
G7	Winter	1044	47*	4.65	***	0.83
	Summer	1764	84	4.81	61.9	0.75
H1	Winter	928	107	5.31	87.0	0.78
	Summer	1057	100	5.19	77.3	0.78
H2	Winter	231	56	4.98	***	0.85
	Summer	239	57	4.93	***	0.84
I1	Winter	1740	125	5.18	76.6	0.76
	Summer	1627	98	4.21	62.9	0.63
I2	Winter	1124	98	5.24	71.2	0.80
	Summer	1585	111	5.25	76.7	0.77
I3	Winter	1724	74	4.37	52.1	0.70
	Summer	2116	95	4 46	57.6	0.68
I4	Winter	2074	99	4.72	62.8	0.71
	Summer	882	70	4.56	58.5	0.74
J1	Winter	1787	105	4.91	74.0	0.73
	Summer	1275	106**	5.29	83.0	0.78
J2	Winter	165	35	4.40	***	0.85
	Summer	150	33	4.06	***	0.80
K1	Winter	2776	63	3.01	33.9	0.51
	Summer	978	74	4.72	59.4	0.76
K2	Winter	11001	99	1.99	30.3	0.30
	Summer	1317	72	4.29	51.1	0.69
K3	Winter	2439	56	3.47	34.3	0.60
	Summer	703	51	4.21	46.6	0.74
K4	Winter	2770	134	5.18	76.2	0.74
	Summer	1924	92	4.85	61.3	0.74
K5	Winter	758	76	3.87	61.8	0.62
	Summer	2377	97	3.65	54.0	0.55

Appendix 6-F. (concluded)

Station	Season	Density (indiv/ 0.6 m^2)	Areal Richness (spp/ 0.6 m^2)	Species Diversity (H'-bits/ indiv)	Numerical Richness (spp/500 indiv)	Species Evenness (J')
K6	Winter	1119	98	5.24	75.9	0.79
	Summer	1396	100	5.14	73.6	0.77
L1	Winter	2634	64	3.36	35.1	0.56
	Summer	658	50	3.54	50.0	0.62
L2	Winter	2707	67	3.66	39.8	0.60
	Summer	2922	56	3.86	36.1	0.66
L3	Winter	825	73	4.34	59.5	0.70
	Summer	1573	72	4.22	52.5	0.68
L4	Winter	1879	107	4.19	62.8	0.63
	Summer	2232	93	4.32	58.2	0.66
L5	Winter	2077	116	3.58	62.4	0.52
	Summer	2738	104	3.25	54.0	0.48
L6	Winter	1003	102	5.31	79.9	0.79
	Summer	1158	105	4.98	81.1	0.74

* in 0.1 m^2
** in 0.5 m^2
*** less than 500 individuals collected

CHAPTER 7

BENTHIC ECOLOGICAL STUDIES: FORAMINIFERA

R. L. Ellison

CHAPTER 7

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CHAPTER 7

BENTHIC ECOLOGICAL STUDIES: FORAMINIFERA

Robert L. Ellison

INTRODUCTION

Assemblages of foraminifera are regarded to be sensitive indicators of sedimentary and hydrographic environments. Because foraminiferal tests are often preserved as fossils, they also may serve as good indicators of ancient environmental conditions. Studies of recent foraminifera on continental shelves generally have been based on total populations (living plus empty [dead] tests) because the numbers of living specimens are relatively small compared to the numbers of empty tests. However, for assessing environmental impact, attention should be focused on living foraminifera which reflect existing conditions.

This study is directed mainly toward a description of the living foraminiferal populations of the Middle Atlantic continental shelf and upper continental slope between New Jersey and Virginia.

METHODS AND MATERIALS

On-Board Processing

Two plastic coring cylinders, 5 cm in diameter, were inserted into one grab at each benthic station. After the sediment cores were withdrawn from the grab, the top 3 cm of sediment was cut off and preserved in buffered formalin, shaken, and stored in the refrigerator during the warm month cruises or on-deck during the cold month cruises. The remainder of the sample, if any, was bagged and archived, but not preserved, for possible study later.

Laboratory Processing

On being delivered to the laboratory, the samples were refrigerated until they were washed. In all cases, the samples were washed within two weeks of delivery to the lab. Washing (sieving) was done through a nest of two sieves (one 0.5 mm and one 0.063 mm), using flowing tap water. Before sieving, the samples were stained overnight with Rose Bengal, and immediately before sieving, the sample volume was measured and recorded. After the first cruise, data sheets were prepared which recorded sample number, volume of sediment, names of lab technicians who prepared each sample, and the dates when the different steps were accomplished.

After the washed and stained samples dried, they were floated in a mixture of 36 parts acetone and 100 parts bromoform. The specific gravity of the resulting liquid (2.30) is such that foraminiferal tests (and little

else) float, and the remainder (mostly grains of quartz) sinks. The floated material was poured through #4 Whatman filter paper and washed thoroughly with acetone to remove excess sticky and poisonous bromoform. After drying, the floated material was placed in labeled vials and catalogued for study. The residual sediment was bagged and archived. All of the floating was done in a fume hood especially modified for working with fumes from heavy liquids.

Before picking the living (stained) foraminifera one must decide whether or not the floated sample must be split. Many samples, especially those from the outer shelf are large and composed almost solely of tests of planktonic foraminifers. These samples were split as many as seven times before a manageable fraction was obtained. The sample (or fraction of the sample) to be picked was spread as evenly as possible over a 100-square grid in a glass Petri dish. The sample was moistened with just enough water to wet the specimens, making it easier and more accurate to determine whether or not a specimen is stained. Working with a binocular microscope (50X to 100X), all (but not more than 300) of the live foraminifera were removed from the sample (or sample fraction) with a 000 sable brush. These were transferred onto a cardboard micropaleontology slide that had been covered with water soluble gum tragacantha. Because of the many splits required for some samples, it was not possible in those cases to pick the entire sample even though 300 specimens were not obtained. A workable minimum number of splits to be picked was three. The data, therefore, are based on either: 1) 300, or slightly more, living specimens picked from part of a sample in which living specimens were abundant, 2) fewer than 300 specimens from small samples in which there were no more living forams, or 3) fewer than 300 specimens from at least 3 fractions of *Globigerina* ooze samples which were so large that several splits were necessary. After the living specimens were picked and mounted and the fractional volume of examined sediment was recorded, the empty tests were counted, but not identified. The empty test counts also were recorded, along with the fractional volume of the examined sediment.

Taxonomic determinations were assisted by consulting the collection of types deposited in the Cushman Laboratory in the U. S. National Museum in Washington, D. C. Final identification and counting was done by the principal investigator after all mounted specimens had been rechecked with regard to their having been alive at the time of collection. Although Rose Bengal does stain protoplasm, it is not unambiguous. Specimens in which fungi and mold are inside a foram chamber also will stain. It was determined that, in specimens where the Rose Bengal was faint, the test should, in addition, have other signs of having been alive, namely: 1) a lustrous sheen, 2) no broken chambers except the last or next-to-last, 3) no holes in the chambers, and 4) no debris filling the chambers. Using these criteria, all samples were reexamined and some (in a few samples, many) specimens were removed that had initially been picked as living foraminifera. This cross-checking of one another's work served as our quality control.

Final identification and counts were recorded on data sheets prepared for that purpose. From these, the data were transferred to coding forms and, from there, to punched cards.

RESULTS

Local variations in foraminiferal densities, even between sample replicates within a single grab, may be very large. Table 7-1 presents population size data for spring 1976 from three of the sampling areas, representing the inner and outer shelf and the shelf break. As might be expected, the standard error of the mean is large because only two replicates (A and B) are taken at each station. Lynts (1966) and Buzas (1968), for example, have shown that foraminiferal densities vary widely over small distances. For example, to reduce the standard error by one-half would require eight rather than two replicates, assuming an equivalent standard deviation. The variation between duplicate samples from the winter cruise is tabulated in Table 7-2. From the table, it can be seen that at three of the stations (A1, B1, and D2), the difference in population density between replicates was greater than an order of magnitude. These data underscore the inhomogeneity of foraminiferal populations on a small scale and the need for taking more replicates, if statistical comparisons are desired. Although most of these differences are real, one cannot completely discount the error introduced by collection, sampling, and laboratory practices.

Population Size

Table 7-3 summarizes the results of population size determinations for each of the areas during each of the four cruises. The densities range from 0 to nearly 1,000, and the average number at the quarterly stations is 110. Although the results are not wholly convincing, populations generally were larger at the deeper stations (A, E, and F) and smaller at the shallower stations. Station D4 for the spring cruise (#3) was an exception, having a very large population (chiefly of *Reophax atlantica*) at a moderate depth. In addition to the cluster areas (A-F), samples also were collected along three transects across the shelf. Figure 7-1 shows the changes in population size along these three transects, plotted against depth. Along all three transects, population density maxima appeared between 25 and 100 meters depth, but beyond 100 meters the three transects varied. Size of living populations increased toward the central and outer shelf along transect G, remained nearly constant along transect K, and decreased toward the 300-m depth along L in the winter, but increased in the summer. Along these transects, living populations were somewhat larger in summer than in winter. In Table 7-4 the quarterly stations have been classified into bathymetric strata, following the procedure used for the macrobenthos (Chapter 6). Although the data are variable, it is clear that the number of living foraminifera per unit volume or area increased from the shallower to the deeper stations.

Population size changed little throughout the course of the year, except in summer 1976. At that time, the average population size had decreased to about one-half its size during the other parts of the year. This was the result of a decrease in numbers at the deeper stations in areas A, E, and F (Table 7-4).

Percentages of Agglutinate Species

At two-thirds of the quarterly stations, species of agglutinate, or arenaceous foraminifers, comprised more than 50 percent of the fauna. By far, the largest contributor to the agglutinate fraction of the fauna was

Table 7-1. Population densities, means ($\bar{x}$), and standard error of the mean ($S_{\bar{x}}$) for three areas typical of inner (C) and outer (B) shelf and shelf break (F) in spring 1976. Stations C4, B4, and F1 are excluded because they are less typical for each of their cluster areas. Other seasons show similar variability (see Table 7-2).

Station:	C1		C2		C3		B1		B2		B3		F2		F3		F4	
Replicate:	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
no./20 cm^3	115	18	23	73	11	34	38	24	108	57	412	159	40	100	29	56	71	127
$\bar{x}$	66.5		48.0		22.5		31.0		82.5		285.5		70.0		42.5		99.0	
$S_{\bar{x}}$	48.5		25.0		11.5		7.0		25.5		126.5		30.0		13.5		28.0	

Table 7-2. Variation in population size from pairs of replicates (A and B) from the same sample grab at selected stations, winter 1976. Values are absolute differences between the logarithms (base 10) of the number of living individuals per 20 cm^3 of wet sample. Other seasons show similar variability.

Station	log A-log B	Station	log A-log B
A1	1.3967	D2	1.1760
A3	0.0969	D3	0.2042
A4	0.9540	D4	0.2856
B1	1.2856	E1	0.0949
B2	0.7937	E2	0.6585
B3	0.6567	E3	0.2443
B4	0.6199	E4	0.0676
C1	0.0970	F1	0.6567
C2	0.1297	F2	0.9020
C3	0.6690	F3	0.0217
D1	0.1498	F4	0.0260

Table 7-3. Mean density (expressed in numbers of individuals per 20 cm^3 of wet sample) of living populations of foraminifera in each of the cluster areas.

