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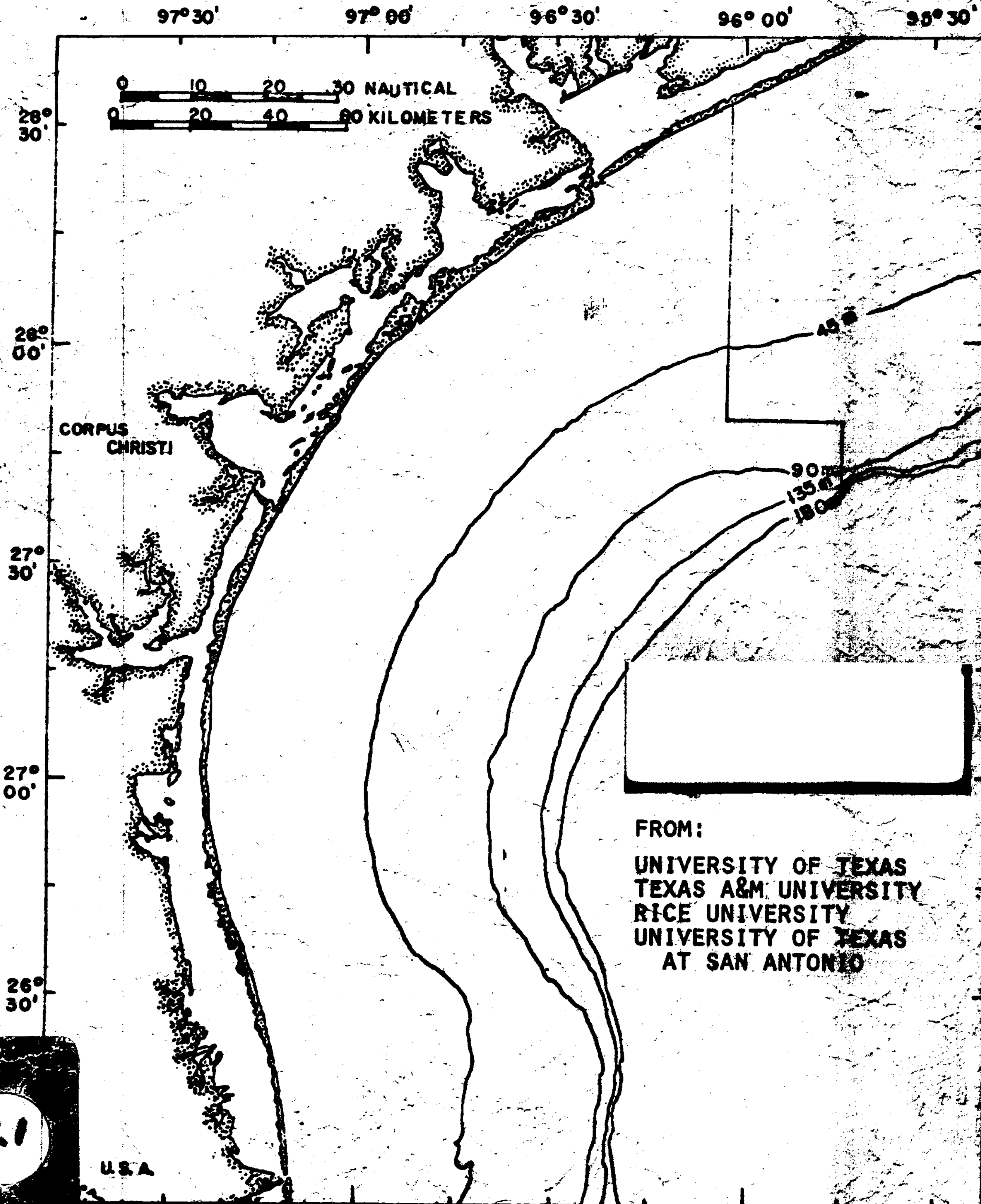
ENVIRONMENTAL STUDIES, SOUTH TEXAS OUTER CONTINENTAL SHELF, BIOLOGY AND CHEMISTRY



FROM:

UNIVERSITY OF TEXAS
TEXAS A&M UNIVERSITY
RICE UNIVERSITY
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AT SAN ANTONIO

61

ENVIRONMENTAL STUDIES,

SOUTH TEXAS OUTER CONTINENTAL SHELF,

BIOLOGY AND CHEMISTRY

Submitted to:

The Bureau of Land Management
Washington, D. C.

by

The University of Texas Marine Science Institute
Port Aransas Marine Laboratory
Port Aransas, Texas 78373

Acting for and on behalf of
A Consortium Program
Conducted by:

Rice University
Texas A&M University
The University of Texas

FINAL REPORT
1976
VOLUME I
CHAPTERS 1 - 8
CONTRACT AA550-CT6-17

September 30, 1977

This report has been reviewed by the Bureau of Land Management and approved for publication. Approval does not signify that the contents reflect the views and policies of the Bureau, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

This study of the South Texas Outer Continental Shelf (STOCS) was conducted on behalf of the U. S. Bureau of Land Management and with the close cooperation of personnel of that agency. The studies reported on herein constituted the second year of a baseline monitoring program of chemical and biological parameters of the STOCS. This study was part of an overall study of the STOCS, other elements being (a) geology and geophysics by the U.S. Geological Survey, (b) fisheries resources and ichthyoplankton populations by the National Oceanographic and Atmospheric Administration/National Marine Fisheries Service, and (c) biological and chemical characteristics of selected topographic features in the Northern Gulf by Texas A&M University. The resultant data from this investigation represent the first step in understanding how to assess and control the impact of petroleum exploration and development in the STOCS area. The central goal of these and other environmental quality surveys of continental shelf areas is the protection of the living marine resources from deleterious effects.

This investigation was the result of the combined efforts of scientists and support personnel from four Universities. The hard work and cooperation of all participants is gratefully acknowledged.

ENVIRONMENTAL STUDIES,
SOUTH TEXAS OUTER CONTINENTAL SHELF,
BIOLOGY AND CHEMISTRY

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CHAPTER ONE

INTRODUCTION

Purpose and Scope of Study

In 1974, the Bureau of Land Management (BLM), as manager of the Outer Continental Shelf Leasing Program, was authorized to initiate a National Outer Continental Shelf Environmental Studies Program. The broad objectives of this program, as stated by the BLM, are:

(a) to provide information about the Outer Continental Shelf (OCS) environment to enable the Department of the Interior to make management decisions regarding OCS oil and gas development; and

(b) to fill environmental information needs of management, regulatory and advisory agencies, both Federal and State, for a broad range of OCS activities, including the preparation and review of environmental impact statements under the National Environmental Policy Act (NEPA) of 1969, issuance of regulations and permits, and implementation of certain other laws, such as the OCS Lands Act, Fish and Wildlife Coordination Act, the Coastal Zone Management Act, and counterpart state laws.

The National Outer Continental Shelf Environmental Studies Program consists of three basic elements: (1) baseline studies, which are conducted during the pre-development period; (2) long-term monitoring studies; and, (3) special studies, which may occur during the baseline and monitoring studies phases. The four major objectives of baseline studies of OCS oil and gas development areas are to:

(a) provide information for predicting the effects of OCS oil and gas development activities upon the components of the ecosystem;

(b) provide a description of the physical, chemical, geological and biological components, and their interactions, against which subsequent changes or impacts can be compared;

(c) identify critical parameters that should be incorporated into a monitoring program; and,

(d) identify and conduct experimental and other special studies as required to meet the baseline objectives.

To accomplish these objectives for the South Texas Outer Continental Shelf (STOCS), the BLM developed the *Marine Environmental Study Plan for the South Texas Outer Continental Shelf*. This plan called for an initial three-year period of intensive study to establish the physical, chemical, geological and biological baseline, a slow decline in funding over the succeeding two years, and a maintenance, or sustaining, level of funding for an indefinite number of years to monitor the long-term effects of OCS oil and gas exploration and development activity.

In addition to the biological and chemical components of this program reported on herein, two other major field programs were conducted concurrently. The U. S. Geological Survey conducted a program designed to investigate suspended sediments flux, normal and storm transport and deposition of sediments, and sediment geochemistry in the STOCS area. The National Oceanic and Atmospheric Administration/National Marine Fisheries Service conducted studies to investigate the historical distribution and abundance of ichthyoplankton in the area, to elucidate the snapper and grouper fisheries resources, and to determine the magnitude and economic significance of the recreational and associated "commercial/recreational" fisheries in the area. In addition to the above studies restricted to the STOCS study area, Texas A&M University is conducting a major field survey of the biological and chemical characteristics of selected topographic features in the Northern Gulf.

Description of the Study Area

Biological Setting

The Texas coastal area is biologically and chemically a two-part marine system, the coastal estuaries and the broad continental shelf. These two marine systems are separated by barrier islands and connected by inlets or passes. The area is rich in finfish and crustaceans, many of which are commercially and recreationally important. Many of the finfish and decapod crustaceans of the STOCS area exhibit a marine-estuarine dependent life cycle, *i.e.* spawning offshore, migrating shoreward as larvae and postlarvae, and utilizing the estuaries as nursery grounds (Galtsoff, 1954; Gunter, 1945). The broad continental shelf supports a valuable shrimp fishery and, as a living resource, contributes significantly to the local economy. An excellent overview of the zoogeography of the northwestern Gulf of Mexico was provided by Hedgepeth (1953).

Location and Bathymetry

The STOCS study area corresponds to the area outlined by the Department of the Interior for oil and gas leasing. The area covers approximately 19,250 km^2 and is bounded by 96°W longitude on the east, the Texas coastline on the west, and the Mexico-United States international border on the south (Figure 1). The bathymetry of the STOCS area is shown in Figure 2. The continental shelf off south Texas has an average width of about 88.5 km and a relatively gentle seaward gradient that averages 2.3 m/km.

Work Plan

Objectives

The broad objective of the 1976 study effort of the STOCS area was to begin assessing the impacts of petroleum exploration and development and to expand the baseline effort to gain additional environmental information

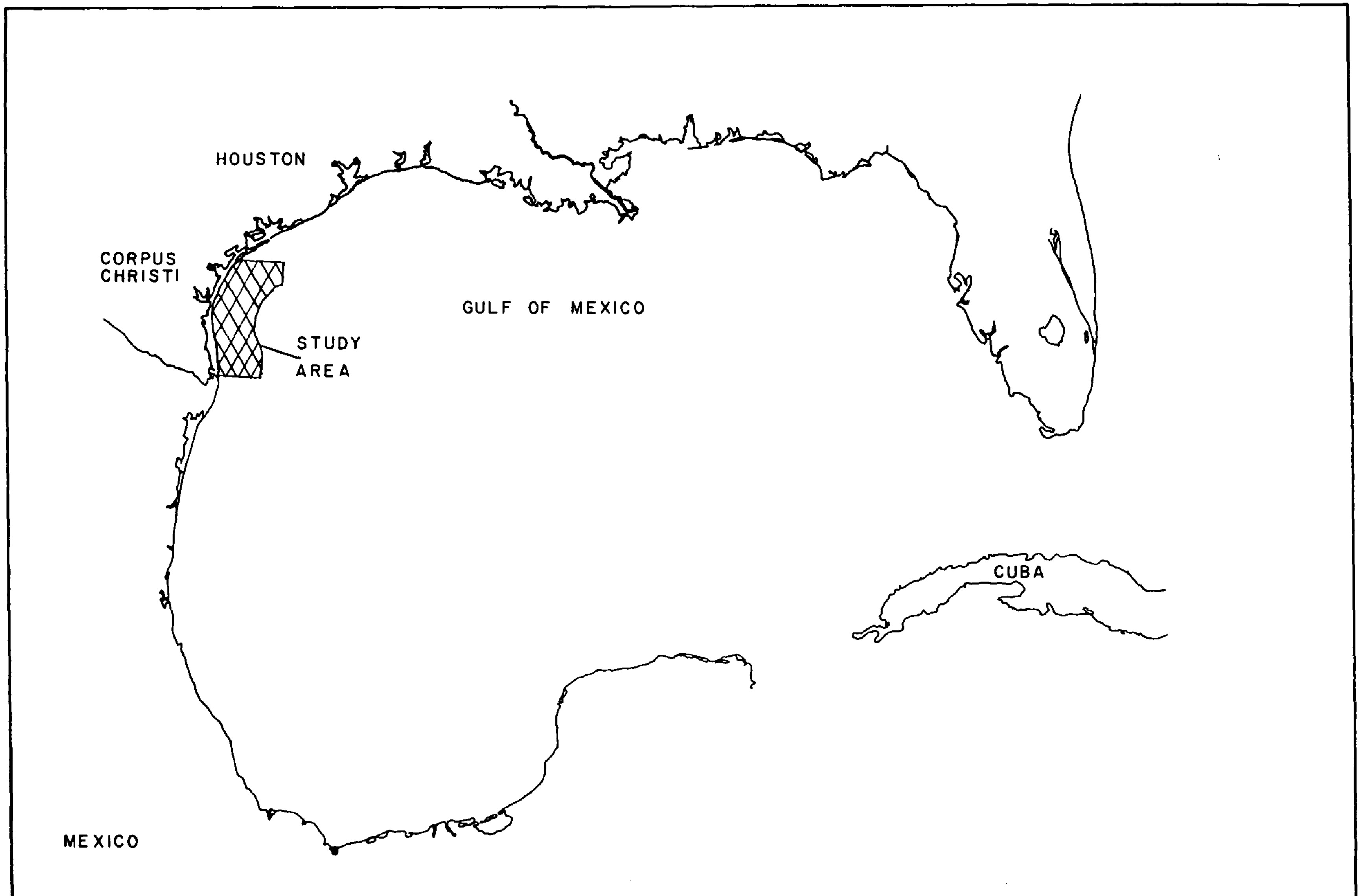

Figure 1. Location of the study area in relation to the Gulf of Mexico.

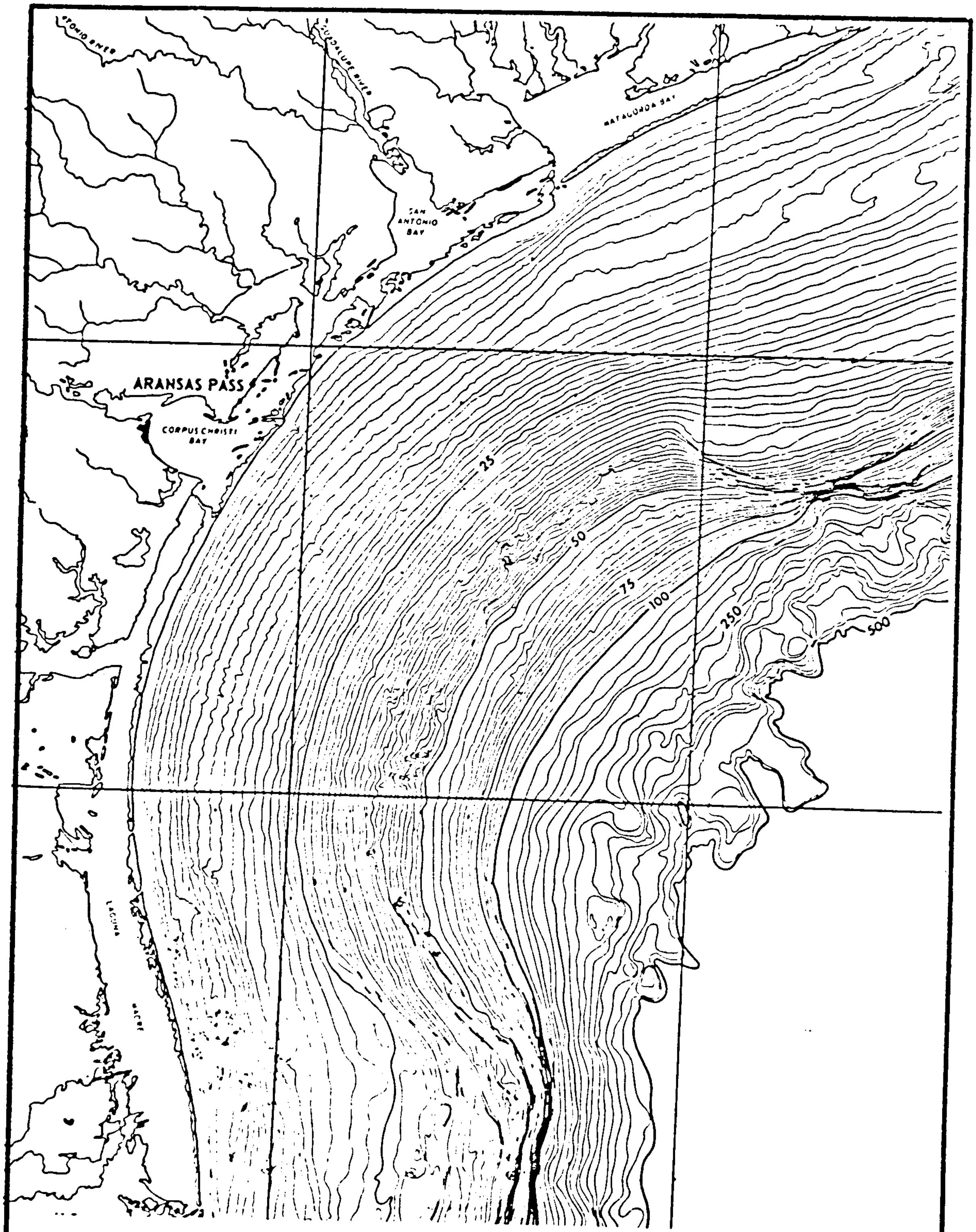

Figure 2. Bathymetry of the South Texas Outer Continental Shelf (Depth in Fathoms) From Berryhill *et al.*, 1976, Part I, Figure 3.

beyond that collected in the first year. A secondary objective of characterizing the effects of drilling muds, cuttings, and other disposals associated with exploratory drilling was met by pre-, during- and post-drilling surveys of the sediments, organisms and water in the immediate vicinity of an exploratory drilling rig. The results of the rig monitoring program are presented in a separate report.

Time Frame

The field investigations for the first year of study began in late October, 1974, and were complete by mid-September, 1975. Laboratory analyses were complete by January 30, 1976. The final report for the chemical and biological component of the 1975 study was submitted to BLM in July, 1976, and the final integrated report of all components of the STOCS study was submitted to BLM in April, 1977.

The field sampling for the second year of study was initiated in mid-January, 1976, and was completed in mid-December, 1976. Laboratory analyses were complete by February 15, 1977. This report contains the results of all 1976 field and laboratory investigations of the chemical and biological components. An integrated report of all components of the 1976 study will be forthcoming in the early part of 1978.

Sampling Stations

During the first year of study (1975), twelve stations on four transects were sampled (Figure 3). Thirteen additional transect stations were sampled during the second year (1976) to increase coverage of three special areas: (1) the near-shore environment (about 20 m depth); (2) a zone in the middle of the study area that appears anomalous in its sediment characteristics, sediment trace metal content and distributions of certain biological populations; and, (3) a zone of active gas seepage

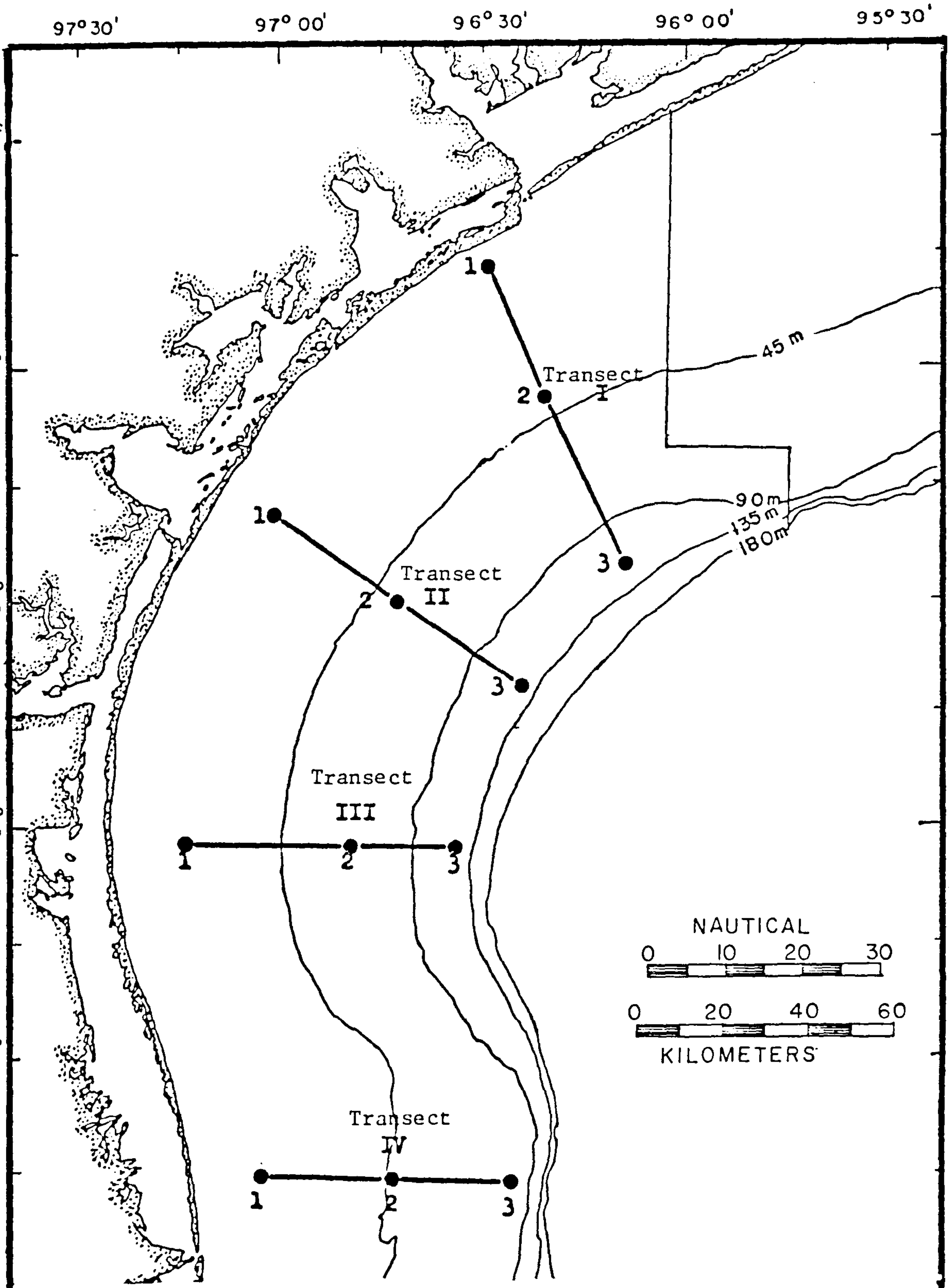

Figure 3. Station Locations for the 1975 South Texas Outer Continental Shelf Study. Depth in Meters.

near the shelf-slope break. Also, four stations on each of two submarine carbonate reefs, Hospital Rock and Southern Bank, were sampled. A total of 33 stations were sampled during 1976 (Figure 4). Table 1 gives the LORAN and LORAC coordinates, latitude and longitude and depths of the sample stations.

Sampling Effort

Samples were collected in 1976 during three biological-meteorological seasons from all transects and the bank stations. The three seasons were Winter (January and February), Spring-Summer (May-June) and Summer-Fall (September-October). In addition to the seasonal samplings, Transect II and the bank stations were sampled in the six months (March, April, July, August, November and December) not included in the three seasonal sampling periods. Table 2 contains a complete list of cruises by date and type.

The sampling effort was broken up into three types of cruises: water column, benthic and histopathology. (Histopathology work elements were initiated in July 1976.) Table 3 gives a breakdown of the different scientific elements by cruise type and sampling frequency. Table 4 lists the sampling gear deployed for each sample type. Complete descriptions of sampling methods are included in each work element reports.

Navigation and station location for water column and histopathology cruises were by LORAN-A. Navigation and station location for the benthic cruises were by LORAC navigational systems.

Table 5 gives a summary of samples collected during the 1976 contracting period. A summary of high-molecular-weight hydrocarbons and trace metal quality control samples collected during the 1976 contracting period is given in Table 6. Hydrocarbon quality control samples have been delivered to the University of New Orleans. Trace metal quality

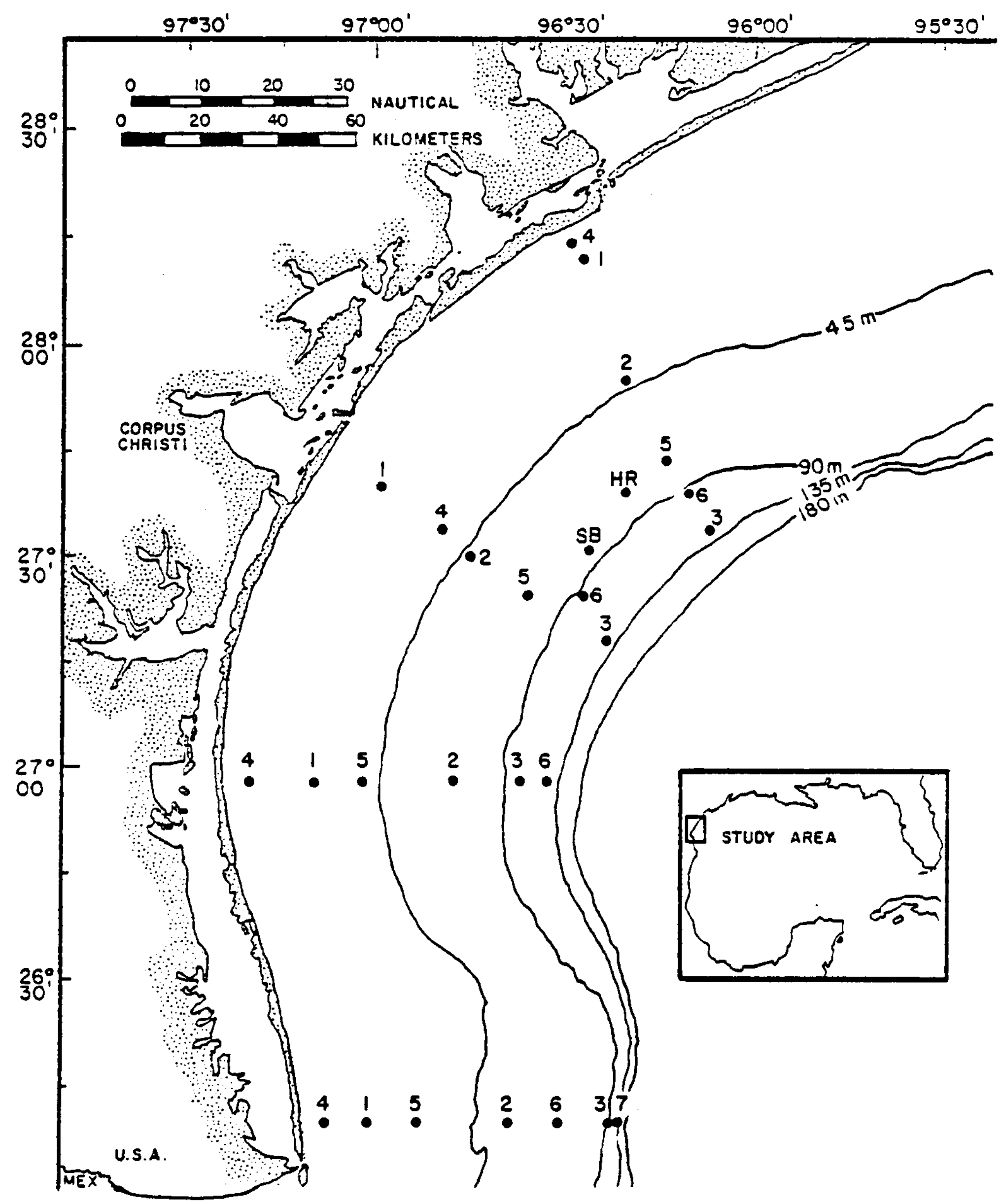

Figure 4. Station Locations for the 1976 South Texas Outer Continental Shelf Study. Depths in Meters.

TABLE 1

BLM STOCS/MONITORING STUDY 1976-STATION LOCATIONS

TRAN.	STA.	LORAN 3H3	LORAN 3H2	LORAC LG	LORAC LR	LATITUDE	LONGITUDE	DEPTH METERS	DEPTH FEET
I	1	2575	4003	1180.07	171.46	28°12'N	96°27'W	18	59
	2	2440	3950	961.49	275.71	27°55'N	96°20'W	42	138
	3	2300	3863	799.45	466.07	27°34'N	96°07'W	134	439
	4	2583	4015	1206.53	157.92	28°14'N	96°29'W	10	33
	5	2360	3910	861.09	369.08	27°44'N	96°14'W	82	269
	6	2330	3892	819.72	412.96	27°39'N	96°12'W	100	328
II	1	2078	3962	373.62	192.04	27°40'N	96°59'W	22	72
	2	2050	3918	454.46	382.00	27°30'N	96°45'W	49	161
	3	2040	3850	564.67	585.52	27°18'N	96°23'W	131	430
	4	2058	3936	431.26	310.30	27°34'N	96°50'W	36	112
	5	2032	3992	498.85	487.62	27°24'N	96°36'W	78	256
	6	2068	3878	560.54	506.34	27°24'N	96°29'W	98	322
	7	2045	3835			27°15'N	96°18.5'W	182	600
III	1	1585	3880	139.13	909.98	26°58'N	97°11'W	25	82
	2	1683	3841	286.38	855.91	26°58'N	96°48'W	65	213
	3	1775	3812	391.06	829.02	26°58'N	96°33'W	106	348
	4	1552	3885	95.64	928.13	26°58'N	97°20'W	15	49
	5	1623	3867	192.19	888.06	26°58'N	97°02'W	40	131
	6	1790	3808	411.48	824.57	26°58'N	96°30'W	125	410
IV	1	1130	3747	187.50	1423.50	26°10'N	97°01'W	27	88
	2	1300	3700	271.99	1310.61	26°10'N	96°39'W	47	154
	3	1425	3663	333.77	1241.34	26°10'N	96°24'W	91	298
	4	1073	3763	163.42	1456.90	26°10'N	97°08'W	15	49
	5	1170	3738	213.13	1387.45	26°10'N	96°54'W	37	121
	6	1355	3685	304.76	1272.48	26°10'N	96°31'W	65	213
	7	1448	3659	350.37	1224.51	26°10'N	96°20'W	130	426
HR	1	2159	3900	635.06	422.83	27°32'05"	96°28'19"	75	246
	2	2169	3902	644.54	416.95	27°32'46"	96°27'25"	72	237
	3	2163	3900	641.60	425.10	27°32'05"	96°27'35"	81	266
	4	2165	3905	638.40	411.18	27°33'02"	96°29'03"	76	250
SB	1	2086	3889	563.00	468.28	27°26'49"	96°31'18"	81	266
	2	2081	3889	560.95	475.80	27°26'14"	96°31'02"	82	269
	3	2074	3890	552.92	475.15	27°26'06"	96°31'47"	82	269
	4	2078	3890	551.12	472.73	27°26'14"	96°32'07"	82	269

TABLE 2

SCHEDULE OF 1976 CRUISES

Cruise No.	Date	Season	Type	Transect
16	1/13-16	W	Water Column	IV
17	1/30-2/4	W	Water Column	I - IV
18	2/8-10	W	Benthos	II
19	2/12-17	W	Benthos	I & II
20	2/19-23	W	Benthos	III & IV
21	2/26-29	W	Benthos	III & IV
22	3/9-12	W	Benthos	I, II & III
23	3/18-20	Mar.	Water Column	II
24	3/25-28	Mar.	Benthos	II
25	4/2-4	Apr.	Water Column	II
26	4/8-11	Apr.	Benthos	II
27	5/29-6/8	S	Water Column	I - IV
28	6/10-15	S	Benthos	I & II
29	6/18-22	S	Benthos	III & IV
30	6/24-29	S	Benthos	I - IV
31	7/10-12	July	Water Column	II
32	7/16-19	July	Benthos	II
33	7/22-23	July	Histopathology	II
34	8/4-7	Aug.	Benthos	II
35	8/9-11	Aug.	Water Column	II
36	8/12-13	Aug.	Histopathology	II
37	8/27-29	Aug.	Make-up	II
38	9/10-16	F	Water Column	I - IV
39	9/19-23	F	Benthos	III & IV
40	9/25-27	F	Pre-Drill Rig Monitoring	
41	10/1-2	Oct.	Histopathology	II
42	10/6-11	F	Benthos	I, II & Banks
43	11/2	Nov.	Water Column	II
44	11/5-6	Nov.	Histopathology	II
45	11/8-10	Nov.	Water Column	II
46	11/15-18	Nov.	Benthos	II
47	12/1-3	Dec.	Water Column	II
48	12/3-4	Dec.	Histopathology	II
49	12/8-10	Dec.	Benthos	II

TABLE 3

SAMPLING FREQUENCY AND STATIONS DURING THE 1976 STOCS STUDY

Monthly and Seasonally	
Water Column Sampling	**Stations**
Meteorology	All Transects and Bank Stations
Hydrography	All Transects and Bank Stations
High-Molecular-Weight Hydrocarbons in Zooplankton and Water	Stations 1-3, All Transects
Low-Molecular-Weight Hydrocarbons, Nutrients, and Dissolved Oxygen	Stations 1-3, All Transects and Bank Stations
Phytoplankton and Phytoplankton Biomass	Stations 1-3, All Transects
Zooplankton	Stations 1-3, All Transects
Shelled Microplankton and General Microplankton	Stations 1-3, All Transects and Bank Stations
Benthic Sampling	
Macroinfauna	All Transects and Bank Stations
Meiofauna	All Transects and Bank Stations
Shelled Microzoobenthon	All Transects and Bank Stations
Sediment Textural Analysis	All Transects and Bank Stations
Macroepifauna (Day & Night)	All Transect Stations
Demersal Fishes (Day & Night)	All Transect Stations
Neuston (Day & Night)	All Transect Stations
High-Molecular-Weight Hydrocarbons in Macronekton	Stations 1-3, All Transects
Trace Metals in Macronekton	Stations 1-3, All Transects
Histopathology*	
Histopathology of Macroepifauna	Stations 1-3, Transect II
Histopathology of Demersal Fishes	Stations 1-3, Transect II
Histopathology: Gonadal Tissues of Macroepifauna and Demersal Fishes	Stations 1-3, Transect II
SEASONALLY ONLY	
Water Column Sampling	
Trace Metals in Zooplankton	Stations 1-3, All Transects
Benthic Sampling	
High-Molecular-Weight Hydrocarbons in Sediment	Stations 1-3, All Transects
High-Molecular-Weight Hydrocarbons in Macroepifauna and Demersal Fishes	Stations 1-3, All Transects
Trace Metals in Macroepifauna and Demersal Fishes	Stations 1-3, All Transects

*Program not initiated until July 1976

TABLE 4

SAMPLING GEAR USED DURING THE 1976 STOCS STUDY

Element	Sampling Gear
Hydrography	Plessey Salinity/Temperature/Depth Profiling System and Nansen Bottles Equipped with Reversing Thermometers
High-Molecular-Weight Hydrocarbons in Water	19-l Glass Carboy in a Stainless Steel Cage
High-Molecular-Weight Hydrocarbons and Trace Metals in Zooplankton	1-m dia., 250 μm mesh net, PVC Frame Towed with a Nylon Rope from a Boom at the Side of Survey Vessel
Low-Molecular-Weight Hydrocarbons in Water	30-l Niskin Bottles
Phytoplankton and Phytoplankton Biomass	30-l Niskin Bottles
Nutrients	30-l Niskin Bottles
Shelled Microzooplankton and General Microplankton (Discrete Depth)	30-l Niskin Bottles
Dissolved Oxygen	Nansen Bottles Equipped with Reversing Thermometers
Zooplankton	1-m dia., 250 μm mesh net, Equipped with Flowmeter and a Time-Depth Recorder
Shelled Microzooplankton and General Microplankton (Integrated Depth)	30-cm Nansen Net, 76 μm Mesh
Neuston	505 μm net, 1 x 2-m Rectangular Mouth, 5-m Length, Equipped with Plastic Floats and a Flowmeter
Macroinfauna	Smith-MacIntyre Grab Sampler (.0125 m^3)
Meiofauna	Smith-MacIntyre Grab Sampler (.0125 m^3)
Shelled Microzoobenthon	Smith-MacIntyre Grab Sampler (.0125 m^3)
Sediment Hydrocarbons	Smith-MacIntyre Grab Sampler (.0125 m^3)
Sediment Trace Metals (USGS)	Smith-MacIntyre Grab Sampler (.0125 m^3)

TABLE 4 CONT.'D

Element	Sampling Gear
Sediment Texture	Smith-MacIntyre Grab Sampler (.0125 m^3)
Macroepifauna	35-ft. (10.7 m) otter trawl
Demersal Fishes	35-ft. (10.7 m) otter trawl
High-Molecular-Weight Hydrocarbons and Trace Metals in Macroepifauna and Demersal Fishes	35-ft. (10.7 m) otter trawl
Histopathology of Demersal Fishes and Macroepifauna	35-ft. (10.7 m) otter trawl
High-Molecular-Weight Hydrocarbons and Trace Metals in Macronekton	Hook and Line

TABLE 5

SUMMARY OF SAMPLES COLLECTED BY TYPE AND NUMBER UNDER BLM CONTRACT AA550-CT6-17

Sample Type	Contracted	Collected
Salinity-Temperature-Depth	147	131[1]
Dissolved Oxygen	256	250[1]
Nutrients	256	250[1]
Chlorophyll a	202	202
Phytoplankton	148	148
ATP	202	202
Microzooplankton	288	288
Zooplankton	162	162
Neuston	108	108
Meiofauna	588	588
Infauna	882	882
Epifauna	222	220[2]
Histopathology	450	450
Sediment Texture	1179	1179
LMW-Hydrocarbons	184	180[1]
HMW-Hydrocarbons	718	617[3]
Trace Metals	409	307[3]
Total Number of Samples	6401	6166

[1]Samples not taken at bank stations during winter cruise; station locations not received from BLM.
[2]Trawl lost on 3/I winter.
[3]Macronekton-only "best effort" was required in the contract.

TABLE 6

SUMMARY OF QUALITY CONTROL SAMPLES COLLECTED UNDER BLM CONTRACT AA550-CT6-17

Sample Type	Hydrocarbon		Trace Metal	
	Contracted	Collected	Contracted	Collected
Macroepifauna and Demersal Fishes	24	24	24	24
Particulate High-Molecular Weight Hydrocarbons	12	12	0	0
Zooplankton	12	12	12	12
Macronekton	4	4	4	4
Sediment	24	24	24	24
Ship's Contaminants	9	9	3	3

control samples are in storage at UTMSI/PAML, pending the naming of a trace metal quality control laboratory.

Survey Vessel

All sampling and measurements, except the placement and recovery of current meters were taken aboard the University of Texas research vessel, the R/V LONGHORN. The R/V LONGHORN, designed and constructed as a coastal research vessel in 1971, is a steel-hulled 24.38 (80 ft.) by 7.42 m (24 ft.), 2.13 m (7 ft.) draft ship. She carries a crew of five and can accomodate a scientific party of ten. The R/V LONGHORN is equipped with a stern-mounted crane, a trawling winch, scan sonar, radar, LORAN-A and LORAC navigational systems, and dry and wet laboratory space.

Participants

The University of Texas Marine Science Institute, Port Aransas Marine Laboratory (UTMSI/PAML), was contracted by the BLM to provide overall project management, logistics, ship time, data management and certain scientific efforts. Additional scientific effort was provided by sub-contracts between the University of Texas and Texas A&M University, The University of Texas at San Antonio, and Rice University.

A total of 22 principal investigators participated in the project. Table 7 lists the principal investigators by institutions represented and scientific responsibility. Ship time was provided for the NOAA/NMFS ichthyoplankton sampling. Supportive work was performed by the USGS (sediment texture and sediment trace metals) and the Topographic Features (sediment texture and transmissometry) components (Appendices O and P, Volume VI).

Program Management

For the second year of environmental studies of the STOCS, the biological and chemical component required a full-time Program Manager and staff. The Program Management staff consisted of a Technical Coordinator,

TABLE 7

STOCS BIOLOGICAL AND CHEMICAL COMPONENT PARTICIPANTS BY WORK ELEMENT AND INSTITUTION

University of Texas Marine Science Institute-Port Aransas Marine Laboratory

Hydrography	Ned P. Smith
High-Molecular-Weight Hydrocarbons in Zooplankton, Sediment and Water	Patrick L. Parker, Richard S. Scalan, J. Kenneth Winters
Phytoplankton and Phytoplankton Biomass	Chase Van Baalen, Daniel L. Kamykowski, Warren M. Pulich
Sediment Texture	E. William Behrens
Macroinfauna and Macroepifauna	J. Selmon Holland
Demersal Fishes	Donald E. Wohlschlag

Texas A & M University

High-Molecular-Weight Hydrocarbons in Macroepifauna, Demersal Fishes and Macronekton	C. S. Giam, H. S. Chan
Trace Metals in Macroepifauna, Demersal Fishes, Macronekton and Plankton	Bobby Joe Presley, Paul N. Boothe
Low-Molecular-Weight Hydrocarbons, Nutrients and Dissolved Oxygen	William M. Sackett, James M. Brooks
Zooplankton	E. Taisoo Park
Neuston	John H. Wormuth, Linda H. Pequegnat
Meiofauna	Willis E. Pequegnat
Histopathology of Macroepifauna	Jerry M. Neff
Histopathology of Demersal Fishes	William E. Haensly

University of Texas at San Antonio

Histopathology: Gonadal Tissues of Macroepifauna and Demersal Fishes	Samual A. Ramirez

Rice University

Shelled Microplankton, General Microplankton and Shelled Microzoobenthos	Richard E. Casey

Data Manager, Program Secretary, marine technicians, draftsperson and ancillary data management personnel. The primary responsibilities of the Program Manager and staff included overall program administration; logistical coordination for field sampling, sample transmittals, lab analyses, data management and meetings; and preparation of required reports.

Meetings were held at the end of each quarter of the contracting period. All Principal Investigators for the biological and chemical component and element leaders of other STOCS projects presented a summary of significant findings and progress reports at these meetings. Following each quarterly conference a Quarterly Summary Report was submitted to BLM. These reports summarized all work accomplished and problems encountered; an updated sample inventory showing all samples taken and their disposition; a summary of significant findings; and the Principal Investigators' quarterly progress reports. To insure communication, coordination, unity of effort, and to act as an editorial board for the preparation of the integrated report, an Administrative Council [consisting of the Program Manager, Technical Coordinator, Data Manager, the Project Element Coordinators of other STOCS projects and the Contracting Officer's Authorized Representative (COAR)] met prior to each quarterly conference.

Data Management

Following the hiring of a Data Manager in June 1976, data management efforts encompassed several major efforts, including: (1) standardization of data reporting procedures and formats; (2) standardization of the inventory record and the salvage of the first 6 months' inventory for 1976; (3) organization of a data filing approach to facilitate data editing and retrieval; and, (4) development and documentation of specialized programs to analyze and report data. Each of these tasks is discussed below in more detail.

To standardize data reporting procedures and formats, meetings were held with the Principal Investigators (PI's) to determine their usual method of recording data. A form was then developed for each PI which would allow ease of keypunching, while still approximating the PI's standard recording format. In many cases this was completely successful, with the PI using the form to record data and sending a copy to Data Management for keypunching.

The number punched in columns 1-7 of most cards (see Coding forms, Figure 5) allows identification of the project and card format. These numbers are a subset of the coding convention used for naming all documented programs and files (Table 8). The four letter code in columns 11-14 is the unique code assigned to each sample at the time of collection to enable later matching with the inventory information for that sample. We are now experimenting with computer-assigned codes and printed coding forms to bypass several potential sources of error.

The importance of the inventory record was not recognized in the early part of this program. The present data management effort had to salvage approximately 5,000 inventory records in which over one-half of the information was randomly placed in a comments column with multiple abbreviations for each condition. In addition, much of the important information was miscoded or omitted. A massive editing operation was undertaken to standardize the abbreviations (Table 9) and make the records machine-readable. New formats were developed (Figure 6) and a program written to interpret the edited file and produce a newly formatted record. The resulting file was then edited in an ongoing attempt to fill

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FOR COMPUTER CENTER USE

HYDROGRAPHIC DATA
DATA REPORTING FORM
PAGE_____OF_____

Individual Responsible for Form_______
Transect______Station_____Depth______
Date_______Time_______ CST/CDT_____

0 0 1 3 0 0 1

Sample name

Calibration Temps (°C)
Bucket therm. temp _____
Revers therm. temps: left_____ right _____
Refer. therm. temps: left_____ right _____
Bottom calibr'n temps: left_____ right _____
avg._____
Calibr'n salinities: sfc._____ btm._____

Depth (M)	Temp. (°C)	Salin. (PPT)	Depth (M)	Temp. (°C)	Salin. (PPT)
15	18	23	15	18	23

Figure 5. Examples of Data Coding Forms Used During the 1976 STOCS Study.

INVERTEBRATE EPIFAUNA and MACROINFAUNA
SPECIAL HYDRODATA
DATA REPORTING FORM

BLM-OCS-001-2-1
6/76

FOR COMPUTER CENTER USE

Cruise ________ Station ________ Transect ________

Surface

0012001 (1) Sample name B___ (11) Temperatue (C°) __.__ (15) Conductivity ratio ____ Salinity (ppt) __.__ (20)

Bottom

	Reference	Reversing	Temperature
left:	________	________	________
right:	________	________	________

0012001 (1) Sample name B___ (11) _ (x) Temperature (C°) __.__ (15) Conductivity ratio ____ Salinity (ppt) __.__ (20)

Figure 5. Cont.'d

INVERTBRATE EPIFAUNA and
MACROINFAUNA
DATA REPORTING FORM
PAGE _____ OF _________

BLM-OCS-006-2-1
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FOR COMPUTER CENTER USE

0062002
1 2 3 4 5 6 7

Sample name __ __ __ __ (8, 9, 10, 11)
Sample type __ (12)
1- EPIFAUNA
2- INFAUNA

Collection Period ________
Station __ __ (13) Transect __ __ (15) Replicate __ (17)
Water Depth __ __ __ (18) M
Day __ __ (21) Month __ __ (23) Yr __ __ (25)
Time __ __ __ __ (27) Day / Night __ (31)

Genus	Species	Total Number	Males	Females	F/ eggs	Comments
32		66	71	74	77	

Enter all numbers in right most portion of space ie month 2 ... 1 8 ... [illegible]

Figure 5. Cont.'d

HYDROCARBON RAW DATA
DATA REPORTING FORM
0 0 8 2 0 0 3
1

BLM-STOCS-008-2-3
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INDIVIDUAL RESPONSIBLE FOR FORM ________

CRUISE ______ TRANS. ______ STA. ______

DATE ________________

Card 0 0 1 (8) Sample Code _ _ _ _ (11) Wet Wt. _ _ _ _ _ _ _ _ _ _ (15) Dry Wt. _ _ _ _ _ _ _ _ _ _ (25)

Total nonsaponifiable wt. (gms) _ _ _ _ _ _ _ _ (35) Total column wt _ _ . _ _ _ _ _ (43)

Card 0 0 2 (8) _ _ _ _ (11) (Dup)

Wt. Hexane Fraction (gms) _ _ . _ _ _ _ _ (15)

Wt. Benzene Fraction (gms) _ _ . _ _ _ _ _ (23)

Wt. Methanol Fraction (gms) _ _ . _ _ _ _ _ (31)

Fraction _ (39) (1=hexane, 2=benzene, 3=methanol)

Total dilution volume (µl) _ _ _ _ . _ (40)

Injection volume _ _ _ _ (46)

Date _ _ (50) / _ _ (52) / _ _ (54) Time _ _ _ _ (56) Machine _ _ (60) Attenuation _ _ _ (62)

Card 0 0 3 (8) _ _ _ _ (11) (Dup) Fraction _ (15)

Time	Known	Int. Value	Time	Known	Int. Value
_ _ _ _ (16)	_ _ _ _ (20)	_ _ _ _ _ _ _ _ . (24)	_ _ _ _ (16)	_ _ _ _ (20)	_ _ _ _ _ _ _ _ . (24)
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .
_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .	_ _ _ _	_ _ _ _	_ _ _ _ _ _ _ _ .

Figure 5. Cont.'d

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FOR COMPUTER CENTER USE

ATP
DATA REPORTING FORM
PAGE ________ OF ________

Individual Responsible for Form ____
Cruise ____________
Date ____________

0 1 0 2 0 0 1

Station	Transect	Depth (m)	Sample name	ATP

Figure 5. Cont.'d

PHYTOPLANKTON
DATA REPORTING FORM
PAGE 3

0112001

55	CHAETOCEROS CRINITUS	- - - - - - - - -
56	CHAETOCEROS CURVISETUS	- - - - - - - - -
57	CHAETOCEROS DADAYI	- - - - - - - - -
58	CHAETOCEROS DANICUS	- - - - - - - - -
59	CHAETOCEROS DEBILIS	- - - - - - - - -
60	CHAETOCEROS DECIPIENS	- - - - - - - - -
61	CHAETOCEROS DECIPIENS V. SINGULARIS	- - - - - - - - -
62	CHAETOCEROS DELICATULUS	- - - - - - - - -
63	CHAETOCEROS DENSUS	- - - - - - - - -
64	CHAETOCEROS DICHAETA	- - - - - - - - -
65	CHAETOCEROS DIDYMUS	- - - - - - - - -
66	CHAETOCEROS DIDYMUS V. ANGLICA	- - - - - - - - -
67	CHAETOCEROS DIDYMUS V. PROTUBERANS	- - - - - - - - -
68	CHAETOCEROS DIVERSUS	- - - - - - - - -
69	CHAETOCEROS DIVERSUS (NEW)	- - - - - - - - -
70	CHAETOCEROS EIBENII	- - - - - - - - -
71	CHAETOCEROS FILIFORMIS	- - - - - - - - -
72	CHAETOCEROS FRAGILIS	- - - - - - - - -
73	CHAETOCEROS FURCELLATUS	- - - - - - - - -
74	CHAETOCEROS GLANDAZII	- - - - - - - - -
75	CHAETOCEROS GRACILIS	- - - - - - - - -
76	CHAETOCEROS HOLSATICUS	- - - - - - - - -
77	CHAETOCEROS INGOLFIANUM	- - - - - - - - -
78	CHAETOCEROS LACINIOSUS	- - - - - - - - -
79	CHAETOCEROS LAUDERI	- - - - - - - - -
80	CHAETOCEROS LORENZIANUS	- - - - - - - - -
81	CHAETOCEROS MESSANENSIS	- - - - - - - - -

PHYTOPLANKTON
DATA REPORTING FORM
PAGE 4

0112001

82	CHAETOCEROS MITRA	- - - - - - - - -
83	CHAETOCEROS MUELLERI	- - - - - - - - -
84	CHAETOCEROS ORIENTALIS	- - - - - - - - -
85	CHAETOCEROS PELAGICUS	- - - - - - - - -
86	CHAETOCEROS PENDULUS	- - - - - - - - -
87	CHAETOCEROS PERUVIANUS	- - - - - - - - -
88	CHAETOCEROS PSEUDOCRINITUS	- - - - - - - - -
89	CHAETOCEROS PSEUDOCURVISETUS	- - - - - - - - -
90	CHAETOCEROS PSEUDODICHAETA	- - - - - - - - -
91	CHAETOCEROS PURPUSILLUS	- - - - - - - - -
92	CHAETOCEROS RADIANS	- - - - - - - - -
93	CHAETOCEROS RIGIDUS	- - - - - - - - -
94	CHAETOCEROS SALTANS	- - - - - - - - -
95	CHAETOCEROS SIMPLEX	- - - - - - - - -
96	CHAETOCEROS SIMPLEX V. CALCITRANS	- - - - - - - - -
97	CHAETOCEROS SOCIALIS	- - - - - - - - -
98	CHAETOCEROS SUBSECUNDUS	- - - - - - - - -
99	CHAETOCEROS SUBTILIS	- - - - - - - - -
100	CHAETOCEROS SEIRACANTHUS	- - - - - - - - -
101	CHAETOCEROS TERES	- - - - - - - - -
102	CHAETOCEROS TETRASTICHON	- - - - - - - - -
103	CHAETOCEROS TORTISSIMUS	- - - - - - - - -
104	CHAETOCEROS VANHEURCKI	- - - - - - - - -
105	CHAETOCEROS VISTULAE	- - - - - - - - -
106	CHAETOCEROS VIXVISIBILIS	- - - - - - - - -
107	CHAETOCEROS SPP.	- - - - - - - - -
108	CLIMACODIUM BICONCAVUM	- - - - - - - - -

Figure 5. Cont.'d

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FLOURESCENCE TRANSECT
DATA REPORTING FORM

DATE ______________

CRUISE ______________

0 1 2 2 0 0 1
1

Sample Code _ _ _ _
11

Distance (Naut. mi)	Depth (meters)	Chlorophylls (μg/l)	Temperature (°C)	Salinity (o/oo)
15 _ _ _	18 _ _ _	21 _ . _ _ _	25 _ _ . _	29 _ _ . _

Figure 5. Cont.'d

BLM-STOCS-016-2-1
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For computer center use

^{14}C PHYTOPLANKTON
DATA REPORTING FORM

DATE ________________

CRUISE ________________

0 1 6 2 0 0 1
1

Trans ________ Sta ________

Sample	^{14}C	Chla	c/chl	
_ _ _ _ (11)	_ _ . _ _ _ (15)	_ . _ _ _ (20)	_ _ . _ _ _ (24)	Total _ _ (29)
_ _ _ _	_ _ . _ _ _	_ . _ _ _	_ _ . _ _ _	Nano _ _ _
_ _ _ _	_ _ . _ _ _	_ . _ _ _	_ _ . _ _ _	Net _ _ _

Trans ________ Sta ________

Sample	^{14}C	Chla	c/chl	
_ _ _ _ (11)	_ _ _ _ _ _ (15)	_ _ _ _ (20)	_ _ _ _ _ _ (24)	Total _ _ (29)
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Nano _ _ _
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Net _ _ _

Trans ________ Sta ________

Sample	^{14}C	Chla	c/chl	
_ _ _ _ (11)	_ _ _ _ _ _ (15)	_ _ _ _ (20)	_ _ _ _ _ _ (24)	Total _ _ (29)
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Nano _ _ _
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Net _ _ _

Trans ________ Sta ________

Sample	^{14}C	Chla	c/chl	
_ _ _ _ (11)	_ _ _ _ _ _ (15)	_ _ _ _ (20)	_ _ _ _ _ _ (24)	Total _ _ (29)
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Nano _ _ _
_ _ _ _	_ _ _ _ _ _	_ _ _ _	_ _ _ _ _ _	Net _ _ _

Figure 5. Cont.'d

BLM-STOCS-27-2-1

1/77

LIGHT PENETRATION

DATA REPORTING FORM

For Computer Center Use

DATE ______________

CRUISE ______________

0 2 7 2 0 0 1

1

Tr-St ______ ______ ______ ______ ______ ______

Sample ____ ____ ____ ____ ____ ____

Depth 11

15 17

Depth						
1	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
2	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
3	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
4	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
5	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
6	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
7	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
8	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
9	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
10	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
11	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
12	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
13	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
14	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
15	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
16	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
17	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
18	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
19	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
20	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
21	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
22	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
23	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
24	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
25	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
26	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
27	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
28	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
29	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
30	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
31	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
32	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
33	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
34	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
35	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
36	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
37	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
38	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
39	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
40	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
41	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
42	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
43	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
44	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
45	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _
Secchi	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _	_ _ . _ _

Figure 5. Cont.'d

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For Computer Center Use

HISTOPATHOLOGY

DATA REPORTING FORM

0 3 0 2 0 0 1 Sample Code _ _ _ _ Cruise __________ Date __________

1 11

Species Code _ _ _ Neff Code _ _ _ _ _ _ _ _ _ _ Haensly Code _ _ _ _ _ _ _ _ _ _

15 18 28

Ramirez Code _ _ _ _ _ _ _ _ _ _ Organ Code _ _ _ _ Sex _

38 48 52

0 3 0 2 0 0 2 Sample Code _ _ _ _

1 11

Level	Location Code	Condition Code	Description
_	_ _ _ _	_ _ _ _	__________
15	16	20	24
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________
_	_ _ _ _	_ _ _ _	__________

Figure 5. Cont.'d

TABLE 8

NAMING CONVENTION FOR FILES AND PROGRAMS

Typical Name: F15201A

First Letter:
- F - File
- P - Program
- M - Macro
- C - Command Stream
- B - Binary
- T - Temporary

Second and Third Numbers: Project Identification

- 01 - Salinity and Temperature
- 02 - Transmissivity
- 03 - Suspended Sediments
- 04 - DO, Nutrients, and LMW Hydrocarbons
- 05 - HMW Hydrocarbons-benthic vertebrates
- 06 - Invertebrate epifauna and infauna
- 07 - Benthic Fish
- 08 - HMW Hydrocarbons - sed, par, dis, zpl
- 09 - Chlorophyll
- 10 - ATP
- 11 - Phytoplankton
- 12 - Flourescence
- 13 - Meiofauna
- 14 - Neuston
- 15 - Trace Metals
- 16 - C_{14}
- 17 - Currents
- 18 - Water Bacteria
- 19 - Sediment Texture
- 20 - Sediment Texture (TAMU)
- 21 - Benthic Bacteria
- 22 - Mycology
- 23 -
- 24 - Zooplankton
- 25 - Nannoplankton
- 26 - TOC and C13
- 27 - Light Absorption
- 28 -
- 29 -
- 30 - Histopathology
- 41 - Bacteriology and mycology
- 42 -
- 54 - Whitehead (Program Development)
- 55 - Data Management

- 60 - NODC - EDS

TABLE 8 CONT.'D

Fourth Number: File or Program Type

0 -
1 - Species Lists
2 - Data Reporting or Data Base Updating
3 - Data Correction Form
4 -
5 -
6 - Reports (Files or Programs)
7 - Data Files
8 - Data Base Definitions
9 - Loader Strings or String Generators or Form-Creator Programs

For 55 Only:

0 - Station Info (Level 0)
1 - Cruise Info (Level 1)
2 - Inventory Info (Level 2)

Fifth and Sixth Positions:

Format or Program Number Within Type

Seventh Position:

Alpha Serial Identifier for Files of Same Name
Alpha Serial Identifier for Versions of Same Program

or T - Temporary
P - Partial Copy for Testing (Subset of File)

TABLE 9

KEY TO CODES

TYPE-USAGE	Disposition and P.I.
LGT - PZ (Photometry)	
INF - MST (Infauna Master)	TAMU - Texas A&M University
INF - TAX (Infauna Taxonomy)	LHP-Linda H. Pequegnat
INF - SED (Infauna Sediment)	CSG-C.S. Giam
	TSP-Taisoo Park
MMS - MST (Meiofauna grab)	BJP-B.J. Presley
MMS - MEI (FA, PA, PB, PC, PD, A)	WMS-William S. Sackett
NEU - TAX (Neuston taxonomy)	WEP-Willis E. Pequegnat
EPI - MST (Epifauna Master)	RR-Richard Rezak
EPI - FSH (Epifauna fish)	WH-William Haensly
EPI - INV (Epifauna invertebrate)	JN-Jerry Neff
CHG - MST (Chemistry grab)	
CHG - TEX (Sediment texture)	UTMSI-Port Aransas Marine Lab
CHG - HC (Sediment hydrocarbons)	PLP-Patrick L. Parker
CHG - TM (Sediment trace metals)	NPS-Ned P. Smith
CHT - MST (Epifauna chemistry trawl)	CVB-Chase Van Baalen
CHT - TM (Epifauna trace metals)	JSH-J. Selmon Holland
CHT - HC (Epifauna hydrocarbons)	DEW-Donald E. Wohlschlag
TDC - ST (Temperature-Depth-conductivity)	DLK-Dan L. Kamykowski
STD - ST (Salinity-Time-Depth)	WMP-Warren M. Pulich
SDG - DEP (Sediment deposition)	UTMSI/Geophysical Lab
WAT - LH (Low-molecular-weight hydrocarbons)	EWB-E. W. Behrens
WAT - MPL (Microzooplankton)	UTSA-Univ. of Texas at San Antonio
VT - MPL (Microzooplankton vertical tow)	SAR-Samual A. Ramirez
WAT - DO (Dissolved Oxygen)	
WAT - NUT (Nutrients)	
WAT - PHY (Phytoplankton)	
WAT - CLP (Chlorophyll-phytoplankton)	
WAT - CLN (Chlorophyll-nannoplankton)	
WAT - ATP (Adenosine tri-phosphate)	U.S.G.S.-Corpus Christi
WAT - HC (Water hydrocarbons)	HB-Henry Berryhill
ZPL - TAX (Zooplankton)	
ZPL - HC (Zooplankton hydrocarbons)	
ZPL - TM (Zooplankton trace metals)	
LMW - HC (Low-Molecular-Weight Hydrocarbons)	
TRM - TUR (Transmissometry-Turbidity)	
WAT - SSM (Water-Suspended Sediment)	

EPI - HPT (Histopathology)

FA - Frozen; living		A - Archive
PA - Preservative	A	Rep - Replicate
B	B	QC - Quality Control
C	C	DP - Depth in meters
D	D	

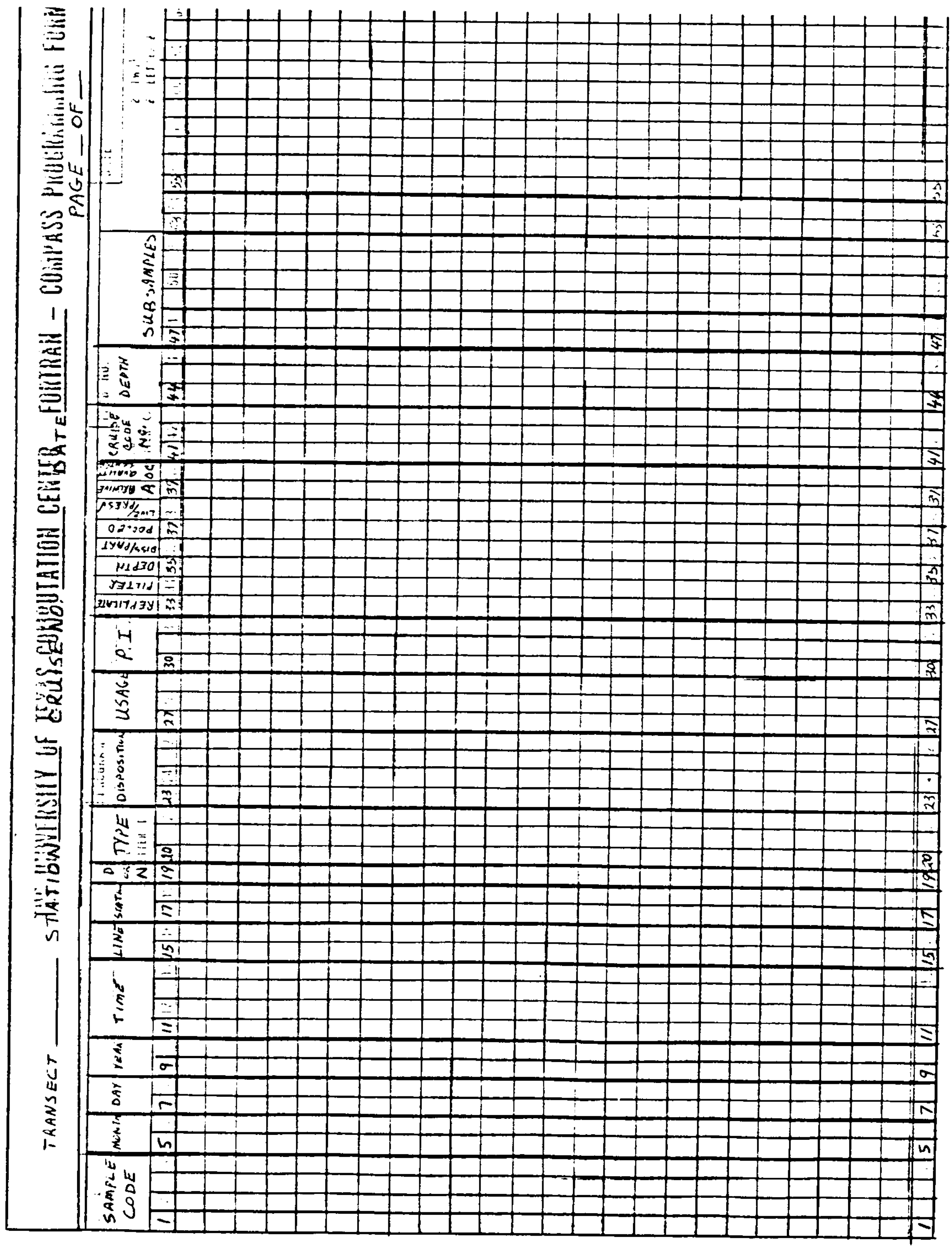

Figure 6. Sample Inventory Coding Form.

BENTHIC CRUISE PAGE 1 OF 3

TRANSECT ______ STATION ______ CRUISE NO. ______ DATE ______

SAMPLE CODE	MAN.I	DAY	YEAR	TIME	LINE	STATION	D/N	TYPE	DISPOSITION	USAGE	P.I.	RETRIEVAL	FILTER	DEPTH	DIGITAL	POS'D	CUT/FIRST	ANIMAL	A OC	CRUISE CODE NO.	DEPTH	SUBSAMPLES
1	5	7	9	11	15	17	19	20	23	27	30	33		35		37		39		41	44	47
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	INF	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	INF	UT	TAX	JSH	0	0	0	0	0	0	0	0		000	55B
B							D	INF	UT	SED	EWB	0	0	0	0	0	0	0	0		000	55B
B							D	MMS	MST	MST	MST	0	0	0	0	0	0	0	0		000	
B							D	MMS	TAMU	MEI	WEP	0	0	0	0	0	1	0	0		000	55B
B							D	MMS	TAMU	MEI	WEP	0	0	0	0	0	3	0	0		000	55B
B							D	MMS	TAMU	MEI	WEP	0	0	0	0	0	2	0	0		000	55B
B							D	MMS	TAMU	MEI	WEP	0	0	0	0	0	2	0	0		000	55B
B							D	MMS	TAMU	MEI	WEP	0	0	0	0	0	2	0	0		000	55B

Figure 6. Cont.'d

any omissions of information. The final inventory record, when complete, will contain the information listed in Table 10. The inventory change form (Figure 7) coordinates the hundreds of changes of information required to update the inventory file.

The bulk of this work was accomplished with typewriter terminals while waiting for the delivery of the remote job entry terminal. All new inventory information, of course, was coded and punched in the new format.

Several approaches were taken to the data filing problem. All inventory records, except for histopathology, have been placed into one System 2000 data base. Some of the results have also been included in this same data base. In addition, separate data bases were established for some of the other data files. A central file is being created to facilitate some of the statistical analyses. The remaining data reside as separate files-all accessed on disk with tape backup. The original cards are retained but not edited, so do not reflect the most recent versions. The tape backups are recreated every three days. We are currently maintaining files within 65 permanent file sets-each with tape backup-and 25 additional tapes.

At every step of the reading, reformatting, editing, storing, retrieving, analyzing, and reporting of data, computer programs are involved. We have written over 100 of these for our own use, and many more in response to special requests. The data service request (Figure 8) enables the efficient scheduling of such requests. The programs and resulting files are documented (Figures 9 and 10) to facilitate intra-group communication, to assure that new users are able to use the system, and to help us return to a safe system for requests or program modifications easily. Table 11 lists some representative programs, while others

TABLE 10

EXAMPLE OF THE TYPE OF INFORMATION CONTAINED ON THE FINAL INVENTORY RECORD

```
1*STATE(INT 99):
2*TRANS(INT 99):
2.1*STA-CODE(INT 9999):
7*WATER-DEPTH(INT 9(5)):
38*PERIOD(NAME X(10)):
39*CRUISE-CODE(INT 9(5)):
40*SAMPLE-CODE(NAME XXXX):
41*DATE-TAKEN(DATE):
42*TIME(INT 9999):
43*DN(NAME X):
44*TYPE(NAME XXXX):
45*USE(NAME XXX):
46*PI(NAME XXX):
47*DISP(NAME XXXX):
48*REPLICATE(INT 99):
49*FILTERED CODE(INT 9):
50*RELATIVE DEPTH CODE(INT 9):
51*DISSOLVED-PARTICULATE CODE(INT 9):
52*POOLED SAMPLE CODE(INT 9):
53*SAMPLE CONDITION CODE(NON-KEY INT 9):
54*ARCHIVE CODE(INT 9):
55*PARENT1 CODE(NAME X(5) WITH MANY FUTURE ADDITIONS):
59*DEPTH(INT 9999):
60*STATUS(INT 9):
61*INSTRUMENT CODE(INT 999):
62*ANALYSIS CODE(INT 999):
63*SPECIES CODE(INT 9(10) WITH SOME FUTURE ADDITIONS):
64*QUALITY CONTROL CODE(INT 9):
65*PZDEPTH(INT 9999):
66*ORGAN(NAME X(10)):
70*LATITUDE(NON-KEY DEC 99.99999):
71*LONGITUDE(NON-KEY DEC 999.99999):
72*ENDING LATITUDE(NON-KEY DEC 99.99999):
73*ENDING LONGITUDE(NON-KEY DEC 999.99999):
COMMAND FILE IS TTY:
```

BLM-OCS-55-2-1

INVENTORY CHANGE FORM

	Change	Changed
Sample code is ________, should be ________	______	________
Trans is _____, should be ________	______	[________]
Station is _________, should be ________	______	[________]
Cruise is ________, should be ________	______	[________]
Type is __________, should be _________	______	________
Use is ______, should be __________	______	________
PI is _________, should be _________	______	________
Depth code is ________, should be ________	______	________
Subsamp. is _________, should be _________	______	________
is _________, should be _________	______	________
is _________, should be _________	______	________
is _________, should be _________	______	________
is _________, should be _________	______	________
is _________, should be _________	______	________

Changed:

On inventory master printout	/ /	________
On computer center data form copy	/ /	________
On permanent file data file ______,PF______	/ /	________
On S2K data base version ______ on tape ______		
saved to tape ___________	/ /	_______

Approved for change __________

Send to: _________ Debbie Kalke ________
_________ C. Griffin ________
_________ PI(   ) ________
_________ ________

Figure 7. Inventory Change Form.

BLM-STOCS-556-2

DATA MANAGEMENT SERVICE REPORT

Date submitted: ____________

Submitted by: ____________

Date Needed: ____________

Type: _____ Data file

_____ Data report

_____ Programming

_____ Consulting

_____ Corrections

For Computer Center Use

Proj. No. ____________

Assigned to ____________

Date: ____________

Completed: ____________

Notes: ____________

Describe: ____________

Figure 8. Data Management Service Request Form.

Date ______________

Program Name ______________________________ Object name __________

Common Name ______________________________

Programmer ______________________________

Source PF ______________________________ Object PF __________

Purpose ____

Special compilation or run requirements ______________________

Execution format ______________________________________

Files:
(Input/output, file name or type, PF where found, use in program, number in program, any special required editing or sorting before use.)

Figure 9. Program Documentation Form-STOCS Study.

File Name: ______________________ Permanent File: ____________

Use: ____

Field Name	Start Byte	Field Type	Field Content/Description

Figure 10. File Documentation Form-STOCS Study.

TABLE 11

REPRESENTATIVE LIST OF PROGRAMS USED IN THE STOCS STUDY

TESORT	- Sorts inventory records
CLUSTER	- Prepares data for cluster analysis
MATRIX	- Builds abundance-weight matrix for each species and calls IMSL subroutines for rank analysis
P01201A	- Updates data base with STD data
P06601A	- Produces data verification report from punched invertebrate data
P08603A	- Produces hydrocarbon OEP report and files
P08703A	- Calculates hydrocarbon concentrations
P09401A	- Calculates chlorophyll concentrations
P30201A	- Updates data base with histopathology results
P55221A	- Produces inventory reports
R07604A	- Reports sums of weight and abundance for fish species
P55501A	- Reports numerical abundance of HMWH gas chromatograph peaks with respect to retention time
P55502A	- Math and statistical calculations of sediment texture raw data and table report
P55503A	- Plots replicate locations at line stations from LORAC fixes on each grab
P55504A	- Calculates linear regression and correlation and plots scatter-grams of data with best fit line
P55505A	- Performs bivariate statistical analysis by Wilcoxon rank-sum demersal fishes

are grouped and discussed in more detail below.

1. Short utility programs. Many standard statistical calculation programs such as chi-square, 1-way analysis of variance, scatter plots and linear regression and correlation have been written for data analysis.

2. Short non-standard routines. Several mathematical and statistical analysis routines have been written which are not user-specific. In general, there are many calculations not available in supporting software packages. In particular, diversity and equitability calculations have been written as function sub-programs and subroutines and imbedded in table-generating programs and used to generate epifauna, infauna, demersal fish and phytoplankton data tables.

3. Large data treatment programs. Several users require multi-stage programs that include mathematical and statistical analyses of "raw" data. These programs are highly user-specific and generally expensive to develop, both in programmer time and computer time. Included in this category are:

(a) Sediment texture analysis; and,

(b) Distribution of HMW-Hydrocarbons gas-chromatograph peaks.

4. Studies: Several investigators have chosen to work with data management in developing programs that go beyond routine reporting of the benchmark data collected. Some of the programs listed below are logical first steps in building predictive models; some are directed towards evaluating the current data acquisition structure in an effort to propose an improved sampling methodology.

(a) Day-night statistics (using Wilcoxon Rank-Sum Analysis). Day-night statistics were worked out and debugged for the demersal fishes data. These could be run on day-night infauna or any other bimodal variable (*e.g.*, Surf to 1/2 photic zone on phytoplankton species data).

(b) Multivariable non-linear regression studies.

(1) multivariate linear regression (expect failure) studies were performed on fish community structure variables (failed due to non-linearities);

(2) scattergrams against all possible independent variables were performed on abundant fish species and a few epifauna species;

(3) empirically choosing nonlinear functions for most likely variables;

(4) least square fitting of these in a multivariate scheme;

(5) propose modified sampling to test predictive abilities.

(c) Spatial variability and structure clumping analysis.

A study of the spatial structure of infauna communities was started by searching for clumping patterns at the species level. Typical separation on the order of meters between the six infaunal replicate grabs and the precision of the LORAC location of these grabs makes such a study feasible. A program was written and tested which plots the replicate grabs at each station. Currently, the program is being modified to plot species abundances to facilitate formulation of hypotheses for testing. This program, when developed, should be directly applicable to a study of small-scale sediment texture variability.

(d) A four-way analysis of variance was written specifically for the four independent variables (station, transect, season, day-night). This program has only been used on the demersal fish dependent variables (total number of individuals, total weight, total number of species, species diversity, etc.) for 1975 and 1976 data. This program should be used at a very early stage in any study of processes at the species level, infauna, epifauna, phytoplankton, as well as fish species.

(e) Cluster analysis programs are being developed.

With the basic organization nearing completion and analysis routines under development, the data management effort is in a position to serve Program Management, the PI's, and BLM with useful reports and valuable data anlysis towards an understanding of what conditions occur in the STOCS study area.

Problems and Recommendations

The usual weather and mechanical problems associated with offshore sampling were encountered and reported to BLM in cruise reports submitted following each cruise. All field sampling was, however, completed in less time than originally estimated. Specific field sampling problems, as well as laboratory analytical and taxonomic problems, are discussed in detail in each of the reports by the Principal Investigators.

General recommendations for improvement and expansion of the STOCS baseline survey, based on 1975 and 1976 efforts, were included in the Contractor's proposal for third year (1977) funding submitted to the BLM in November, 1976. Several of the reports by the Principal Investigators also include specific recommendations for improvement of such studies.

Publications/Works in Progress

A number of publications and presentations have resulted from the 1975-1977 STOCS studies. These, along with works in progress, are presented in Table 12. It is anticipated that the number and rate of publications will increase as additional data are available and analyzed.

TABLE 12

PAPERS AND PRESENTATIONS

HYDROGRAPHY

Smith, N. P. 1977. Nearshore cross-shelf motion in the northwestern Gulf of Mexico. Presented to the Am. Geophys. Un. June 1977. Washington, D. C.

________. In Preparation. Cross-shelf variability in nearshore circulation. (Based on rig monitoring current and wind data)

________. In Preparation. Vertical coherence in wind-driven shelf motions. (Based on spring circulation study)

________. In Preparation. Longshore coherence in nearshore motion. (Based on early summer circulation study)

________. In Preparation. Cross-shelf variability in shelf circulation. (Based on late summer circulation study)

________. 1977. Longshore coherence in nearshore motion. To be presented at the Am. Geophys. Un. Fall, 1977.

PHYTOPLANKTON AND PRODUCTIVITY

Morgan, J. C. 1975. Studies on the diatoms of the northwestern Gulf of Mexico: identification, distribution and cultural studies. M. A. thesis. Univ. Of Texas, Austin, Texas. 67 pp.

MICROZOOPLANKTON

Anepohl, J. K. 1976a. Seasonal occurrence of living benthonic Foraminifera, South Texas Outer Continental Shelf. Abstr. Prog. Geol. Soc. Am. 8:2-3. (Abstr.)

________. 1976b. Seasonal distribution of living benthonic Foraminifera of the South Texas Outer Continental Shelf. M. A. thesis. Univ. of Texas, Austin, Texas. 130 pp.

Bauer, M. A. 1976. Ecology and distribution of living planktonic Foraminifera of the South Texas Outer Continental Shelf. M. A. thesis. Rice Univ., Houston, Texas. 125 pp.

Casey, R. E. In preparation. Cenozoic radiolarians: Paleogeography and evolution. To be presented at the N. Am. Paleontol. Conv., II. August 1977. Univ. of Kansas.

________., and M. A. Bauer. 1976. A seasonal study of Radiolaria and Foraminifera in the waters overlying the South Texas Outer Continental Shelf. Abstr. Prog. Geol. Soc. Am. 8:11. (Abstr.)

TABLE 12 CONT.'D

________., and K. J. McMillen. In Press. Cenozoic radiolarians of the Atlantic basin margins. *In* F. Swain, (ed.) Stratographic micropaleontology of the Atlantic Basin and borderlands.

____________., and M. A. Bauer. 1975. Evidence for and paleo-oceanographic significance of relict radiolarian populations in the Gulf of Mexico and Caribbean. Abstr. Prog. Geol. Soc. Am. 7:1022-1023 (Abstr.)

NEUSTON

Pequegnat, L. H. In Preparation. Pelagic tar concentrations in the Gulf of Mexico over the South Texas Outer Continental Shelf. To be submitted to Contr. in Mar. Sci.

Wormuth, J. H., and S. P. Berkowitz. 1977. Annual changes in the neuston of the South Texas Outer Continental Shelf and their relationship to other physical and biological variables. Presented at the annual ASLO meetings. 20-23 June 1977. East Lansing, Michigan.

INVERTEBRATE EPIFAUNA AND MACROINFAUNA

Holland, J. S., and S. A. Holt. In preparation, Estimating accuracy and efficiency of marine benthic sampling.

McKinney, L., R. D. Kalke, and J. S. Holland. In press. New species of amphipods from the western Gulf of Mexico. Cont. Mar. Sci. Vol. 21.

DEMERSAL FISHES

Cole, J. F. 1977. Numerical analysis of trawled benthic fishes from the South Texas Outer Continental Shelf. M. A. Thesis. Univ. of Texas, Austin, Texas.

Vetter, E. F. In Preparation. Diel variations in otter trawl vulnerability of fishes from the South Texas Outer Continental Shelf. M. A. Thesis. Univ. of Texas, Austin, Texas.

Wohlschlag, D. E. 1976a. Distribution and abundance of STOCS benthic fishes. Presented at the annual ASLO meeting. 21-24 June 1976. Savannah, Georgia.

________. 1976b. Benthic fish distribution and abundance patterns over the South Texas Outer Continental Shelf. Presented at the GERS meeting. 30 October 1976. Lafayette, Louisiana.

________. 1977. Seasonal and annual contrasts in distribution and abundance indices for South Texas continental shelf fishes. To be presented at the annual AIBS meetings. August 1977. East Lansing, Michigan.

TABLE 12 CONT.'D

LOW MOLECULAR WEIGHT HYDROCARBONS, NUTRIENTS, DISSOLVED OXYGEN

Brooks, J. M., B. B. Bernard, and W. M. Sackett. 1976. Input of low-molecular-weight hydrocarbons from petroleum operations into the Gulf of Mexico. Presented at the Fates and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms meeting. 10-12 November 1976. Seattle, Washington.

HIGH MOLECULAR WEIGHT HYDROCARBONS IN SEDIMENTS, ZOOPLANKTON AND WATER

Fry, B., R. S. Scalan, and P. L. Parker. In preparation. Stable carbon isotope evidence for two sources of organic matter in coastal sediments, sea grasses and plankton.

Parker, P. L. 1976a. Petroleum hydrocarbons in Gulf of Mexico coastal waters: chemical characteristics and biological effects. Presented at the AIBS Symposium on Sources, Effects and Sinks of Hydrocarbons in the Aquatic Environment. 9-11 August 1976. Washington, D. C.

________. 1976b. Preliminary results of a chemical and biological survey of the south Texas shelf. Abstr. Prog. Geol. Soc. Am. 8:57. (Abstr.)

Scalan, R. S. 1976. Hydrocarbons in zooplankton from the STOCS. Presented to the Southern Regional Geochemists. 14 May 1976. Tulsa, Oklahoma.

Winters, J. K., and P. L. Parker. 1977. Water soluble components of crude oils, fuel oils and used crankcase oils. Presented at the Oil Spill Conference. 8-10 March 1977. New Orleans, Louisiana.

HIGH MOLECULAR WEIGHT HYDROCARBONS IN EPIFAUNA AND MACRONEKTON

Giam, C. S., H. S. Chan, and G. S. Neff. 1976. Aliphatic heavy hydrocarbon composition in the benthic macroepifauna of the South Texas Outer Continental Shelf. Presented at the 32nd annual ACS Southwestern meeting. 1-3 December 1976. Fort Worth, Texas.

____________. In press. Distribution of n-paraffins in selected marine benthic organisms. Bull. Env. Contam. Toxicol.

TRACE METAL CONCENTRATIONS IN EPIFAUNA, ZOOPLANKTON AND MACRONEKTON

Horowitz, A., and B. J. Presley. In press. Trace metal concentrations and partitioning in zooplankton, neuston and benthos from the STOCS. Arch. Env. Contam. Toxicol.

Sims, R. R., and B. J. Presley. 1976. Heavy metal concentrations in organisms from an actively dredged Texas bay. Bull Env. Contam. Toxicol. 16(5):520-527.

LITERATURE CITED

Berryhill, H. L., Jr., *et al.* 1976. Environmental studies of the South Texas Outer Continental Shelf, 1975; Geology: Part I, Geologic description and interpretation, 270pp, 115 figs.; Part II, Basic analytical data. A report to the U.S. Bureau of Land Management. U.S. Geological Survey.

Galtsoff, P. S. 1954. Gulf of Mexico, Its' origin, waters and marine life. Fishery Bull. 55. U.S. Fish and Wildl. Ser.

Gunter, G. 1945. Marine fishes of Texas. Publ. Inst. Mar. Sci. 1:1-190.

Hedgepeth, J. W. 1953. An introduction to the zoogeography of the northwestern Gulf of Mexico with reference to the invertebrate fauna. Publ. Inst. Mar. Sci. 2:7-124.

CHAPTER TWO

SUMMARY OF SIGNIFICANT FINDINGS

Reports by the Principal Investigators responsible for the various work elements of the 1976 study are included herein in Chapters 3 through 18. The significant findings reported by each Principal Investigator are summarized below:

Hydrography (Dr. Smith, UTMSI/PAML)

Temperature-Salinity (T-S) diagrams indicate that distinctly different hydrographic climates occur both horizontally across the South Texas OCS and vertically at any given location. Time-depth plots of temperature and salinity show the creation and destruction of thermohaline stratification. T-S gradients change from a predominantly vertical orientation in the spring and summer months to a predominantly horizontal orientation in the late fall and winter. Time series of T-S pairs indicate clearly different time scales, and presumably driving forces, characteristic of inshore and offshore waters. Advective and possible internal wave motions occurring at mid- and near-bottom levels over the outer shelf will require self-recording instrumentation to investigate the characteristics of natural variability.

Phytoplankton and Productivity (Drs. Kamykowski, Pulich and Van Baalen, UTMSI/PAML)

The 1976 phytoplankton and productivity studies consisted of: 1) water column light measurements; 2) phytoplankton species counts; 3) chlorophyll a determinations; and, 4) ATP determinations.

An offshore decrease in concentration was observed in all biomass parameters. This pattern was especially true of the net chlorophyll a fraction. Secchi depth generally increased offshore. An along-shelf gradient apparently occurred, characterized by higher biomass at Stations 1/I, 2/I and 1/II. ATP exhibited highest concentrations at Stations 1/I and 1/III. Depth profiles of chlorophyll a often showed sub-surface maxima. Monthly changes at Stations 1/II and 2/II followed a bimodal cycle with a major peak in April and a minor rise between September and December. Station 3/II showed a very broad rise between June and December.

The phytoplankton species were grossly divided into two groups at Stations 1/II and 2/II, December-April and May-November. Station 3/II exhibited less seasonality in species composition. Low diversity (<2.00) occurred on five occasions during 1976 and was associated with blooms of *Skeletonema costatum*, *Nitzschia delicatissima* or *Leptocylindrus danicus*.

The interrelationships among Secchi depth, phytoplankton abundances and chlorophyll a were good. ATP concentration was related to chlorophyll a concentration during the spring, but not during the summer and fall. The relationships between salinity and biomass suggested that freshwater runoff was a significant nutrient source in the study area.

Shelled Microzooplankton, General Microplankton and Shelled Microzoobenthos (Dr. Casey, Rice University)

Shelled microzooplankton and general microplankton data were compared to the physical oceanography of the study area by use of density, diversity and other plots of biological data as compared to temperature and salinity diagrams, isohaline and isothermal contouring, and other plots of physical oceanographic data. These comparisons revealed: ponds of shallow offshore water moving onto the shelf during the winter and into spring; strong upwelling or upbowing of water onto the shelf in the spring and early summer with a penetration to inshore stations in August, and a detachment of shelf water and their movement Gulfward overriding upwelled (open ocean estuarine upwelling) water which extended as far inshore as Station 1; and, an incursion of a proposed anticyclonic gyre that had detached from the Loop Current onto the shelf during late summer and early fall. Using cluster analyses, certain of the shelled microzooplankton were designated as biological indicators of shelf water, estuarine outflow water, open Gulf shallow water, open Gulf deep water, upwelling, shelf circulation, the intrusion of Sub-tropical Underwater; and of "eutrophism and oligotrophism".

Studies of living benthonic foraminiferans revealed an average standing crop of 27.64 individuals/10 m^2; species indicative of nearshore, nearshore to mid-shelf, mid-shelf, mid-shelf to outer-shelf and outer-shelf; species indicative of regions of "eutrophism and oligotrophism: geographically, and to some extent, seasonally.

Down-core studies illustrated that some cores penetrated sediments older than 100,000 years, with two cores penetrating through sediments of the last glacial. Rates of sedimentation ranged from a low of 0.6 cm/1000 years to a maximum of at least 15 cm/1000 years.

Zooplankton (Dr. Park, TAMU)

Zooplankton abundance in terms of biomass and number displayed considerable spatial, as well as temporal variation. These variations were progressively extensive from deep to shallow stations. The zooplankton generally showed a seaward decrease which was highly pronounced in spring and summer months when abundance usually increased to an annual maximum at Stations 1 and 2 and decreased to the lowest annual value at Station 3. Copepods were the most abundant group, comprising approximately 60 percent of the zooplankton by number. When the zooplankton increased in spring and summer, the relative abundance of copepods decreased, indicating that other organisms were increasing faster.

Other numerically important groups were Cladocera, Ostracoda, barnacle larvae, Mollusca, Chaetognatha and tunicates. The Cladocera and Ostracoda showed a highly restricted spatial distribution, occurring mainly at Stations 1 and 2, respectively. The occurrence of barnacle larvae was highly sporadic. Consisting mainly of veliger larvae, molluscs were most abundant at shallow stations in spring and summer. Chaetognaths and tunicates occurred regularly throughout the study area the year round.

In contrast with total zooplankton, copepods did not show extensive seasonal variation. Approximately 75 percent of the copepods belonged to the Calanoida, the remainder belonging mostly to the Cyclopoida. The relative abundance of calanoids increased in winter while that of cyclopoids increased in summer. Throughout the year, the development stages comprised nearly 50 percent of the total copepod population, indicating a sustained copepod reproduction the year round. A total of 168 species of adult female copepods was identified. The most abundant calanoid species were *Paracalanus indicus, Paracalanus quasimodo* and *Clausocalanus furcatus*. The first two species were abundant at shallow stations while the latter was abundant at deep stations. The most abundant cyclopoid copepods were *Oncaea venusta, Oncaea mediterranea* and *Farranula gracilis*; the first was abundant throughout the area but the last two were abundant at offshore stations.

Species diversity indices and coefficients of equitability, based on adult female copepods, generally increased seaward in conformity to the number of species.

Of the other biological and physical data, salinity and chlorophyll a values seemed to be most closely correlated with the zooplankton. This was most readily discernible in spring when the zooplankton was highly productive in low-salinity water.

Neuston (Drs. L. Pequegnat and Wormuth, TAMU)

Differences in numerical abundances of taxonomic groups were determined in relation to seasonal, diurnal, distance-from-shore, and geographic considerations and are discussed for such major taxonomic groups as Foraminifera, Cnidaria, Ctenophora, Nematoda, Polychaeta, Mollusca, Crustacea, Echinodermata, Chaetognatha, Tunicata, Insecta and ichthyoplankton.

Species groups which occurred frequently and showed relationships to each other were determined by recurrent group analysis. The targeted species were analyzed further by a two-way analysis of variance to determine station and transect differences.

Biomass calculations (dry and ash-free dry weights) for the June through December samples showed considerable seasonal, geographic, and diurnal variations as did species diversity and dry weight of floating tar. Species diversities were greater at night, at offshore stations and at Transect II. Dry weights of tar showed overall average values consistent with those reported previously from the Gulf of Mexico.

Detailed species analyses were provided for decapods, decapod larvae (85 taxa) and fish eggs and larvae (110 taxa). Decapod larvae were consistently more abundant and diverse in night samples with the most abundant taxa being the sergestid shrimp, *Lucifer faxoni*, portunid crab megalops larvae, *Callinectes* zoea larvae, *Portunus* zoea larvae, sergestid shrimp postlarvae, and pinnotherid crab larvae. Fish eggs were most abundant in March, while fish larvae, most abundant in June, were represented most commonly by the families Clupeidae, Sciaenidae, Mugilidae, Exocoetidae, Mullidae, Engraulidae and Gobiidae.

Meiofauna (Dr. W. Pequegnat, TAMU)

In general, meiofauna populations tended to decrease with increasing depth between 10 and 134 m; however, this trend was not uniform. The true meiofauna (metazoan animals) exhibited strong seasonal population increases in March, November and especially July. Nematodes were the predominant component of the true meiofauna, not only in terms of populations but also taxal diversity. Ninety (90) taxa at and above the genus level were identified.

Both physical and biological controls, some of which are still speculative, were demonstrated. Nematodes were highly correlated with sediment granulometry, increasing substantially in number when the sand component attained or exceeded 60 percent. Harpacticoid copepods tended not to respond to this factor, but responded to some as yet unknown characteristic of sediments around the bases of the banks. It was assumed that the unknown factor was available organic carbon. These observations reinforce the proposition that the harpacticoid/nematode ratio can be developed into a valuable yardstick of environmental degradation and recovery.

Strong indications of competitive elimination of many nematode taxa throughout the year were noted. There was evidence that predation was a potent control of nematode populations, but the kinds of predators are as yet unknown although some are likely nematodes.

Invertebrate Epifauna and Macroinfauna (Dr. Holland, UTMSI/PAML)

Based on cluster analyses, macroinfauna collections were divided into three station groups, shallow, mid-depth and deep. (Stations 3/IV and 6/IV were separated as a sub-group of the deep-station group.)

Three habitat types were identified based on location and sediment: shallow muddy-sands and mid-depth transitional sediments; deep silty-clays; and, deep muddy sands. Infaunal densities were highest in shallow and deep muddy-sand sediments.

Cluster analyses of invertebrate epifauna grouped stations by depth with a major separation between inner-shelf stations (10-49 m) and outer-shelf stations (65-134 m). Number of species was generally greater in the outer-shelf area, but number of individuals was much greater in the inner-shelf.

An assessment of small-scale distribution patterns revealed that macroinfauna populations were more aggregated inshore than at deeper, offshore stations. Inshore communities were distributed on a smaller scale, *i.e.*, the same sampling effort obtained a greater percentage of the inshore species than of the offshore species.

Demersal Fishes (Dr. Wohlschlag, UTMSI/PAML)

For each trawl sample, numbers of individual species, weights, numbers of individuals per species, and individual weights and lengths provided the basic data, all of which except lengths and weights provided primary data for this study. Calculations of Shannon diversity indices (both numerical and ponderal), the Hurlbert probability of interspecific encounter (PIE) and the Lloyd and Ghelardi equitability value (E) provided derived data for various comparisons among the 1976 collections and between 1976 and equivalent 1975 collections.

For equivalent times and stations, the 1976 numbers of species, individuals, and biomasses were less than in 1975. Whether the slight change in sampling nets caused the declines or whether there were actually fewer fish in 1976 could not be demonstrated with completely tenable explanations. In general, both numerical and ponderal diversity indices were lower in 1976. Isopleth plots for day-night and seasonal data indicated that there were pronounced day-night differences in most cases throughout the year. In the winter and spring, gradients for the various data tended to be depth-related with some indication of north-south transect differentiation by autumn. Analysis of variance revealed that few individual effects (depths, transects, day-night, seasons) were consistently and statistically significant, but interactions involving seasons and individual effects were more so.

A pooled yearly comparison of day-night catches by species indicated that day species were ordinarily those that had schooling propensities; predominantly nocturnal species tended to be solitary. Comparisons by the Wilcoxon rank sum showed statistically significant diurnal prominence for 10 species and nocturnal prominence for 36. Of the fishes not showing significant day-night prevalence in numbers or weights for pooled data, a breakdown of catches into seasons yielded statistically significant maxima in day-night differences in the spring and minima in the autumn. From published data, the day-night differences were related to activity and aggregational associations, to food habits, and to feeding tactics.

With species as attributes of the individual stations, the Bray-Curtis cluster technique with flexible sorting by normal analysis showed clearly that there were depth related groupings, three in winter and four in spring and autumn. With stations as attributes of the species, inverse analysis showed seven species-groups in winter, eight in spring and six in autumn. The two-way relationships of station-groups and species-groups showed species-environmental relationships clearly for most of the species, 67 of 96 in winter, 68 of 89 in spring and 62 of 82 in autumn.

Cluster analyses also indicated that zonation was depth-related, with temperature and seasonal migration patterns as major associative features of the groups through the seasons. There was little evidence that zonation was directly related to sediment type or salinity. The shallowest station groupings had high numbers of individuals, especially in winter and spring, and generally lower species diversities through the year. When temperatures were highest in late summer and autumn, nearshore species associations tended to dissipate; midwater and deepwater associations were somewhat more stable throughout the year; midshelf groups had the highest species diversity throughout. There was a weak indication of species associations breaking into north-south groupings in autumn only, which implied that north or south movements to or from areas outside STOCS was relatively unimportant for most species. However, within the STOCS area there was considerable species "shuffling" during the year to the extent that clearcut species-domination by one or a few species was not suggested.

Histopathology of Invertebrate Epifauna (Dr. Neff, TAMU)

In shrimp, the most common pathological condition of internal organs was due to nematodes. The most common symbionts in shrimp gills were ciliates. The most common gill pathology other than symbionts was deformed gills with excess cellularity and atrophy (etiology unknown). Shrimp had the lowest percentage of pathologies, other than symbionts, in internal organs.

In crabs, nematodes were the most common symbiont of internal organs. The most common symbionts in crab gills were unknown. The most common gill pathologies, other than symbionts, were small cyst aggregates. Crabs had the lowest percentage of symbionts in tissues and the highest percentage of pathologies other than symbionts in internal organs.

Molluscs had the highest percentage and largest variety of symbionts in their internal organs. Trematode larvae were the most common symbiont. Molluscan gills were free from symbionts except for some bacteria infecting a few squid gills. Mollusc gills had the lowest percentage of pathologies other than symbionts.

No pathological conditions were found in echinoderms.

Histopathology of Demersal Fishes (Dr. Haensly, TAMU)

Thirty-four percent (286) of organ samples from ten species of demersal fishes demonstrated lesions. The rock sea bass had the smallest percentage of lesions and the vermilion snapper the largest. The vermilion snapper also demonstrated the largest percentage of cardiac lesions. There was a tendency for kidney and muscle lesions to be more numerous in the sand seatrout. Kidney, muscle and liver lesions tended to more numerous in the last three cruises than in the first two. Stomach and liver were more frequently involved pathologically than the muscle, kidney and heart, but this was apparently unrelated to species, station or cruise. The percentage of lesions was larger in fish obtained from the Southern Bank than at other stations, and the smallest percentage occurred in fish from Station 2. These observations were due to the vermilion snapper being sampled at the Southern Bank and the rock sea bass at Station 2. All stations showed a tendency for the percentages of lesions to increase over the last three cruises (October, November and December).

Parasitism was the primary cause of lesions by both protozoan and helminth parasites. Parasitism caused varying degrees of necrosis, especially in the liver and stomach. The general integrity of the organ tissues was maintained adjacent to the lesions.

Histological-Histopathological Survey of Gonadal Tissue of Macroepifauna and Demersal Fishes (Dr. Ramirez, UTSA)

The purpose of this portion of the histopathological effort was two-fold: 1) to establish the normal seasonal (physiological) changes in the histology of the male and female gonads; and 2) to examine the gonads for pathological conditions. Tissues were collected during the period July through December 1976. Seventeen (17) species and 456 specimens were collected. Seasonal changes in the histology of the gonads were only partially established, since the survey was conducted for only six months. Gonadal tissues were examined for pathological conditions and/or parasites. A number of pathological conditions was found in the tissues, but the incidence of pathology in the gonads was only 16.7 percent.

Sediment Texture (Dr. Behrens, UTMSI/Geophysical Lab)

Variability of textures (grain size distribution) within sampling stations was greatest in the Rio Grande delta region and at Station 5/I, possibly related to the ancestral Colorado-Brazos delta to the north of the study area. Textural variability was least in the outer-shelf clays. Significant seasonal variability was scattered, but most consistent in the spring loss of fine clay from the outer-shelf regions.

Coulter Counter and pipette methods gave highly correlatable results so that both should show any significant relationships between textures and biological or chemical parameters. However, Coulter Counter techniques resulted in considerably coarser and better-sorted apparent textures due to the different computational procedures required with the data.

Selected Water Column Measurements: Low-Molecular-Weight Hydrocarbons, Nutrients and Dissolved Oxygen (Drs. Sackett and Brooks, TAMU)

Methane showed considerable variation in concentration in the STOCS area. Near-bottom seepage was detected in bottom waters at some stations (*e.g.*., Station 3/IV). At mid-depth there was a seasonal maximum that developed following stratification of the water column in summer and fall. Methane seemed to show a good correlation with transmissometry (suspended material) traces. Ethene and propene showed the same general trend as productivity; low surface values were observed in the winter with higher values in the spring, summer and fall. Ethene generally showed a maximum at some shallow depth (20 to 40 m) in the water column. The olefins generally dominated over their saturated analogs in the STOCS area. The lower Texas shelf is relatively "clean", as most of the light hydrocarbons of this shelf are presently derived from natural sources.

Throughout the year, oxygen levels in the upper 60 m of the water column were controlled mainly by physical processes (seasonal changes in temperature and salinity) rather than productivity. Surface and near-shore values were highest in winter and lowest in summer. The intrusion of 200-300 m Western Gulf Water was always observed below 70 m.

Nutrient concentrations were typically low, being representative of open Gulf surface water. Nitrate was limiting to productivity and disappeared during the summer and early fall. Phosphate and silicate were affected by the spring increase in productivity, but were generally regenerated by fall. Increased continental runoff during the spring months was reflected by high silicate values at nearshore stations.

High-Molecular-Weight Hydrocarbons in Zooplankton, Sediment and Water
(Drs. Parker, Scalan and Winters, UTMSI/PAML)

An extensive survey of the level of natural and petroleum type hydrocarbons in seawater, zooplankton and sediment was made. The presence or absence of indicator parameters including, n-paraffins, odd-even ratios, unresolved GLC humps, and GC/MS confirmation of aromatic hydrocarbons, were taken as a measure of petroleum contamination.

The zooplankton samples showed unambiguous and substantial petroleum contamination. Twenty-six of the 84 samples examined showed contamination. A similar observation was made during the 1975 STOCS study, and, in fact, there was a slight increase in the percent of samples contaminated. This contamination was probably due to micro-tar-balls in the zooplankton tows. Further study is recommended.

Dissolved and particulate hydrocarbons in seawater were determined in 73 and 70 samples, respectively. The data indicated that concentrations of dissolved and particulate hydrocarbons were similar in magnitude. Hydrocarbons in both fractions decreased in concentration with distance offshore. Seasonal trends in concentration were also indicated for both fractions but were difficult to interpret. The hydrocarbon composition of the two fractions was often similar with a slight odd carbon preference indicated among n-alkanes. Hydrocarbons in the C_{25} - C_{33} molecular weight range were generally the most abundant.

Analyses of 175 sediment samples from the open shelf revealed that sediment hydrocarbon chemistry is complex. The observed hydrocarbon patterns require multiple sources, including plankton, bacteria, infauna and perhaps higher plant detritus. Detection of traces of petroleum hydrocarbon in this matrix will require detailed studies of sediment as an active sink for organic matter.

Heavy Molecular Weight Hydrocarbons in Macroepifauna and Macronekton
(Drs. Giam and Chan, TAMU)

A total of 278 samples of macroepifauna and macronekton were analyzed. These analyses included samples of muscle, liver and gills. Selected samples were also analyzed by GC/MS techniques. Most muscle samples had very low hydrocarbon levels (generally less than 2 ppm), with C_{15} and C_{17} n-alkanes predominating. The hydrocarbons detected were mainly of biogenic origin, as indicated by the dominance of the C_{15} and C_{17} n-alkanes, pristane and by the absence of aromatic hydrocarbons (squalene was the only compound detected in the aromatic fraction). The absence of correlations in the pristane/phytane/C_{17}, phytane/C_{18} and CPI_{14-20} ratios also implied the absence of significant levels of petroleum in the study area.

Thus, the data obtained provide present baseline hydrocarbon concentrations and distributions against which future monitoring data can be compared.

Trace Metals in Epifauna, Zooplankton and Macronekton (Drs. Presley and Boothe, TAMU)

Concentrations of 10 metals (Al, Ca, Cd, Cu, Cr, Fe, Ni, Pb, V, Zn) were determined in 312 samples including: zooplankton (62); muscle tissue from fish (140), shrimp (19) and squid (14); fish gill (31) and liver tissue (29); and whole oysters (15).

No indication of substantial heavy metal pollution was observed. Levels of Cd, Cu and Pb appeared to be higher in the north. Sample groups in order of decreasing total trace metals content (except Al, Ca) were zooplankton, liver, oyster, gill, shrimp, squid and fish flesh.

No significant changes in annual mean trace metals concentrations were found for any sample group between 1975 and 1976. The number of metals in these comparisons was limited, however, because of the systematic overestimation in 1975 of Cd, Cr, Ni and Pb in many types of samples.

There was considerable variability in the trace metals data. Sample groups in order of decreasing variability were zooplankton, liver, fish flesh, gill, shrimp, squid and oyster. Variability within species was only moderately less than that in groups. With this level of variability, only differences of $\geq$ 100 percent could be resolved statistically.

Replication of samples for individual species was poor. Samples from 29 species were analyzed, but only 11 species had $\geq$ 9 samples for analysis. Statistically valid interspecific comparisons could only be made between the annual mean trace metals concentrations of these 11 species. Smaller scale geographical and seasonal comparisons could only be made within the larger groupings of similar species. Similar interspecific comparisons were infeasible. An improvement in the replication of samples by decreasing the number of species analyzed is essential for future work.

Incorporation of aluminosilicate detritus was significant only for zooplankton samples. This incorporation was lowest in the spring and decreased offshore in all seasons. Levels of Cu, Ni and Pb decreased in the south. Lead concentrations decreased offshore, and Cd levels were lower inshore.

Fish, shrimp and squid muscle tissue had generally low, uniform trace metals levels with few apparent geographical, seasonal or inter-specific differences.

Gill and liver tissue from vermilion snapper had generally higher concentrations of trace metals than similar tissues from red snapper. Cd levels were higher in livers than gills for both species. Cadmium levels were higher in samples from Hospital Rock than from Southern Bank.

Oysters had generally higher levels of all trace metals. Levels of

Cd, Pb and Zn were significantly higher in samples from East Flower Garden than from four other bank stations.

CHAPTER THREE

HYDROGRAPHIC PROJECT

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ABSTRACT

Hydrographic data from the South Texas Outer Continental Shelf are presented and discussed for a 1-yr period from January through December 1976. Tables of computed hydrographic variables are included as an appendix. Monthly cruises along a transect off Port Aransas, Texas are used to define seasonal features, including spring run-off effects, summer stratification, the fall overturn and winter cooling.

Temperature-Salinity (T-S) diagrams indicate that distinctly different hydrographic climates occur both horizontally across the shelf and vertically at any given location. Time-depth plots of temperature and salinity show the creation and destruction of thermohaline stratification. T-S gradients change from a predominantly vertical orientation in the spring and summer months to a predominantly horizontal orientation in the late fall and winter. Time series of T-S pairs indicate clearly different time scales, and presumably driving forces, characteristic of inshore and offshore waters. Advective and possible internal wave motions occurring at mid- and near-bottom levels over the outer shelf will require self-recording instrumentation to investigate the characteristics of natural variability in these areas.

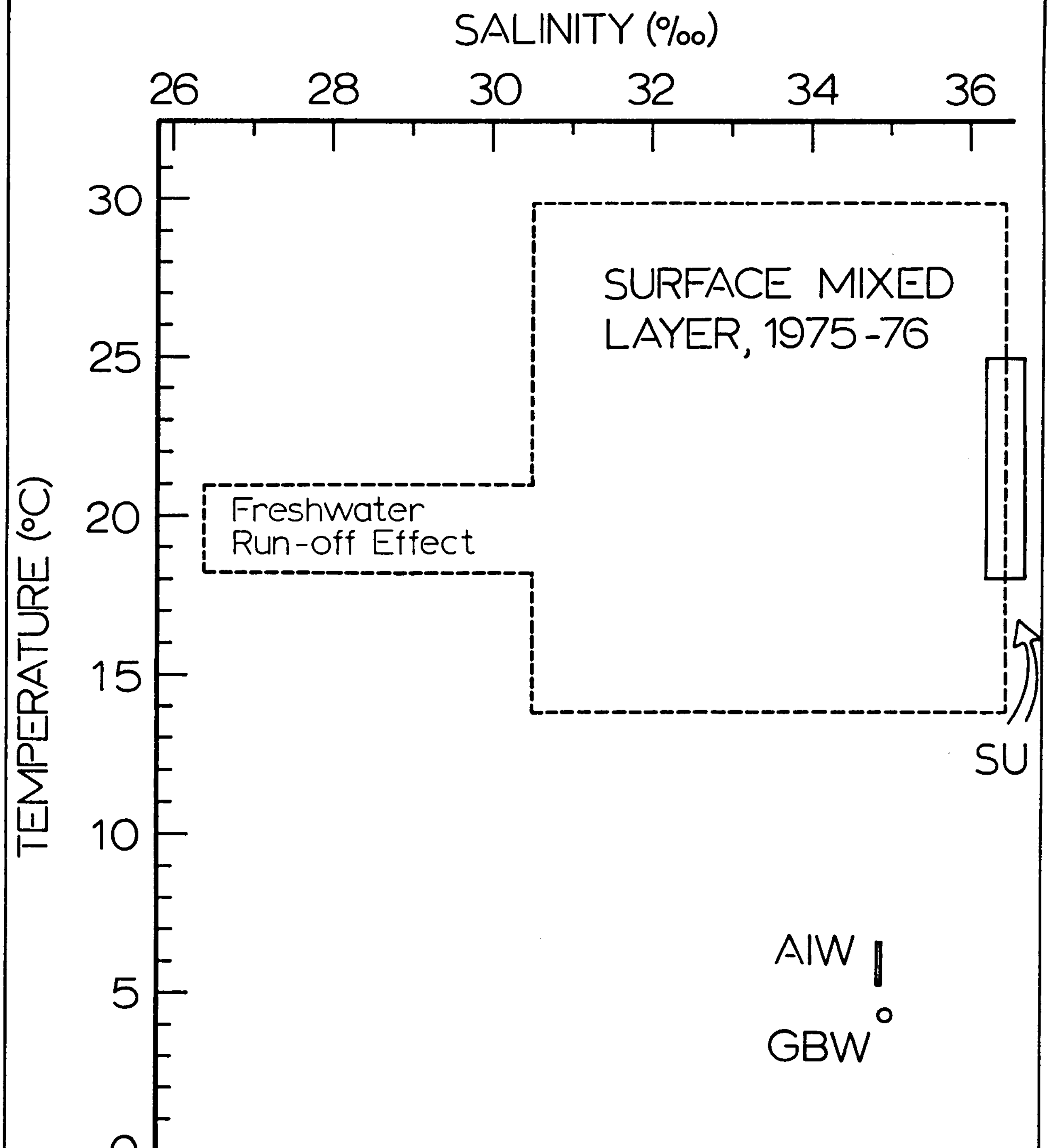
INTRODUCTION

To put the South Texas Outer Continental Shelf hydrographic data in a proper perspective, it is instructive to begin with a brief overview of the temperature and salinity (T-S) ranges characteristic of the Gulf of Mexico and, to a lesser extent, the Caribbean Sea. For this purpose, survey papers by Wüst (1964) and Nowlin (1971) have been consulted.

Water mass distributions in the Gulf of Mexico are a result of inflow through the Straits of Yucatan and from a series of rivers entering the Gulf along its northern rim. There is also a significant amount of local water mass modification by internal mixing and surface processes involving precipitation-evaporation balances and air-sea energy exchanges associated with heating and cooling occurring over a variety of time scales. Due to the relative isolation of the northwestern Gulf from advective processes, and because of the relatively shallow depths over the Texas continental shelf, local conditioning of water masses plays a relatively important role.

The sill depth of approximately 2,000 m, between the Yucatan Peninsula of Mexico and the western tip of Cuba, exerts a dynamically significant influence on the distribution of T-S properties in the Gulf of Mexico. Below the sill depth, both the temperature and salinity are characterized by great spatial homogeneity due to the isolation from the Deep and Bottom Water found in the Atlantic and the Caribbean. Gulf Basin Water, found below approximately 1,500 m, is characterized by potential temperatures between approximately 4.2° and 4.4°C, and salinities between 34.96 ppt and 34.98 ppt. This water mass is indicated by "GBW" in Figure 1.

Above the Gulf Basin Water, potential temperatures increase gradually, however, the salinity decreases to a minimum of approximately 34.86 ppt



SU - Subtropical Underwater
AIW - Antarctic Intermediate Water
GBW - Gulf Basin Water

Figure 1.

within a layer between 900 and 1,100 m before increasing again with decreasing depth. The salinity minimum reflects the influence of Antarctic Intermediate Water (AIW) and can be traced back through the Caribbean Sea, across the tropical Atlantic Ocean and into high southern latitudes to a source at the antarctic polar front at 45-50°C.

Both temperature and salinity increase with decreasing depth above the layer of Antarctic Intermediate Water. A maximum in salinity is characteristically found between approximately 100 and 300 m. This feature can also be traced back through the Caribbean and upstream along the subtropical undercurrent to a source under the semi-permanent high pressure center in the Atlantic Ocean east of Bermuda (Wüst, 1964; Nowlin, 1971). In the Caribbean, the Subtropical Underwater has a salinity range of 36.0 ppt to 36.7 ppt. In the Gulf of Mexico, due to vertical mixing from above and below, the range is somewhat narrower, and salinities are generally between 36.2 ppt and 36.7 ppt, as indicated on Figure 1. Temperatures characteristic of this layer vary between about 18° and 26°C in open Gulf waters.

The surface mixed layer lies atop the three distinct water masses discussed above. Due to the direct or indirect contact this uppermost layer has with the air-sea interface, and its relatively rapid response to changes in the windspeed, relative humidity and temperature of the surface layer of the atmosphere, the surface mixed layer of the Gulf is highly variable in T-S properties, as well as in depth. The vertical extent of the mixed layer can vary anywhere from a few centimeters to 100 m or more. Temperature variations characteristic of the mixed layer of the inner shelf range from approximately 11-13°C in late winter to 28-29°C in late summer. Salinity variations in nearshore waters are similarly variable, ranging from open Gulf values of just over 36 ppt to

25 ppt or less during the spring run-off or periods of heavy rainfall. Mixed layer T-S variations decrease somewhat with increasing distance from shore, but even over the outer shelf, annual variations on the order of 10°C and 2-3 ppt are not uncommon for the Texas shelf.

The great temporal variability of the surface mixed layer, coupled with the spatial variability and the mobility of the water column, make it inadvisable to attempt to sub-classify surface mixed layer water with adjectives relating to season, longshore or cross-shelf location and/or vertical position. T-S conditions measured at a particular point and time may be unrepresentative in a temporal or spatial sense, or of an ephemeral nature and thus not worthy of a name more distinct that the general classification of Surface Mixed Layer Water. The region inside the hatched line in Figure 1 indicates the approximate T-S ranges found during the first two years of sampling on the Texas Outer Continental Shelf.

It is this highly variable surface mixed layer that is the central focus of the hydrographic study. While it may be inadvisable to label it more definitely, it is still necessary to investigate it thoroughly, documenting its spatial and temporal variability and trying to understand the local and advective processes which result in the observed patterns. The hydrographic component of the baseline monitoring study has had, and continues to have as its primary objective the characterization of the Texas shelf waters and the understanding of the advective and local modification processes, as well as the creation of a suitable data base for the use of other investigators. It is toward these objectives that this annual report is directed.

The 1975 hydrographic data base provided a preliminary look at both spatial and temporal variations in T-S distributions. Sampling was carried out at only 12 locations and at three times during the year. It became apparent that both a higher station density and sampling frequency would be required to adequately define the hydrographic climate of the Texas Outer Continental Shelf. At the same time, a number of features were documented. A well-mixed surface layer characterized the temperature cross-sections constructed from the winter cruise data. Lowest temperatures found over the inner shelf in December-January, 1974-1975, were 16-18°C, though substantially lower temperatures could have occurred later. Significant cross-shelf salinity gradients were found along all four transects. Significant warming had occurred by the spring cruise. Salinity patterns showed strong freshwater run-off effect, though the distance that the low-salinity water extended offshore was highly variable. The summer temperature data showed a strong thermal stratification below a surface mixed layer in the upper 20-30 meters. Freshwater run-off effects were still well defined in August-September. Highest temperatures were just over 29°C. Taken together, the data show an annual alternation from a predominantly vertical to a predominantly horizontal orientation of the isopleths, as the water column alternates from unstratified to stratified. The stratification is a reflection of vertical salinity gradients in the late spring and early summer, and seasonal heating in mid and late summer.

The hydrographic data presented in this annual report extend the available data base and address some of the questions that still exist with regard to the hydrographic climate of the Texas Outer Continental Shelf. The 1976 sampling program is characterized by a substantially better station density and sampling frequency. Hydrographic data were obtained from 6-7 stations along each of the four transects. Six monthly sampling cruises were added to the three seasonal cruises. The data presented and discussed here include 75 STD/TDC profiles from seasonal cruises

(3 x 25 stations), and 36 profiles from monthly cruises (6 x 6 stations) for a total of 111 profiles. The additional 18 profiles required for the 129 profile minimum sampling effort are from the Bank Stations. These have been discussed in the Quarterly reports and will not be included here. The Bank Station data are, however, included in Appendix A.

In the sections that follow, the data and methods of analysis are described in somewhat greater detail than was the case in the Quarterly reports. There follows a revised statement of the results from the individual seasonal cruises and the monthly cruises. Further results, combining patterns from two or more of the individual cruises, are appended in the Results section. The report concludes with an integrated discussion, based on the entire 1976 data base, to summarize the present understanding of the characteristics of the Surface Mixed Layer Water over the Texas Outer Continental Shelf.

METHODS

Hydrographic data collected during the 1976 contract year were obtained in one of three ways. The primary sampling instrument was a PLESSEY Model 9060 Self-Contained Salinity/Temperature/Depth Profiler (STD). This instrument provided analog plots of the vertical distribution of both salinity and temperature. Temperatures were read to the nearest 0.01°C; salinities to the nearest 0.01 ppt. The precision of the STD is nominally ± 0.1°C and ± 0.05 ppt.

In shallow water, through surface layers of low-salinity water, or at times when the STD was being repaired, hydrographic data were obtained with a Martek Model TDC Metering System (TDC). This instrument provides a direct readout of temperature, depth and conductivity, and data are recorded at discrete levels. The raw temperature, conductivity and pressure values are then used to compute salinities at each of the levels (see next section). Temperatures are read to the nearest 0.1°C; however, the stated precision of the sensor is ± 0.2°C. Conductivities are read to the nearest 0.1 mmho/cm; however, in reality the precision is closer to ± 1 or 2 mmho/cm, depending on the full scale used. Depth is read to the nearest 0.1 m, which represents an average estimated on a rolling boat. The precision of the computed salinity is estimated to be on the order of ± 0.5 ppt, incorporating both the top and bottom calibration data.

Temperature and salinity (T-S) data obtained with reversing thermometers and Nansen bottle samples (salinities determined by laboratory salinometer) were used to extend T-S profiles obtained with the TDC in deeper water, and to calibrate both STD and TDC profiles at top and/or bottom levels. Reversing thermometer temperatures were read to the nearest 0.01°C and have a precision of ± 0.01; salinities determined with the laboratory salinometer were read to the nearest 0.001 ppt, with a precision of ± 0.001 ppt.

Hydrographic data were digitized at 3-m intervals when analog plots were provided by the STD. When the TDC was used for data collection, readings were taken at approximately 3-m intervals, depending on the nature of vertical T-S gradients through the water column. When Nansen bottles with reversing thermometers were used to extend the TDC profiled in deeper water, bottles were positioned on the hydrographic wire at 10- or 20-m intervals, depending on water depth.

Calibration data, obtained at surface and near-bottom levels, were used to calibrate both STD and TDC profiles. These corrections were applied as the first step in a computer program used to compute a group of temperature-, salinity- and pressure-related variables. When TDC values provided the input data at a given station, the computer program was first used to compute the salinity using the equations discussed by

Bennett (1976).

A series of hydrographic variables was computed from the calibrated salinity and temperature profiles, using a computer program initially developed by the Pacific Oceanographic and Meteorological Laboratories. Our version has undergone significant modifications to (1) incorporate the calibration T-S data, (2) plot vertical profiles of temperature, salinity and sigma-t, and (3) compute the Brunt-Vaisala frequency of internal wave oscillations. The basic form of the computer program computes sigma-t, the potential temperature (°C), the specific volume anomaly (cm^3/gm), the dynamic height (dyn-cm), the potential energy anomaly ($gm\,m^2/sec^2$) and the sound speed (m/sec). Tables of these computed hydrographic variables are presented, along with the calibrated T-S profiles, in Appendix A.

Tables of calibrated T-S profiles and computed hydrographic variables were used to present the data in several ways. Calibration T-S data from the seasonal cruises were plotted on a plan-view base map and contoured at intervals of 1-2°C or ppt. Where instructive, bottom T-S calibration data were plotted and contoured in a similar manner. Monthly cruise data were used to construct cross-sections of temperature, salinity or sigma-t along Transect II. By superimposing two cross-sections, values from a given point could be graphically subtracted to determine the net change over any given interval of time. This technique was useful for investigating spring warming, fall cooling or the annual temperature range along Transect II.

T-S pairs from a given location and depth on Transect II were plotted on a standard sigma-t diagram (with the sigma-t lines removed). The polygon-like figure obtained by connecting the dots provides a good overview of the relative importance and actual magnitudes of temperature and salinity variations over the time interval the data were collected. Finally, temperature, salinity and sigma-t profile data were entered on a depth vs time graph. The resulting figure indicates the vertical movement of the isopleths over the associated time interval.

RESULTS

The results of the 1976 hydrographic sampling program are presented chronologically. Within each seasonal or monthly cruise, temperature and salinity data from a given transect are discussed separately. The section is concluded with further results which involve a combination of data from two or more times at a given location. This integration of the year's data is for the purpose of investigating seasonal and shorter-period temporal variability.

Winter Seasonal Cruise (30 January - 3 February 1976)

Transect I (2-3 February 1976)

Temperature stratification at the inner three stations (Figure 2) was confined to the upper 25 m, with surface temperatures between 2 and 3°C colder than temperatures at intermediate and near-bottom levels. The water column was very nearly isothermal through the upper 95 m over the outer shelf, above the permanent thermocline. Horizontal temperature gradients were confined to the area between Stations 1/I and 5/I.

The salinity cross-section (Figure 3) showed a thin lens of relatively low salinity water in the upper 10 m extending out nearly to Station 2. Lowest salinities were just under 32 ppt at the surface at Stations 4/I and 1/I. A strong halocline was found at these two stations, centered at about the 5-m level. Vertical salinity variations were much less at Station 2/I and the water column at the outer three stations was very nearly isohaline.

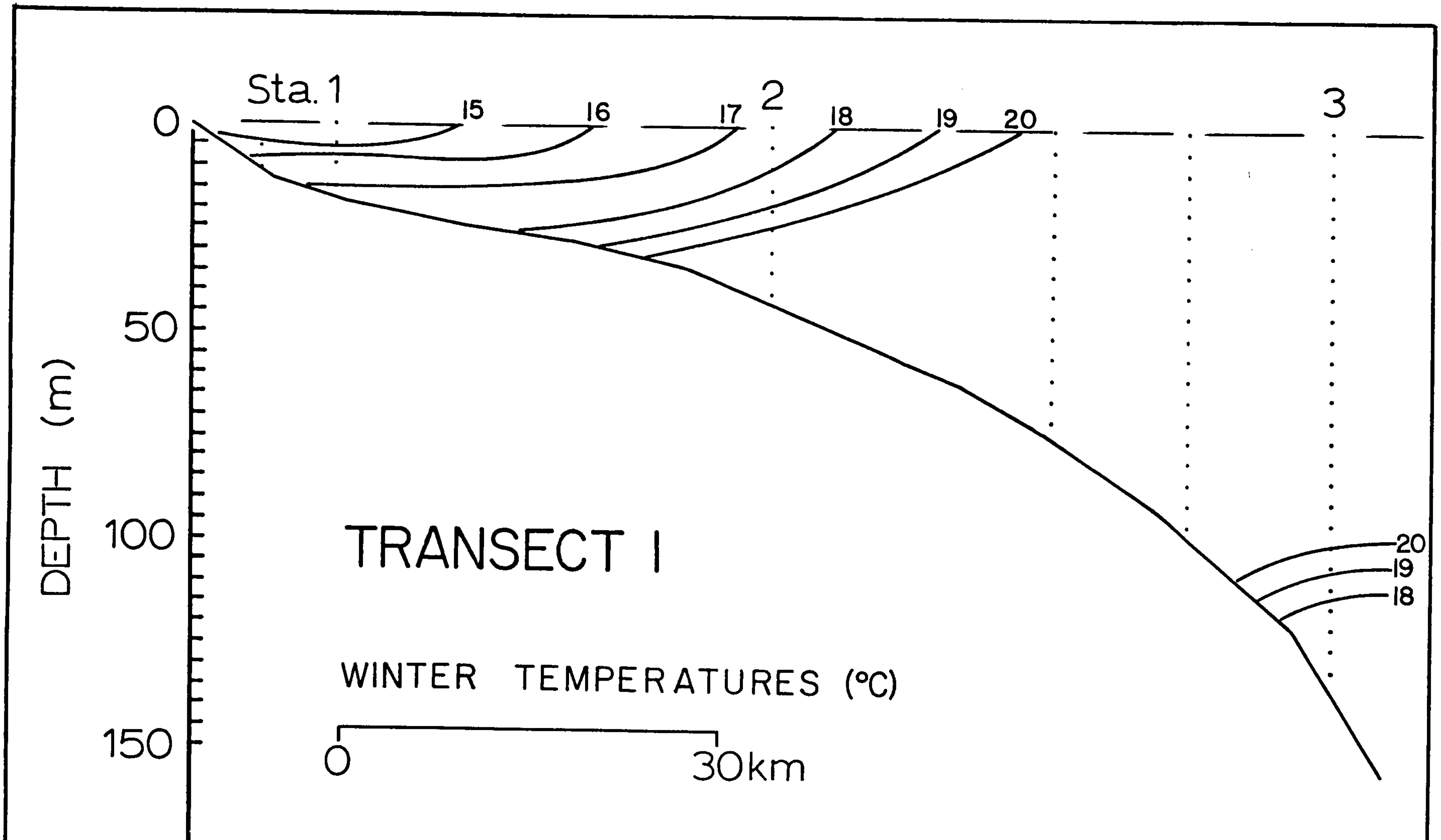

Sta. 1
2
3
0
50
100
150
DEPTH (m)
15
16
17
18
19
20
20
19
18
TRANSECT I
WINTER TEMPERATURES (°C)
0
30km

FIGURE 2.

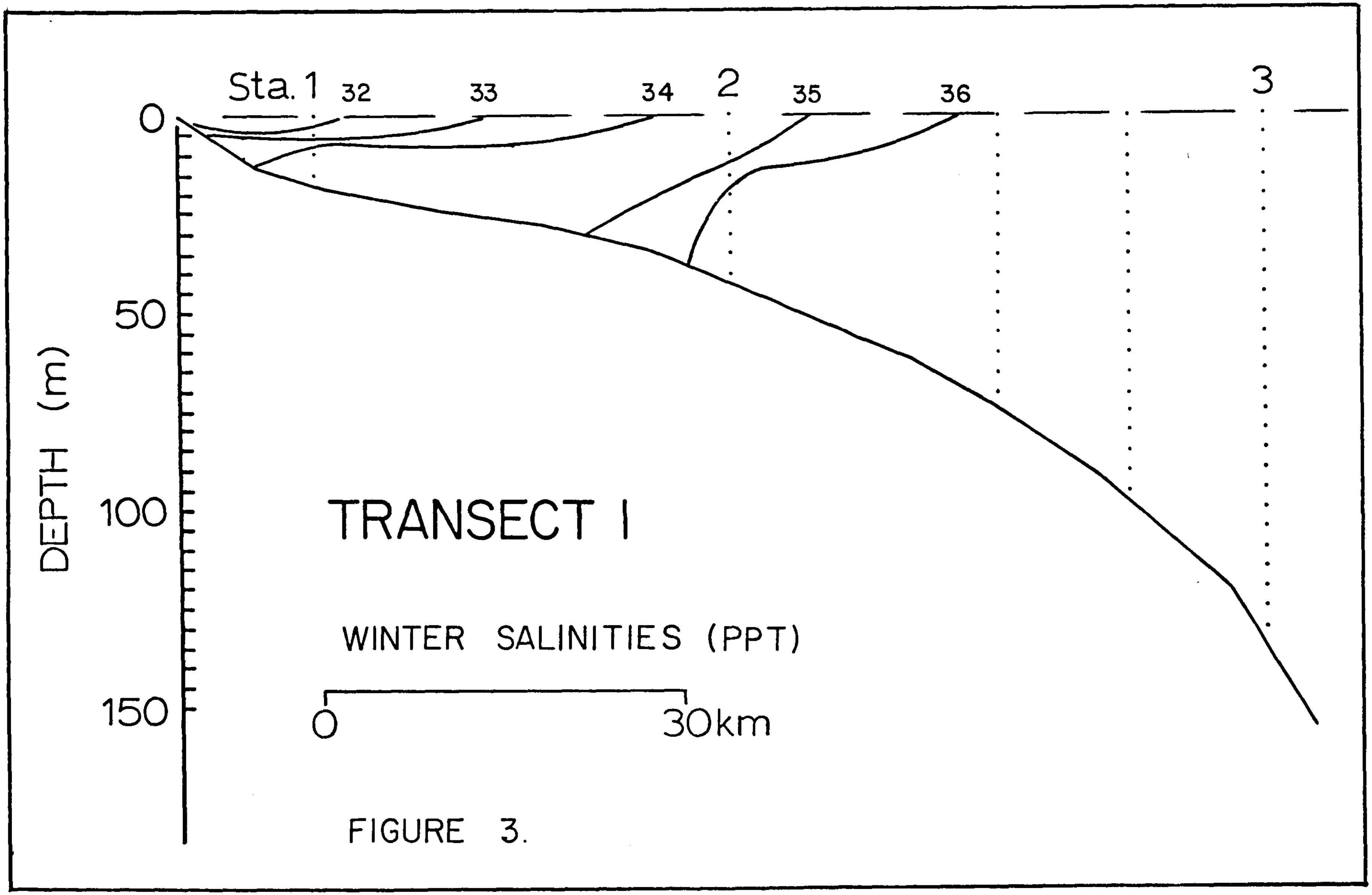

Sta. 1
2
3
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT I
WINTER SALINITIES (PPT)
0
30km

FIGURE 3.

Transect II (1-2 February 1976)

A well-developed reverse thermocline was found between approximately 10-15 m at Stations 1/II and 4/II (Figure 4). Horizontal temperature gradients were confined primarily to the area between Stations 4/II and 5/II. Temperatures were spatially very uniform beyond Station 5/II and above the top of the thermocline at approximately 80 m.

A strong halocline at about the 10-m level was found at Station 1/II (Figure 5), and to a lesser extend at Station 4/II. Vertical variations in salinity were less than 0.6 ppt at Station 2/II, and less than 0.3 ppt at each of the outer three stations. Water from the inner shelf appeared to extend out only slightly beyond Station 4/II.

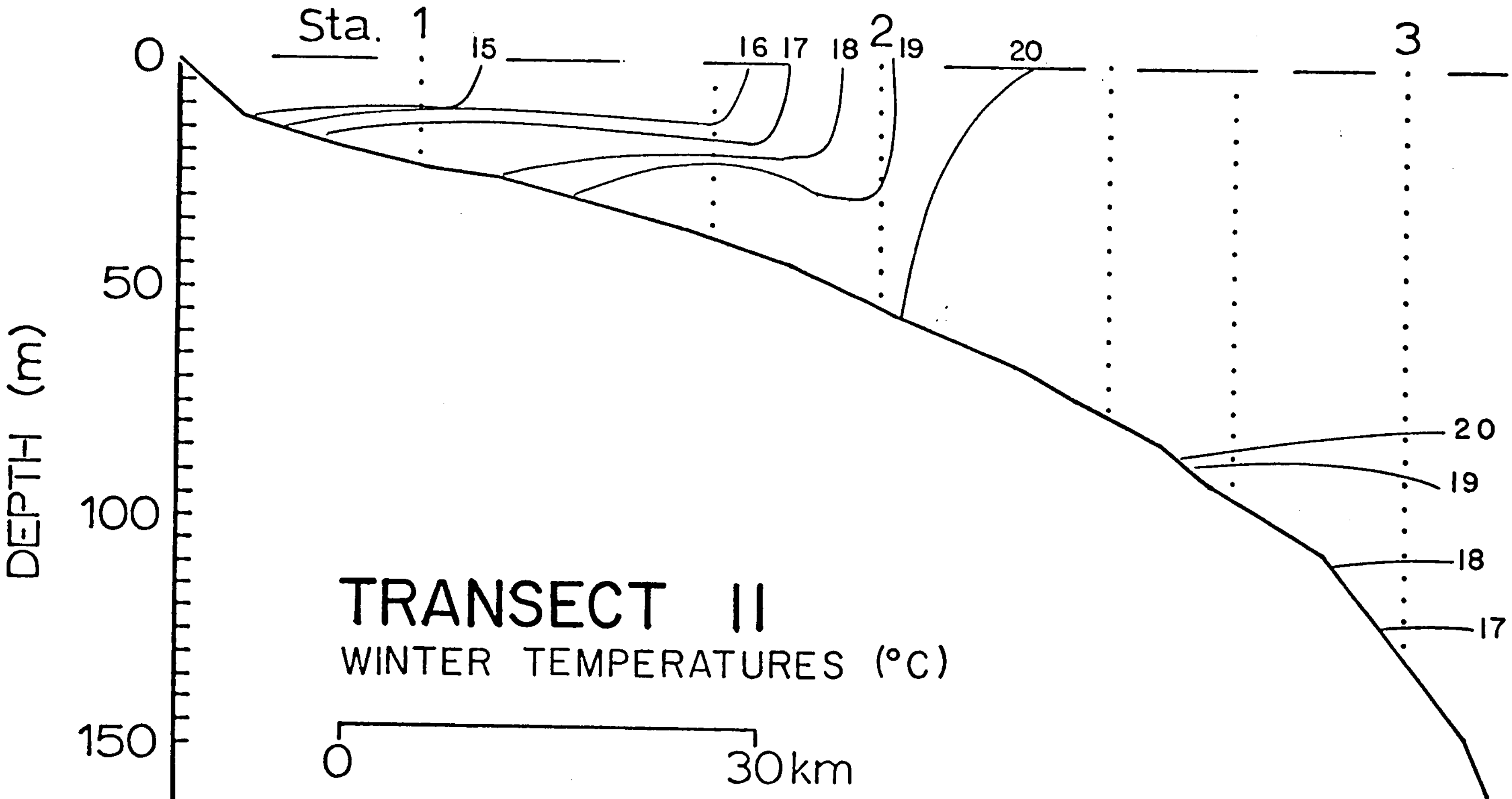
Transect III (30 January - 1 February 1976)

Very nearly isothermal water columns were recorded everywhere except at Station 5/III, where a well-developed, reverse thermocline extended through the upper 20 m (Figure 6). At the outer two stations, the top of the permanent thermocline was found at the 90-m level. Above that depth, waters over the outer shelf were very nearly isothermal at approximately 20.7°C.

Relatively low salinity water from the inner shelf extended out through the upper layers to beyond Station 5 (Figure 7). Horizontal salinity gradients were confined to within Station 2/III. All water at the outer three stations had salinities greater than 36 ppt.

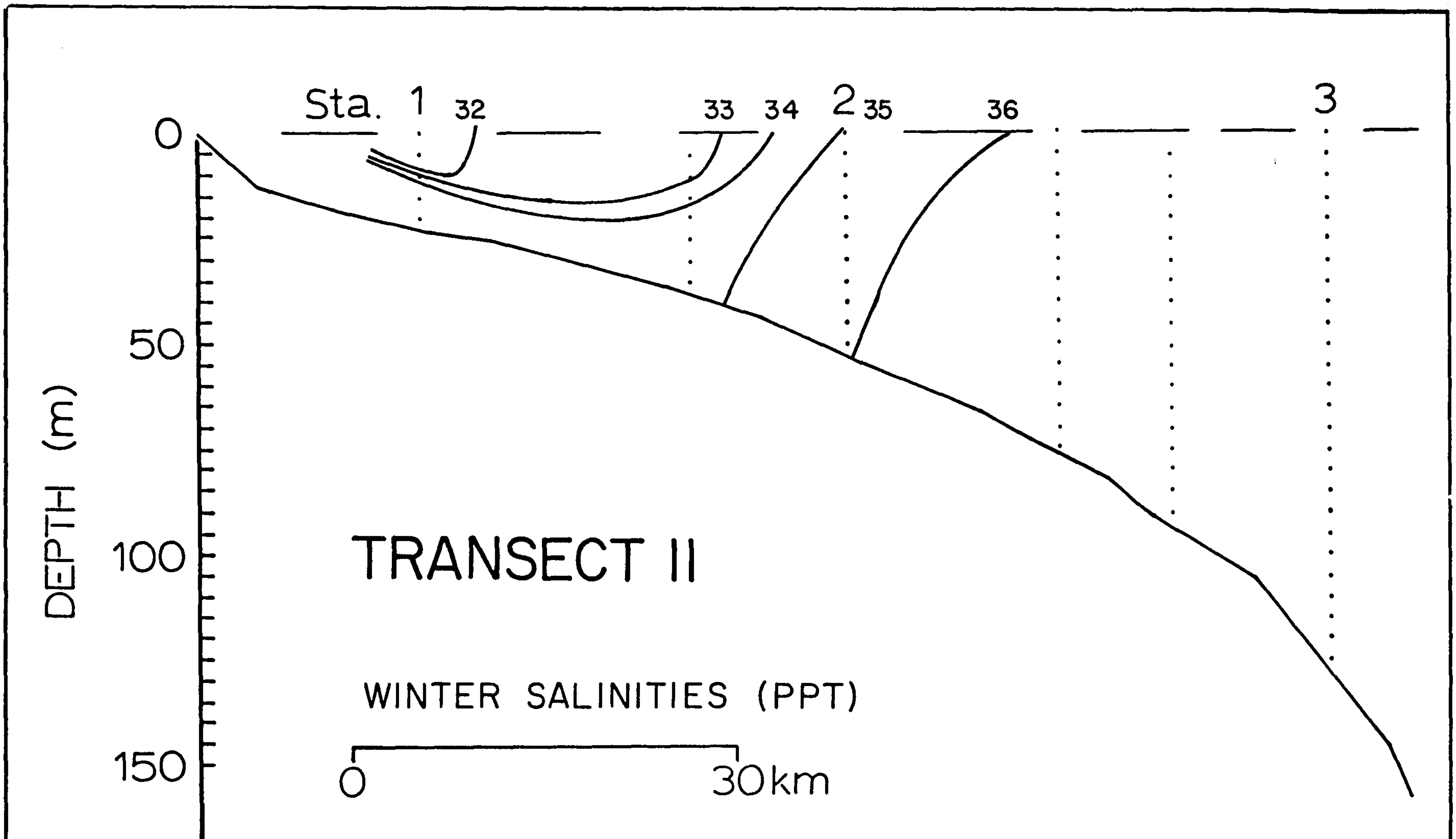
Transect IV (30 January 1976)

Vertical temperature variations through the upper 90 m were less than 1.2°C at all stations (Figure 8). A substantial horizontal gradient, however, was found across the entire shelf. The pattern reflected considerable vertical overturning and mixing.



Sta. 1
2
3
15
16
17
18
19
20
20
19
18
17
0
50
100
150
DEPTH (m)
TRANSECT II
WINTER TEMPERATURES (°C)
0
30km

FIGURE 4.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32
33
34
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35
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3
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50
100
150
DEPTH (m)
TRANSECT II
WINTER SALINITIES (PPT)
0
30km

FIGURE 5.

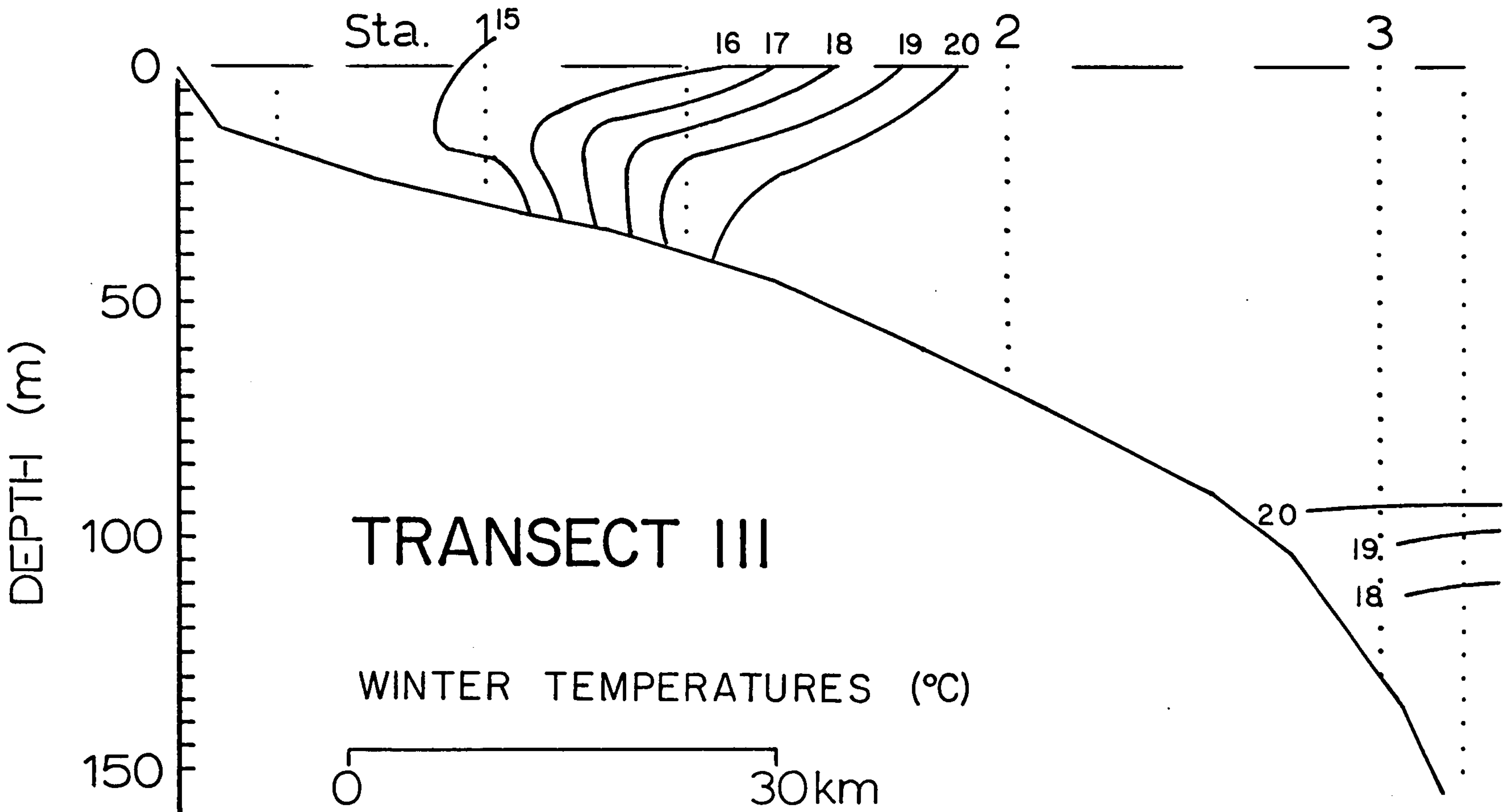

Sta. 1
2
3
15
16
17
18
19
20
0
50
100
150
DEPTH (m)
TRANSECT III
WINTER TEMPERATURES (°C)
0
30km
20
19
18

FIGURE 6.

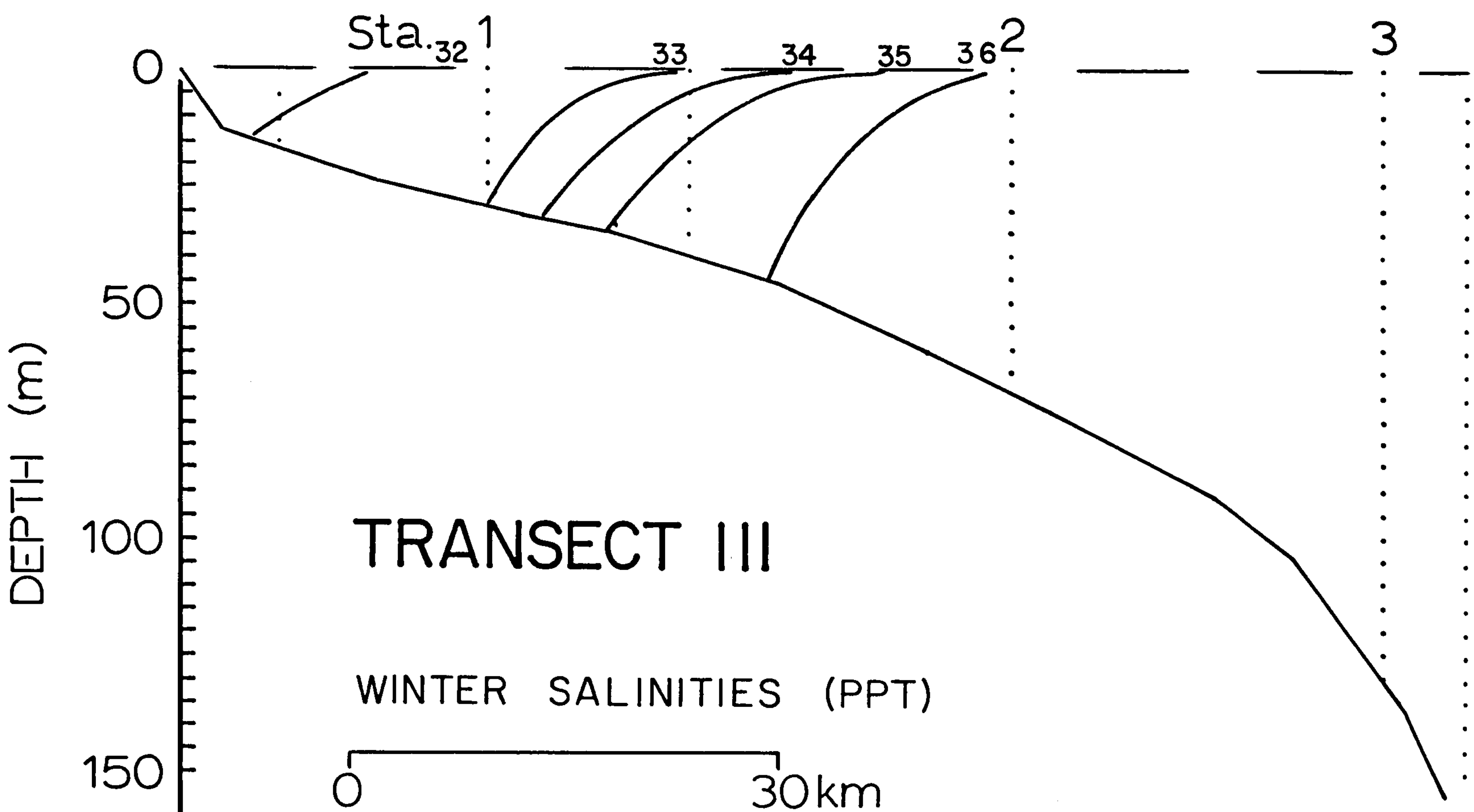

Sta.
1
2
3
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT III
WINTER SALINITIES (PPT)
0
30km

FIGURE 7.

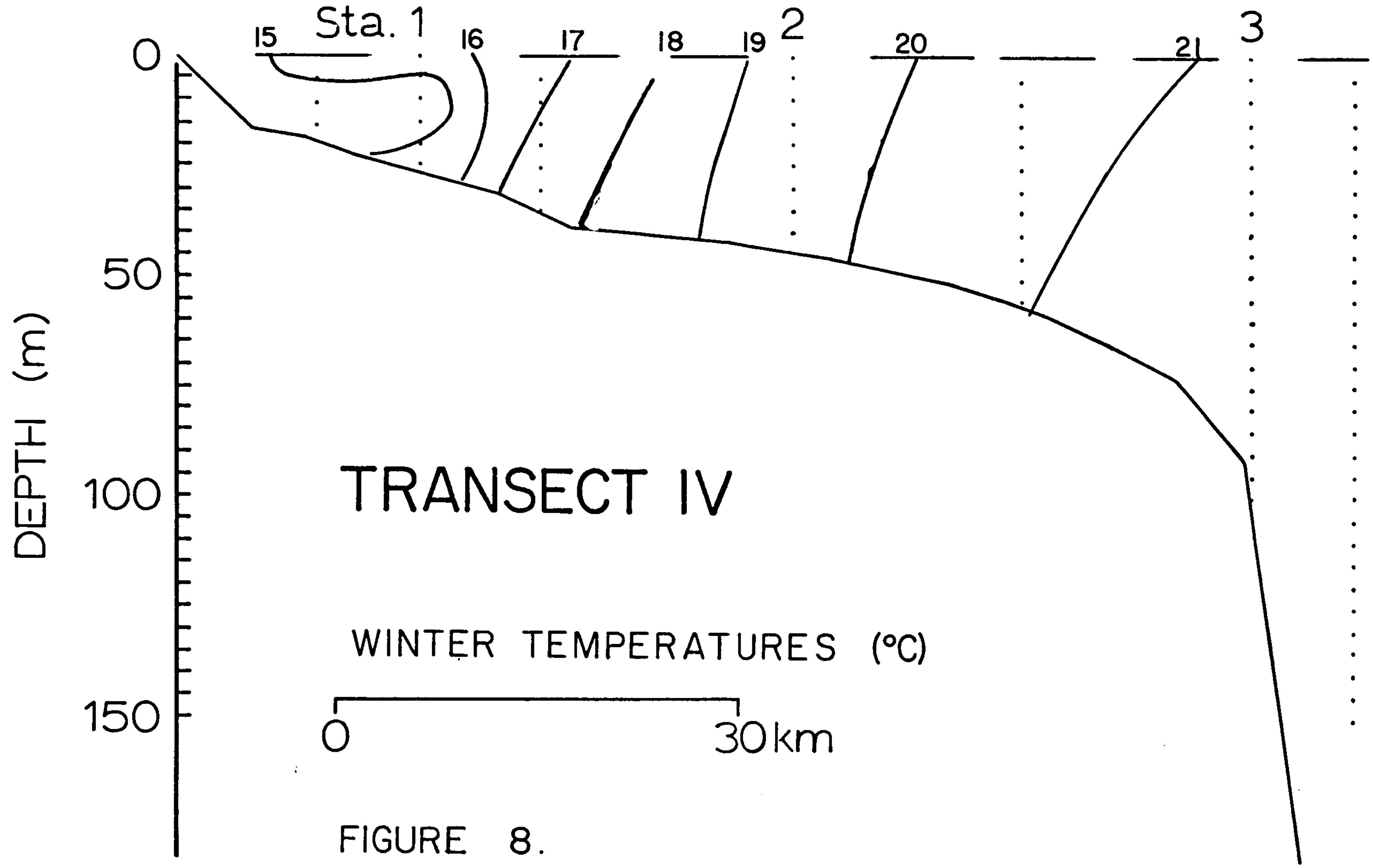

Sta. 1
2
3
15
16
17
18
19
20
21
0
50
100
150
DEPTH (m)
TRANSECT IV
WINTER TEMPERATURES (°C)
0
30km

FIGURE 8.

The salinity cross-section was lacking in significant features (Figure 9). Salinities increased gradually from just over 32 ppt at Station 1/IV to approximately 36 ppt at Station 6/IV. Little vertical variation was found at any single station.

Spatial Variations in Seasonal Hydrographic Data

Surface Temperature Pattern

Surface isotherms were oriented very nearly parallel to the coast (Figure 10), indicating very little cross-shelf motion. Strongest temperature gradients were found across the middle shelf. Surface temperatures varied only slightly through the first 25-30 km, and beyond approximately 50 km from the coast. Nearshore temperatures of between 14 and 15°C probably represented the annual minimum.

Surface Salinity Pattern

Surface isohalines were similarly oriented parallel to the coast (Figure 11). Horizontal variations were inside Station 2 along most transects. Lowest salinities were above 31 ppt, indicating relatively little freshwater run-off through the estuaries at this time of year.

March Monthly Cruise (18-19 March 1976)

A vertical temperature structure was nearly absent at all stations through the upper 65 m (Figure 12). The top of the permanent thermocline was poorly defined over the outer shelf. The water enclosed by the 21°C isotherm at Stations 5/II and 6/II may have represented a small eddy that had moved onto the shelf, though near-surface water at Station 5 was only 0.7°C warmer than at Station 3.

