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PB81-174773

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

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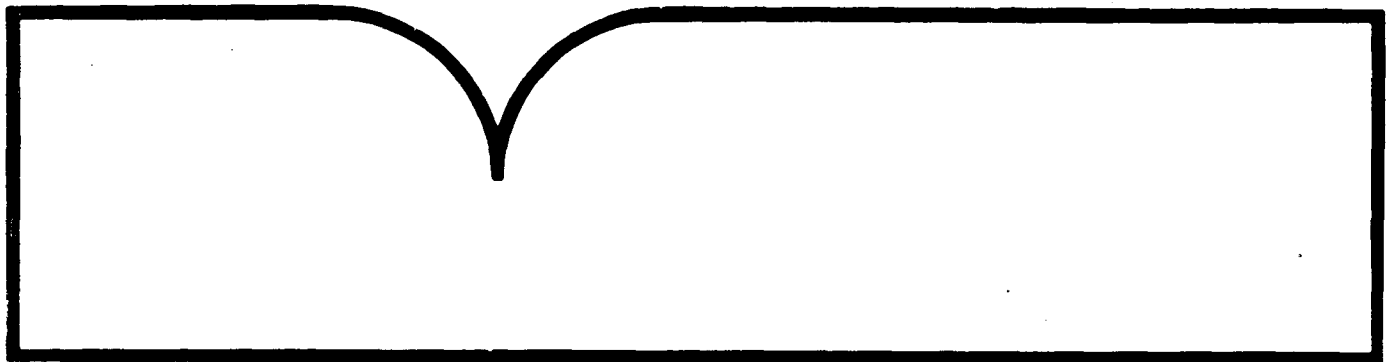
CT6-62

Virginia Inst. of Marine Science
Gloucester Point

Prepared for

Bureau of Land Management
Washington, DC

Jul 79



U.S. Department of Commerce
National Technical Information Service

NTIS

MIDDLE ATLANTIC OUTER CONTINENTAL SHELF ENVIRONMENTAL STUDIES

VOLUME IIC. CHEMICAL AND BIOLOGICAL BENCHMARK STUDIES

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

with the
Bureau of Land Management
United States Department of Interior

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Printed July 1979

PRODUCT OF:
**NATIONAL TECHNICAL
INFORMATION SERVICE**
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

REPORT DOCUMENTATION PAGE		1. REPORT NO. BLM/YL/EC-70/4	2.	3. Recipient's Accession No. P981 174773
4. Title and Subtitle Middle Atlantic Outer Continental Shelf Environmental Studies Volume IIC. Chemical and Biological Benchmark Studies		5. Report Date July 1979		
7. Author(s) G.R. Sedberry, E. J. Foell, J. A. Musick, J.A. Colvocoresses, H.I. Kator		6. Performing Organization Rept No.		
9. Performing Organization Name and Address Virginia Institute of Marine Science Gloucester Point, Virginia 23062		10. Project/Task/Work Unit No.		
12. Sponsoring Organization Name and Address Branch of Environmental Studies (733) Bureau of Land Management, U.S. Dept. of Interior 18th & C Streets, N.W. Washington, D. C. 20240		11. Contract(C) or Grant(G) No. (C) BLM AA550-CT6-62 (G)		
15. Supplementary Notes Report prepared by VIMS for BLM. Second of three volumes (Part 3).		13. Type of Report & Period Covered Final Sept. 76 - Aug. 77		
16. Abstract (Limit: 200 words) This volume contains element reports for community structure analysis and food habits of fishes, historical community structure analysis of finfishes, and bacteriology. The fish food habits section contains data on seasonal community structure of demersal fishes and food habits of dominant species. A discussion of the influence of ridge and swale topography on community structure and feeding habits is included. The historical community structure analysis chapter is a discussion of NMFS Middle Atlantic Bight finfish data collected from 1967 through 1976 and VIMS data from 1967. Abundance, biomass and community structure is analyzed seasonally. The bacteriology chapter includes data on the distribution and abundance of heterotrophic and petroleum-degrading bacteria in sediments and the water column, and results of petroleum degradation and chitin degradation laboratory experiments.				
17. Document Analysis a. Descriptors Environmental Baseline Outer Continental Shelf Community Structure Petroleum Degradation b. Identifiers/Open-Ended Terms Biological Oceanography Bacteriology Ichthyology c. COSATI Field/Group				
18. Availability Statement Release Unlimited		19. Security Class (This Report) Unclassified		21. No. of Pages approx. 650
		20. Security Class (This Page) Unclassified		22. Price

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

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PREFACE

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

Volume I. Executive Summary.

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

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

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

Volume III. Geologic Studies.

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

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

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

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

Eugene M. Burreson
Program Manager

ACKNOWLEDGEMENTS

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

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

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

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

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CHAPTER 9

COMMUNITY STRUCTURE ANALYSIS AND FOOD HABITS OF FISHES

SECTION I: FOOD HABITS OF FISHES¹

George R. Sedberry
John A. Musick

INTRODUCTION

Fishes are usually at or near the top of marine food chains (Odum 1971), and studies of their food habits in environmental benchmark studies are instructive for several reasons. First, a pollutant affecting lower levels of the food chain, such as planktonic or benthic invertebrates, may have an effect on fish production. Second, since fishes are important predators of benthic invertebrates, which are a principal focus of the descriptive benchmark study, they may cause fluctuations in populations of these invertebrates and may play an important role in the regulation of population size and community structure of benthic invertebrates (Dayton and Hessler 1972; Paine 1974; Virnstein 1977). An analysis of fish feeding can provide insight into the mechanisms structuring macrobenthic communities and affecting their dynamics, and will thus enhance the "baseline" on which to interpret fluctuations caused by man-induced environmental change. Third, mesoscale habitat distribution of fishes on the OCS may be related to mesoscale distribution of benthic invertebrates (Chapter 6). An analysis of food habits of fishes within the different habitats of the OCS would indicate which habitats are most important as feeding grounds for fishes, and should thus be protected. In addition, competitive success of different fish species may be related to feeding. A change in species composition of benthic invertebrates may cause a change in the community structure of fishes feeding on these invertebrates.

Few studies have dealt with feeding of entire communities of shelf fishes or with the trophic relationships between fishes and the benthos. Smith (1950) studied the relationships between the benthos and fishes in Block Island Sound, and Tyler (1972) studied the feeding relationships of fishes in Passamoquoddy Bay, New Brunswick. Stomach contents of some of the dominant species on the Middle Atlantic OCS have been reported in faunal and taxonomic works and in life history studies (Bigelow and Welsh 1925; Nicholas and Breder 1927; Bigelow and Schroeder 1953 a, b; Olsen and Merriman 1946; Fitz and Daiber 1963;

¹ Section I is based on a dissertation in progress by G. R. Sedberry.

Richards et al. 1963; Sikora et al. 1972). Food habits studies have been done on some species common to the Middle Atlantic OCS (Jensen and Fritz 1960; Barans 1969; Sikora et al. 1972; McEachran et al. 1976) but were restricted in geographic coverage and thus have limited applicability to OCS benchmark studies in the principal area of interest on the outer shelf off New Jersey.

The purpose of this report is to describe the food habits of dominant fishes on the Middle Atlantic OCS and to relate them to macrobenthos abundance and distribution with respect to bottom topography.

MATERIALS AND METHODS

Study Area

Two areas were selected for intensive sampling: Area B off Atlantic City, New Jersey, and Area E off Delaware Bay (Figure 9-1). These areas were chosen because of their unique and complex topography. The bottom is characterized by a series of ridges, swales, scarps, and flats. Both study areas were stratified into a total of seven a priori habitat strata, based mainly on depth data taken from U.S. Geological Survey Charts of the area (Figure 9-2) and also on some data on the distribution of bottom sediments and previous sampling of macrobenthos. These strata consisted of the following features:

- | <u>Area B</u> | <u>Area E</u> |
|-----------------------|-----------------------|
| 1. ridge | 1. ridge |
| 2. swale | 2. swale |
| 3. deep flank/flat | 3. deep flank/flat |
| 4. shallow flank/flat | 4. shallow flank/flat |
| 6. plateau | 5. slope |
| 7. muddy flat | |

Habitat Delineation

In addition to trawling for fishes, Smith-McIntyre grab and small biology trawl (SBT) samples were taken in the study area in fall 1976 at randomly selected stations within the a priori strata (see Chapter 6 for details). The purpose of this study was to determine the distribution of sediments and benthic invertebrates in relation to the a priori strata and to redefine these strata based on depth, sediment, and invertebrate distribution data. Based on the results of these data (see Chapter 6 for details), the following new a posteriori habitat strata were defined for each area:

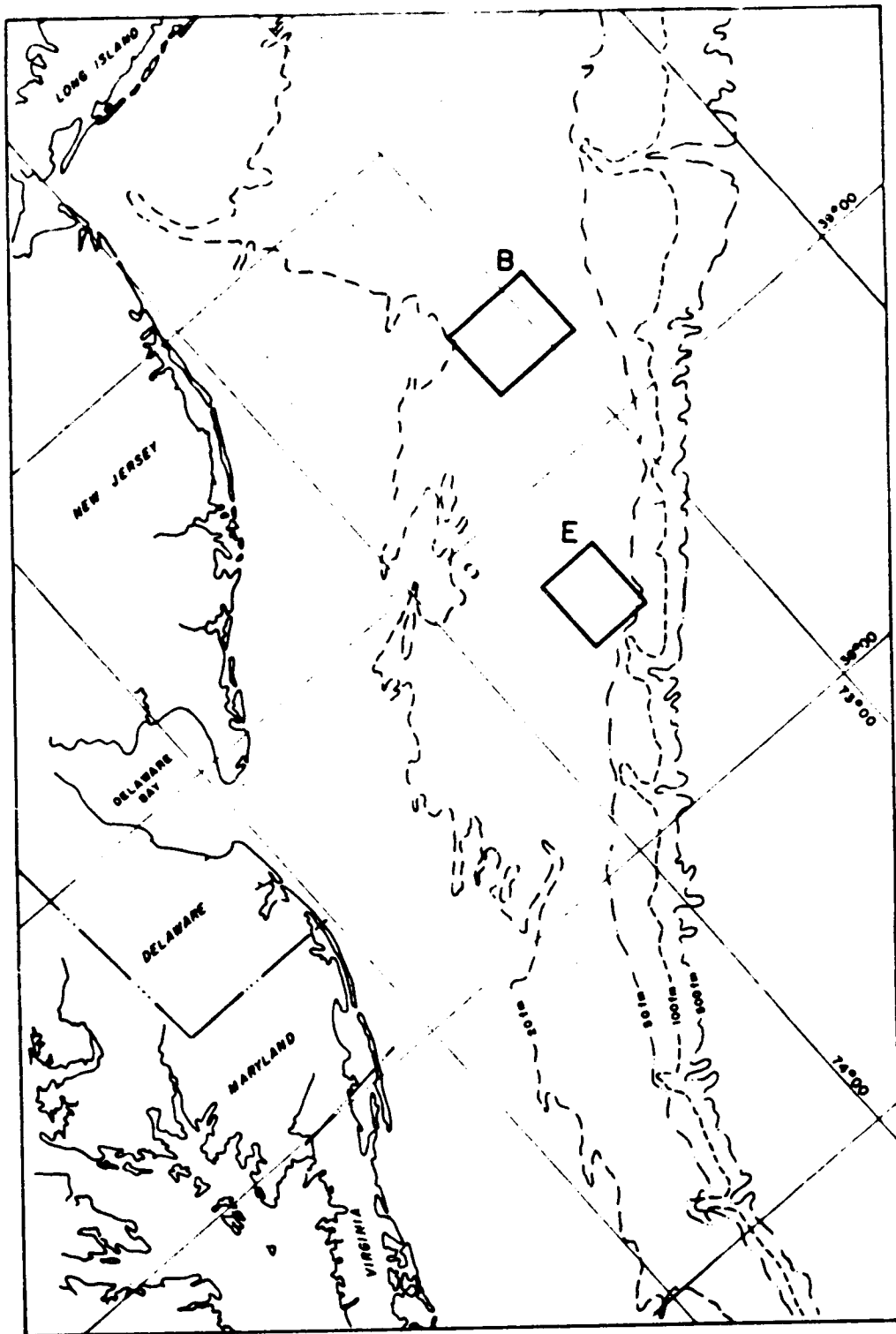


Figure 9-1. Location of areas B and E.

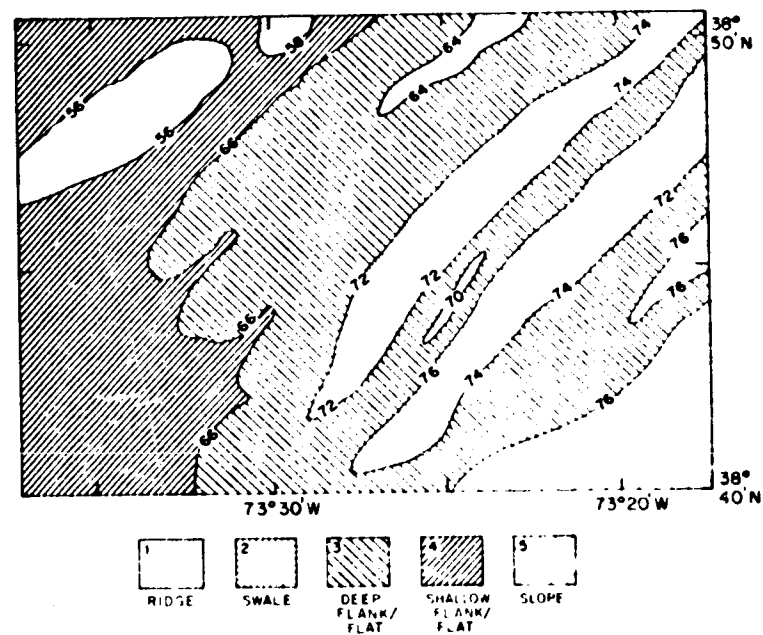
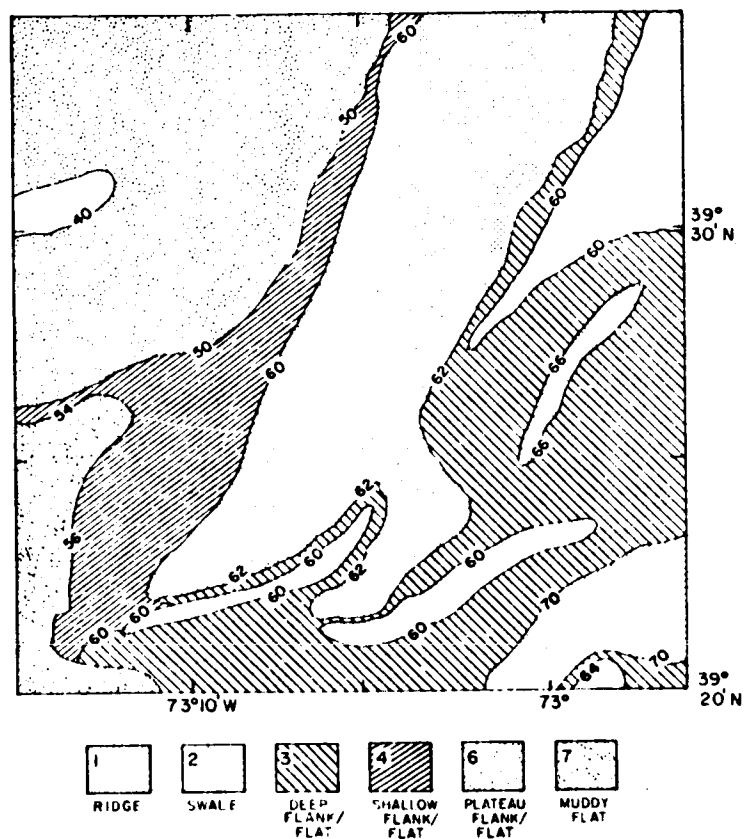


Figure 9-2. Areas B (left) and E (right) showing depth contours (in meters) and a priori habitat strata.

- Area B
1. terrace
 - 2A. ridge
 - 2B. medium sand flank
 - 3A. medium-fine sand flank
 - 3B. eroded flank
 4. shallow swale
 5. deep swale

- Area E
- 1A. ridge
 - 1B. megaripples
 2. medium-fine sand flank
 - 3A. shallow swale
 - 3B. deep swale
 4. eroded swale
 - 5A. upper shelf break
 - 5B. mid-shelf break

Fish stomach data from the fall cruise were analyzed, according to the a posteriori strata (Figure 9-3), to determine the preference of fishes for certain prey in relation to prey abundance and distribution among these strata. Because of their faunal similarity and spatial proximity, substrata (A and B above) were combined for the food habits study, resulting in a larger sample size for each stratum.

Sampling of Fishes

Sampling consisted of 15-minute tows with a 45 ft. (13.7 m) headrope, lined, semi-balloon trawl with the following stretch-mesh dimensions: 4.45 cm in the wings, 3.81 cm in the body, 3.96 cm in the cod end, and 1.27 cm in the cod end liner. Trawls were made at a vessel speed of about 3.5 knots, and in a direction parallel to the bottom feature being sampled. Six stations were randomly selected in each a priori habitat stratum for each cruise. In order to adequately sample those fishes which may show diel feeding periodicity, three stations were done during daylight and three during darkness within each stratum. Samples were collected seasonally on four cruises.

All fishes captured were identified, counted, measured, and weighed. Standard length was measured to the nearest mm on all dominant species with the exception of Raja erinacea (disc width) and Macrozoarces americanus (total length). Weight was measured using an Ohaus Dial-o-Gram balance, which was accurate to the nearest gram, even in rough seas. Each fish was dissected and its stomach excised if not conspicuously empty. On large catches of some dominant species, subsamples (at least 30 stomachs) were collected. Each stomach was labeled, individually wrapped in cheesecloth and fixed in 10% seawater formalin.

Laboratory Analysis

After proper fixation, stomachs were soaked in water and transferred to either 40% isopropanol or 70% ethanol. For analysis, each stomach was cut open and its contents sorted by taxa and counted. Fragments such as crustacean parts, polychaete setae, or fish bones were counted as one animal, unless abundance could be estimated by

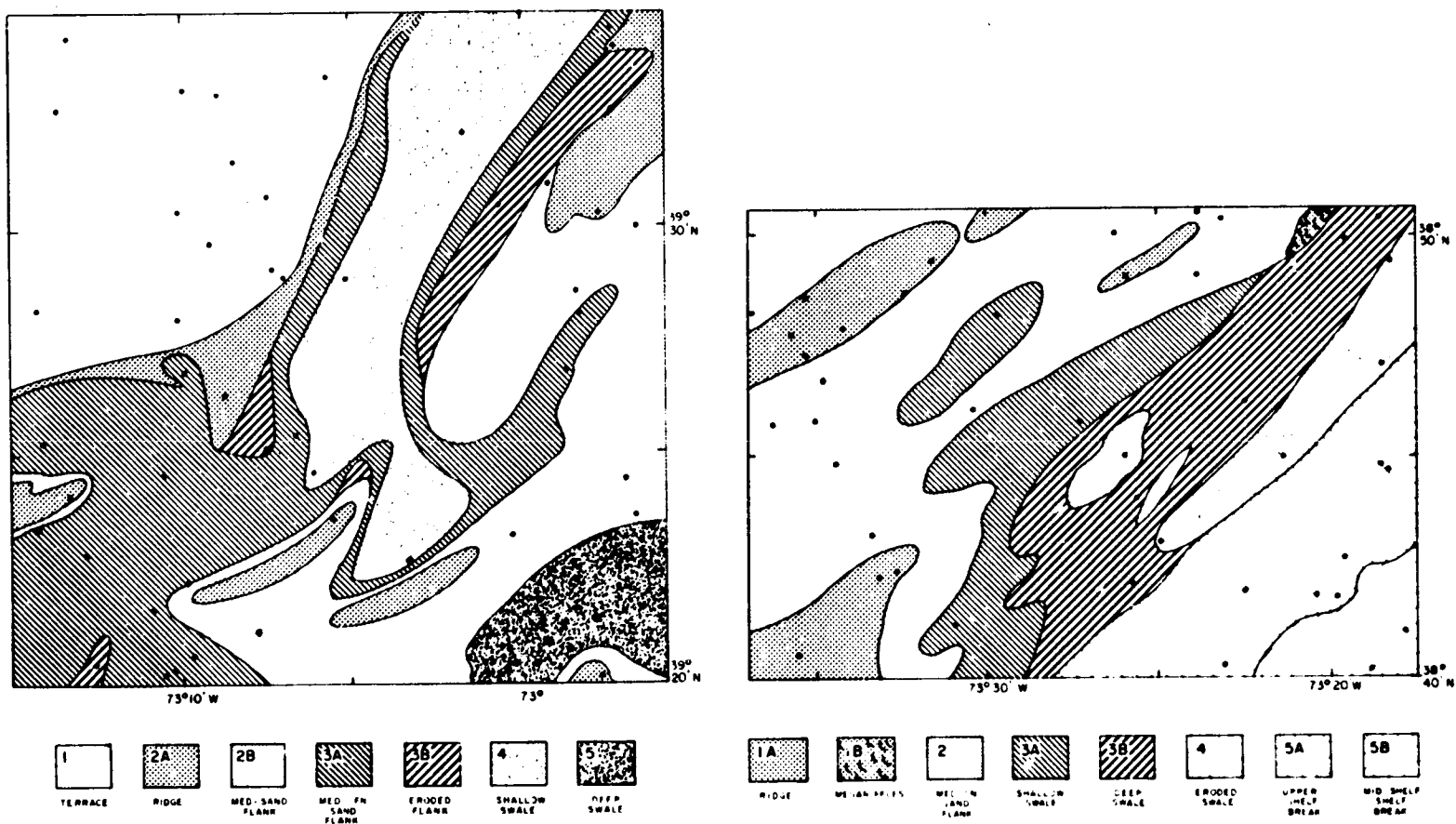


Figure 9-3. Areas B (left) and E (right) showing a posteriori habitat strata.

counting pairs of eyes or antennal scales (crustaceans), otoliths (fishes), and other parts.

Volume displacement of food items was measured either by using a graduated cylinder (Windell 1971) or a calibrated vial and buret (McEachran et al. 1976). Displacement of small species was estimated by measuring the volume of several species together and using a grid to estimate the percent of this total volume contributed by each species (Windell 1971; Sedberry and Musick 1978).

Data Analysis (Food Habits)

Since methods of food habits analysis are variously biased (Hynes 1950; Pinkas et al. 1971; Windell 1971), the relative contribution of different food items to the total diet was determined using three methods: (1) the number of stomachs in which a food item occurred was expressed as a percentage of the total number of stomachs of a series containing food (percent frequency of occurrence); (2) the number of individuals of each type of food was expressed as a percentage of the total number of food items from all stomachs for a series (percent numerical abundance); (3) the volume displacement of food items was expressed as a percentage of the total volume of food from all stomachs examined of a series (percent volume displacement).

From these three measurements an index of relative importance, IRI (Pinkas et al. 1971), was calculated for each prey species and higher taxon as follows:

$$IRI = (N + V) F$$

where: IRI = index of relative importance

N = numerical percentage

V = volumetric percentage

F = frequency of occurrence percentage

This index has been useful in evaluating the relative importance of different food items found in fish stomachs (Pinkas et al. 1971; McEachran et al. 1976; Sedberry and Musick 1978). The IRI was used in the present study to describe the food habits of each species and to determine seasonal differences in the relative importance of food items.

Selectivity of predators on the macrobenthos was determined using Ivlev's (1961) index of electivity, calculated as follows:

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where: E = electivity

r_i = percent of species i in the diet

p_i = percent of species i in the benthos

Electivity values range from -1 (total selection against a prey species) to +1 (total selection for a prey species); a value near 0 implies no active selection. For the purposes of this study the absence of a food item from stomachs and from benthic samples for a particular stratum was considered as zero electivity.

Overlap in diet among dominant predators was measured using numerical classification techniques (cluster analysis). Stomachs of predators were treated as collections and were subjected to normal cluster analysis on the basis of prey similarity, using percent standardized numerical abundance. Flexible sorting (Lance and Williams 1967; Clifford and Stephenson 1975), with $\delta = -0.25$, was used, based on resemblance expressed by the Bray-Curtis measure (Bray and Curtis 1957). This is a measure of dissimilarity and the complement is used to yield a similarity measure (Clifford and Stephenson 1975). The Bray-Curtis similarity measure can be expressed as:

$$S_{jk} = 1 - \frac{\sum_i |x_{ji} - x_{ki}|}{\sum_i (x_{ji} + x_{ki})}$$

where S_{jk} is the similarity between the entities (stomachs) j and k, x_{ji} is the abundance of the i^{th} attribute (prey) for entity j; and x_{ki} is the abundance of the i^{th} attribute for entity k. In normal analysis predator stomachs are the entities and prey species are the attributes.

RESULTS

A total of 6087 stomachs representing nine species was examined. Initially, only seven species, Raja erinacea, Lophius americanus, Urophycis chuss, Merluccius bilinearis, Stenotomus chrysops, Citharichthys arctifrons, and Hippoglossina oblonga were to be examined. Urophycis regius and Macrozoarces americanus were added to this list because they became dominant species in the catches in summer 1977 (Table 9-1).

In this section, a species-by-species description and discussion of the food habits of dominant fishes will be presented. General discussion and conclusions will be presented in the discussion section.

Table 9-1. Fishes selected for food habits analysis, and percent of total catch by number (N) and weight (W) comprised by each, for each cruise.

Species	Fall 1976		Winter 1977		Spring 1977		Summer 1977	
	N	W	N	W	N	W	N	W
Rajidae								
<u>Raja erinacea</u>	6.7	21.2	13.4	14.7	24.2	28.6	5.2	15.6
Lophiidae								
<u>Lophius americanus</u>	1.5	18.3	2.8	11.5	3.3	12.7	1.2	10.5
Gadidae								
<u>Urophycis chuss</u>	25.0	0.3	39.8	33.4	36.6	33.6	17.3	15.4
<u>Urophycis regius</u>	1.2	1.4	0.1	0.1	0.6	0.9	7.2	12.0
Merluciidae								
<u>Merluccius bilinearis</u>	16.7	5.1	22.8	25.3	10.2	14.1	27.0	32.1
Zoarcidae								
<u>Macrozoarces americanus</u>	0.5	0.4	1.8	0.9	5.3	3.8	8.2	3.7
Sparidae								
<u>Stenotomus chrysops</u>	26.7	25.9	0.1	0.1	0.4	0.2	0.0	0.0
Bothidae								
<u>Citharichthys arctifrons</u>	11.7	0.1	7.9	0.1	7.1	0.3	26.9	1.8
<u>Hippoglossina oblonga</u>	5.2	7.1	5.0	2.8	9.2	4.2	1.9	5.3
Total	95.2	79.80	93.7	88.9	96.9	98.4	94.9	96.4

Raja erinacea

The little skate, Raja erinacea, was abundant in the study area at all times of the year. It fed mainly on amphipods, decapods, cumaceans, and polychaetes (Figure 9-4). Pelecypods, fishes, and isopods were also consumed. The relative importance of these major taxa of food remained constant seasonally, although juvenile fishes were somewhat more important and cumaceans less important in fall samples. Juvenile fishes were also important in the diet of R. erinacea in the summer.

Although the relative importance of the major taxa was nearly constant seasonally, the species composition of these taxa in the diet changed seasonally (Table 9-2). Among the Amphipoda, tube dwelling ampeliscids, especially Byblis serrata and Ampelisca vadorum, were the most important species in the fall, followed by Unciola irrorata, Trichophoxus epistomus, and Erichthonius rubricornis. In winter and spring, U. irrorata was the most important amphipod, followed by E. rubricornis and B. serrata. A. vadorum was a less important food item at this time but Leptocheirus pinguis was important. T. epistomus was not an important food item in other seasons. In the summer, the relative importance of different amphipod species exhibited a pattern intermediate between fall and winter-spring samples. In summer, B. serrata, E. rubricornis, and U. irrorata were consumed in almost equal numbers, and were the most important amphipod prey items. A. vadorum again became important food and Monoculodes edwardsi, previously rare in the diet, became important.

Cancer irroratus was the most important decapod at all times of the year. Crangon septemspinosa was important in the diet of skates in fall and summer.

Cumaceans were most important in winter, spring, and summer and consisted mainly of nearly equal numbers of Diastylis sculpta and D. bispinosa.

Most polychaete species were present in approximately equal numbers, with the dominant species varying seasonally. Sthenelais limicola and Clymenura sp. A were generally important at all seasons.

Ensis directus, the only identifiable pelecypod consumed, was most important as a food item in winter and spring. The ability of this fast-moving clam to avoid predators may diminish with colder temperatures, and it thus became an important part of the diet of R. erinacea at this time.

Fishes were important in the diet of the little skate in summer and somewhat less so in fall. Juvenile hakes, Merluccius bilinearis and Urophycis chuss, were most abundant in the study area in summer, diminishing somewhat in fall and were virtually absent in winter and spring, and this is reflected in the food of R. erinacea.

(TEXT CONTINUES ON PAGE 9-17)

Raja erinacea

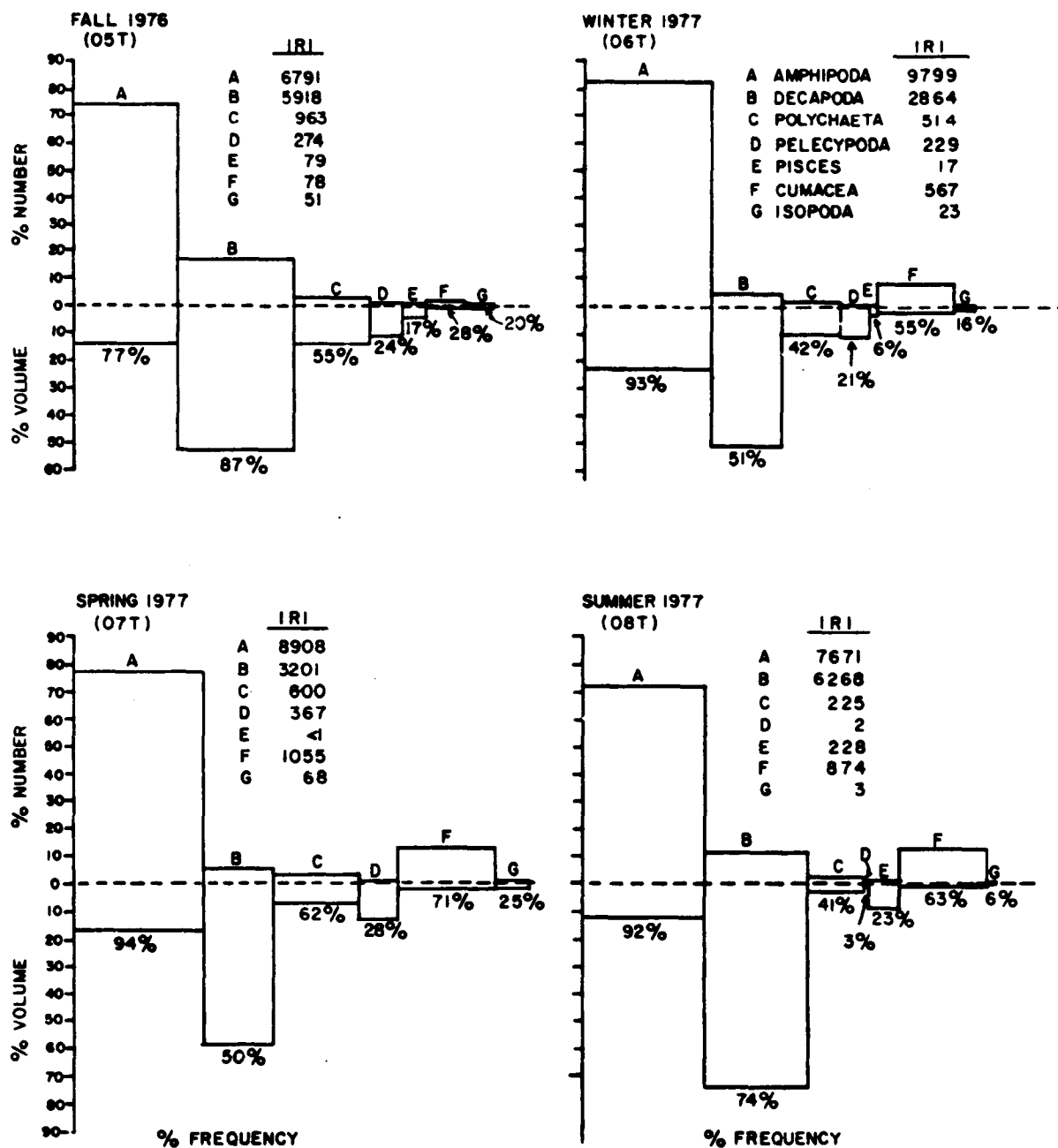


Figure 9-4. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Raja erinacea*, by season.