Area Station	Fall 1975	Winter 1976	Spring 1976	Summer 1976	Mean
A	254	316	112	97	195
B	65	90	101	70	82
C	24	18	63	54	40
D	17	37	278	34	92
E	98	125	129	70	106
F	279	134	78	77	142
mean	123	120	127	67	110

Table 7-4. Mean number of living foraminifera per 20 cm^3 of wet sediment, and estimated number per m^2. Note: three values are unusually large due to a single station: *D4 has 986/20 cm^3; **A1 has 688; and ***F4 has 639.

Bathymetric Stratum (Stations)	Number living / 20 cm^3					Estimated No. per m^2
	Fall	Winter	Spring	Summer	Overall	
25-49 m (B4,C1-C4,D1-D4)	20	26	152*	44	61	76,250
59-99 m (A1,B1-B3,E1-E4,F1)	81	139**	93	54	92	115,000
100-199 m (A2-A4,F2-F4)	299***	128	94	94	154	192,500

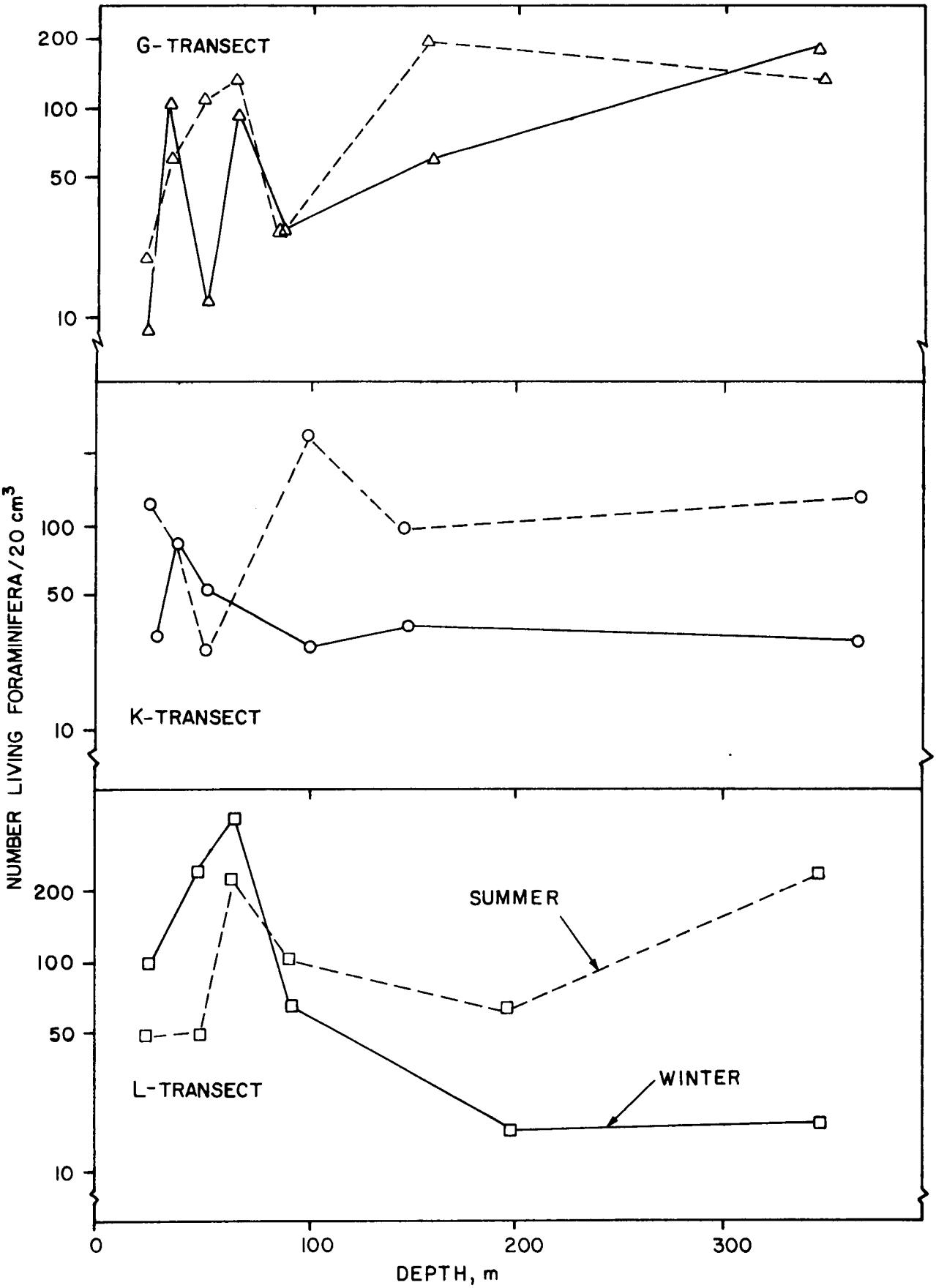

Figure 7-1. Density (N/20 cm^3) of living foraminifera along transects G, K. and L, plotted against depth (m).

Reophax atlantica (*Saccammina atlantica* of some authors and *Proteonina atlantica* of others). This was the most abundant of all living species of foraminifera on the shelf. Figure 7-2 shows the relationship between the agglutinate proportions and depth as determined from the quarterly grab stations for the summer cruise. The percentages of agglutinate specimens were maximum between 30 and 100 meters and decreased with depth, contrasting with results obtained by other investigators working with empty test distributions. For example, Sen Gupta (1976) showed a clear relationship between increasing proportions of agglutinate specimens and increasing depth on the Georgia continental shelf. If these two areas are comparable, it may be that agglutinate forms are not incorporated into the fossil sediments in numbers corresponding to their importance in the living assemblages. In particular, the tests of *R. atlantica* are fragile and may be destroyed rather easily by wave action and bottom current movement in the shallower water.

Diversity

Faunal diversity, calculated and expressed in various ways, is an indicator of the structure of an ecological system. Shannon's diversity measure H' (Ref. as in Chapter 6), is summarized in Figure 7-3 for the quarterly grab stations, averaged within a sampling area. The diversity values were derived from raw data on living specimens rather than from calculated values expressed in numbers per unit volume. Except at the shallow stations, diversity generally was greater than 2.0 bits/individual. At some stations, diversity was minimum in winter, and at other stations the minimum was spring or summer. Although diversity varied in an apparently erratic fashion, it increased slightly with depth and distance offshore. To better evaluate the relation between depth and diversity, the diversity values calculated for the stations along the three cross-shelf transects (G, K, and L) for the winter cruise have been plotted against depth in Figure 7-3. Here, too, the calculated values show no obvious trend, and each transect had a somewhat different pattern. The greatest diversity along transect G was at the outermost and deepest station, whereas the greatest diversity along transect K was at the most shoreward and shallowest station. Few studies of foraminifera on continental shelves have been concerned soley with living specimens; most have considered total foraminifera (living specimens plus empty tests, most of which are the latter) and therefore, their results are not directly comparable with those obtained in the present study. Utilizing such total foraminifera distributions, numerous workers (Bandy and Arnal 1957; Schnitker 1971; Gibson and Buzas 1973) have found that diversity increases with depth and distance offshore. However, this is not always the case. Sen Gupta and Kilbourne (1974), working on the Georgia shelf, found diversity increased to a depth of about 15 m, and remained nearly constant to the shelf edge. Off Japan, Ikeya (1971) records diversity maxima between 60 and 70 m and between 600 and 700 m. On that portion of the shelf presently under study, the diversity data show no general trend with depth; the results are ambiguous and influenced largely by variations in concentrations of *Reophax atlantica*, which reduced the evenness component of diversity and thus lowered H' even though the number of species may be high.

Similar attempts to correlate diversity with other environmental parameters (percent silt-clay and organic carbon) were unsuccessful. In addition, there seems to be little correlation between diversity values for particular stations from season to season, at least for the transect stations (e.g. the G, K, and L stations in winter and summer).

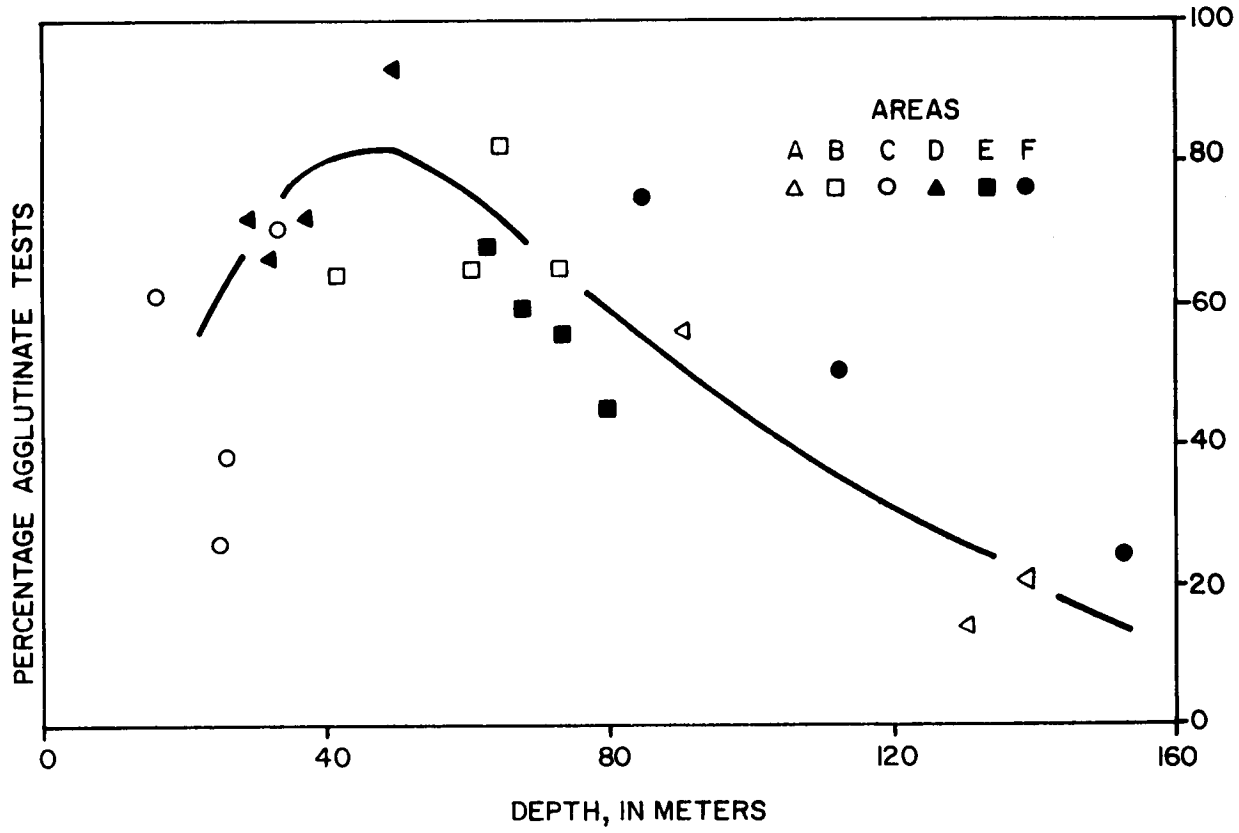

Figure 7-2. Relationship of percentage of total population of living foraminifera composed of agglutinate species to depth for each of the quarterly stations during summer 1976.