Significantly lower salinities were found in March (Figure 13), with lowest values of just under 28 ppt at the surface at Station 1/II. A

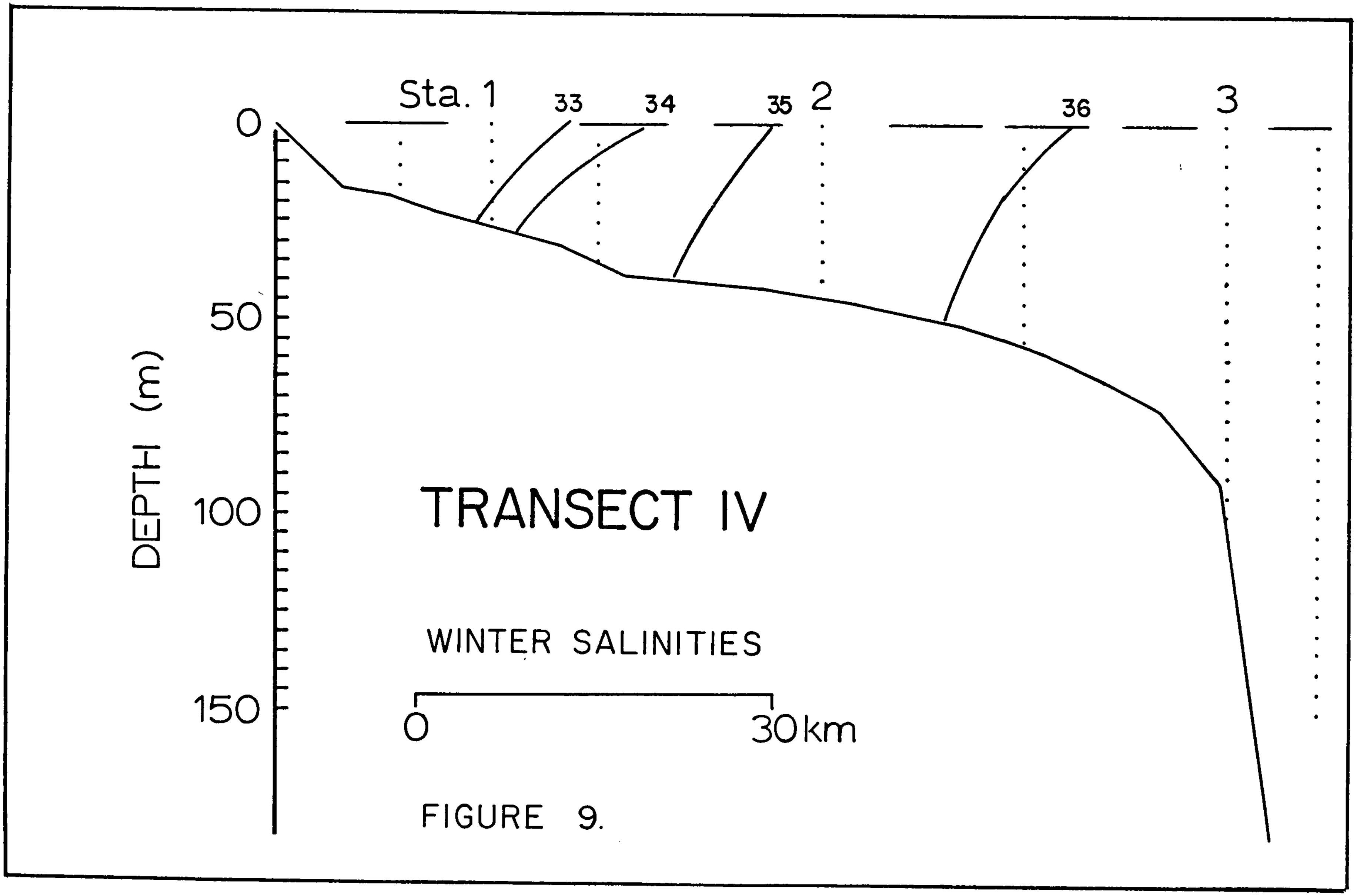

Sta. 1
2
3
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT IV
WINTER SALINITIES
0
30km

FIGURE 9.

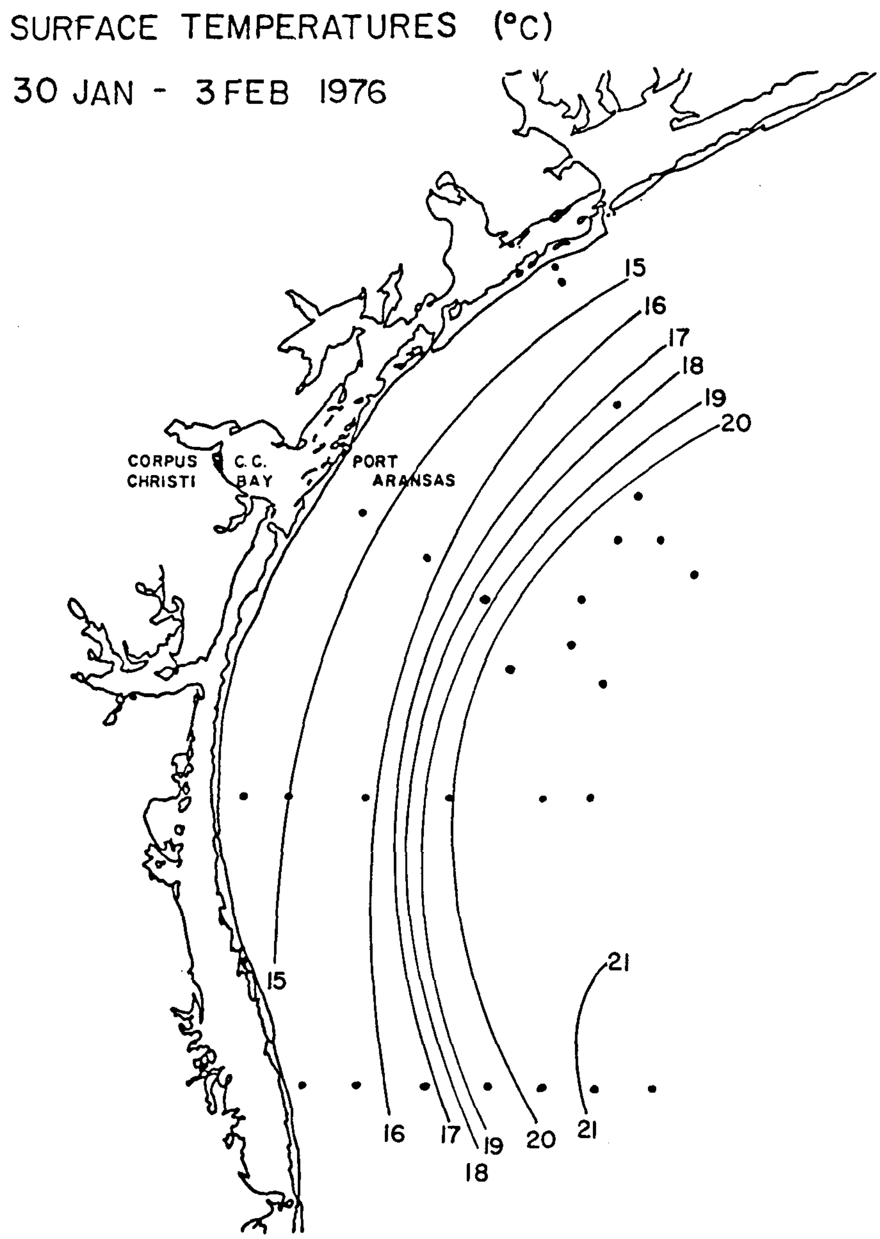

SURFACE TEMPERATURES (°C)
30 JAN - 3 FEB 1976
CORPUS CHRISTI
C.C. BAY
PORT ARANSAS
15
16
17
18
19
20
21

FIGURE 10.

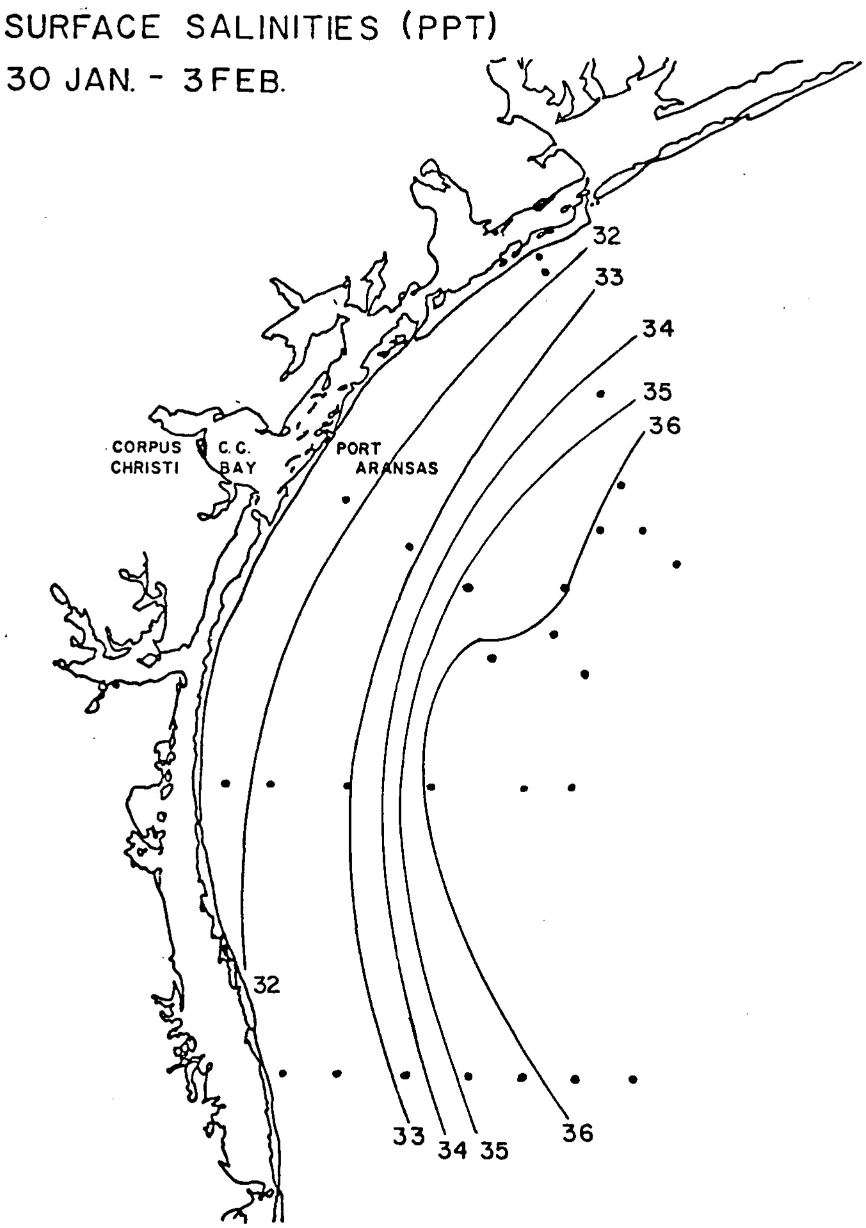
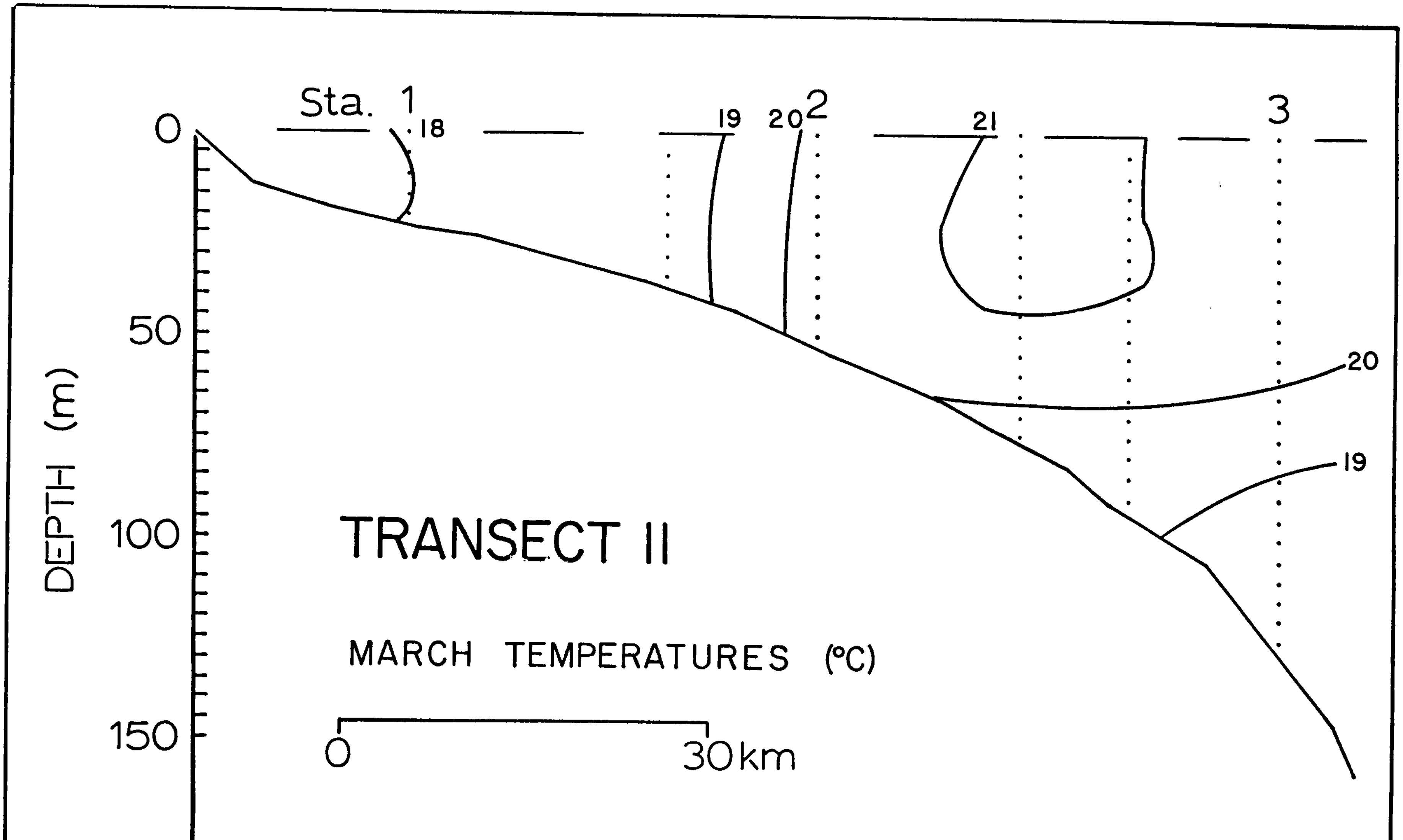
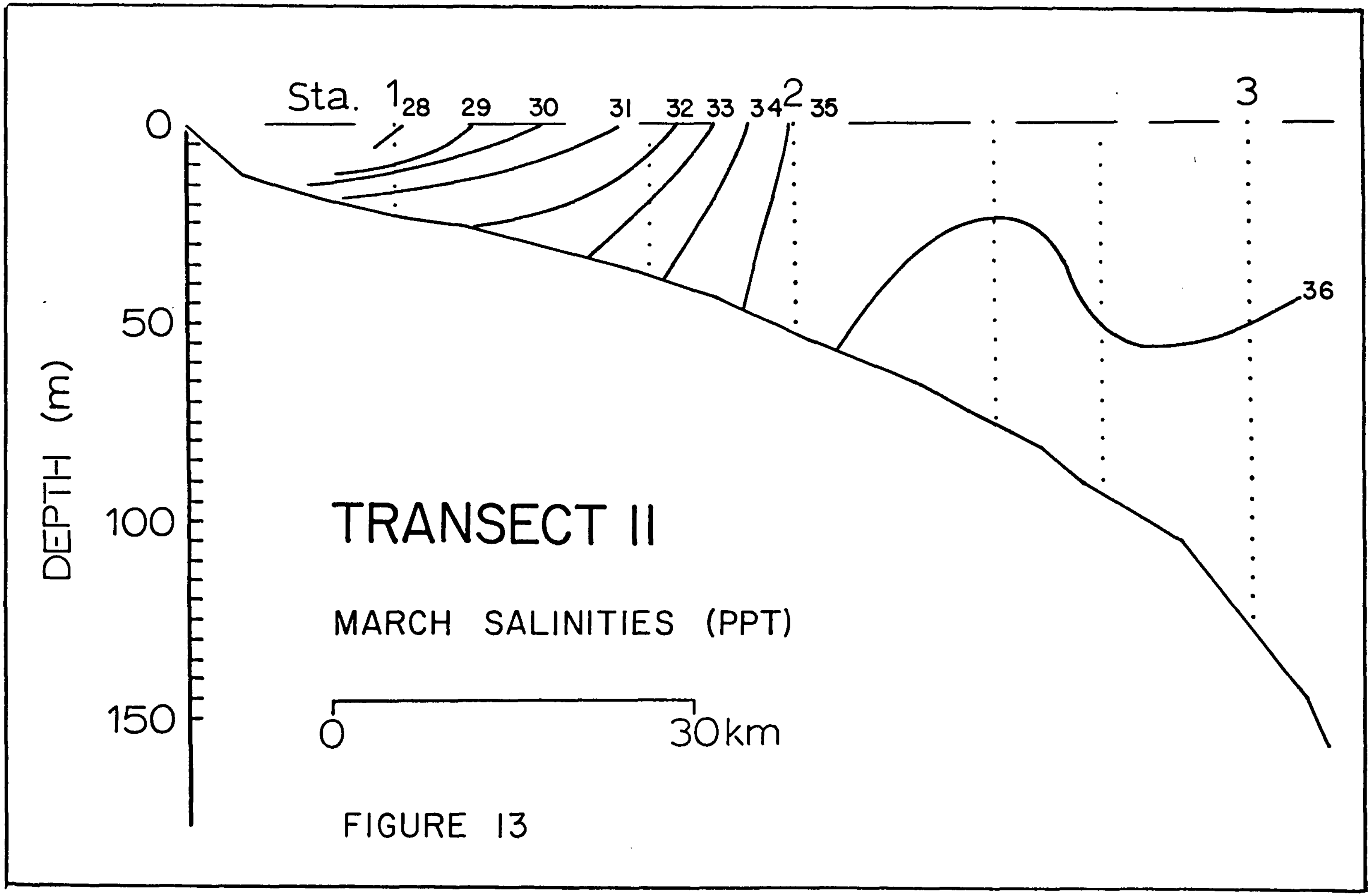

SURFACE SALINITIES (PPT)
30 JAN. - 3 FEB.
CORPUS CHRISTI
C.C. BAY
PORT ARANSAS
32
33
34
35
36
32
33
34
35
36

FIGURE 11.


Sta. 1
2
3
18
19
20
21
20
19
0
50
100
150
DEPTH (m)
TRANSECT II
MARCH TEMPERATURES (°C)
0
30km
FIGURE 12.


Sta. 1 28 29 30 31 32 33 34 2 35 3
36
0
50
100
150
DEPTH (m)
TRANSECT II
MARCH SALINITIES (PPT)
0
30km
FIGURE 13

strong halocline was found over the inner shelf, diminishing at Station 4/II and missing altogether at and beyond Station 2/II. Horizontal salinity gradients were confined to waters inside Station 2/II. No surface water with a salinity greater than 36 ppt was found on this cruise.

April Monthly Cruise

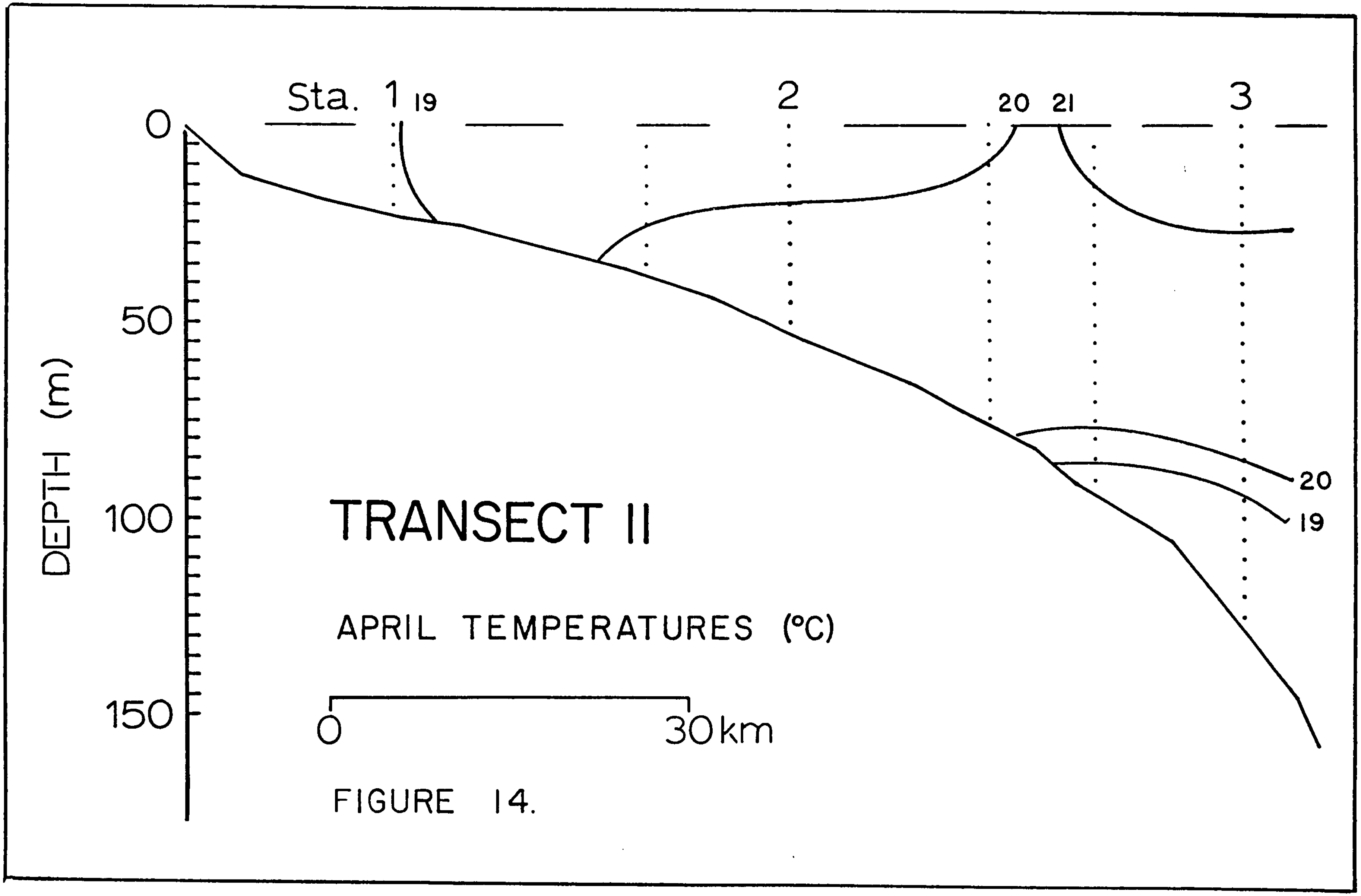
Analyses of the temperature cross-section for the second monthly cruise (Figure 14) showed a transition from nearshore waters, at temperatures of approximately 19°C, to offshore waters, with temperatures over 21°C, occurring between Stations 5/II and 6/II. The water column at all stations was nearly isothermal above the top of the permanent thermocline at approximately the 75-m level. Little temperature variability was found in intermediate depths over the middle and outer shelf.

The salinity cross-section (Figure 15) showed a tongue of relatively low salinity water extending nearly 70 km out from the coast. A very strong halocline was seen at approximately the 15 to 20-m level at Station 1/II. A strong horizontal gradient occurred between Stations 1/II and 4/II in the upper layers. Little horizontal variation was found at any depth beyond Station 5/II.

Spring-Summer Seasonal Cruise (30 May - 7 June 1976)

Transect I (7 June 1976)

Temperatures were quite uniform through the upper 20 m along Transect I (Figure 16), varying from just under 26°C to approximately 27.5°C. A well-developed seasonal thermocline was found between 20 and 25 m at Station 2/I, though isotherms diverged quickly with increasing distance seaward. At the outer two stations, temperatures decreased quite uniformly with increasing depth below approximately 40 m. Minimum temperatures of just above the bottom at Station 3/I, indicating essentially no


Sta. 1
19
2
20
21
3
0
50
100
150
DEPTH (m)
20
19
TRANSECT II
APRIL TEMPERATURES (°C)
0
30km
FIGURE 14.

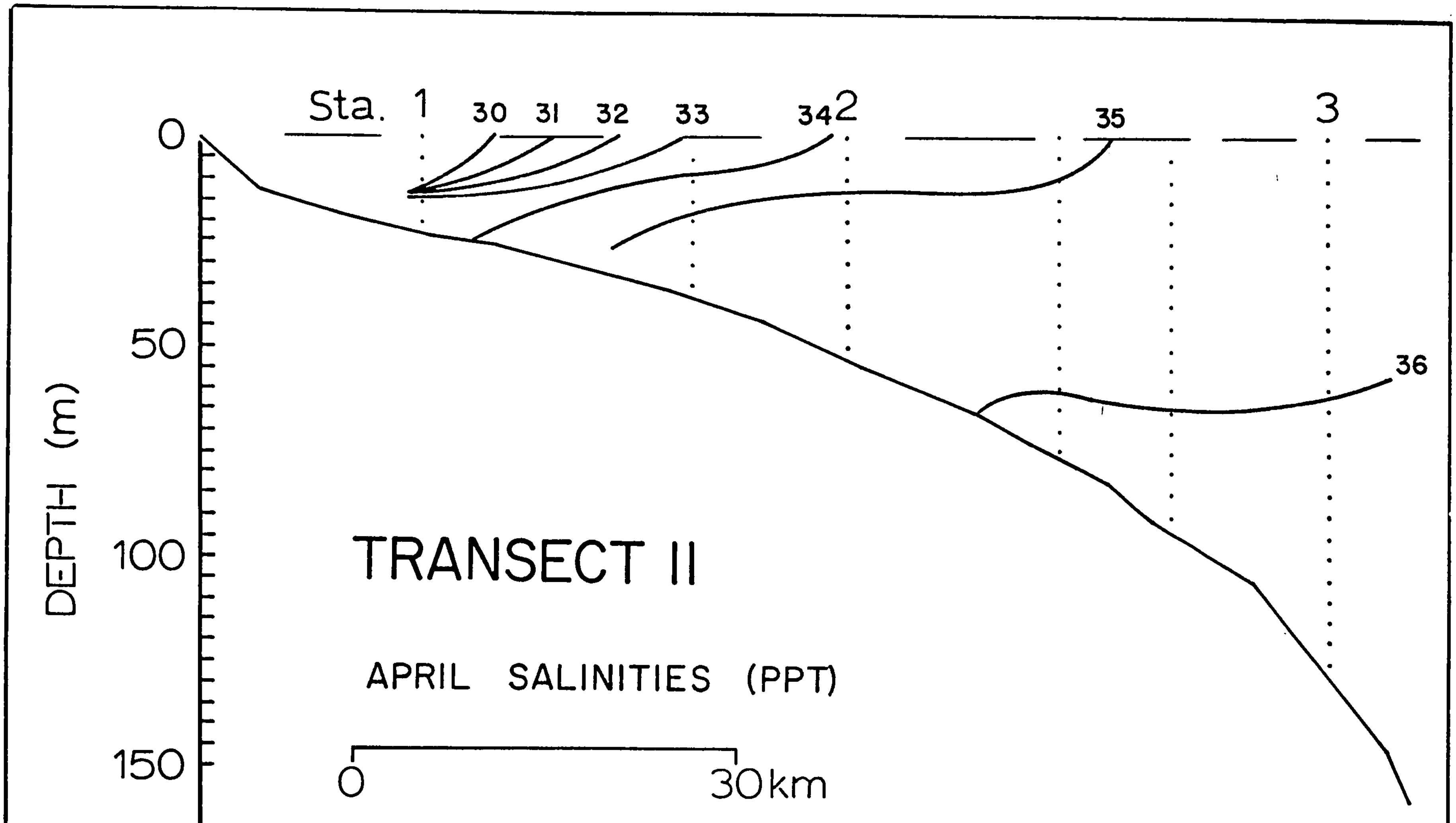
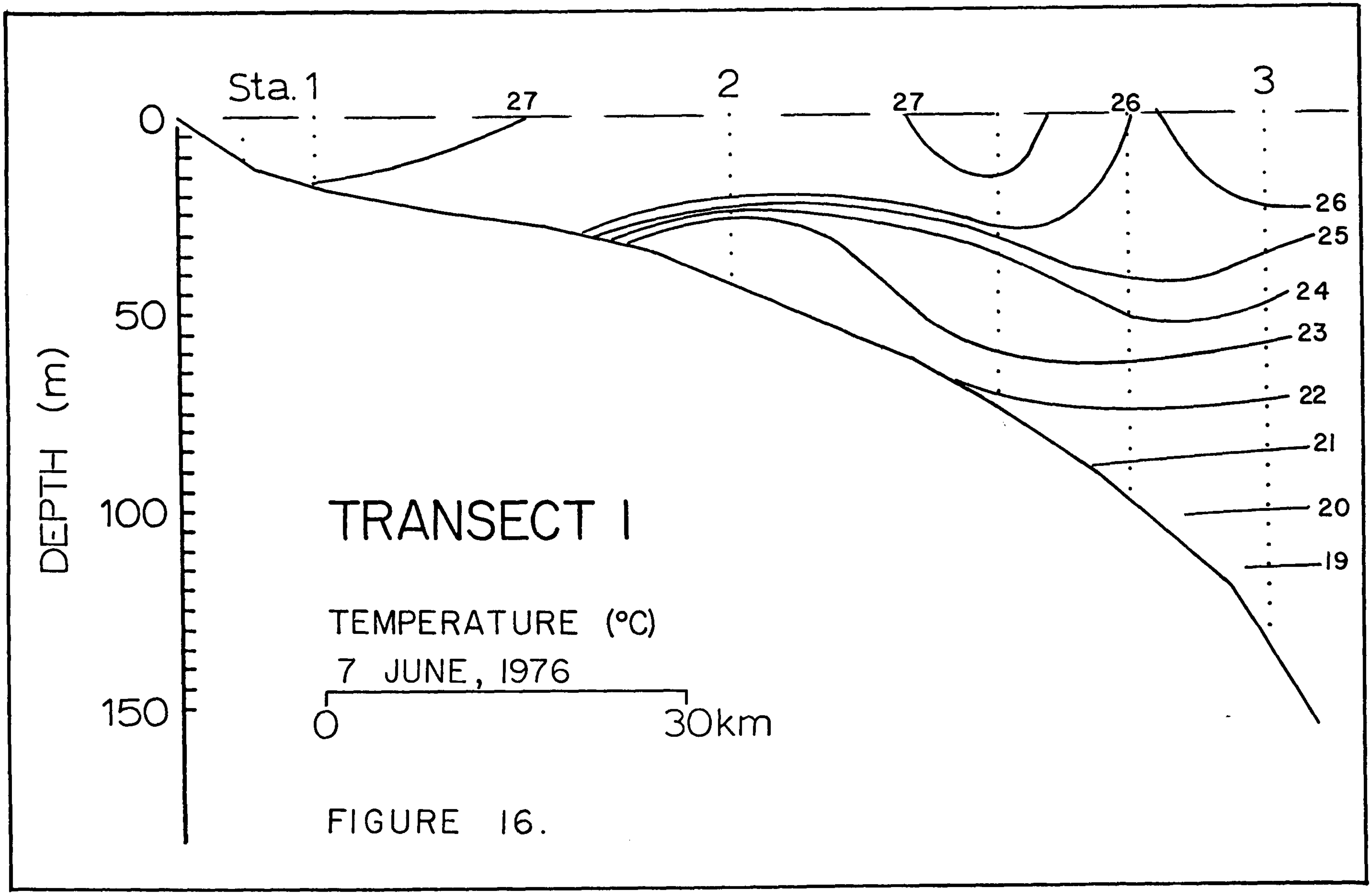

Sta. 1
2
3
30
31
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT II
APRIL SALINITIES (PPT)
0
30km

FIGURE 15.



Sta. 1
2
3
27
27
26
26
25
24
23
22
21
20
19
0
50
100
150
DEPTH (m)
TRANSECT I
TEMPERATURE (°C)
7 JUNE, 1976
0
30km

FIGURE 16.

change from the data collected during the first seasonal cruise on 2-3 February 1976.

The salinity cross-section (Figure 17) showed a lens of relatively low salinity water in the upper 30-35 m, extending out to beyond the seaward end of the transect. Highest salinities were just under 35 ppt at Station 3/I. The greatest cross-shelf surface salinity gradients were found between Stations 5/I and 6/I. A well-developed halocline, centered at 20-25 m between Stations 2/I and 6/I, was enclosed by the 32 and 35 ppt isohalines. Salinities greater than 36 ppt were found only below the 45-m level at the outer three stations.

Transect II (3-6 June 1976)

The upper 10-15 m of Transect II (Figure 18) were characterized by great thermal homogeneity due to uniform heating and wave mixing. Temperatures varied only between 26.1 to 26.5°C at the surface over the entire outer shelf. A well-developed seasonal thermocline was found between 10 and 20 m at Station 4/II and between 10 and 20 m at 2/II. Isotherms then diverged rapidly with increasing distance from shore, and at the outer three stations temperatures decreased nearly uniformly through the water column.

The salinity cross-section (Figure 19) showed a shallow pool of relatively low salinity water, enclosed by the 31-ppt isohaline, cut off from the coast. A very strong halocline sloped upward from between 10-30 m at Station 4/II to the upper 20 m at Station 6/II. Salinities greater than 36 ppt were found below the 30-m level at the outer three stations.

Transect III (3-5 June 1976)

The temperature cross-section (Figure 20) was characterized by very

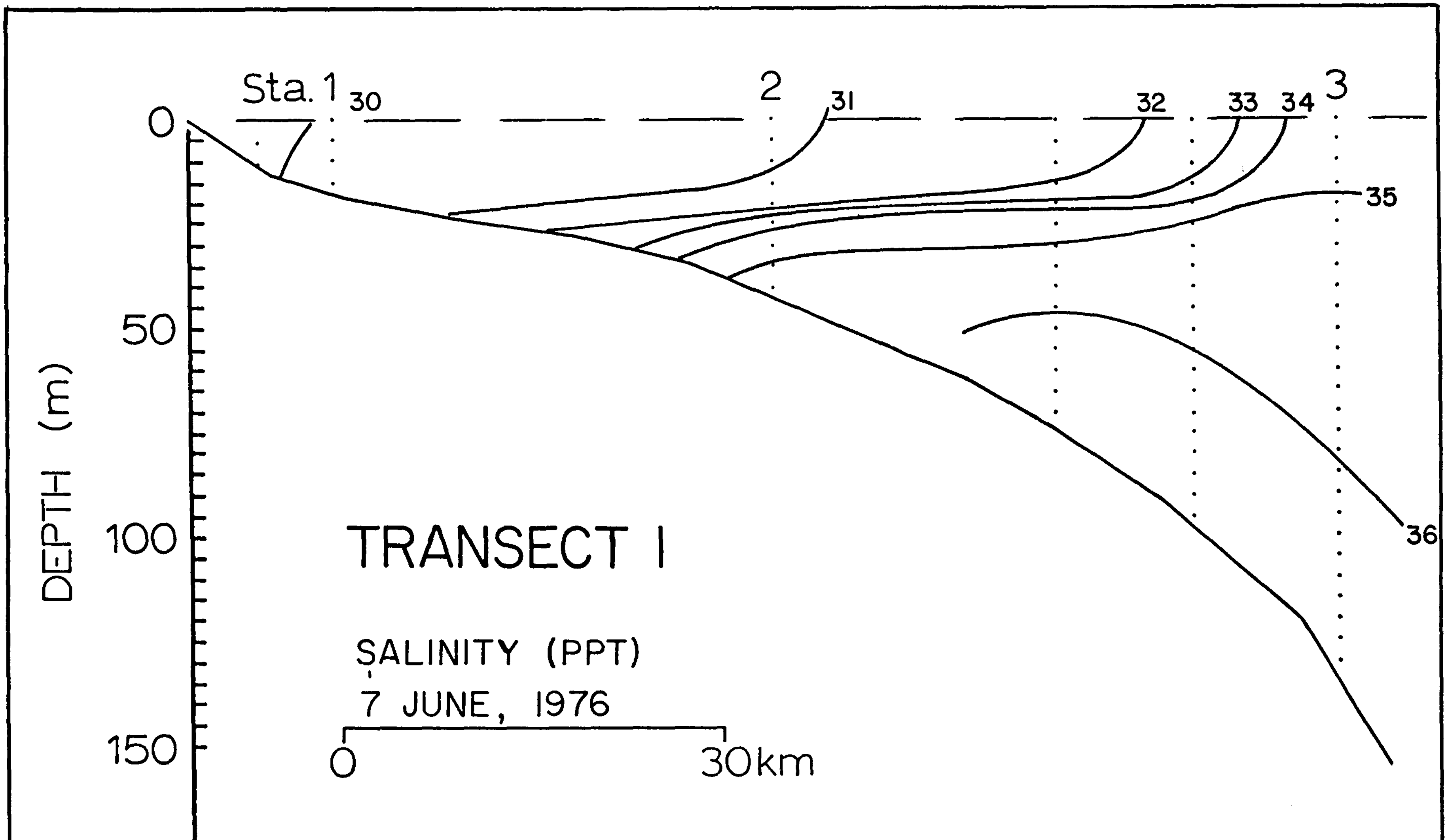
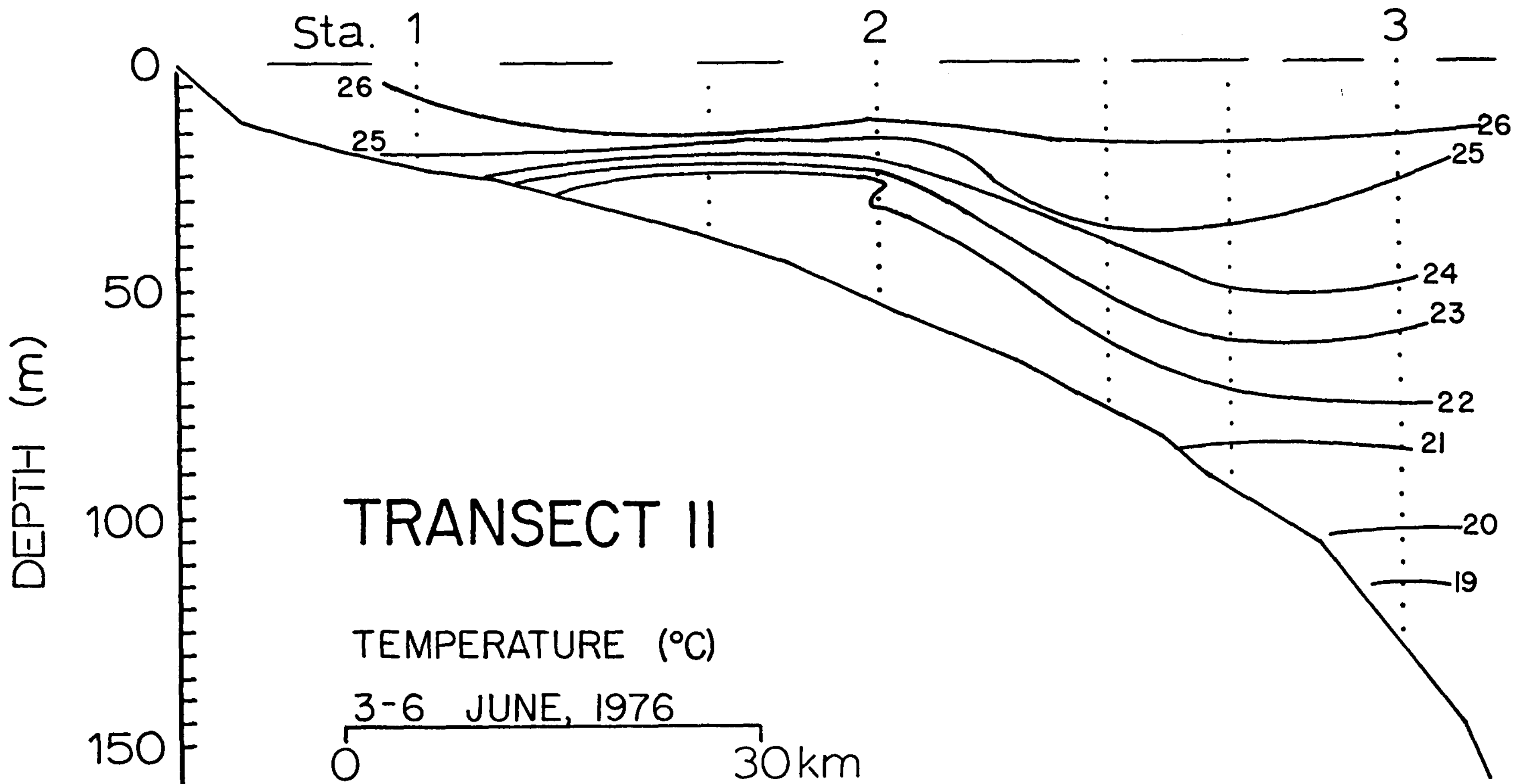

Sta. 1
2
3
30
31
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT I
SALINITY (PPT)
7 JUNE, 1976
0
30km

FIGURE 17.



Sta. 1
2
3
0
50
100
150
DEPTH (m)
26
25
26
25
24
23
22
21
20
19
TRANSECT II
TEMPERATURE (°C)
3-6 JUNE, 1976
0
30 km

FIGURE 18

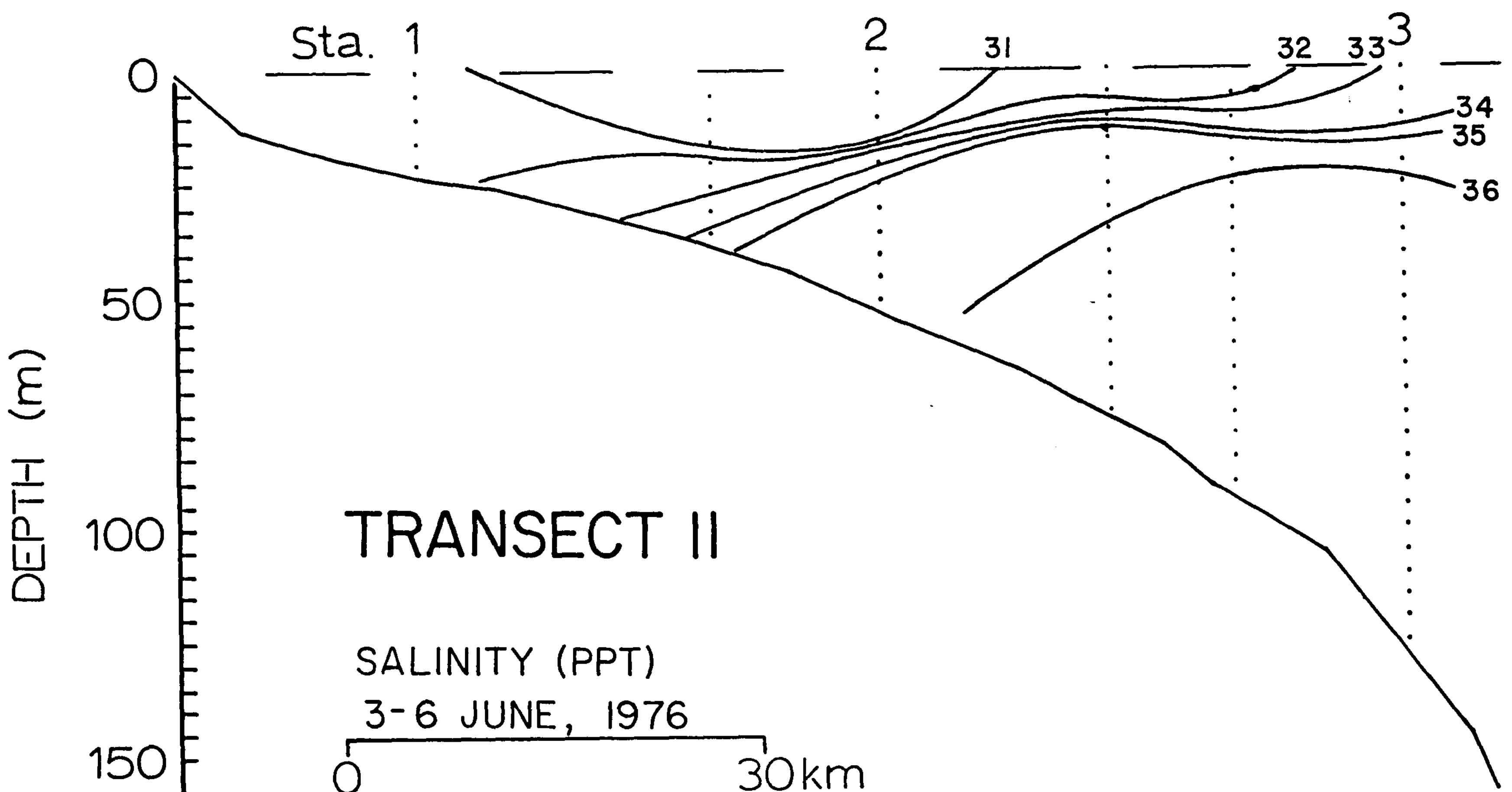
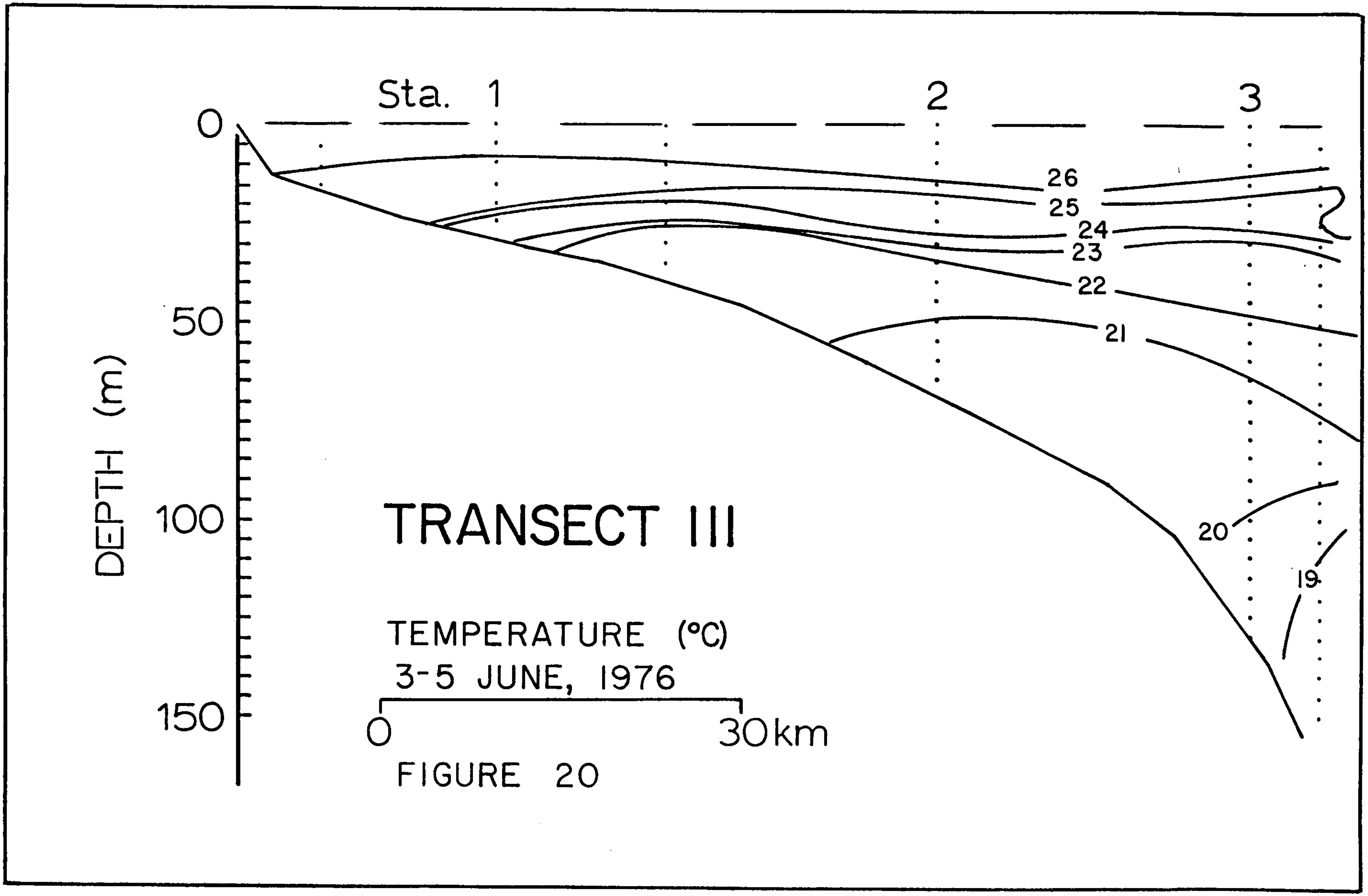

Sta. 1
2
3
31
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT II
SALINITY (PPT)
3-6 JUNE, 1976
0
30km

FIGURE 19.



Sta. 1
2
3
0
50
100
150
DEPTH (m)
26
25
24
23
22
21
20
19
TRANSECT III
TEMPERATURE (°C)
3-5 JUNE, 1976
0
30km

FIGURE 20

nearly horizontal isotherms, except at near-bottom levels at the outer two stations, and a pronounced seasonal thermocline, enclosed by the 26° and 22° isotherms. The near-bottom temperatures at Stations 3/III and 6/III were essentially unchanged from those observed during the first seasonal cruise on 1 February 1976.

A well-developed halocline (Figure 21), enclosed by the 32- and 35-ppt isohalines, formed just seaward of Station 1/III and extended beyond the end of the transect. In sharp contrast, the water column at the inner two stations, and particularly at Station 4/III, was nearly isohaline. Salinities greater than 36 ppt were found below the 50-m level at the outer three stations.

Transect IV (30-31 May 1976)

A strong and quite shallow seasonal thermocline sloped downward through the inner three stations (Figure 22). The depth of the maximum temperature gradient increased from 10 to 20 m between Stations 4/IV and 5/IV. Isotherms diverged with increasing distance from shore, and below the wind-mixing layer, temperatures decreased relatively uniformly with increasing depth at the outer two stations. Lowest temperatures were again just below 18°C.

Surface salinities below 33 ppt extended the length of the transect, (Figure 23) except for a value of 33.30 ppt at the surface at Station 4/IV. Vertical salinity gradients were greatest between approximately the 10- and 20-m levels. This sharp halocline was a continuous feature over nearly the entire length of the transect. Salinities over 36 ppt were found below the 30-m level at the outer four stations.

Spatial Variations in Seasonal Hydrographic Data

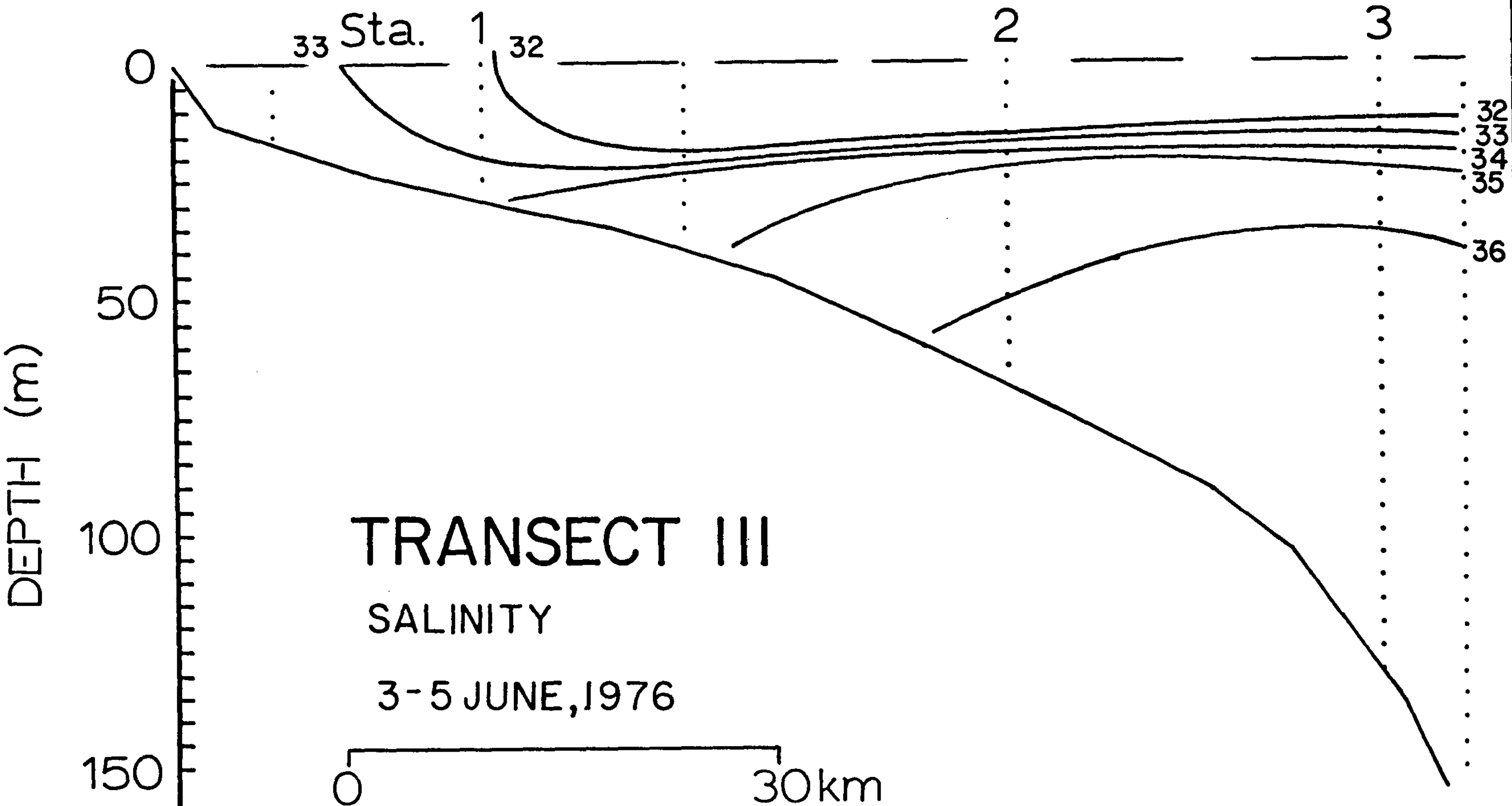
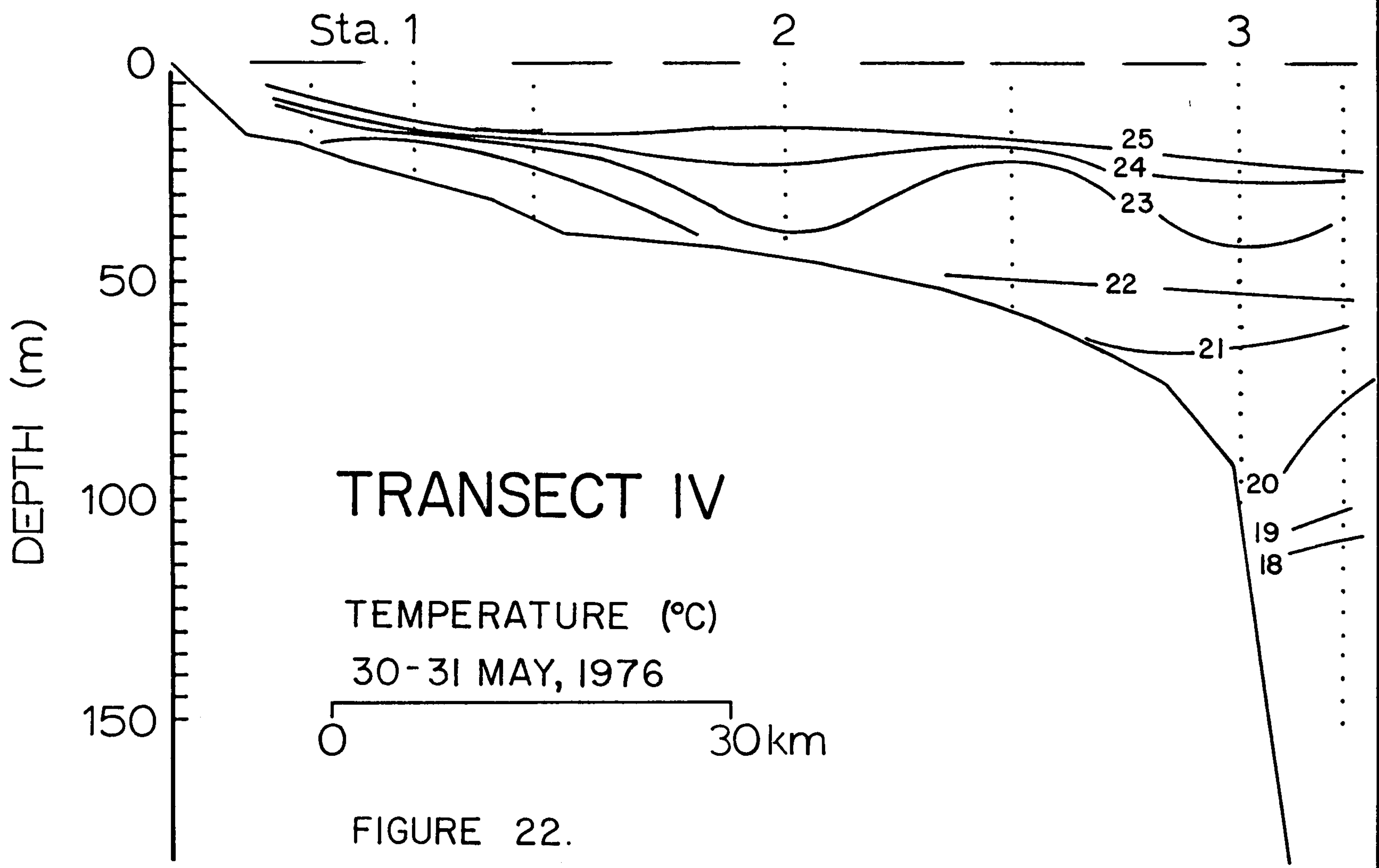

Sta. 1
2
3
0
50
100
150
DEPTH (m)
33
32
32
33
34
35
36
TRANSECT III
SALINITY
3-5 JUNE, 1976
0
30km

FIGURE 21.



Sta. 1
2
3
0
50
100
150
DEPTH (m)
25
24
23
22
21
20
19
18
TRANSECT IV
TEMPERATURE (°C)
30-31 MAY, 1976
0
30km

FIGURE 22.

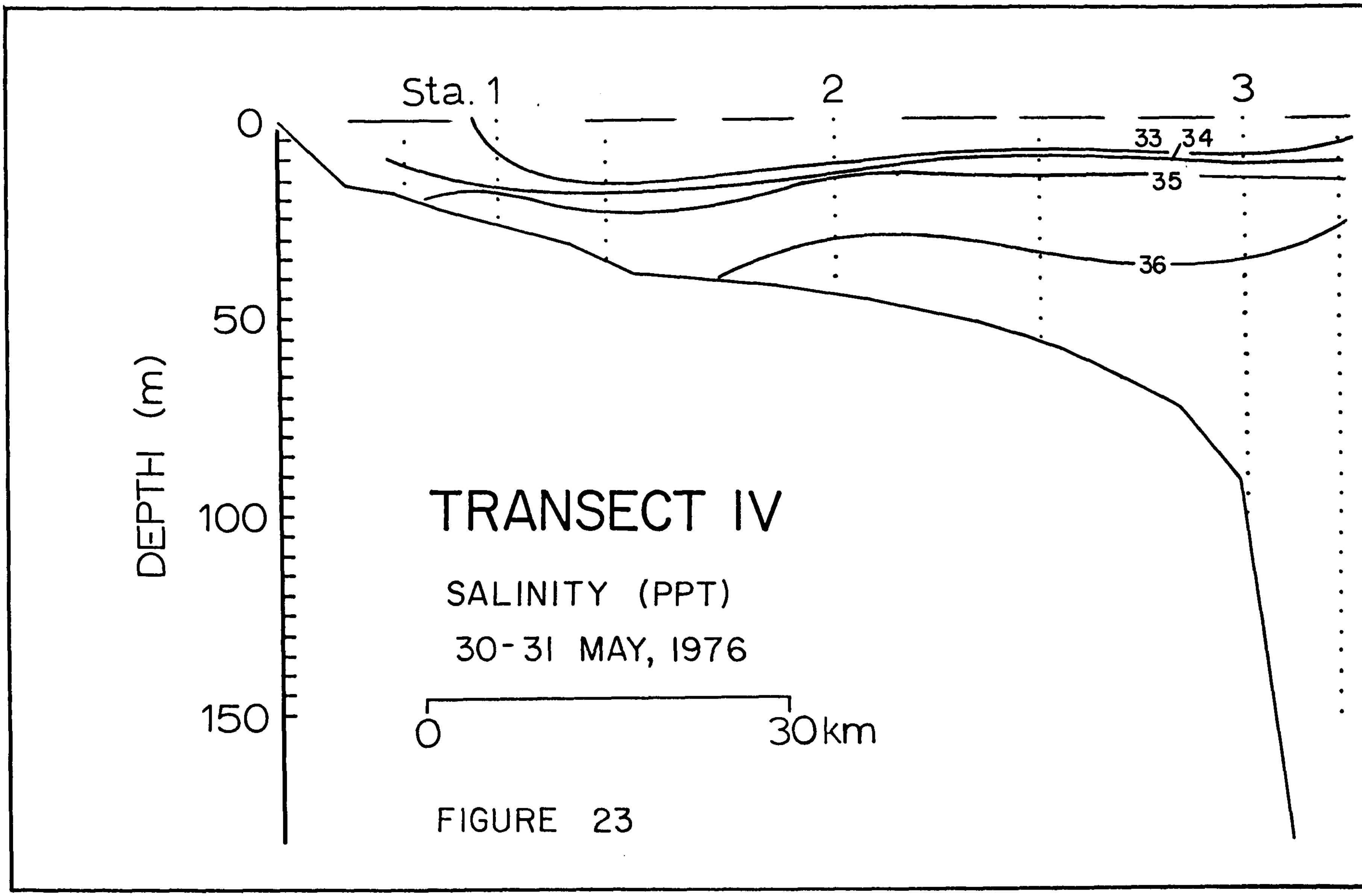

Sta. 1
2
3
0
50
100
150
DEPTH (m)
33
34
35
36
TRANSECT IV
SALINITY (PPT)
30-31 MAY, 1976
0
30km

FIGURE 23

Surface Temperature Pattern

The composite of the surface calibration temperatures (Figure 24) was rather uninteresting due to the great spatial uniformity. The pattern was characterized by surface temperatures between 26.1°C and 26.9°C along the nothern three transects, and between 25.4 and 25.95°C along Transect IV. This may be attributed to the spatial uniformity in surface heating and a lack of vertical overturning, which would otherwise produce a pattern which was depth-dependent. Heat is thus retained within the layer above the seasonal thermocline, that is, within the upper 10-20 m over the entire outer continental shelf.

Surface Salinity Pattern

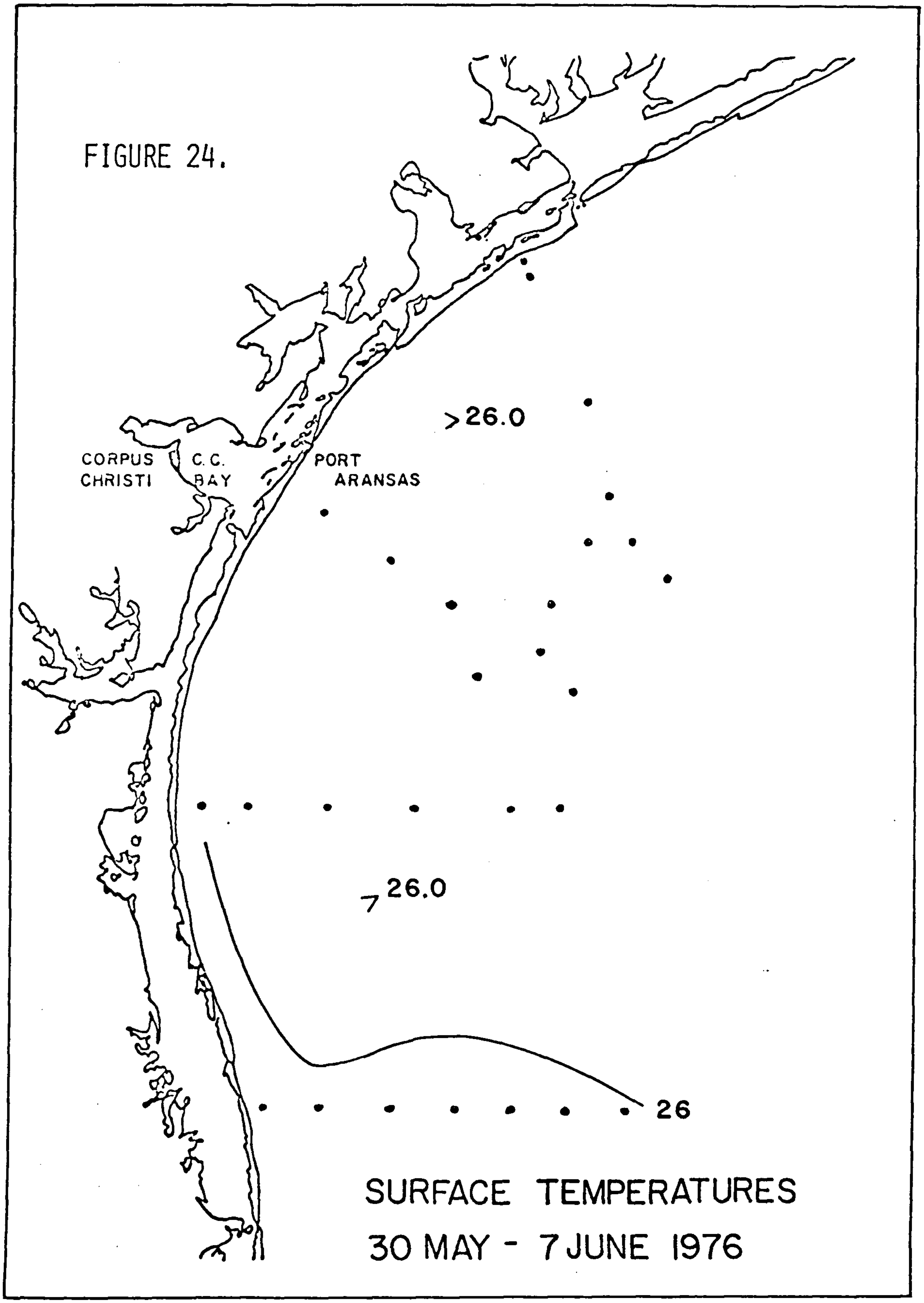
Surface isohalines (Figure 25) show clearly the effects of the spring run-off as a broad layer of relatively low salinity water. Surface salinities were between 30.4 and 34.9 ppt over the entire Texas outer continental shelf.

The pattern was a disorganized one, with little continuity extending over the entire study area. The data may indicate a plume of low salinity water, cut off from the coast and moving southward. This interpretation is supported by the 31- and 32-ppt isohalines, but direct current measurements are not available to verify the postulated movement of shelf waters. Highest salinities were found at the outer station on Transect I, and along the coast between Transects III and IV.

July Monthly Cruise (10-11 July 1976)

Surface temperatures were nearly uniform (Figure 26), increasing only from 26.8 to 27.8°C between Stations 1/II and 3/II. The wave-mixed, isothermal layer extended through approximately the upper 20 m, with temperatures varying as little as 0.04°C at four of the six stations.

FIGURE 24.



SURFACE TEMPERATURES
30 MAY - 7 JUNE 1976

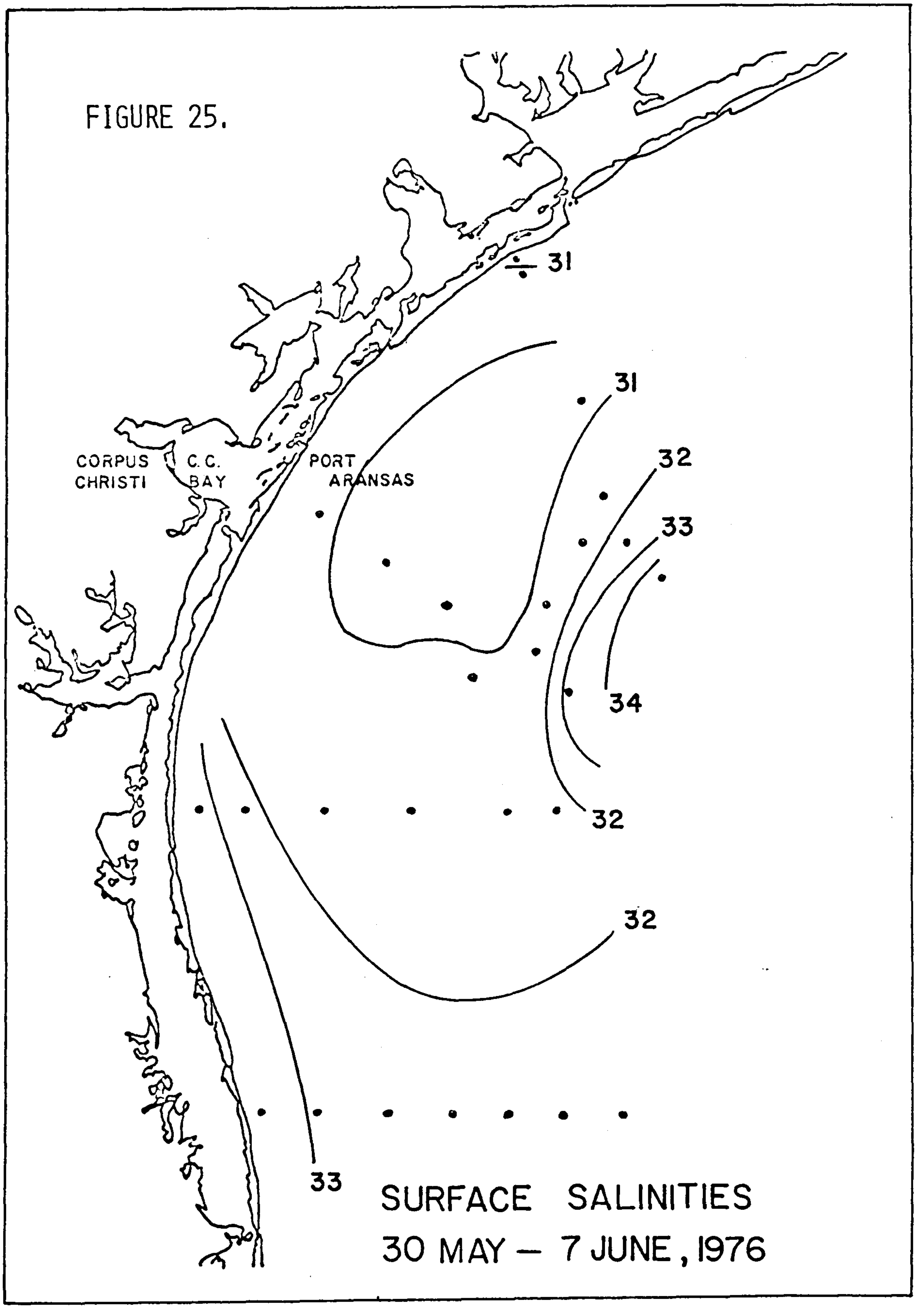


FIGURE 25.
CORPUS CHRISTI
C.C. BAY
PORT ARANSAS
31
31
32
33
34
32
32
33
SURFACE SALINITIES
30 MAY — 7 JUNE, 1976

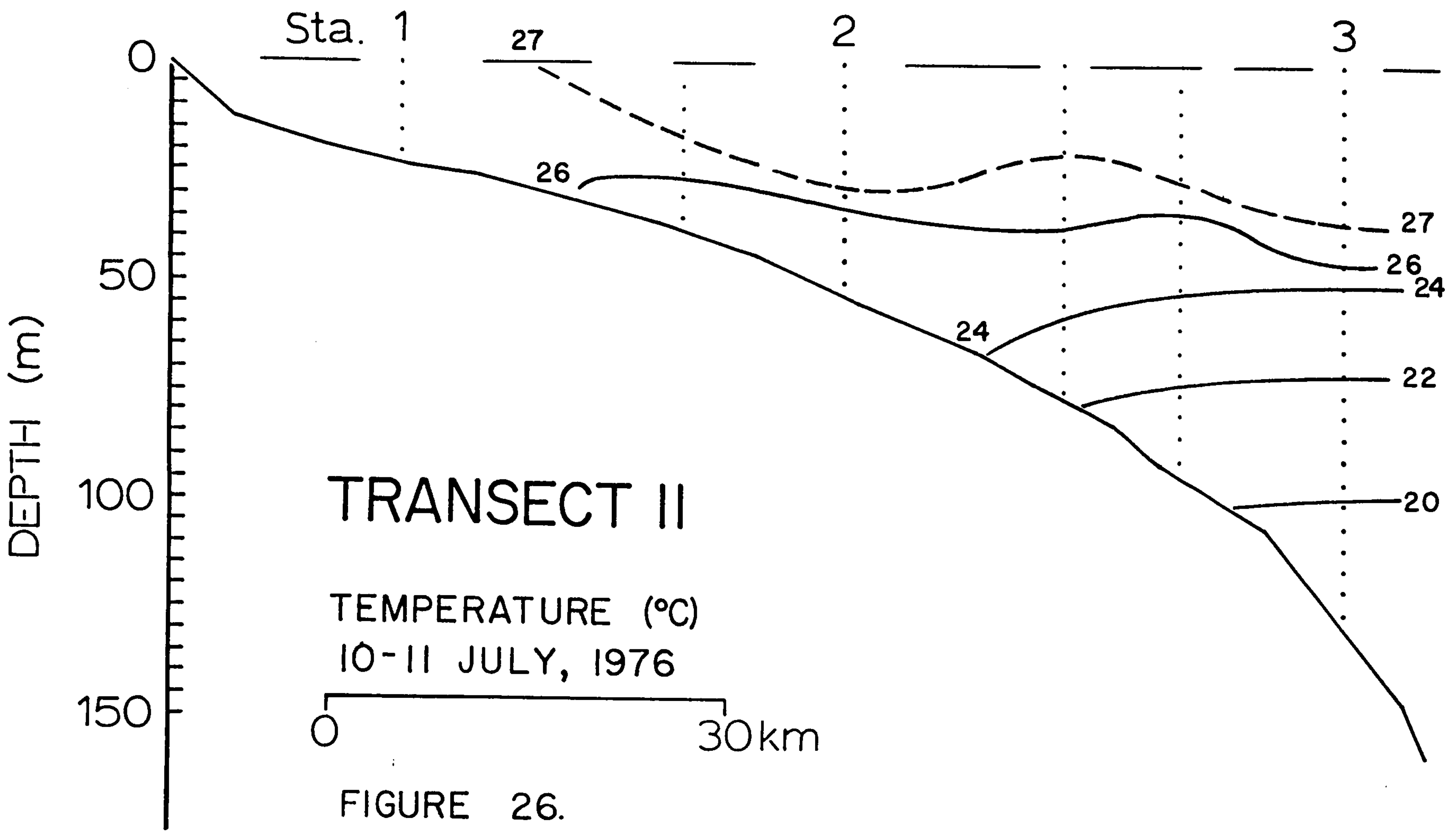

Sta. 1
2
3
0
50
100
150
DEPTH (m)
27
26
24
22
20
TRANSECT II
TEMPERATURE (°C)
10-11 JULY, 1976
0
30km

FIGURE 26.

The top of the seasonal thermocline occurred at the 25- to 30-m level. The decrease of temperature with increasing depth varied somewhat along Transect II, with stronger vertical gradients at the outer stations. Lowest temperatures recorded were slightly over 18°C just above the bottom at Station 3/II.

The salinity cross-section (Figure 27) indicated somewhat lower values along the inner shelf, and again well-mixed conditions in the upper part of the water column. Salinities just over 34 ppt were recorded in the near-surface layer at Station 1/II. The 35-ppt isohaline intersected the water column at Station 4/II at approximately the 20-m level. Vertical salinity gradients were minor along the outer part of the transect, and nearly absent below about 45 m.

August Monthly Cruise (9-11 August 1976)

The general temperature pattern (Figure 28) showed that seasonal heating in the upper part of the water column has resulted in surface temperatures between 1 and 2°C warmer than those found on the July monthly cruise. Surface temperatures varied between 28.7 and 29.3°C, and again increased slightly in an offshore direction. At the same time, near-bottom temperatures at Station 3/II were almost 1°C cooler than those recorded in July. While the vertical temperature gradient was greater in August, the thermocline tended to be relatively weak, with the exception of the near-bottom layer at Station 5/II, where the temperature decreased nearly 7°C between the 60- and 70-m levels.

The salinity cross-section (Figure 29) was relatively undistinguished. However, it is noteworthy that lowest salinities were found in a shallow lens which had been displaced approximately 30 km from the coast. Vertical salinity gradients at all stations were weak.

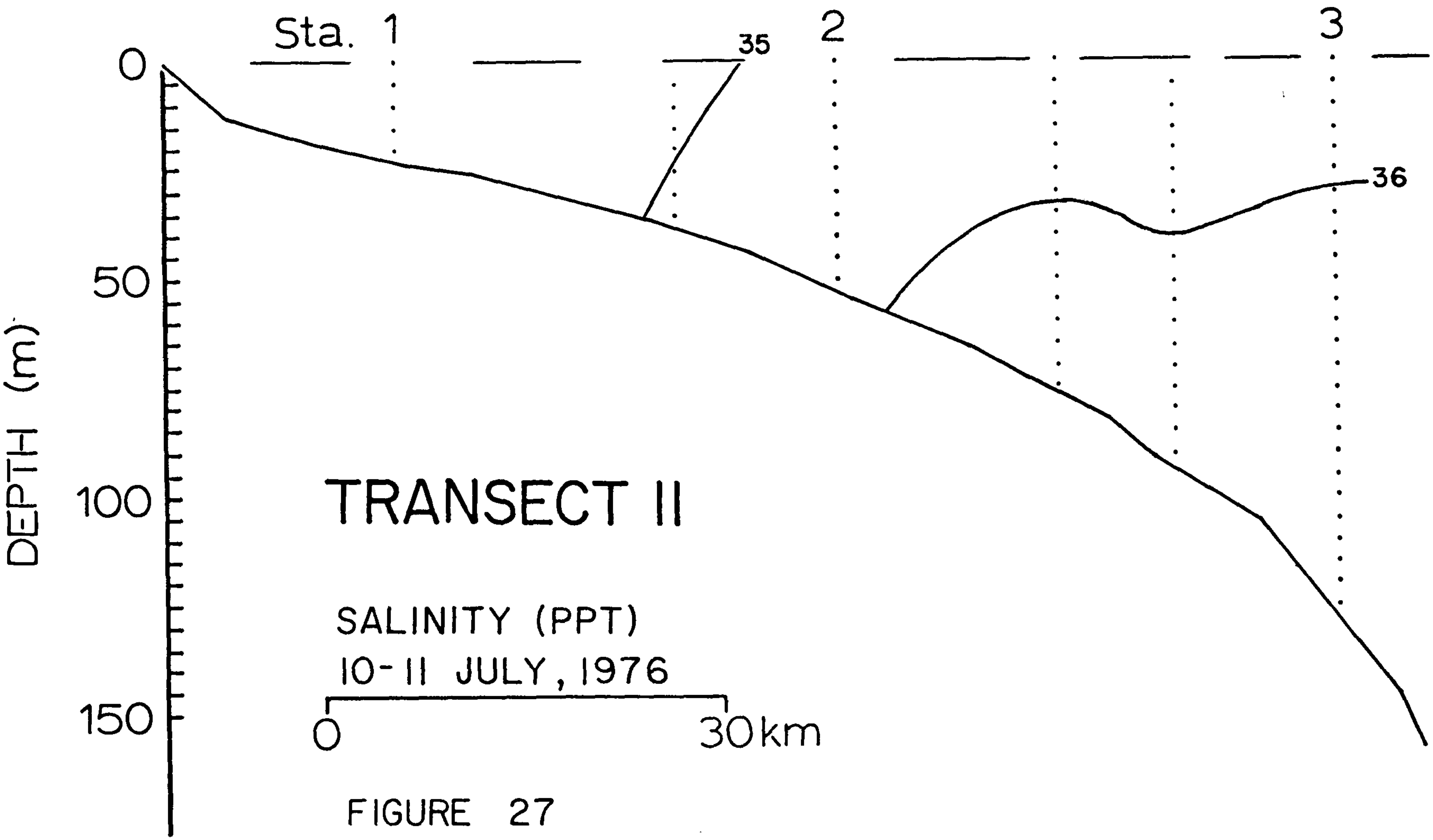
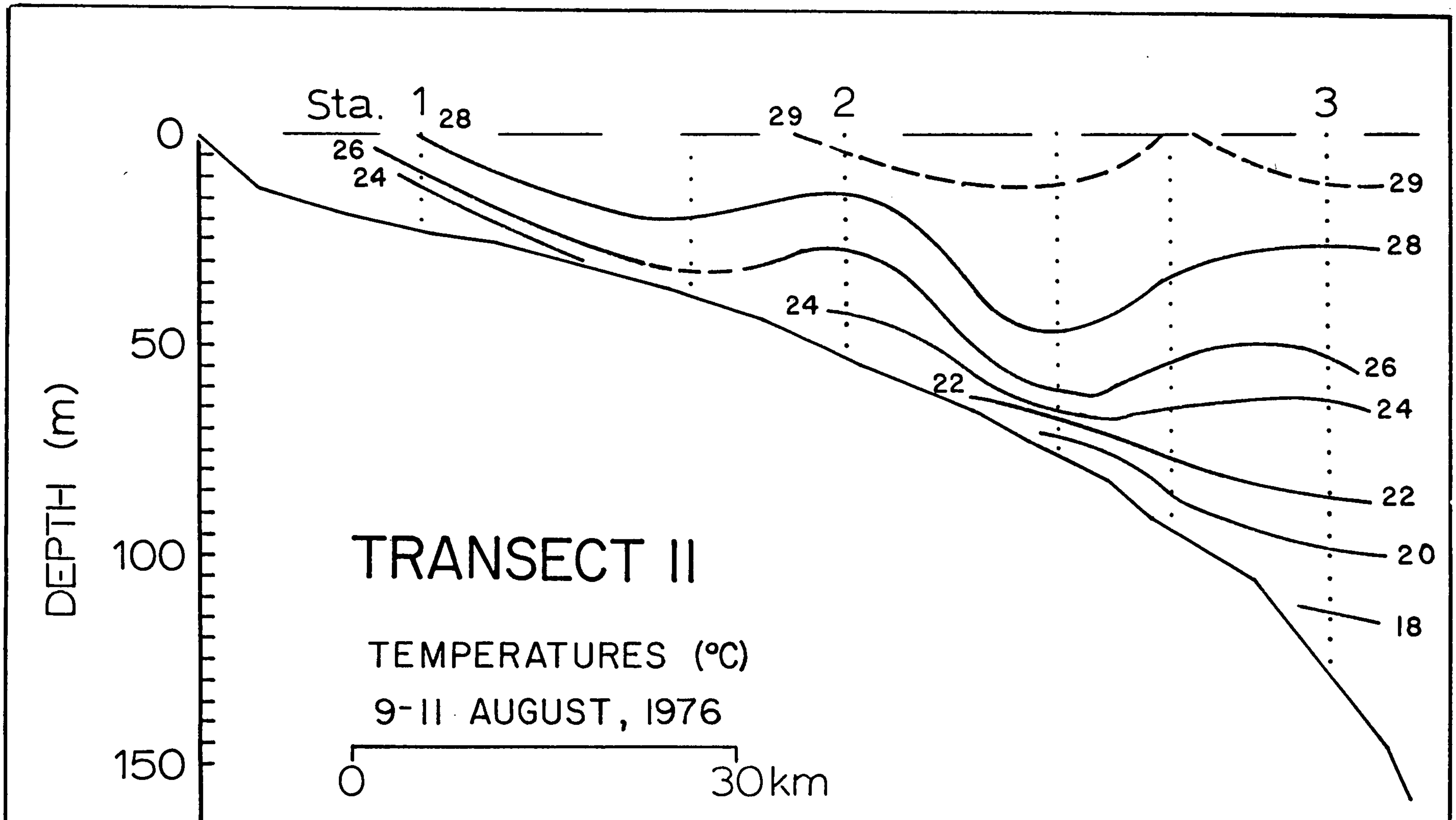

Sta. 1
2
3
35
36
0
50
100
150
DEPTH (m)
TRANSECT II
SALINITY (PPT)
10-11 JULY, 1976
0
30km

FIGURE 27



Sta. 1
2
3
28
29
26
24
22
20
18
0
50
100
150
DEPTH (m)
TRANSECT II
TEMPERATURES (°C)
9-11 AUGUST, 1976
0
30km

FIGURE 28.

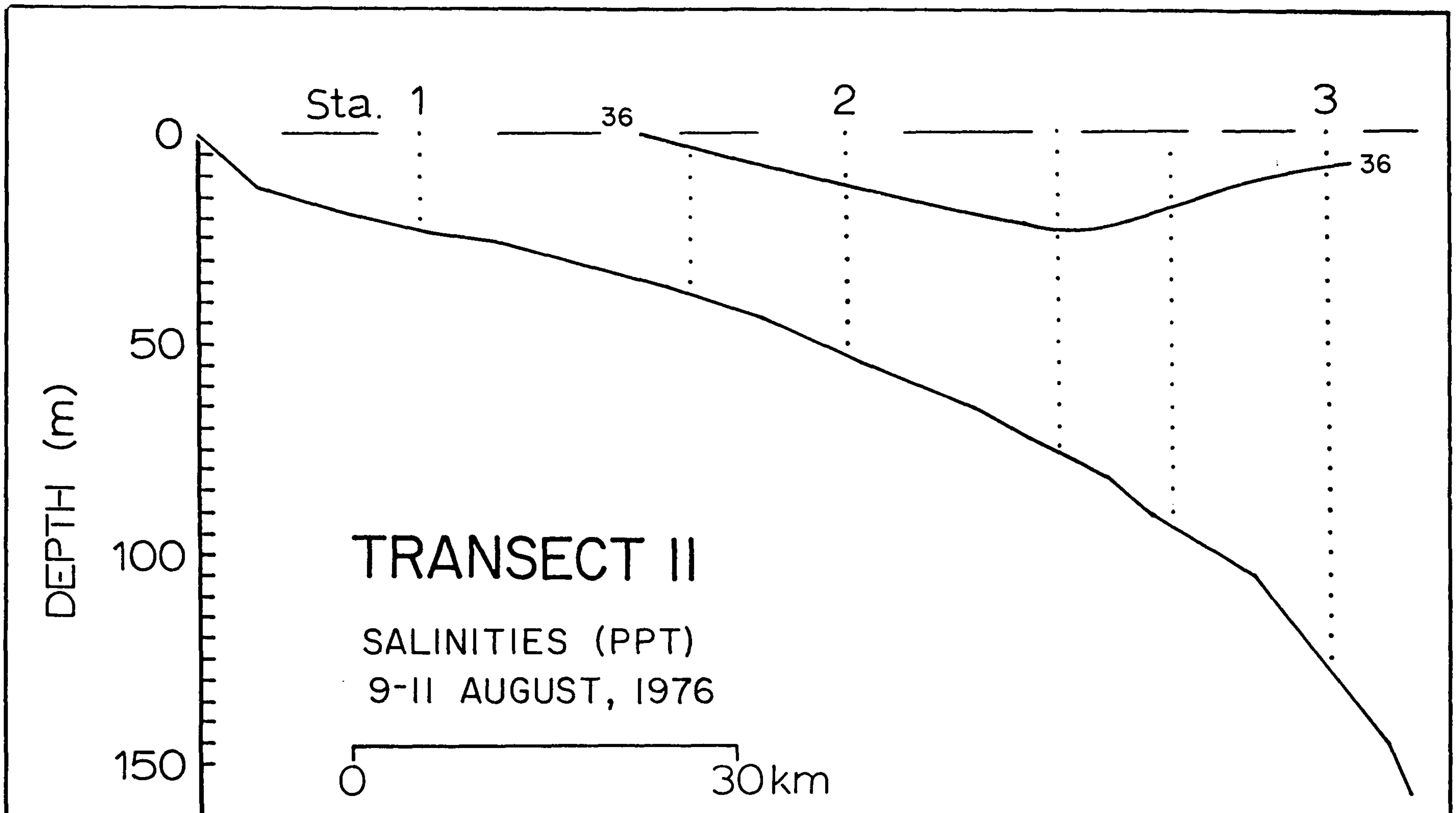

Sta. 1
2
3
36
36
0
50
100
150
DEPTH (m)
TRANSECT II
SALINITIES (PPT)
9-11 AUGUST, 1976
0
30km

FIGURE 29.

Summer-Fall Seasonal Cruise (10-16 September 1976)

Temperature Cross-Sections, Transects I through IV

The four temperature cross-sections are most appropriately considered together. There were some features shared in all cases, and the differences are best brought out by a direct comparison.

All four cross-sections (Figures 30, 31, 32, 33) showed a relatively isothermal surface layer extending down through the upper 20-40 m. Wave mixing seemed to have extended deeper into the water column along Transects I and IV (Figures 30 and 33). A characteristic of the postulated surface layer convergence along central Padre Island (Leipper, 1954) would be a thickening of the surface layer as isothermal surfaces were depressed in this area.

Near-bottom water along the outer parts of Transects I and IV was approximately 1.5-2.0° colder, with lowest temperatures below 17°C.

Strongest vertical temperature gradients through the seasonal thermocline occurred irregularly at Transects I, III and IV. Temperatures along Transect II fell somewhat more uniformly with depth below the wave-mixed layer. Strongest vertical temperature gradients occur in mid-shelf waters along Transect IV.

Salinity Cross-Sections, Transects I through IV

The salinity cross-sections along the four transects (Figures 34, 35, 36 and 37) showed a gradual north-to-south decrease in the influence of freshwater run-off. The pattern along the inner shelf at Transect I (15-16 September 1976) was somewhat reminiscent of that found during the spring seasonal cruise. Lowest salinities of 32.9 ppt were found at Station 4/I, and salinities over 36 ppt were found only in the near-bottom waters at Station 2/I. The 36-ppt isohaline reached nearly

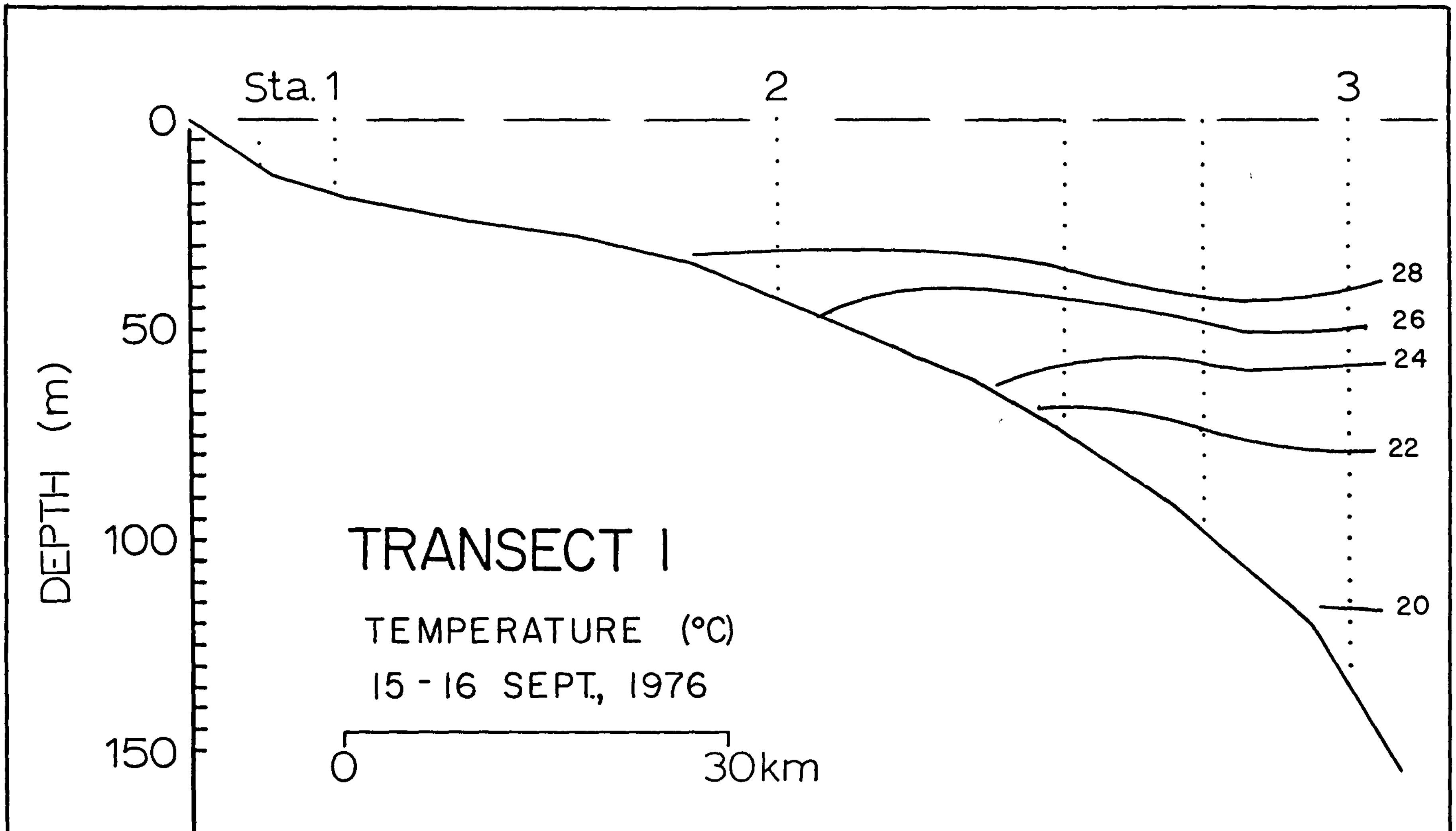

Sta. 1
2
3
0
50
100
150
DEPTH (m)
28
26
24
22
20
TRANSECT I
TEMPERATURE (°C)
15 - 16 SEPT., 1976
0
30km

FIGURE 30

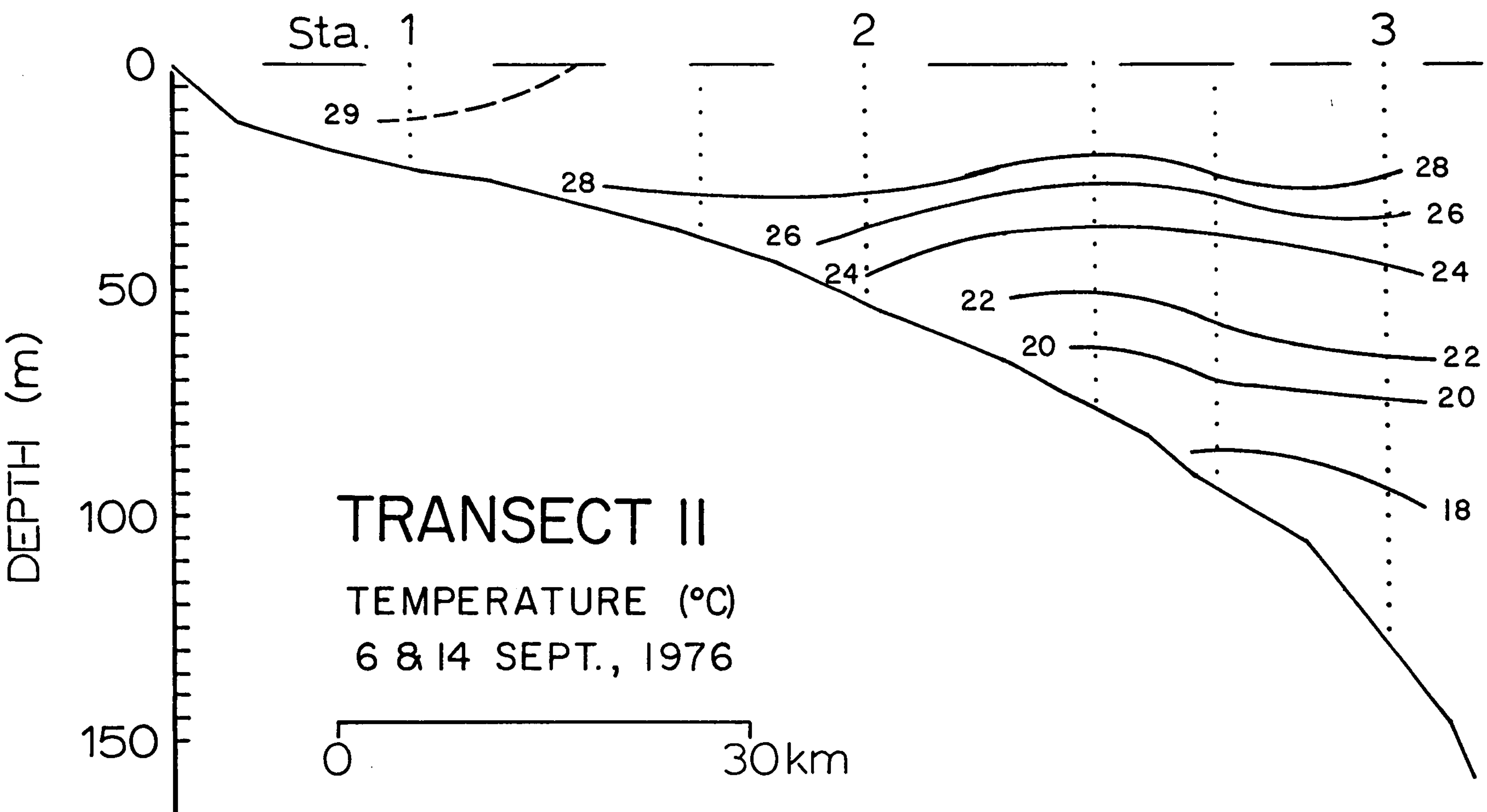
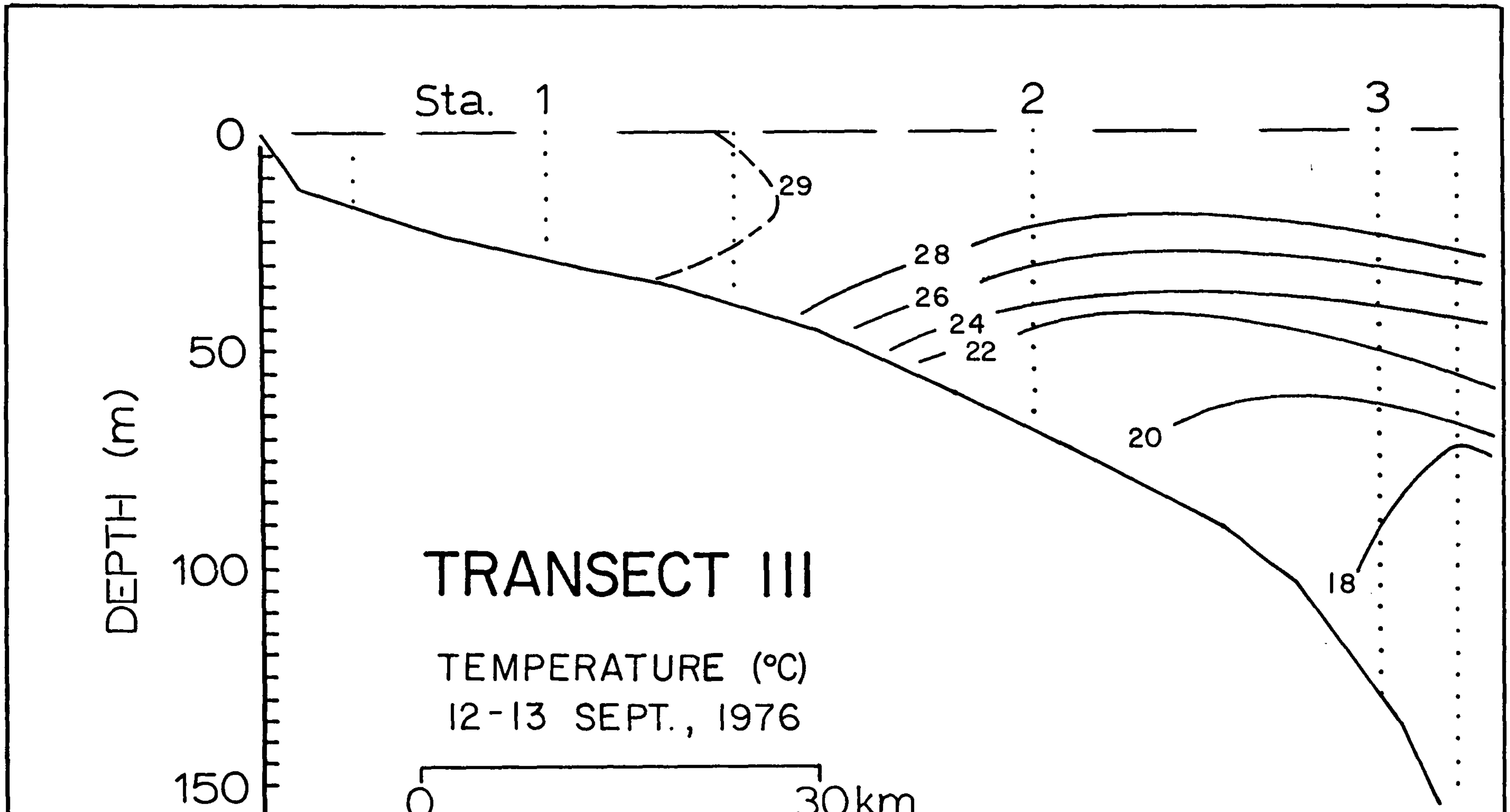

Sta. 1
2
3
0
50
100
150
DEPTH (m)
29
28
26
24
22
20
18
TRANSECT II
TEMPERATURE (°C)
6 & 14 SEPT., 1976
0
30km

FIGURE 31.



Sta. 1
2
3
0
50
100
150
DEPTH (m)
29
28
26
24
22
20
18
TRANSECT III
TEMPERATURE (°C)
12-13 SEPT., 1976
0
30km

FIGURE 32.

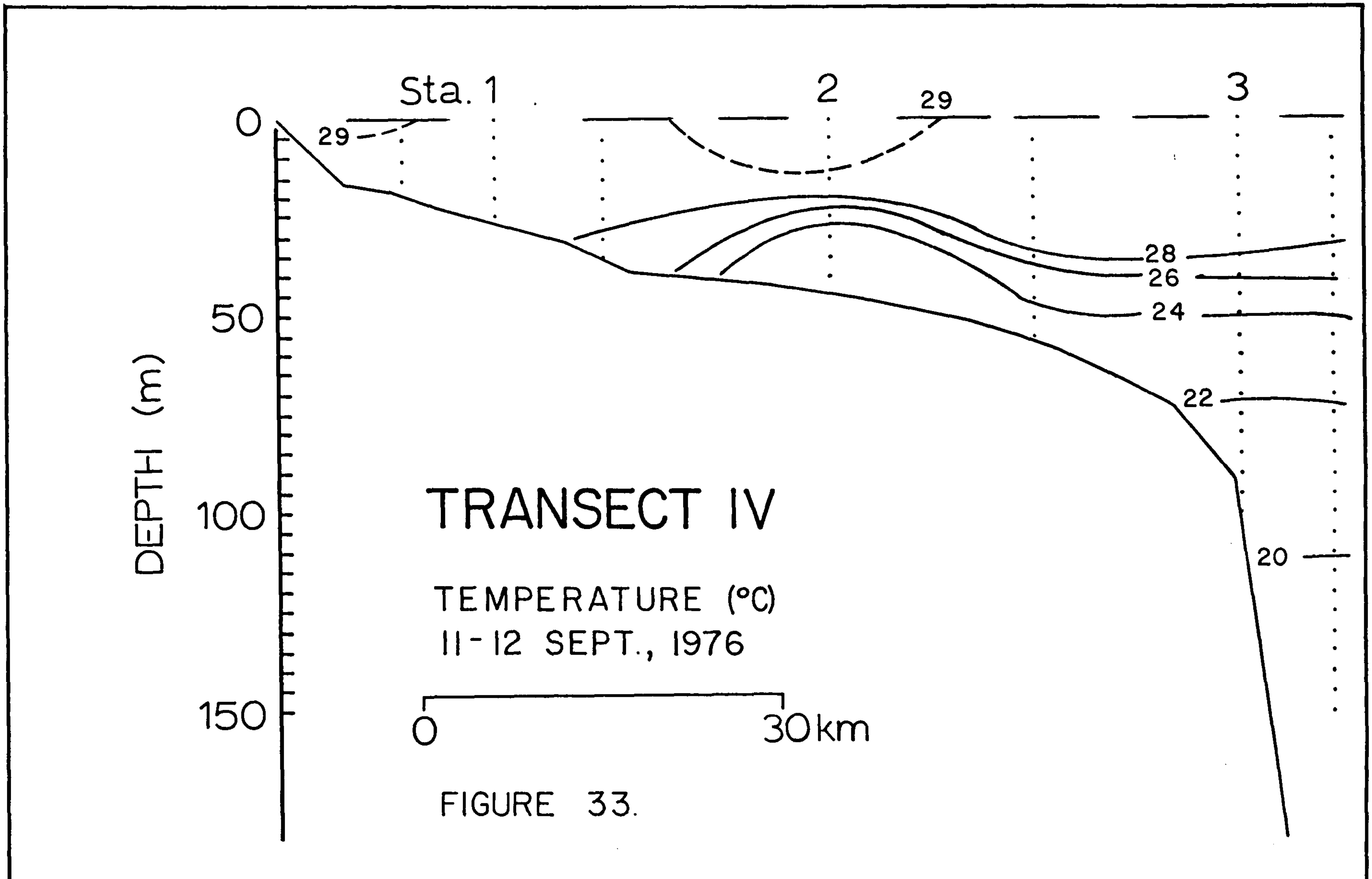

Sta. 1
2
3
29
29
28
26
24
22
20
0
50
100
150
DEPTH (m)
TRANSECT IV
TEMPERATURE (°C)
11-12 SEPT., 1976
0
30km

FIGURE 33.

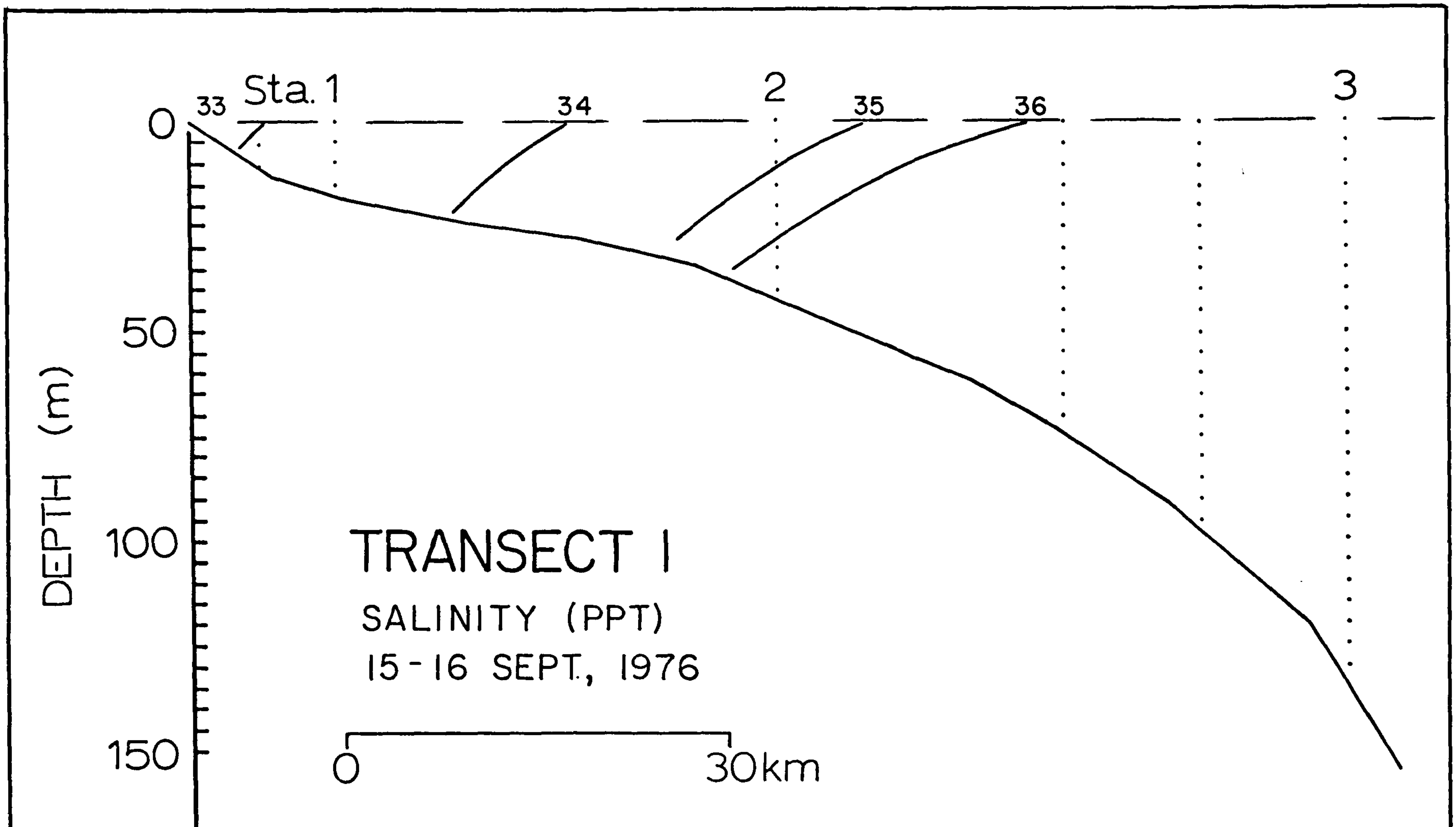

Sta. 1
2
3
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT I
SALINITY (PPT)
15-16 SEPT., 1976
0
30km

FIGURE 34

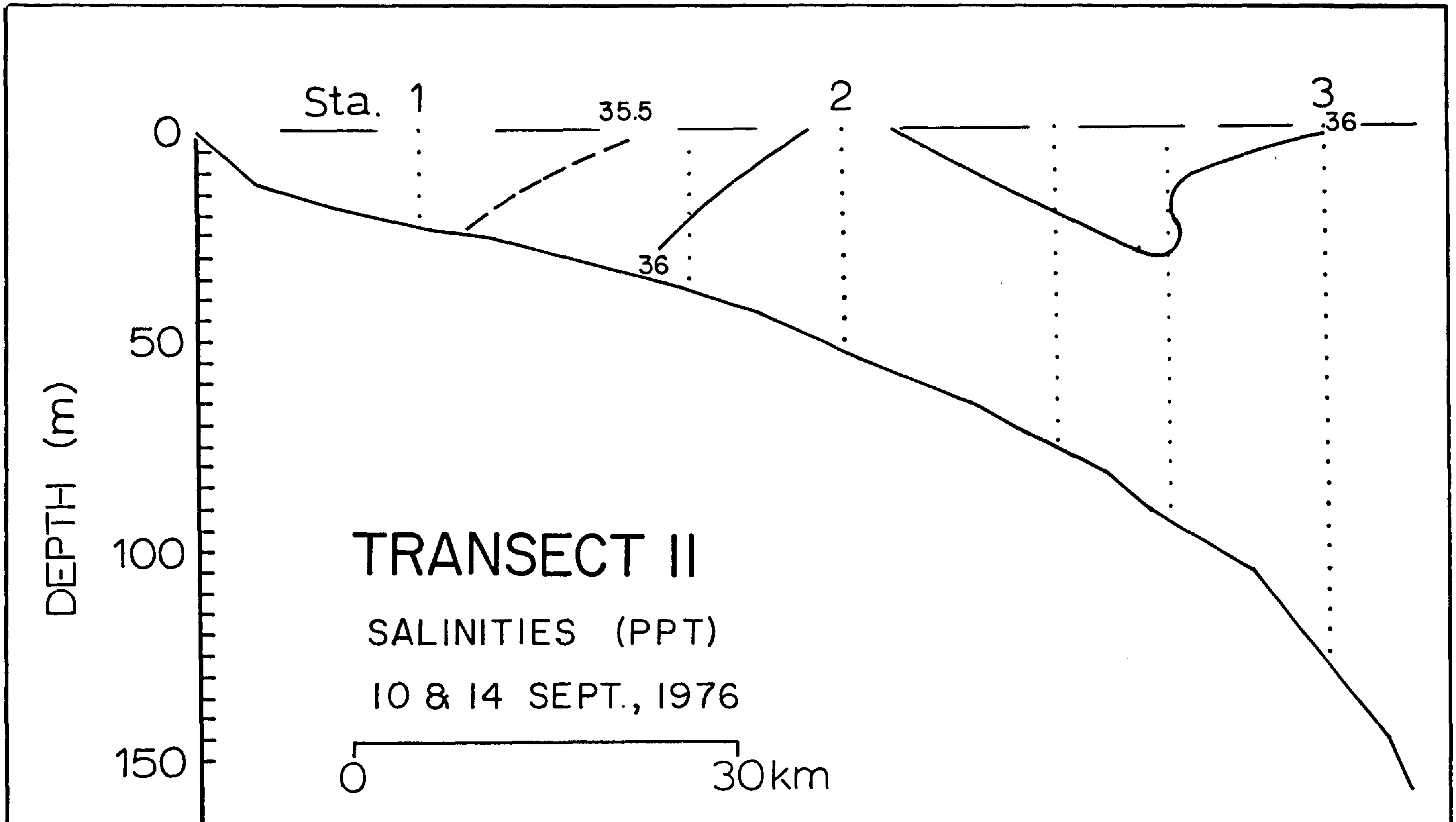

Sta. 1
2
3
35.5
36
36
0
50
100
150
DEPTH (m)
TRANSECT II
SALINITIES (PPT)
10 & 14 SEPT., 1976
0
30km

FIGURE 35.

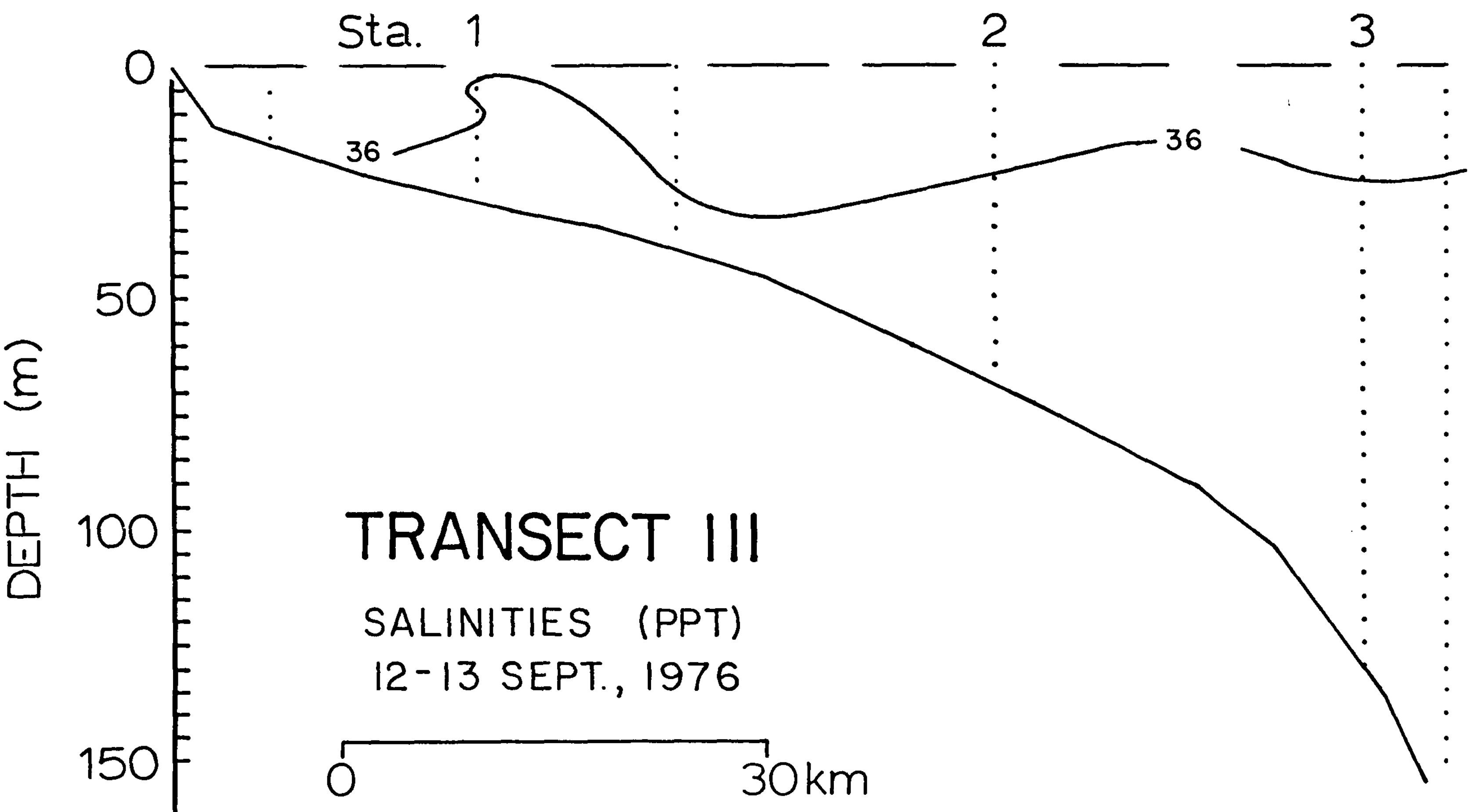

Sta. 1
2
3
0
50
100
150
DEPTH (m)
36
36
TRANSECT III
SALINITIES (PPT)
12-13 SEPT., 1976
0
30km

FIGURE 36.

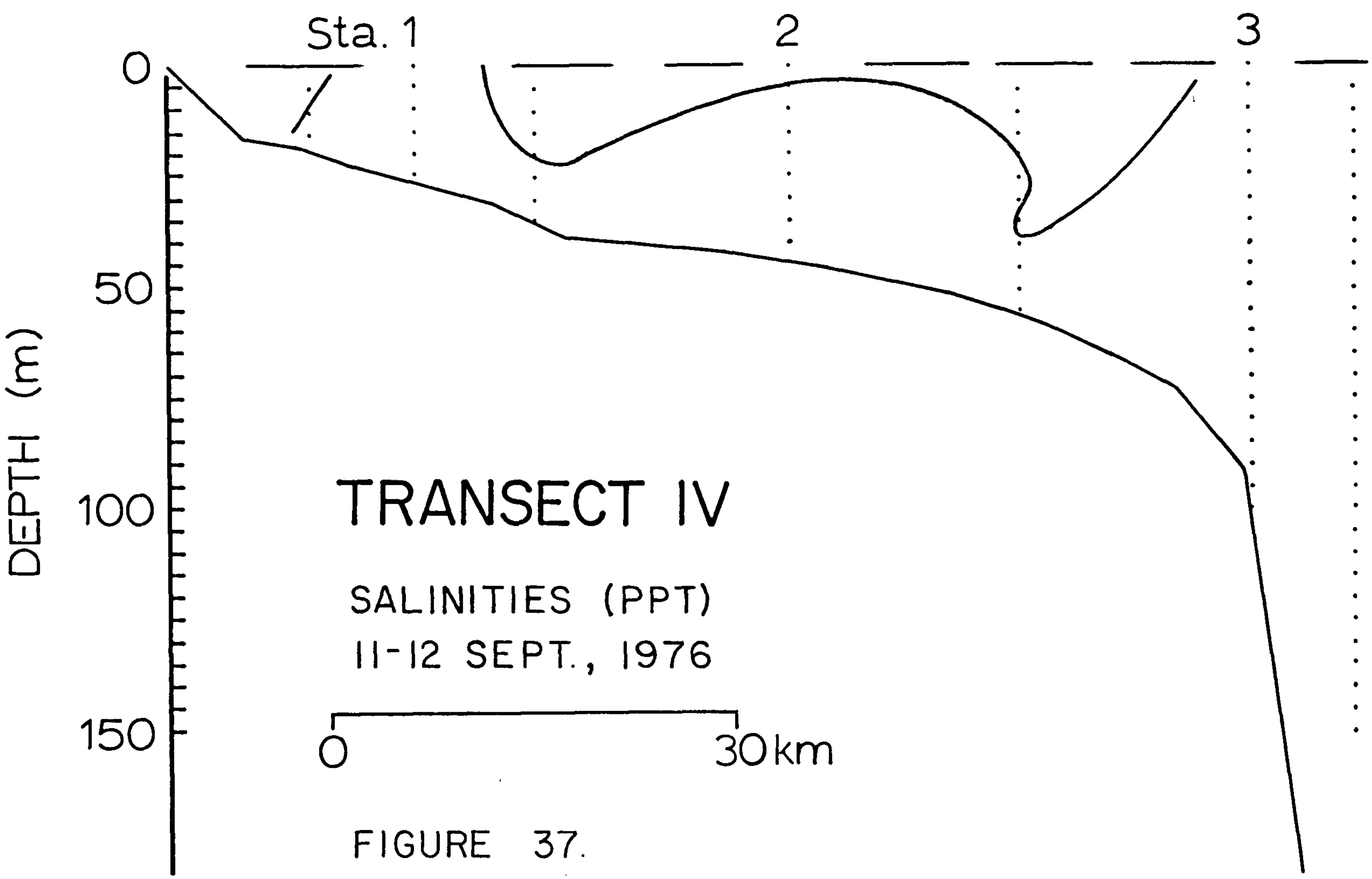

Sta. 1
2
3
0
50
100
150
DEPTH (m)
TRANSECT IV
SALINITIES (PPT)
11-12 SEPT., 1976
0
30km

FIGURE 37.

to Station 5/I. The outer three stations showed nearly isohaline salinity profiles.

The southern three transects showed an essentially similar pattern. The 36-ppt isohaline extended well onto the shelf, as salinities less than 36 ppt formed a surface layer of variable thickness which covered nearly the entire outer continental shelf.

Spatial Variations in Seasonal Hydrographic Data

Surface Temperature Pattern

All surface temperatures were within the narrow range of 28.5 - 29.7°C (Figure 38), apparently reflecting at least to some extent the effects of local diurnal heating and cooling. These temperatures describe conditions during the warmest part of the seasonal temperature curve. The surface layer was very nearly isothermal with perhaps a slight tendency for warmer temperatures along the inner continental shelf.

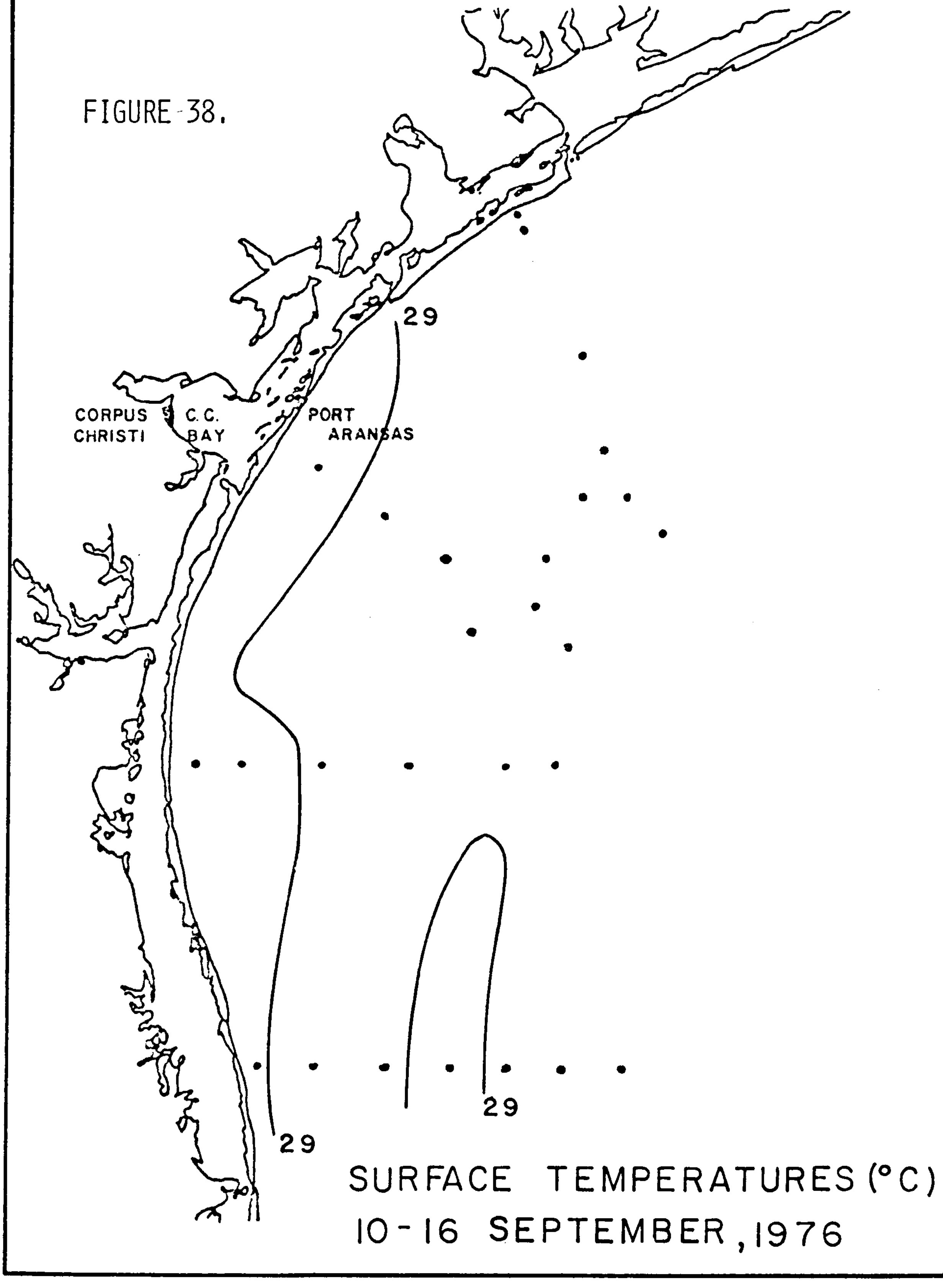
Bottom Temperature Pattern

The plan view presentation of bottom temperatures (Figure 39) shows a pattern which is primarily depth-dependent, but which also suggests water from somewhat greater depths moving up onto the outer shelf along Transects II and III. The curve in the isotherms is significantly more concave than the local isobaths. The Topographic High bottom temperatures were not used in this presentation.

Surface Salinity Pattern

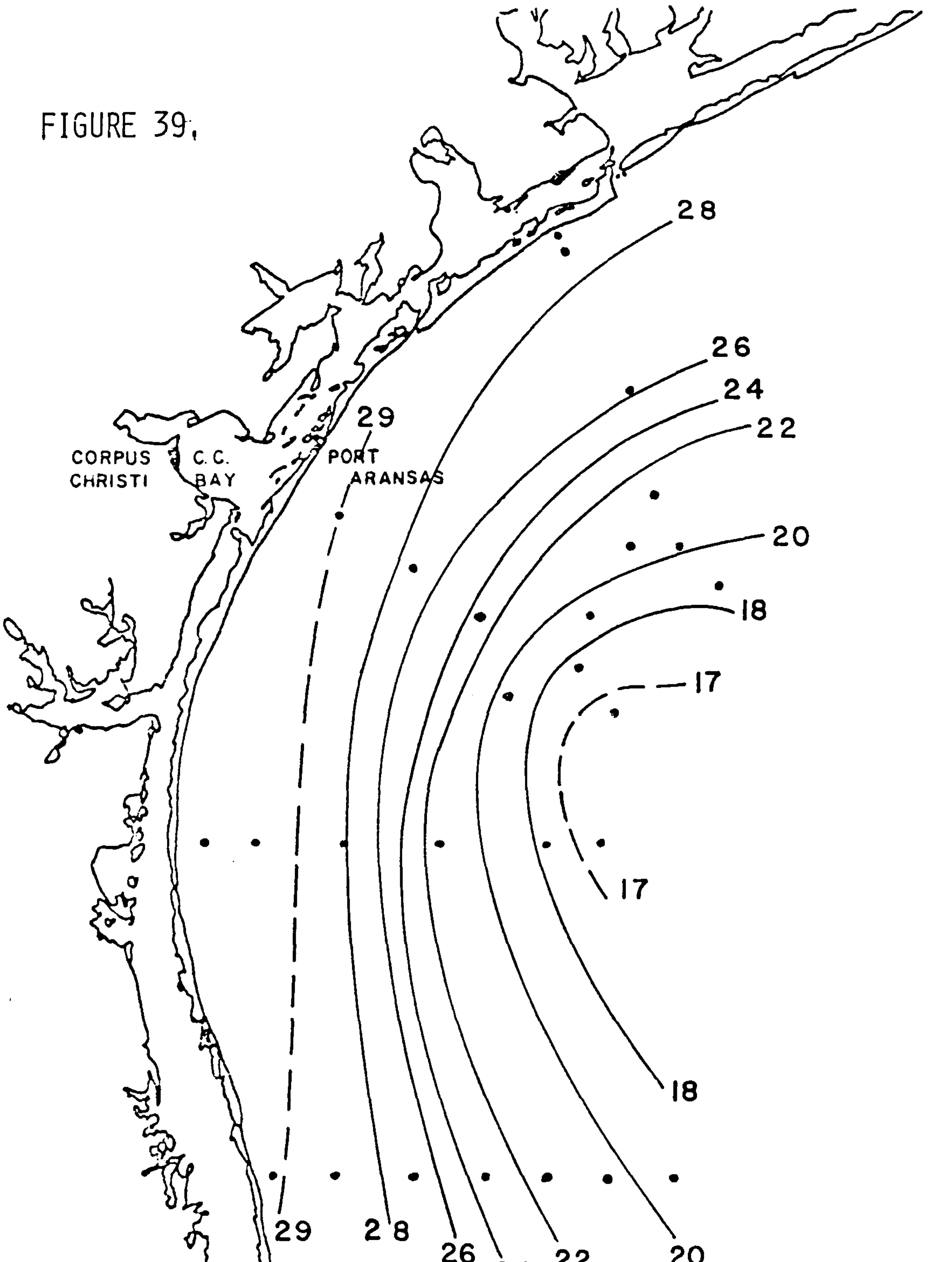
Surface salinities along the southern three transects (Figure 40) were within a fairly narrow range, varying between 35.2 and 36.3 ppt. Along Transect III and IV, there was some suggestion that lower salinity

FIGURE 38.



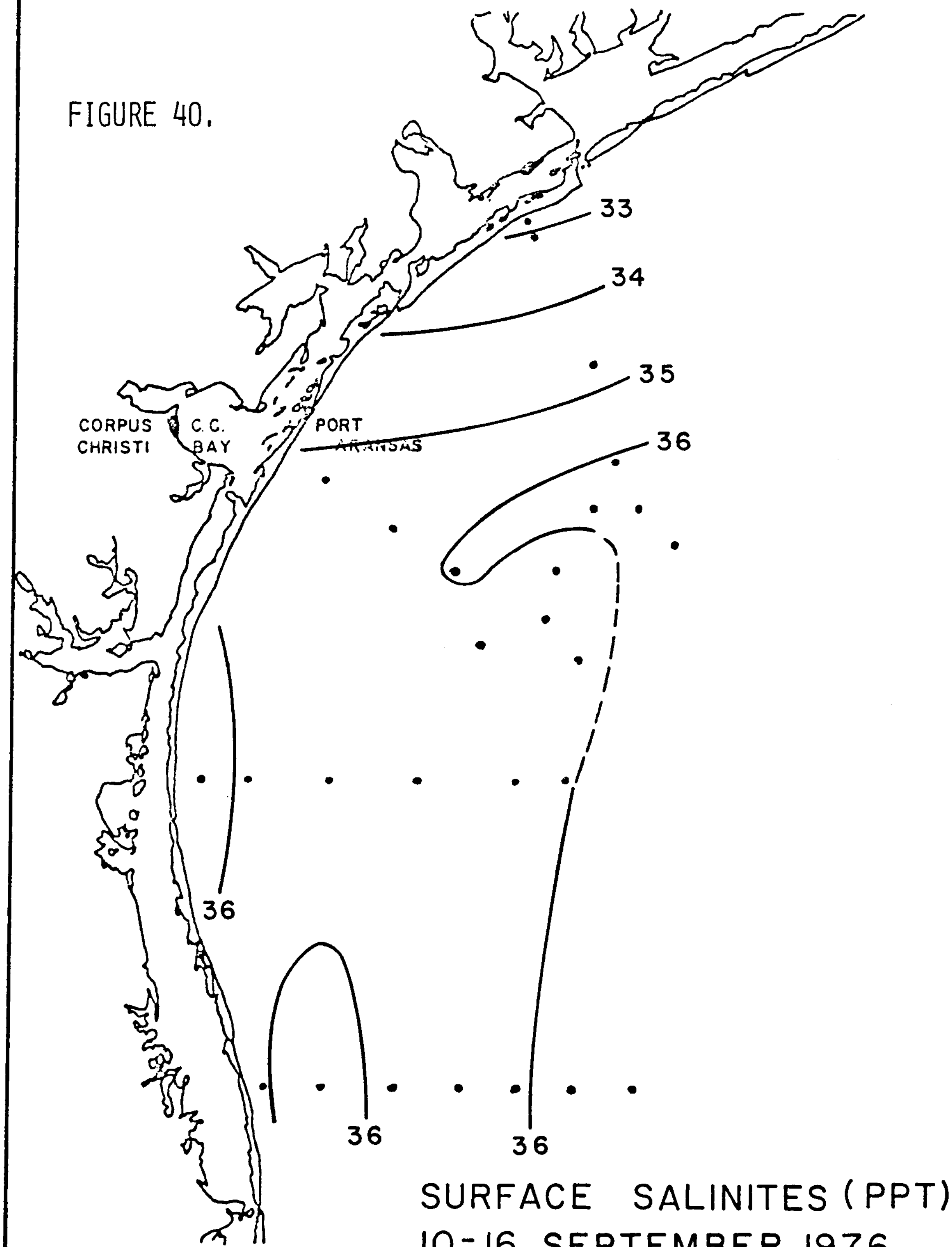
SURFACE TEMPERATURES (°C)
10-16 SEPTEMBER, 1976

FIGURE 39.



BOTTOM TEMPERATURE (°C)
10-16 SEPTEMBER, 1976

FIGURE 40.



SURFACE SALINITES (PPT)
10-16 SEPTEMBER, 1976

water was being pulled away from the coast as the gradient was directed seaward through the inner three stations.

A lens of relatively low salinity surface water occurred at Transect I, with values below 35 ppt found at the inner three stations, and the lowest salinity of just under 33 ppt measured at Station 4/I.

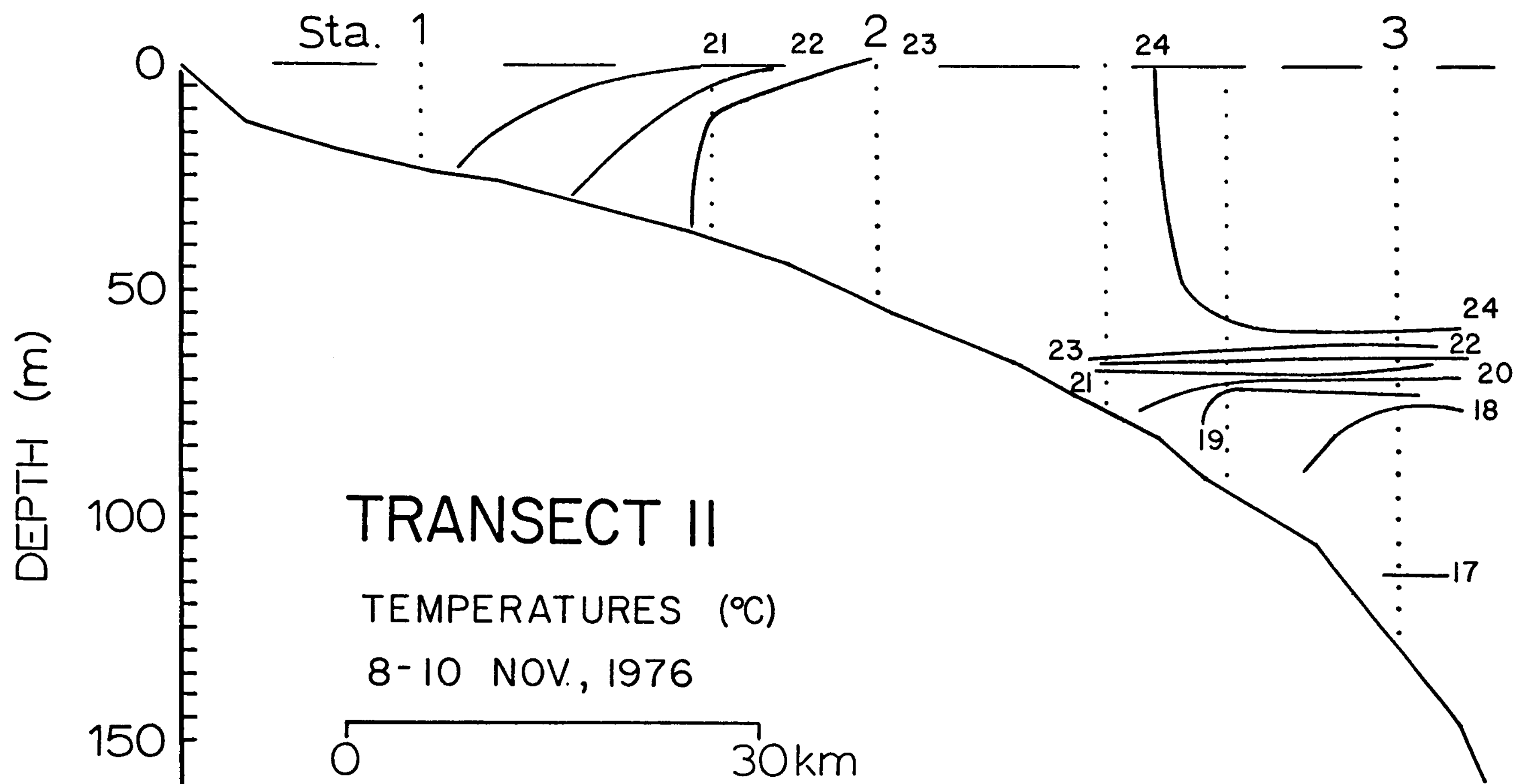
November Monthly Cruise (8-10 November 1976)

Temperature profiles showed isothermal conditions through the upper 55-60 m (Figure 41), except at Station 4/II, where some stratification was found through the upper 10 m. This was probably due to water spreading out from the inner shelf. The transition between the relatively cool waters of the inner shelf and the relatively warm waters of the outer shelf was found between Stations 4/II and 2/II at the surface, and between 1/II and 4/II at sub-surface levels. At the outer three stations, isotherms changed from a predominantly vertical to a predominantly horizontal orientation. The top of the permanent thermocline was found at approximately the 60-m level, with temperatures decreasing 4-6°C through a relatively thin, 10 to 15-m layer. Relatively little cooling was indicated in near-bottom layers at Station 3/II since the Summer-Fall Seasonal Cruise.

The Transect II salinity cross-section for the November Monthly Cruise (Figure 42) showed a near-surface layer of relatively low salinity water extending through the water column at Station 1/II, but primarily through the upper 5 m at Station 4/II. All salinities at and seaward of Station 5/II were 36 ppt or greater.

December Monthly Cruise (1-2 December 1976)

The cross-section of December temperatures (Figure 43) showed



Sta. 1
2
3
21
22
23
24
24
22
23
20
21
18
19
17
0
50
100
150
DEPTH (m)
TRANSECT II
TEMPERATURES (°C)
8-10 NOV., 1976
0
30km

FIGURE 41.

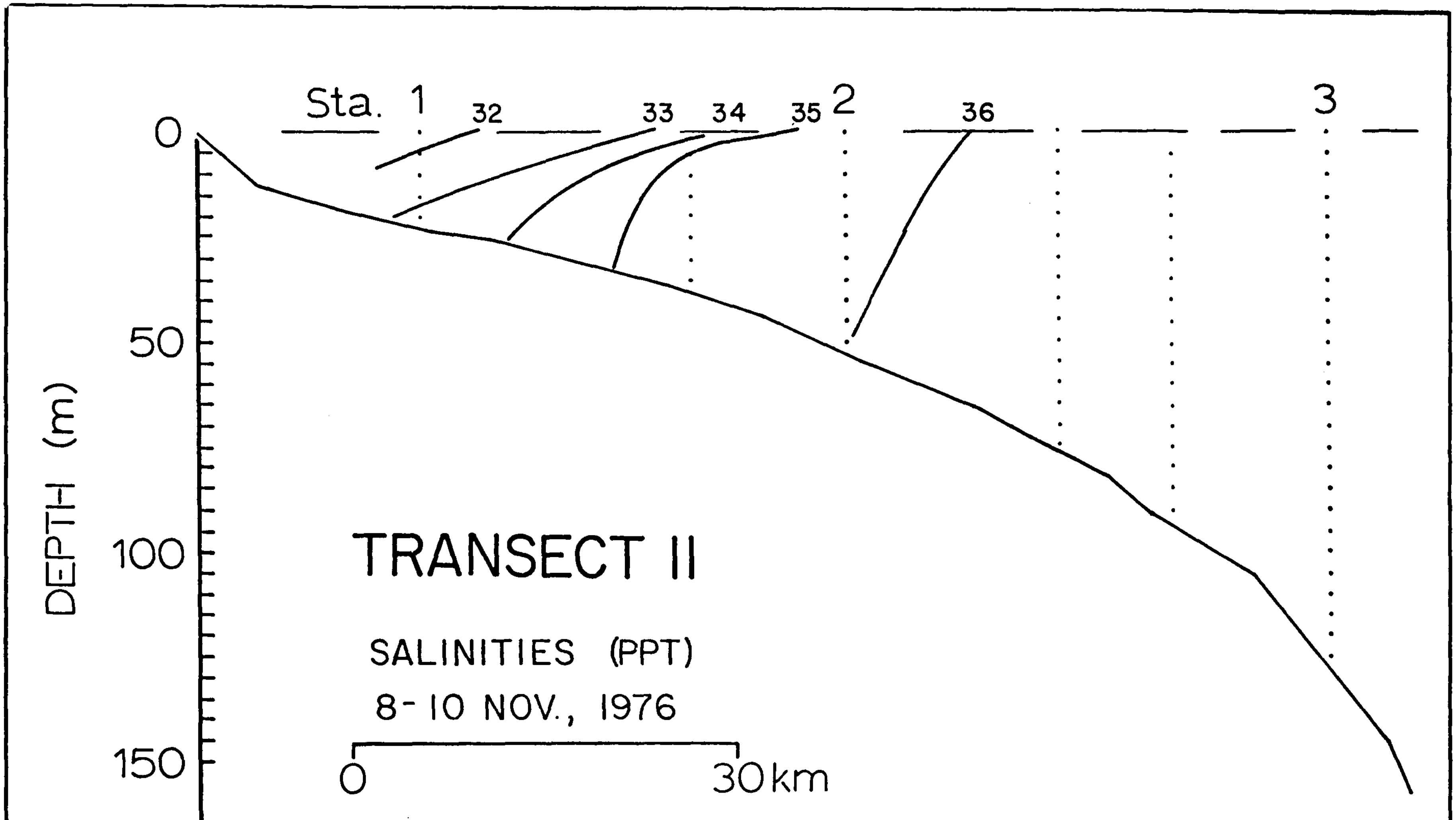

Sta. 1
2
3
32
33
34
35
36
0
50
100
150
DEPTH (m)
TRANSECT II
SALINITIES (PPT)
8-10 NOV., 1976
0
30km

FIGURE 42.

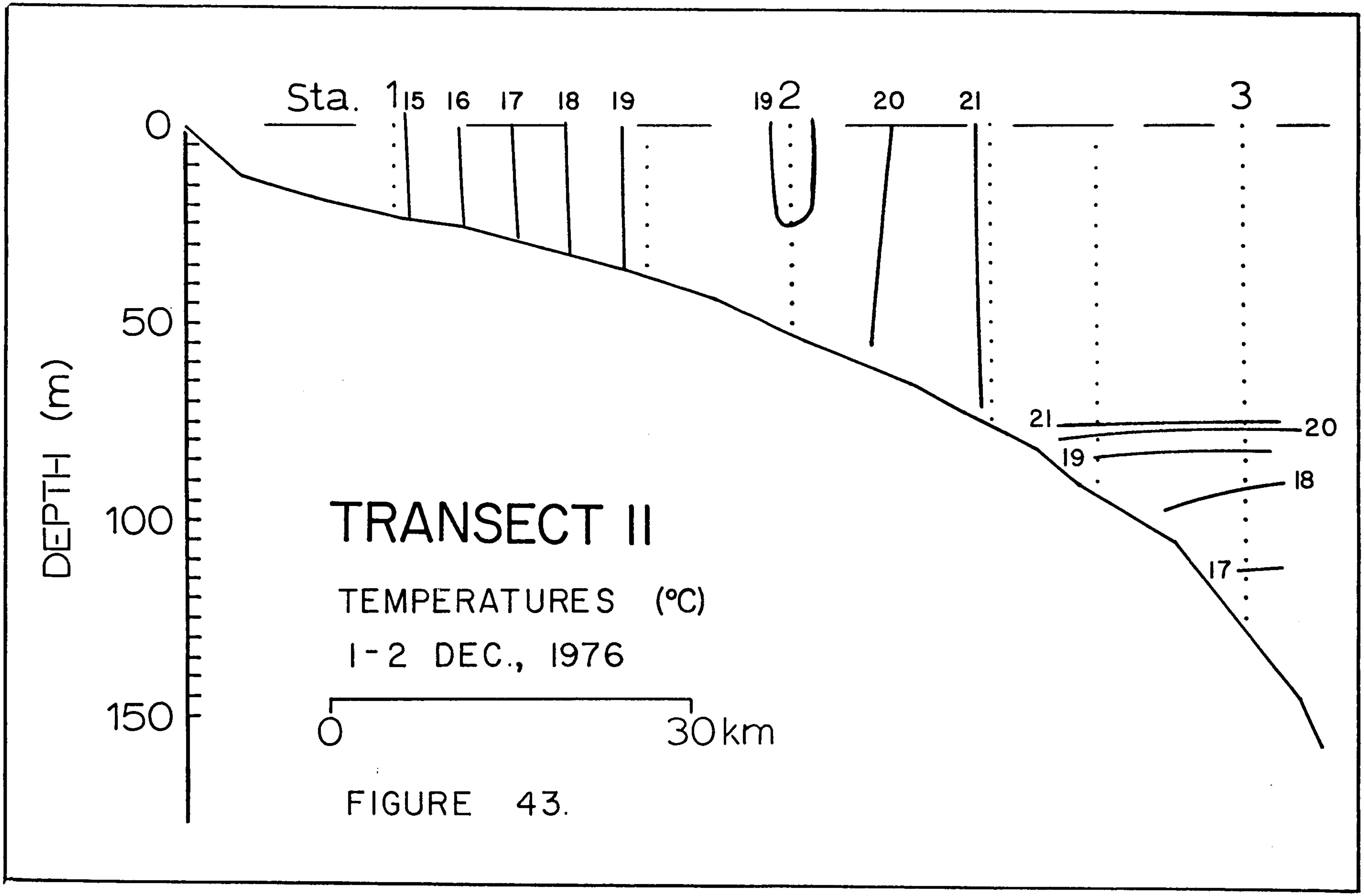


FIGURE 43.

3-63

clearly the effects of several fronts having moved onto the Texas shelf since the November Monthly Cruise. Lowest temperatures of just under 15°C were found through the water column at Station 1/II, rather than just above the bottom at Station 3/II. Isotherms at the inner four stations were nearly vertical, and the water column appeared to be vertically mixed through the upper 75 m. The top of the permanent thermocline was below this homogeneous layer at the outer two stations.

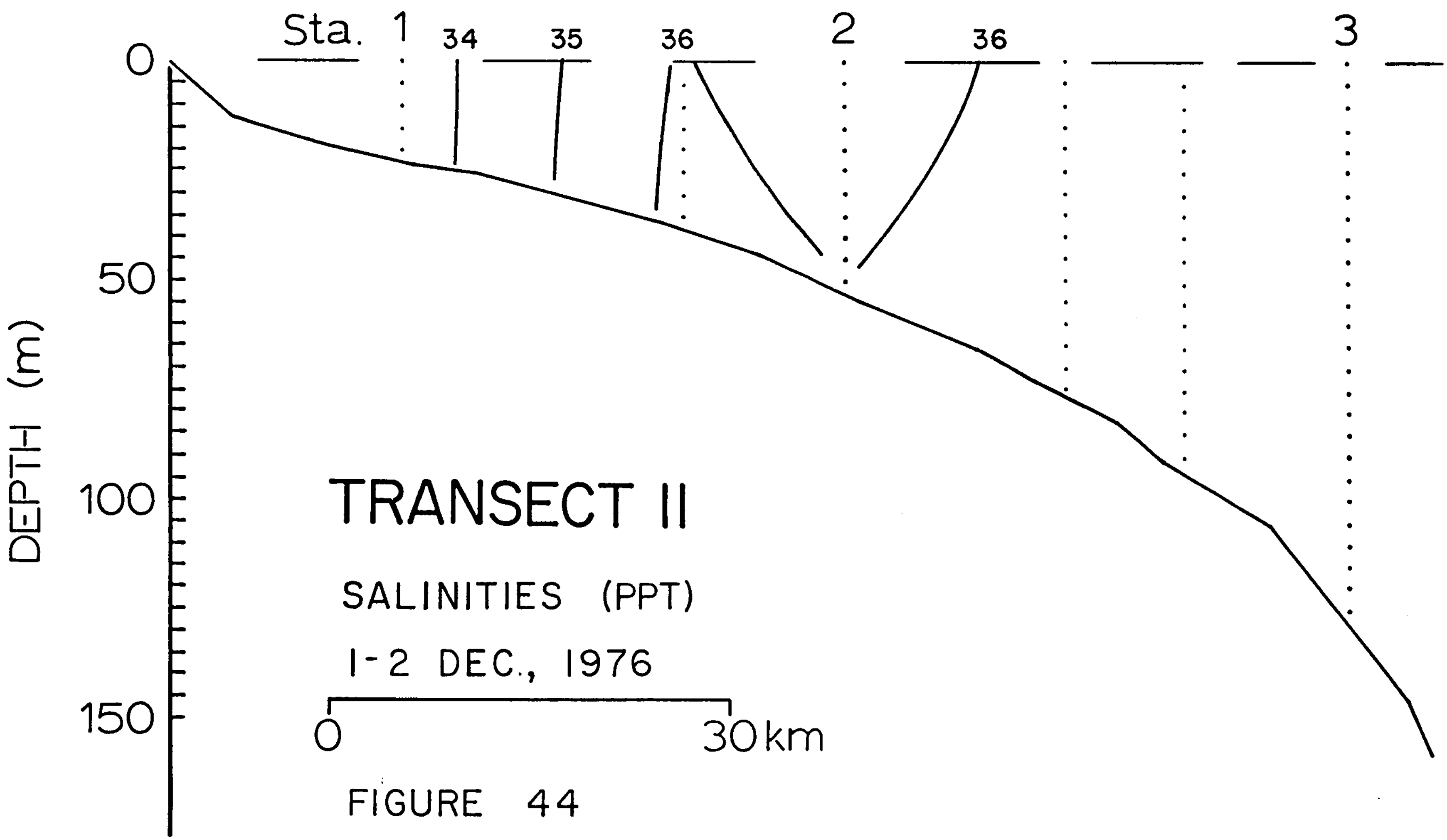
The salinity cross-section from the December Monthly Cruise (Figure 44) showed both a slight freshwater run-off influence and the result of strong vertical overturning. Isohalines were oriented very nearly vertically. Salinities increased regularly through the inner two stations to just over 36 ppt at Station 4/II. Salinities of just under 36 ppt were recorded throughout the water column at Station 2/II, suggesting the possibility of an eddy-like motion influencing the salinity distribution of the middle shelf. Salinities at the outer three stations were quite homogeneous and above 36 ppt.