Table 9-2. Raja erinacea. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cnidaria																
Hydrozoa																
<u>Eudendrium</u> spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Anthozoa																
Unidentified	-	-	-	-	-	-	-	-	1.13	.03	.36	<1	-	-	-	-
Annelida																
Polychaeta																
<u>Aphrodite</u> <u>hastata</u>	3.67	.12	1.63	6	2.08	.07	1.90	4	1.13	.03	.52	1	-	-	-	-
<u>Harmothoe</u> <u>extenuata</u>	.41	.01	.25	<1	.70	.03	.03	<1	10.94	.58	.22	7	7.05	.30	.13	3
<u>Sthenelais</u> <u>limicola</u>	3.67	.17	.17	1	7.29	.48	1.28	13	17.36	.67	1.89	44	4.41	.15	.26	2
Phyllodoceidae	-	-	-	-	-	-	-	-	.35	.01	.01	<1	.58	.03	.02	<1
Nereidae spp.	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nereis spp.	.41	.01	.00	<1	-	-	-	-	.38	.01	.00	<1	4.41	.18	.20	2
<u>N. grayi</u>	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Nephtyidae spp.	-	-	-	-	-	-	-	-	1.13	.03	.15	<1	-	-	-	-
<u>Aglaophanus</u> <u>circinatus</u>	4.10	.11	.86	4	1.73	.04	.72	1	.75	.02	.03	<1	1.32	.04	.08	<1
<u>Nephtys</u> spp.	-	-	-	-	-	-	-	-	.75	.02	.23	<1	-	-	-	-
<u>N. buccata</u>	-	-	-	-	-	-	-	-	.38	.01	.04	<1	-	-	-	-
<u>N. incisa</u>	.41	.01	.83	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Glycera</u> spp.	2.86	.08	.24	1	2.78	.06	.10	<1	.75	.02	.05	<1	.88	.03	.08	<1
<u>G. dibranchiata</u>	6.53	.20	.81	7	-	-	-	-	12.08	.31	1.30	19	3.08	.09	.56	2
<u>Godiada</u> <u>norvegica</u>	.41	.03	.69	<1	11.46	.31	2.29	30	-	-	-	-	-	-	-	-
<u>G. brunnea</u>	-	-	-	-	.35	.01	.26	<1	-	-	-	-	-	-	-	-
<u>Sealibyrma</u> <u>inflatum</u>	.41	.01	.01	<1	.69	.02	.01	<1	6.42	.14	.25	3	3.96	.11	.14	1
<u>Ophelia</u> <u>denticulata</u>	1.22	.03	.23	<1	.69	.02	.04	<1	.38	.01	.08	<1	-	-	-	-
<u>Ophelia</u> spp.	4.04	.75	.51	5	.35	.01	.02	<1	.75	.04	.04	<1	8.81	.76	.61	12
Maldanidae spp.	.51	.02	.02	<1	1.04	.03	.13	<1	.38	.01	.01	<1	5.53	.16	.22	2
<u>Clymenella</u> <u>torquata</u>	.41	.01	.02	<1	.35	.01	.02	<1	.38	.01	.01	<1	.58	.03	.04	<1
<u>Euclymene</u> <u>collaris</u>	.41	.01	.02	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Clymenura</u> sp. A	8.57	.24	.58	7	8.67	.22	.96	10	10.19	.23	.67	9	1.32	.04	.05	<1
Spionidae	.41	.01	.03	<1	-	-	-	-	.75	.02	.02	<1	.44	.01	.00	<1
<u>Spiophanes</u> <u>bombyx</u>	-	-	-	-	-	-	-	-	.33	.01	.01	<1	-	-	-	-
<u>Onuphis</u> <u>pallidula</u>	-	-	-	-	-	-	-	-	.75	.02	.01	<1	.44	.01	.03	<1
<u>Marphysa</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Amphirone</u> <u>arctica</u>	2.45	.07	.76	2	1.39	.03	.22	<1	1.51	.03	.12	<1	.44	.01	.07	<1
<u>Ampharete</u> <u>arctica</u>	1.22	.03	.02	<1	7.98	.23	.37	5	3.77	.10	.15	1	1.32	.04	.01	<1
<u>Pherusa</u> <u>affinis</u>	2.04	.11	.56	1	2.08	.08	.28	1	1.51	.08	.42	1	-	-	-	-
Sabellidae spp.	1.22	.06	.94	1	-	-	-	-	-	-	-	-	.58	.03	.39	<1
<u>Chone</u> <u>infundibuliformis</u>	3.01	.22	.77	5	3.47	.08	.16	1	3.02	.07	.18	1	.44	.01	.00	<1
<u>Filograna</u> <u>implexa</u>	.41	.01	.50	<1	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	29.80	.97	3.83	143	14.93	.37	1.26	24	20.38	.47	.60	22	10.13	.31	.30	6
Total Polychaeta	54.69	3.32	14.28	963	42.31	2.08	10.07	515	61.51	2.73	7.03	600	49.23	2.34	3.20	225

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Table 9-2.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Mollusca																
Scapnopoda																
Unidentified	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda																
Unidentified	.41	.01	.08	<1	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Pelecypoda																
<i>Ensis directus</i>	10.61	.29	3.10	36	20.48	.51	10.30	221	27.17	.63	12.61	360	3.08	.10	.62	2
Unidentified	13.47	.37	7.61	108	.69	.02	.19	<1	.38	.01	.00	<1	-	-	-	-
Total Pelecypoda	24.08	.67	10.71	274	20.83	.52	10.49	229	27.55	.64	12.62	365	3.08	.10	.62	2
Cephalopoda																
<i>Loligo pealeii</i>	.41	.01	1.25	1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Rossia tenera</i>	.82	.02	.01	<1	-	-	-	-	.38	.01	.00	<1	.44	.01	.20	<1
<i>Octopus vulgaris</i>	-	-	-	-	-	-	-	-	-	-	-	-	.88	.03	.08	<1
Unidentified	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Total Cephalopoda	1.22	.03	1.26	2	-	-	-	-	.75	.02	.00	<1	1.32	.04	.28	<1
Total Mollusca	25.71	.72	12.06	329	21.18	.53	10.49	233	28.30	.66	12.62	376	4.41	.14	.90	5
Crustacea																
Copepoda																
<i>Calanus finmarchicus</i>	-	-	-	-	-	-	-	-	1.51	.04	.00	<1	3.08	.10	.00	<1
<i>Paracalanus</i> spp.	-	-	-	-	1.39	.08	.00	<1	-	-	-	-	-	-	-	-
<i>Centropages typicus</i>	-	-	-	-	1.73	.05	.00	<1	-	-	-	-	.44	.01	.00	<1
<i>Candacia armata</i>	-	-	-	-	-	-	-	-	-	-	-	-	13.22	.47	.01	<1
<i>Metridia lucens</i>	-	-	-	-	.35	.01	.00	<1	1.51	.03	.00	<1	.44	.01	.00	<1
<i>Caligus</i> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Unidentified	.41	.01	.00	<1	.69	.02	.00	<1	.75	.02	.00	<1	-	-	-	-
Total Copepoda	.41	.01	.00	<1	3.82	.16	.00	1	3.40	.09	.00	<1	15.42	.60	.01	7
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	1.32	.04	.05	<1
Mysidacea																
<i>Heteromysis formosa</i>	.41	.01	.00	<1	.69	.02	.00	<1	.75	.02	.01	<1	.48	.03	.01	<1
<i>Erythrops erythrophthalma</i>	-	-	-	-	-	-	-	-	.75	.02	.00	<1	.48	.03	.00	<1
Total Mysidacea	.41	.01	.00	<1	.69	.02	.00	<1	1.50	.03	.01	<1	1.76	.05	.01	<1
Cumacea																
<i>Eudorella</i> spp.	-	-	-	-	.35	.01	.00	<1	2.26	.05	.00	<1	.44	.01	.00	<1
<i>E. hispidus</i>	-	-	-	-	.69	.02	.00	<1	1.13	.03	.00	<1	-	-	-	-
<i>Diastyllis</i> spp.	2.45	.17	.02	<1	3.13	.26	.02	1	.38	.01	.00	<1	.44	.01	.00	<1
<i>D. sculpta</i>	.41	.01	.00	<1	33.68	4.26	.53	161	60.75	8.65	1.21	594	42.73	6.97	.76	323
<i>D. bispinosa</i>	22.04	1.84	.36	49	35.76	4.10	1.00	182	42.26	4.29	.56	205	42.26	3.39	.71	296
<i>D. polita</i>	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
Nannastacidae spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
<i>Petalosarsia declivis</i>	-	-	-	-	1.39	.05	.00	<1	1.51	.07	.00	<1	2.04	.08	.00	<1
Unidentified	6.53	.37	.04	2	2.43	.06	.01	<1	-	-	-	-	.44	.01	.00	<1
Total Cumacea	28.16	2.34	.43	78	54.86	8.77	1.56	567	70.94	13.09	1.77	1055	61.44	12.47	1.31	874

Table 9-2.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Isopoda																
<i>Chirodotea</i> spp.	.41	.01	.00	<1	.35	.01	.00	<1	.38	.02	.00	<1	.44	.03	.00	<1
<i>C. tufesi</i>	2.04	.07	.01	<1	.35	.01	.00	<1	1.38	.01	.00	<1	.88	.04	.01	<1
<i>C. arenicola</i>	-	-	-	-	-	-	-	-	1.51	.07	.02	<1	.44	.01	.00	<1
<i>Edotea triloba</i>	.41	.01	.00	<1	2.43	.05	.01	<1	12.83	.54	.09	8	.88	.04	.01	<1
<i>Cirolana</i> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>C. polita</i>	18.78	1.10	1.27	44	13.19	.36	.93	17	11.32	.59	1.38	22	3.08	.10	.22	1
<i>Janira alta</i>	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
Unidentified	.41	.01	.00	<1	.69	.02	.02	<1	-	-	-	-	-	-	-	-
Total Isopoda	20.40	1.20	1.28	51	15.97	.44	.97	23	24.91	1.24	1.51	68	6.17	.21	.24	3
Amphipoda																
<i>Ampelisca</i> spp.	4.08	.32	.02	1	1.39	.05	.01	<1	.75	.02	.00	1	.44	.01	.00	<1
<i>A. vadorum</i>	38.78	9.46	1.74	436	22.92	1.20	.34	34	22.26	.94	.26	34	42.29	9.31	1.53	438
<i>A. macrocephala</i>	.41	.02	.01	<1	.69	.02	.01	<1	.38	.01	.00	<1	-	-	-	-
<i>A. agassizi</i>	2.86	.10	.03	<1	1.73	.04	.01	<1	3.40	.13	.01	<1	5.73	.19	.03	1
<i>Byblis serrata</i>	62.45	49.82	9.32	3694	57.64	9.43	2.64	696	67.55	11.26	3.04	966	69.16	19.49	4.06	1629
<i>Leptocheirus pinguis</i>	8.57	.67	.33	9	18.05	2.05	1.17	58	14.34	.85	.45	19	8.81	.37	.16	5
<i>Argissa hematipes</i>	-	-	-	-	4.17	.16	.02	1	.75	.02	.00	<1	2.20	.06	.00	<1
<i>Coropium</i> spp.	.41	.01	.00	<1	.35	.01	.00	<1	-	-	-	-	-	-	-	-
<i>Erichthonius rubricornis</i>	26.53	1.84	.18	53	66.67	17.64	1.89	1302	74.34	28.30	3.69	2379	71.37	14.98	1.14	1152
<i>Unciola</i> spp.	-	-	-	-	-	-	-	-	.44	.01	.00	1	.44	.01	.00	1
<i>U. irrorata</i>	51.43	8.06	1.50	491	87.15	50.65	15.86	5797	87.92	33.91	9.28	3798	77.09	15.51	3.24	1446
<i>Pseudonicolea obliqua</i>	-	-	-	-	-	-	-	-	.38	.01	.00	<1	-	-	-	-
<i>Siphonocetes caithianus</i>	.41	.01	.00	<1	-	-	-	-	-	-	-	-	1.76	.08	.01	<1
<i>Melita dentata</i>	.41	.01	.00	<1	1.39	.04	.02	<1	.38	.02	.02	<1	.44	.01	.00	<1
<i>Casco bigelovi</i>	1.72	.03	.03	<1	.69	.02	.01	<1	2.64	.06	.02	<1	3.96	.14	.08	1
<i>Jerbarnia</i> sp. A	-	-	-	-	.35	.01	.00	<1	1.13	.10	.01	<1	-	-	-	-
<i>Protochaustorius wigleyi</i>	1.63	.05	.01	<1	3.47	.10	.02	<1	1.89	.12	.01	<1	2.64	.08	.00	<1
<i>Photis</i> spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	.38	.02	.00	<1
<i>Photis dentata</i>	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
<i>Protomedea fasciata</i>	-	-	-	-	-	-	-	-	3.02	.09	.01	<1	-	-	-	-
<i>Hippomedon serratus</i>	4.49	.15	.06	<1	2.78	.06	.06	<1	3.02	.08	.09	<1	1.32	.04	.01	<1
<i>Anonyx sarei</i>	1.22	.03	.02	<1	.35	.01	.02	<1	2.64	.06	.17	1	-	-	-	-
<i>A. liljeborgi</i>	.41	.01	.00	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
<i>Oedicerotidae</i> spp.	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Monoculodes</i> spp.	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Monoculodes edwardsi</i>	2.04	.08	.01	<1	4.17	.29	.07	1	1.13	.03	.00	<1	5.63	9.08	1.19	561
<i>Synchelidium americanum</i>	.32	.02	.00	<1	-	-	-	-	.38	.01	.00	<1	-	-	-	-
<i>Phuconcephalus holbolli</i>	.41	.01	.00	<1	1.04	.02	.00	<1	2.64	.06	.01	<1	5.85	.20	.02	1
<i>Trichophoxus epistomus</i>	21.63	2.20	.32	55	4.86	.12	.02	1	7.92	.23	.05	2	6.17	.19	.03	1
<i>Harpinia propinqua</i>	1.22	.05	.00	<1	-	-	-	-	.38	.01	.00	<1	.44	.01	.00	<1
<i>Stenopleustis inermis</i>	.82	.02	.00	<1	2.78	.06	.00	<1	6.79	.25	.01	2	11.01	.35	.00	4
<i>Hyperidae</i> spp.	1.63	.05	.01	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Parathemisto gaudichaudi</i>	6.12	.20	.02	1	1.39	.03	.00	<1	.75	.02	.00	<1	29.07	1.34	.12	46
<i>Caprellidae</i> spp.	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
<i>Aeginina longicornis</i>	.82	.02	.00	<1	15.63	.67	.31	15	16.98	.75	.21	16	7.00	.30	.07	3
Unidentified	16.33	.94	.24	19	2.43	.07	.03	<1	3.02	.13	.01	<1	.44	.01	.00	<1
Total Amphipoda	77.14	74.20	13.83	6791	93.06	82.79	22.52	9800	93.96	77.45	17.35	8908	91.63	72.02	11.70	7671

Table 9-2.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Euphausiacea																
Euphausiidae spp.	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Decapoda																
<u>Leptochela bermudensis</u>	1.22	.03	.02	<1	-	-	-	-	-	-	-	-	1.32	.05	.02	<1
<u>Dichelopandalus leptocerus</u>	6.94	.28	1.79	14	1.73	.05	.24	1	4.53	.10	.02	1	18.06	.74	1.43	39
Crangonidae spp.	.82	.02	.00	<1	-	-	-	-	-	-	-	-	.44	.01	.00	<1
<u>Crangon septemspinosa</u>	28.98	1.27	2.09	97	12.15	.82	.54	17	7.17	.21	.28	4	44.65	3.06	1.77	213
<u>Munida iris</u>	-	-	-	-	.35	.01	.04	<1	-	-	-	-	-	-	-	-
<u>Axius serrata</u>	.82	.02	.36	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Pagurus</u> spp.	.41	.01	.01	<1	.69	.02	.06	<1	-	-	-	-	1.32	.04	.01	<1
<u>P. arcuatus</u>	.41	.01	.03	<1	-	-	-	-	.38	.01	.10	<1	-	-	-	-
<u>P. acadianus</u>	-	-	-	-	.39	.03	.14	<1	.38	.01	.02	<1	.44	.01	.03	<1
<u>Albunea</u> spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Calappidae spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
Callinectes spp. zoea	-	-	-	-	-	-	-	-	-	-	-	-	.44	.01	.00	<1
<u>Cancer</u> spp.	8.16	.59	.36	8	2.08	.05	.09	<1	.38	.02	.01	<1	-	-	-	-
<u>C. borealis</u>	11.02	.50	1.31	20	3.13	.10	.58	2	3.02	.11	1.49	5	5.96	.20	5.48	24
<u>C. irroratus</u>	72.65	13.29	45.57	4284	42.71	3.86	59.77	2290	43.77	4.12	57.28	2685	51.30	7.05	64.30	3803
Unidentified	11.43	1.05	1.68	31	1.04	.02	.07	<1	-	-	-	-	.44	.01	.00	<1
Total Decapoda	83.08	17.18	53.21	5918	50.69	4.95	51.54	2864	50.19	4.57	59.21	3201	74.01	11.24	73.46	6268
Unidentified Crustacea	9.80	.36	.84	12	3.13	.09	.05	1	1.51	.03	.00	<1	1.32	.04	.01	<1
Total Crustacea	99.59	95.30	69.59	16421	100.00	97.22	76.63	17386	100.00	96.52	79.85	17036	100.00	96.69	86.79	13345
Nemertea																
<u>Phascolion strombi</u>	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Ectoprocta																
Unidentified	-	-	-	-	.35	.01	.00	<1	-	-	-	-	-	-	-	-
Echinodermata																
Echinoidea																
<u>Echinarachnius parma</u>	.82	.02	.00	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
Asteroida																
Unidentified	.41	.01	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Total Echinodermata	1.22	.03	.01	<1	.35	.01	.01	<1	-	-	-	-	-	-	-	-
Chaetognatha																
<u>Sagitta elegans</u>	-	-	-	-	-	-	-	-	.75	.02	.00	<1	-	-	-	-
Chordata																
Pisces																
<u>Teleostei</u> spp.	11.02	.36	1.65	22	2.78	.06	1.57	5	.75	.02	.01	<1	1.32	.04	1.02	14
<u>Urophycis chusa</u>	4.08	.18	.43	3	1.39	.03	.84	1	-	-	-	-	1.32	.04	7.12	16
<u>Merluccius bilinearis</u>	.41	.01	.08	<1	.35	.01	.21	<1	-	-	-	-	.44	.01	.00	<1
<u>Lepophidium cervinum</u>	.41	.02	1.83	1	.69	.02	.13	<1	.38	.02	.12	<1	-	-	-	-
<u>Liparis inquilinus</u>	-	-	-	-	-	-	-	-	.38	.01	.00	<1	.44	.01	.03	<1

Table 9-2.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<i>Ammodytes</i> spp.	-	-	-	-	.69	.02	.06	<1	.34	.01	.02	.41	-	-	-	-
<i>Githarichthys arcifrons</i>	1.22	.05	.08	.41	-	-	-	-	-	-	-	-	3.72	.09	.17	1
<i>Limanda ferruginea</i>	-	-	-	-	-	-	-	-	-	-	-	-	4.33	.17	.37	3
Total Plaice	16.73	.62	4.08	79	5.90	.13	2.80	17	1.49	.05	.13	4.1	22.81	.43	2.17	228
Total stomachs examined:		269				296				272				243		
Total examined stomachs with food:		245				254				265				225		

Isopods, mainly Cirolana polita, were eaten in small amounts at all times of the year, but less so in summer.

Results of the electivity analysis are shown in Figure 9-5. In the lower graphs, relative abundance of important prey species, expressed as a percent of the total number of individuals of all species, is plotted for both stomach contents (dashed line) and macrobenthos samples (solid line) for each stratum. Strata in which no fish were captured have been omitted. In the upper graph, Ivlev's (1961) electivity index for each prey species is plotted against the corresponding strata in the lower graph. Thus, each corresponding pair of graphs indicates the relative numerical abundance of selected prey species in stomachs and in the benthos for each stratum, and the corresponding selectivity of the predator for these prey species in each stratum. Although relative abundances of prey species fluctuated greatly both in fish stomachs and in grab samples among strata, some patterns of prey abundance and selectivity can be seen (Figure 9-5).

Important species of amphipods such as Byblis serrata, Unciola irrorata, Ampelisca vadorum, and Trichophoxus epistomus were generally more abundant at shallower habitat strata, decreasing in relative abundance in deeper habitats in both study areas. Two patterns of electivity were found for these amphipods. The first, exhibited for B. serrata and A. vadorum, consisted of great fluctuations in their relative abundance in the diet, but generally with a strong positive selection for these food items. The second, exhibited by U. irrorata and T. epistomus, consisted of variations in the importance of the amphipods in the diet among strata, but with corresponding fluctuations in the electivity value from positive to negative.

The other important amphipods, Erichthonius rubricornis and Ampelisca agassizi, were generally more abundant in deeper strata. Electivity values for these species fluctuated greatly among the strata, ranging from strong positive selection to strong avoidance of these prey species. A. agassizi was particularly avoided, in spite of high relative abundance in the benthos of some strata, apparently in favor of the other less abundant ampeliscids, A. vadorum and B. serrata.

Decapods, particularly Cancer irroratus and Crangon septemspinosa, exhibited low abundance in grab samples but a high relative abundance in skate stomachs and a correspondingly strong positive selection. These epifaunal decapods were very abundant in the study areas as was apparent in trawl and megabenthos samples, but because of their relatively large size they occurred in lower densities than the smaller peracarideans. Other important prey species such as Diastylis bispinosa, Cirolana polita, and Ensis directus were generally found in low numbers in both the benthos and in skate stomachs. This caused great variation in electivity values, since a difference of only one or two individuals in the abundance of

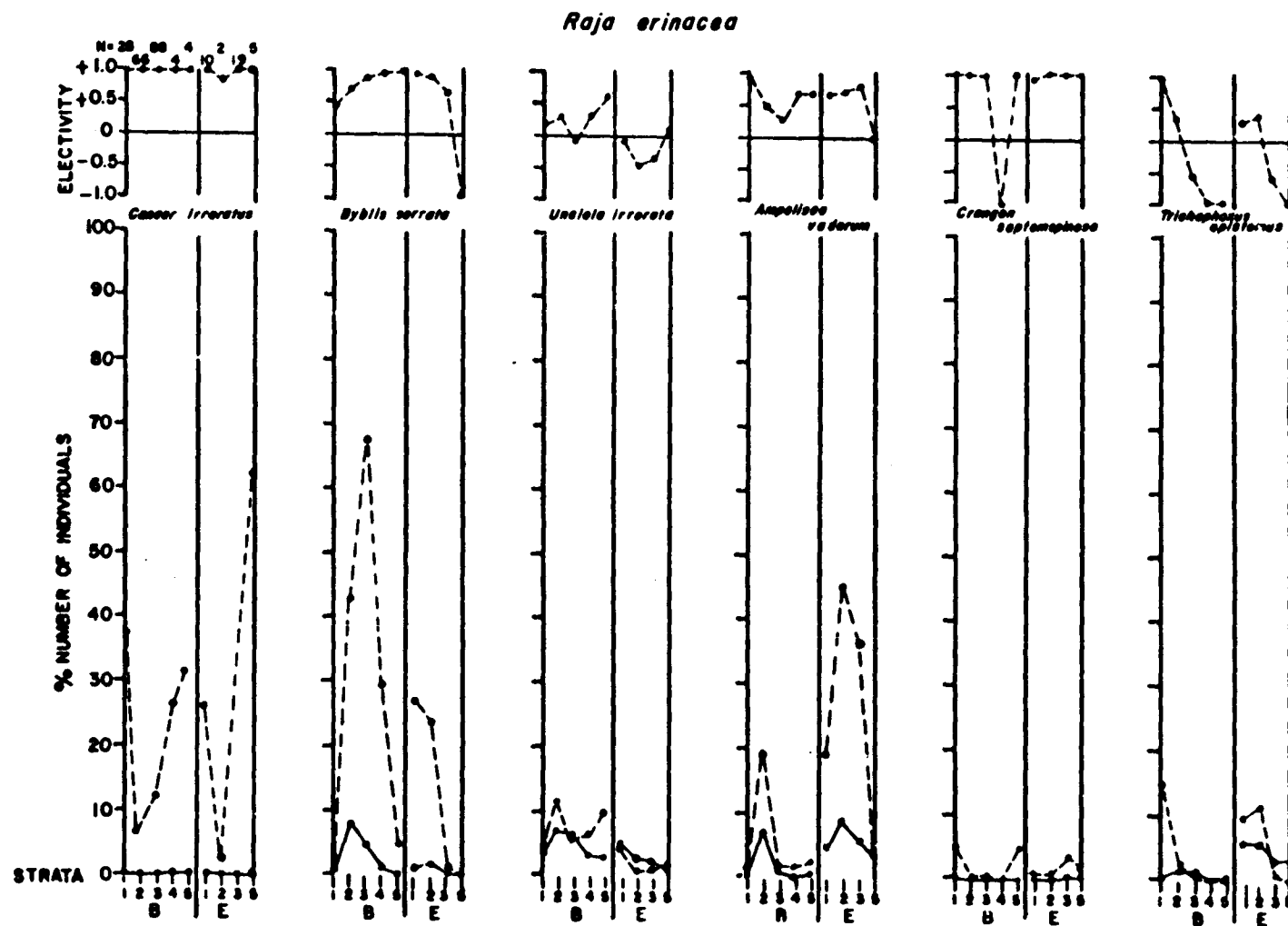


Figure 9-5. Relative abundance in *Raja erinacea* stomachs (---•) and grab samples (—•), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

Raja erinacea (cont)

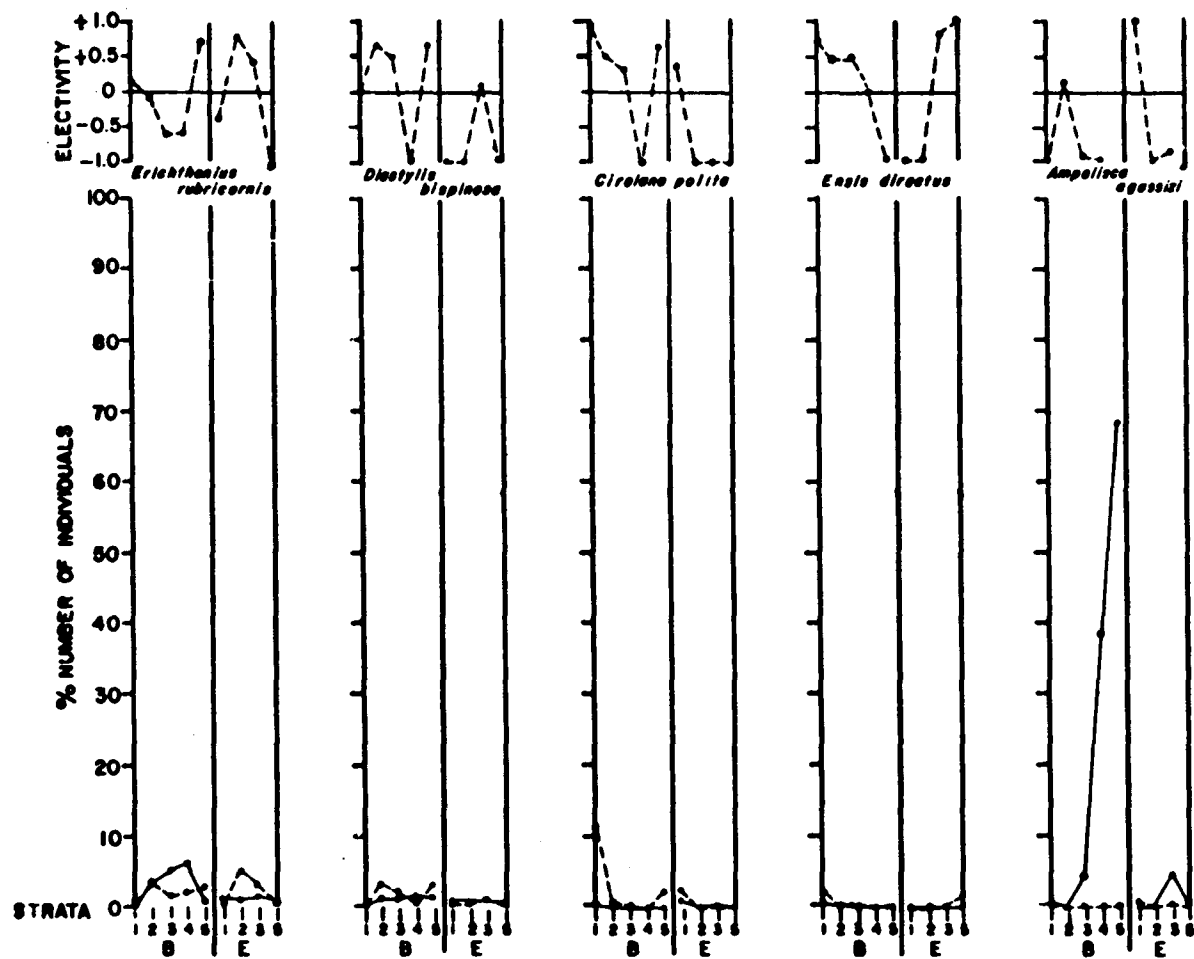


Figure 9-5. (Continued)

these animals in the stomach or in grab samples can cause a large difference in the electivity value.

Lophius americanus

The goosefish, Lophius americanus, though not as abundant as many other fishes on the outer shelf was common and comprised a considerable portion of the biomass of fishes in the study area because of its large size (Table 9-1). L. americanus fed mainly on fishes during all seasons, and few benthic invertebrates were consumed (Figure 9-6). Urophycis chuss was the most important prey species throughout the year (Table 9-3). Stenotomus chrysops was an important prey during the fall, when it was abundant in the study area. Merluccius bilinearis, Lepophidium cervinum, and Citharichthys arctifrons were also important prey species. Decapods and cephalopods were less important as food and polychaetes, amphipods, asteroids, and chaetognaths were only occasionally found in stomachs. Lophius americanus is almost exclusively piscivorous, having little direct impact on benthic invertebrates.