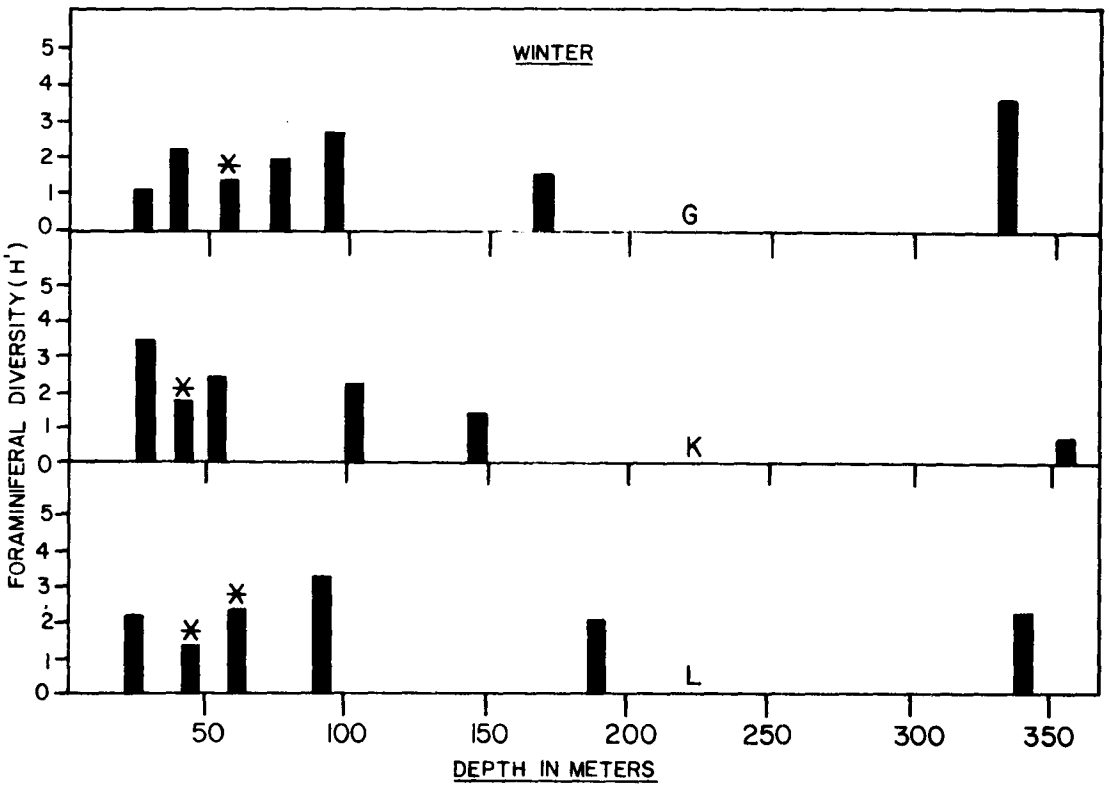

Figure 7-3. Species diversity (H') of collections along transects G, K, and L, winter 1976. Samples composed of more than 50% *Reophax atlantica* indicated by asterisk. Values for summer 1976, similarly erratic.

Population Size of Empty Tests

The density of empty tests (number per 20 cm^3), as shown in Table 7-5, was greater for the outer shelf and shelf break stations (areas A, E, and F) than for the central shelf areas. At stations less than about 75 m deep, the average density was less than 2,000/20 cm^3. At Station A2, during the spring cruise, the maximum density was recorded--over 99,000/20 cm^3, at a depth of 132 m. This corresponds very well with data obtained by Schnitker (1971) on the North Carolina shelf where the maximum occurred at about 140 m depth. In general, however, empty test populations across the North Carolina shelf are somewhat larger than those on the Delaware-New Jersey shelf presently being studied.

Table 7-5. Mean density (expressed in numbers of individuals per 20 cm^3 of wet sample) of empty tests of foraminifera, in each of the cluster areas.

Station Area	Fall 1975	Winter 1976	Spring 1976	Summer 1976	Mean
A	8,401	37,360	45,388	29,935	29,849
B	403	1.871	1,058	540	968
C	43	38	856	408	403
D	55	408	727	114	326
E	1,033	3,293	1,816	1,656	1,950
F	5,674	11,764	12,495	25,919	13,963
mean	2,602	9,122	10,390	9,762	7,910

In conjunction with the empty test distribution, their comparison with the living distribution by means of live/empty (L/E) test ratios offers some insight into depositional rates. The more rapid the rate of sedimentation, the greater will be the sediment dilution of accumulation of empty tests. Consequently, the ratio of living specimens to empty tests (per unit volume of surface sediment) will be greater where the rate of sedimentation is greater, and vice versa. Table 7-6 summarizes the L/E ratios for the quarterly grab stations. Maximum ratios, and presumably maximum rates of sedimentation, were found on the central and inner shelf, inshore of the 50 m isobath; and the values diminish progressively toward the shelf edge. The higher average values on the shelf, however, chiefly arise from the very high values obtained at a few stations (e.g. B4, C3, and D2).

Table 7-6. Mean live/empty test ratio averaged in each of the cluster areas. Higher values are suggestive of more rapid rates of deposition of sediment.

Station Area	Fall 1975	Winter 1976	Spring 1976	Summer 1976	Mean
A	0.042	0.007	0.007	0.005	0.015
B	0.400	0.181	0.176	0.569	0.332
C	0.676	0.572	0.256	0.177	0.420
D	0.521	0.366	1.624	0.340	0.713
E	0.186	0.135	0.131	0.111	0.141
F	0.059	0.040	0.018	0.008	0.031
mean	0.314	0.217	0.370	0.202	0.275

Species Composition and Distribution

Approximately 172 species and varieties of foraminifera were found in this study (Table 7-7). Of these, about one-fourth (40) comprised more than 5 percent of the living foraminifers in at least one sample. The other three-fourths occurred only in small numbers and proportions. Twenty-three of these common species were dominant, i.e. were most abundant in the samples (ranked first in at least one sample). Of these, seven were especially common, namely: *Bulimina marginata, Cibicides lobatulus, Eggerella advena, Elphidium excavatum* forma *clavatum, Elphidium incertum, Fursenkoina fusiformis,* and *Reophax atlantica.*

Following the procedures described in Chapter 6, the data from the 24 quarterly stations for each of the four seasons were numerically analyzed and classified. Two classifications result: (1) a classification of stations into station groups on the basis of similarity of species composition; and (2) a classification of species into species groups on the basis of similarity of occurrence.

The station groups shown in Table 7-8 correspond with natural bathymetric classes. Generally, the membership of a station to a particular station group persists throughout the year. Classifying all 51 stations for summer 1976 yields a similar aggregation of stations. The summer station groups also divide into natural bathymetric classes (Table 7-9) which are illustrated in Figure 7-4.

Table 7-9. Station groups selected from numerical classification of foraminifera from 51 stations sampled during summer 1976.

Area	Station Group	Stations
Inner and Central Shelf	1	C1, C2, C3, D2, D3, G1, K1, L1
Central and Outer Shelf	2	B2, B4, C4, E3, K3, L3
	3	B1, D1, D4, G2, G3, G4, K2, L2
Outer Shelf-Shelf Break	4	B3, E1, E2, E4, I1, I2
	5	A1, F2, G5
	6	F1, K4, L4, L5
Shelf Break	7	A2, A3, A4, F3, F4, K5
Upper Slope	8	H1, H2, K6
	9	G6, G7, I3, I4, J1, L6
Middle Slope	10	J2

The relationship between station groups and the distribution of species in the 10 species groups shown in Table 7-10 was examined by nodal analysis (Chapter 6, Boesch 1977). "Constancy" (Figure 7-5) expresses frequency of occurrence of species within a species group (e.g. the nine species in

Table 7-7. Species of foraminifera from which living individuals were collected.

MILIOLIDAE
- *Quinqueloculina jugosa*
- *Quinqueloculina lamarckiana*
- *Quinqueloculina poeyanum*
- *Quinqueloculina poeyanum* (immature)
- *Quinqueloculina seminula*
- *Quinqueloculina* sp. A
- *Pyrgo sarsi*
- *Pyrgo* sp. A
- *Pyrgo* sp. B
- *Pyrgo* sp. C
- *Scutuloris* sp. A
- *Sigmoilina tenuis*
- *Triloculina* sp. A
- *Triloculina* sp. B

FISHERINIDAE
- *Cyclogyra planorbis*

BULIMINIDAE
- *Bulimina aculeata*
- *Bulimina auriculata*
- *Bulimina marginata*
- *Bulimina* sp. A
- *Bulimina* sp. B
- *Bulimina* sp. C
- *Bulimina* sp. D
- *Buliminella elegantissima*
- *Globobulimina turgida*
- *Stainforthia compressa*
- *Stainforthia* sp. A
- *Bolivina alata*
- *Bolivina lanceolata*
- *Bolivina pseudoplicata*
- *Bolivina spathulata*
- *Bolivina subaenarensis*
- *Bolivina subaenarensis mexicana*
- *Bolivina* sp. A

ISLANDIELLIDAE
- *Islandiella subglobosa*
- *Islandiella* sp. A

UVIGERINIDAE
- *Trifarina angulosa*
- *Trifarina bradyi*
- *Uvigerina auberiana*
- *Uvigerina peregrina*
- *Uvigerina* sp. A
- *Uvigerina* sp. B
- *Uvigerina* sp. C

ALABAMINIDAE
- *Gyroidina soldanii*

ANOMALINIDAE
- *Hanzawaia concentrica*

CASSIDULINIDAE
- *Cassidulina laevigata*
- *Cassidulina neocarinata*
- *Cassidulina subcarinata*
- *Cassidulinoides bradyi*

CAUCASINIDAE
- *Fursenkoina fusiformis*

NONIONIDAE
- *Chilostomella oolina*
- *Nonion grateloupi*
- *Nonion labradoricum*
- *Nonion* sp. A
- *Nonionella atlantica*
- *Nonionella* sp. A
- *Pullenia* sp. A

DISCORBIDAE
- *Cancris sagra*
- *Valvulineria laevigata*
- *Buccella frigida*
- *Buccella* sp. A
- *Buccella* sp. B
- *Discorbinella* sp. A
- *Discorbis* sp. B
- *Rosalina candeiana*
- *Rosalina floridana*
- *Rosalina floridensis*
- *Rosaline globularis*

ASTERIGERINIDAE
- *Asterigerinata* sp. A

SPIRILLINIDAE
- *Patellina corrugata*

GLANDULINIDAE
- *Fissurina lucida*
- *Fissurina stewarti*
- *Oolina melo*

Table 7-7. (continued)

NODOSARIIDAE
- *Astacolus crepidulus*
- *Dentalina communis*
- *Dentalina* sp. A
- *Lagena acuticosta*
- *Lagena laevis*
- *Lagena tenuis*
- *Lagena* sp. A
- *Lagena* sp. B
- *Lenticulina stephensoni*
- *Lenticulina peregrina*
- *Lenticulina* sp. A
- *Lenticulina* sp. B
- *Lenticulina* sp. C
- *Lenticulina* sp. D
- *Marginulina bachei*
- *Marginulina* sp. A
- *Marginulina* sp. B
- *Marginulopsis* sp. A
- *Nodosaria catesbyi*
- *Nodosaria pyrula*
- *Nodosaria* sp. A
- *Sarcenaria italica*

POLYMORPHINIDAE
- unknown genus
- *Polymorphina* sp. A
- *Pseudopolymorphina novangliae*
- *Pseudopolymorphina pappilosa*
- *Pseudopolymorphina* sp. A
- *Guttulina lactea*
- *Guttulina* sp. A
- *Webbinella concava*

CIBICIDIDAE
- *Cibicides lobatulus*
- *Cibicides pseudungerianus*
- *Cibicides* sp. A
- *Cibicides* sp. B
- *Planulina arminensis*
- *Planulina mera*
- *Planulina ornata*
- *Planulina* sp. A
- *Planulina* sp. B (cf. large *Planulina*)