Combined Results of the 1976 Hydrographic Study

T-S profiles, or data points along profiles, which were discussed individually above, may be combined to look at temporal variations in Texas Outer Continental Shelf hydrography. While time series obtained in the 1976 sampling leave something to be desired, it is still possible to describe various features of the hydrographic climate of Texas shelf waters, and to postulate regarding the driving forces producing the observed T-S variations.

September-December Net Cooling

Temperature cross-sections constructed from the September and December Transect II hydrographic data were used to calculate the net



TRANSECT II

SALINITIES (PPT)

1-2 DEC., 1976

FIGURE 44

fall and early winter cooling off Port Aransas. Greatest temperature differences of just over 14°C were found over the inner shelf (Figure 45). This was as expected, since cold air outbreaks are more intense at the coast than further out on the shelf, and because the heat content of the water column is directly proportional to the depth. Between Stations 1/II and 4/II, isotherms of net cooling were oriented nearly vertically. In both the September and December cross-sections, temperatures in this area were vertically quite uniform, well-mixed by wave action above the seasonal thermocline in September, and vertically mixed by convective overturning in December.

The 8° and 9°C net cooling isotherms intersected the surface outside Station 2/II, but for the most part the isotherms assumed a horizontal orientation. A net cooling of just over 7°C occurred during this time interval in the upper 20-25 m. Below this level there was a sharp vertical gradient, as net cooling decreased to zero at the 65 to 75-m level. This rapid drop reflected the destruction of the seasonal thermocline.

It is interesting that a layer of net warming was indicated at depths between approximately 65 and 100 m. This occurred as the top of the permanent thermocline was forced to somewhat greater depths by the wind-mixing and convective overturning associated with frontal passages. The effects of advective processes were, of course, included in the net cooling pattern. This component of the observed change cannot be discussed without supporting direct current observations. It is noteworthy that bottom temperatures at the outer most station varied only 0.02°C between September and December, demonstrating the great thermal stability of layers sufficiently removed from the air-sea energy exchange processes.

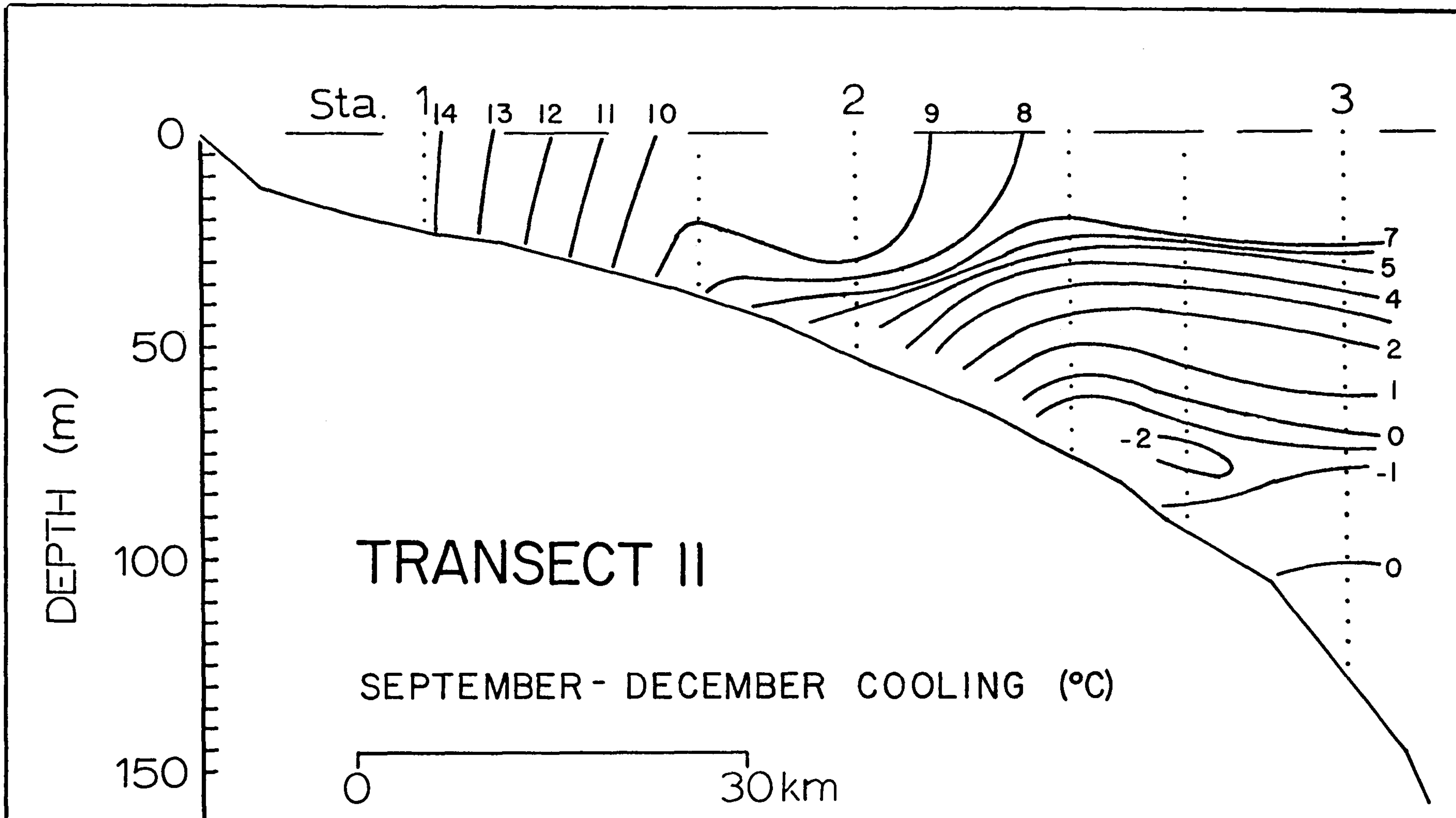

Sta. 1 2 3
14 13 12 11 10 9 8
7 5 4 2 1 0 -1 -2 0
0 50 100 150
DEPTH (m)
TRANSECT II
SEPTEMBER - DECEMBER COOLING (°C)
0 30km

FIGURE 45.

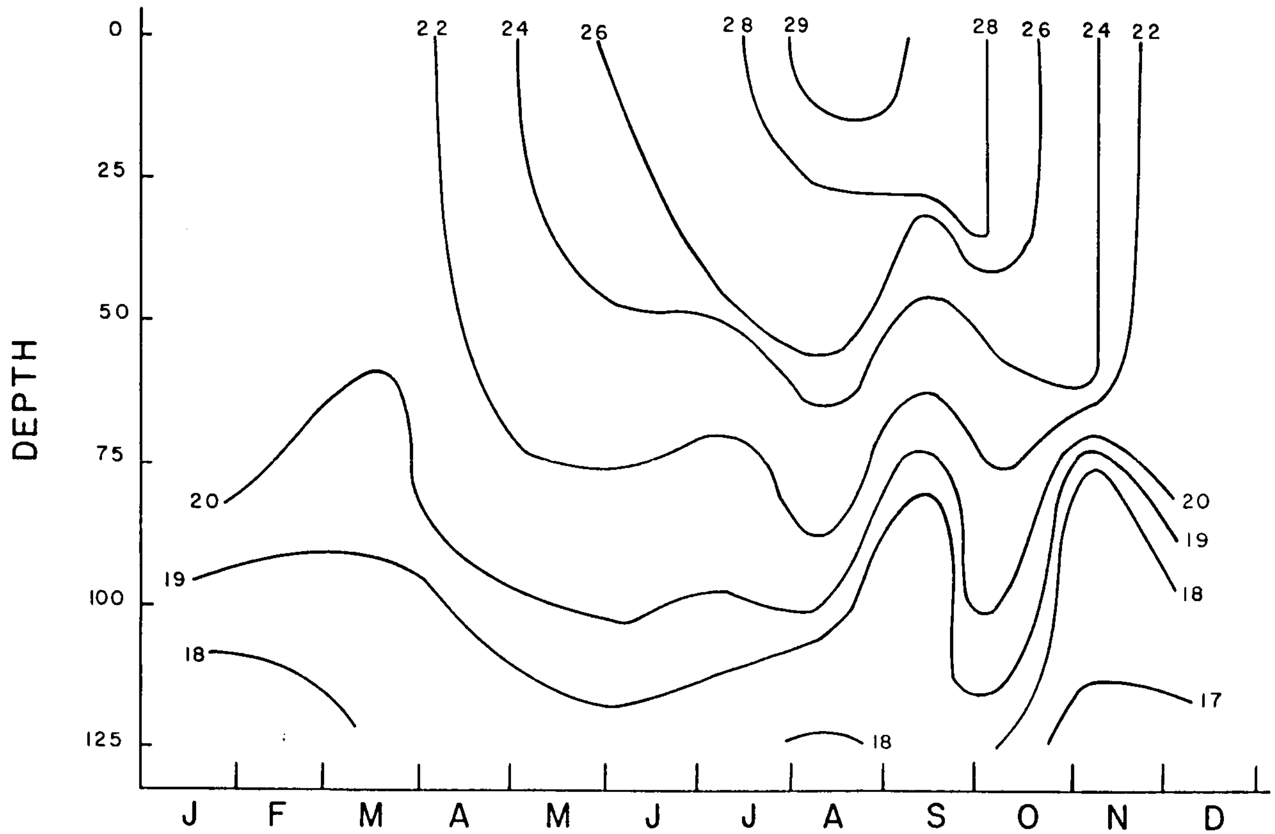
Seasonal Temperature Variations in the Station 3/II Water Column 1976

By plotting and contouring temperature profile data from Station 3/II on a depth-time diagram (Figure 46), a picture of the vertical movement of isothermal surfaces over the course of the 1976 sampling program is obtained. The pattern that emerges is comprised of two parts. An upper envelope, defined by the 22°C isotherm, reflected the seasonal heating in the water column. The waters above approximately the 8-m level remained nearly isothermal, both vertically and in time, until early April. A slow warming began as the 22-26°C isotherms appeared and descended quickly to form a seasonal thermocline. Highest temperatures of just over 29°C appeared briefly in August before the first cold fronts arrived to start the fall overturn. Winter cooling proceeded somewhat faster than spring warming, though this may not be the case in other years.

At mid-depths, isothermal surfaces showed substantial vertical movement during the late summer and fall months. In some cases, isotherms rose or fell as much as 50 m between consecutive cruises. This indicates substantial internal activity, though the characteristic time scales cannot be resolved from the available data. The observed variations may in fact reflect activity occurring over substantially shorter time intervals.

Near the bottom, temperature variations were slight and not well-correlated with the seasonal heating and cooling noted in the surface layers. Highest temperatures of just under 19°C occurred in May-June and again briefly in early October. Lowest temperatures of just under 17°C were found in November and December, approximately 2 months before minimum temperatures are expected at the surface. The temperature range recorded just above the bottom was approximately 2°C, while at the

FIGURE 46.
TEMPERATURES (°C)
3/11, 1976



surface the temperature range was just under 9°C.

Seasonal Salinity Variations in the Station 3/II Water Column 1976

The pattern obtained by plotting and contouring salinity profile data from Station 3/II (Figure 47) is relatively simple. At this location, salinities greater than 36 ppt were found throughout the water column in the fall and winter months, and always below the 100-m level. The only significant feature revealed by the isohaline was the influence of freshwater run-off which occurred during the late spring and early summer months. The 35-ppt isohaline appeared for less than 3 months, and never descended below the 20-m level. Salinities below 34 ppt were found in the upper 15 m only on the June Seasonal Cruise.

Temperature-Salinity Variations in Surface Waters, Station 1/II 1976

T-S pairs were plotted on a standard T-S diagram to describe the surface hydrographic climate at Station 1/II (Figure 48). The open-ended, polygon-like figure constructed by connecting the dots shows the relative importance of temperature and salinity variations, as well as the actual recorded ranges. The pattern obtained from the 1976 data resembles a quarter-moon, curving into lower salinities during the spring warming and, to a lesser extent, during the fall cooling. Lowest salinities of approximately 28 ppt were found in March and April. Increasing salinities occurred as summer heating continued through August. The last part of summer heating, however, was accompanied by a drop in salinity of nearly 1.0 ppt. This presumably reflected the late summer-early fall precipitation maximum characteristic of the central Texas coast. The combination of slightly increased temperatures and decreased salinities caused the polygon to cross over itself as fall cooling began, sometime after mid-September. Cooling proceeded, with a continued slight

FIGURE 47.
SALINITY (PPT)
3/11, 1976

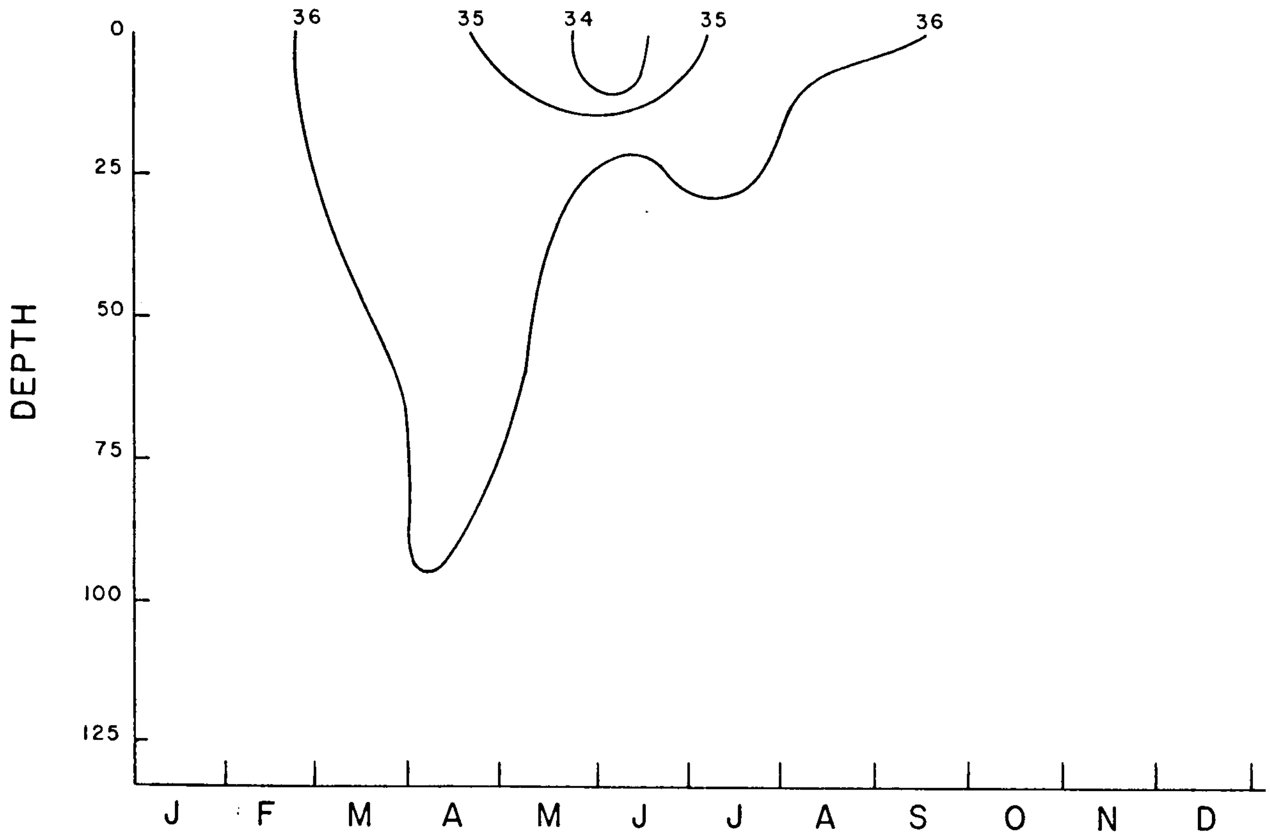
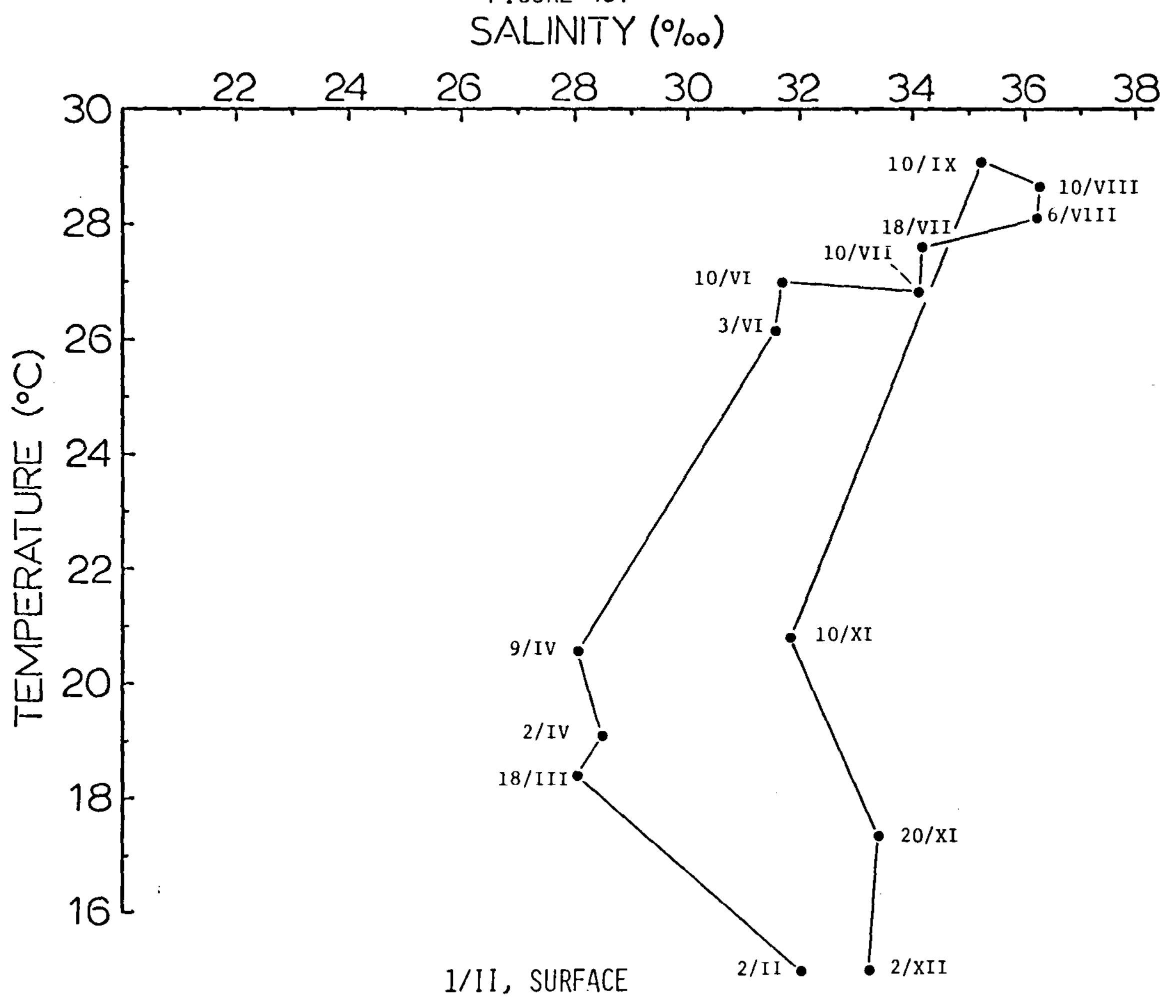


FIGURE 48.



SALINITY (‰)
22
24
26
28
30
32
34
36
38
TEMPERATURE (°C)
30
28
26
24
22
20
18
16
10/IX
10/VIII
6/VIII
18/VII
10/VII
10/VI
3/VI
9/IV
10/XI
2/IV
18/III
20/XI
2/II
2/XII
1/II, SURFACE

freshening, through early December to a temperature very similar to that recorded at the start of the sampling year. The temperature range recorded at this location was approximately 14°C, while the salinity range was approximately 8 ppt.

Temperature-Salinity Variations in Bottom Waters, Station 1/II 1976

The polygon-like figure formed from the T-S pairs from bottom samples at Station 1/II (Figure 49) shows a configuration similar to that found at the surface, though the curving into lower salinities are largely absent in the spring and fall data. This suggests that the waters of the inner shelf were characterized by vertical salinity gradients at these times of year (though there are better ways to demonstrate this). The annual salinity range in Station 1/II bottom waters was only about 4 ppt.

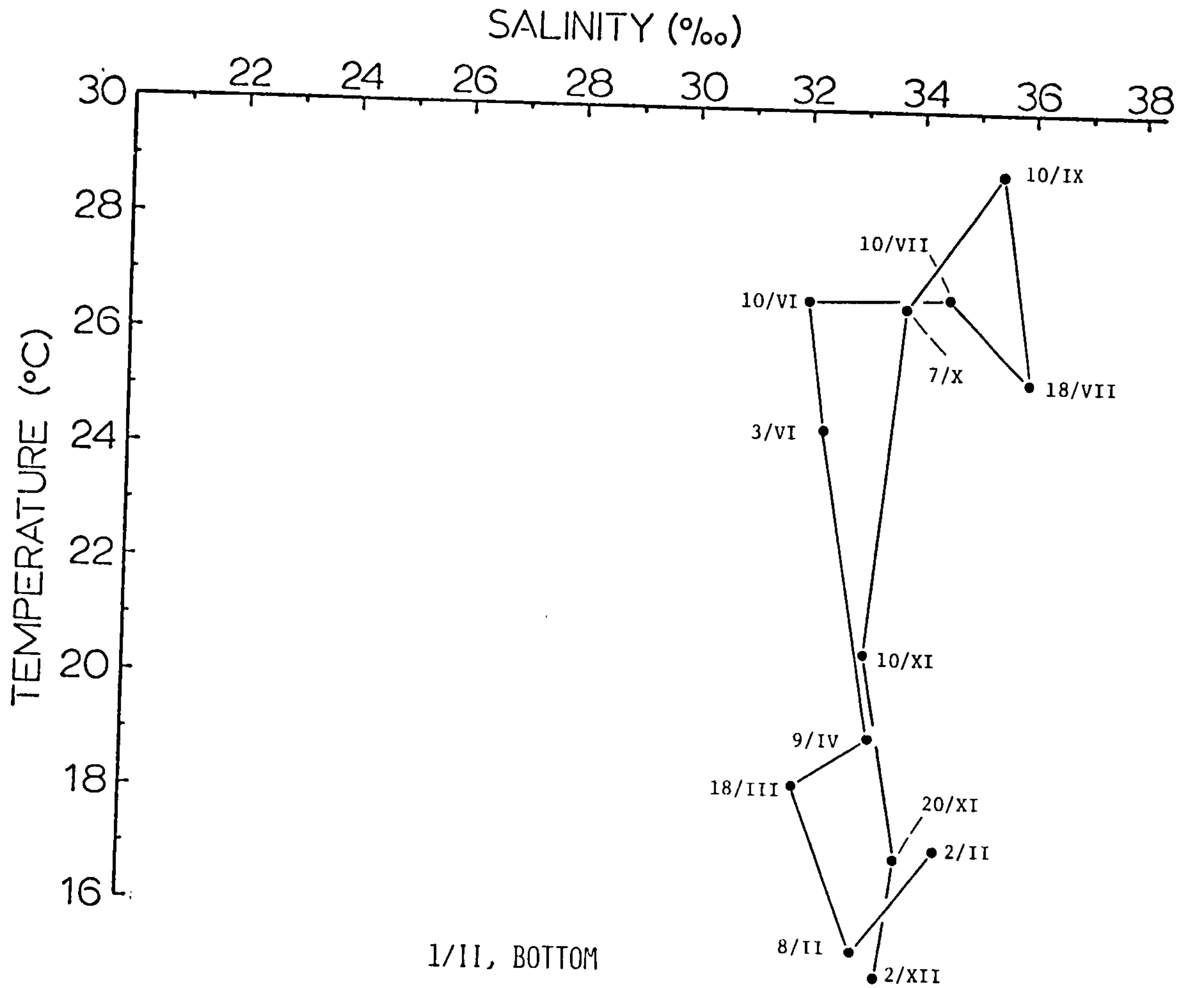
The bottom T-S pairs also cross over in the late summer and early fall months, again reflecting the seasonal precipitation maximum. Fall and winter cooling began shortly after mid-September and proceeded rapidly into the winter months.

Temperature-Salinity Variations in Surface Waters, Station 3/II 1976

The polygon constructed from the surface T-S data from Station 3/II (Figure 50) is noticeably truncated at temperatures of about 20°C. This represents the mid-winter minimum temperature over the Texas Outer Continental Shelf (in 1976). The total annual temperature range was therefore reduced to approximately 9°C. Salinities varied from about 33.5 ppt to just over 36 ppt. There was a slight cross-over in the polygon during August as salinities quickly increased again as fall cooling proceeded.

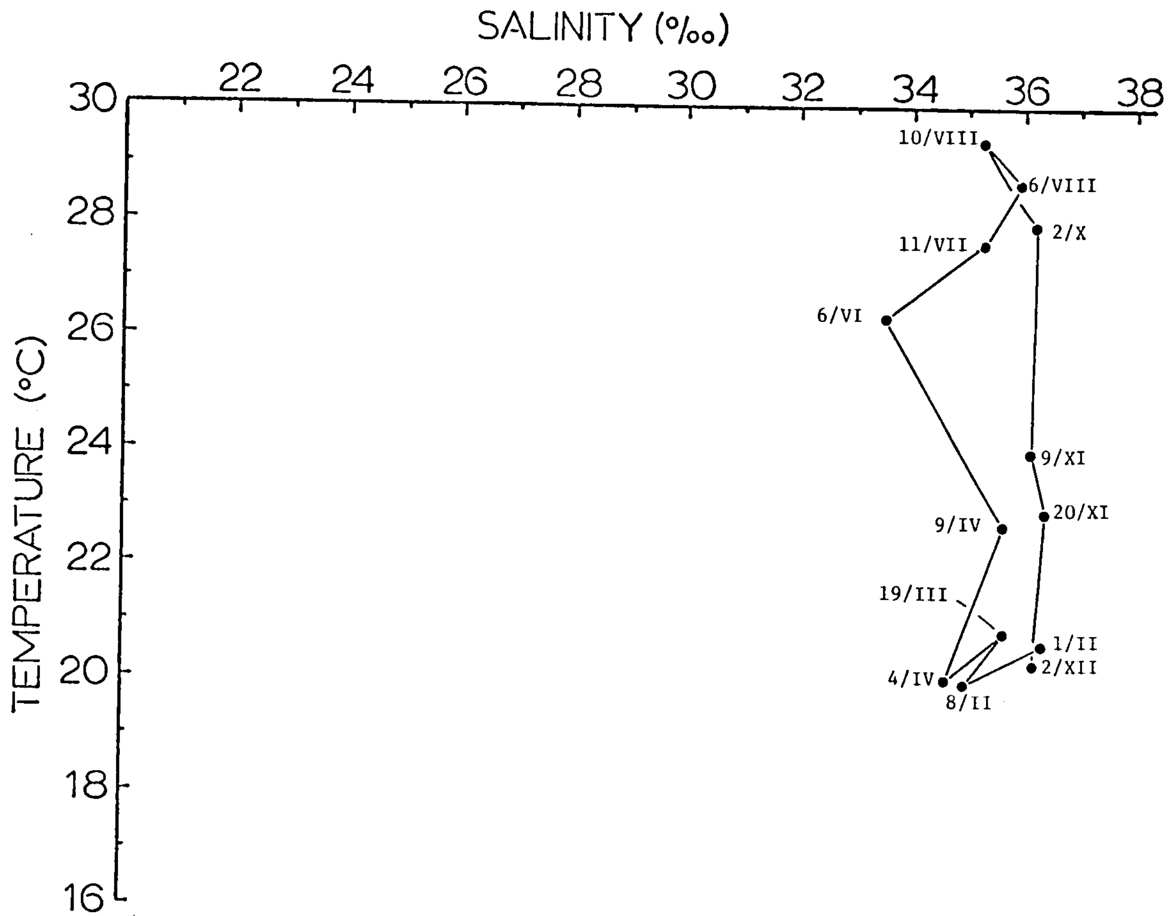
Temperature-Salinity Variations in Bottom Waters, Station 3/II 1976

FIGURE 49.



SALINITY (‰)
22
24
26
28
30
32
34
36
38
TEMPERATURE (°C)
30
28
26
24
22
20
18
16
10/IX
10/VII
10/VI
7/X
18/VII
3/VI
10/XI
9/IV
18/III
20/XI
2/II
8/II
2/XII
1/II, BOTTOM

FIGURE 50.

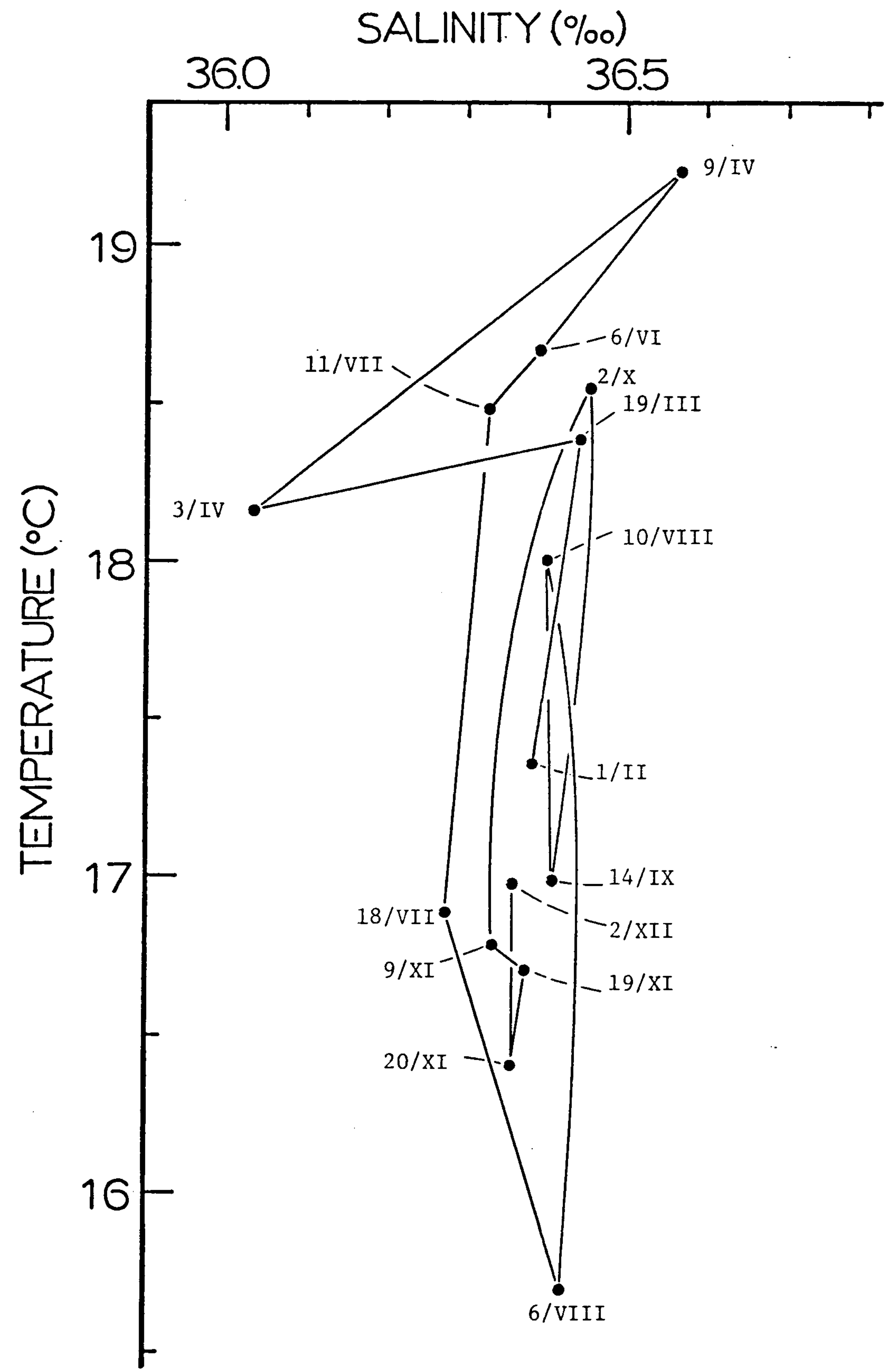


3/II, SURFACE

Substantially smaller T-S variations in near-bottom layers over the outer shelf require that the data be plotted on expanded axes (Figure 51). The total temperature range in the 1976 data was only 3.5°C, and salinities varied by less than 0.6 ppt. The most notable feature of the figure is the absence of a well-defined seasonal variation in either temperature or salinity. Instead, T-S variations appear to occur over much shorter time scales. Relative maxima and minima can be identified in the approximately monthly data, but substantial T-S variability probably occurs over shorter time intervals. T-S data from both the Water Column and Benthos Cruises were used in constructing this figure. This enables the examination of T-S changes over as little as 4 to 6 days, when Station 3/II was sampled late on one cruise and early on the next. Some of the largest variations were apparent over these short time intervals. For example, between 3 and 9 April, salinity values increased from the year's lowest to the year's highest (as detected by this sampling program). Similarly, from 6 to 10 August, the temperature increased approximately 2.3°C or 62 percent of the total recorded range. This suggests that entirely different processes are responsible for near-bottom T-S variations over the entire shelf. At the same time, the question is raised regarding the adequacy of the existing sampling program for describing and understanding the hydrography of the waters of the Texas Outer Continental Shelf.

Bank Station Hydrography

This section deals exclusively with hydrographic data collected at the eight Bank Stations visited during 1976. No data were obtained during the first seasonal cruise, since transmissometer data were not being obtained at that time.



3/II, 117 M FIGURE 51.

The description of spatial variability contained in the following section relates directly to the tabular data and analog profiles contained in Appendix A. These data are summarized by the time plots of T-S profiles which are included later in this section.

March 20, 1976-Southern Bank 1, 4; Hospital Rock 1, 2

Both Southern Bank (SB) stations showed little vertical variation in the salinity profile, though some spring warming was indicated in the temperature profile. The upper 40 m of the water column appeared to be well-mixed, with salinity increasing only 0.14 ppt and temperature varying through a range of 0.07°C. The thermocline occurred between 40 and 50 m, though the temperature continued to decrease slowly through the bottom of the water column. Both upper and lower portions of the water column were isohaline with most of the variation in salinity occurring between 40 and 50 m.

The Hospital Rock (HR) profiles showed a gradual increase in salinity throughout the water column. The total top-to-bottom salinity difference was less than 0.08 ppt in both cases. The temperature profiles indicated isothermal conditions through approximately the upper 35 m, with a decrease of 0.2 to 0.4°C, occurring primarily at the bottom of the water column.

April 3-4, 1976-Southern Bank 2, 3; Hospital Rock 1, 3

Station SB 2 showed an isothermal layer in the upper 12 m. Temperatures then increased approximately 0.4°C to a maximum at 24 m. Below that level, the water column was nearly isothermal. At SB 3, the following morning, temperatures increased to a maximum at the 12-m level. An isothermal layer extended between 21 and 63 m, at which point temperatures decreased relatively quickly to lowest values just above the bottom.

were indicated in mid-depth layers. Water at HR 3 was 1-2°C warmer at depths between approximately 25 and 55 m. Salinity profiles showed inconsistent differences between 15 and 55 m, with differences on the order of 1 ppt. Near-surface and near-bottom layers were spatially or temporally isohaline and appeared to be well-mixed.

<u>July 11, 1976-Southern Bank 1 and Hospital Rock 1</u>

Temperature data at SB showed a well-mixed, seasonally-heated surface epilimnion layer through the upper 30 m. Temperatures decreased fairly uniformly at about 1.5°C/10 m below a depth of 45 m. Salinity variations were slight and not concentrated through any particular layer. The top-to-bottom salinity difference was only 1 ppt.

A similar pattern appeared at HR 1, with temperatures decreasing somewhat more quickly with increasing depth below the surface mixed layer. Vertical salinity variations were slight.

<u>August 11, 1976-Southern Bank 4 and Hospital Rock 3</u>

The temperature profile at SB 4 showed a double seasonal thermocline. A small temperature decrease of 1.2°C was noted between 21 and 24 m, but the main decrease in temperature occurred below the 40 m level. Salinity increased irregularly through the upper 21 m, with a suspiciously high maximum of just over 37 ppt at a depth of 24 m.

The HR 3 data showed a well-mixed surface layer through the upper 15 m. Between 15 and 18 m, there was a slight decrease in temperature and a substantial increase in salinity. The top of the seasonal thermocline, however, appeared to be at about the 40-m level.

<u>September 14, 1976-Southern Bank 1 and Hospital Rock 1</u>

The SB temperature profile may be divided into three fairly distinct

Vertical salinity variations at SB showed marked differences during the 12 hours between the two STD profiles. During that time, and/or between these two locations, surface salinities decreased by 0.4 ppt and bottom salinities increased by 0.4 ppt. The result was a somewhat more stratified water column at SB 3. This was probably more a temporal than a spatial variation.

The two HR stations were visited within an hour of each other, yet substantial variations were noted. Top and bottom temperatures were similar at the two locations, but at mid-depth temperatures were nearly 1°C warmer at HR 1. Similarly, top and bottom salinities were nearly identical, yet salinities at mid-depth were approximately 0.3 ppt higher at HR 1. It is interesting, however, that the sigma-t profiles at these two locations were nearly identical. One may tentatively conclude that substantial spatial temperature-salinity variations exist over relatively short horizontal distances in mid-shelf waters. This immediately raises questions regarding the spatial representativeness of hydrographic data from stations well-removed from the Bank Stations.

June 6, 1976-Southern Bank 3, 4; Hospital Rock 3, 4

Significant spring/summer warming was indicated by the June seasonal cruise data from the Bank Stations. Surface temperatures at the two SB stations were well over 26°C. A seasonal thermocline had formed between approximately the 35 and 40-m levels, and an unusual layer of relatively cool water was found at about the 10-m level in both profiles. Vertical salinity variations showed the effects of the spring run-off in the upper 15 m, with surface values less than 31 ppt.

Near-surface homogeneity was indicated in the upper 10-15 m, but substantial temporal and/or spatial variations, primarily in temperature, segments. An isothermal upper layer extended through the upper 20 m. Temperatures then decreased nearly uniformly at a rate of about 1°C/5 m to a depth of 70 m. The near-bottom water was again well-mixed. Salinities increased irregularly with increasing depth to suspiciously high values in the lower half of the water column. The salinities seemed to be about 0.5 ppt too high.

HR temperatures showed the epilimnion extending through the upper 25 m and the seasonal thermocline lying between 25 and 60 m. Salinities again seemed too high by about 0.5 ppt below the 35 m level.

<u>November 8-9, 1976-Southern Bank 1, 4; Hospital Rock 1, 2</u>

Both SB temperature profiles showed nearly isothermal water through the upper 60 m, with temperatures varying less than 0.3°C. The remnants of the seasonal thermocline were found in the lower part of the water column. The salinity profile indicated nearly isohaline water, both in the horizontal between the two stations and in the vertical.

The HR data were similar, with nearly isohaline water extending the length of the profiles, and nearly isothermal water occurring through the upper 60 m. Both profiles indicated a rapid drop in temperature of nearly 3°C through the lowest 6 m.

<u>December 1, 1976-Southern Bank 2 and Hospital Rock 4</u>

The SB hydrographic data clearly showed the result of convective overturning driven by fall and early winter cooling. Temperatures varied between 20.9 and 21.2°C throughout the water column, and salinity varied by only 0.1 ppt.

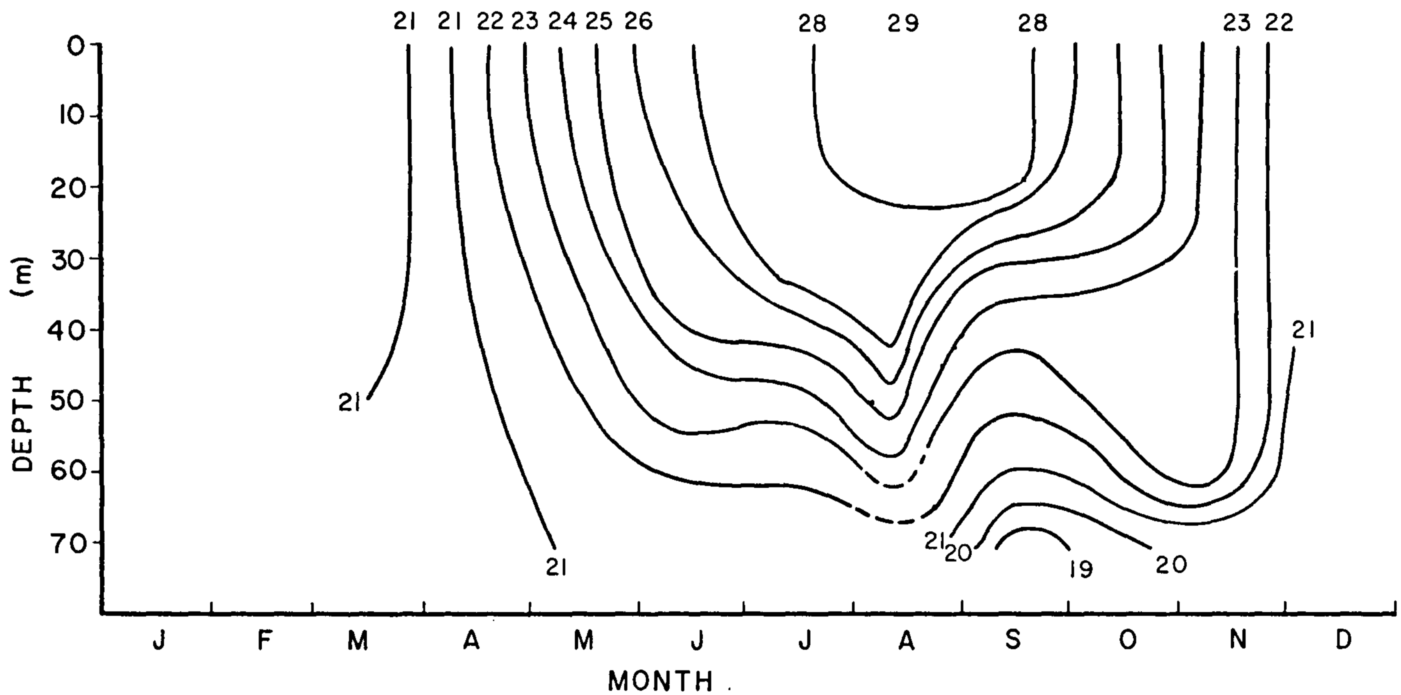
At HR, the upper 50 m were nearly isothermal, though a slight decrease was seen in the upper 15-20 m. Salinities varied by less than 0.6 ppt, with higher values in the upper part of the water column.

The individual T-S profiles contained in Appendix A and described above are summarized by the four time-depth plots (Figures 52-55). These figures were constructed by entering profile data at the appropriate depth along a time axis and by contouring isopleths of temperature and salinity. The T-S time plots from Southern Bank and Hospital Rock used hydrographic data from all cruises to improve temporal resolution. Thus, any or all of the four stations at each of the Bank Stations may have been used in constructing Figures 52-55.

Both temperature and both salinity time plots show essentially the same features and, being comparable, are discussed together.

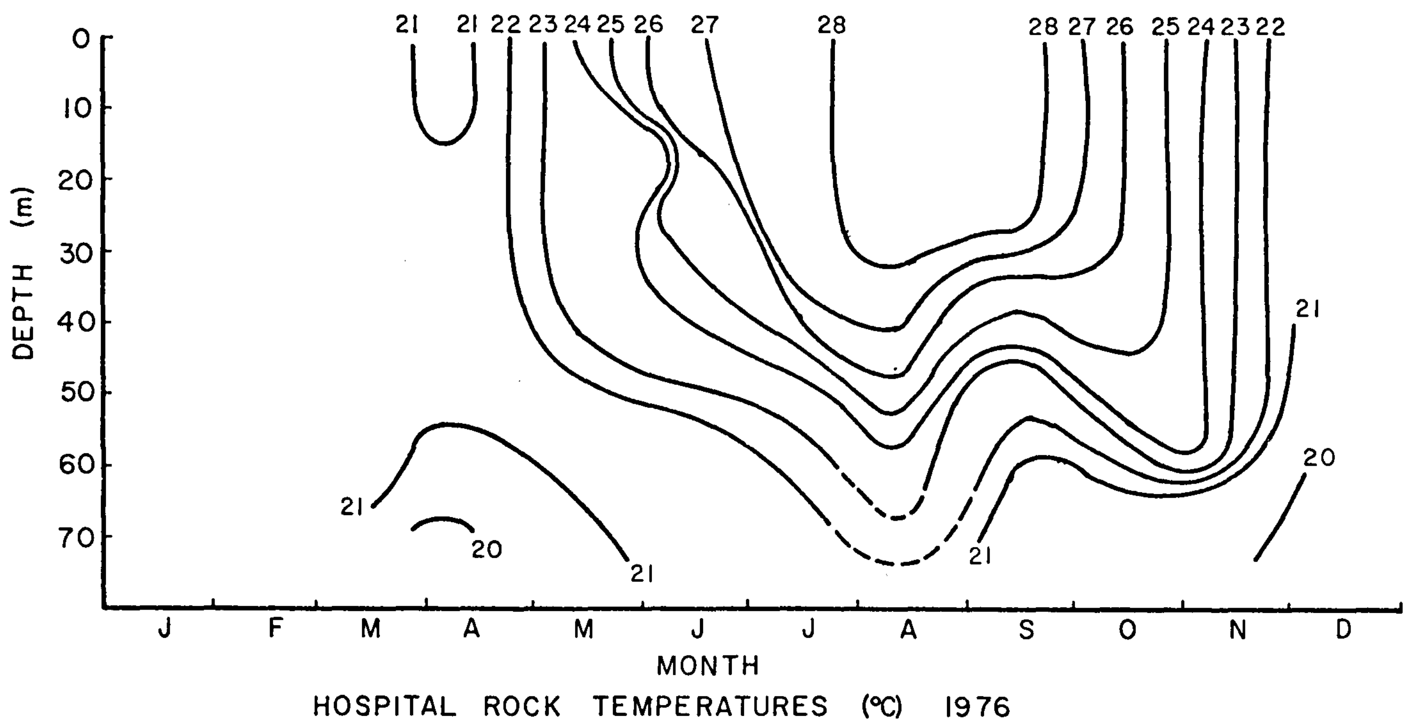
Temperature time plots from Southern Bank and Hospital Rock are shown in Figures 52 and 53, respectively. The water column was characterized by nearly isothermal conditions throughout the winter and spring months, and through the upper 20-30 m, above the seasonal thermocline, in the summer and early fall months. The temperature data indicate that most rapid warming in the near-surface layer occurred during April and May, and that cooling at the same rate occurred from late September through November. Seasonal heating penetrated through most of the water column over the banks, and the thermocline in August was between 40 and 60 m. Surface temperatures varied between 21 and 29°C over the course of the year, and the bottom temperature range was 19 to 21°C.

The salinity data (Figures 54 and 55) show that most of the annual variation at these locations was in the upper 20 m and between April and July. The spring run-off thus seemed to be the dominant process affecting bank station salinity profiles. Lowest surface values of just over 31 ppt were measured on the June Seasonal Cruise. Near-bottom water over the banks was temporally isohaline, with all values above 36 ppt. As noted



SOUTHERN BANK TEMPERATURES (°C)

Figure 52.



21
21
22
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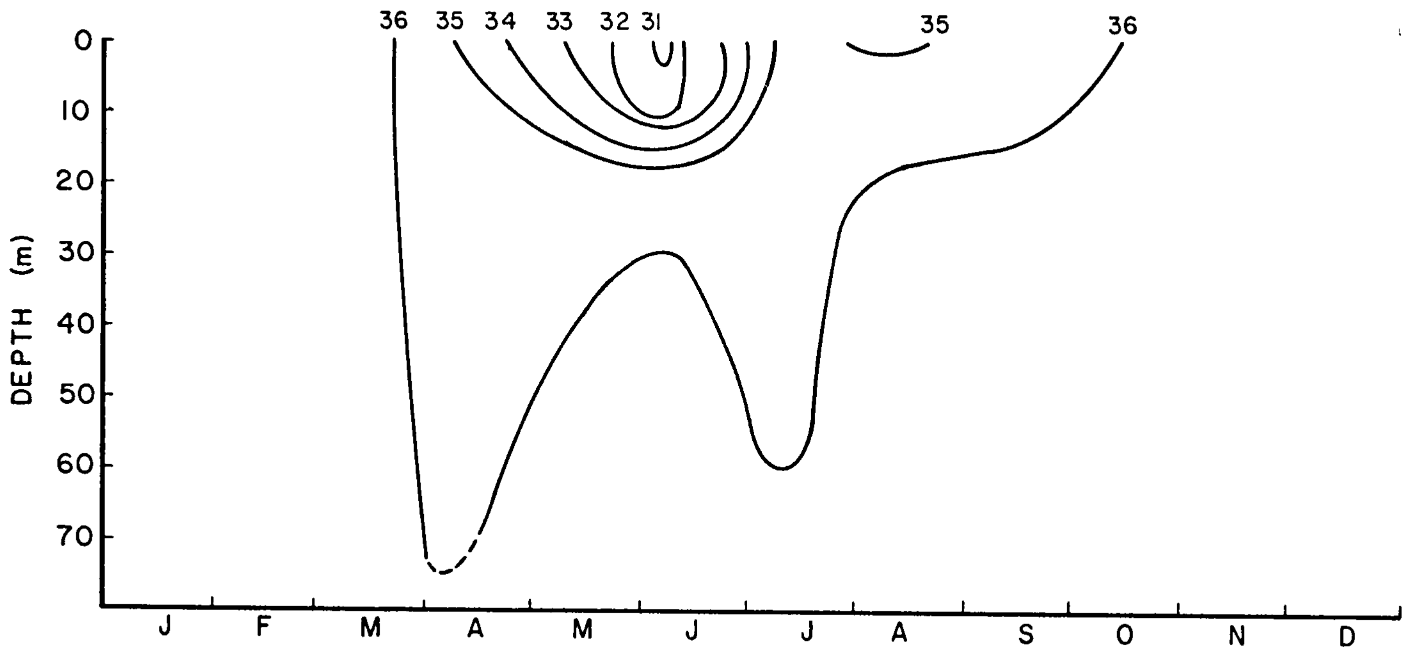
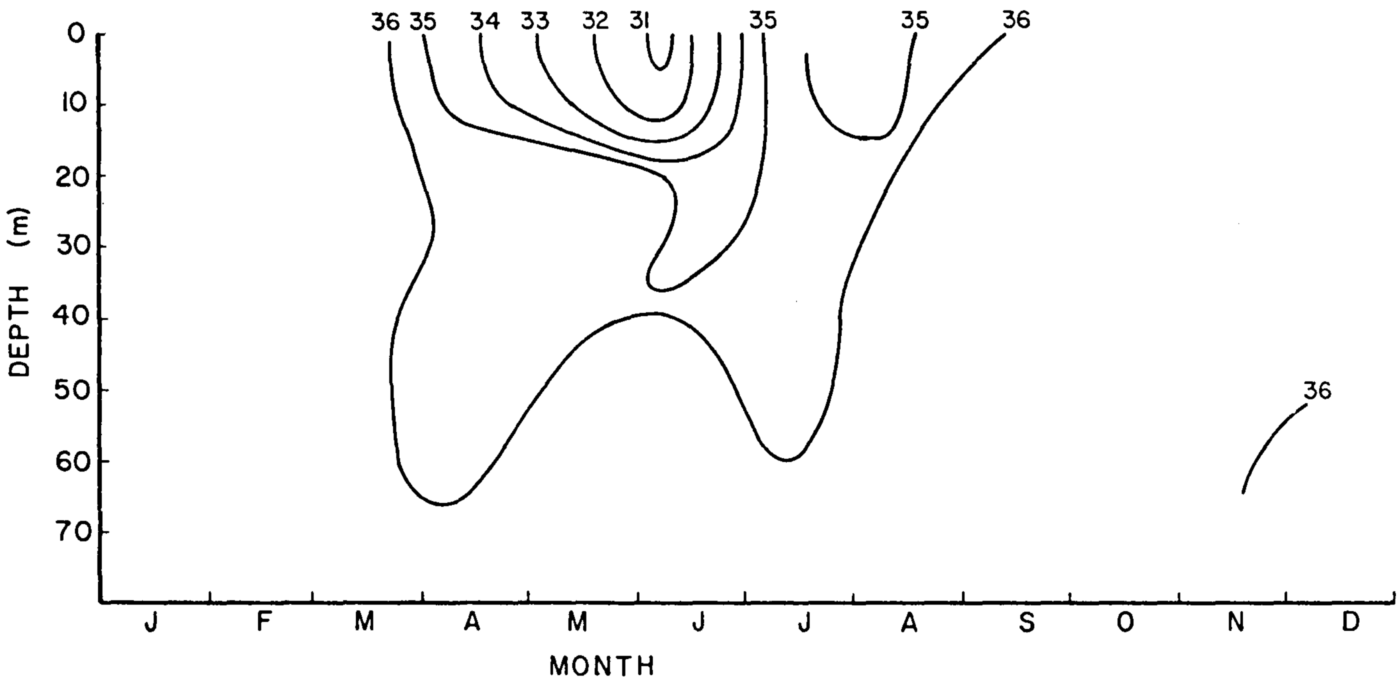
28
28
27
26
25
24
23
22
21
20
21
20
21
21
0
10
20
30
40
50
60
70
DEPTH (m)
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
HOSPITAL ROCK TEMPERATURES (°C) 1976

Figure 53.



SOUTHERN BANK SALINITIES (ppt) 1976

Figure 54.



HOSPITAL ROCK SALINITIES (ppt) 1976

Figure 55.

earlier, salinities over about 36.45 ppt were highly suspect and probably reflect instrumentational errors.

DISCUSSION

Spatial Variations in Temperature and Salinity

Gradients in annual temperature ranges are directed generally downward and in the offshore direction. Minimum T-S variations occur in near-bottom levels over the outer shelf. The greater T-S variability over the inner shelf reflects the more rapid response to heating and cooling processes characteristic of a shorter water column, and the closer proximity of the inner shelf to the freshwater run-off through the estuaries. For comparison, the surface temperature range at Station 1/II and bottom temperature range at Station 3/II were approximately 14° and 2°C, respectively. Salinity ranges were 8 ppt and 0.6 ppt, respectively. Still to be determined is the difference in the temperature or salinity range at a given location that can be expected from one year to the next. The question of natural variability, even over annual time scales, is a crucial aspect of a baseline monitoring program.

The seasonal transition from stratified to unstratified conditions is depicted by plotting and contouring computed sigma-t profiles from the Station 3/II data (Figure 56). The pattern is somewhat reminiscent of the plot of Station 3/II temperature profile data (Figure 46) in that it is comprised of two parts. An upper envelope, defined here by the 25 sigma-t isopleth, represents the portion of the water column which becomes stratified as densities are decreased by seasonal heating or freshwater run-off effects. In the 1976 data, this is approximately the upper 75 m. The influence of the spring run-off (Figure 47) is clearly seen in the

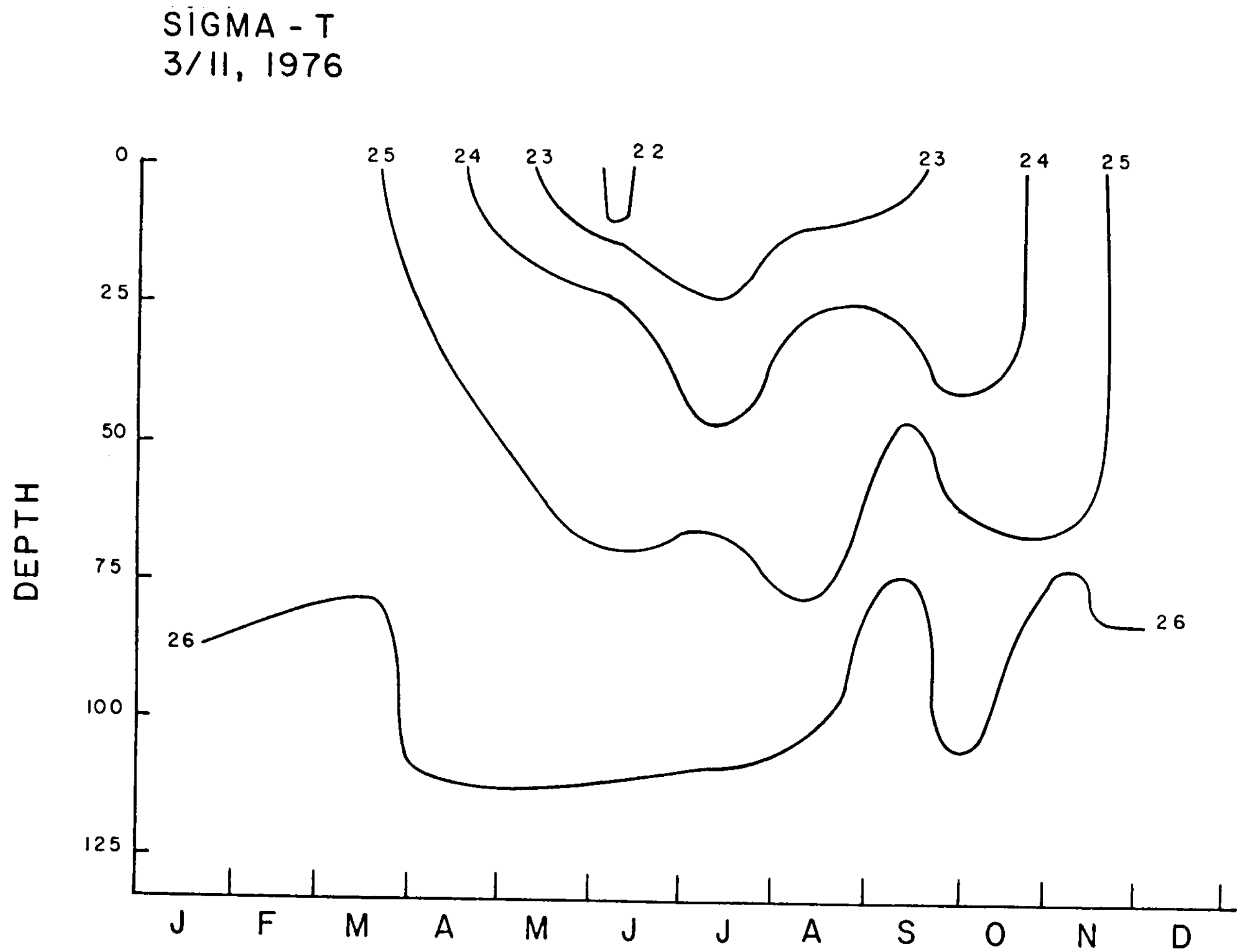

SIGMA - T
3/11, 1976
DEPTH
0
25
50
75
100
125
25
24
23
22
23
24
25
26
26
J
F
M
A
M
J
J
A
S
O
N
D

Figure 56.

upper 10 m in late May and early June. This low density water, with the associated strong density stratification, quickly disappears, though the 23 sigma-t line is carried along by seasonal heating through mid-September. There is some indication of a slight convergence of the sigma-t isopleths during the summer months, but, with the exception noted above, the stratification of Texas shelf waters does not appear to be particularly strong. The buckling of the 25 and 26 sigma-t isopleths at greater depths corresponds closely with the vertical migrations of isothermal surfaces noted in Figure 46. One may tentatively conclude that mid-summer density stratification is strongly influenced by the same shorter-period, cross-shelf motion that produce the observed large vertical migrations of isothermal surfaces. The causes and characteristics of these cross-shelf motions remain poorly understood.

Dominant Time Scales Affecting T-S Distributions

The important time scales over which major T-S changes occur cannot be fully investigated with the existing sampling program. Shorter-period, advective and periodic processes may occur over time scales well within the approximately monthly sampling of the water column cruises. For example, Smith (1975) documented reversals in the longshore motion over the inner shelf occurring over time intervals on the order of 1-2 weeks. Similarly, the Brunt-Vaisala frequencies computed from the T-S profile data (see Appendix A) indicate that internal waves may occur at frequencies of 50-100 cycles per hour. The investigation of T-S variations over such short time intervals clearly requires a completely different sampling program based on self-recording instrumentation.

The available data, however, do indicate a dominant annual periodicity in the waters of the inner shelf. This is shown most clearly in the

T-S plots from Station 1/II. A polygon that forms a single circular, elliptical or back-and-forth pattern reflects a dominance of annual heating and cooling, along with whatever precipitation/evaporation balance effects might be superimposed. This is the case at surface and bottom levels at Station 1/II, and at the surface at Station 3/II. With data points more closely spaced in time, there would undoubtedly be a substantial amount of higher frequency "noise" superimposed onto the existing shape, but it is probable that the basic pattern would remain essentially the same.

At near-bottom levels over the outer shelf, the basic pattern is very different. Instead of a single loop, the pattern is one of a series of back-and-forth sweeps warming and cooling through a very narrow salinity range. Thus, the dominant time scale decreases from an annual one to one on the order of days or weeks. The length of time cannot be resolved from the available data. It is clear, however, that the sampling program designed to monitor seasonal or annual hydrographic variations over the inner shelf is not suitable to document hydrographic variations at near-bottom levels over the outer shelf.

The time scales, and the timing associated with T-S variations gives some indication of the physical processes responsible for the observed changes. The annual heating and cooling observed in shelf waters, along with estuarine waters and the near-surface waters of the open ocean are both dominant processes and the best understood. They are conceptually straight-forward and need not be described in detail here. Similarly, the spring salinity minimum and the late summer-early fall cross-over in the T-S polygon can be easily explained as a direct result of the spring freshwater run-off and the annual precipitation maximum. Together, they give the T-S polygon an interesting and unique signature, but they present no great mystery in their interpretation.

The shorter time scales, found in the near-bottom data from Station 3/II, do, however, present a mystery in the interpretation. This may reflect, to varying degrees, local internal wave activity, internal tides or advective processes in longshore and/or cross-shelf directions. The determination of the characteristic time scales, and certainly the understanding of the driving forces, requires closely-spaced time series measurements of sub-surface currents and temperatures. The observed temperature variations, occurring over time scales on the order of a few weeks, may be directly related to the encroachment of offshore waters onto the shelf. If so, the effect these motions have on the cross-shelf transport of suspended materials and planktonic forms of life makes this aspect of the physical oceanography of shelf waters of primary importance for further study. Regardless of the causal mechanisms, the fact remains that there is a substantial amount of relatively short period hydrographic variability. An important goal in the hydrographic component of the Texas Outer Continental Shelf is, and should continue to be, the determination and understanding of the limits and other statistics of natural variability. This is a logical and necessary aspect of any baseline monitoring program.

LITERATURE CITED

Bennett, A. 1976. Conversion of *in situ* measurements of conductivity to salinity. Deep-Sea Res. 23:157-165.

Leipper, D. 1954. Physical oceanography of the Gulf of Mexico. Pages 119-137. *In* Gulf of Mexico, its origin, waters and marine life. Fish. Bull. Fish and Wildl. Serv., Wash. 55:119-137.

Nowlin, W. 1971. Water masses and general circulation of the Gulf of Mexico. Oceanology International 1971 (Feb.):28-33.

Smith, N. 1975. Seasonal variation in nearshore circulation in the northwestern Gulf of Mexico. Cont. in Mar. Sci. 19:49-65.

Wüst, G. 1964. Stratification and circulation in the Antillean-Caribbean basins. Part I. Columbia Univ. Press, N. Y. 201pp.

CHAPTER FOUR

PHYTOPLANKTON AND PRODUCTIVITY

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Bill Allshouse

ABSTRACT

The 1976 phytoplankton and productivity studies consisted of 1) water column light measurements, 2) phytoplankton species counts, 3) chlorophyll a determinations, and 4) ATP determinations. General methods for each technique are presented in flow charts.

An offshore decrease in concentration was observed in all biomass parameters. This pattern was especially true of the net chlorophyll a fraction. Secchi depth generally increased offshore. An along-shelf gradient apparently occurred characterized by higher plant biomass at Stations 1/I, 2/I and 1/II. ATP exhibited highest concentrations at Stations 1/I and 1/III. Depth profiles of chlorophyll a often showed subsurface maxima. Monthly changes at Stations 1/II and 2/II followed a bimodal cycle with a major peak in April and a minor rise between September and December. Station 3/II showed a very broad rise between June and December.

The phytoplankton species were grossly divided into two groups at Stations 1/II and 2/II, December-April and May-November. Station 3/II exhibited less seasonality in species composition. Low diversity (<2.00) occurred on five occasions during 1976 and was associated with blooms of *Skeletonema costatum, Nitzschia delicatissima* or *Leptocylindrus danicus*.

The interrelationships among Secchi depth, phytoplankton abundances and chlorophyll a were good. ATP concentration was related to chlorophyll a concentration during the spring, but not during the summer and fall. The relationships between salinity and plant biomass suggested that freshwater runoff was a significant nutrient source in the study area.

INTRODUCTION

The purposes of the 1976 BLM STOCS phytoplankton and productivity work element were to 1) measure the light extinction of the water column; 2) enumerate phytoplankton species; 3) determine chlorophyll a concentrations in net- and nannophytoplankton fractions; and 4) determine ATP concentration in total suspended particulate. These measurements provide a baseline of phytoplankton and microplankton biomass under relatively pristine Texas shelf conditions.

Each of these measurements is backed by extensive literature. Water column light measurements including Secchi depth determinations, were reviewed by Strickland (1958). Jerlov and Steeman-Nielsen (1974) provided a recent discussion of optical oceanography. Steidinger (*In* El Sayed *et al.*, 1972) discussed phytoplankton species enumerations in the eastern Gulf of Mexico. Parsons and Takahashi (1973) reviewed the applications of the chlorophyll a and ATP techniques.

Studies of phytoplankton and microplankton on the STOCS prior to the BLM program are almost non-existent. Occasional collections by Texas A&M University have been made (El Sayed, personal communication). General inferences applicable to the study area were given by El Sayed *et al.* (1972). The best source of previous data is the 1975 BLM Final Report (Van Baalen, 1976).

METHODS AND MATERIALS

Samples for chlorophyll a and phytoplankton ATP biomass determinations were taken with 30-ℓ Niskin bottles seasonally at the 12 primary stations of the STOCS study area and monthly at the three primary stations along Transect II. Samples were taken at the surface, one-half the depth of the photic zone and near-bottom. Samples for phytoplankton identification and enumeration were taken at those stations listed above and only at two depths; surface and one-half the depth of the photic zone. Replicates for each sample type were taken at the discretion of the Principal Investigator.

The detailed experimental procedures used in making the various measurements are given in the following subsections.

Water Column Light Measurements

Secchi depth determinations were made at each station. Supplementary observations were obtained with a LAMBDA submarine photometer dependent on weather conditions and instrument availability. Photosynthetically active radiation (PAR) profiles obtained with the LAMBDA submarine photometer are included as Figure 1, Appendix B.

Chlorophyll a and ATP Determinations

The methods used for chlorophyll a and ATP determinations follow basically the procedures outlined in Strickland and Parsons (1968). Chlorophyll a concentrations were calculated using various equations. The whole absorption curves between 570-710 nm are given in Appendix B to allow future calculations with improved equations derived at some later date.

30-l Niskin Bottle

Chlorophyll a

3-5 l of water filtered through 20 μm NITEX mesh; 2-4 l of filtrate filtered through 0.4 μm 47 mm NUCLEOPORE filter (4 filters) with gentle suction; time 30-40 minutes.

↓

Place filters in CORNING 8446 tube and freeze immediately; return sample to lab.

↓

ATP

Jan.-June: 1-4 l water filtered through 0.4 μm, 47 mm NUCLEOPORE filter (2-4 filters) with gentle suction; filtering time 30-40 minutes;
July-Dec.: 1 l water filtered through 0.4 μm, 47 mm NUCLEOPORE filter (2 filters) with gentle suction; filtering time 10 minutes.

↓

Filters placed in 4-dram vial, add 5 ml of 0.02 M TRIS buffer, pH 7.6, and heat at 100°C for 5 minutes; immediately freeze; return sample to lab.

↓

Add 4 ml of 90 percent acetone (redistilled) and approximately 1 mg $NaHCO_3$, disturb with glass rod, extract at room temperature in dark for 1 hour.

↓

Filter through fine porosity sintered glass filter (CORNING) 36060, size 15F; wash tube and filter and make to 5 ml.

↓

Record absorbance 570 to 710 nm, 1 cm cuvette, CARY 118C spectrophotometer; acidify sample and rerun spectrum

Thaw just before assay; place 0.4 ml in quartz vial, 16 mm OD, positioned in front of photomultiplier; add 0.1 ml of FLE-50 (Sigma Chemical Co., St. Louis) firefly extract; record light output curve for 2 minutes:
1) Jan.-June: Photomultiplier RCA 4473, operated at 720 volts (Keithley 246), anode signal detected on Keithley 414 S Picoammeter and recorded.
2) July-Dec.:
ATP content of sample compared to crystalline ATP (Sigma Chemical Co.) standards run at same time on AMINCO Photomultiplier.

Phytoplankton Counts

The quantitative counts of netphytoplankton follow the procedures of Utermohl (1931). The semi-quantitative counts of coccolithophorids provide a rough estimate of their abundance.

Same 30-l Niskin Bottle

↓

Preserve 1-l water in 2 percent formalin solution; return to lab

↓

Pour preserved water aliquot into 10, 50 or 100 ml settling chamber (ZEISS); let stand for 24 hours

↓

Examine half or whole slide at 200X magnification on an inverted microscope; record species and abundance

↓

Return counted aliquots to 1-l sample bottle; settle total column; siphon off supernatant until 10 ml remains

↓

Pipette 1 ml of preserved water aliquot into Sedgewick-Rafter cell; examine 2-4 transects at 200X magnification; record abundance of coccolithophorids

Return counted aliquot to concentrate; archive remaining liquid and cells

RESULTS

The results presented herein analyze the data for significant patterns and trends. The raw data were presented in the previous quarterly reports and are included in Appendix B that accompanies this report.

Seasonal Surface Patterns

The seasonal surface patterns of measured parameters are given in Figures 1-5. As shown in Figure 1, Secchi depth generally increased offshore in response to changes in water depth and phytoplankton biomass. There was not an apparent nor consistent along-shore pattern in water clarity as relatively clear or turbid patches of water were scattered among the four transects.

Seasonal phytoplankton counts are compared in Figure 2. An offshore decrease in cell number occurred along Transects I and II, whereas Transects III and IV displayed a more even distribution. The highest counts generally occurred at Stations 1/I, 2/I and 1/II.

Figures 3 and 4 show the area trends in chlorophyll a concentration[1]. Total chlorophyll a concentration decreased offshore on all transects. The highest values occurred at Station 1/I with intermediate abundances at Stations 2/I, 1/II, 1/III and 1/IV. Distribution of the chlorophyll a nannophytoplankton and netphytoplankton fractions are compared in Figure 4. The former followed the trends previously mentioned for total chlorophyll a (Figure 3). The latter (netplankton chlorophyll a) was detectable only at Stations 1/I, 2/I, 1/II, 1/III and 1/IV.

[1]The absorbance curves from which all chlorophyll a values were calculated are included in Appendix B.

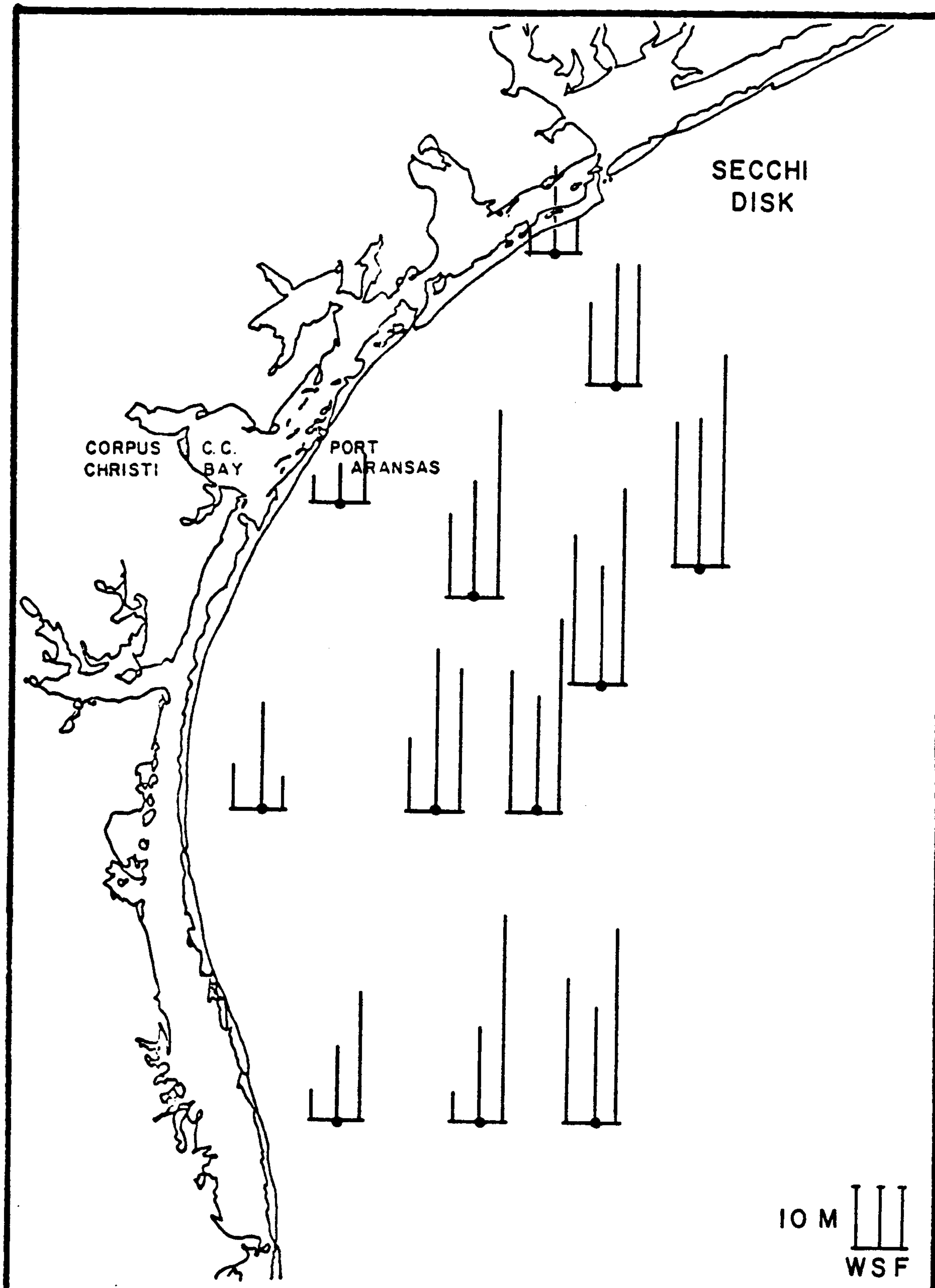

Figure 1. Seasonal Secchi Depth (m) Variation in the STOCS Study Area. (W=Winter, S=Spring, F=Fall)

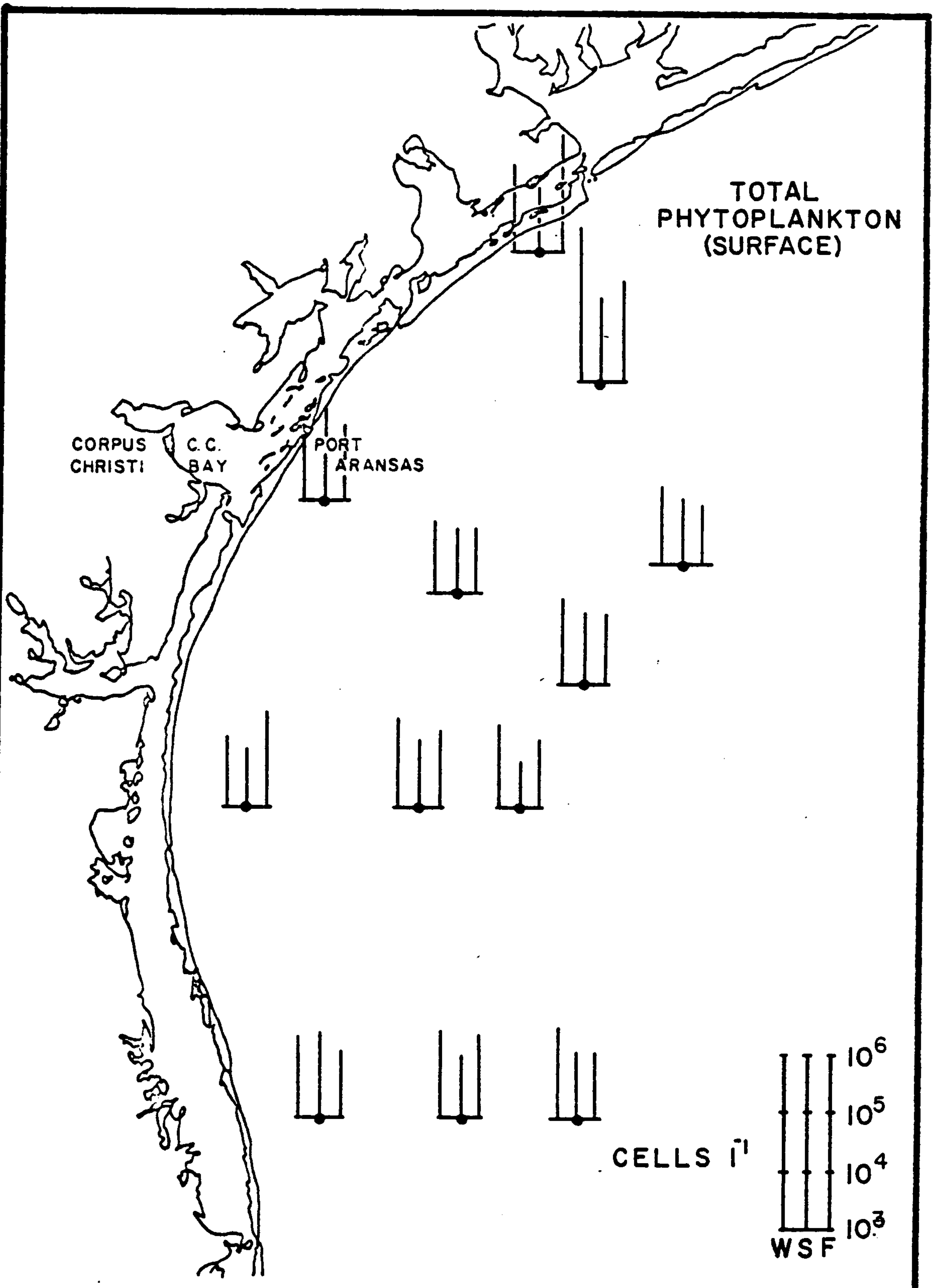

Figure 2. Seasonal Phytoplankton Abundance (Cells l^{-1}) Variation at the Surface in the STOCS Study Area.

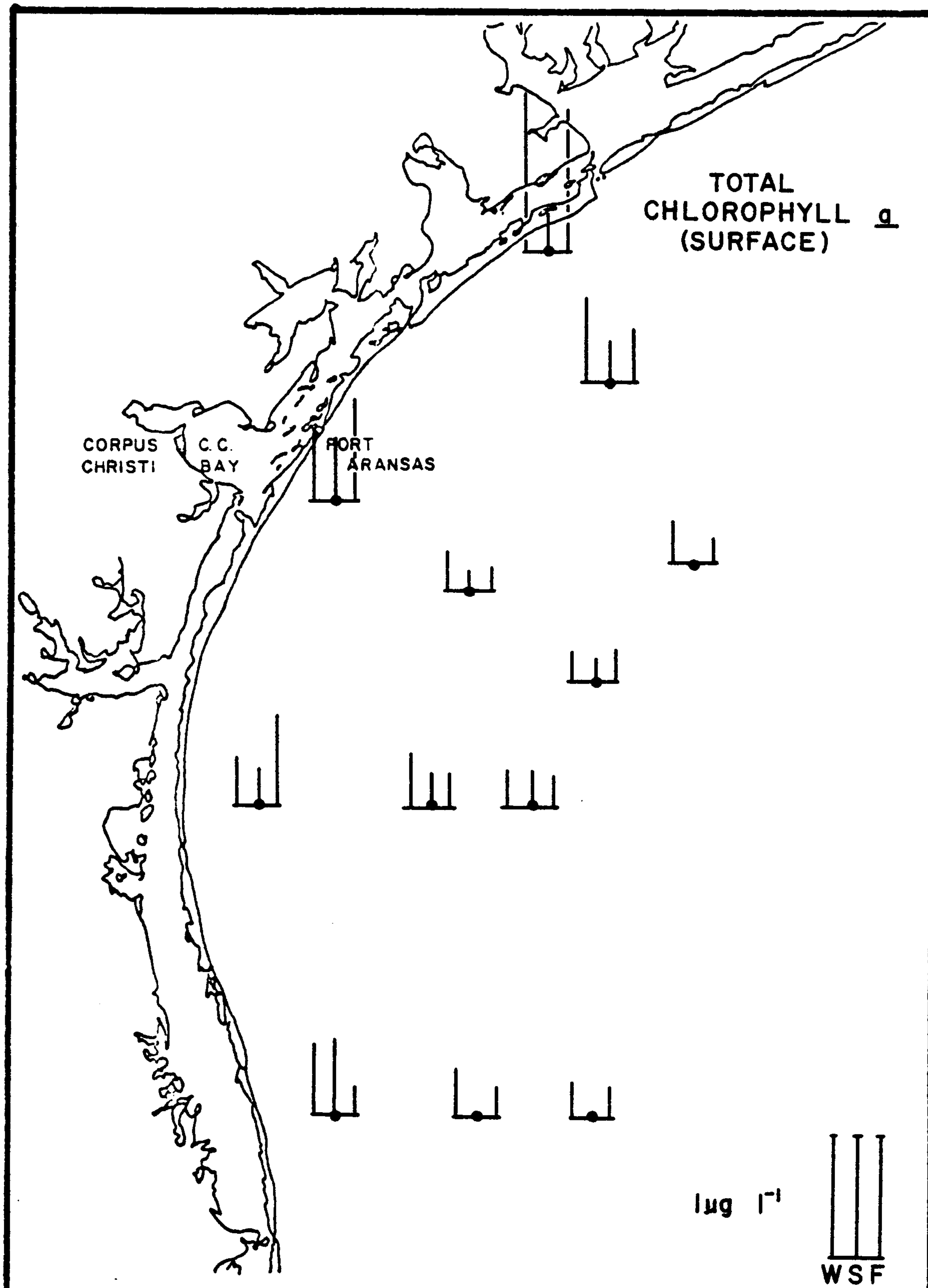

Figure 3. Seasonal Total Chlorophyll a (µg l^{-1}) Variation at the Surface in the STOCS Study Area.

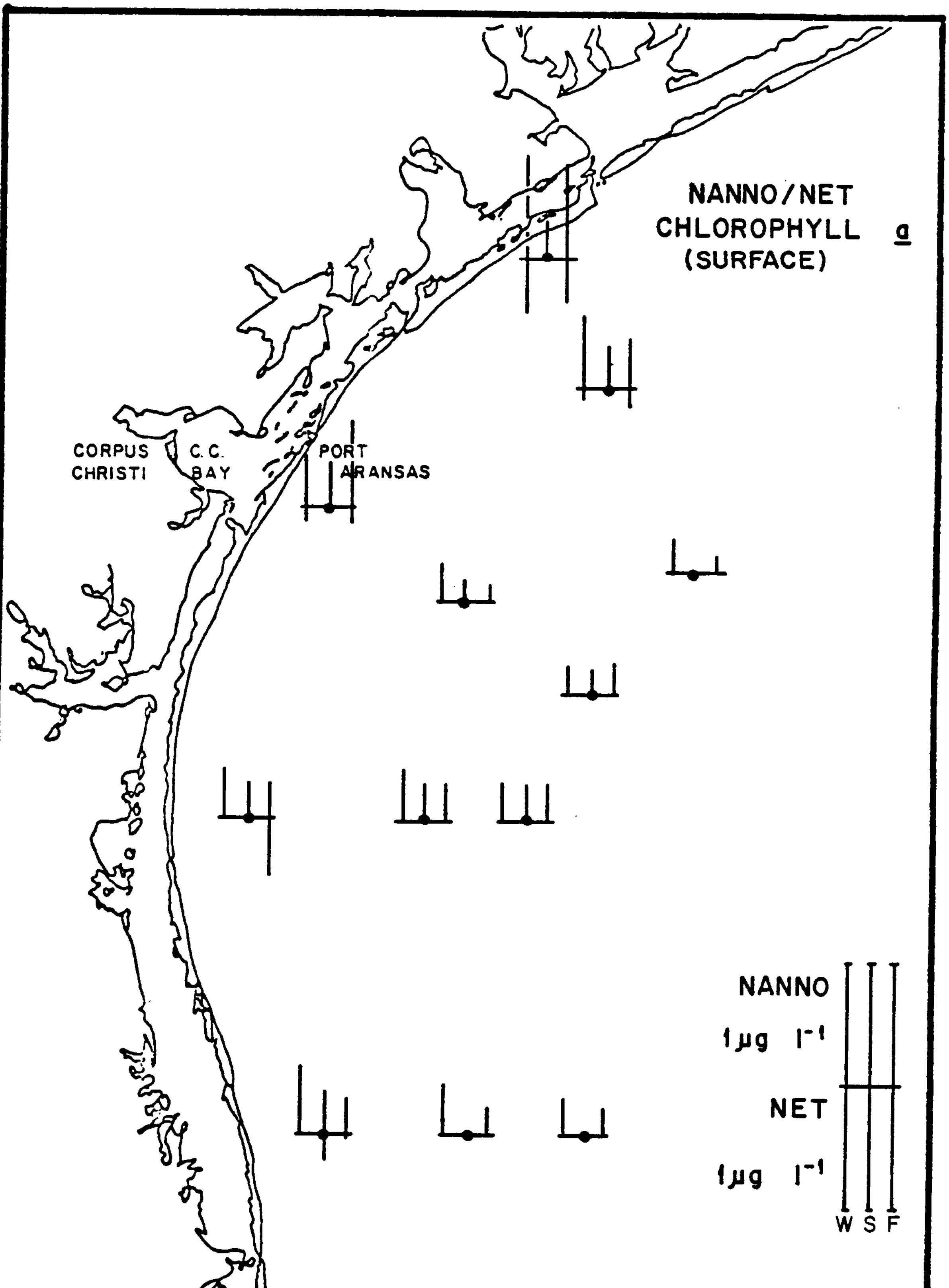

Figure 4. Seasonal Nanno- and Netphytoplankton Chlorophyll a ($\mu g\ l^{-1}$) Variation at the Surface in the STOCS Study Area.

Figure 5 displays seasonal variation in surface ATP concentration. A general offshore decrease was detectable on all transects. Highest values occurred during the Fall at Stations 1/I and 1/III. Occasional intermediate values were scattered among the four transects.

Depth Patterns

The seasonal depth patterns of phytoplankton biomass are given in Figures 6-7. Figure 6 shows the depth pattern of net chlorophyll a. During the winter, Station 1 (all transects) showed the highest concentration in bottom samples, especially Station 1/I. Stations 2 and 3 (all transects) generally showed a mid-depth minimum, except at Stations 2/I and 3/II where a mid-depth maximum occurred. During the spring, Station 1 (all transects) maintained bottom maxima, especially at Station 1/III. Stations 2 and 3 generally showed uniformly low concentrations with depth except for the bottom maximum at Station 2/I. During the fall, Stations 1/I, 1/II and 1/III showed increasing amounts of chlorophyll a with depth at successively higher concentrations. Station 1/IV displayed a uniformly low chlorophyll a concentration with depth. Stations 2 and 3, all transects, generally showed uniformly low concentrations with depth, except at Station 2/I which had a subsurface minimum.

Figure 7 shows the depth pattern of nannophytoplankton chlorophyll a. This size fraction was generally detectable at all stations during all seasons at some point within the water column. During the winter, Station 1, all transects, displayed uniform distributions with depth. Station 2, all transects, also showed uniform distributions with depth, except at Station 2/I where a mid-depth minimum occurred. Station 3, all transects, showed significant chlorophyll a concentrations from the surface to the half-photic zone, but low concentrations in bottom samples. During the spring,

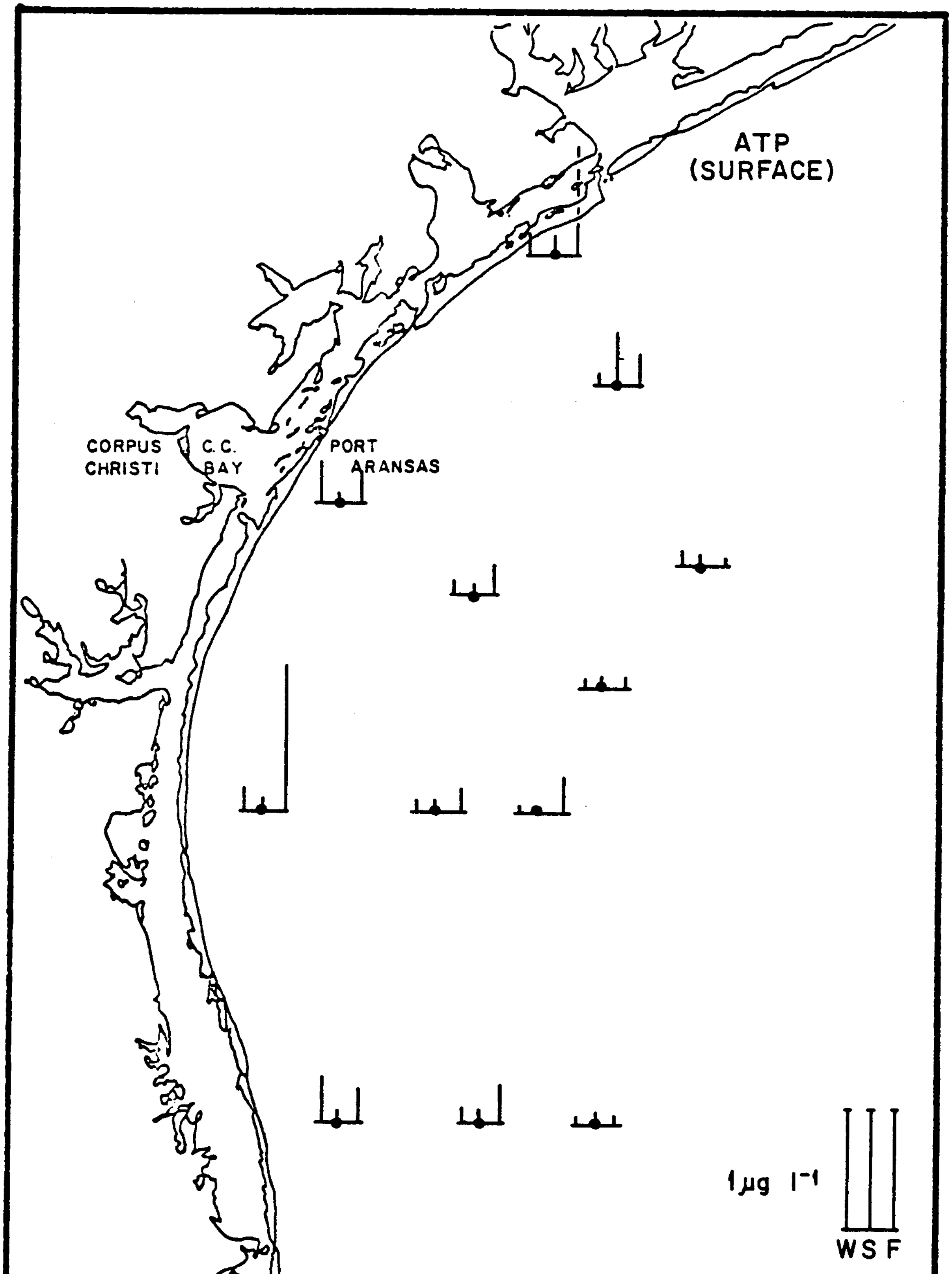

Figure 5. Seasonal ATP (µg l^{-1}) Variation at the Surface in the STOCS Study Area.

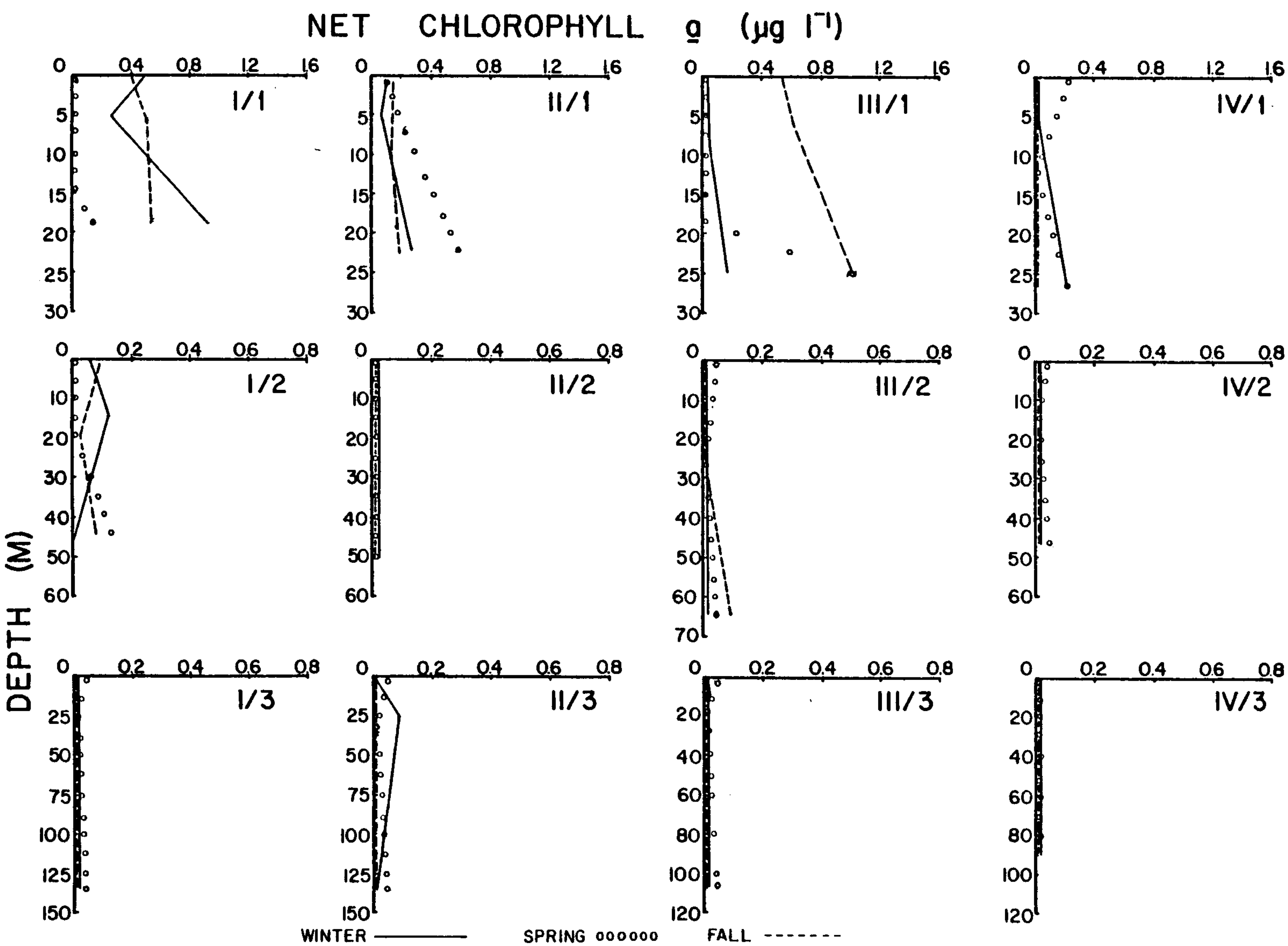

Figure 6. Seasonal Depth Variation of Netphytoplankton Chlorophyll a ($\mu g\ l^{-1}$) in the STOCS study area.

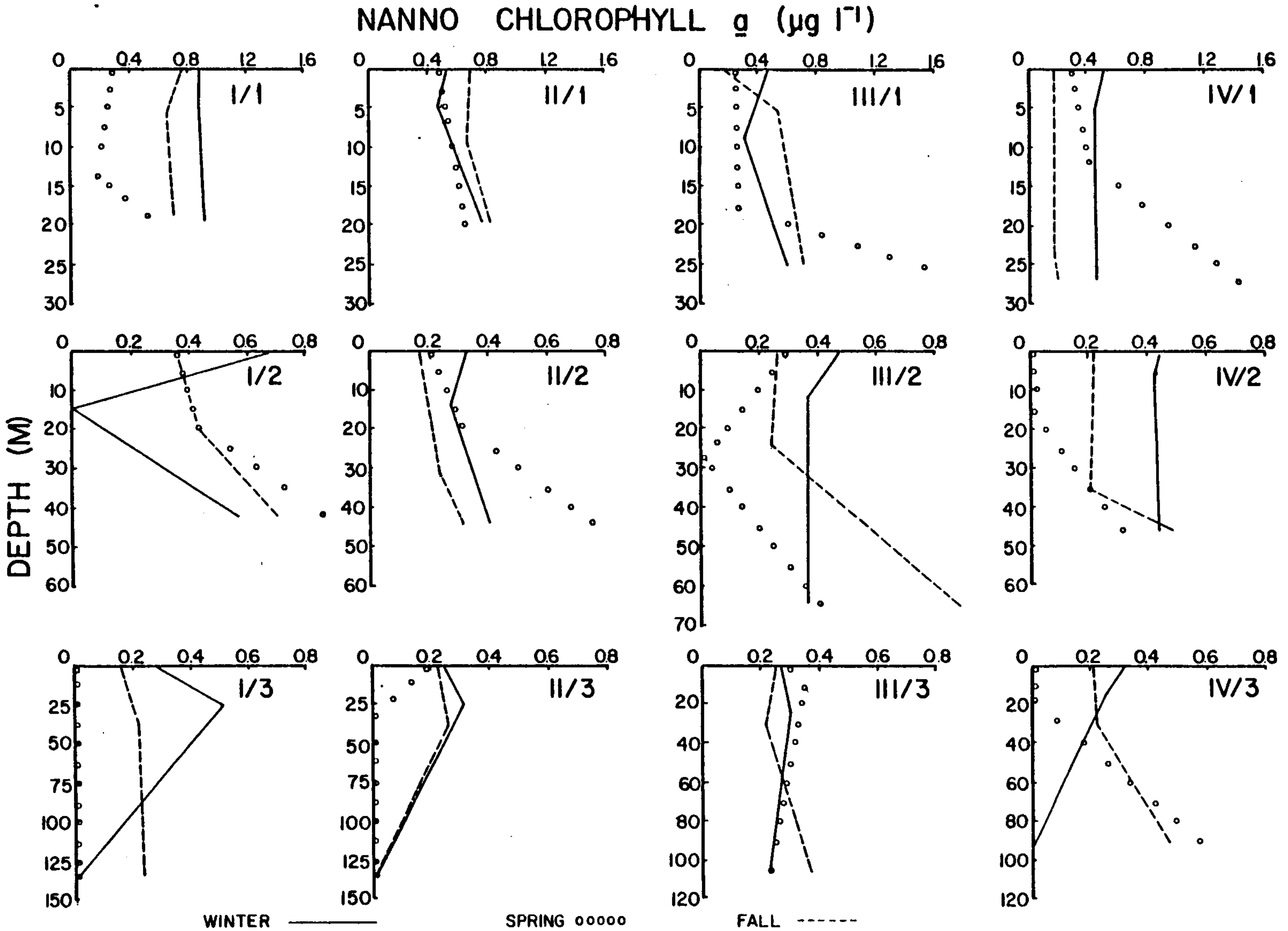

Figure 7. Seasonal Depth Variation of Nannophytoplankton Chlorophyll $\underline{a}$ ($\mu g\ l^{-1}$) in the STOCS Study Area.

Stations 1 and 2, all transects, generally displayed highest concentrations in bottom samples. Station 3, all transects, showed a complex pattern. Station 3/I was uniformly low in chlorophyll a with depth; 3/II showed a surface maximum; 3/II showed a mid-depth maximum; and 3/IV showed a bottom maximum. During the fall, Station 1, all transects, was again generally uniform in chlorophyll a concentration with depth. Station 2, all transects, showed highest concentrations in bottom samples. Station 3, all transects, generally showed an increase with depth, except at Station 3/II.

Monthly Temporal Patterns

Figures 8-11 display the monthly temporal patterns of the various measurements at various depths along Transect II. Figure 8 shows monthly Secchi depth variation through the year. Water clarity was generally relatively low at Stations 1/II, 2/II and 3/II between December and June. Water clarity generally increased between July and November. Though Secchi depth determinations generally increased offshore, the water column at Station 2/II was, at times, clearer than that at Station 3/II.

Figure 9 shows monthly phytoplankton counts at the surface and half-photic zone. Station 1/II increased in cell numbers in March at both depths and Stations 2/II and 3/II increased in cell numbers in April at both depths. The spring peak was generally dominant at all three stations. Cell numbers gradually decreased at all three stations through May and June, reached summer low values in July, and maintained these values through November. The three stations generally showed increased phytoplankton numbers at both depths in December.

Figure 10 shows total chlorophyll a concentrations through the year. Station 1/II displayed about the same pattern at all depths, *i.e.*, con-

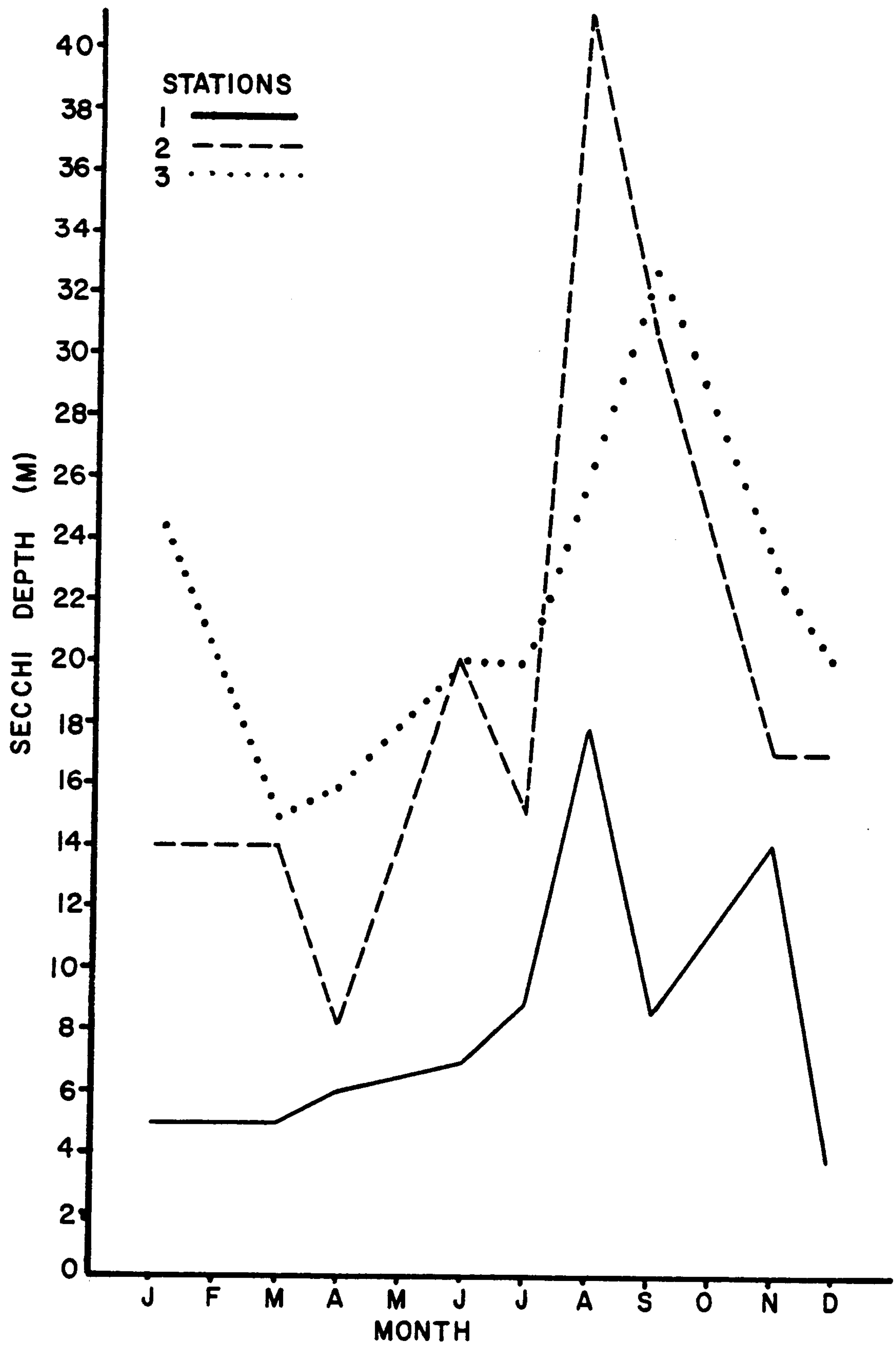

Figure 8. Monthly Variation in Secchi Depth (m) along Transect II.

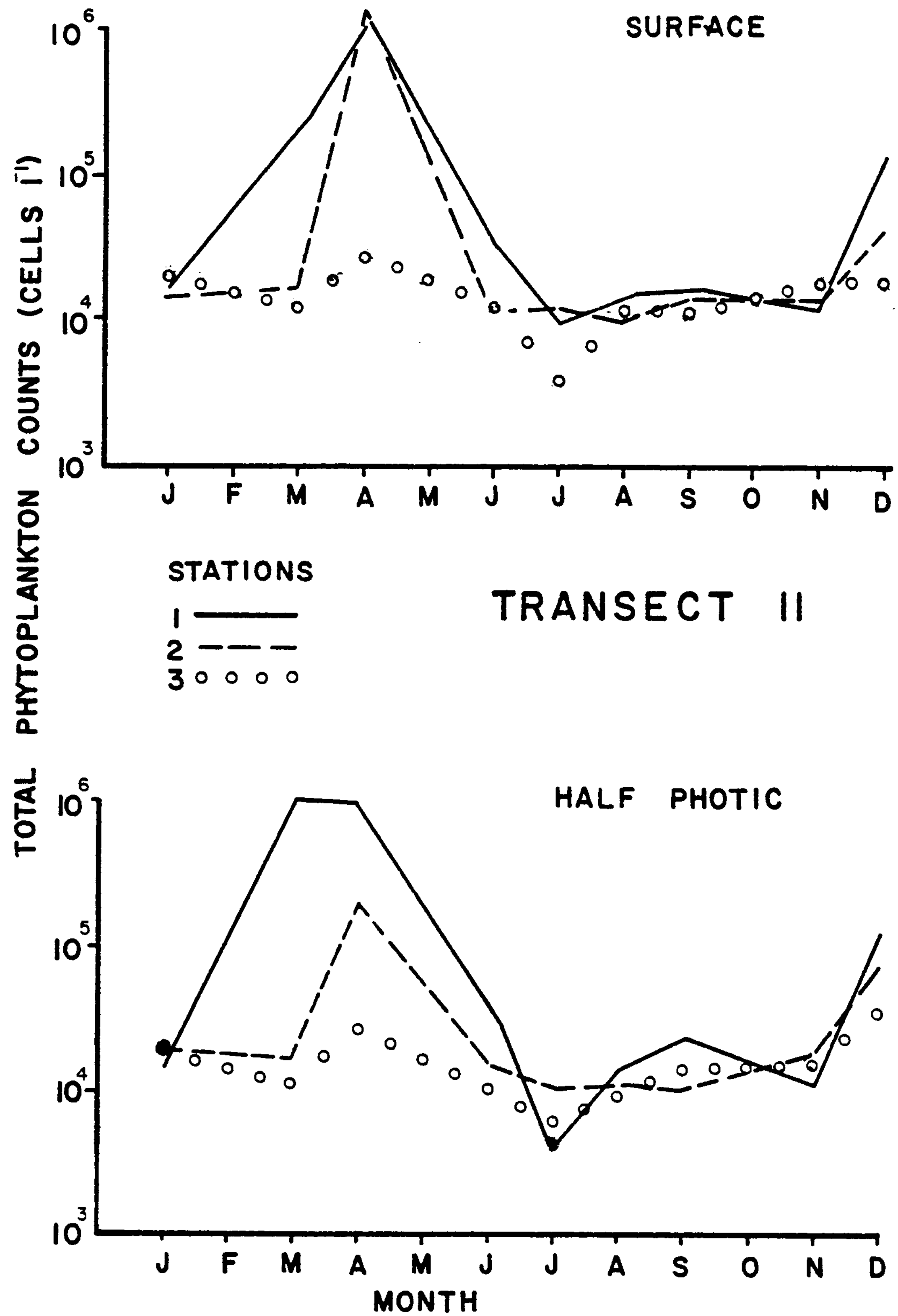

Figure 9. Monthly Variation of Phytoplankton Abundance (cells l^{-1}) Along Transect II at the Surface and One-Half the Photic Zone.

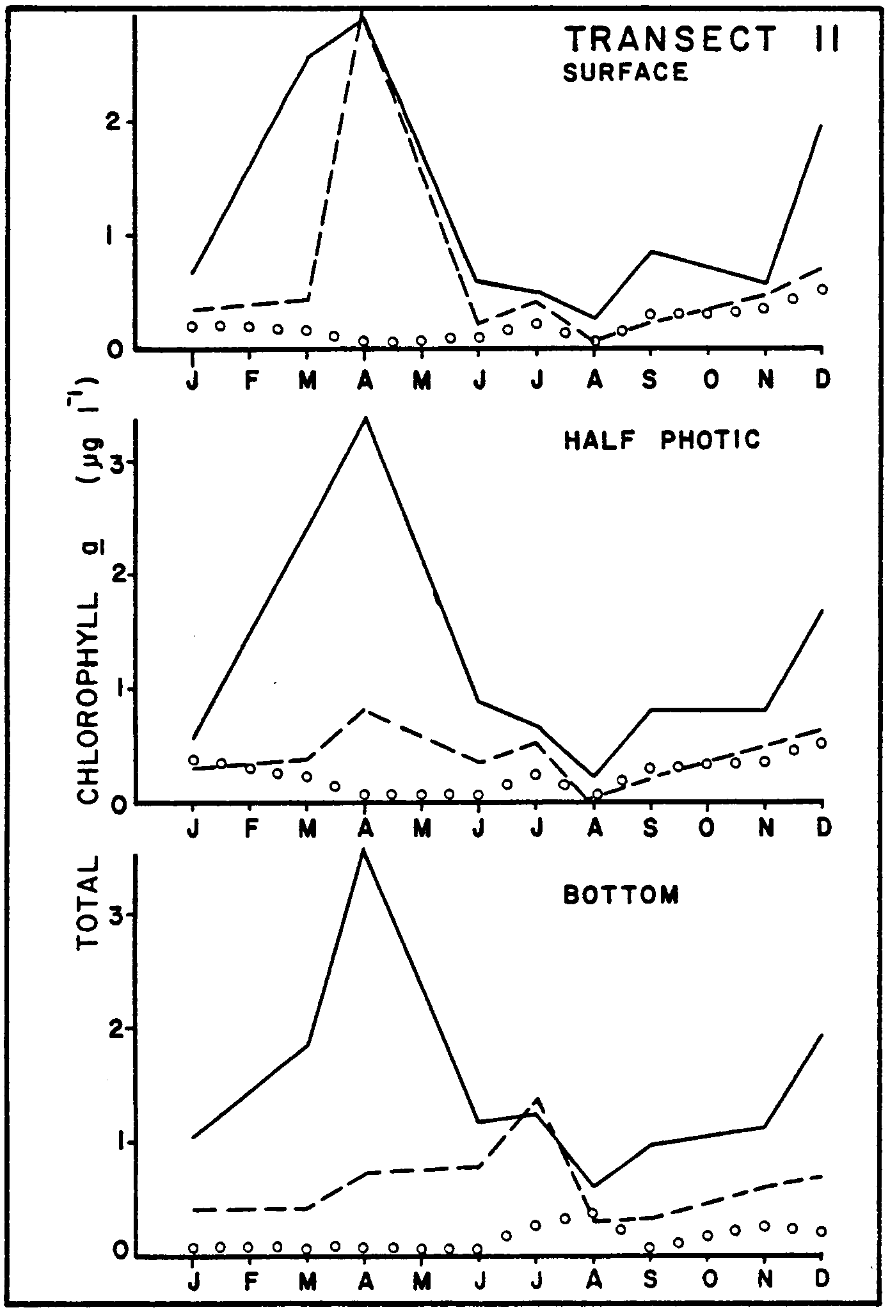

Figure 10. Monthly Variation of Total Chlorophyll a (µg l^{-1}) Along Transect II at the Surface, One-Half the Photic Zone and Bottom.

centrations increased from January to April, decreased from April to June, maintained low levels from June to November and increased in December. Station 2/II displayed similar patterns at the surface and one-half the photic zone and corresponded with the dynamics at Station 1/II. The amplitude, however, was less in the one-half photic zone samples. The bottom sample at Station 2/II showed a total chlorophyll a maximum in July.

Station 3/III did not show a spring maximum as observed at Stations 1/II and 2/II. The surface, one-half the photic zone and bottom samples showed an increase in concentration in the latter half of the year. The bottom sample showed a maximized concentration in August. The total chlorophyll a concentrations greater than 1 $\mu g\ l^{-1}$ were generally caused by significant populations of the netphytoplankton fraction. The remaining pattern was primarily due to changes in the nannophytoplankton fraction.

Figure 11 shows the annual cycle of ATP concentration. Two general peaks were evident at all depths of Stations 1/II and 2/II. The first peak occurred in April and the second between September and December. Station 3/II showed higher surface and one-half photic zone concentrations between January and April and between September and November. The bottom samples showed a single higher value in July.

The rank order of phytoplankton species abundance by sampling date, depth and station are presented in Table 1, Appendix B. Similar information for total coccolithophorids abundance is included in Table 2, Appendix B.

The monthly temporal pattern of phytoplankton species composition for Stations 1/II, 2/II and 3/II are presented in Tables 1-3. Data from the surface and one-half photic zone samples were lumped in compiling these tables. Using the data in Table 1, Appendix B, Tables 1-3 were

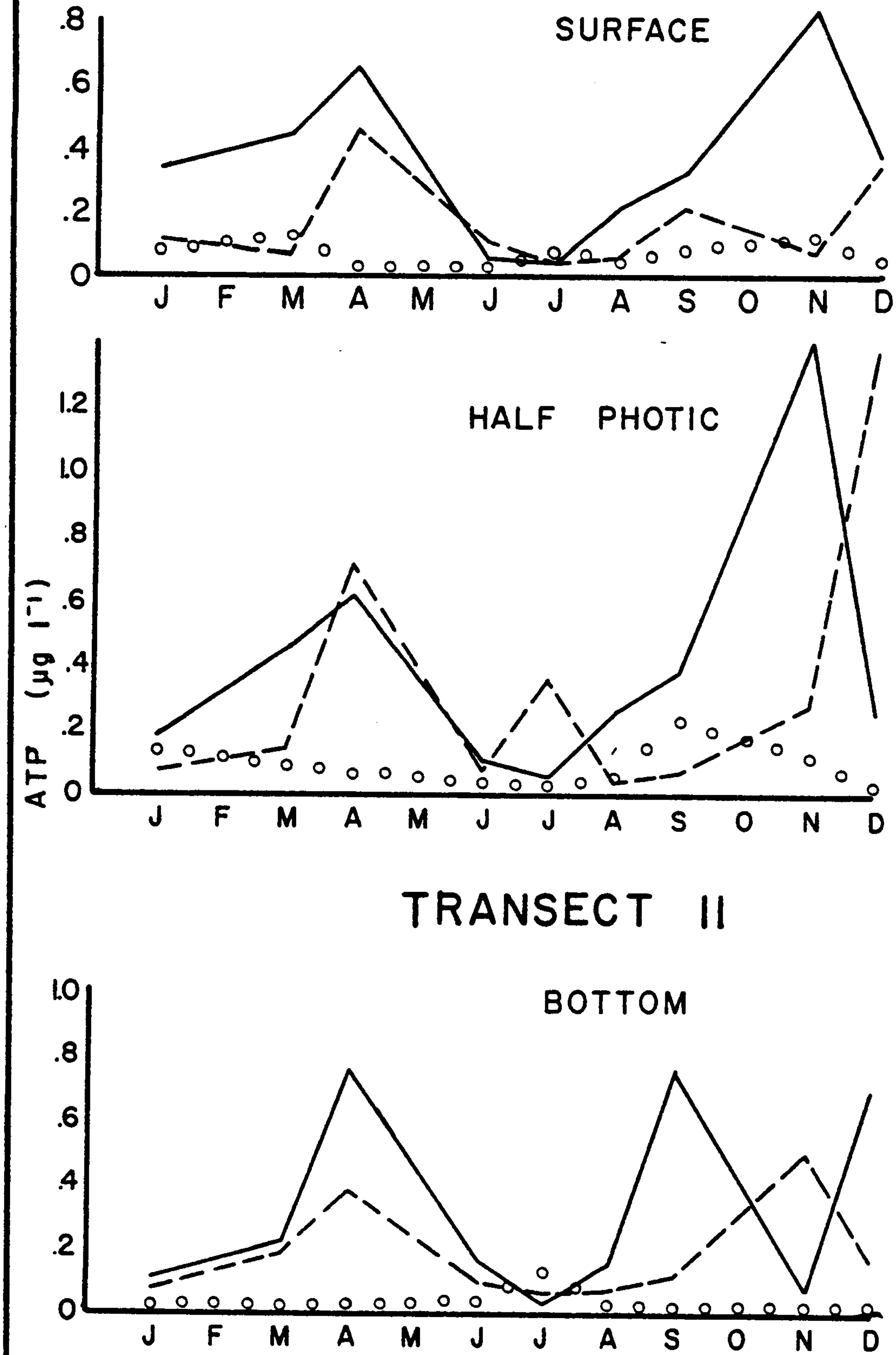

Figure 11. Monthly Variation of ATP (μg l^{-1}) along Transect II at the Surface, One-Half the Photic Zone and Bottom.

TABLE 1

MONTHLY CHANGES IN PHYTOPLANKTON SPECIES COMPOSITION AT STATION 1/II. NUMBERS UNDER EACH CRUISE HEADING GIVE RANK ORDER OF DECREASING ABUNDANCE

SPECIES	WINTER	MARCH	APRIL	SPRING	JULY	AUGUST	FALL	NOVEMBER	DECEMBER
Prorocentrum compressum	1								
Skeletonema costatum	2	1	4						1
Prorocentrum micans	3							8	
Nitzschia pungens	4	7		5					
Thalassiosira decipiens	5	5							
Gonyaulax polygramma	6					4			
Nitzschia pacifica	7								
Nitzschia longissima	8								
Leptocylindrus danicus	9			4					
Pyrophacus horologium	10								
Leptocylindrus minimus		2	2						
Thalassiosira rotula		3		9					6
Nitzschia delicatissima		4	1						5
Coscinosira polychorda		8		10		1			
Thalassionema nitzschioides		9							
Nitzschia seriata		6	3					6	12
Coscinosira oestrupii		11				5			2
Asterionella glacialis		12							
Ditylum brightwellii			5						10
Chaetoceros mitra			6						
Cerataulina bergonii			7						
Rhizosolenia stolterfothii			8	1	5				
Chaetoceros pseudocurvisetus			9						9
Chaetoceros didymus v. protuberans			10						
Chaetoceros decipiens				2				4	
Bacteriastrum hyalinum				3			3		
Chaetoceros pseudocrinitus				6					
Rhizosolenia calcar avis				7					
Guinardia flaccida				8				5	
Gonyaulax minima					1		1	3	
Rhizosolenia alata v. alata					2				
Nitzschia closterium					3		4		
Thalassiothrix frauenfeldii					4				
Rhizosolenia alata v. indica									
Ceratium longinum					6				
Amphidinium acutissimum					7				
Navicula distans					8		2	1	7
Chaetoceros diversus						2			
Peridinium cerasus						3			
Chaetoceros messanensis						6			
Chaetoceros tetrastichon						7			
Chaetoceros coarcticus								2	
Chaetoceros didymus v. anglica								7	
Rhizosolenia robusta								9	
Chaetoceros compressus									3
Chaetoceros affinis									4
Eucampia zoodiacus									8
Rhizosolenia styliformis									11

TABLE 2

MONTHLY CHANGES IN PHYTOPLANKTON SPECIES COMPOSITION AT STATION 2/II.
NUMBERS UNDER EACH CRUISE HEADING GIVE RANK ORDER OF DECREASING ABUNDANCE

SPECIES	WINTER	MARCH	APRIL	SPRING	JULY	AUGUST	FALL	NOVEMBER	DECEMBER
Skeletonema costatum	1	2	1						1
Chaetoceros curvisetus	2			6					
Chaetoceros decipiens	3	6	11	4		5	5		2
Cerataulina bergonii	4		5						
Nitzschia pacifica	5								
Chaetoceros pseudocurvisetus	6		9						3
Chaetoceros mitra	7		7						
Nitzschia pungens	8	9		11					
Nitzschia longissima	9		3	1		3	1	10	
Nitzschia delicatissima	10	1		7				5	
Bacteriastrum hyalinum	11	8							
Navicula membranacea	12								
Chaetoceros didymus v. protuberans	13			2		7		9	
Nitzschia closterium		3							
Chaetoceros socialis		4							
Dinophysis caudata v. pedunculata		5							
Chaetoceros compressus		7			1				
Chaetoceros messanensis		10							8
Nitzschia seriata		11	4			4			5
Leptocylindrus minimus			2						
Ditylum brightwellii			6						
Chaetoceros affinis			8						
Rhizosolenia stolterfothii			10	8				1	10
Leptocylindrus danicus				3	3				
Trichodesmium spp.				5					
Bacteriastrum elongatum				9					
Guinardia flaccida				10				3	
Chaetoceros pelagicus				12					
Chaetoceros lacinosus					2				
Dactyliosolen antarcticus					4				
Chaetoceros peruvianus					5				
Rhizosolenia alata v. alata					6				
Chaetoceros diversus					7				
Navicula warwrikae					8				
Amphidinium acutissimum					9	8	3		
Thalassionema nitzschioides						1	4	8	4
Hemiaulus sinensis						2			
Thalassiothrix fraunfeldii						6			9
Gonyaulax minima							2		
Chaetoceros costatus								2	
Chaetoceros furcellatus								4	
Bacteriastrum mediterraneum								6	
Rhizosolenia styliformis v. longispina								7	
Chaetoceros glandazii								8	
Thalassiosira rotula									6
Coscinosira polychorda									7

TABLE 3

MONTHLY CHANGES IN PHYTOPLANKTON SPECIES COMPOSITION AT STATION 3/II. NUMBERS UNDER EACH CRUISE HEADING GIVE RANK ORDER OF DECREASING ABUNDANCE

SPECIES	WINTER	MARCH	APRIL	SPRING	JULY	AUGUST	FALL	NOVEMBER	DECEMBER
Nitzschia delicatissima	1	2	1	3		3	7	1	3
Thalassionema nitzschioides	2				1	1		2	1
Skeletonema costatum	3		2						
Chaetoceros decipiens v. singularis	4		6						
Bacteriastrum elongatum	5								
Bacteriastrum hyalinum	6	7							
Chaetoceros compressus	7		5		2				7
Nitzschia longissima	8	4							
Melosira sulcata	9								
Nitzschia closterium	10	1							6
Chaetoceros decipiens	11	3		6	3	2	6	4	2
Thalassiothrix frauenfeldii	12								
Chaetoceros glandazii		5							
Leptocylindrus danicus		6	9	1		8	6		
Rhizosolenia alata v. indica		8							
Hemiaulus hauckii		9							
Chaetoceros messanensis		10							
Amphidinium acutissimum		11			5	6	2	5	
Chaetoceros didymus v. protuberans			3			7			
Chaetoceros affinis			4						
Rhizosolenia alata v. gracillima			7	10	4				
Chaetoceros diversus			8					3	
Chaetoceros laciniosus			10						
Chaetoceros pseudocurvisetus			11						
Chaetoceros pseudocrinitus				2					
Guinardia flaccida				4				6	
Rhizosolenia stolterfothii				5					4
Rhizosolenia styliformis v. longispina				7					
Dactyliosolen antarcticus				8					
Trichodesmium spp.				9					
Thalassiothrix longissima				11					
Ceratium concilians				12					
Peridinium tuba				13		10			
Chaetoceros simplex				14					
Rhizosolenia imbricata				15					
Gonyaulax minima					6			8	
Ceratium kofoidii					7				
Hemiaulus sinensis						4	5		8
Bacteriastrum elegans						5			
Pyrophacus horologium						9			
Rhizosolenia alata v. alata							1		
Rhizosolenia calcar avis							3		
Striatella interrupta							4		
Chaetoceros tetrastichon							8		
Chaetoceros curvisetus								7	5
Chaetoceros densus								9	
Streptotheca thamesis								10	
Nitzschia seriata									8

generated by listing the 10 most abundant species at each station during successive cruises in rank order of decreasing abundance. The numbers under each cruise heading gives the rank order of abundance within that period. For example, at Station 1/II, March, *Skeletonema costatum* was the most abundant species and *Asterionella glacialis* was the least abundant species listed on Table 1, Appendix B.

The tables express in a simple way the community changes observed at Stations 1/II, 2/II and 3/II during 1976. Some general observations applicable to the three tables are:

1) Successive monthly cruises unfailingly added new species to the overall list of most abundant species. Station 3/II exhibited a large number of new species during the spring cruise;

2) The communities may be grossly divided into two temporal groups, a) December-April, and b) May-November;

3) Stations 1/II and 2/II exhibit more seasonality in species composition than Station 3/II.

The dominant species at each station during the periods defined in 2a and b above were:

1/II December-April: *Skeletonema costatum, Leptocylindrus minimus, Nitzschia delicatissima, Nitzschia seriata.*

May-November: *Rhizosolenia stolterfothii, Chaetoceros decipiens, Bacteriastrum hyalinum, Gonyaulax minima, Nitzschia closterium, Navicula distans.*

2/II December-April: *Skeletonema costatum, Chaetoceros decipiens, Nitzschia delicatissima.*

May-November: *Chaetoceros decipiens, Leptocylindrus danicus, Amphidinium acutissimum.*

3/II December-April: *Nitzschia delicatissima, Skeletonema costatum, Thalassionema nitzschoides, Chaetoceros decipiens, Leptocylindrus danicus.*

May-November: Same as December-April, *Amphidinium acutissimum, Gonyaulax minima, Hemialus sinensis.*

A more detailed analysis of community structure and spatial patterns will be attempted when appropriate cluster techniques become available.

Table 4 lists the monthly diversity indices for each sample collected during 1976. Replicated samples are represented by the median of the three values available. Diversity index values less than 2.0 occurred at Station 2/I, one-half the photic zone, winter; Station 3/II, surface, April; Station 3/II, one-half the photic zone, spring; Station 1/II, surface, December; and Station 1/II, one-half the photic zone, December. No diversity index values less than 2.0 were observed between the July and November cruises. The diversity index values less than 2.0 generally reflected the extreme dominance of a single species. These, respectively, were *Skeletonema costatum, Nitzschia delicatissima, Leptocylindrus danicus, Skeletonema costatum,* and *Skeletonema costatum* for the five samples mentioned above. These three former species appear to be the main "bloom" species on the South Texas Outer Continental Shelf.

DISCUSSION

Relationships Among Phytoplankton and Productivity

Figure 12 compares Secchi depth determinations with surface total chlorophyll a concentrations. This semi-log plot [Log(Chl a) = 0.140-0.036(S.D.)] demonstrates that high surface-chlorophyll a concentrations were associated with shallow Secchi depths and that low surface chlorophyll a concentrations were associated with deeper Secchi depths. The deviations from the regression line were probably caused by turbidity from non-phytoplankton sources and by sub-surface patches of phytoplankton biomass.

TABLE 4

MONTHLY CHANGES IN SPECIES DIVERSITY (H)[1] IN SURFACE AND ONE-HALF PHOTIC ZONE SAMPLES FROM ALL STATIONS

Station	Depth	Winter	March	April	Spring	July	August	Fall	November	December
1/I	0	3.10			3.59			3.48		
	.5P	2.73			3.55			2.72		
2/I	0	4.01			3.58			4.03		
	.5P	1.20			3.88			4.07		
3/I	0	4.65			3.23			3.30		
	.5P	4.25			3.76			3.04		
1/II	0	3.16	3.78	3.15	4.84	4.06	3.51	3.55	3.02	1.21
	.5P	3.98	2.66	3.00	4.85	3.52	3.48	3.52	3.54	1.57
2/II	0	4.25	4.30	3.30	3.93	3.77	2.72	3.02	4.06	2.88
	.5P	3.50	4.38	3.38	2.49	2.29	3.94	2.97	4.35	2.35
3/II	0	5.14	3.15	1.81	3.01	2.81	3.54	3.21	3.32	4.05
	.5P	4.69	3.05	2.14	1.66	3.56	3.19	3.21	3.63	3.58
1/III	0	4.67			4.39			2.68		
	.5P	4.12			4.36			2.70		
2/III	0	4.66			3.39			3.57		
	.5P	4.81			3.91			3.57		
3/III	0	5.06			2.77			3.62		
	.5P	4.55			2.93			3.40		
1/IV	0	3.94			4.14			3.87		
	.5P	3.64			4.59			3.48		
2/IV	0	4.61			4.16			3.62		
	.5P	4.50			3.92			3.75		
3/IV	0	4.47			4.48			2.68		
	.5P	4.30			3.15			3.08		

[1] $H = \sum_{i} = Pi \log_2 Pi$

where,

$$Pi = \frac{\text{abundance } i^{th} \text{ species}}{\text{total abundance}}$$

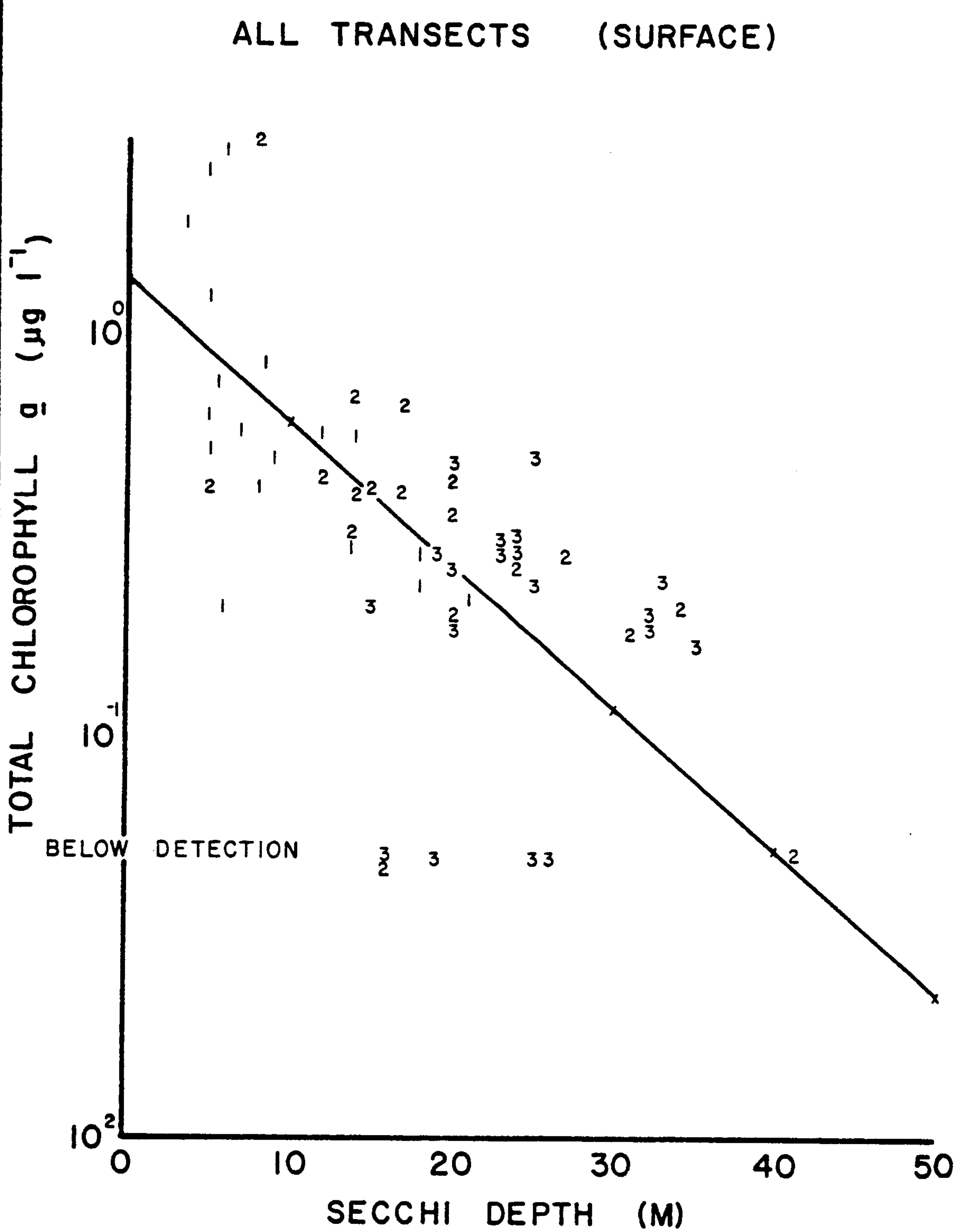

Figure 12. Relationship between Secchi Depth (m) and Surface Total Chlorophyll a ($\mu g\ l^{-1}$).

Figure 13 compares the surface patterns of total chlorophyll a concentrations and total phytoplankton cell numbers. This semi-log plot [Log (Tot Phyt) = 4.102 + 0.670 (Tot Chl a)] demonstrates that these two measurements of plant biomass exhibited parallel trends. Variation around the regression line was primarily caused by changes in the amount of chlorophyll a per cell in different species.

Figure 14 examines the relationship between centric diatom cell numbers and net chlorophyll a concentrations in surface samples. Generally, the chlorophyll a in the net fraction was not detectable until centric diatom cell counts exceeded 10,000 cells l^{-1}. At greater cell densities, the chlorophyll a concentration generally increased with centric diatom cell numbers. The data suggests that centric diatoms contributed significantly to the variations of net chlorophyll a concentrations.

Figures 15 and 16 depict the relationships between total phytoplankton numbers and ATP concentrations, and between ATP and chlorophyll a concentrations. Figure 15 shows that phytoplankton numbers and ATP concentrations were poorly related. Figure 16 suggests, however, a somewhat more direct relationship between ATP and chlorophyll a. The scatter associated with this plot may be partially explained by considering the correspondence between the carbon predicted by various C/Chl a ratio (Eppley, 1972) and the carbon predicted by ATP concentration (Holm-Hansen, 1966). Eppley (1972) suggested that natural phytoplankton populations normally have C/Chl a ratios between 30 and 60 under nutrient rich conditions, between 90 and 120 in coastal, low-nutrient conditions, and between 120 and 150 in the central ocean deserts. These standards can be applied to the present data. The points that fall between C/Chl a ratios of 30 and 150 probably represent suspended organic matter closely

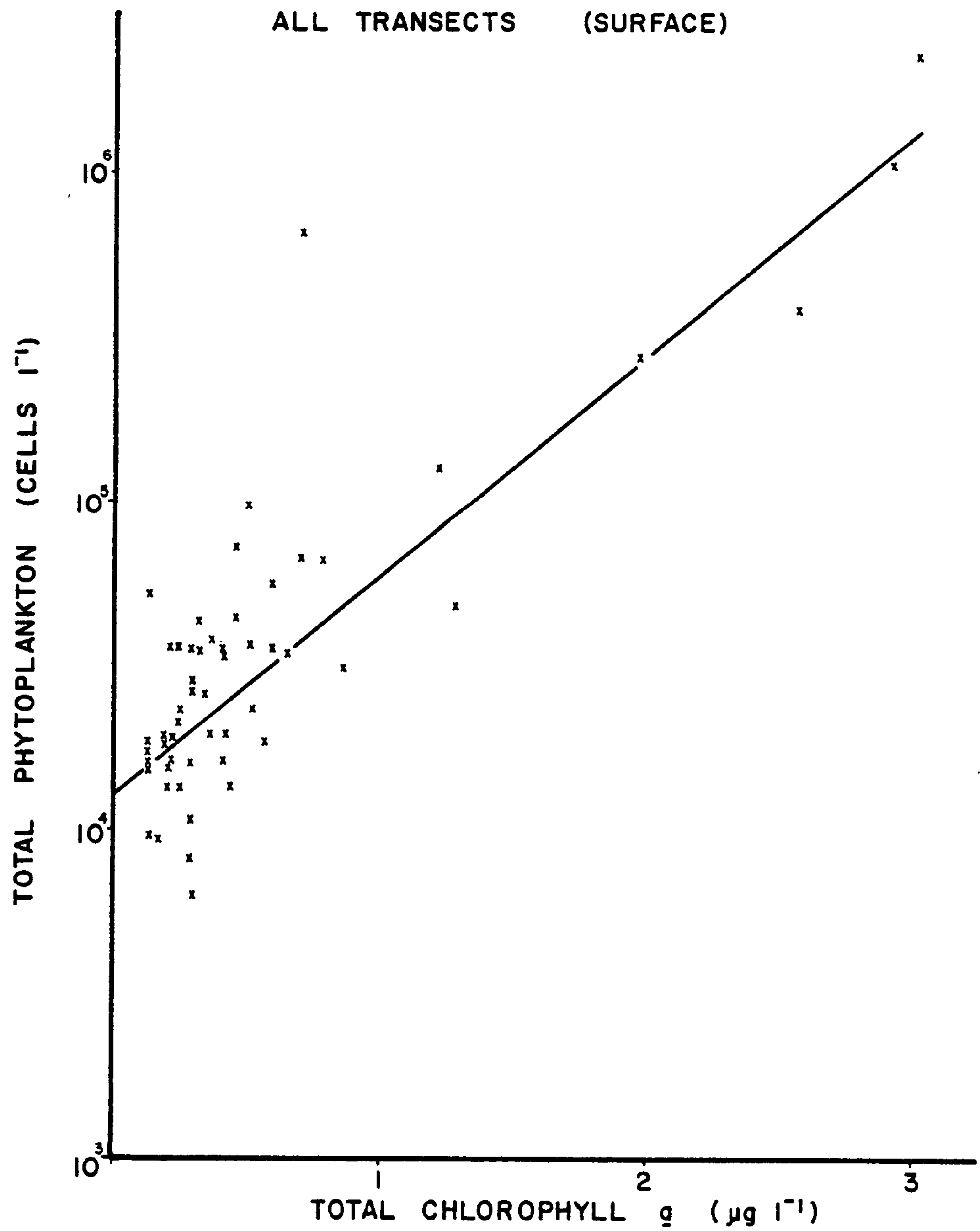

Figure 13. Relationship Between Total Chlorophyll a ($\mu g\ l^{-1}$) and Total Phytoplankton Abundance ($cells\ l^{-1}$) at the Surface.

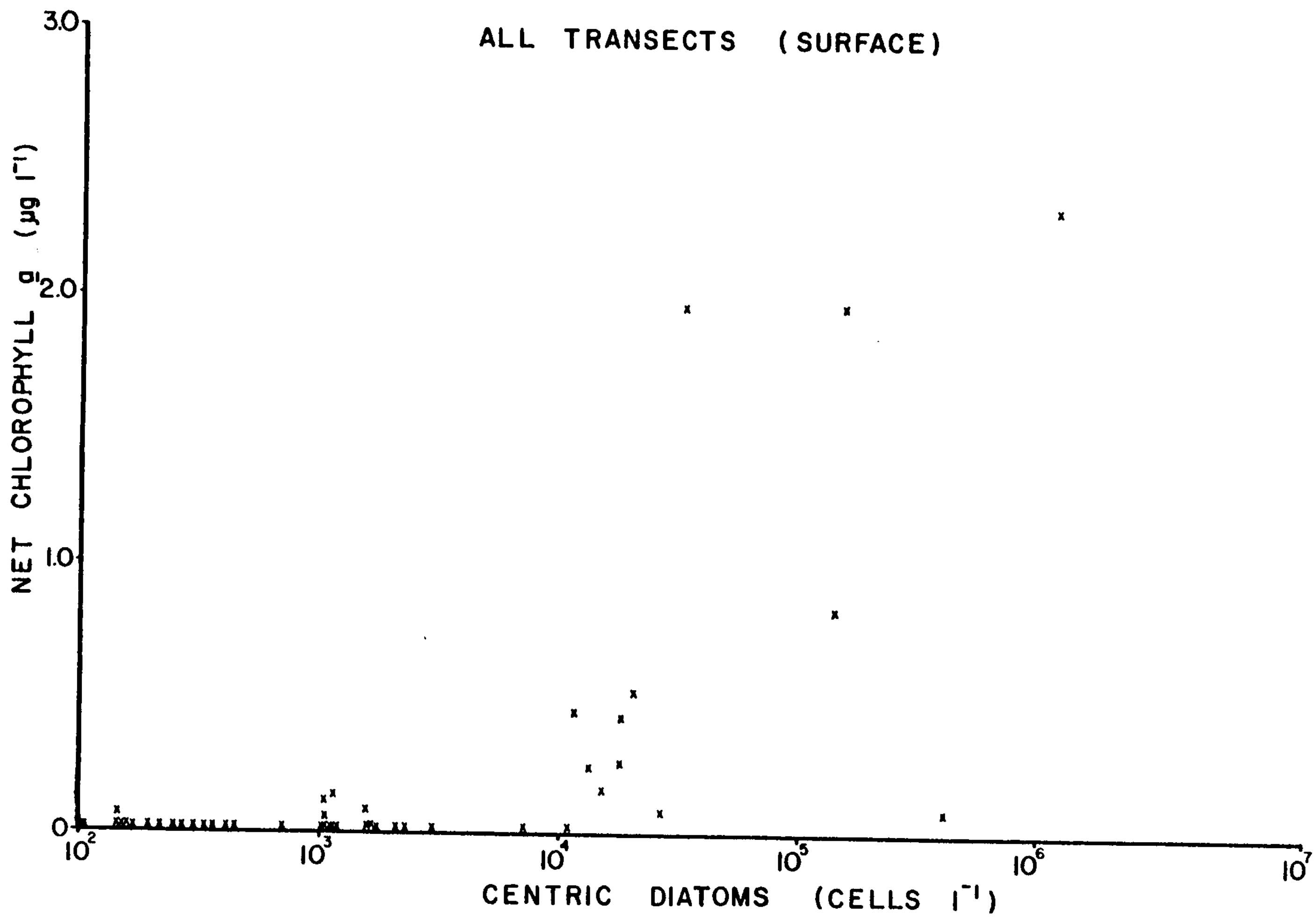

Figure 14. Relationship Between Centric Diatom Abundance (cells 1^{-1}) and Netphytoplankton Chlorophyll a ($\mu g\ 1^{-1}$) of the Surface.

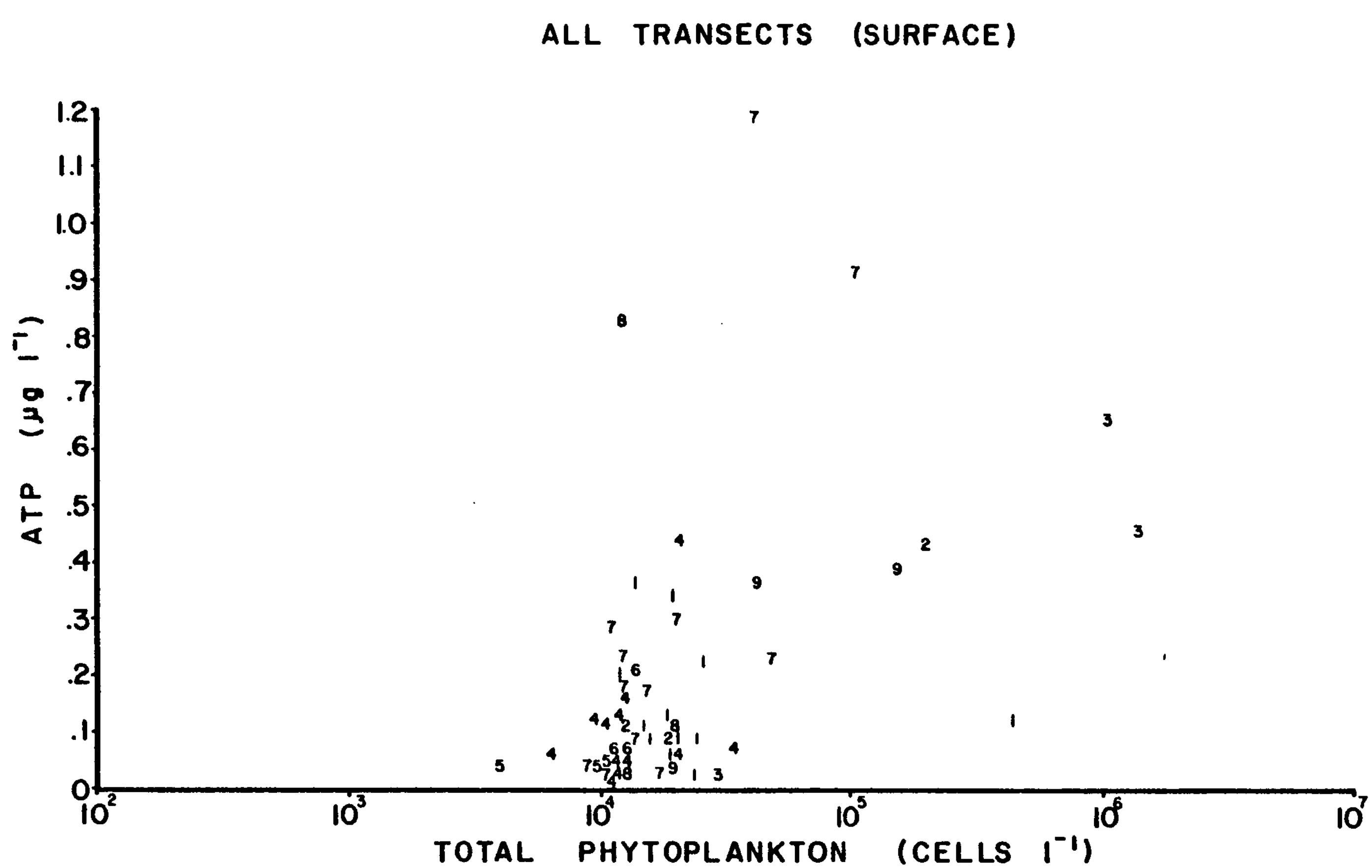

Figure 15. Relationship Between Total Phytoplankton Abundance (cells l^{-1}) and ATP ($\mu g\ l^{-1}$) at the Surface.

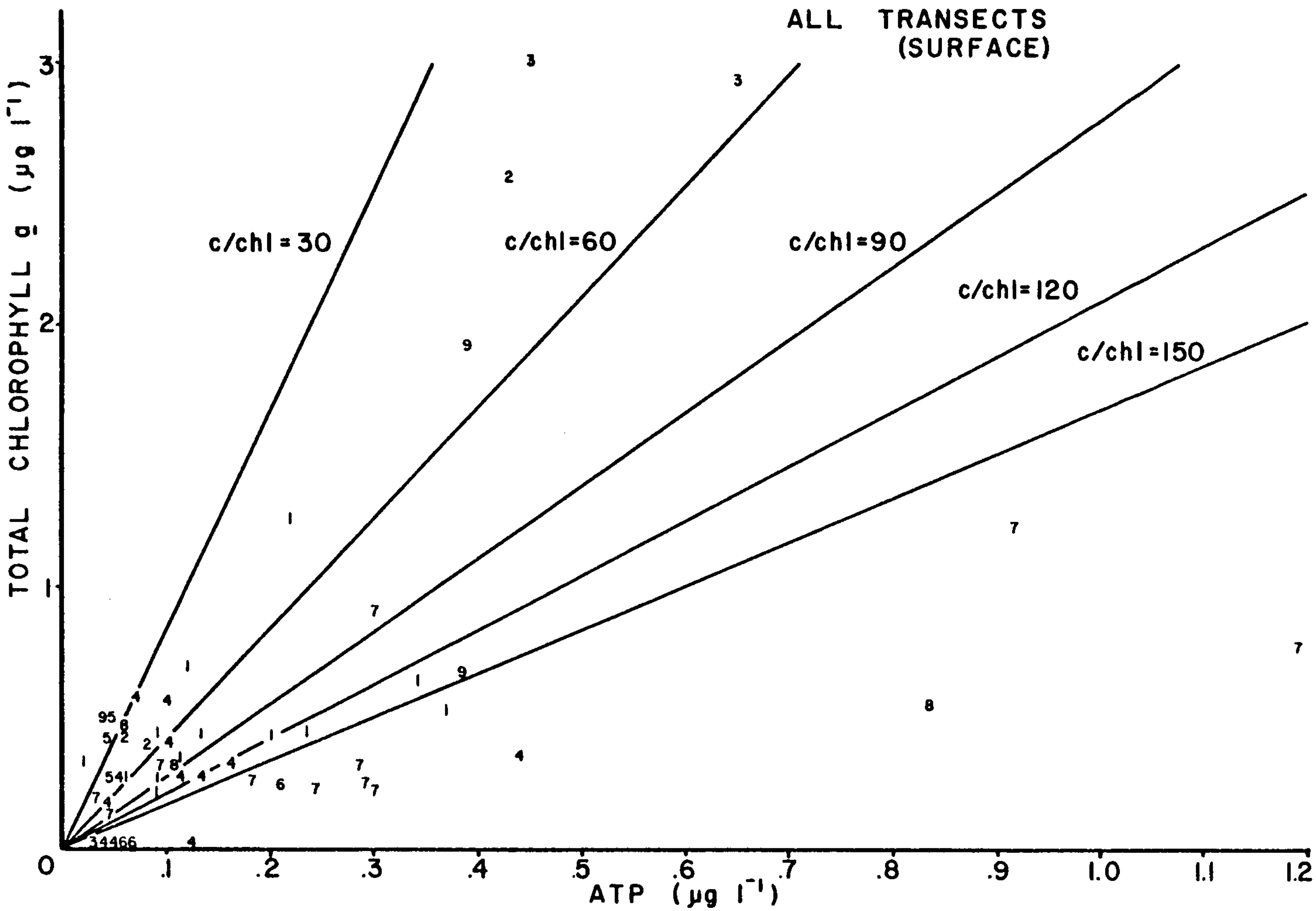

Figure 16. Relationship Between ATP (μg 1^{-1}) and Total Chlorophyll a (μg 1^{-1}) at the Surface.

related to phytoplankton. Most of these represent winter-spring samples. The points below the C/Chl a ratio of 150 probably represent suspended organic matter that results from sources other than phytoplankton. Most of these points represent summer-fall samples.