Urophycis chuss

Red hake, Urophycis chuss, were abundant in the study area on all four cruises; however, the same portion of the population was not present year round. Juveniles predominated in fall ($\bar{x}$ length = 49 mm) and summer ($\bar{x}$ length = 147 mm) and were virtually absent in winter and spring, when larger fish moved into the area ($\bar{x}$ lengths = 251 and 238 mm respectively). This was reflected in the much smaller contribution of this species toward the biomass of fishes during the fall and summer (Table 9-1).

Urophycis chuss fed primarily on amphipods, which were important as food at all times of the year, especially in fall, when they made up most of the diet (Figure 9-7). Decapods and polychaetes were also important and, with the exception of fall samples, remained relatively constant in their importance in the diet. Copepods were important in the fall and winter, and pelecypods and isopods were of minor importance in the winter, spring, and summer and unimportant in the fall diet of U. chuss. Fishes were of minor importance in the diet, especially in winter. Chaetognaths, absent from the diet in fall and winter, became quite important as food during the spring and summer.

Much seasonal variation in importance took place in the diet at the species level within these higher taxa (Table 9-4). Within the amphipods, pelagic hyperiids dominated in the fall and were also important, but much less so, in the summer. Unciola irrorata was the second most important amphipod in fall samples and the most important amphipod in winter, spring, and summer. Erichthonius rubricornis followed in importance for all seasons. Byblis serrata was fairly

(TEXT CONTINUES ON PAGE 9-31)

Lophius americanus

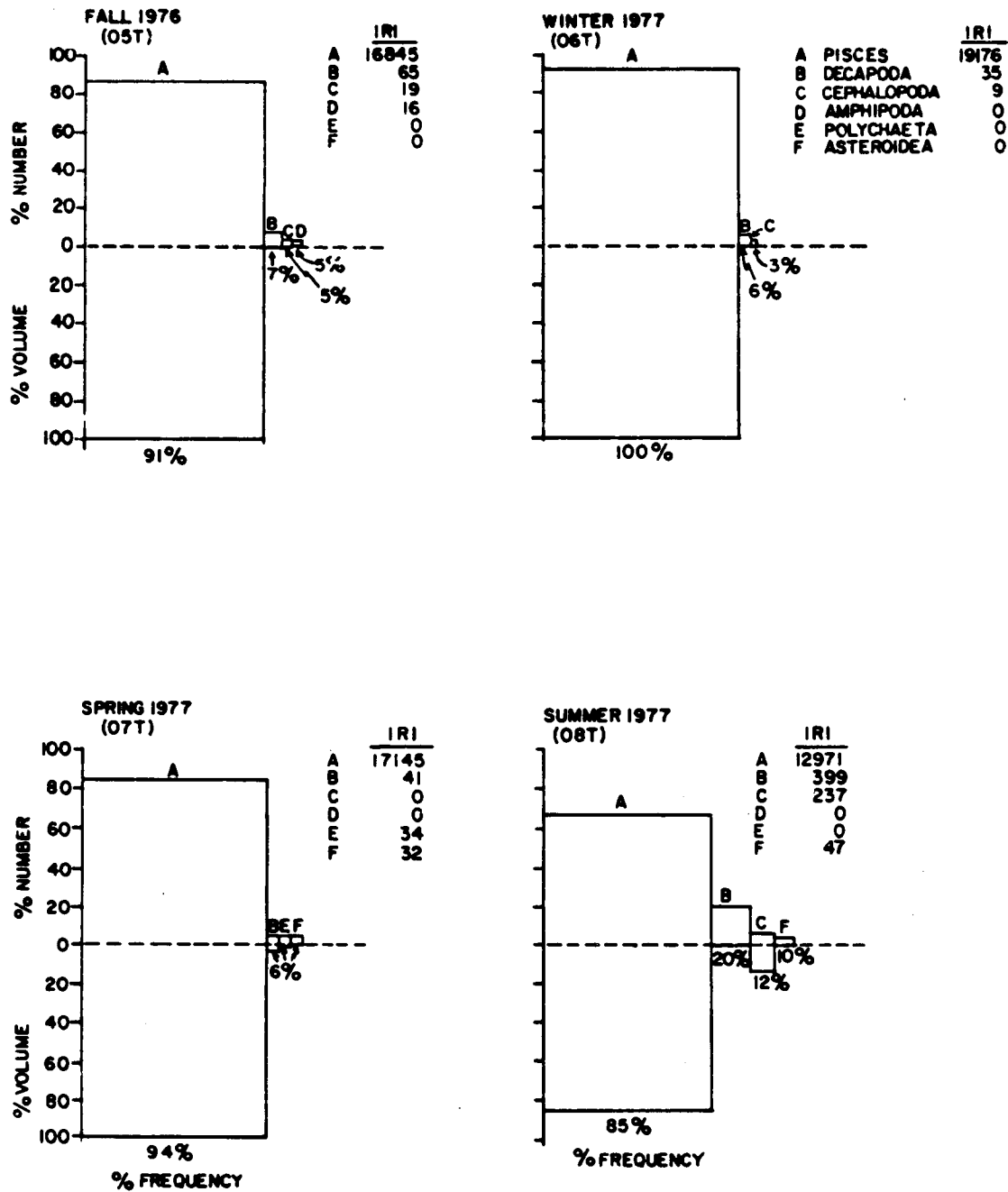


Figure 9-6. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Lophius americanus*, by season.

Table 9-3. Lophius americanus. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
<u>Aphrodite hastata</u>	-	-	-	-	-	-	-	-	6.25	5.00	.41	34	-	-	-	-
Mollusca																
Cephalopoda																
<u>Loligo pealeii</u>	4.54	3.45	.69	19	-	-	-	-	-	-	-	-	7.32	3.33	11.47	108
<u>Kossia tenera</u>	-	-	-	-	3.23	2.63	.19	9	-	-	-	-	2.44	1.11	.02	3
unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	2.39	9
Total Cephalopoda	4.54	3.45	.69	19	3.23	2.63	.19	9	-	-	-	-	12.20	5.56	13.89	237
Crustacea																
Amphipoda																
<u>Bythia serrata</u>	4.54	3.45	.00	16	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda																
<u>Dichelopandalus leptocerus</u>	9.09	6.90	.22	65	6.45	5.26	.16	35	-	-	-	-	17.07	16.67	.36	291
<u>Crangon septemspinosa</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	.02	3
<u>Cancer borealis</u>	-	-	-	-	-	-	-	-	6.25	5.00	1.63	41	-	-	-	-
<u>C. irroratus</u>	-	-	-	-	-	-	-	-	-	-	-	-	4.88	2.22	.05	11
Total Decapoda	9.09	6.90	.22	65	6.45	5.26	.16	35	6.25	5.00	1.63	41	19.51	20.00	.43	399
Echinodermata																
Asteroides																
<u>Asterias vulgaris</u>	-	-	-	-	-	-	-	-	6.25	5.00	.08	32	7.32	3.33	.28	26
<u>Astropecten americanus</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	.12	3
Total Asteroides	-	-	-	-	-	-	-	-	6.25	5.00	.08	32	9.76	4.44	.40	47
Chaetognatha																
<u>Sagitta elegans</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	3.33	.00	8
Chordata																
Pisces																
<u>Squalus acanthias</u>	-	-	-	-	6.45	5.26	.97	40	-	-	-	-	-	-	-	-
<u>Raja</u> spp.	-	-	-	-	3.23	2.63	.23	9	-	-	-	-	-	-	-	-
Teleostei spp.	27.27	20.69	10.69	856	35.48	28.95	40.20	2454	25.00	20.00	12.96	824	29.27	15.55	25.46	1200
<u>Lophius americanus</u>	-	-	-	-	-	-	-	-	6.25	5.00	.24	33	-	-	-	-
<u>Urophycis chuss</u>	27.27	24.14	6.20	827	48.39	50.00	54.75	5068	43.75	35.00	33.21	2994	25.39	11.11	25.36	890
<u>H. rexius</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	8.37	23
<u>Merluccius bilinearis</u>	4.54	3.45	.24	17	-	-	-	-	6.25	5.00	26.89	199	7.32	18.89	.65	143
<u>Lepophidium cervinum</u>	13.64	10.34	8.33	255	3.23	2.63	2.03	15	6.25	5.00	1.63	41	12.19	5.55	5.68	137
<u>Liparis inquilinus</u>	-	-	-	-	-	-	-	-	-	-	-	-	4.88	2.22	.02	11
<u>Stenotomus chrysops</u>	9.09	10.34	70.76	737	-	-	-	-	6.25	5.00	4.89	62	-	-	-	-
Scombridae spp.	-	-	-	-	-	-	-	-	6.25	5.00	17.93	143	-	-	-	-
<u>Citharichthys arctifrons</u>	4.54	13.79	.19	64	-	-	-	-	6.25	5.00	.12	32	17.07	10.00	4.20	242
<u>Pseudopleuronectes americanus</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	13.15	35
<u>Limanda ferruginea</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1.11	2.39	9
Total Pisces	90.91	86.21	99.08	16845	100.00	92.11	99.65	19176	93.75	85.00	97.88	17145	55.37	60.67	55.28	12971
Total number of stomachs examined		37				40				18				45		
Examined stomachs with food:		22				31				16				41		

Urophycis chuss

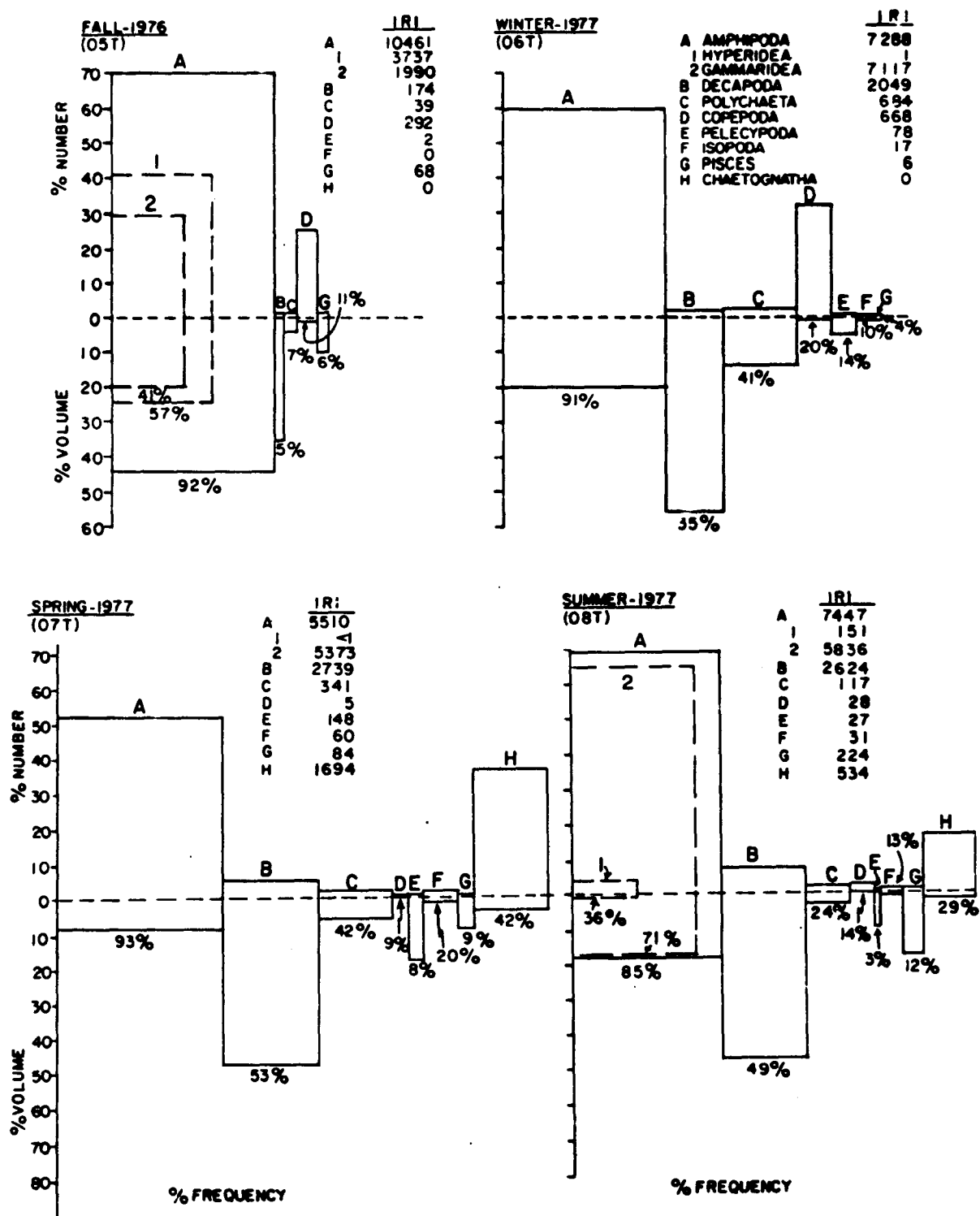


Figure 9-7. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Urophycis chuss*, by season.

Table 9-4. Urophycis chuss. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	V	N	IRI
Plant																
<u>Sargassum</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.38	.02	.01	<1
Poacea spp.	-	-	-	-	.32	.01	.16	<1	-	-	-	-	-	-	-	-
Cnidaria																
Hydrozoa																
Unidentified	-	-	-	-	-	-	-	-	1.04	.03	.00	<1	-	-	-	-
Anthozoa																
Unidentified	-	-	-	-	.32	.01	.05	<1	.26	.01	.00	<1	-	-	-	-
Rhynchocoela																
Anopla																
<u>Carinomella lactea</u>	-	-	-	-	.32	.01	.08	<1	-	-	-	-	-	-	-	-
Annelida																
Polychaeta																
<u>Aphrodita hastata</u>	-	-	-	-	2.22	.07	2.55	6	8.33	.27	3.84	34	-	-	-	-
<u>Harmothoe</u> spp.	-	-	-	-	.32	.01	.07	<1	-	-	-	-	-	-	-	-
<u>H. extenuata</u>	-	-	-	-	3.49	.14	.11	1	3.13	.11	.05	<1	1.53	.08	.04	<1
<u>Sthenalalis limicola</u>	-	-	-	-	1.90	.06	.27	1	4.17	.14	.12	1	2.30	.11	.28	1
<u>Phyllodoce</u> spp.	-	-	-	-	.32	.01	.02	<1	.26	.01	.00	<1	-	-	-	-
<u>P. mucosa</u>	-	-	-	-	.32	.01	.00	<1	-	-	-	-	-	-	-	-
<u>Syllis</u> spp.	-	-	-	-	-	-	-	-	.52	.02	.00	<1	-	-	-	-
<u>Nereis</u> spp.	-	-	-	-	-	-	-	-	.52	.02	.00	<1	-	-	-	-
<u>N. grayi</u>	-	-	-	-	-	-	-	-	.26	.01	.01	<1	-	-	-	-
Nephtyidae	-	-	-	-	-	-	-	-	-	-	-	-	1.53	.08	.08	<1
<u>Aglaophamus circinata</u>	-	-	-	-	-	-	-	-	1.82	.05	.03	<1	-	-	-	-
<u>Glycera dibranchiata</u>	-	-	-	-	-	-	-	-	.52	.02	.01	<1	-	-	-	-
<u>Goniada</u> spp.	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<u>G. brunnea</u>	-	-	-	-	.32	.01	.04	<1	-	-	-	-	-	-	-	-

Table 9-4. (Continued)

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<u>Scalibregma inflatum</u>	-	-	-	-	-	-	-	-	.26	.01	.01	<1	-	-	-	-
<u>Ophelina</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	1.53	.08	.05	<1
<u>Maldanidae</u> spp.	-	-	-	-	-	-	-	-	1.04	.03	.02	<1	1.91	.12	.07	<1
<u>Euclymene collaris</u>	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<u>Clymenura</u> sp. A	.43	.08	.73	<1	7.30	.24	.74	7	5.47	.18	.18	2	4.20	.23	.35	2
<u>Praxillura longissima</u>	-	-	-	-	-	-	-	-	.26	.01	.02	<1	-	-	-	-
<u>Spionidae</u> spp.	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	<1	-	-	-	-
<u>Spiophanes bombyx</u>	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<u>Onuphis pallidula</u>	-	-	-	-	-	-	-	-	2.34	.11	.05	<1	-	-	-	-
<u>Marphysa</u> spp.	-	-	-	-	1.27	.04	.50	1	-	-	-	-	.38	.02	.22	<1
<u>M. sanguinea</u>	-	-	-	-	1.27	.05	1.06	1	-	-	-	-	-	-	-	-
<u>M. belli</u>	-	-	-	-	.63	.02	.04	<1	-	-	-	-	-	-	-	-
<u>Lumbrineris</u> spp.	.43	.08	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>L. fragilis</u>	-	-	-	-	6.35	.23	2.81	19	3.65	.13	.22	1	1.91	.09	.66	1
<u>L. cruzensis</u>	-	-	-	-	.63	.03	.02	<1	-	-	-	-	.38	.02	.01	<1
<u>L. impatiens</u>	-	-	-	-	-	-	-	-	-	-	-	-	.76	.04	.01	<1
<u>L. albidentata</u>	-	-	-	-	.32	.01	.03	<1	.26	.01	.00	<1	-	-	-	-
<u>Lumbrinerides</u> spp.	-	-	-	-	.32	.01	.02	<1	-	-	-	-	-	-	-	-
<u>Arabella iricolor</u>	-	-	-	-	.32	.07	1.10	<1	.52	.05	.13	<1	-	-	-	-
<u>Driloneris longa</u>	-	-	-	-	-	-	-	-	.26	.02	.02	<1	-	-	-	-
<u>D. magna</u>	-	-	-	-	.63	.02	.19	<1	-	-	-	-	.38	.02	.04	<1
<u>Cirratulidae</u> spp.	-	-	-	-	.32	.01	.01	<1	1.82	.05	.10	<1	.38	.02	.07	<1
<u>Tharyx</u> spp.	-	-	-	-	.32	.01	.04	<1	-	-	-	-	-	-	-	-
<u>T. acuta</u>	-	-	-	-	1.59	.06	.22	<1	-	-	-	-	-	-	-	-
<u>Ampharete arctica</u>	-	-	-	-	8.25	.57	.94	12	1.30	.05	.03	<1	-	-	-	-
<u>Terebellidae</u> spp.	-	-	-	-	-	-	-	-	.26	.01	.03	<1	-	-	-	-
<u>Nicoles venustula</u>	-	-	-	-	.32	.01	.02	<1	-	-	-	-	-	-	-	-
<u>Terebellides stroemi</u>	-	-	-	-	.32	.01	.04	<1	-	-	-	-	-	-	-	-
<u>Pherusa affinis</u>	-	-	-	-	.95	.03	.13	<1	2.86	.10	.31	1	1.15	.10	.27	<1
<u>Chone infundibuliformis</u>	-	-	-	-	4.13	.23	.25	2	5.21	.19	.33	3	1.91	.10	.30	1
Unidentified	6.44	1.18	3.28	29	17.78	.68	2.68	60	16.67	.57	.44	17	8.78	.48	.73	11
Total Polychaeta	7.30	1.34	4.01	39	41.27	2.68	13.90	684	41.93	2.17	5.96	341	24.43	1.58	3.20	117

Table 9-4. (Continued)

Taxon Food Item	Fall 1977				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Mollusca																
Gastropoda																
<i>Lunatia heros</i>	-	-	-	-	-	-	-	-	.26	.01	1.99	1	-	-	-	-
<i>Mitrella</i> spp.	-	-	-	-	.95	.03	.01	<1	.26	.01	.00	<1	-	-	-	-
Pyramidellidae spp.	-	-	-	-	.95	.03	.01	<1	-	-	-	-	-	-	-	-
<i>Odostomia</i> spp.	-	-	-	-	.32	.01	.00	<1	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	.63	.02	.00	<1	-	-	-	-	-	-	-	-
Total Gastropoda	-	-	-	-	2.54	.09	.02	<1	.52	.02	2.00	1	-	-	-	-
Pelecypoda																
<i>Lacopecten magellanicus</i>	-	-	-	-	1.90	.07	2.88	6	3.65	.15	16.83	62	1.15	.06	8.97	10
<i>Astarte</i> spp.	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	1	-	-	-	-
<i>A. undata</i>	-	-	-	-	.159	.05	.16	<1	.26	.01	.00	1	-	-	-	-
<i>Cyclocardia borealis</i>	-	-	-	-	.95	.04	.13	<1	.26	.01	.00	1	.76	.04	.00	<1
<i>Ensis directus</i>	-	-	-	-	6.98	.29	.50	5	3.13	.09	.23	1	.38	.02	.75	<1
Unidentified	.86	.16	2.48	2	4.76	.21	1.21	7	1.04	.03	.95	1	.38	.02	.26	<1
Total Pelecypoda	.86	.16	2.48	2	13.97	.67	4.88	78	8.07	.29	18.02	145	2.67	.13	9.97	27
Cephalopoda																
<i>Rossia</i> spp.	-	-	-	-	-	-	-	-	1.56	.05	.01	<1	-	-	-	-
<i>Illex illecebrosus</i>	-	-	-	-	-	-	-	-	1.82	.05	4.70	9	-	-	-	-
Unidentified	-	-	-	-	.32	.01	.04	<1	1.30	.04	.45	1	-	-	-	-
Total Cephalopoda	-	-	-	-	.32	.01	.04	<1	4.43	.15	5.16	23	-	-	-	-
Unidentified Mollusca	.43	.08	.07	<1	.63	.02	.01	<1	-	-	-	-	-	-	-	-
Total Mollusca	1.29	.24	2.55	4	16.82	.80	4.94	97	12.50	.45	25.17	344	2.67	.13	9.97	27
Arthropoda																
Ostracoda																
Unidentified	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Copepoda																
<i>Calanus finmarchicus</i>	-	-	-	-	-	-	-	-	4.43	.19	.00	1	1.53	.08	.00	<1
<i>Rhincalanus nasutus</i>	-	-	-	-	.32	.01	.00	<1	-	-	-	-	-	-	-	-
<i>Nannocalanus minor</i>	.43	.24	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Paracalanus</i> spp.	-	-	-	-	10.48	15.67	.27	167	3.65	.16	.00	1	.76	.08	.00	<1
<i>Pseudocalanus</i> spp.	.43	.08	.00	<1	.32	.02	.00	<1	-	-	-	-	-	-	-	-
<i>Temora longicornis</i>	-	-	-	-	2.54	.18	.00	<1	.26	.02	.00	<1	.38	.02	.00	<1

Table 9-4. (Continued)

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<u>Centropages typicus</u>	9.01	24.49	.88	229	9.21	.73	.01	7	.78	.05	.00	1	2.29	.56	.02	1
<u>Candacia armata</u>	-	-	-	-	-	-	-	-	-	-	-	-	4.20	.27	.01	1
<u>Metridia lucens</u>	.43	.08	.00	<1	-	-	-	-	-	-	-	-	4.58	.31	.01	4
<u>Euchaeta marina</u>	-	-	-	-	-	-	-	-	-	-	-	-	.38	.02	.00	<1
Harpacticoida	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<u>Microsetella norvegica</u>	-	-	-	-	.53	.02	.00	<1	-	-	-	-	-	-	-	-
<u>Caligus</u> spp.	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Unidentified	1.72	.39	.00	1	10.48	15.65	.28	167	1.56	.05	.00	<1	1.91	.11	.00	<1
Total Copepoda	11.16	25.28	.88	292	20.32	32.30	.57	668	9.38	.50	.00	5	14.12	1.94	.05	28
Stomatopoda																
Unidentified (larvae)	-	-	-	-	-	-	-	-	.26	.01	.00	<1	.38	.02	.00	<1
Mysidacea																
<u>Heteromysis formosa</u>	-	-	-	-	.63	.02	.01	<1	.52	.02	.00	<1	1.14	.06	.02	<1
Cumacea																
<u>Eudorella</u> spp.	-	-	-	-	-	-	-	-	.78	.02	.00	<1	-	-	-	-
<u>E. hispidia</u>	-	-	-	-	1.27	.06	.01	<1	2.34	.08	.00	<1	-	-	-	-
<u>Petalosarsia declivis</u>	-	-	-	-	-	-	-	-	6.25	.73	.02	5	-	-	-	-
<u>Diastylis</u> spp.	-	-	-	-	.95	.03	.00	<1	1.56	.07	.00	<1	-	-	-	-
<u>D. sculpta</u>	-	-	-	-	2.22	.09	.01	<1	10.94	.67	.04	8	2.67	.17	.02	1
<u>D. bispinosa</u>	-	-	-	-	4.44	.20	.05	1	13.28	.66	.04	9	12.60	1.52	.37	24
Unidentified	.43	.08	.07	<1	1.27	.08	.01	<1	1.04	.03	.00	<1	-	-	-	-
Total Cumacea	.43	.08	.07	<1	9.52	.47	.09	5	28.13	2.25	.10	66	13.36	1.69	.40	28
Tanaidacea																
<u>Tanaissus lilljeborgi</u>	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	<1	-	-	-	-
Isopoda																
<u>Chiridotea</u> spp.	-	-	-	-	.32	.02	.00	<1	.52	.02	.00	<1	-	-	-	-
<u>C. tuftsi</u>	-	-	-	-	.63	.02	.01	<1	.26	.01	.00	<1	-	-	-	-
<u>C. arenicola</u>	-	-	-	-	.32	.01	.00	<1	.26	.01	.00	<1	-	-	-	-
<u>Edotea triloba</u>	-	-	-	-	.32	.02	.00	<1	1.30	.05	.00	<1	2.29	.13	.04	<1
<u>Ptilanthura tricarina</u>	-	-	-	-	.63	.02	.00	<1	.26	.01	.00	<1	1.53	.31	.04	1
<u>Cirolana</u> spp.	-	-	-	-	.32	.01	.01	<1	.26	.01	.00	<1	-	-	-	-
<u>C. polita</u>	-	-	-	-	6.67	.37	1.11	10	16.67	1.33	1.51	47	10.31	.67	1.11	18
<u>Janira alta</u>	-	-	-	-	.32	.01	.00	<1	.52	.02	.00	<1	.38	.02	.00	<1
Unidentified	-	-	-	-	.95	.04	.09	<1	.52	.02	.00	<1	-	-	-	-
Total Isopoda	-	-	-	-	9.52	.53	1.24	17	20.05	1.46	1.52	60	13.36	1.13	1.19	31

Table 9-4. (Continued)

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Amphipoda																
<i>Ampelisca</i> spp.	.86	.16	.00	<1	2.22	.16	.02	<1	-	-	-	-	-	-	-	-
<i>A. vadorum</i>	3.43	.71	.58	4	16.82	1.39	.29	28	9.11	.39	.04	4	13.69	1.08	.31	15
<i>A. macrocephala</i>	-	-	-	-	-	-	-	-	-	-	-	-	.38	.02	.00	<1
<i>A. agassizi</i>	.43	.08	.07	<1	5.08	1.88	.30	11	4.69	.44	.02	2	5.73	.77	.13	5
<i>Byblis serrata</i>	7.30	2.84	2.85	42	10.79	.41	.14	6	15.63	.97	.19	17	20.61	2.50	.87	69
Ampithoidae spp.	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Aoridae spp.	-	-	-	-	-	-	-	-	.26	.01	.01	<1	-	-	-	-
<i>Leptocheirus pinguis</i>	.43	.08	.22	<1	6.67	.29	.36	4	4.43	.14	.05	1	1.91	.13	.13	1
<i>Argissa hamatipes</i>	-	-	-	-	2.86	.14	.04	1	1.30	.04	.00	<1	-	-	-	-
<i>Erichthonius rubricornis</i>	14.16	5.45	1.82	103	70.48	16.69	3.82	1446	67.97	13.58	.97	988	45.42	16.11	2.08	826
<i>Unciola</i> spp.	.86	.24	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>U. irrorata</i>	27.90	16.74	12.48	815	77.78	33.93	13.56	3694	85.16	31.13	5.28	3105	46.57	39.58	12.85	2441
<i>U. serrata</i> (?)	.43	.08	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pseudunciola obliqua</i>	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<i>Siphonocetes smithianus</i>	1.29	.24	.00	<1	.95	.03	.00	<1	.26	.01	.00	<1	.76	.04	.00	<1
<i>Rhachotropis oculata</i>	.43	.08	.07	<1	-	-	-	-	-	-	-	-	-	-	-	-
Gammaridae spp.	-	-	-	-	.95	.04	.01	<1	-	-	-	-	-	-	-	-
<i>Melita dentata</i>	.86	.16	.15	<1	13.33	.82	.62	19	9.38	.45	.08	5	2.67	.13	.06	1
<i>Macro ganae</i>	-	-	-	-	.95	.03	.02	<1	.26	.02	.01	<1	-	-	-	-
<i>Casco bigelowi</i>	-	-	-	-	-	-	-	-	1.56	.05	.02	<1	2.29	.13	.12	1
<i>Jerbania</i> sp. A	-	-	-	-	.63	.05	.01	<1	-	-	-	-	.38	.02	.00	<1
<i>Protohaustorius wigleyi</i>	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<i>Photis</i> spp.	-	-	-	-	.32	.01	.00	<1	.78	.02	.00	<1	-	-	-	-
<i>P. dentata</i>	-	-	-	-	2.86	.23	.02	1	4.43	.18	.01	1	1.14	.06	.00	<1
<i>P. macrocoxa</i>	-	-	-	-	-	-	-	-	.52	.02	.00	<1	.38	.02	.00	<1
Lysianassidae	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
<i>Orchomenella pinguis</i>	-	-	-	-	-	-	-	-	.52	.02	.00	<1	-	-	-	-
<i>Hippomedon serratus</i>	-	-	-	-	.95	.03	.02	<1	11.20	.45	.16	7	2.29	.13	.04	<1
<i>Anonyx lilljeborgi</i>	-	-	-	-	.32	.02	.02	<1	-	-	-	-	.38	.02	.01	<1
<i>A. garsi</i>	-	-	-	-	-	-	-	-	1.30	.05	.06	<1	.76	.04	.01	<1
<i>Monoculodes edwardsi</i>	.43	.08	.00	<1	2.86	.14	.04	1	2.34	.07	.01	<1	22.14	2.77	.61	75
<i>Phoxocephalus holbolli</i>	-	-	-	-	6.03	.28	.05	2	22.14	1.72	.11	40	9.92	.67	.05	7
<i>Trichophoxus epistomus</i>	1.29	.24	.07	<1	15.87	1.24	.30	24	8.07	.35	.04	3	9.54	.69	.17	8

Table 9-4. (Continued)