EPONIDIDAE
- *Eponides repandus*
- *Eponides umbonata*
- *Eponides tumidulus*
- *Eponides* sp. A
- *Eponides* sp. D
- *Eponides* sp. E
- *Eponides* sp. F

CERATOBULIMINIDAE
- *Höglundina elegans*

ROTALIIDAE
- *Ammonia beccarii*

ELPHIDIIDAE
- *Elphidium advena*
- *Elphidium excavatum clavatum*
- *Elphidium incertum*
- *Elphidium subarcticum*
- *Elphidium* sp. A
- *Elphidium* sp. B
- unknown genus

AMMODISCIDAE
- *Ammodiscus catinus*
- *Ammodiscus* sp. A
- *Glomospira gordialis*

SACCAMMINIDAE
- *Psammosphaera fusca*

ATAXOPHRAGMIIDAE
- *Eggerella advena*
- *Karreriella novangliae*
- *Listerella (Pseudoclavulina) novangliae*
- *Valvulina conica*
- *Gaudryina atlantica*

HORMOSINIDAE
- *Reophax atlantica*
- *Reophax curtus*
- *Reophax difflugiformis*
- *Reophax* sp. A
- *Reophax* sp. B
- *Reophax* sp. C
- *Reophax* sp. D
- *Reophax* sp. E
- cf. *Reophax*

LITUOLIDAE
- *Haplophragmoides canariensis*
- *Haplophragmoides glomeratum*
- *Haplophragmoides* sp. A
- *Haplophragmoides* sp. B
- *Haplophragmoides* sp. C

Table 7-7. (concluded)

Ammobaculites sp. A	TROCHAMMINIDAE
Ammobaculites sp. B	*Trochammina advena*
	Trochammina lobata
TEXTULARIIDAE	*Trochammina ochracea*
Siphotextularia rolshausensi	*Trochammina squamata*
Textularia candeiana	
Textularia conica	RZEHAKINIDAE
Textularia "costata"	*Miliammina* sp. A
Textularia sp. A	
Textularia sp. B	AMPHITREMATIDAE (Order Gromida)
Textularia	*Marenda nematoda*
	Marenda testacea

Table 7-8. Station groups selected from numerical classification of seasonal collections of foraminifera at the 24 cluster stations.

Area	Station Group	Fall	Winter	Spring	Summer
Inner Shelf	1	B4	B4	B4	
		C1	C1	C1	C1
		C2	C2	C2	C2
		C3	C3	C3	C3
Central Shelf	2	D1		D1	D1
		D2	D2	D2	D2
		D3		D3	D3
Inner and Central Shelf Swales	3			B1	
		C4	C4	C4	
			D1		
			D3		
		D4	D4	D4	D4
Outer Shelf	4	B1	B1		B1
		B2		B2	B2
					B4
					C4
		E1	E1	E1	
		E3	E3	E3	E3
Outer Shelf	5	A1		A1	
		B3	B3	B3	B3
					E1
		E2	E2	E2	E2
		E4	E4	E4	E4
		F1	F1	F1	
Shelf Break	6				A1
				A2	A2
			A3	A3	
			B2		
					F1
				F2	F2
			F3	F3	F3
			F4	F4	F4
Shelf Break	7		A1		
		A2			
		A3			
		F2	F2		
		F4			
Shelf Break	8				A3
		A4	A4	A4	A4
		F3			

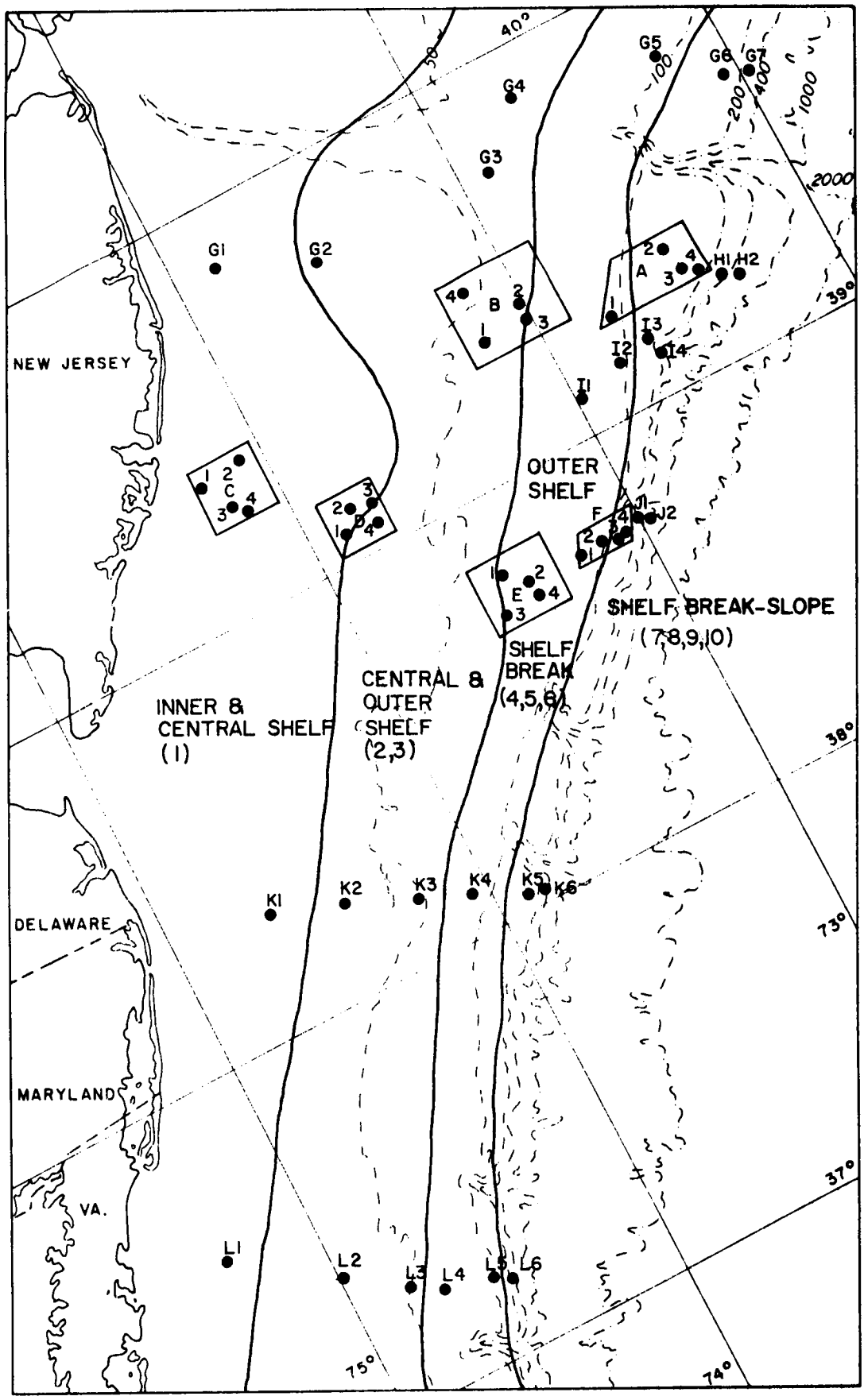

Figure 7-4. Distribution of station groups (Table 7-8) in summer 1976. Typical of other seasons.

species group 1 of Table 7-10) within stations of a particular station group. The occurrence of these species groups is most likely related to the total environmental "climate" (water mass characteristics, including temperature, salinity, and nutrients; and hydraulic regime on the bottom, including current velocity and turbulence which influence substrate conditions), rather than to any single environmental factor. Each species in a group has its own combination of environmental tolerances; the species assemblage, therefore, represents a collective response to the setting of physical, chemical, and biological conditions.

The following observations can be made from relationships shown in Figure 7-5: 1) species composing species groups 1 and 8 are relatively ubiquitous, although group 1 is found largely on the outer shelf and beyond, and group 8 is found largely on or inside the outer shelf; 2) species groups 2 and 3 (especially the latter) are adapted to conditions prevailing toward the edge of the shelf and on the slope; 3) species groups 9 and 10 are chiefly inner and central shelf assemblages. Species group 10 is found expecially in station group 1 (stations B4 and C1-C3) throughout the year, where medium-coarse sands prevail, with few fines and little organic material. Stations C1, C2, and C3 are on ridges and ridge-flanks, and Station B4 is on a 40-m terrace inshore of Tiger Scarp. These four stations are sites of considerable agitation and movement of the bottom sediment.

If any seasonality exists in the relationship between species groups and station groups, it is not immediately obvious. To examine the question of seasonality, data from station group 5 were used because three stations (B3, E2, and E4) persist in group 5 through all four seasons. Table 7-11 shows the numbers of living specimens of the dominant species for the six group-5 stations for each season. Although the data are variable and not statistically significant, a tendency toward larger living populations in the winter and smaller populations in the summer is evident. Conversely, examination of living populations from samples in station group 1 (Table 7-12), indicates that living forams here (C1, C2, C3, and B4) are more abundant in spring-summer than in fall-winter. Like diversity, the density of living foraminifera is a collective measure that masks the dynamics of what is taking place at the species level.

Dominant Species

For each of the quarterly stations, the most abundant species (as many as eight) have been listed in Appendix 7-A for each quarterly sampling. Although a more intensive analysis may uncover subtle seasonal changes, these "dominant" species generally persist through the year with little or no seasonal shuffling of rank.

The inner shelf stations are dominated by the three species of *Elphidium*, especially *E. excavatum clavatum* (*E. clavatum* in Appendix 7-A). Rather large populations of *Trochammina squamata*, *T. ochracea*, *Quinqueloculina seminula*, and *Eggerella advena* also are typical of the inner shelf.

On the central shelf, *Reophax atlantica* assumes a dominant role in the foraminiferal assemblages, a dominance that continues to the edge of the shelf. The numbers of other species are almost always overshadowed by those of *R. atlantica* from the central shelf to the shelf break. In the area of the central shelf, *Eggerella advena* and *Q. seminula* continue to be important, but species of *Elphidium* are only occasionally represented.

Table 7-10. Species groups selected from numerical classification of seasonal collections of foraminifera at 24 cluster stations.