Since freshwater runoff is considered one of the major nutrient sources driving phytoplankton production, Figures 17, 18 and 19 show the relationships between biological parameters and salinity. The plot of surface salinity vs Secchi depth in Figure 17 shows that at salinities below 34 ppt Secchi depth was generally less than 8 m, but at salinities above 34 ppt Secchi depth ranged from 5 to 41 m. Only the data from the May cruise depart significantly from the general pattern. During May, at salinities between 30-34 ppt Secchi depth ranged from 7 to 27 m. This clear, low-salinity water may have originated from the Mississippi River.

Figure 18 shows the surface relationship between salinity and total chlorophyll a. Due to the lower concentrations of chlorophyll a encountered during 1976, the trend of increasing chlorophyll a with decreasing salinity was not as strong as the relationship noted in 1975.

Figure 19 shows that the netphytoplankton fraction [Net Chl a = 4.55 - 0.13 Sal] was generally more responsive to changes in salinity than the nannophytoplankton fraction [Nano Chl a = 0.76 - 0.01 Sal].

Figure 20 shows the relationship between ATP concentration and salinity at the surface of all transects. The pattern varied with time of year. The main outliers from the pattern of increasing ATP with decreasing salinity occurred in September and November.

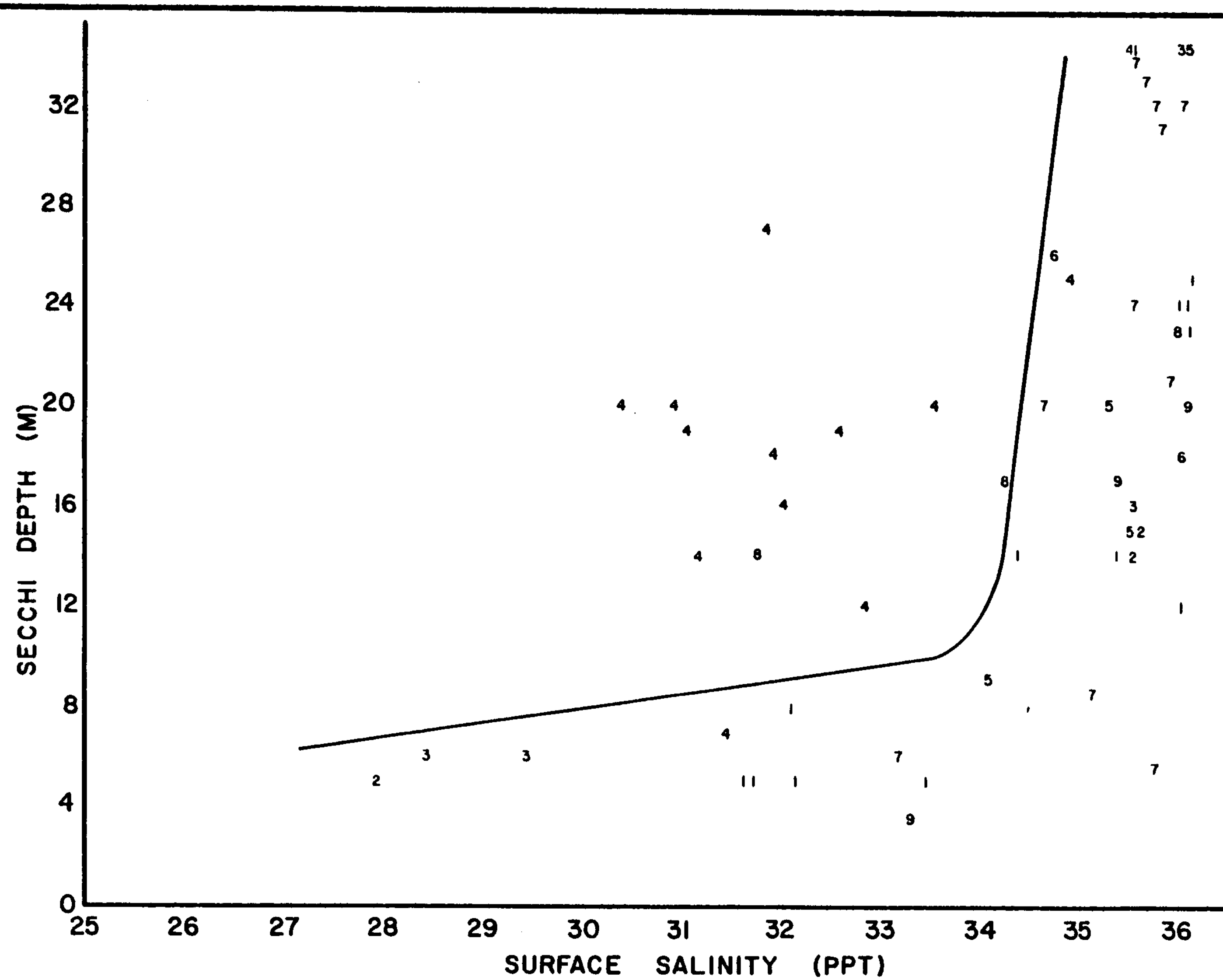

Figure 17. Relationship Between Surface Salinity (ppt) and Secchi Depth (m).

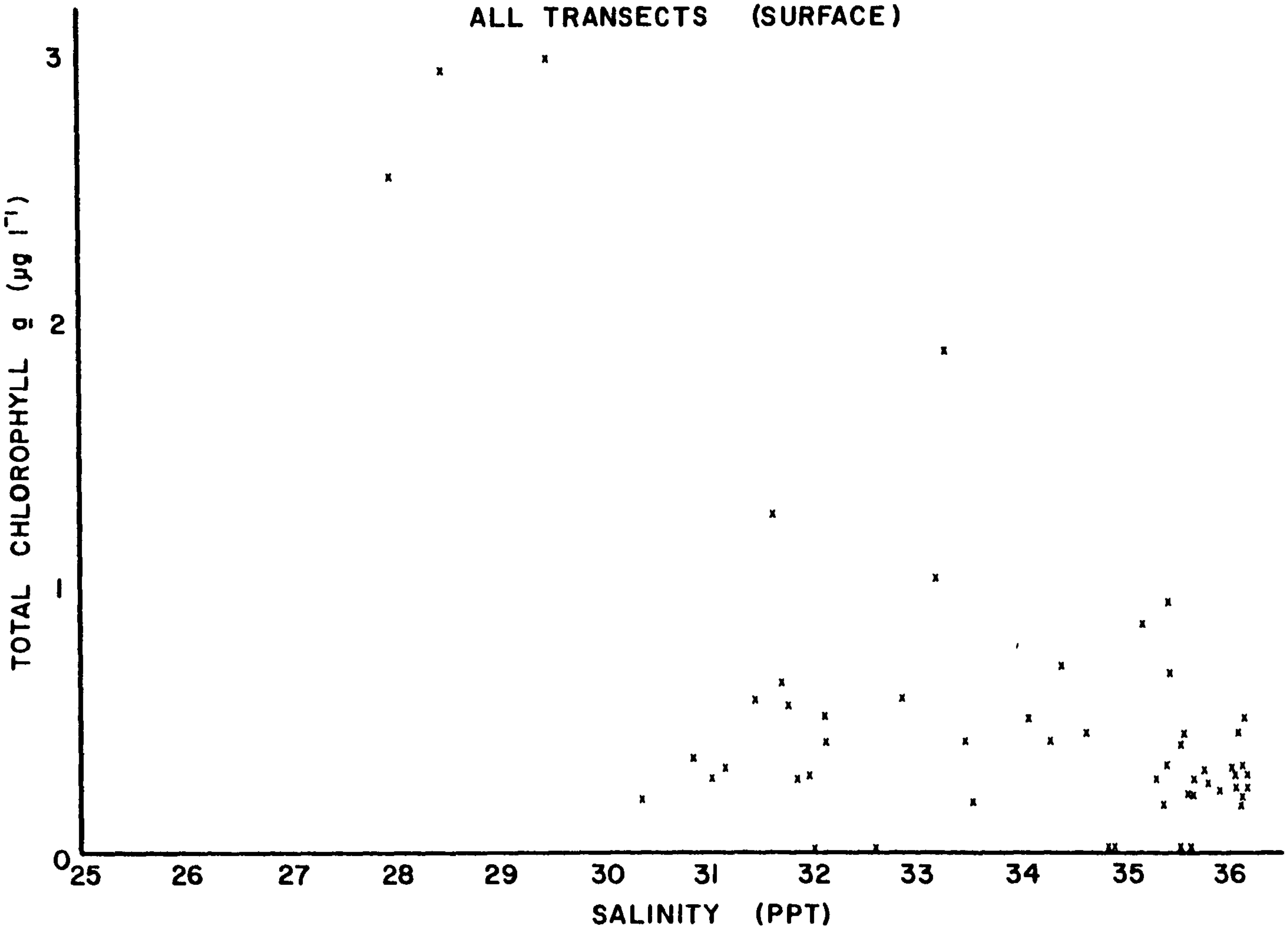

Figure 18. Relationship Between Salinity (ppt) and Total Chlorophyll a ($\mu g\ l^{-1}$) at the Surface.

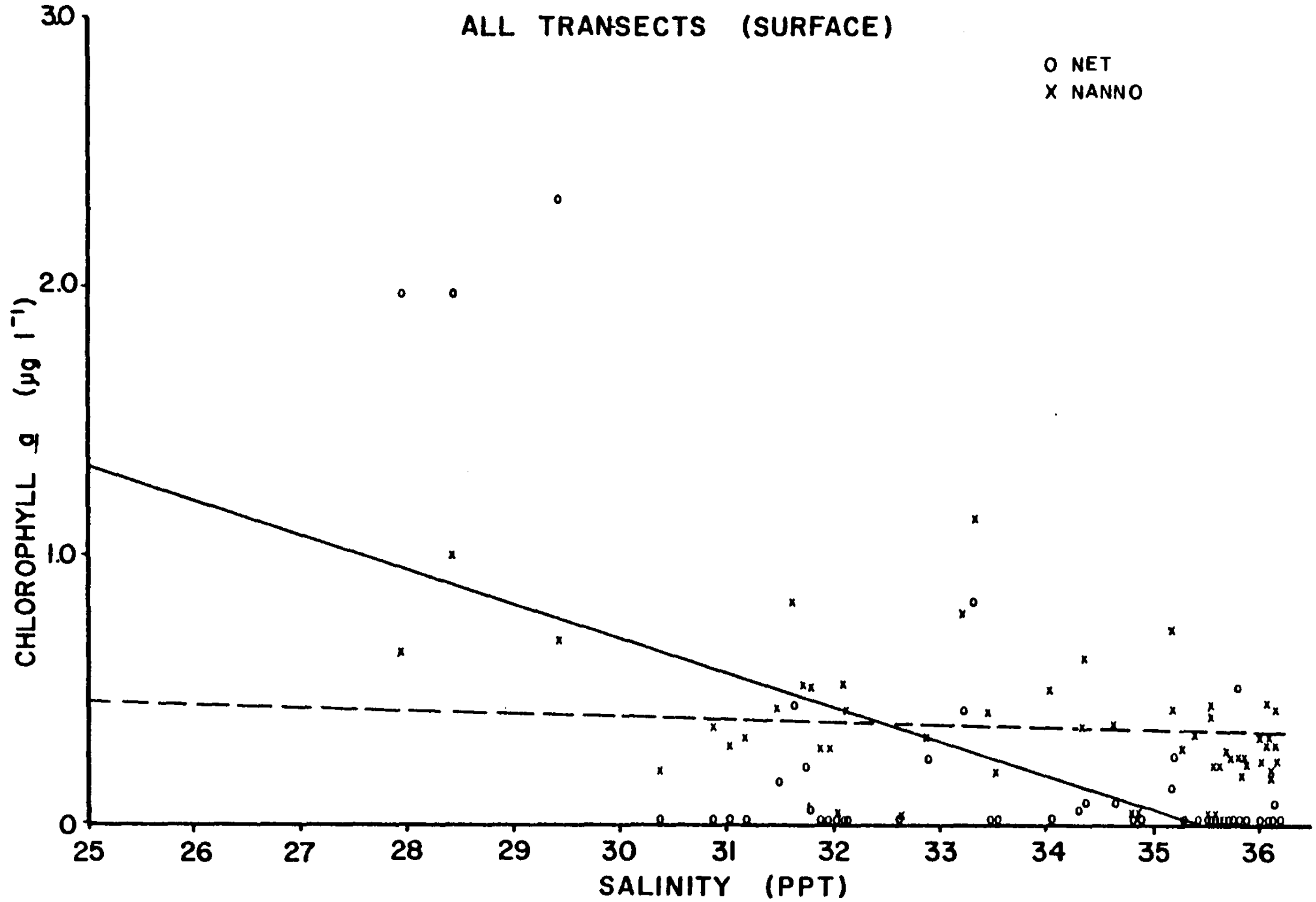

Figure 19. Relationship Between Salinity (ppt) and Both Netphytoplankton and Nannophytoplankton Chlorophyll a ($\mu g\ l^{-1}$) at the Surface.

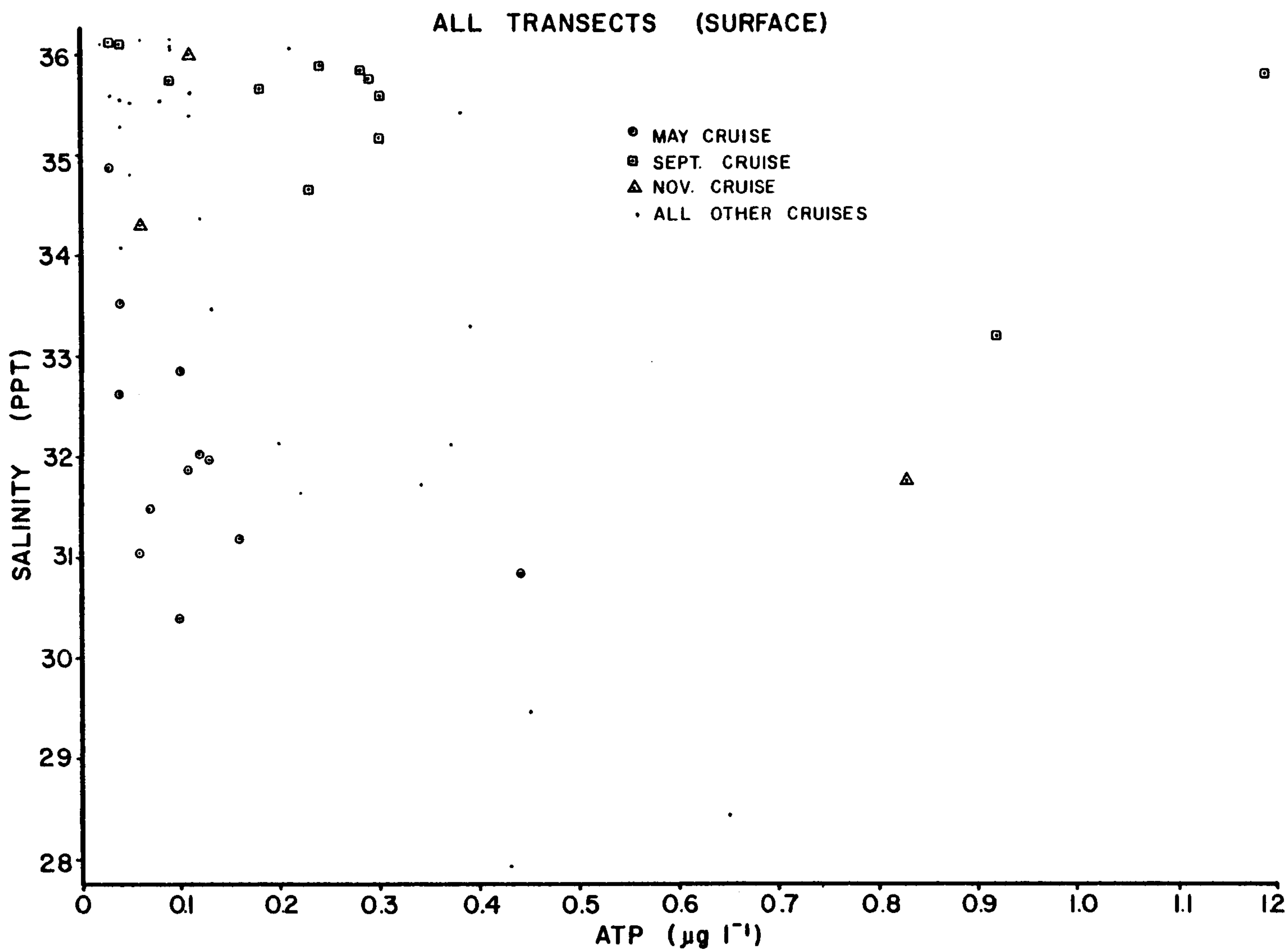

Figure 20. Relationship Between Salinity (ppt) and ATP ($\mu g\ l^{-1}$) at the Surface.

CONCLUSIONS

1) Seasonal surface patterns of all measured parameters showed an offshore decrease in biomass and suggested decreasing biomass from north to south.

2) The netphytoplankton fraction (>20 μm) occurred in detectable concentrations only at the inshore stations.

3) Chlorophyll a concentrations often showed subsurface maxima, in both net and nannoplankton fractions.

4) The monthly temporal patterns of all parameters at all depths at Station 1, showed a bimodal cycle of production characterized by a major peak in April and a minor rise between September and December. The surface samples at Station 2 followed the dynamics at Station 1, but the deeper samples appeared to lag the surface with a broad rise that lasted through July. Station 3 showed a very broad rise at all depths between June and December.

5) The phytoplankton species grossly divide into two groups at Stations 1/II and 2/II: December-April and May-November. Station 3/II exhibited less seasonality in species composition with a few species being abundant throughout the year.

6) Low diversity occurred at five occasions during 1976 associated with blooms of *Skeletonema costatum, Nitzschia delicatissima* or *Leptocylindrus danicus*.

7) Secchi depth, phytoplankton abundances and chlorophyll a concentrations are closely related. ATP concentration was related to chlorophyll a concentration more so during the spring than during late summer and fall.

8) The relationships between salinity and biomass parameters suggested that freshwater runoff was a significant nutrient source in the STOCS study area.

LITERATURE CITED

El Sayed, S. Z., W. M. Sackett, L. M. Jefferey, A. D. Fredericks, R. P. Saunders, P. S. Conger, G. A. Fryxell, R. A. Steidinger, and S. A. Earle. 1972. Serial atlas of the marine environment. Folio 22. Chemistry, primary productivity, and benthic algae of the Gulf of Mexico. Am. Geophys. Soc. 29pp.

Eppley, R. W. 1972. Temperature and phytoplankton growth in the sea. Fish. Bull. 70:1063-1086.

Holm-Hansen, W., and C. R. Booth. 1966. The measurement of adenosine triphosphate in the ocean and its ecological significance. Limnol. Oceanog. 11:510-579.

Jerlov, W. G., and E. Steeman-Nielsen. 1974. Optical aspects of oceanography. Academic Press, London. 494pp.

Parsons, T. R., and M. Takahashi. 1973. Biological oceanographic processes. Pergamon Press, Oxford. 186pp.

Strickland, J. D. H. 1958. Solar radiation penetrating the ocean. A review of requirements, data and methods of measurement with particular reference to photosynthetic productivity. J. Fish. Res. Bd. Can. 15:453-493.

________., and T. P. Parsons. 1968. A practical handbook of seawater analysis. Fish. Res. Bd. Can. Bull. 167:311pp.

Utermohl, H. 1931. Neve wage in der quantitativen erfassung des plankton. Int. Ass. Theor. Appl. Limnol. 5:567-595.

Van Baalen, C. 1976. Phytoplankton and phytoplankton biomass. Pages 46-81. *In* Parker, P.L. (ed.), Environmental studies of the south Texas outer continental shelf, biology and chemistry, 1975. Final report submitted to the Bureau of Land Management, Washington, D. C. Contract No. AA550-CT5-17.

CHAPTER 5

SHELLED MICROZOOPLANKTON, GENERAL MICROPLANKTON AND SHELLED MICROZOOBENTHON OF THE SOUTH TEXAS OUTER CONTINENTAL SHELF

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ABSTRACT

Nansen net, Niskin bottle and sub-cores from bottom grab samples were collected in the BLM-STOCS study area seasonally and monthly during 1976. Shelled microzooplankton and general microplankton were studied from Nansen net and Niskin bottle samples; living benthonic foraminiferans were studied from grab samples; and dead benthonic and planktonic foraminiferans were studied from down-core samples.

The shelled microzooplankton and general microplankton data from the net and bottle samples were compared to the physical oceanography of the study area by use of density, diversity and other plots of biological data as compared to temperature and salinity diagrams, to isohaline, isothermal contouring, and to other plots of the physical oceanographic data. These comparisons revealed: ponds of shallow offshore water moving onto the shelf from offshore during the winter and into spring; strong upwelling or upbowing of water onto the shelf in the spring and early summer with a penetration to the inshore stations in August and a detachment of the shelf water and their movement Gulfward overriding upwelled (open ocean estuarine upwelling) water which extended as far inshore as Station 1; and, an incursion of a proposed anticyclonic gyre that had detached from the Loop Current onto the shelf during late summer and early fall. With the aid of cluster analyses, certain of the shelled microzooplankton were designated as biological indicators of shelf water, estuarine outflow water, open Gulf shallow water, open Gulf deep water, upwelling, shelf circulation, the intrusion of Sub-tropical Underwater, and of "eutrophism and oligotrophism".

Studies of living benthonic foraminiferans revealed: an average standing crop of 27.64 individuals/10 m^2; species indicative of nearshore, nearshore to mid-shelf, mid-shelf, mid-shelf to outer-shelf and outer-shelf; species indicative of regions of "eutrophism and oligotrophism" geographically, and to some extent, seasonally.

The down-core studies illustrated that some cores had penetrated sediments older than 100,000 years, with two cores penetrating through sediments of the last glacial. Rates of sedimentation in these cores ranged from a low of 0.6 cm/1000 years to a maximum of at least 15 cm/1000 years.

INTRODUCTION

Purpose

This component of the BLM-STOCS studies is charged with the baseline inventory and monitoring of shelled microzooplankton, general micro-plankton and shelled microzoobenthon; correlation of these with other biological, chemical and physical oceanographic data; and, the detection and use of certain species as biological indicators of oceanographic processes. Toward these ends, this study involves the taxonomic identification and enumeration of shelled microzooplankton, general microplankton and shelled microzoobenthon. The shelled microzooplankton are studied from Nansen tows (integrated samples), the general microplankton from Niskin bottle filtrates (discrete samples), and the shelled microzoobenthon from known-surface area subsamples of grab samples and a few down-core samples from gravity cores collected by the USGS. These data are placed on computer cards, and R mode cluster analyses performed for significant stations, species and groups resulting in dendrograms. These dendrograms, and selected species, group densities, diversities and dominances are correlated to the literature and other oceanographic components (biological, physical, chemical and geological) of the STOCS study area.

Literature Survey and Previous Work

Shelled Microzooplankton

There have been few studies on living Radiolaria. Haeckel (1887) examined plankton tows from the CHALLENGER expedition. Popofsky (1907, 1908, 1912, and 1913) examined Radiolaria from the Deutsche Sudpolar Expedition and observed bipolarity as well as water-mass preferences. Reshetnyak (1955) studied vertical distribution in the Kuril-Kamchatka

Deep. Casey (1966, 1971a, 1971b, and In Press) studied seasonal variations of Radiolaria in the southern California Borderland, established the preference of individual species for specific water masses, and determined the taxa indicative of seasonality of the area. Petrushevskaya (1971) studied living Radiolaria from the southwestern Pacific, and Renz (1973) studied assemblages of the central Pacific. The only studies of radiolarians from the Gulf of Mexico have been those by this principal investigator and his former graduate student, K. J. McMillen. These studies, some of which are in progress, are on the South Texas Outer Continental Shelf (BLM-STOCS) and the open Gulf of Mexico and Caribbean (supported by NSF).

McMillen (1976), Casey and McMillen (In Press), and McMillen and Casey (In Press) delineated the radiolarians "endemic" to the major water masses of the Gulf of Mexico. Casey and McMillen (In Press) delineated the radiolarians indicative of seasonal trends (1975) on the South Texas Outer Continental Shelf and the densities and diversities of these forms. Casey, McMillen and Bauer (1975) noted a fauna of relict radiolarians in the Gulf of Mexico and STOCS area.

Living planktonic Foraminifera have been studied to a much greater extent than radiolarians and a brief, incomplete review follows. Schott (1935) made preliminary investigations in the North Atlantic; Be (1960) studied seasonal distribution in the North Atlantic; and Cifelli (1965, 1974) examined the distribution of planktonic Foraminifera in the vicinity of the North Atlantic Current and in the Mediterranean and adjacent Atlantic waters. Few studies have been done on the planktonic Foraminifera of the Gulf of Mexico. Phleger (1951) examined species and abundances for 27 plankton tows in the northwest Gulf (close to the BLM-

STOCS area). Jones (1968) inferred the source regions for planktonic Foraminifera in the southern Gulf of Mexico and Straits of Florida to be of Caribbean origin. Bauer (1976) and Casey and Bauer (1976) studied the seasonal distribution of planktonic foraminiferans in the BLM-STOCS area in 1975 and found a seasonality that could be related to the physical oceanography of the area. They also noted that a benthonic foraminiferan (*Bolivina* or *Brizalina lowmani*) occurred commonly at the innermost stations and may have been meroplanktonic.

McGowan (1960, 1967 and 1971), Fager and McGowan (1963), Chen and Hillman (1970), and Hida (1957) showed that pteropods are good biological indicators of water masses and currents and Herman and Rosenberg (1969) showed that pteropods can be used as bathymetric indicators. As early as 1933 Burkenroad (1933) studied the pteropods off Louisiana. Other major works on pteropods in the Gulf of Mexico have been unpublished theses by Hughes (1968) and Snider (1975) which related specific pteropods to the water masses of the Gulf. Casey (1976) identified and listed the pteropods taken on the South Texas Outer Continental Shelf in 1975.

General Microplankton

Many studies in the Gulf of Mexico included some microplankton work. The BLM-STOCS investigation of the general microplankton is patterned after and compatible with the investigations of Beers and Stewart (1967, 1969a, 1969b, 1970 and 1971) and Beers, Reid and Stewart (1975). Their work has been mainly in the waters off southern California and in the central and equatorial Pacific. The only compatible investigations in the Gulf of Mexico to the aforementioned investigations are those currently being carried out under the auspices of the BLM-STOCS reported herein.

Shelled Microzoobenthon (Benthonic Foraminifera)

Most of the studies of the Foraminifera of the Gulf of Mexico and its continental shelf have concerned the distribution of dead and total assemblages. There have been relatively few studies of living populations of the northwest Gulf of Mexico. Of these, the most useful are those of Phleger (1951, 1956). There have been no comprehensive seasonal studies except for the current BLM-STOCS study and Parker, Phleger and Peirson's (1953) studies of Texas bays. An unpublished thesis by Tresslar (1974) reported on the living benthonic foraminiferal fauna of the West Flower Garden Bank. A thesis of Anepohl (1976) concerned the benthonic foraminiferans collected for BLM in the STOCS study area during 1975.

METHODS AND MATERIALS

Collecting Procedures

Nansen Tows (Integrated Samples)

Nansen tows were taken at Stations 1-3, all transects, and at Bank Stations HR 1/1 and SB 1/1 (14 stations) during the seasonal samplings, and at Stations 1-3, Transect II, and Bank Stations HR 1/1 and SB 1/1 (5 stations) during the monthly samplings. At each station, a Nansen net with a mouth opening of 30 cm and a mesh size of 76 μm was placed on a wire (Figure 1), lowered to just off the bottom and slowly (about 20 m/minute) towed to the surface. The net was then washed with seawater from the outside of the mesh and the material in the cod end was preserved in a 500-ml Nalgene bottle with a 5 percent formalin solution containing sodium borate, strontium chloride and rose Bengal. This preservative solution is prepared in the following manner: 1 gal of 37 percent (stock)

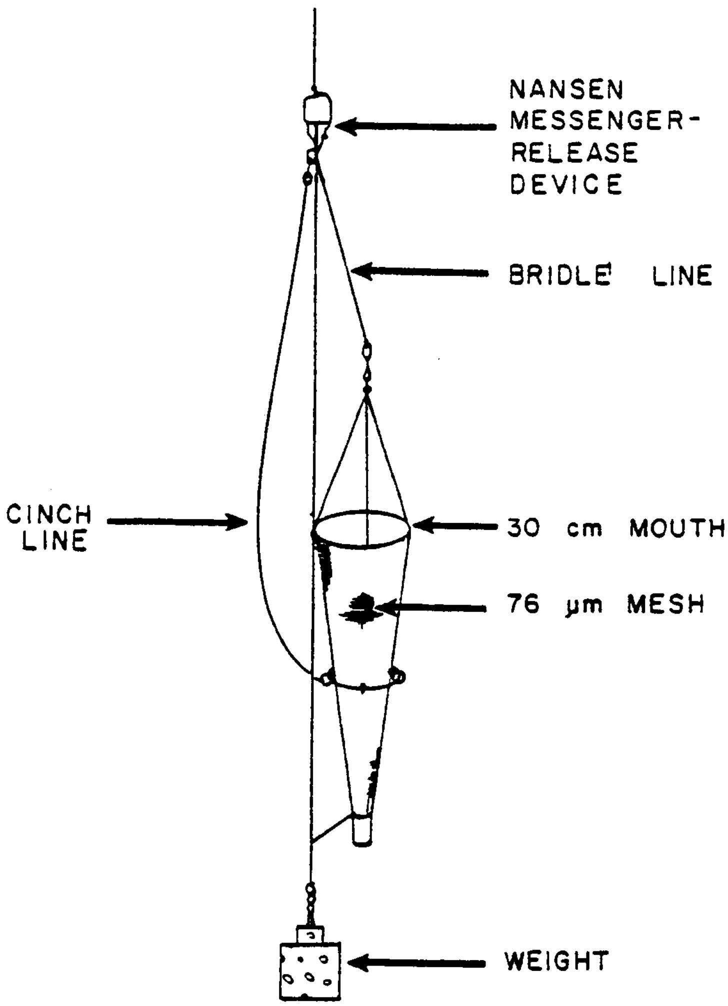


Figure 1. Rigging for Nansen Net Used in Sampling.

formaldehyde + 80 gm $Na_2B_4O_7 \cdot 10H_2O$ (sodium borate) + 18.2 gm $SrCl_x \cdot 6H_2O$ (strontium chloride) + 2 gm rose Bengal. Each bottle was then labeled, a shipboard data sheet compiled, and the samples and data sheets were transmitted to the Principal Investigator

Niskin Bottle Samples (Discrete Samples)

Niskin samples during seasonal samplings were taken at 10 m and one-half the depth of the photic zone (as determined with a Secchi disk or photometer) at Stations 1 and 2, all transects; at 10 m, one-half the depth of the photic zone, the photic zone, and one-half the distance between the photic zone and bottom or just off the sea floor at Station 3, all transects; and, at Bank Stations HR 1/1 and SB 1/1. Samples during monthly samplings were taken at 10 m and one-half the depth of the photic zone at Stations 1 and 2, Transect II; at 10 m, one-half the depth of the photic zone, the photic zone, one-half the distance between the photic zone and the bottom or just off the sea floor at Station 3, Transect II, and, at Bank Stations HR 1/1 and SB 1/1. From each 30-l Niskin bottle case, 1 l was removed and archived for possible future use; the remaining 29 l were filtered through a 38-μm mesh stainless steel screen. The filtrate was washed into a 500-ml Nalgene bottle and preserved in a 2 to 3 percent preservative solution as described for the Nansen tows, except no rose Bengal was used. Each bottle was then labeled, the shipboard data sheet completed and the samples and data sheets transmitted to the Principal Investigator.

Bottom Sediment Samples for Shelled Microzoobenthon (Foraminifera)

Bottom samples were obtained by subsampling Smith-MacIntyre grabs at Stations 1-7, all transects, and at Bank Stations HR 2/2 and SB 2/2 (29 stations) during seasonal samplings and at Station 1-6, Transect II, and Bank Stations HR 2/2 and SB 2/2 (10 stations) during monthly samplings. Subsampling was accomplished by inserting a 6.5-cm coring tube, or a 3.5-cm plunger, at least 5 cm into the sediment from the sediment surface. Each sample was placed in a container and 25 ml of formalin solution (as described under the Nansen collecting techniques) were added. The bottles were then sealed and shaken to mix sediment and solution. Bottles were labeled, the shipboard data sheets completed and the samples and data sheets were transmitted to the Principal Investigator.

Post-Collecting Procedures

Nansen Samples

In the laboratory the samples were split into two aliquots with a plankton splitter. One aliquot was archived and the second was sorted for microplankton. The samples were either hand-picked using a breaking pipette and a plankton microscope and placed on slides or identified and counted directly with the plankton microscope (the prior for seasonal samples from the primary stations).

The other Nansen samples were handled by taking a 1/20 aliquot and identifying and counting using the plankton microscope. All worked samples and slides were saved.

Data were placed on computer cards and cluster analyses were performed on the seasonal data from the 12 primary stations, resulting in dendrograms. The dendrograms and radiolarian seasonal density and diversity plots were compared to other oceanographic phenomena.

Niskin Samples

The samples were allowed to settle for several days in the original collection bottles. The supernatant of each sample was then decanted and saved for archiving. The residue was placed in a plankton counting chamber which was then placed on the modified stage (which holds it in place) of a plankton microscope. The first 100 organisms (or fecal pellets) were identified and counted by starting at the top of the chamber. The surface area of the chamber traversed during counting was recorded. The residue and supernatant of each sample were then combined and archived.

The data were placed on computer cards, cluster analyses performed and dendrograms prepared on the seasonal data from the 12 primary stations. The dendrograms and seasonal density data were compared to other oceanographic phenomena.

Microzoobenthon Samples

The samples were mixed and split with a large, modified plankton splitter. One-half of the sample was archived and one-half was washed through a 63 μm screen. The sands on the screen were dried in an oven at 70°C. If only a small amount of material remained on the screen, the sample was ready for picking or identifying. If considerable non-organic material remained, the sample was floated as described below. A 400-ml beaker was filled with 200 ml of carbon tetrachloride, a 500 μm screen was placed over the beaker, and the dried sands were sprinkled through the screen. The floating fraction was then decanted onto a paper towel folded as a filter and supported by a glass funnel. The residue was swirled to suspend lighter material, allowed to stand for 2 seconds and decanted. (This process was repeated several times to process a large sample by aliquots). The paper towel plus filtrate was oven-dried at 70°C as was the residue. Both portions were placed in labeled bottles.

The seasonal samples from the 12 primary stations were hand-picked under a dissecting microscope for live foraminiferans and other live, shelled microzoobenthon and placed on cardboard foraminiferan slides.

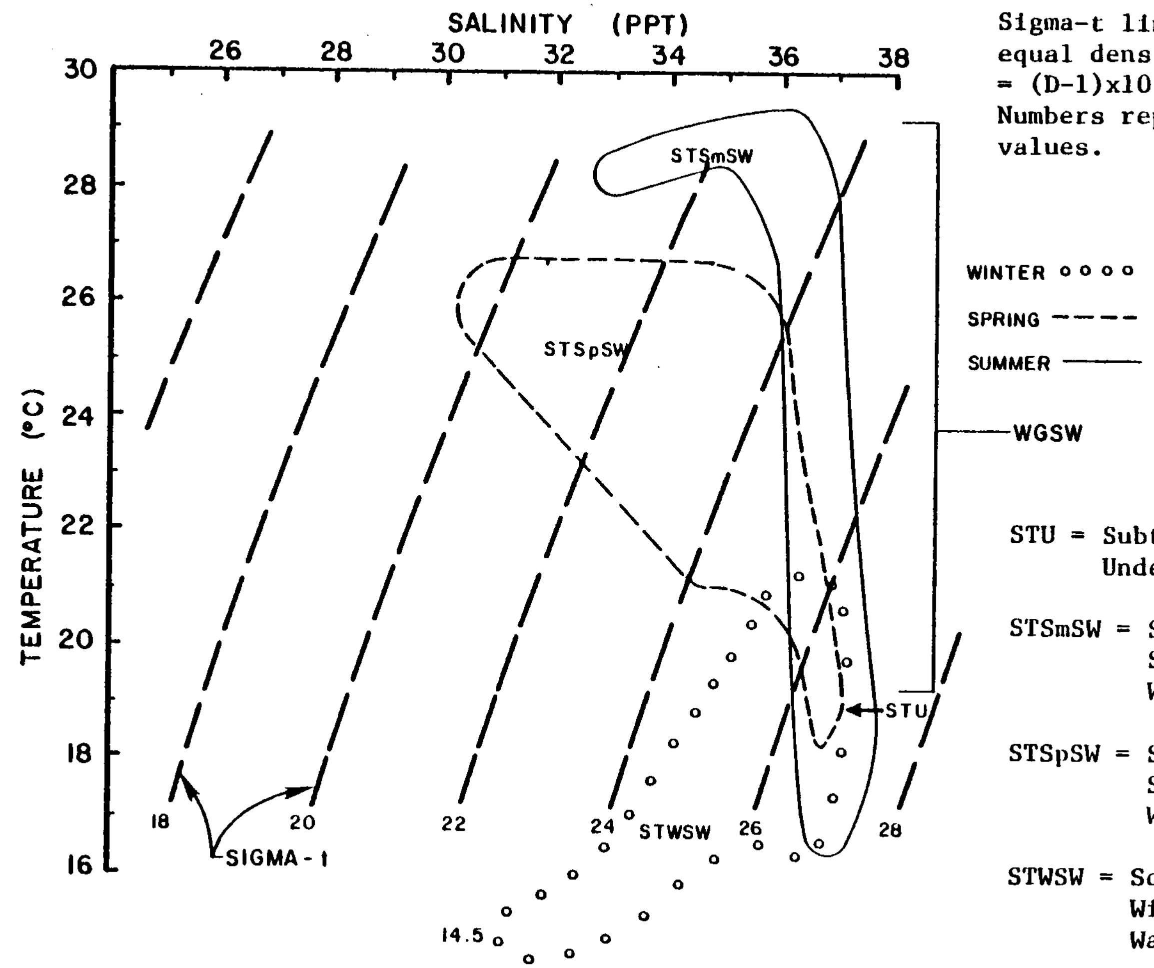
The picked organisms were then identified to the lowest possible taxon and counted. The data were placed on computer cards and cluster analyses were performed and dendrograms prepared as described above. The dendrograms, seasonal density plots, and seasonal faunal maps were compared to data on other oceanographic parameters.

Samples from the remaining bottom stations (other than the 12 primary stations) were processed as above, except they were not hand-picked. The processed samples were identified and counted for dominant foraminiferans only.

RESULTS AND DISCUSSION

Physical and Chemical Oceanographic Setting

Water masses of the STOCS in 1976 were plotted on a Temperature-Salinity (T-S) diagram (Figure 2). The T-S diagram for 1976 was very similar to that for 1975 (Figure 3) with a core of Western Gulf Surface Water (WGSW) always present on the outer shelf and fairly distinct local water masses present during the three seasons. The main difference between the 2 years was apparently a definite incursion of Subtropical Underwater (STU) during the summer of 1976, and perhaps a slight indication of such water during the spring of 1976. These incursions are discussed later because of their significance relative to the distribution of the shelled microzooplankton and general microplankton. The summer incursion of Subtropical Underwater during 1976 was, we believe, in reality the incursion of an anticyclonic ring that broke from the Loop Current and was identified chemically by the salinity maximum of its included Subtropical Underwater and biologically by its inclusion of shelled microzooplankton considered to be endemic to the Subtropical Underwater Water Mass.



Sigma-t lines are lines of equal density where Sigma-t = $(D-1)x10^3$
Numbers represent Sigma-t values.

STU = Subtropical Underwater

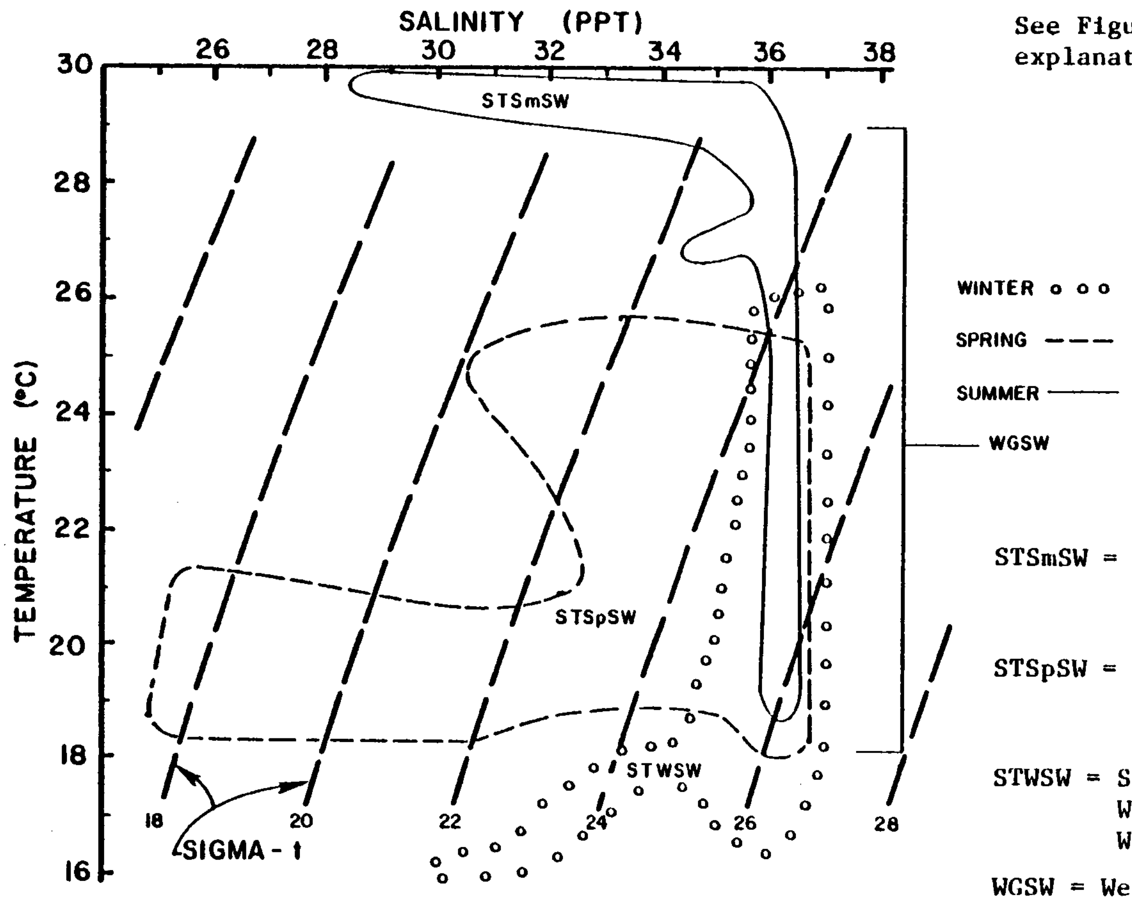
STSmSW = South Texas Summer Shelf Water

STSpSW = South Texas Spring Shelf Water

STWSW = South Texas Winter Shelf Water

WGSW = Western Gulf Surface Water

Figure 2. Water Mass Characterization of the STOCS, 1976.



See Figure 2 for explanation of Sigma-t.

STSmSW = South Texas Summer Shelf Water

STSpSW = South Texas Spring Shelf Water

STWSW = South Texas Winter Shelf Water

WGSW = Western Gulf Surface Water

Figure 3. Water Mass Characterization of the STOCS, 1975.

The water mass envelope for the winter of 1976 (Figure 4) was more compact and colder than for 1975 (Figure 3) and appeared to be chemically and physically the simplest of the three 1976 seasons. The winter 10-m temperatures increased smoothly Gulfward (Figure 5) as did the winter 10-m salinities (Figure 6). Winter bottom temperatures (Figure 7) and salinities (Figure 8) illustrate that the South Texas Winter Shelf Water (STWSW) touched bottom only at the inner stations. The temperature increase at mid-shelf bottom and decrease at shelf-edge bottom suggested an "upwelling" or "upbowing" of deeper Gulf waters onto the outer shelf.

The water mass envelope for the spring of 1976 (Figure 9) was different than for the spring of 1975 (Figure 3). Surface waters in the spring of 1975 were quite variable in terms of temperature and salinity whereas in the spring of 1976 the water mass envelope was compact. There appeared to be two main water masses on the shelf during the spring, the South Texas Spring Shelf water (STSpSW) and the Western Gulf Surface Water, and perhaps a little Subtropical Underwater (Figure 2, arrow). On certain parts of the shelf and at various depths, there appeared to be mixing between STSpSW and STU and between STSpSW, WGSW and STU. Mixing between STSpSW and cool WGSW occurred mostly at the inner stations on all transects. Although mixing occurred, a strong pycnocline was present over much of the shelf at depths between 15 and 25 m, separating warm, low-salinity surface water from cool, high-salinity deeper water.

Isotherm (Figure 10) and isohaline (Figure 11) maps show that the incursion of offshore water in the winter of 1976 continued into the spring. Bottom waters were more saline in 1976 (Figure 12) than in 1975. The 36-ppt isohaline was found near Stations 5 and 2 all along the shelf. Bottom waters were cooler offshore toward the shelf break and

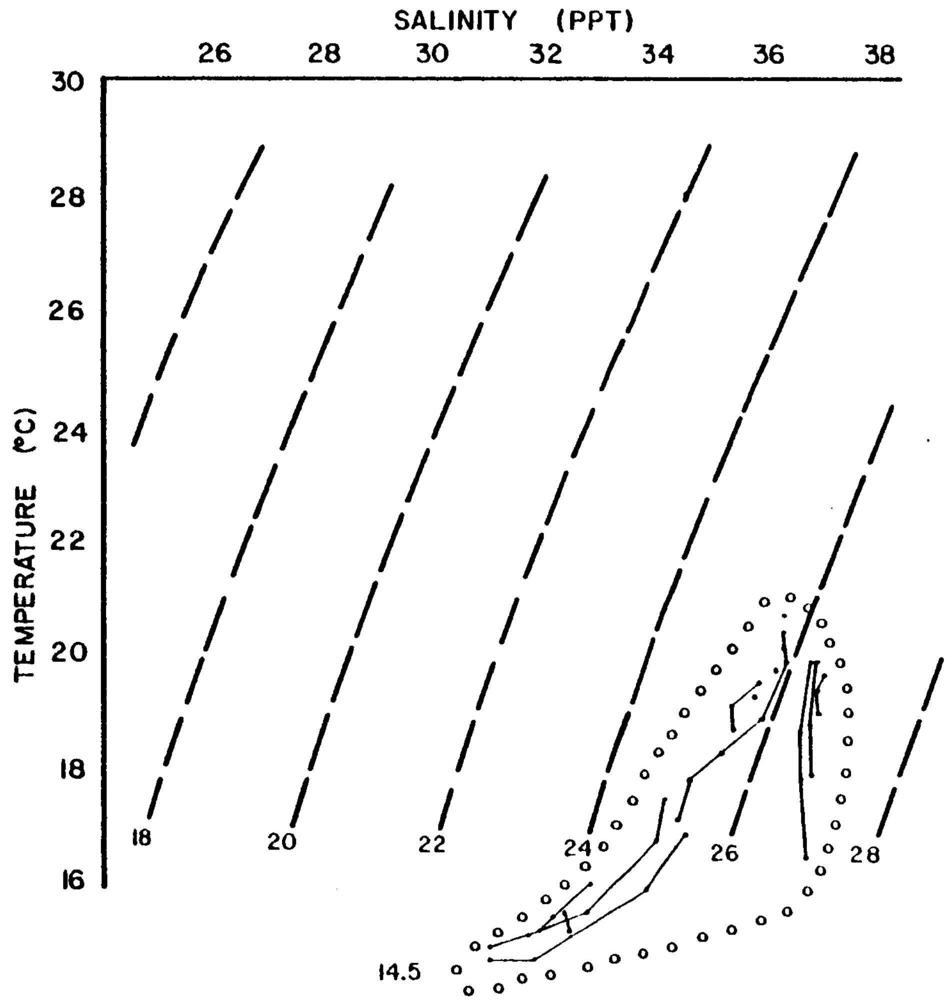


Figure 4. Water Mass Characterization of the STOCS, Winter 1976.

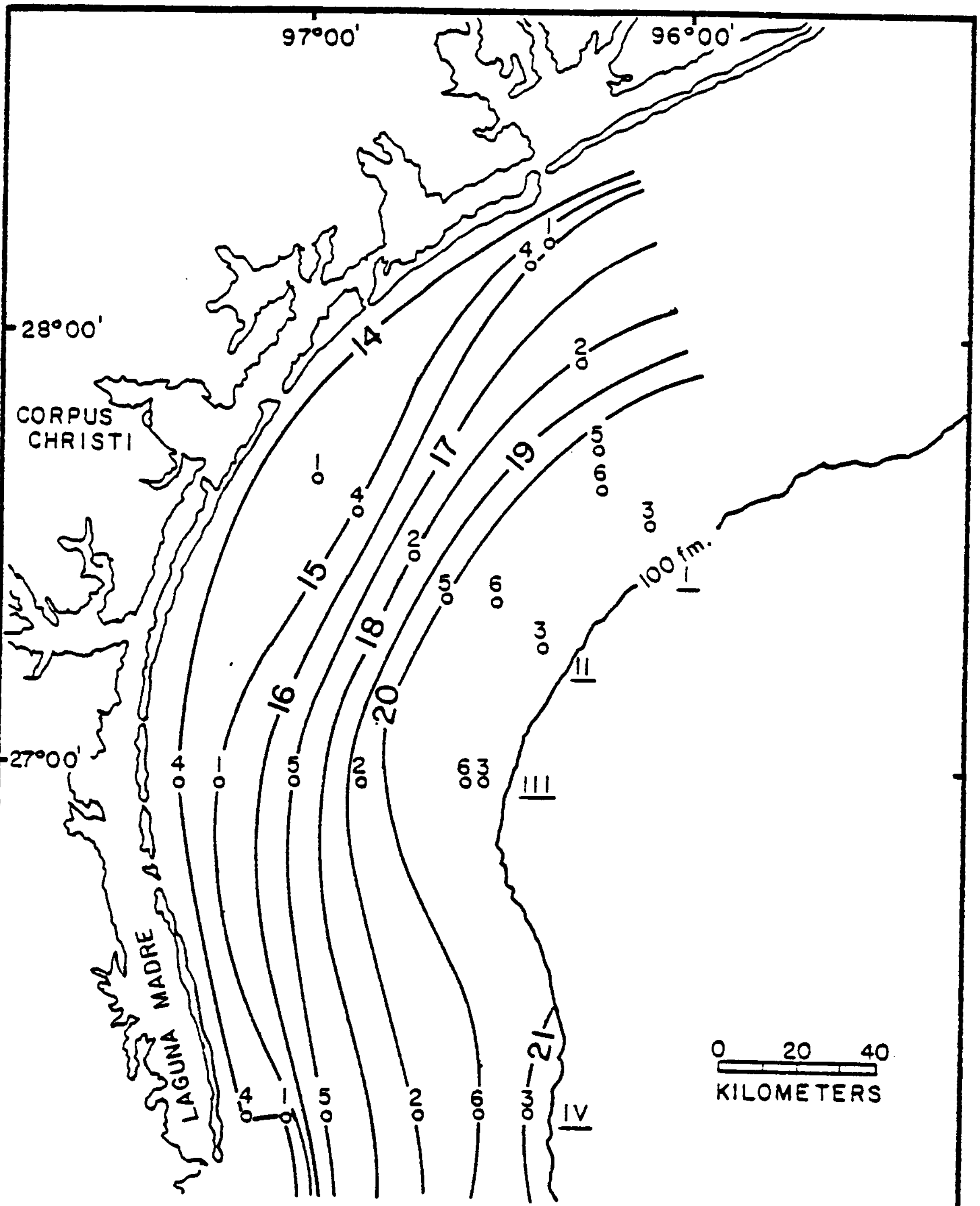


Figure 5. Winter Temperatures (°C) at the 10-m Depth, 1975-1976.

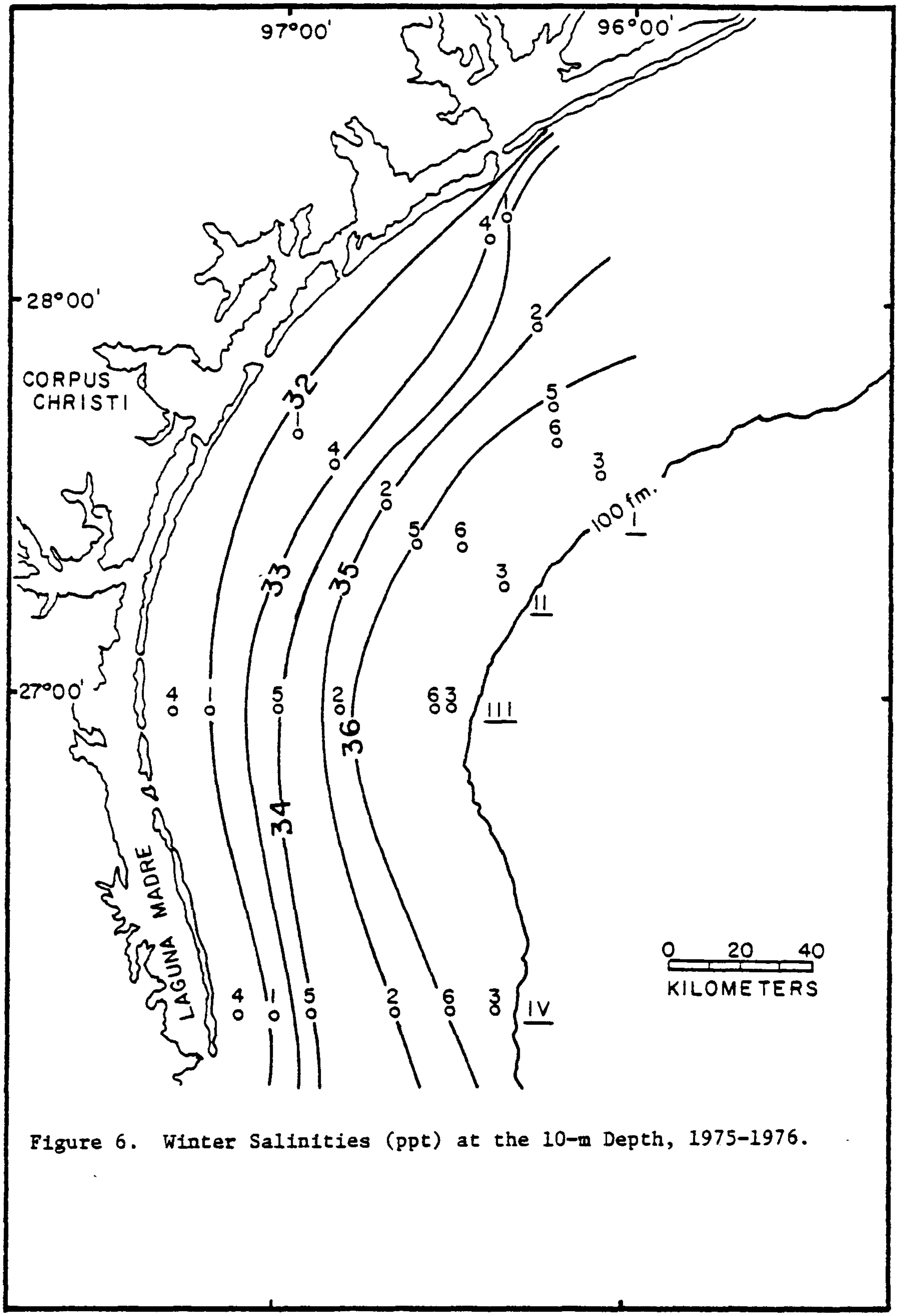


Figure 6. Winter Salinities (ppt) at the 10-m Depth, 1975-1976.

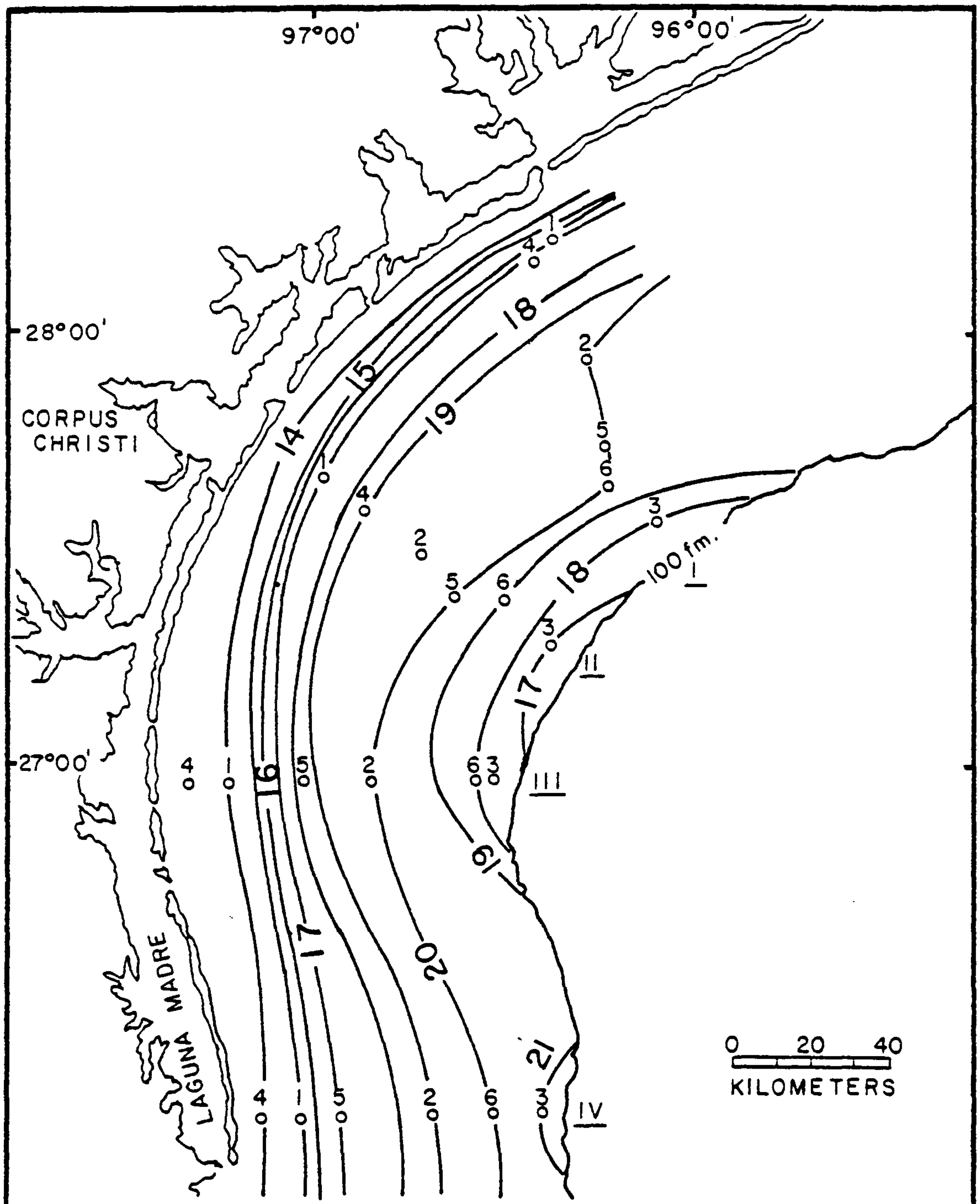


Figure 7. Winter Bottom Temperatures (°C), 1975-1976.

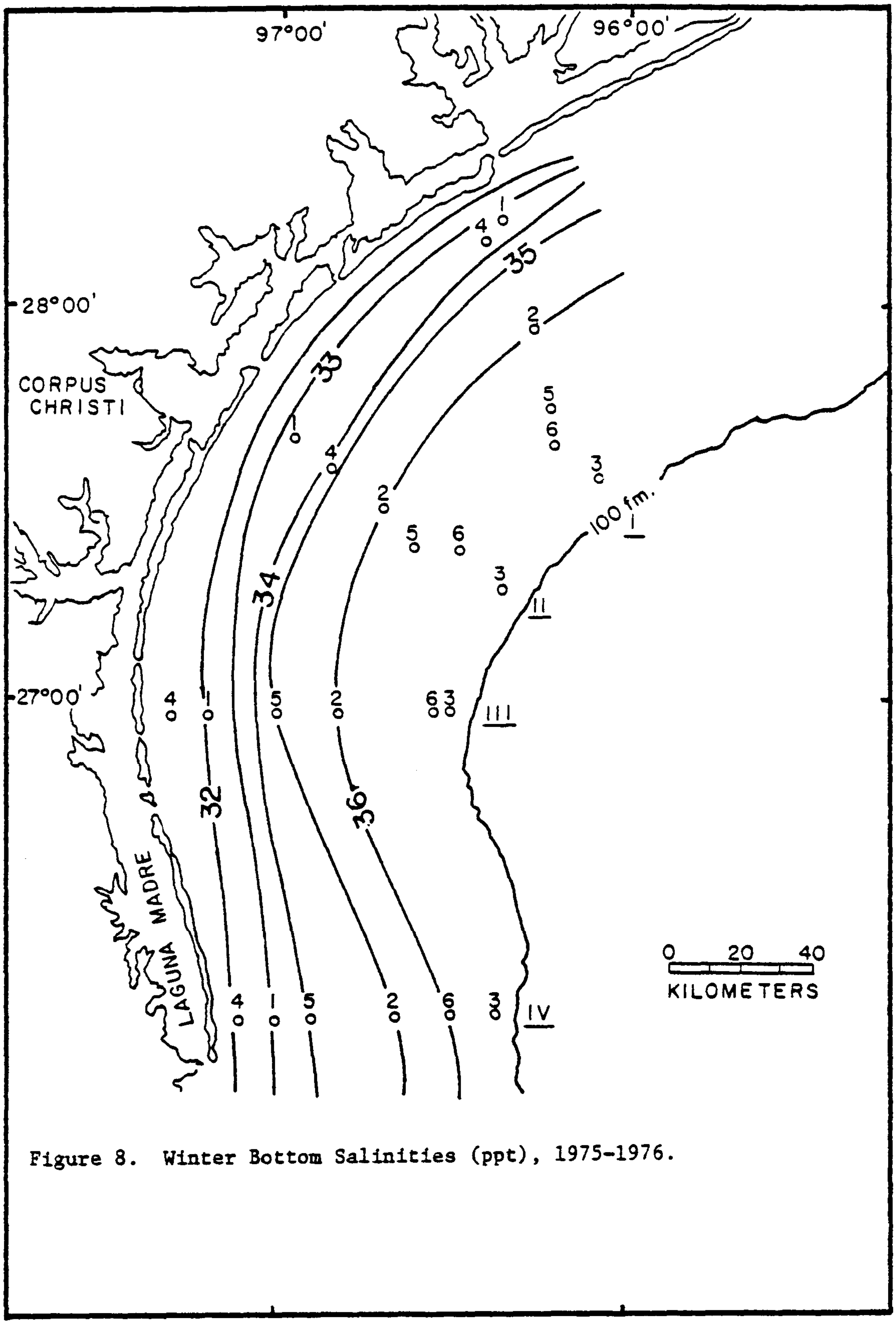


Figure 8. Winter Bottom Salinities (ppt), 1975-1976.

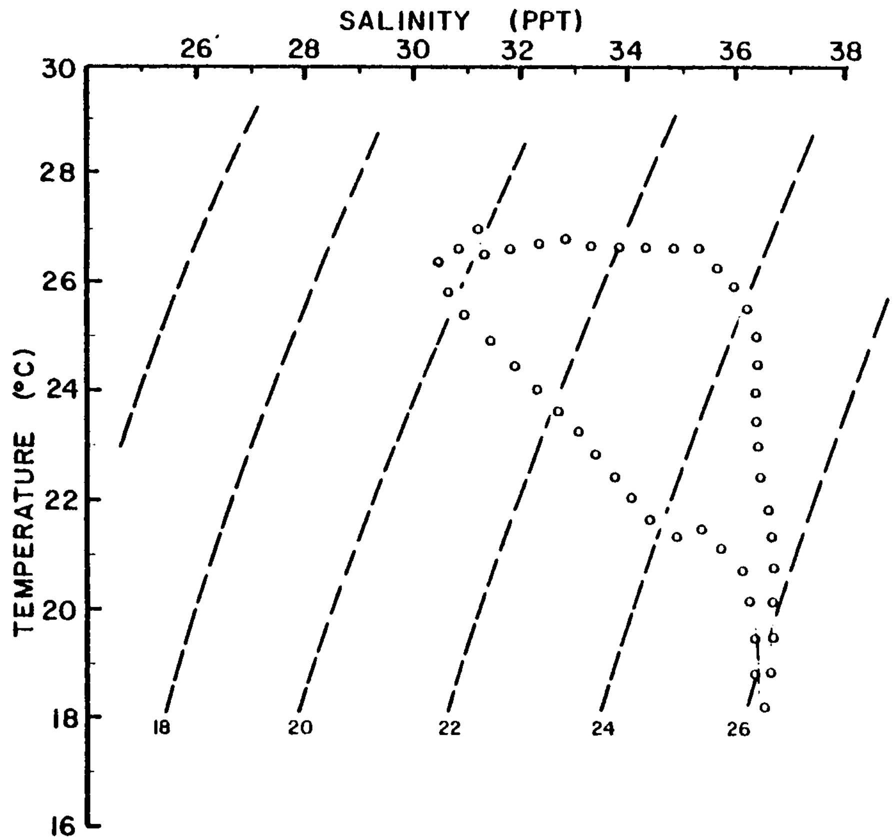


Figure 9. Water Mass Characterization of the STOCS, Spring 1976.

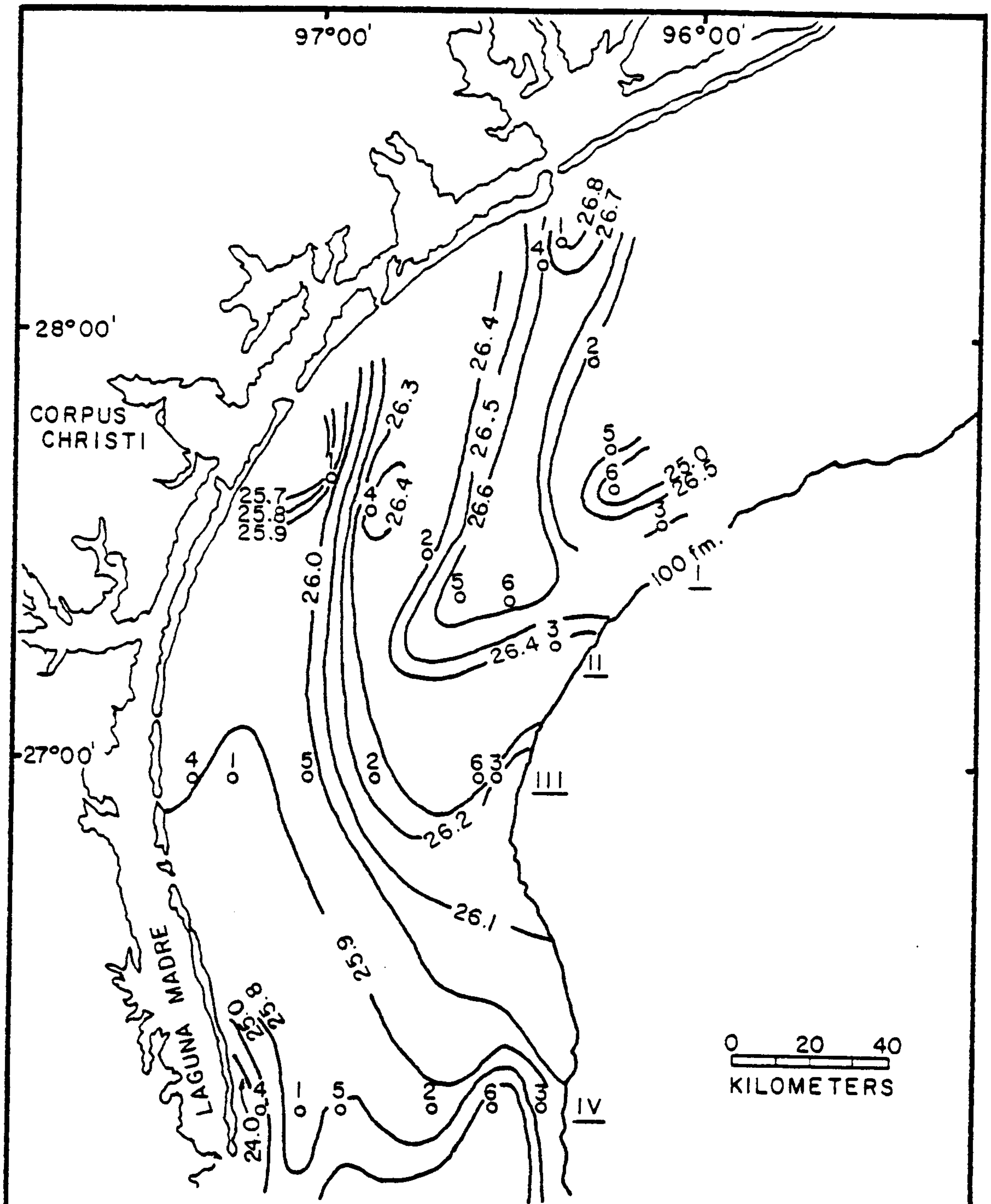


Figure 10. Spring Temperatures (°C) at 10 m, 1976.

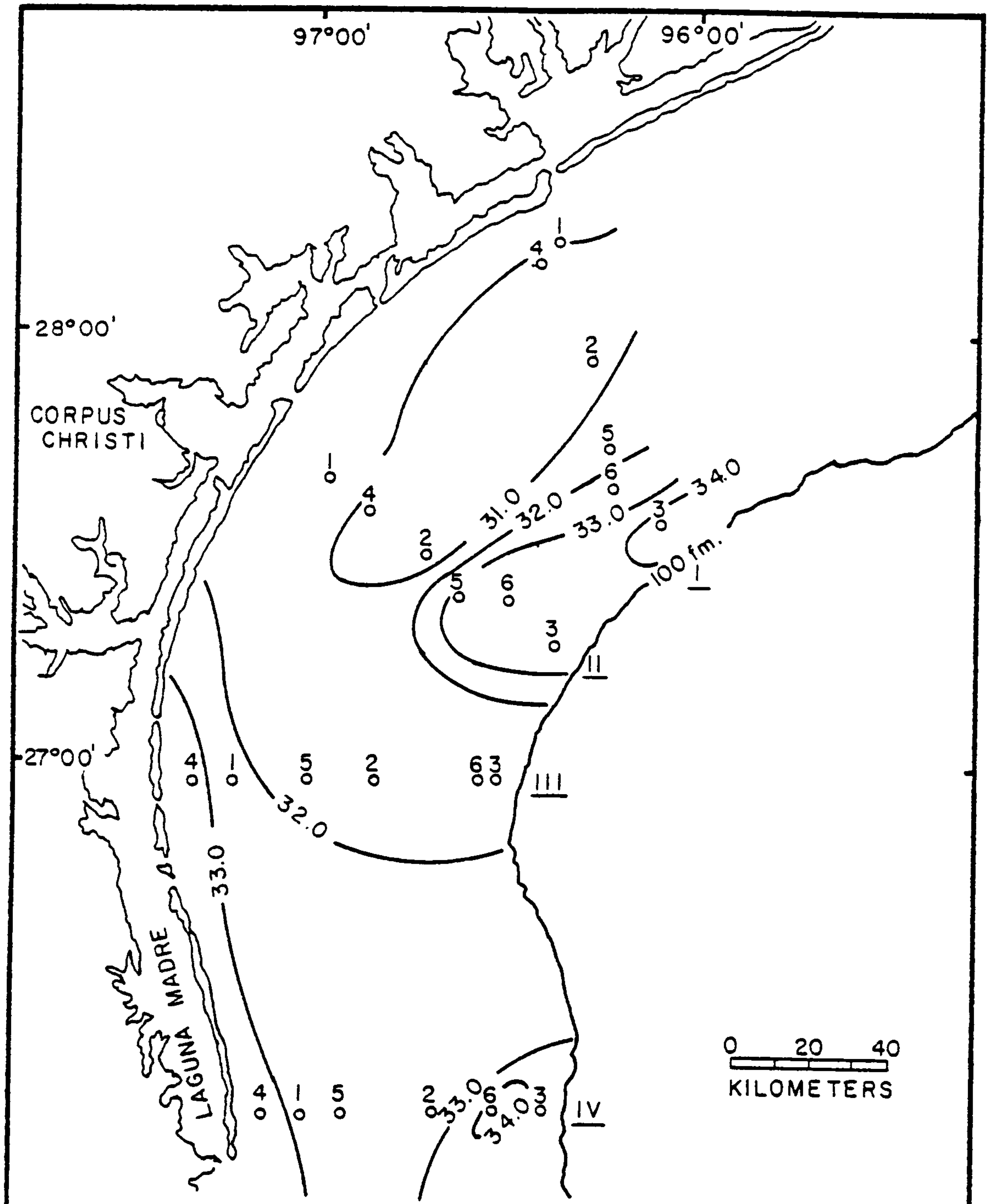


Figure 11. Spring Salinities (ppt) at 10 m, 1976.

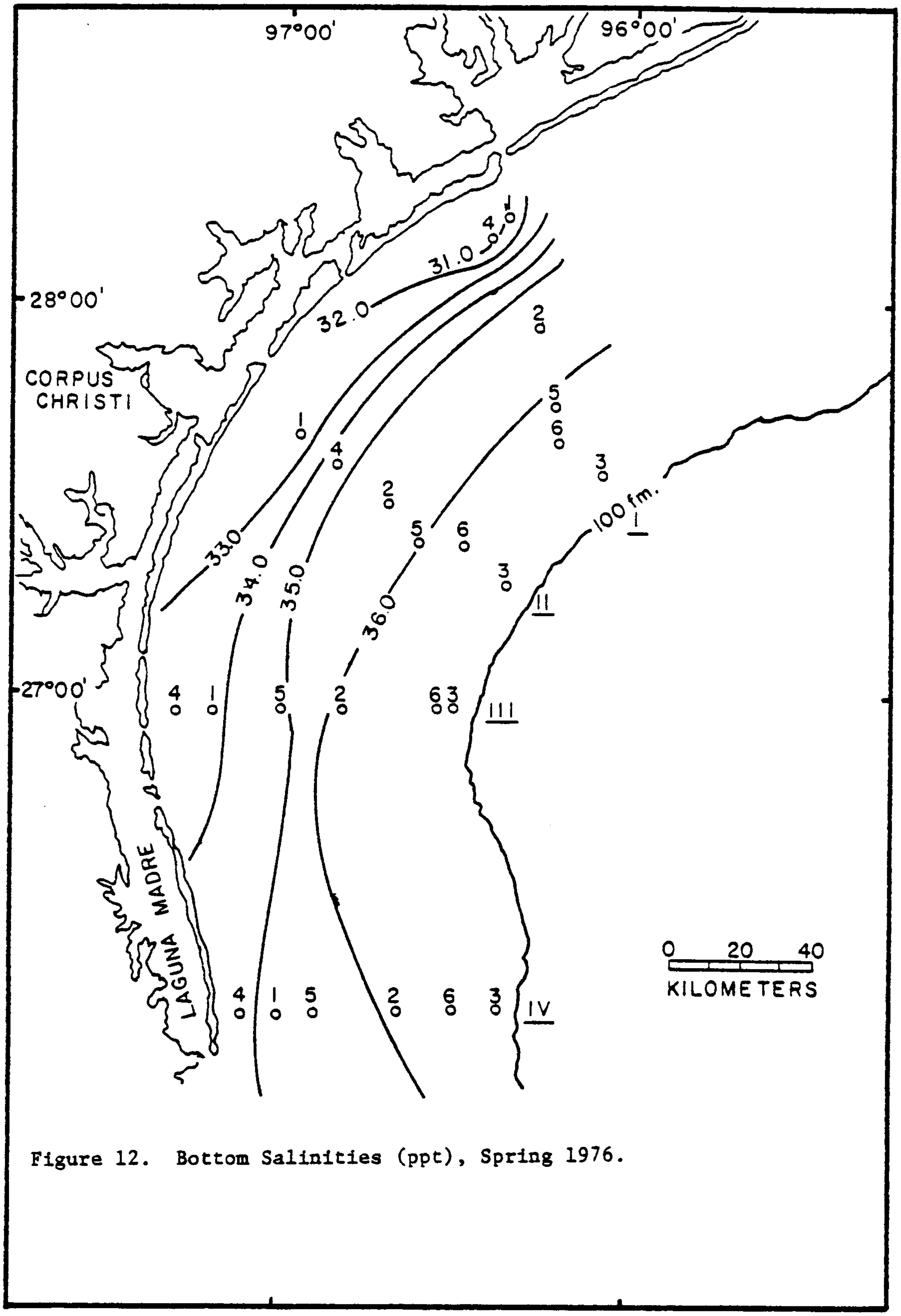


Figure 12. Bottom Salinities (ppt), Spring 1976.

inshore waters were much warmer than in 1975 (Figure 13).

As compared to 1975, spring salinities and temperatures at 10 m were more uniform throughout the STOCS area. A strong pycnocline at 15 to 25 m separated the uniform surface water from underwater that had encroached from offshore. At 30 m (Figure 14) this encroachment centered on Transects II and IV. At the sea floor, the encroachment was pervasive all along the shelf (Figures 12 and 13). This condition probably represented an open ocean type of estuarine upwelling with a pond of low salinity water (runoff generated) moving offshore which caused an incursion of WGSW to dive under STSpSW and move onto the shelf (as a salt water wedge) with the two water masses being separated over much of the shelf by a strong pycnocline represented by the 22 sigma-t surface.

The water mass envelope for summer (or summer-fall, 1976)(Figure 15) was generally similar to the summer of 1975 (Figure 3) with two significant differences: the 10-m temperature did not exceed 29.5°C and the 10-m salinity did not drop below 34 ppt except at Station 1/I; and salinities greater than 37 ppt occurred at depths of 70 to 80 m at Stations 2/III, 3/III and 3/IV (Figures 16, 17, 18 and 19). The core of WGSW was evident below 30 m at all mid- and outer- primary stations (Figure 20). The presence of salinities greater than 37 ppt probably represented a strong incursion of STU, not only because of the characteristic salinity maximum but also because of the simultaneous occurrence of a radiolarian indicative of these waters (*Theoconus hertwigii*) at outer stations during July and August. This suggested that waters from 100-m to 200-m depths offshore were encroaching onto the shelf to mid-shelf. The 30-m salinity contours (Figure 20) suggest that this encroaching water was as shallow as 30 m at Station 3/IV. The bottom salinities suggested an encroachment onto the shelf of open Gulf waters

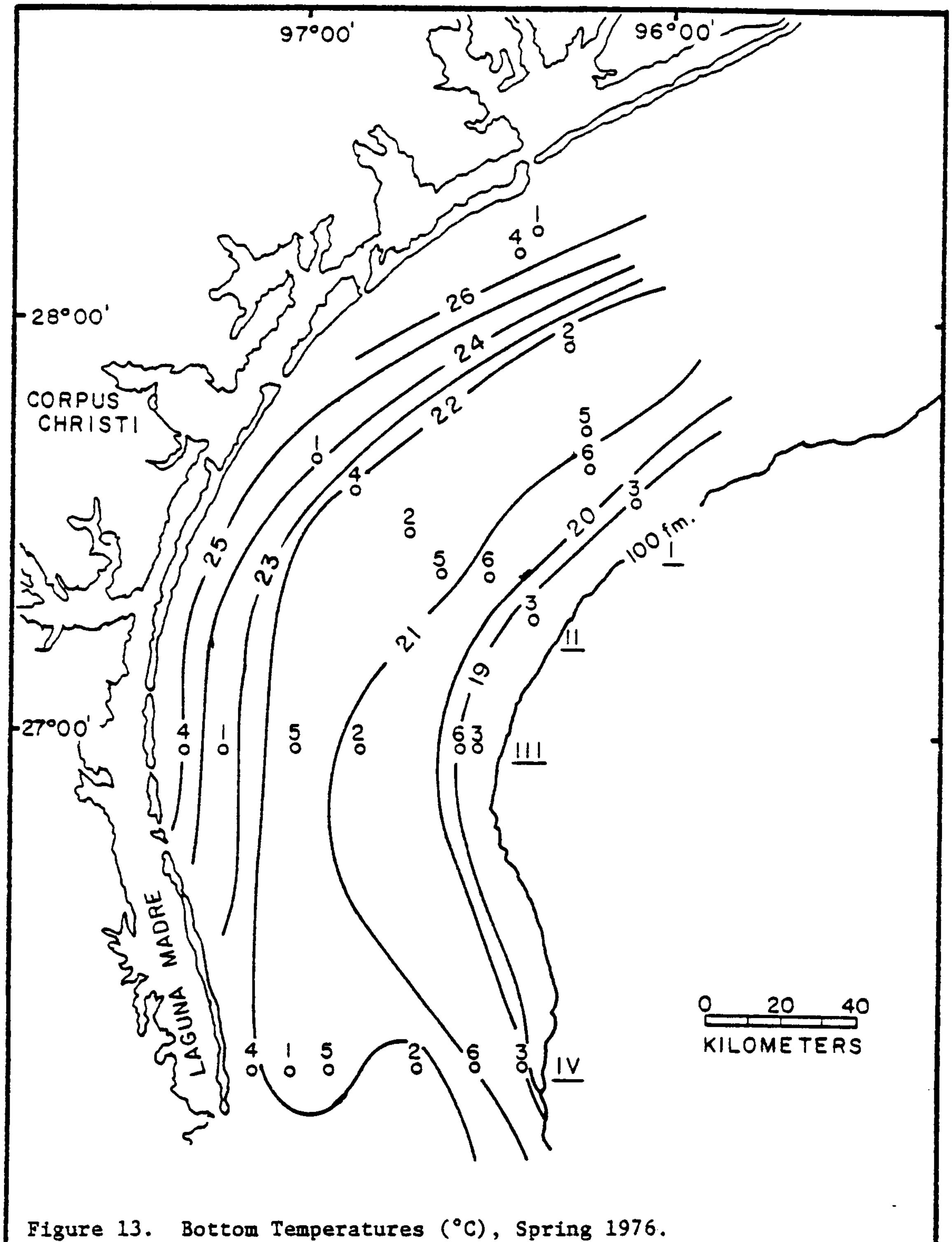


Figure 13. Bottom Temperatures (°C), Spring 1976.

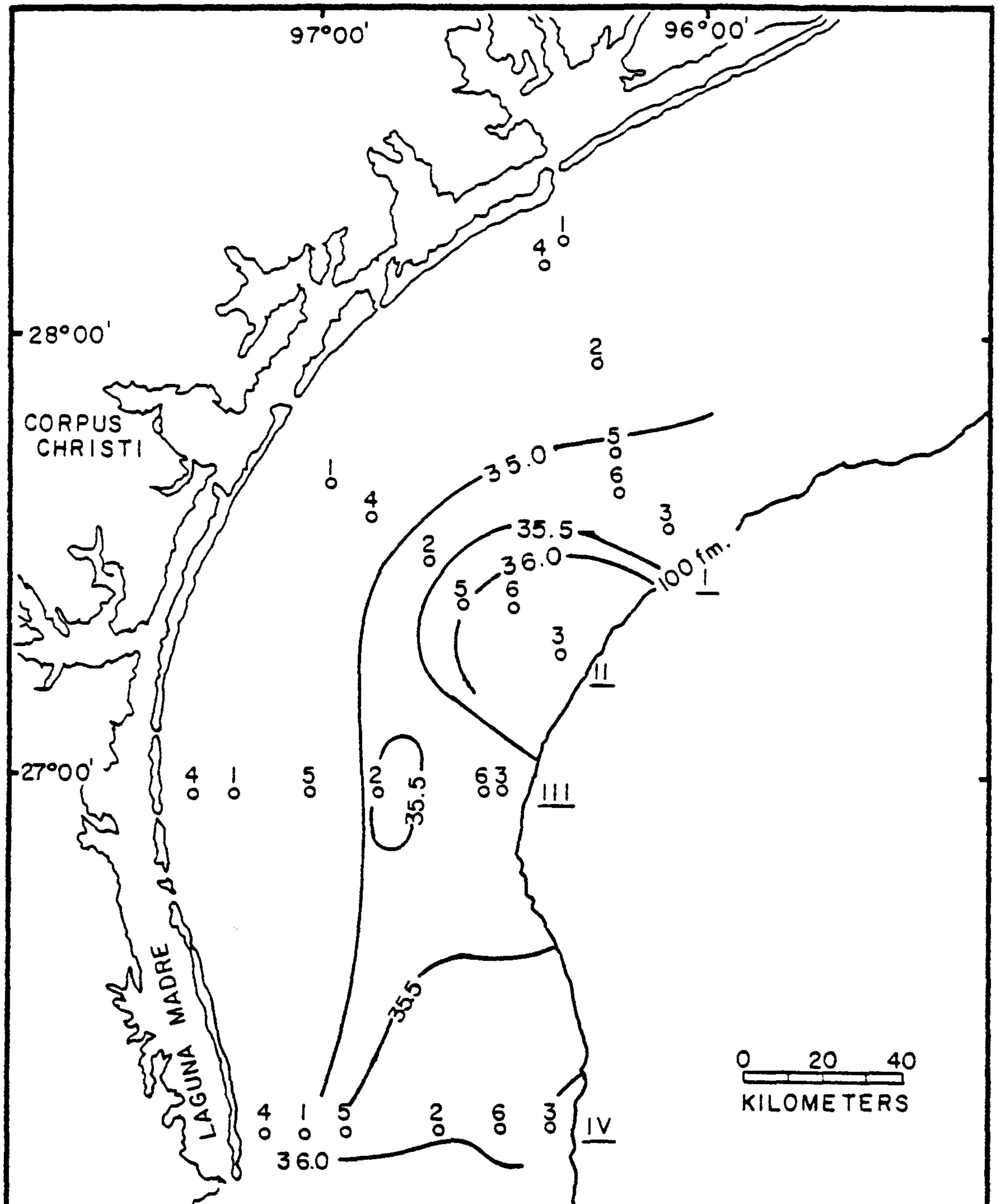


Figure 14. Spring Salinities (ppt) at 30 m, 1976.

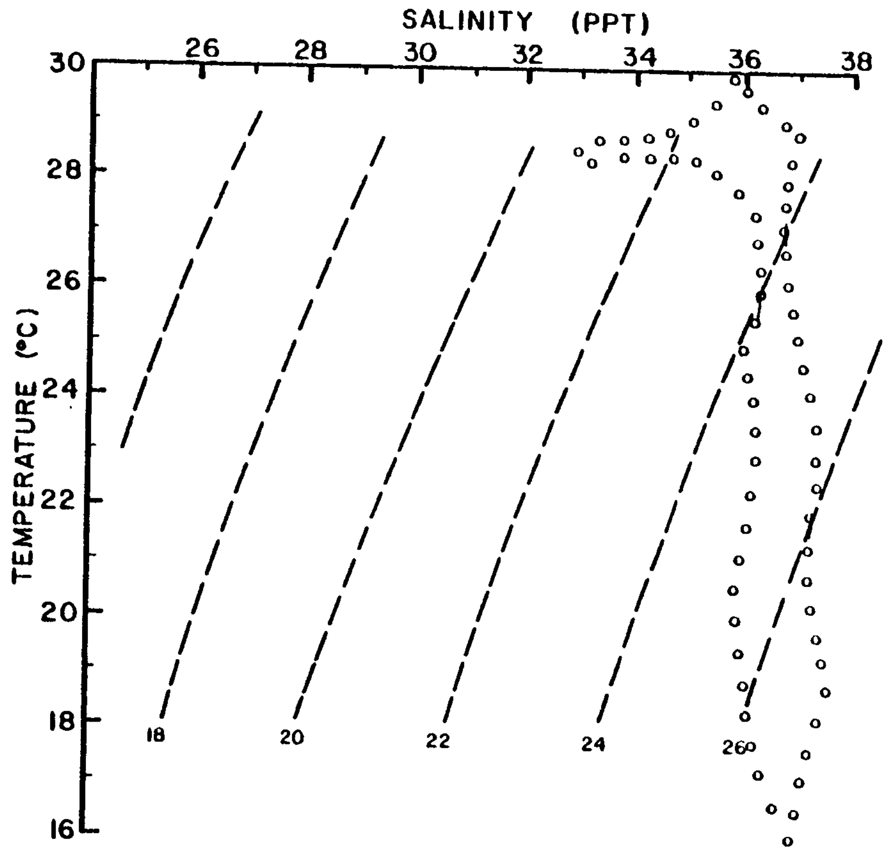


Figure 15. Water Mass Characterization of the STOCS, Summer 1976.

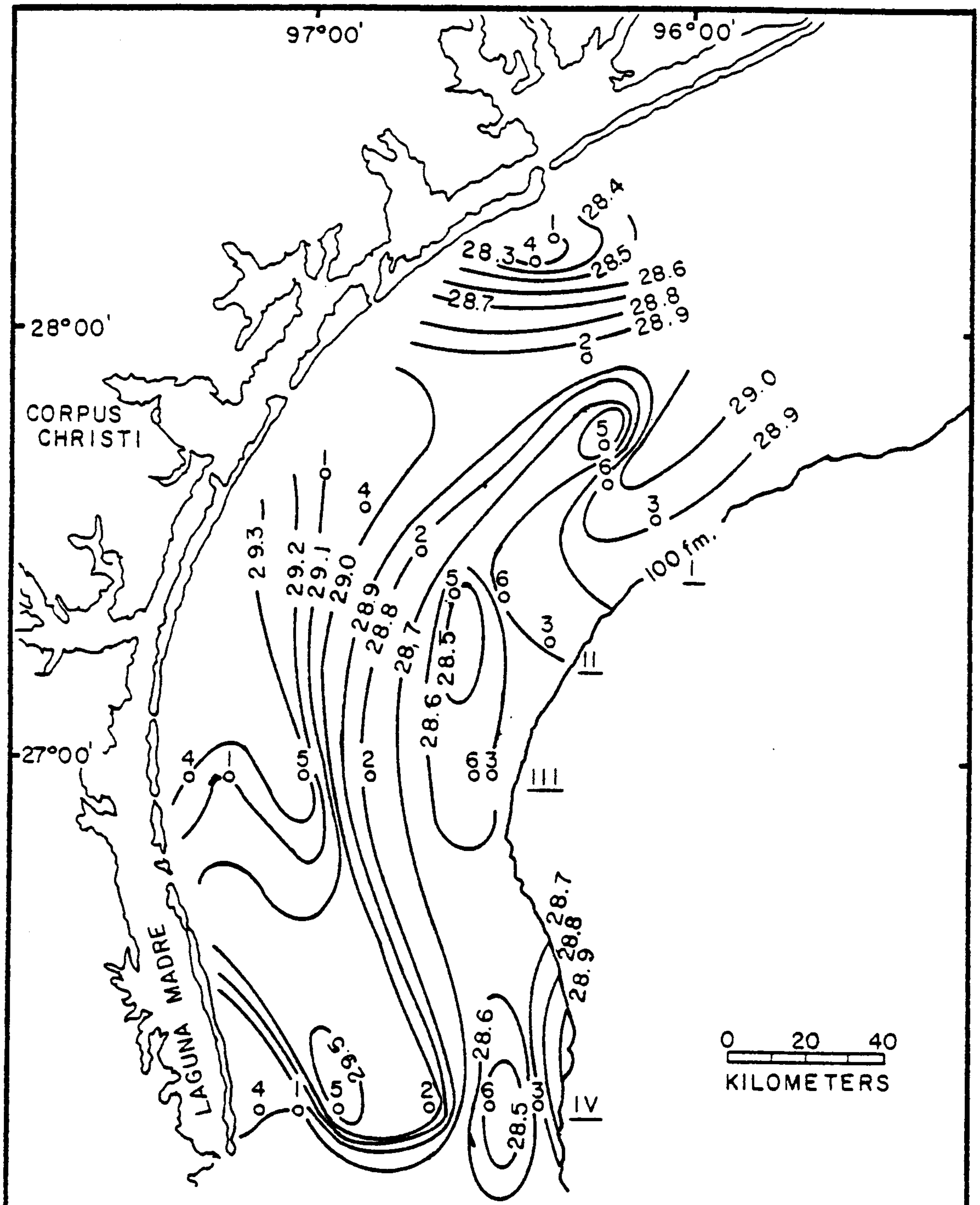


Figure 16. Summer Temperatures (°C) at 10 m, 1976.

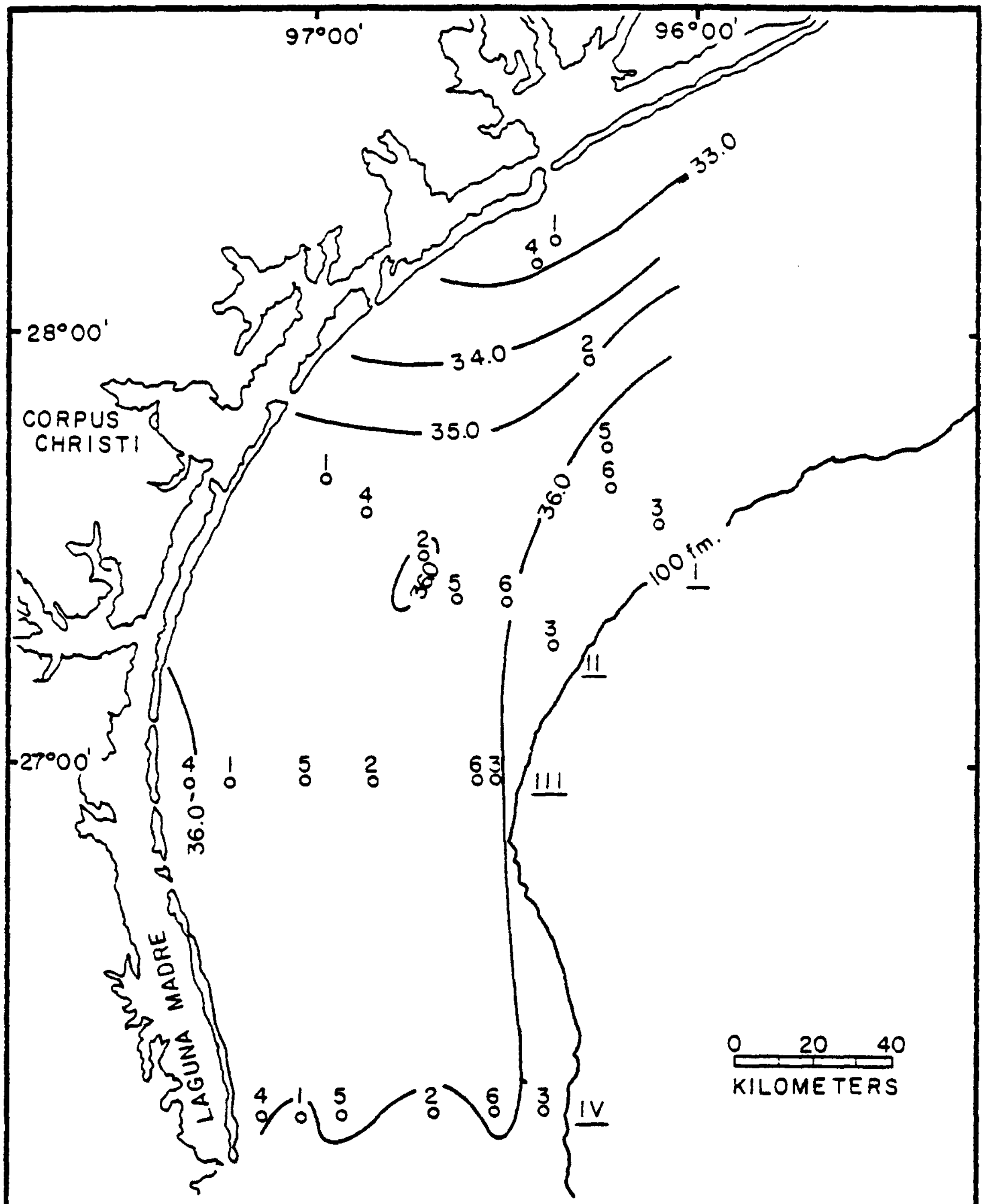


Figure 17. Summer Salinities (ppt) at 10 m, 1976.

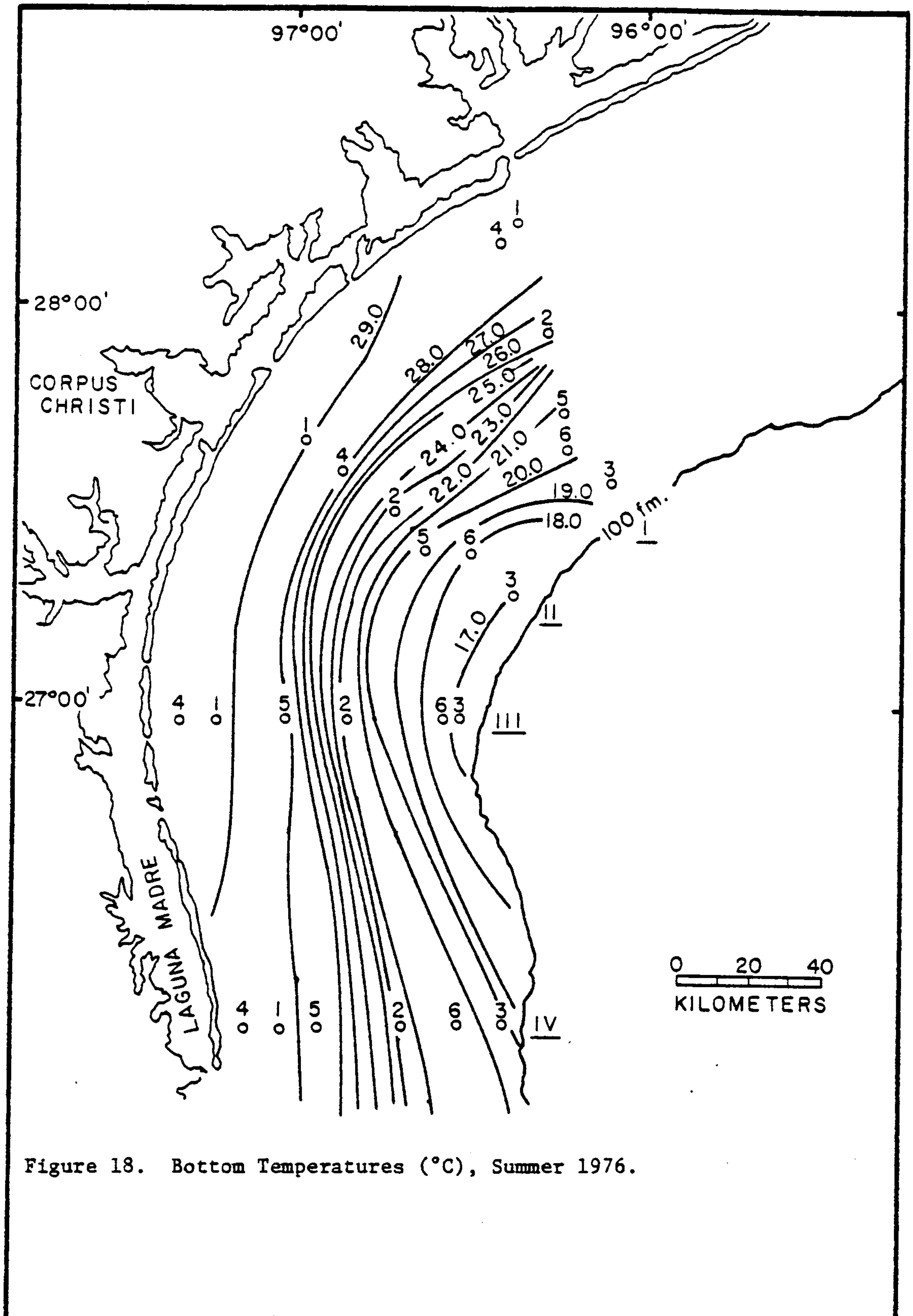


Figure 18. Bottom Temperatures (°C), Summer 1976.

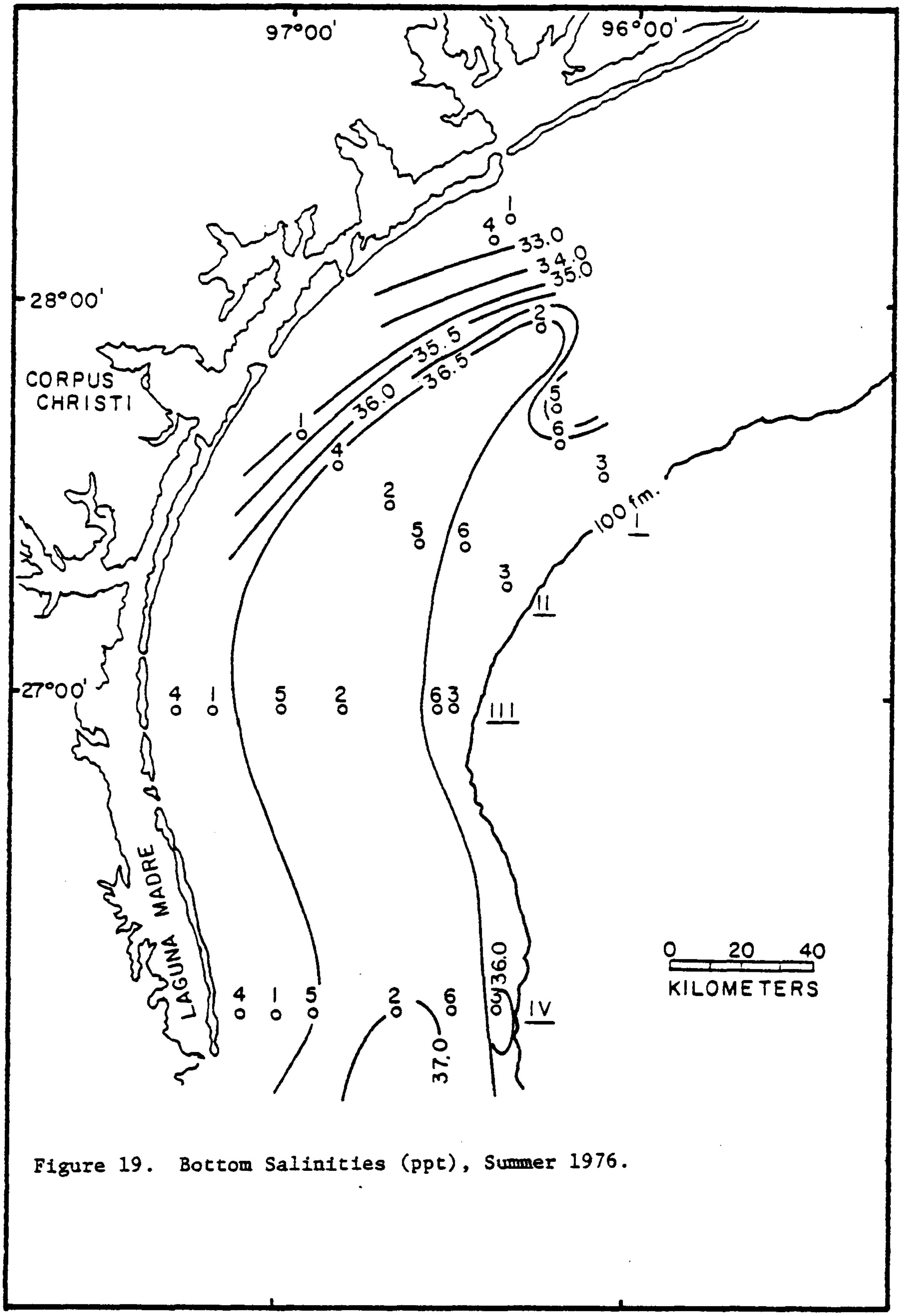


Figure 19. Bottom Salinities (ppt), Summer 1976.

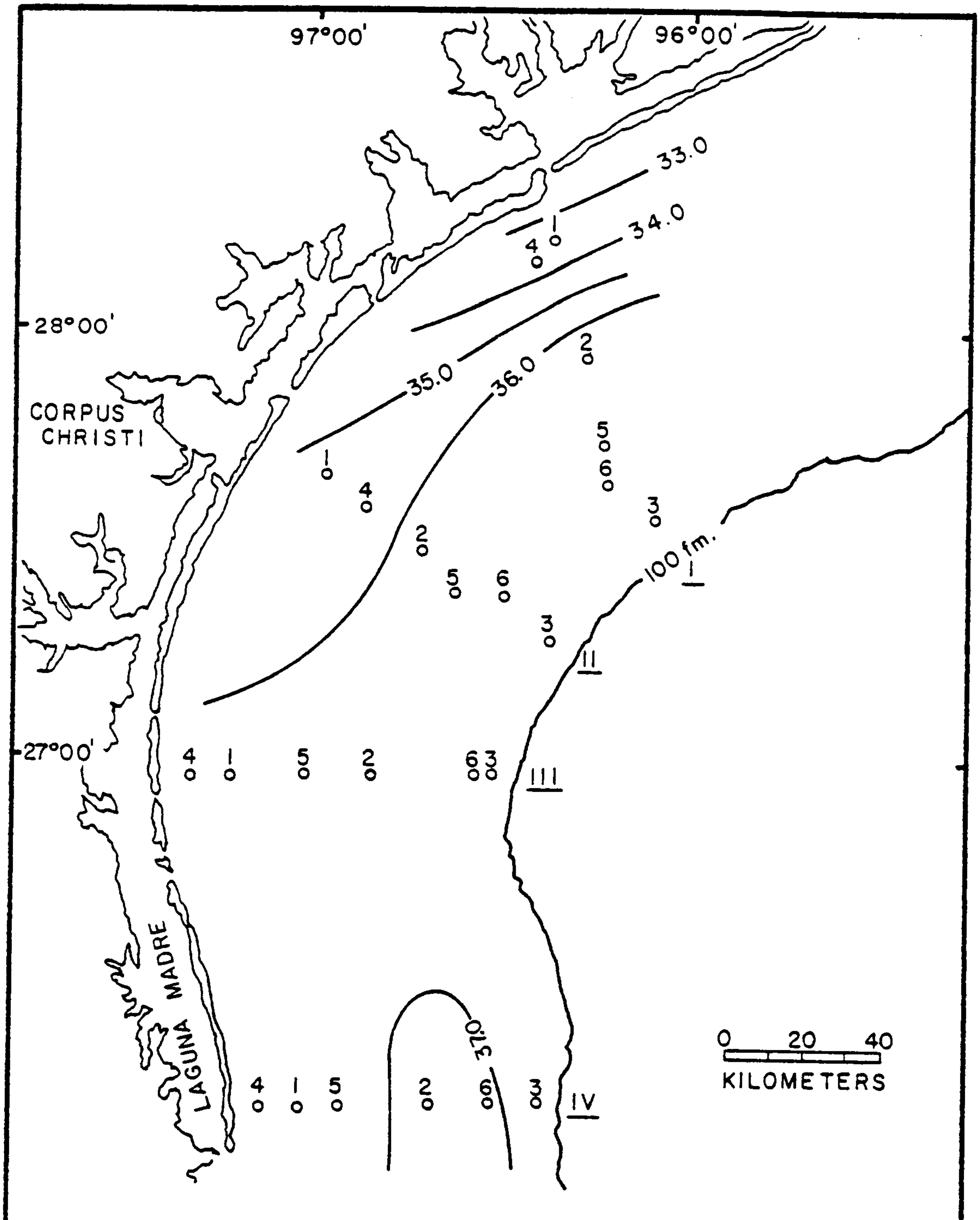


Figure 20. Summer Salinities (ppt) at 30 m, 1976.

which apparently overrode less saline water (or dragged this water with it from below) and encountered the shelf at mid-shelf between the 36.5-m contours (Figure 19). Figure 21, illustrating the occurrence of *T. hertwigii* and/or 37 ppt water (either at any depth in the water column), may best delineate this incursion of STU. These data (Figure 21) depict an upbowing of STU onto the southern shelf (over the shelf break along Transects II and IV) and a movement north and south.

Temperatures less than 20°C are characteristic of waters greater than 150 m in depth in the open Gulf (Armstrong and Grady, 1968) and the summer bottom temperatures (Figure 19) suggested an incursion of low temperature, deep water onto the south Texas shelf. This incursion of STU may have been brought in by an anticyclonic gyre or ring broken off from the Loop Current. Reasons for this suggestion are discussed below along with the shelled microzooplankton.

Three water masses apparently occupied the South Texas Outer Continental Shelf during the summer of 1976. These water masses were roughly separated by pycnoclines at 30 m (with waters of less than a 24 sigma-t above and greater than 24 below) and 60 m (with waters of less than 25 a sigma-t above and greater than 25 below). The shallow-water mass (above 30 m) was of low salinity nearshore and increased in salinity offshore and to the south. These waters physically appeared to be STSmSW. Below this water (deeper than 60 m but above the bottom at many localities), characteristics of STU were apparent.

Upbowing (or upwelling) of deeper water during the summer was apparent but not as dramatic as in the spring of 1975 or 1976. However, at no time during 1975 or 1976, other than in the summer of 1976, did there appear such a strong incursion of STU.

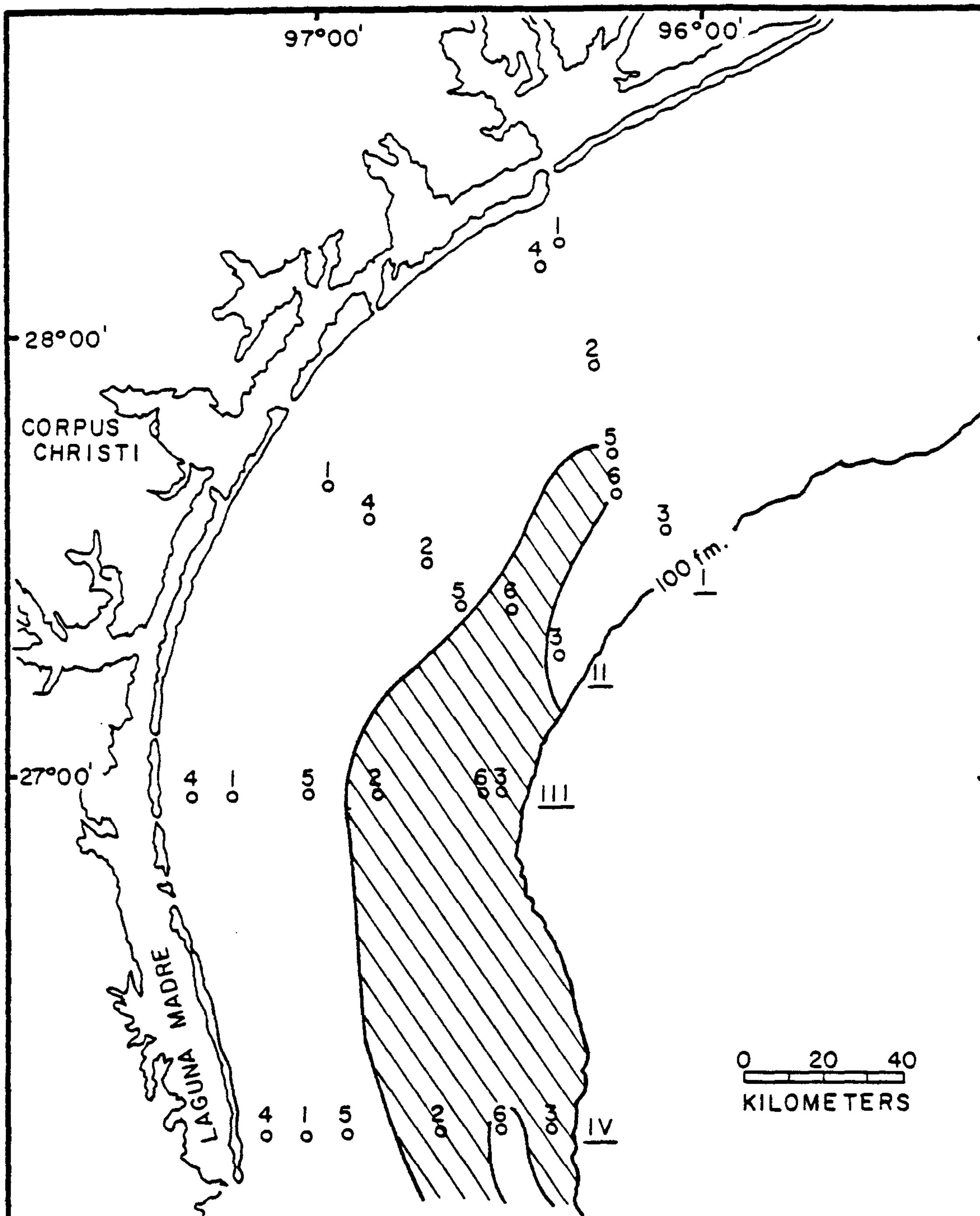


Figure 21. Contour of the Occurrence of *Theoconus hertwigii* and/or 37 ppt Water, Summer 1976.

Surface water conditions for the summer of 1976 may be summarized by stating that STSmSW was only present in characteristic form at inner stations (1 and 4) of Transect I while the remainder of the shelf was covered by WGSW or mixtures of WGSW most likely brought in by an anticyclonic gyre or ring. The only major anomaly departing from this simplified surface water summary was the presence of shallow lens of cooler water at mid-shelf throughout the entire area. This may have represented a "physically upwelled" deeper water pushed onto the shelf with the anticyclonic gyre or perhaps "upwelled", or dragged onto the shelf, by the combined coriolis and drag effect of the anticyclonic circulation pattern of this gyre. The evidence for this suggestion is presented in the discussion of the shelled microzooplankton.

Seasonal Circulation Patterns for the BLM-STOCS Study Area During 1976

There apparently was a net transport to the southwest during the winter, most probably related to "northerners". There was an apparent drift all along the shelf, with perhaps enough coriolis effect to produce an upbowing of deep shelf waters onto the shelf. During the spring there was a strong "estuarine upwelling" and a net transport south. The combination of the coriolis effect (produced by the net southward movement) and fresh water moving offshore producing the "open ocean estuarine effect" upwelling described above, appeared to produce the greatest upwelling of any season. The summer pattern showed the effects of an anticyclonic gyre or ring impinging on the shelf, with a resulting north-directed transport of entrained offshore, and perhaps deep, water at mid-shelf. The nearshore currents during the summer appeared to alternate between north and south movements. The evidence for the mid-shelf, north transport during the summer-fall is discussed below along with the shelled microzooplankton. Figure 22 gives a generalized picture of the seasonal circulation patterns of the STOCS study area during 1976.

Detailed Comparison of General Microplankton with the Physical Oceanography Along Transect II for Portions of 1976

Smith (1976a), reported inner shelf water out to Station 4 during the February seasonal cruise. This corresponded with the occurrence of a dominant component of dinoflagellates in the Niskin casts at Station 1 and a decline of dinoflagellates at Stations 2 and 3 (Figure 23). This recognition resulted in the addition of general Niskin microplankton counts to the analysis of the remaining Nansen tows which proved to show, perhaps, the most significant small-scale trends noted in this study.

In March, an "eddy" was described by Smith (1976a) between Stations 2 and 3 (Figure 23). This "eddy" appeared to be a pond of offshore shallow water with a significant component of planktonic foraminiferans and radiolarians indicative of such water. The occurrence of *Hexalonche anamimandri* and *Actinoma* B indicated that this water possessed a component of underwater water (McMillen, 1976). This same fauna was not found at Stations 3 or HR, but was present at Stations 5 and SB, suggesting the occurrence of an elongate pond of offshore water with dimensions of about 20 km wide and 40 km long in a north-south strike.

In April, Smith (1976a) recorded a tongue of relatively low salinity water extending shoreward past Station 2 (Figure 23). The absence of planktonic Foraminifera (usually restricted to offshore shallow waters) and the presence of spumellarian radiolarians (which come closer to shore than nassellarian radiolarians) indicated that typically mid-shelf waters were wedged under this shallow water (probably below the pycnocline). The presence of planktonic foraminiferans and both spumel-

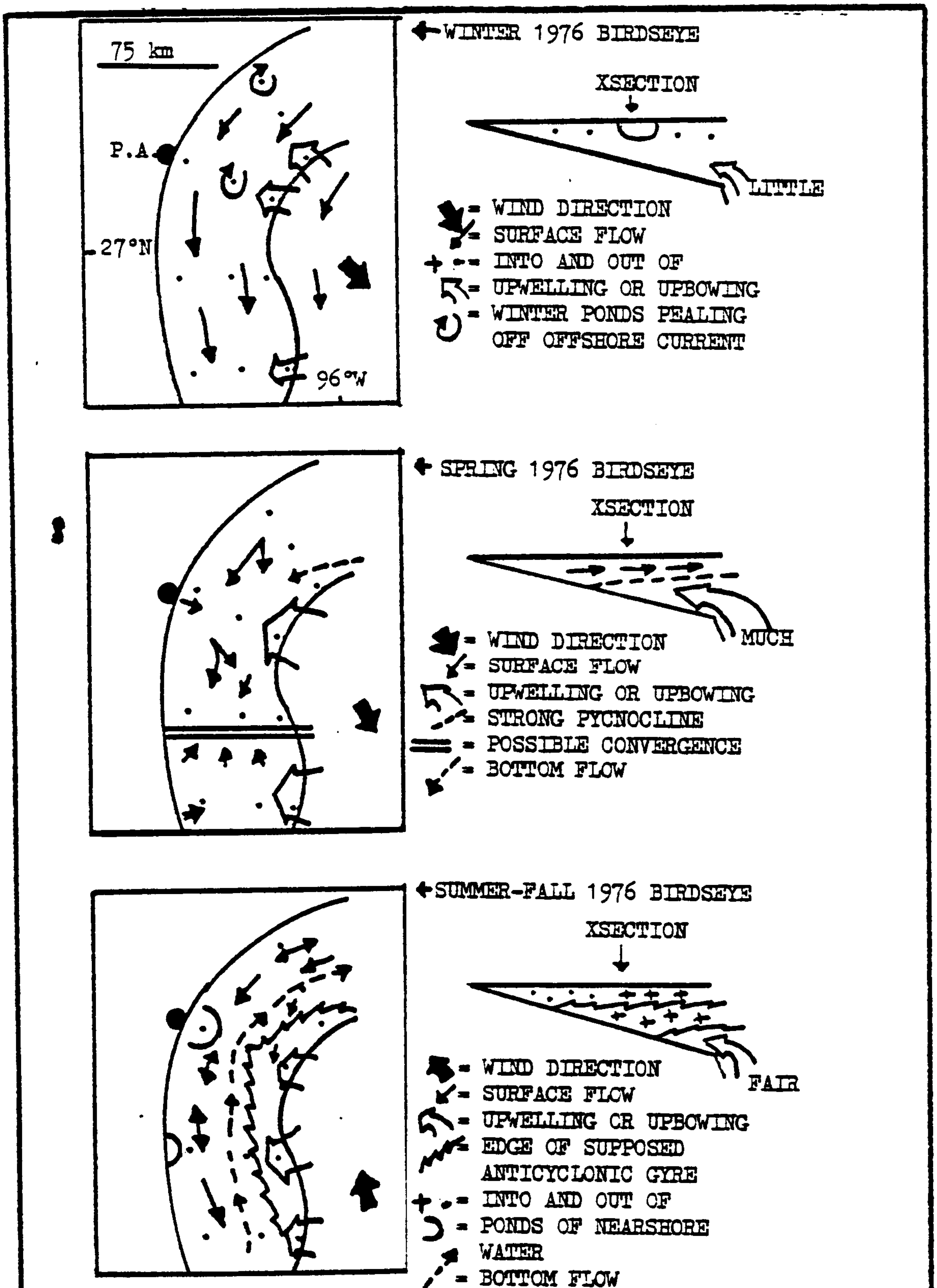


Figure 22. Generalized Picture of the Seasonal Circulation Patterns of the STOCS During 1976.

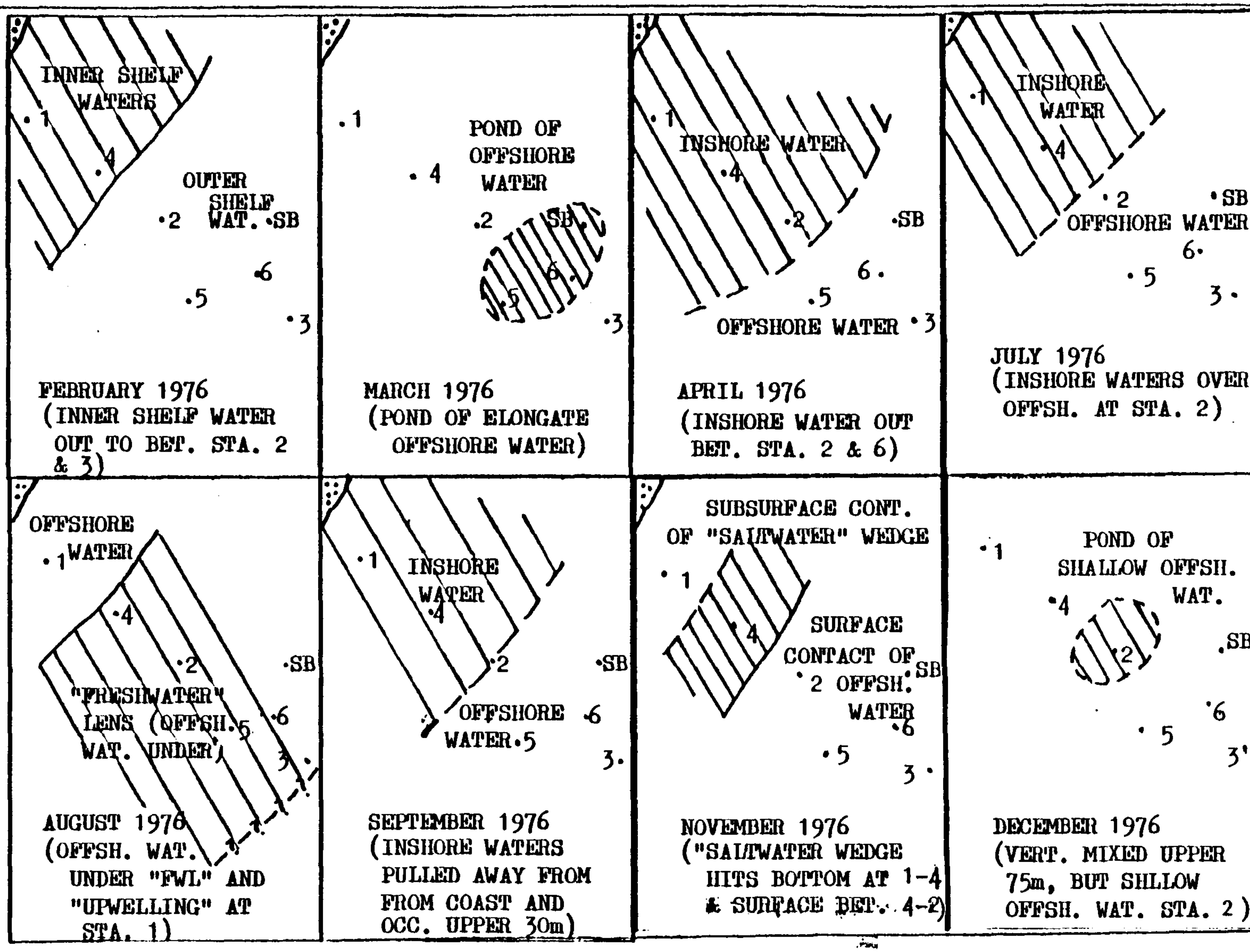


Figure 23. Nansen and Niskin Microplankton Data Related to the Physical Oceanography Data of Smith From BLM-STOCS Quarterly Reports and Quarterly Conferences.

larians and nassellarians at Station 3 suggested an incursion of offshore Gulf water (probably along the bottom).

In July, Smith (1976b) suggested that inshore waters extended past Station 4, and perhaps to Station 2 (Figure 23). Our data indicated no planktonic foraminiferans or nassellarians at Station 1, but the presence of *Spongotrochus glacialis* at this station suggested the exclusion of shallow, offshore water and a definite presence of deep, offshore (upwelled) water moving along the bottom. These forms (*S. glacialis*) are rare, so this offshore water was probably very mixed. However, at Station 2 planktonic foraminiferans, spumellarians and nassellarians were all present, being limited to the deepest 4 to 5 m at this station and below about 40 m of the Gulfward extent of the inshore upper water lens. At Stations 3, HR and SB, planktonic foraminiferans, spumellarians and nassellarians were all common which illustrated offshore incursion during this time. Comparing densities of these forms in the water column indicated their presence in only about 4 to 5 m of water (the deepest portion most likely).

In August, Smith (1976c) recorded a displaced, shallow lens of inshore water 30 km from the coast (Figure 23). Planktonic foraminiferans, spumellarians and nassellarians were recorded at all stations along this transect in the Nansen tows, suggesting that offshore water penetrated below this lens, perhaps completely replacing it at Station 1. Dinoflagellates were common at all stations except Station 1, suggesting that this lens was indeed detached from the coast and extending out to Station 3.

In September, Smith (1976c) suggested offshore water moving in along Transect II with lower salinities being pulled away from the coast through the inner three stations. Planktonic foraminiferans, spumellarians and nassellarians were collected into Station 2 which agreed with Smith's data (Figure 23).

In November, Smith (1977) suggested that cool water was moving out from the coast with its outer-surface limit being between Stations 4 and 2 and its subsurface extent intersecting the bottom between Stations 1 and 4 (Figure 23). No planktonic foraminiferans, spumellarians or nassellarians at Station 1 and the presence of these groups at Stations 2 and 3 agreed with the physical oceanographic data of Smith.

In December, Smith (1977) suggested a slight freshwater runoff with a strong vertical overturn (perhaps an open-ocean shelf type of estuarine-type upwelling), with an eddy of water at Station 2 (Figure 23). High diatom counts at Stations 1 and 2 (overturn) and a mixed pond of offshore water at Station 2 (or perhaps an ecotone) with the highest counts of planktonic foraminiferans, spumellarians and nassellarians of all stations on this transect showed agreement with Smith's statement.

In summary, the general groups appeared to be indicative of small-scale physical oceanographic conditions and, in fact, indicated these conditions as biological indicators now that the relationships are known. In other words, we believe that small-scale seasonal trends can be indicated using Nansen tows alone. By working mainly at the group level, other investigators could use these same procedures to determine major trends, but probably not the fine-scale trends where specific identifications are necessary (such as the encroachment of upwelled water into Station 1 by the use of the biological indicator *Spongotrochus glacialis*).

The general biological indicators are as follows: inshore waters = absence of or sparseness of planktonic foraminiferans, spumellarians and nassellarians, but abundances of diatoms and dinoflagellates; shallow offshore waters = abundant of planktonic foraminiferans and spumellarians; deeper offshore water = abundance of nassellarians with planktonic foraminiferans and spumellarians common.

Correlation of Nansen (Integrated) Tows with Physical Oceanography

Tables 1, 2 and 3 illustrate standing crops and Figures 24 and 25 the dendrograms produced by cluster analysis of various species of radiolarians, planktonic foraminiferans and pteropods. An attempt was made to place these species into biological-oceanographic-indicator groups in these tables and dendrograms. See Appendix C, Tables 1-6, for tabulations of all Nansen data.

Winter radiolarian densities are shown in Figure 26. The general increase in radiolarian density Gulfward was interrupted by two areas of high density at Stations 1/I and 2/II. The patch of high density at Station 1/I was due to a high concentration of *Spongosphaera streptacantha* which accounted for 87 percent of the total polycystine radiolarians at that station. This species was commonly found in the BLM-STOCS study area during the winter of 1975 at the outer stations. Its presence at Station 1/I, along with other radiolarians, and a good component of shallow-water winter planktonic foraminiferans (Table 2), suggested that a pond or ring of offshore water had moved in from offshore. The high density concentration at Station 2/II also suggested an offshore intrusion, but the inclusion of other forms (*Spongotrochus glacialis*) also suggested that this patch had brought in some deeper or perhaps upwelled water. The suggestion of water coming into the area from offshore was reinforced by the trend of high radiolarian diversity moving in along Transect II (Figure 27). This was similar to the 1975 BLM-STOCS data which showed ponds, eddies or small rings coming in during the winter. In the section herein on the detailed comparison of general microplankton and physical oceanography along Transect II, it was noted that these

TABLE 1

AVERAGE NUMBER OF RADIOLARIANS/m^3 FOR SPECIES INDICATIVE OF SEASONALITY, UPWELLING OR SUBTROPICAL UNDERWATER AT THE 12 PRIMARY STATIONS.
SPECIES ARE DIVIDED INTO INDICATOR GROUPS (IN PARENTHESES)

	Winter	Spring	Summer
(SUMMER-STRONG INDICATORS)			
Botryosyrtis scutum	0	.02	5.40
Euchitonia elegans	.19	0	2.03
Hymeniastrum profundum	2.81	1.01	9.21
Ommatartus tetrathalamus	.15	.18	2.03
Polysolenia lappacea	0	0	1.08
Pterocorys zancleus	.10	.56	7.85
(SUMMER-NOT STRONG INDICATORS)			
Astrophaera hexagonis	0	.09	.33
"circular" spongodiscid	.06	.03	.53
Disolenia zanquebarica	1.30	0	5.80
"elliptical" spongodiscid	0	0	.02
Hexalonche anaximandri	0	.04	.61
Lipmanella vichowii	.20	.04	.37
Lithopera baca	0	0	.02
Peromelissa phalacra	0	0	.04
Spirocyrtis scalaris (may be upwelling)	0	.06	.39
Spongaster tetras tetras	.19	.07	1.06
(WINTER-NOT STRONG INDICATORS)			
Cladococcus scoparius	.06	0	0
Euchitonia furcata	.57	.03	.02
(SPRING-VERY WEAK, BUT POSSIBLE INDICATORS-MAY BE INDICATIVE OF UPWELLING)			
Lampromitra parabolica	0	.02	0
Lithelius minor	0	.03	0
Lophophaena cylindrica	0	.26	.07
Pterocanium praetextum eucolpum	.03	.12	0
Pterocanium trilobum	0	.16	0
"six arm star"	0	1.47	0
(SUBTROPICAL UNDERWATER INDICATORS)			
Amphirhopalum ypsilon	0	.03	.08
Theoconus hertwigii	0	.07	.76
(UPWELLING INDICATORS)			
Challengeriids (best upwell ind.)	0	2.13	.31
Corocalyptra craspedota (? ind.)	0	.02	0
Eucyrtidium accuminatum (? ind.)	.37	.08	.11
Lamprocyclas nupitalis (? ind.)	0	.08	.06
Spirocyrtis scalaris (may be summer)	0	.06	.39
Spongotrochus glacialis (and cold)	1.69	.52	.85

TABLE 2

AVERAGE NUMBER OF PLANKTONIC FORAMINIFERA/m^3
FOR EACH SPECIES AVERAGED FOR THE 12 PRIMARY STATIONS BY SEASON.
SPECIES ARE DIVIDED INTO INDICATOR GROUPS (IN PARENTHESES)

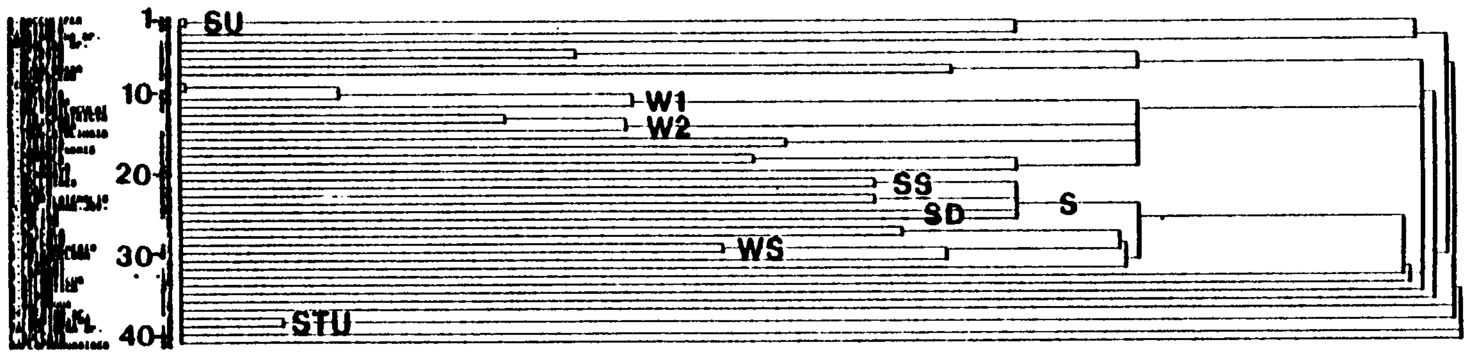
	Winter	Spring	Summer
(WINTER ASSEMBLAGE)			
Globigerina falconensis	9.37	0	0
Globigerina quinqueloba	18.65	0	.23
(SUMMER ASSEMBLAGE)			
Globigerina bulloides	1.64	.16	4.49
Globigerinoides ruber	1.46	1.98	10.30
(UPWELLING ASSEMBLAGE)			
Globigerinoides sacculifer	0	.06	0
Globoratalia scitula	0	.06	0
(OTHER)			
Globigerina calida	0	.09	.83
Globigerina rubescens	.06	0	0
Globigerinella aequilateralis	.54	.02	.02
Globorotalia crassiformis	0	0	.03
Globoratalia inflata	.03	0	0
Globoratalia menardii	.03	0	0
Globorotalis truncatulinoides	.59	0	0
Hastigerina pelagica	.11	0	.20
Orbulina universa	.02	0	.03

TABLE 3

AVERAGE NUMBER OF PTEROPODS/m^3
AVERAGED FOR THE 12 PRIMARY STATIONS BY SPECIES AND SEASON.
SPECIES DIVIDED INTO INDICATOR GROUPS (IN PARENTHESES)

	Winter	Spring	Summer
(SUMMER ASSEMBLAGE AND UPWELLING ASSEMBLAGE)			
Creseis acicula[1]	5.75	167.82	79.31
Spiratella inflata[2]	4.71	49.00	100.60
Spiratella lesueruri[3]	5.27	9.66	8.33
(OTHER SPECIES)			
Cavolina longirostrus[4]	0	0	.05
Clio polita[5]	.11	0	3.38
Creseis virgula constricta[6]	.48	0	0
Euclio campylura	.39	0	0
? *Peraclis*	.02	0	0

[1] Indicative of Gulf waters south of 26°N and frequently reported in neritic Gulf waters (Hughes, 1968).
[2] Most common in the central Gulf (Hughes, 1968) and usually occurs deeper than 100 m (Snider, 1975).
[3] Most common of the southern Gulf, south of 26°N (Hughes, 1968), and usually occurs deeper than 100 m (Snider, 1975).
[4] A species common to the Sargasso Sea (Hughes, 1968) and may come in with Subtropical Underwater from that region.
[5] Considered typically a bathypelagic form and its presence in the summer may represent the incursion of Subtropical Underwater, or at least the incursion of deeper, open-ocean Gulf waters onto the shelf.
[6] Occurs in the upper 100 m (Hughes, 1968).

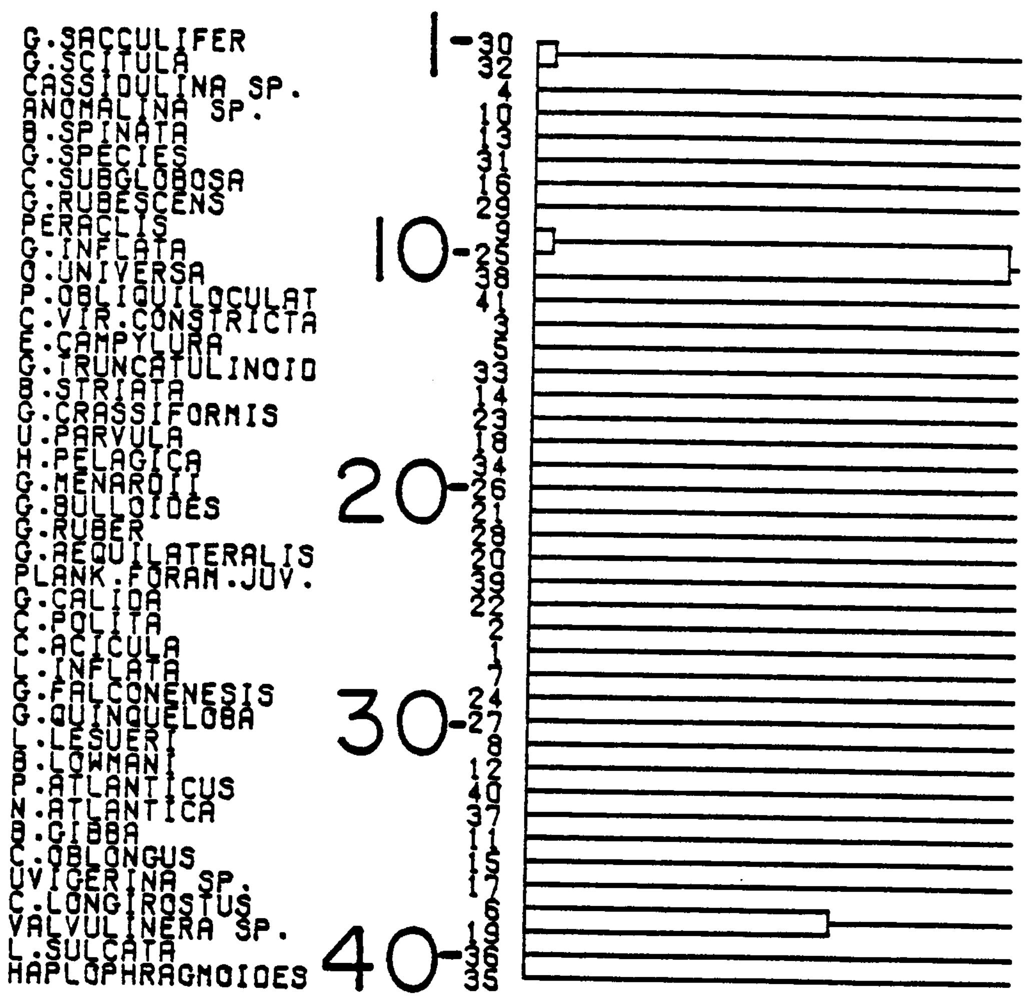


Key:

SS - summer shallow
S - summer
SD - summer deep
STU- subtropical underwater
SU - spring upwelling
W1 - winter 1
W2 - winter 2

Figure 24. R-Mode Analysis of Planktonic Foraminifera and Pteropods, 1976.
(See Key on Next Page.)

Figure 24. Key to R-Mode Planktonic Foraminifera and Pteropods, 1976.



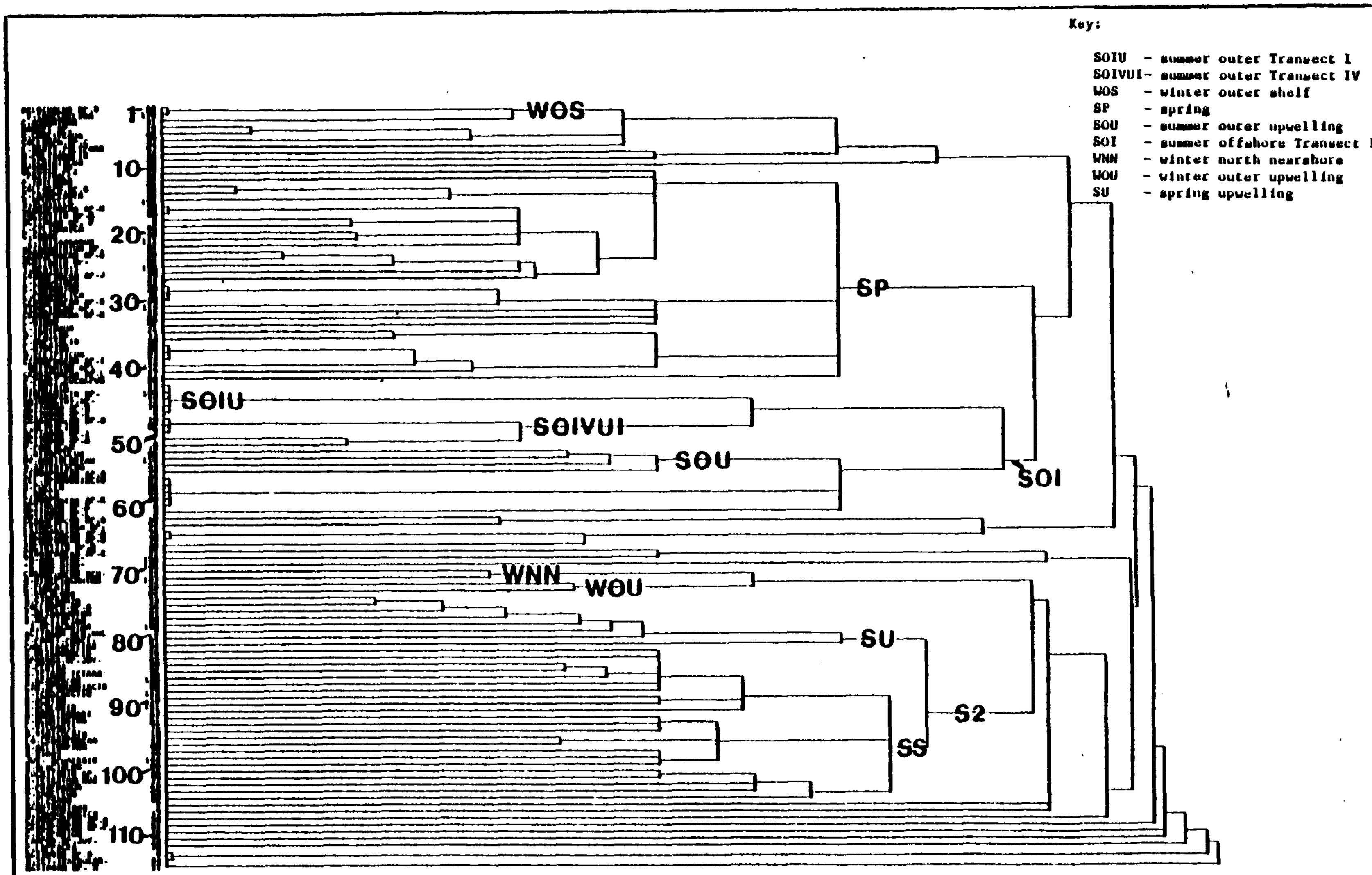


Figure 25. R-Mode Analysis of Radiolarians, 1976. (See Key on Next Page.)

Figure 25. Key to R-Mode Radiolarians, 1976.

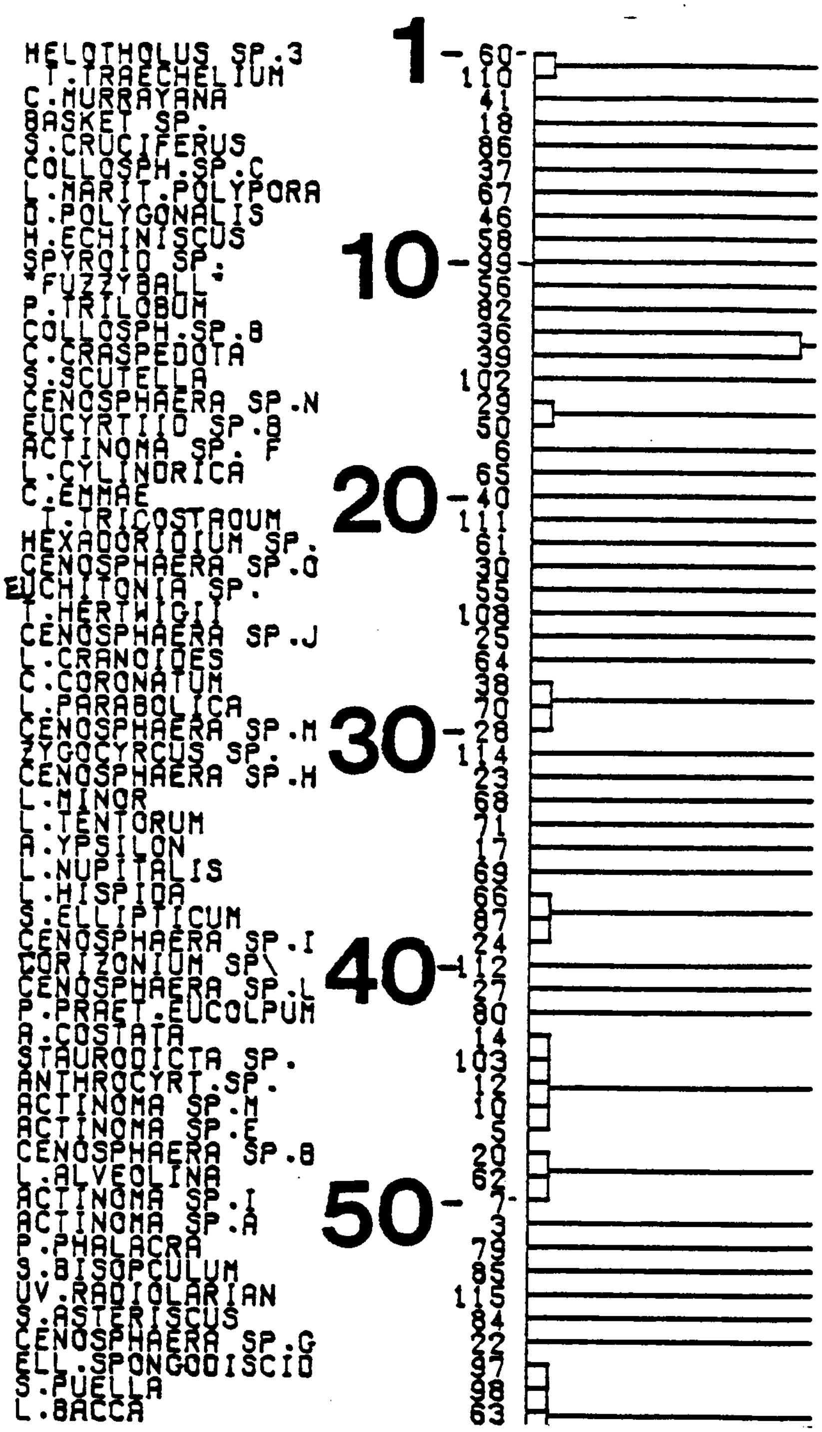
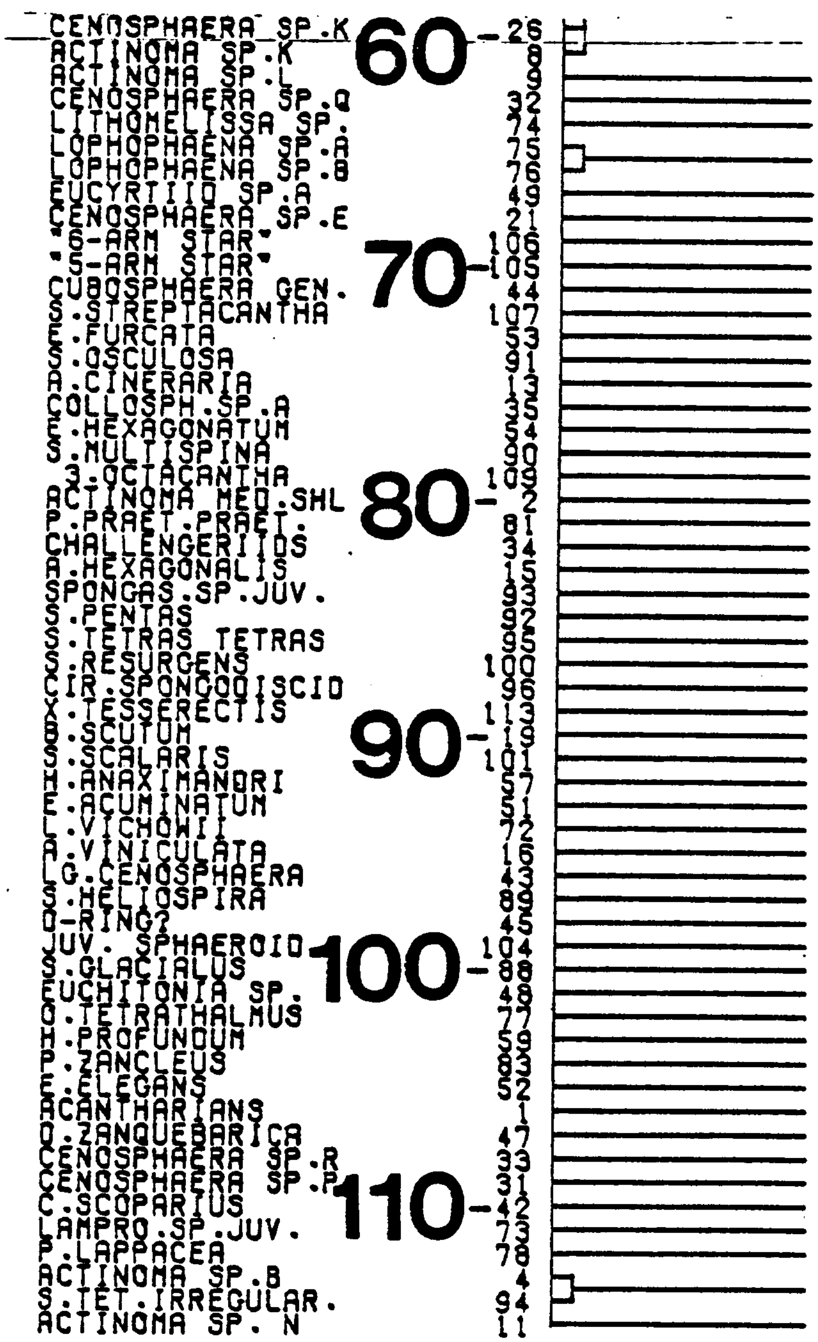


Figure 25. Key Continued.