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<i>Harpinia propinqua</i>	-	-	-	-	2.54	.10	.02	<1	.52	.02	.00	<1	.38	.02	.00	<1
<i>Stenopleustes gracilis</i>	-	-	-	-	.32	.01	.00	<1	1.30	.07	.00	<1	.38	.02	.00	<1
<i>S. inermis</i>	-	-	-	-	-	-	-	-	1.30	.04	.00	<1	1.14	.06	.00	<1
<i>Dulchhia porrecta</i>	-	-	-	-	.95	.03	.00	<1	-	-	-	-	-	-	-	-
Stenothoidae	-	-	-	-	-	-	-	-	.78	.02	.00	<1	-	-	-	-
Hyperliidae spp.	19.74	6.24	3.36	189	.95	.03	.01	<1	.26	.01	.00	<1	-	-	-	-
<i>Parathemisto gaudichaudi</i>	46.78	34.44	20.95	2591	.32	.01	.00	<1	.26	.01	.00	<1	35.88	3.75	.48	152
<i>Aeginina longicornis</i>	1.29	.32	.29	1	8.25	.51	.21	6	20.83	1.23	.22	30	4.58	.50	.11	3
Unidentified	6.44	1.50	1.17	17	22.54	.92	.62	35	4.17	.16	.00	1	1.91	.17	.01	<1
Total Amphipoda	91.85	69.67	44.23	10461	91.11	59.46	20.53	7288	93.49	51.73	7.21	5510	98.11	69.43	18.06	744
Euphausiacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphausiidae spp.	-	-	-	-	.32	.01	.01	<1	-	-	-	-	-	-	-	-
Decapoda	-	-	-	-	-	-	-	-	.26	.01	.00	<1	.38	.02	.04	<1
<i>Eualus pusiolus</i>	-	-	-	-	-	-	-	-	4.17	.16	.83	4	24.05	3.36	11.52	358
<i>Dichelopandalus leucomeris</i>	.43	.08	1.31	1	2.86	.30	5.26	16	8.07	.32	.33	5	8.78	.72	1.10	16
<i>Carinon septemspinosa</i>	2.15	.55	4.31	10	4.76	.20	.68	4	.52	.02	.03	<1	-	-	-	-
<i>Axiu serrata</i>	-	-	-	-	1.27	.04	.92	1	1.04	.04	.13	<1	.38	.02	1.57	1
<i>Munida iris</i>	-	-	-	-	5.40	.28	1.88	12	.52	.02	.03	<1	.76	.04	.01	<1
Pagurus spp.	-	-	-	-	.63	.03	.38	<1	1.30	.04	.86	1	-	-	-	-
<i>P. acadianus</i>	-	-	-	-	.63	.02	.24	<1	-	-	-	-	-	-	-	-
<i>P. arcuatus</i>	-	-	-	-	.63	.02	.16	<1	-	-	-	-	-	-	-	-
Calappidae spp. (megalopae)	-	-	-	-	-	-	-	-	-	-	-	-	.76	.06	.03	<1
Cancer spp.	-	-	-	-	1.59	.05	.56	1	.52	.02	.01	<1	1.53	.13	.98	?
<i>C. borealis</i>	-	-	-	-	8.25	.48	14.91	127	7.29	.44	5.99	47	1.53	.08	.45	1
<i>C. irroratus</i>	.86	.55	29.42	26	21.59	1.47	28.54	648	43.75	3.45	38.84	1850	31.68	2.29	31.17	1060
Unidentified	1.72	.32	.29	1	3.49	.16	2.65	10	.26	.01	.00	<1	.76	.04	.09	<1
Total Decapoda	4.72	1.50	35.33	174	34.60	3.05	56.18	2049	53.13	4.51	47.06	2731	48.85	6.77	46.95	2624
Unidentified Crustacea	2.15	.39	2.41	6	4.76	.16	.32	2	1.04	.04	.01	1	.76	.04	.01	<1
Total Crustacea	95.71	96.92	82.92	17212	96.82	96.01	78.95	16940	98.70	60.52	55.91	11491	93.66	81.08	66.69	13987
Insecta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-

Table 9-4. (Concluded)

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Nemertea																
<i>Plascolion strombi</i>	-	-	-	-	-	-	-	-	.26	.01	.00	<1	-	-	-	-
Ectoprocta																
Unidentified	-	-	-	-	.95	.03	.01	<1	1.30	.04	.00	<1	.76	.04	.01	<1
Echinodermata																
Asteroidea																
<i>Asterias vulgaris</i>	-	-	-	-	.32	.01	.04	<1	-	-	-	-	-	-	-	-
Echinoidea																
<i>Echinarachnius parma</i>	.43	.08	.58	<1	4.13	.13	.12	1	-	-	-	-	-	-	-	-
Echinothuroidea																
<i>Stereoderma unisemita</i>	-	-	-	-	-	-	-	-	.26	.01	.02	<1	-	-	-	-
<i>Havelockia scabra</i>	-	-	-	-	.95	.03	.65	1	-	-	-	-	-	-	-	-
Total Echinodermata	.43	.08	.58	<1	5.08	.18	.81	5	.26	.01	.02	1	-	-	-	-
Chaetognatha																
<i>Sagitta elegans</i>	-	-	-	-	-	-	-	-	42.19	36.44	3.71	1694	29.34	16.13	2.03	534
Chordata																
Larvacea																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.08	.12	.01	<1
Pisces																
<i>Raja erinacea</i>	-	-	-	-	-	-	-	-	.26	.01	.16	1	-	-	-	-
Teleostei spp.	1.29	.24	.88	1	1.27	.05	.28	<1	3.39	.11	5.83	29	6.11	.31	1.01	8
<i>Grophycis chuss</i>	.86	.16	1.46	1	.63	.02	.01	<1	2.35	.07	1.69	4	1.91	.10	.57	1
<i>Merluccius bilinearis</i>	-	-	-	-	.63	.02	.07	<1	.26	.01	.02	1	.76	.15	.96	1
<i>Lepophidium cervinum</i>	.43	.08	.73	<1	1.27	.15	.61	1	.78	.03	.29	1	.35	.02	.02	1
<i>Liparis inquilinus</i>	-	-	-	-	-	-	-	-	.32	.02	.00	1	-	-	-	-
<i>Ammodytes</i> spp.	-	-	-	-	.32	.01	.01	<1	.52	.02	.02	1	-	-	-	-
<i>Citharichthys arcifrons</i>	4.72	.0	6.86	37	.32	.01	.08	<1	1.82	.05	1.35	3	1.05	.31	15.54	48
Total Pisces	6.01	1.42	9.93	68	4.44	.27	1.05	6	8.85	.31	9.22	34	11.83	.88	18.09	24
Aves																
(unidentified feathers)	-	-	-	-	-	-	-	-	.26	.01	.00	1	-	-	-	-
Total number of stomachs examined:	295				352				418				284			
Examined stomachs with food:	232				315				384				262			

important at all seasons except winter, when Ampelisca vadorum and A. agassizi became important. Other seasonally important amphipods were Melita dentata and Trichophoxus epistomus in winter, Phoxocephalus holboellii in spring and again, as for Raja erinacea, Monoculodes edwardsi became important in the summer.

Decapod species varied little in relative importance seasonally, and consisted mainly of Cancer irroratus, Dichelopandalus leptocerus, and Crangon septemspinosa. D. leptocerus became more important as food in summer and consisted mainly of post larval and juvenile stages at this time.

With the exception of Aphrodita hastata in the spring and Lumbrineris fragilis in the winter, no single polychaete species was significantly more important than other species within a season or among seasons.

Copepods were important only in fall and winter samples. Centropages typicus was the most important copepod in the fall, and Paracalanus spp. was most important in the winter. All other species of copepods were of minor importance.

Placopecten magellanicus, the deep sea scallop, was the only important pelecypod species and was consumed only by larger fish and is thus absent from the diet in the fall.

Cirolana polita was again the most important isopod at all times of the year, and Citharichthys arctifrons was the most important fish consumed during all seasons except spring, when Urophycis chuss was equally important.

Chaetognaths were only important in the spring and summer, and all identifiable specimens were Sagitta elegans.

Patterns of prey selectivity by Urophycis chuss with respect to prey strata were erratic, and each important prey species exhibited a different pattern (Figure 9-8). Pelagic hyperiid amphipods were, as expected, infrequent in grab samples, but were very important as food items, and comprised over 90% of the total number of individuals in some strata. Relative abundance in stomachs varied greatly, but since relative abundance in benthic samples was consistently very low, electivity values were strongly positive in all strata. This pattern was similar to that found between decapods, which were also not numerous in grab samples, and Raja erinacea.

The relative abundance of Byblis serrata in red hake stomachs followed closely with the relative abundance of this amphipod in the different strata. However, unlike Raja erinacea, red hake did not show a generally strong positive selection for B. serrata. Red hake appeared to consume the amphipods in proportion to their abundance in the benthos and demonstrated almost neutral or strong positive

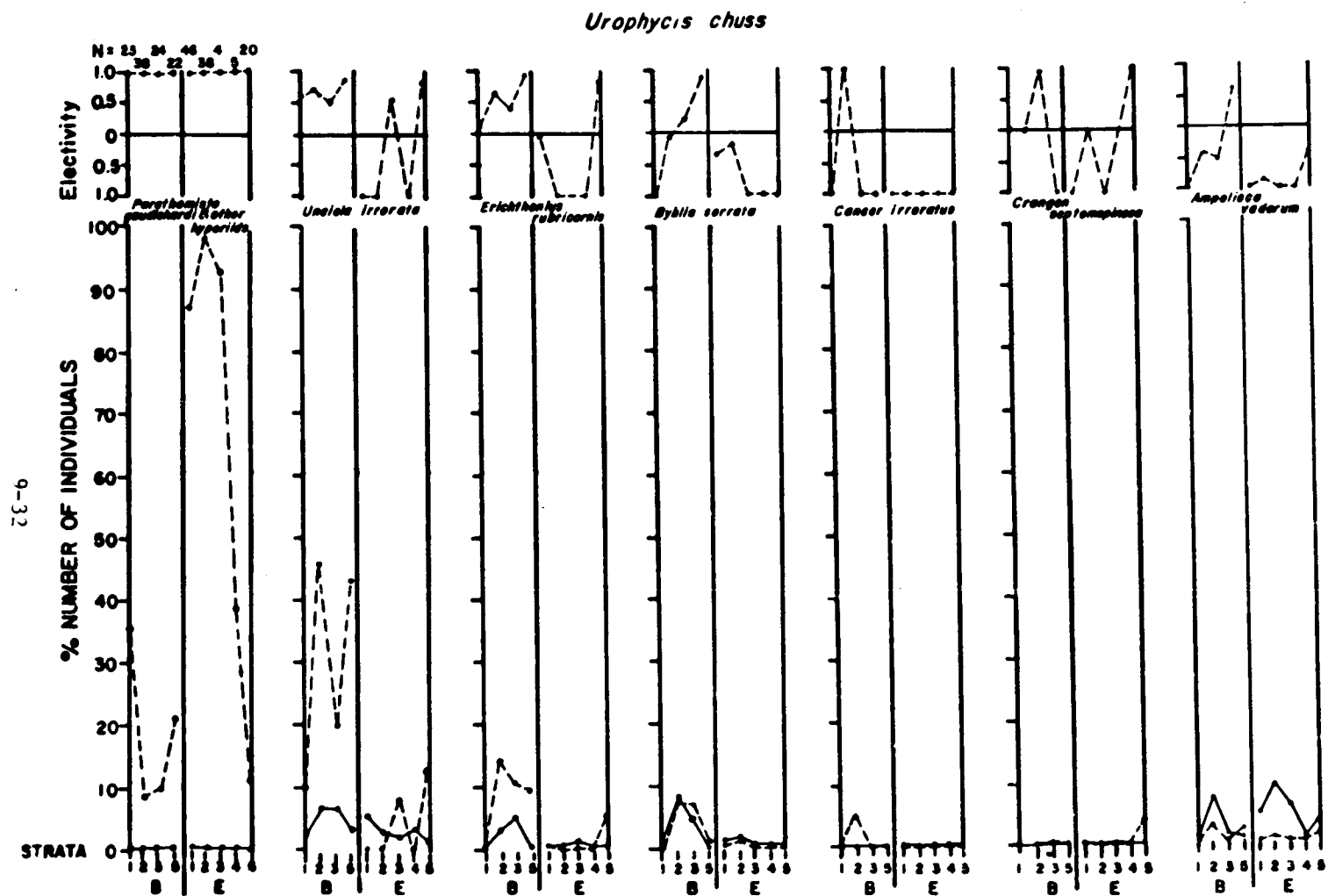


Figure 9-8. Relative abundance in *Urophycis chuss* stomachs (•--•) and grab samples (•—•), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

selection for them where they were abundant. However, when B. serrata was present in low numbers they were consumed in lower numbers or not at all.

The abundance of Ampelisca vadorum among the various strata, like that of Byblis serrata, had a similar trend in abundance in both the benthos and the diet, but in this case the amphipod was generally consumed in much smaller numbers resulting in generally negative electivity value.

Predation by red hake on Erichthonius rubricornis did not appear to be proportional to the abundance of this amphipod in the benthos. However, as in Byblis serrata, positive selection was exhibited when this amphipod was relatively abundant, but it was not an important prey when it was relatively scarce.

Decapods were relatively unimportant in the diet of red hake in the fall, and, due to their low relative abundance in both stomachs and benthic samples, electivity values fluctuated greatly. However, since decapods were very important in the diet of larger hake collected in other seasons, it is likely that red hake show a consistently high positive selectivity for decapods, as has been observed in Raja erinacea.

In addition to the previously discussed prey species, Urophycis chuss fed heavily on several prey species which were absent from grab samples because they are either highly mobile or pelagic. These prey species include calanoid copepods and fishes such as small U. chuss and Citharichthys arctifrons.

Urophycis regius

Spotted hake, Urophycis regius, were common in the study area in fall and were abundant in summer. They were rare in the colder months, and only two were captured in winter.

Decapod Crustacea was the most important higher taxon of food for spotted hake during all seasons for which adequate data were available (Figure 9-9). Fishes and amphipods were next in importance in fall and summer, and the relative importance of these and other taxa of food was similar during these seasons. The relative importance of these taxa was different in spring samples, but this may be a reflection of the small sample size available. In spring, decapods were followed in importance by cephalopods, fishes, and pelecypods, with amphipods and isopods being of nearly equal low importance.

At the species level, food habits changed considerably seasonally (Table 9-5). Crangon septemspinosa was by far the most important decapod prey species in fall, followed by Cancer irroratus and Dichelopandalus leptocerus. In spring, Cancer irroratus became the

Urophycis regius

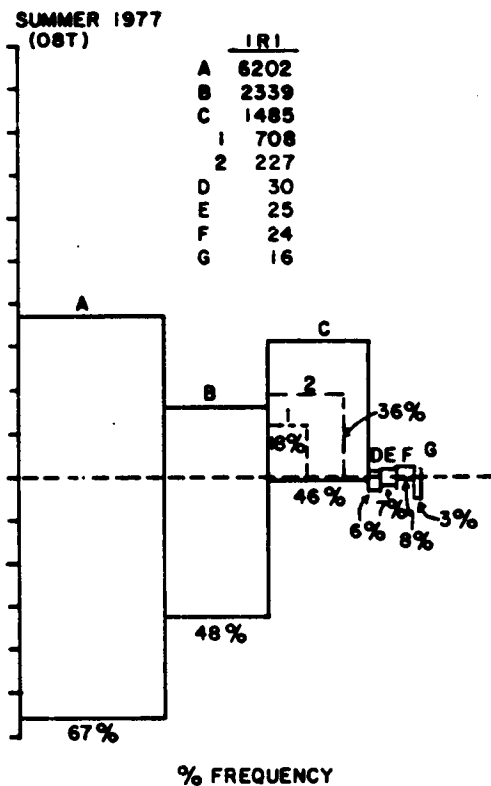
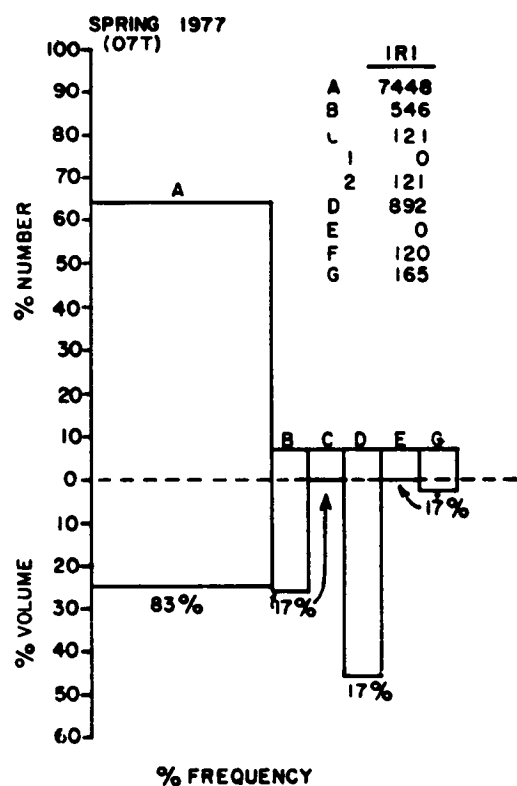
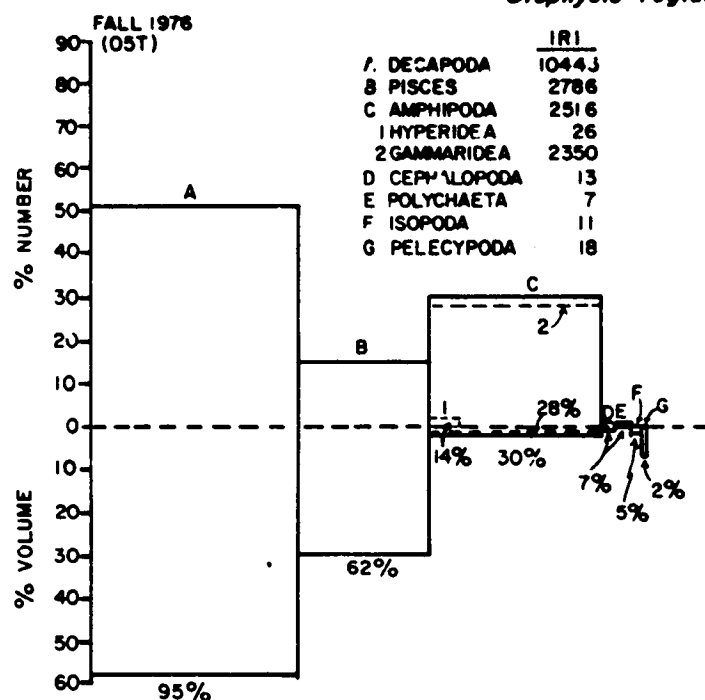


Figure 9-9. Percent frequency occurrence, percent number, percent volume displacement, index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Urophycis regius*, by season.

Table 9-5. Urophycis regius. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
<u>Harmothoe extenuata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	.41
<u>Sthenelais limicola</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.19	.41
Nephtyidae	2.38	.28	.07	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Aglaophanus circinatus</u>	2.38	.28	.07	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Onuphis pallidula</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.51	.06	1
Eunicidae spp.	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	1.50	2
Unidentified	2.38	.28	.00	1	-	-	-	-	-	-	-	-	2.68	.68	.07	2
Total Polychaeta	7.14	.85	.14	7	-	-	-	-	-	-	-	-	6.71	1.88	1.95	25
Mollusca																
Pelecypoda																
<u>Placopecten magellanicus</u>	2.38	.28	7.15	18	-	-	-	-	16.67	7.14	2.73	164	2.01	.51	5.39	12
<u>Ensis directus</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	.41
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.68	.68	5.42	16
Total Pelecypoda	2.38	.28	7.15	18	-	-	-	-	16.67	7.14	2.73	165	-	-	-	-
Cephalopoda																
<u>Illex illecebrosus</u>	-	-	-	-	-	-	-	-	16.67	7.14	46.36	892	-	-	-	-
<u>Rossia tenera</u>	7.14	.85	.95	13	-	-	-	-	-	-	-	-	5.37	1.37	3.30	25
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.06	.41
Total Cephalopoda	7.14	.85	.95	13	-	-	-	-	16.67	7.14	46.36	892	5.04	1.54	3.36	30
Total Mollusca	9.52	1.14	8.11	80	-	-	-	-	33.33	14.29	49.09	2117	8.05	2.22	8.78	89
Crustacea																
Copepoda																
<u>Calanus finmarchicus</u>	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	.41
<u>Centropages typicus</u>	2.38	.57	.00	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Canthacis armata</u>	2.38	.28	.00	1	-	-	-	-	-	-	-	-	.67	.17	.00	.41
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.68	.00	1
Total Copepoda	2.38	.85	.00	2	-	-	-	-	-	-	-	-	4.03	1.20	.00	5
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.03	.41
Cumacea																
<u>Eudorella</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	.41
Isopoda																
<u>Cirolana polita</u>	4.76	.57	1.67	11	-	-	-	-	16.67	7.14	.05	120	7.38	2.39	.46	21
<u>Janira alta</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.01	.41
Total Isopoda	4.76	.57	1.67	11	-	-	-	-	16.67	7.14	.05	120	8.05	2.56	.47	24
Amphipoda																
<u>Ampelisca</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	.41

Table 9-5.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<u>A. vadorum</u>	2.38	1.42	.12	4	-	-	-	-	-	-	-	-	4.03	1.20	.03	5
<u>A. agassizi</u>	4.76	.85	.07	4	-	-	-	-	-	-	-	-	3.36	1.37	.01	5
<u>Bylis serrata</u>	14.29	1.70	.00	24	-	-	-	-	-	-	-	-	.67	.17	.00	41
<u>Leptocheirus pinguis</u>	2.38	.28	.24	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Erichthonius rubricornis</u>	14.29	1.99	.02	29	-	-	-	-	-	-	-	-	4.03	1.37	.01	6
<u>Unciola irrorata</u>	59.52	20.45	1.50	1307	-	-	-	-	-	-	-	-	14.76	9.74	.26	148
<u>Rhachotropis oculata</u>	2.38	.57	.00	1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Melita dentata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.02	41
<u>Protohastorius wigleyi</u>	-	-	-	-	-	-	-	-	-	-	-	-	1.34	.34	.00	1
<u>Hippomedon serratus</u>	-	-	-	-	-	-	-	-	16.67	7.14	.14	121	1.34	.34	.01	41
<u>Anonyx sarai</u>	2.38	.28	.12	1	-	-	-	-	-	-	-	-	1.34	.34	.00	41
<u>Monoculodes edwardsi</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.68	.85	.01	2
<u>Phoxocephalus holballi</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.01	.51	.00	1
<u>Trichophoxus spistomus</u>	2.38	.28	.00	1	-	-	-	-	-	-	-	-	8.05	2.56	.06	21
<u>Parathemisto gaudichaudi</u>	14.29	1.70	.10	26	-	-	-	-	-	-	-	-	18.12	12.31	.22	227
<u>Aeginina longicornis</u>	2.38	.28	.02	1	-	-	-	-	-	-	-	-	-	-	-	-
Total Amphipoda	78.57	29.83	2.19	2516	-	-	-	-	16.67	7.14	.14	121	46.31	31.45	.62	1485
Euphausiacea																
<u>Thysanoessa inermis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	41
Decapoda																
<u>Dichelopandalus leptocerus</u>	19.05	5.40	12.57	342	-	-	-	-	-	-	-	-	44.67	27.01	14.05	1846
<u>Crangon septemspinosa</u>	85.71	32.10	4.54	4740	-	-	-	-	16.67	14.29	.55	247	3.36	1.03	.23	4
<u>Munida iris</u>	9.52	1.42	.33	17	-	-	-	-	-	-	-	-	2.08	.68	1.63	6
<u>Cancer spp.</u>	2.38	.57	.12	2	-	-	-	-	-	-	-	-	-	-	-	-
<u>C. borealis</u>	7.14	3.41	5.96	67	-	-	-	-	16.67	14.29	4.91	320	1.34	.34	.13	1
<u>C. irroratus</u>	26.19	8.24	13.71	575	-	-	-	-	83.33	35.71	19.63	4612	24.16	7.52	39.56	1137
Unidentified	2.38	.28	.00	1	-	-	-	-	-	-	-	-	.67	.17	.06	41
Total Decapoda	95.24	51.42	58.23	10443	-	-	-	-	83.33	64.29	25.09	7448	67.11	36.75	55.66	6202
Unidentified Crustacea	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.01	41
Total Crustacea	95.24	82.67	62.09	13787	-	-	-	-	83.33	78.57	25.28	8654	66.58	72.82	56.79	11222
Sipuncula																
<u>Phascolion strombi</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.00	1
Chaetognaths																
<u>Sagitta elegans</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	6.32	.06	4
Chordata																
Pisces																
<u>Teleostei spp.</u>	2.38	.28	.02	1	100	100	100	20000	16.67	7.14	25.63	546	22.15	5.64	4.21	218
<u>Etrumeus sadina</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	5.01	3
<u>Urophycis chuss</u>	7.14	.85	3.93	34	-	-	-	-	-	-	-	-	3.36	.85	9.68	35
<u>Merluccius bilinearis</u>	2.38	.28	1.91	5	-	-	-	-	-	-	-	-	6.74	4.27	5.33	59
<u>Lepophidium cervinum</u>	14.29	1.99	5.72	110	-	-	-	-	-	-	-	-	.67	.17	.06	41
<u>Liparis inquilinus</u>	-	-	-	-	-	-	-	-	-	-	-	-	.67	.17	.06	41
<u>Citharichthys stictifrons</u>	50.00	11.93	18.07	1500	-	-	-	-	-	-	-	-	16.11	5.30	7.85	212
Total Pisces	61.90	15.34	29.66	2786	100	100	100	20000	16.67	7.14	.26	546	47.65	16.58	32.51	2339
Number of stomachs examined:		45				2				7				150		
Examined stomachs with food:		42				1				6				149		

most important decapod, followed by Cancer borealis and Crangon septemspinosa. D. leptocerus was not consumed at all in the spring, but was the most important decapod prey in summer, when many postlarvae and juveniles were consumed. Cancer irroratus was also important in the summer, but Crangon septemspinosa was of minor importance.

Among the fishes, Citharichthys arctifrons was the most important prey species. Lepophidium cervinum was an important prey in the fall, and Urophycis chuss and Merluccius bilinearis were important in fall and summer.

Unciola irrorata was the most important amphipod prey in the fall, followed by Erichthonius rubricornis, Parathemisto gaudichaudii, and Byblis serrata. In summer, the pelagic hyperiid P. gaudichaudii was the most important amphipod, followed by U. irrorata and Trichophoxus epistomus.

Rossia tenera was the most important cephalopod during the warmer fall and summer seasons. Illex illecebrosus was frequently captured in the study area in winter and spring, but was absent in summer and fall, and this is reflected in the diet of Urophycis regius.

Polychaetes were consumed infrequently, and no one polychaete species was dominant in the diet. The deep-sea scallop, Placopecten magellanicus, was the most important bivalve consumed, and Cirolana polita was the most important isopod.

Results of the electivity index analysis for Urophycis regius were quite erratic and generally uninterpretable (Figure 9-10). Because U. regius was not abundant in the fall, sample sizes for each stratum were very small. Also, U. regius fed heavily on animals, such as fishes and cephalopods, that were not captured by grabs. For these reasons, few patterns of selection with respect to strata could be found.

Crangon septemspinosa was important in the diet in all strata, and Urophycis regius exhibited a consistently high positive selectivity for this decapod (Figure 9-10). If strata with extremely low sample sizes (2, 4, and 5 in area B) are ignored, Cancer irroratus and Dichelopandalus leptocerus abundance and electivity were similar to those of C. septemspinosa. Cancer borealis was abundant in the benthos in deeper habitat strata, but this crab was not a frequent food item. The amphipods Unciola irrorata and Erichthonius rubricornis were quite abundant in fish stomachs from some strata, but this abundance was not correlated with abundance in the benthos, and electivity values fluctuated widely. Hyperiid amphipods were generally not eaten, but due to low relative abundance in the benthos, a high positive selectivity was found when these amphipods were consumed.

Urophycis regius

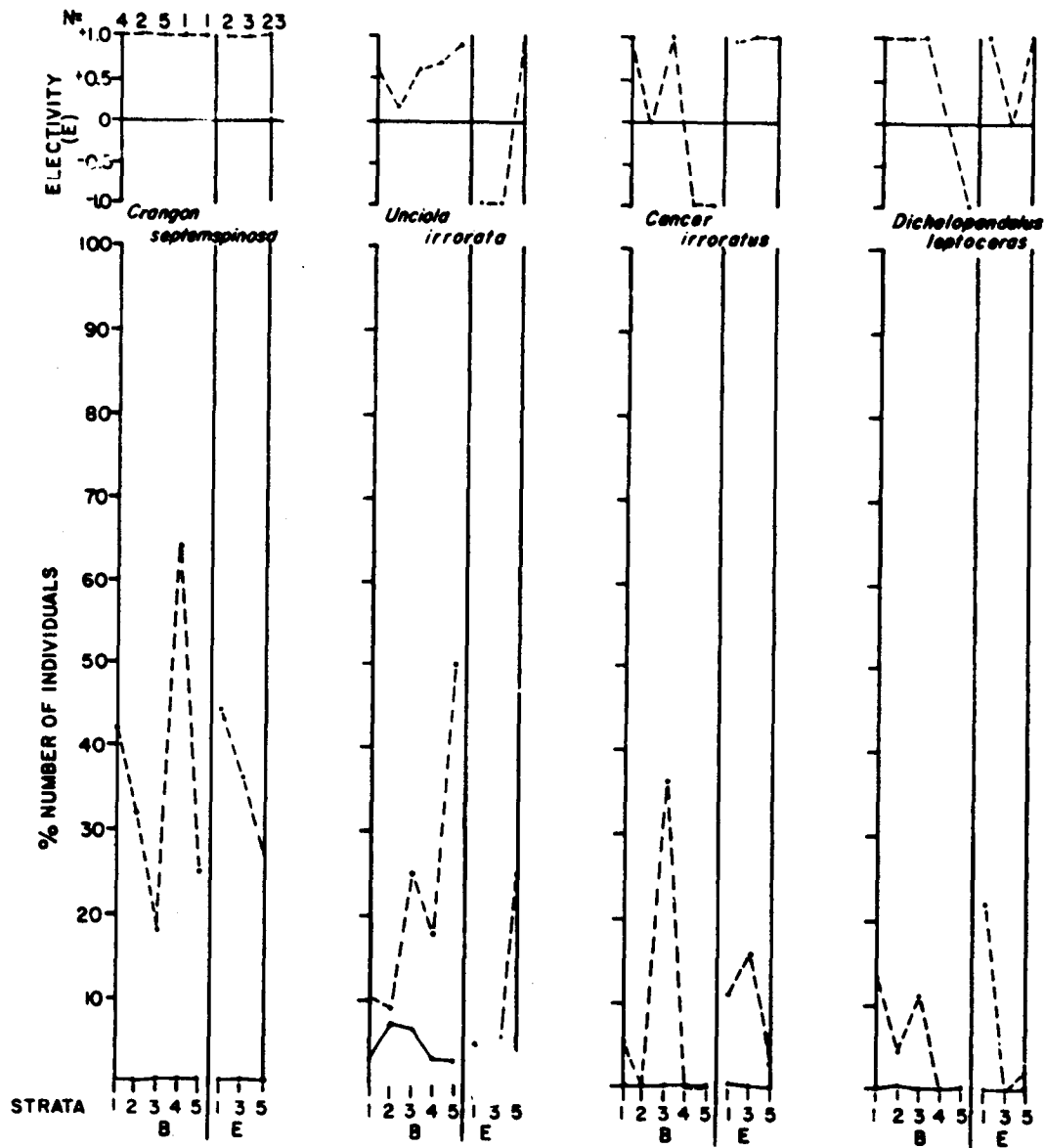


Figure 9-10. Relative abundance in *Urophycis regius* stomachs (---○---), and grab samples (—●—), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

Urophycis regius (cont.)