SPECIES GROUP 1
- *Reophax curtus*
- *Lenticulina stephensoni*
- *Bulimina marginata*
- *Cibicides pseudungerianus*
- *Trifarina angulosa*
- *Discorbis* sp. A
- *Cibicides lobatulus*
- *Fursenkoina fusiformis*
- *Reophax atlantica*

SPECIES GROUP 2
- *Cassidulina subcarinata*
- *Islandiella subglobosa*
- *Bulimina auriculata*
- *Höglundina elegans*
- *Marginulina bachei*

SPECIES GROUP 3
- *Haplophragmoides glomeratum*
- *Planulina mera*
- *Gyroidina soldanii*
- *Stainforthia compressa*
- *Cassidulina neocarinata*
- *Bolivina spathulata*
- *Nonion grateloupi*

SPECIES GROUP 4
- *Glomospira gordialis*
- *Rosalina floridana*
- *Buccella* sp. B
- *Textularia conica*
- *Reophax* sp. A

SPECIES GROUP 5
- *Trochammina advena*
- *Fissurina lucida*
- *Cassidulinoides bradyi*

SPECIES GROUP 6
- *Buccella frigida*
- *Nonionella atlantica*
- *Rosalina floridensis*
- *Pseudopolymorphina novangliae*
- *Pyrgo sarsi*
- *Quinqueloculina poeyanum* (immature)
- *Bolivina pseudoplicata*

SPECIES GROUP 7
- *Marenda nematoda*

SPECIES GROUP 8
- *Ammodiscus catinus*
- *Ammodiscus* sp. A
- *Webbinella concava*
- *Elphidium excavatum clavatum*
- *Elphidium incertum*
- *Elphidium subarcticum*
- *Guttulina lactea*
- *Quinqueloculina seminula*
- *Trochammina lobata*

SPECIES GROUP 9
- *Quinqueloculina lamarckiana*
- *Reophax* sp. B

SPECIES GROUP 10
- *Trochammina ochracea*
- *Trochammina squamata*
- *Eponides* sp. E
- *Eponides* sp. D
- *Quinqueloculina poeyanum*

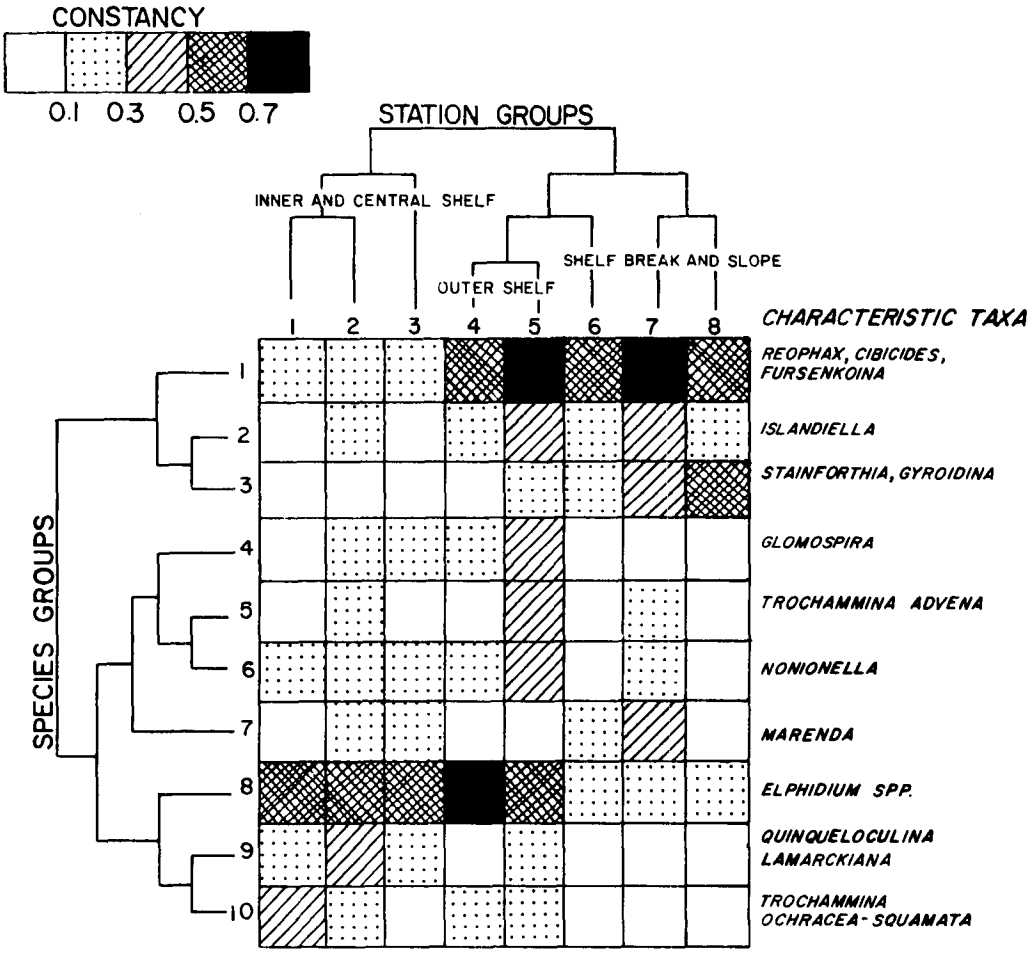

Figure 7-5. Normal and inverse classification hierarchies and nodal constancy for station-species group coincidence based on quarterly collections at the 24 cluster stations, fall 1975 to summer 1976.

Table 7-11. Numbers of living specimens (per 20 cm^3) of foraminiferal species listed as dominants (Appendix 7-A) in collections belonging to station group 5.

Station	(Depth, m)	Fall	Winter	Spring	Summer	$\bar{x}$
E1	(68)	--	--	--	61	61
E2	(69)	62	172	275	88	150
B3	(73)	132	202	198	88	155
E4	(78)	165	188	54	30	109
F1	(85)	138	137	64	--	113
A1	(90)	158	--	94	--	126
$\bar{x}$		131	175	137	67	

Table 7-12. Numbers of living specimens (per 20 cm^3) of foraminiferal species listed as dominants (Appendix 7-A) in collections belonging to station group 1.

Station	(Depth, m)	Fall	Winter	Spring	Summer	$\bar{x}$
C1	(16)	10	9	102	90	53
C2	(24)	30	34	41	21	32
C3	(25)	12	17	20	18	17
B4	(41)	11	32	6	--	16
$\bar{x}$		16	23	43	43	

On the outer shelf, *R. atlantica*'s dominance is joined by that of numerous species that comprise this fauna. *Fursenkoina fusiformis, Cibicides lobatulus, Bulimina marginata,* and *Lenticulina stephensoni* are among the more dominant species on the outer shelf. This zone of the shelf is diverse in addition to being productive in terms of the size of living populations (Table 7-3).

In the "shelf break" region, the dominant species include *F. fusiformis, Stainforthia compressa, Cibicides pseudungerianus, Trifarina angulosa, Gyroidina soldanii,* and *Reophax curtus*. Populations here are even larger than those of the outer shelf.

The dominants at slope stations are more variable than elsewhere. *Haplophragmoides canariensis, Cassidulina neocarinata,* and *F. fusiformis* dominate a few stations, but numerous other species such as *Trochammina advena, Bolivina subaenarensis mexicana, B. alata,* and *Chilostomella oolina* are only locally important.

The importance of *Reophax atlantica* as a dominant species on the central and outer shelf of Delaware and New Jersey cannot be overemphasized. Table 7-13 shows clearly that this species is an important constituent of the foraminiferal faunas of areas B, D, and E where it makes up more than 40% of the living population. If all of the quarterly sampling stations are considered, *R. atlantica* comprises more than one-third of the average population of living foraminifera.

Table 7-13. Mean numbers of living *Reophax atlantica* per 20 cm^3 of wet sediments, and mean percentages of the total foraminiferal population comprised of *R. atlantica*. Numbers in parentheses are values that were calculated omitting two extremely large samples (Winter-A1 and Spring-D4).

	Fall		Winter		Spring		Summer		$\bar{x}$	
Area	no.	%	no.	%	no.	%	no.	%	no.	%
A	33	13	164 (8)	52 (5)	14	13	21	22	58 (19)	30 (14)
B	11	17	60	67	43	43	16	23	33	40
C	6	25	16	89	0	0	8	15	8	19
D	8	47	31	84	240 (12)	86 (30)	18	53	74 (17)	81 (49)
E	24	24	76	61	72	56	27	39	50	47
F	5	2	49	37	30	38	11	14	24	17
$\bar{x}$	15	12	66 (40)	55 (43)	67 (29)	52 (32)	17	25	41 (25)	37 (27)

Influence of Ridge-Swale Topography on Foraminiferal Distributions

Superimposed on the regional distributional pattern of living foraminifera is a local pattern that reflects the strong correspondence of foraminiferal numbers and taxa with local submarine topography. Ridges transecting the shelf, oriented NNE to NE, and their intervening broad swales are represented in each of the areas B, C, D, and E (Chapters 2 and 5). The different local environmental conditions associated with the ridges and with the swales are strikingly reflected in the distribution of foraminifera. These data are depicted in Figure 7-6. Foraminiferal populations were much smaller on the ridges where the substrate generally is coarser (Chapter 5) than in the adjacent swales. Some swales, however, are veneered with coarse lag material. For areas B, C, and D, the swale populations of foraminifera were more than 4 times as large as those on the ridges. Similarly, in area E, populations in swales were larger than those on the ridges, but the differences are smaller. From the species composition, it is apparent that the increase in the numbers of living forams in the swales is due largely to an increase in the numbers of the agglutinate species *Reophax atlantica*, and, to a lesser extent, to species belonging to species group 5 (chiefly *Elphidium* spp.). The greater population density in swales is probably a result of increased sediment stability and concomitant increased food supply.

Influence of Depth, Sediment Type, and Organic Carbon

Relationships between the size of foraminiferal populations and depth, and between populations and sediment characteristics were examined. As has already been shown, there are some population maxima at certain depths (Figure 7-1), and average population sizes increase with depth and with distance offshore (see Table 7-4). Populations on the outer shelf and in the shelf-break region are nearly double the size of those on the inner and central shelf. Furthermore, the composition of the foraminiferal assemblages clearly parallels changing depth and distance offshore. While depth itself may not be the controlling factor, those conditions associated with increasing depth influence the size and composition of the foraminiferal assemblages.

Table 7-14 chassified the stations for winter 1976 on the basis of percent silt-clay and the amount of organic carbon in mgC/g of sediment. Living foraminifera are reduced in abundance in the silty and clayey sediment that is high in organic carbon and organic nitrigen content and is found on the outermost shelf and upper slope. Foraminifera are most concentrated in the sediments with 5-10% silt and clay, found in the shelf-break region and in the shelf-swales. The last column in Table 7-14 shows that *R. atlantica* prefers sediment with little silt or clay. Because of its large numbers, this species exerts considerable influence on sample statistics; therefore, the effect of this species was examined more closely. Table 7-15 summarizes data on *R. atlantica* from stations in the six cluster areas. From these data it is apparent that: 1) this species dominated the foraminiferal assemblages on the shelf (comprising an average of 37% of the population); 2) it was particularly important in areas B, D, and E (outer shelf and shelf break); and 3) although it was found throughout the year in significant numbers, concentrations of living *R. atlantica* were strikingly greater in winter and spring than in summer and fall. Environmental conditions favoring success of this species would appear to be those which prevail from January to June, such as cooler (or cooling) temperatures.

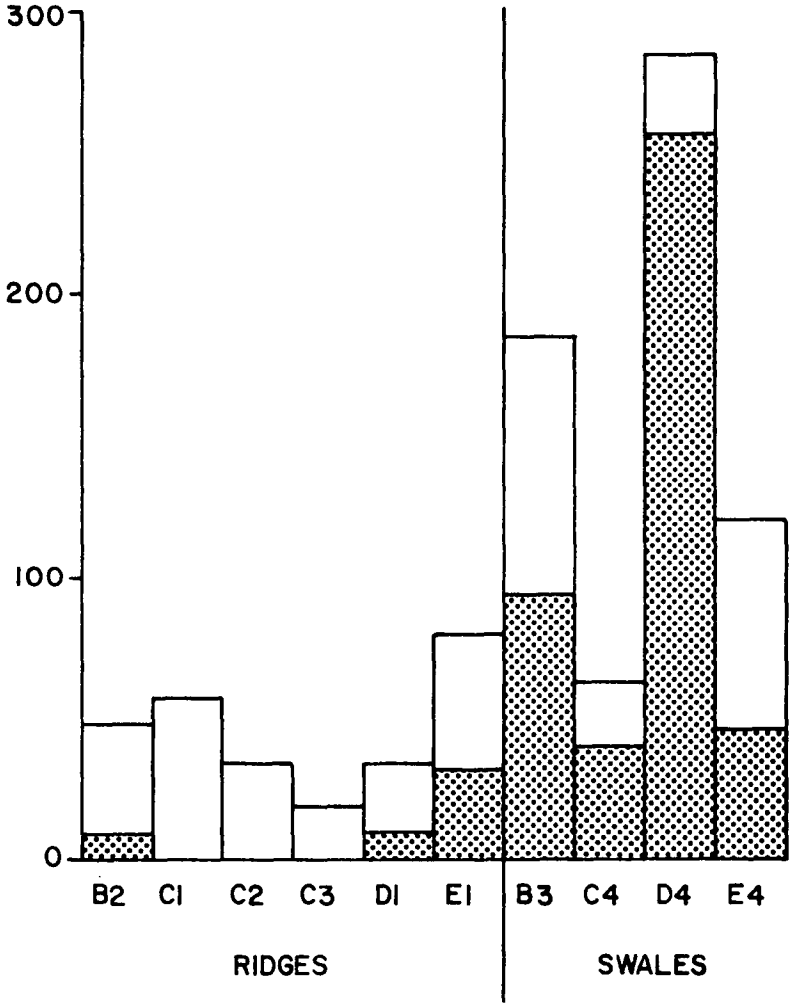

Figure 7-6. Number of living foraminifera per 20 cm^3. Values are averages for the year. *Reophax atlantica* shaded.