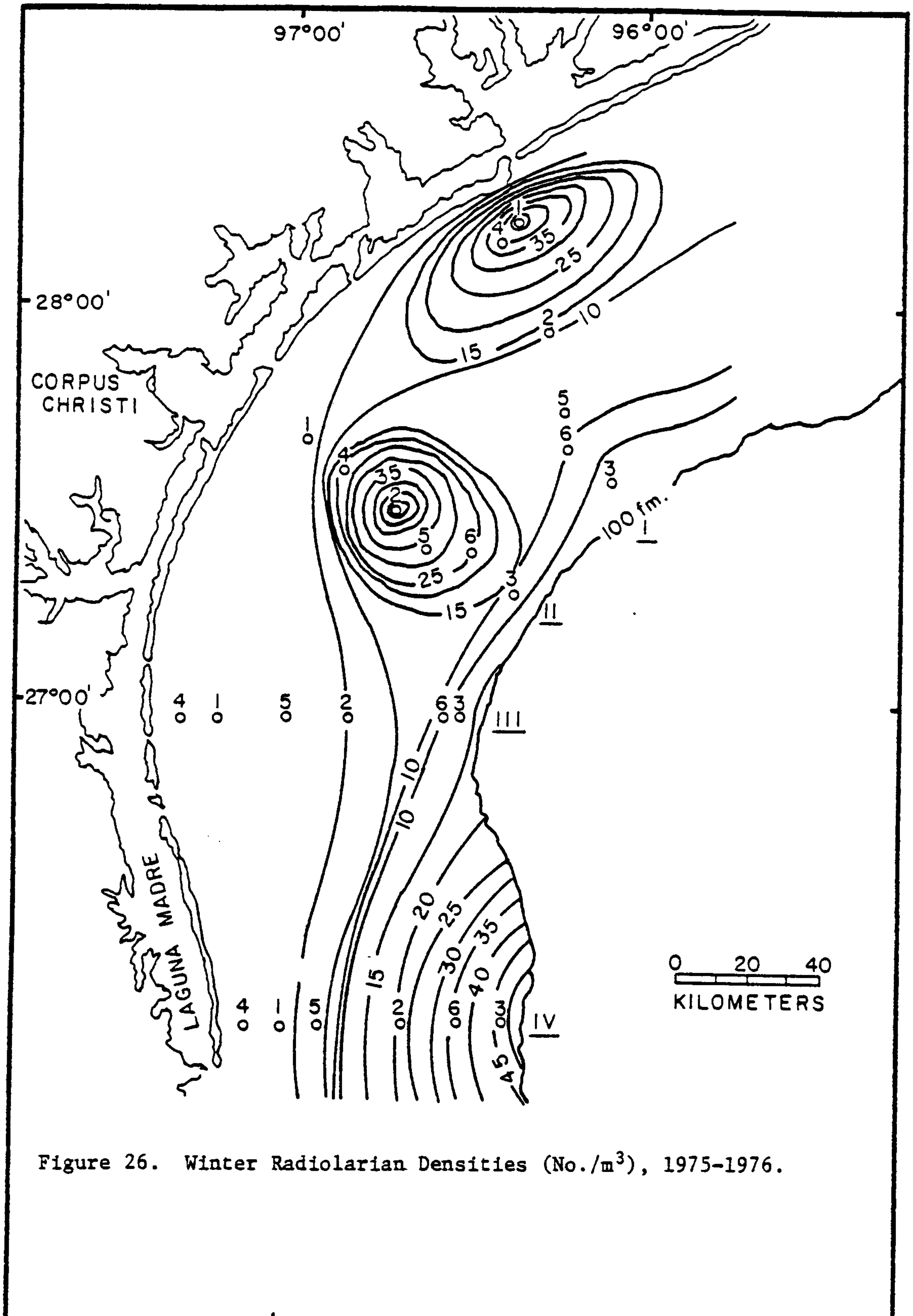


Figure 26. Winter Radiolarian Densities (No./m^3), 1975-1976.

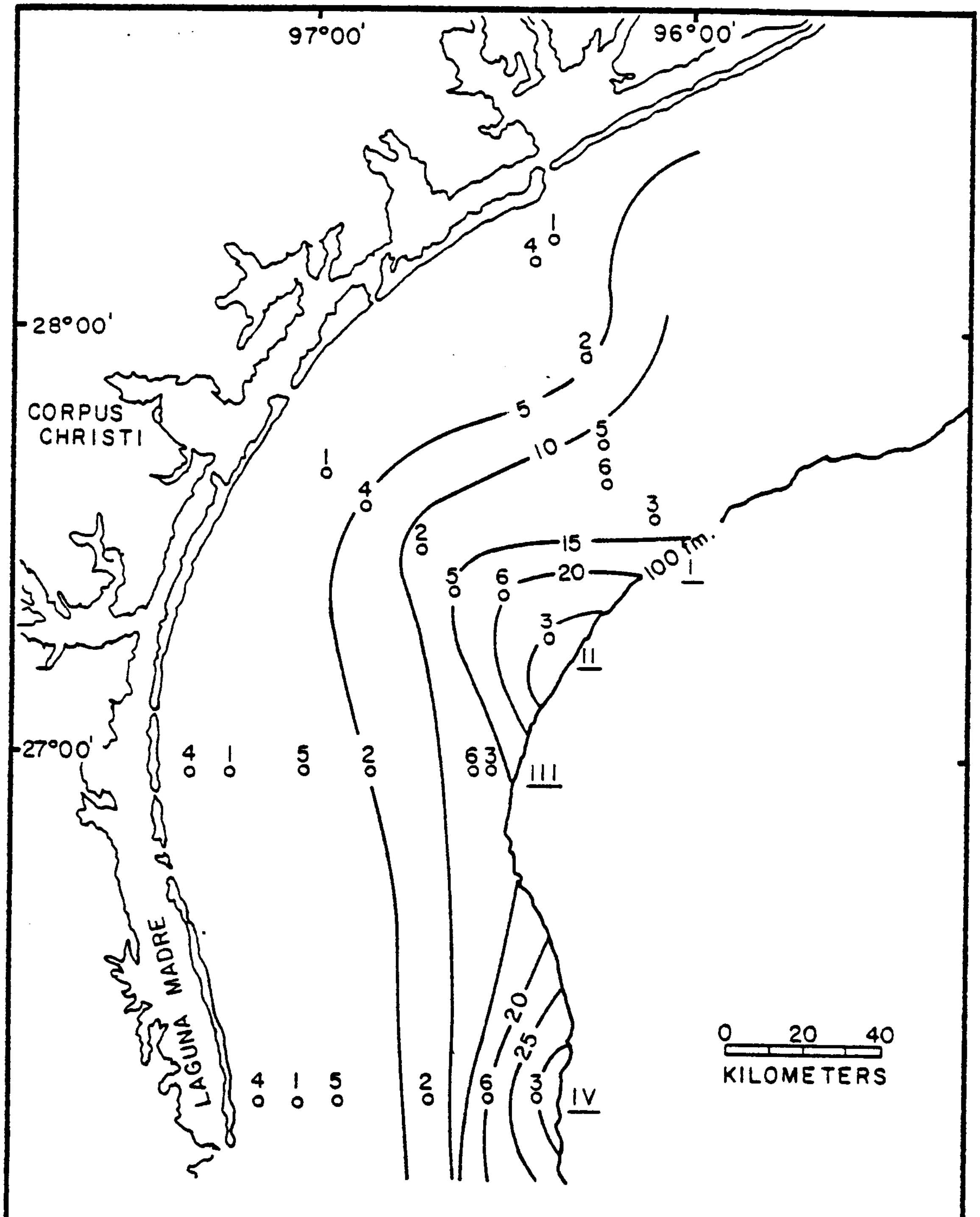


Figure 27. Radiolarian Diversity (Species/Tow), Winter 1975-1976.

small rings also occurred in March. This phenomenon of small rings also occurred in March. This phenomenon of small rings detaching and coming in was apparently common from winter into spring in the BLM-STOCS study area. They may represent small rings or blobs detached from the general offshore transport to the south, and might be brought into the area due to the Ekman effect.

The dendrogram of the R-mode analysis of planktonic foraminiferans and pteropods (Figure 24) clustered *Globigerina falconensis* and *Globigerina quinqueloba* which were indicative of the winter assemblage (W5) in both 1975 and 1976. Bounding the *G. falconensis* - *G. quinqueloba* cluster was the pteropod species which was common to the southern Gulf of Mexico (Table 3). A group of clusters (labeled W1 and W2) included the pteropods ? *Peraclis, Euclio campylura* and *Creseis virgula constricta* which only occurred in the winter of 1976 (Table 3). Enclosed in these same clusters were the planktonic foraminiferan species *Globorotalia inflata* and *Globorotalia truncatulinoides* which also occurred only in the winter of 1976 (Table 2). These paired clusters (W1 and W2) were considered indicative of the "unique" winter planktonic foraminiferans and pteropods.

Figure 25 illustrates the R-mode cluster analysis of radiolarians as a dendrogram. The cluster labeled WNN represented a nearshore northern component dominated by the radiolarian *Spongosphaera streptacantha*. This species was dominant at Stations 1/I and 2/II during the winter of 1976. On this same dendrogram, WO"U" represents a cluster comprised of a dominant winter form (*Euchitonia furcata)* and one normally considered as an upwelling form (*Spongopyle osculosa*) which only occurred during 1976 in the winter. The occurrence of *S. osculosa* in shallow water during 1976 was probably not due to upwelling but rather to the extremely low winter temperatures. It was perhaps maintaining a depauperate fauna left over from the previous year. The only other probable winter cluster (WOS) clustered out at a high level of association due to few species occurrences but in the same winter samples. This cluster was a winter outer-shelf (WOS) assemblage.

Spring radiolarian densities (Figure 28) were the lowest of the year. Figure 29 illustrates the lowest diversities of the year for polycystine radiolarians, a condition similar to 1975. Large amounts of freshwater lensing out over the shelf produced a depauperate radiolarian fauna in shallow waters, but pulled in offshore radiolarians (upwelling or upbowing of Gulf water as shown by high concentrations of deep-water Challengeriids at the outer stations). The ratio of living nassellarians to spumellarians (Figure 30) was a good indication of offshore intrusion (a higher ratio equals offshore water). The abundance of planktonic foraminiferans (Figure 31) depicted offshore water intruding into the shelf. There was a slight intrusion from north to south at the surface (Figure 31) as shown by the foraminiferans and intrusion of deeper water from all along the shelf break as shown by the Challengeriids and radiolarian diversity and density. The density of pteropods (Figure 32) was similar in general to that of the planktonic foraminiferans. Shelled microzooplankton indicators of low-salinity, shelf-water circulation patterns are exemplified by the plots of densities of acantharians (Figure 33). This flow of shallow, less-saline water south through the mid-section of the area may have been related to the flow of the Mississippi River Water Mass. The abundance of bivalve veligers (Figure 34) apparently illustrated the movement of estuarine water out of Corpus Christi and the Rio Grande estuarine systems. The density of *Hymeniastrum profundum* (a spongy euryhaline radiolarian common over

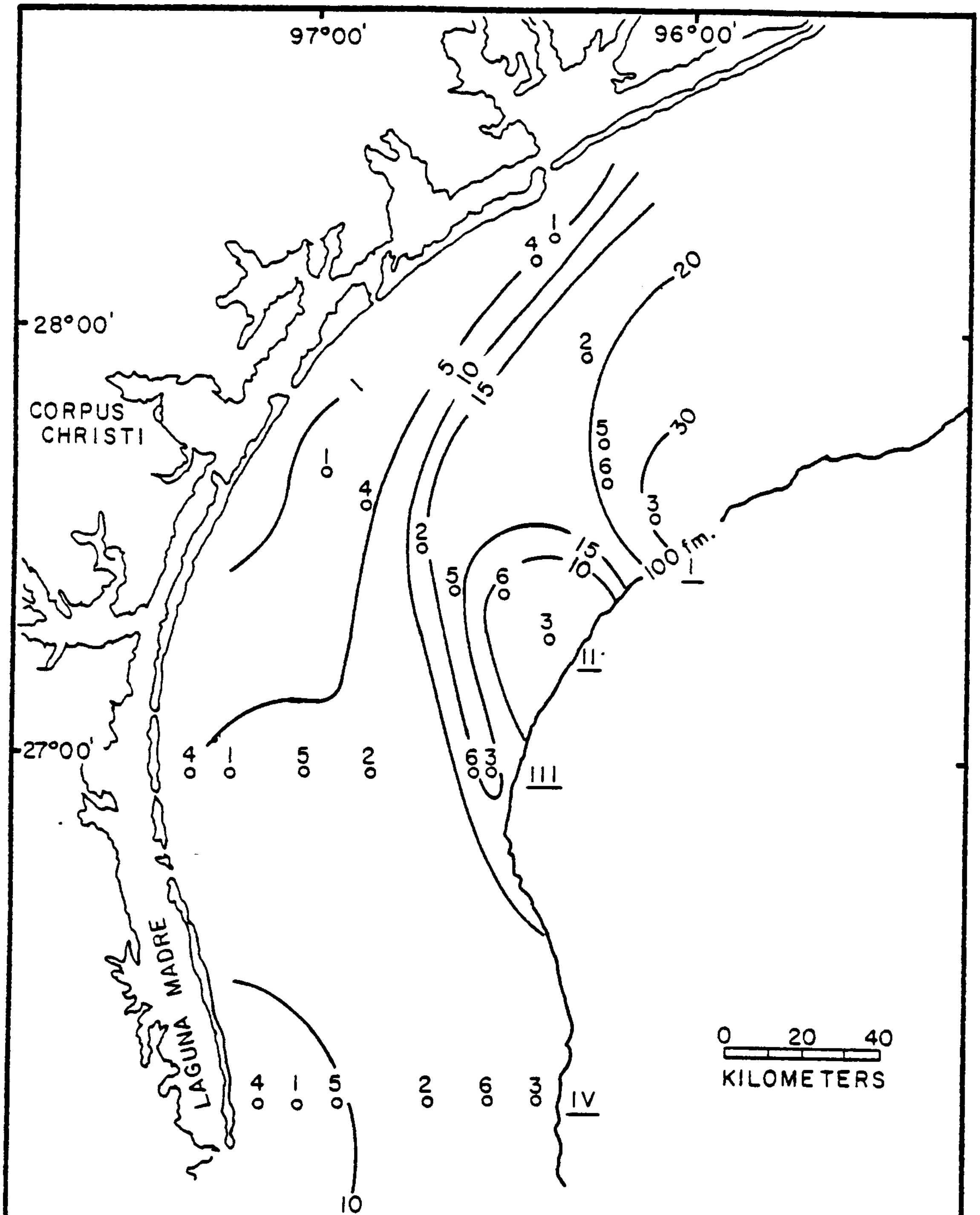


Figure 28. Abundance of Polycystine Radiolarians (No./m^3), Spring 1976.

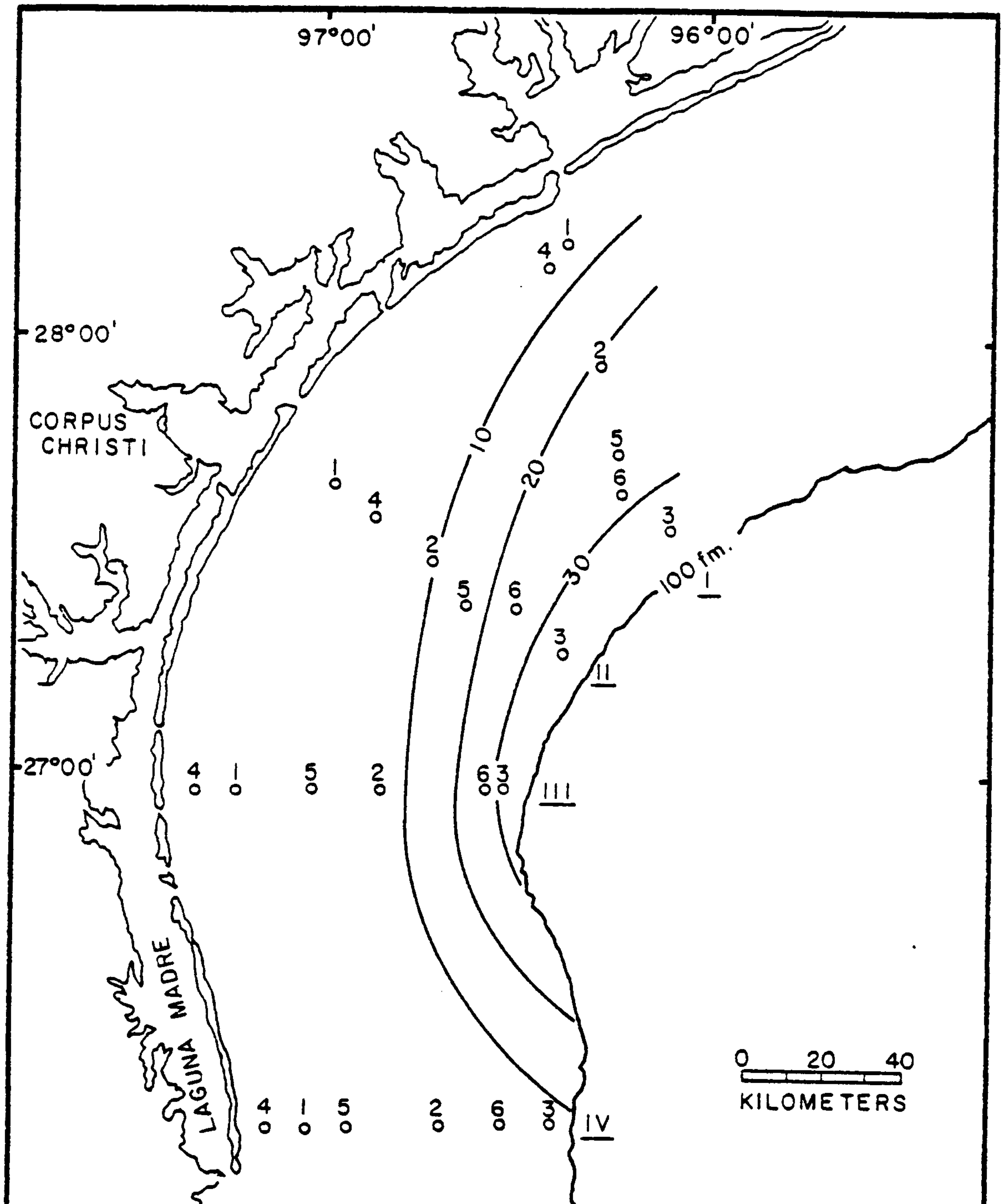


Figure 29. Polycystine Radiolarian Diversity (Species/Tow), Spring 1976.

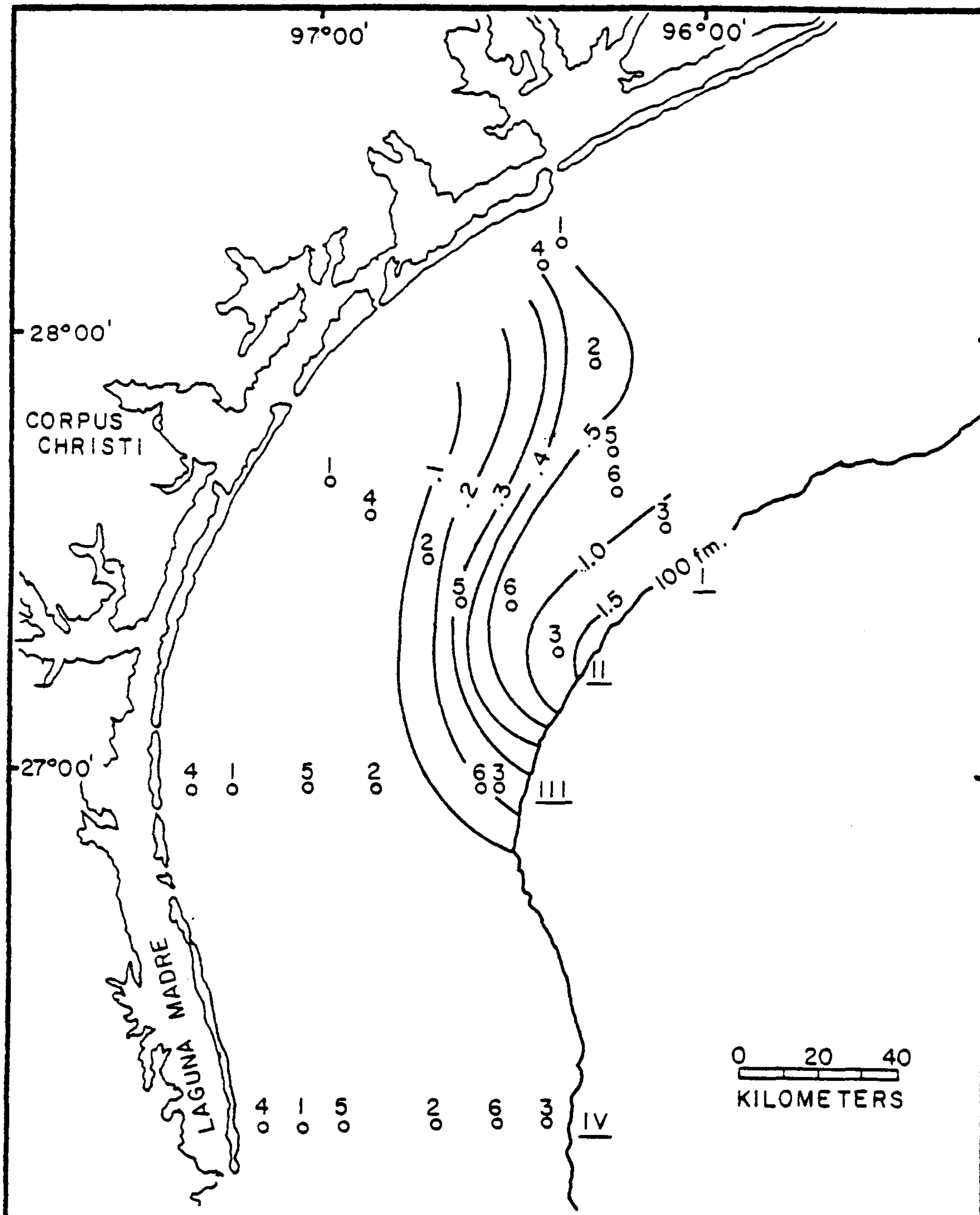


Figure 30. Ratio of Living Nasellarians to Spumellarians, Spring 1976.

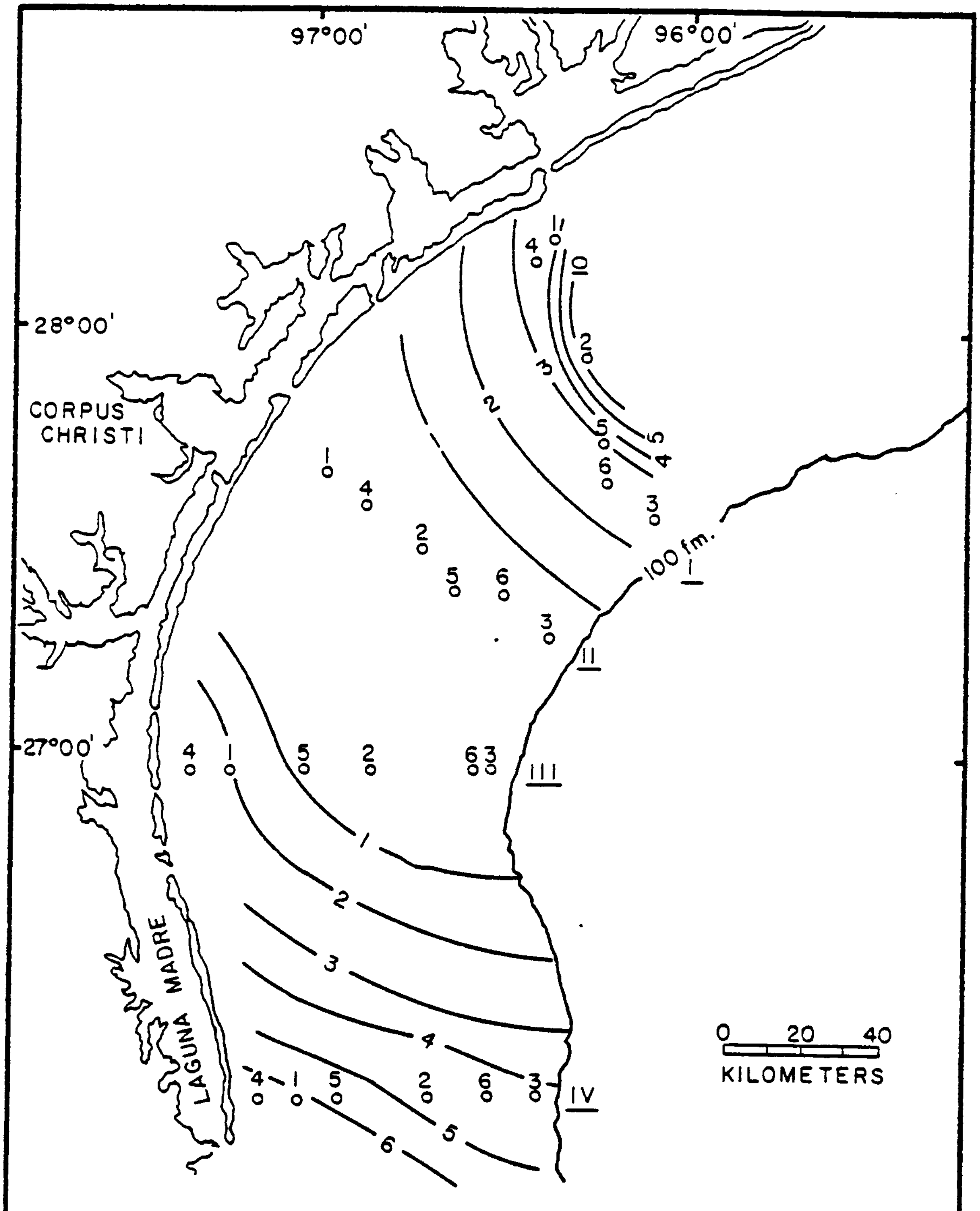


Figure 31. Abundance of Planktonic Foraminiferans (N./m^3), Spring 1976.

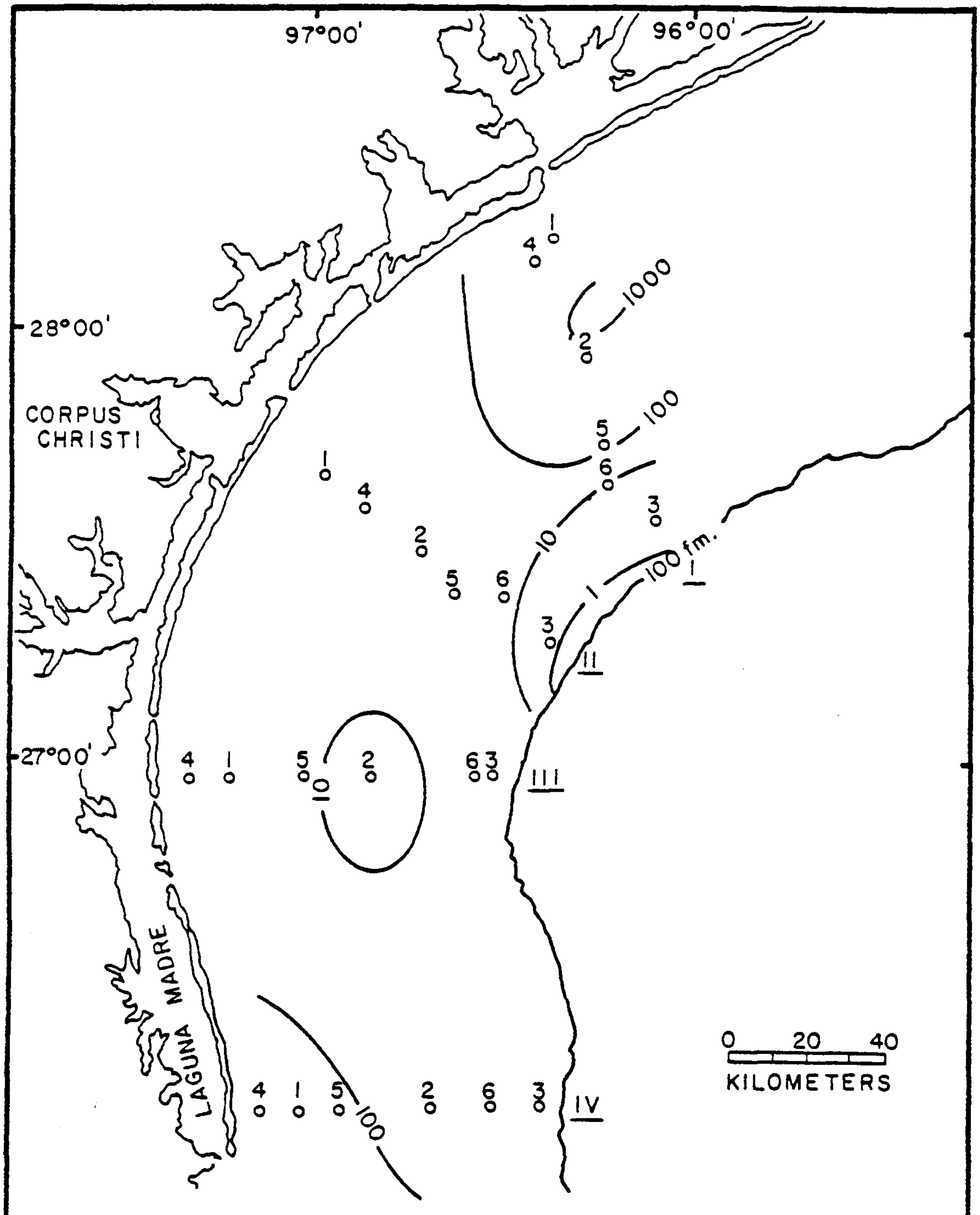


Figure 32. Abundance of Pteropods (No./m^3), Spring 1976.

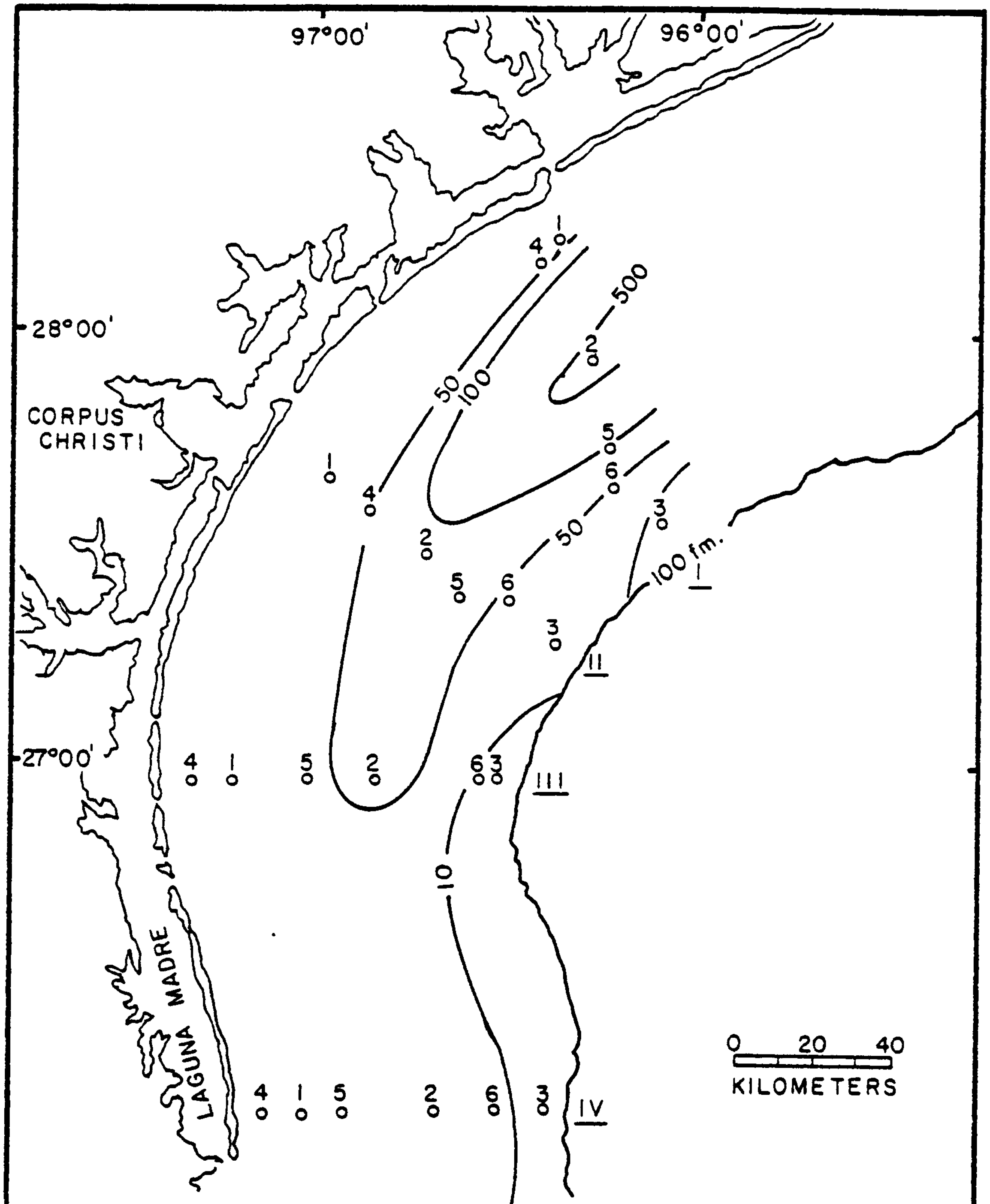


Figure 33. Abundance of Acantharian Radiolarians (No./m^3), Spring 1976.

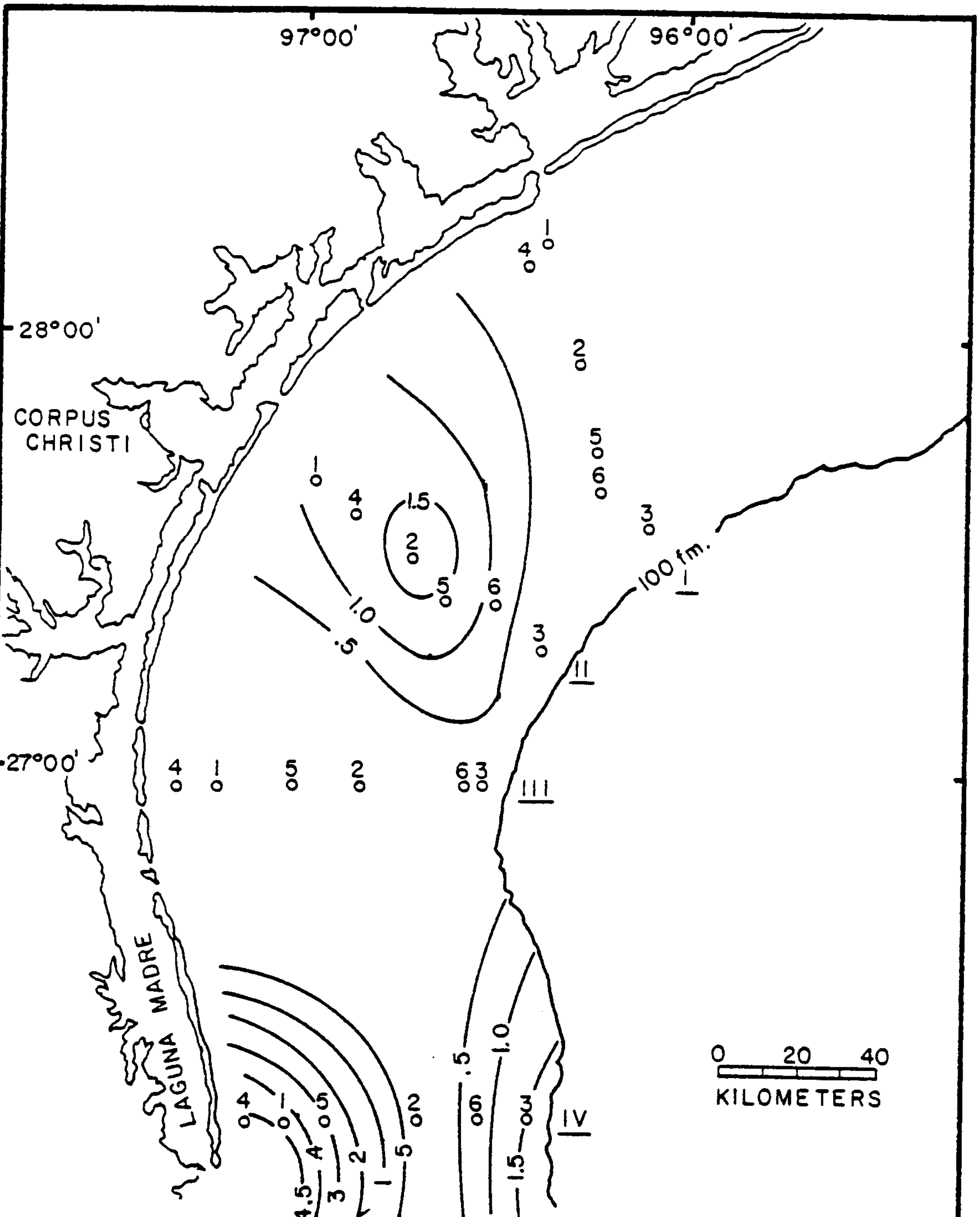


Figure 34. Abundance of Bivalve Veligers (No./m^3), Spring 1976.

much of the shelf) was a good indicator of shelf circulation (Figure 35). The plot of benthonic foraminiferan abundance in the water column (Figure 36) may be interpreted in several ways: the northern encroachment may be related to suspension (or preferential flotation by *Brizalina lowmani*, the dominant planktonic-benthonic); it may trace the nepheloid layer at that specific time; or, the "pond" off the Rio Grande may be correlated with run-off or the presence of the nepheloid layer. However, these interpretations may be related to a stirring of the bottom and suspension of these benthonic forms by circulation, waves or internal waves.

The dendrogram of the R-mode analysis of planktonic foraminiferans and pteropods (Figure 24) clustered two significant groups labeled SU and STU. *Globigerinoides sacculifera* and *Globorotalia scitula* represented a spring upwelling assemblage. *G. scitula* is a deep-living form, found usually at depths greater than 500 m in subtropical waters (Be, 1967) and in the Gulf of Mexico at 100 m (Phleger, 1951). *G. sacculifer* was found mainly below 100 m in the Gulf of Mexico (Phleger, 1951). These species occurred only during the spring of 1976 in the STOCS study area (Table 2).

The R-mode analysis of radiolarians as a dendrogram is given as Figure 25. A large, loose cluster labeled SP clustered most of the species considered indicative of spring conditions in the STOCS study area (Table 1). Included in this cluster were *Pterocanium trilobum*, *Lampromitra parabolica* and *Lithelius minor*, species that only occurred in the spring, and *Lophophaena cylindrica* and *Pterocanium praetextum eucolpum* that were dominant in the spring but present in other seasons. *Theoconus hertwigii* and *Amphirhopalum ypsilon* occurred within this loose cluster (SP) and were considered indicative of Subtropical Underwater

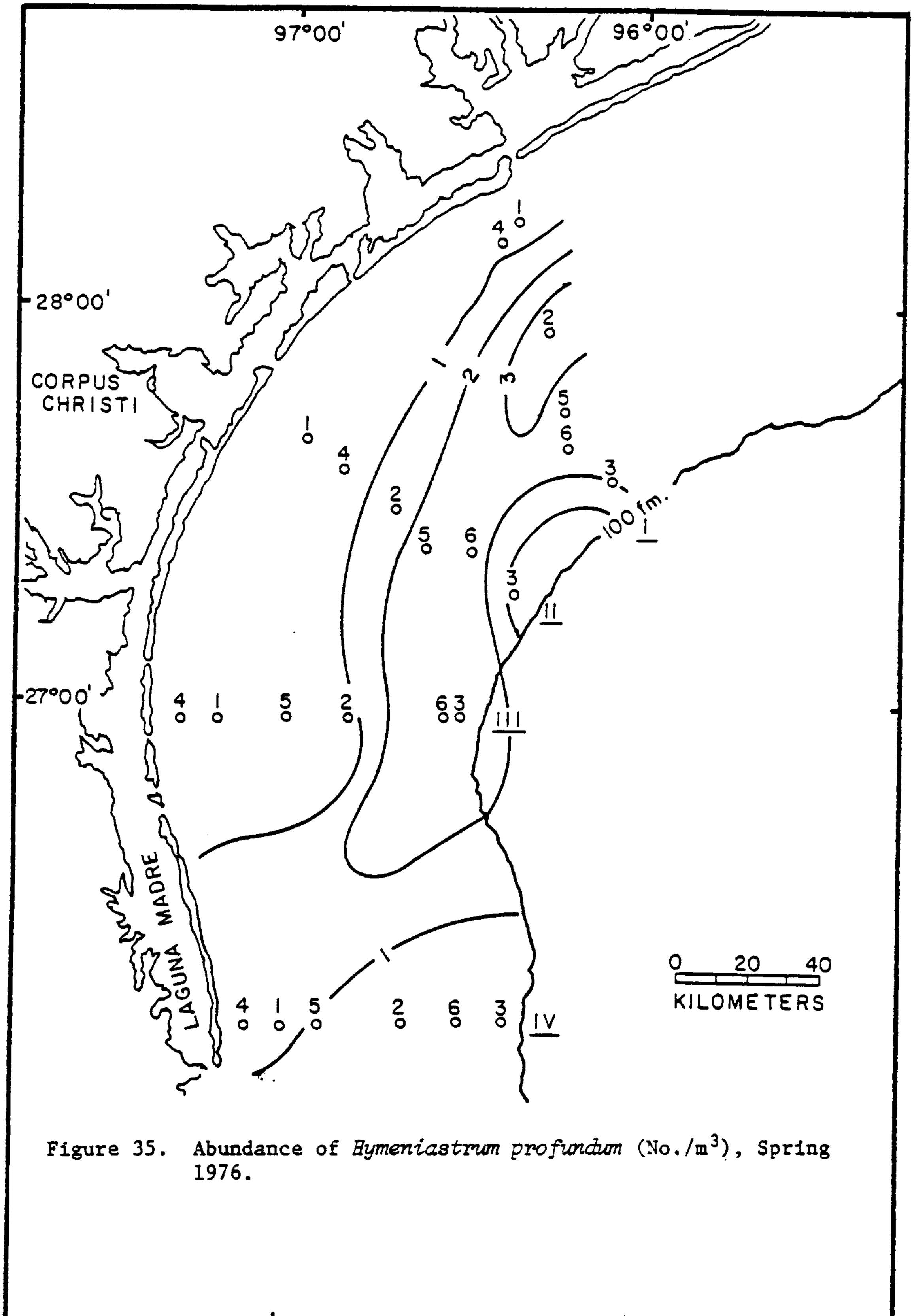


Figure 35. Abundance of *Hymeniastrum profundum* (No./m^3), Spring 1976.

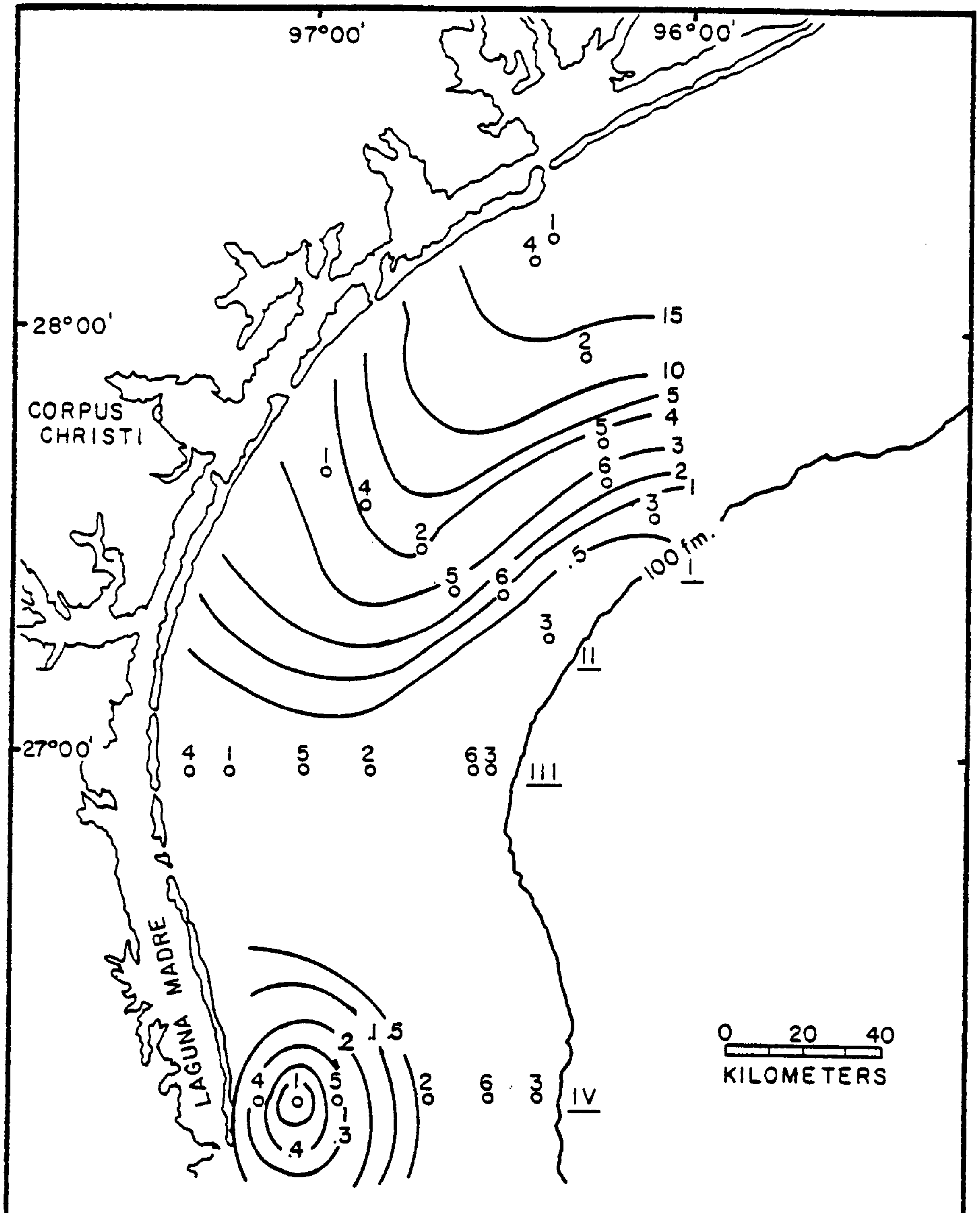


Figure 36. Abundance of Benthonic Foraminifera (No./m^3) in the Water Column, Spring 1976.

(Table 1 and McMillen, 1976). Therefore, there was likely some Subtropical Underwater intrusion into the STOCS study area during the spring of 1976. The occurrence of *Callimitra emmae, Spongotrochus scutella, Lamprocyclas nupilalis* and others within this same cluster suggested strong upwelling or encroachment of deeper waters onto the shelf (McMillen, 1976).

In general the spring of 1976 in the BLM-STOCS study area may be crudely generalized as in Figure 22. There was a general transport of a freshwater lens offshore. This was discussed in the section comparing general microplankton with physical oceanography along Transect II. This condition existed into July, and in August, a displaced lens of this freshwater moved offshore (perhaps representing the termination of spring conditions during the year and the initiation of summer conditions). This movement was apparently squeezed somewhat (at least during the seasonal spring cruise) by north and south shallow waters (Figure 31), and the lens itself apparently caused the strongest upwelling of the year (upbowing over the shelf) which during August resulted in an open ocean type of estuarine upwelling that penetrated to Station 1/II.

Summer-Fall radiolarian densities were greatest during the BLM-STOCS 1976 sampling (Figure 37). This was similar to the 1975 trend. However, the densities did not show a simple outward increase as in 1975, but indicated encroachments onto the shelf along Transects III and IV and an anomalous high trending between Stations 1 and 2 detached from the encroaching highs from offshore along Transects III and IV. This probably reflected the grounding of an anticyclonic gyre or ring that moved to the STOCS area after detachment (spin-off) from the Loop Current months before. Reasons for this interpretation are discussed below.

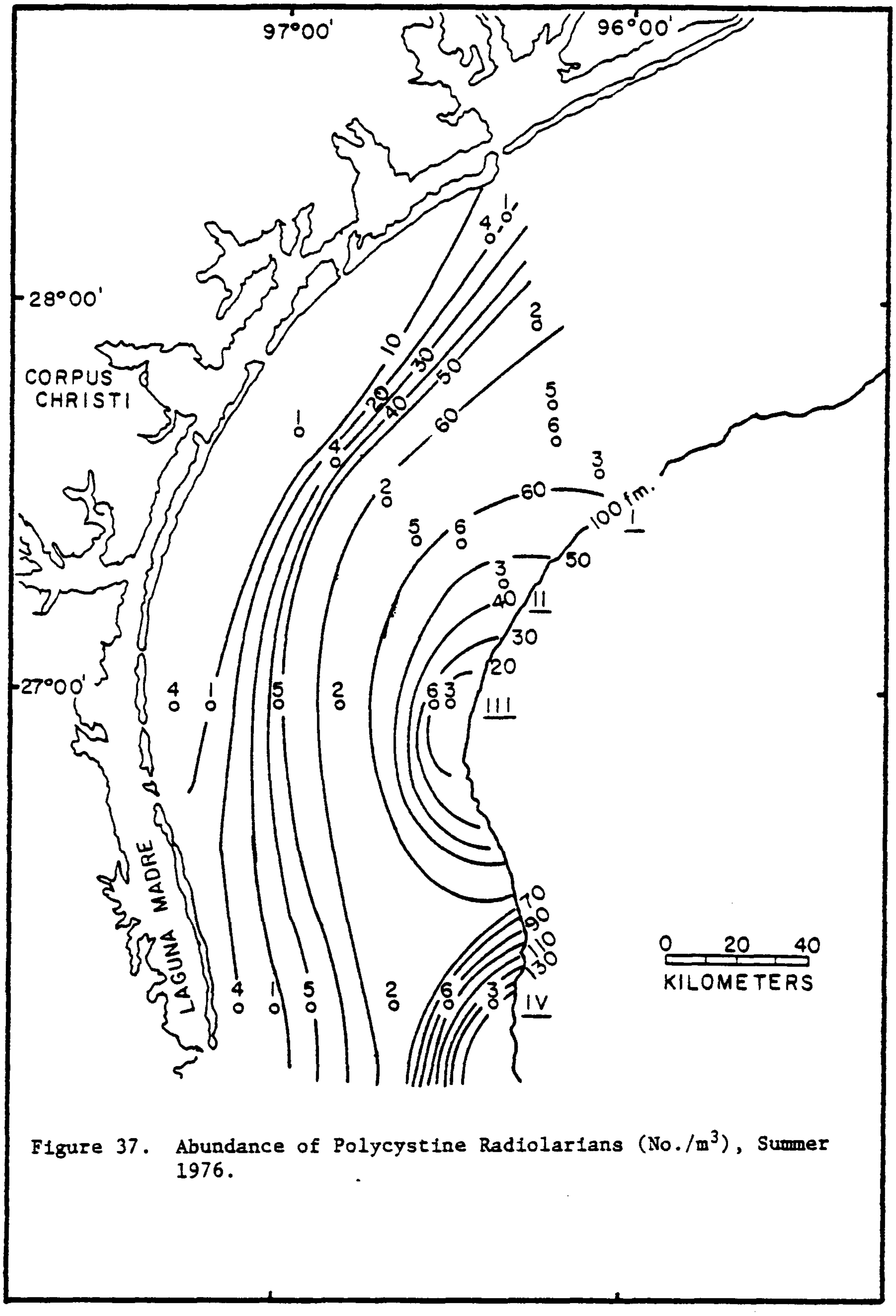


Figure 37. Abundance of Polycystine Radiolarians (No./m^3), Summer 1976.

In the Fourth Quarterly Report (Casey, 1977) it was suggested that "the occurrence of *Theoconus hertwigii* and/or 37 ppt water at any depth delineated the incursion of Subtropical Underwater" (Figure 21, herein). We believe this Subtropical Underwater was brought in incorporated in an anticyclonic ring for the following reasons: radiolarians indicative of Subtropical Underwater occurred in samples taken on the outer- and mid-shelf [*T. hertwigii* and *Amphirhopalum ypsilon*, both of which were shown by McMillen (1976) as indicative of such waters]; the anomalous trend of high radiolarian diversities between Stations 1 and 2 were detached from the more offshore highs and contained species different than the other highs and an even greater concentration of upwelling species (Challengeriids and *Spongotrochus glacialis*), even though they were in shallower water which probably reflected a pushing of these waters onto the shelf by the gyre, or perhaps, an upwelling along the margin of the gyre offshore (due to the Ekman effect of the anticyclonic motion) and a dragging or entrainment of this water which was shoved and thrown onto the shelf in front and detached from the gyre itself; the ratio of living nassellarians to spumellarians (Figure 38) illustrated what might have been a northerly movement produced by this gyre at Station 2/IV; the 100 isopleth of pteropod abundance ($\#/m^3$) appeared to outline the ring (Figure 39) as did the $10/m^3$ contour of benthonic foraminiferans in the water column (Figure 40) (few benthonic foraminiferans would be expected to be brought in with the ring as illustrated in Figure 40); the abundance of planktonic foraminiferans (Figure 41) illustrated a relatively low density in the gyre (as expected in a "biologically-depleted water mass") which was surrounded by highs that reflected the pushed water from offshore; and the break in foraminiferan abundance at Station 2/III (but no break in radiolarian density, high inshore of this, Figure 37)

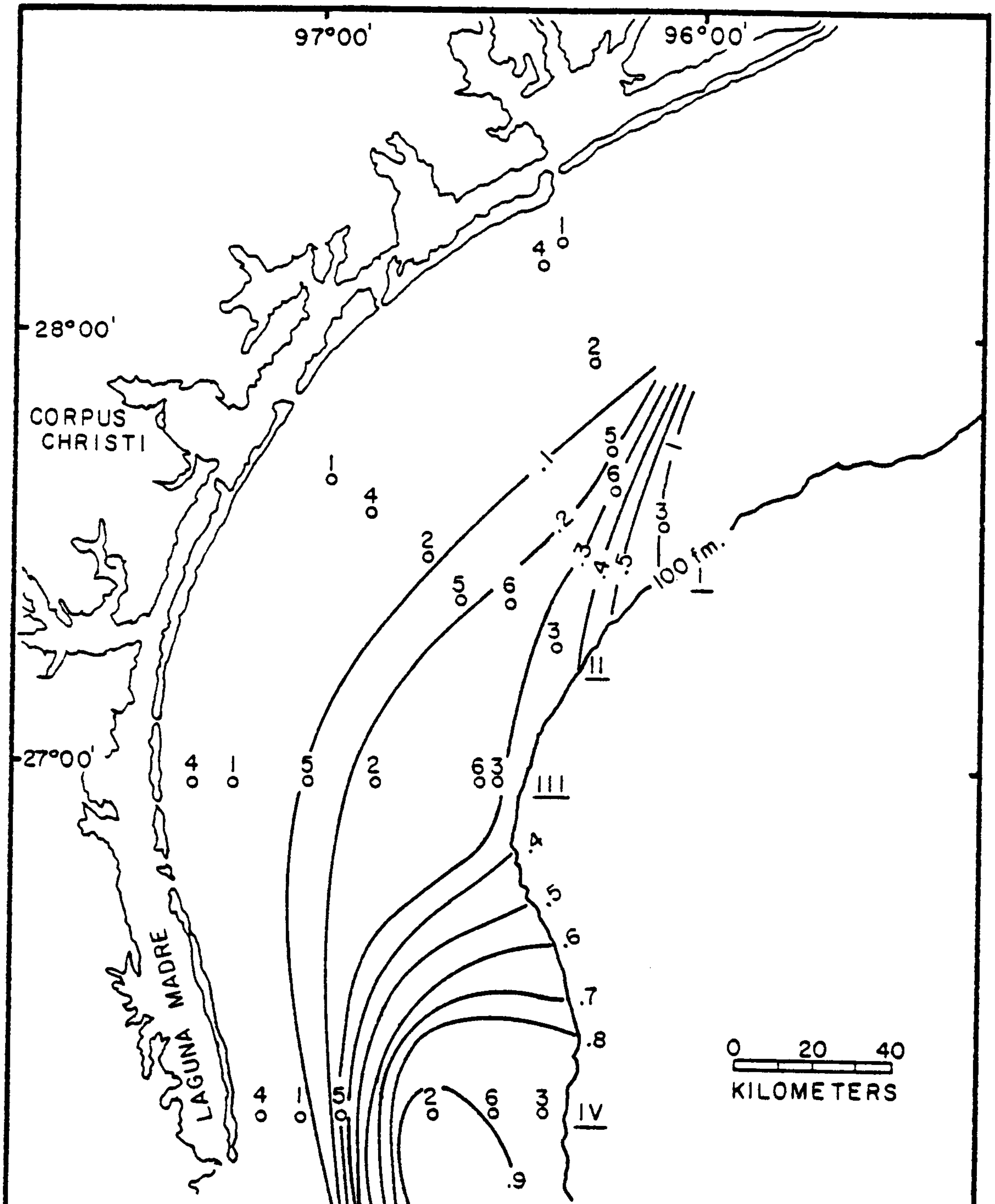


Figure 38. Ratio of Living Nassellarians to Spumellarians, Summer 1976.

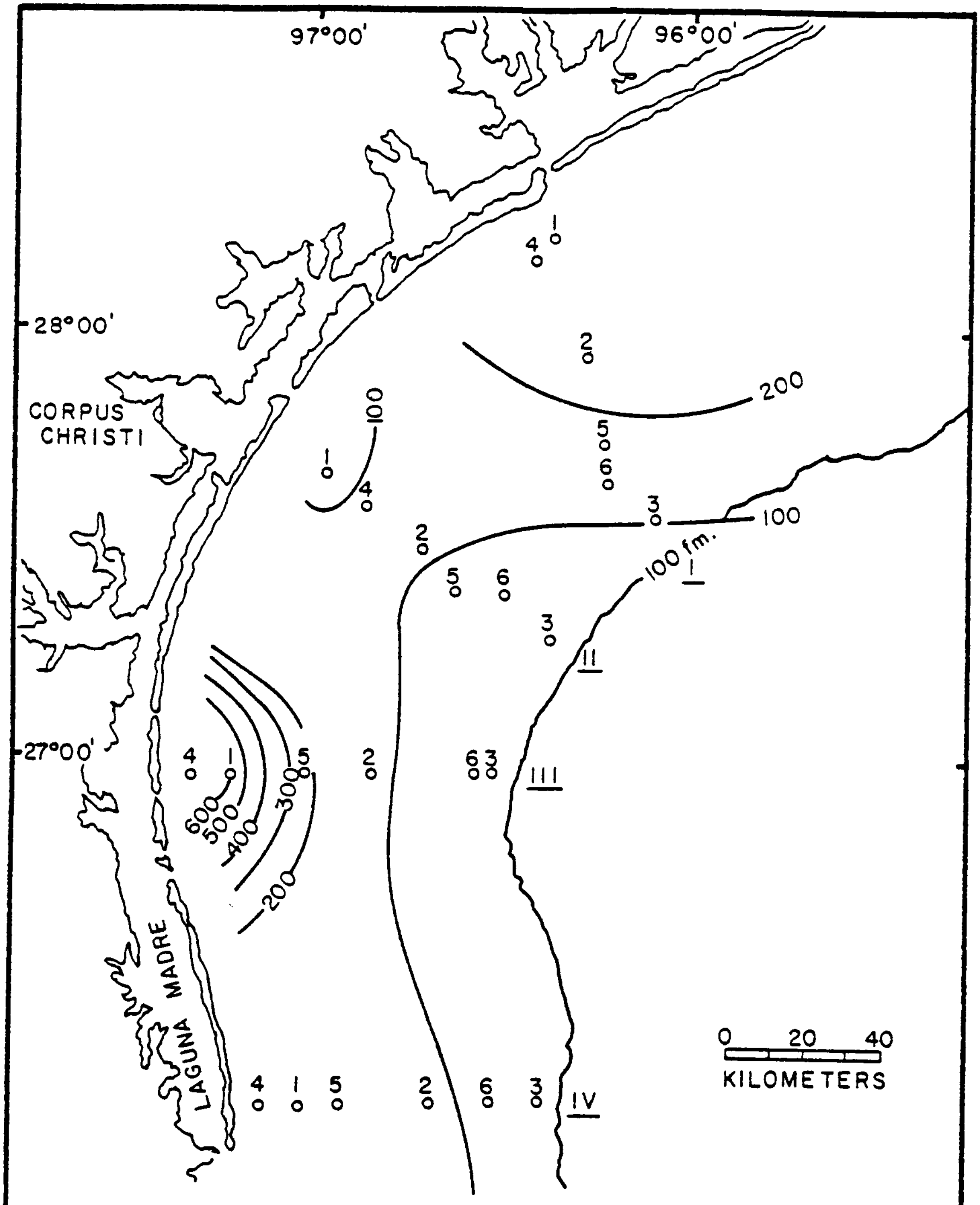


Figure 39. Abundance of Pteropods (No./m^3), Summer 1976.

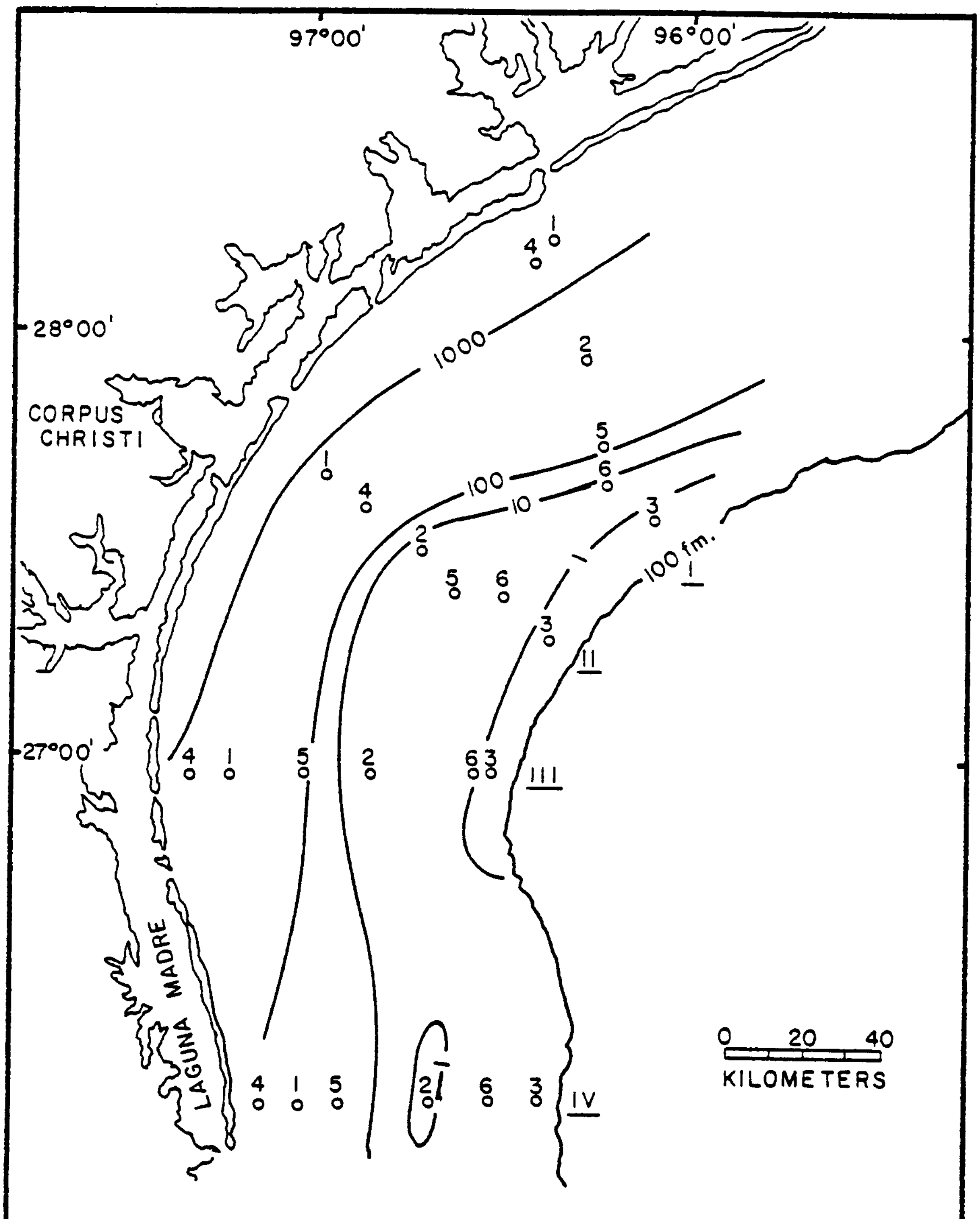


Figure 40. Abundance of Benthonic Foraminifera (No./m^3) in the Water Column, Summer 1976.

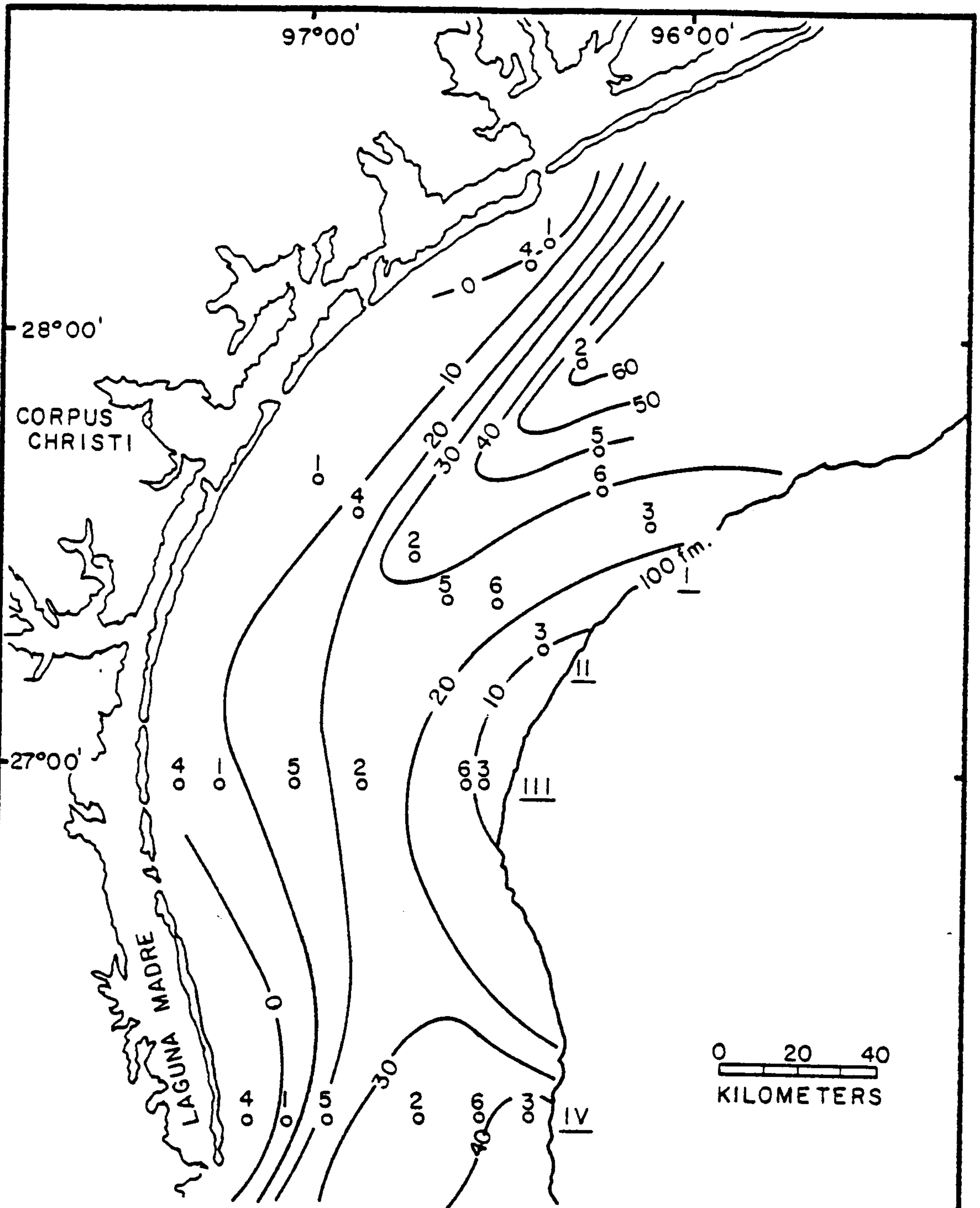


Figure 41. Abundance of Planktonic Foraminifera (No./m^3), Summer 1976.

suggested that the shallow, inpushed waters were breaking up, but not the deeper, inpushed waters; the 10-m temperatures (Figure 16) suggested a northern anticyclonic movement of this water with their displaced isotherms; and lastly, bottom salinities (Figure 19) illustrated movement of the STU to the north at mid-shelf as shown by the 36.5 and 37 ppt isohalines.

The abundance of bivalve veligers (Figure 42) suggested that the gyre detached a component of shelf water at Station 2/I, and was holding or dragging (from the Rio Grande, perhaps) a pond of inshore shelf water at or along Station 1/III. The diversity of radiolarians (Figure 43) illustrated that offshore water had indeed encroached onto the shelf, but tended to average the data as shown on the diversity plot (Figure 37). The abundance of *Hymeniastrum profundum*, very useful in illustrating shelf circulation in the spring of 1976 (Figure 35), was disturbed by the summer ring but showed a pond of offshore water (deep Gulf offshore water in all likelihood) centered at Station 2/II (Figure 44). The abundance of acantharian radiolarians (Figure 45), as expected, reflected the same inshore circulation as did the bivalve veligers.

The dendrogram for the R-mode cluster analysis of planktonic foraminiferans and pteropods in presented as Figure 24. The dominant planktonic pair, labeled SS (summer shallow), the foraminiferans *Globigerina bulloides* and *Globigerinoides ruber* which, as in 1975, were indicative of summer conditions in the STOCS study area in 1976. This pair was a subcluster within the larger cluster labeled S (summer). The planktonic foraminiferan *Globigerina calida* and the pteropod *Clio polita* occurred in this large cluster and were probably indicative of the incursion of Subtropical Underwater. *G. calida* is considered by Berger

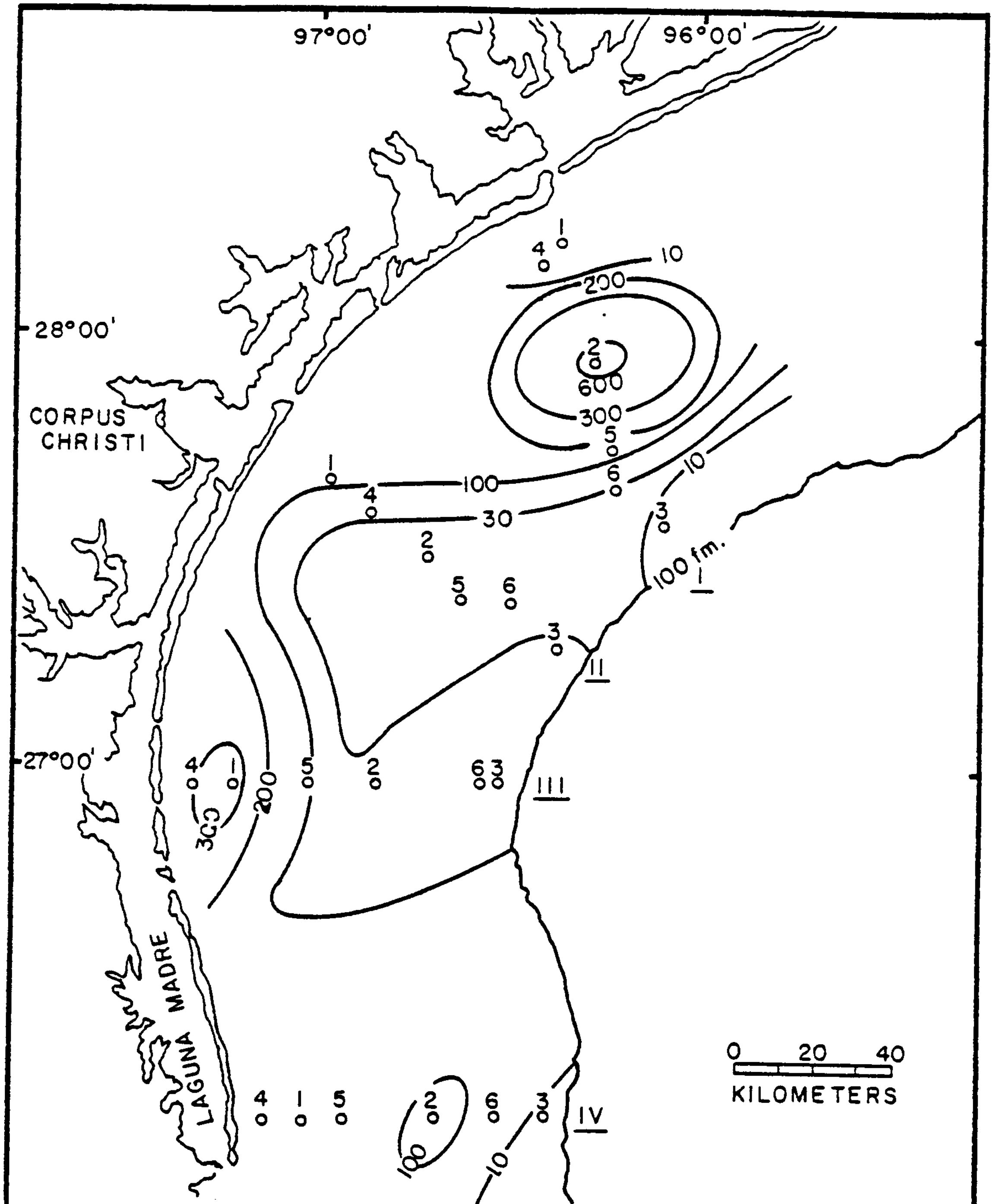


Figure 42. Abundance of Bivalve Veligers (No./m³), Summer 1976.

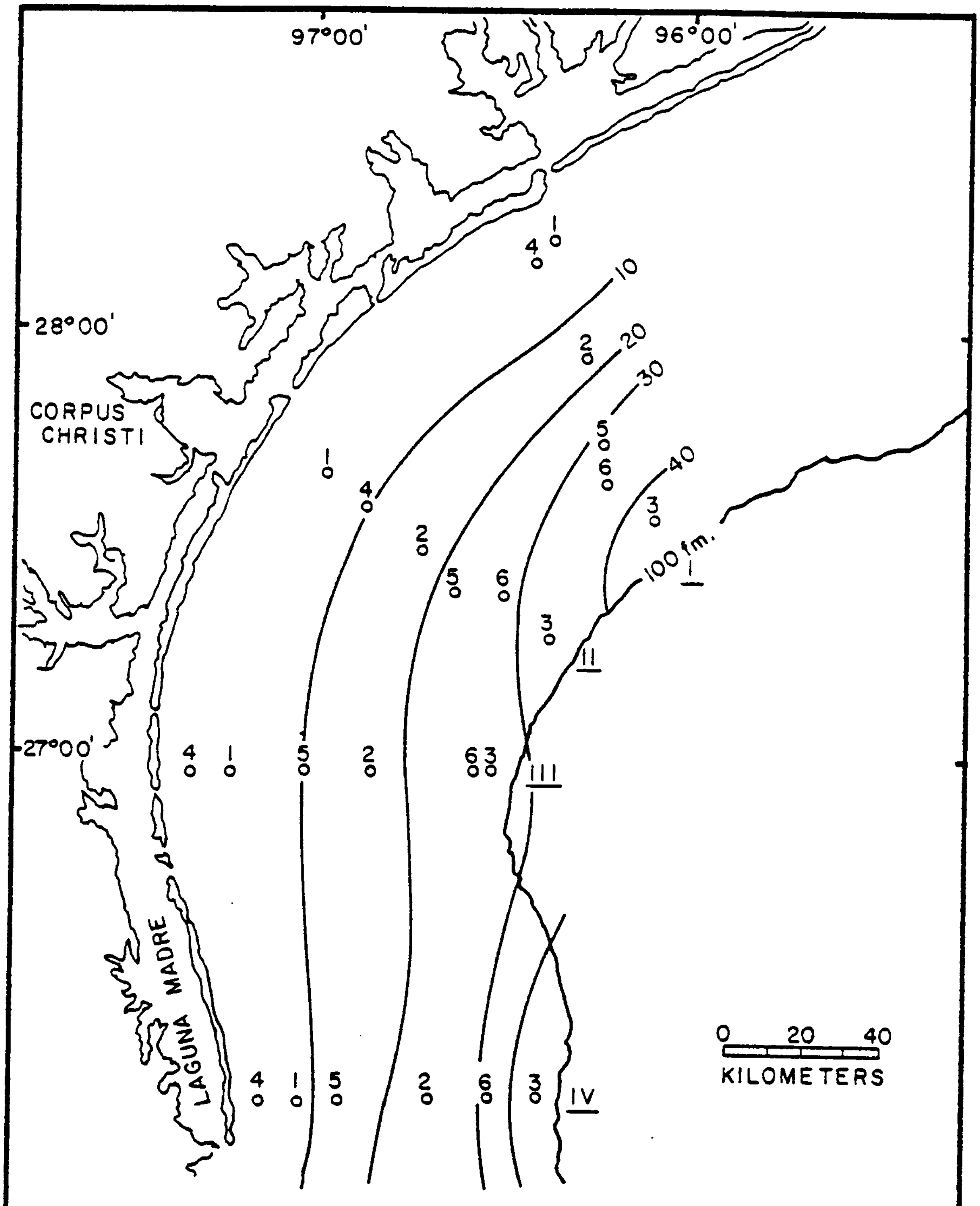


Figure 43. Polycystine Radiolarian Diversity (Species/Tow), Summer 1976.

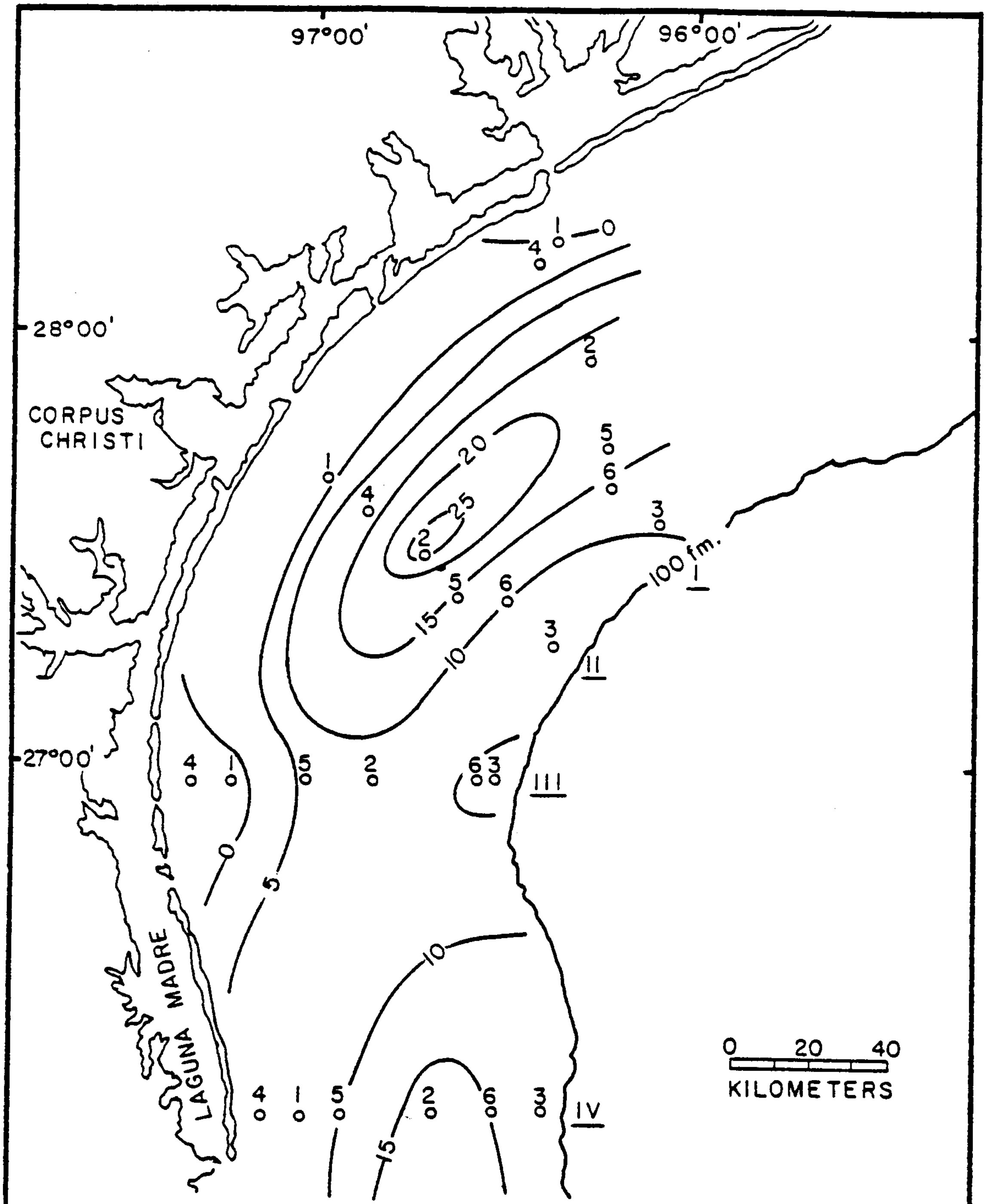


Figure 44. Abundance of *Hymeniastrum profundum* (No./m^3), Summer 1976.

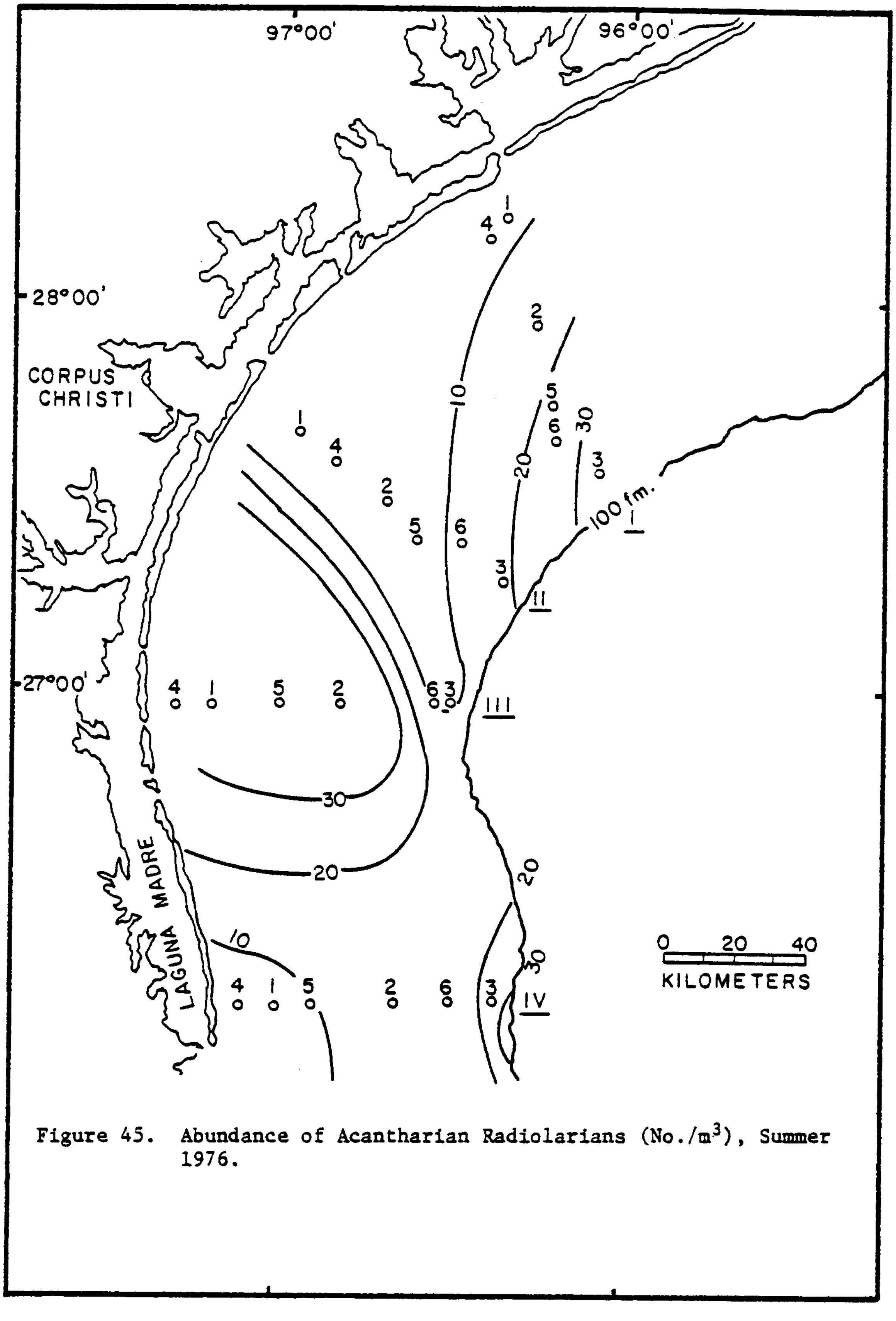


Figure 45. Abundance of Acantharian Radiolarians (No./m^3), Summer 1976.

(1969) to live in waters immediately below the mixed layer, and *Clio polita* is typically considered a bathy-pelagic form (Hughes, 1968). Therefore, these species represented deep waters brought in by upwelling or upbowing of the Subtropical Underwater and were labeled as an SD (Summer Deep) subcluster of the S (Summer) larger cluster. The best cluster representing the intrusion of STU was composed of the pteropod *Carolina longirostrus* which is common to the Sargasso Sea (Hughes, 1968) and may represent the STU that dive from this region, and the benthonic species *Valvulinera* sp. considered an outer shelf or deeper species by Murray (1973). These may cluster due to the incursion of STU on the shelf (the anticyclonic ring incursion with *Carolina longirostrus* included) and the suspension of the benthonic species *Valvulinera* sp. due to the water "feeling bottom" and the subsequent movement of all shoreward.

The dendrogram for the R-mode cluster analysis of radiolarians is given as Figure 25. There were two summer clusters, S01 and S2. The S01 cluster contained subclusters which sorted out at very significant levels. It was composed of a closely associated group of radiolarians labeled SOIU (Summer Outer I), including *Amphispyris costata, Staurodicta* sp., *Acanthocyrtidium* spp., *Actinoma* sp. M and *Actinoma* sp. E which only occurred at Station 3/I during the summer. The next cluster (SOIVUI, or Summer Outer IV) was comprised of *Cenosphaera* sp. B, *Lithelius alreolina* and *Actinomma* sp. I which only occurred at Station 3/IV during the summer. The SOIU cluster apparently represented underwater intrusion since *Amphispyris costata* and *Actinoma* sp. E have been designated as underwater species (McMillen, 1976). The SOIV cluster probably represented deeper underwater, and perhaps some intermediate water since

Lithelius alreolina, Actinoma sp. A and *Actinoma* sp. I are indicative of such waters (McMillen, 1976). The cluster labeled SOU (Summer Outer Upwelling) contained a looser assemblage composed of *Cenosphaera* sp. G (underwater to intermediate, McMillen, 1976), *Stylochlamidium asteriscus* (underwater to intermediate, McMillen, 1976) and *Stylocontarium bisopaulum* (surface to underwater, McMillen, 1976) and was apparently indicative of upwelling or upbowing along the outer stations. The last bottom cluster in SOI was a tight cluster indicative of Station 3/II.

Cluster S2 was looser than cluster SOU with the SU subcluster being indicative of upwelling (exemplified by the Challengeriids and others) and the large, loose subclusters containing most of the shallow, summer radiolarians such as *Spongaster pentas, Spongaster tetras tetras,* and *Pterocorys zancleus* (surface, McMillen, 1976) with a few upwelling forms such as *Spongotrochus glacialis* and *Spirocyrtis scalaris* being brought onto the shelf (Casey, 1976).

These results and conclusions agree with those stated in the detailed comparison of general microplankton and physical oceanography along Transect II. On Transect II in September, offshore water was moving along the shelf under the lower salinity, inshore water, apparently resulting from the gyre moving in along the bottom. In November, cool waters moved out from the coast with some incursion of offshore water inward along the bottom (but with the least amount of upwelling or upbowing of any season in 1976). By December winter conditions had returned.

The shelled microplankton data, as related to physical oceanography, were the basis for construction of the generalized picture of seasonal circulation patterns of the STOCS study area during 1976 (Figure 22).

It may be possible to estimate the dimensions of the supposed anti-cyclonic gyre. By using the average curvature of the Figures illustrating the presence of the gyre (Figures 19, 21, 37, 39 and 40), a gyre with a diameter ranging between 200 and 250 km is suggested.

Niskin Samples (Discrete Depth) for General Microplankton

General Trends of the General Microplankton Data

Dinoflagellates were dominant at Station 1, all transects, except Station 1/I (where diatoms were dominant) at one-half the depth of the photic zone during the winter of 1976 (Figure 46). Diatoms were the dominant phytoplankters during the winter at other stations, and during spring and summer at all stations (Figures 47 and 48). See Appendix G, Table 6, for tabulations of Niskin data.

For 1976, the average general microplankton standing crop at one-half the depth of the photic zone was about 100,000 individuals/m^3 during the winter and spring and about 70,000/m^3 during the summer. The summer drop (especially offshore) probably reflected the incursion of shallow offshore water.

Copepods generally increased offshore during all seasons (Figures 46, 47 and 48) as did naupliar larvae.

In comparing these general trends with 1975 data for one-half the depth of the photic zone (Figures 49, 50 and 51), diatoms were the dominant phytoplankters at all stations in 1975 but copepods did not show such a pronounced offshore increase.

Q-Mode Cluster Analysis

The results of the Q-mode cluster analyses for 1975 and 1976 Niskin data are given as dendrograms (Figures 52 and 53, respectively). After defining seasonal clusters for both years, the samples in each cluster were examined to determine if representative nearshore, offshore, or

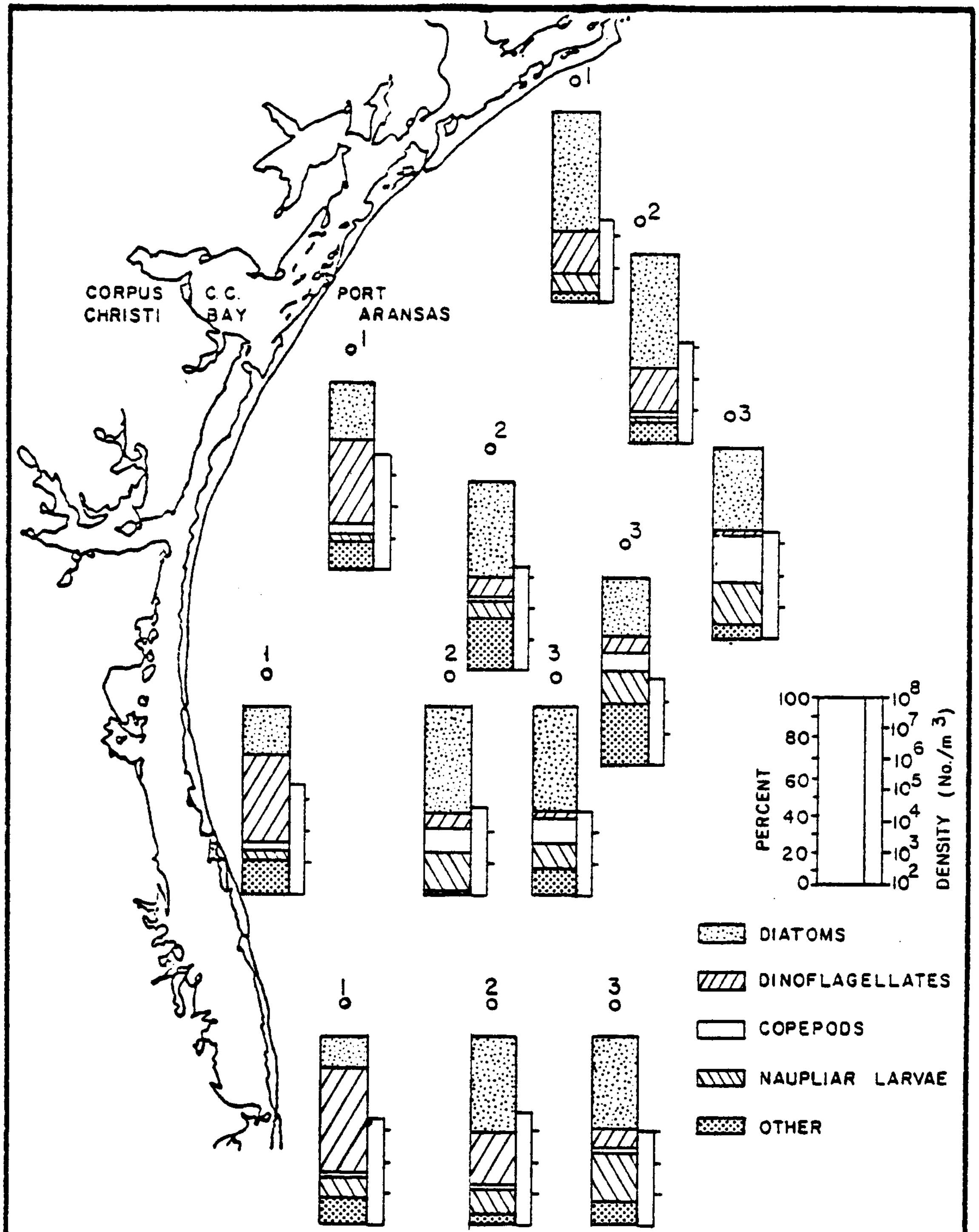


Figure 46. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Winter 1976.

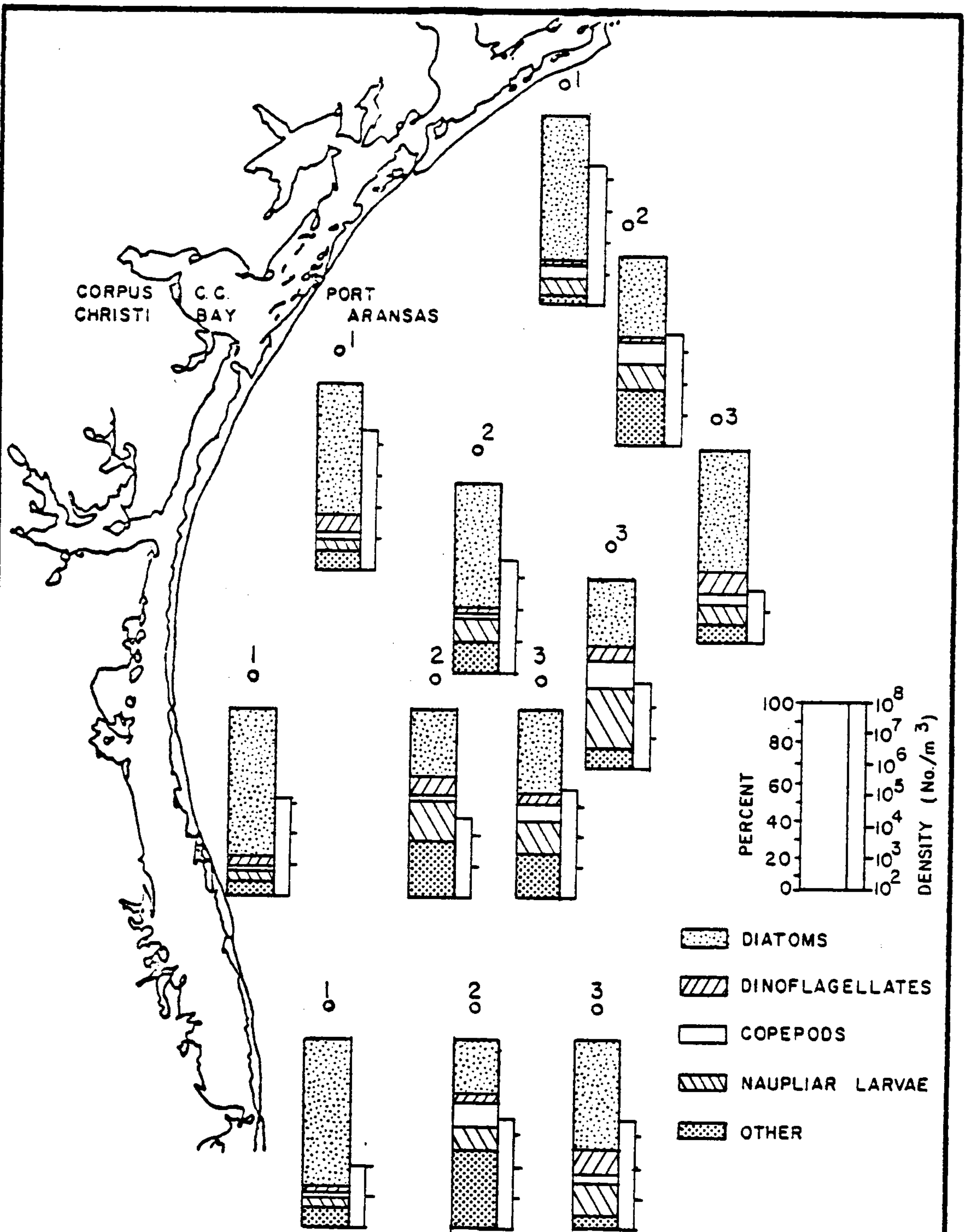


Figure 47. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Spring 1976.

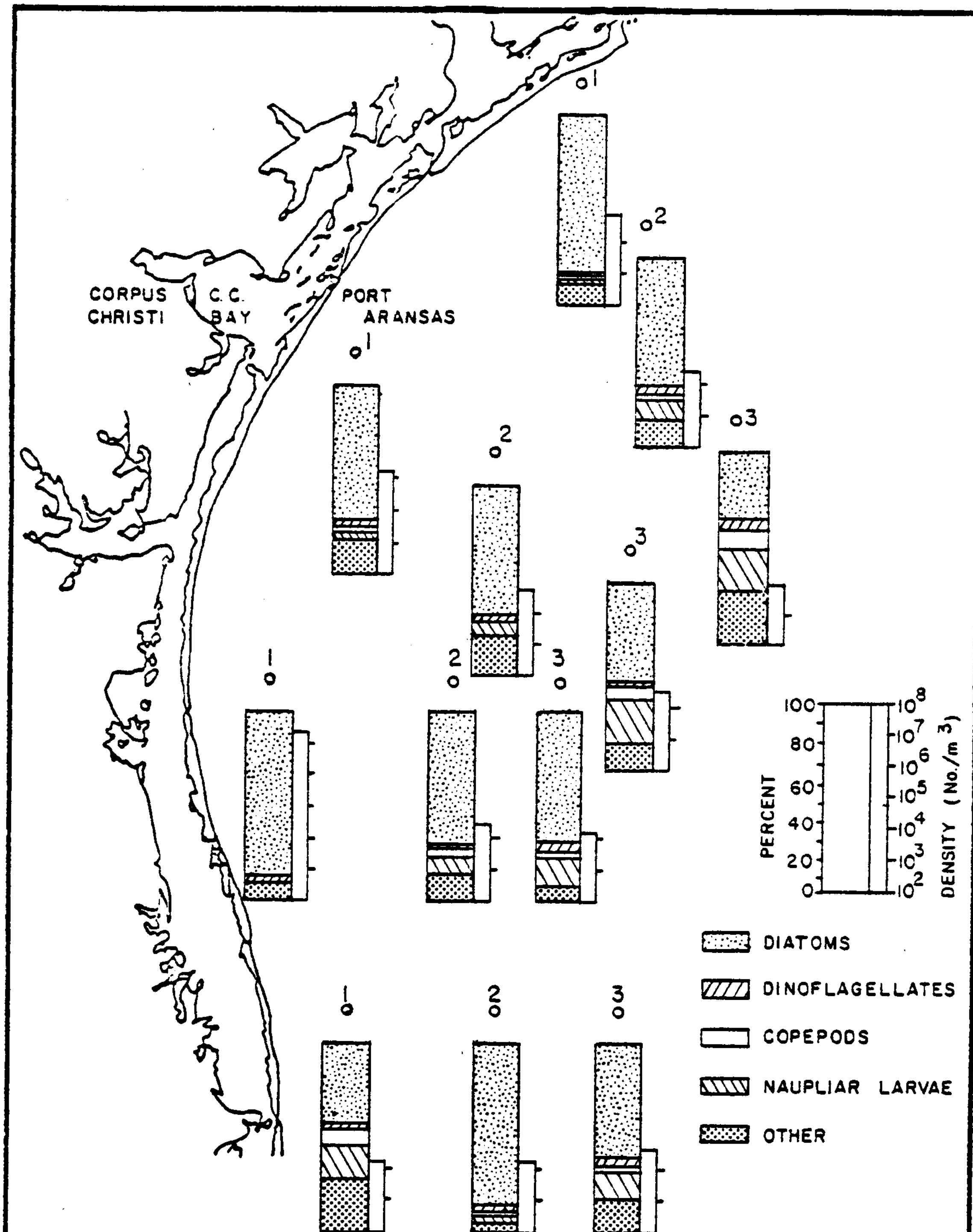


Figure 48. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Spring 1976.

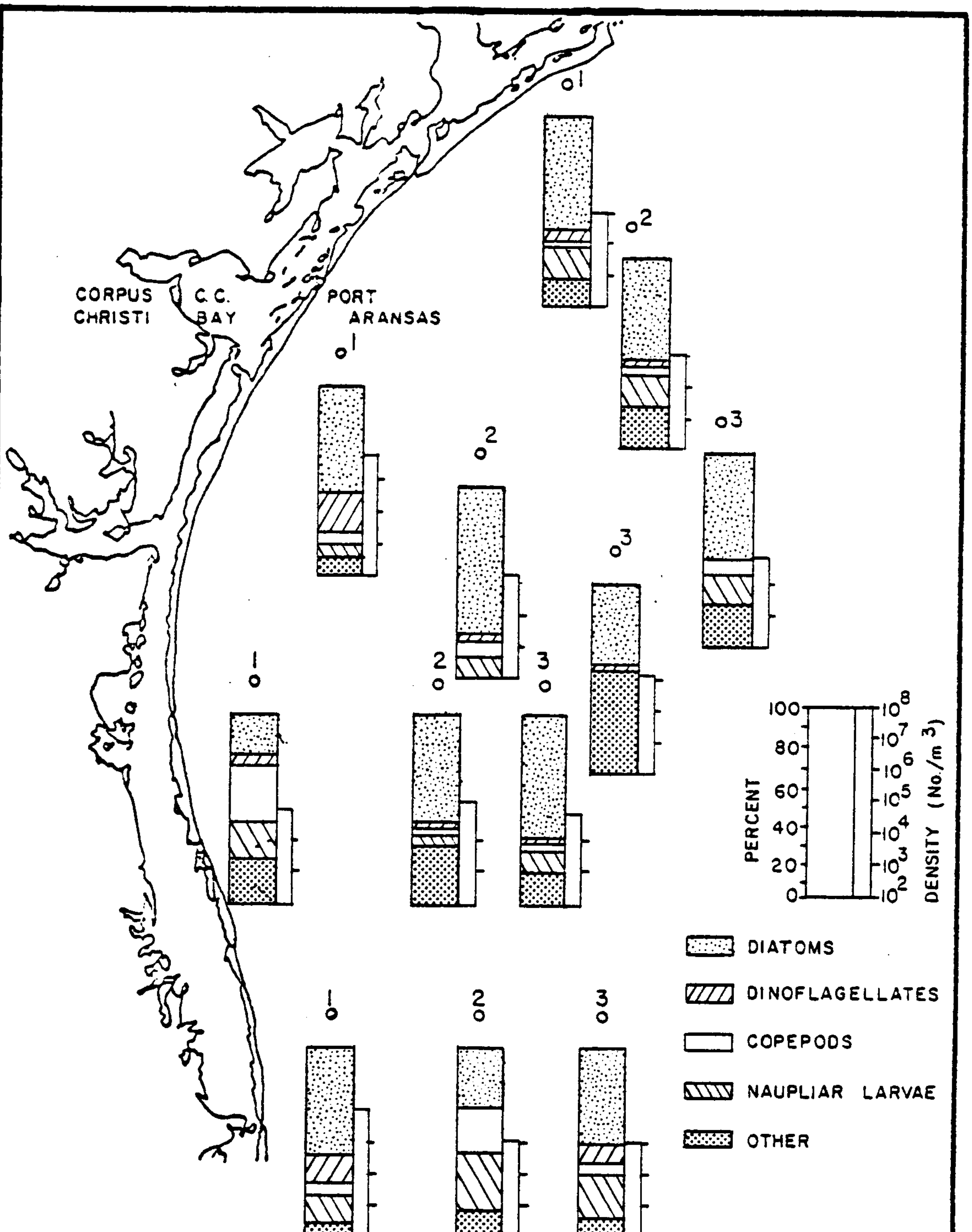


Figure 49. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Winter 1975.

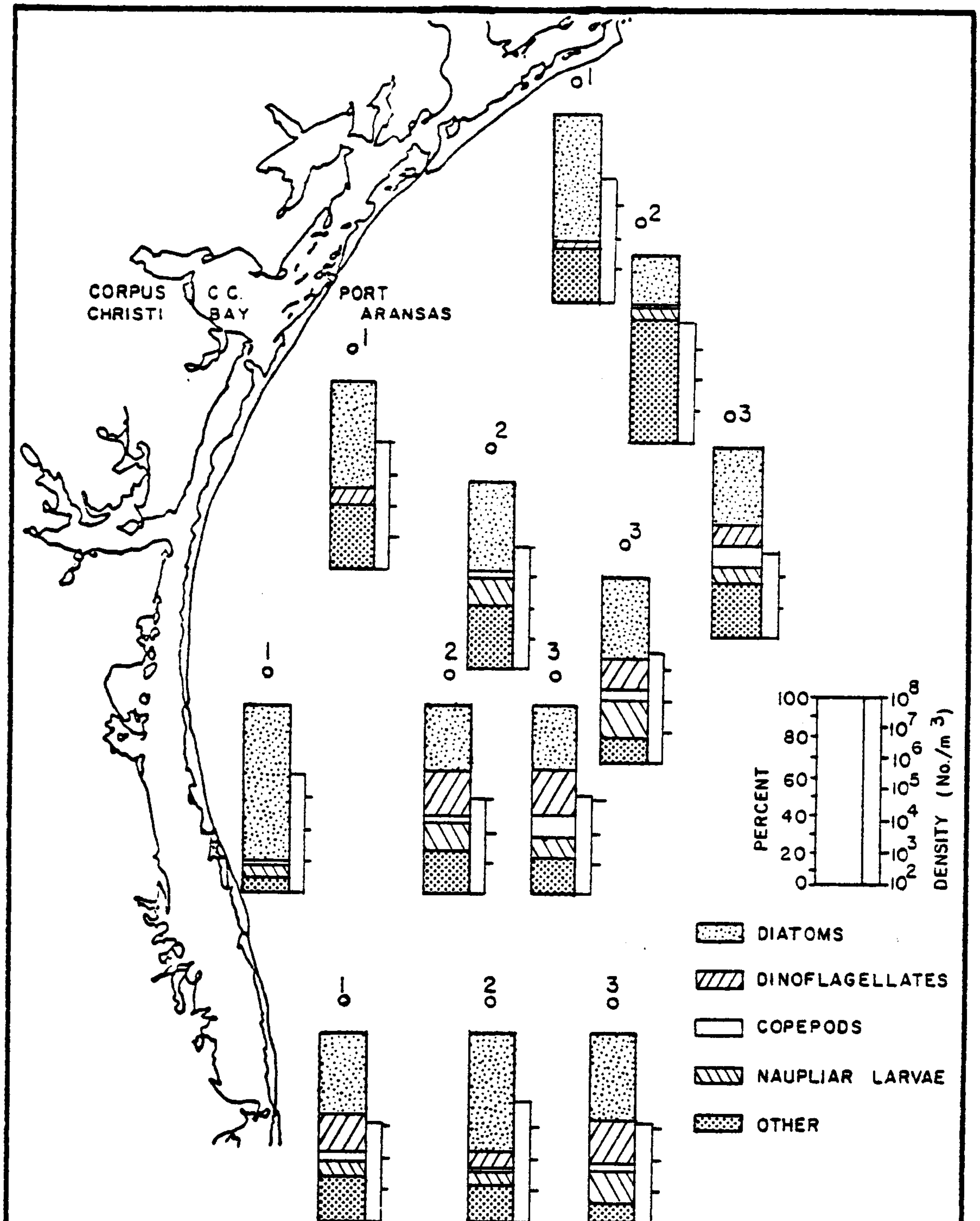


Figure 50. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Spring 1975.

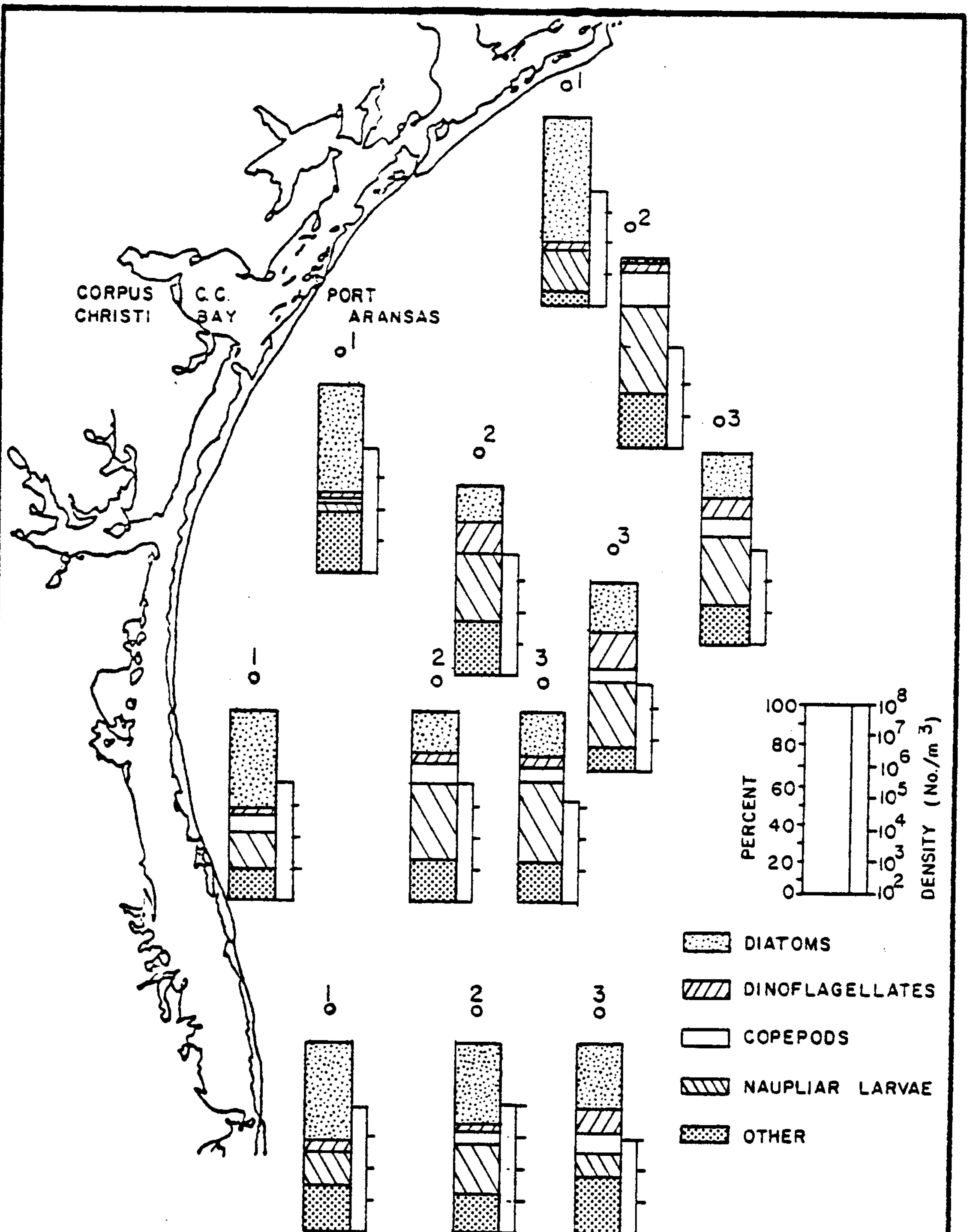


Figure 51. Relative Abundance (percent of total) of Major Groups and Total Density in Niskin Samples, Summer 1975.

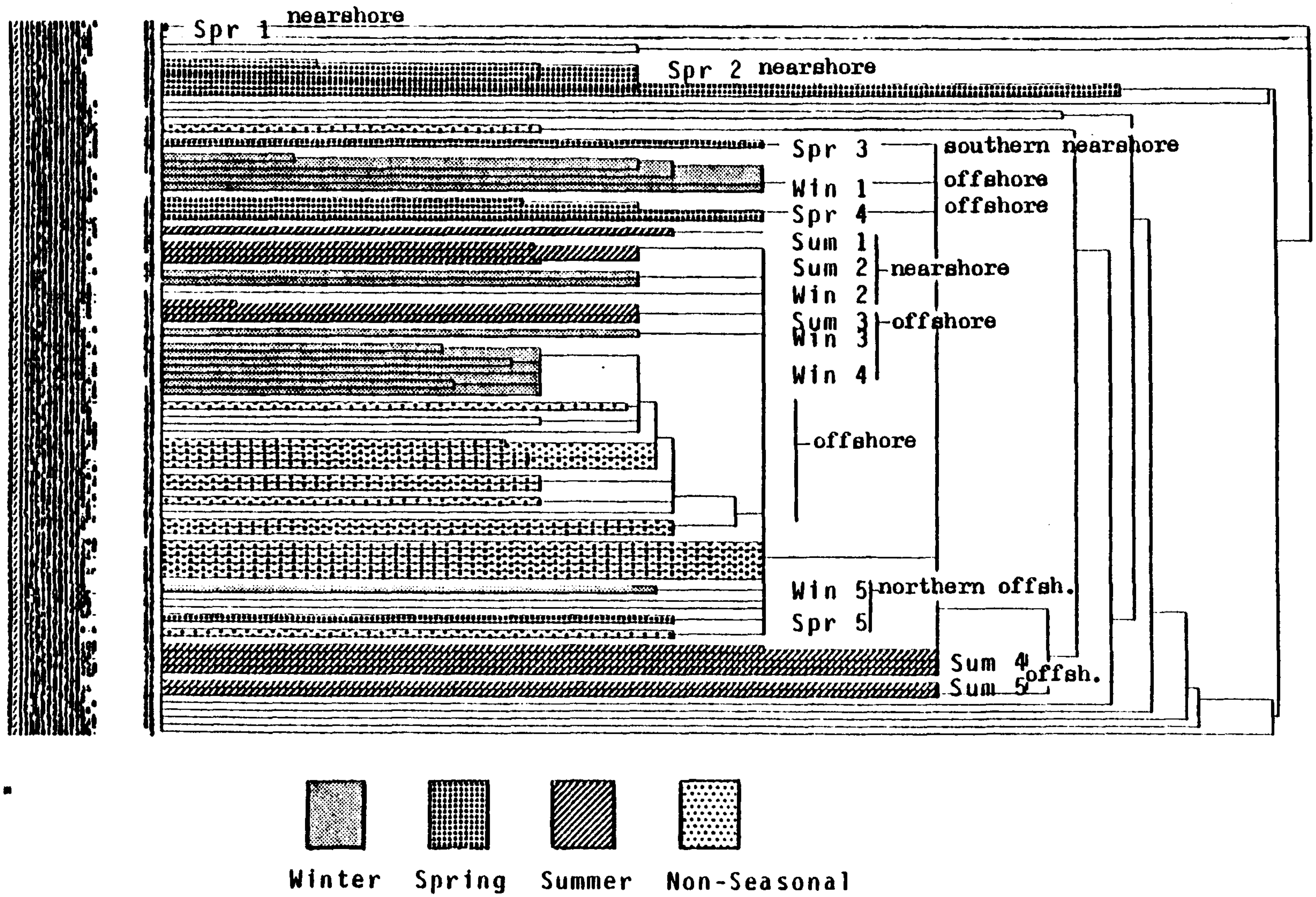


Figure 52. Q-Mode Analysis of 1975 Niskin Data. (See Key on Next Page).

Figure 52. Key to Q-Mode 1975 Niskin Data.

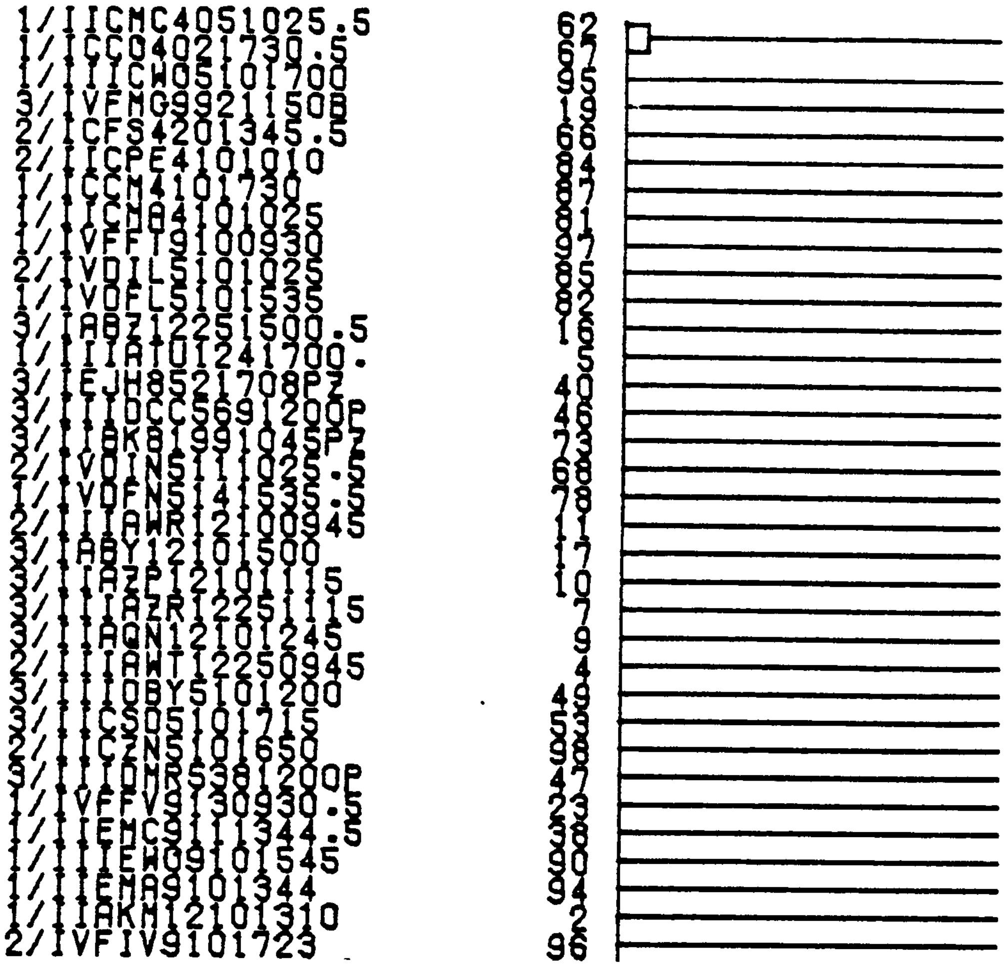


Figure 52. Key Continued.

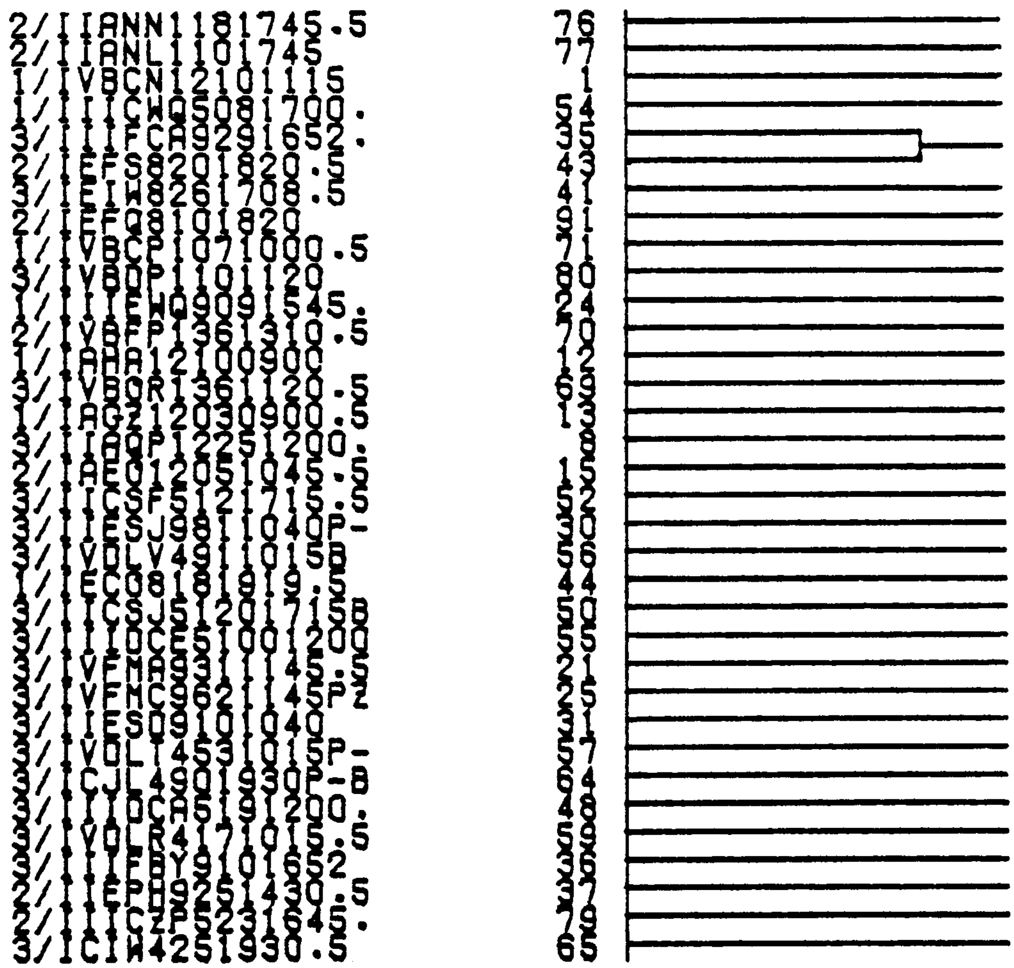
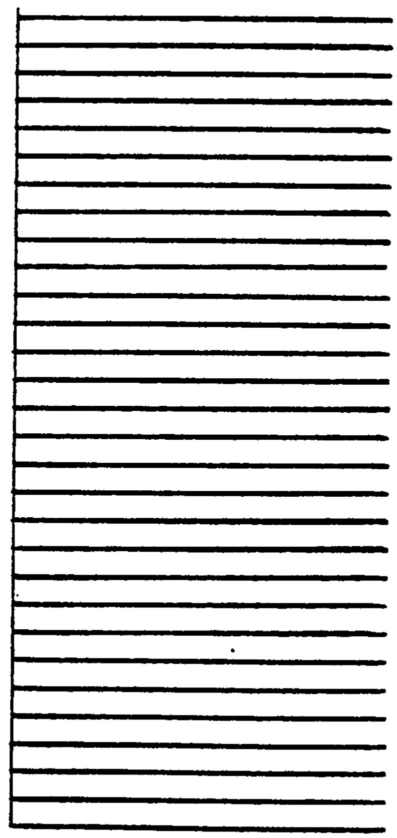


Figure 52. Key Continued.

3/IIESH9581040PZ	27
2/IIEPF9101430	93
3/ICIU4101930	18
1/IIIATS12101700	6
2/IVFIX9131723.5	22
2/IIIEZP9261835.	29
2/IVBFN1101310	83
3/IIIFCC9581652P	33
3/IVFLY9101145	86
2/IAEL12101730	14
3/IBJK1109133OP-	74
3/ICJN41301930B	63
3/IBIP1841330PZ	75
3/IICSH5711715P-	51
2/ICFQ4101345	88
2/IICPG4151010.5	61
1/IECM8101919	89
3/IIESL91051040B	26
3/IIIFCE9921652P	32
3/IVFME9771040P-	20
3/IIIFCG9921652B	34
3/IIBK01115104 5P	72
3/IEIU8101708	42
2/IIIEZN9101835	92
3/IVOLP4101015	60
3/IEJL8931708P-B	45
3/IEJN81341708B	39
3/IIESF9291040.5	28
3/IVOMT4351015PZ	58
1/IIIAK012051300.	3



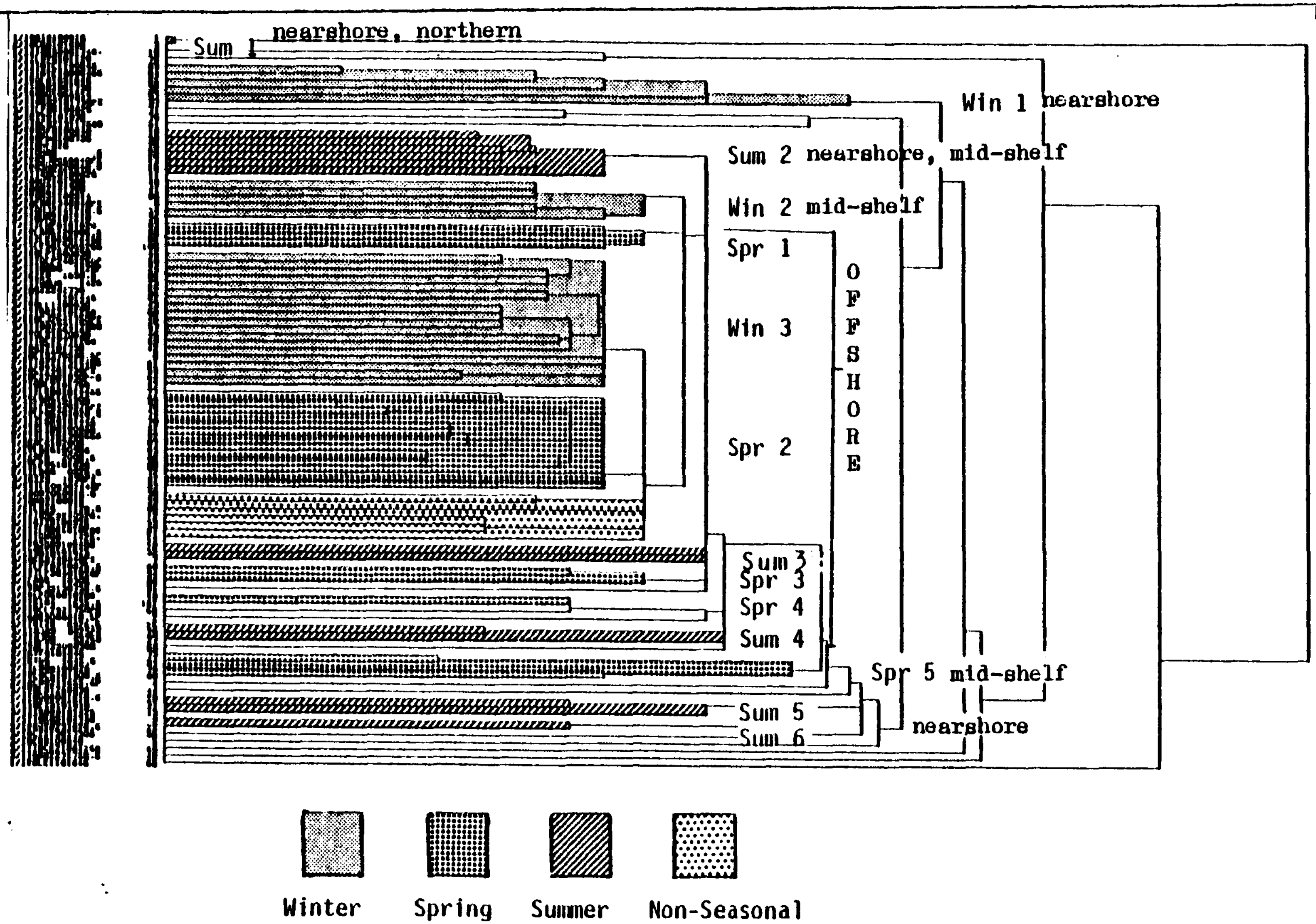


Figure 53. Q-Mode Analysis of 1976 Niskin Date. (See Key on Next Page.)

Figure 53. Key to Q-Mode 1976 Niskin Data.

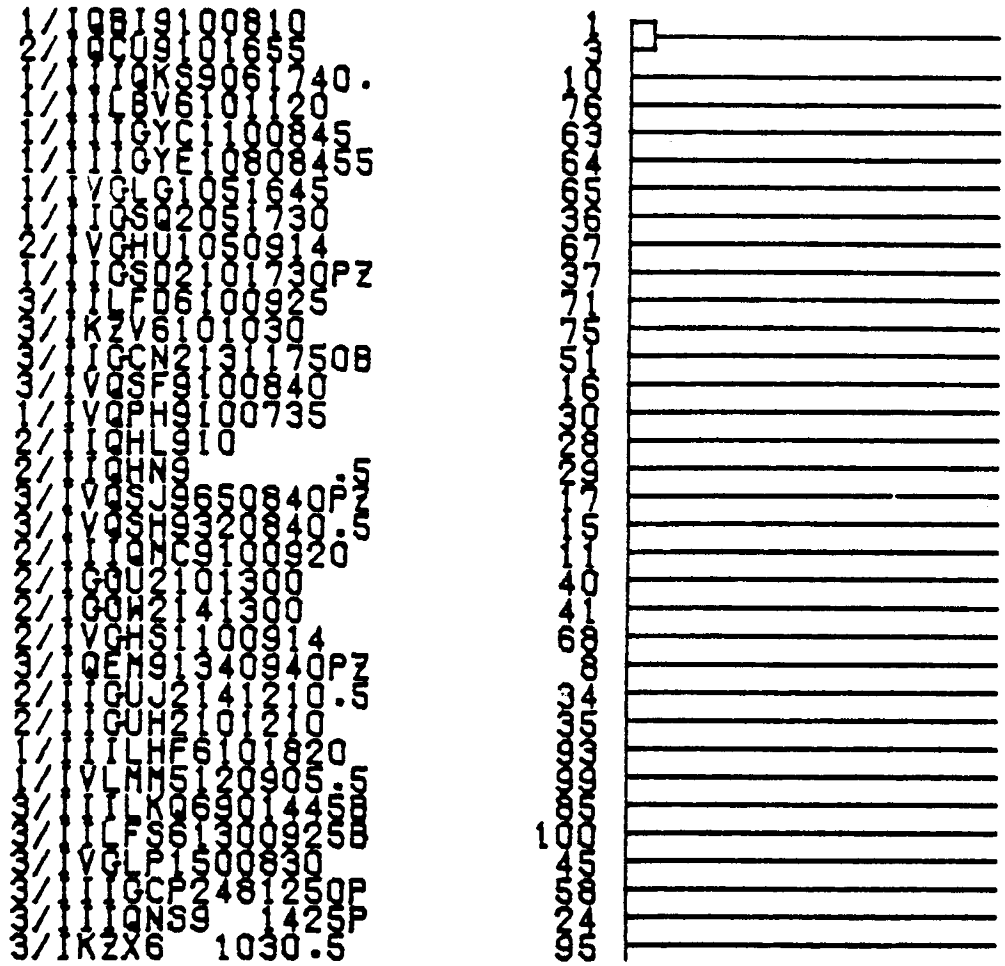
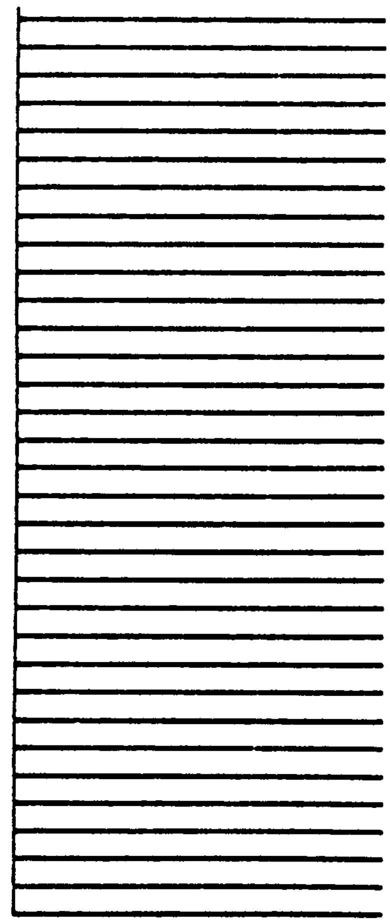


Figure 53. Key Continued.

3/IIIQNU9 1425	23
3/IQQZ2241730	52
2/III 1101445	62
3/IVGLL1100830	43
3/IIIGBX2101250	56
3/IIGCJ2541750PZ	49
3/IIGBZ22412505	57
3/IVGLR1670830	46
3/IIGCT2771250	59
3/IGQX2101730	42
3/IQEI9370940.5P	6
2/IIGZZ1131445 5	61
3/IGCV2481730PZ	53
3/IGCX2891930P-B	54
3/IIGWL2101750	47
3/IIILKM61914455	77
2/IVLQA5101900	89
3/IILFH6420925PZ	70
3/IVLPQ5201020.5	74
3/IIILKK6101445	78
2/IIILIW6100855	91
2/IIILIV61308555	92
1/IKAC6102000	87
1/IVLMK5100905	83
1/IKAE6 2000.5	86
3/IVLPG5101020	98
2/IILDD6 0925.5	72
3/IKZZ6 1030PZ	81
3/IIILKQ6381445P	82
1/IGDN2050815.5	38
1/IGNB2100815	39
1/IILBX6 1120.5	80
2/IIIQME9240920.	12
3/IIQIX9100925 _	33

Figure 53. Key Continued.

1/IIILHH6181820S	97
3/IIIQNQ9 1425.	14
3/IVQSM9910840B	18
2/IVQQT9101625	32
3/IQEK9740940PZ	7
3/IIILFF6210925.5	90
3/IIILPS5401020P	94
3/ILAB6 1030B	96
1/IVQPJ9130735.5	31
3/IVLPU5901020B	19
3/IIKIW4 1635.5	101
3/IIGCL2921750PB	50
1/IQBK9060810.5P	2
3/IIQIZ9 0925.5	25
3/IIQJB9 0925PZ	26
3/IIQJD9 0925B	27
3/IVGLT2900830B	69
2/IKYF6101645	73
2/IKYH6 1645.5	84
2/IILDM6100925	79
2/IVLQC5161900.5	88
2/IQCW9211655.5P	4
3/IVGLN1250830	44
1/IIQGB9081610.5	20
1/IIQFZ9101610	21
3/IIIQNQ9101425	13
1/IIIQKQ9101740	9
2/IVQQV9231625.5	22
3/IGCZ21301730B	55
3/IQEB9100940	5
3/IIIGCR21061250	60
3/IIGWN2271750.5	48
1/IVGLEI101645	66



other spatial parameters.

Two important trends were apparent: location on the shelf appeared to be the first tier of the clustering hierarchy; and seasonality appeared to be the next most important parameter and represented at the second hierarchical tier. Furthermore, offshore clusters were generally related at a higher similarity level to one another, reflecting the greater stability in biological composition of more normally oceanic microplankton populations as compared to nearshore clusters where localized environmental changes were more dramatic.

Depth is generally considered a very important factor in determining the distribution of plankton populations. While this is undoubtedly the case, only some of the data clustered well according to depth. This may be partially accounted for by the settling out of individuals from the eupohtic zone, thus giving lower portions of the water column the same general appearance in terms of microplankton composition as waters in the euphotic zone. Density differences (not represented in the microplankton densities depicted in this report) showed a predictable decrease in microplankton density with depth below the photic zone.

R-Mode Cluster Analysis

The results of the R-mode cluster analysis dendrograms for 1975 and 1976 are depicted in Figures 54 and 55, respectively. As previously stated, the two dendrograms were generally similar. Overall trends in the clustering hierarchy (i.e. dendrogram shape), and the ordering of groups from top to bottom confirmed this basic similarity. In the 1975 R-mode cluster, centric solitary diatoms, naupliar larvae, calanoid copepods, *Ceratium* (the most common dinoflagellate genus), tintinnids, pennate solitary diatoms, and fecal pellets showed a very intimate asso-

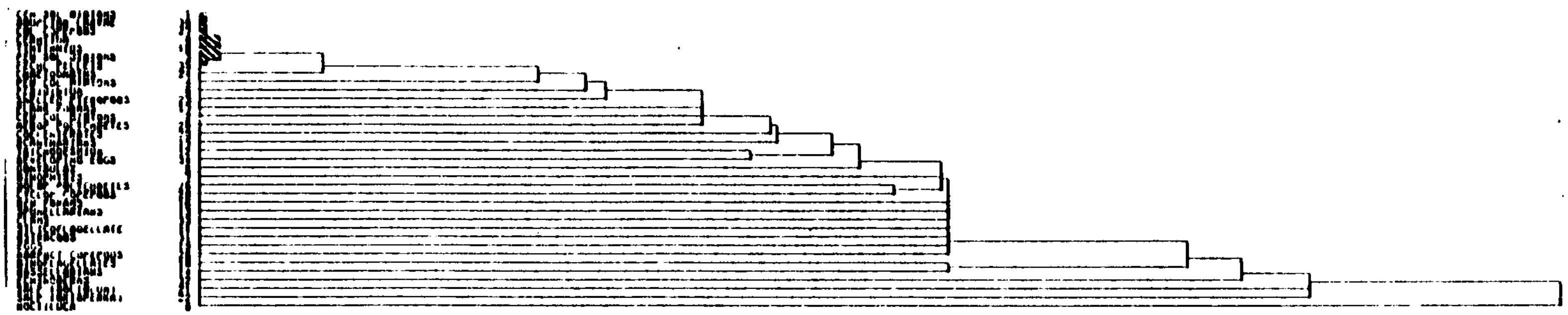
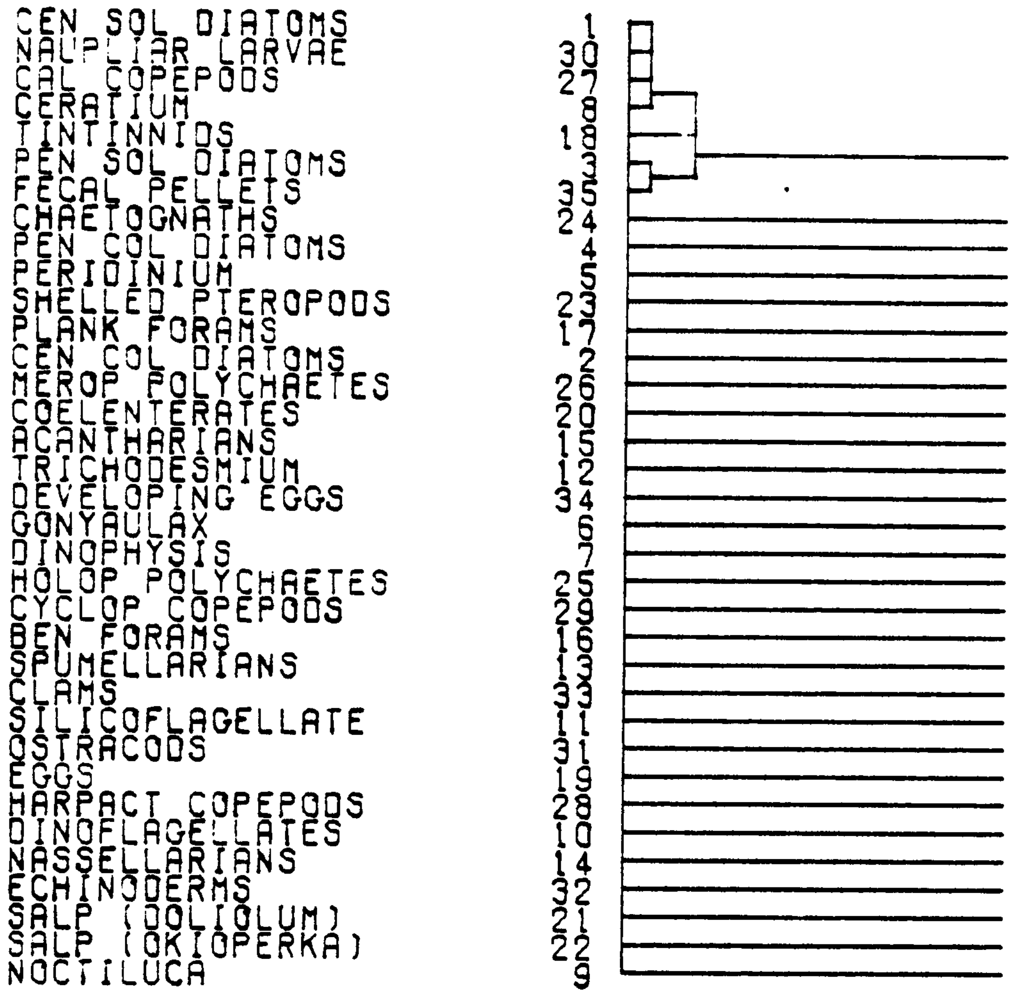


Figure 54. R-Mode Cluster Analysis of 1975 Niskin Data. (See Key on Nex Page.)

Figure 54. Key to R-Mode 1975 Niskin Data.



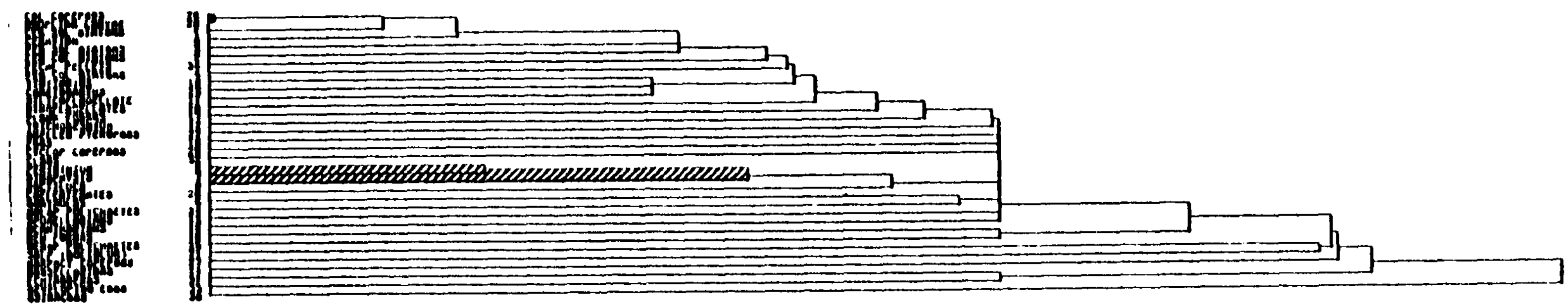
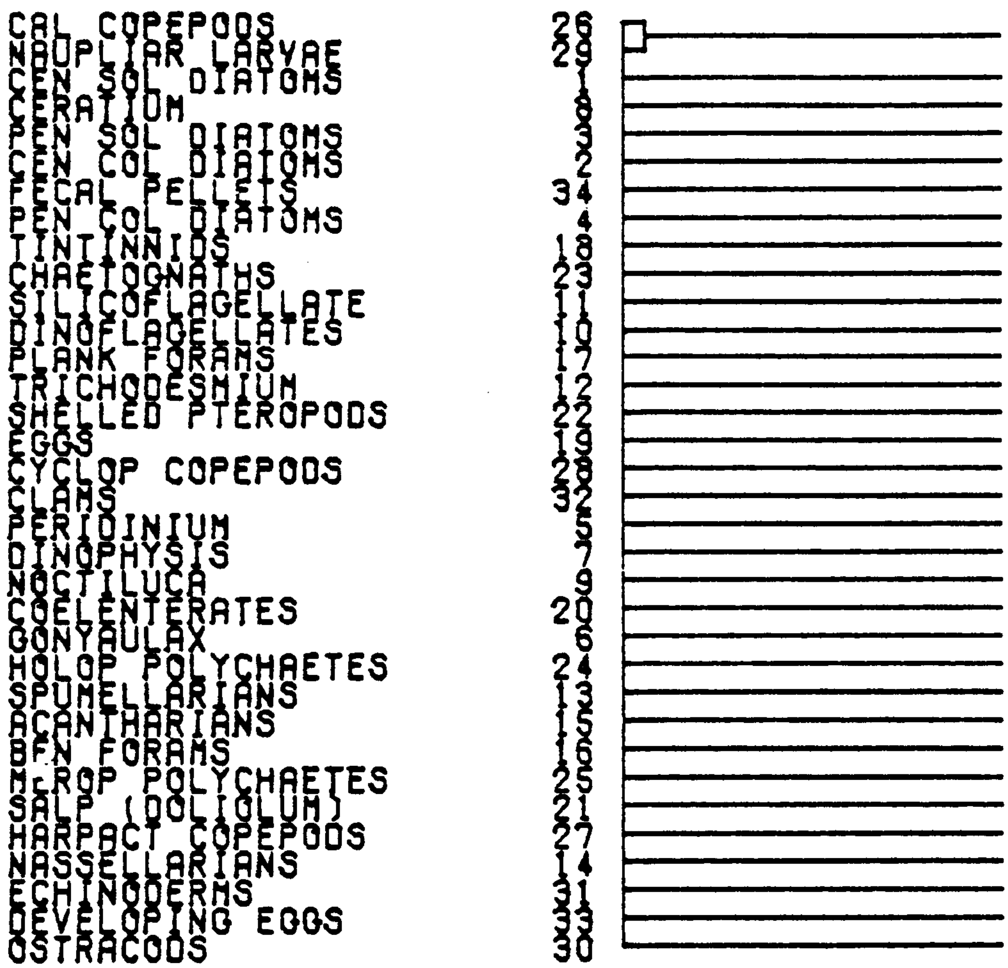


Figure 55. R-Mode Cluster Analysis of 1976 Niskin Data. (See Key on Next Page.)

Figure 55. Key to R-Mode 1976 Niskin Data.



ciation. Tintinnids, copepods, and naupliar larvae are herbivores and the diatoms and dinoflagellate listed above are probably the basic constituents of their diet.

In contrast, only calanoid copepods and naupliar larvae showed as intimate an association in the 1976 R-mode dendrogram. However, a good cluster of four dinoflagellate genera was observable at a lower level of similarity.

In general, the clusters seemed to represent a descending hierarchy of relatively abundant organisms clustering together, with relatively rare and extremely rare organisms being added to the cluster at lower similarity levels. Such a result is expected when consistently abundant variables are clustered together with very rare ones.

Microplankton Densities

The average density of microplanktonic organisms in winter seasonal samples taken at one-half the photic zone at all stations was $2.9 \times 10^5/m^3$ in 1975 and $2.2 \times 10^5/m^3$ in 1976 winter samples; $5.4 \times 10^5/m^3$ in 1975 and $4.7 \times 10^5/m^3$ in 1976 spring samples; and $4.5 \times 10^5/m^3$ in 1975 and $1.5 \times 10^7/m^3$ in 1976 summer samples. These density calculations were in general agreement between years except during the summer of 1976. Probably, a more realistic density average for general conditions on the shelf in the summer of 1976 is obtained by excluding one extremely dense sample ($8.7 \times 10^8/m^3$; Station 1/III) from consideration, in which case, the average density for all remaining stations was $2.4 \times 10^5/m^3$. This revised density was probably more indicative of the average situation during 1976 when an oceanic water mass (the incursion of an anticyclonic ring) was thought to have been on the shelf. If this was indeed the case, lower densities would be expected for microplankton populations in such oligotrophic waters.

The general microplankton densities (Figures 56 through 62) indicated a decrease in microplankton abundance offshore and in a southerly direction in the STOCS area. These results correlated well with phytoplankton data for the BLM-STOCS study area. Phytoplanton productivity was highest nearshore, and higher at Station 1/I and 1/II than at Stations 1/III and 1/IV (Van Baalen, 1976). Likewise, Van Baalen (1976) reported that phytoplankton productivity showed an inverse relatioship between salinity and chlorophyll a concentration. Apparently, surface runoff was the major nutrient supply. Correlations with silicate, nitrate, and other nutrient concentrations were not significant, indicating that nutrient concentrations in the water column at a given time may not be the best measure of eutrophism or oligotrophism. Results of a mathematical model of plankton patch dynamics by Wroblewski and O'Brien (1976), as well as findings of several other investigator's, indicate that exmetabolite excretion of nutrients by zooplankters may be a significant source of nutrients in a phytoplankton patch. Nutrient cycling within a plankton patch could explain why high nutrient concentrations are not always found in conjunction with areas of high productivity.

Microplankton standing crops from seasonal Niskin samples are compared in Figure 63 with results of other investigators. Beers and Stewart (1967, 1969) did a similar study of zooplankton relative abundances in a continental shelf and borderland area along the California coast. Increasing numbers of copepods and naupliar larvae were present offshore, indicating the same general trend as seen in the density data in Figure 63 and the 1975 and 1976 Niskin data for the STOCS study area (Figures 56 through 62).

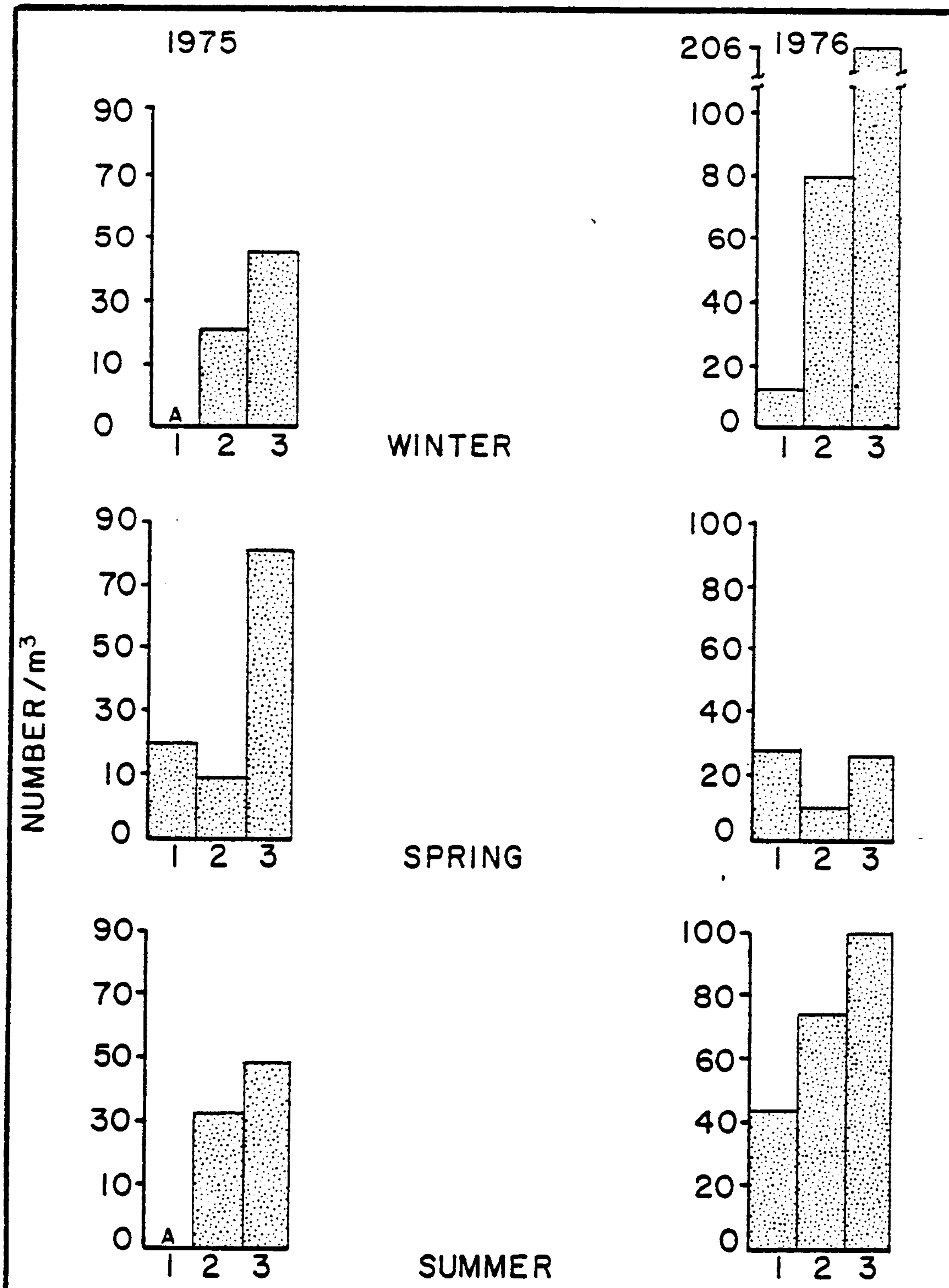


Figure 56. Seasonal Densities (No./m^3) of Planktonic Foraminiferans at Stations 1-3, Transect II, 1975 and 1976 (A-blank spaces indicate organisms not present).