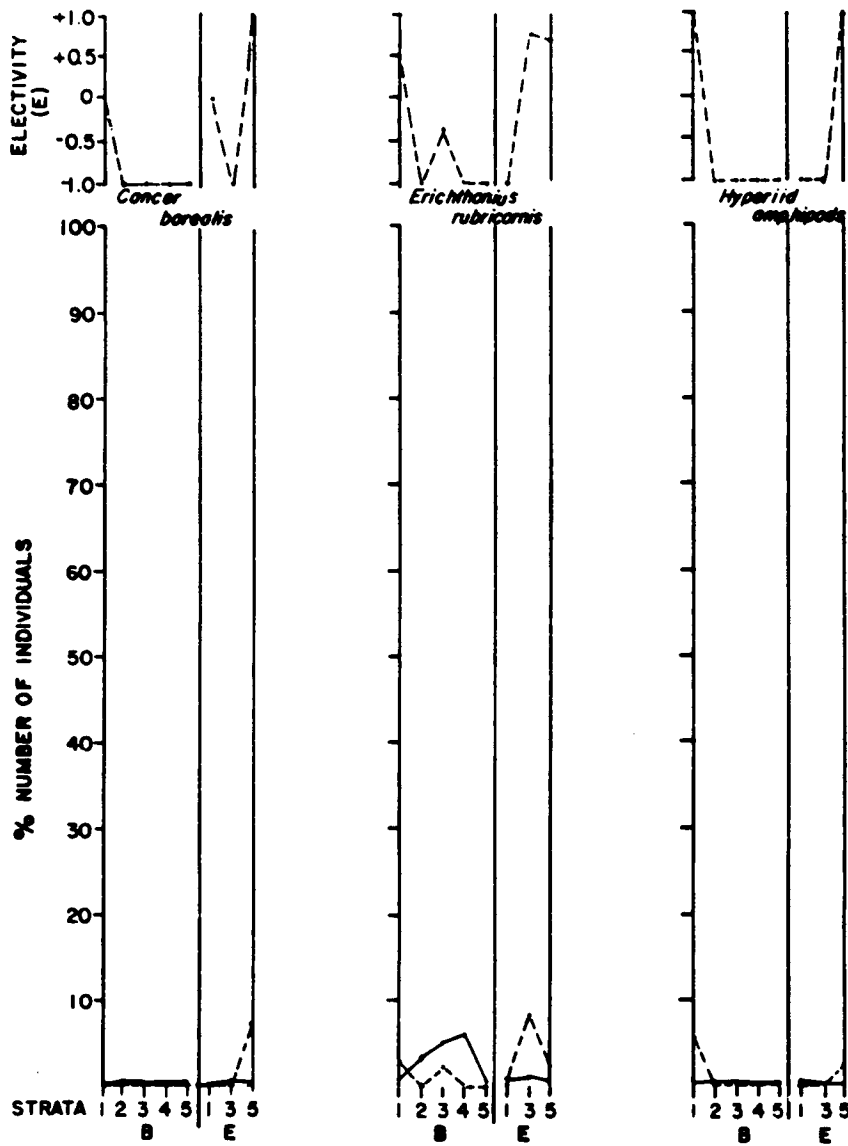


Figure 9-10. (Continued)

Merluccius bilinearis

The silver hake, Merluccius bilinearis, was abundant in the study area at all times of the year but less so in spring. Again, as in red hake, small juvenile fish dominated the catches in fall and summer (Table 9-1). Food habits of this species varied greatly with season (Figure 9-11). Amphipods were the most important group of food items in fall, winter, and summer. Fishes were second in importance in winter and summer and were relatively unimportant in fall and spring. Cephalopods replaced fishes as the second most important food group in spring and were quite important in fall also. They were consumed little in winter and summer, when fishes were second in importance. Decapods were third in importance in winter and summer, whereas copepods were third in importance in fall and amphipods in spring. Chaetognaths were absent in the diet in fall, were relatively unimportant in winter, but were the most important prey taxon in spring. They were also consumed frequently in the summer.

Planktonic hyperiid amphipods (Parathemisto gaudichaudii) were the most important amphipods during all seasons (Table 9-6). Byblis serrata and Ampelisca vadorum were important in fall and summer, and A. agassizi was also an important prey species in summer. Hippomedon serratus was frequently consumed in the winter but spring fish that fed on amphipods ate P. gaudichaudii almost exclusively.

The relative importance of different fish species in the diet also changed seasonally. Round herring, Etrumeus sadina, was the most important species in the fall, followed by small Merluccius bilinearis and Citharichthys arctifrons. M. bilinearis became the most important fish in the diet in winter and summer, and C. arctifrons was most important in spring. Red hake, Urophycis chuss, was seasonally important especially in summer.

Species composition of cephalopods in the diet changed seasonally, reflecting changes in species composition of these squids in the trawl catches. Loliginids, probably all Loligo pealei, were most important in the warmer seasons, fall and summer. Illex illecebrosus was by far the most important squid eaten in spring, and Rossia tenera was eaten in small amounts all year.

Dichelopandalus leptocerus was the most important decapod food at all times of the year. Crangon septemspinosa was also important at all times of the year except spring, when few decapods were eaten. Brachyuran larvae (zoea and megalopae) were frequently consumed in the fall and summer, probably reflecting peaks in abundance of these stages in the near-bottom plankton. Copepods were significant in the diet in fall and winter only and consisted primarily of Centropages typicus in the fall and Paracalanus spp. in the winter. All identifiable chaetognaths were Sagitta elegans, and these were a very important food item in spring. Cumaceans in the diet were primarily

Merluccius bilinearis

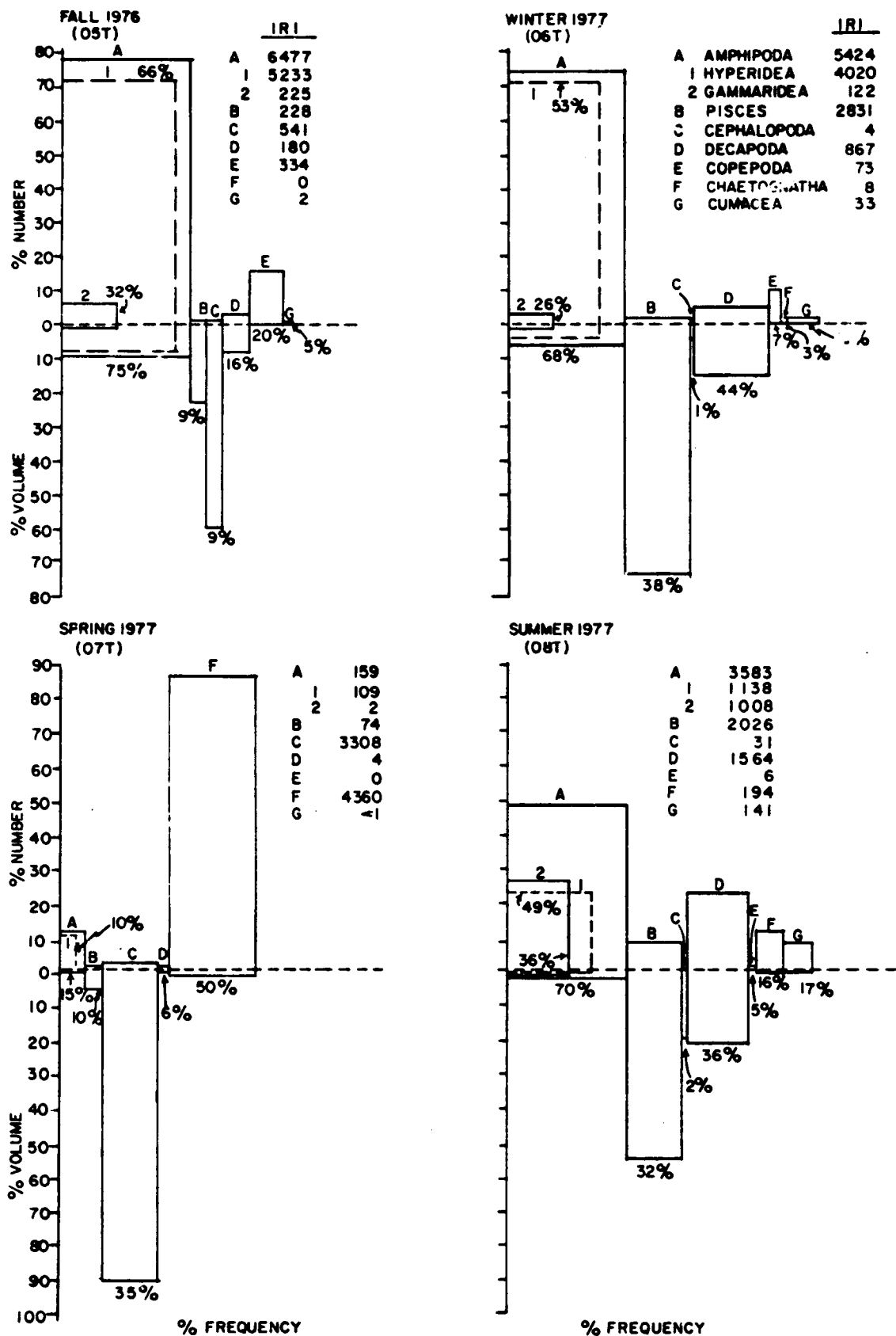


Figure 9-11. Percent frequency occurrence, percent number, percent volume displacement, a index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Merluccius bilinearis*, by season.

Table 9-6. Merluccius bilinearis. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

24-6

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977				
	Food Item	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cnidaria																	
Hydrozoa																	
Unidentified	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-	-
Annelida																	
Polychaeta																	
<u>Harmothoe extenuata</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.02	<1
<u>Nereis</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	.60	.11	.08	<1
Nephtyidae spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.02	<1
<u>Agiacophanus circinata</u>	-	-	-	-	.50	.05	.00	<1	-	-	-	-	-	-	-	-	-
<u>Ophelina</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Clymenella torquata</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.04	<1
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.04	<1
Total Polychaeta	-	-	-	-	.50	.05	.00	<1	-	-	-	-	-	2.11	.38	.21	1
Mollusca																	
Cephalopoda																	
Loliginidae spp.	3.28	.31	29.45	98	.50	.02	3.40	2	-	-	-	-	-	.30	.05	16.10	5
<u>Loligo pealeii</u>	3.69	.40	28.21	106	-	-	-	-	2.08	.10	8.46	18	-	-	-	-	-
<u>Rossia</u> spp.	-	-	-	-	-	-	-	-	2.08	.20	.01	<1	-	-	-	-	-
<u>R. tenera</u>	.82	.06	.40	<1	.50	.02	.15	<1	4.17	.30	.41	3	-	.90	.16	3.78	4
<u>Illex illecebrosus</u>	-	-	-	-	-	-	-	-	25.00	1.40	80.72	2053	-	-	-	-	-
Unidentified	1.64	.12	.99	2	-	-	-	-	2.08	.10	1.69	4	-	.30	.05	.12	<1
Total Cephalopoda	9.02	.89	59.06	541	1.00	.05	3.55	4	35.42	2.10	91.29	3308	-	1.51	.27	20.01	31
Arthropoda																	
Copepoda																	
<u>Calanus finmarchicus</u>	-	-	-	-	1.00	.05	.00	<1	-	-	-	-	-	.90	.33	.01	<1
<u>Paracalanus</u> spp.	-	-	-	-	5.97	9.01	.02	54	-	-	-	-	-	-	-	-	-
<u>Minicalanus nasutus</u>	2.05	.22	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Nannocalanus minor</u>	2.46	.34	.00	1	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Centropages typicus</u>	15.93	14.90	.02	269	1.49	.68	.00	1	-	-	-	-	-	.30	.05	.00	<1
<u>Candacia armata</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	2.41	.44	.00	1
<u>Metridia lucens</u>	.82	.12	.00	<1	-	-	-	-	-	-	-	-	-	.60	.11	.00	<1
<u>Caligus</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
Unidentified	4.10	.71	.00	3	1.00	.05	.00	<1	-	-	-	-	-	.60	.11	.00	<1
Total Copepoda	20.49	16.29	.02	334	7.46	9.78	.02	73	-	-	-	-	-	5.12	1.10	.02	6
Cumacea																	
<u>Eudorella</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	.90	.22	.01	<1
<u>E. emarginata</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>E. hispidula</u>	-	-	-	-	1.00	.05	.00	<1	-	-	-	-	-	.60	.27	.01	<1
<u>Diastyllis</u> spp.	-	-	-	-	1.99	.22	.01	<1	-	-	-	-	-	-	-	-	-
<u>D. sculpta</u>	-	-	-	-	14.43	1.28	.07	19	2.08	.10	.00	<1	-	3.01	.66	.01	2
<u>D. hispidosa</u>	2.46	.28	.03	1	1.00	.07	.00	<1	-	-	-	-	-	12.65	6.43	.32	85
Unidentified	7.05	.19	.01	<1	.50	.02	.00	<1	-	-	-	-	-	.60	.11	.00	<1
Total Cumacea	4.51	.46	.04	2	18.91	1.65	.08	33	2.08	.10	.00	<1	-	17.47	7.77	.34	141
Isopoda																	
Unidentified	.41	.03	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Cirolana polita</u>	.41	.03	.04	<1	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Isopoda	.82	.06	.04	1	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 9-6.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Amphipoda																
<u>Ampelisca</u> spp.	.82	.06	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>A. yadonii</u>	19.67	2.34	.32	52	2.49	.15	.70	2	-	-	-	-	4.52	1.59	.11	8
<u>A. macrocephala</u>	.41	.03	.01	<1	.50	.02	.00	<1	-	-	-	-	-	-	-	-
<u>A. agassizii</u>	1.64	.22	.02	<1	.50	.02	.00	<1	-	-	-	-	5.42	2.75	.14	16
<u>Byblis serrata</u>	12.70	3.21	.44	46	1.49	.10	.01	<1	2.08	.10	.00	<1	20.48	14.90	1.23	330
<u>Argissa hamatipes</u>	-	-	-	-	4.48	.34	.02	2	-	-	-	-	-	-	-	-
<u>Erichthonius rubricornis</u>	.82	.06	.00	<1	-	-	-	-	-	-	-	-	4.82	1.21	.02	6
<u>Unciola irrorata</u>	.41	.06	.00	<1	4.48	.36	.05	2	-	-	-	-	1.81	.33	.02	1
<u>Hastoriidae</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Photis dentata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.30	.22	.00	<1
<u>Orchomenella minuta</u>	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>O. pinguis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Hippomedon serratus</u>	-	-	-	-	7.46	1.09	.24	10	2.08	.30	.01	1	.06	.11	.04	<1
<u>Anonyx sarsi</u>	-	-	-	-	1.49	.61	.30	1	-	-	-	-	-	-	-	-
<u>Monoculodes</u> spp.	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-
<u>M. edwardsi</u>	-	-	-	-	4.98	.31	.02	2	-	-	-	-	5.72	1.59	.04	9
<u>Harpinia propinqua</u>	.41	.03	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Phoxocephalus holboellii</u>	-	-	-	-	-	-	-	-	-	-	-	-	1.81	.93	.02	2
<u>Trichophoxus epistomus</u>	-	-	-	-	-	-	-	-	-	-	-	-	5.12	2.31	.08	12
<u>Stenopliastes inermis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Hyperidae</u> spp.	9.84	2.09	.42	23	1.99	.73	.10	2	-	-	-	-	-	-	-	-
<u>Parathemisto gaudichaudi</u>	61.89	69.42	7.87	4784	52.24	70.43	4.27	3902	10.42	10.42	.06	109	49.10	22.43	.75	1138
<u>Aeginina longicornis</u>	-	-	-	-	.50	.02	.00	<1	-	-	-	-	-	-	-	-
Unidentified	2.05	.19	.03	<1	2.99	.19	.03	1	-	-	-	-	-	-	-	-
Total Amphipoda	74.59	77.72	9.12	6477	67.66	74.40	5.76	5424	14.58	10.82	.07	159	70.18	48.60	2.46	3583
Euphausiacea																
<u>Euphausiidae</u> spp.	-	-	-	-	.50	1.84	.91	1	-	-	-	-	-	-	-	-
<u>Thysanoessa raschii</u>	.41	.06	.00	<1	.50	2.35	1.06	2	-	-	-	-	-	-	-	-
<u>T. inermis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.01	<1
Total Euphausiacea	.41	.06	.00	<1	1.00	4.19	1.97	6	-	-	-	-	.30	.05	.01	<1
Decapoda																
<u>Libinia</u> spp.	5.74	1.54	7.81	54	23.88	2.88	11.66	347	6.25	.50	.17	4	29.92	18.14	19.10	1077
<u>Grapsidae</u> spp.	-	-	-	-	1.49	.10	.03	<1	-	-	-	-	.30	.05	.00	<1
<u>Crangon septemspinosa</u>	2.87	.28	.30	2	25.87	1.94	2.74	121	-	-	-	-	13.25	4.12	2.35	86
<u>Callinectes</u> spp. megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Geryon quinquevittatus</u> megalopae	-	-	-	-	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Cancer</u> spp. zoea & megalopae	5.74	1.30	.00	7	-	-	-	-	-	-	-	-	.30	.05	.00	<1
<u>Cancer irroratus</u>	-	-	-	-	.50	.02	.33	<1	-	-	-	-	-	-	-	-
Unidentified	2.46	.22	.08	1	1.00	.05	.05	<1	-	-	-	-	-	-	-	-
Total Decapoda	15.57	3.33	8.20	180	43.78	4.99	14.81	867	6.25	.50	.17	4	35.54	22.34	21.46	1564
Unidentified Crustacea	2.87	.31	.06	1	3.48	.17	.05	1	-	-	-	-	-	-	-	-
Total Crustacea	78.69	98.24	17.48	9106	87.06	95.18	22.69	10762	18.75	11.42	.24	219	55.34	40.04	24.29	8436
Echinodermata																
Asteroidae																
<u>Asterias vulgaris</u>	-	-	-	-	.50	.02	.14	<1	2.08	.10	.05	<1	-	-	-	-
<u>Astropecten americanus</u>	.41	.03	.06	<1	-	-	-	-	-	-	-	-	-	-	-	-
Total Asteroidae	.41	.03	.06	<1	.50	.02	.14	<1	2.08	.10	.05	<1	-	-	-	-

Table 9-6.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Echinoidea																
<u>Echinorachnius perma</u>	-	-	-	-	1.99	.10	.77	2	4.17	.20	.34	2	-	-	-	-
Total Echinodermata	.41	.03	.06	.41	2.49	.12	.90	3	6.25	.30	.39	4	-	-	-	-
Chaetognatha																
<u>Sagitta elegans</u>	-	-	-	-	2.99	2.40	.15	8	20.00	85.57	1.62	4360	16.27	11.60	.33	194
Chordata																
Pisces																
Teleostei spp.	2.05	.15	2.61	6	19.40	.94	13.03	271	4.17	.20	.11	1	13.55	2.64	10.62	177
Clupeidae spp.	-	-	-	-	1.49	.07	14.29	21	-	-	-	-	-	-	-	-
<u>Etrumeus sadina</u>	.82	.06	19.10	16	1.00	.05	30.92	31	-	-	-	-	1.30	.95	7.21	1
<u>Urophycis chuss</u>	3.28	.25	.77	3	1.99	.15	5.56	11	-	-	-	-	3.92	.77	22.46	93
<u>Merluccius bilinearis</u>	1.23	.09	.51	1	10.45	.53	8.69	96	-	-	-	-	12.15	3.19	4.92	99
<u>Ammodytes</u> spp.	-	-	-	-	3.98	.44	.30	3	-	-	-	-	1.83	.55	11.64	22
<u>Peprilus triacanthus</u>	-	-	-	-	-	-	-	-	2.08	.20	4.23	9	-	-	-	-
<u>Citharichthys arctifrons</u>	2.46	.28	.41	2	-	-	-	-	4.17	.20	2.12	10	2.41	.49	3.12	9
Total Pisces	9.43	.83	23.40	229	37.81	2.18	72.71	2831	10.42	.60	6.46	24	31.23	7.79	55.17	2096
Total number of stomachs examined:		272				282				109				185		
Examined stomachs with food:		244				201				48				132		

Diastylis sculpta in winter and spring and D. bispinosa in fall and summer.

Analysis of food habits and selectivity of Merluccius bilinearis with respect to strata revealed few consistent patterns (Figure 9-12). Much of the food of the silver hake consisted of pelagic invertebrates (hyperiids, cephalopods, copepods, chaetognaths) and highly mobile fishes. Hyperiid amphipods are found in low numbers in grabs from all strata, and electivity values for them were consistently high. Dichelopandalus leptocerus occurred in low numbers or was completely absent from grab samples. When it occurred in low numbers, M. bilinearis showed a strong positive selection for it. However in strata where it was not taken, such as all of area E, it was not consumed, indicating that M. bilinearis opportunistically feeds on this species when it is present in high enough concentrations but does not actively search for it when it is rare. With the exception of stratum 4 in area E which had a small sample size, the abundance of Ampelisca vadorum in stomachs closely paralleled its abundance in the benthos, with M. bilinearis showing a generally moderate positive selection for this amphipod. Predation on another important amphipod, Byblis serrata, was quite erratic. In area B this amphipod was consumed in high numbers where it was abundant in benthic samples, but in area E this relationship did not hold. This may be an artifact of the smaller sample size for strata in area E.

Macrozoarces americanus

The ocean pout, Macrozoarces americanus, varied greatly in its relative abundance, but at times made up a significant portion of the catch (Table 9-1). Abundances were low in fall (23 individuals), winter (46 individuals), and spring (84 individuals). In summer, however, many juveniles were present in the study area, and abundance of ocean pout increased tremendously (397 individuals).

Macrozoarces americanus fed mainly on amphipods and decapods (Figure 9-13), which made up a large proportion of the diet at all seasons of the year for which data were available (none of the fishes taken in fall had food in their stomachs). Polychaetes were important in the diet in winter and spring but were of minor importance in summer. Cumaceans were eaten in small amounts during all seasons, and pelecypod molluscs were slightly important in winter and summer. Echinoids were important in the diet in winter but were unimportant or absent from the diet at other times of the year.

At the species level, food habits were somewhat different seasonally (Table 9-7). Unciola irrorata, an important amphipod in the diet at all times of the year, was most important in winter. Erichthonius rubricornis was the most important food item in spring and summer, but was second to U. irrorata in winter. These two species were by far the most important amphipods in the diet of

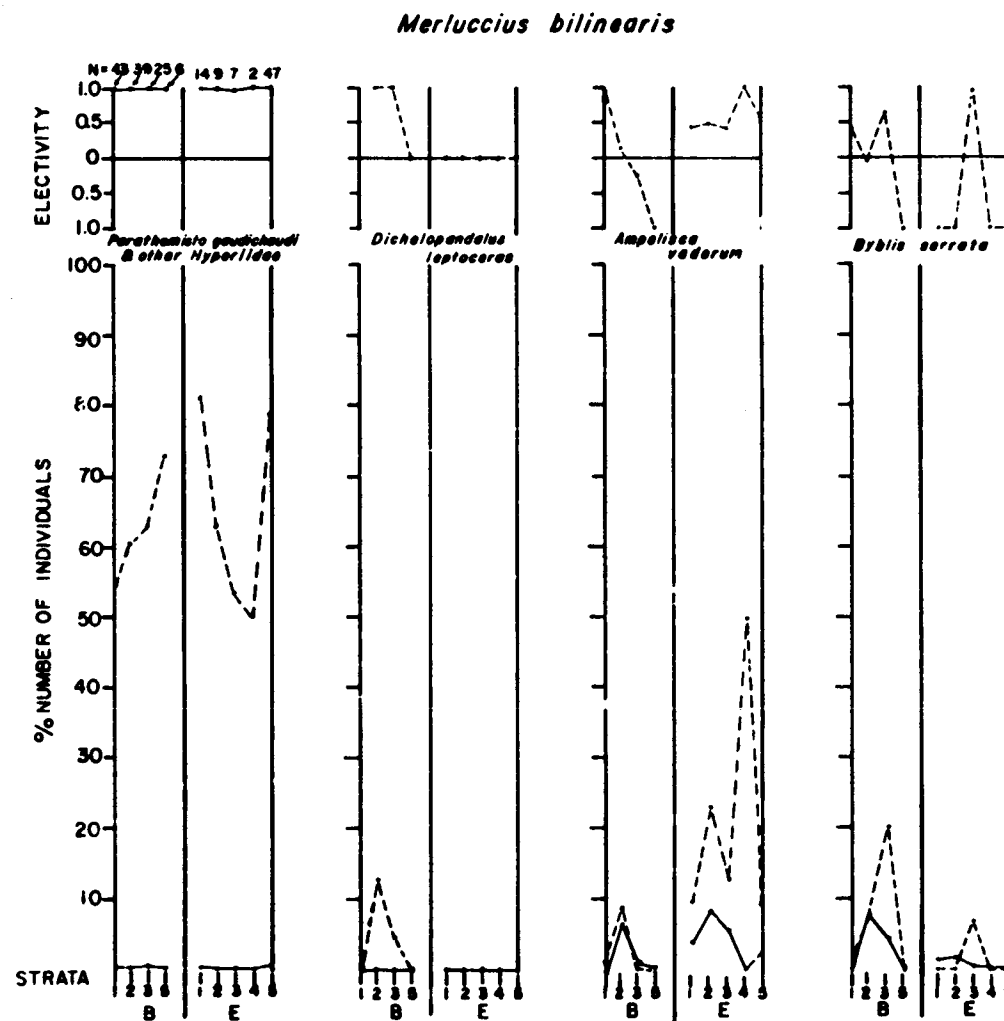


Figure 9-12. Relative abundance in *Merluccius bilinearis* stomachs (•--•) and grab samples (•—•), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

Macrozoarces americanus

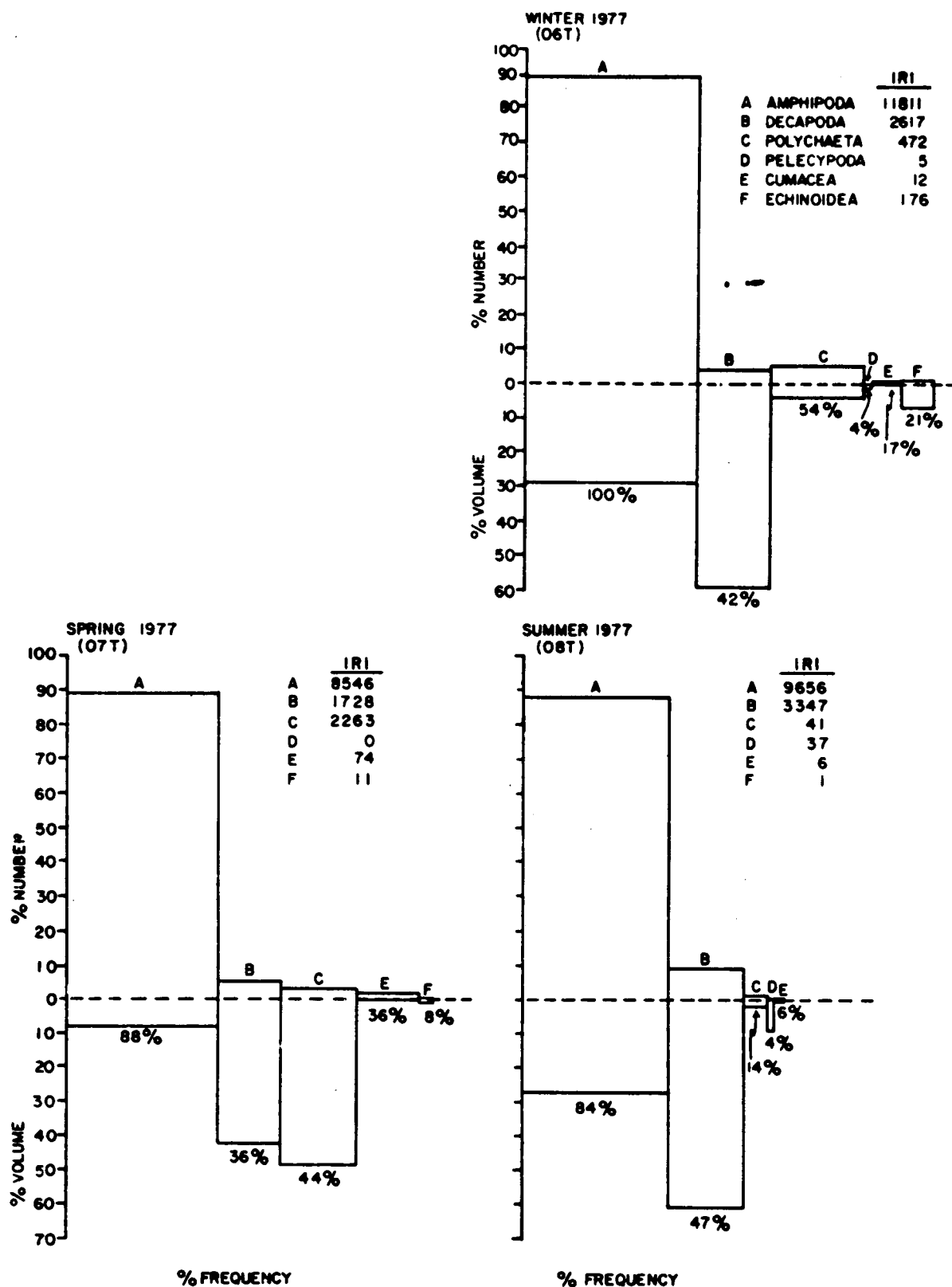


Figure 9-13. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Macrozoarces americanus*, by season.