Table 7-14. Data from winter 1976 showing relationship between living foraminifera and sediment characteristics (percent silt-clay, and amount of organic carbon).

Percent Silt-Clay	Organic C (mg/g)	Stations	Mean Total No. Live/20 cm^3	No. Live *Reophax*/20 cm^3
>20	>4	A2, A3, H1, H2, I4, J1, L6	23	11
>10	>3	A4, G5, G6, K6	73	2
> 5	>2	A1, B3, E2, E4, F3, F4, G3, I3, K4, K5, L5	151	83
> 0	>0	B1, B2, B4, C1-C4, D1-D4, F1, F2, G1, G4, I1, I2, J2, K1-K3, L1-L4	85	44

Table 7-15. Mean numbers of living *Reophax atlantica* per 20 cm^3 of wet sediments, and mean percentages of the total foraminiferal population comprised of *R. atlantica*. Numbers in parentheses are values that were calculated omitting two extremely large samples (Winter-A1 and Spring-D4).

	Fall		Winter		Spring		Summer		$\bar{x}$	
Area	no.	%	no.	%	no.	%	no.	%	no.	%
A	33	13	164 (8)	52 (5)	14	13	21	22	58 (19)	30 (14)
B	11	17	60	67	43	43	16	23	33	40
C	6	25	16	89	0	0	8	15	8	19
D	8	47	31	84	240 (12)	86 (30)	18	53	74 (17)	81 (49)
E	24	24	76	61	72	56	27	39	50	47
F	5	2	49	37	30	38	11	14	24	17
$\bar{x}$	15	12	66 (40)	55 (43)	67 (29)	52 (32)	17	25	41 (25)	37 (27)

DISCUSSION

The foraminiferal fauna of the continental shelf is diverse and large. Nearly 200 species, which can be classified into ten species groups, are tuned to the varying environmental conditions on the shelf floor. Average living populations of 110/20 cm^3 (= 55,000/m^2) are comparable with those described elsewhere for the shelf off the southeastern U.S. Calculated diversity values also are not unlike those obtained by other investigators, but show no consistent trend with depth, nor any predictable seasonal pattern.

The most obvious environmental parameter as well as the easiest to measure is depth. By itself, depth probably is not so much a controlling factor as are other depth-related factors such as temperature, and nature and mobility of the substrate. Nearly all studies of shelf foraminifera involve a depth classification. Parker (1948) classified the North Atlantic shelf into three numbered (2, 3, and 4) depth zones. Bandy and Arnal (1957) recognized an "inner shelf fauna" and an "outer shelf fauna" off the west coast of Central America. Schnitker (1971) saw several depth thantotopes: "near shore", "central shelf" and "shelf edge". All of these studies, however, have focused primarily on empty test distributions. In the present study of living foraminifera, the relationship between depth and foraminiferal density is not totally unambiguous. Although foraminiferal numbers based on quarterly station-averages increase with depth, those based on values obtained for the traverse stations (G, K, and L) during winter 1976 reveal a maximum at a depth of between 25 and 75 meters. Exceptions to general rules are numerous, and the three largest populations were found at markedly different depths (see Table 7-4). Some seasonality in population numbers is apparent, with the summer apparently being a period of smaller populations. This partly reflects the reduction in numbers of *Reophax atlantica* in the summer.

A particularly striking feature of the distribution of living foraminifera is the correspondence between species assemblages and bathymetry. Basically, the foraminifera are divided into inner shelf, central shelf, outer shelf, shelf break and slope assemblages that parallel the distributional pattern of the macrobenthos. This pattern as well as the boundaries between these biotopes, changes only slightly between seasons; and the foraminiferal assemblages, composed of overlapping species groups (as determined by cluster and nodal analyses) have a reasonably distinctive taxonomic identity that remains intact throughout the year.

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Appendix 7-A. The most numerically abundant species at each quarterly station, during each collection period. No number is given if a species is represented by less than 1 living individual per 200 cc wet sediment.

Station	Rank	Species	Mean Density (no./20 cm^3)	Species	Mean Density (no./20 cm^3)
A1		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	56	*Reophax atlantica*	476
	2	*Bulimina marginata*	25	*Lenticulina stephensoni*	48
	3	*Fursenkoina fusiformis*	23	*Bulimina marginata*	43
	4	*Reophax curtus*	18	*Cibicides pseudoungerianus*	32
	5	*Lenticulina stephensoni*	14	*Trifarina angulosa*	23
	6	*Trifarina bradyi*	8	*Guttulina lactea*	23
	7	*Reophax* sp. A	8	*Reophax curtus*	16
	8	*Cibicides lobatulus*	6	*Islandiella subglobosa*	7
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	37	*Reophax atlantica*	69
	2	*Fursenkoina fusiformis*	24	*Bulimina marginata*	9
	3	*Lenticulina stephensoni*	8	*Cibicides pseudungerianus*	8
	4	*Bulimina marginata*	7	*Cassidulina neocarinata*	6
	5	*Eponides tumidulus*	5	*Cassidulina laevigata*	2
	6	*Bolivina spathulata*	5	*Lenticulina stephensoni*	2
	7	*Buccella frigida*	4		
	8	*Nonionella atlantica*	4		

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
A2		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	90		
	2	*Bulimina marginata*	57		
	3	*Stainforthia compressa*	49		
	4	*Cibicides pseudungerianus*	32		
	5	*Reophax atlantica*	23		
	6	*Bolivina subaenarensis*	20	no samples	
	7	*Ammodiscus* sp. A	13		
	8	*Nonion grateloupi*	9		
		SPRING 1976		SUMMER 1976	
	1	*Fursenkoina fusiformis*	61	*Fursenkoina fusiformis*	23
	2	*Reophax atlantica*	13	*Bulimina marginata*	18
	3	*Nonionella atlantica*	6	*Stainforthia compressa*	14
	4	*Polymorphina* sp.	6	*Reophax atlantica*	9
	5	*Buccella frigida*	4	*Lenticulina stephensoni*	7
	6	*Textularia* sp. A	4	*Globobulimina turgida*	5
	7	*Stainforthia compressa*	4	*Textularia* sp. B	5
	8	*Buccella frigida*	4	*Marginulina bachei*	5

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
A3		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	75	*Reophax atlantica*	10
	2	*Bulimina marginata*	42	*Gyroidina soldauii*	8
	3	*Reophax* sp. B	30	*Marginulina bachei*	7
	4	*Reophax atlantica*	21	*Bulimina marginata*	4
	5	*Cibicides lobatulus*	19	*Cibicides pseudungerianus*	4
	6	*Stainforthia compressa*	19	*Bolivina subaenarensis*	4
	7	*Cibicides pseudungerianus*	16	*Bulimina auriculata*	4
	8	*Trifarina angulosa*	12	*Marginulina* sp. A	4
		SPRING 1976		SUMMER 1976	
	1	*Stainforthia compressa*	8	*Stainforthia compressa*	13
	2	*Textularia* sp. B	4	*Cheilostomella oolina*	12
	3	*Cheilostomella oolina*	4	*Haplophragmoides glomeratum*	8
	4	*Bolivina subaenarensis*	4	*Bulimina marginata*	5
	5	*Reophax atlantica*	4	*Reophax atlantica*	5
	6	*Bulimina marginata*	4	*Cibicides pseudumgerianus*	5
	7	*Marenda nematoda*	4	*Fursenkoina fusiformis*	4
	8	*Ammobaculites* sp. A	4	*Trochammina lobata*	4

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
A4		FALL 1975		WINTER 1976	
	1	*Cassidulina neocarinata*	14	*Cibicides pseudungerianus*	28
	2	*Gyroidina soldanii*	10	*Stainforthia compressa*	24
	3	*Fursenkoina fusiformis*	8	*Bolivina spathulata*	18
	4	*Elphidium clavatum*	6	cf. *Reophax*	18
	5	*Trifarina angulosa*	6	*Lenticulina stephensoni*	14
	6	*Bolivina spathulata*	6	*Islandiella subglobosa*	10
	7	*Stainforthia compressa*	6	*Gyroidina soldanii*	10
	8	*Eponides tumidulus*	6	*Reophax atlantica*	5
		SPRING 1976		SUMMER 1976	
	1	*Stainforthia compressa*	21	*Trifarina angulosa*	17
	2	*Haplophragmoides glomeratum*	18	*Stainforthia compressa*	14
	3	*Bulimina marginata*	18	*Cassidulina neocarinata*	11
	4	*Cibicides* sp. B	14	*Reophax curtus*	11
	5	*Reophax curtus*	14	cf. *Reophax*	9
	6	*Ammobaculites* sp. A	11	*Trochammina lobata*	8
	7	*Marginulina bachei*	11	*Gyroidina soldanii*	8
	8	*Gyroidina soldanii*	11		

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
B1		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	9	*Reophax atlantica*	101
	2	*Eggerella advena*	5	*Elphidium incertum*	7
	3	*Cibicides lobatulus*	5	*Cibicides lobatulus*	7
	4	*Elphidium subarcticum*	3	*Eggerella advena*	4
	5	*Elphidium incertum*	3	*Reophax curtus*	4
	6	*Trochammina lobata*	2	*Ammodiscus catinus*	2
	7	*Fursenkoina fusiformis*	2	*Elphidium clavatum*	1
	8	*Reophax difflugiformis*	2	*Fursenkoina fusiformis*	1
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	23	*Reophax atlantica*	54
	2	*Fursenkoina fusiformis*	3	*Eggerella advena*	16
	3	*Eggerella advena*	2	*Elphidium clavatum*	3
	4	*Elphidium incertum*	1	*Trochammina lobata*	3
	5	cf. *Reophax*		*Fursenkoina fusiformis*	2
	6	*Webbinella concava*		*Cibicides lobatulus*	2
	7	*Trochammina lobata*		*Quinqueloculina seminula*	2
	8	*Quinqueloculina lamarckiana*		*Elphidium subarcticum*	2