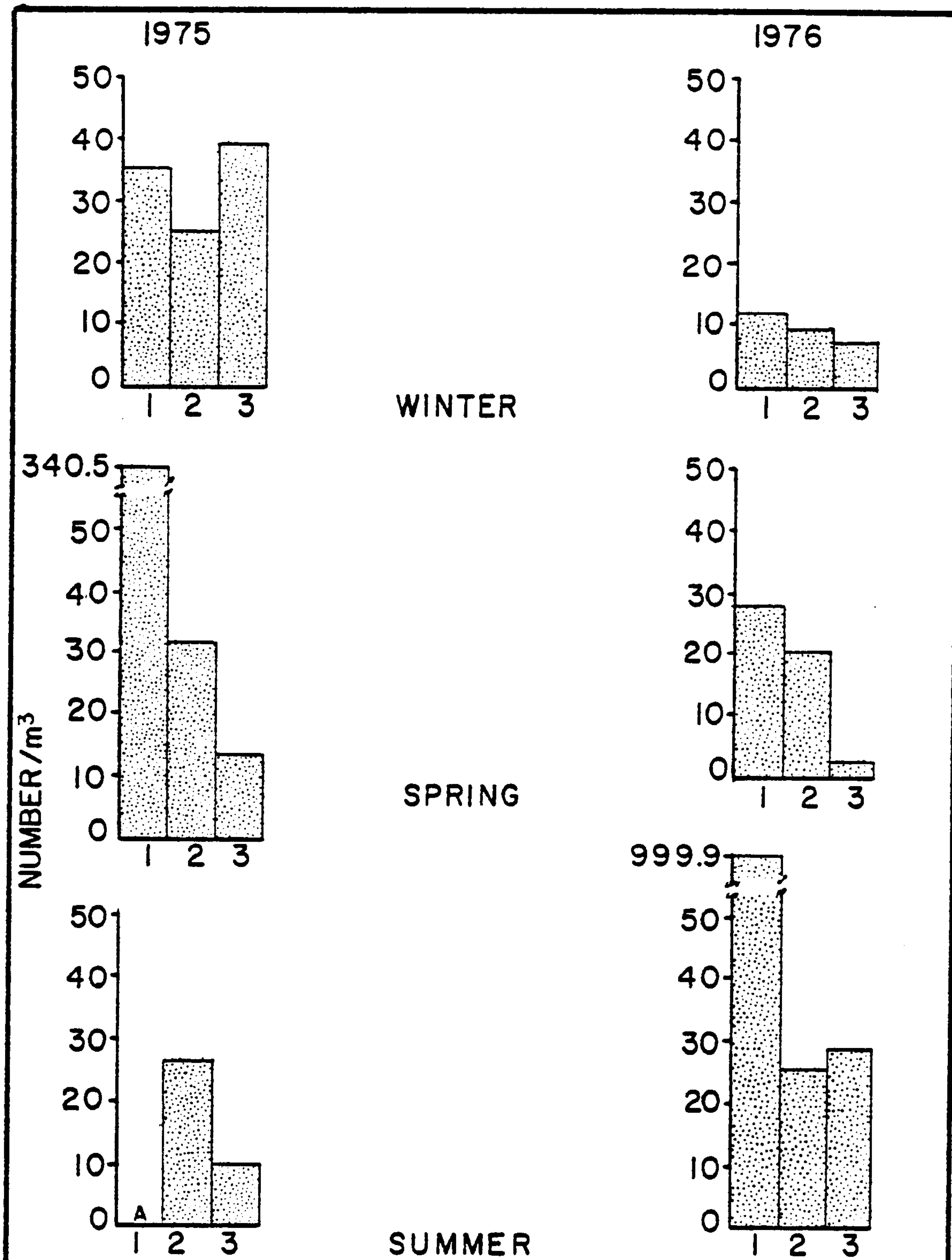


Figure 57. Seasonal Densities (No./m^3) of Benthonic Foraminiferans at Stations 1-3, Transect II, 1975-1976 (A-blank spaces indicate organisms not present).

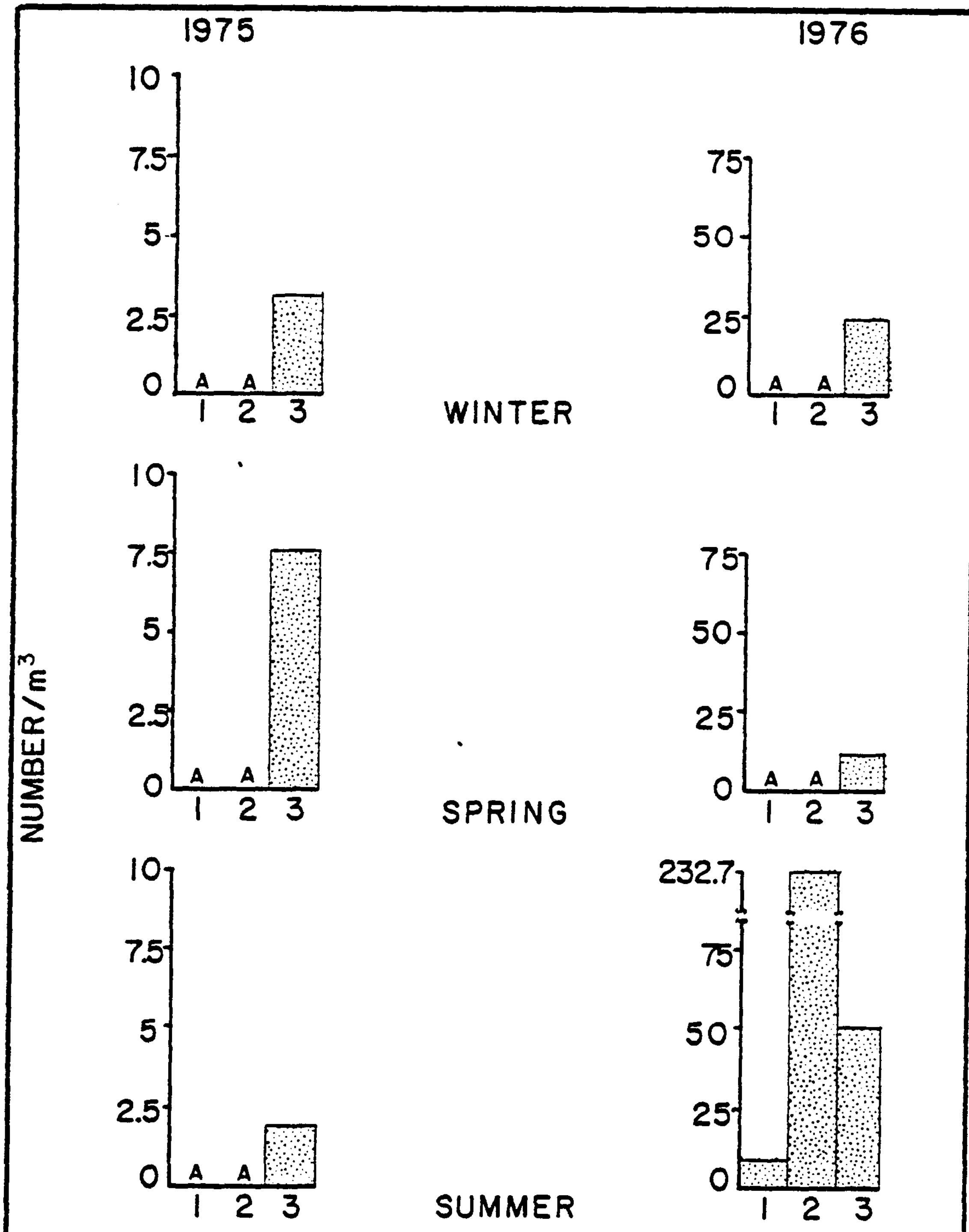


Figure 58. Seasonal Densities (No./m^3) of Nassellarians at Stations 1-3, Transect II, 1975 and 1976 (A-blank spaces indicate organisms not present).

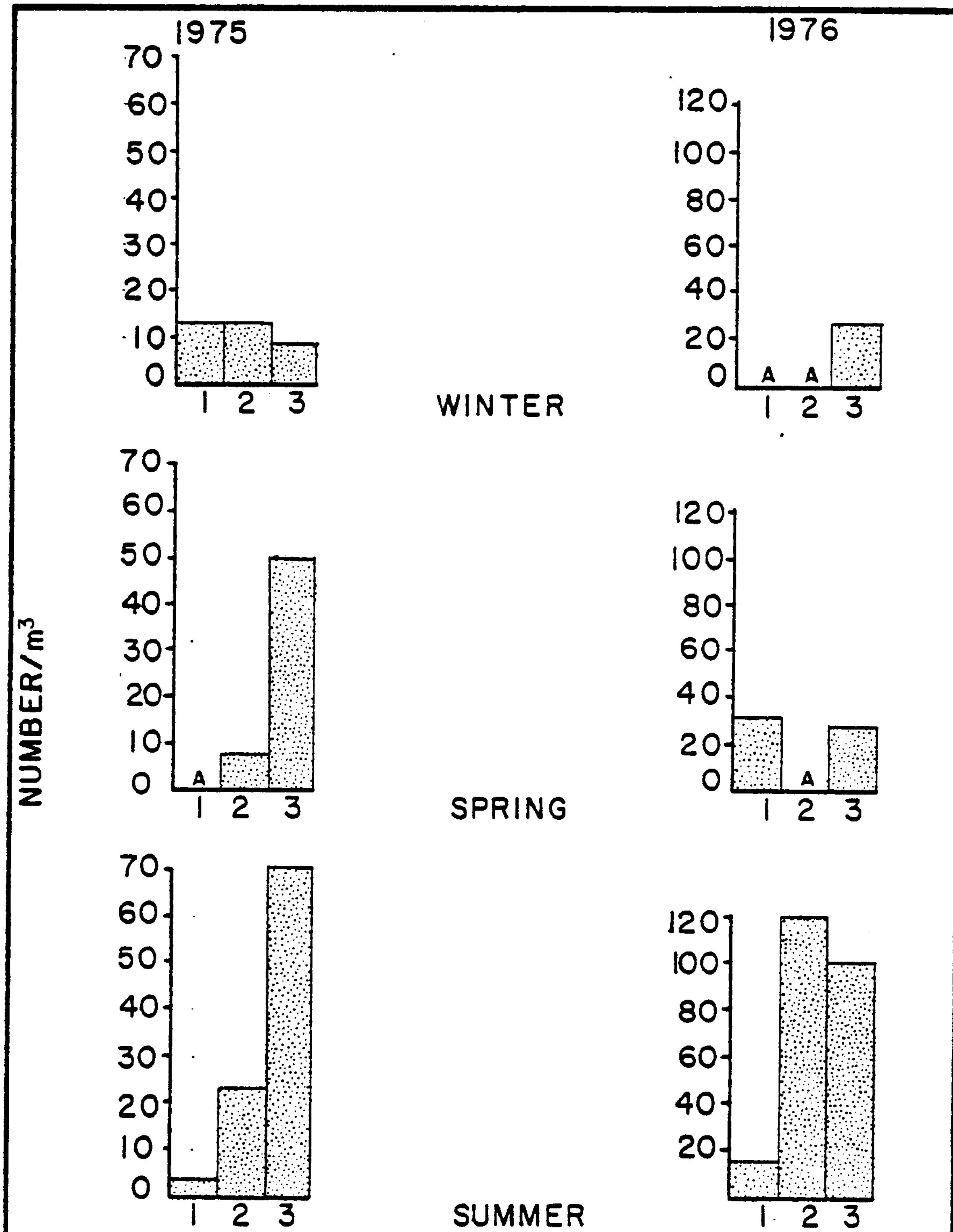


Figure 59. Seasonal Densities (No./m^3) of Spumellarians at Stations 1-3, Transect II, 1975-1976 (A-blank spaces indicate organisms not present).

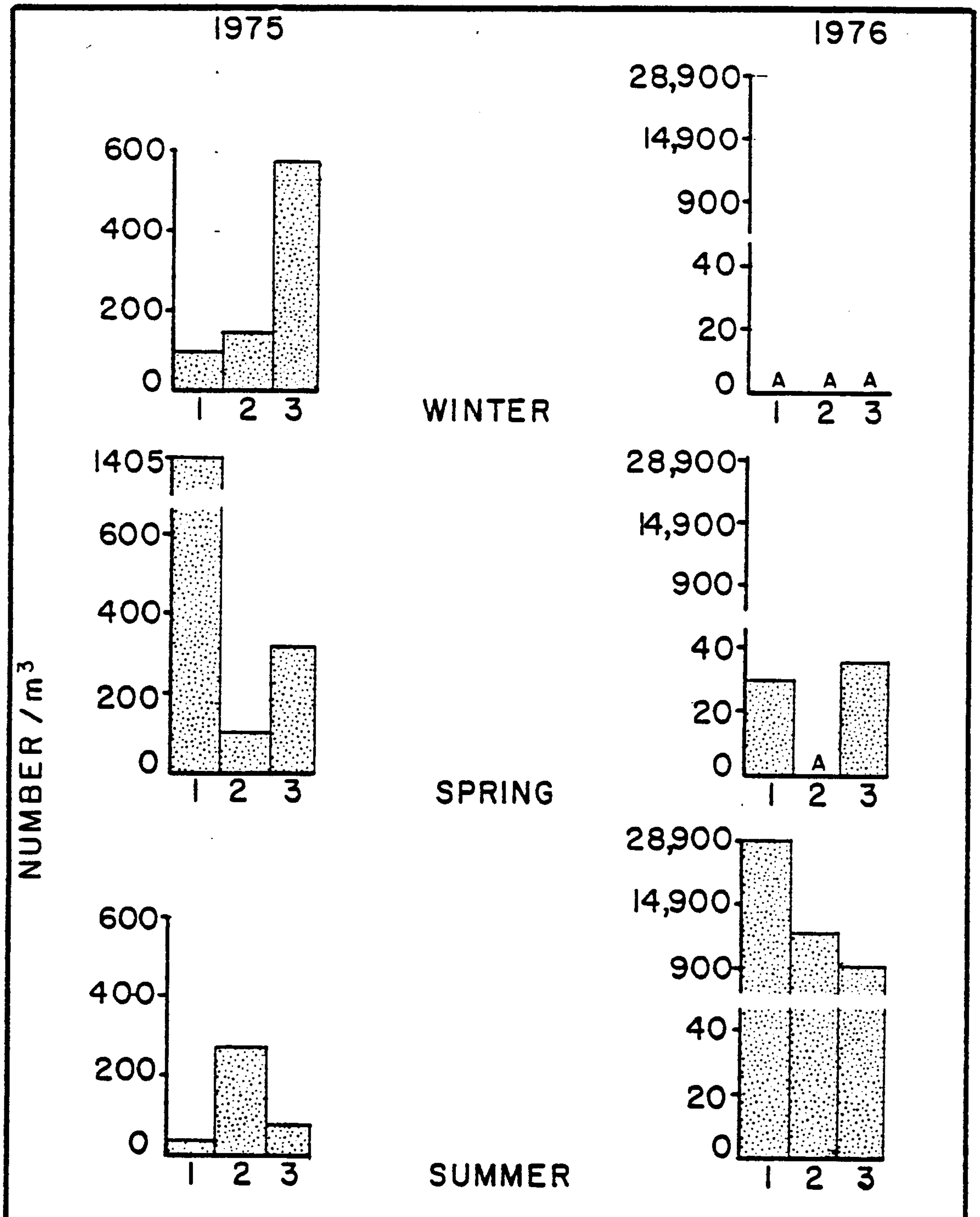


Figure 60. Seasonal Densities (No./m^3) of Acantharians at Stations 1-3, Transect II, 1975-1976 (A-blank spaces indicate organisms not present).

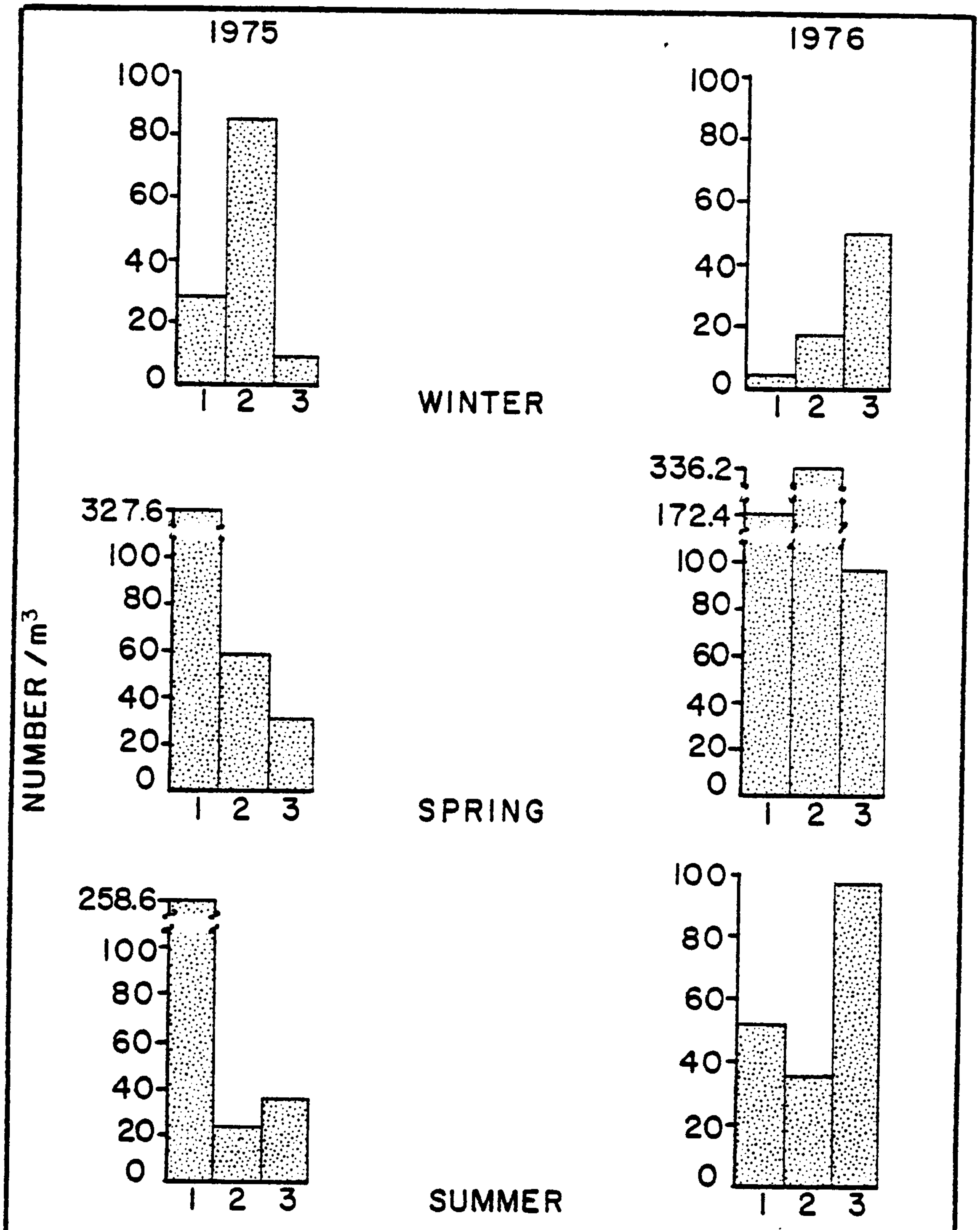


Figure 61. Seasonal Densities (No./m^3) of Pteropods at Stations 1-3, Transect II, 1975-1976.

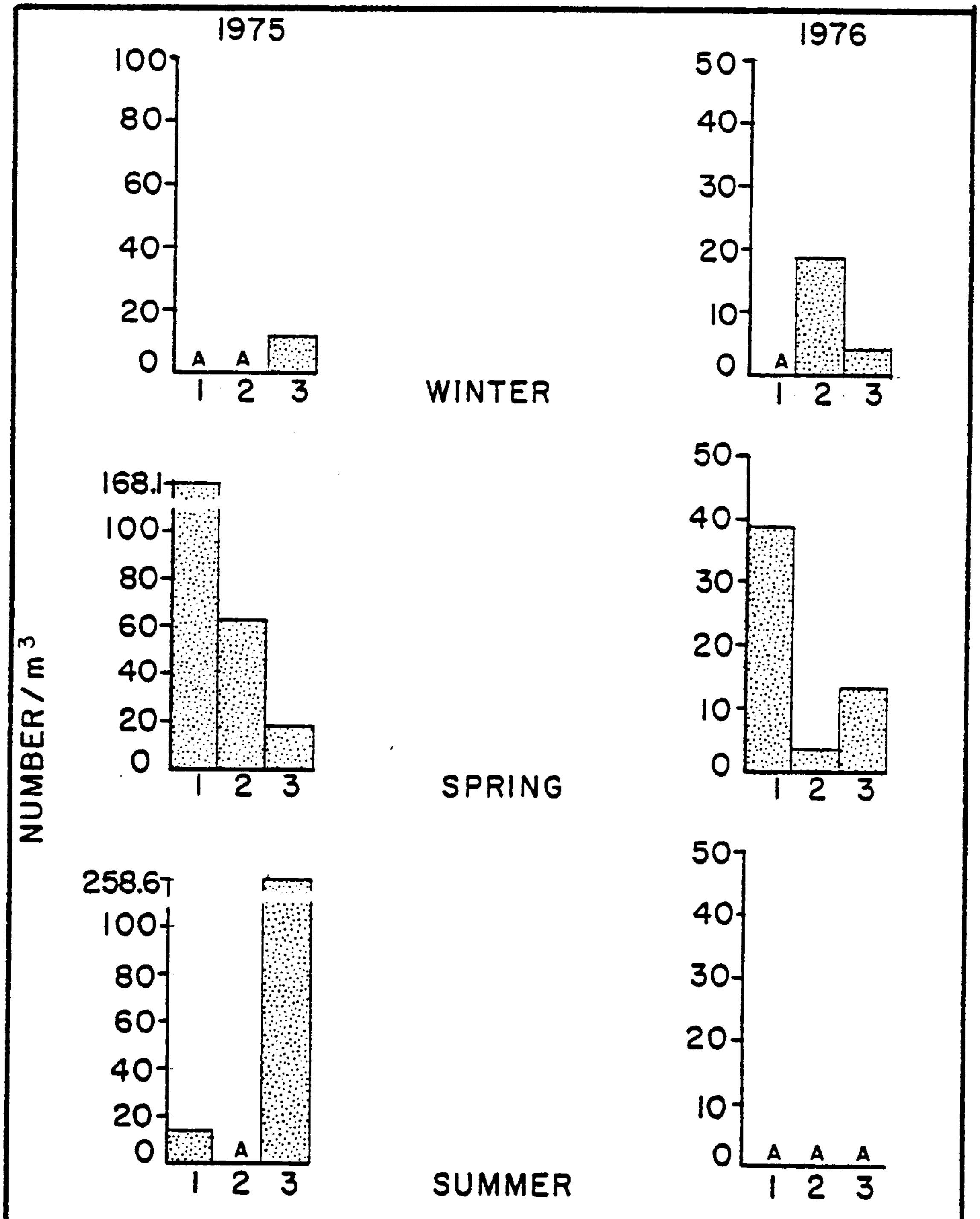


Figure 62. Seasonal Densities (No./m^3) of Ostracods at Stations 1-3, Transect II, 1975-1976 (A-blank spaces indicate organisms not present).

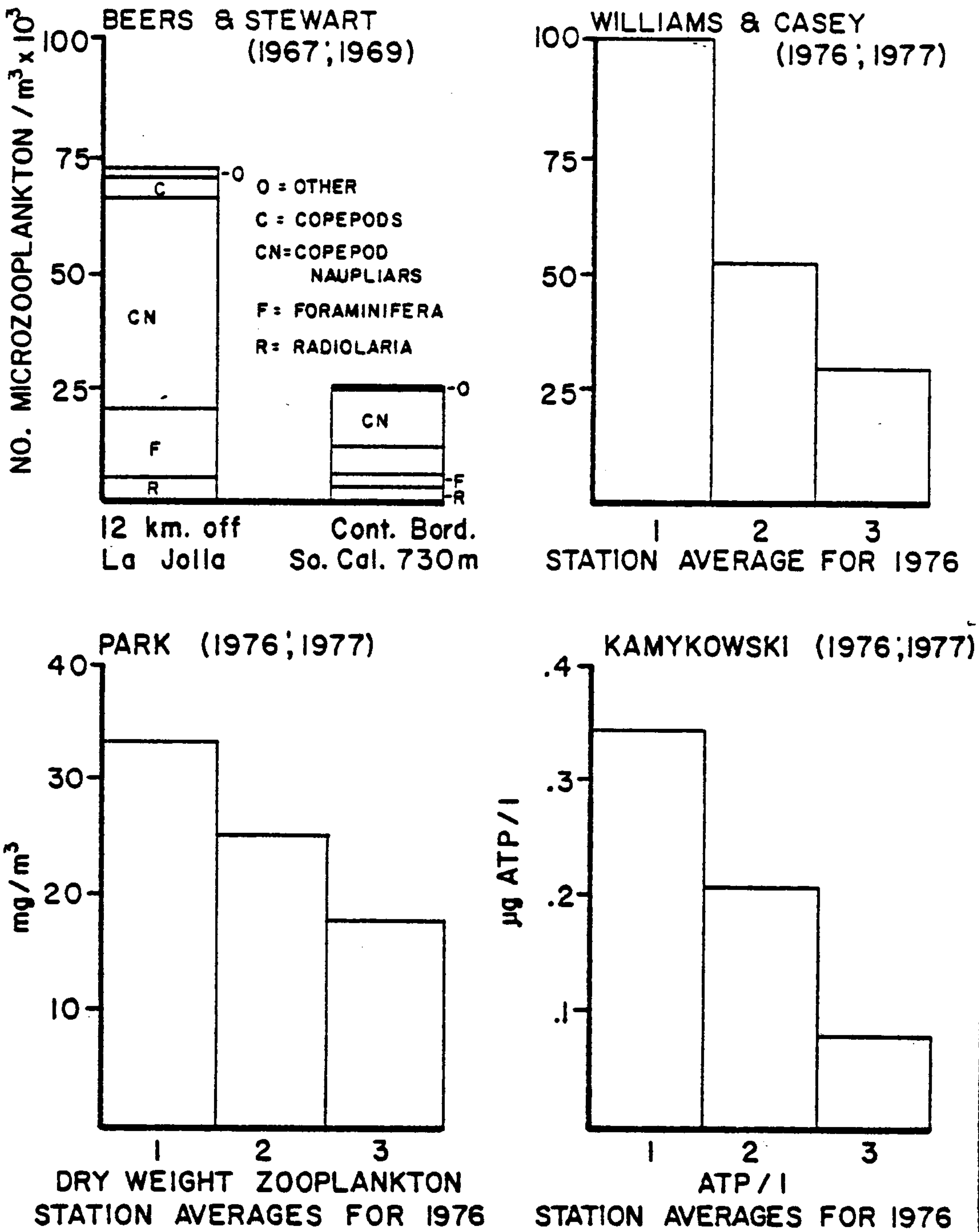


Figure 63. Comparison of BLM-STOCS Microplankton (Niskin) Standing Crop (Williams and Casey) with Data from Beers and Stewart, Park and Kamykowski.

Standing crop estimates based on 1976 and 1977 data for zooplankton biomass (Park, 1976, 1977) and 1976 and 1977 data for ATP concentration/l (Kamykowski, et al., 1976a, 1976b, 1977) both showed a stepwise decrease moving offshore. Their data for samples collected concurrently with microzooplankton samples show good agreement with the microplankton density data presented herein. This suggests that the microplankton populations were mirroring conditions in both higher (larger zooplankton) and lower trophic levels (nannoplankton).

Shelled Microplankton Densities

Planktonic Foraminiferans

A comparison of planktonic foraminiferan densities for the two sampling years showed some obvious differences, but the general trends were similar (Figure 56). The major genus represented in the Niskin casts was *Globigerina*. Planktonic foraminiferans showed a predictable seaward increase in density, reflecting their typically normal marine habitat (Bauer, 1976). The 1975 data indicated that the dominant increase in density occurred during the spring when the greatest amount of upwelling was thought to have occurred (Casey, 1976). During 1976, winter and summer both showed higher planktonic foraminiferan densities which may reflect the incursion of an anticyclonic ring into the STOCS study area.

Benthonic Foraminiferans

Benthonic foraminiferan densities (Figure 57) generally reflected the predominantly shallow water, nearshore occurrence of *Brizalina lowmani* and its suspension due to nearshore turbulence (shallower than 30 m; Phleger, 1956) or its existence as a meroplanktonic organism. *B. lowmani* was the dominant foraminiferan in the Niskin casts and apparently has a meroplanktonic juvenile stage in the STOCS study area (Bauer, 1976).

Densities for both years were consistently higher at Station 1, with 1975 winter and spring densities being higher than the corresponding seasons in 1976. Highest densities were recorded at Station 1 during the summer of 1976. The tremendous increase in benthonic foraminiferans during this time period may have been related to nearshore eutrophism (also evidenced in the microplankton densities which were the highest recorded at this station during the summer). The probable cause of eutrophic conditions in the STOCS study area was high volumes of surface runoff due to extremely heavy rainfall during the summer of 1976. See Appendix C, Table 7, for a tabulation of benthic foraminiferan data.

Nassellarians

Nassellarian densities were low during both years (Figure 58), except during the summer of 1976. During this season, nassellarian densities at Stations 2 and 3 showed an increase of over one order of magnitude. The presence of relatively large numbers of these typically open-ocean pelagic organisms at mid-shelf was possibly the strongest support for the occurrence of open-ocean water (a possible anticyclonic ring) over a significant portion of the STOCS study area in the summer of 1976.

Spumellarians

Spumellarian densities for the 2 years (Figure 59) were similar, except during the summer of 1976. The occurrence of one, deep-living species, *Spongotrochus glacialis*, in shallow Niskin casts was a good environmental indicator of upwelled or displaced deeper waters (Casey, 1976c). *S. glacialis* was present in a number of Niskin samples during the summer of 1976. Likewise, the increase in spumellarian densities in the spring of 1975 was considered indicative of upwelling at the offshore stations.

Acantharians

Acantharians are non-polycystine radiolarians which can be distinguished from the other radiolarian groups by their organic-walled test and nearshore, low-salinity habitat preference. The spring of 1975 (Figure 60) showed a significant increase in acantharian densities which was probably tied to surface run-off. However, the greatest increase in acantharian densities during the two sampling years occurred during the summer of 1976 (Figure 60). A log plot of acantharian densities vs station location (Figure 64) depicts what appears to be an exponential decrease in density away from shore during the summer of 1976. The tremendous increase of acantharian densities from spring to summer during 1976 might have been due to a lag between the time of heaviest rainfall (June) and the full expression or development of a eutrophic, microplankton bloom in the summer (August and early September).

Pteropods

In general, there were no significant differences between pteropod densities for the 2 years (Figure 61). Slight differences in the magnitudes for each year were present, but the trends were similar. Densities were lowest in the winter, and increased in the spring with a slight tapering off in the summer. Pteropods behave like most general microplankton groups by decreasing in numbers in an offshore direction.

Ostracods

Ostracods were well-represented in the larger zooplankton size classes (Park, 1976a, 1976b, 1977), but were almost non-existent in the 1976 Niskin samples (Figure 62). Significantly greater densities were recorded in 1975, but no general trends other than a spring increase were evident.

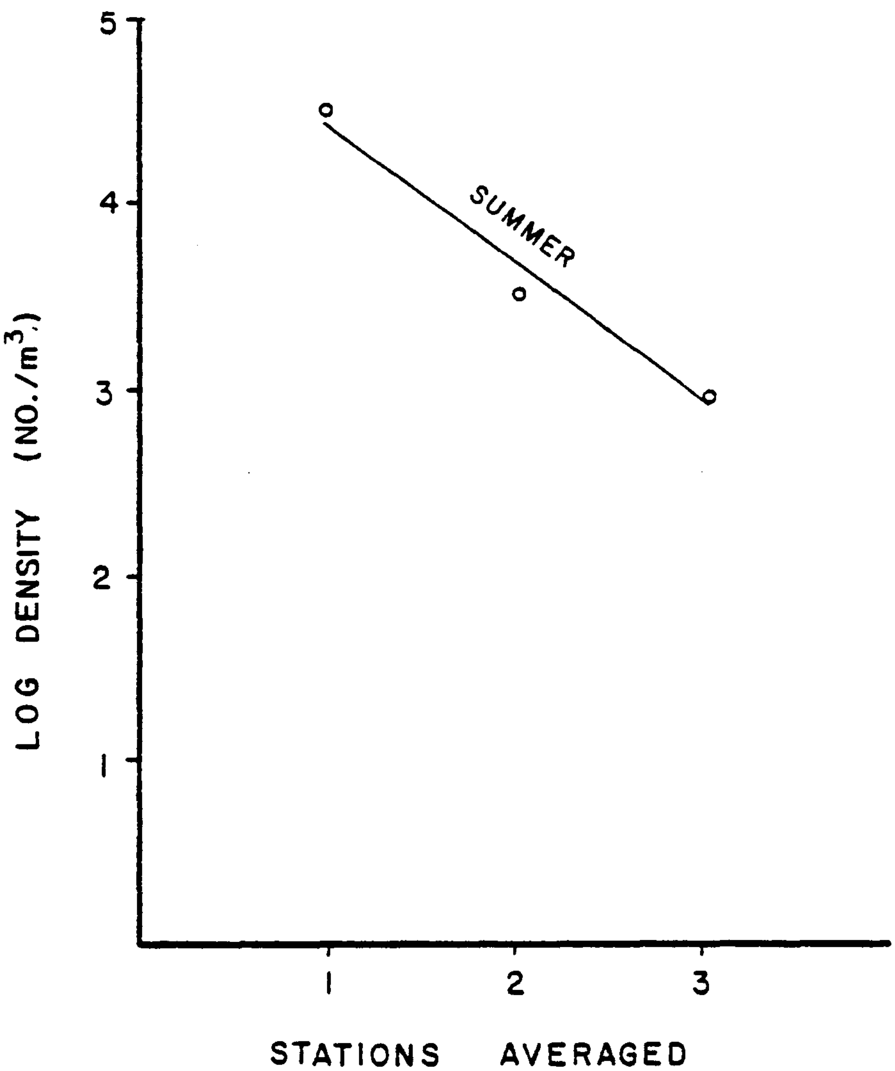


Figure 64. Acantharian Densities During the Summer of 1976.

Detail Comparison of Monthly Niskin and Nansen Data with the Physical Oceanography for Portions of 1976

The combination of monthly Niskin samples (from Transect II), along with Nansen tows collected concurrently, depicted what may be the best small-scale trends noted in this work element.

In February, Smith (1976a) recorded inner-shelf water out past Station 2, Transect II. This corresponded with a dominant component of dinoflagellates at Station 1 and a decline of dinoflagellates at Station 2 and 3. The winter clusters (Table 4) reflected this condition.

In March, Smith described (1976a) an "eddy" between Stations 2 and 3. This eddy appeared to be a pond of offshore, shallow water with a significant portion of planktonic foraminiferans, and radiolarians indicative of such water in the Niskin and Nansen samples. The occurrence of the radiolarians *Hexalonche anamimandri* and *Actinoma* (in Nansen tows) indicated that this pond of water possessed a component of underwater (McMillen, 1976).

In April, Smith (1976b) recorded a tongue of relatively low-salinity water extending past Station 2. The absence of planktonic foraminiferans (usually restricted to offshore, shallow water) along with the presence of radiolarians, indicated that mid-shelf waters were wedged under this shallow water. The presence of planktonic foraminiferans and both radiolarian groups at Station 3 indicated an incursion of offshore Gulf water.

In July, Smith (1976c) suggested that nearshore waters extended out to Station 2. The Niskin and Nansen data suggested an exclusion of shallow, offshore water (no foraminiferans), but the presence of deep offshore (upwelled) water moving along the bottom and into Station 1 (*Spongotrochus glacialis* present). As further evidence, cluster Spr 1

TABLE 4

CLUSTER COMPOSITION USING 1976 NISKIN DATA

	WINTER			SPRING					SUMMER					
	Win 1	Win 2	Win 3	Spr 5	Spr 2	Spr 4	Spr 1	Spr 3	Sum 3	Sum 5	Sum 4	Sum 2	Sum 6	Sum 1
Cal Copepods	2	2	10	9	5	2	4	10	6	2	4	1		
Naupliar Larvae	7	5	16	19	15	5	8	22	20	3	11	6	2	2
Cen Sol Diatoms	26	32	24	27	30	20	37	33	19	45	18	32	63	7
Pen Sol Diatoms	4	6	10	6	13	6	4	5	2	9	16	16	4	2
Cen Col Diatoms	4	8	12	4	8	32	17	1	19	10	37	17	24	82
Pen Col Diatoms	1	9	7	2	1	23	12	1		3	2	6	2	3
Fecal Pellets	11	17	5	1	1	1	2		1		1	2		
Tintinnids	1	2	1	10	11	2	5	1	5		1	2		1
Chaetognaths			1	7	3		1	1	3	1				
Trichodesmium			1	2		2	1	1	2	19	1	3		2
Shelled Pteropods			1	2		1								
Eggs						1	1	1						
Cyclop Copepods					1		1	1	1					
Clams	1			3										
Silicoflagellates				5	1		1							
Dinoflagellates	1		2	1	1			2	1					
Ceratium	6	6	3	1	6	2	2	8	5	3	1	2	3	
Peridinium	6	1			1			1	1					
Dinophysis	10	1				1			1		1			
Noctiluca	7	2							1	1				
Gonyaulax	9	4						2	2					
Holop Polychaetes		1												
Merop Polychaetes									1		1			
Coelenterates	2									2				
Plank Forams	1	1	3					1	2			1		
Spumellarians								1						
Nasellarians								1	1					
Acantharians			1				1				3	11		
Salp (Doliolum)								1						
Echinoderms										1				
Ostracods								1						
Ben Forams											1			

(Figure 53) was composed of organisms from bottom samples at Station 3 and 10-m samples at Station 1, suggesting that the assemblages at these locales might be the same. At Station 2, planktonic foraminiferans, spumellarians, and nassellarians were present in the Niskin and Nansen samples, probably below the nearshore lens of water. At Station 3, spumellarians, nassellarians, and planktonic foraminiferans were common, illustrating the incursion of offshore waters during July. The presence of these groups (up to 25 percent of the total counts) in large numbers in the shallow Niskin casts suggested that the presence of an anticyclonic ring as postulated earlier was well-established at this time.

In August, Smith (1976c) recorded the same lens of nearshore water mentioned above displaced from the coast by some 30 km. The presence of planktonic foraminiferans, spumellarians, and nassellarians at all stations, Transect II, in both Niskin and Nansen samples suggested that offshore water had penetrated below this lens, perhaps displacing it completely at Station 1. Further evidence was the abundance of dinoflagellates at Stations 2 and 3, but not at Station 1 (the opposite of the normal case). Cluster Sum 3 (Table 4) was representative of this condition with a generally offshore biological composition (nassellarians and planktonic foraminiferans) occurring simultaneously with a nearshore assemblage (dinoflagellate totals were high at 11 percent).

In September, Smith (1976c) suggested that offshore water was still moving in along Transect II, with lower salinity water being pulled away from the coast through the inner three stations. Planktonic foraminiferans, spumellarians, and nassellarians were present into Station 2 in the Niskin and Nansen samples, again agreeing with Smith's data.

Summary Monthly Niskin Data for Transect II

The general microplankton groups from both the Nansen and Niskin samples were good indicators of small-scale physical oceanographic conditions. Comparison of discrete Niskin sample data with Nansen tow data (channel samples) enabled formulation and reinforcement of the following generalizations:

1) nearshore waters are characterized by the absence or sparseness of planktonic foraminiferans, spumellarians, and nassellarians, while diatoms and dinoflagellates are abundant;

2) shallow, offshore waters are characterized by abundant planktonic foraminiferans, spumellarians, and relatively high numbers of copepods and naupliar larvae;

3) deeper offshore waters are characterized by an abundance of nassellarians and copepod-naupliar larvae groups, with spumellarians and planktonic foraminiferans common.

Shelled Microzoobenthon

Living Benthonic Foraminiferans

The average standing crop of benthonic foraminiferans for the 12 primary seasonal stations throughout the year was 27.64 individuals/10 cm^2. This value was lower than during 1975 as reported by Anepohl (1976). Average values for shelf and marginal marine environments are 50 to 200/10 cm^2 (Murray, 1973). However, Phleger (1956), studying approximately the same area as the BLM-STOCS study area, reported an average from 21/10 cm^2 for his southern transect (a transect that extended from about between Station 1/II and 1/III to 3/III), to 61/10 cm^2 for a more northerly transect which ran from about midway between BLM-STOCS Stations 1/I and 1/II terminating offshore at about Station 3/II. If Stations 1/II and 1/III are combined (as a composite station) and that composite is considered with Stations 2/III and 3/III, a station distribution close to Phleger's southern transect was obtained which had an average density of 10.99/10 cm^2 during 1976. Averages for these stations seasonally were 12.17 for the winter, 6.1 for the spring, and 14.7 for the summer. Phleger's samples were collected in late June which was closest seasonally to the BLM-STOCS spring (our lowest density) collecting period. When Stations 1/I and 1/II were combined as a composite nearshore station and averaged with Stations 2/II and 3/II a density of 31.79 was obtained for 1976. The averages for these stations seasonally were 54.87 for the winter, 23.05 for the spring, and 17.45 for the summer. These densities were about one-half those reported by Phleger (1956), which may be accounted for by his sampling only during one season or use of a different (and perhaps better) sampling method (a corer). However, considering the small sample size taken in both studies and the variability and patchiness in distribution of benthonic foraminiferans, the data were considered reasonably compatible.

The average standing crop for all stations during the winter of 1976 was 47.19/cm^2, 25.2 for spring and 10.53 for summer. Combining Transects I and II as a northern section, and Transects III and IV as a southern section, the northern section had a greater standing crop in the winter (64.79 vs 29.59) and summer (19.95 vs 1.1) and standing crops were about even in the spring (21.68 vs 23.2). The higher standing crops of benthonic foraminiferans along the northern transects were probably representive of the greater productivity of the overlying waters (more eutrophic conditions) noted continuously from the first cruises of the BLM-STOCS study. There probably is a lag time between plankton productivity (both primary and secondary) and benthonic foraminiferan productivity (represented by standing crop). The data suggest that, in general, the high spring plankton productivity is not reflected in the shelled microzoobenthon (benthonic foraminiferans) until the following winter.

Figures 65 through 67 illustrate standing crop (in numbers of individuals/10 cm^2) and dominant species (in percent) for each of the 12 primary stations for winter, spring and summer of 1976, respectively. During all seasons there was a general decrease in standing crop shelfward, with a yearly average for Station 1, all transects, being 47.93/10 cm^2, 27.88 for Station 2, all transects, and 5.69 for Station 3, all transects. Seasonal averages for Stations 1, 2 and 3, respectively, were 75.91, 61.50 and 4.34 for winter, 55.65, 16.35 and 1.58 for spring and 23.48, 5.78 and 2.33 for summer.

The nature of the communities at the species level also changed seasonally. The dominant species (in abundance) on the shelf was *Brizalina lowmani* which exhibited an interesting seasonal pattern (Figures 65 through 67), being dominant at Stations 1, all transects, and at Station 2, Transects I and II, during the winter. Dominance by *B. lowmani* alone almost accounted for the total density dominance in winter. During the spring this species was dominant at Transect III stations, common at all stations on Transect IV, but essentially played a sub-dominant (or was absent) in the northern section. In summer, *B. lowmani* started to become re-established in the northern section. *B. lowmani* may be a good immediate indicator of eutrophism in the benthic environment as the abovementioned trends suggest. Other seasonal trends were an increase in the percentages of *Nonionella basiloba* in the spring and summer and an increase in the percentages of *Vigulinella* sp. in the spring (northern transects).

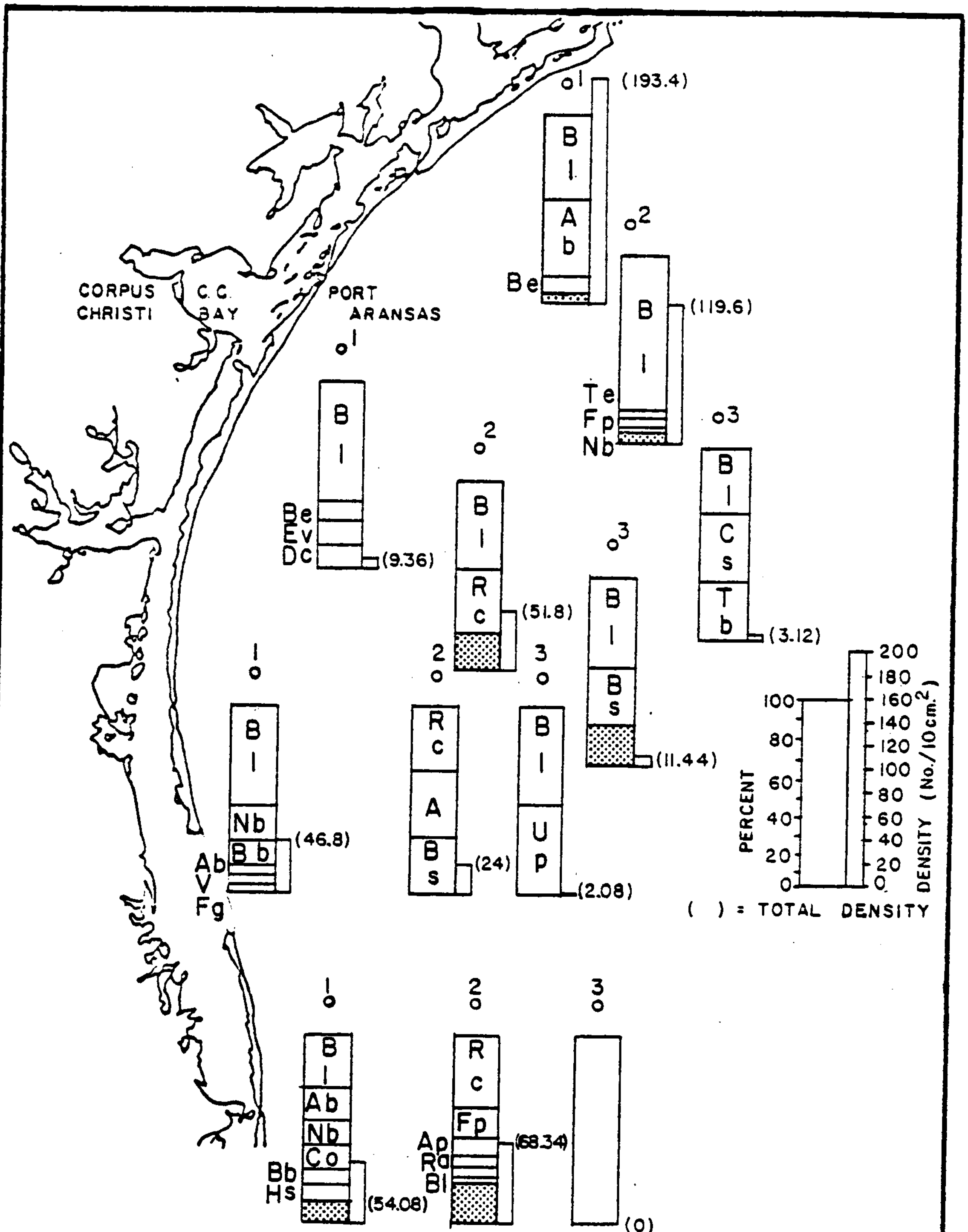


Figure 65. Relative Abundance (percent of total) and Total Standing Crops (density in No./10 cm²) of Benthonic Foraminiferans, Winter 1976. (Capital letters refer to genus, lower case letters refer to species; see text or Appendix C for complete names.)

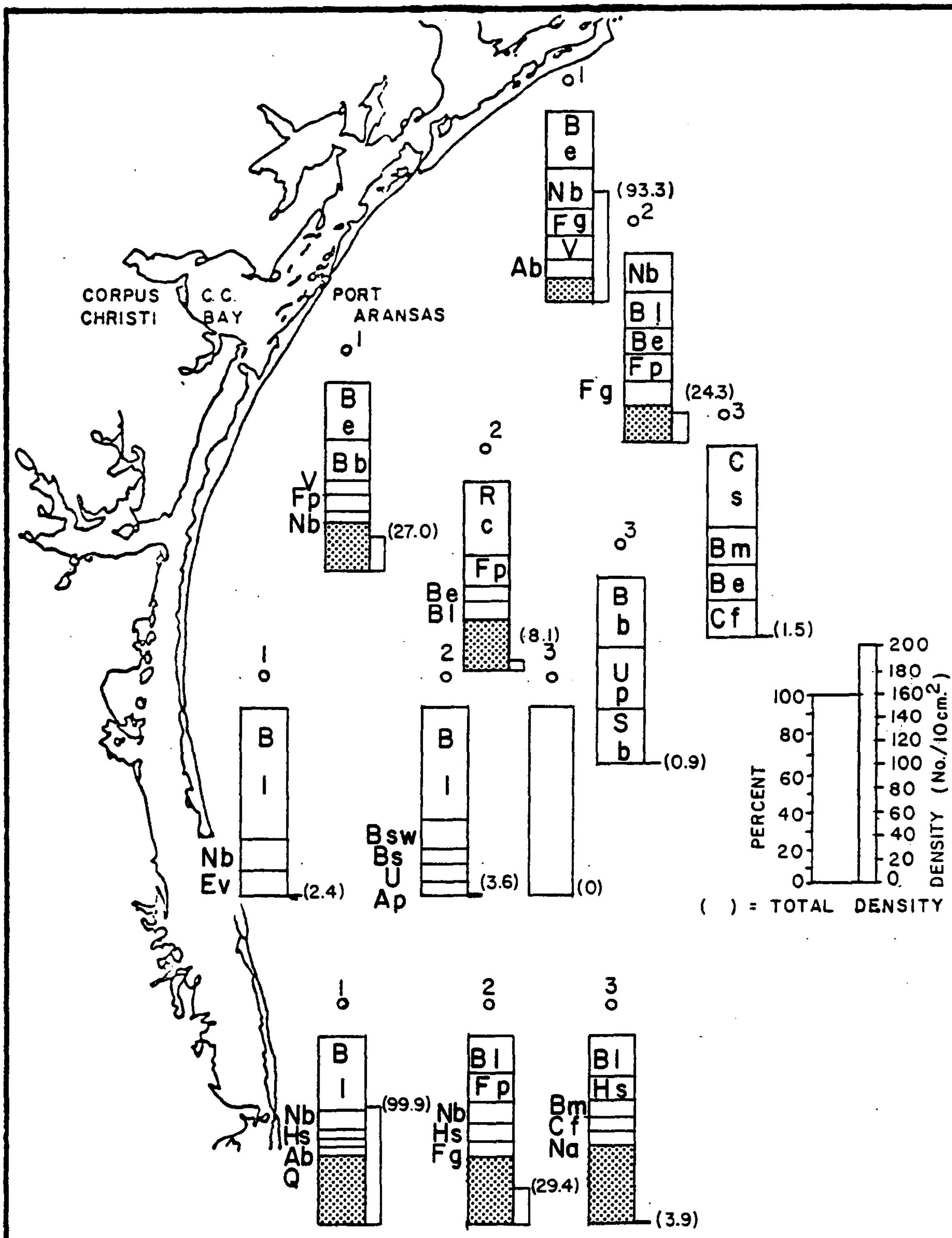


Figure 66. Relative Abundance (percent of total) and Total Standing Crops (density in No./10 cm^2) of Benthonic Foraminiferans, Spring 1976. (Capital letters refer to genus, lower case letters refer to species; see Appendix C for complete names.)

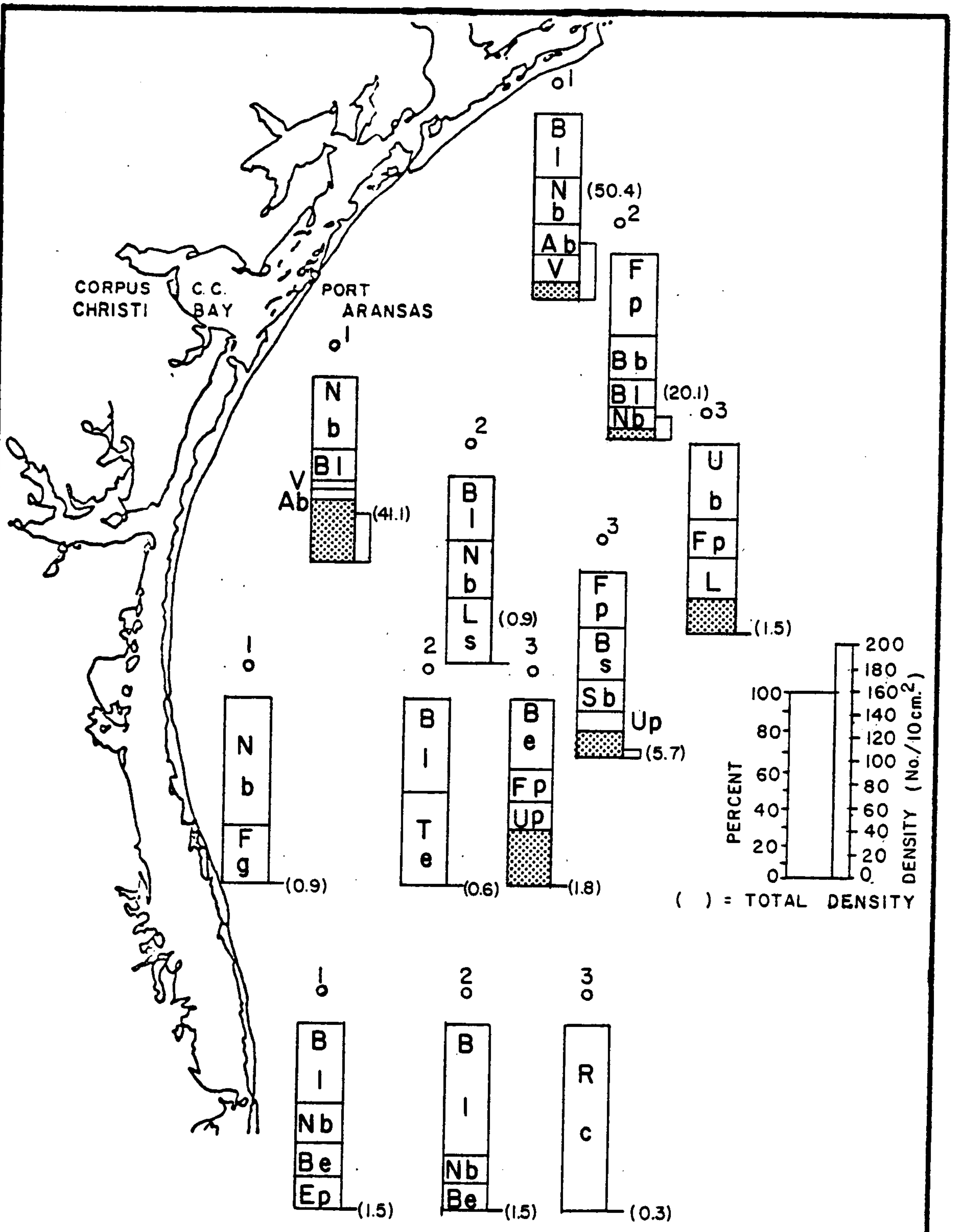


Figure 67. Relative Abundance (percent of total) and Total Standing Crops (density in No./10 cm^2) of Benthonic Foraminiferans, Summer 1976. (Capital letters refer to genus, lower case letters refer to species; see text or Appendix C for complete names.)

An apparent supra-species seasonal trend was indicated in the northern section by the dominance of a few species at Stations 1 and 2; a loss of dominance during the spring and an increase in it was seen in the summer. This trend reinforces the previously-stated idea that high plankton productivity is reflected in a benthonic foraminiferan high (standing crop) the following winter. It also reinforces the suggestion that *B. lowmani* might be a good indicator of benthic productivity and that its increasing density in the summer and dominance in the winter (northern sector) demonstrates eutrophism of the northern sector; *B. lowmani* may well be an opportunistic species which takes advantage of this eutrophism, perhaps at the expense of others. At the same level, the benthic foraminiferans of the southernmost transect (IV) apparently illustrate the more oligotrophic conditions of this transect. Shared dominance and low standing crops are the rule in the southern portion of the study area.

Perhaps the most obvious correlations of species and standing crop distributions were with depth. *Ammonia beccarri, Brizalina lowmani* and *Nonionella basiloba* were dominant at inner and mid-shelf Stations 1 and 2. *Fursenkoina pontoni*, and perhaps *Reophax comprima*, were seemingly indicative of the mid-shelf (Station 2), but the major bathymetric break in the benthonic foraminiferan populations appeared to be mainly between Stations 2 and 3, or at 60 to 70 m as was first noted for the study area by Phleger (1956). Outer shelf depths were indicated by the occurrence of *Uvigerina peregrina, Bulimina marginata, Bolivinia subspinescens,* and *Brizalina spinata* at the species level, and more generally by increases in *Cibicides, Siphonina* and other species of *Brizalina* and *Bolivina.*

The R-mode cluster analysis dendrogram for benthonic foraminiferan is given as Figure 68. Clustering was predominantly influenced by depth

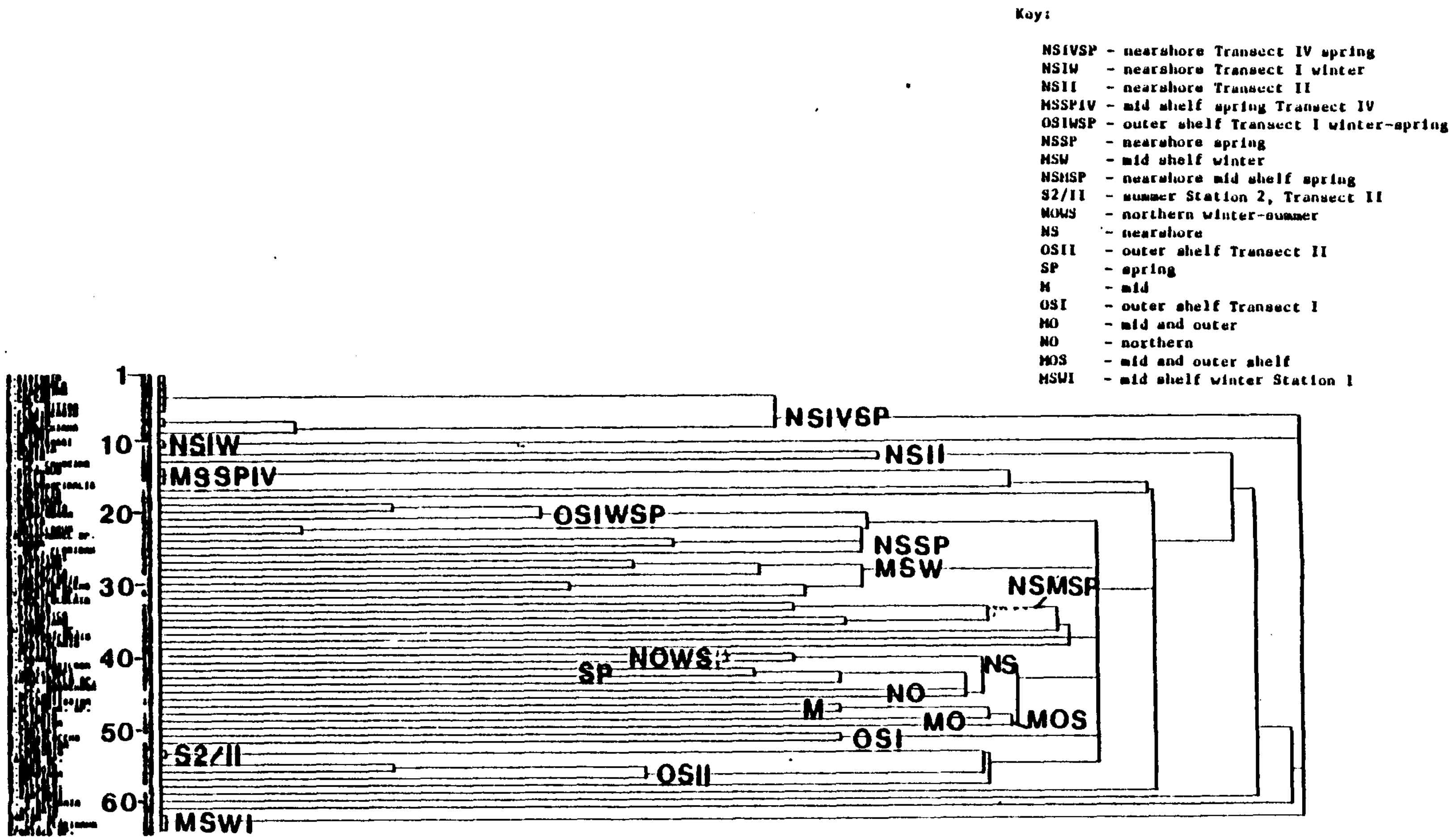


Figure 68. R-Mode Analysis of Benthonic Foraminifera, 1976. (See Key on Next Page.)

Figure 68. Key to R-Mode Benthonic Foraminifera, 1976.

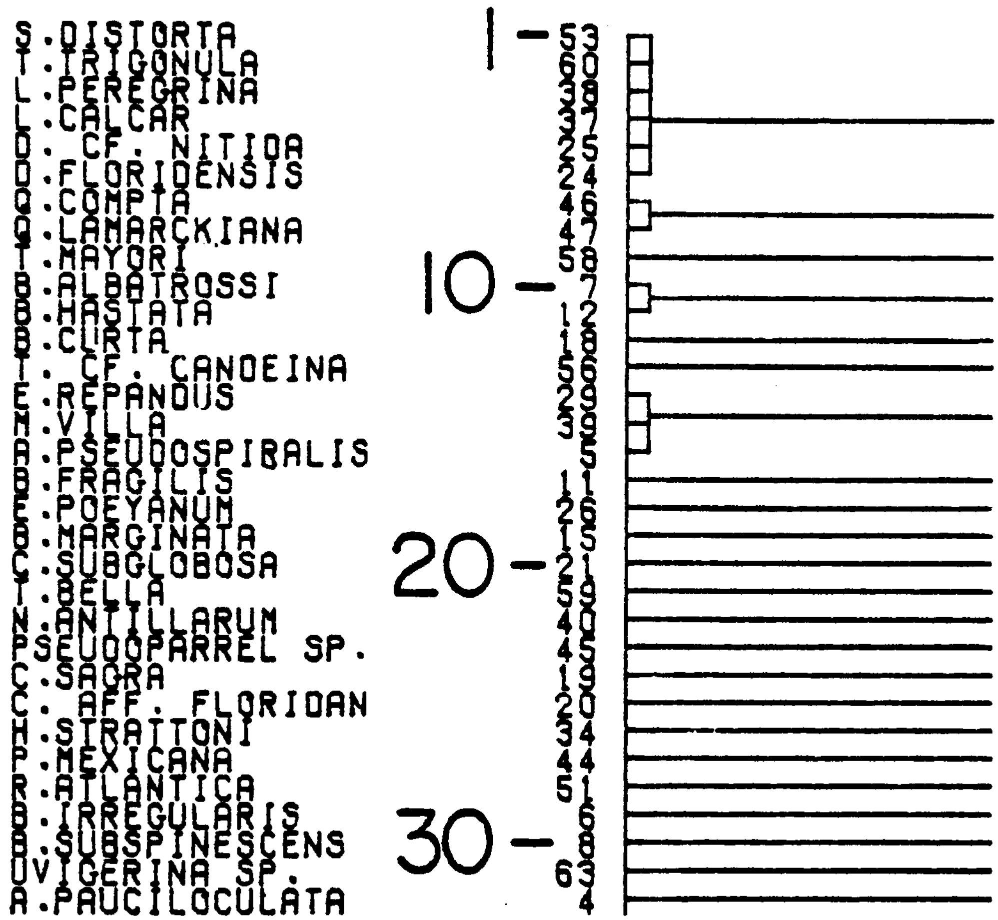
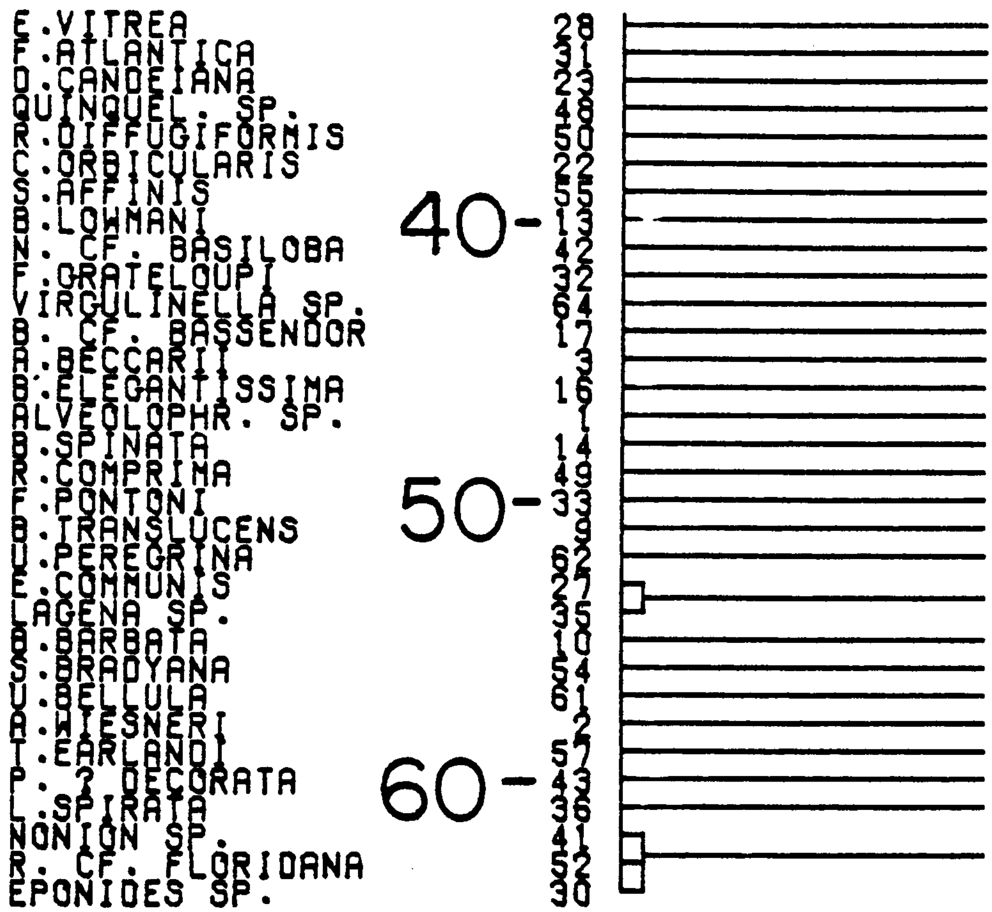


Figure 68. Key Continued.



and secondarily by seasonality. Correlating this dendrogram with information on the average number of benthonic foraminiferans/10 cm^2 for species indicative of depth, latitude, seasonality and combinations thereof (Table 5), the following conclusions were drawn. Depth appeared to be the dominant factor controlling the distribution of benthonic foraminiferans in the STOCS study area. Nearshore forms showed a greater seasonality than mid or outer-shelf forms. Mid and outer-shelf forms generally occurred in inner-shelf samples and were designated as mid or outer-shelf forms primarily because standing crops were maintained in deeper waters whereas forms designated more nearshore decreased in standing crop.

The dominant nearshore (Station 1) species were *Ammonia beccarii, Bulliminella elegantissima, Florilus grateloupi, Nonionella* cf. *basiloba, Bulliminella* cf. *bassendorfensis, Virgulinella* sp. and *Quinqueloculina* sp. *Ammonia becarrii* and *Bulliminella elegantissima* were dominant along northern transects (I and II) with *A. becarrii* dominating in the winter and *B. elegantissima* in the spring (Table 5). In Figure 68 these nearshore species (except for *Quinqueloculina* which is composed of four rare, but separate species) comprise the cluster labeled NS (nearshore). This cluster was subdivided into three subclusters, NOWS, SP and NO. The NOWS cluster (northern-winter-summer) was composed of *B. lowmani* and *N. basiloba* which, respectively, were indicative of winter and summer conditions at the nearshore, northern stations. *F. grateloupe* and *Virgulinella* sp. were indicative of nearshore spring and were labeled as an SP subcluster of the larger NS cluster. The last NS subcluster, NO (northern) was composed of *A. beccarii* and *B. elegantissima*. Immediately below the NS cluster on Figure 68 is a cluster labeled MOS which was attached to the NS cluster at a low level of similarity. This MOS

TABLE 5

AVERAGE NUMBER OF BENTHONIC FORAMINIFERANS/10 cm^2 FOR SPECIES INDICATIVE OF DEPTH (NEARSHORE, MID-SHELF OR OUTER SHELF), LATITUDE (NORTH = TRANSECTS I AND II, SOUTH = TRANSECTS III AND IV), SEASONALITY (WINTER, SPRING, SUMMER-FALL) OR COMBINATIONS OF ANY OF THESE PARAMETERS

SPECIES	STATIONS 1	2	3	NORTH	SOUTH	WINTER	SPRING	SUMMER
NEARSHORE								
(North-Winter)								
Ammonia beccarii	7.05	1.01	0	4.78	.69	7.63	.79	.22
(North-Spring)								
Bulliminella elegantissima	5.69	.58	.15	4.11	.17	2.08	4.18	.15
(Spring)								
Florilus grateloupi	2.38	.53	0	1.35	.58	.35	2.05	.51
(Summer)								
Nonionella cf. *basiloba*	5.18	.90	.03	2.37	1.87	1.73	1.98	2.67
(Other Nearshore)								
Buliminella cf. *bassendorfensis*	2.08	.46	.18	1.49	.43	.80	.90	1.18
Virgulinella sp.	2.05	0	0	1.26	.12	.18	1.23	.65
Quinqueloculina sp.	.66	.18	0	.06	.38	.26	.58	0
NEARSHORE TO MID-SHELF								
(North-Winter)								
Brizalina lowmani	13.55	10.58	.50	13.03	3.14	16.47	5.46	2.08
MID-SHELF								
Fursenkoina pontoni	.14	2.52	.18	1.06	.83	1.22	.71	1.43
MID-SHELF TO OUTER SHELF								
Brizalina spinata	.11	.49	.58	.57	.22	.78	.28	.13
Bulimina marginata	.05	.16	.11	.15	.08	.17	.03	.03
OUTER SHELF								
Uvigerina peregrina	0	0	.16	.05	.11	.09	0	.08

cluster was composed of two subclusters, M and MO. The MO subcluster was composed of the mid- and outer-shelf species *Alveolophragnium* sp. and *B. spinata,* and the M subcluster was composed of the mid-shelf species *Fursenkoina pontoni* and *Reophax comprima.* Immediately below this cluster was the OSI (outer shelf, Transect I) cluster composed of the outer-shelf species *Uvigerina peregrina* and *Bolivina translucens* (Table 5). The above-named clusters were the most diagnostic. Other clusters on Figure 68 were: NSIVSP (nearshore- Transect IV-spring); NSIW (nearshore-Transect I-winter); NSII (nearshore-Transect II); MSSPIV (mid-shelf-spring-Transect IV); OSIWSP (outer-shelf-Transect I-winter-spring); NSSP (nearshore-spring); MSW (mid-shelf-winter); NSMSP (near-shore-mid-shelf-spring); S2/II (summer-Station 2-Transect II); OSII (outer-shelf-Transect II); and, MSWI (mid-shelf-winter-Transect I). Most of these clusters appeared to cluster as to season and transect due to few but common species occurrences.

In relating the benthonic foraminiferan studies to geological studies of Berryhill et al. (1976), a good relationship between sediment type and benthonic foraminiferan distribution was not evident. However, at the Fifth BLM-STOCS Quarterly Conference (April 1977) Berryhill suggested that: the major sediment depocenter was in the northern sector mid-shelf; that little current sedimentation was occurring south of 26° north on the shelf; that perhaps a convergence existed which divided the shelf into north and south components; and perhaps internal waves were important in this division of the South Texas Outer Continental Shelf into these geologically (and biologically and physically) northern and southern components. We suggest that the major break in the foraminiferal faunas at 60-to 70-m depth is related to the shallowest common incursion of offshore waters (Phleger, 1956 stated a similar conclusion), or to distribution of the nepheloid layer (which might be related to internal waves stirring the bottom), and that the north-south differences in communities (and standing crops) might well be related to a South Texas Shelf Convergence along Transect III.

Down Core Studies

Approximately 200 samples were taken from the USGS gravity cores 12, 38, 42, 70, 81, 82, 88, 95, 114, 115, 157, 160, 176, 193, 214, 241 and 256 (see Figure 69 and Table 6 for locations) were sampled at 20-cm intervals in amounts of approximately 27 cc each. Seven of the cores proved worthy of micropaleontological analysis (cores 70, 95, 114, 115, 157, 88 and 256) and were processed for microfossils. For taxonomic work, the sample was processed by washing through a 63 μm screen. Counts and species identifications were made using a reflected light microscope at magnification to 120X.

Four gravity cores were used for paleomagnetic studies (cores 70, 42, 95 and 115). These cores were sampled with paleomagnetic boxes at 20-cm intervals. Because of their relatively low magnetic intensities (10^{-4} to 10^{-5} emu), these samples were studied using the cryogenic magnetometer at the University of Texas, Marine Science Institute, Galveston Geophysical Laboratory. Samples were taken from the middle of the core to avoid contamination and possible man-made "reworking" due to the coring process. Each sample was marked to indicate core orientation. Normal remnant magnetization (NRM) was determined for the horizontal and vertical components of each sample. Secondary viscous components were satisfactorily removed by alternation field demagnetization to 200 oersteds. From these data, the total intensity, inclination, and declination of each sample was derived.

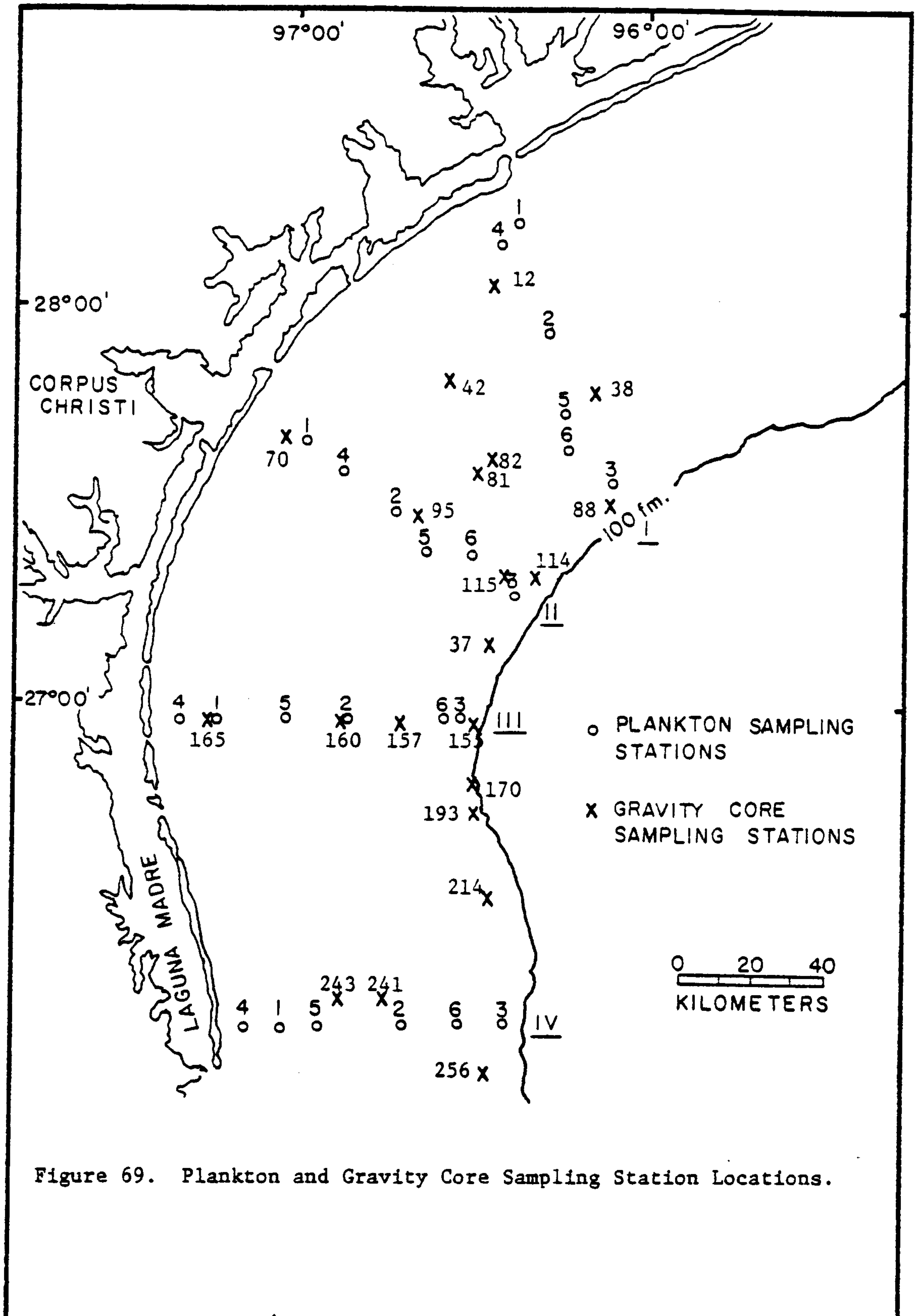


Figure 69. Plankton and Gravity Core Sampling Station Locations.

TABLE 6

LATITUDES AND LONGITUDES OF CORE SAMPLING LOCATIONS
FROM U.S. GEOLOGICAL SURVEY SAMPLES

Sample Number	Latitude	Longitude
12	28°05'30"	96°26'15"
38	27°49'28"	96°11'58"
42	27°50'00"	96°35'30"
70	27°39'58"	96°59'08"
81	27°33'38"	96°28'56"
82	27°35'04"	96°26'59"
88	27°28'45"	96°06'35"
95	27°29'13"	96°41'38"
114	27°18'29"	96°18'17"
115	27°18'34"	96°24'13"
157	26°57'52"	96°39'12"
160	26°58'00"	96°47'57"
176	26°47'21"	96°27'37"
193	26°42'02"	96°27'55"
214	26°31'39"	96°25'10"
241	26°16'06"	96°24'50"
256	26°05'17"	96°22'90"

Three cores were useful for a study of shelf history (U.S.G.S. cores 88, 115 and 256). Following the technique of Kennett and Huddleston (1972), attempts were made to biostratigraphically date the cores, and to determine the paleotemperature (related to time) of one of the cores. The abundant occurrences of the *Globorotalia menardii* complex, *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens* (all or any) were used to designate warm water conditions (interglacial) cold water (glacial) conditions were indicated by *Globigerina bulloides* and *G. falconensis* in the absence of or with few warm forms. A marginally warm interval was indicated by *Globorotalia truncatulinoids* and *Globigerinoides sacculifer*. Core OCS-GC 88 was the best for determining a relative paleotemperature curve using the above-mentioned criteria (Figure 70).

Ericson and Wollin (1956, 1968), for the tropical and subtropical Atlantic, and Kenneth and Huddlestun (1972), for the Gulf of Mexico, utilized a semi-quantitative evaluation of the relative abundance of the *Globorotalia menardii* complex to develop a sequence of zones designated Q-Z in order of decreasing age. These zones represented alternating warm and cold intervals and were supported by oxygen isotope curves. Of interest were zones Z, Y and X which apparently were represented in at least a few of the South Texas Shelf cores. The age of the Z-Y boundary was the Holocene-Pleistocene boundary (about 10,000 to 11,000 ybp), and the Y-X boundary was most likely a datum within the Pleistocene designating the base of the last glacial (about 90,000 to 95,000 ybp). Core OCS-GC 88 (Figure 70) penetrated to the X zone and was about 10,000 years between 40 and 60 cm and 90,000 years between 140 and 160 cm. This core was composed of lightly bioturbated mud

DEPTH IN CORE IN CM.	PLANKTONIC FORAMINIFERA: WARM: G. MENARDII	P. OBLIQUELOCULATA	S. DEHISCENS	MARG. WARM: G. TRUNCATULINOIDES	G. SACCULIFER	COLD: G. INFLATA	G. FALCONENSIS	G. BULLOIDES	G. DIGITATA	PALEOTEMPERATURES (COLD – WARM)	BIOSTRATIGRAPHIC ZONES KENNET AND HUDDLESTUN TECHNIQUE MODIFIED	BENTHONIC FORAMINIFERA (DEEPER →): A. BECCARII	B. LOWMANI	BULIMINELLA	N. BASILOBA	FURSENLOINA	SIPHONINA	CIBICIDES	EPONIDES	BRIZALINA (OTHER THAN LOWMANI)	U. PEREGRINA	OTHER: BRYOZOANS ABUNDANT	ABUNDANT SHELL DEBRIS	ECHINOID SPINES	DEPTH OF DEP. (INNER TO MID SHELF – OUTER SHELF)	BENTHONIC FORAM./PLANKTONIC FORAM.
0-3	X	X	X	X	X						Z	R	R	R	R	R	C	A	R	C	C					40/60
20-23	X	X	X	X	X							R	R	R	R	R	C	A	R	A	C					50/50
40-43	X	X	X	X	X							R	R-C	R	R	R	C-R	C	R	A	C-R					50/50
60-63	R	X		X							Y	R	R-C	R	R-C	R-C	R	C	R-C	C	R	X				60/40
80-83	R	R		X	X							R-C	C	R-C	R-C	R-C	R	C	R-C	C-R	R	X				70/30
100-103	R	X		X	X							C	C	R-C	C	C-R	R	C-R	C	C-R	R	X	X			80/20
120-123				X			X	X				C-R	C	R-C	C	C-R	R	C-R	C-R	C-R	R		X	X		90/10
140-143				X		X	X	X				C	C	C	C-R	C	R	R-C	C-R	C	R			X		95/5
160-163	X	X		X							X	R	R-C	R	R	R	A	A	R	A	C					50/50

FIGURE 70 Biostratigraphy, paleotemperatures and paleodepths determined from planktonic foraminiferans, benthonic foraminiferans and other organisms. X = present, R = rare (or less than 1 % in the case of the benthonic foraminiferans), C = common (about 5 % of the benthonic foraminiferans), A = abundant (about 10 % or more of the benthonic foraminiferans). For core OCS-GC 88.

(Berryhill _et al._, 1976), with shell remains in the interval designated herein as the Y zone. Rates of sedimentation for the Holocene portion (Z zone) were about 4 cm/1000 yrs and about 1 cm/1000 yrs for the period representing the last glacial (Y zone). Core OCG-GC 115 (Figure 71) did not penetrate the Z zone; therefore, a minimum sedimentation rate of about 15 cm/1000 yrs was indicated. Core OCS-GC 256 (Figure 72) represented the slowest sedimentation rates of the three cores with rates of about 3 cm/1000 yrs for the Holocene, 0.6 cm/1000 yrs for the last glacial (Y zone), and an unknown amount for the X zone.

These cores were on the outer shelf and were below sea level during the times represented in the cored intervals. The Y zone was "compressed" in relation to the Z zone due to a drop in sea level at this time (Y time), resulting in slow rates of deposition and probably erosion. Shell remains of macroinvertebrates were noted in the Y interval of core OCS-GC 88 (Berryhill _et al._, 1976), and shell hash (of macroinvertebrates) and terrigenous sands were noted in the Y interval in core OCS-GS 256. The shell hashes most likely represented a scouring and reworking of sediments during the lowering of sea level. Also during this lowering in sea level, shallow water foraminiferans invaded the region of core OCS-GC 88 (Figure 70).

Samples from cores 42, 70, 95, and 115 were taken to determine paleomagnetism (Table 7). Figures 73, 74, 75 and 76 give the average total intensity, inclination and declination for the samples of each core.

Inshore areas are more affected by sedimentation rates and types than offshore regions. There is a great volume of sediment being carried into the Gulf from a system of several major rivers by a counter-

DEPTH IN CORE IN CM.	WARM: G. MENARDII	WARM: P. OBLIQUELOCULATA	WARM: S. DEHISCENS	MARG. WARM: G. TRUNCATULINOIDES	MARG. WARM: G. SACCULIFER	COLD: G. INFLATA	COLD: G. FALCONENSIS	COLD: G. BULLOIDES	COLD: G. DIGITATA	PALEOTEMPERATURES (COLD / WARM)	BIOSTRATIGRAPHIC ZONES KENNETT AND HUDDLESTUN
0-3	X	X									Z
20-23	X	X									
40-43	X	X		X							
60-63	X	X		X							
80-83	X	X		X							Z
100-103	X	X		X							
120-123	X	X		X							
140-143	X	X		X							Z
150-153	X	X		X							

FIGURE 71 Biostratigraphy and paleotemperatures for core OCS-GC 115. (X = common)

DEPTH IN CORE IN CM.	WARM: G. MENARDII	WARM: P. OBLIQUELOCULATA	WARM: S. DEHISCENS	MARG. WARM: G. TRUNCATULINOIDES	MARG. WARM: G. SACCULIFER	COLD: G. INFLATA	COLD: G. FALCONENSIS	COLD: G. BULLOIDES	COLD: G. DIGITATA	PALEOTEMPERATURES (COLD / WARM)	BIOSTRATIGRAPHIC ZONES KENNETT AND HUSSIESTUN
0-3	X	X		X							Z
20-23		X		X							
40-43	R	R		X				X			Y
80-83				X	X			X			
100-103	X	X		X							
120-123	X	X		X							X
130-133	X	X		X							

FIGURE 72 Biostratigraphy and paleotemperatures for core OCS-GC 256. (X=common; R = rare)

TABLE 7

PALEOMAGNETIC DATA FOR CORE SAMPLES

CORE NUMBER	DEPTH OF INTERVAL	MOMENT	DECLINATION	INCLINATION
Normal Remnant Magnetization				
70	0-3 cm	.08035	355.7108	8.8561
70	20-23 cm	.16305	14.95735	-13.38665
70	40-43 cm	1.138	32.7026	3.793
70	60-63 cm	1.0159	20.2484	-36.9571
70	80-83 cm	4.276	45.1398	-18.7504
70	100-103 cm	1.6745	15.1114	-6.49775
70	120-123 cm	1.15865	334.273	-42.377775
70	140-143 cm	3.3032	315.00269	-50.78803
70	160-163 cm	2.92675	254.8958	-55.4293
Demagnetization @ 200 Oersteds				
70	0-3 cm	.3969	270.4275	40.3485
70	20-23 cm	.19635	305.9309	22.4469
70	40-43 cm	.2699	19.91195	-14.64195
70	60-63 cm	.36455	21.6829	-8.99545
70	80-83 cm	1.58455	64.15955	-22.7132
70	100-103 cm	.8068	352.53901	-17.3415
70	120-123 cm	.677	327.4829	-84.2209
70	140-143 cm	2.0652	309.3628	-38.85085
70	160-163 cm	1.71465	289.66535	-33.53465
Normal Remnant Magnetization				
42	3-6 cm	3.46475	91.8468	-12.1225
42	18-20 cm	1.82335	176.8289	73.27005
42	21.5-23 cm	2.6057	118.5031	-37.90466
42	41-43 cm	2.3824	39.80957	41.4856
42	53-55 cm	2.19175	83.73338	-3.6475
42	57-59 cm	2.2894	139.4006	27.1527
42	80-82 cm	.44515	205.44885	17.4495
42	87-89 cm	2.73885	229.48545	50.06025
42	97-99 cm	4.1847	193.15028	15.38203
Demagnetization @ 200 Oersteds				
42	3-6 cm	1.15845	92.338	-23.7426
42	18-20 cm	1.2568	244.64495	60.76475
42	21.5-23 cm	.60425	183.95395	-8.928
42	41-43 cm	.8955	200.14945	81.29845
42	53-55 cm	.28635	156.8979	10.68766
42	57-59 cm	.8520	190.17385	37.2666
42	80-82 cm	.26815	248.92055	10.5488
42	87-89 cm	1.30435	256.8795	35.4209
42	97-99 cm	2.4347	221.0759	15.91125
42	100-102 cm	1.52216	287.8149	68.080405

TABLE 7 CONT.'D

CORE NUMBER	DEPTH OF INTERVAL	MOMENT	DECLINATION	INCLINATION
Normal Remnant Magnetization				
95	0-3 cm	6.3492	3.1742	56.91415
95	20-23 cm	1.12	94.7042	-79.7415
95	40-43 cm	7.5943	90.9866	46.7539
95	60-63 cm	3.0845	12.91545	21.71885
95	80-83 cm	9.3953	24.80105	37.9431
95	100-103 cm	4.77045	112.50855	57.9884
95	120-123 cm	8.6353	86.72875	54.66175
95	140-143 cm	3.66355	47.156	28.58565
95	160-163 cm	9.04175	86.46925	64.3937
Demagnetization @ 200 Oersteds				
95	0-3 cm	4.792	29.8994	48.62175
95	20-23 cm	2.9904	316.6232	-69.1731
95	40-43 cm	3.27745	68.81915	70.76065
95	60-63 cm	1.37445	326.0891	50.45025
95	80-83 cm	4.3092	33.88965	43.70185
95	100-103 cm	2.9699	101.3507	74.0262
95	120-123 cm	3.68335	94.97115	67.4188
95	140-143 cm	.9071	44.26505	40.40025
95	160-163 cm	4.7032	137.75225	77.06315
Normal Remnant Magnetization				
115	0-3 cm	15.1637	168.13515	50.2882
115	20-23 cm	15.9424	158.0736	54.4572
115	40-43 cm	13.7912	166.10035	43.23275
115	60-63 cm	17.9213	129.45615	29.90155
115	80-83 cm	19.69505	157.66955	38.3868
115	100-103 cm	12.56223	153.6257	34.0528
115	120-123 cm	15.63565	164.4835	46.3392
115	140-143 cm	12.2921	179.9599	61.78345
Demagnetization @ 200 Oersteds				
115	0-3 cm	9.78845	178.2757	45.24625
115	20-23 cm	9.11985	163.6845	52.55335
115	40-43 cm	8.6764	170.462	40.4834
115	60-63 cm	7.1379	155.7715	36.5499
115	80-83 cm	11.2735	163.02185	33.24255
115	100-103 cm	8.5443	168.7363	36.8625
115	120-123 cm	8.9953	186.52135	39.24065
115	140-143 cm	4.1704	272.68805	50.85265

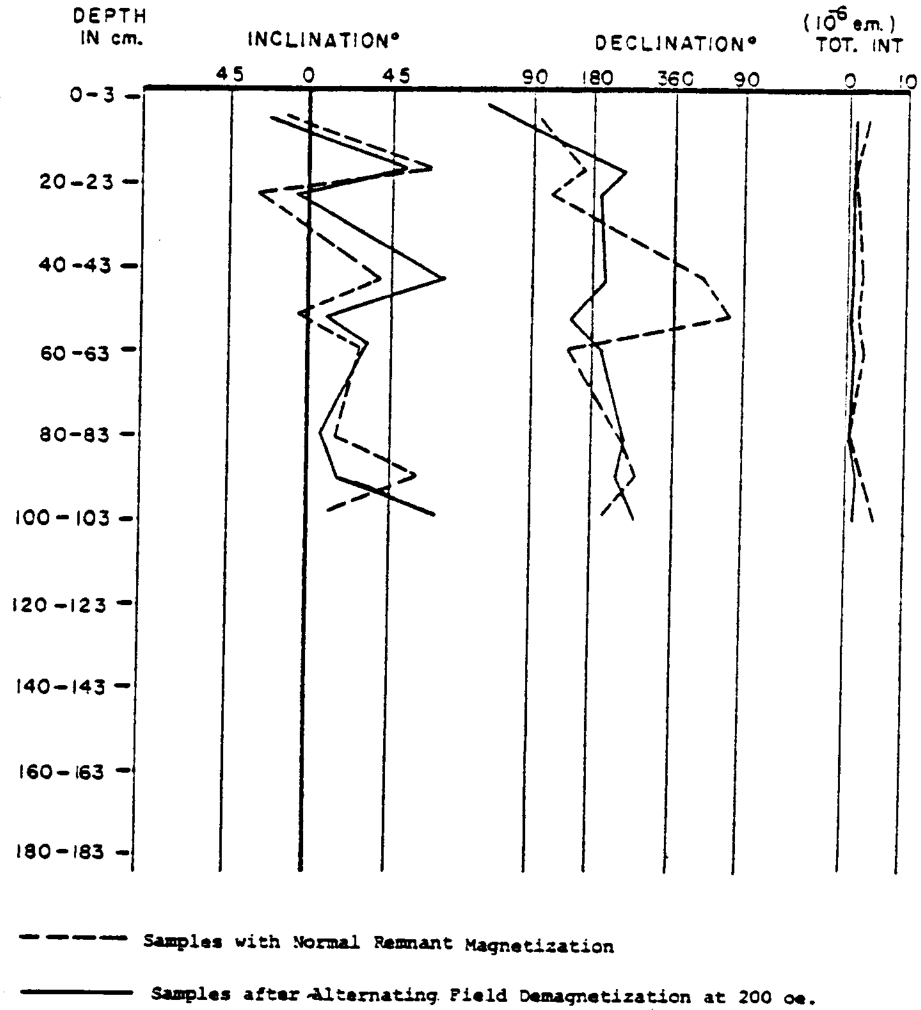
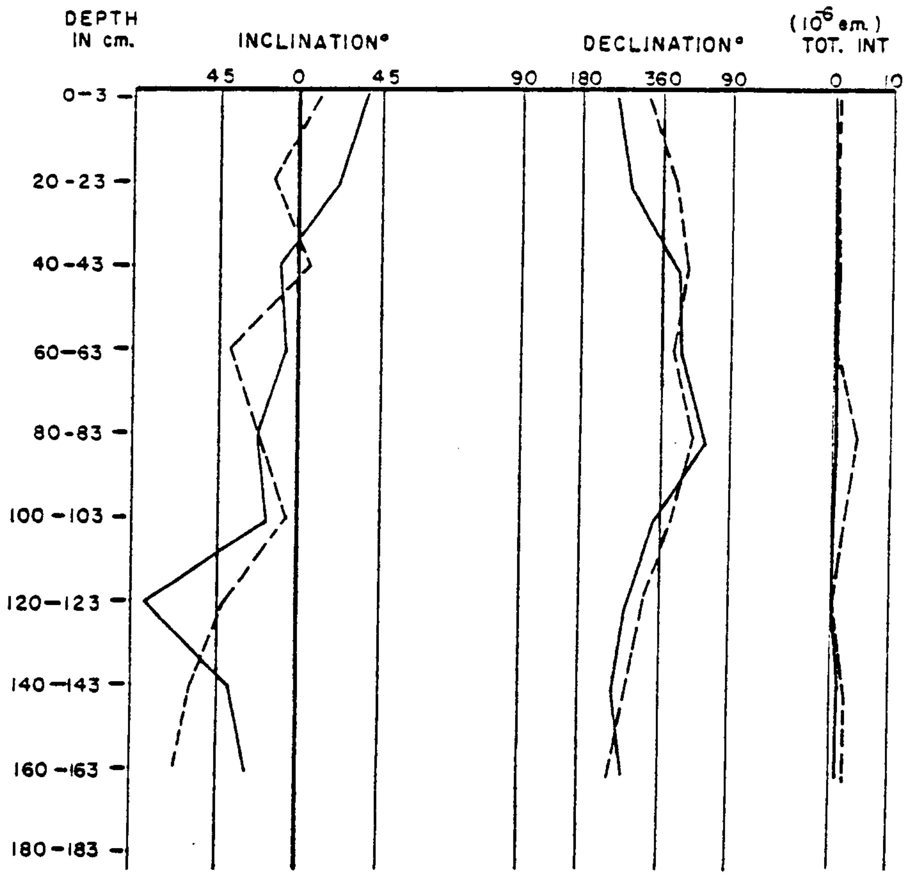


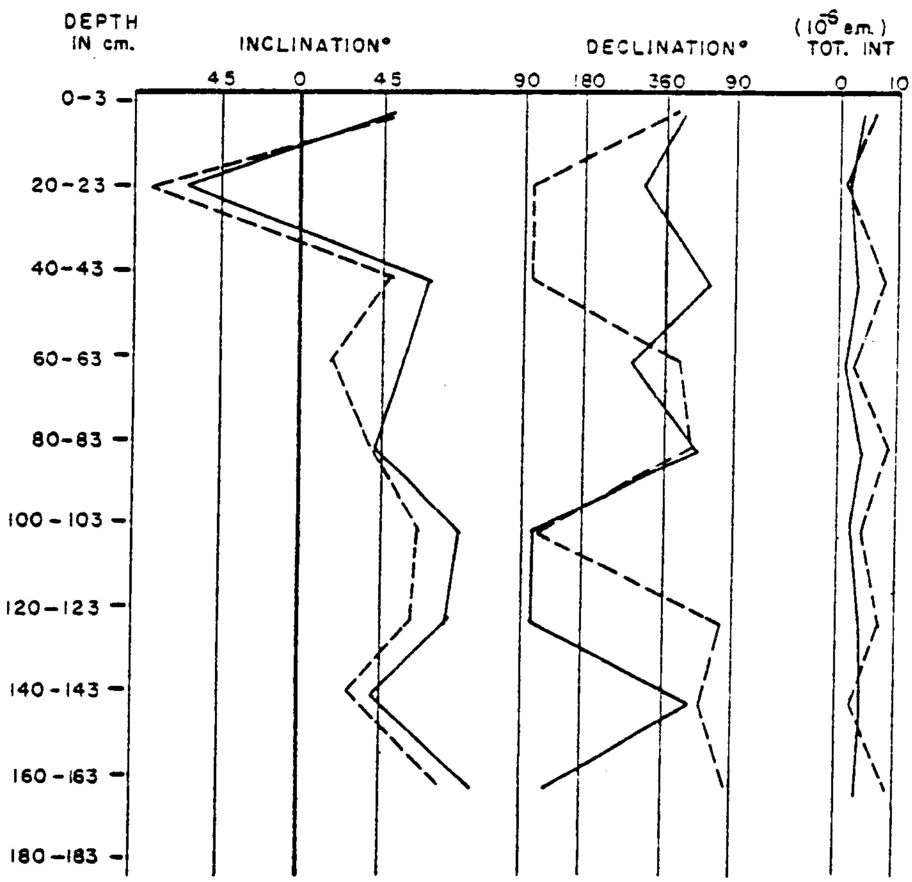
Figure 73. Average Total Intensity, Inclination and Declination Per Sample at Depth for OCS-GS Core No. 42.



――――― Samples with Normal Remnant Magnetization

――――― Samples after Alternating Field Demagnetization at 200 oe.

Figure 74. Average Total Intensity, Inclination and Declination per Sample at Depth for OCS-GS Core No. 70.



Samples with Normal Remnant Magnetization

Samples after Alternating Field Demagnetization at 200 oe.

Figure 75. Average Total Intensity, Inclination and Declination per Sample at Depth for OCS-GS Core No. 95.

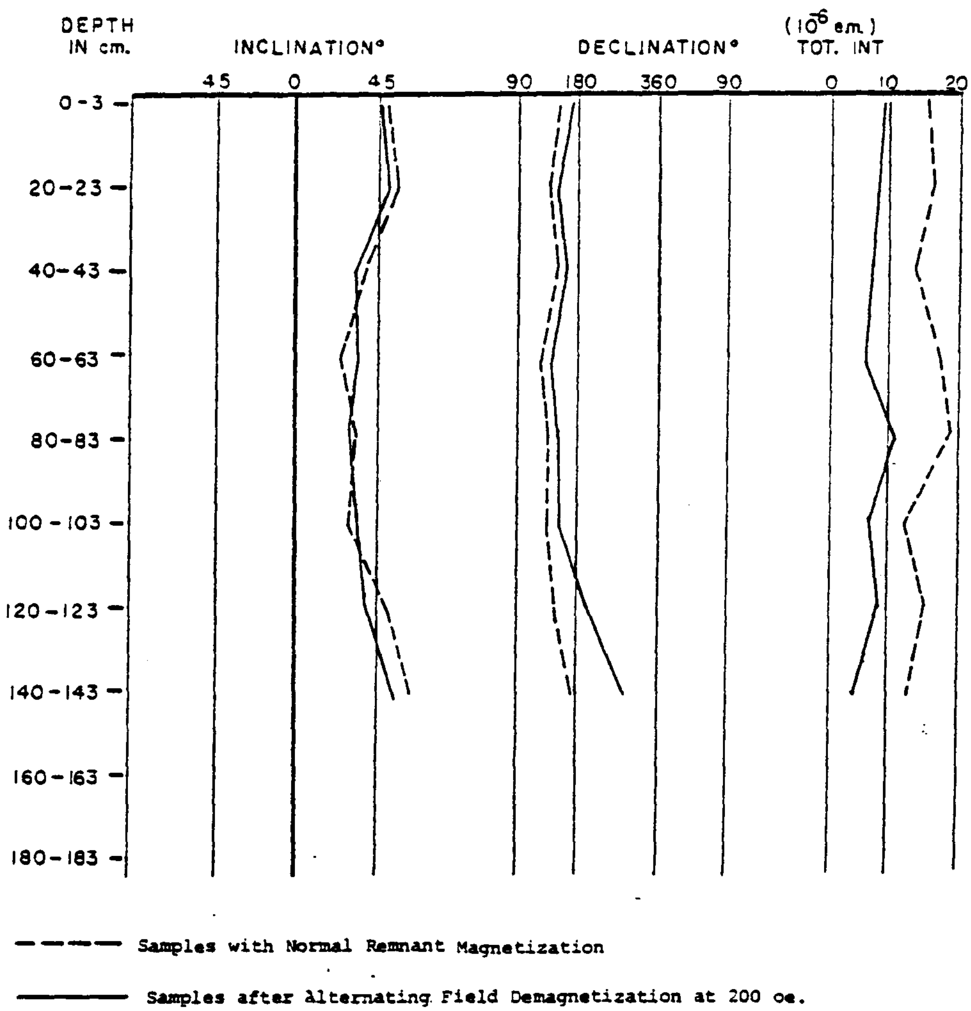


Figure 76. Average Total Intensity, Inclination and Declination per Sample at Depth for OCS-GS Core No. 115.

clockwise current. These factors make the northwest Gulf of Mexico a clastic reservoir. In this case, the absence of polar reversals at the outer shelf locations is perhaps just as significant as the large number of reversals at the inshore stations. Considering that the inclinations depicted in Figure 74 are true indications of normal remnant magnetizations, then the reversals of Core 70 could indicate a high rate of sedimentation in a magnetic-reversed field. Core 115 was normal as would be expected from the biostratigraphy (Figure 71). Cores 42 and 95 may represent transitional phases between an area of high or no deposition on the shelf, with respect to a particular time interval. Sedimentation varies proportionately to position on the shelf. There is a sand-sized fraction increase toward shore, indicating a higher shoreward energy regime. Core 115 was at a location dominated mainly by clay deposition, representative of biogenous pelagic sedimentation and suspended sediment influx. This homogeneous clay occurred only at the outer shelf edge. Also, sedimentation rate can be a controlling factor in compression, diagenesis, and lithification of sediments, all of which control the degree of magnetic orientation. Areas of high sedimentation rates may show anomalous magnetic inclinations. A wide range of paleoenvironments may be represented by this different sedimentation. In the analyses reported herein, a lack of polar reversals is just as significant as their presence.

LITERATURE CITED

Anepohl, J. K. 1976. Seasonal distribution of living benthonic Foraminifera of the South Texas Outer Continental Shelf. M. A. thesis. Univ. of Texas at Austin, Austin, Texas. 130 pp.

Armstrong, R. S., and J. R. Grady. 1968. The late-summer waters of the Gulf of Mexico. Comml. Fish. Rev. 30:56-60.

Bauer, M. A. 1976. Ecology and distribution of living planktonic Foraminifera, South Texas Outer Continental Shelf. M. A. thesis. Rice Univ., Houston, Texas. 125 pp.

Be, A. W. H. 1960. Ecology of recent planktonic Foraminifera: Part II bathymetric and seasonal distributions in the Sargasso Sea off Bermuda. Micropaleontology. 6:373-392.

Beers, J.R., F. M. H. Reid, and G. L. Stewart. 1975. Microplankton of the North Pacific central gyre, population structure and abundance, June 1973. Int. Rev. ges. Hydrobiol. 60:607-638.

________., and G. L. Stewart. 1967. Micro-zooplankton in the euphotic zone at five locations across the California current. J. Fish. res. Bd. Canada. 24:2053-2068.

___________. 1969a. Micro-zocplankton and its abundance relative to the larger zooplankton and other seston components. Mar. Biol. 4:182-189.

___________. 1969b. The vertical distribution of micro-zooplankton and some ecological observations. J. Cons. perm. int. Explor. Mer 33:30-44.

___________. 1970. The preservation of acantharians in fixed plankton samples. Limnol. Oceanogr. 15:825-827.

___________. 1971. Micro-zooplankters in the plankton communities of the upper waters of the eastern tropical Pacific. Deep Sea Res. 18:861-883.

Berger, W. H. 1969. Ecological patterns of living planktonic Foraminifera. Deep Sea Res. 16:1-24.

Berryhill, H. L., Jr., G. L. Shideler, C. W. Holmes, G. W. Hill, S. S. Barnes, and R. G. Martin, Jr. 1976. Environmental assessment of the South Texas Outer Continental Shelf-geologic investigations. Submitted to the Bureau of Land Management. Washington, D. C. 273 pp. (Draft)

Burkenroad, M. D. 1933. Pteropods from Louisiana. Nautilus 47:54-57.

Casey, R. E. 1966. A seasonal study on the distribution of polycyctine radiolarians from waters overlying the Catalina Basin, southern California. Ph. D. Dissertation. Univ. of Southern California, Los Angeles, California. 137 pp.

________. 1971a. Distribution of polycystine radiolarians in the oceans in relation to physical and chemical conditions. Pages 151-159 *in* B. M. Funnel and W. R. Riedel, eds. The micropalaeontology of oceans. Cambridge Univ. Press, Cambridge.

________. 1976a. Shelled microzooplankton and microzoobenthos. Pages 183-228 *in* Third quarterly report for 1976 of the chemical and biological survey component of the environmental assessment of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management, Washington, D. C. Contract No. AA550-CT6-17.

________. 1976b. Microzooplankton and microzoobenthos project. Pages 82-153 *in* P. L. Parker ed. Environmental assessment of the South Texas Outer Continental Shelf, chemical and biological survey component. Submitted to the Bureau of Land Management. Washington, d. C. Contract No. AA550-CT6-17.

________. 1977. Microzooplankton and microzoobenthos project. Pages 215-244 *in* Fourth quarterly report, environmental studies, South Texas Outer Continental Shelf, biology and chemistry. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. In press. The ecology and distribution of recent Radiolaria. *in* T. S. Ramsay, ed. Oceanic micropalaeontology. Academic Press, London.

________, and M. A. Bauer. 1976. A seasonal study of Radiolaria and Foraminifera in the waters overlying the South Texas Outer Continental Shelf. Abstr. Prog. Geol. Soc. Am. 8:11. (Abstr.)

________, and K. J. McMillen. In press. Cenozoic radiolarians of the Atlantic basin and margins. *in* F. Swain, ed. Stratigraphic micropaleontology of the Atlantic basin and borderlands.

____________, and M. A. Bauer. 1975. Evidence for and paleo-oceanographic significance of relict radiolarian populations in the Gulf of Mexico and Caribbean. Abstr. Prog. Geol. Soc. Am. 7:1022-1023. (Abstr.)

Chen, C., and N. S. Hillman. 1970. Shell-bearing pteropods as indicators of water masses off Cape Hatteras, North Carolina. Bull. Mar. Sci. 2:250-267.

Cifelli, R. 1965. Planktonic Foraminifera from the North Atlantic. Smithsonian Misc. Colln. 148:1-36.

________. 1974. Planktonic Foraminifera from the Mediterranean and adjacent Atlantic water (Cruise 49 of the Atlantic II, 1969). J. Foram. Res. 4:171-183.

Ericson, D. B., and G. Wollin. 1956. Correlation of six cores from the equatorial Atlantic and the Caribbean. Deep Sea Res. 3:104-125.

___________. 1968. Pleistocene climates and chronology in deep-sea sediments. Science 162:1227-1234.

Fager, W. W., and J. A. McGown. 1963. Zooplankton species groups in the North Pacific. Science 140:453-460.

Haeckel, E. 1887. Report on the Radiolaria collected by H. M. S. CHALLENGER during the years 1873-1876. Chall. Rep., Zool. 18.

Herman, Y., and P. E. Rosenberg. 1969. Pteropods as bathymetric indicators. Mar. Geol. 7:169-173.

Hida, T. S. 1957. Chaetognaths and pteropods as biological indicators in the North Pacific. U. S. Fish. Wildl. Serv., Spec Sci. Rep. Fish. 215:1-13.

Hughes, W. A. 1968. The thecosomatous pteropods of the Gulf of Mexico. M. S. thesis. Texas A & M Univ., College Station, Texas. 59 pp.

Jones, J. I. 1968. The relationship of planktonic foraminiferal populations to water masses in the western Caribbean and lower Gulf of Mexico. Bull. Mar. Sci. 18:946-982.

Kamykowski, D. L., C. van Baalen, and W. M. Pulich. 1976. Phytoplankton and productivity. Pages 159-182 *in* Third quarterly report for 1976 of the chemical and biological survey component of the environmental assessment of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

___________. 1977. Phytoplankton and productivity. Pages 189-214 *in* Fourth quarterly report, environmental studies, South Texas Outer Continental Shelf, biology and chemistry. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

Kennett, J. P., and P. Huddlestun, 1972. Late Pleistocene paleoclimatology, foraminiferal biostratigraphy and tephrochronology, western Gulf of Mexico. Quatern. Res. 2:38-69.

McGowan. J. A. 1960. The systematics, distribution, and abundance of Euthecosomata of the North Pacific. Ph. D. Dissertation. Univ. of California, San Diego, La Jolla, California. 197 pp.

________. 1967. Distributional atlas of pelagic molluscs in the California current region. CALCOFI Atlas. 6:1-218.

McMillen, K. J. 1976. Ecology, distribution, and preservation of polycystine Radiolaria in the Gulf of Mexico and Caribbean Sea. Ph. D. Dissertation. Rice Univ., Houston, Texas. 121 pp.

________., and R. E. Casey. In press. Distribution of living polycystine radiolarians in the Gulf of Mexico and Caribbean Sea, and comparison with the sedimentary record. Mar. Micropaleontol.

Murray, J. W. 1973. Distribution and exology of living benthonic foraminiferids. Crane, Russak and Co., Inc., New York. 274 pp.

Park, E. T. 1976a. Zooplankton. Pages 161-174 *in* Second quarterly report for 1976 of the chemical and biological survey component of the environmental assessment of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. 1976b. Zooplankton. Pages 229-246 *in* Third quarterly report for 1976 of the chemical and biological survey component of the environmental assessment of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. 1977. Zooplankton. Pages 245-285 *in* Fourth quarterly report, environmental studies, South Texas Outer Continental Shelf, biology and chemistry. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

Parker, F. L., F. S. Phleger, and J. F. Peirson. 1953. Ecology of Foraminifera from San Antonio Bay and environs, southwest Texas. Cushman Found. Foram. Res. Spec. Pub. No. 2.

Petrushevskaya, M. G. 1971. Spumellarian and nassellarian Radiolaria in the plankton and bottom sediments of the central Pacific. Pages 309-317 *in* B. M. Funnell and W. R. Riedel, eds. Micro-palaeontology of oceans. Cambridge Press.

Phleger, F. B. 1951. Ecology of Foraminifera, northwest Gulf of Mexico, Pt. 1, foraminiferal distribution. Geol. Soc. Am., Mem. 46:1-88.

________. 1956. Significance of living foraminiferal populations along the central Texas coast. Cont. Cushman Found. Foram. Res. 8:106-151.

Popofsky, A. 1907. Neue radiolarien der Deutschen Sudpolar Expedition. Zool. Anz. 31:698-705.

________. 1908. Die radiolarien der Antarcktis. Deutschen Sudpolar Expedition 1901-1903. 10:183-305.

________. 1912. Die sphaerellarien des warmwassergebeites. Deutschen Sudpolar Expedition 1901-1903. 13:73-159.

________. 1913. Dies nassellarien des warmwassergebeites. Deutschen Sudpolar Expedition 1901-1903. 14:217-416.

Renz, G. W. 1973. The distribution and ecology of Radiolaria in the central Pacific plankton and surface sediments. Ph. D. Dissertation. Univ. of California, San Diego, La Jolla, California. 251 pp.

Reshetnayak, V. V. 1955. Vertical distribution of the Radiolaria of the Kurilian-Kamchtka Deep. Tr. Zool., inat ANSSR. 21:94-101.

Schott, W. 1935. Die foraminiferen in den aquatorialen teil des Atlantischen Ozeans. Deutsche Atlantische Expedition II. Heft 6:411-616.

Smith, N. P. 1976a. Hydrography. Pages 19-39 *in* First quarterly report for 1976 of the chemical and biological survey component of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. 1976b. Hydrography. Pages 39-57 *in* Second quarterly report for 1976 of the chemical and biological survey component of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. 1976c. Hydrography. Pages 53-75 *in* Third quarterly report for 1976 of the chemical and biological survey component of the South Texas Outer Continental Shelf. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

________. 1977. Hydrography. Pages 45-54 *in* Fourth quarterly report, environmental studies, South Texas Outer Continental Shelf, biology and chemistry. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

Snider, J. E. 1975. Quantitative distribution of shelled pteropods in the Gulf of Mexico including related sampling studies. Ph. D. Dissertation. Texas A & M Univ., College Station, Texas 205 pp.

Tresslar, R. C. 1974. The living benthonic foraminiferal fauna of the West Flower Garden Bank coral reef and biostrome. M. S. thesis. Texas A & M Univ., College Station, Texas. 205 pp.

Van Baalen, C. 1976. Phytoplankton and phytoplankton biomass. Pages 46-81 *in* P. L. Parker, ed. Environmental assessment of the South Texas Outer Continental Shelf, chemical and biological survey component. Submitted to the Bureau of Land Management. Washington, D. C. Contract No. AA550-CT6-17.

Wroblewski, J. S., and J. J. O'Brien. 1976. A spatial model of phytoplankotn patchiness. Mar. Biol. 35:161-175.

CHAPTER SIX

ZOOPLANKTON

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ABSTRACT

Reported herein are results of the second year (1976) efforts of the baseline zooplankton study of the South Texas Outer Continental Shelf initiated in October 1974. The study was based on zooplankton samples collected from four transects across the shelf, each transect consisting of three stations. The four transects were sampled during three seasons (winter, spring and summer) and one of the four transects (II) was also sampled during six intervening months to obtain a series of monthly samples.

Zooplankton abundance in terms of biomass and number displayed a considerable degree of spatial, as well as temporal variation, and these variations were progressively extensive from the deep to shallow stations. In general, the zooplankton showed a seaward decrease which was highly pronounced in the spring and summer months when the zooplankton usually increased to an annual maximum at Stations 1 and 2 and decreased to the lowest annual value at Station 3. Copepods were the most abundant group, comprising approximately 60 percent of the zooplankton by number. When the zooplankton increased in spring and summer, the relative abundance of copepods decreased, indicating that other organisms were increasing faster than copepods.

Numerically important groups besides copepods were Cladocera, Ostracoda, barnacle larvae, Mollusca, Chaetognatha and tunicates. The Cladocera and Ostracoda showed a highly restricted spatial distribution, occurring mainly at Stations 1 and 2, respectively. As expected, the occurrence of barnacle larvae was highly sporadic. Consisting mainly of veliger larvae, the molluscs were most abundant at shallow stations in spring and summer. Chaetognaths and tunicates occurred regularly throughout the study area the year round.

In contrast with the total zooplankton, the copepods did not show extensive seasonal variation. Approximately 75 percent of the copepods belonged to the Calanoida, with the remainder belonging mostly to the Cyclopoida. The relative abundance of calanoids increased in winter while that of cyclopoids increased in summer. Throughout the year, the development stages comprised nearly 50 percent of the total copepod population, indicating a sustained copepod reproduction the year round. A total of 168 species of adult female copepods was identified. The most abundant calanoid species were *Paracalanus indicus, Paracalanus quasimodo* and *Clausocalanus furcatus*. The first two species were abundant at shallow stations while the last was abundant at deep stations. The most abundant cyclopoid copepods were *Oncaea venusta, Oncaea mediterranea* and *Farranula gracilis*; the first was abundant throughout the area but the last two were abundant at offshore stations.

Species diversity indices and coefficients of equitability, based on adult female copepods, generally increased seaward in conformity to the number of species.

Of the other biological and physical data obtained at the time of zooplankton collection, salinity and chlorophyll a values seemed to be most closely correlated with the zooplankton. This correlation was most readily discernible in spring when the zooplankton was highly productive in low-salinity water.

INTRODUCTION

This report concerns results of the second year (1976) baseline studies of the zooplankton of the South Texas Outer Continental Shelf initiated in October 1974.

The study was initially designed to gain a general picture of the zooplankton community in terms of biomass, species composition and the relative abundance of each component taxon on the basis of three seasonal series of day and night samples. The first year efforts generated a large amount of data which disclosed most of the fundamental features of the community, such as species composition and overall abundance of each component species. However, distribution of zooplankton in the study area was deemed highly complex, and understanding this complexity required continued investigations.

Essentially, the second year effort was a repeat of the first year of study and designed to generate additional data for a better understanding of the zooplankton community and to determine community variability from year to year. During the second year, the four transects were studied on a seasonal basis as in the first year. To look closely at zooplankton variability, the study was expanded in the second year to investigate one of the four transects on a monthly basis. In light of the first year's experience, some sampling modifications were introduced. For example, since the whole water column was sampled by oblique hauls, no significant differences were found between day and night samples. Therefore, night sampling was eliminated during the second year. However, two replicate samples collected consecutively at each station during the first year sometimes differed from each other to such an extent that it was not possible to determine whether the differences were due to sampling error or distributional variability. Therefore, in the second year of study, three replicate samples were collected at each station and two comparable samples were selected for analysis.

The samples were analyzed according to the same procedures as in the first year, except that during the second year the Foraminifera and Radiolaria were included in complicance with the contract.

METHODS

Sampling

The study was based on zooplankton samples collected from 12 stations, three on each of four transects. All 12 stations were sampled during three seasonal sampling periods (January-February, May-June, and September). In addition to the seasonal sampling, the three Transect II stations were sampled during six monthly sampling periods (March, April, July, August, November and December). During each sampling, each station was occupied once and three replicate samples were taken. The sampling data, including depth, date, time of tow and volume of water filtered are shown in Table 1, Appendix D.

Standard 1-m NITEX nets of 233 μm mesh size were used. A digital flowmeter (Model 2030, GENERAL OCEANICS) was mounted centrally in the mouth of the net to determine the amount of water filtered in each tow, and a time-depth recorder (Model 1170-250, BENTHOS) was attached near the net to determine the maximum sampling depth. The water column was sampled from the surface to near-bottom by means of oblique tows of about 15-minute duration. During the tow, ship speed was maintained constant at about 2.5 knots. The volume of water filtered was calculated from flowmeter and tow duration data. As shown in Table 1, Appendix D, the amount of water filtered by the net during each tow varied between 131.5

and 1101.2 m^3. After the tow, the net was rinsed down using the deck hose. The contents of the cod-end were drained through a 100-μm NITEX net, transferred to a jar, and preserved with buffered formalin.

Sample Analysis

Two comparable samples were selected for analysis from the three replicate samples taken at each station according to the similarity in the amount of water filtered and in the settling volume of organisms. The samples were split with a FOLSOM plankton splitter to achieve adequate subsamples for archiving and analysis. The subsample size for biomass determination was adjusted to the capacity of the crucible to be used (50 ml). As the samples were variable in size, the subsample used for biomass determination ranged from 1/32 to 1/8 aliquot, depending on original sample size (Table 1, Appendix D).

For dry weight determination, subsamples were washed with tap water through tared, PYREX 50-ml filtering crucibles with fritted discs of 40- to 60-μm pore size. Suction filtration at 10-15 psi was used to expedite removal of interstitial water. The subsamples were dried in the crucibles at 55°C to a constant weight and the weight of the crucible plus sample was recorded to the nearest milligram. Ashing to a constant weight was accomplished in a muffle furnace (BLUE "M", Model M25A-1A) at 550°C and the weight of crucible plus ash was recorded to the nearest milligram. The weight of the empty crucible was subtracted, yielding the subsample dry weight and ash weight from which the ash-free dry weight was calculated.

The subsample size examined for species and their abundance varied between 1/1024 and 1/64, and the number of zooplankters counted in the subsamples varied from 966 to 16,505 (Table 2, Appendix D). Each subsample was sorted into major taxa in a BOGOROV plankton sorting tray and all individuals were counted. The copepods, which were usually the numerically dominant form, were most intensively studied. They were first separated into three suborders (Calanoida, Cyclopoida, and Harpacticoida) and then each suborder was separated into adult females, males and immature copepodid forms for enumeration. All adult female copepods were identified to species and enumerated.

The species diversity index was calculated for each sample on the basis of adult female copepods and according to the Shannon-Weaver function. The coefficient of equitability was calculated for each sample using the formula:

$$E = \frac{H\ (S)}{H_{max}\ (S)}$$

Where $H(S)$ = observed species diversity, and $H_{max}(S) = \log_2 S$ (maximum species diversity for a given S).

RESULTS AND DISCUSSION

Biomass

The zooplankton biomass in terms of dry weight per m^3 of water filtered (Table 1, Appendix D) varied considerably from station to station and from season to season as in the first year of study (1975). However, replicate samples analyzed for each station showed a lesser degree of variation than in 1975. This difference may be attributable to the fact that in 1976 two comparable samples were selected for analysis from the three replicate samples collected at each station, while in 1975, four replicate samples were collected and all were analyzed. For easy comparison, the biomass values of replicate samples were averaged to provide a single value for each station (Table 1).

TABLE 1

BIOMASS (DRY WEIGHT, mg/m^3) AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER				SPRING				SUMMER			
		Station				Station				Station			
		1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
1975	I	15.0	16.2	4.5	11.9	89.4	27.3	9.1	41.9	72.8	12.4	7.7	31.0
	II	29.9	15.4	15.8	20.4	37.6	35.1	7.0	26.6	49.1	10.8	6.9	22.3
	III	23.7	17.3	17.5	19.5	28.9	9.9	7.7	15.5	32.2	15.4	12.0	19.9
	IV	20.4	16.7	15.7	17.6	47.5	28.1	8.8	28.1	22.3	38.2	11.1	23.9
	Mean	22.3	16.4	13.4	17.4	50.9	25.1	8.2	28.1	44.1	19.2	9.4	24.2
1976	I	9.7	26.7	11.5	16.0	51.3	60.5	8.1	40.0	28.5	26.4	4.4	19.8
	II	15.1	31.0	15.4	20.5	38.0	69.0	8.6	38.5	20.1	8.2	14.6	14.3
	III	16.0	13.6	19.5	16.4	71.3	70.6	22.0	54.6	69.7	13.3	21.6	34.9
	IV	26.0	14.0	10.7	16.9	27.0	19.3	7.7	18.0	20.5	16.3	5.3	14.0
	Mean	16.7	21.3	14.3	17.4	46.9	54.9	11.6	37.8	34.7	16.1	11.5	20.8

The highest biomass was at Station 1/III in spring (71.3 mg/m^3) and the lowest at Station 3/I in summer (4.4 mg/m^3), while in 1975, the highest biomass was at Station 1/I in spring (89.4 mg/m^3) and the lowest at Station 3/I in winter (4.5 mg/m^3). The highest and lowest biomass values were, therefore, most frequently found on Transect I. As in 1975, biomass generally showed a decrease from shallow to deep stations on all transects. However, in contrast to 1975, Station 2 showed higher values than Station 1 on Transects I and II in winter and spring. When biomass values of the four transects were averaged by station for each season (Table 2), it was clear that the spring and summer zooplankton increases were restricted to Stations 1 and 2, and that the zooplankton biomass at Station 3 was higher in winter rather than spring or summer, therefore, showing a different trend from the other stations. When data from the two sampling years were combined, the highest average biomass was 48.9 mg/m^3 (Station 1, spring), followed by 40.0 mg/m^3 (Station 2, spring).

When biomass values among transects for each season were compared (Table 3), the differences were not as great as those among stations. However, each transect showed a variable degree of seasonal change as well as annual variations. In 1975, highest and lowest biomass values were in spring (41.9 mg/m^3) and winter (11.9 mg/m^3) on Transect I, while in 1976, they were on Transect III in spring (54.6 mg/m^3) and Transect IV in summer (14.0 mg/m^3). The annual average biomass showed a relatively low variation among transects, ranging between 18.3 mg/m^3 (Transect III) and 28.3 mg/m^3 (Transect I) during 1975 and between 16.3 mg/m^3 (Transect IV) and 35.3 mg/m^3 (Transect III) during 1976. When data from the two years were combined, the highest average biomass

TABLE 2

AVERAGE SEASONAL BIOMASS (DRY WEIGHT, mg/m^3) FOR EACH STATION
MEAN OF FOUR TRANSECTS FOR EACH STATION

Year	Station	Winter	Spring	Summer	Mean
1975	1	22.3	50.9	44.1	39.1
	2	16.4	25.1	19.2	20.2
	3	13.4	8.2	9.4	10.3
Mean		17.4	28.1	24.2	23.2
1976	1	16.7	46.9	34.7	32.8
	2	21.3	54.9	16.1	30.8
	3	14.3	11.6	11.5	12.5
Mean		17.4	37.8	20.8	25.3
1975 & 1976	1	19.5	48.9	39.4	35.9
	2	18.9	40.0	17.7	25.5
	3	13.9	9.9	10.5	11.4
Mean		17.4	32.9	22.5	24.3

TABLE 3

AVERAGE SEASONAL BIOMASS (DRY WEIGHT, mg/m^3) FOR EACH TRANSECT
MEAN OF THREE STATIONS FOR EACH TRANSECT

Year	Transect	Winter	Spring	Summer	Mean
1975	I	11.9	41.9	31.0	28.3
	II	20.4	26.6	22.3	23.1
	III	19.5	15.5	19.9	18.3
	IV	17.6	28.1	23.9	23.2
Mean		17.4	28.0	24.3	23.2
1976	I	16.0	40.0	19.8	25.2
	II	20.5	38.5	14.3	24.4
	III	16.4	54.6	34.9	35.3
	IV	16.9	18.0	14.0	16.3
Mean		17.5	37.8	20.8	25.4
1975 & 1976	I	14.0	41.0	25.4	26.8
	II	20.5	32.6	18.3	23.8
	III	18.0	35.1	27.4	26.8
	IV	17.3	23.1	19.0	19.8
Mean		17.5	33.0	22.5	24.3

(26.8 mg/m^3) was on Transects I and III and the lowest (19.8 mg/m^3) on Transect IV.

To examine closely temporal zooplankton variation, all three stations on Transect II were sampled on a monthly basis during 1976. As shown in Table 4, monthly biomass on Transect II varied from 4.7 mg/m^3 (Station 3, July) to 69.0 mg/m^3 (Station 2, May/June). At Stations 1 and 2, the highest values were in May/June, while at Station 3, the highest biomass occurred in March. Biomass peaks were found in May/June, August and November at Station 1; in January/February, May/June and November at Station 2; and in March and September at Station 3. Monthly average values of all three stations on Transect II showed the highest biomass in May/June (38.5 mg/m^3) and the lowest in July (14.0 mg/m^3). The annual average at each station showed a seaward decrease which was very abrupt between Stations 2 and 3.

Numerical Abundance of Zooplankton

The number of zooplankters per m^3 of water filtered (Table 5) was approximately proportional to the biomass and varied from 475.6 (Station 3/II, spring) to 7872.1 (Station 1/III, summer). These values were close to those obtained in 1975 (317.0, Station 3/I, winter and 8380.8, Station 1/I, spring), although they occurred at different stations and in different seasons. In general agreement with the biomass distribution, the number of zooplankters was usually highest at Station 1 on each transect. Exceptions to this pattern were Stations 2/I-winter, 2/IV-spring, and 2/III and 2/IV-summer in 1975; and Stations 2/I, all three seasons, and 2/II-spring in 1976. The number at Station 3 was usually considerably smaller than that of Station 1 or 2. In winter and summer, however, the number at Station 2 occasionally

TABLE 4

BIOMASS (DRY WEIGHT, mg/m^3) ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	15.1	31.0	15.4	20.5
March	21.1	16.1	17.2	18.1
April	28.6	14.9	12.2	18.6
May/June	38.0	69.0	8.6	38.5
July	21.3	15.9	4.7	14.0
August	28.3	11.8	13.3	17.8
September	20.1	8.2	14.6	14.3
November	36.2	18.1	11.4	21.9
December	17.6	15.0	11.4	14.7
Mean	25.1	22.2	12.1	19.8

TABLE 5

NUMERICAL ABUNDANCE OF ZOOPLANKTON PER m^3 AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER				SPRING				SUMMER			
		Station				Station				Station			
		1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
1975	I	1061.3	1255.5	317.0	877.9	8380.8	1087.5	494.5	3320.9	2701.5	1261.3	807.3	1590.0
	II	2848.0	1490.0	1054.5	1797.5	3516.5	2809.5	451.8	2259.3	3006.0	453.0	651.3	1370.1
	III	2196.8	1471.0	920.0	1529.3	2292.3	676.8	539.5	1169.5	1654.3	1740.0	1221.0	1538.4
	IV	2355.3	1268.0	1023.3	1548.9	1538.0	1617.5	880.8	1345.4	1536.3	3572.0	754.3	1954.2
	Mean	2115.3	1371.1	828.7	1438.4	3931.9	1547.8	591.6	2023.8	2224.5	1756.6	858.5	1613.2
1976	I	743.9	1370.7	948.1	1020.9	2001.4	5090.6	589.9	2560.6	907.8	1881.4	844.8	1211.3
	II	1948.3	1411.8	918.4	1426.2	1866.9	3705.3	475.6	2015.9	3756.8	324.9	954.7	1678.8
	III	1474.5	660.0	849.3	994.6	2397.1	2247.2	1316.9	1987.1	7872.1	1600.5	2055.6	3842.7
	IV	3915.1	1602.9	586.3	2034.8	2149.4	941.9	519.6	1203.6	1565.0	660.3	640.8	955.4
	Mean	2020.4	1261.3	825.5	1369.1	2103.7	2996.2	725.5	1941.8	3525.4	1116.8	1124.0	1922.1

decreased below that of Station 3 on Transects II and III.

When the numerical data of all four transects are averaged by stations for each season (Table 6), the numerical abundance of zooplankton shows a close similarity to the biomass distribution; that is, the spring increase of zooplankton is observed only at Stations 1 and 2 and at Station 3 the zooplankton actually decreases to the lowest number in spring. When the two years data are combined, the highest number (3017.8/m^3) was found at Station 1 in spring and the lowest number (658.5/m^3 at Station 3 in spring.

When the numerical abundance of zooplankton are compared among transects (Table 7), the transect that had the highest number during 1975 was Transect I in spring and during 1976 it was Transect III in summer. Transects that had the lowest number during 1975 and 1976 were Transect I in winter and Transect IV in summer, respectively. As for biomass, the annual average numbers of zooplankters showed little variation among transects ranging from 1412.4 (Transect III) to 1929.6 (Transect I) in 1975, and from 1397.9 (Transect IV) to 2274.8 (Transect III) in 1976. When data for the two years were combined, the lowest average zooplankton number (1507.0/m^3) was found on Transect IV and the highest (1843.6/m^3) on Transect III.

Monthly numerical abundance data obtained on Transect II (Table 8) showed a wider amplitude of variation than the seasonal data, and ranged from 324.9/m^3 (Station 2, September) to 12141.5/m^3 (Station 1, in August). Peaks of abundance were found in April, August and December at Station 1; in January/February, May/June and December at Station 2; and in March and November at Station 3. It was apparent from these observations that the three stations have different patterns of temporal variation. The annual average at each station showed a gradual seaward decrease

TABLE 6

AVERAGE SEASONAL NUMERICAL ABUNDANCE OF ZOOPLANKTON PER m^3
FOR EACH STATION
MEAN OF FOUR TRANSECTS FOR EACH STATION

Year	Station	Winter	Spring	Summer	Mean
1975	1	2115.3	3931.9	2224.5	2757.2
	2	1371.1	1547.8	1756.6	1558.5
	3	828.7	591.6	858.5	759.6
Mean		1438.4	2023.8	1613.2	1691.8
1976	1	2020.4	2103.7	3525.4	2549.8
	2	1261.3	2996.2	1116.8	1791.4
	3	825.5	725.5	1124.0	891.7
Mean		1369.1	1941.8	1922.1	1744.3
1975 & 1976	1	2067.8	3017.8	2874.9	2653.5
	2	1316.2	2272.0	1436.7	1675.0
	3	827.1	658.5	991.2	825.6
Mean		1403.7	1982.8	1767.6	1718.0

TABLE 7

AVERAGE SEASONAL NUMERICAL ABUNDANCE OF ZOOPLANKTON PER m^3
FOR EACH TRANSECT
MEAN OF THREE STATIONS FOR EACH TRANSECT

Year	Transect	Winter	Spring	Summer	Mean
1975	I	877.9	3320.9	1590.0	1929.6
	II	1797.5	2259.3	1370.0	1808.9
	III	1529.3	1169.5	1538.4	1412.4
	IV	1548.9	1345.4	1954.2	1616.2
Mean		1438.4	2023.8	1613.1	1691.8
1976	I	1020.9	2560.6	1211.3	1597.6
	II	1426.2	2015.9	1678.8	1707.0
	III	994.6	1987.1	3842.7	2274.8
	IV	2034.8	1203.6	955.4	1397.9
Mean		1369.1	1941.8	1922.0	1744.3
1975 & 1976	I	949.4	2940.7	1400.6	1763.6
	II	1611.8	2137.6	1524.4	1757.9
	III	1261.9	1578.3	2690.5	1843.6
	IV	1791.8	1274.5	1454.8	1507.0
Mean		1403.7	1982.8	1767.6	1718.0

TABLE 8

NUMERICAL ABUNDANCE OF ZOOPLANKTON PER m^3
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	1948.3	1411.3	918.4	1426.2
March	3784.8	997.8	956.1	1912.9
April	5123.1	1145.2	736.0	2334.8
May/June	1866.9	3705.3	475.6	2015.9
July	2401.8	1779.2	412.0	1531.0
August	12141.5	666.0	768.8	4525.4
September	3756.8	324.9	954.7	1678.8
November	2062.6	1270.1	1230.8	1521.2
December	4008.1	2818.6	1140.6	2655.8
Mean	4121.5	1568.7	843.7	2178.0

instead of an abrupt seaward decrease as observed for the biomass between Stations 2 and 3.

In nearly all samples, the Copepoda were the most abundant group, comprising approximately 60% of the zooplankton by number (Table 3, Appendix D). This figure was slightly lower than that obtained in 1975 (approximately 70%). As shown in Tables 9 and 10, the relative abundance of copepods in the zooplankton was lower in spring and summer than in winter. Therefore, the spring and summer increase in zooplankton was more attributable to other forms than to copepods. Other than the Copepoda, the numerically important groups were the Cladocera, Ostracoda, barnacle larvae, Mollusca, Chaetognatha, and tunicates (Tables 3 and 4, Appendix D).

The Cladocera (*Penilia* sp.) often occurred in large numbers at Station 1 in winter and summer months. The highest concentration was $10331.1/m^3$ (Station 1/II, August 1976). Another taxon that showed a highly regionalized spatial distribution was the Ostracoda, composed mostly of a single species *Euconchoecia chierchiae*. The number of ostracods per m^3 varied between 0 (Stations 1/I, 1/II, 1/III, summer 1976) and 2043.5 (Station 2/IV, summer 1975), and high concentrations were usually found at Station 2, all transects. On Transect II where ostracods were studied on a monthly basis during 1976, there were two clear peaks, one in winter and another in summer.

The number of amphipods ranged between 0.3 (Station 1/I, winter 1975) and $264.3/m^3$ (Station 1/III, summer 1976) and high concentrations were usually found at shallow stations in spring and summer on all transects. However, monthly data for Transect II in 1976 showed a high peak

TABLE 9

PERCENTAGE COMPOSITION OF COPEPODS IN TOTAL ZOOPLANKTON AT EACH STATION MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976[1]

Year	Transect	WINTER				SPRING				SUMMER			
		Station			Mean	Station			Mean	Station			Mean
		1	2	3		1	2	3		1	2	3	
1975	I	85.5	57.8	72.7	72.0	92.0	76.0	64.3	77.4	61.8	59.6	66.6	62.7
	II	85.9	74.6	70.0	76.8	61.4	34.3	82.4	59.4	71.9	66.7	79.9	72.8
	III	93.0	82.7	66.6	80.8	84.1	63.5	66.3	71.3	67.5	66.2	72.3	68.7
	IV	89.4	79.8	77.5	82.2	52.5	67.2	40.3	53.3	63.4	36.3	80.9	60.2
	Mean	88.5	73.7	71.7		72.5	60.3	63.3		66.2	57.2	74.9	
1976	I	61.9	46.6	75.6	61.4	46.1	36.2	73.9	52.1	53.6	34.7	69.1	52.5
	II	74.2	52.1	72.8	66.4	58.6	50.8	73.9	61.1	18.8	75.2	68.1	54.0
	III	58.1	76.5	85.0	73.2	31.0	56.8	68.6	52.1	52.9	66.6	63.5	61.0
	IV	77.7	47.2	63.4	62.8	68.8	73.1	68.1	70.0	75.0	69.3	75.2	73.2
	Mean	68.0	55.6	74.2		51.1	54.2	71.1		50.1	61.5	69.0	

[1] For purposes of comparison between 1975 and 1976 the Foraminifera and Radiolaria, which were included in 1976 study but not in 1975, were omitted from the calculation of 1976 data presented here.

TABLE 10

PERCENTAGE COMPOSITION OF COPEPODS IN TOTAL ZOOPLANKTON
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	74.1	50.8	71.4	65.4
March	38.4	55.5	72.2	55.4
April	39.1	77.6	66.0	60.9
May/June	52.2	50.6	71.8	58.2
July	45.0	42.5	52.6	46.7
August	4.2	50.9	59.1	38.1
September	18.8	74.4	66.1	53.1
November	66.4	65.3	39.4	57.0
December	50.1	41.5	55.6	49.1
Mean	43.1	56.6	61.6	53.8

of amphipods in May/June and low numbers afterward. The decapod *Lucifer*, the only holoplanktonic decapod genus found in the study, occurred regularly and their number usually increased in spring and summer at shallow stations. Barnacle larvae (nauplius and cypris stages) showed a highly sporadic occurrence. During 1975, they appeared in large numbers throughout the study area in spring and at Stations 2 and 3, Transect III, in summer. During 1976, however, they occurred in high numbers only at Stations 1 and 2, Transect I, in winter. Copepod nauplii were found the year round in most samples. They were, however, too small to be adequately sampled by the nets employed.

Other crustacean larvae, including decapod zoea and megalops, showed a clear seasonality and increased in abundance at shallow stations in spring and summer.

Most of the molluscs were gastropod and pelecypod larvae, and were most abundant at shallow stations in spring and summer. The highest concentration in 1976 was 2699.1 per m^3 (Station 1/II, April). Even in winter months, the molluscans maintained an average abundance of about 50 per m^3.

The Chaetognatha, mainly composed of small neritic species, occurred regularly throughout the study area in all samplings. Their number per m^3 ranged from 7.0 (Station 1/II, March 1976) to 235.8 (Station 1/I, spring 1976) with higher numbers usually occurring at shallow stations in spring and summer.

Another taxon with a regular and consistent occurrence were the Larvacea, composed mainly of the genus *Oikopleura*. Their number per m^3 varied from 2.3 to 277.4 (Stations 1/II and 1/III, respectively, summer 1976) but did not show any discernible pattern of spatial or temporal variation. Pelagic tunicates, other than the Larvacea, were mostly of species in thaliacean genera *Doliolum* and *Salpa*. They occurred throughout the study area the year round, although their number exceeded 10 per m^3 only occasionally.

Jelly fish were mostly small hydromedusae and zoöids of the Siphonophora and occurred at all stations the year round. The highest jelly fish concentration during the study was 356.9 per m^3 at Station 1/IV in winter 1976.

Numerical Abundance of Copepods

The number of copepods, including all developmental stages, ranged from 216.4/m^3 (Station 3/II, July) to 4156.7/m^3 (Station 1/III, summer) while in 1975 numbers varied from 229.7/m^3 (Station 3/I, winter) to 7683.1/m^3 (Station 1/I, spring) (Table 11). When the numbers for all four transects were averaged by station for each season (Table 12), it was clear that the copepods were usually much more abundant at Station 1 than at Stations 2 and 3. Differences between Stations 2 and 3 were relatively small except in winter 1975 and spring 1976. Differences in copepod abundance among transects were relatively insignificant (Table 13). However, in 1976, Transects III and IV had higher copepod numbers than Transects I and II, while in 1975, the order was reversed. In contrast with the total zooplankton, copepods showed almost no seasonal variation in abundance according to data for the seasonal samples. Average numbers for the entire study area ranged from 971.1/m^3 (summer) to 1376.7/m^3 (spring) in 1975, and from 904.1/m^3 (winter) to 1068.3/m^3 (summer) in 1976. However, monthly samples on Transect II (Table 14) showed a relatively higher temporal variation ranging from 425.9/m^3 (August) to 1258.0/m^3 (December). It is noteworthy that the lowest

TABLE 11

NUMERICAL ABUNDANCE OF COPEPODS PER m^3 AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER				SPRING				SUMMER			
		Station			Mean	Station			Mean	Station			Mean
		1	2	3		1	2	3		1	2	3	
1975	I	909.0	712.9	229.7	617.2	7683.1	741.8	317.2	2914.0	1569.9	741.4	534.4	948.6
	II	2489.5	1110.8	734.5	1444.9	2174.3	913.8	372.6	1153.6	2074.7	295.7	520.4	963.6
	III	2047.8	1229.6	577.0	1284.8	1928.6	425.9	343.7	899.4	1129.9	1011.1	891.6	1010.9
	IV	2119.5	1009.4	794.4	1307.8	668.9	463.0	487.6	539.8	959.9	1312.9	611.5	961.4
	Mean	1891.5	1015.7	583.9	1163.7	3113.7	636.1	380.3	1376.7	1433.6	840.3	639.5	971.1
1976	I	459.7	637.4	714.6	603.9	925.4	1829.6	419.8	1058.3	483.1	686.6	565.2	578.3
	II	1443.0	717.5	655.3	938.6	978.6	1822.4	340.9	1047.3	694.5	241.8	624.6	520.3
	III	857.4	494.3	713.3	688.3	744.5	1252.0	889.4	962.0	4156.7	1054.6	1272.9	2161.4
	IV	3042.6	746.0	368.0	1385.5	1465.9	682.3	342.1	830.1	1175.4	451.1	399.8	675.4
	Mean	1450.7	648.8	612.8	904.1	1028.6	1396.6	498.0	974.4	1627.4	608.5	715.6	983.9

TABLE 12

AVERAGE SEASONAL NUMERICAL ABUNDANCE OF COPEPODS PER m^3 FOR EACH STATION
MEAN OF FOUR TRANSECTS FOR EACH STATION

Year	Station	Winter	Spring	Summer	Mean
1975	1	1891.5	3113.7	1433.6	2146.3
	2	1015.7	636.1	840.3	830.7
	3	583.9	380.3	639.5	534.6
Mean		1163.7	1376.7	971.1	1170.5
1976	1	1450.7	1028.6	1627.4	1368.9
	2	648.8	1396.6	608.5	884.6
	3	612.8	498.0	715.6	608.8
Mean		904.1	974.4	983.8	954.1
1975 & 1976	1	1671.1	2071.1	1530.5	1757.6
	2	832.2	1016.3	724.4	857.6
	3	598.3	439.1	677.5	571.6
Mean		1033.9	1175.5	977.5	1062.3

TABLE 13

AVERAGE SEASONAL NUMERICAL ABUNDANCE OF COPEPODS PER m^3 FOR EACH TRANSECT
MEAN OF THREE STATIONS FOR EACH TRANSECT

Year	Transect	Winter	Spring	Summer	Mean
1975	I	617.2	2914.0	948.6	1493.3
	II	1444.9	1153.6	963.6	1187.4
	III	1284.8	899.4	1010.9	1065.0
	IV	1307.8	539.8	961.4	936.3
Mean		1163.7	1376.7	971.1	1170.5
1976	I	603.9	1058.3	578.3	746.8
	II	938.6	1047.3	520.3	835.4
	III	688.3	962.0	2161.4	1270.6
	IV	1385.5	830.1	1013.1	1076.2
Mean		904.1	974.4	1068.3	982.3
1975 & 1976	I	610.6	1986.1	763.4	1120.0
	II	1191.7	1100.4	741.9	1011.3
	III	986.5	930.7	1586.1	1167.8
	IV	1346.6	684.9	987.2	1006.2
Mean		1033.8	1175.5	1019.6	1076.3

TABLE 14

NUMERICAL ABUNDANCE OF COPEPODS PER m^3
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES PER STATION

Month \ Station	1	2	3	Mean
January/February	1443.0	717.5	655.3	938.6
March	1435.5	516.6	690.4	880.8
April	2045.0	884.1	485.4	1138.2
May/June	978.6	1822.4	340.9	1047.3
July	1118.2	652.0	216.4	662.2
August	484.6	338.8	454.4	425.9
September	694.5	241.8	624.6	520.3
November	1361.6	830.8	473.0	888.5
December	1970.8	1158.7	644.5	1258.0
Mean	1281.3	795.9	509.4	862.2

copepod number occurred in August when the total zooplankton number was the highest due to an extreme abundance of the cladoceran *Penilia*. Approximately 75 percent of the copepods belonged to the suborder Calanoida, usually less than 2 percent belonged to the suborder Harpacticoida, with the rest belonging to the suborder Cyclopoida (Table 6, Appendix D). The relative abundance of the Calanoida was highest in winter and gradually decreased as the abundance of Cyclopoida increased toward summer, when Cyclopoida often comprised as much as 50 percent of the total copepods. Developmental stages were abundant throughout the year, comprising nearly 50 percent in the Calanoida and about 20 percent in the Cyclopoida. These percentage values showed no significant change with season, indicating a sustained copepod reproduction in the area (Table 6, Appendix D). The relative abundance of developmental stages in the total copepods was approximately 50 percent in the 1976 seasonal samples (Table 15). However, in winter and spring 1975, relative abundance of developmental stages often exceeded 60 percent. Monthly samples from Transect II (Table 16) showed average relative abundance of developmental stages ranging from 39.9 percent (September) to 63.3 percent (December), again indicating a sustained copepod reproduction throughout the year.

The number of adult female copepods per m^3 varied in close agreement with the total copepods. Adult female copepods often occurred in high concentration at Station 1, irrespective of transect or season (Tables 17 and 18). However, the average number of adult female copepods in the entire study area remained at approximately 500/m^3 throughout the year. A total of 168 species of adult female copepods were identified during 1976, consisting of 107 calanoid species, 57 cyclopoid species and 4 harpacticoid species (Table 7, Appendix D).

TABLE 15

PERCENTAGE COMPOSITION OF IMMATURES IN TOTAL COPEPODS AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER Station 1	WINTER Station 2	WINTER Station 3	WINTER Mean	SPRING Station 1	SPRING Station 2	SPRING Station 3	SPRING Mean	SUMMER Station 1	SUMMER Station 2	SUMMER Station 3	SUMMER Mean
1975	I	35.2	58.8	77.2	57.1	50.4	75.9	63.1	63.1	49.8	59.6	51.8	53.7
	II	52.6	38.8	50.7	47.4	65.1	78.4	67.7	70.4	61.0	46.8	45.7	51.2
	III	92.7	64.0	43.7	66.8	46.2	65.5	73.7	61.8	50.7	46.3	47.2	48.1
	IV	88.4	69.8	72.2	76.8	73.3	47.8	53.1	58.1	44.4	39.3	55.3	46.3
	Mean	67.2	57.9	61.0	62.0	58.8	66.9	64.4	63.4	51.5	48.0	50.0	49.8
1976	I	49.2	28.8	23.3	33.8	61.5	41.7	60.7	54.6	59.0	67.5	41.4	56.0
	II	33.5	24.3	77.5	45.1	43.8	39.6	54.8	46.1	35.0	35.5	49.2	39.9
	III	43.1	82.7	67.1	64.3	54.9	45.9	40.8	47.2	83.2	29.2	31.9	48.1
	IV	73.3	65.9	88.6	75.9	41.1	24.1	63.2	42.8	42.8	30.3	42.1	38.4
	Mean	49.8	50.4	64.1	54.8	50.3	37.8	54.9	47.7	55.0	40.6	41.2	45.6

TABLE 16

PERCENTAGE COMPOSITION OF IMMATURES IN TOTAL COPEPODS
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	33.5	24.3	77.5	45.1
March	25.5	41.9	61.2	42.9
April	17.8	62.4	55.0	45.1
May/June	43.8	39.6	54.8	46.1
July	52.4	40.2	65.3	52.6
August	60.2	42.8	46.8	49.9
September	35.0	35.5	49.2	39.9
November	66.7	63.4	40.5	56.9
December	62.4	69.1	58.5	63.3
Mean	44.1	46.6	56.5	49.1

TABLE 17

NUMERICAL ABUNDANCE OF ADULT FEMALE COPEPODS PER m^3 AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER Station 1	WINTER Station 2	WINTER Station 3	WINTER Mean	SPRING Station 1	SPRING Station 2	SPRING Station 3	SPRING Mean	SUMMER Station 1	SUMMER Station 2	SUMMER Station 3	SUMMER Mean
1975	I	490.0	313.4	109.1	304.2	3436.1	363.4	158.2	1319.2	621.6	392.4	342.3	452.1
	II	1245.1	685.2	419.5	783.3	1339.5	382.4	185.9	635.9	1035.9	174.9	338.1	516.3
	III	769.9	670.2	336.7	592.3	640.8	235.9	156.9	344.5	508.1	671.6	584.6	588.1
	IV	1060.5	440.0	320.0	606.8	239.7	228.5	251.9	240.0	502.6	718.6	352.9	524.7
	Mean	891.4	527.2	296.3	571.7	1414.0	302.6	188.2	634.9	667.1	489.4	404.5	520.3
1976	I	249.6	334.3	327.1	303.7	370.2	816.5	238.6	475.1	182.1	294.0	364.1	280.1
	II	871.8	346.9	244.3	487.7	424.9	796.1	178.6	466.5	307.3	143.5	398.5	283.1
	III	504.4	175.4	296.6	325.5	299.9	645.1	534.4	493.1	1970.8	768.7	978.7	1239.4
	IV	1770.8	338.5	128.1	745.8	875.3	502.7	196.0	524.7	801.4	327.3	303.2	477.3
	Mean	849.1	298.8	249.0	465.7	492.6	690.1	286.9	489.9	815.4	383.4	511.1	570.0

TABLE 18

NUMERICAL ABUNDANCE OF ADULT FEMALE COPEPODS PER m^3
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	871.8	346.9	244.3	487.7
March	1073.9	298.4	340.4	570.9
April	1769.1	521.8	277.3	856.1
May/June	424.9	796.1	178.6	466.5
July	564.5	385.0	134.2	361.2
August	203.9	222.7	272.6	233.1
September	307.3	143.5	398.5	283.1
November	465.4	394.9	308.0	389.4
December	885.9	566.1	342.5	598.2
Mean	729.6	408.4	277.4	471.8

By identifying and counting all adult female copepods in the subsample, the numerical abundance of each copepod species per m^3 was determined (Table 8, Appendix D).