Table 9-7. Macrozoarces americanus. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
<u>Aphrodita hastata</u>	-	-	-	-	-	-	-	-	4.00	.33	47.44	191	-	-	-	-
<u>Harmothoe extenuata</u>	-	-	-	-	25.00	1.11	1.57	67	28.00	1.11	.33	40	4.55	.31	.85	5
<u>Pholoe minuta</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.08	<1
<u>Scalibregma inflatum</u>	-	-	-	-	-	-	-	-	4.00	.11	.05	1	-	-	-	-
Maldanidae spp.	-	-	-	-	4.17	.11	.27	2	-	-	-	-	.65	.04	.04	<1
<u>Clymenura</u> sp. A	-	-	-	-	-	-	-	-	4.00	.11	.02	1	.65	.04	.04	<1
<u>Lumbrinella fragilis</u>	-	-	-	-	4.17	.11	.05	1	-	-	-	-	-	-	-	-
<u>Ampharete arctica</u>	-	-	-	-	16.67	1.22	1.41	44	-	-	-	-	-	-	-	-
<u>Fiabelligeridae</u> sp. A	-	-	-	-	-	-	-	-	4.00	.22	.19	2	-	-	-	-
<u>Brada</u> spp.	-	-	-	-	4.17	1.11	.27	6	-	-	-	-	-	-	-	-
<u>Euchone</u> spp.	-	-	-	-	8.33	.88	.22	9	-	-	-	-	-	-	-	-
<u>Chone infundibuliformis</u>	-	-	-	-	-	-	-	-	12.00	1.11	.40	18	3.25	.52	.19	2
Unidentified	-	-	-	-	8.33	.22	.16	3	-	-	-	-	4.55	.31	.53	4
Total Polychaeta	-	-	-	-	54.17	4.76	3.95	472	44.00	2.99	48.43	2263	13.64	1.27	1.78	41
Mollusca																
Pelecypoda																
<u>Placopecten magellanicus</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.60	.22	8.57	23
<u>Cyclocardia borealis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.22	.19	<1
<u>Ensis directus</u>	-	-	-	-	4.17	.11	1.08	5	-	-	-	-	1.30	.13	.23	<1
Total Pelecypoda	-	-	-	-	4.17	.11	1.08	5	-	-	-	-	3.90	.57	8.99	37
Crustacea																
Copepoda																
<u>Gandacia armata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Cumacea																
<u>Eudorella hispidia</u>	-	-	-	-	-	-	-	-	4.00	.11	.00	1	-	-	-	-
<u>Diastylis sculpta</u>	-	-	-	-	12.50	.44	.00	6	32.00	1.33	.57	45	3.25	.26	.08	1
<u>D. bispinosa</u>	-	-	-	-	4.17	.22	.05	1	12.00	.55	.00	7	3.25	.39	.15	2
Total Cumacea	-	-	-	-	16.67	.66	.05	12	36.00	1.99	.57	74	6.49	.65	.23	5
Isopoda																
<u>Janira alta</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
Amphipoda																
<u>Ampelisca</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.65	.26	.12	<1
<u>A. vadorum</u>	-	-	-	-	4.17	.11	.00	1	16.00	1.22	.14	22	11.67	2.40	1.08	4
<u>A. agassizi</u>	-	-	-	-	-	-	-	-	4.00	.88	.12	4	-	-	-	-
<u>Byblis serrata</u>	-	-	-	-	4.17	.11	.05	1	4.00	.11	.00	<1	1.95	.13	.04	<1
<u>Leptocheirus pinguis</u>	-	-	-	-	-	-	-	-	4.00	.11	.12	1	.65	.04	.04	<1
<u>Erichthonius ruber</u> cornis	-	-	-	-	70.83	43.69	6.11	3528	84.00	71.90	5.79	6526	72.08	63.74	13.20	3346
<u>Unciola irrorata</u>	-	-	-	-	100.00	44.91	22.84	6775	72.00	13.50	1.85	1105	63.65	21.25	12.54	2150
<u>Melita dentata</u>	-	-	-	-	-	-	-	-	8.00	.22	.00	2	-	-	-	-
<u>Photis dentata</u>	-	-	-	-	-	-	-	-	8.00	.44	.02	4	.65	.04	.00	<1
<u>Monoculodes edwardi</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
<u>Phoxocephalus holbailli</u>	-	-	-	-	4.17	.11	.00	1	4.00	.11	.00	1	.65	.04	.00	<1
<u>Stenopleustes irrmis</u>	-	-	-	-	-	-	-	-	8.00	.33	.00	3	-	-	-	-
<u>Parathemisto gaudichaudi</u>	-	-	-	-	-	-	-	-	-	-	-	-	1.30	.04	.00	<1

Table 9-7.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
<u>Aeginina longicornis</u>	-	-	-	-	4.17	.11	.05	1	8.00	.22	.02	2	2.60	.17	.04	<1
Total Amphipoda	-	-	-	-	100.00	89.05	29.06	11811	88.00	89.05	8.06	3546	83.77	88.22	27.06	9656
Decapoda																
<u>Crangon septemspinosa</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.39	<1
<u>Calappidae spp. megalopae</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.00	<1
<u>Cancer spp.</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.12	<1
<u>C. borealis</u>	-	-	-	-	4.17	.11	1.08	5	4.00	.33	1.07	6	4.55	.31	6.10	29
<u>C. irroratus</u>	-	-	-	-	41.67	3.98	57.63	2567	36.00	5.20	41.39	1677	44.16	8.64	54.92	2806
Total Decapoda	-	-	-	-	41.67	4.09	58.71	2617	36.00	5.53	42.46	1728	47.40	9.08	61.52	3347
Total Crustacea	-	-	-	-	100.00	93.31	87.93	18163	100.00	96.57	50.59	14716	96.10	98.04	88.81	17957
Echinodermata																
Echinoidea																
<u>Echinarachnius parma</u>	-	-	-	-	20.83	1.33	7.14	176	8.00	.33	.95	10	1.30	.09	.23	<1
Ophiuroidea																
<u>Amphiopus macilentus</u>	-	-	-	-	-	-	-	-	4.00	.11	.02	1	-	-	-	-
Total Echinodermata	-	-	-	-	20.83	1.33	7.14	176	8.00	.44	.97	11	-	-	-	-
Chordata																
Pisces																
<u>Teleostei spp.</u>	-	-	-	-	-	-	-	-	-	-	-	-	.65	.04	.19	<1
Number of stomachs examined:		7				27				31				359		
Examined stomachs with food:		0				24				25				154		

Macrozoarces americanus, and other amphipods were relatively unimportant as prey. Decapods in the diet were dominated by Cancer irroratus, and a few Cancer borealis and Crangon septemspinosa were also consumed.

Harmothoe extenuata was an important polychaete at all times of the year. Aphrodita hastata was important in the spring due to the consumption of a few large individuals. Lumbrineris fragilis was important in the winter. Other polychaetes were occasionally consumed.

Pelecypods were only occasionally eaten, but Placopecten magellanicus was an important part of the diet in summer. Cumaceans, mainly Diastylis sculpta were important in the spring. Echinoderms were important in the winter and spring and consisted mainly of sand dollars, Echinarachnius parma.

No stomachs containing food were taken on the fall cruise, and thus no comparison of the diet of Macrozoarces americanus with the macrobenthos could be made. However, M. americanus appears to be much more specialized in its diet than other fishes examined and shows a strong selectivity for epifaunal macrobenthic crustaceans, especially Erichthonius rubricornis, Unciola irrorata, and Cancer irroratus.

Stenotomus chrysops

Scup were abundant in the study area in the fall, with only a few individuals taken on other cruises. Food habits analysis was limited to fall samples.

Stenotomus chrysops fed mainly on amphipods and polychaetes, and these taxa were nearly equal in importance in the diet (Figure 9-14). Decapods, copepods, gastropods, and cumaceans were of lesser importance. Numerous other taxa were infrequently consumed.

Scup had a very diverse diet, feeding on at least 106 species (Table 9-8). Most of these were rare in stomach contents, but there were many species of important food items.

Within the Amphipoda, Erichthonius rubricornis was the most important species (Table 9-8). Unciola irrorata was second in importance followed by Parathemisto gaudichaudii. Ampelisca agassizi, the most abundant ampeliscid in the diet, was fourth in importance, followed by A. vadorum, Phoxocephalus holbolli, and Byblis serrata. Other (21+) species of amphipods were eaten only occasionally.

Chone infundibuliformis dominated the polychaetes in the diet of scup. Several other species were quite important, including Nicolea venustula, Glycera dibranchiata, Clymenura sp. A, Phyllodoce spp., and

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Stenotomus chrysops

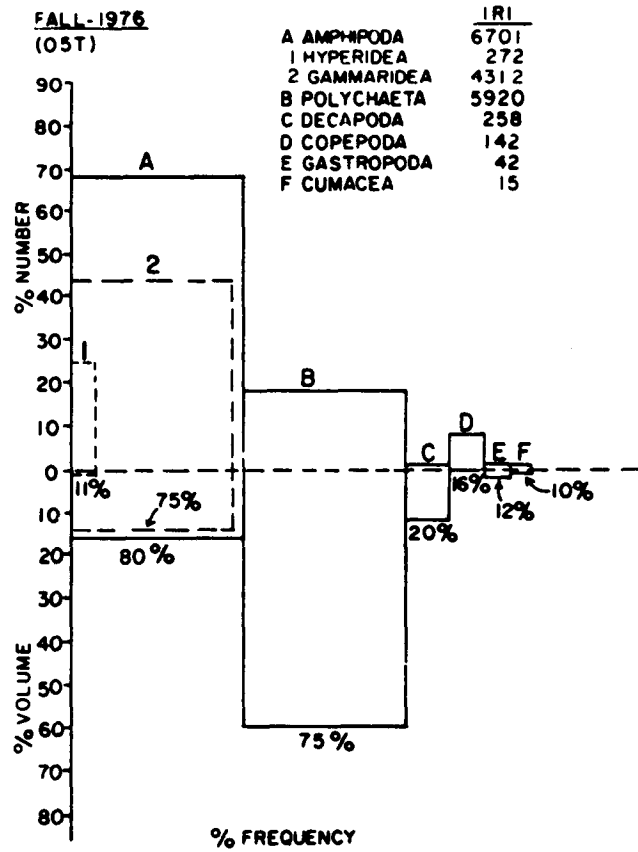


Figure 9-14. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Stenotomus chrysops*, fall, 1976.

Table 9-8. Stenotomus chrysops. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs from fall samples.

Taxon		F	N	V	IRI
Food Item					
Cnidaria					
Anthozoa					
Unidentified		1.51	.19	.18	1
Nematoda					
Unidentified		.75	.04	.00	<1
Annelida					
Polychaeta					
<u>Aphrodita</u> spp.		.38	.01	.43	<1
<u>A. hastata</u>		.75	.04	.64	1
<u>Harmothoe extenuata</u>		.38	.01	.01	<1
<u>Sthenelais limicola</u>		2.64	.10	.77	2
<u>Phyllodoce</u> spp.		.38	.01	.01	<1
<u>Paranaitis speciosa</u>		.75	.02	.02	<1
<u>Phyllodoce</u> spp.		1.51	.25	.27	1
<u>P. mucosa</u>		.38	.01	.03	<1
<u>P. groenlandica</u>		12.83	1.19	1.08	29
<u>Eulalia bilineata</u>		.75	.02	.09	<1
<u>Syllis</u> sp.		.38	.01	.01	<1
<u>Neris grayi</u>		3.02	.12	.14	1
<u>N. zonata</u>		.38	.01	.04	<1
<u>N. riisei</u>		.38	.01	.04	<1
<u>Nephtyidae</u> spp.		.38	.01	.01	<1
<u>Aglaophamus circinata</u>		8.30	.45	3.01	29
<u>Glycera</u> spp.		1.13	.04	.59	1
<u>G. dibranchiata</u>		6.79	.21	4.85	34
<u>G. robusta</u>		.38	.01	.26	<1
<u>Goniada norvegica</u>		.75	.04	.61	<1
<u>Scalibregma inflatum</u>		4.91	.15	1.31	7
<u>Ophelina</u> spp.		4.15	.25	.85	5
<u>Maldanidae</u> spp.		1.51	.07	.19	<1
<u>Clymenella torquata</u>		1.13	.06	.13	<1
<u>Euclymene collaris</u>		6.04	.46	.28	4
<u>Clymenura</u> sp. A		12.83	.76	1.89	34
<u>Aricidea neosuecia</u>		1.89	.07	.04	<1
<u>Spio</u> spp.		.75	.02	.07	<1
<u>Onuphis pallidula</u>		5.77	1.32	2.37	14
<u>Marphysa</u> spp.		2.26	.10	1.61	4
<u>Marphysa bellii</u>		.38	.01	.01	1
<u>Lumbrineridae</u>		.38	.01	.01	<1

Table 9-8. (Continued)

Taxon	F	N	V	IRI
Food Item				
<u>Lumbrineris</u> spp.	13.20	.78	.92	21
<u>L. fragilis</u>	3.02	.10	.48	2
<u>L. impatiens</u>	1.13	.04	.03	<1
<u>L. albidentata</u>	2.64	.17	.32	1
<u>Ninoe nigripes</u>	2.26	.08	.61	2
<u>Drilonereis</u> spp.	3.02	.10	.17	1
<u>D. longa</u>	.38	.01	.03	<1
<u>D. magna</u>	3.02	.13	.67	2
<u>Cirratulidae</u>	.75	.07	.09	<1
<u>Tharyx</u> spp.	1.51	.05	.23	<1
<u>T. acutus</u>	7.92	.87	.49	11
<u>Oweniidae</u>	.38	.01	.02	<1
<u>Melinna cristata</u>	1.13	.04	.15	<1
<u>Ampharete arctica</u>	6.41	.32	.52	5
<u>Terebellidae</u>	.75	.02	.30	<1
<u>Pista maculata</u>	.38	.01	.69	<1
<u>Nicolea venustula</u>	15.85	2.43	2.27	74
<u>Terebellides stroemi</u>	3.77	.19	.43	2
<u>Pherusa affinis</u>	2.26	.08	.84	2
<u>P. plumosa</u>	.75	.02	.26	<1
<u>Sabellidae</u>	1.51	.06	1.43	2
<u>Potamilla reniformis</u>	1.89	.06	.20	<1
<u>Chone infundibuliformes</u>	22.64	5.28	13.48	425
Unidentified	37.36	1.65	14.11	589
Total Polychaeta	75.09	18.43	60.41	5920
Mollusca				
Scaphopoda				
Unidentified	.38	.01	.04	<1
Gastropoda				
<u>Mitrella</u> spp.	6.42	1.00	.69	11
<u>Nassarius trivittatus</u>	.38	.01	.00	<1
<u>Pleurobranchaea tarda</u>	6.42	.40	1.35	11
Unidentified	1.51	.05	.10	<1
Total Gastropoda	11.70	1.46	2.14	42
Pelecypoda				
<u>Placopecten magellanicus</u>	.38	.01	.74	<1
Unidentified	.38	.01	.09	<1
Total Pelecypoda	.75	.02	.82	1

Table 9-8 (Continued)

Taxon		F	N	V	IRI
Food Item					
Cephalopoda					
Unidentified		.75	.02	.10	<1
Total Mollusca		13.21	1.52	3.10	61
Crustacea					
Copepoda					
<u>Eucalanus</u> spp.		.38	.01	.00	<1
<u>Nannocalanus</u> minor		.75	.02	.01	<1
<u>Temora</u> longicornis		.38	.01	.00	<1
<u>Centropages</u> typicus		15.85	8.25	.41	137
<u>Xanthocalanus</u> spp.		.38	.01	.00	<1
Unidentified		.38	.02	.00	<1
Total Copepoda		16.23	8.32	.42	142
Cumacea					
<u>Eudorella</u> hispida		.38	.01	.00	<1
<u>Diastylis</u> spp.		1.89	.14	.17	1
<u>D. sculpta</u>		.38	.01	.01	<1
<u>D. bispinosa</u>		4.91	.31	.34	3
Unidentified		3.40	.20	.24	2
Total Cumacea		10.19	.68	.76	15
Tanaidacea					
<u>Tanaissus</u> lilljeborgi		.38	.01	.00	<1
Isopoda					
<u>Edotea</u> acuta		.38	.01	.04	<1
<u>E. triloba</u>		.38	.02	.04	<1
<u>Ptilanthura</u> tricarina		4.53	.26	.08	2
<u>Cirolana</u> polita		1.51	.05	.25	<1
Total Isopoda		6.79	.34	.42	5
Amphipoda					
<u>Ampeliscidae</u> spp.		.75	.02	.04	<1
<u>Ampelisca</u> spp.		5.66	.44	.21	4
<u>A. vadorum</u>		20.00	1.88	.87	55
<u>A. agassizi</u>		25.28	4.17	1.63	147
<u>Byblis</u> serrata		18.49	1.07	.50	29
<u>Aoridae</u> spp.		.38	.01	.00	<1
<u>Leptocheirus</u> pinguis		3.40	.12	.09	1
<u>Argissa</u> hamatipes		1.51	.05	.02	<1
<u>Corophium</u> spp.		.75	.04	.04	<1
<u>C. crassicorne</u>		.38	.02	.01	<1
<u>Erichthonius</u> spp.		.75	.08	.03	<1
<u>E. rubricornis</u>		61.13	25.81	5.44	1910

Table 9-8. (Continued)

Taxon				
Food Item	F	N	V	IRI
<u>Unciola irrorata</u>	44.53	6.48	3.68	452
<u>Siphonoecetes smithianus</u>	3.02	.10	.05	<1
<u>Rachotropis inflata</u>	.38	.01	.01	<1
<u>Gammarus</u> spp.	.38	.01	.01	<1
<u>Melita dentata</u>	1.89	.14	.05	<1
<u>Casco bigelowi</u>	.75	.02	.13	<1
<u>Protohaustorius wigleyi</u>	.38	.01	.00	<1
<u>Photis</u> spp.	.75	.02	.01	<1
<u>P. dentata</u>	1.51	.07	.03	<1
<u>P. macrocoxa</u>	.38	.01	.00	<1
<u>Podoceropsis nitida</u>	.75	.02	.02	<1
<u>Anonyx sarsi</u>	.38	.01	.02	<1
<u>Melphidippidae</u> spp.	.38	.01	.03	<1
<u>Monoculodes</u> spp.	.38	.01	.01	<1
<u>M. edwardsi</u>	.75	.02	.03	<1
<u>Phoxocephalidae</u> spp.	.38	.01	.00	<1
<u>Phoxocephalus holbolli</u>	21.51	1.39	.49	41
<u>Trichophoxus epistomus</u>	4.15	.19	.05	1
<u>Harpinia propinqua</u>	5.28	.39	.41	4
<u>H. truncata</u>	.38	.02	.01	<1
<u>Stenopleustes gracilis</u>	.38	.01	.00	<1
<u>S. inermis</u>	3.40	.13	.01	<1
<u>Hyperiididae</u> spp.	.75	.05	.01	<1
<u>Parathemisto gaudichaudi</u>	9.81	24.72	.94	252
<u>Caprellidae</u> spp.	.38	.01	.02	<1
<u>Aeginina longicornis</u>	7.17	.31	.37	5
Unidentified	11.32	.69	.28	11
Total Amphipoda	79.62	68.63	15.53	6701
Euphausiacea				
Euphausiidae	.38	.01	.00	<1
Decapoda				
<u>Dichelopandalus leptocerus</u>	2.64	.13	3.05	8
<u>Crangon septemspinosa</u>	.75	.02	.35	<1
<u>Axiu serrata</u>	.75	.02	.03	<1
<u>Pagurus</u> spp.	.75	.02	1.04	1
<u>Cancer</u> spp.	3.02	.12	.74	3
<u>C. borealis</u>	2.26	.08	.48	1
<u>C. irroratus</u>	10.19	.42	5.53	61
Unidentified	1.89	.06	.57	1
Total Decapoda	20.38	.88	11.79	258
Unidentified Crustacea	7.92	.38	4.70	40
Total Crustacea	86.79	79.27	33.61	9797

Table 9-8 (Concluded)

Taxon		F	N	V	IRI
Food Item					
Priapulida					
<u>Priapulus caudata</u>		.75	.02	.53	<1
Ectoprocta					
Unidentified		.38	.01	.00	<1
Echinodermata					
Asteroidea					
<u>Asterias vulgaris</u>		.38	.01	.01	<1
Unidentified		.38	.02	.00	<1
Total Asteroidea		.75	.04	.01	<1
Echinoidea					
<u>Echinarachnius parma</u>		4.53	.15	.52	3
Ophiuroidea					
<u>Amphioplus macilentus</u>		1.13	.08	.22	<1
<u>Axiognathus squamata</u>		2.64	.11	.08	<1
Unidentified		.38	.01	.00	<1
Total Ophiuroidea		4.15	.20	.29	2
Total Echinodermata		9.06	.39	.82	11
Chordata					
Ascideacea					
Unidentified		.38	.01	.05	<1
Pisces					
<u>Teleostei spp.</u>		1.51	.05	.74	1
<u>Urophycis chuss</u>		.75	.02	.56	<1
<u>Cobiidae spp. larvae</u>		.38	.04	.00	<1
Total Pisces		2.64	.11	1.30	4
Total number of stomachs examined:			563		
Number of examined stomachs with food:			265		

Aglaophamus circinata. The remaining (36+) species were of lesser importance, and several were represented by only one specimen.

Again, as in other fishes, Cancer irroratus was an important decapod in the diet. Dichelopandalus leptocerus was also occasionally consumed. Large numbers of copepods, especially Centropages typicus, were frequently consumed but, due to their small biomass, were relatively unimportant in the diet. Gastropods in the diet were mainly Mitrella spp. and the shell-less opisthobranch, Pleurobranchaea taida. Diastylis bispinosa was the most abundant cumacean in the diet.

The most important prey species, Erichthonius rubricornis, was generally strongly selected for in the diet (Figure 9-15). Relative abundance in the benthos and in stomachs fluctuated greatly, but relative abundance in the stomachs greatly exceeded that of the benthos. An exception to this was seen in stratum 1 in area B, the terrace habitat. Scup captured in this stratum were generally smaller individuals and had been feeding heavily on pelagic hyperiid amphipods and copepods, and as a result, selection for all benthic invertebrates was negative in this stratum.

Predation on Unciola irrorata among the strata was similar to that on Erichthonius rubricornis, but electivity values for this species were generally lower. In both species, trends in abundance in scup stomachs did not follow relative abundance in the benthos, but selection was generally positive.

Unlike other fishes, Stenotomus chrysops generally fed heavily on Ampelisca agassizi, usually in proportion to its relative abundance. Because this amphipod was very abundant in some strata, selectivity values fluctuated between strongly positive and strongly negative selection. Other important amphipods such as A. vadorum, Phoxocephalus holbolli, and Byblis serrata were only occasionally preyed upon heavily in some strata. Relative abundance of these amphipods in scup stomachs was generally not related to relative abundance in the benthos and hence electivity values fluctuated markedly.

The polychaetes Nicolea venustula and Glycera dibranchiata were important in the diet of scup but were low in relative abundance in the benthos. N. venustula was consumed in high numbers in some strata and avoided in others and electivity values reflect this. G. dibranchiata was eaten in low numbers in most strata in area B and was generally not eaten in area E.

The only important decapod in the diet of scup, Cancer irroratus, was only occasionally consumed in high numbers. Whereas most other predators on this species fed heavily on it and showed consistent strong positive selection, scup fed heavily on this species in a few strata only. Scup usually avoided large decapods, and the

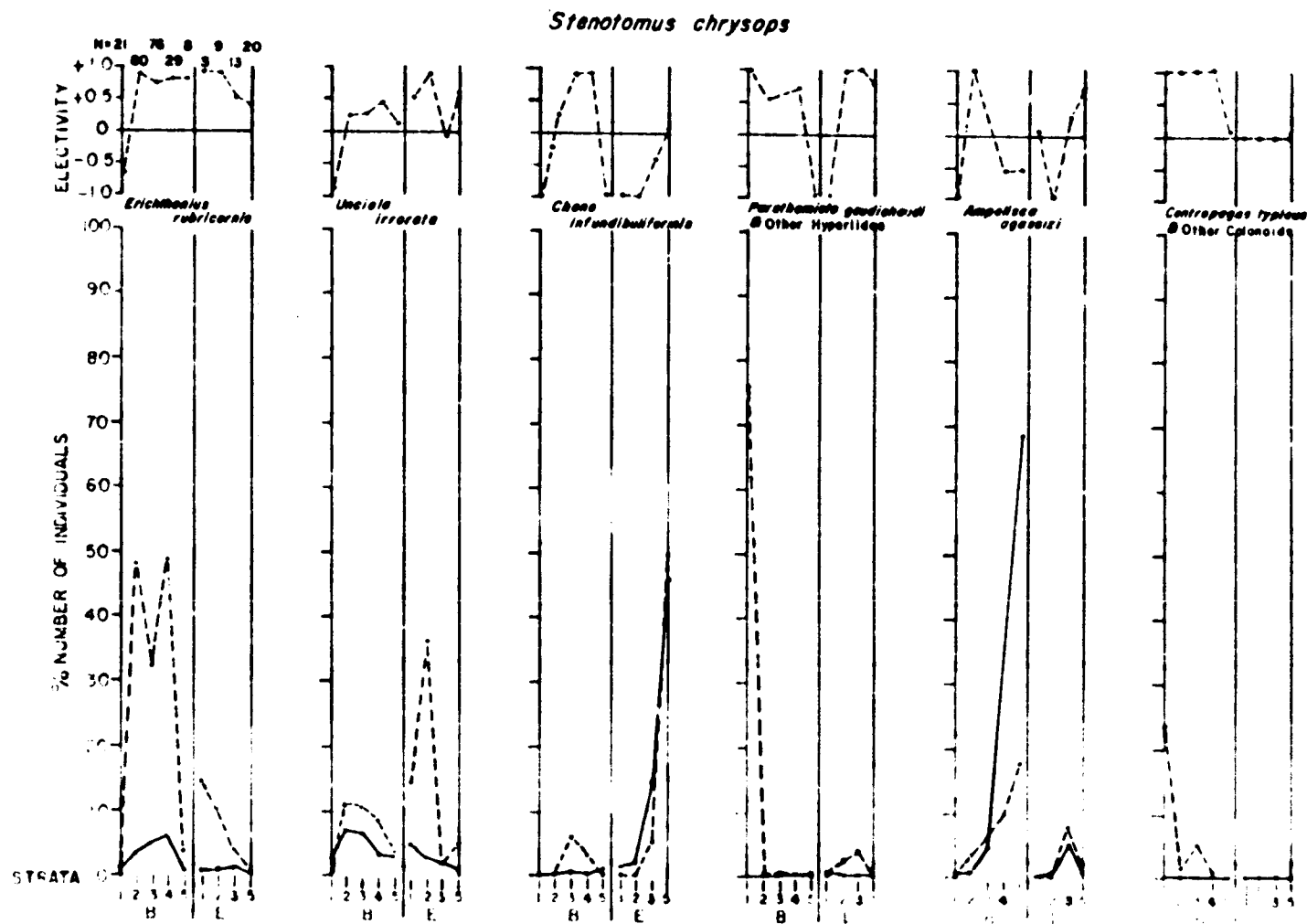


Figure 9-15. Relative abundance in *Stenotomus chrysops* stomachs (•-•) and grab samples (•-•), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

feeding by this fish on C. irroratus in certain strata may have been related to size distribution of these crabs among the strata.

Citharichthys arctifrons

The Gulf Stream flounder, Citharichthys arctifrons, was abundant at all times of the year, especially summer and fall (Table 9-1). The food habits of this small flounder varied considerably seasonally. Among the higher taxa of food items, amphipods were the most important group in fall, winter, and summer (Figure 9-16). Polychaetes preceded amphipods in relative importance in the spring and were second in importance at other seasons. Copepods were relatively important only in the fall, and cumaceans were important in winter and spring. Several other groups were quite important seasonally. Larvaceans were very important in the diet of spring fishes. Fishes were very important in summer, and ostracods, of minor importance, were consumed only in the fall.

Unciola irrorata was the most important species of amphipod consumed during the fall, winter, and spring, and was slightly exceeded in importance by Erichthonius rubricornis in the summer (Table 9-9). E. rubricornis was second in importance in winter and spring but third in fall. Ampeliscid amphipods were always important, but Byblis serrata dominated in the fall and spring, whereas Ameplisca vadorum dominated in winter and summer. Hyperiid amphipods, primarily Parathemisto gaudichaudii, were important in fall and summer.

Chone infundibuliformis was the most important polychaete consumed in the spring and summer. The maldanid Clymenura sp. A was important during all seasons. Sthenelais limicola and Aglaophamus circinata were important in spring and summer, and Ampharete arctica was consumed primarily in winter and spring. Several other polychaetes were also consumed.

Larvaceans and ostracods, which were seasonally important, could not be identified due to their poor condition in fish stomachs. Juvenile Merluccius bilinearis were important in the diet only in summer, when they were abundant in the study area. Decapods were also important only in summer and consisted mainly of postlarval and juvenile shrimps, Dichelopandalus leptocerus and Crangon septemspinosa.

Citharichthys arctifrons was abundant in only a few strata on the fall cruise. Only one or two stomachs containing food were found in some strata, and electivity analysis was not performed for these strata. Comparison of stomach contents of these fishes with benthic invertebrates by strata is thus limited (Figure 9-17).

Unciola irrorata was consumed in high numbers in all strata and had a consistently high electivity value. Byblis serrata,

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Citharichthys arctifrons

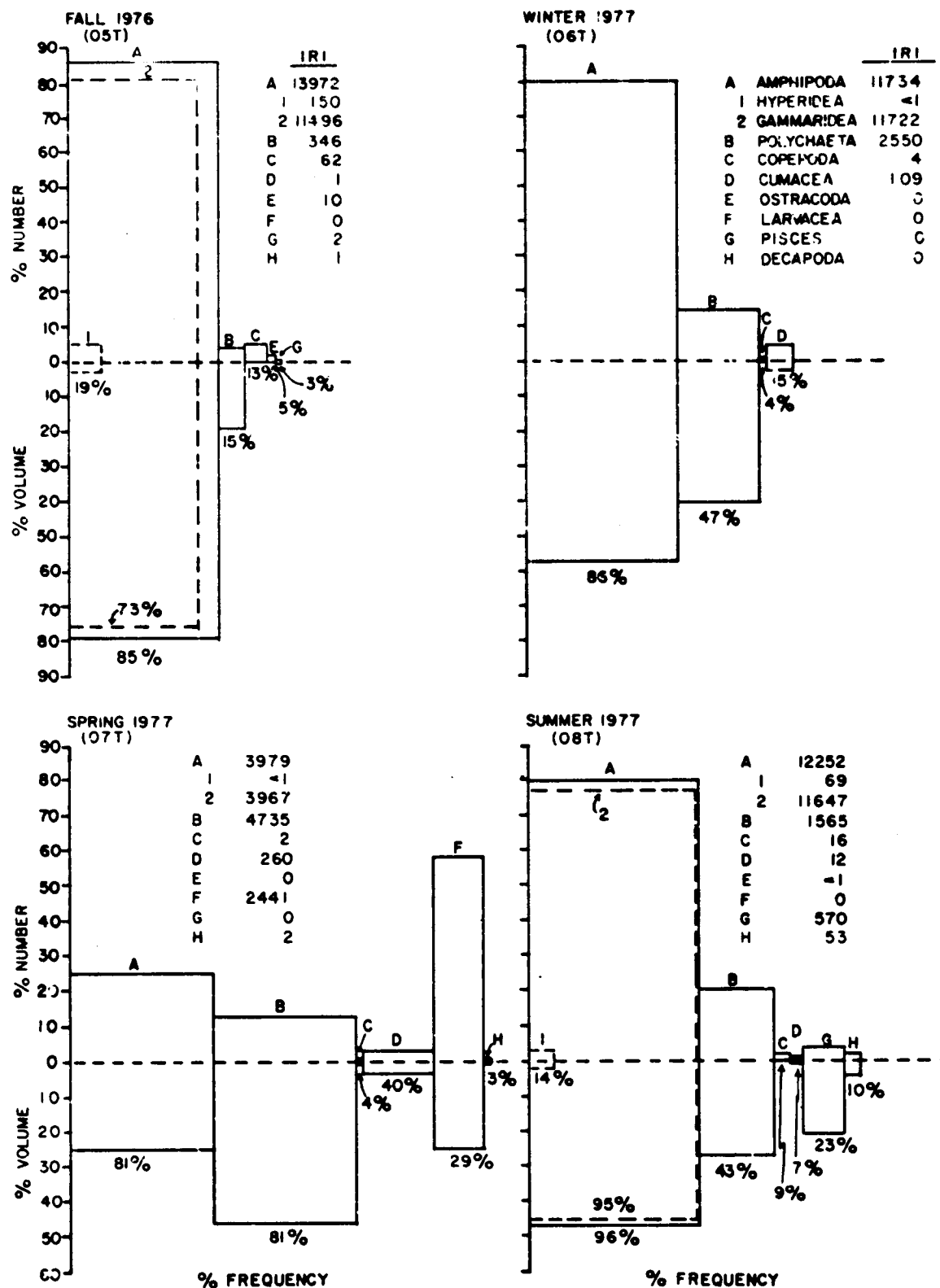


Figure 9-16. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Citharichthys arctifrons*, by season.