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
B2		FALL 1975		WINTER 1976	
	1	*Bulimina marginata*	14	*Stainforthia compressa*	15
	2	*Cibicides lobatulus*	7	*Fursenkoina fusiformis*	14
	3	*Elphidium incertum*	5	*Reophax atlantica*	4
	4	*Fursenkoina fusiformis*	4	*Eponides tumidulus*	4
	5	*Elphidium clavatum*	3	*Cassidulina laevigata*	4
	6	*Ammodiscus catinus*	1	*Sigmoilina tenuis*	4
	7	*Quinqueloculina seminula*	1	*Marginulina bachei*	4
	8	*Triloculina* sp. B	1	*Dentalina communis*	4
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	26	*Eggerella advena*	20
	2	*Eggerella advena*	19	*Cibicides lobatulus*	7
	3	*Cibicides lobatulus*	16	*Reophax atlantica*	3
	4	*Quinqueloculina lamarckiana*	3	*Elphidium incertum*	2
	5	*Elphidium incertum*	3	*Guttulina lactea*	1
	6	*Fursenkoina fusiformis*	3	*Buccella* sp. B	1
	7	*Elphidium clavatum*	3	*Ammodiscus catinus*	1
	8	*Quinqueloculina seminula*	2	*Elphidium clavatum*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
B3		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	36	*Reophax atlantica*	133
	2	*Bulimina marginata*	36	*Bulimina marginata*	37
	3	*Elphidium clavatum*	18	*Guttulina lactea*	10
	4	*Cibicides lobatulus*	16	*Lenticulina stephensoni*	5
	5	*Fursenkoina fusiformis*	9	*Triloculina* sp. B	5
	6	*Discorbis* sp. A	6	*Elphidium clavatum*	5
	7	*Trochammina advena*	6	*Reophax curtus*	5
	8	*Reophax curtus*	5	*Eggerella advena*	2
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	124	*Reophax atlantica*	57
	2	*Bulimina marginata*	45	*Bulimina marginata*	9
	3	*Reophax* sp. B	7	*Cibicides lobatulus*	6
	4	*Reophax difflugiformis*	5	*Fursenkoina fusiformis*	5
	5	*Cibicides lobatulus*	5	*Trochammina lobata*	3
	6	*Lenticulina stephensoni*	4	*Eggerella advena*	3
	7	*Elphidium clavatum*	4	*Lenticulina stephensoni*	2
	8	*Reophax curtus*	4	*Ammodiscus catinus*	3

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
B4		FALL 1975		WINTER 1976	
	1	*Elphidium incertum*	7	*Cibicides lobatulus*	16
	2	*Cibicides lobatulus*	2	*Elphidium incertum*	9
	3	*Eggerella advena*	1	*Quinqueloculina seminula*	2
	4	*Elphidium clavatum*	1	*Elphidium subarcticum*	2
	5	*Quinqueloculina seminula*		*Elphidium clavatum*	1
	6	*Pseudopolymorphina novangliae*		*Bolivina pseudoplicata*	1
	7	*Bolivina pseudoplicata*		*Textularia "conica"*	1
	8	*Ammonia beccarii*			
		SPRING 1976		SUMMER 1976	
	1	*Elphidium incertum*	4	*Eggerella advena*	19
	2	*Cibicides lobatulus*	1	*Reophax atlantica*	7
	3	*Ammodiscus catinus*	1	*Elphidium incertum*	3
	4	*Quinqueloculina poeyanum*		*Elphidium subarcticum*	2
	5	*Pseudopolymorphina novangliae*		*Trochammina ochracea*	2
	6	*Elphidium subarcticum*		*Cibicides lobatulus*	2
	7	*Webbinella concava*		*Fursenkoina fusiformis*	2
	8	*Patellina corrugata*		*Quinqueloculina seminula*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
C1		FALL 1975		WINTER 1976	
	1	*Elphidium clavatum*	5	*Elphidium clavatum*	5
	2	*Trochammina squamata*	1	*Trochammina squamata*	1
	3	*Elphidium incertum*	1	*Quinqueloculina poeyanum*	1
	4	*Quinqueloculina jugosa*	1	*Elphidium incertum*	1
	5	*Quinqueloculina poeyanum*	1	*Elphidium subarcticum*	1
	6	*Quinqueloculina seminula*	1	*Ammodiscus catinus*	
	7	*Eggerella advena*		*Reophax* sp. B	
	8	*Trochammina ochracea*		*Rosalina floridensis*	
		SPRING 1976		SUMMER 1976	
	1	*Elphidium clavatum*	35	*Eggerella advena*	50
	2	*Quinqueloculina poeyanum*	24	*Elphidium clavatum*	18
	3	*Trochammina ochracea*	20	*Trochammina squamata*	5
	4	*Eponides* sp. E	10	*Elphidium incertum*	5
	5	*Eggerella advena*	10	*Quinqueloculina poeyanum*	4
	6	*Ammodiscus catinus*	1	*Trochammina ochracea*	3
	7	*Eponides* sp. D	1	*Elphidium subarcticum*	3
	8	*Reophax* sp. B	1	*Rosalina floridensis*	2

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
C2		FALL 1975		WINTER 1976	
	1	*Elphidium clavatum*	11	*Elphidum subarcticum*	13
	2	*Elphidium incertum*	10	*Elphidium clavatum*	10
	3	*Discorbis* sp. A	3	*Quinqueloculina seminula*	2
	4	*Quinqueloculina seminula*	2	*Elphidium incertum*	2
	5	*Eggerella advena*	1	*Guttulina lactea*	2
	6	*Cibicides lobatulus*	1	*Pseudopolymorphia novangliae*	2
	7	*Bolivina pseudoplicata*	1		
	8	*Trochammina squamata*	1		
		SPRING 1976		SUMMER 1976	
	1	*Elphidium clavatum*	10	*Elphidium subarcticum*	5
	2	*Elphidium incertum*	8	*Elphidium incertum*	4
	3	*Reophax* sp. B	5	*Eggerella advena*	4
	4	*Eggerella advena*	5	*Elphidium clavatum*	3
	5	*Quinqueloculina poeyanum*	4	*Quinqueloculina seminula*	2
	6	*Trochammina ochracea*	4	*Quinqueloculina poeyanum*	1
	7	*Ammodiscus* sp. A	3	*Ammodiscus* sp. A	1
	8	*Webbinella concava*	2	*Trochammina ochracea*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
C3		FALL 1975		WINTER 1976	
	1	*Elphidium clavatum*	6	*Elphidium clavatum*	8
	2	*Elphidium incertum*	3	*Elphidium subarcticum*	7
	3	*Trochammina squamata*	1	*Trochammina ochracea*	1
	4	*Eponides* sp. E	1	*Asteriginata* sp. A	1
	5	*Rosalina floridensis*	1	*Reophax atlantica*	
	6	*Elphidium subarcticum*		*Elphidium incertum*	
	7	*Chilostomella oolina*			
	8	*Eggerella advena*			
		SPRING 1976		SUMMER 1976	
	1	*Elphidium clavatum*	6	*Elphidium incertum*	7
	2	*Elphidium incertum*	6	*Elphidium clavatum*	5
	3	*Eggerella advena*	4	*Quinqueloculina seminula*	2
	4	*Reophas atlantica*	2	*Elphidium subarcticum*	1
	5	*Fursenkoina fusiformis*	1	*Eggerella advena*	1
	6	*Discorbis* sp. A	1	*Webbinella concava*	1
	7	*Valvulineria laevigata*		*Quinqueloculina poeyanum*	1
	8	*Reophax* sp. B		*Pseudopolymorphina novangliae*	

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
C4		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	25	*Reophax atlantica*	62
	2	*Trochammina ochracea*	6	*Eggerella advena*	8
	3	*Elphidium clavatum*	3	*Elphidium clavatum*	3
	4	*Ammodiscus* sp. A	2	*Elphidium incertum*	1
	5	*Elphidium incertum*	1	*Quinqueloculina seminula*	1
	6	*Reophax* sp. B	1	*Ammodiscus* sp. A	
	7	*Quinqueloculina seminula*	1	*Fursenkoina fusiformis*	
	8	*Fursenkoina fusiformis*	1	*Cibicides pseudungerianus*	
		SPRING 1976		SUMMER 1976	
	1	*Reophax* sp. B	3	*Reophax atlantica*	30
	2	*Trochammina ochracea*		*Eggerella advena*	17
	3	*Saracenaria italica*		*Cibicides lobatulus*	5
	4	*Nonion grateloupi*		*Fursenkoina fusiformis*	3
	5			*Elphidium clavatum*	2
	6			*Elphidium incertum*	1
	7			*Trifarina angulosa*	1
	8			*Guttulina lactea*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
D1		FALL 1975		WINTER 1976	
	1	*Eggerella advena*	7	*Reophax atlantica*	52
	2	*Quinqueloculina seminula*	1	*Fursenkoina fusiformis*	3
	3	*Elphidium clavatum*	1	*Reophax* sp. A	1
	4	*Reophax atlantica*	1	*Quinqueloculina seminula*	1
	5	*Cibicides lobatulus*		*Trochammina lobata*	
	6	*Trochammina ochracea*		*Guttulina lactea*	
	7	*Trochammina lobata*		*Elphidium clavatum*	
	8	*Elphidium incertum*		*Elphidium subarcticum*	
		SPRING 1976		SUMMER 1976	
	1	*Fursenkoina fusiformis*	4	*Eggerella advena*	19
	2	*Eggerella advena*	3	*Reophax atlantica*	9
	3	*Trochammina ochracea*	2	*Quinqueloculina seminula*	4
	4	*Quinqueloculina seminula*	2	*Reophax* sp. B	2
	5	*Trochammina lobata*	1	*Rosalina floridana*	2
	6	*Cassidulinoides bradyi*	1	*Bolivina pseudoplicata*	2
	7	*Marginulopsis* sp.	1	*Trochammina squamata*	1
	8	unknown sp.	1	*Ammodiscus catinus*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
D2		FALL 1975		WINTER 1976	
	1	*Eggerella advena*		*Elphidium clavatum*	1
	2	*Elphidium clavatum*		*Eggerella advena*	1
	3	*Bolivina pseudoplicata*		*Reophax atlantica*	
	4	*Rosalina floridana*		*Bolivina spathulata*	
	5			*Quinqueloculina seminula*	
	6			*Webbinella concava*	
	7			*Elphidium subarcticum*	
	8				
		SPRING 1976		SUMMER 1976	
	1	*Eggerella advena*	9	*Reophax atlantica*	6
	2	*Quinqueloculina lamarckiana*	3	*Quinqueloculina seminula*	4
	3	*Reophax atlantica*	3	*Eggerella advena*	2
	4	*Quinqueloculina poeyanum*	1	*Reophax* sp. B	2
	5	*Ammodiscus catinus*	1	*Trochammina advena*	1
	6	*Quinqueloculina seminula*	1	*Quinqueloculina poeyanum*	1
	7	*Reophax* sp. B	1	*Elphidium clavatum*	1
	8	*Reophax* sp. A	1	*Guttulina lactea*	

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
D3		FALL 1975		WINTER 1976	
	1	*Eggerella advena*	14	*Reophax atlantica*	14
	2	*Reophax atlantica*	5	*Elphidium clavatum*	3
	3	*Quinqueloculina seminula*	1	*Quinqueloculina seminula*	1
	4	*Ammodiscus catinus*	1	*Quinqueloculina lamarckiana*	1
	5	*Quinqueloculina lamarckiana*	1	*Reophax* sp. A	
	6	*Trochammina ochracea*	1	*Guttulina lactea*	
	7	*Ammodiscus* sp. A	1	*Eggerella advena*	
	8	*Trochammina lobata*		*Rosalina floridensis*	
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	33	*Reophax atlantica*	3
	2	*Quinqueloculina seminula*	24	*Eggerella advena*	2
	3	*Eggerella advena*	6	*Reophax* sp. B	1
	4	*Reophax* sp. B	5	*Webbinella concava*	1
	5	*Reophax* sp. A	3	*Quinqueloculina seminula*	1
	6	*Quinqueloculina poeyanum*	2	*Marenda nematoda*	1
	7	*Elphidium clavatum*	2	*Quinqueloculina poeyanum*	
	8	*Ammodiscus catinus*	2	*Pseudopolymorphia novangliae*	