The most abundant calanoid species were *Paracalanus indicus*, *Paracalanus quasimodo*, *Clausocalanus furcatus*, *Centropages velificatus*, *Temora turbinata*, *Paracalanus aculeatus*, *Eucalanus pileatus*, *Clausocalanus jobei* and *Temora stylifera*. *Paracalanus indicus* and *Paracalanus quasimodo* are morphologically and distributionally so similar that their taxonomic validity is questionable. Thus, their numbers were combined and treated as a single taxon. As shown in Table 19, their number reached a high of $1502.4/m^3$ (Station 1/IV, winter 1976) and they showed a pronounced regionality as well as a moderate seasonality in their quantitative distribution; *i.e.*, they were highly abundant at Station 1 usually in winter months where they comprised more than 70 percent of the total female copepods. The same pattern of quantitative distribution was displayed in monthly samples from Transect II (Table 20).

Clausocalanus furcatus, on the other hand, usually increased in number with distance from shore (Tables 21 and 22). However, on Transect IV in 1976, numbers increased shoreward in all seasonal samplings and the number at Station 1/IV ($370.6/m^3$) was the highest number found during the two years of study. *Centropages velificatus* was found throughout the year but usually in small numbers. In spring 1976, however, it occurred in unusually high concentrations at Stations 1 and 2, Transects I and II, where numbers exceeded $200/m^3$. In general this species was more abundant toward shore. Another species that had a similar distribution pattern was *Eucalanus pileatus*. The highest concentration of this species, however, was only $81.8/m^3$ (Station 1/I, spring). *Temora turbinata* also increased in number toward shore but was more abundant

TABLE 19

NUMERICAL ABUNDANCE OF *Paracalanus indicus* AND *Paracalanus quasimodo* PER m^3 AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER Station 1	WINTER Station 2	WINTER Station 3	WINTER Mean	SPRING Station 1	SPRING Station 2	SPRING Station 3	SPRING Mean	SUMMER Station 1	SUMMER Station 2	SUMMER Station 3	SUMMER Mean
1975	I	264.0	70.8	2.0	112.3	578.0	195.4	12.8	262.1	232.7	40.5	1.8	91.7
	II	749.1	247.2	49.7	348.7	1125.3	199.5	9.3	444.7	566.7	3.4	2.5	190.9
	III	515.9	30.6	30.2	192.2	205.9	65.7	7.7	93.1	123.1	55.1	19.2	65.8
	IV	927.1	154.2	18.5	366.6	122.7	41.7	22.0	62.1	66.1	121.9	25.0	71.0
	Mean	614.0	125.7	25.1	255.0	508.0	125.6	13.0	215.5	247.2	55.2	12.1	104.9
1976	I	134.7	115.5	33.0	94.4	102.0	154.3	8.2	88.2	63.6	54.5	2.0	40.0
	II	737.4	60.0	7.6	268.3	10.6	140.8	8.2	53.2	33.2	2.3	1.9	12.5
	III	367.1	7.1	99.2	157.8	56.5	85.6	46.6	62.9	1121.0	38.5	15.7	391.7
	IV	1502.4	200.6	1.6	568.2	141.3	112.5	10.4	88.1	1.0	16.3	1.5	6.3
	Mean	685.4	95.8	35.4	272.2	77.6	123.3	18.4	73.1	304.7	27.9	5.3	112.6

TABLE 20

NUMERICAL ABUNDANCE OF *Paracalanus indicus* and *Paracalanus quasimodo*
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	737.4	60.0	7.6	268.3
March	768.3	126.9	12.3	302.5
April	1564.7	256.9	11.5	611.0
May/June	10.6	140.8	8.2	53.2
July	170.0	23.7	0.2	64.6
August	75.9	22.9	10.6	36.5
September	33.2	2.3	1.9	12.5
November	144.3	93.4	22.5	86.7
December	568.1	103.7	29.2	233.7
Mean	452.5	92.3	11.6	185.5

TABLE 21

NUMERICAL ABUNDANCE OF *Clausocalanus furcatus* PER m^3 AT EACH STATION
MEAN OF FOUR SAMPLES FOR 1975 AND TWO SAMPLES FOR 1976

Year	Transect	WINTER Station 1	WINTER Station 2	WINTER Station 3	WINTER Mean	SPRING Station 1	SPRING Station 2	SPRING Station 3	SPRING Mean	SUMMER Station 1	SUMMER Station 2	SUMMER Station 3	SUMMER Mean
1975	I	4.2	35.9	25.1	21.7	4.4	14.8	28.9	16.0	1.3	129.6	91.6	74.2
	II	67.4	150.1	201.1	139.5	8.5	10.2	30.7	16.5	9.7	55.5	96.5	53.9
	III	11.3	346.7	133.8	163.9	1.1	22.6	30.7	18.1	13.5	248.2	145.7	135.8
	IV	29.9	108.1	74.9	71.0	1.9	5.6	38.3	15.3	14.6	128.5	142.6	95.2
	Mean	28.2	160.2	108.7	99.0	4.0	13.3	32.2	16.5	9.8	140.5	119.1	89.8
1976	I	6.1	11.8	55.1	24.3	0.4	31.0	27.3	19.6	0	8.7	142.3	50.3
	II	10.9	8.0	22.5	13.8	24.6	10.1	22.1	18.9	0.9	36.9	117.7	51.8
	III	14.4	16.3	47.4	26.0	16.8	68.5	34.9	40.1	2.5	262.5	281.3	182.1
	IV	54.9	11.7	8.4	25.0	370.6	75.5	8.8	151.6	344.9	139.7	82.7	189.1
	Mean	21.6	12.0	33.4	22.3	103.1	46.3	23.3	57.6	87.1	112.0	156.0	118.4

TABLE 22

NUMERICAL ABUNDANCE OF *Clausocalanus furcatus* PER m^3
ON TRANSECT II IN 1976
MEAN OF TWO SAMPLES AT EACH STATION

Month \ Station	1	2	3	Mean
January/February	10.9	8.0	22.5	13.8
March	10.0	48.7	65.1	41.3
April	12.4	31.7	75.4	39.8
May/June	24.6	10.1	22.1	18.9
July	72.1	53.8	5.4	43.8
August	1.7	12.3	24.7	12.9
September	0.9	36.9	117.7	51.8
November	14.8	82.1	127.8	74.9
December	12.3	119.1	77.3	69.6
Mean	17.7	44.7	59.8	40.7

in winter and summer than in spring. The highest number was 316.0/m^3 (Station 1/III, summer 1976). The congeneric species *Temora stylifera*, however, was more abundant in spring. *Paracalanus aculeatus* showed a fairly uniform spatial as well as temporal distribution, although numbers were generally higher in summer reaching as high as 50.9/m^3 (Station 1/II). *Clausocalanus jobei* had a distributional pattern almost identical to that of *Clausocalanus furcatus*, although the former was much less abundant than the latter. *Acartia tonsa*, which occurred in a concentration of 2656.4/m^3 (Station 1/I, spring 1975), was found during 1976 only in small numbers at shallow stations in winter and spring and its highest number reached only 63.9/m^3 (Station 1/II, winter).

The most abundant cyclopoid copepods were *Oncaea venusta*, *Oncaea mediterranea*, *Farranula gracilis*, *Oithona plumifera*, and *Corycaeus americanus*. *Oncaea venusta* occurred throughout the study area throughout the year, and showed a pronounced increase in number in summer months with the highest concentration (176.7/m^3) at Station 1/IV in summer 1976. No obvious spatial variation was displayed by this species. *Oncaea mediterranea*, on the other hand, showed a pronounced seaward increase in abundance with little seasonal change. *Farranula gracilis* showed a pronounced seaward increase, as well as a seasonal increase from winter through summer when density reached as high as 248.7/m^3 (at Station 3/III). *Oithona plumifera* and *Corycaeus americanus* occurred throughout the year. The former showed a seaward increase with little seasonal change, but the latter showed a pronounced shoreward increase as well as a seasonal change with highest numbers occurring in spring.

Species Diversity

The number of adult female copepods identified, number of copepod species found, species diversity index based on the adult female copepods, and coefficient of equitability calculated from the diversity index for each station are presented in Table 10, Appendix D. Contrary to the trend of numerical abundance, the number of copepod species increased considerably from shallow to deep stations. Species diversity indices and coefficients of equitability generally increased from shallow to deep stations in conformity to the number of species. However, the two highest coefficients of equitability observed in 1976 were for Stations 1/II in August (0.8240) and 1/III in May/June (0.8105) when the number of species and species diversity indices were low. The lowest species diversity index (1.1296) and coefficient of equitability (0.2994) were for Station 1/II in April when the number of adult female copepods ($1769.1/m^3$) was the highest of all monthly values obtained for Transect II. By and large the coefficients of equitability (E) were considerably lower than the theoretical maximum value of 1.0, suggesting that the copepod community in the study area was far from being well-organized into a stable community structure.

Spatial and Temporal Variation Between 1975 and 1976

The pertinent 1976 results concerning seasonal and regional distributions of the total zooplankton and its numerically significant constituents have been discussed in previous sections. When the data for 1976 were compared with those of 1975, more similarities than differences appeared in the two years of analysis. Biomass and the numbers of zooplankton showed similar patterns of variation in abundance with changes in season and stations. Some variation between the two years appeared when the data were compared by transects. In 1975, Transect I produced the highest biomass and number of organisms, whereas in 1976, Transect III was the most productive.

Copepods accounted for the largest percentage of the zooplankton during both years, however, percentages were somewhat lower in 1976 than in 1975. Variations in Copepoda numbers with changes in seasons and stations were similar during the two years. However, as in the biomass, the highest number in each season occurred on Transect I or II in 1975 but on Transect III or IV in 1976. Ostracods appear to be concentrated at Station 2 during both years except in the summer of 1976 when they were more abundant at Station 3. The numbers of Mollusca were somewhat larger in 1976 than in 1975. Chaetognaths were significantly more abundant in the spring of 1976 than in the same season of 1975, but showed fair agreement during the other two seasons. *Lucifer* was the most abundant in 1975 summer samples at Station 1/I, but more prominent in the spring of 1976 at Station 1/III. Larvacea and jelly fish consistently appeared in the samples of both years. Both taxa were more abundant in 1976 than in 1975. Cladocera and barnacle larvae were irregular in occurrence but occasionally important contributors to the zooplankton. Cladocera were best represented in the summer of both years, especially in 1976 when they accounted for 59% of the zooplankton at Station 1/III. According to the two years of data, barnacle larvae were the least predictable of the forms considered as numerically important fractions of the zooplankton.

Indicator species among the Copepods have been identified in an earlier section. Among these, the calanoid species *Paracalanus indicus*, *Paracalanus quasimodo*, *Clausocalanus furcatus*, and the Cyclopoid species *Oncaea venusta*, *Oncaea mediterranea*, and *Farranula gracilis* occurred in the greatest numbers. *Paracalanus indicus* and *P. quasimodo*, considered as a single taxon, were highly concentrated at Station 1 of all transects during 1975 and in the winter and summer of 1976. In spring 1976, they were uniformly distributed between Stations 1 and 2. *Clausocalanus fur-*

catus, the second most abundant calanoid, did not show a consistent distributional pattern. In 1975, their peaks of abundance were found at Station 2/III in the winter and summer. In 1976, however, they were extremely abundant at Station 1/IV in the spring and summer. The cyclopoid *Oncaea venusta* did not establish easily definable patterns of seasonal or regional distribution in either year of the study. *Oncaea mediterranea* established a reasonably well defined population center at Station 3 during both years. This center often extended shoreward along Transects II, III or IV, without consistency. *Farranula gracilis* developed only weakly defined seaward centers of abundance during both years.

In view of the nature of zooplankton variability, which is a continuous process affected by complicated interactions of various environmental parameters, it cannot be expected that seasonal samples such as we have studied will reveal correctly their annual pattern of variation. It is therefore difficult to ascertain how much of the observed variation is real and how much can be expected as results of natural time lags during seasonal and annual cycles. Monthly samples taken on Transect II in 1976 and 1977 may provide some insight into the scope of this problem.

Interrelationship Between Zooplankton and Environmental Parameters

Data for physical and biological parameters obtained by other investigators at the time of zooplankton collections were examined for possible relationships with the zooplankton. Of all environmental parameters studied by other investigators, temperature, salinity and chlorophyll a seemed to have readily discernible relationships with the zooplankton. The surface values for temperature and salinity and average values of chlorophyll a concentration for the entire water column are considered in the discussion below.

Winter water temperature in 1976 was considerably lower than that in 1975, particularly at Station 1 on Transects I through III. The low temperature at these stations in 1976 was accompanied by low zooplankton abundance, and the lowest zooplankton biomass was obtained at Station 1/I where temperature was the lowest. In spring, however, water temperature was on the average 4°C higher in 1976 than in 1975 and average zooplankton biomass was approximately 1.3 times higher in 1976 than in 1975. Contrary to biomass, average numerical abundance was higher in 1975 than 1976. This reversed relationship was due mainly to the unusually high number of small zooplankters (mainly *Acartia tonsa*) at Station 1/I in 1975 where the temperature and salinity were the lowest. Monthly temperature data on Transect II showed a regular seasonal pattern reaching the highest in August. At Station 1, the gradual warming of the water from January through June was accompanied by a steady increase in zooplankton abundance. At Station 3, however, the zooplankton showed a steady decrease through July, displaying an inverse relation with temperature.

Salinity seemed to be strongly correlated with the zooplankton in the study area, mainly in the spring when high zooplankton standing crops were usually found at stations with low salinity values. In 1975 the unusually low salinity at Station 1/I was accompanied by an extreme abundance of zooplankton (mainly *Acartia tonsa*). In 1976 the two highest zooplankton numbers were at stations with the lowest salinities. The relationship between salinity and zooplankton was, however, not readily discernible during other seasons. The monthly data for Transect II also showed a close relationship between salinity and zooplankton, with low salinity values often corresponding to high zooplankton abundance. The largest zooplankton biomass found on Transect II was from Station 2 when salinity was lowest. At Station 1, the zooplankton increased from March through June and in November when the salinity was low. It is interesting to note that on Transect II, the highest zooplankton number (mainly the cladoceran genus *Penilia*) occurred at Station 1 in August when the salinity was unusually high.

The chlorophyll a concentrations generally showed a pattern of distribution similar to that of zooplankton abundance, *i.e.*, a general increase from deep to shallow stations and from winter through spring months. In each season the high zooplankton standing crop appeared to be associated with high chlorophyll a values. On Transect II the chlorophyll a values showed a spring increase at Stations 1 and 2 which was followed by large zooplankton biomass values. However, it was not always possible to correlate zooplankton abundance with chlorophyll a and sometimes an inverse relationship was noted.

Linear correlation coefficients of the 1976 zooplankton data against the three physical and biological parameters considered above generally support the relationships discussed (Table 23). Correlation coefficients based on seasonal data were somewhat lower than those for the monthly data and probably reflect the inability of such widely-spaced samplings to properly accomodate natural lag periods between changes in physical parameters and the zooplankton community.

Of the major zooplankton groups, the copepods and molluscs showed a relatively high correlation with salinity and chlorophyll a values when monthly data for Transect II were considered. For the molluscs this relationship seemed to result from their spatial distribution which was mainly restricted to shallow stations with low salinity. Of the copepods, the most abundant species were *Paracalanus indicus* and

TABLE 23

CORRELATION COEFFICIENTS FOR CERTAIN BIOLOGICAL AND HYDROLOGICAL DATA COLLECTED SEASONALLY FOR THE ENTIRE STUDY AREA AND MONTHLY ON TRANSECT II IN 1976

Zooplankton	Correlation Coefficient			
	Monthly		Seasonal	
	Salinity (ppt)	Chlorophyll a	Salinity (ppt)	Chlorophyll a
Dry Weight (mg/m^3)	-0.5525	0.1988	-0.4699	0.3947
Number of Zooplankters per M^3	-0.2730	0.3623	-0.0391	0.5000
Number of Copepoda per M^3	-0.7925	0.7530	-0.1786	0.3811
Number of Copepod Species	-0.5685	-0.6078	0.3201	-0.6665
Number of Cladocera per M^3	0.0776	-0.0047	0.2005	0.4271
Number of Ostracoda per M^3	-0.0451	-0.1132	-0.3694	0.1797
Number of Mollusca per M^3	-0.5881	0.7334	-0.3987	0.3091
Number of Chaetognatha per M^3	-0.3093	0.1678	0.4600	0.3507
Number of *Paracalanus parvus* group per M^3	-0.7694	0.8869	-0.1870	0.3386
Number of *Clausocalanus furcatus* per M^3	0.4704	-0.2778	-0.3141	0.1309

Paracalanus quasimodo which were primarily inshore species. These species showed a strong correlation with salinity and chlorophyll a when monthly data for Transect II were considered. However, such a relation was not clearly displayed in the seasonal data. On the other hand, *Clausocalanus furcatus*, an oceanic species usually dominant at offshore stations, displayed only a moderate correlation with salinity. Strong correlations between certain zooplankton data and chlorophyll a and salinity values suggest that land drainage which lowers salinity at near-shore stations provides nutrients which support phytoplankton blooms and ultimately increases zooplankton production.

CONCLUSIONS

1. Zooplankton abundance in terms of both biomass and number displayed a considerable degree of spatial, as well as temporal, variation and these variations were progressively extensive toward shore.
2. The zooplankton showed a usual seaward decrease, and the decrease was highly pronounced in spring and summer when the zooplankton generally increased to an annual maximum at Stations 1 and 2 and decreased to the lowest annual value at Station 3.
3. Copepods were the most abundant group, comprising approximately 60 percent of the zooplankton by number. When the zooplankton increased in spring and summer, the relative abundance of copepods decreased, indicating that other organisms were increasing faster than copepods.
4. Numerically important groups besides copepods were Cladocera, Ostracoda, barnacle larvae, Mollusca, Chaetognatha and tunicates. Cladocera and Ostracoda occurred mainly at Stations 1 and 2, respectively. The occurrence of barnacle larvae was highly sporadic. Consisting mainly of veliger larvae, the molluscs were most abundant at shallow stations

in spring and summer. Chaetognaths and tunicates were abundant throughout the study area throughout the year.

5. Approximately 75 percent of the copepods belonged to the Calanoida, with the remainder belonging mostly to the Cyclopoida. The relative abundance of calanoids increased in winter while that of cyclopoids increased in summer. Throughout the year, the developmental stages comprised nearly 50 percent of the total copepod population, indicating a sustained copepod reproduction throughout the year.

6. The most abundant calanoid species were *Paracalanus indicus, P. quasimodo* and *Clausocalanus furcatus*. The first two species were abundant at shallow stations while the latter was abundant at deep stations. The most abundant cyclopoid species were *Oncaea venusta, O. mediterranea* and *Farranula gracilis*. The first was abundant throughout the study area, but the latter two were abundant at offshore stations.

7. Species diversity indices and coefficients of equitability, based on adult female copepods, generally increased seaward in conformity to the number of species.

8. Of the other biological and physical data obtained at the time of zooplankton collection, salinity and chlorophyll a values seemed to be most closely correlated with the zooplankton. This correlation was most readily discernible in spring when the zooplankton was highly productive in low-salinity water.

CHAPTER SEVEN

NEUSTON PROJECT

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ABSTRACT

A total of 108 day and night neuston samples from 12 stations along four transects sampled regularly during 1976 on the South Texas Outer Continental Shelf were subjected to taxonomic analyses.

Differences in numerical abundances of taxonomic groups were determined in relation to seasonal, diurnal, distance-from-shore, and geographic considerations. These differences are discussed for such major taxonomic groups as Foraminifera, Cnidaria, Ctenophora, Nematoda, Polychaeta, Mollusca, Crustacea, Echinodermata, Chaetognatha, Tunicata, Insecta and ichthyoplankton.

Species groups which occurred frequently and showed relationships to each other were determined by recurrent group analysis, and the targeted species were analyzed further by a two-way analysis of variance to determine station and transect differences.

Biomass calculations (dry and ash-free dry weights) are presented for the June through December samples and showed considerable seasonal, geographic, and diurnal variations as did species diversity and dry weight of floating tar. Species diversities were greater at night, at the offshore stations and at Transect II during 1976. Dry weights of tar showed overall average values consistent with those reported previously from the Gulf of Mexico.

Detailed species analyses were provided for decapods, decapod larvae (85 taxa) and fish eggs and larvae (110 taxa). Decapod larvae were consistently more abundant and diverse in night samples with the most abundant decapod taxa being the sergestid shrimp *Lucifer faxoni*, portunid crab megalops larvae, *Callinectes* zoea larvae, *Portunus* zoea larvae, sergestid shrimp postlarvae, and pinnotherid crab zoeas. Fish eggs were most abundant in March, while fish larvae, most abundant in June, were represented most commonly by the families Clupeidae, Sciaenidae, Mugilidae, Exocoetidae, Mullidae, Engraulidae and Gobiidae.

INTRODUCTION

Purpose

The purpose of this study is to perform a taxonomic analysis of the neuston community occupying the upper 15-20 cm of the water column at specified locations sampled on a regular basis over the South Texas Outer Continental Shelf. This taxonomic analysis, which also includes quantitative enumeration of species, dry weight and ash-free dry weight determinations and weight of tar, is designed to serve as a baseline study of existing environmental conditions prior to possible environmental perturbations which might occur as a result of future offshore drilling and exploration.

The neuston environment and its organisms are important to the water column ecosystem in that they occupy a relatively thin skin of the ocean surface where air-sea mixing initially occurs. Many potential pollutants are thought to enter the oceans through this route, and any biological impact might first manifest itself in changes in the neuston.

Although the neuston defies a strict biological definition in terms of species, there are certain taxonomic groups which are commonly found in the upper 15-20 cm of the water column during significant portions of each day. There is considerable variability not only in the abundance of neuston, either as total numbers of organisms or in terms of dry weight, but also in taxonomic composition. This is due, in part, to diurnal vertical migration, but is also probably due to various types of environmental heterogeneity. Day-night sampling is, therefore, done to minimize the former variation, but the latter source of variability is not generally monitored.

In this report an attempt is made to identify the variations in numerical abundance of the various taxonomic categories of neuston in relation to diurnal, seasonal, geographic, and distance-from-shore considerations as they existed during 1976 in the sampling area. In addition, attempts were made to analyze for relationships between species as co-occurring groups and to determine their significant levels of station and transect variation patterns.

Literature Survev and Previous Work

It is only within the last 15 years that much has become known about marine neuston, although the neuston of freshwater ponds and pools has been studied since Newman first applied the term to surface film organisms in 1917 (Zaitsev, 1970).

Marine neuston was studied fairly extensively in the Black Sea and Sea of Azov (Zaitsev, 1961; 1968, 1970) and in the North Sea, Norwegian Sea, and subtropical Northeast Atlantic (Hempel and Weikert, 1972). Neuston studies in most other areas, however, have been limited, usually concentrating on specific taxonomic groups. These include various reports on aspects of Mediterranean neuston fauna, studies of pontellid copepods of the Pacific (Heinrich, 1969; 1971), and ichthyofauna of the subtropical Eastern Atlantic (Hartman, 1970).

No complete quantitative faunal analysis of neuston samples has been published. Although Weikert's (1972) study of the zooplankton of the subtropical Atlantic comes close, it omits several major zooplankton groups such as cnidarians and tunicates, and does not provide identifications of species of calanoid copepods.

Two recent unpublished theses present the most complete quantitative and detailed analyses of neuston organisms to date. The first, a study of neuston of the Northwest Atlantic (Morris, 1975), compared the zooplankton in the neuston with the subsurface zooplankton and reports on definite seasonal and diel cycles of neuston biomass. The area of study included the southeastern Gulf of Mexico and Caribbean Sea, as well as the northwestern Atlantic between Bermuda and Nova Scotia. The second, a thesis by Berkowitz (1976), an Assistant Investigator for the present BLM neuston study, was a comparison of neuston and near-surface zooplankton in the northwestern Gulf of Mexico in oceanic waters off Texas above the 1000-fathom bottom contour of the continental slope zone, which reported the neuston in the area to be relatively impoverished as compared to plankton concentrations 1 m below the surface. However, the above two studies did not include detailed analyses of fish eggs and larvae or decapod larvae as in the present BLM study.

Other neuston studies in the Gulf of Mexico, have been sparse and incomplete until the above-cited theses. Zaitsev (1970) found neuston from the Gulf of Mexico to be poor in areas of upwelling where biomass (wet, fresh weight) did not exceed 100-200 mg/m^3, but where the water converged in the center of the Gulf, the wet-weight biomass reached 410 mg/m^3. Studies by TerEco Corporation (1974, 1975) and by Pequegnat *et al.* (1976) in the northern Gulf of Mexico reported on neuston qualitatively and in terms of relative abundances of the taxa in each sample; these studies were, however, of short-term duration and did not express concentrations of organisms per unit volume of water nor in terms of biomass.

Jeffrey *et al.* (1974) reported on relative abundance of pelagic tar in the Gulf of Mexico from neuston samples but did not report on the biotic aspects. A cursory study of the latter was reported on briefly, however, by Pequegnat *et al.* (1976).

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METHODS AND MATERIALS

Field

A neuston net frame having an inside opening of 1 x 2 m was constructed of solid aluminum rod. A net with mesh size of 500 μm was lashed to the frame, and the entire net system was made to fish to an average depth of 15 cm by the addition of a styrene pontoon affixed to each of the short sides of the frame. A flowmeter was suspended beneath the frame by two stainless steel rods.

It was determined that 700 rpm on the R/V LONGHORN engine produced a speed of approximately 2.4 knots. All neuston tows were taken with the engine at approximately 700 rpm. Immediately prior to a tow, the flowmeter reading was recorded, and then the net was hoisted over the starboard railing and lowered in the water by the telescoping crane (cherry picker) located on the stern of the R/V LONGHORN. Timing began when the mouth passed below the surface. The net fished about 2 to 5 m away from the side of the ship. At the end of a tow, retrieval was begun so that the net left the water after about 15 minutes of fishing. Immediately after the net was brought on deck the flowmeter was read. The net was then thoroughly rinsed with the deck hose, and the contents of the cod end were transferred to an appropriate-sized jar and preserved in a 10 percent buffered formalin solution.

Laboratory

Each sample was initially poured into a large pan, and all organisms or objects approximately 1.5 cm in size or larger, as well as those which were otherwise conspicuous, were picked out. This assemblage was called the "large fraction". Its members were counted and identified as far as possible, and any tar particles were dried at 60°C for one hour and weighed. The remainder of the sample was then split in a Folsom Plankton Splitter, with one-half (chosen at random) saved for archiving. The remaining one-half was then split as necessary to produce a fraction containing approximately 1-2,000 organisms. This fraction became the "aliquot", and its constituents were counted and identified as far as possible. Any tar in the aliquot was dried and weighed. Thus, the minimum effort for each sample was the identification of the organisms and other materials contained in the large fraction and the aliquot. In the case of the detailed analysis of fish eggs and fish larvae, the large fraction and the entire non-archived half of the neuston sample (except for one of the final aliquots saved for ashing) were analyzed.

Dry weight determinations were performed on each sample starting with the spring 1976 samples. Ash-free dry weight determinations were added starting with the fall seasonal samples. Of the two aliquot samples produced by the final split of each original sample, one was randomly selected for taxonomic analysis and the other was used for dry weight determinations. The latter was rinsed in distilled water, placed in a pre-weighed aluminum pan, and dried at 60°C in a drying oven until its weight was constant (not less than 3 hours). After the weight of the pan was subtracted, the resulting figure was multiplied by the denominator of the fraction of the original sample which the aliquot represented, and then by a volume filtered factor, to obtain the dry weight in g/1000 m^3 of water filtered. After the dry weight was determined, the sample was placed in a muffle furnace and incinerated for a period of 3 hours at a temperature of 500-550°C. The sample was then cooled in a desiccator and weighed. The difference between dry weight and ash weight was the ash-free dry weight or dry weight of organics. Because dry weights were determined on the aliquot, the large and conspicuous organisms removed from the sample initially as the "large fraction" before splitting were not calculated as part of the dry weights.

RESULTS AND DISCUSSION

Field Sampling

Stations 1, 2 and 3, Transects I, II, III and IV, were sampled during three seasonal sampling periods in 1976 (winter, spring and fall). Day and night samples were collected at each station for a total of 72 seasonal samples. In addition, during six monthly sampling periods (March, April, July, August, November and December), day and night samples were taken at Stations 1, 2 and 3, Transect II, for a total of 36 monthly samples. Thus, the 108 neuston samples analyzed for 1976 were as follows:

Transect	Station 1	Station 2	Station 3	Totals
I	6	6	6	18
II	18	18	18	54
III	6	6	6	18
IV	6	6	6	18
Totals	36	36	36	108

The sampling technique was described above. It should be pointed out, however, that the neuston tows were collected on the "benthic" cruises rather than the "water column" cruises. This means that temperature, salinity, oxygen, nutrient, zooplankton and chlorophyll measurements were not taken synoptically with the neuston tows. Several days and sometimes weeks usually separated hydrographic observations from neuston tows at the same location. For this reason, correlations with these parameters have not been attempted.

Another limitation on interpretation and analysis was the lack of replication. We attempted to evaluate this weakness by collecting several replicates on a histopathology cruise in August. We obtained only two sets of two replicates. The analyses of these samples were discussed in the Third Quarterly Report (p. 304-305). We suggested then, and still feel that this problem should be examined further.

Biomass

Figures 1 and 2 show the dry weight biomass for neuston samples plotted against time during 1976. Biomass determinations were made starting with the spring (June) samples; thus, no data are available for the winter, March or April sampling periods. On Transect II (Figure 1), neuston biomass was higher in day samples at the nearshore station

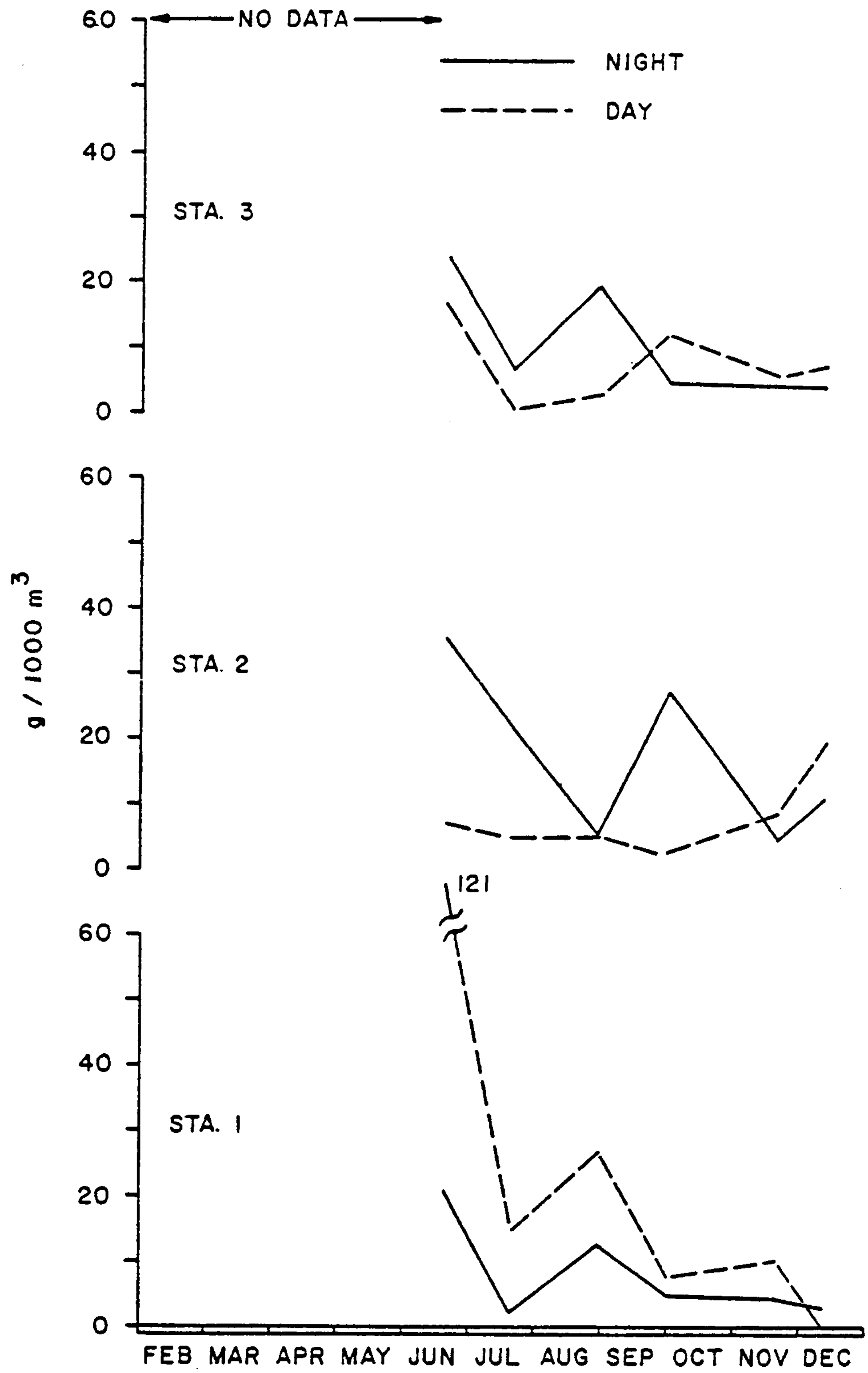

Figure 1. Dry Weight Biomass of Neuston Samples at Transect II during 1976.

(Station 1), but tended to be higher in night samples at the two offshore stations. The greatest biomass at Station 1 was in the spring (121 g/1000 m^3 in the day sample). At Station 2 the peaks were in spring and fall, especially in night samples, while at Station 3 the peaks were in spring and August. The spring highs were as expected because of the generally higher productivity at that time and the greater abundance of larval forms.

Neuston biomass on other transects sampled seasonally (Figure 2) also showed highs in the spring (June). Daytime biomass tended to be higher at nearshore stations on all transects, while nighttime biomass was higher at offshore Stations 2 and 3, all transects.

Ash-free dry weights, which were determined only on fall, November and December samples, are presented in Table 1.

Numerical Abundance

Figures 3 and 4 show numerical abundances plotted against time, and the results were similar to the biomass plots (Figures 1 and 2). On Transect II (Figure 3), Station 2 night samples were consistently higher in numerical abundance than day samples. However, at Station 1 (the nearshore station), day numerical abundances were higher than night, except in February, March, April and December. Station 3 showed more variation between day and night abundances, but also showed higher night values for February, March, April and December.

The high spring abundance at Station 1 (1,551/m^3) was dominated by the copepods *Centropages furcatus, Temora stylifera* and *Pontella* spp. (immature) as well as high numbers of hyperiid amphipods (212/m^3). The high spring night sample at Station 2 was dominated by some of the same copepods (*C. furcatus, T. stylifera,* and other unidentified calanoids),

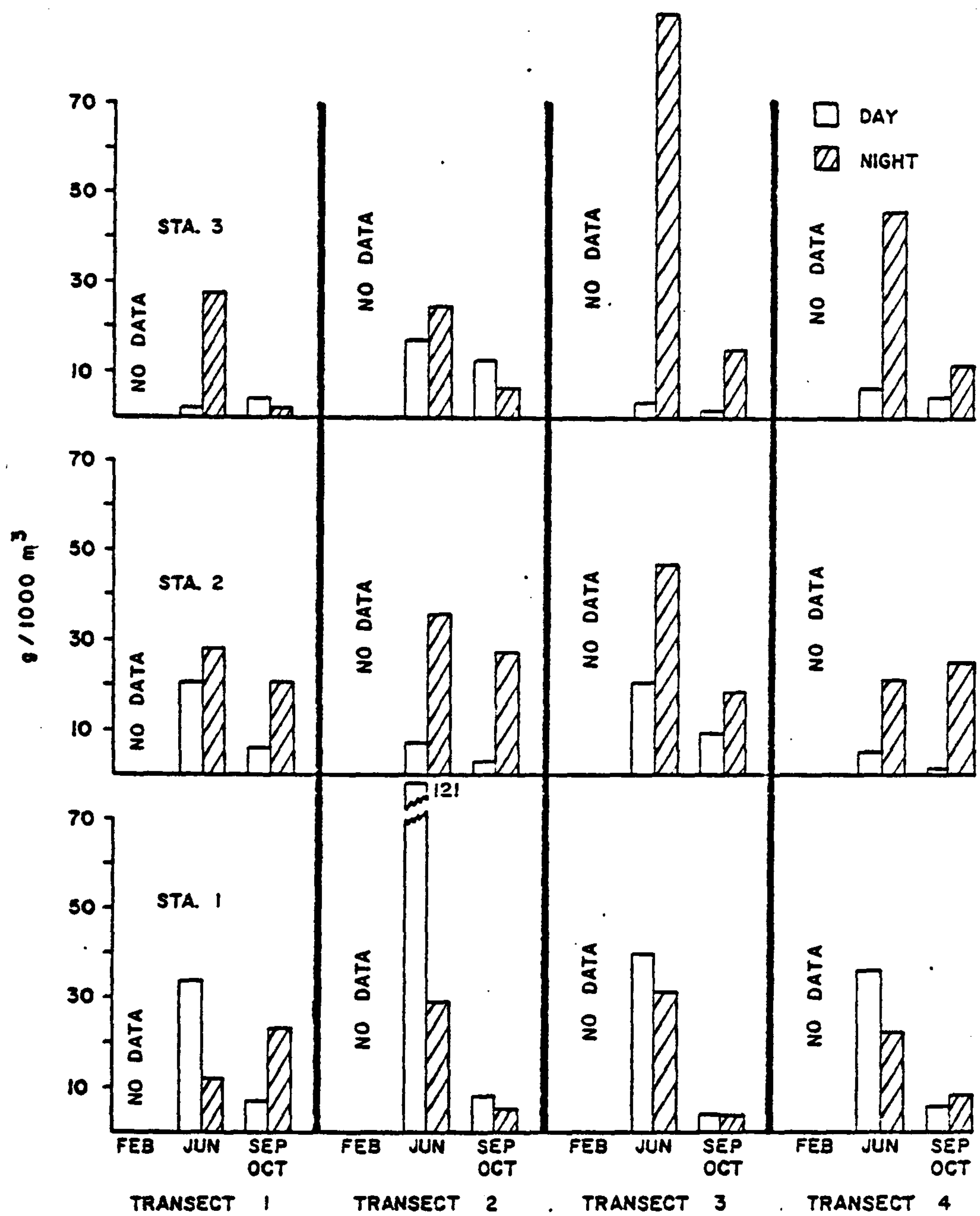

Figure 2. Dry Weight Biomass of Neuston samples at Transects I, II, III, and IV sampled seasonally during 1976.

TABLE 1

ASH-FREE DRY WEIGHTS FOR 1976 NEUSTON SAMPLES
TAKEN IN FALL, NOVEMBER, AND DECEMBER

STATION	ASH-FREE DRY WEIGHT ($g/1000\ m^3$)		
	FALL	NOVEMBER	DECEMBER
1/I/D	5.7900		
1/I/N	20.0362		
2/I/D	4.6764		
2/I/N	16.3278		
3/I/D	2.6995		
3/I/N	1.4388		
1/II/D	6.3843	9.4735	0.3980
1/II/N	3.5261	3.5487	2.4081
2/II/D	2.1181	7.6867	16.2275
2/II/N	14.2612	4.0935	10.4846
3/II/D	10.3938	4.8592	5.7271
3/II/N	5.0921	5.1896	4.4135
1/III/D	3.5258		
1/III/N	2.2156		
2/III/D	7.9011		
2/III/N	16.1354		
3/III/D	0.5944		
3/III/N	13.4478		
1/IV/D	5.0777		
1/IV/N	7.5329		
2/IV/D	0.6973		
2/IV/N	14.5604		
3/IV/D	1.1421		
3/IV/N	7.5137		
AVERAGES	7.2120	5.8085	6.6098

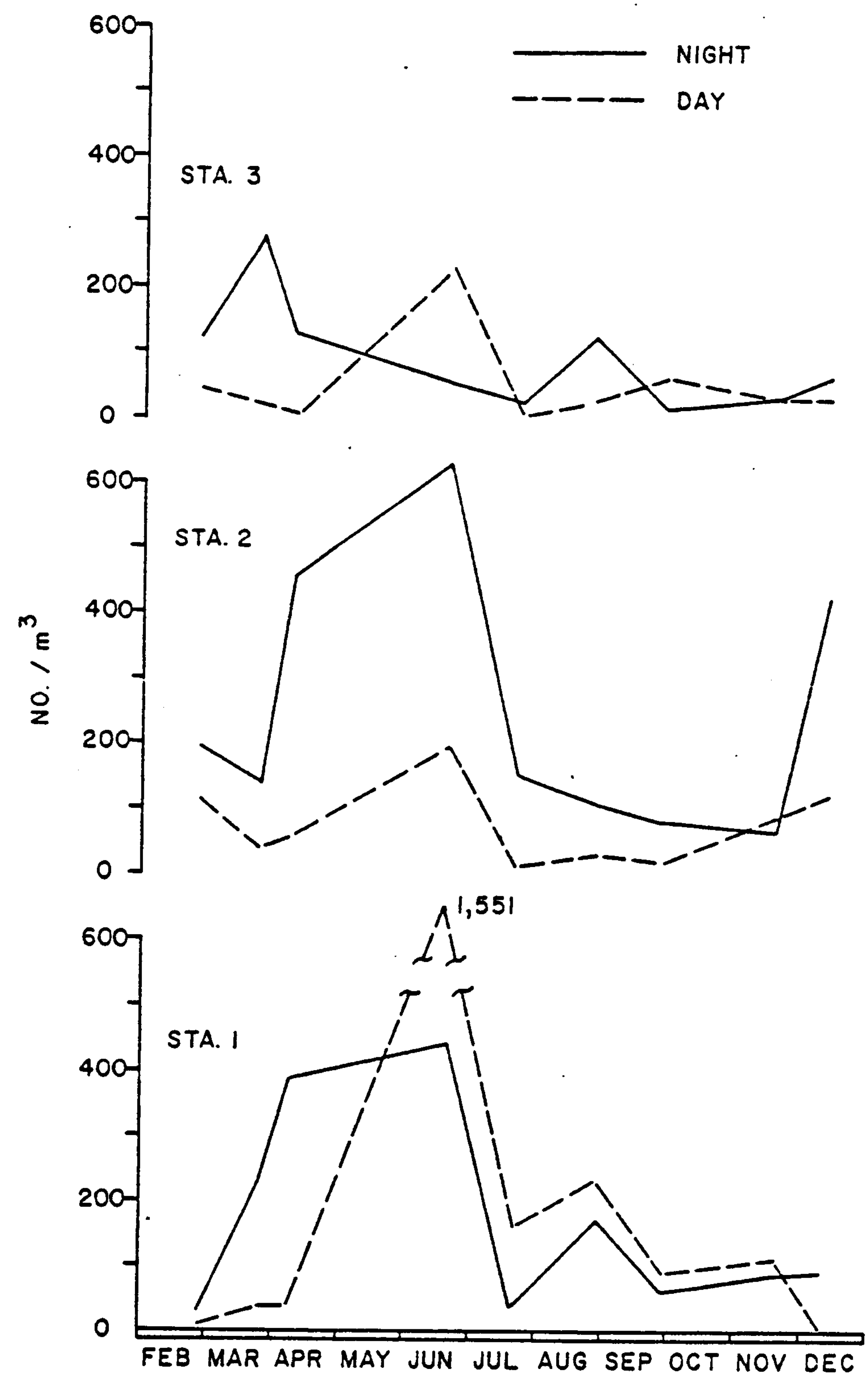

Figure 3. Numerical abundance of neuston organisms from Transect II samples during 1976.

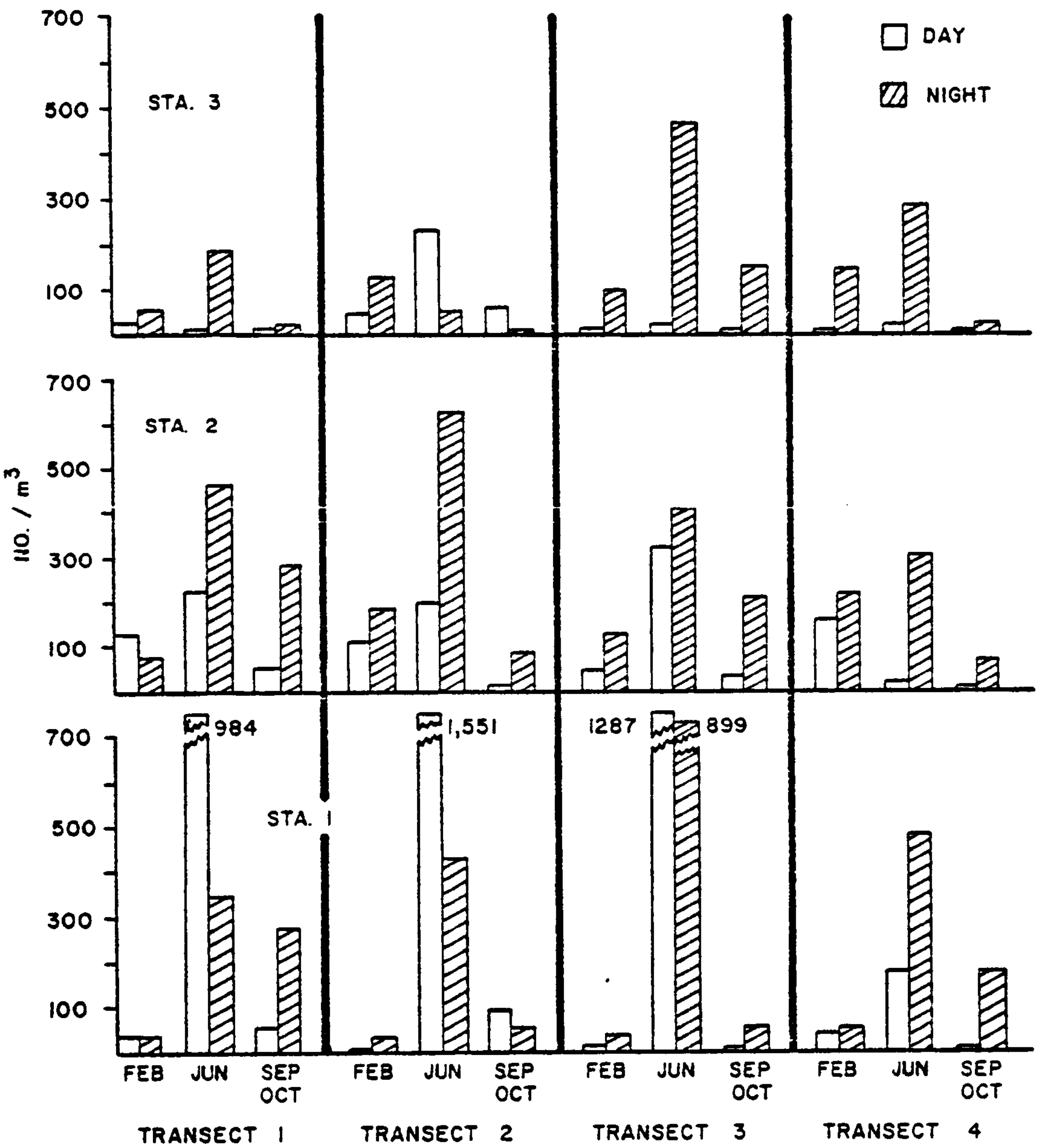

Figure 4. Numerical abundance of neuston organisms at Transects I, II, III, and IV sampled seasonally during 1976.

chaetognaths (60/m^3), and brachyuran crab megalops larvae (27.6/m^3). At Station 3, the high March night sample was dominated by a variety of organisms, *viz.*, hyperiid amphipods (78.7/m^3), the copepod *Nannocalanus minor* (55.9/m^3), brachyuran megalops larvae (19.5/m^3), salps (18.2/m^3), and *Lucifer faxoni* (14.2/m^3), while the high spring day sample was dominated primarily by one organism, the copepod *Temora stylifera* (178/m^3).

Numerical abundances on other transects sampled seasonally (Figure 4) also showed the highest figures for June. Considering the nearshore stations, at Station 1, Transect I, the June daytime high was accounted for by the copepods *Labidocera aestiva* (626/m^3), *Centropages furcatus* (196/m^3), *Labidocera* immature (69/m^3), and *Pontella meadii* (34/m^3). The June high day count at Station 1, Transect III, was also accounted for by the copepods *Labidocera* immature (1,035/m^3), *Labidocera aestiva* (92/m^3), and *L. scotti* (90/m^3). The high night count at the same station (1/III) in June was dominated by *Labidocera* immature (158/m^3), unidentified calanoids (151/m^3), *Temora stylifera* (101/m^3) and the sergestid shrimp *Lucifer faxoni* (112/m^3).

At the intermediate Station 2, Transect I, the high night counts in June were accounted for by the copepods *Temora stylifera* (118/m^3), *Centropages furcatus* (81/m^3) and unidentified calanoids (64/m^3), as well as by chaetognaths (38/m^3) and hyperiid amphipods (38/m^3). The high June night count at Station 2, Transect III, was accounted for by hyperiid amphipods (170/m^3), brachyuran megalops larvae (50/m^3), and the copepods *Centropages furcatus* (36/m^3) and unidentified calanoids (33/m^3). Station 2/IV/N SPRING, with a somewhat lower count than the same station on other transects, was dominated by hyperiid amphipods (83/m^3) and the copepods *Centropages furcatus* (52/m^3), *Temora stylifera* (39/m^3), and unidentified calanoids ($25/m^3$).

The highest neuston counts at the offshore stations (Station 3) were at Transect III in June at night. This sample was not dominated by copepods, but rather by hyperiid amphipods ($346/m^3$), chaetognaths ($28/m^3$), brachyuran zoea larvae ($14/m^3$), and the sergestid shrimp *Lucifer faxoni* ($13/m^3$).

Species Diversity

Using the number of taxa in each sample as an indication of species diversity, some generalizations concerning diversity on the basis of seasonal, diurnal, geographical, and distance-from-shore were made.

Out of the possibility of 136 taxa routinely identified (not including the more detailed analyses of decapod larvae and fish larvae), the greatest diversity on a seasonal basis was during the March and August sampling periods with 40 and 39 average number of taxa per sample, respectively (Table 2).

The night samples had consistently higher diversity than day samples (39 versus 31 taxa per sample, overall average).

Considering geographical variation in diversity, Transect II had the highest average diversity (37) and Transect IV had the lowest (31). Transects I and III were intermediate with 35 and 34 average taxa per sample, respectively.

On a nearshore-offshore basis, the offshore stations (Station 3) showed the highest average diversity (38 taxa) as compared to the intermediate stations (31 taxa) and nearshore stations (31 taxa).

Analysis of Data

Over the course of 1976, over 160 taxa were routinely identified. Of these, more than half were at the species level and only a few were at

TABLE 2

SPECIES DIVERSITIES IN NEUSTON
SAMPLES COLLECTED DURING 1976

SAMPLES	NUMBER OF TAXA PER SAMPLE DAY RANGE (Ave.)	NIGHT RANGE (Ave.)	DAY/NIGHT AVERAGE
Winter	14-46 (29)	30-59 (43)	36
March	26-42 (34)	32-55 (46)	40
April	17-43 (29)	34-41 (38)	34
Spring	20-31 (26)	17-47 (35)	31
July	26-29 (28)	32-38 (35)	32
August	23-43 (32)	41-48 (45)	39
Fall	28-40 (32)	32-47 (39)	36
November	28-49 (36)	34-38 (35)	36
December	30-39 (36)	33-42 (36)	36
	Total Day Ave. = 31	Total Night Ave. = 39	

the phylum level. It was necessary to eliminate some of the taxa from consideration and to identify a subset of taxa for a more detailed analysis. To this end, recurrent group analysis (Fager, 1957) was selected which has previously been used to examine species groupings in zooplankton samples (Fager and McGowan, 1963). In this analysis groups of species are formed on the basis of co-occurrence in samples. The purpose is to identify groups of species that are frequently found together and possibly indicative of a certain unique set of conditions or a similar response to changing conditions. This co-occurrence or level of affinity can be set at any level between 0 and 1 (total absence of affinity and complete affinity, respectively). The following formula was used:

$$\text{I.A.} = \frac{J_{ab}}{(N_a N_b)1/2} - \frac{1}{2(N_b)1/2}$$

where I.A. = index of affinity (0 - 1.0)

J_{ab} = joint occurrences of a, b

N_a = total occurrences of a

N_b = total occurrences of b

and $N_b \geq N_a$.

We set I.A. = 0.8, 0.7, 0.6 and 0.5 on successive but separate runs using all 1976 data for DAY and NIGHT separately. The 0.5 level gave large and unwieldy groups while the 0.8 level yielded small groups. The 0.7 level was selected for presentation (Figures 5 and 6). The DAY results showed five groups. The largest (Group 1D; D=day) contained two copepod species, one sergestid shrimp and brachyuran zoea larvae. Group 2D consisted of males and females of another species of copepod, *Pontellopsis villosa*, and immatures of that genus. This group showed a weak connection to Group 1D. A third group (3D) contained males, females and immatures of a species of pontellid copepod, *Anomalocera ornata*; it appeared to show no attraction to other groups. Group 4D encompassed the immatures of two pontellid copepod genera, *Labidocera* and *Pontella*; it also showed a weak attraction to 1D. The last group, 5D, consisted of males and females of a species of pontellid copepod, *Labidocera aestiva*. Single species or taxa showed affinities to 1D and are illustrated in Figure 5. The major change if the level of affinity was lowered to 0.6 was that 2D joined with 1D. One must be reminded that this analysis deals only with presence and absence, not quantitative values. It was selected for a first pass because of the large variation that existed in the data.

A similar analysis of the pooled night data at the same level of affinity (0.7) produced five groups. The largest, 1N, contained all the members in 1D with the addition of a pteropod (*Limacina trochiformis*), brachyuran megalops larvae, and another calanoid copepod (*Nannocalanus minor*). There were a number of "associate members" of this group which are shown in Figure 6. A second group, 2N, consisted of males and females of one copepod species (*Calanopia americana*), and a second species of calanoid copepod (*Temora turbinata*). This group showed a strong bond to 1N. The third group (3N) was the same as 3D (*Anomalocera ornata* males, females and immature) and again was isolated by itself. Group 4N was very similar to 2D with the absence of immatures of a pontellid copepod species (*Pontellopsis villosa*) being the only difference. Group 5N was the same as 5D (*Labidocera aestiva*, males and females).

These analyses served to identify species that occurred rather frequently during 1976 and showed relationships with other species. Since Transect II was sampled every cruise, Stations 1-3 were averaged and the results plotted on semi-log graphs (Figures 7-11). This was done to visually reduce the variability (log scale) and to reduce the amount of data (averaging Stations 1-3). It is realized that averaging

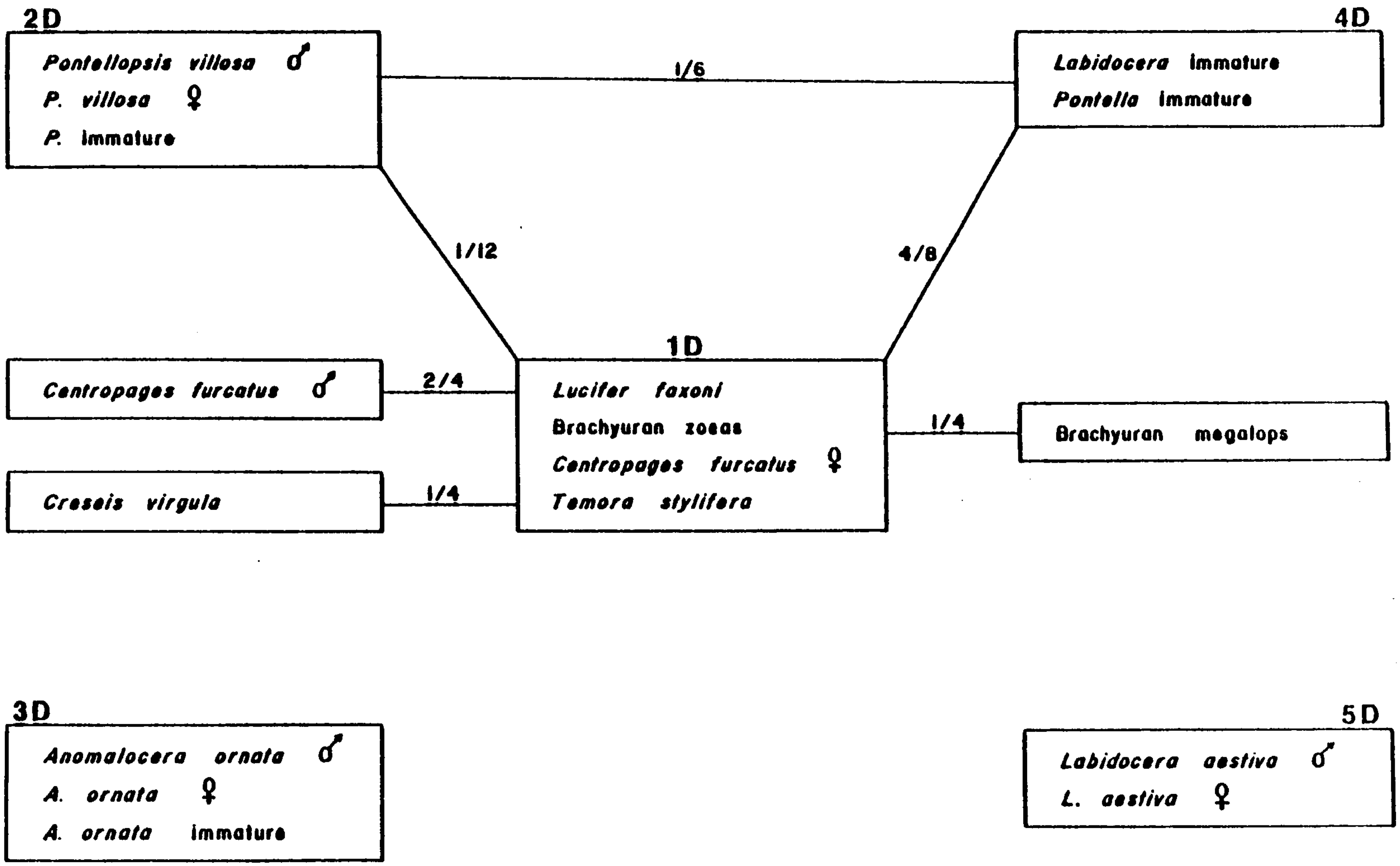

Figure 5. Groups formed from all 1976 Day samples using recurrent group analysis at the 0.7 level.

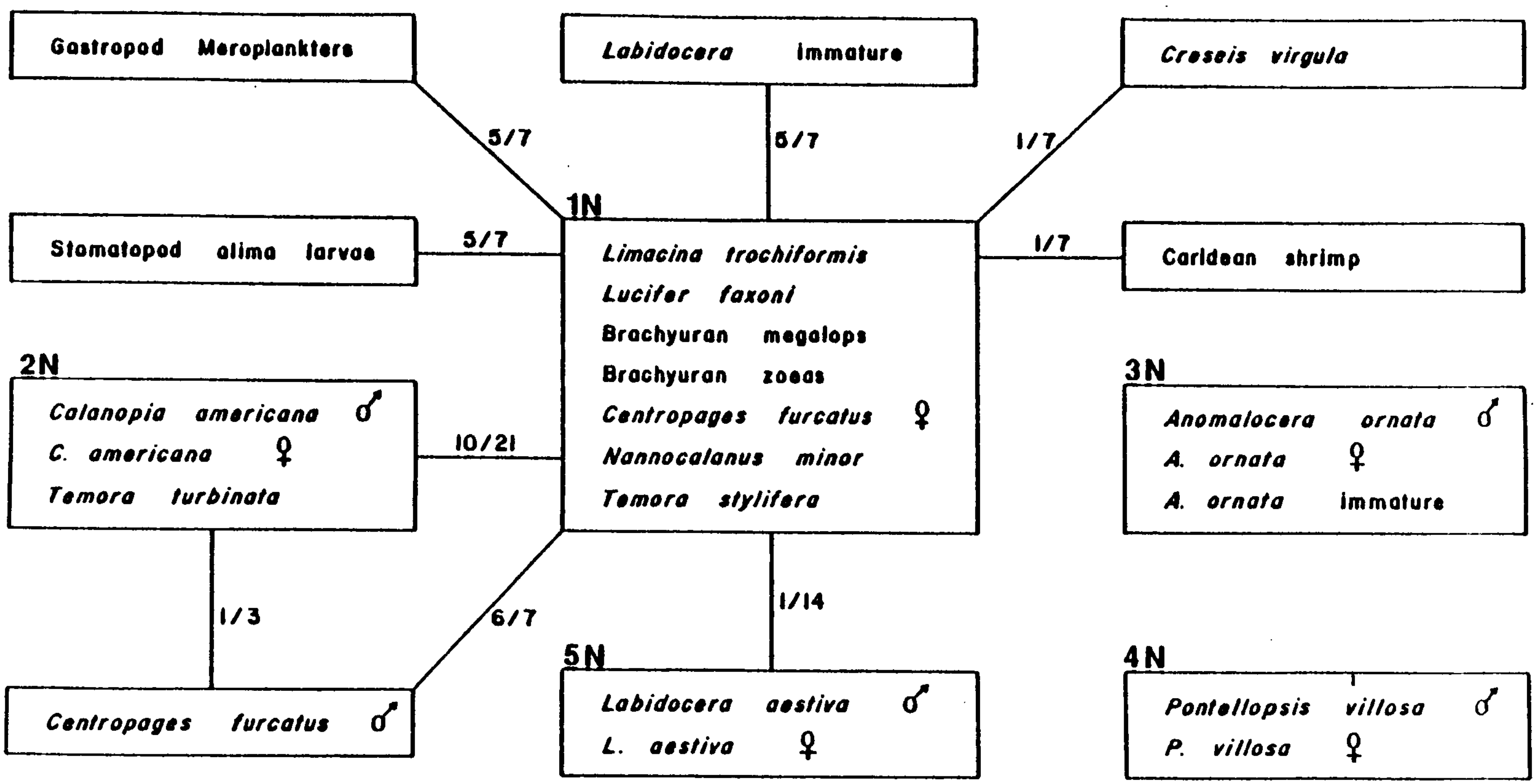

Figure 6. Groups formed from all 1976 Night samples using recurrent group analysis at the 0.7 level.

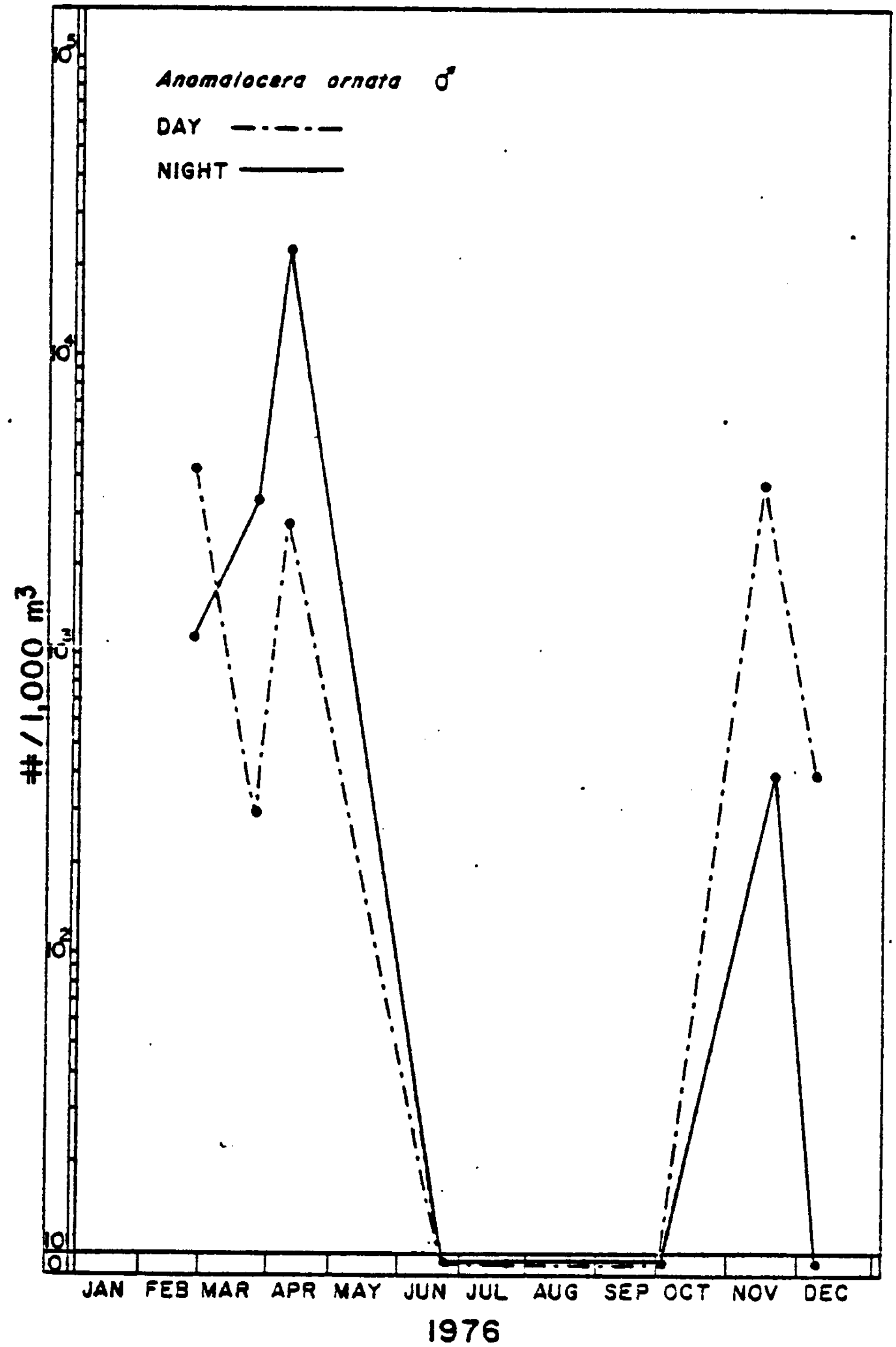

Figure 7. Transect II averages plotted against time for Anomalocera ornata males.

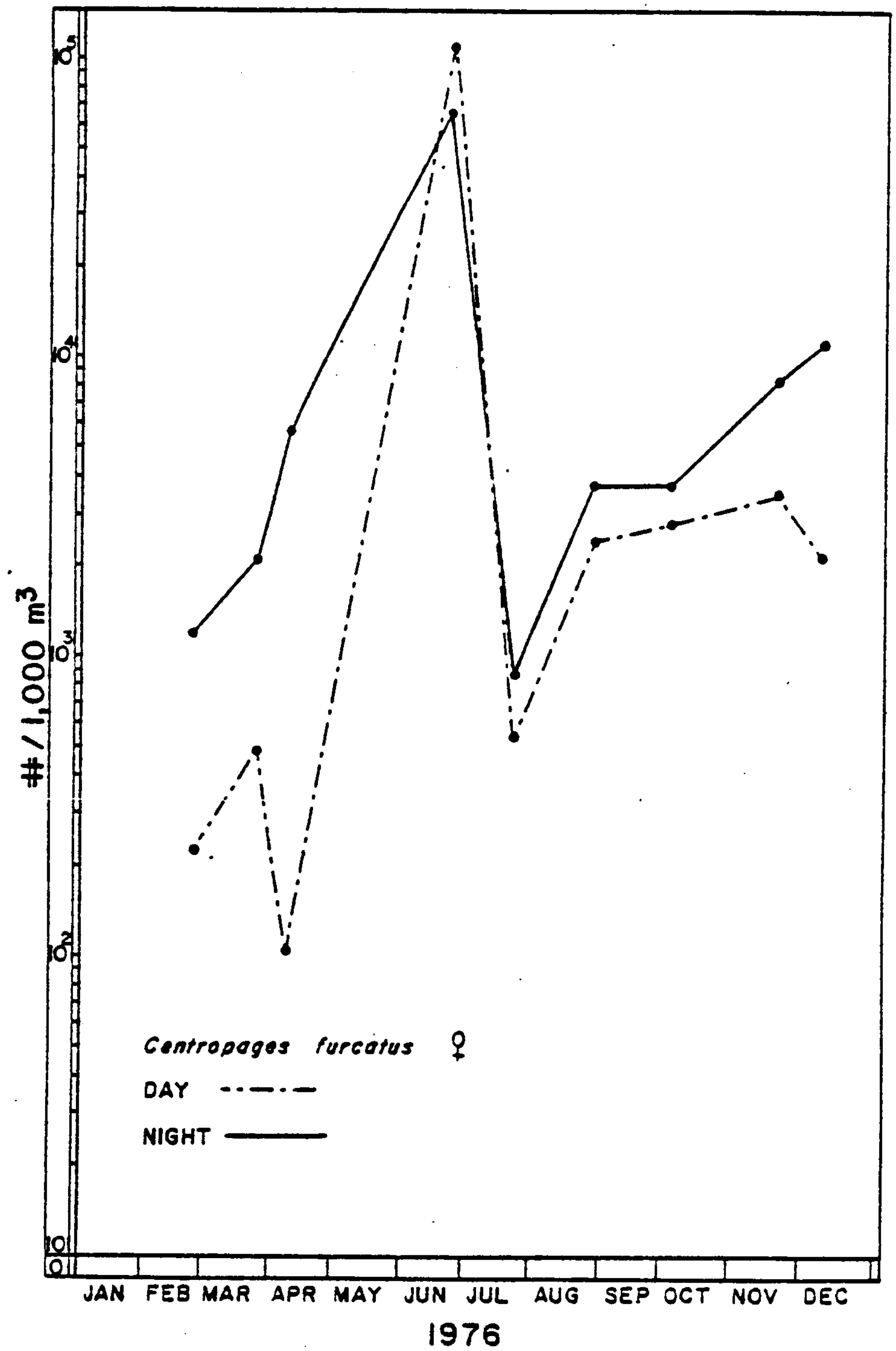

Figure 8. Transect II averages plotted against time for Centropages furcatus females.

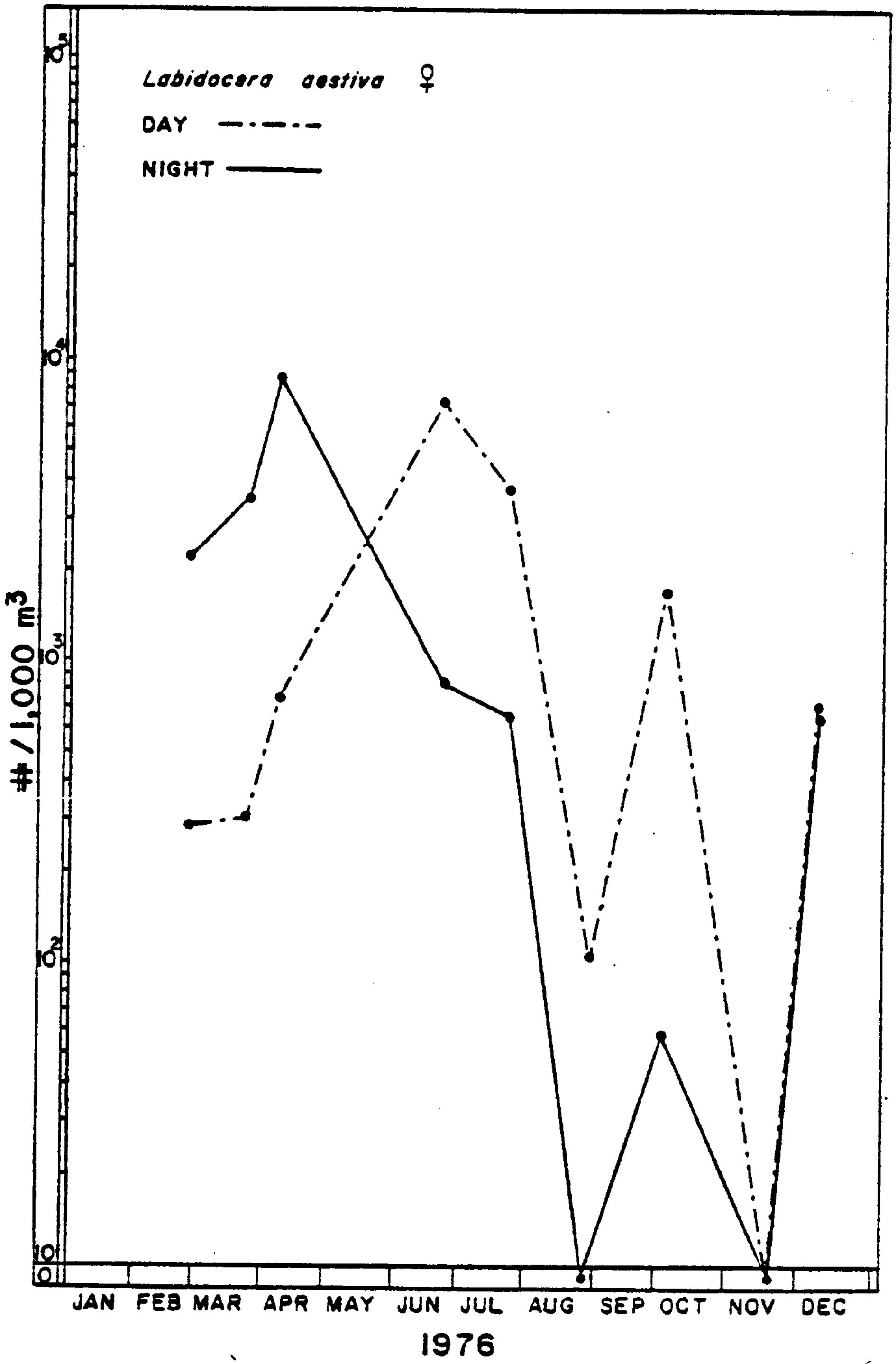

Figure 9. Transect II averages plotted against time for *Labidocera aestiva* females.

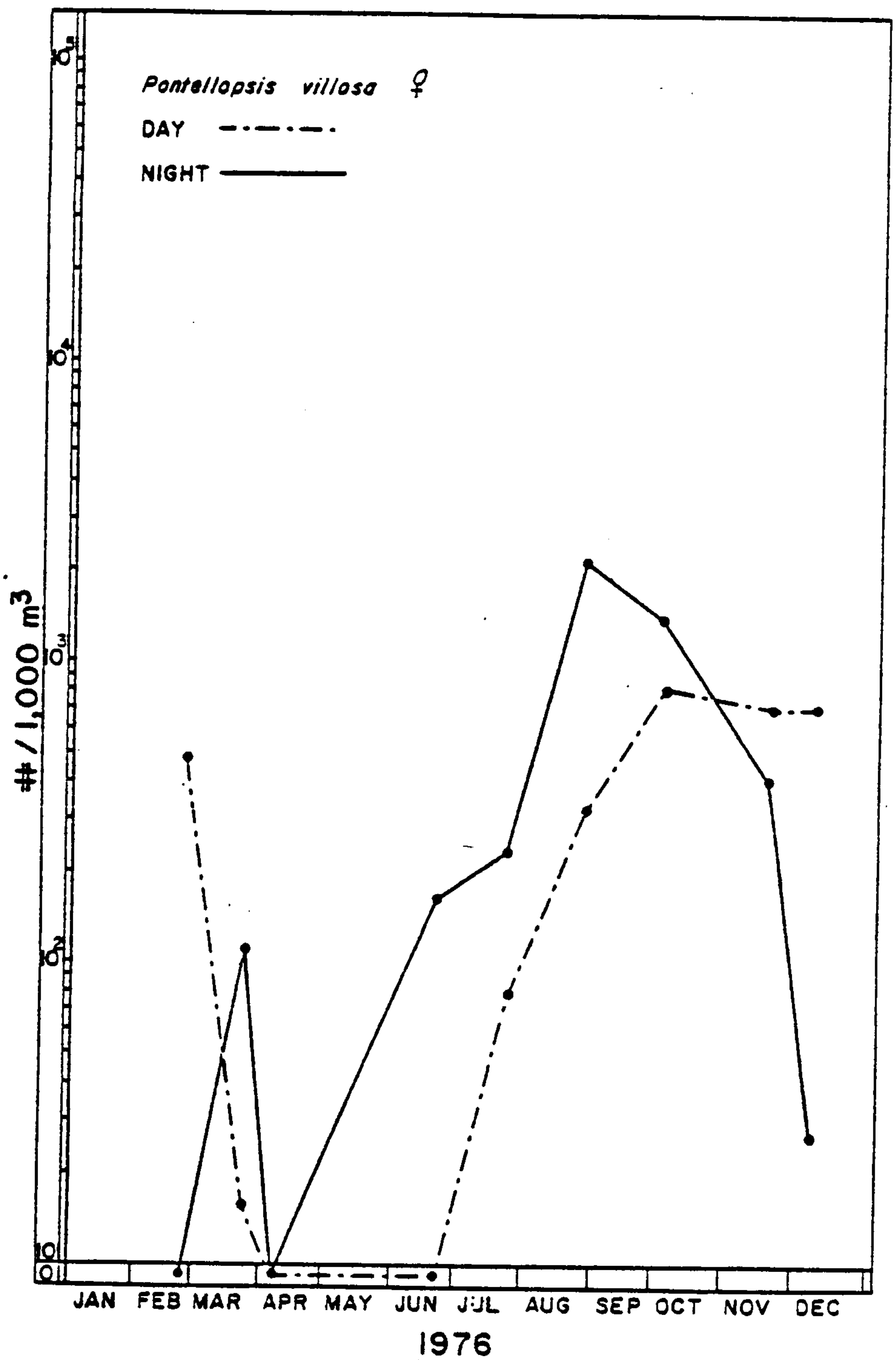

Figure 10. Transect II averages plotted against time for Pontellopsis villosa females.

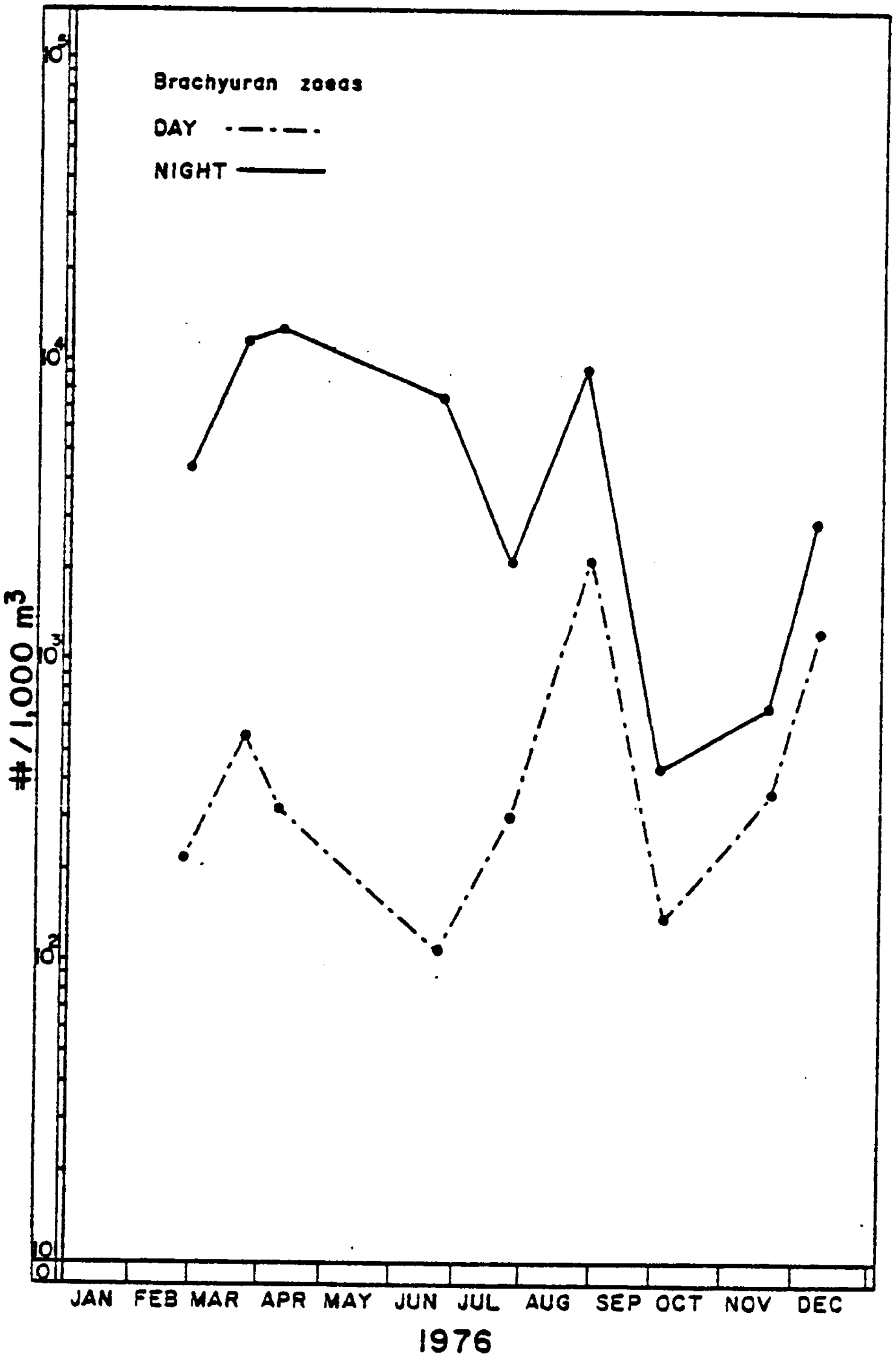

Figure 11. Transect II averages plotted against time for Brachyuran zoeas.

may obscure some important onshore-offshore differences, but the next procedure discussed examined these possibilities.

The third analytical technique was a two-way analysis of variance using the winter seasonal cruise (Station vs Transect) and Transect II over the nine cruises (Month vs Station). This was done for some of the targeted species and the results are presented in Tables 3 and 4. The values in Table 3 show that only two species and one larger taxon had significant station effects for the winter cruise. Two species and one larger taxon had significant transect effects. Table 4 shows that five species had significant monthly effects, while one species and one larger taxon had significant station effects.

Taxonomic Groups

The taxa from each neuston sample were tallied and ranked according to their numerical abundance in the sample. Those taxa receiving the highest rankings throughout the samples, *i.e.*, those ranking 1-6 in the most samples, are presented in Table 5 in descending order of dominance. A detailed phylogenetic listing of all taxa identified from the 1976 neuston samples is given in Appendix E, Table 1. Numerical abundance totals for selected taxonomic groups at each station are given in Appendix E, Table 2. Computer-printouts of the detailed taxonomic analyses of neuston samples from each sampling period are presented in Appendix E, Table 3.

Foraminifera

Foraminiferans were never very dominant in the 1976 neuston samples. Their greatest numerical abundance was 18,084/1000 m^3 in the spring at Station 3/II/N. They were more common in night samples than in day samples and considerably more common at offshore Station 3 than at the more inshore stations. They were more common in the winter and fall than

TABLE 3

ANALYSIS OF VARIANCE FOR SELECTED SPECIES
FOR THE WINTER SEASONAL CRUISE
(VALUES WERE LOG TRANSFORMED)

TAXON	F VALUE		LEVEL OF SIGNIFICANCE	
	STATION	TRANSECT	STATION	TRANSECT
Lucifer faxoni	5.87	1.42	.04*	.32
Anomalocera ornata immature	5.49	0.44	.04*	.73
Anomalocera ornata male	7.90	0.30	.02*	.83
Anomalocera ornata female	4.90	0.42	.05*	.74
Limacina trochiformis	0.45	0.59	.66	.64
Centropages furcatus female	3.35	0.88	.11	.50
Labidocera aestiva male	0.65	8.19	.55	.02*
Temora turbinata	1.04	5.64	.41	.04*
Temora stylifera	4.25	4.50	.07	.06
Nannocalanus minor	2.99	1.86	.13	.24
Calanopia americana male	1.00	3.99	.42	.07
Calanopia americana female	0.46	0.60	.46	.60
Brachyuran zoeas	5.47	5.40	.04*	.04*
Brachyuran megalops	1.61	1.63	.27	.28

*indicates significance at the .05 level.

TABLE 4

ANALYSIS OF VARIANCE FOR SELECTED SPECIES USING LOG TRANSFORMED DATA FOR TRANSECT II FOR ALL NINE CRUISES

TAXON	F VALUE		LEVEL OF SIGNIFICANCE	
	MONTH	STATION	MONTH	STATION
Lucifer faxoni	1.80	0.85	.15	.45
Anomalocera ornata male	3.97	4.29	.01*	.03*
Limacina trochiformis	2.29	1.47	.08	.26
Centropages furcatus female	3.61	3.17	.01*	.07
Labidocera aestiva male	1.73	7.85	.17	.004*
Temora turbinata	4.41	0.38	.005*	.69
Temora stylifera	2.99	0.76	.03*	.48
Nannocalanus minor	1.03	0.85	.45	.45
Calanopia americana male	1.45	3.19	.25	.07
Calanopia americana female	2.87	2.67	.03*	.10
Brachyuran zoeas	1.91	6.42	.13	.01*
Brachyuran megalops	0.53	0.55	.82	.59

*indicates significance at the .05 level.

TABLE 5

TAXA RANKED IN ORDER OF DECREASING DOMINANCE IN 1976 NEUSTON SAMPLES

		Sum of Ranks*	No. of Samples with #1, 2, or 3 ranking
1.	Hyperiid amphipods	72	29
2.	Unidentified calanoid copepods	65	30
3.	Chaetognaths	56	35
4.	*Anomalocera ornata*	45	17
5.	*Temora stylifera*	44	22
6.	Fish eggs	44	20
7.	*Centropages furcatus*	42	26
8.	*Lucifer faxoni*	40	18
9.	Brachyuran megalops larvae	35	17
10.	*Pontellopsis villosa*	21	10
11.	*Labidocera* immature	21	9
12.	*Labidocera scotti*	16	7
13.	*Labidocera aestiva*	15	9
14.	*Nannocalanus minor*	13	8
15.	Ostracods	13	6
16.	Salps	10	6
17.	Brachyuran zoea larvae	9	5
18.	*Pontella* immature	8	4
19.	*Calanopia americana*	7	5
20.	Fish larvae	6	2

*Most abundant species = Rank 3
Second most abundant species = Rank 2
Third most abundant species = Rank 1

in the spring.

Cnidaria

The large siphonophores *Physalia, Velella* and *Porpita* were sometimes quite conspicuous in neuston samples during 1976, primarily during February. They were rare or entirely absent during June, July, August and November.

Porpita reached its greatest concentrations in winter and March (1293/1000 m^3 at Station 2/II/N, March).

Velella reached its peak concentration of around 1600/1000 m^3 at Transect I (Stations 1 and 2) in winter.

Although the *Physalia* were often large in size, they never occurred in large numbers. They were most abundant at Transect I, Stations 1 and 2, in February where greatest abundances were only 10-15/1000 m^3.

Medusae reached their greatest abundances (200-874/1000 m^3) in night samples at all three stations on all transects throughout the year.

Ctenophora

Ctenophores were quite rare and found in only three samples during the 1976 sampling period. All were from the same station, 1/I/D, in April, November and December. Ctenophore numbers were low, ranging from 17 to 75/1000 m^3.

Nematoda

Nematodes were not common, occurring in only seven samples in numbers ranging from 24 to 180/1000 m^3. They were found only at Station 1, Transects I and II, in winter and December samples and at Station 3/II in August and December. Nematodes never appeared at Station 2 (the intermediate station) on any of the transects.

Polychaeta

Typhloscolecids were the dominant polychaetes and occurred at all stations on all transects. Highest numbers occurred in the spring at Station 1/I/D (1358/1000 m^3).

Alciopids were less common, occurring only at Stations 2 and 3, Transects I and II. Their concentrations ranged between 41 and 191/1000 m^3. Alciopods occurred in winter, April, spring and August.

Tomopterid polychaetes, often common in plankton samples (especially in open-ocean areas), were rare in the 1976 neuston samples, occurring only once at Station 3/II/N in December (117/1000 m^3).

Other unidentified polychaetes occurred at all stations on all transects and had highs of 2400 and 2218/1000 m^3 at Station 1/IV/D in the spring and at Station 1/III/D in August.

Mollusca

Pteropods

Certain species of pteropods were relatively abundant in some neuston samples during 1976. *Creseis acicula* and *Limacina trochiformis* were dominant in several samples. The former was the most abundant organism at Station 1/IV/D in the fall, while the latter was the most abundant taxon at Station 1/III/D in the fall. *Cresies virgula* also ranked relatively high, *i.e.*, in the top six taxa, in several samples throughout the year, ranking highest (No. 2) at Station 3/II/D in the fall.

Pteropods, in general, tended to occur somewhat more frequently in night samples than day samples (49:44), and occurred more frequently at the offshore station than at the two nearshore stations. They were more common in spring and fall than in winter. The highest pteropod concentration was 44,137/1000 m^3 in spring at Station 2/II/N.

Bivalve Larvae

Bivalve larvae were considerably more frequent in night samples than in day samples (23:8) and were more common at Station 1 and 2 than at the offshore Station 3(1:2:3::10:14:6). They were considerably more common in winter than in spring or fall. Bivalve larvae were the least common on Transect IV. Their greatest abundance (4805/1000 m^3) occurred in April at Station 1/II/N.

Gastropod Larvae

In contrast to bivalve larvae, gastropod larvae were only slightly more abundant in night vs day samples (37:27). They were also more common at Stations 1 and 2 than at Station 3 (1:2:3::24:23:17), and tended to be more common in winter samples than in spring or fall. Gastropod larvae were most common on Transect III. Their greatest abundance (20,086/1000 m^3) was in spring at Station 1/IV/N.

Crustacea

Hyperiid Amphipods

These organisms were often extremely abundant (up to 346,000/1000 m^3) and ranked as the most dominant taxon during the year (Table 5). Figures 12 and 13 show their numerical abundance during the 1976 sampling period. Nighttime abundance was consistently greater than daytime numbers, with the exception of Station 1/II/D in spring where the situation was reversed. Except for the spring peak at Transect II, hyperiids were otherwise most abundant at Transects III and IV at the two offshore stations (Stations 2 and 3). At Transect III, hyperiids were most abundant in the spring and fall, while at Transect IV, they were most abundant in the winter and spring (Figure 13).

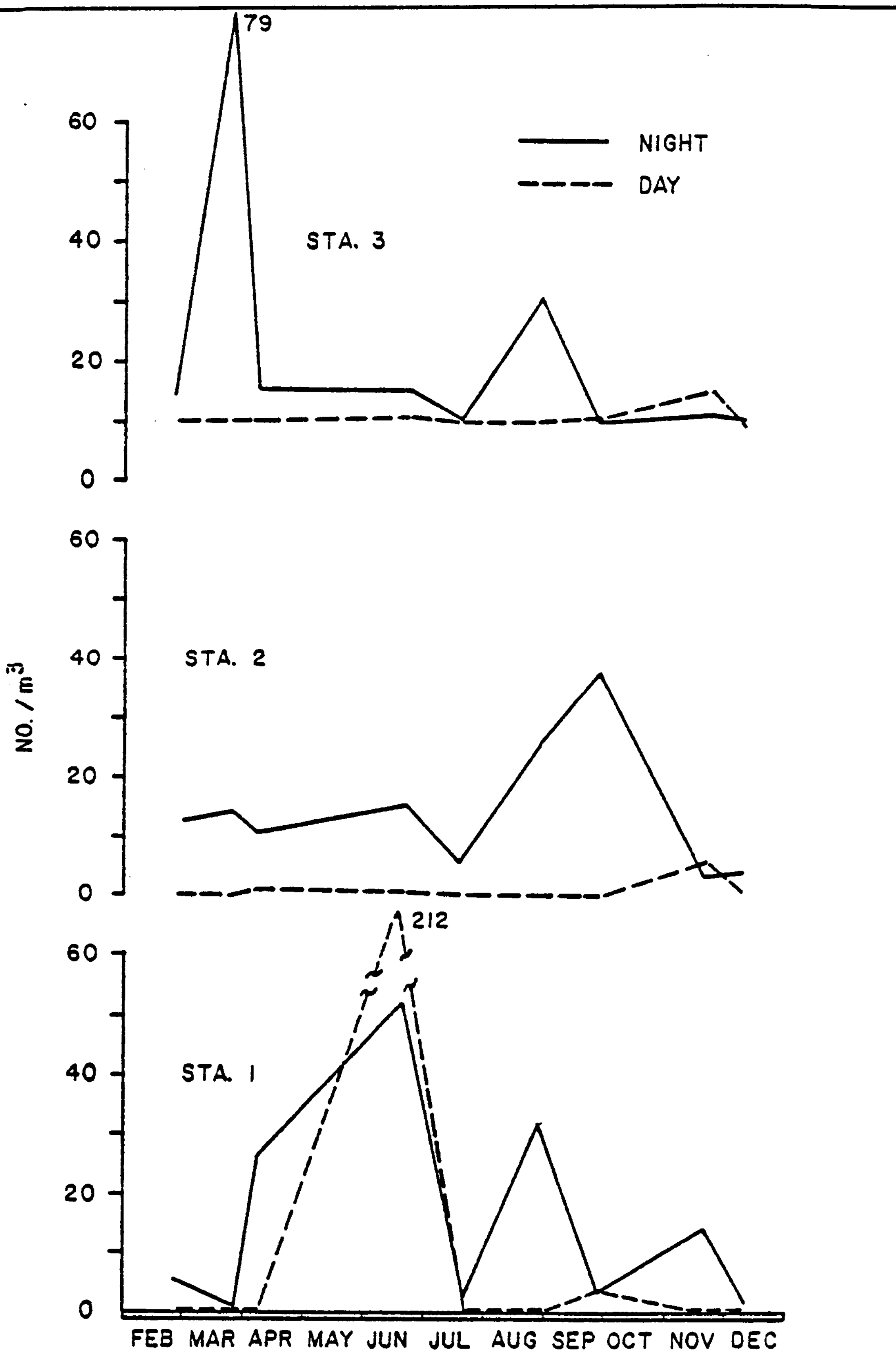

Figure 12. Hyperiid Amphipods at Transect II Stations During 1976.

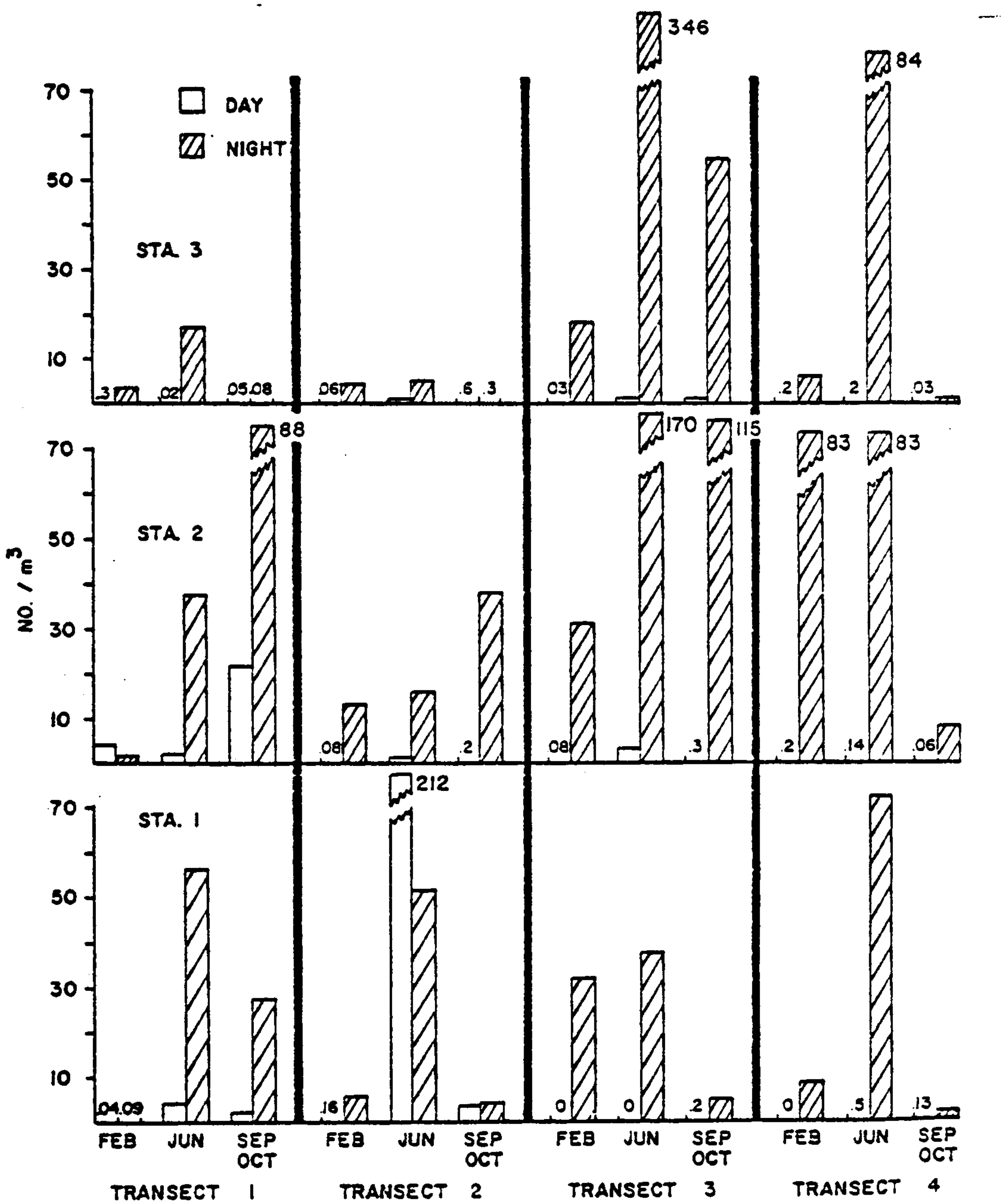

Figure 13. Hyperiid amphipods at Transect I, II, III, and IV stations sampled seasonally during 1976.

Barnacle Larvae

Barnacle larvae were almost entirely restricted to winter and early spring and were practically non-existent from June through November. They were found slightly more frequently at the offshore station than at the two more inshore stations. Barnacle larvae were most common along Transect I and least common along Transect IV.

Barnacle nauplii (the first of the barnacle larval stages) occurred almost exclusively in night samples, while cyprids (the last stage) occurred almost exclusively in day samples. Barnacle nauplii reached their peak abundances of 1747 and 1624/1000 m^3 at Stations 1/I/N (April) and 1/I/N (Winter), while barnacle cyprids reached their peak of 4,893/ 1000 m^3 at Station 3/II/D in December.

Decapod and Decapod Larvae

This group was studied in considerable detail. A total of 85 decapod taxa, including the different larval stages, were identified from the 1976 South Texas neuston samples (see Appendix E, Table 1). The decapod larvae exhibited a very strong nocturnal increase in abundance over daytime levels (Figures 14 and 15), apparently due to vertical migrations to the surface at night.

At Transect II, the only Transect sampled monthly during 1976 (Figure 14), decapod larvae reached peaks in March, June and August at Station 1; at Station 2 the peaks were in the March-April-June period with another smaller peak in December; and at Station 3, the peaks were in March and August. On Transect II the greatest concentration of decapod larvae was 41.7/m^3 at Station 1/N in August. This sample had a high decapod species diversity with 27 taxa, and the dominant taxa were pinnotherid crab zoeas (8/m^3), portunid crab megalops (8/m^3), portunid crab

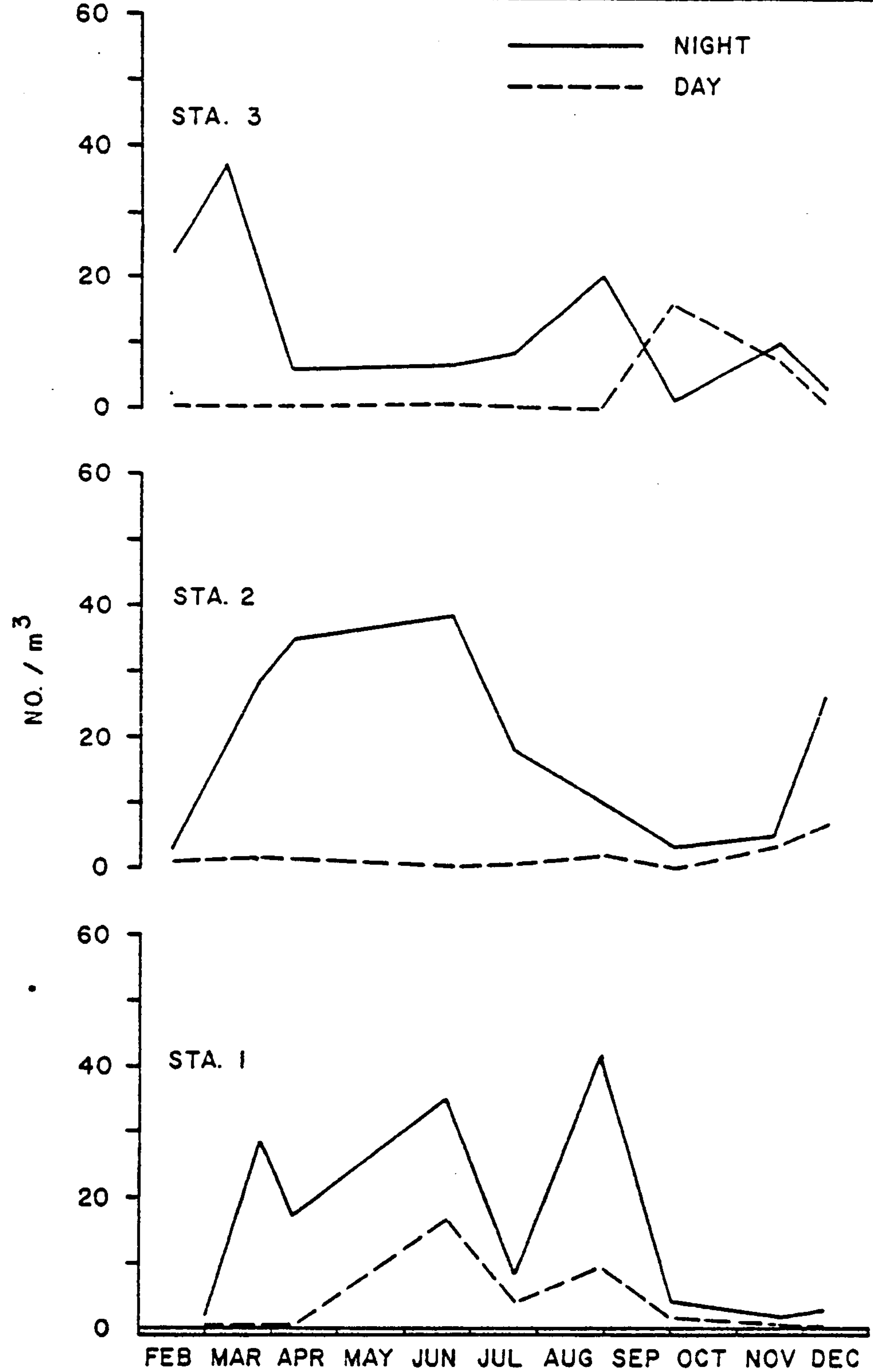

Figure 14. Decapod larvae at Transect II Stations During 1976.

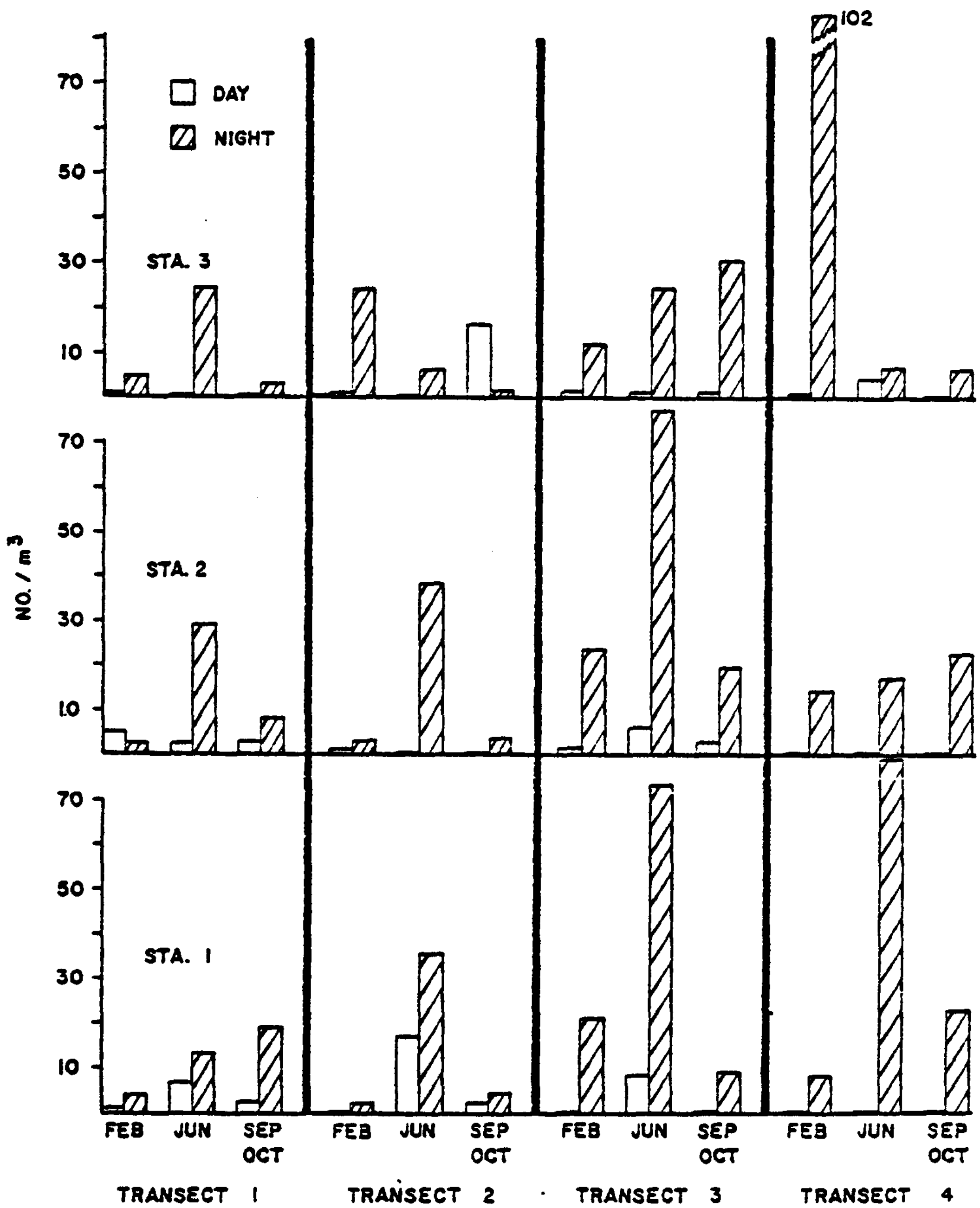

Figure 15. Decapod larvae at Transect I, II, III and IV Stations sampled seasonally during 1976

zoeas ($8/m^3$) and brachyuran sp. B megalops ($6/m^3$).

Figure 15 compares the numbers of decapod larvae at Transect I, II, III and IV during February, June and September-October. Most of the Transects showed a June peak, except for Transect IV, Station 3, which had a peak of $102/m^3$ in February. This sample had a total of only seven decapod taxa dominated by portunid megalops larvae ($91/m^3$) and portunid zoea larvae ($9/m^3$). The peak of $83/m^3$ at Station 1/IV/N in June was composed of 21 decapod taxa dominated by portunid crab zoeas ($39/m^3$) and pinnotherid crab zoeas ($18/m^3$). On Transect III, the peaks of 73 and $78/m^3$ in June at Stations 1 and 2 at night were dominated by pinnotherid crab zoeas ($18/m^3$), caridean shrimp larvae ($10/m^3$), and *Albunea* (Anomuran) larvae ($7/m^3$) at Station 1, and by *Portunus* megalops ($48/m^3$) and caridean shrimp larvae ($26/m^3$) at Station 2.

Considering total decapod species diversity throughout 1976, a consistently higher diversity was found in night vs day samples. This was as expected due to the nocturnal migration toward the surface by many decapods, especially decapod larvae.

Thus, taking only the night neuston samples into consideration, species diversity ranged from a low of five decapod taxa (Station 2, Transect I, winter) to a high of 28 decapod taxa at Station 1, Transect III, in the fall. Considering monthly averages for Transect II alone (the only transect sampled monthly), the greatest decapod species diversity occurred in August (average = 20 taxa per sample). Next was July with an average of 17 taxa per sample. Lowest species diversity averages were April with 9 taxa and winter with 10 taxa per sample.

Also, using only the night sample averages, average species diversities which reflected nearshore-offshore differences, north-south geographical differences (or transect differences) and seasonal differences were obtained (Table 6). This table shows that the nearshore station (Station 1) has the highest average decapod species diversity (17 taxa per sample), that the transect with the highest average number of decapod taxa per sample (15.8) was Transect III, and that the season with the highest average decapod taxa per sample was the fall (15 taxa per sample).

When the dominant decapod taxa in the 1976 neuston samples were ranked, the following order of dominance was obtained:

1. *Lucifer faxoni*
2. Portunid megalops
3. *Callinectes* zoeas
4. *Portunus* zoeas
5. Sergestid sp. A postlarvae
6. Pinnotherid zoeas

The sergestid shrimp, *Lucifer faxoni*, frequently occurred in very high numbers and ranked first in dominance of decapod taxa and number 8 in dominance of all neuston taxa (Table 5). *Lucifer faxoni* reached greatest abundance at nearshore stations (Station 1) with daytime abundance usually exceeding nighttime abundance at this station on Transect II (Figure 16). Peak concentrations of *L. faxoni* occurred at Station 1/II/D in August (186/m^3) and June (147/m^3). The other two peak occurrences of *L. faxoni* were on Transect III (Station 1N, 112/m^3) and Transect IV (Station 1D, 102/m^3)(Figure 17).

Offshore stations generally had lower numbers of *L. faxoni* than nearshore or intermediate stations, and the species tended to be more abundant in night samples as compared to day samples at offshore stations with the exception of a moderate daytime peak of nearly 30 per m^3 at

TABLE 6

SPECIES DIVERSITY AVERAGES FOR DECAPOD CRUSTACEA IN NIGHTTIME NEUSTON SAMPLES FOR 1976

		Station 1	Station 2	Station 3
Nearshore-offshore Differences:		17	11.7	10.4
	Transect I	Transect II	Transect III	Transect IV
Geographical (Transect) Differences:	9.6	12.6	15.8	13.8
		Winter	Spring	Fall
Seasonal Differences:		10.3	13.6	15

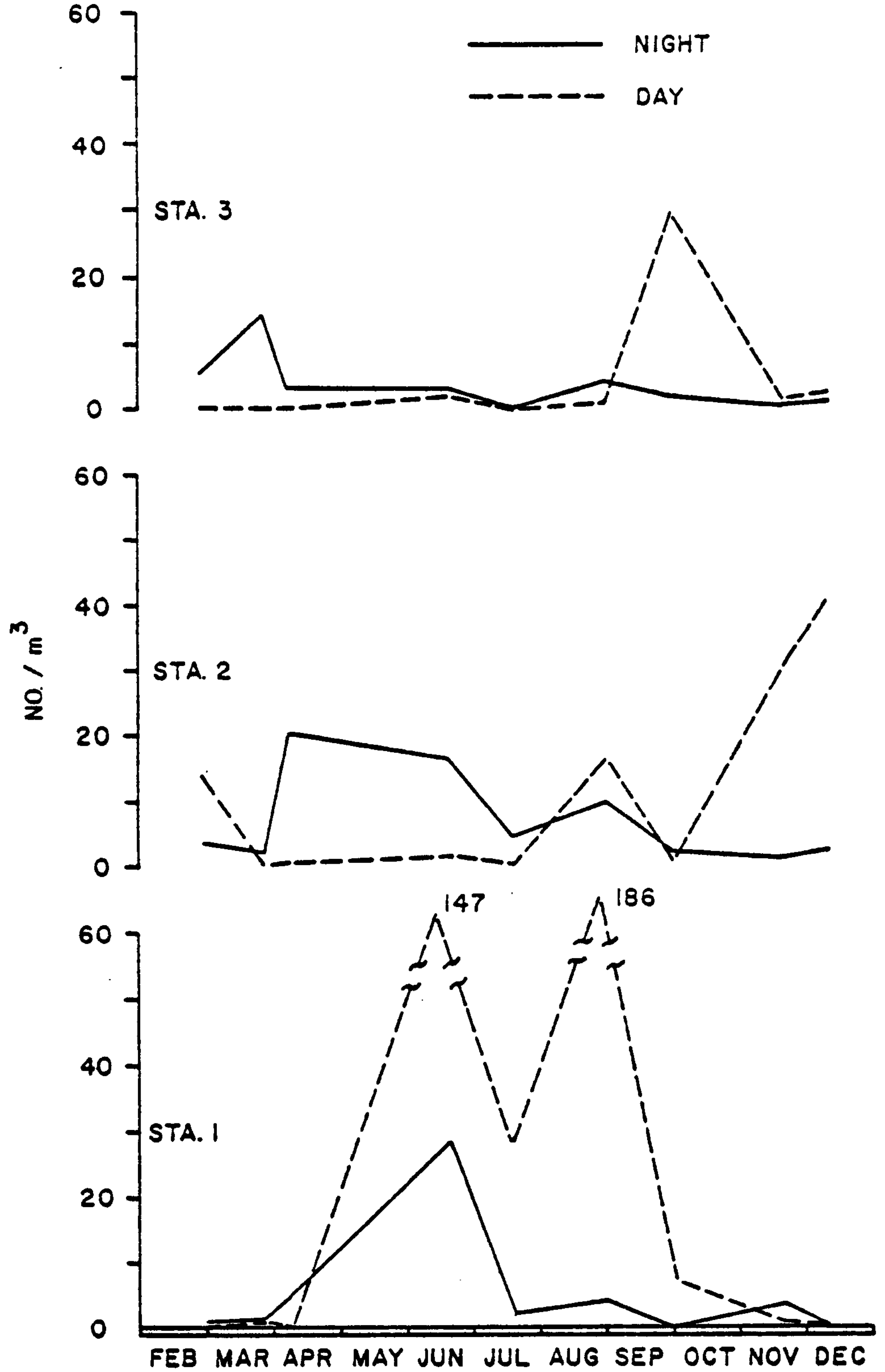

Figure 16. Abundance of *Lucifer faxoni* at Transect II Stations During 1976.

Station 3/II/D Fall (Figure 17).

Daytime abundances of *L. faxoni* on Transect I were greater at the intermediate station (Station 2) in February and June than at the near-shore or offshore stations (Stations 1 or 3). Abundances at Station 2/I were also greater than at intermediate stations on any other transects during these months (Figure 17).

Another species of *Lucifer*, *L. typus*, occurred occasionally in South Texas neuston samples. Considered to be an indicator of oceanic water (Bowman and McCain, 1977; Harper, 1968), *L. typus* was taken only at off-shore stations (Station 3) between June and November, except for one occurrence at Station 2/II/N in July.

Lucifer typus was taken at the following stations in the following concentrations during 1976:

Sample	No/1000 m^3
3/II/N Spring	547
3/IV/N Spring	2005
2/II/N July	1064
3/II/N July	40
3/II/D Fall	318
3/II/N Fall	37
3/II/D November	889

It is interesting that *L. typus* occurred most often at Transect II, Station 3 (five of seven occurrences), and did not occur on Transects I or III. *L. typus* also occurred more frequently in night tows than in day tows, with five of seven occurrences being at night.

Portunid crab megalops larvae were occasionally quite abundant (Figure 18) and were more abundant at the two offshore stations than at the

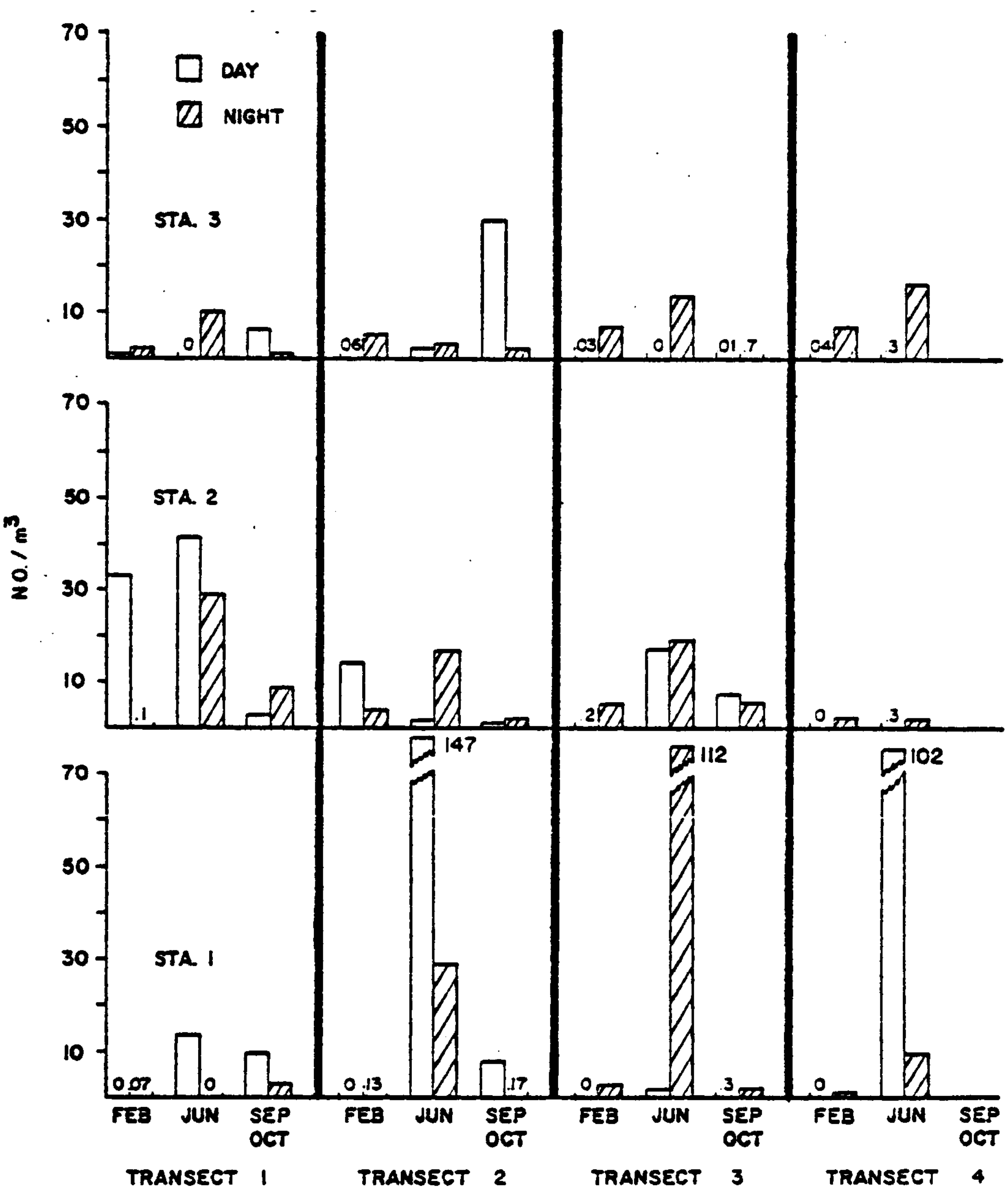

Figure 17. *Lucifer faxoni* at Transect I, II, III and IV Stations sampled seasonally during 1976.

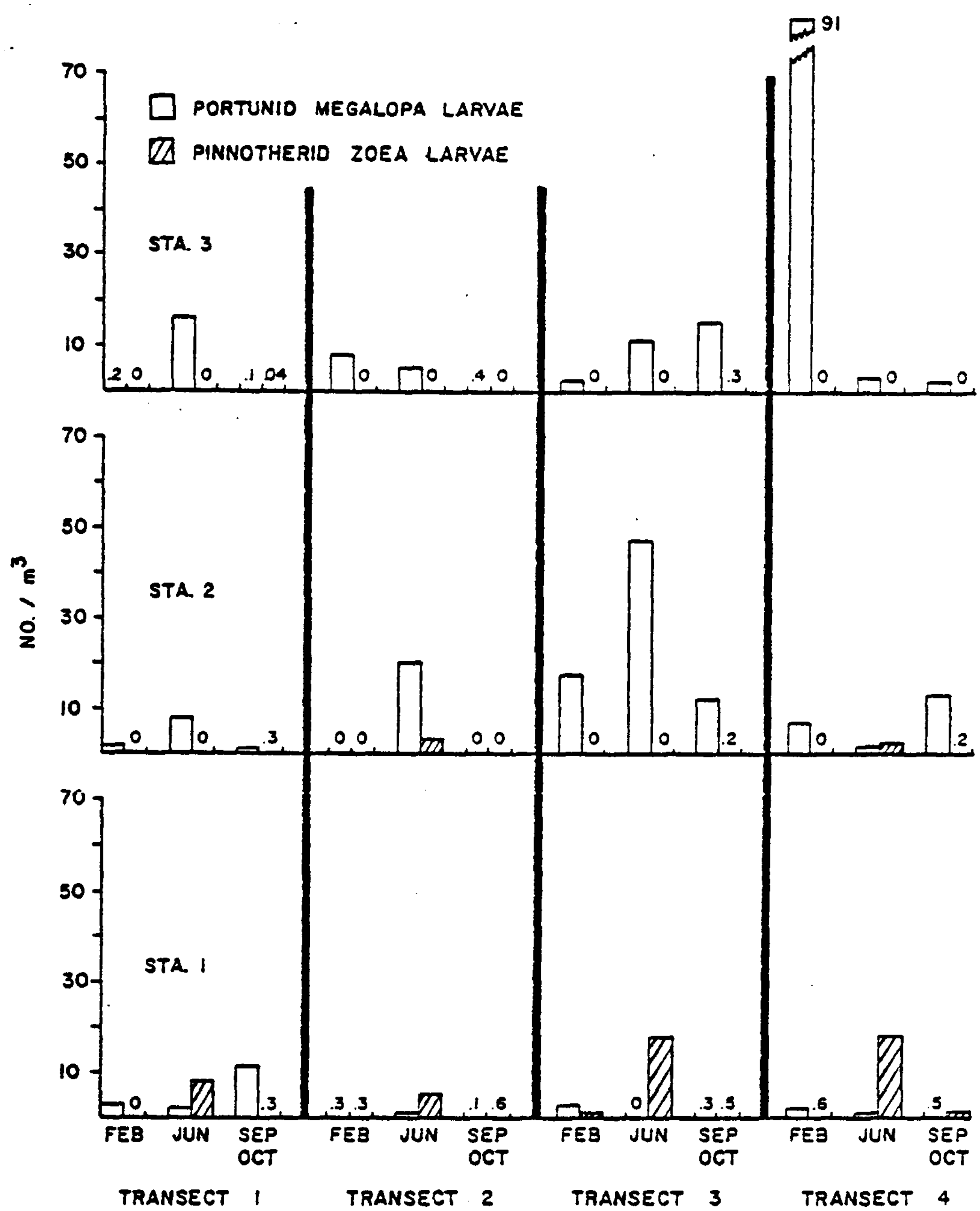

Figure 18. Portunid megalopa and pinnotherid zoea larvae at Transect I, II, III and IV Stations Sampled Seasonally During 1976.

nearshore stations. Their peak abundance ($91/m^3$) was at Station 3/IV/N in February. They were also abundant at Station 2/III/N in June ($48/m^3$).

Two types of portunid zoea larvae were identified, *viz.*, *Portunus* sp. and *Callinectes* sp. The *Callinectes* zoeas were usually the more abundant, especially at nearshore stations (Stations 1 and 2). *Callinectes* zoeas reached peak abundance ($31/m^3$) in June at Station 1/IV/N. *Portunus* zoeas also occurred at this station at one of their more abundant levels ($9/m^3$). The peak abundance for *Portunus* zoeas, however, was $11/m^3$ in February at an offshore station (3/II/N).

The following five species of juvenile or adult portunid crabs were also taken: *Callinectes similis, Portunus gibbesii, P. sayi, P. spinicarpus* and *P. spinimanus*.

All but *Portunus sayi* (a pelagic species which lives among floating *Sargassum*) were also found in South Texas benthic samples (Holland, 1977).

Zoea larvae of the pinnotherid crabs were most abundant at nearshore stations (Station 1) and were almost never taken at Station 3 (Figure 18). Highest concentrations only reached $18/m^3$ in June at Stations 1/III/N and 1/IV/N. Pinnotherid crabs are often commensal or parasitic in molluscs, ascidians, worm tubes, or echinoderms, but free-living or migratory stages are occasionally taken in open water (Williams, 1965). Felder (1973) lists eight species of pinnotherid crabs from coastal waters (to 35 fathoms) of the northwestern Gulf. The 1976 South Texas neuston samples yielded zoea larvae of six species: *Pinnixa chaetopterana, P. sayana, P.* sp. (cf. *cylindrica*), *Pinnotheres* sp., Pinnotherid sp. A, Pinnotherid sp. B and Pinnotherid sp. C. Holland (1977) listed six species of pinnotherid crabs from the BLM South Texas benthic stations. It is interesting that, of the 38 families and/or genera of decapod larvae from the 1976 neuston samples, 29 were also represented as adults in Dr. Holland's benthic species lists.

Total numbers of brachyuran zoea larvae were averaged from Stations 1, 2 and 3, Transect II, and plotted against time in Figure 11 (presented earlier in this report).

Penaeid larvae occurred in very low numbers (maximum of $5/m^3$) in the spring at Stations 1/III/N and 1/IV/N. The most common penaeid larvae were *Sicyonia* and *Trachypenaeus*. Larvae of the commercially important genus, *Penaeus*, were very rare. Penaeid larvae were most common and most abundant at nearshore stations (Station 1) and least so at offshore stations (Station 3).

Stomatopoda

Stomatopod alima larvae were considerably more common and abundant in the spring than at other seasons, although they never reached very high numbers as compared to other larval forms (*e.g.* portunid crab larvae). Greatest concentrations reached $7/m^3$ at Station 3/II/N in the spring. Stomatopod larvae were least common and least abundant in the fall samples. They were considerably more common and reached highest concentrations in night samples as compared to day samples. They were common at all three stations, but somewhat more common at offshore Stations 2 and 3. Although stomatopod larvae occurred on all four transects, they were more common, although not necessarily more abundant, at Transect IV stations.

Euphausiacea.

Euphausiids were neither common nor abundant. They occurred between February and July, disappeared in August and fall, and reappeared in

November and December. Euphausiid larvae were present in March and June. Euphausiids occurred only at the more offshore stations (Stations 2 and 3) and were never taken at Station 1. They were more common in night samples than in day samples and were present on all transects. The highest concentration (7944/1000 m^3) occurred in March at Station 3/II/N.

Mysidacea

Five species of mysid shrimps were identified, only one of which, *Siriella thompsoni*, is truly pelagic. *S. thompsoni* occurred nearly always at the offshore stations (Stations 2 and 3). The other four species were benthic species that frequently swarm to surface waters at night. The five species of mysids are listed in Table 7 in order of most common occurrence.

Anchialina typica was the most commonly occurring mysid and present in 18 samples; *Siriella thompsonii* was next (15 stations). *Brasilomysis castroi* was quite rare and was taken only once.

Ostracoda

Ostracods were considerably more common and abundant in night samples than in day samples. They were also more common at offshore Stations 2 and 3 than at nearshore Station 1. They occurred throughout all seasons, but peak abundance was in December at Station 2/II/N (152/m^3). The 10 samples in which ostracods reached highest concentrations were:

Sample		No/m^3
2/II/N	December	152
2/I/N	Spring	35
2/IV/N	Winter	23
2/II/N	Winter	21
1/IV/N	Spring	20

Sample		No/m^3
3/II/N	December	18
1/II/N	December	18
2/IV/N	Spring	14
2/III/N	Fall	13
3/II/N	March	12

It should be noted that Station 2, all transects, was the most common station for high ostracod concentrations.

Cladocera

Cladocera were sporadic in their presence and abundance in the 1976 neuston samples. They were present in February through June, absent in July, present in fall, and absent in November and December. Peak abundance of 27,959/1000 m^3 occurred in April at Station 1/II/N. However, this was a unique peak, for average concentration throughout the year was 2,093/1000 m^3 and the average for all stations excluding the April peak at Station 1/II/N was only 656/1000 m^3. Cladocera were equally common and more or less equally abundant in day and night samples. They were more common at nearshore Stations 1 and 2 than at offshore Stations (3).

Copepoda

Copepods accounted for an average of 48 percent of the total organisms in the 1976 neuston samples. Highest dominance was in April when they averaged 62 percent. Their lowest percentage occurred in August and averaged 30 percent. Individual samples ranged from 96 percent copepods (1/I/D in the spring) to 6 percent copepods (3/II/N, spring). Copepod average dominance by season, station (*i.e.*, distance from shore) transect (north-south geographical differences) and in day and night samples

TABLE 7

MYSID SHRIMP SPECIES AND THEIR DISTRIBUTIONS IN 1976 NEUSTON SAMPLES

SPECIES	STATIONS	SEASON	TRANSECTS	GREATEST ABUNDANCE ($NO./1000\ m^3$)
Anchialina typica	1, 2, and 3	All Seasons	II, III, IV	11,324 2/II/N NOVEMBER
Siriella thompsoni	1, 2, and 3	All Seasons	All Transects	2,192 3/II/N SPRING
Mysidopsis bigelowi	Station 1 only	Winter, July, and August	All Transects	1,884 2/III/N WINTER
Promysis atlantica	1, 2, and 3	Spring, Fall, and December	I, II, and III	615 2/II/N APRIL
Brasilomysis castroi	Station 1 only	Winter only	II only	45 1/II/N WINTER

were as follows:

Month	Percent	Station	Percent	Transect	Percent	Day	Night
Winter (Feb)	49	1	59	I	55	54	43
March	41	1	50	II	52		
April	62	3	37	III	39		
Spring (June)	56			IV	42		
July	47						
August	30						
Fall (Sept-Oct)	42						
November	54						
December	54						

Of the 20 taxa ranked in order of dominance in the 1976 neuston samples (Table 5), 11 were copepod taxa as follows:

Rank	Taxon
2	Unidentified calanoid copepods
4	*Anomalocera ornata*
5	*Temora stylifera*
7	*Centropages furcatus*
10	*Pontellopsis villosa*
11	*Labidocera* immature
12	*Labidocera scotti*
13	*Labidocera aestiva*
14	*Nannocalanus minor*
18	*Pontella* immature
19	*Calanopia americana*

Of these 11 taxa, four were singled out earlier as species that occurred rather frequently and showed relationships with other species by recurrent group analysis. Figures 7-10 show average concentrations (averaging Stations 1, 2 and 3) at Transect II plotted against time for *Anomalocera ornata* males, *Centropages furcatus* females, *Labidocera aestiva* females, and *Pontellopsis villosa* females.

Anomalocera ornata was an interesting taxon which occurred in high numbers during February, March and April, disappeared between June and October and appeared again in relatively high numbers in November. Totaling the males, females and juveniles of this species at each station, concentrations greater than $10/m^3$ occurred at 16 stations (15 percent of the 1976 samples) whereas they were absent from 72 samples (67 percent of the total samples). *A. ornata* was present in larger numbers only at the two nearshore stations and not at different stations. It was abundant on all transects and slightly more abundant in day than night samples.

By contrast, *Centropages furcatus, Labidocera aestiva* and*Pontellopsis villosa* females reached peaks of abundance during June for the first two species, and August-September-October for the latter species (when *Anomalocera ornata* was absent).

Centropages furcatus males and females collectively achieved concentrations greater than $10/m^3$ in 23 samples (21 percent) and were absent in only 12 samples (11 percent). Peak concentrations of $235-237/m^3$ were reached in the spring (June) at Stations 1/II/D and 1/I/N. They were more abundant in night samples than in day samples (18:5) and most abundant on the northernmost transect (Transect I). Like *Anomalocera ornata*, they were more abundant at nearshore stations than at the offshore stations 1 and 2 in all transects.

Labidocera aestiva male and female totals reached concentrations greater than $10/m^3$ in 12 samples (11 percent) and were absent in 45 samples (42 percent). Their greatest concentration of $626/m^3$ was in the spring at Station 1/II/D. The next highest concentration was only $92/m^3$ at Station 1/III/D, also in the spring. Greater concentrations occurred only slightly more often at night than day (7:5), and they were considerably more abundant at Station 1, next at Station 2, and were never greater than $10/m^3$ at Station 3. They were slightly more abundant along Transect II and least abundant on Transects I and IV.

Pontellopsis villosa was never as abundant as the above-mentioned three copepod species, reaching concentrations of over 10/m^3 in only eight (or 7 percent) of the total samples. The maximum concentration was only 34/m^3 at Station 1/I/N in the fall. Highest concentrations were reached in late summer and fall, rather than in the spring as for *Centropages furcatus* and *Labidocera aestiva*. *P. villosa* reached greater abundances at Station 2 more often than at other stations, but least often at offshore Station 3. They were relatively more abundant along Transects I and III, considerably less abundant on Transects II and IV, and were only slightly more abundant in night samples than in day samples.

Temora stylifera occurred in large numbers and was frequently dominant in the 1976 neuston samples, ranking number 1, 2 or 3 in 20 percent of the samples. It was dominant more often in the spring (June) at the two offshore stations on all transects and was rarely dominant between September and December. Greatest concentrations, 230/m^3 and 179/m^3, occurred in the spring at Stations 1/II/D and 3/II/D, respectively.

Considering the 17 samples in which *Temora stylifera* was present in concentrations exceeding 10/m^3, 12 were night samples and only 5 were day samples. The species was nearly evenly distributed among the three stations and four transects.

Summarizing the five dominant copepod species mentioned above, greatest concentrations (> 10/m^3) were at the following times of day, seasons, stations and transects:

			Greatest Abundance		
Species	Day	Night	Season	Station	Transect
Anomalocera ornata	63%	37%	Winter	1 & 2	I
Centropages furcatus	22%	78%	Spring	1 & 2	I
Labidocera aestiva	42%	58%	Spring	1	II
Pontellopsis villosa	38%	62%	Fall	1 & 2	I & III
Temora stylifera	29%	71%	Spring	All	All

Echinodermata

Echinoderm larvae were sparse, occurring in only five of the 108 samples analyzed. Although most common in the fall, the peak abundance of 679/1000 m^3 occurred in June at Station 1/I/D. They were absent from February to June, and again in July and August. Echinoderm larvae were present in both day and night samples and nearshore, intermediate, and offshore stations (Stations 1, 2 and 3). They were present on the two northern transects, but absent from the two southern transects.

Chaetognatha

Chaetognaths were often dominant in numerical abundance, ranking number three in dominance among the taxa listed in Table 5. They ranked 1, 2 or 3 in 35 of the 108 neuston samples. Peak abundance (60,138/1000 m^3) was reached in the spring at Station 2/II/N. Chaetognaths were present in concentrations greater than 10,000/1000 m^3 in 29 samples. Greatest concentrations were reached in the spring and lowest concentrations in July and August. Considerably more night samples showed higher concentrations of chaetognaths (*i.e.*,> 10,000/1000 m^3) than day samples (24:5). They were more abundant at nearshore stations (Stations 1 and 2) than at the offshore station (Station 3), and were equally abundant on all transects.

Tunicata

Doliolida

Doliolids occurred in concentrations greater than $1/m^3$ in 21 of the 108 samples collected during 1976. They were most common in winter (February) samples, but peak abundance was $5.8/m^3$ at Station 2/II/N in March. Doliolids were much more common at the two offshore stations than at the inshore Station 1. They were most abundant along Transect I and least abundant along Transect IV. Doliolids were completely absent from spring (June) samples on Transects III and IV. Highest concentrations occurred much more frequently in night samples than in day samples (3 day vs 18 night samples where doliolid concentrations exceeded $1/m^3$).

Salpida

In contrast to the doliolids, salps reached greatest abundances in spring and were at their lowest concentrations during winter when the doliolids were high. The peak abundance was $66/m^3$ at Station 2/III/D in the spring. Salps were absent from Transect I and II samples in February and from Transect II in November. Salps were present in concentrations greater than $1/m^3$ in 18 of 108 samples during 1976.

Also, unlike the doliolids, salps did not show great diurnal differences. Salps were most abundant at the intermediate stations (Station 2), next at offshore Station 3, and least abundant at nearshore stations. Salps were most abundant on Transect III and least abundant on Transect IV.

Larvacea

Larvaceans occurred in concentrations greater than $1/m^3$ in 15 of the 108 samples. They were somewhat more common in night tows than in day tows. Larvaceans were present in concentrations of $1/m^3$ or more during all sampling periods, but were most abundant in April samples with a peak of $7.4/m^3$ at Station 1/II/N. Larvaceans were most abundant at intermediate stations (Station 2) and least abundant at offshore Station 3. They were most abundant along Transect II and least abundant on Transects III and IV. Larvaceans were completely absent from Transect IV stations in the fall and from Transect II stations in November.

Insecta

The hemipterid "water-strider", *Halobates micans*, occurred in concentrations exceeding 100/1000 m^3 in 36 of the 108 samples and was most common in spring and fall samples. Peak abundances of 4597/1000 m^3 was at Station 2/IV/N in the fall. It was more abundant at offshore stations (Stations 2 and 3) than at the inshore stations, and more abundant on Transects III and IV than at the two northern transects.

Ichthyoplankton

During 1976, 495,580 fish eggs and 77,195 larvae were collected during the neuston survey (Appendix E, Table 4)[1]. Along Transect II, the only transect sampled monthly as well as seasonally, 169,000 eggs and 53,871 larvae were captured during the year. A total of 380,381 eggs and 42,679 larvae were collected during the three seasonal surveys on all four transects. On Transect II the greatest abundant of eggs (24 percent) was collected during the March monthly survey, and the greatest number of larvae (21 percent) was collected during the spring (June) survey. The lowest number of eggs and larvae were captured on the December and winter (February) cruises, respectively.

During the seasonal samplings of all transects, the winter cruise yielded the greatest number of eggs and the spring cruise the greatest number of larvae. The fall and winter cruises yielded the least number of eggs and larvae of the seasonal cruises.

A total of 110 taxa of larval fishes was collected during the year (Appendix E, Table 4). Species richness at Transect II was greatest

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[1]This table replaces previous miscalculated fish egg and larva data presented in the 1976 Quarterly Reports in similar tables, which should, therefore, be disregarded and replaced by data in Table 4, Appendix E, of this report.

during the spring and March cruises with 50 taxa and 34 taxa being collected on the two cruises, respectively. The spring seasonal cruise, sampling all four transects, yielded 63 taxa, while the winter and fall seasonal cruises yielded 57 taxa.

Over the entire survey, 84,054 (49.7 percent) of the eggs and 35,493 (65.9 percent) of the larvae were collected during the night, while 84,949 (50.3 percent) eggs and 18,378 (34.11 percent) larvae were collected during the day. A greater number of larval taxa (73, or 57 percent) were collected during the night than during the day (55 taxa or 42.9 percent).

A relatively large percentage of larvae (42.7 percent) was captured during the daytime on the spring survey at Transect II, and the smallest percentages of daytime captures were during winter (1.14 percent) and August (1.19 percent). On the seasonal surveys of all four transects, the greatest percentage of daytime captures of larvae was in spring (70 percent), and the least percentage was in the fall (5.5 percent).

Over the entire year, 152,936 (40.2 percent) eggs and 16,766 (39 percent) larvae were captured at the inshore station (Station 1, Transects I, II, III and IV) on the seasonal cruises. A total of 53,830 (31.9 percent) eggs and 21,870 (43.3 percent) larvae was collected at the inshore station at Transect II. The mid-depth station (2/II) yielded 95,559 (56.5 percent) eggs and 14,679 (29 percent) larvae over the year on the monthly cruises, while mid-depth stations on seasonal cruises (Station 2, Transects I, II, III and IV) yielded 201,908 (53.1 percent) eggs and 13,113 (30.7 percent) larvae during the year. The deepest station (3/II) yielded 19,614 (11.6 percent) eggs and 13,939 (27.6 percent) larvae during the year on the monthly cruises and the deepest stations on seasonal cruises (3/I, 3/II, 3/III, 3/IV) yielded 25,293 (6.7 percent) eggs and 12,8000 (30 percent) larvae.

On Transect II during the entire year, 48 taxa were collected at Station 1, 49 at Station 2 and 46 at Station 3. On the seasonal surveys at all four transects, 66 taxa were captured at the four inshore stations, 66 taxa at the four intermediate stations and 74 taxa at the four offshore stations. At the inshore and intermediate stations on Transect II, diversity was greatest during spring (June). At the inshore and offshore stations in seasonal surveys of all four transects, diversity was greatest during the spring.

On the three seasonal surveys, the greatest number of eggs and larvae were collected along Transect II, and the least number were collected along Transect I. However, Transect I had the greatest diversity of taxa over the three seasonal surveys. Transect II had the greatest number of larvae during the spring and least number during the winter seasonal survey.

Transect II is used to describe the distribution of ichthyoplankton taxa since this transect was sampled monthly and larvae collected along this transect were representative of those collected along the other three transects during the seasonal surveys. The ten most abundant families during the survey were Clupeidae (23.26 percent), Sciaenidae (16.23 percent), Mugilidae (11.98 percent), Exocoetidae (6.71 percent), Mullidae (6.06 percent), Engraulidae (5.97 percent), Gobiidae (3.12 percent), Gerreidae (1.73 percent), Carangidae (1.49 percent) and Bothidae (1.09 percent)(Table 8). The abundance of the above families varied seasonally (Figures 19-28). Mullidae and Exocoetidae comprised 27.8 percent and 27.5 percent of the larvae during the spring, but only 0.5 percent and 10.3 percent of the larvae during the fall. Gobiidae comprised only 1.0 percent of the larvae during the spring, but were 39.4 percent of the larvae during the fall. Engraulidae were more abundant during the spring than fall, comprising 8.2 percent and 2.8 percent of the larvae in the

TABLE 8

TEN MOST ABUNDANT FAMILIES CAPTURED ON TRANSECT II[1].

FAMILY	TOTAL NO./1000 m^3/YEAR	PERCENT TOTAL OF LARVAE
Clupeidae	12,529	23.26%
Sciaenidae	8,742	16.23%
Mugilidae	6,455	11.98%
Exocoetidae	3,612	6.71%
Mullidae	3,266	6.06%
Engraulidae	3,217	5.97%
Gobiidae	1,678	3.12%
Gerreidae	933	1.73%
Carangidae	805	1.49%
Bothidae	588	1.09%
TOTAL	41,825	77.64%

[1]A total of 53,871 fishes as captured on Transect II during the survey.

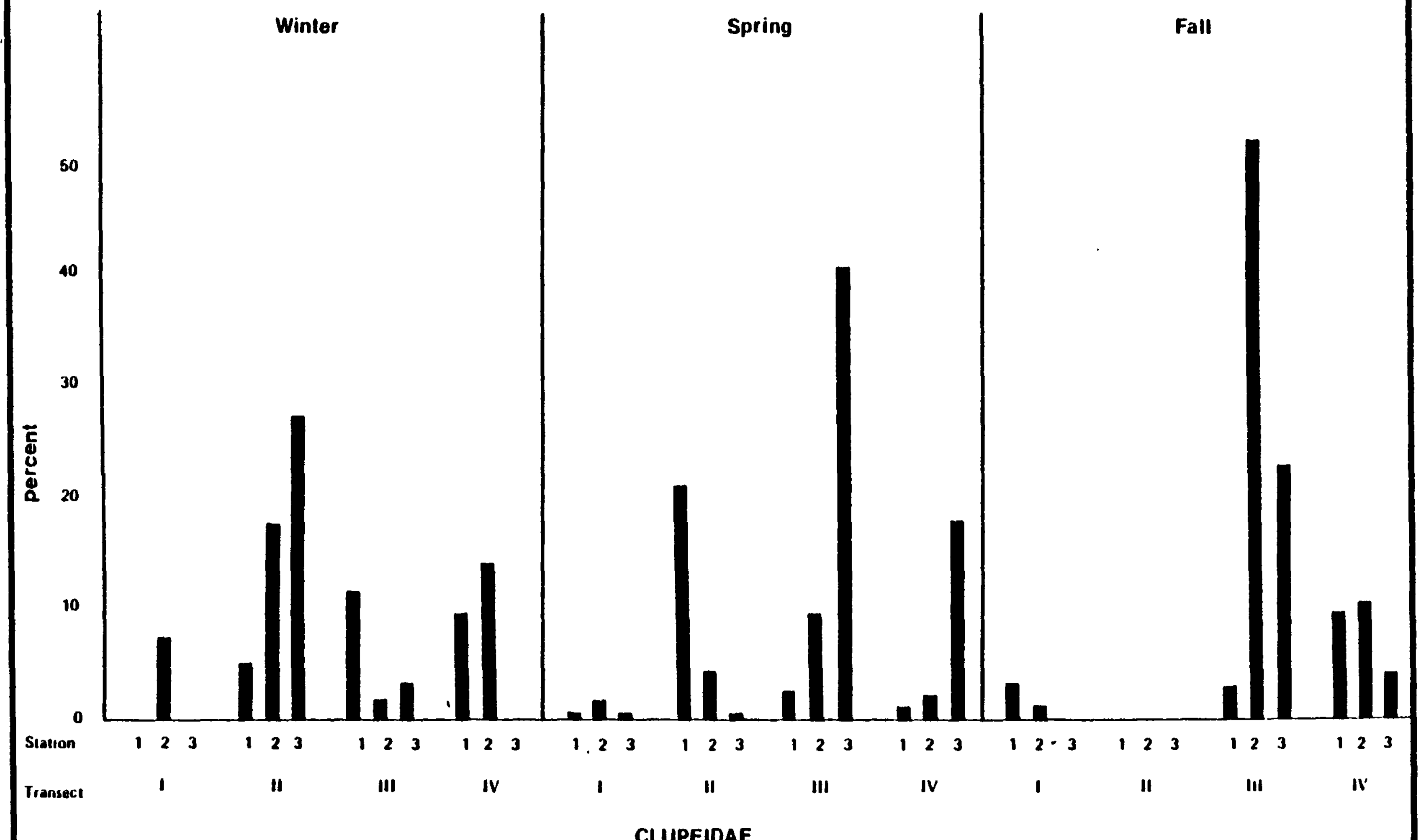


Figure 19. Relative Abundance of Clupeidae at each Station Along the Four Transects During the Three Seasonal Cruises.

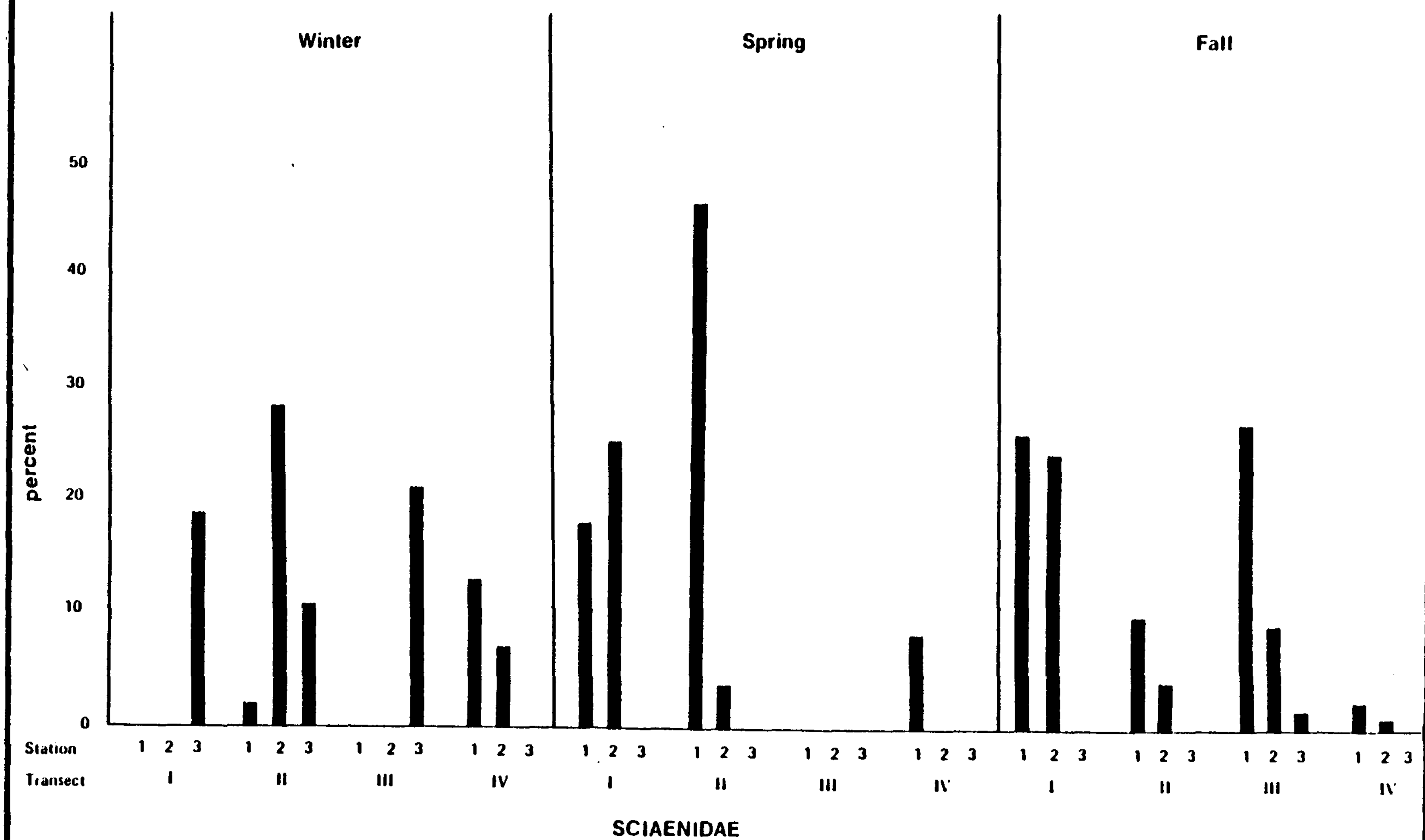


Figure 20. Relative Abundance of Sciaenidae at each Station Along the Four Transects During the Three Seasonal Cruises.