Table 9-9. Citharichthys arctifrons. Percent frequency occurrences (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Annelida																
Polychaeta																
<u>Nemethoe extenuata</u>	1.28	.28	.39	1	-	-	-	-	10.68	.76	1.26	22	2.17	.40	1.36	4
<u>Scheneleia limicola</u>	-	-	-	-	2.16	.44	2.93	7	9.71	.71	8.03	85	5.79	1.03	5.96	40
<u>Phyllodoce</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.09	<1
<u>Nephytidae</u> spp.	-	-	-	-	-	-	-	-	.97	.05	.19	1	.36	.06	.45	<1
<u>Aglaophamus circinata</u>	-	-	-	-	1.44	.29	2.13	3	10.68	.76	5.13	63	2.89	.46	3.25	11
<u>Opheliidae</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
<u>Ophelia denticulata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
<u>Ophelia</u> spp.	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
<u>Maldanidae</u>	1.28	.28	.77	1	.72	.15	.27	<1	4.85	.25	1.06	6	2.53	.40	1.08	4
<u>Clymenella torquata</u>	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
<u>Clymenura</u> sp. A	6.41	1.42	13.51	96	5.75	1.76	10.67	72	21.36	1.58	8.03	205	6.86	1.49	4.25	39
<u>Paraonidae</u> spp.	-	-	-	-	-	-	-	-	1.94	.25	.68	2	-	-	-	-
<u>Spionidae</u> spp.	-	-	-	-	1.44	.29	.00	<1	1.94	.15	.19	1	.36	.06	.90	<1
<u>Spiothraus bombyx</u>	-	-	-	-	-	-	-	-	1.94	.20	.58	2	1.08	.17	.18	<1
<u>Onuphis pallidula</u>	-	-	-	-	1.44	.73	2.40	5	6.79	.76	3.68	30	.72	.11	.18	<1
<u>Lumbrineris</u> spp.	-	-	-	-	.72	.15	.27	<1	.97	.05	.00	<1	.36	.06	.09	<1
<u>L. fragilis</u>	-	-	-	-	-	-	-	-	2.91	.15	1.55	5	.36	.06	.45	<1
<u>L. cruzensis</u>	-	-	-	-	4.32	.88	1.33	10	2.91	.15	.48	2	1.80	.29	.45	1
<u>L. impatiens</u>	-	-	-	-	1.44	.29	.53	1	-	-	-	-	.72	.11	.09	<1
<u>Drilonereis</u> spp.	-	-	-	-	.72	.15	.00	<1	-	-	-	-	.36	.06	.00	<1
<u>Ampharete arctica</u>	-	-	-	-	8.63	2.20	6.13	72	13.59	.76	1.84	35	1.80	.29	1.36	3
<u>Pherusa affinis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
<u>Sabellidae</u>	-	-	-	-	.72	.15	.27	<1	-	-	-	-	-	-	-	-
<u>Euchone</u> spp.	-	-	-	-	-	-	-	-	.97	.05	.10	<1	-	-	-	-
<u>Clione antedibuliformis</u>	-	-	-	-	3.60	2.20	2.40	17	38.83	5.65	9.67	595	9.02	2.46	2.17	42
Unidentified	8.97	1.99	3.86	53	22.30	4.84	10.67	346	10.68	.56	3.38	42	13.00	2.29	3.79	79
Total Polychaeta	15.38	3.98	18.53	346	46.76	14.54	40.00	2550	80.58	12.92	45.84	4735	42.96	10.14	26.29	1365
Mollusca																
Gastropoda																
Unidentified	-	-	-	-	.72	.15	.00	<1	-	-	-	-	-	-	-	-
Pelecypoda																
Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Crustacea																
Ostracoda																
Unidentified	5.13	1.99	.00	10	-	-	-	-	-	-	-	-	.36	.06	.00	<1
Copepoda																
<u>Calanus finmarchicus</u>	-	-	-	-	-	-	-	-	3.88	.36	.10	2	2.17	.57	.09	1
<u>Paracalanus</u> spp.	1.28	.28	.00	<1	.72	.15	.00	<1	-	-	-	-	-	-	-	-
<u>Centropages typicus</u>	2.56	.85	.00	2	2.88	.73	.00	2	-	-	-	-	-	-	-	-
<u>Candacia armata</u>	-	-	-	-	-	-	-	-	-	-	-	-	5.41	.17	.00	5
<u>Mettidia lucens</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.00	<1
<u>Harpacticoid</u> spp.	2.56	1.14	.00	3	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	6.41	2.56	.00	16	.72	.15	.00	<1	-	-	-	-	.72	.17	.00	<1
Total Copepoda	12.82	4.83	.00	62	4.32	1.03	.00	4	3.88	.36	.10	2	-	-	.09	16

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Table 9-9.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cumacea																
<i>Eudorella</i> spp.	-	-	-	-	-	-	-	-	.97	.05	.00	<1	.36	.06	.00	<1
<i>E. hispidula</i>	-	-	-	-	1.44	.29	.00	1	.97	.05	.00	<1	-	-	-	-
<i>Diastylis</i> spp.	-	-	-	-	1.49	.44	.00	1	.97	.05	.00	<1	-	-	-	-
<i>D. subulata</i>	-	-	-	-	5.04	1.03	1.33	12	16.50	1.2	1.45	44	2.89	.57	.36	3
<i>D. biispinosa</i>	-	-	-	-	3.60	1.03	.53	6	24.27	1.83	1.84	89	2.89	.46	.36	2
<i>Petalosquilla declivis</i>	-	-	-	-	3.60	1.47	.80	8	.97	.05	.00	<1	.36	.06	.00	<1
Unidentified	1.28	.28	.39	1	1.44	.29	.00	1	-	-	-	-	-	-	-	-
Total Cumacea	1.78	.28	.39	1	15.11	4.55	2.67	109	39.81	3.26	3.29	260	6.50	1.15	.72	12
Tanaidacea																
<i>Tanaidus lilljeborgia</i>	1.29	.28	.00	1	-	-	-	-	.97	.05	.00	1	-	-	-	-
Isopoda																
<i>Edotea triloba</i>	-	-	-	-	-	-	-	-	-	-	-	-	1.44	.23	.36	1
<i>Janira alta</i>	-	-	-	-	-	-	-	-	.97	.05	.00	1	2.53	.46	.36	2
Total Isopoda	-	-	-	-	-	-	-	-	.97	.05	.00	1	3.97	.69	.72	6
Amphipoda																
<i>Ampelisca</i> spp.	2.56	.85	.39	3	1.44	.29	.00	<1	.97	.05	.00	<1	.72	.11	.00	<1
<i>A. macrocephala</i>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.45	<1
<i>A. vadorum</i>	14.10	7.95	3.86	167	12.23	4.70	4.27	110	11.65	.66	.87	18	30.69	8.76	7.05	485
<i>A. agassizii</i>	3.85	1.14	1.16	9	4.32	1.03	1.33	10	2.91	.20	.19	1	1.08	.17	.09	<1
<i>Byblis serrata</i>	32.05	17.90	26.25	1415	7.19	2.94	3.20	44	13.59	1.17	2.32	47	15.88	4.81	6.05	172
<i>Leptocheirus pinguis</i>	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
<i>Argissa hamatipes</i>	-	-	-	-	-	-	-	-	.97	.05	.19	<1	-	-	-	-
<i>Erichthonius</i> spp.	1.28	.28	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
<i>E. rubricornis</i>	21.79	7.39	1.93	233	48.20	25.70	18.93	2151	42.72	8.24	8.32	707	61.47	35.22	11.02	2838
<i>Unciola irrorata</i>	58.97	35.79	30.89	3932	56.11	34.95	27.73	3517	58.25	10.58	11.51	1257	63.18	23.42	17.80	2604
<i>Siphonocetes smithianus</i>	1.28	.28	.39	1	-	-	-	-	-	-	-	-	-	-	-	-
<i>Melita dentata</i>	1.28	.28	.39	1	-	-	-	-	3.88	.20	.10	1	2.89	.57	.54	3
<i>Casco bigelovi</i>	-	-	-	-	1.44	.29	.27	1	.97	.05	.10	<1	.72	.11	.18	<1
<i>Jerbarnia</i> spp.	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
<i>Photia</i> spp.	-	-	-	-	.72	.15	.00	<1	-	-	-	-	-	-	-	-
<i>P. dentata</i>	1.28	.28	.39	1	4.32	1.17	.53	7	5.82	.44	.19	1	1.44	.29	.09	1
<i>P. macrocoxa</i>	-	-	-	-	1.44	.73	.00	1	1.94	.15	.00	<1	-	-	-	-
<i>Podocarpopsis nitida</i>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	<1
<i>Orchomonella pinguis</i>	-	-	-	-	-	-	-	-	.97	.05	.10	<1	-	-	-	-
<i>Monoculodes</i> spp.	-	-	-	-	.72	.44	.00	<1	-	-	-	-	-	-	-	-
<i>M. edwardsi</i>	-	-	-	-	.72	.15	.27	<1	-	-	-	-	10.43	2.29	2.08	47
<i>Phoxocephalus holbolli</i>	1.28	.28	.39	1	2.16	.44	.00	1	1.94	.10	.10	<1	2.17	.34	.00	1
<i>Trichophoxus epistomus</i>	6.41	1.70	.39	13	2.16	.44	.00	1	4.85	.25	.39	3	2.17	.34	.09	1
<i>Stenopleustes gracilis</i>	-	-	-	-	-	-	-	-	2.91	.20	.00	1	-	-	-	-
<i>S. inermis</i>	-	-	-	-	8.63	3.08	.00	27	15.53	1.93	.29	35	.72	.11	.00	1
Stenothoidae	1.28	.28	.00	<1	-	-	-	-	-	-	-	-	-	-	-	-
Hyperliidae	8.97	1.99	.77	25	.72	.15	.00	<1	-	-	-	-	-	-	-	-
<i>Parathemisto gaudichaudi</i>	10.26	3.13	1.93	52	-	-	-	-	1.94	.10	.00	<1	14.08	2.92	1.99	69
<i>Aegina longicornis</i>	-	-	-	-	-	-	-	-	.97	.05	.00	<1	-	-	-	-
Unidentified	29.49	6.82	9.65	486	9.55	3.08	.80	36	1.94	.10	.00	<1	2.59	.46	.00	1
Total Amphipoda	84.62	86.36	78.76	13972	85.61	79.74	57.33	11735	80.58	24.72	24.66	3979	96.03	80.17	47.52	12252

Table 9-9.

Taxon Food Item	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Decapoda																
<u>Leptochela bermudensis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.27	.41
<u>Dichelopandalus leptoceras</u>	-	-	-	-	-	-	-	-	2.91	.15	.48	2	3.97	.63	.90	6
<u>Crangon septemspinosa</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.89	.51	1.72	6
<u>Cancer spp.</u>	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.09	.41
<u>C. borealis</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.11	.18	.41
<u>C. irroratus</u>	-	-	-	-	-	-	-	-	-	-	-	-	1.44	.23	.45	1
Unidentified	1.28	.28	.39	1	-	-	-	-	-	-	-	-	.36	.06	.09	.41
Total Decapoda	1.28	.28	.39	1	-	-	-	-	2.91	.15	.48	2	9.75	1.78	3.70	53
Unidentified Crustacea	6.41	1.42	1.54	19	-	-	-	-	-	-	-	-	.72	.11	.09	.41
Total Crustacea	93.59	95.45	81.08	16522	86.33	85.32	60.00	12545	86.41	28.59	28.63	4943	97.11	85.62	52.85	13447
Sipuncula																
<u>Phascolion strombi</u>	-	-	-	-	-	-	-	-	.97	.05	.00	.41	-	-	-	-
Echinodermata																
Ophiuroidea																
<u>Axiognathus squamata</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.09	.41
Chaetognatha																
<u>Sagitta elegans</u>	-	-	-	-	-	-	-	-	.97	.05	.10	.41	1.44	.23	.00	.41
Chordata																
Larvacea																
Unidentified	-	-	-	-	-	-	-	-	29.13	58.39	25.44	2442	-	-	-	-
Pisces																
Teleostei spp.	2.56	.57	.39	2	-	-	-	-	-	-	-	-	17.23	2.81	12.92	272
<u>Merluccius bilinearis</u>	-	-	-	-	-	-	-	-	-	-	-	-	4.69	.92	7.05	37
<u>Ammodytes spp.</u>	-	-	-	-	-	-	-	-	-	-	-	-	.36	.06	.45	.41
<u>Citharichthys arctifrons</u>	-	-	-	-	-	-	-	-	-	-	-	-	.72	.11	.36	.41
Total Pisces	2.56	.57	.39	2	-	-	-	-	-	-	-	-	23.10	3.89	20.78	570
Number of stomachs examined:		195				189				110				315		
Examined stomachs with food:		78				139				103				277		

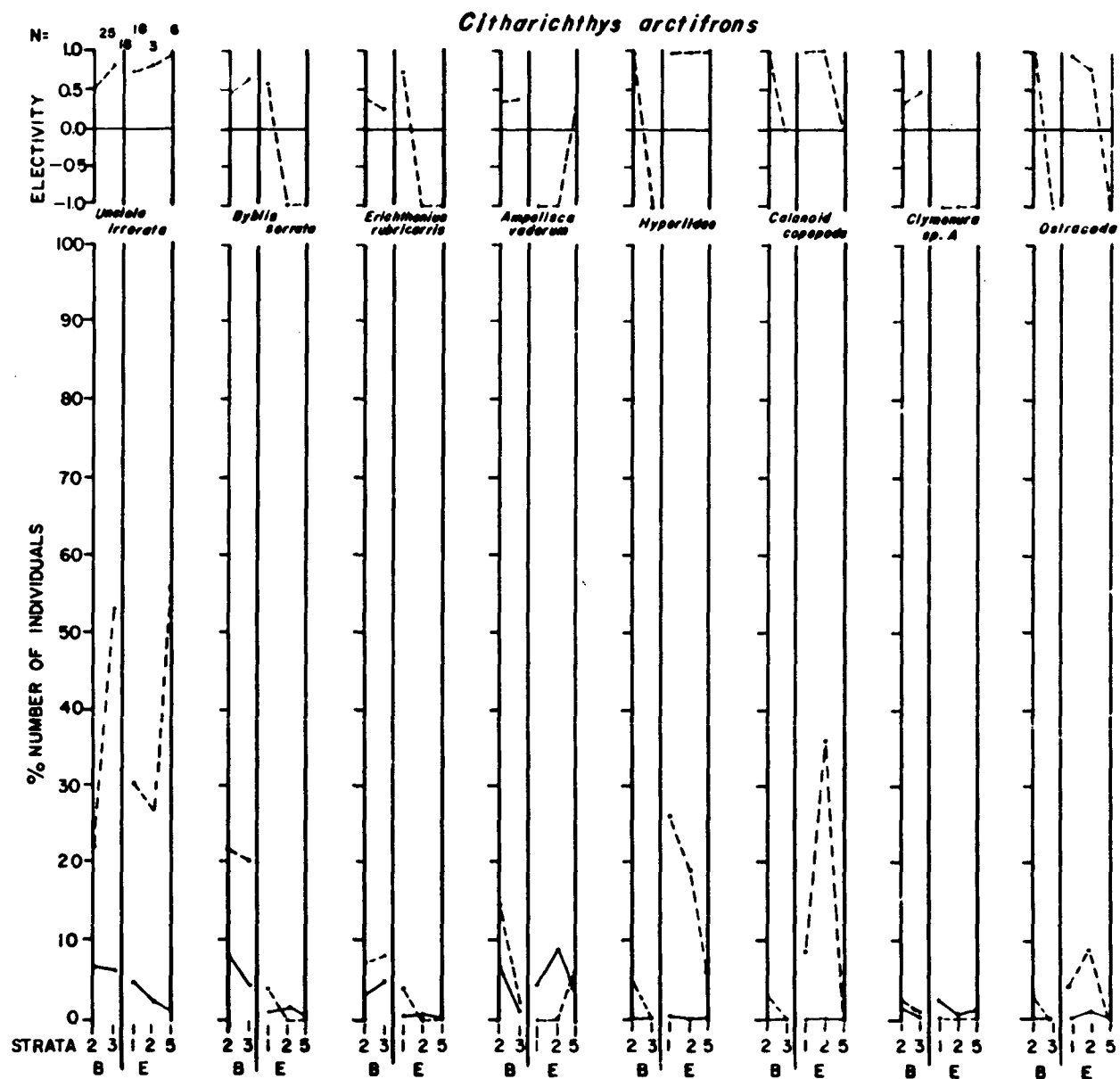


Figure 9-17. Relative abundance in *Citharichthys arcifrons* stomachs (---) and grab samples (—), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

Erichthonius rubricornis, and Ampelisca vadorum were moderately selected for in area B. In area E hyperiid amphipods, calanoid copepods, and ostracods replaced these amphipods in the diet, and their relative abundance was low in area B. Clymenura sp. A was important in the diet only in area B. Differences in food habits between area B and E were size related. Large species of food items were more important in the diet of fish from area B. This reflects the size distribution of these fishes with more larger fish occurring in area B ($\bar{x}$ length = 53 mm) than in area E ($\bar{x}$ length = 27 mm).

Hippoglossina oblonga

Fourspot flounder, Hippoglossina oblonga, were common in the study area on all cruises. Decapods were the most important higher taxon of prey at all times of the year (Figure 9-18). Amphipods were very important in winter and spring, but were of much lesser importance in fall and summer. Fishes were very important in the diet in fall and summer and apparently replace amphipods in the diet at this time. This seasonal shift from amphipods to fishes reflects the seasonal abundance of small fishes in the study area and also seasonal differences in the size composition of the predator population. H. oblonga captured in winter and spring were slightly smaller ($\bar{x}$ length = 196 and 180 mm respectively) than those taken in fall and summer ($\bar{x}$ length = 214 and 221 mm respectively) and fed more on smaller prey items such as amphipods. Polychaetes and cephalopods were of minor importance in winter, spring, and summer. Polychaetes were absent in fish stomachs in the fall, but cephalopods were quite important at this time.

As expected, Cancer irroratus was the most important decapod species at all times of the year (Table 9-10). Dichelopandalus leptocerus was nearly as important as C. irroratus in the spring, and was second most important decapod in fall and summer. Crangon septemspinosa was important at all times of the year. Mundia iris and Cancer borealis were frequently consumed in the winter.

Unciola irrorata was the most important amphipod in the diet during all seasons. Erichthonius rubricornis was important during all seasons except summer. A few other amphipods were occasionally consumed.

Merluccius bilinearis had the highest relative importance among fishes and was most important in the diet in summer, when juveniles were abundant in the area. M. bilinearis was also important in fall and winter. Urophycis chuss was the most important fish consumed in fall and spring.

Polychaetes were important in the diet during winter and spring and Chone infundibuliformis was the most important species eaten. Sthenelais limicola was occasionally consumed, and the few remaining

Hippoglossina oblonga

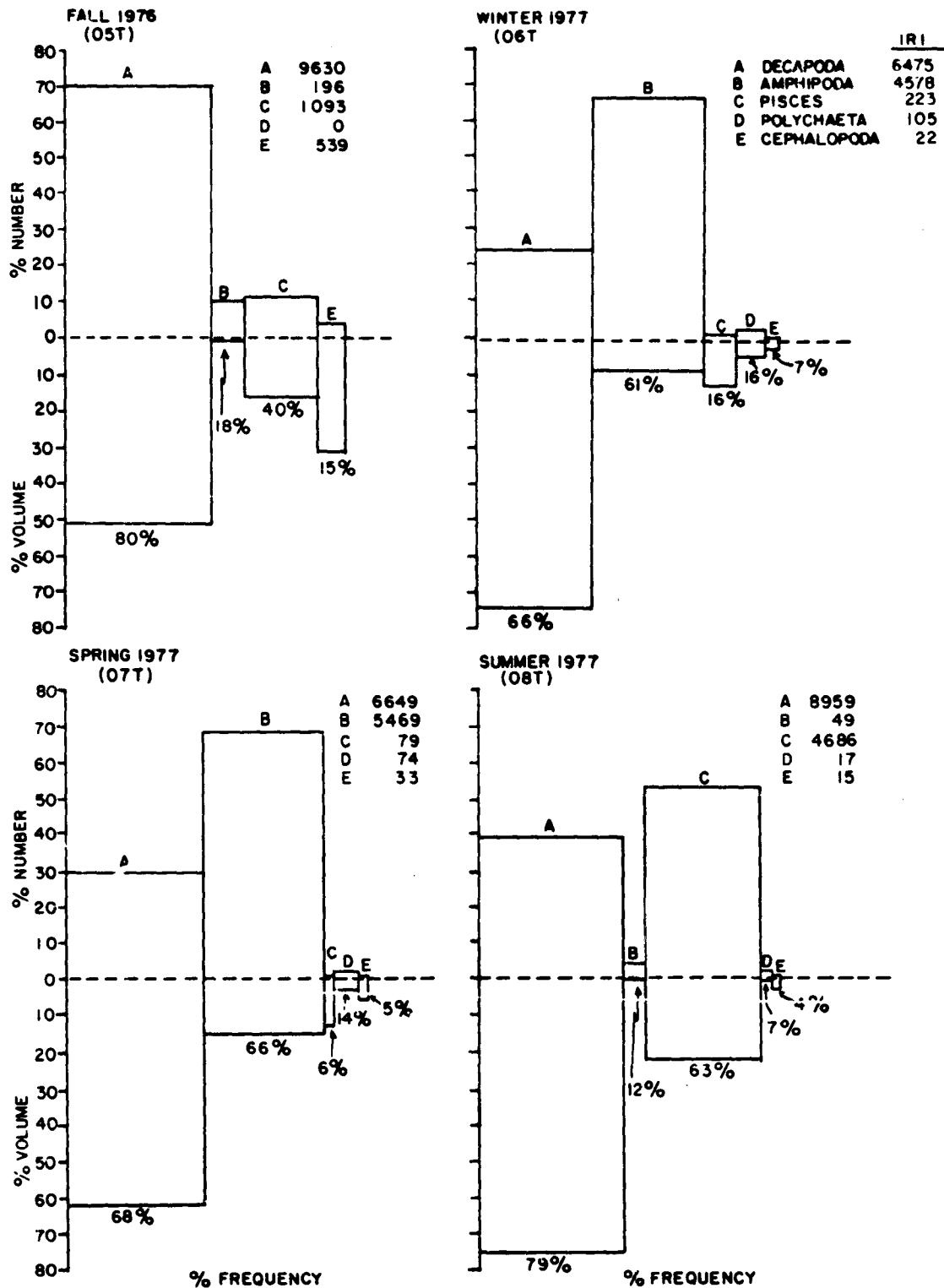


Figure 9-18. Percent frequency occurrence, percent number, percent volume displacement, and index of relative importance (IRI) of higher taxonomic groups of food in the diet of *Hippoglossina oblonga*, by season.

Table 9-10. Hippoglossina oblonga. Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in stomachs, by cruise.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Cnidaria																
Hydrozoa																
<u>Eudendrium</u> spp.	.77	.17	.08	<1	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	-	-	-	-	.94	.10	.00	<1	-	-	-	-
Annelida																
Polychaeta																
<u>Harmothoe</u> <u>extenuata</u>	-	-	-	-	1.11	.18	.11	<1	.94	.10	.02	<1	1.33	.29	.04	<1
<u>Scheuchzeria</u> <u>limicola</u>	-	-	-	-	2.22	.35	.80	3	4.72	.52	.68	6	2.67	.57	.09	2
Maldanidae spp.	-	-	-	-	-	-	-	-	.94	.10	.28	<1	1.33	.29	.04	<1
<u>Clymenura</u> sp. A	-	-	-	-	1.11	.18	.92	1	1.89	.21	.22	1	-	-	-	-
Spionidae spp.	-	-	-	-	1.11	.18	.05	1	-	-	-	-	-	-	-	-
<u>Ampharete</u> <u>arctica</u>	-	-	-	-	1.11	.18	.11	<1	-	-	-	-	-	-	-	-
<u>Chone</u> <u>infundibuliformis</u>	-	-	-	-	5.55	.88	1.95	16	6.60	.93	2.04	20	1.33	.29	.16	1
Unidentified	-	-	-	-	4.44	.70	.14	4	.94	.10	.02	<1	2.67	.57	.17	2
Total Polychaeta	-	-	-	-	15.56	2.65	4.08	105	14.15	1.96	3.26	74	6.67	2.01	.51	17
Mollusca																
Pelecypoda																
<u>Placopecten</u> <u>magellanicus</u>	.77	.17	.01	<1	-	-	-	-	-	-	-	-	-	-	-	-
<u>Cyclocardia</u> <u>borealis</u>	.77	.17	.01	<1	1.11	.18	.11	<1	-	-	-	-	-	-	-	-
<u>Ensis</u> <u>directus</u>	.77	.17	.08	<1	-	-	-	-	.94	.10	.02	<1	-	-	-	-
Unidentified	2.31	.68	.21	2	-	-	-	-	-	-	-	-	-	-	-	-
Total Pelecypoda	4.62	1.19	.31	7	1.11	.18	.11	<1	.94	.10	.02	<1	-	-	-	-
Cephalopoda																
Loliginidae spp.	2.31	.51	9.91	24	-	-	-	-	1.89	.31	4.07	8	1.33	.29	1.31	2
<u>Loligo</u> <u>pealei</u>	3.08	.85	18.49	60	-	-	-	-	-	-	-	-	-	-	-	-
Rossia spp.	3.85	.85	.62	6	5.55	.88	2.11	17	1.89	.21	.09	1	1.33	.29	.00	<1
<u>R. tenera</u>	2.31	.51	1.66	5	1.11	.35	.00	<1	.94	.10	2.22	2	1.33	.29	1.64	3
Unidentified	3.85	1.02	.60	6	-	-	-	-	-	-	-	-	-	-	-	-
Total Cephalopoda	15.38	3.74	31.28	539	6.67	1.23	2.11	22	-	-	-	-	4.00	.86	2.95	15
Unidentified Mollusca	5.38	1.70	.32	11	-	-	-	-	4.72	.62	6.38	33	-	-	-	-
Total Mollusca	22.31	6.62	31.90	859	7.78	1.41	2.23	28	5.66	.73	6.40	40	4.00	.86	2.95	15
Crustacea																
Copepoda																
<u>Centropages</u> <u>typicus</u>	-	-	-	-	1.11	.35	.00	<1	-	-	-	-	-	-	-	-
<u>Candacia</u> <u>armata</u>	-	-	-	-	-	-	-	-	-	-	-	-	2.67	.57	.00	2
Total Copepoda	-	-	-	-	1.11	.35	.00	<1	-	-	-	-	2.67	.57	.00	2
Stomatopoda																
Unidentified	-	-	-	-	-	-	-	-	.94	.10	.09	<1	-	-	-	-
Mysidacea																
<u>Neomysis</u> <u>americana</u>	-	-	-	-	-	-	-	-	.94	.10	.02	<1	-	-	-	-
Cumacea																
<u>Diastyllis</u> <u>sculpta</u>	-	-	-	-	-	-	-	-	.94	.10	.00	<1	-	-	-	-

Table 9-10.

Taxon	Fall 1976				Winter 1977				Spring 1977				Summer 1977			
	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI	F	N	V	IRI
Amphipoda																
<u>Ampelisca</u> spp.	.77	.17	.00	.41	-	-	-	-	-	-	-	-	-	-	-	-
<u>A. vadorum</u>	.77	.17	.00	.41	-	-	-	-	-	-	-	-	-	-	-	-
<u>A. agassizi</u>	.77	.17	.01	.41	-	-	-	-	.94	.10	.00	.41	-	-	-	-
<u>Byblis serrata</u>	6.15	3.40	.19	22	5.55	2.29	.39	15	18.87	7.48	2.53	189	-	-	-	-
<u>Leptocheirus pinguis</u>	-	-	-	-	-	-	-	-	.94	.10	.09	.41	-	-	-	-
<u>Erichthonius rubricornis</u>	2.31	.68	.01	2	38.89	21.69	1.74	911	24.53	9.24	1.33	259	1.33	.29	.00	.41
<u>Unciola irrorata</u>	10.77	3.23	.19	37	53.33	42.33	5.55	2554	51.89	50.57	11.25	3206	6.67	2.58	.10	18
<u>Trichophomus spistomus</u>	1.54	.34	.01	1	-	-	-	-	-	-	-	-	-	-	-	-
Hyperliidae spp.	2.31	.68	.01	2	-	-	-	-	-	-	-	-	-	-	-	-
<u>Parathemisto gaudichaudi</u>	2.31	1.02	.02	2	1.11	.70	.02	1	.94	.10	.00	.41	4.00	1.15	.00	5
Unidentified	1.54	.34	.01	1	1.11	.18	.00	.41	-	-	-	-	-	-	-	-
Total Amphipoda	18.46	10.19	.44	196	61.11	67.20	7.71	4578	66.04	67.60	15.21	5469	12.00	4.01	.10	49
Decapoda																
<u>Dichelopandalus leptocerus</u>	7.69	4.75	8.18	99	7.78	1.59	6.72	65	38.68	16.51	14.51	1200	25.33	10.31	3.71	355
Crangonidae spp.	-	-	-	-	-	-	-	-	.94	.10	.02	.41	-	-	-	-
<u>Crangon septemspinosa</u>	11.54	3.56	2.34	68	12.22	3.53	4.89	103	25.47	5.50	6.62	309	22.47	8.60	2.22	245
<u>Scyllarus</u> spp.	-	-	-	-	-	-	-	-	.94	.10	.45	1	-	-	-	-
<u>Munida iris</u>	-	-	-	-	7.78	2.12	4.93	55	.94	.10	.76	1	-	-	-	-
<u>Cancer</u> spp.	10.00	5.09	1.82	69	2.22	.53	.44	2	1.89	.21	.31	1	-	-	-	-
<u>C. borealis</u>	3.85	1.02	.47	6	3.33	1.23	6.54	26	.94	.10	.09	.41	-	-	-	-
<u>C. irroratus</u>	61.54	42.61	31.70	4573	44.44	16.05	49.91	2931	28.30	5.92	39.13	1275	46.67	20.34	68.71	4156
<u>Colletes robustus</u>	-	-	-	-	1.11	.18	.11	.41	-	-	-	-	-	-	-	-
Unidentified	25.38	12.73	6.09	478	-	-	-	-	.94	.10	.09	1	-	-	-	-
Total Decapoda	80.00	69.78	50.60	9630	65.56	25.22	73.54	6475	73.58	28.66	61.70	6649	78.67	39.26	74.63	8959
Unidentified Crustacea	2.31	.68	.35	2	3.33	.53	.76	4	-	-	-	-	-	-	-	-
Total Crustacea	86.92	80.65	51.39	11477	93.33	93.30	82.01	16362	95.28	96.57	77.02	16341	81.33	43.84	74.73	9644
Echinodermata																
Echinoidea																
<u>Echinarechnius parma</u>	6.92	1.53	.34	13	-	-	-	-	-	-	-	-	1.33	.29	.04	.41
Chordata																
Pisces																
<u>Teleostei</u> spp.	22.31	5.26	8.28	302	10.00	1.59	4.54	61	1.89	.21	3.70	7	24.00	5.60	3.35	247
<u>Urophycis chuss</u>	9.23	3.56	6.04	89	1.11	.18	1.84	2	1.89	.21	8.88	17	1.33	.29	.08	.41
<u>Merluccius bilinearis</u>	5.38	1.36	1.37	15	3.33	.53	3.67	14	.94	.10	.56	1	40.00	44.13	18.34	2475
<u>Glyptocephalus</u> spp.	3.85	.85	.60	6	2.22	.35	1.63	4	.94	.10	.19	.41	-	-	-	-
Total Pisces	40.00	11.04	16.29	1093	15.56	2.65	11.68	223	5.66	.62	13.32	79	62.67	53.01	21.77	4646
Total number of stomachs examined		169				101				125				75		
Examined stomachs with food:		130				90				106				75		

polychaetes were rare in the diet. Cephalopods were seasonally important in the diet and consisted mainly of loliginids in the fall and spring and Rossia spp. during other seasons.