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
D4		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	24	*Reophax atlantica*	58
	2	*Eggerella advena*	1	*Fursenkoina fusiformis*	2
	3	*Guttulina lactea*	1	*Marenda nematoda*	1
	4	*Reophax* sp. A		*Elphidium clavatum*	
	5	*Trochammina lobata*		*Elphidium incertum*	
	6	*Ammodiscus catinus*		*Pseudopolymorphia novangliae*	
	7	*Ammodiscus* sp. A		*Trochammina lobata*	
	8	*Quinqueloculina seminula*		*Ammodiscus catinus*	
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	923	*Reophax atlantica*	53
	2	*Eggerella advena*	13	*Eggerella advena*	4
	3	*Quinqueloculina seminula*	12	*Trochammina lobata*	1
	4	*Elphidium clavatum*	10	*Quinqueloculina seminula*	1
	5	*Trochammina lobata*	4	*Fursenkoina fusiformis*	1
	6	*Fursenkoina fusiformis*	8	*Bolivina pseudoplicata*	1
	7	*Miliammina* sp.	3	*Reophax* sp. A	
	8	*Cibicides pseudungerianus*	2	*Ammodiscus* sp. A	

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
E1		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	35	*Reophax atlantica*	27
	2	*Reophax atlantica*	13	*Cibicides lobatulus*	12
	3	*Eggerella advena*	10	*Guttulina lactea*	2
	4	*Cibicides lobatulus*	4	*Eggerella advena*	1
	5	*Trochammina lobata*	4	*Marginulina bachei*	1
	6	*Ammodiscus catinus*	3	*Trifarina angulosa*	1
	7	*Elphidium clavatum*	3	*Elphidium clavatum*	1
	8	*Ammodiscus* sp. A	2	*Trochammina ochracea*	1
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	61	*Reophax atlantica*	33
	2	*Cibicides lobatulus*	6	*Cibicides lobatulus*	10
	3	*Elphidium clavatum*	6	*Eggerella advena*	5
	4	*Bulimina marginata*	5	*Bulimina marginata*	3
	5	*Elphidium incertum*	5	*Elphidium incertum*	3
	6	*Eggerella advena*	4	*Guttulina lactea*	3
	7	*Pseudopolymorphina* sp. A	2	*Fursenkoina fusiformis*	2
	8	*Textularia* sp. A	2	*Trochammina lobata*	2

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
E2		FALL 1975		WINTER 1976	
	1	*Reophax atlantica*	34	*Reophax atlantica*	137
	2	*Cibicides lobatulus*	7	*Reophax* sp. A	11
	3	*Bulimina marginata*	6	*Bulimina marginata*	10
	4	*Eggerella advena*	5	*Lenticulina stephensoni*	6
	5	*Fursenkoina fusiformis*	4	*Elphidium clavatum*	3
	6	*Discorbis* sp. A	3	*Cibicides pseudungerianus*	2
	7	*Elphidium incertum*	2	*Pseudopolymorphia movangliae*	2
	8	*Elphidium clavatum*	2	*Elphidium incertum*	1
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	156	*Reophax atlantica*	29
	2	*Reophax curtus*	35	*Bulimina marginata*	26
	3	*Cibicides lobatulus*	25	*Eggerella advena*	20
	4	*Bulimina marginata*	19	*Fursenkoina fusiformis*	5
	5	*Reophax* sp. A	18	*Lenticulina stephensoni*	4
	6	*Eggerella advena*	11	*Reophax curtus*	2
	7	*Guttulina lactea*	6	*Ammodiscus catinus*	1
	8	*Lenticulina stephensoni*	5	*Guttulina lactea*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
E3		FALL 1975		WINTER 1976	
	1	*Cibicides lobatulus*	7	*Cibicides lobatulus*	23
	2	*Fursenkoina fusiformis*	6	*Reophax atlantica*	20
	3	*Eggerella advena*	4	*Elphidium subarcticum*	4
	4	*Reophax atlantica*	4	*Trifarina angulosa*	2
	5	*Elphidium subarcticum*	2	*Elphidium clavatum*	2
	6	*Bulimina marginata*	2	*Ammodiscus* sp. A	2
	7	*Trifarina angulosa*	1	*Webbinella concava*	2
	8	*Ammodiscus* sp. A	1		
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	45	*Reophax atlantica*	29
	2	*Eggerella advena*	27	*Cibicides lobatulus*	10
	3	*Cibicides lobatulus*	14	*Eggerella advena*	10
	4	*Pyrgo sarsi*	7	*Bulimina marginata*	3
	5	*Ammodiscus* sp. A	5	*Elphidium incertum*	2
	6	*Ammodiscus catinus*	5	*Elphidium subarcticum*	1
	7	*Fursenkoina fusiformis*	3	*Webbinella concava*	1
	8	*Trochammina ochracea*	2	*Trifarina angulosa*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
E4		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	70	*Reophax atlantica*	120
	2	*Reophax atlantica*	43	*Bulimina marginata*	21
	3	*Bulimina marginata*	18	*Cibicides lobatulus*	15
	4	*Cibicides lobatulus*	15	*Lenticulina stephensoni*	14
	5	*Lenticulina stephensoni*	10	*Reophax curtus*	6
	6	*Elphidium clavatum*	5	*Fursenkoina fusiformis*	6
	7	*Islandiella subglobosa*	2	*Cibicides pseudungerianus*	3
	8	*Eggerella advena*	2	*Marginulina bachei*	3
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	25	*Reophax atlantica*	16
	2	*Bulimina marginata*	10	*Bulimina marginata*	4
	3	*Lenticulina stephensoni*	9	*Cibicides lobatulus*	3
	4	*Cibicides lobatulus*	4	*Fursenkoina fusiformis*	2
	5	*Fursenkoina fusiformis*	2	*Lenticulina stephensoni*	2
	6	*Eggerella advena*	2	*Eggerella advena*	1
	7	*Trifarina angulosa*	1	*Elphidium clavatum*	1
	8	*Marginulina bachei*	1	*Elphidium subarcticum*	1

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
F1		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	74	*Reophax atlantica*	95
	2	*Bulimina marginata*	17	*Cibicides lobatulus*	11
	3	*Trochammina lobata*	14	*Bulimina marginata*	11
	4	*Quinqueloculina poeyanum*	8	*Reophax curtus*	6
	5	*Trochammina advena*	7	*Trifarina angulosa*	5
	6	*Pyrgo sarsi*	6	*Cibicides pseudungerianus*	4
	7	*Discorbis* sp. A	6	*Reophax* sp. A	3
	8	*Cibicides lobatulus*	6	*Polymorphina* sp.	2
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	41	*Reophax atlantica*	21
	2	*Fursenkoina fusiformis*	6	*Reophax* sp. A	16
	3	*Cibicides lobatulus*	4	*Discorbis* sp. A	5
	4	*Bulimina marginata*	4	*Fursenkoina fusiformis*	4
	5	*Eggerella advena*	3	*Reophax curtus*	4
	6	*Trochammina ochracea*	2	*Buccella* sp. B	3
	7	*Elphidium incertum*	2	*Valvulina conica*	3
	8	*Webbinella concava*	2	*Textularia "conica"*	2

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
F2		FALL 1975		WINTER 1976	
	1	*Trifarina angulosa*	34	*Reophax atlantica*	49
	2	*Fursenkoina fusiformis*	25	*Cibicides pseudungerianus*	31
	3	*Reophax atlantica*	17	*Fursenkoina fusiformis*	23
	4	*Cibicides lobatulus*	17	*Trifarina angulosa*	21
	5	*Cibicides pseudungerianus*	12	*Discorbis* sp. A	13
	6	*Islandiella subglobosa*	10	*Textularia "conica"*	12
	7	*Cassidulina subcarinata*	8	*Bulimina marginata*	10
	8	*Lenticulina stephensoni*	7	*Cibicides lobatulus*	10
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	35	*Reophax atlantica*	23
	2	*Pyrgo sarsi*	8	*Fursenkoina fusiformis*	8
	3	*Fursenkoina fusiformis*	6	*Rosalina floridana*	5
	4	*Trochammina lobata*	5	*Bulimina auriculata*	3
	5	*Cibicides pseudungerianus*	3	*Marginulina bachei*	3
	6	*Buccella* sp. B	2	*Bulimina marginata*	1
	7	*Reophax curtus*	2	*Eponides repandus*	1
	8	*Marginulina bachei*	1		

Appendix 7-A (continued)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
F3		FALL 1975		WINTER 1976	
	1	*Fursenkoina fusiformis*	140	*Reophax atlantica*	28
	2	*Cassidulina neocarinata*	9	*Marenda nematoda*	12
	3	*Bulimina marginata*	5	*Marginulina bachei*	8
	4	*Reophax atlantica*	4	*Cibicides lobatulus*	5
	5	*Reophax curtus*	4	*Pseudoclavulina novangliae*	5
	6	*Bolivina spathulata*	3	*Reophax curtus*	4
	7	*Islandiella subglobosa*	3	*Islandiella subglobosa*	4
	8	*Nonion grateloupi*	3	*Lenticulina stephensoni*	4
		SPRING 1976		SUMMER 1976	
	1	*Reophax atlantica*	24	*Lenticulina stephensoni*	12
	2	*Stainforthia compressa*	6	*Eggerella advena*	10
	3	*Höglundina elegans*	6	*Cassidulina laevigata*	5
	4	*Bolivina pseudoplicata*	5	*Fursenkoina fusiformis*	4
	5	*Fursenkoina fusiformis*	5	*Dentalina communis*	3
	6	*Nonion* sp. A	3	*Höglundina elegans*	3
	7	*Karreriella novangliae*	3	*Stainforthia compressa*	3
	8	*Gyroidina soldanii*	3		

Appendix 7-A (concluded)

Station	Rank	Species	Mean Density (no./20cm^3)	Species	Mean Density (no./20cm^3)
F4		FALL 1975		WINTER 1976	
	1	*Trifarina angulosa*	136	*Reophax atlantica*	23
	2	*Cassidulina subcarinata*	100	*Reophax curtus*	14
	3	*Fursenkoina fusiformis*	79	*Bulimina auriculata*	7
	4	*Lenticulina stephensoni*	51	*Lenticulina stephensoni*	7
	5	*Cassidulina neocarinata*	31	*Elphidium clavatum*	3
	6	*Cibicides lobatulus*	25	*Islandiella subglobosa*	3
	7	*Islandiella subglobosa*	25	*Stainforthia compressa*	3
	8	*Nonion grateloupi*	22	*Cibicides lobatulus*	3
		SPRING 1976		SUMMER 1976	
	1	*Cassidulina neocarinata*	34	*Globobulimina turgida*	29
	2	*Reophax atlantica*	21	*Bulimina marginata*	19
	3	*Ammobaculites* sp. A	9	*Bolivina spathulata*	19
	4	*Buccella* sp. B	7	*Lagena* sp. B	19
	5	*Lenticulina stephensoni*	7	*Fusenkoina fusiformis*	10
	6	*Eponides repandus*	7	*Bulimina* sp. A	10
	7	*Textularia candeiana*	5	*Lenticulina stephensoni*	10
	8	*Marginulina bachei*	5	*Nodosaria pyrula*	10