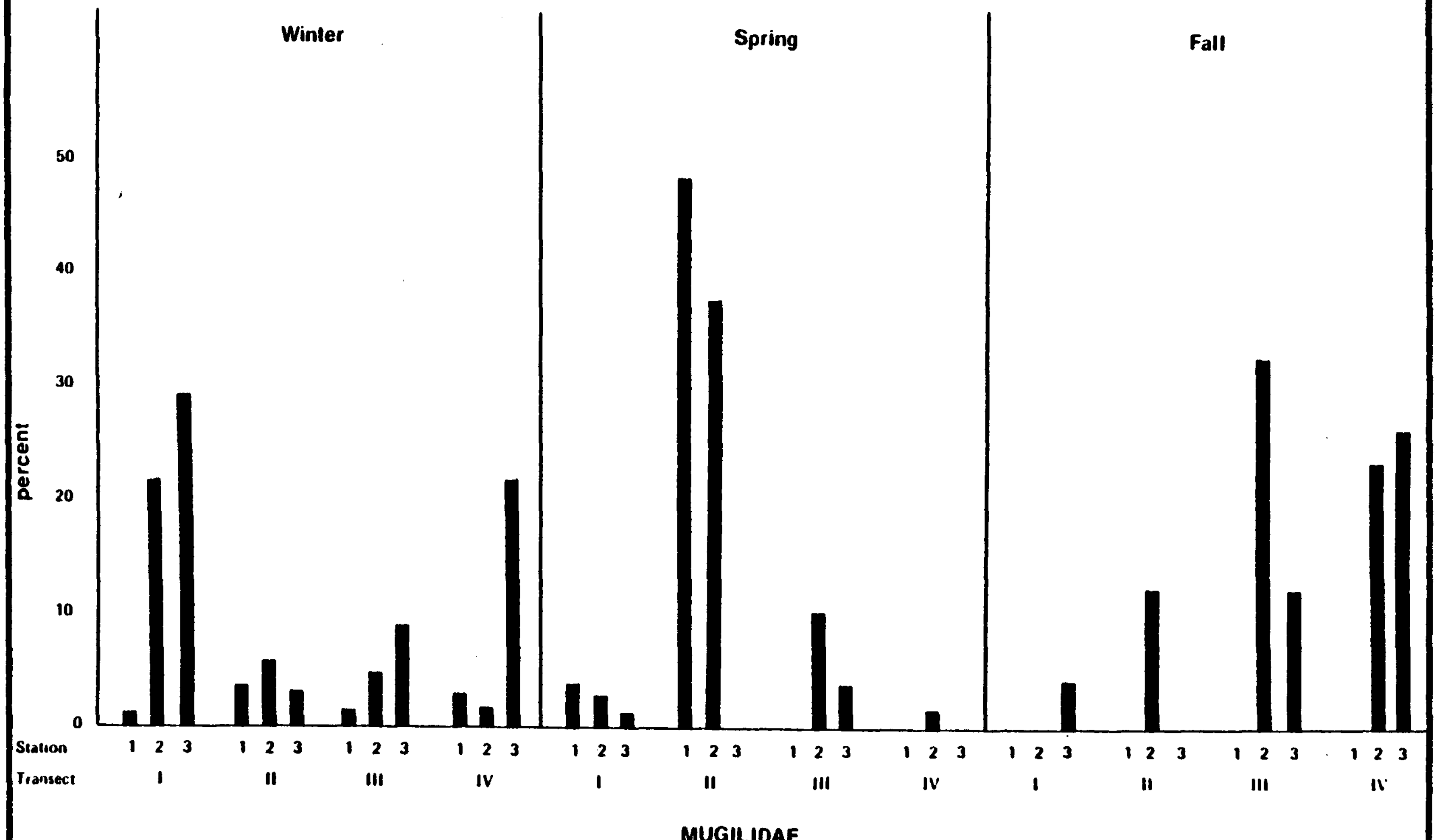
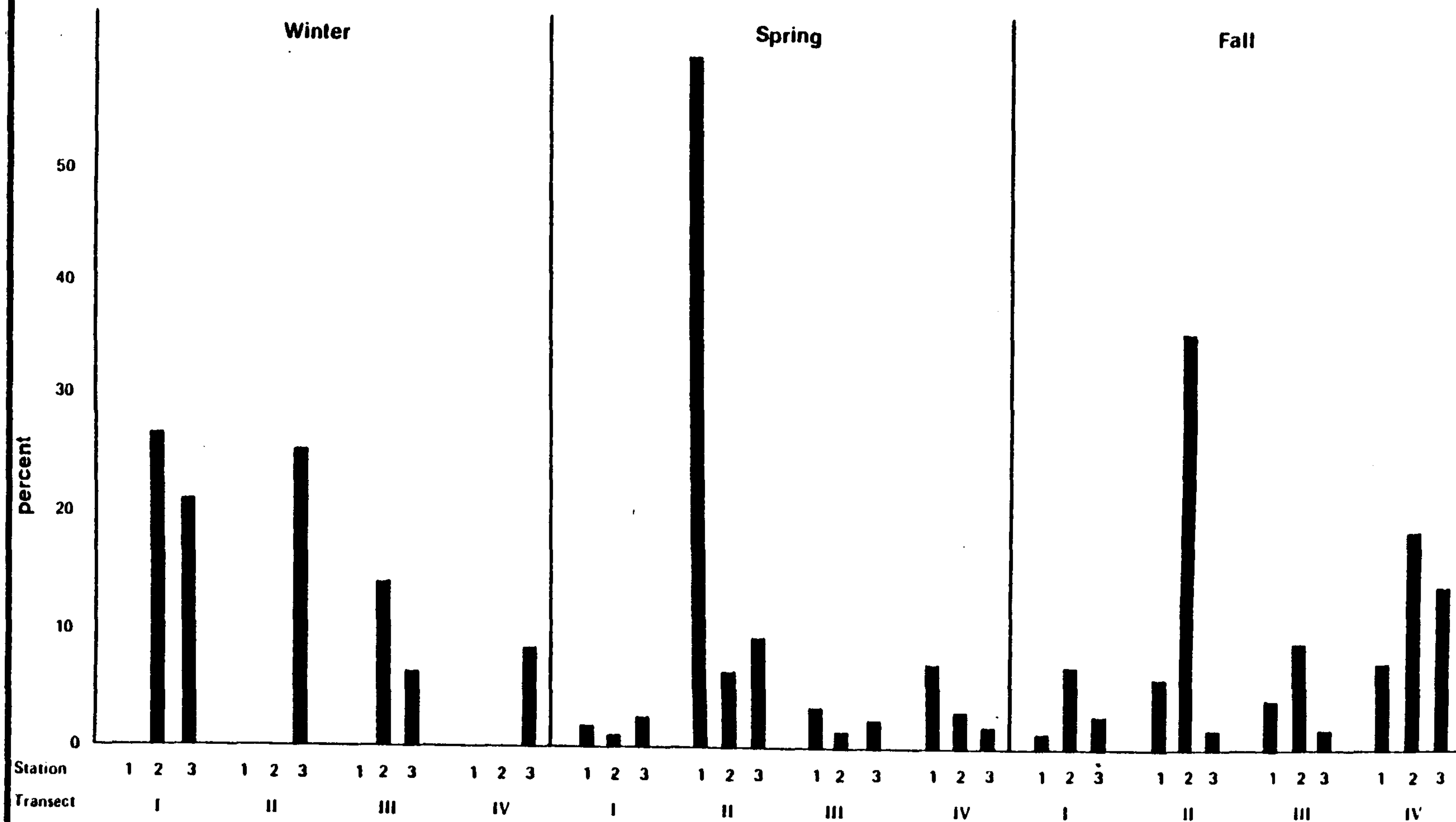


Figure 21. Relative Abundance of Mugilidae at each Station Along the Four Transects During the Three Seasonal Cruises.



EXOCOETIDAE

Figure 22. Relative Abundance of Exocoetidae at each Station Along the Four Transects During the Three Seasonal Cruises.

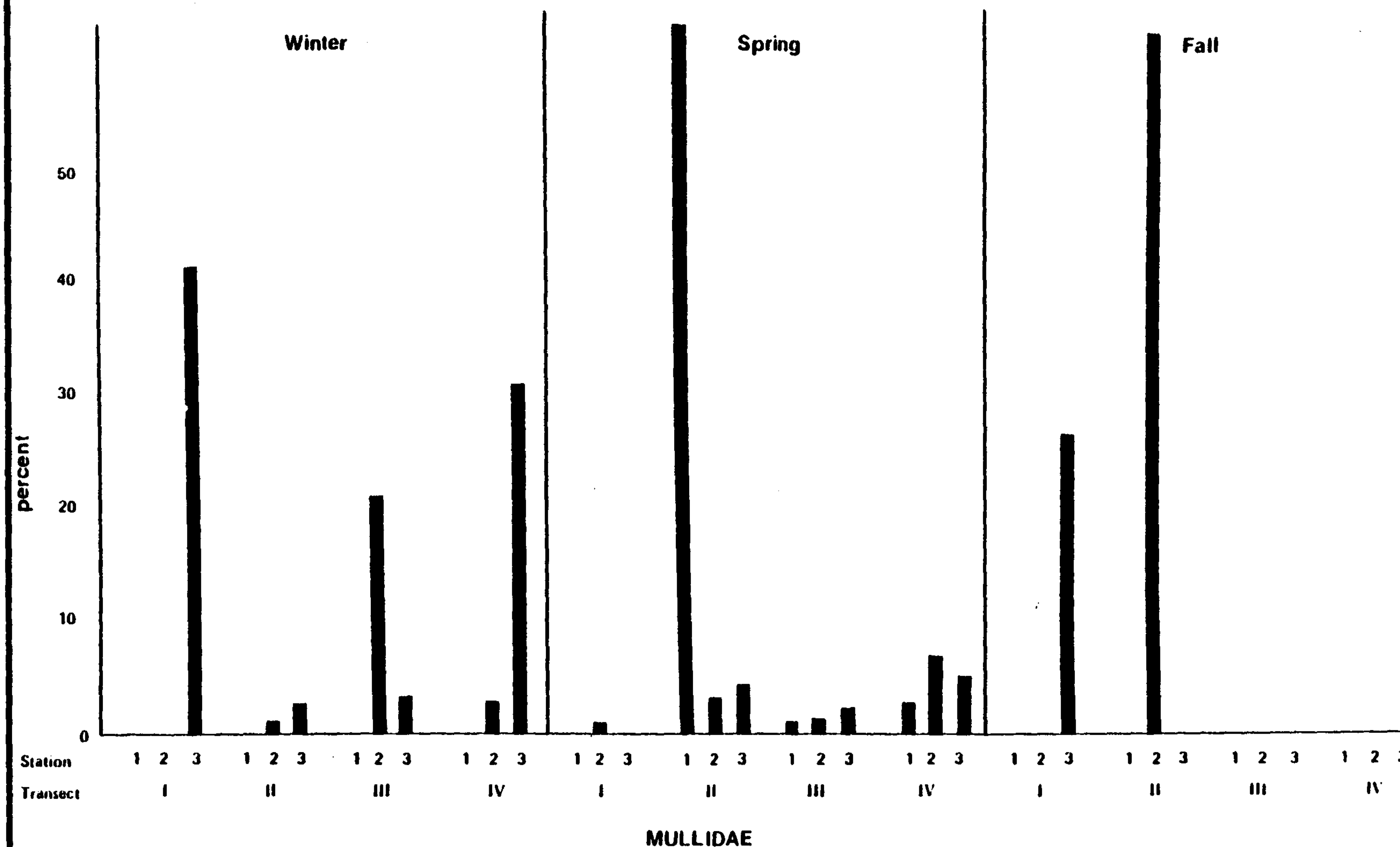


Figure 23. Relative Abundance of Mullidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

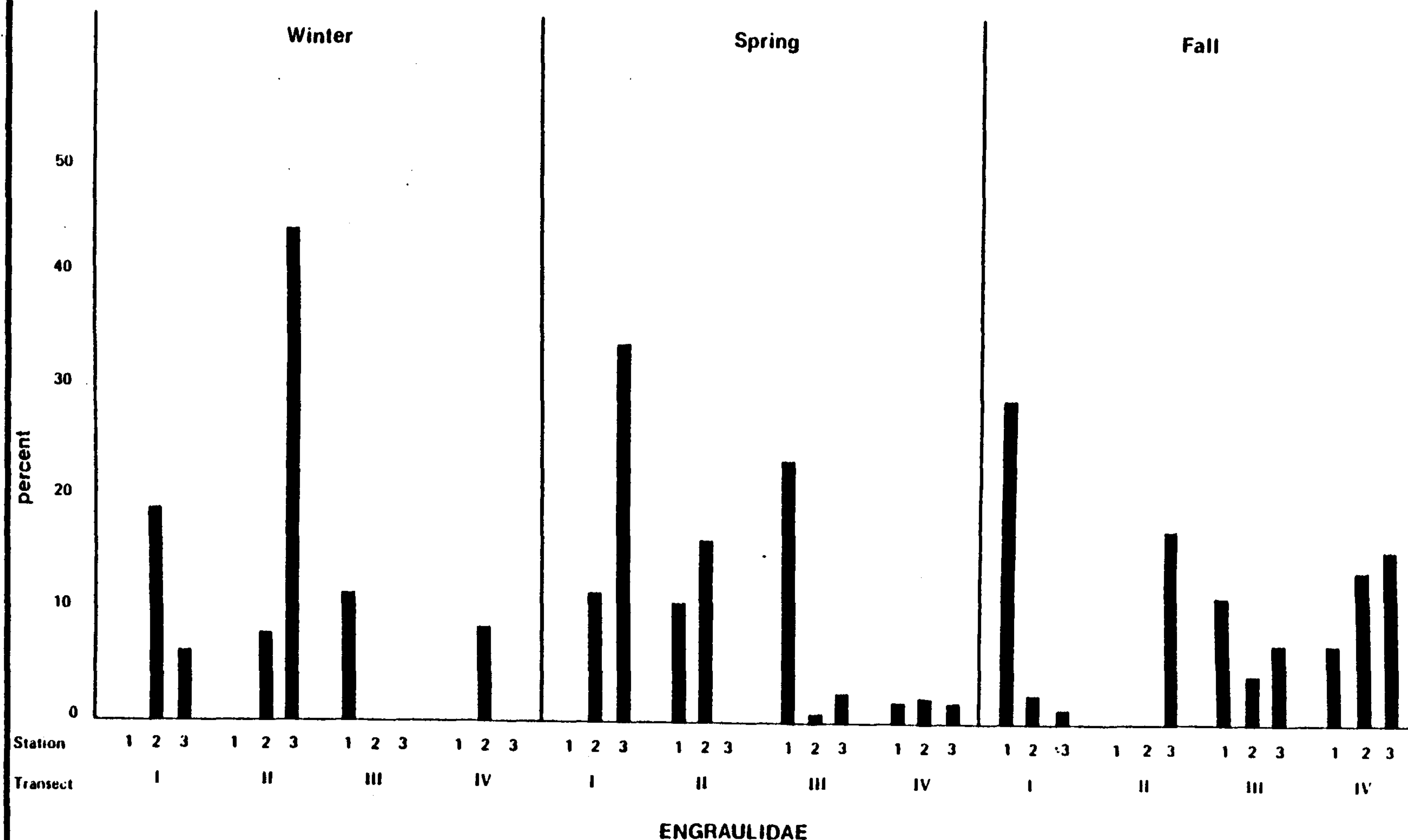


Figure 24. Relative Abundance of Engraulidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

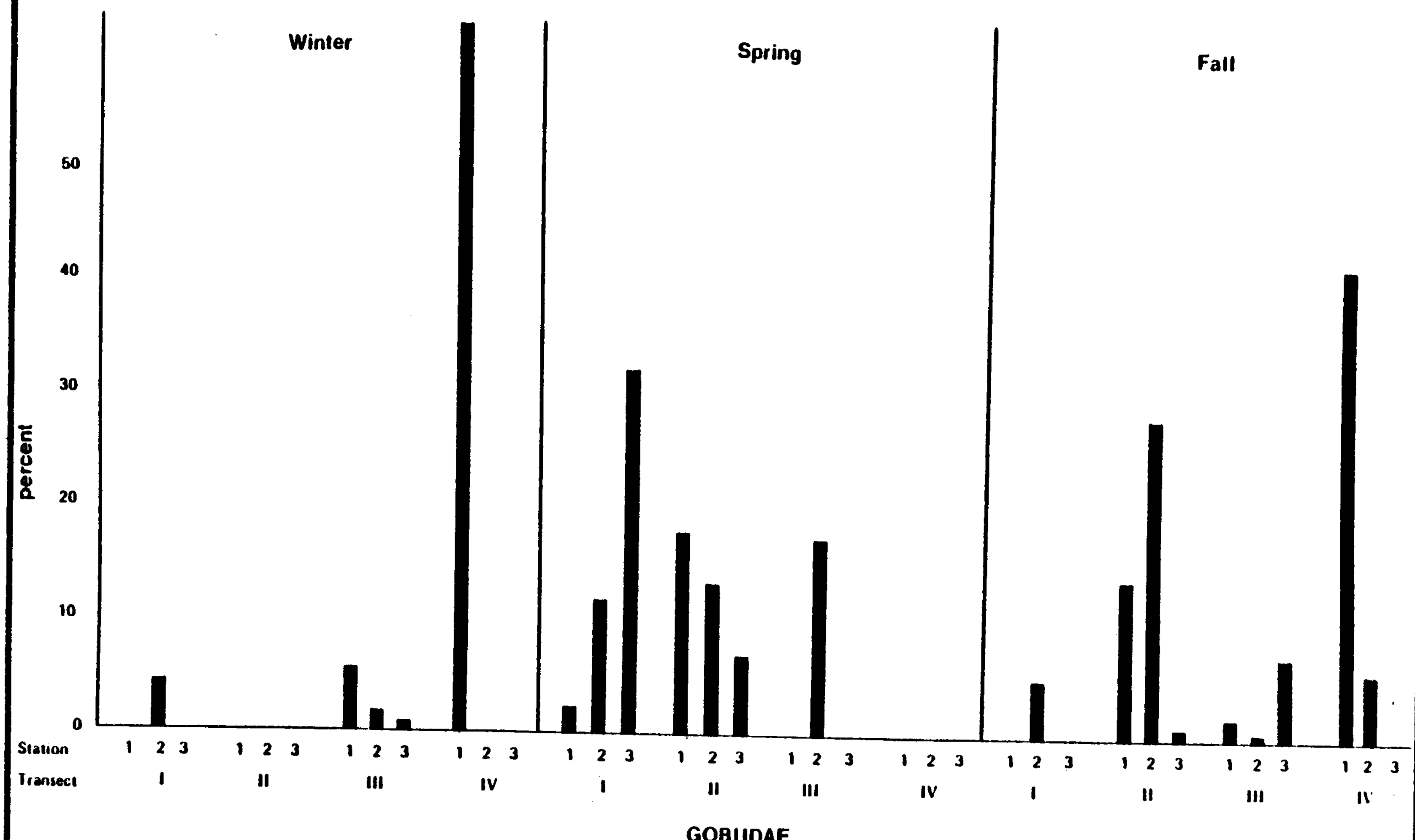


Figure 25. Relative Abundance of Gobiidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

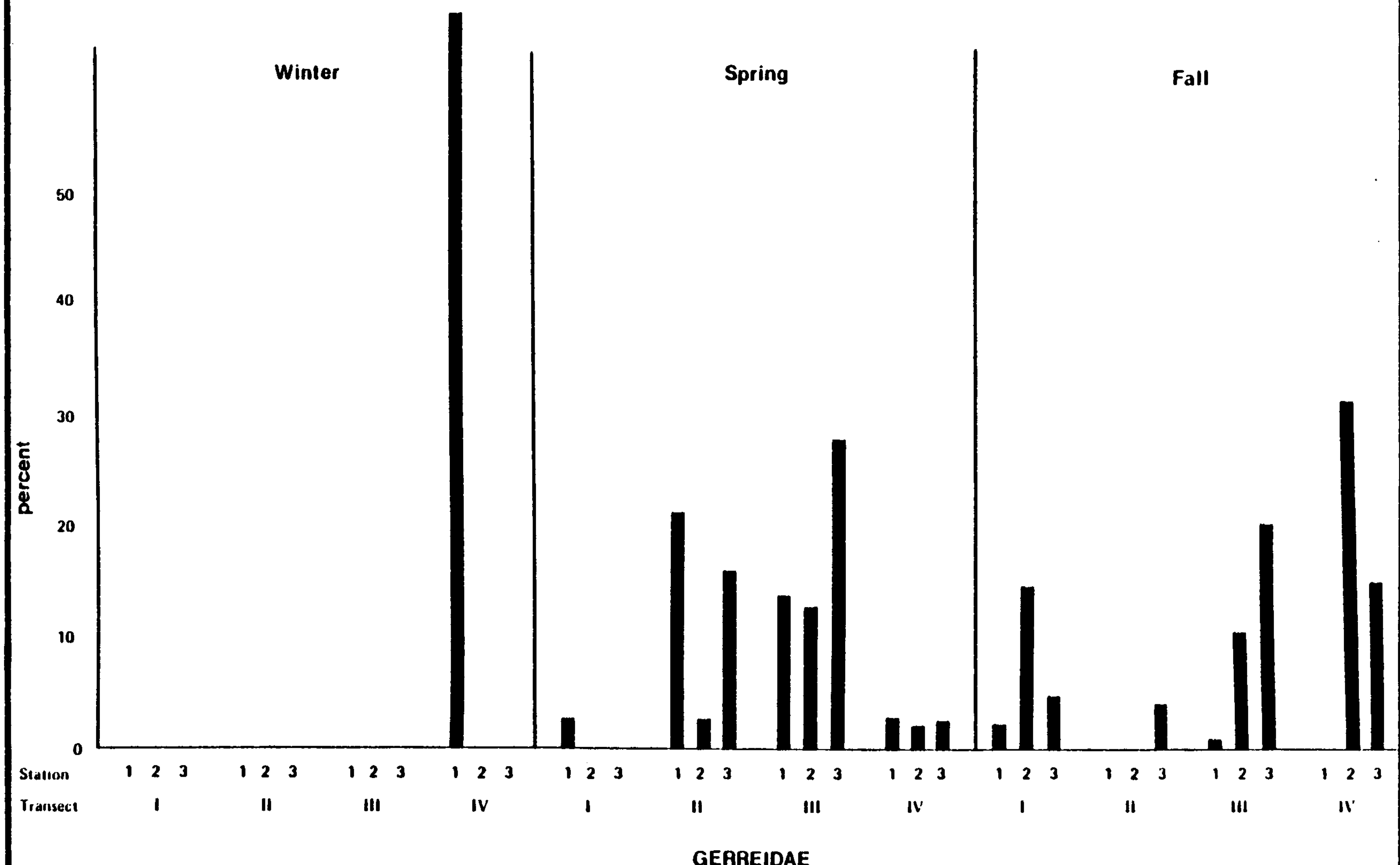


Figure 26. Relative Abundance of Gerreidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

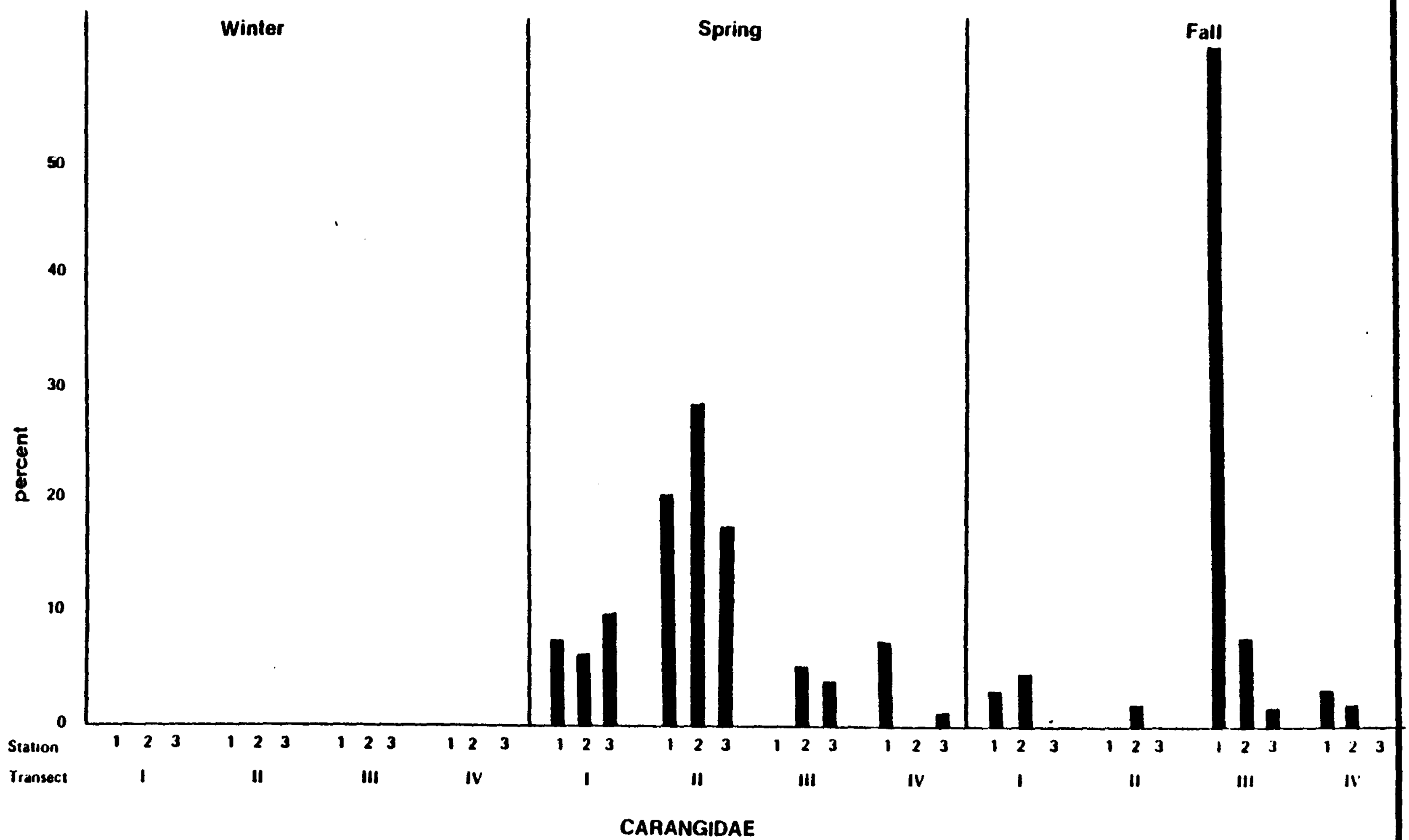


Figure 27. Relative Abundance of Carangidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

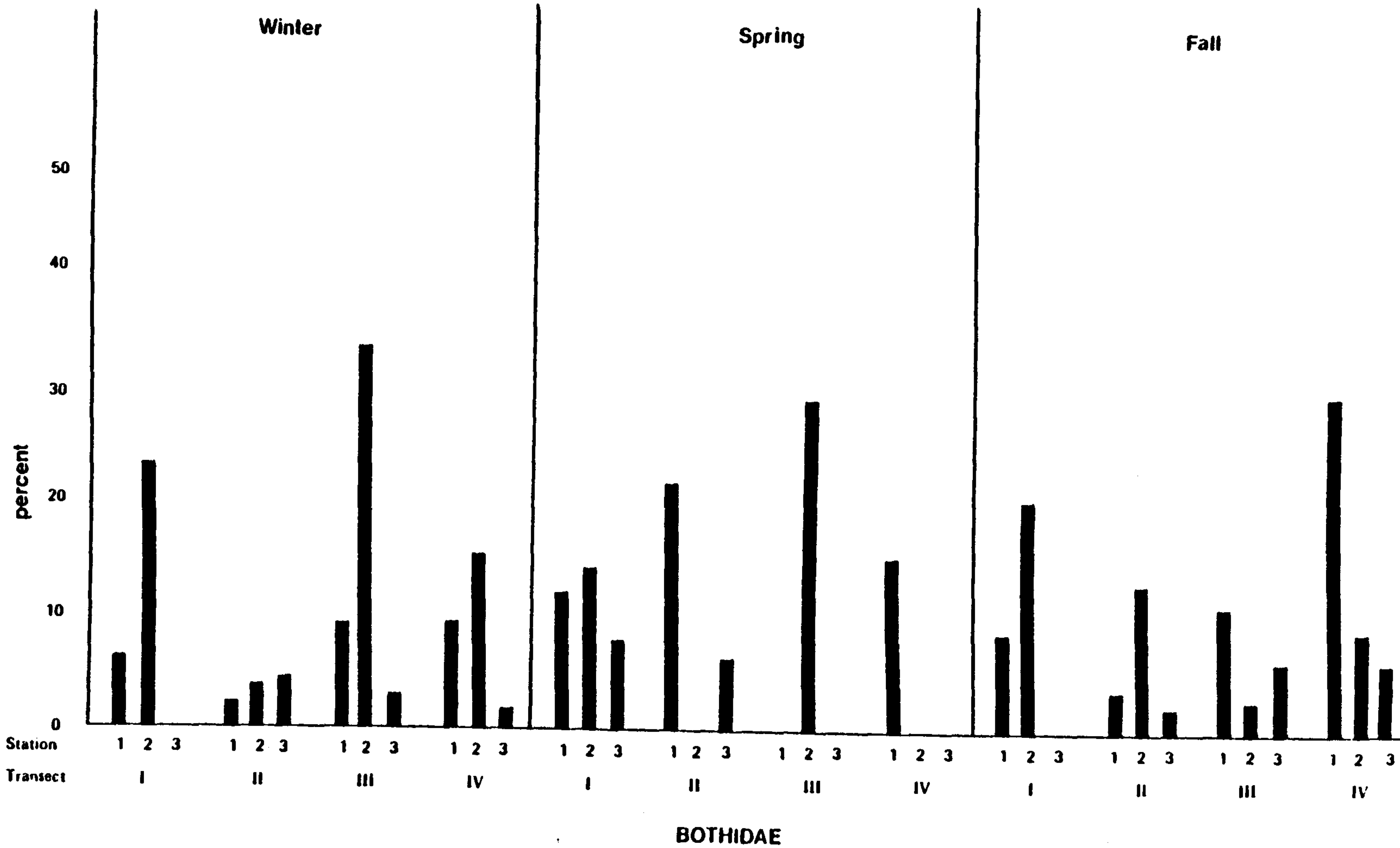


Figure 28. Relative Abundance of Bothidae at Each Station Along the Four Transects During the Three Seasonal Cruises.

two seasons, respectively.

The abundance of Mugilidae and Sciaenidae varied among stations along Transect II. Mugilidae increased in abundance with distance offshore and comprised 1.6 percent, 10.7 percent and 32.6 percent of the larvae at Stations 1, 2 and 3, respectively. Sciaenidae decreased in abundance with distance offshore and comprised 30.4 percent, 11.2 percent and 3.2 percent of the larvae at Stations 1, 2 and 3, respectively.

Although more larvae were captured at night and most families were more abundant during the night, several families were predominantly captured during the day. Clupeidae (30.3 percent), Sciaenidae (26.3 percent) and Gobiidae (5.20 percent) predominated in night samples and Exocoetidae (15.9 percent), Mugilidae (32 percent) and Mullidae (17.3 percent) predominated in day samples (Table 9).

The ten most abundant species were *Mugil cephalus* (10.63 percent), *Harengula jaguana* (9.9 percent), *Mullus auratus* (6.0 percent), *Cynoscion* sp. (5.5 percent), *Micropogon undulatus* (4.0 percent), *Brevoortia* sp. (3.7 percent), *Parexocoetus brachypterus* (2.0 percent), *Opisthonema oglinum* (2.0 percent), *Hirundichthys rondeleti* (1.9 percent) and *Engraulis eurystole* (1.8 percent).

The species of Sciaenidae and Clupeidae varied seasonally in relative abundance. The sciaenids *Leiostomus xanthurus* and *Micropogon undulatus* were captured during the December, winter and March cruises, but were absent during other cruises. *Menticirrhus* sp. and *Cynoscion* sp. were most abundant during the August and fall cruises.

The clupeids *Brevoortia* sp. and *Etrumeus teres* were captured in large numbers during the winter (February) and March cruises, but were absent from the collections during the June, July, August and September-October cruises. *Harengula jaguana* was most abundant during the June,

TABLE 9

PERCENTAGE OF LARVAE OF TEN MOST ABUNDANT FAMILIES CAPTURED DURING THE DAYTIME, NIGHTTIME AND AT EACH STATION ALONG TRANSECT II

FAMILY	TOTAL NO./1000 m^3/YEAR	% CAPTURED DURING DAY	% CAPTURED DURING NIGHT	% OF LARVAE CAPTURED AT EACH STATION		
				1	2	3
Clupeidae	12,529	24.4%	75.6%	31.2%	47.7%	21.1%
Sciaenidae	8,742	6.0%	94.0%	76.1%	18.8%	5.1%
Mugilidae	6,455	91.2%	8.8%	5.3%	24.3%	70.4%
Exocoetidae	3,612	80.8%	19.2%	73.9%	13.0%	13.1%
Mullidae	3,266	97.5%	2.5%	91.6%	3.1%	5.3%
Engraulidae	3,217	10.4%	89.6%	38.8%	36.3%	24.9%
Gobiidae	1,678	2.2%	97.8%	26.2%	44.5%	29.3%
Gerreidae	933	15.3%	84.7%	39.5%	23.0%	37.4%
Carangidae	805	23.7%	76.3%	61.2%	22.7%	16.0%
Bothidae	588	14.5%	85.5%	43.0%	43.9%	13.1%

July, August and September-October cruises, but was absent during the remaining months.

The greatest abundance of eggs during the winter season indicated that most spawning occurred at that time. A few months later in the spring, large numbers of larvae were captured showing a correlation with winter spawning. Clupeidae and Engraulidae were most abundant in the spring. *Opisthonema oglinum* and *Anchoa hepsetus* were the most abundant species of these two families.

Larval captures at the inshore and offshore stations indicated that most fishes, such as Sciaenidae and Gerreidae spawn inshore, while a few others, such as Mugilidae, spawn offshore.

Most larvae were collected at night, indicating that most larvae inhabit the neuston layer at night and seek greater depths during the day or have a greater ability to avoid the sampling gear during the day. Mugilidae, Exocoetidae and Mullidae were more abundant during the daytime indicating that they are surface dwellers during the day and are either located below the neuston layer at night or are less-able to avoid the sampling gear during the daytime than other taxa.

In the 1975 STOCS ichthyoplankton survey, Finucane (1976) stated that the most abundant families were Engraulidae, Gobiidae, Bregmacerotidae, Clupeidae, Sciaenidae, Carangidae, Bothidae, Synodontidae, Myctophidae and Serranidae. However, Bregmacerotidae, Synodontidae and Myctophidae were uncommon in the present neuston survey. The discrepancy in faunal composition between the two studies might be due to differences in sampling techniques or differences in abundance of the fish taxa between the two years. In the 1975 ichthyoplankton survey, the sampling gear was towed obliquely and almost the entire water column was sampled (Finucane, 1976). The neuston sampling gear was towed at the surface and only the upper 0.5 m of the water column was sampled. The three families abundant in the 1975 ichthyoplankton survey but not the neuston survey may be concentrated below the depths sampled by the neuston net.

Tar

As an additional observation during the neuston study, floating tar from each neuston sample was dried and weighed, the results of which are plotted in Figures 29 and 30. From these data, it appears that the distribution of floating tar over the South Texas Outer Continental Shelf was patchy. To determine any seasonal, offshore-onshore, or geographical differences in tar distribution, Table 10 was prepared to show average amounts of tar by time of year, station, and transect. Two noticeable observations were the relatively higher levels of tar at the two offshore stations as compared to the inshore station and the relatively higher tar levels along Transect II as compared to other transects. The months with highest tar values were April and December.

In previous studies on floating tar, Horn *et al.* (1970) were the first to report semiquantitatively on the concentrations of pelagic tar using a water displacement method. They found concentrations in the Mediterranean Sea of up to 540 mg/m^2 with a mean concentration of 20/mg/m^2. Morris (1971), using a wet weight method, reported considerably lower quantities of floating tar in the northwestern Atlantic, *i.e.*, a range of 0.1 to 9.7 mg/m^2 with a mean of 2.2 mg/m^2. Morris and Butler (1973) made biweekly tows approximately 20 miles southeast of Bermuda in the Sargasso Sea in 1971 and 1972 and reported tar concentrations ranging from 0.1 to 40 mg/m^2 with a mean of 9.4 mg/m^2.

Jeffrey *et al.* (1974), using a quantitative extraction method, reported the Gulf of Mexico and Caribbean Sea to be less polluted with

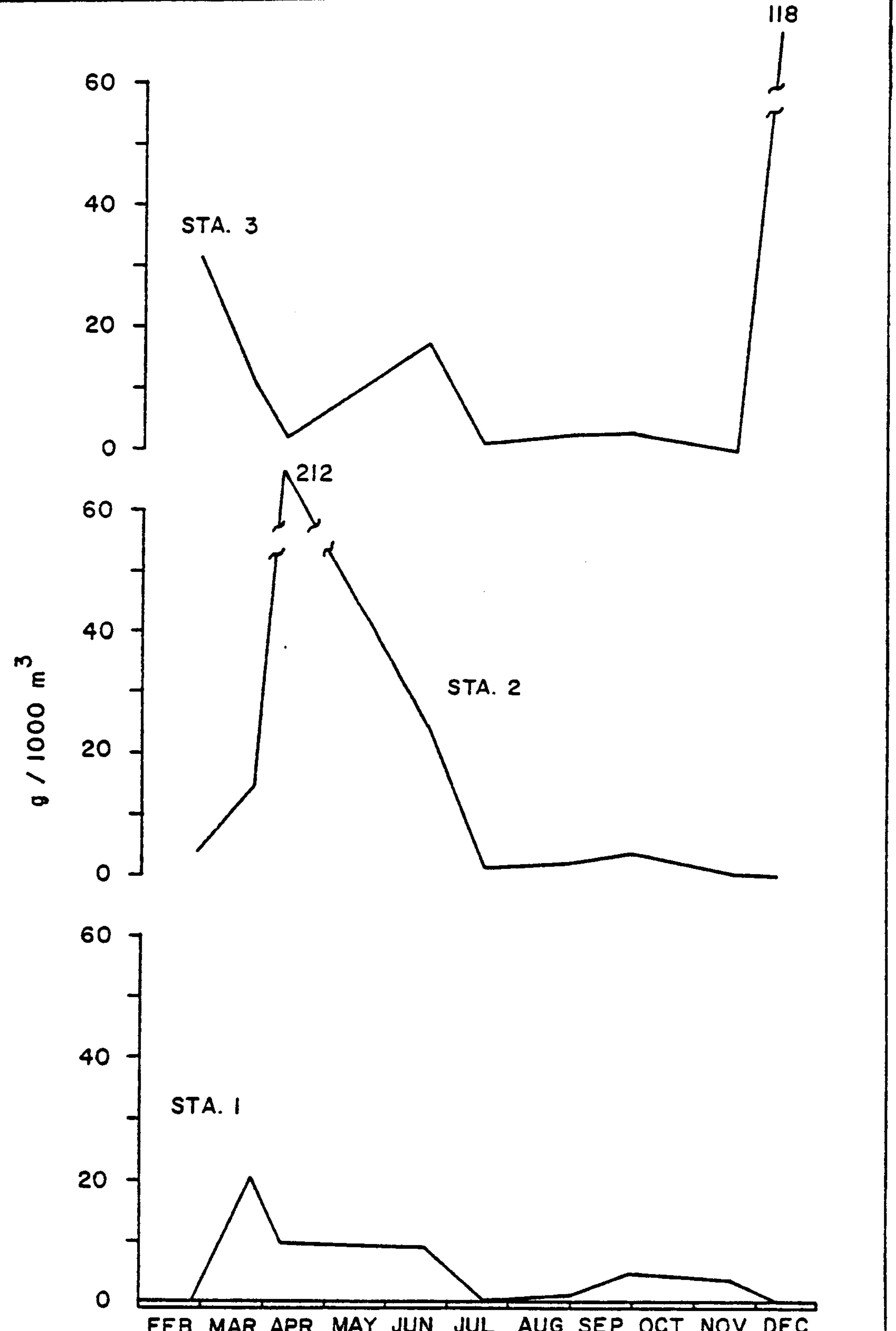


Figure 29. Day-night averages for dry weight of tar from Transect II neuston samples during 1976.

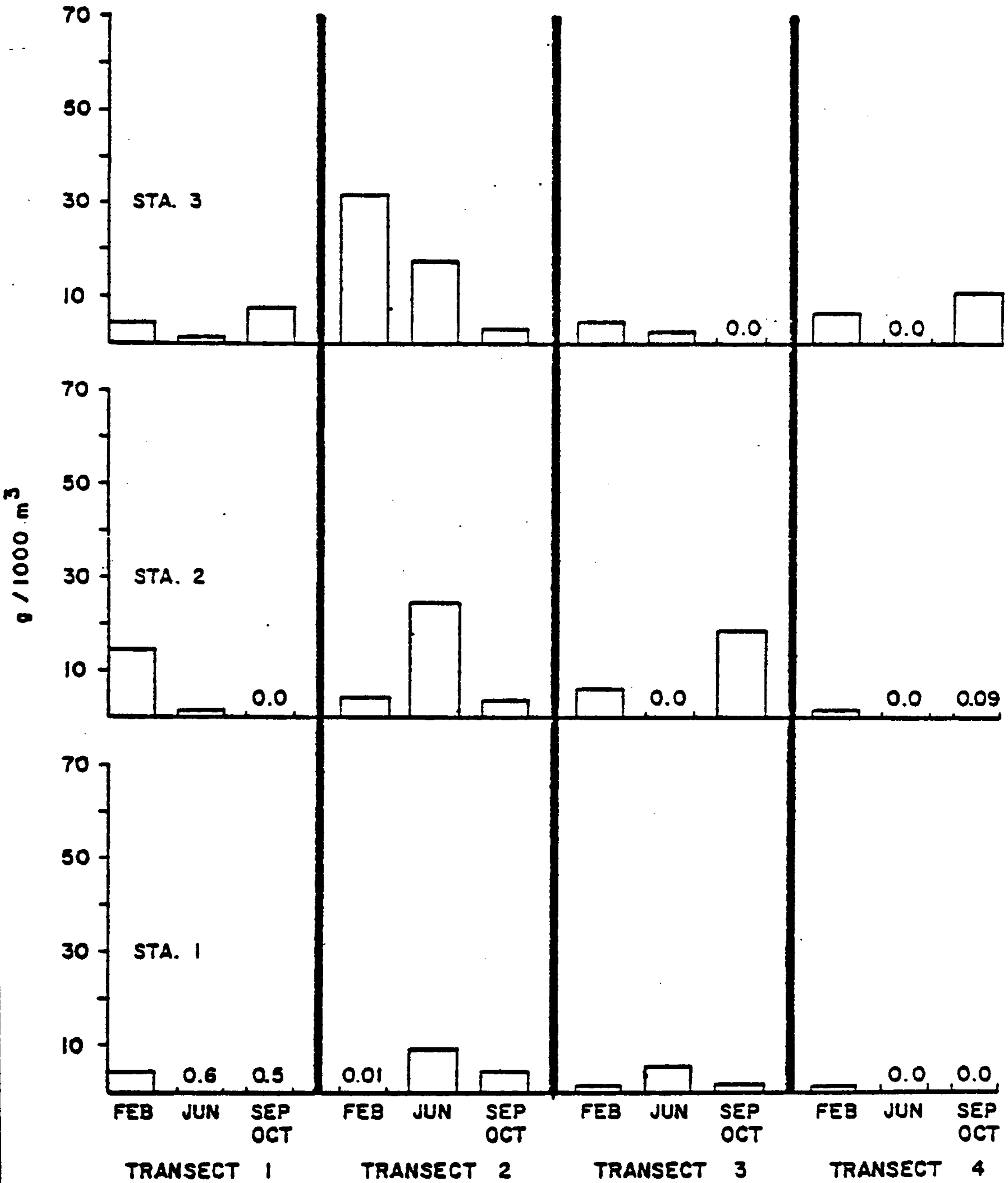


Figure 30. Day-night averages for dry weight of tar from Transects I, II, III, and IV sampled seasonally during 1976.

TABLE 10

AVERAGE DRY WEIGHTS OF FLOATING TAR
BY SEASON, STATION, AND TRANSECT

MONTH	TAR ($g/1000\ m^3$)	TAR mg/m^2
WINTER (Feb.)	6.57	0.99
MARCH	14.98	2.25
APRIL	74.75	11.21
SPRING (June)	5.18	0.78
JULY	0.78	0.12
AUGUST	1.83	0.27
FALL (Sept.-Oct.)	4.16	0.62
NOVEMBER	1.21	0.18
DECEMBER	39.47	5.92
STATION		
1	3.49	0.52
2	16.88	2.53
3	12.39	1.86
TRANSECT		
I	3.85	0.58
II	18.39	2.76
III	4.36	0.65
IV	2.16	0.32
OVERALL 1976 AVERAGE:	10.93	1.64

pelagic tars (1.20 and 0.773 mg/m^2, respectively) than the Mediterranean and Sargasso Seas but more polluted than the Northeast Pacific, and about the same as the Gulf Stream. Measurements based on a chemical extraction method reduce the previously reported levels of pelagic tar concentrations since debris accounts for, on average, approximately one-third of the tar lump's mass and, therefore, are not strictly comparable to previous reports (Jeffrey *et al.*, 1974). They suggest that some of the pelagic tar is swept into the Gulf of Mexico through the Yucatan Straits and comes primarily from shipping and tanker cleaning operations. Bimodal gas chromatogram traces also relate many tars to crude oil sludges or tanker wastes dumped at sea (Sherman *et al.*, 1974; Jeffrey *et al.*, 1974).

Translating the tar values into units of mg/m^2 (Table 10) so as to be comparable to previous studies, an overall 1976 average from all stations sampled on the South Texas Outer Continental Shelf was 1.64 mg/m^2, a figure only slightly higher than the 1.20 mg/m^2 reported by Jeffrey *et al.*, (1974) for the Gulf of Mexico.

CONCLUSIONS

South Texas neuston samples during 1976 showed variations in biomass, species diversity, numerical abundance of the taxonomic components, and dry weight of tar. These variations can be related to diurnal, seasonal, geographic, and distance-from-shore considerations.

For example, this study has shown very definitely that certain taxa are more abundant in the surface waters at night than during the day. This is probably accounted for by nocturnal vertical migrations to the surface at night which are known to occur in many organisms. Examples of taxa more abundant in night tows were: foraminiferans, medusae, bivalve mollusc larvae, hyperiid amphipods, barnacle nauplius larvae, decapod larvae, stomatopod larvae, euphausiids, mysids, ostracods, chaetognaths, doliolids, most fish larvae, the sergestid shrimp *Lucifer typus*, and the copepods, *Centropages furcatus, Temora stylifera* and *Pontellopsis villosa*. On the other hand, those taxa more abundant or common in day samples included the copepod *Anomalocera ornata* and fish larvae of the families Mugilidae, Exocoetidae and Mullidae.

Seasonal differences were apparent in the following taxa, which are listed under their season of greatest abundance:

February: *Velella, Physalia*, bivalve larvae, gastropod larvae, *Brasilomysis castroi* (mysid shrimp), *Anomalocera ornata* (copepod) and fish eggs

February and March: *Porpita*, barnacle larvae and doliolids

April: Larvaceans

June: Pinnotherid crab zoeas, chaetognaths, salps, fish larvae, copepods in general, but especially *Centropages furcatus, Labidocera aestiva* and *Temora stylifera*

September-October: *Pontellopsis villosa* (copepod)

December: Ostracods

June had the highest average biomass and highest numerical abundance of total organisms, while August had the highest species diversity. The highest tar values were in April.

Geographical differences, as determined by greatest abundance on certain transects, was noticeable for certain taxa, but others appeared to occur ubiquitously throughout the four transects off the South Texas coast. Among those taxa which showed geographic limitations and/or preferences were:

Transect I: *Velella, Physalia*, barnacle larvae, doliolids, copepods in general, but especially *Anomalocera* *ornata* and *Centropages furcatus*

Transects I
& II: Echinoderm larvae

Transect II: Larvaceans

Transect III: Gastropod larvae and salps

Transect III
& IV: Hyperiid amphipods and *Halobates micans*

More taxa were absent from or showed least abundant distributions on Transect IV than any other transect. Transect IV was also lowest in species diversity, average biomass, numerical abundance of total organisms and dry weight of tar. Transect III had the highest average biomass, while Transect II had the highest average species diversity and the highest dry weight of tar.

As with geographic differences, distance-from-shore differences were noticeable in only certain taxa which were most common at certain stations as follows:

Station 1: Pinnotherid crab zoea larvae, penaeid larvae, *Lucifer faxoni*, the mysid shrimps *Mysidopsis bigelowi* and *Brasiliomysis castroi*, copepods in general, but especially *Labidocera aestiva* and fish larvae of the families Sciaenidae and Gerridae

Stations 1
& 2: *Physalia*, *Velella*, bivalve larvae, gastropod larvae, Cladocera, chaetognaths, the copepods *Anomalocera ornata*, *Centropages furcatus* and *Pontellopsis villosa*

Station 2: Larvaceans

Stations 2
& 3: Portunid megalops larvae, euphausiids, *Siriella thompsoni* (mysid shrimp), ostracods, hyperiid amphipods, doliolids, salps and *Halobates micans*

Station 3: Foraminifera, barnacle larvae, the sergestid shrimp *Lucifer typus* and fish larvae of the family Mugilidae.

Station 1 showed the highest average biomass. Station 3, which showed the lowest average biomass throughout 1976, showed the highest species diversity. Dry weight of tar was highest at Station 2 and lowest at Station 1.

The above observations point out the great variability of the South Texas Outer Continental Shelf neuston during 1976. Since the 1976 data are not comparable to the 1975 neuston study because of different sampling methods and gear, different analytical techniques, and lack of quantification in the 1976 study, no real comparisons can be made between the two years. Thus, the 1977 study and subsequent neuston studies become more urgent to determine yearly norms for neuston in the STOCS study area.

LITERATURE CITED

Berkowitz, S. P. 1976. A comparison of the neuston and near-surface zooplankton in the Northwest Gulf of Mexico. M.S. Thesis in Oceanography, Texas A&M University. 148pp.

Bowman, T. E. and J. C. McCain. 1967. Distribution of the planktonic shrimp, *Lucifer*, in the western North Atlantic. Bull. Mar. Sci., 17(3):660-671.

Fager, E. W. 1957. Determination and analysis of recurrent groups. Ecology, 38(4):586-595.

________. and J. A. McGowan. 1963. Zooplankton species groups in the North Pacific. Sci. 140(3566):453-460.

Felder, D. L. 1973. An annotated key to crabs and lobsters (Decapoda, Reptantia) from coastal waters of the northwestern Gulf of Mexico. Ctr. for Wetland Resources, L.S.U., Baton Rouge, Publ. No. LSU-SG-73-02. 103pp.

Finucane, J. H. 1976. Baseline survey of the ichthyoplankton. pp. 20-31. *In* NOAA Final Report to BLM: Environmental studies of the South Texas outer continental shelf 1975. Vol. 1.

Harper, D. E., Jr. 1968. Distribution of *Lucifer faxoni* (Crustacea: Decapoda: Sergestidae) in neretic waters off the Texas coast, with a note on the occurrence of *Lucifer typus*. Contrib. in Mar. Sci., 13:1-16.

Hartman, J. 1970. Verteilung und Nahrung des Ichthyoneuston im subtropischen Nordostatlantik. METEOR Forsch. - Ergebnisse, D8:1-60.

Heinrich, A. K. 1969. The distribution of neustonic copepods in the Pacific (in Russian). Zool. Zhur., 98(10):1456-1466.

________. 1971. On the near-surface zooplankton of the eastern South Pacific. Mar. Biol. 10(4):290-294.

Hempel, G. and H. Weikert. 1972. The neuston of the subtropical and boreal northeastern Atlantic Ocean. A Review. Mar. Biol. 13(1):70-88.

Holland, J. S. 1977. Invertebrate epifauna and macroinfauna, pp. 415-459. *In* Environmental studies, south Texas outer continental shelf, biology and chemistry. Fourth Quarterly Report, 1976. Prepared for the Bureau of Land Management, Washington, D. C.

Horn, M. H., J. M. Teal, and R. H. Backus. 1970. Petroleum lumps on the surface of the sea. Sci. 168:245-246.

Jeffrey, L. M., W. E. Pequegnat, E. A. Kennedy, A. Vos, and B. M. James. 1974. Pelagic tar in the Gulf of Mexico and Caribbean Sea. NBS Spec. Publ. 409, Marine Pollution Monitoring (Petroleum), Proc. of a Symposium and Workshop, Gaithersburg, Maryland. 317pp.

Morris, B. F. 1971. Petroleum: tar quantities floating in the northwestern Atlantic taken with a new quantitative neuston net. Sci. 173:430-432.

________. 1975. The neuston of the northwest Atlantic. Thesis (Ph.D.) Dalhousie Univ. pp. 1-54, 1-77, 1-69, 1-67, 1-12 and 1-18.

________. and J. N. Butler. 1973. Petroleum residue in the Sargasso Sea and Bermuda beaches. Proc. Joint Conf. on Prevention and Control of Oil Spills, API, Washington. 195pp.

Pequegnat, W. E., R. M. Darnell, B. M. James, E. A. Kennedy, L. H. Pequegnat and J. T. Turner. 1976. Ecological aspects of the upper continental slope of the Gulf of Mexico. Report prepared for the U.S. Dept. of the Interior, Bureau of Land Management, Div. of Minerals Environmental Assessment. 305pp.

Sherman, K., J. B. Colton, R. L. Dryfoos, K. D. Knapp and B. S. Kinnear. 1974. Distribution of tar balls and neuston sampling in the Gulf Stream system. NBS Spec. Publ. 409, Marine Pollution Monitoring (Petroleum). Proc. of a Symposium and Workshop, Gaithersburg, Md., 317pp.

TerEco Corporation. 1975. Sea-level monitoring of the incineration of organic chloride waste by M/T VULCANUS in the northern Gulf of Mexico, shell waste burn no. 2. Rept. for the Environmental Protection Agency, Washington, D. C. 39pp and appendices.

________. 1975. A field monitoring study of the effects of organic chloride waste incineration on the marine environment in the northern Gulf of Mexico. Rept. for Shell Chemical Co., Houston, Texas. 32pp and appendices.

Weikert, H. 1972. Verteilung und tagesperiodik des evertebratenneuston im subtropischen nordosatlantik wahrend der (Atlantischen Kupenfahrten 1967). von F. S. METEOR. METEOR Forsch. Erge. 11:30-87.

Williams, A. B. 1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. 65(1):298pp.

Zaitsev, Y. P. 1970. Marine neustonology. K. A. Vinogradov, (ed.), Translation by Israel Program for Scientific Translations, Jerusalem. 264pp.

________. 1968. La neustonologic marine: objit mithodes, realisations principales, et problems. Pelagos, 8:1-48.

________. 1961. The surface pelagic biocenosis of the Black Sea. Zool. Zhur., 40(6):818-825.

CHAPTER EIGHT

MEIOFAUNA PROJECT

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ABSTRACT

A total of 294 sediment samples collected between February and December 1976, from 25 transect stations and eight bank stations on the South Texas Outer Continental Shelf were analyzed for establishment of meiofauna populations and communities. In general, populations tended to decrease with increasing depth between 10 and 134 m; however, this trend was not uniform. It was established that the true meiofauna (metazoan animals) exhibit strong seasonal population increases in March, November, and especially July. Nematodes were by far the predominant component of the true meiofauna, not only in terms of populations but also taxal diversity. Up to now 90 taxa at and above the genus level were identified from the sampling stations.

Both physical and biological controls, some of which are still speculative, were demonstrated. Nematodes were highly correlated with sediment granulometry, increasing substantially in number when the sand component attained or exceeded 60 percent. Harpacticoid copepods tended not to respond to this factor, but responded to some as yet unknown characteristic of sediments around the bases of the banks. It was assumed that the unknown factor was available organic carbon. These observations reinforce the proposition that the harpacticoid/nematode ratio can be developed into a valuable yardstick of environmental degradation and recovery.

Strong indications of competitive elimination of many nematode taxa throughout the year were noted. Also, there was some evidence that predation was a potent control of nematode populations, but the kinds of predators are as yet unknown although some of them are likely to be nematodes.

The value of the meiofauna study could be compounded by undertaking monthly sampling on a second transect and by permitting a comparative analysis of the available organic content of sediments rich and poor in harpacticoids.

INTRODUCTION

Purpose

The major objective of the present investigation was to determine in a relatively small geographical area of the South Texas Outer Continental Shelf the distributions, abundances and environment of the taxonomic components of the meiofauna. It is anticipated that these findings can be used to aid in establishing baseline conditions and to discern when and if environmental disturbances are having measurable biologic impacts. It is hoped that upon completion, this study will have established certain in-meiofauna ratios as reliable indicators of environmental quality. This is dependent in part upon measuring environmental parameters that are not now a part of the overall study.

Background

Definitions

The term meiobenthos was introduced by Mare (1942) to apply to benthic organisms that live in marine soft bottoms and that are intermediate in size between the microfauna and the better known macrofauna. In early studies, the meiofauna was separated from the latter by means of sieves having a mesh size of 1.0 mm; more recently, however, the upper limit of size is taken as 0.5 mm (McIntyre, 1964; Tietjen, 1969, 1971; Coull, 1970; McIntyre and Murison, 1973). The lower limit has also been variable, but 0.062 mm is now the more common mesh size employed. Accordingly, the meiofauna in this study is defined by retention on a 62 μm screen, whereas all organisms taken by the grab and retained on a 0.5 mm sieve are designated as macrofauna. The term megafauna is applied to those large organisms, both invertebrate and vertebrate, that one cannot sample effectively with a grab.

Permanent and Temporary Meiofauna

The meiofauna is composed of both a permanent and more numerically stable set of organisms as well as a temporary, numerically variable group composed of juvenile macroinfaunal forms (McIntyre, 1961, 1964; Thorson, 1966). The permanent or true meiofauna differs from the macroinfauna not only in size but also in regard to number, average generation time, and morphological adaptations to their environment. Some protozoans meet the size requirements of the meiofauna but, as Thiel (1975) pointed out, the Foraminifera have been excluded from most investigations on deep water meiofauna. Up to now, the foraminifera are grouped together with the multicellular meiofauna in only three publications (Wigley and McIntyre, 1964; Tietjen, 1971; and Thiel, 1975). There are several reasons for this deletion, among them being the difficulty of separating live from dead individuals because material in the tests other than protoplasm may stain red with rose bengal. On the basis of numbers alone, it would appear that they should be included in meiofaunal studies. The present study, as well as the work of others (Wigley and McIntyre, 1964; Tietjen, 1971; and Thiel, 1975), shows that the Foraminifera often are either the most numerous group or the second in abundance behind the nematodes.

Even so, in this report the metazoan meiofauna are placed in the category of "true" meiofauna (all of which are permanent) and the Foraminifera and temporary meiofauna are lumped into a second category.

Previous Work

As Thiel notes, effective work on offshore meiofauna was started as late as 1964 when Wigley and McIntyre (1964) obtained quantitative samples from a transect on the North American Atlantic shelf and down the continental slope to about 600 m. In addition, quantitative samples were taken from slope to abyss by McIntyre from DISCOVERY (Warwick, 1973) and by Thiel from METEOR (Thiel, 1966) both in 1964/1965 in the Arabian Sea.

The meiofauna have received very little attention in the sublittoral of the Gulf of Mexico. Pequegnat and Gettleson (1974) listed the number of individuals in major meiofaunal and macroinfaunal taxa from five stations in the vicinity of Stetson Bank. In 1976 they examined meiofaunal-sediment correlations from 24 stations located on the outer continental shelf of west Texas. In the same year, Gettleson and Pequegnat (1976) reported on an intensive study of the wet weight and abundance of the meiofauna and macroinfauna from 10 stations on the outer continental shelf of east Texas. Prior to this report there have been only a limited number of sublittoral studies in which the wet weight and/or abundance of the meiofauna and macroinfauna have been compared. Krogh and Spärck (1936) described the fauna contained within several cores taken in Copenhagen Harbor; Mare (1942) examined the flora and fauna of a small area in the English Channel; Sanders (1958) examined the macroinfauna and Wieser (1960) the meiofauna of three stations in Buzzards Bay, Massachusetts; McIntyre (1961, 1964) studied two areas off Scotland (Loch Nevis and Fladden Ground, North Sea); Wigley and McIntyre (1964) analyzed ten samples from a transect (40 to 567 m off Massachusetts;

Guille and Soyer (1968, 1974) studied the fauna off the French Banyuls-sur-Mer coast (Mediterranean); Stripp (1969) examined samples from the Helgoland Bight (North Sea); Ankar and Jansson (1973), Elmgren (1972), Ankar and Elmgren (1975) and Jansson and Wulff (1977) analyzed samples from the Baltic Sea.

Nematodes usually dominate the meiofauna; however, their systematics and ecology have been neglected to a great extent. Only six known papers have been published on Gulf of Mexico nematology, all on material from the littoral zone (Chitwood, 1951; Chitwood and Timm, 1954; Hopper, 1961a, 1961b, and 1963; King 1962). Hulings (1967) reviewed previous papers dealing with the systematics and ecology of podocopid and platycopid ostracods in the Gulf of Mexico. Disregarding the foraminiferans, no other published reports on the components of the permanent meiofauna of the sublittoral Gulf are known. There are, however, a number of papers describing the living, soft-bottom foraminiferans of the Gulf. Phleger's (1951) study dealt with an area similar to that of the present study, but his total number of identified living forms was very low (16) due to the unreliable biuret test used to distinguish living from dead individuals. Phleger (1956) used the more accurate rose bengal method to detect living forams. Walton (1964), in a study of the central Texas coast and continental shelf, was able to describe four depth-related assemblages on the shelf. Other foraminiferal studies in the Gulf of Mexico have also resulted in depth-related biofacies. Phleger (1951) recognized six depth facies, Bandy (1954) three within water depths of 8 to 37 m, Parker (1954) six in the northeast Gulf, and Bandy (1956) described five major facies also in the northeast Gulf. Phleger (1960) reviewed much of the Gulf of Mexico foram work. Other studies of living, sublittoral, Gulf of Mexico foraminiferal distributions since 1960 include Walton (1964), Loep (1965), Lankford (1966), Greiner (1970), Poag and Sweet (1971) and Buzas (1967, 1972).

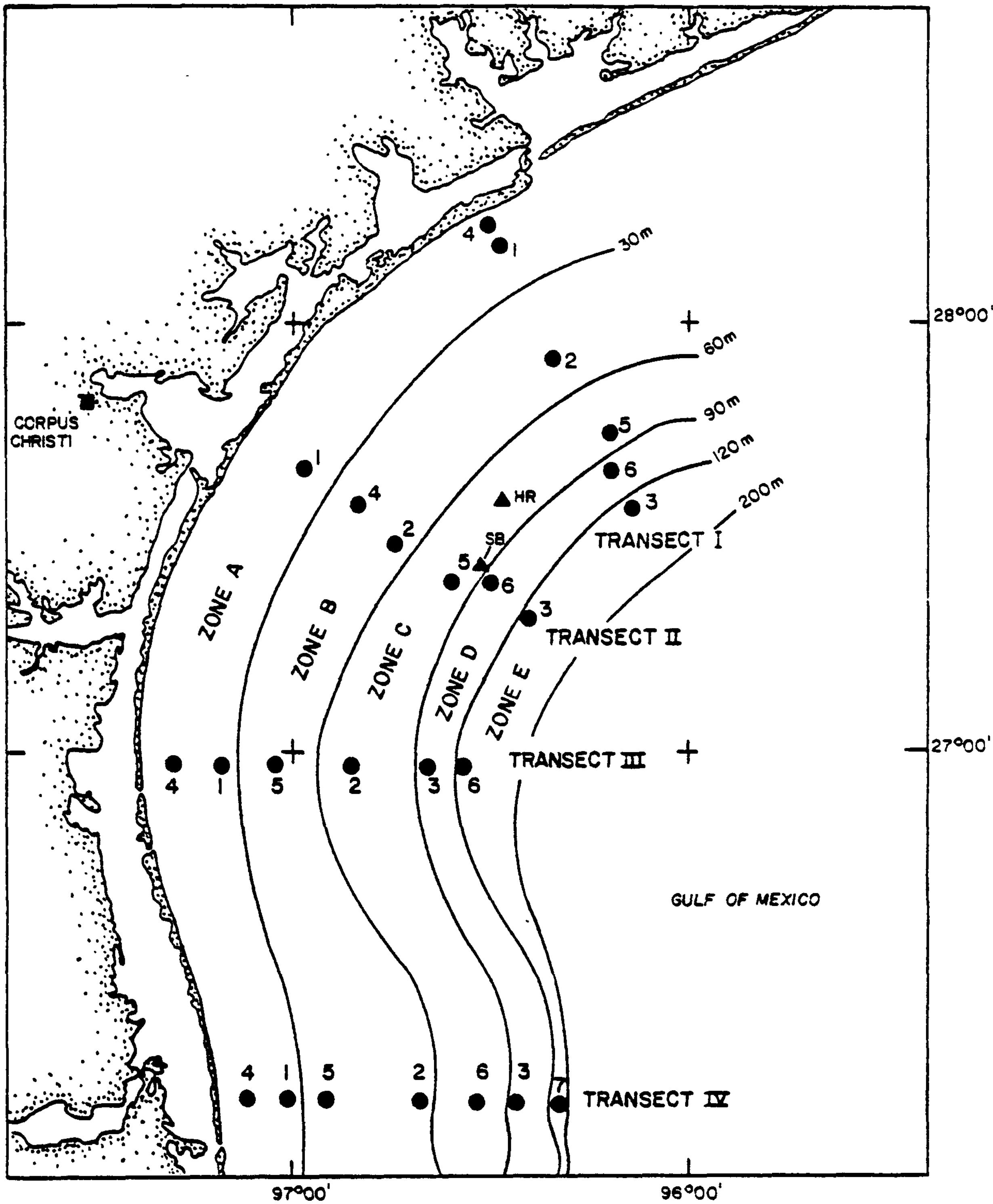
METHODS AND MATERIALS

Sampling Transects and Stations

The meiofaunal samples were collected with a Smith-MacIntyre grab on four transects and two hard banks. The locations of the 25 transect stations are shown in Figure 1. Note also the locations of Hospital Rock (HR) and Southern Bank (SB) in Zone C. Two stations were sampled at each hard bank (topographic feature) during each of nine sampling periods. More detailed information on specific depths of each station is given in Figure 2. Note particularly that Transect II is located more or less in line with the channel entrance to Corpus Christi Bay and that Transect IV has seven stations, whereas the others have six. Also, Station 7, Transect IV, is actually slightly beyond the shelfbreak which may account for some of its unique faunal characteristics.

Frequency of Sampling and Sample Inventory

Stations were sampled either on a seasonal or a so-called monthly basis or both. All 25 transect stations and the four bank stations were visited three times on the seasonal schedule. In addition, the six stations of Transect II and the four bank stations were sampled an additional six times on the monthly schedule. Two replicate samples were taken from each grab for laboratory analysis, giving a total of 294 samples (Table 1).



LOCATION OF TRANSECTS, SAMPLING STATIONS, AND ZONES

Figure 1. Location of South Texas OCS Baseline Study transects (roman) and stations (arabic). Note also the location of Southern Bank (SB) and Hospital Rock (HR) topographic highs in Zone C.

SOUTH TEXAS OCS BASELINE SURVEY

ZONES ← SW	TRANSECTS AND STATIONS: IV STATIONS	III STATIONS	II STATIONS		I STATIONS	NE →
ZONE A	4 (15m)	4 (15m)	1 (22m)		4 (10m)	
	1 (27m)	1 (25m)			1 (18m)	
30m						ISOBATH
ZONE B	5 (37m)	5 (40m)	4 (34m)		2 (42m)	
	2 (47m)		2 (49m)			
60m						ISOBATH
				HR		
ZONE C	6 (65m)	2 (65m)	5 (78m)		5 (82m)	
				SB		
90m						ISOBATH
ZONE D	3 (91m)	3 (106m)	6 (98m)		6 (100m)	
120m						ISOBATH
ZONE E	7 (130m)	6 (125m)	3 (131m)		3 (134m)	

Figure 2. Zonal distribution and depths of the 25 transect stations and the two bank stations on the South Texas Outer Continental Shelf. Also see Figure 1.

TABLE 1

SOURCE AND TIME OF COLLECTION OF THE
294 MEIOFAUNA SAMPLES COLLECTED AND ANALYZED IN 1976

SAMPLING DATES 1976	TRANSECTS I	II	III	IV		HARD BANK SOUTHERN BANK	HOSPITAL ROCK	
February 13-20	12	12	12	14		4	4	
March 25-27		12				4	4	
April 9-10		12				4	4	
June 13-25	12	12	12	14		4	4	
July 17-18		12				4	4	
August 16-27		12				4	4	
October 8- 9	12	12	12	14		4	4	
November 16-19		12				4	4	
December 9-10	—	12	—	—		4	4	
SUB TOTALS	36	108	36	42	= 222	36	36	= 72

GRAND TOTAL 294 samples analyzed

Analysis of Samples

Shipboard

All meiofauna samples were taken with a standard Smith-McIntyre grab. On deck, a plexiglass core tube of 3.42 cm diameter (area = 9.187 cm^2) was pushed into the sediment to a depth of 5 cm. Four such cores were taken and the enclosed sediment was extruded into 8 oz. glass jars. One sample was frozen immediately. The remaining three samples were anesthetized in isotonic $MgCl_2$ for 10 minutes and then placed in 10% buffered formalin. Only two of the three samples were to be sorted and these received rose bengal in the formalin.

Laboratory

In the laboratory the stained samples were sieved through 8-inch diameter 500 and 62 μm mesh sieves. The material retained on the 62 μm sieve was washed into 2 oz. squat jars with 10 percent buffered formalin, to which 10 ml of rose bengal in formalin (200 mg/l) was added. After the sample had been allowed to stain (1-2 days), it was first washed in a 3-inch diameter, 62 μm mesh sieve to remove excess stain and then aliquoted into an 80 x 40 mm rectangular sorting dish marked off in a 7 mm square grid. The whole sample was then examined microscopically and the sorted animals placed in vials. When the number of nematodes exceeded 150, the first 150 were vialed and the remainder were only counted.

RESULTS

Transect Populations

Considering all taxa of the true meiofauna, the Transect IV stations yielded the highest number of individuals and the Transect II stations the smallest number. The sums of the means of individuals of true meiofauna taken at all stations of Transect I through IV during the three seasonal sampling periods were as follows:

Sampling Period		Transect			
1976		I	II	III	IV
Winter		241	35	176	303
Spring		111	52	234	275
Fall		183	58	270	421
	Totals	535	145	680	999

Transects I and III supported intermediate population levels. These differences between transects were statistically significant. The above table demonstrates that Transect II was the aberrant sampling line. Since populations increased in both directions (northeast and southwest) from Transect II, it is suggested that the low populations were somehow related to the fact that the stations were in line with the entrance to Corpus Christi Harbor. This situation was supported by the analysis of populations of the individual stations. The complete analysis of both monthly and seasonal samples from the 25 transect stations is given in Appendix F, Tables 1 and 2.

Population Trends by Station

Since the transects run normal to the coast and station depths range from 10 to 134 m, it was not particularly surprising that substantial changes in station populations were observed along the transects. The general trend was a marked reduction in true meiofauna populations as depth increased (Figure 3). The major exception was on Transect II, where the shallow station not only supported low populations but also differed most from the conditions along other transects. In Figure 3 note that the Foraminiferida followed essentially the same patterns as the true meiofauna. However, the outermost station (Station 7) of Transect IV had very low populations, because this station was on the upper continental shelf. More taxonomic work will be required with the foram samples before the implications of this observation can be understood.

Population Trends by Season

Populations of the true meiofauna reached three seasonal peaks. There was a minor peak in late March and early April, a maximum peak in July, and an intermediate peak in November. As shown in Figure 4, this seasonality would not have been detected by sampling only during the three so-called seasonal periods in February, June and October, since these periods were out of phase with the population increases.

Figure 5 shows clearly that the so-called seasonal samples alone would result in a false picture of the meiofauna standing crop. Examining the depth-related population response to season (Figure 6), it was evident that such responses occurred at all station depths sampled in this study. However, more pronounced seasonal population changes occurred at the shallow stations (22-34 m) as compared with the deepest stations (98-131 m). The response of the intermediate depth stations showed a prolonged summer peak (Figure 6) and a fall peak in December

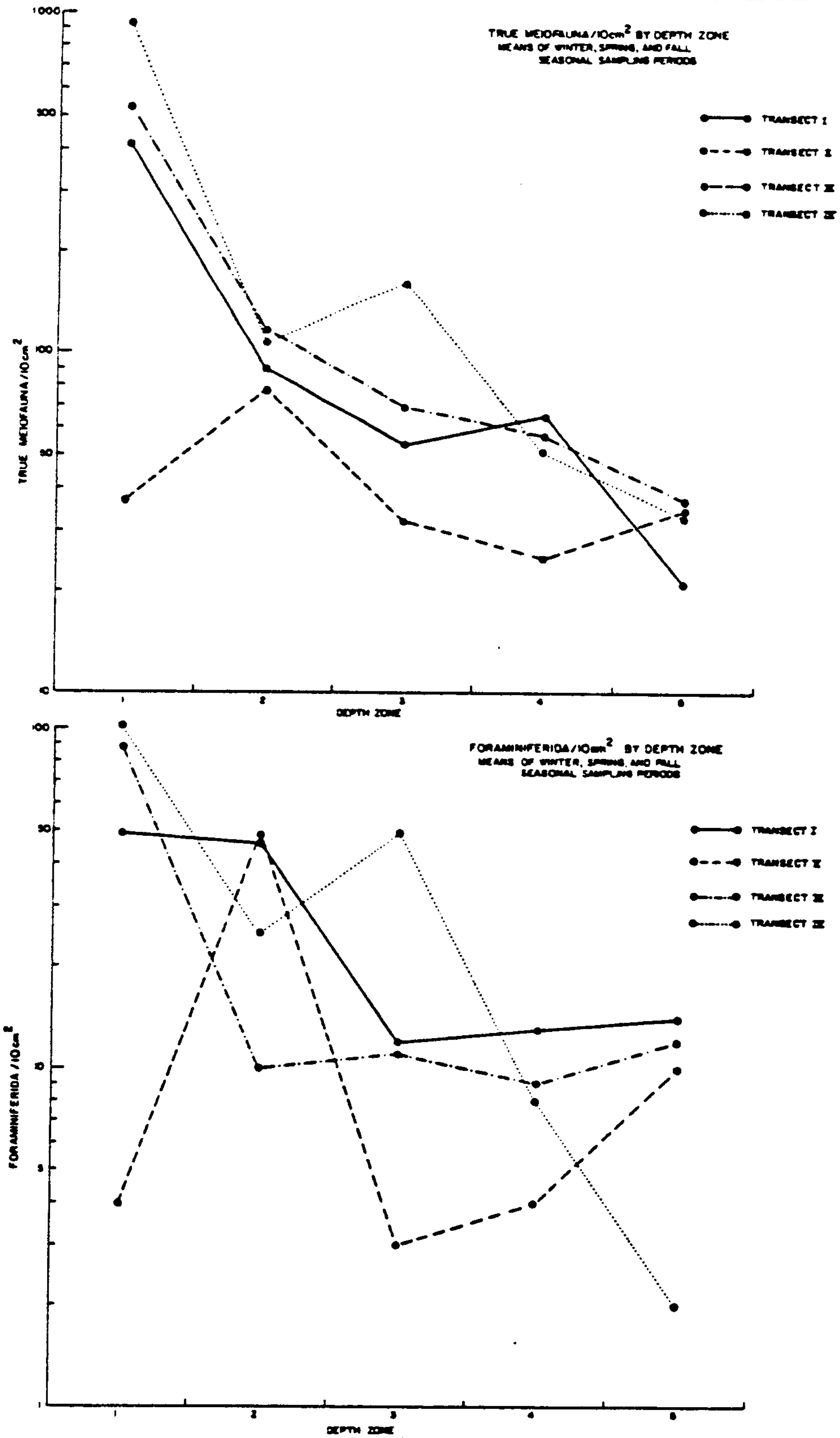


Figure 3. Distribution of true meiofauna and Foraminiferida during the winter, spring, and fall sampling periods by depth zone (Note: depth zone 1 = A, 2 = B, etc. of Figures 1 and 2).

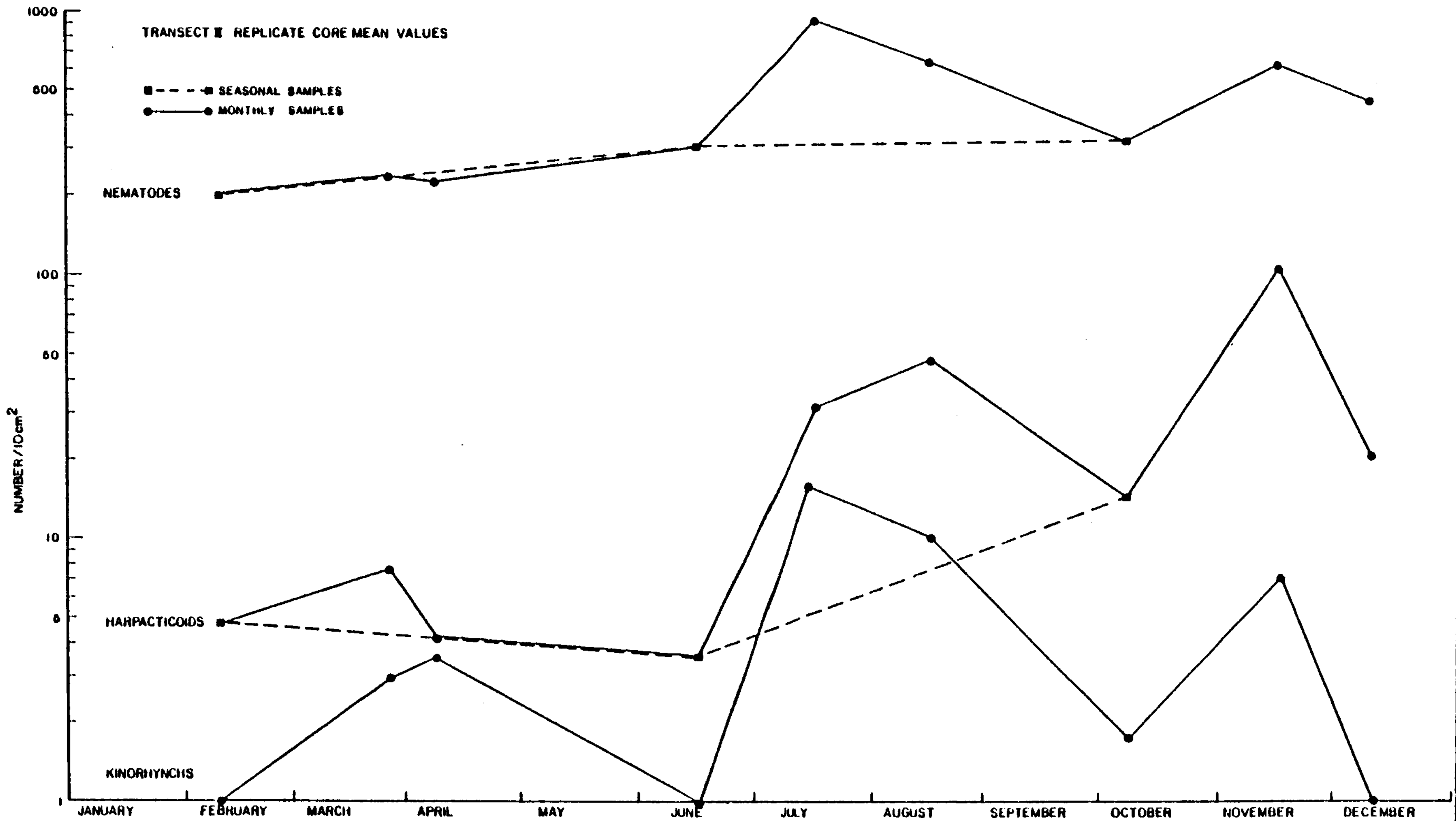


Figure 4. Transect II seasonal versus monthly sampling. Numbers represent totals of replicate core means adjusted to 10 cm^2. Results of monthly sampling reveal March, July, and November peaks in populations of Nematoda, Harpacticoida, and Kinorhyncha that are missed by the seasonal sampling.

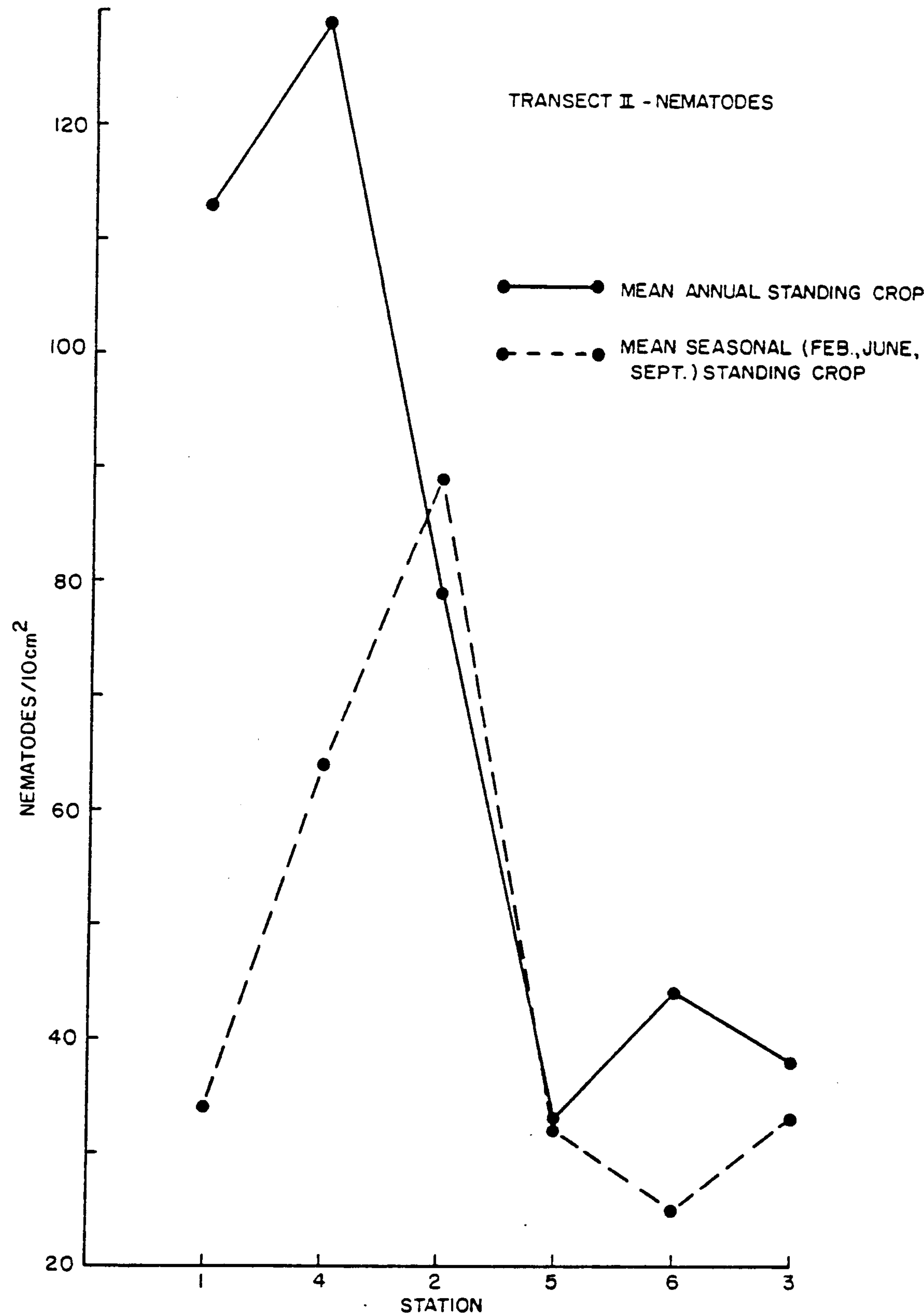


Figure 5. Transect II mean annual nematode standing crop by station (offshore to right) calculated for the 9 monthly sampling periods and for the three seasonal sampling periods. Use of the so-called seasonal samples leads to an underestimation at 5 of the 6 stations and a slight overestimation at Station 2. (One nematode = 6.93 μg, wet weight)

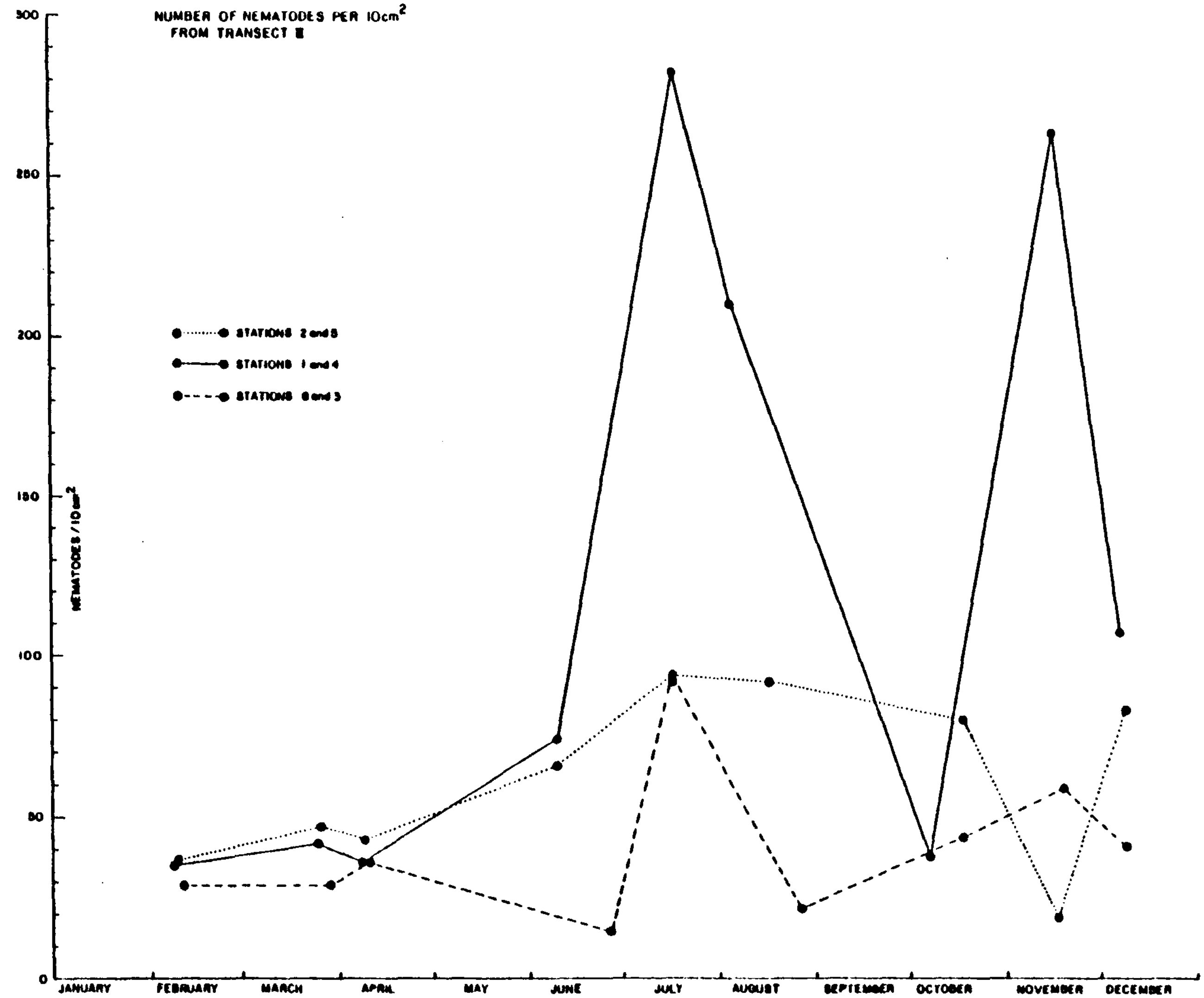


Figure 6. Transect II monthly samples showing distribution of Nematoda at inshore stations (1 and 4), midway stations (2 and 5) and offshore stations (6 and 3). Spring, summer, and late fall peaks occur at both inshore and offshore stations with the greater fluctuations occurring inshore. The midway stations have a very prolonged summer peak.

instead of November. The same seasonal result in shown for nematodes from Transect II considered as a whole in the upper half of Table 2.

Bank Populations

The meiofauna of Southern Bank and Hospital Rock was similar to that of the transect stations but exhibited some instructive differences. As with transects, nematodes predominated among the true meiofauna, followed by the harpacticoids. All sampling periods considered, nematodes were more abundant on Hospital Rock than on Southern Bank, whereas foraminiferans and harpacticoids were more abundant on Southern Bank. The sum of the means of individual per 10 cm^2 of four important meiofauna taxa from the nine sampling periods on the hard banks was as follows:

	Southern Bank	Hospital Rock
Nematodes	441	538
Harpacticoids	72	59
Foraminiferans	759	205
Polychaetes	29	32

If the two banks are compared on the basis only of the seasonal sampling, then Hospital Rock appears to exceed Southern Bank in regard to all categories.

Population data from the banks can be compared to that from the transects, provided only Zone C stations where the banks are located are considered (see Figure 1). Such a comparison indicates that the banks and transects support similar populations. It was very interesting to note, however, that whereas the populations of both banks were larger than those of the homologous station (5) of Transect II, populations of the Southern Bank were smaller than those of all other transects while

TABLE 2

MEANS PER CORE SAMPLE AND STATION TOTALS OF NEMATODE POPULATIONS ON TRANSECT II AND A COMPARISON BETWEEN THE NEMATODE POPULATIONS OF THE SHALLOWEST STATIONS ON TRANSECTS II (1) AND IV (4) AND BETWEEN THOSE AND THE DEEPEST STATION OF TRANSECT II (3)

	FEBRUARY 20 (WINTER)	MARCH 25	APRIL 9	JUNE 16 (SPRING)	JULY 8	AUGUST 16	OCTOBER 8 (FALL)	NOVEMBER 17	DECEMBER 9
NEMATODES Mean/Core Transect II	33.6	39.3	38.3	51.5	155.7	108.2	53.9	113.8	77.0
NEMATODES Total Transect II	379	433	422	568	1716	1193	594	1254	844
NEMATODES Total Station 1/II	43	46	30	38	78	270	12	355	58.5
NEMATODES Total Station 4/IV	817			673			899		
NEMATODES Total Station 3/II	17.5	14	61.5	11.5	54	21.5	63	39.5	31.5

populations of the Hospital Rock were larger than all but Transect IV (Table 3). References to Figure 1 shows that Southern Bank is much closer to Transect II than Hospital Rock. This was another excellent example of meiofaunal sensitivity to environmental conditions.

The meiofauna of the banks exhibited seasonal peaks in population numbers resembling those on the transects. In fact, the summer peak was stretched out or plateaued essentially as was the case of the two mid-transect stations shown in Figure 6. See Appendix F, Table 3, for a complete analysis.

Nematode Populations

Thus far 90 nematode taxa at the same level and above have been collected (Table 4) from the transect and bank stations. There is no doubt that nematodes predominated not only in numbers of individuals, but also in number of taxa. Althouth the taxonomy of the harpacticoids and kinorhynchs has not been completed, only a few species appeared to be involved in the former and only five genera have thus far been encountered in the kinorhynchs (Table 6). In Table 4 the nematode taxa taken at the inner most stations of Transects II and IV and the outermost station of Transect II are shown.

Twenty-one of the above 90 taxa occurred at all three stations. These were:

Campylaimus
Desmodorella
Desmoscolex
Dorylaimopsis metatypica
Graphonema
Halalaimus
Ironella
Laimella
Linhomoeidae
Monhysteridae
Neotonchus
Pomponema
Pselionema
Ptycholaimellus
Sabatiera
Synonchiella
Terschellingia
Theristus
Tricoma
Viscosia
Unknowns

TABLE 3

MEAN NUMBER OF INDIVIDUALS PER 10 cm^2 OF ALL TRUE MEIOFAUNA TAKEN FROM THE HARD BANKS AND THE HOMOLOGOUS TRANSECT STATION.
THE SAME DATA ARE GIVEN FOR THE FORAMINIFERA AND TEMPORARY MEIOFAUNA; SEASONAL SAMPLINGS ONLY

TRUE MEIOFAUNA

		TRANSECT I STATION 5	TRANSECT II STATION 5	TRANSECT III STATION 2	TRANSECT IV STATION 6
WINTER		43.5	12.5	30.5	185.6
SPRING		51.2	47.4	63.1	93.6
FALL		69.7	40.8	111.0	209.4
	TOTAL	164.4	100.7	204.6	488.6

		SOUTHERN BANK	HOSPITAL ROCK
WINTER		70.5	13.0
SPRING		42.5	74.5
FALL		26.5	117.5
	TOTAL	139.5	205.0

FORAMS AND TEMPORARY MEIOFAUNA

		TRANSECT I STATION 5	TRANSECT II STATION 5	TRANSECT III STATION 2	TRANSECT IV STATION 6
WINTER		64.2	13.6	34.3	263.4
SPRING		56.6	51.2	74.6	127.9
FALL		84.4	47.9	131.7	274.3
	TOTAL	205.2	112.7	240.6	665.6

		SOUTHERN BANK	HOSPITAL ROCK
WINTER		92	18
SPRING		57	106
FALL		46	151
	TOTAL	195	275

The principal genera among these 21 may be rank ordered on the basis of the frequency of their occurrence at three stations on Transects II and IV (Table 4). Considering the substantial amount of taxonomical work required to deal with the nematodes, it was decided to concentrate on the innermost (shallowest) stations of Transect II (having the sparsest meiofauna) and of Transect IV (having the richest meiofauna) and then compare these with the deepest station of Transect II. As shown in Table 4, Stations 1 and 3, Transect II, were sampled nine times and Station 4, Transect IV, only three times during the seasonal regimen. The rank order of nematode genera was as follows:

		Percent Occurrence Highest Possible = 300
1.	*Sabatieria*	300
2.	*Theristus*	278
3.	*Halalaimus*	244
4.	*Dorylaimposis metatypica*	233
5.	*Neotonchus*	178
6.	*Terschellingia*	177
7.	*Synonchiella*	167
8.	*Viscosia*	166
9.	*Laimella*	156
10.	*Ptycholaimellus*	144

The distribution of the 90 taxa among the three stations of the two transects was of some interest. A comparison of the number of Nematoda genera common to the two shallowest stations 1 and 4, Transects II and IV, respectively, and the deepest station (3) of Transect II is given below. Found only at the given station:

Number of Nematode Taxa in Common			Number on Unique Taxa		
1/II & 4/IV	4/IV & 3/II	1/II & 3/II	1/II	4/IV	3/II
26	31	21	2	18	22

TABLE 4

NEMATODE TAXA AT GENUS LEVEL AND ABOVE,
FOUND AT TWO INSHORE STATIONS AND ONE OFFSHORE STATION

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Actinonema	3	33	2	67		
Aegialoalaimus	2	22				
Alaimella			2	67		
Amphimonhystera					3	33
Axonolaimus					3	33
Bathylaimus			1	33		
Camacolaimus					1	11
Campylaimus	1	11	2	67	3	33
Ceramonema			1	33		
Cervonema			1	33	2	22
Chaetonema			1	33		
Cheironchus					3	33
Chromadoridae			3	100	1	11
Chromaspirina			1	33		
Comesoma			2	67		

TABLE 4. CONT.'D

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Comesomatidae			1	33	1	11
Coninckia			1	33		
Cyatholaimidae			3	100	2	22
Dasynemella			1	33		
Desmodorella	3	33	1	33		
Desmodoridae			1	33	2	22
Desmolaimus	1	11				
Desmoscolex	1	11	1	33	3	33
Dichromadora					1	11
Diploscapter	1	11				
Diplopeltis					2	22
Diplopeltula			1	33	2	22
Dorylaimopsis metatypica	8	89	3	100	4	44
Dorylaimopsis spp.					6	67
Dorylaimopsis sp. 6					1	11
Eleutherolaimus					1	11

TABLE 4. CONT.'D

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Elzalia	1	11			2	22
Enoplidae			2	67	1	11
Enoplus					1	11
Eubostrichus	2	22			2	22
Graphonema	4	44	1	33	1	11
Halalaimus	7	78	3	100	6	67
Halichoanolaimus	1	11	1	33		
Haliplectus					1	11
Hopperia	1	11			3	33
Ironella	1	11	1	33	1	11
Laimella	7	78	2	67	1	11
Latronema			3	100		
Leptolaimus	1	11	1	33	1	11
Leptosomatidae					1	11
Linhomoeidae	5	56	3	100	5	56
Longicyatholaimus			1	33		
Mesodorylaimus	2	22			2	22
Mesotheristus	5	56	2	67		

TABLE 4. CONT.'D

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Metachromadora					1	11
Microlaimus			1	33	1	11
Monhysteridae	6	67	2	67	6	67
Neotonchus	7	78	1	33	6	67
Odontophora			2	66		
Onchium					1	11
Oncholaimellus			3	100	1	11
Oxystomina	3	33			3	33
Paracumesoma			3	100		
Paracyatholaimus			1	33		
Paralinhomoeus					1	11
Parallelocoilas			2	67		
Paratarvaia			1	33		
Paradontophora					2	22
Pomponema	1	11	1	33	1	11
Pselionema	1	11	1	33	2	22
Ptycholaimellus	3	33	3	100	1	11

TABLE 4. CONT.'D

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Rhabdodemania					1	11
Rhips			1	33		
Rhynchonema			1	33		
Richtersia					2	22
Sabatieria	9	100	3	100	9	100
Setoplectus					1	11
Siphonalaimus			1	33	1	11
Southernia					1	11
Sphaerolaimus	8	89			9	100
Spilophorella			1	33		
Steineria	1	11	1	33		
Stilbonematidae	3	33			7	78
Symplocastoma					1	11
Synonchiella	1	11	3	100	5	56
Syringolaimus					2	22
Tarvaia			1	33		
Terschellingia	9	100	1	33	4	44
Thalassoalaimus	1	11			2	22

TABLE 4. CONT.'D

	TRANSECT II STATION 1		TRANSECT IV STATION 4		TRANSECT II STATION 3	
	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 3)	PERCENT	FREQUENCY OF OCCURRENCE (Maximum 9)	PERCENT
Theristus	9	100	3	100	7	78
Tricoma	6	67	1	33	1	11
Tycnodora					1	11
Viscosia	4	44	3	100	2	22
Xyala			2	67		
Unknowns	7	78	2	67	4	44

These distributions appear to indicate that Transect II is an extremely aberrant environment on its inner extremity with more "normal" conditions on its seaward extension. For example, note that the shallow station of Transect IV was more closely related to the deep station of Transect II than it was to the shallow Station of Transect II (31 vs 26 common genera). Secondly, note that Station 1/II had only two unique genera whereas Station 3/II had 22; this would not be particularly surprising except that the innermost station of Transect IV had 18 unique genera. This seems to indicate that the meiofauna was severely "stressed" toward the harbor entrance and that these stresses were not present on the transects seaward end. The dominant position of nematodes in the meiofauna community is shown in Table 5 where they accounted for from 62 to 100 percent of the individuals of the true meiofauna.

Kinorhynch Populations

Five genera of kinorhynchs were collected from the transect and bank stations (Table 6). These organisms were confined principally to the shallow stations. As shown in Figure 4, they exhibited three marked seasonal population increases in March, July and November. On the basis of their frequency of occurrence among stations, the genera were ranked as follows:

1. *Echinoderes*
2. *Pycnophyes*
3. *Trachydemus*
4. *Semnoderes*
5. *Centroderes*

Polychaete Populations

The polychaetes were the principal group of the temporary meiofauna. The species collected during the first half of 1976 are listed in Table 7.

TABLE 5

NEMATODE AND HARPACTICOID
MEAN PERCENT OF TRUE MEIOFAUNA BY
TRANSECT, MONTH, STATION

TRANSECT I

STATION NUMBER	4	1	2	5	6	3
February						
Nematodes	0.97	0.97	1.00	0.98	1.00	0.92
Harpacticoids	0.02	0.03	0.0	0.0	0.0	0.0
June						
Nematodes	0.96	0.98	1.00	0.97	0.96	0.98
Harpacticoids	0.02	0.0	0.0	0.02	0.03	0.02
Sept.-October						
Nematodes	0.98	0.97	0.94	0.94	1.00	1.00
Harpacticoids	0.01	0.01	0.03	0.04	0.0	0.0

TRANSECT II

STATION NUMBER	1	4	2	5	6	3
February						
Nematodes	0.95	0.95	0.97	1.00	0.97	1.00
Harpacticoids	0.05	0.02	0.03	0.0	0.03	0.0
June						
Nematodes	1.00	0.99	0.99	0.95	0.94	0.96
Harpacticoids	0.0	0.0	0.01	0.05	0.06	0.0
Sept.-October						
Nematodes	0.62	0.93	0.97	0.96	1.00	0.93
Harpacticoids	0.26	0.03	0.03	0.01	0.0	0.04

TABLE 5. CONT.'D

TRANSECT III

STATION NUMBER	4	1	5	2	3	6
February						
Nematodes	0.89	0.92	0.92	0.95	1.00	0.98
Harpacticoids	0.11	0.08	0.07	0.0	0.0	0.30
June						
Nematodes	0.79	0.87	0.88	0.96	0.93	0.76
Harpacticoids	0.13	0.07	0.0	0.03	0.02	0.18
Sept.-October						
Nematodes	0.94	0.92	0.94	0.98	0.92	0.86
Harpacticoids	0.05	0.06	0.03	0.02	0.03	0.11

TRANSECT IV

STATION NUMBER	4	1	5	2	6	3	7
February							
Nematodes	0.99	0.96	0.99	0.99	0.94	0.98	1.00
Harpacticoids	0.01	0.01	0.0	0.0	0.06	0.01	0.0
June							
Nematodes	0.87	0.99	0.99	0.98	0.98	0.98	0.96
Harpacticoids	0.09	0.0	0.0	0.01	0.01	0.01	0.02
Sept.-Oct.							
Nematodes	0.97	0.94	0.94	0.84	0.82	0.93	0.94
Harpacticoids	0.03	0.04	0.03	0.07	0.13	0.03	0.0

TABLE 5. CONT.'D

TRANSECT II STATION NUMBER	1	4	2	5	6	3
March						
Nematodes	0.99	0.97	0.91	0.90	0.94	1.00
Harpacticoids	0.01	0.0	0.06	0.0	0.04	0.0
April						
Nematodes	0.98	0.99	0.96	1.00	1.00	0.94
Harpacticoids	0.02	0.0	0.03	0.0	0.0	0.03
July						
Nematodes	0.98	0.95	0.91	0.99	0.90	0.96
Harpacticoids	0.0	0.02	0.06	0.0	0.08	0.01
August						
Nematodes	0.83	0.93	0.94	0.96	0.89	0.98
Harpacticoids	0.09	0.04	0.06	0.03	0.02	0.0
November						
Nematodes	0.73	0.97	0.91	0.97	0.92	0.98
Harpacticoids	0.18	0.02	0.09	0.03	0.06	0.01
December						
Nematodes	0.97	0.98	0.91	0.95	0.87	0.85
Harpacticoids	0.03	0.02	0.05	0.02	0.09	0.09

TABLE 6

KINORHYNCHA COLLECTED IN 1976

SAMPLE	STATION & TRANSECT	GENUS	NUMBER OF INDIVIDUALS
WINTER	1/I	*Echinoderes*	2
	4/I		3
	5/III		1
	1/Southern Bank		1
	1/IV	*Pycnophyes*	1
MARCH	2/II	*Echinoderes*	2
	6/II		1
	6/Hospital Rock	*Pycnophyes*	1
APRIL	3/II	*Centroderes*	1
	4/II	*Echinoderes*	1
SPRING	1/IV	*Centroderes*	1
	4/I	*Echinoderes*	3
	1/III		6
	1/IV		4
	2/II	*Pycnophyes*	1
	3/Southern Bank		1
	4/III	*Trachydemus*	1
JULY	1/II	*Echinoderes*	2
	2/II		4
	4/II		22
	6/II		2
	1/Hospital Rock		1
	2/Hospital Rock		1
	1/Southern Bank		3
	2/II	*Pycnophyes*	1
	1/Southern Bank	*Semnoderes*	1
AUGUST	1/II	*Echinoderes*	16
	3/Southern Bank		3
	3/Southern Bank	*Pycnophyes*	1
	3/Southern Bank	*Semnoderes*	2

TABLE 6. CONT.'D

SAMPLE	STATION & TRANSECT	GENUS	NUMBER OF INDIVIDUALS
FALL	1/I	*Echinoderes*	12
	2/I		1
	5/I		2
	1/II		1
	4/II		2
	4/III		4
	1/IV		30
	2/IV		4
	4/IV		3
	2/Hospital Rock		1
	1/I	*Pycnophyes*	1
	1/IV		4
	2/Southern Bank		1
	1/Hospital Rock	*Semnoderes*	4
	1/I	*Trachydemus*	5
	4/I		1
	2/IV		1
NOVEMBER	1/II	*Echinoderes*	10
	1/Hospital Rock		3
	1/II	*Semnoderes*	1
	6/II		1
	1/Hospital Rock		2
	2/Southern Bank	*Trachydemus*	1
DECEMBER	4/II	*Echinoderes*	1
	5/II		1
	4/Hospital Rock		1
	4/Hospital Rock	*Pycnophyes*	1
	2/II	*Trachydemus*	1
		TOTAL	190

TABLE 7

POLYCHAETA FOUND IN MEIOFAUNA SAMPLES DURING THE FIRST HALF OF 1976

FAMILY	GENUS SPECIES	SEASON: TRANSECT/STATION (NUMBER OF INDIVIDUALS)
Amphinomidae	*Paramphinome pulchella*	WINTER: SB/1 (1)
Pilargidae	*Ancistrosyllis papillosa*	MARCH: II/1 (1); SPRING: IV/4 (2)
	Sigambra tentaculata	WINTER: I/1 (1); III/3 (1); III/4 (1); IV/4 (1) SPRING: IV/4 (2)
Syllidae	*Brania clavata*	SPRING: IV/4 (1)
	Exogone dispar	WINTER: HR/1 (2); SB/1 (2); APRIL II/3 (1)
	Exogone gemmifera	MARCH: II/6 (1); APRIL: II/3 (1)
	Exogone verrugera	APRIL: II/3 (1)
	Odontosyllis enopla	WINTER: SB/1 (1)
	Sphaerosyllis erinaceus	MARCH: HR/1 (5)
	Sphaerosyllis pirifera	APRIL: II/3 (1)
	Undetermined sp.	WINTER: IV/1 (1); IV/6 (1)
Nereidae	Undetermined sp.	WINTER: IV/4 (3)
Glyceridae	*Glycera tesselata*	MARCH: SB/1 (1)
	Undetermined sp.	WINTER: IV/4 (1)
Eunicidae	*Marphysa* sp. (juvenile?)	SPRING: IV/4 (2)
Lumbrineridae	*Lumbrineris* cf. *albidentata*	MARCH: HR/2 (1)
	Lumbrineris parvapedata	WINTER: I/1 (1); I/2 (1); SPRING: IV/4 (1)
	Undetermined sp.	WINTER: II/1 (1); III/6 (1); MARCH: II/6 (1)
Arabellidae	*Drilonereis magna*	WINTER: IV/1 (1); IV/6 (1); MARCH: II/5 (1)
Dorvilleidae	*Dorvillea* cf. *neglecta*	WINTER: IV/4 (2)
	Dorvillea rudolphi	WINTER: III/1 (1)
	Dorvillea sociabilis	WINTER: SB/1 (2); IV/6 (1); SPRING: IV/4 (2)
	Dorvillea sp.	APRIL: SB/2 (3)
	Protodorvillea sp. A	WINTER: III/2 (1); HR/2 (1); IV/3 (1); IV/5 (1) MARCH: HR/1 (1); II/6 (2); APRIL: HR/3 (2)
	Protodorvillea sp. B	MARCH: II/6 (1); APRIL: II/3 (2);

TABLE 7. CONT.'D

FAMILY	GENUS SPECIES	SEASON: TRANSECT/STATION (NUMBER OF INDIVIDUALS)
Dorvilleidae (Cont'd.)	Undetermined sp.	WINTER: IV/1 (1); IV/6 (1)
Spionidae	*Laonice cirrata*	WINTER: I/4 (5)
	Paraprionospio pinnata	WINTER: I/4 (2)
	Prionospio cirrobranchiata	WINTER: IV/1 (1); MARCH: HR/1 (2); SPRING: IV/1 (2)
	Prionospio cristata	SPRING: IV/4 (6)
	Prionospio ehlersi	WINTER: IV/6 (1); SPRING: IV/4 (1)
	Prionospio steenstrupi	WINTER: SB/1 (1)
	Prionospio sp.	WINTER: IV/1 (1); APRIL: II/3 (1)
	Rhynchospio sp.	SPRING: IV/4 (1)
	Spiophanes bombyx	WINTER: I/4 (1)
	Undetermined sp.	WINTER: I/4 (1); III/5 (1); IV/1 (2); IV/4 (1) APRIL: SB/3 (1); SPRING IV/4 (2)
Magelonidae	*Magelona phyllisae*	WINTER: III/4 (1)
Cirratulidae	*Chaetozone setosa*	WINTER: II/4 (1)
	Cirriformia filigera	SPRING: IV/4 (1)
	Tharyx annulosus	WINTER: IV/1 (3)
	Tharyx setigera	WINTER: SB/1 (1); III/4 (6); IV/1 (18); IV/6 (4); MARCH: II/1 (1); II/2 (1); APRIL: HR/4 (1); SPRING: IV/1 (5); IV/4 (1)
	Tharyx sp.	WINTER: III/5 (1)
	Undetermined sp.	WINTER: III/4 (4); IV/1 (5); IV/2 (1); SPRING: IV/4 (1)
Heterospionidae	*Heterospio longissima*	WINTER: IV/1 (4); IV/6 (1)
Paraonidae	*Aedicira belgicae*	WINTER: III/3 (1); IV/1 (1), IV/4 (3); SPRING: IV/4 (6)
	Aricidea cerruti	WINTER: II/1 (1); II/2 (1[a]); II/4 (1); III/1 (2), APRIL: II/1 (1); SPRING IV/1 (1)
	Aricidea fauveli	WINTER: IV/1 (2)
	Aricidea suecica	WINTER: I/2 (1), III/5 (1); IV/1 (2)
	Cirrophorus branchiatus	WINTER: II/2 (1); APRIL: II/2 (1)

TABLE 7. CONT.'D

FAMILY	GENUS SPECIES	SEASON: TRANSECT/STATION (NUMBER OF INDIVIDUALS)
Paraonidae (Cont'd.)	*Cirrophorus lyriformis*	WINTER: IV/1 (1)
	Paraonides lyra	WINTER: IV/1 (1); IV/4 (1); IV/6 (1)
	Paraonis gracilis	WINTER: I/6 (1), II/2 (1), II/4 (1), III/1 (1) III/5 (4); III/6 (1); IV/1 (5); IV/4 (1), IV/5 (2) IV/6 (1), IV/7 (1); HR/2 (1); MARCH: II/2 (1) HR/1 (1); SB/1 (2); SB/4 (1); APRIL: II/3 (1), II/4 (2); III/5 (1); HR/4 (2); SB/2 (1); SB/3 (2) SPRING: IV/1 (3)
	Undetermined sp.	WINTER: IV/1 (15); SPRING: IV/4 (5[a])
Opheliidae	*Tachytrypane* cf. *jeffreysii*	WINTER: III/3 (1)
Cossuridae	*Cossura delta*	WINTER: II/2 (2); IV/1 (1); IV/5 (2); SB/1 (1) APRIL: SB/2 (2[a])
	Cossura sp. A	WINTER: II/2 (3); SB/1 (1[a]); APRIL: SB/3 (1)
Arenicolidae	*Branchiomaldane* sp.	WINTER: IV/5 (1)
Capitellidae	*Mediomastus californiensis*	WINTER: IV/1 (2); IV/4 (1); IV/6 (6); SB/2 (1) MARCH: HR/2 (1); SB/1 (1); APRIL: HR/3 (1) SPRING: IV/4 (4)
Maldanidae	*Clymenella torquata*	SPRING: IV/4 (1)
Pectinariidae	*Pectinaria gouldii*	WINTER: IV/1 (1)
	Undetermined sp.	APRIL: II/2 (1)
Terebellidae	Undetermined sp.	WINTER: I/4 (1)
Sabellidae	Undetermined sp.	MARCH: II/2 (1); SB/4 (1)
ARCHIANNELIDA		
Nerillidae	sp. A	WINTER: II/4 (1)
Polygordiidae	*Protodrillus* sp. A	WINTER: II/4 (1)
Unidentified juveniles		WINTER: I/4 (5); III/1 (6); MARCH: II/2 (7)

[a]juveniles

DISCUSSION

ANOVA analyses demonstrated that the total meiofauna, true meiofauna, nematodes alone, and temporary meiofauna were significantly different (< 0.01) with respect to:

1) transect
2) depth zones within transects, and
3) depth zones among transects.

Most of this difference can be accounted for in the difference between Transect II and the other three transects, particularly at the shallower depths in Zones A and B (Figure 1). This was essentially what J.S. Holland *et al.* (1977) found in regard to the macroinfauna. The depauperate meiofauna on the innermost station of Transect II may or may not be due to the fact that it is 7 m deeper than the homologous stations of the other transects, as suggested by Holland *et al.* (1977). The forams showed significant differences by depth only (< 0.01), with no observed differences among transects.

ANOVA analyses indicated that the true meiofauna as a whole and the nematodes alone were not significantly different with respect to seasonal sampling in February, June and October. The total meiofauna and nematodes were slightly different at the 0.07 level, primarily due to the fact that forams showed a significant seasonal difference at the < .01 level and the temporary meiofauna showed a slight seasonal difference at the 0.09 level.

Construction of a linear regression model showed that there was a significant positive relationship between the presence of nematodes and the total meiofauna (significance level = < 0.01) and that 61% of the variation found in the total meiofauna could be explained in terms of the presence of nematodes. In other words, the total meiofauna community appeared to be responding in the same way as the nematode component. Thus, there seemed not to be any serious competition between nematodes and the rest of the community at the population levels observed in this study.

The forams, on the other hand, were related to a much lesser degree, with only 36 percent of their population variations being explained in terms of the presence of nematodes. Even so, whatever relationship present was positive instead of negative (negative might imply competitive exclusion); hence it appears that forams were responding more definitively to parameters other than those controlling nematodes and the rest of the meiofauna.

Correlations were calculated between meiofauna populations and nine physical parameters measured throughout the study (Table 8). As shown in Table 8, sediment texture gave the best correlations with nematodes, harpacticoids, true meiofauna and temporary meiofauna, whereas temperature gave the best correlation, albeit low, with the forams. The fact that the harpacticoid/nematode ratio gave poor correlations seems to indicate that we are not measuring the critical abiotic factor for control of harpacticoid populations. Evidence presented in the past indicates that this may well be available organic matter in sediments.

Interestingly, seasonal population data gave better correlations for nematodes and harpacticoids with abiotic factors than the overall data (*i.e.* including the monthly sampling) (Table 9). The explanation for this seems to be the fact that the "odd" Transect II is represented in the overall data six more times than the other more "normal" transects, whereas they are equally represented in the seasonal data.

Limiting the analysis of nematodes on Transect II only, correlations with abiotic factors were highly variable over time, both with respect to which factors were important and the overall (mean) importance of abiotic factors (Table 10). The only reasonable explanation for this seems to be that, at times, biotic factors exert increasingly important controls.

As shown in Table 11, correlations were calculated between bank populations and the same nine abiotic factors used for the transect populations. As compared with the transect populations, greatly lowered correlations were observed for nematodes, true meiofauna, and temporary meiofauna (see Table 8) and greatly improved correlations for harpacticoids. Forams had about the same correlations, except salinity replaced temperature with the highest correlation. The harpacticoid/nematode ratio gave the best correlations due to the presence of increased numbers of harpacticoids in bank samples as compared with nematodes. In our opinion, the harpacticoid increases were more related to organic enrichment of the sediments surrounding the banks than to the fauna on the bank proper. This is another indication that this parameter should be measured in future studies.

Possible interaction between abiotic and biotic factors as controls of meiofauna populations is shown in Figure 7. The mean correlation coefficient (r) appears to give a very sensitive estimate of the roles of physical and biological factors in accounting for population fluctuations of nematodes. Graphing nematode population numbers against the mean r (a statistically unorthodox practice) or correlation coefficient

TABLE 8

OVERALL CORRELATIONS (ALL SAMPLES, ALL TIMES) OF SELECTED GROUPS PLUS HARPACTICOID-NEMATODE RATIO WITH ABIOTIC FACTORS

NEMATODES

r^2	
.0095	Salinity
.069	Latitude
.196	Depth
.238	Temperature
.286	Distance from shore
.375	Silt
.383	Clay
.448	Mean ø
.531	Sand

HARPACTICOIDS

r^2	
.030	Latitude
.041	Salinity
.077	Temperature
.110	Depth
.161	Silt
.172	Distance from shore
.186	Clay
.196	Mean ø
.244	Sand

TRUE MEIOFAUNA

r^2	
.013	Salinity
.068	Latitude
.020	Depth
.230	Temperature
.290	Distance from shore
.368	Silt
.380	Clay
.441	Mean ø
.524	Sand

FORAMINIFERIDA

r^2	
.000012	Salinity
.002	Latitude
.063	Silt
.194	Sand
.200	Depth
.219	Clay
.219	Mean ø
.222	Distance from shore
.245	Temperature

TEMPORARY MEIOFAUNA

r^2	
.008	Salinity
.102	Latitude
.106	Depth
.151	Temperature
.166	Distance from shore
.269	Clay
.328	Silt
.334	Mean ø
.411	Sand

HARPACTICOID/NEMATODE RATIO $\frac{H}{N}$

r^2	
.00006	Salinity
.0003	Latitude
.002	Sand
.003	Silt
.006	Mean ø
.011	Clay
.014	Depth
.020	Distance from shore
.035	Temperature

TABLE 9

SEASONAL CORRELATIONS OF NEMATODES AND HARPACTICOIDS WITH ABIOTIC FACTORS

NEMATODES r^2		HARPACTICOIDS r^2	
WINTER			
.015	Latitude	----	----
.377	Temperature	----	----
.384	Depth	----	----
.458	Salinity	----	----
.494	Distance from shore	----	----
.501	Clay	----	----
.561	Silt	----	----
.631	Sand	----	----
SPRING			
r^2		r^2	
.046	Salinity	.025	Latitude
.080	Latitude	.045	Salinity
.148	Temperature	.189	Temperature
.275	Depth	.119	Depth
.379	Silt	.154	Silt
.392	Distance from shore	.202	Distance from shore
.511	Clay	.231	Mean ϕ
.529	Mean ϕ	.251	Clay
.582	Sand	.266	Sand
FALL			
r^2		r^2	
.004	Salinity	.005	Salinity
.053	Latitude	.121	Latitude
.239	Temperature	.176	Depth
.245	Depth	.180	Temperature
.364	Distance from shore	.244	Distance from shore
.511	Clay	.392	Clay
.514	Silt	.455	Mean ϕ
.570	Mean ϕ	.472	Silt
.675	Sand	.563	Sand

TABLE 10

CORRELATIONS OF TRANSECT II NEMATODES
WITH NINE ABIOTIC FACTORS BY MONTH

MARCH

r^2	r	
.001	.03	Temperature
.042	.20	Salinity
.079	.28	Sand
.082	.29	Silt
.156	.39	Distance from shore
.156	.39	Mean ϕ
.172	.41	Clay
.183	.43	Latitude
.194	.44	Depth

$\bar{X}$ = .32

APRIL

r^2	r	
.00005	.02	Salinity
.003	.05	Distance from shore
.005	.07	Depth
.009	.09	Latitude
.009	.09	Clay
.013	.11	Mean ϕ
.015	.12	Temperature
.029	.17	Sand
.043	.21	Silt

$\bar{X}$ = .10

JUNE

r^2	r	
.004	.06	Salinity
.053	.23	Temperature
.110	.33	Latitude
.132	.36	Distance from shore
.185	.43	Depth
.197	.44	Silt
.254	.50	Mean ϕ
.256	.51	Clay
.284	.53	Sand

$\bar{X}$ = .38

JULY

r^2	r	
.001	.03	Sand
.014	.12	Mean ϕ
.020	.14	Clay
.040	.20	Silt
.128	.36	Distance from shore
.143	.38	Latitude
.188	.43	Depth
.198	.44	Salinity
.262	.51	Temperature

$\bar{X}$ = .29

AUGUST

r^2	r	
----	---	Salinity
.035	.19	Silt
.340	.58	Sand
.388	.62	Mean ϕ
.466	.68	Clay
.598	.77	Temperature
.631	.79	Depth
.759	.87	Distance from shore
.761	.87	Latitude

$\bar{X}$ = .67

OCTOBER

r^2	r	
.000004	.002	Depth
.00004	.006	Temperature
.010	.10	Distance from shore
.023	.15	Latitude
.030	.17	Silt
.153	.39	Clay
.163	.40	Mean ϕ
.234	.48	Salinity
.399	.63	Sand

$\bar{X}$ = .26

TABLE 10. CONT.'D

NOVEMBER r^2	r		DECEMBER r^2	r	
.010	.10	Temperature	.0002	.04	Sand
.026	.16	Clay	.010	.10	Salinity
.034	.18	Mean ϕ	.022	.15	Temperature
.059	.24	Sand	.053	.23	Mean ϕ
.191	.44	Silt	.057	.24	Clay
.277	.53	Depth	.084	.29	Silt
.406	.64	Distance from shore	.183	.43	Latitude
.460	.68	Latitude	.185	.43	Distance from shore
.728	.85	Salinity	.260	.51	Depth
$\bar{X}$ =	.42		$\bar{X}$ =	.27	

TABLE 11

CORRELATIONS OF SELECTED GROUPS PLUS HARPACTICOID-NEMATODE RATIO WITH ABIOTIC FACTORS AT BANK STATIONS

NEMATODES

r^2	
.0002	Clay
.0008	Latitude
.002	Depth
.008	Sand
.033	Silt
.052	Distance from shore
.089	Salinity
.132	Temperature

HARPACTICOIDS

r^2	
.017	Distance from shore
.018	Salinity
.022	Temperature
.034	Latitude
.039	Depth
.300	Clay
.311	Silt
.411	Sand

TRUE MEIOFAUNA

r^2	
.008	Latitude
.011	Depth
.034	Clay
.049	Distance from shore
.087	Salinity
.089	Sand
.121	Silt
.132	Temperature

FORAMINIFERIDA

r^2	
.0001	Silt
.0003	Distance from shore
.002	Sand
.003	Depth
.017	Clay
.038	Latitude
.071	Temperature
.212	Salinity

TEMPORARY MEIOFAUNA

.0002	Distance from shore
.005	Latitude
.055	Salinity
.061	Temperature
.124	Depth
.129	Clay
.215	Sand
.284	Silt

HARPACTICOID-NEMATODE RATIO $\frac{H}{N}$

.001	Distance from shore
.002	Temperature
.003	Salinity
.011	Latitude
.031	Depth
.404	Silt
.433	Clay
.576	Sand

of 9 physical factors appears to bear this out (Figure 7). At no time can more than 67 percent of the variability be explained by physical factors. In Figure 7, when the values of mean r for physical factors are declining, it is concluded that biological factors are more important in controlling population (April, June-July and September). When the mean r is increasing, it is likely that physical factors may be the principal controls. This is not to say that one or the other is wholly responsible for the observed population shifts, but merely indicates the relative importance of each.

As shown in Tables 8 and 9, there is a good correlation between nematode populations and some amount of sand in the sediments. In Figure 8 this observation is refined by linear regression analysis to show that the influence of sand on nematode numbers is not significant until it accounts for 60 percent or more of the sediment by weight. Sand is probably important because it allows the meiofauna to live deeper in the sediments thereby increasing the numbers per unit area.

Undoubtedly, some portion of the population fluctuations seen in the nematode data is due to biological factors not measured in the present sampling program. However, one way of assessing these factors is to analyze population numbers (lower part of Figure 9) in conjunction with changes in the number of taxa present (upper part of Figure 9). The figure shows this kind of analysis for three stations *viz.*, 1/II, 3/II and 4/IV. It is apparent that, even at this taxonomic level, there is substantial fluctuation in numbers of taxa through the year. This holds for both the inshore (1) and offshore (3) stations of Transect II. At Transect IV, Station 4, there is evidence for competitive exclusion, particularly in the period from June and October when nematode population numbers

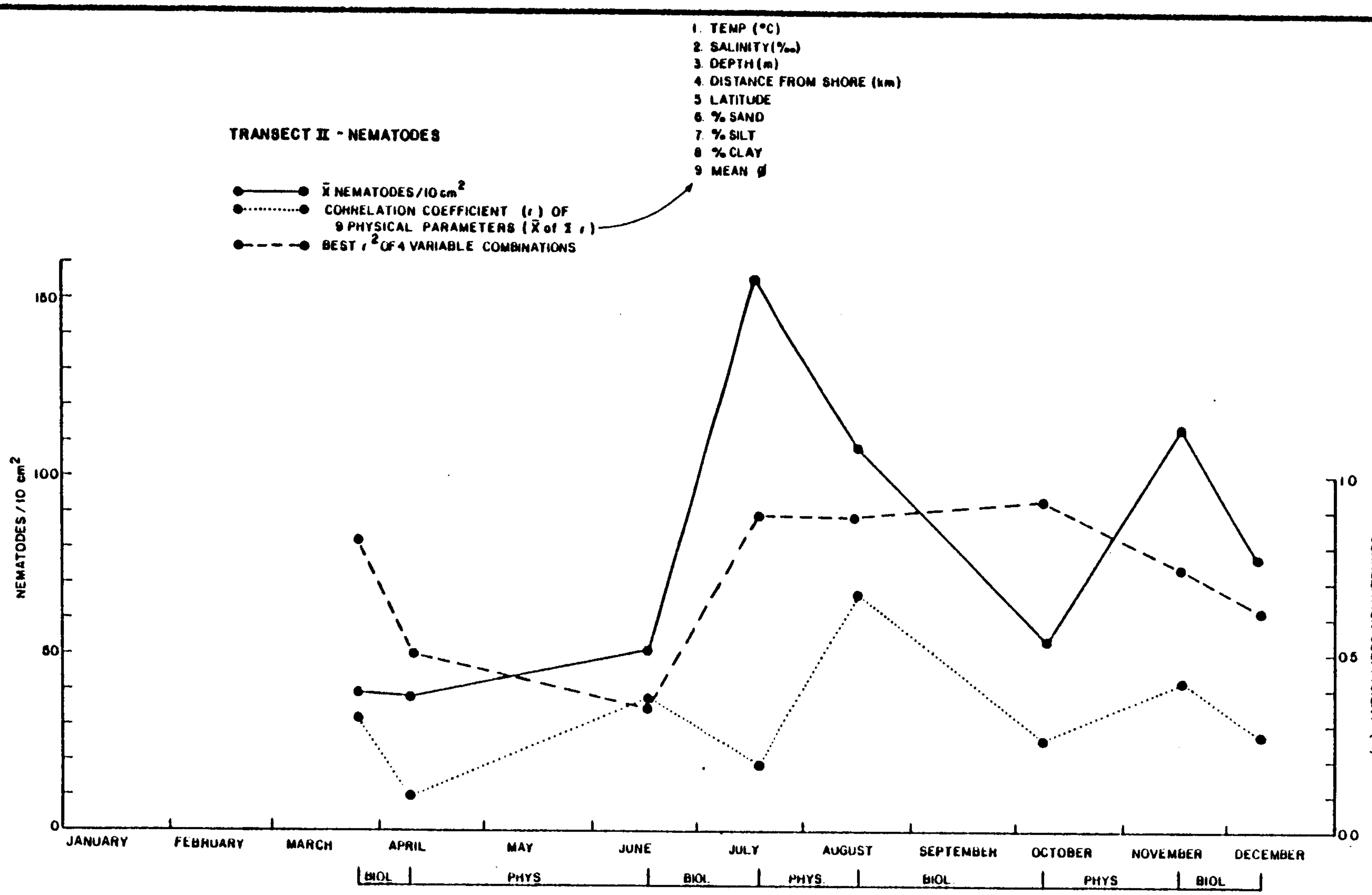


Figure 7. Transect II monthly mean numbers of nematodes per 10 cm^2 compared with the average correlation coefficient (γ) and the best r^2 for the combination of four variables together for the corresponding monthly sampling periods. Periods during which mean r for physical factors is declining (April) may indicate that biological factors are more important in controlling population, and where it is increasing, physical factors may be more important.

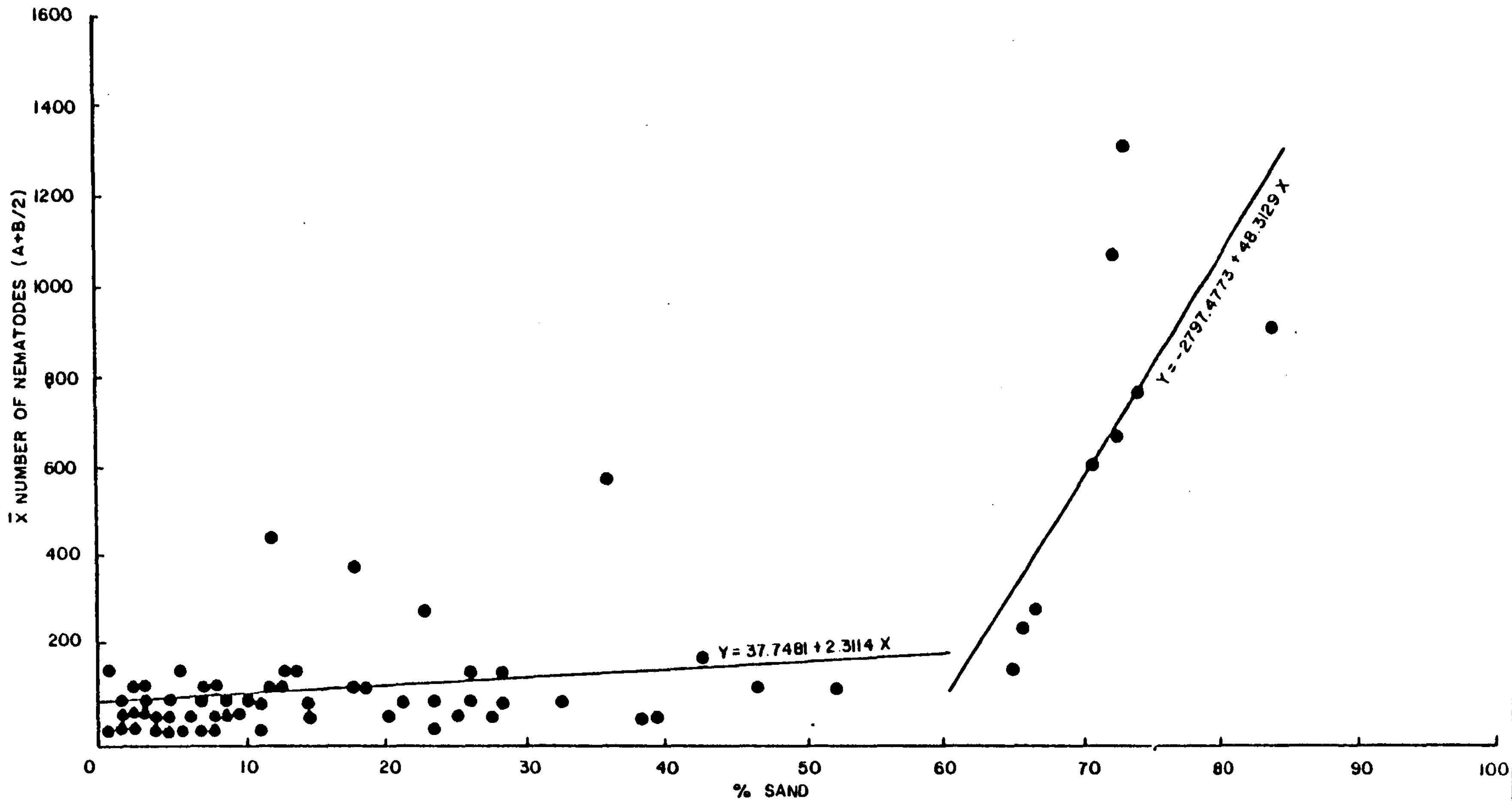


Figure 8. Plot of mean numbers of nematodes at particular stations against the percent of sand found at some stations on occasion (all stations from March to December considered). Dramatic increase in nematode numbers is indicated when the amount of sand exceeds 60%. Slopes of regressions are significantly different beyond the 0.01 level.

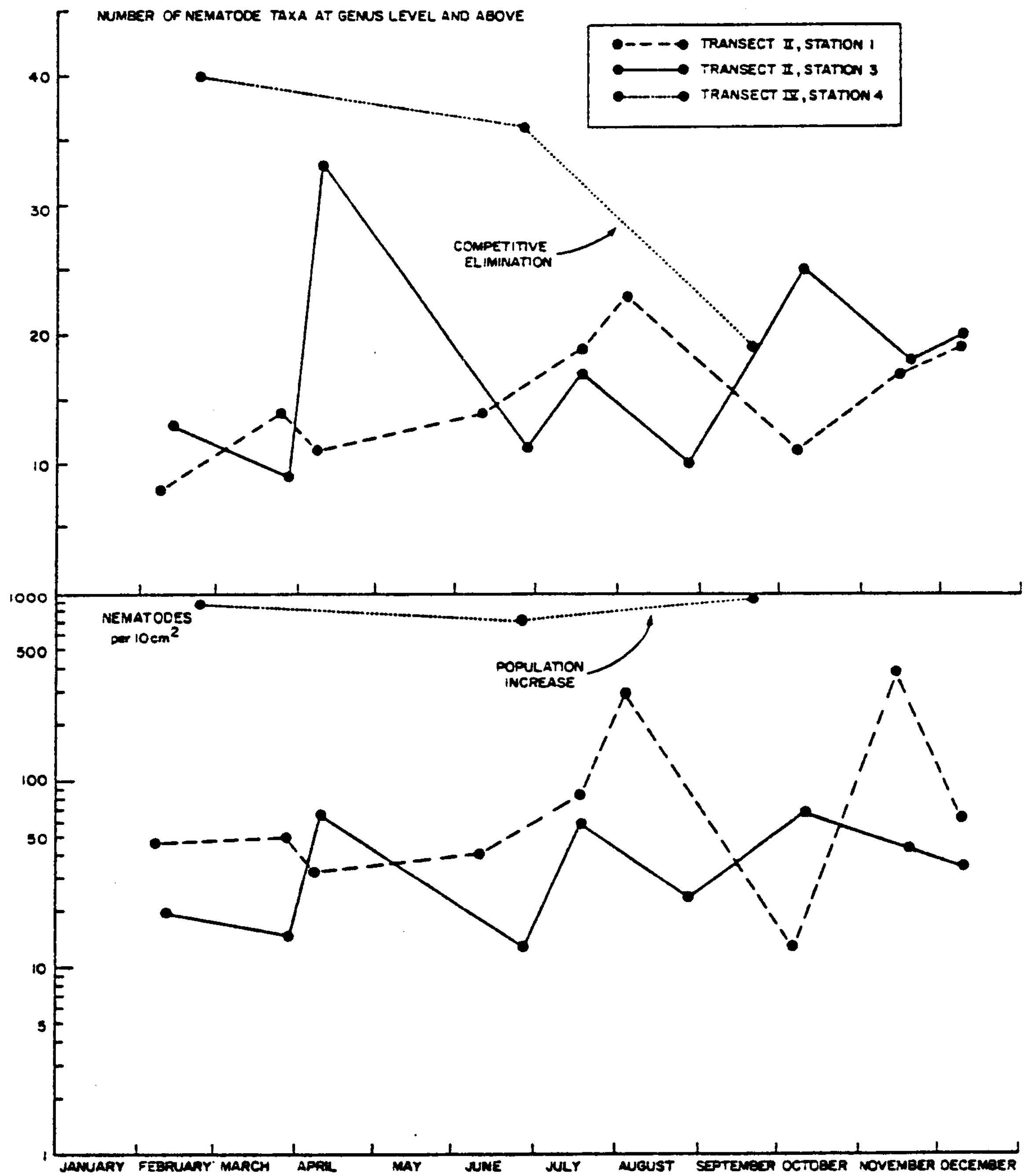


Figure 9. Nematode taxa at genus level and above at Transect II, Stations 1 and 3, and Transect IV, Station 4, compared with mean numbers of nematodes per 10 cm^2 found at the same stations and times. Evidence for the biological factor of competitive exclusion exists at Transect IV, Station 4, for the period between spring and fall when population numbers increased while the number of taxa decreased.

(Figure 8) are increasing and nematode genera are decreasing. Interestingly, this does not occur at either the inshore or offshore stations on Transect II; however, it may be seen that even at the deep offshore station (3) there is considerable taxal fluctuation in this presumably more stable environment.

In the period between November and December, the converse of this occurs, *i.e.*, while population numbers are dropping, numbers of genera are increasing. Most other times during the year both population numbers and genera increase or decrease together.

Returning to the situation of competitive exclusion which occurred from June to October at Station 4/IV, the graph (Figure 8) indicates a loss of 17 genera in the period. Actually, 21 of the genera present in June were eliminated by October, but four genera appeared at the station for the first time in October.

The four genera occurring in October but not in June were: *Gnophonema*, *Leptolaimus*, *Microlaimus* and *Paratravaia*. The following 21 taxa were present in June but not in October:

Actinonema
Alaimella
Campylaimus
Comesoma
Coninckia
Desmodorella
Desmodoridae
Desmoscolex
Dorylaimopsis
Enoplidae
Halichoanolaimus
Ironella
Mesotheristus
Monhysteridae
Odontophora
Pomponema
Rhynconema
Siphonolaimus
Spilophorella
Steineria
Xyala

Undoubtedly, the meiofauna is preyed upon by several types of predators, including nematodes. Since nematodes are the predominant component of the offshore meiofauna, it is appropriate to examine the possible role of predation from all sources in accounting for the observed fluctuations in nematode populations at all stations of Transect II throughout the nine sampling periods. This analysis is presented in Figure 10. The inshore station (1) is at the top of the figure and we move progressively offshore toward the bottom of the ordinate. Moving along the abscissa, the relative times of sampling the transect and its stations are shown. Note that the sampling periods in some cases are not well spaced (e.g. March-April). Nevertheless, one can see the three population peaks in March, July and November, as noted previously. The shaded circles indicate nematode populations that are lower than would be expected at certain stations as sampling is conducted on the transect both at a given period and in successive periods. Both the open and shaded figures are accurate portrayals of the populations. It is assumed that predation is the principal cause of the unexpectedly low populations noted by shading. The arrows denote speculations as to the movements of predators preying upon nematodes, and thereby depleting their numbers.

The Harpacticoid/Nematode Ratio

Although the harpacticoid/nematode ratio is not featured in this study, it is still considered one of the most promising ways to estimate the degree of environmental perturbation, whether caused by physical or chemical factors, and the degree of recovery. To refine this method would require measurement of the available organic

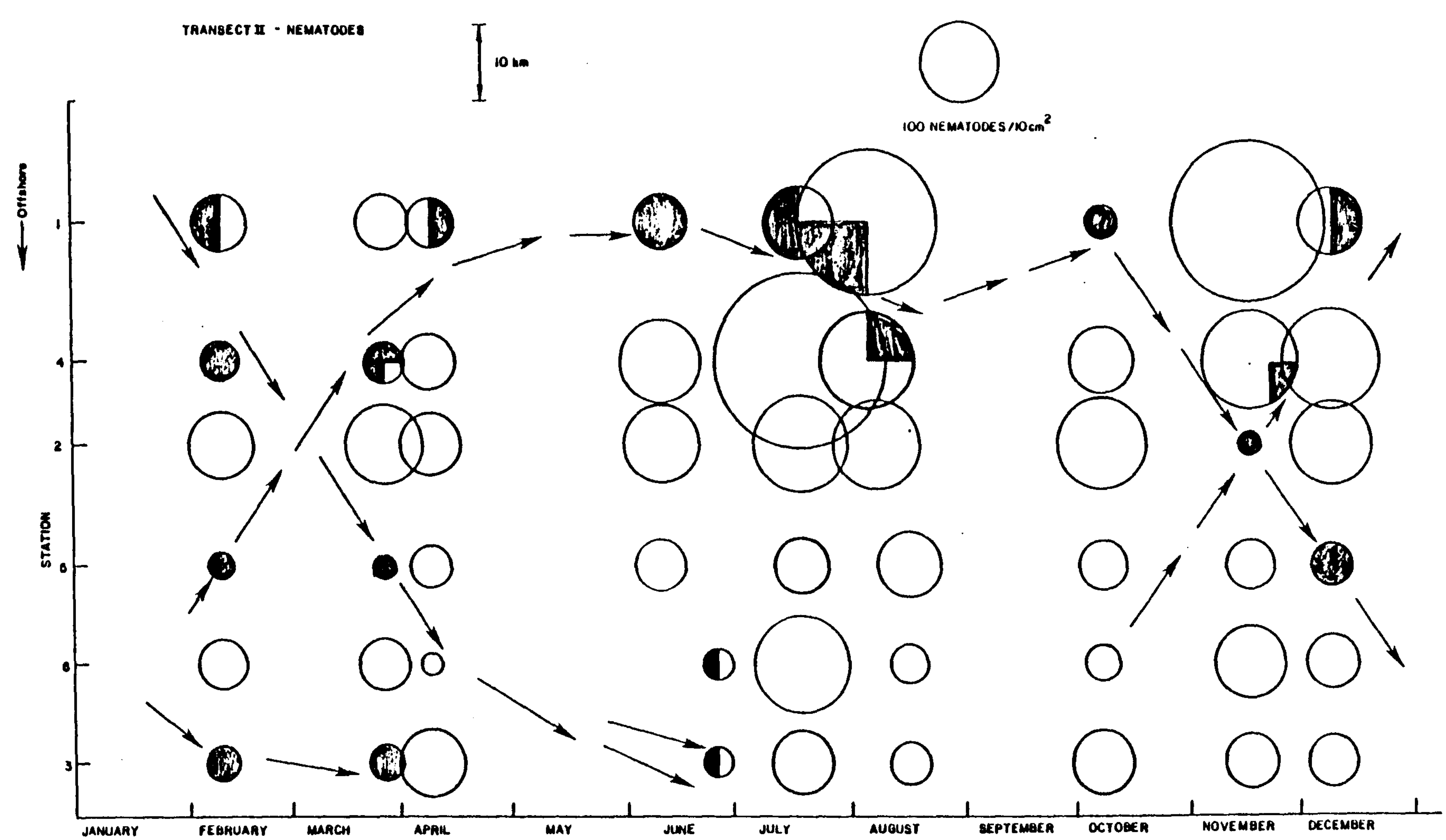


Figure 10. Transect II through time (abscissa) and space (ordinate), indicating population densities of nematodes. Shaded areas indicate nematode population values lower than expected. Arrows indicate pattern of movement of large populations of hypothetical predators which could be responsible for lowered nematode numbers.

matter in the sediment envelope as requested on several occasions. Nevertheless, two facts support the original contention that nematodes are very responsive to changes in sediment granulometry whereas harpacticoids are sensitive to sediment organic chemistry. Note in Table 8 the relatively high correlation of nematodes and the lower correlation of harpacticoids with sedimental characteristics. We believe the fact that harpacticoid populations are substantially higher at stations around the banks than on the transects is related to the input of organic matter derived from the macrofaunal populations of the bank proper. This speculation should be tested by appropriate sampling.

CONCLUSIONS

1. The meiofauna populations of the continental shelf of the northwest Gulf of Mexico exhibited seasonally related population peaks in March, July and November. The lowest peak was in March and the highest in July. It is noted that this fact could not have been determined by the present schedule of "seasonal" sampling in February, June and October, which actually corresponded with intermediate population lows.

2. Present work demonstrated that both physical and biological factors exert strong controls on meiofauna populations, and that these factors interact throughout the year to account for the observed population fluctuations.

3. Even though 90 taxa of nematodes at the genus level or above were identified from the transect and bank stations, only a few of these appeared to be of substantial importance.

4. The fact that nematodes were strongly correlated with sediment characteristics, particularly the percentage of sand at and above 60 percent, and that harpacticoids were not, lends further support to the importance

of the harpacticoid/nematode ratio as an indicator of environmental degradation and recovery. Some provision should be made for the determination of available organic carbon in sediments.

5. Finally, it is concluded that the value of the meiofauna study could easily be compounded by permitting the taking of monthly samples on a more typical transect such as Transect III.

LITERATURE CITED

Ankar, S., and R. Elmgren. 1975. A survey of the benthic macro- and meiofauna of the Askö-Landsort area. Merentutkimuslait. Julk./Havs-Forskningsinst. Skr. 239:257-264.

________., and B. Jansson. 1973. Effects of an unusual natural temperature increase on Baltic soft-bottom community. Mar. Biol. 18:9-18.

Bandy, O.L. 1954. Distribution of some shallow-water forminifera in the Gulf of Mexico. Geol. Survey., Prof. Paper. 254-F.

________. 1956. Ecology of forminifera in the Northeastern Gulf of Mexico. Geol. Survey., Prof. Paper. 274-G.

Buzas, M. A. 1967. An application of canonical analysis as a method for comparing faunal areas. J. Anim. Ecol. 36:563-577.

________. 1972. Biofacies analysis of presence or absence data through canonical variate analysis. J. Paleontol. 46:55-57.

Chitwood, B. G. 1951. North American marine nematodes. Tex. J. Sci. 3:617-672.

________., and R. W. Timm. 1954. Free-living nematodes of the Gulf of Mexico. pp. 313-323. *In* P. S. Galstoff (ed.) Fish. Bull. No. 89, U. S. Fish. Wildl. Serv., 55.

Coull, B. C. 1970. Shallow water meiobenthos of the Bermuda platform. Oecologia (Berl.) 4:325-357.

Elmgren, R. 1972. Introductory studies of the sublittoral meiofauna of the Askö-Landsort area. Subreport No. 9 to the Swedish Environment Protection Board.

Gettleson, D. A., and W. E. Pequegnat. 1976. Meiofauna-sediment correlations on samples from submarine banks in the Gulf of Mexico. pp. 223-265. *In* A Biological and Geological Reconnaissance of Selected Topographical Features on the Texas Continental Shelf. Final Rept. to U.S. Dept. of Interior, Bureau of Land Management.

Greiner, G. O. G. 1970. Distribution of major benthonic foraminiferal groups in the Gulf of Mexico Continental shelf. Micropalaeontol. 16:83-101.

Guille, A., and J. Soyer. 1968. La fauna benthique des substrats meublés du Banyuls-sur-Mer. Premiéres données qualitatives et quantitatives. Vie Milieu. 19(2B):323-360.

___________. 1974. Bionomie benthique du plateau Continental de la côte Catalane Francaise. VIII. Macrofaune et meiofaune. Rapports quantitatifs et biocénotiques. Vie Milieu. 24(2B):301-320.

Holland, J. S., S. Holt, R. Kalke, and M. Poff. 1977. Invertebrate epifauna and macroinfauna. pp. 415-459. *In* Environmental Studies, South Texas Outer Continental Shelf, biology and chemistry. 4th Quarterly Report to the Bureau of Land Management. Univ. of Tex. Mar. Sci. Inst.

Hopper, B. E. 1961a. Marine nematodes from the coastline of the Gulf of Mexico. Can. J. Zool. 39:183-199.

________. 1961b. Marine nematodes from the coastline of the Gulf of Mexico. II. Can. J. Zool. 39:359-365.

________. 1963. Marine nematodes from the coastline of the Gulf of Mexico. III. Additional species from Gulf Shores, Alabama. Can. J. Zool. 41:841-863.

Hulings, N. C. 1967. A review of the recent marine podocopid and platycopid ostracods of the Gulf of Mexico. Publ. Inst. Mar. Sci. Univ. Tex. 12:80-100.

Jansson, B., and F. Wulff. 1977. Ecosystem analysis of a shallow sound in the northern Baltic--A joint study by the Askö group. Cont. No. 18, Asko Lab. Univ. of Stockholm, Sweden.

King, C. E. 1962. Some aspects of the ecology of psammonlittoral nematodes in the northwestern Gulf of Mexico. Ecol. 43:515-523.

Krogh, A., and R. Spärck. 1936. On a new bottom-sampler for investigation of the microfauna of the sea bottom with remarks on the quality and significance of the benthonic microfauna. Kgl. Danske Videnskab. Selkskab, Biol. Medd. 13:3-12.

Lankford, R. 1966. Patterns of foraminiferal distribution of recent foraminifera in the northwest Gulf of Mexico. Trans. Gulf Coast Assoc. Geol. Soc. 16:167-175.

Loep, K. J. 1965. A study of ecology and distribution of recent foraminifera in the northwest Gulf of Mexico. Trans. Gulf Coast Assoc. Geol. Soc. 15:167-177.

McIntyre, A. D. 1964. Meiobenthos of sublittoral muds. J. Mar. Biol. Assoc. U.K. 44:665-674.

________. 1961. Quantitative differences in the fauna of boreal mud associations. J. Mar. Biol. Assoc. U.K. 41:599-616.

________., and D. J. Murison. 1973. The meiofauna of a flat fish nursery ground. J. Mar. Biol. Assoc. U.K. 53:93-118.

Mare, M.F. 1942. A study of a marine benthic community with special reference to the micro-organisms. J. Mar. Biol. Assoc. U.K. 25: 517-554.

Parker, F. L. 1954. Distribution of the foraminifera in the northeastern Gulf of Mexico. Bull. Mus. Comp. Zool. 111:454-588.

Pequegnat, W. E., and D. Gettleson. 1974. The meiofauna and macro-infauna of Stetson Bank. pp. 39-59. *In* Baseline survey of Stetson Bank Gulf of Mexico, Biology. A report to Signal Oil and Gas Co.

Phleger, F. B. 1951. Ecology of Foraminifera, northwest Gulf of Mexico. Part I: Foraminifera distribution. Geol. Soc. Am. Mem. 46:1-88.

________. 1956. Significance of living foraminiferal populations along the central Texas coast. Contrib. Cushman Found. Foram. Res. 7:106-151.

________. 1960. Ecology and distribution of recent Foraminifera. Johns Hopkins Press. Baltimore, Md.

Poag, C. W., and W. E. Sweet, Jr. 1972. Claypile Bank, Texas continental shelf. pp. 223-261. *In* R. Rezak and V. J. Henry (eds.), Contributions on the Geological and Geophysical Oceanography of the Gulf of Mexico, Gulf Publ. Co., Houston.

Sanders, J. L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationships. Limnol. Oceanogr. 3:245-258.

Stripp, K. 1969. Der verhaltnis von makronfauna und meiofauna in den sedimenten de Helgolander Bucht. Veröff, Inst. Meeresforsch. Bremerk. 12:143-148.

Thiel, H. 1966. Quantitative untersuchungen über die Meiofauna des Tiefenbodens. Veröff. Inst. Meeresforsch. Bremerhaven, Sonderbd. 2:131-148.

________. 1975. The size structure of the deep-sea benthos. Int. Revue ges. Hydrobiol. 60:575-606.

Thorson, G. 1966. Some factors influencing the recruitment and establishment of marine benthic communities. Neth. J. Sea Res., 3:267-293.

Tietjen, J. H. 1969. The ecology of shallow water meiofauna in two New England estuaries. Oecologia (Berl.) 2:251-291.

________. 1971. Ecology and distribution of deep-sea meiobenthos off North Carolina. Deep-Sea Res. 18:941-957.

Walton, W. R. 1964. Recent foraminiferal ecology and paleoecology. pp. 151-237. *In* J. Imbrie and N. D. Newell (eds.), Approaches to Paleoecology. John Wiley and Sons, New York.

Warwick, R. M. 1973. Free-living marine nematodes from the Indian Ocean. Bull. Brit. Mus. Nat. Hist. (Zool.) 25:85-117.

Wieser, W. 1960. Population dichte und Vertikalverteilung der Meiofauna mariner Böden. Int. Revue ges. Hydrobiol. 45:487-492.

Wigley, R. L., and A. D. McIntyre. 1964. Some quantitative comparisons of offshore meiobenthos and macrobenthos south of Martha's Vineyard. Limnol. Oceanogr. 9:485-493.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.