Hippoglossina oblonga fed heavily on species that were rare in grab samples and selectivity patterns indicate this (Figure 9-19). Relative abundance of the decapod Cancer irroratus in stomachs was always high, resulting in a high positive electivity value for this species. Other decapods (Dichelopandalus leptocerus, Crangon septemspinosus, and Cancer borealis) were eaten in high numbers in some strata but were not eaten at all in other strata, and this is reflected in a highly variably electivity value for these species. Unciola irrorata, the most important amphipod prey was moderately selected for or against in area B, but was not consumed in area E, where it was relatively less abundant. Byblis serrata was consumed only in strata where it was relatively abundant. Echinarachnius parma was occasionally consumed, but not in relation to its abundance in grab samples. Other important prey species, such as fishes and cephalopods, were not taken by the the grab and selectivity for these species was always +1 or zero.

Overlap in Diet

Overlap in diet was found to vary seasonally, with changes in species composition of the predators and intraspecific predator size differences (Figure 9-20). Merluccius bilinearis and Urophycis chuss showed the greatest similarity in diet in fall (Figure 9-20-A), when smaller individuals dominated the study area and fed mainly on small planktonic crustaceans such as Parathemisto gaudichaudii and Centropages typicus. Stenotomus chrysops, which also fed heavily on these two species, was also classified with this group. Raja erinacea and Citharichthys arctifrons, both of which fed heavily on Unciola irrorata, Byblis serrata, and Ampelisca vadorum, were grouped together. Hippoglossina oblonga and U. regius were similar in their diet in fall. Decapods and fishes were the two most abundant food taxa for these species in the fall, and amphipods were also important for both species. Lophius americanus, being primarily piscivorous, was included in this group.

In winter, predator groups changed for several reasons (Figure 9-20-B). First, Stenotomus chrysops was absent from the study area, and Macrozoarces americanus became common and was included in the classification. Also larger Urophycis chuss ($\bar{x}$ length = 250.0 mm) and Merluccius bilinearis ($\bar{x}$ = 281.5 mm) were present. In winter, Unciola irrorata and Erichthonius rubricornis were the most abundant food items for Hippoglossina oblonga, M. americanus, Raja erinacea, Citharichthys arctifrons and U. chuss, and all of these species formed a group with high similarity (Figure 9-20-B). Within this group, Cancer irroratus was the third most abundant prey for H. oblonga and M. americanus. Decapods, especially C. irroratus, were also important

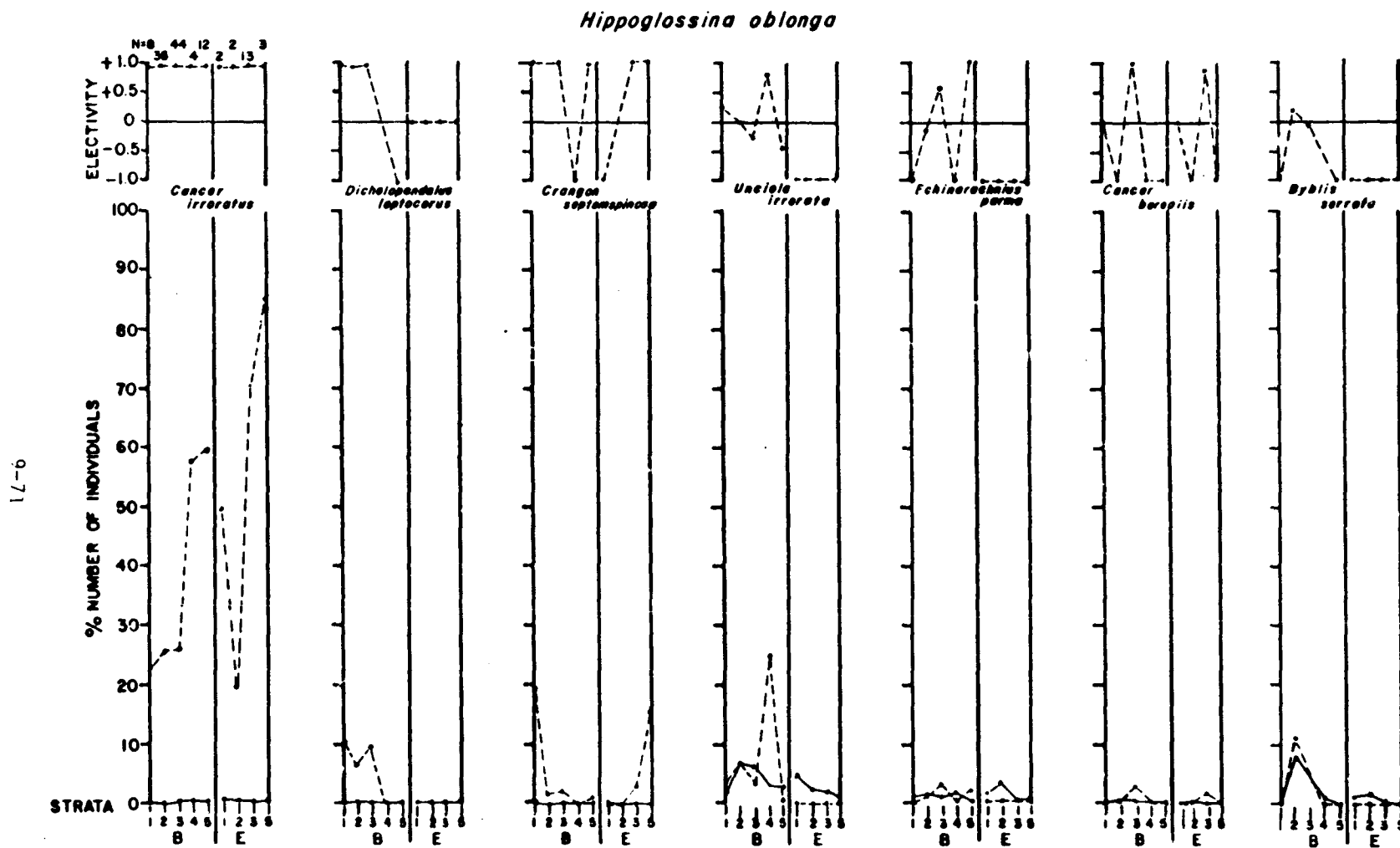
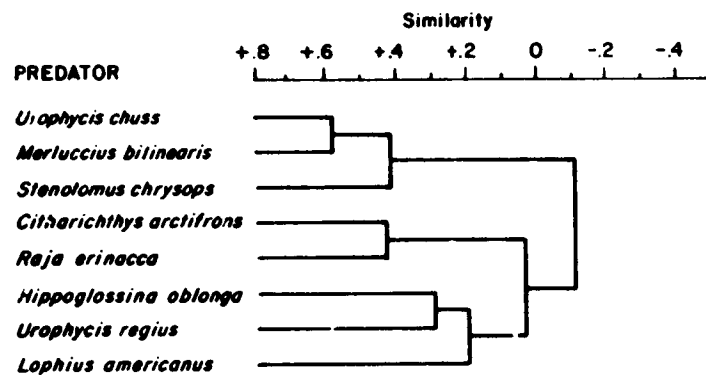
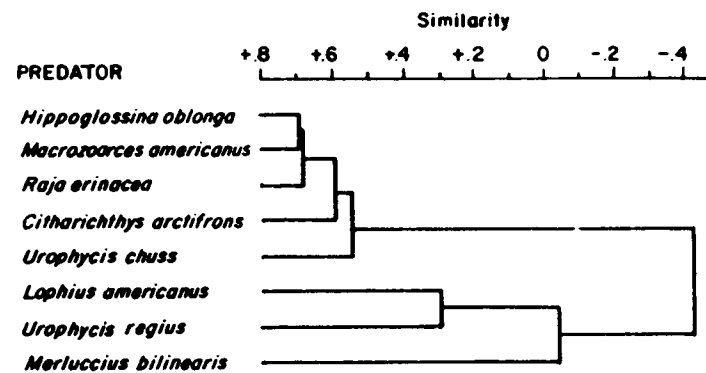


Figure 9-19. Relative abundance in *Hippoglossina oblonga* stomachs (•--•) and grab samples (•—•), and electivity (E) of selected invertebrates from a posteriori habitat strata in areas B and E.

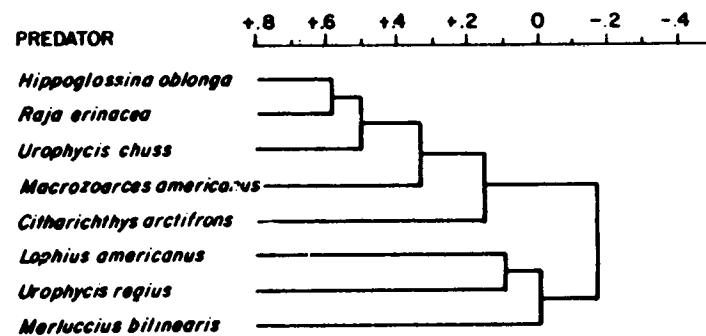
(A) FALL



(B) WINTER



(C) SPRING



(D) SUMMER

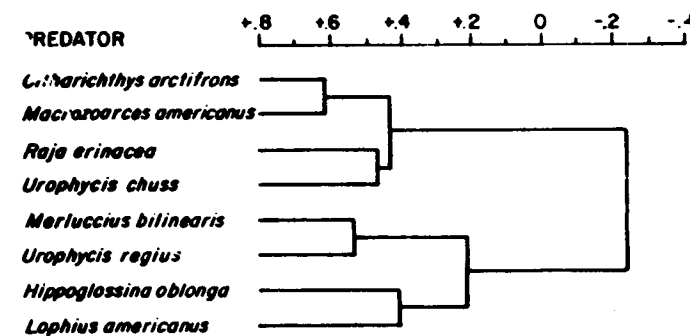


Figure 9-20. Dendrograms depicting diet similarity among predators, by season.

for R. erinacea, which was included in this group at a relatively high level of similarity. Polychaetes and copepods were also consumed by C. arctifrons and U. chuss, respectively. The one U. regius captured had eaten fish and clustered with Lophius americanus in the classification. M. bilinearis, which fed mainly on hyperiids, copepods, Dichelopandalus leptocerus and chaetognaths, differed in its diet from all other species. However, since M. bilinearis consumed fishes, it was joined to this latter group at a low level of similarity. Larger M. bilinearis present in the winter fed on different species than smaller M. bilinearis present in fall and co-occurring large U. chuss in winter. Thus, although they were very similar in diet in fall as juveniles, adults are quite dissimilar in diet in winter, with large U. chuss switching to more benthic prey, and M. bilinearis continuing to feed on planktonic species. Also in winter, H. oblonga fed on more amphipods than decapods and was grouped with other amphipod feeders.

In spring (Figure 9-20-C), Unciola irrorata and Erichthonius rubricornis were again the most important food for several predators, and the classification was similar to winter. Hippoglossina oblonga and Raja erinacea fed heavily on U. irrorata, E. rubricornis and B. serrata and showed the highest similarity of any predator pair. Urophycis chuss, Citharichthys arctifrons and Macrozoarces americanus also fed heavily on U. irrorata and E. rubricornis and were included in this group, although they fed heavily on other species also (chaetognaths and Cancer irroratus for U. chuss; larvaceans and Chone infundibuliformis for C. arctifrons and C. irroratus for Macrozoarces americanus). Lophius americanus, U. regius and Merluccius bilinearis, though somewhat dissimilar in diet, fed more on pelagic prey and were dissimilar from other predators, and formed a separate group. L. americanus fed mainly on fish, but one C. borealis was consumed. U. regius fed mainly on C. irroratus and C. borealis, but fishes and cephalopods were also consumed. M. bilinearis fed mainly on Sagitta elegans and Parathemisto gaudichaudii, but cephalopods (Illex illecebrosus) and fishes were also consumed.

In summer, Citharichthys arctifrons and Macrozoarces americanus displayed the greatest similarity in diet, when C. arctifrons again fed heavily on amphipods and Erichthonius rubricornis and Unciola irrorata were the most abundant species consumed by both. Raja erinacea and Urophycis chuss again fed heavily on both these species during summer and were included in this group, but R. erinacea also fed heavily on Byblis serrata and Ampelisca vadorum whereas U. chuss consumed many Sagitta elegans and Parathemisto gaudichaudii. P. gaudichaudii and Dechelopandalus leptocerus were the most abundant species consumed by Merluccius bilinearis and U. regius, both of which also fed on fishes. Hippoglossina oblonga switched to a fish and decapod diet in summer and was classified with Lophius americanus since both fed heavily on fishes, primarily M. bilinearis. D. leptocerus was also consumed by both species, so they were included in a group with M. bilinearis and U. regius.

DISCUSSION

Studies on the food habits of the outer continental shelf fishes comparable to the present one have not been published. Studies of the feeding of fish communities have been limited to estuaries (Darnell 1956; Odum and Heald 1972; Carr and Adams 1973; Kimmel 1973; Stickney et al. 1974, 1975), coral reefs (Randall 1967; Davis and Birdsong 1973; Hobson 1974) and other shallow marine habitats (Smith 1950; Richards 1963; Tyler 1972; Brook 1977).

Food habits of many of the species discussed herein have only been reported by other workers in faunal and taxonomic works and in life history studies. Data reports published by the Northeast Fisheries Center, NMFS, Woods Hole, have listed the stomach contents of outer shelf fishes, but food items were generally not identified to species (Bowman 1975; Maurer and Bowman 1975; Bowman et al. 1976). Some of the species included herein have been the subject of intensive food habits studies, but these studies have been performed in other areas or include specimens from throughout the fishes range. The diet of these fishes is dependent on prey availability, as can be seen by comparing the food habits reported here with the available literature. Generally, the important higher taxonomic groups of prey, e.g. polychaetes, amphipods, decapods, etc., are important in the diet of these fishes throughout their range, but the species consumed depends on availability of these prey items. Thus, Smith (1950) and Richards et al. (1963) found that Raja erinacea fed mainly on amphipods and decapods in the waters around Long Island, as has been found in the present study. However, the amphipod Leptocheirus pinguis, of minor importance in the diet of skates in this study, was the most abundant species in the diet. Smith (1950) reported that this amphipod was a dominant species in the benthos of Long Island waters. McEachran et al. (1976) found no significant differences in the higher taxonomic composition of the diet of R. erinacea from four areas including the Middle Atlantic Bight, Georges Bank, the Gulf of Maine, and the Nova Scotian shelf. However, species composition of the most important prey changed from north to south, probably reflecting changes in the benthic fauna. Previous food habits studies of the other dominant species conducted in other localities show similar results (Hildebrand and Schroeder 1927; Olsen and Merriman 1946; Bigelow and Schroeder 1953b; Jensen and Fritz 1960; Richards 1963; Barans 1969; Sikora et al. 1972; Bowman 1975; Maurer and Bowman 1975; Bowman et al. 1976).

Diversity and Seasonality of Prey Availability

The diets of several outer shelf fishes were quite diverse. Raja erinacea fed on at least 107 species, Urophycis chuss fed on about 129 species, Stenotomus chrysops fed on 106 species, and Citharichthys arctifrons fed on about 70 prey species. Other predators such as U. regius (45 species of prey) and Merluccius bilinearis (51 species of prey) were somewhat more specialized in their diet. Macrozoarces

americanus was even more restricted in its diet (39 species), feeding mainly on a few species of decapods and amphipods. Hippoglossina oblonga (34 species) was also more specialized in its diet. Lophius americanus was the most specialized predator, feeding on only 24 prey species, mostly fishes.

Although many species of prey were consumed by the fish community, only a few species were of major importance in the diet of each predator. Most species that were important in the diet of any one predator were also important for other predators as well. Many of these important prey species are abundant, ubiquitous invertebrates of the shelf (Chapter 6). These include the amphipods Ampelisca vadorum, Byblis serrata, Leptocheirus pinguis, Erichthonius rubricornis, Unciola irrorata, and Trichophoxus epistomus. Other important prey species such as Scalibregma inflatum, Chone infundibuliformis, Diastylis bispinosa, Ampelisca agassizi, and Photis dentata, though not ubiquitous across the shelf, are numerical dominants on the outer shelf, in areas B and E (Boesch et al. 1978). Other dominant outer shelf species, (Boesch et al. 1978), mainly polychaetes such as Caulericiella sp., Euchone spp., Exogone spp., Tharyx spp., Spilophanes bombyx, Notomastus latericeus, Goniadella gracilis, Lumbrinerides acuta, and other invertebrates such as Echinarachnius parma and Cyclocardia borealis were usually avoided as prey.

Because many predators depend on a few species of prey, competition among these predators could be intense and populations of these important prey species might be decimated. Apparently these prey species are extremely abundant and are prolific enough to withstand predation mortalities (see discussion in Chapter 6).

In addition to those prey species that were important for many predators, there were some prey species that were important to only a few predators. These included such species as Ensis directus (preyed on mainly by Raja erinacea), Clymenura sp. A (prey for Citharichthys arctifrons), fishes (fed on by Lophius americanus and seasonally important for Urophycis regius, Hippoglossina oblonga, and Merluccius bilinearis) and cephalopods (important for U. regius, M. bilinearis, and H. oblonga).

Many prey species, mostly planktonic invertebrates, were only seasonally important in the diet of some predators. These included the copepods Centropages typicus and Paracalanus spp., hyperiid amphipods, decapod larvae, chaetognaths, larvaceans, and juvenile fishes. Seasonally important benthic invertebrates included Diastylis sculpta, Cirolana polita, Trichophoxus epistomus, Monoculodes edwardsi, Dichelopandalus leptocerus, and Crangon septemspinosa. However, most benthic food items were equally important in the diet of the predators during all seasons. Seasonal importance of pelagic food items was probably related to abundance of these taxa in the near-bottom plankton community. Concentrations of chaetognaths near the bottom must have occurred in winter and spring, when they were

important food for demersal fishes. Larval stages of decapods were also seasonally important, and this is related to abundance of these stages in near-bottom plankton (Grant 1978). Importance of pelagic prey is also related to predator size, with smaller fishes feeding more on planktonic organisms.

Selectivity on the Macrobenthos

Patterns of selectivity with respect to prey abundance and habitat strata have been presented for all important prey species for each predator. A review of these patterns for each important prey species is in order.

Several prey species found in generally low numbers in most strata were abundant only in a few strata and it was only in these strata that they were important food items. Chone infundibuliformis was low in relative abundance in area B but was very abundant in the swales and shelf break in area E and was very important in the diet of Stenotomus chrysops in these habitats. Predation by Urophycis chuss and Hippoglossina oblonga on Byblis serrata and S. chrysops on Ampelisca agassizi and B. serrata also demonstrate this pattern. Predation on A. agassizi was particularly interesting. This amphipod was very high in relative abundance in swales, especially in area B, but S. chrysops was the only predator to take advantage of this abundant food supply. Other predators were unable to utilize this species, even where abundant, and preyed selectively on other ampeliscid amphipods.

Other important prey species, mainly decapods, were found in low relative abundance in grab samples in all strata, but were positively selected for by many predators. Thus decapod predators such as Raja erinacea, Urophycis regius, Merluccius bilinearis, and occasionally Stenotomus chrysops and Hippoglossina oblonga generally showed high positive selectivity for Cancer irroratus, Crangon septemspinosa, and Dichelopandalus leptocerus. Dredge and trawl collections of such megabenthos indicate that these mobile decapods may be more abundant than the grab data indicate, although dredge and trawl data are only semi-quantitative (Boesch et al. 1978) and should be viewed with caution. In any case it is clear that such large epibenthic invertebrates are very common in all habitat strata.

Many prey species fluctuated in abundance among the strata. Clymenura sp. A, Trichophoxus epistomus, Byblis serrata, Unciola irrorata, and Ampelisca vadorum were more abundant on terrace, ridge and eroded flank strata, and Erichthonius rubricornis was more abundant on flanks and in swales. Abundance of these prey in fish stomachs either followed the abundance pattern in the benthos, resulting in low to moderately positive or negative selectivity values in strata where they were consumed; or abundance in stomachs also

fluctuated greatly among the strata without any relation to abundance in the benthos. Raja erinacea and Urophycis chuss predation on B. serrata and A. vadorum; Merluccius bilinearis predation on A. vadorum; and Stenotomus chrysops predation on U. irrorata demonstrate the former pattern. Examples of the latter pattern are numerous and include R. erinacea predation on T. epistomus and E. rubricornis; and U. chuss predation on U. irrorata and E. rubricornis.

Other important invertebrate prey such as Diastylis bispinosa, Ensis directus, Nicolea venustula, Phoxocephalus holbolli, Glycera dibranchiata, ostracods, and Echinarachnius parma were present in low abundance or were absent from some strata. They were generally low in relative abundance in fish stomachs but were consumed in moderate numbers in some strata. Electivity values for these species fluctuated greatly from stratum to stratum. Pelagic hyperiid amphipods, obviously low in relative abundance in grab samples, generally had high positive values because of their low abundance in the benthos and their occasionally heavy consumption by some predators.

Many abundant species in the benthos are unimportant in the diet of dominant fishes on the outer shelf. Although many of these predators appear to have diverse and euryphagous food habits, they are actually rather selective when the species composition of their diets is compared with the prey communities. The apparent avoidance of some dominant benthic animals may be related to size of these animals (some may be too small or too large to be consumed) or to an ability of these animals to avoid predation. Ross (1977) found prey size rather than prey species to be the most important axis of resource partitioning among co-occurring triglid fishes.

Overlap in Diet

Most predators shared many abundant prey species, particularly corophiid and ampeliscid amphipods and decapod crustaceans. Other fish feeding studies indicate that when food is abundant, sympatric predators will be generalists and overlap in their food habits (Keast 1965; Zaret and Rand 1971). However, the relationship between food abundance and competition is not completely clear (Zaret and Rand 1971), and some workers have argued that the lower abundance of food, the greater the diversity of food consumed and hence the more generalized the predator (Ivlev 1961; MacArthur and Pianka 1966; Schoener 1971). The data presented herein indicate that abundant food species (Chapter 6) are shared among many dominant predators. Seasonal intrusions of abundant pelagic prey, such as chaetognaths, are also shared among several predators. Because of the great amount of resource sharing, it should be predicted that important prey species must be abundant at all times of the year. Studies of the macrobenthos indicate that there is temporal persistence of dense populations of benthic crustaceans on the outer shelf (Chapter 6).

Seasonal consumption of planktonic prey by several predators indicates that macrozooplankton (copepods, hyperiids, chaetognaths, decapod larvae) are seasonally abundant in near bottom plankton. This is also evident from plankton studies on the OCS (Grant 1977). In addition to the abundant species shared by many predators, most predators selectively fed on some prey more intensely than other predators, so that there was never complete overlap in the diets of two predators.

Intra- and interspecific competition changed considerably with season. When Stenotomus chrysops moved out of the study area, adult Urophycis chuss moved in and utilized some of the prey resources previously exploited by S. chrysops. Mainly juvenile U. chuss co-occured with S. chrysops, and their food habits were somewhat similar in fall (Figure 9-20). The larger red hake which appeared in winter fed heavily on decapods, polychaetes, and copepods, taxa that were abundant in the diet of S. chrysops in fall.

Overlap in diet between closely related species is generally lower than that for unrelated species, suggesting resource partitioning. Thus the congeners Urophycis chuss and U. regius show a low similarity in diet (Figure 9-20). Still, no predator monopolized any trophic resource.

Fish Food Habits and Impact Assessment

The potential impact of oil and gas development and production on outer continental shelf finfish may be mainly related to their food habits, feeding mechanisms and behavior, and marine food chain structure. From the data presented herein, it is clear that certain macrobenthic invertebrates are a very important food source for the demersal fish community of the outer shelf. The benthic environment is the community most likely to be affected by oil and gas development on the OCS (Boesch et al. 1974). Overboard discharge of drill cuttings, drilling mud and sand may cause smothering of benthic organisms. These effects would probably be localized, but would result in localized areas of reduced prey abundance and, hence, potentially reduced abundance of benthic feeding fishes. Introduction of petroleum hydrocarbons and other potentially toxic compounds as a result of drilling or production could either reduce prey availability or lead to concentrations of toxic materials in fishes feeding in the area.

The potential damage from oil spills could also affect prey abundance. Sanders et al. (1972) found that in heavily oiled bottoms, benthic invertebrates were virtually eliminated. In addition, and perhaps more importantly, certain sensitive species were eliminated in the peripheral areas of the spill. These sensitive species included ampeliscid amphipods, a very important food source for many demersal fishes.

Besides eliminating food resources, oil development has other potential effects on the feeding of demersal fishes. A major effect of petroleum on marine organisms is reduction in the chemosensory activity of the animal (Kittredge 1974). Feeding behavior in fishes is often initiated by chemoreception (Kleerekoper 1969; Hara 1971). Chemosensory cues have been shown to be important in the feeding behavior of Urophycis chuss, Prionotus spp. (Bardach and Case 1965) and flatfishes (de Groot 1969). It is likely that other OCS fishes rely primarily on chemical cues in feeding and would also be affected by oil spills. Increased turbidity caused by drilling would also affect visual feeders.

Fish are highly mobile and may be able to avoid localized areas contaminated by oil development. However, certain habitats on the outer shelf have been found to be particularly productive for macrobenthic invertebrates. Swale areas, in particular, are more productive (Chapter 6). Some predator species (Stenotomus chrysops, Merluccius bilinearis, Hippoglossina oblonga, Raja erinacea) examined herein feed on high concentrations of some invertebrate species (Unciola irrorata, Erichthonius rubricornis, Chone infundibuliformis, Ampelisca agassizi, A. vadorum) that are found in the swales. Some of these species are amphiscid amphipods, which are among the more sensitive members of the benthos (Sanders et al. 1972). As Boesch et al. (1978) have suggested, these productive areas are likely to collect contaminants because they collect finer sediments, and special precaution should be taken in developing these swale areas.

Summary of Significant Findings

1. Dominant demersal fishes of the outer continental shelf feed primarily on macrobenthic invertebrates. Some species also feed heavily on fishes, cephalopods, and planktonic invertebrates.
2. Prey of fishes change seasonally, especially at the species level. Planktonic invertebrates are seasonally important in the diet of many fishes.
3. Selectivity patterns of predators on the benthos were varied with respect to strata. Many dominant benthic species were not selected as food. Other rarer species were positively selected for. Species that fluctuated in abundance among the strata were either eaten in proportion to their abundance in all strata, were eaten only when very abundant, or were consumed in moderate amounts regardless of their abundance in the benthos.
4. Most predators consumed prey species in common. Overlap in diet among the predators varied seasonally, with overlap relationships changing as species and size class composition of the predators changed. Although many important prey species were consumed by several predators, some were selectively consumed by only a few predators.

ACKNOWLEDGEMENTS

The following personnel assisted on trawl cruises: D. Benner, H. Brooks, R. K. Carpenter, J. A. Colvocoresses, E. J. Foell, J. Gourley, N. P. Heil, J. Krauter, R. E. Matheson, L. P. Mercer, R. W. Middleton, L. Murray, C. Peet, W. G. Raschi, W. Rizzo, L. Schaffner, J. W. Smith, J. van Montfrans, M. Vecchione, D. Wadsworth and C. A. Wenner. J. A. Colvocoresses also helped in cruise preparation and in the tedious process of picking and plotting stations. N. P. Heil and L. T. Fletcher assisted in sorting and counting stomach contents, measuring volumes and coding data. Thanks are extended to the following personnel for their assistance in determining the identity of sometimes mangled stomach contents: M. A. Bowen confirmed identification of many amphipods; E. L. Wenner and J. van Montfrans confirmed many of the decapods; G. Gaston identified some of the polychaetes and confirmed many identifications; G. C. Grant identified many of the copepods and chaetognaths; P. O. Smyth identified many of the decapod larvae.

W. P. Blystone wrote or modified the computer programs used in data analysis; J. F. Millen, B. J. Taylor and L. C. Orselli typed early drafts of the manuscript; and Beverly Laird assisted in preparation of the manuscript. D. F. Boesch made available his data on macrobenthos and made many helpful suggestions which improved the manuscript. Special thanks are extended to J. Buffett who provided inspiration and moral support during the cruises.

SECTION II. COMMUNITY STRUCTURE ANALYSIS OF FISHES

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John A. Musick

INTRODUCTION

Studies on the community structure of demersal fishes on the outer continental shelf (OCS) region off the Middle Atlantic States are of great interest in the Benchmark Studies Program because this region supports both commercial and recreational fishing activity. Many species of fishes carry out extensive north-south and onshore-offshore migrations governed by seasonal, thermal, and bathymetric conditions, while others move less extensively or are resident in a particular geographic or topographic region. Community structure analysis using numerical classification and other statistical techniques has proven to be a useful tool in the elucidation of these often complex patterns of fish distribution. Such methods have been used to describe faunal patterns of demersal fish communities on the OCS off the Middle Atlantic States using historical data derived from NMFS groundfish surveys (1963-76) and VIMS industrial trawl surveys (1967-68). Results of these analyses are presented in Chapter 10.

Detailed baseline information on the faunal assemblages seasonally associated with specific habitat types in specific geographic areas is required to support planning and management decisions. The possible effects of OCS resource development upon the demersal fish community can be detected and evaluated only if prior information is available on the structure of the fish community present in any given area and season under relatively undisturbed conditions.

The benchmark studies on demersal fish communities reported in this section focus upon intensive data collected from two study areas situated within the prime lease tracts which are of immediate concern.

MATERIALS AND METHODS

A description of the study areas and of the materials and methods utilized for field collections are given in Section I (Food Habits of Fishes) of this chapter and are not repeated here. Similarly, the rationale for habitat delineation and detailed descriptions of the various categories and sub-categories of the stratification scheme have been previously given (Chapter 6 and Section I of the present chapter) and are not belabored further.

Data Analysis

Community similarity and species distribution were examined initially with the use of normal and inverse cluster analysis. Several cluster strategies were employed including a combination of log-transformed $[\ln(x + 1)]$ species abundance, flexible sorting with $B = -0.25$ and either the Canberra Metric or Bray-Curtis similarity coefficient resulting in polythetic, agglomerative hierarchical classifications (Clifford and Stephenson 1975; Boesch 1977).

Stations were then grouped according to a somewhat modified form of the a posteriori stratification scheme described in Chapter 6. Strata sub-categories were combined into single categories as follows:

Area B

- Stratum 1. terrace
- Stratum 2. ridge and medium sand flank
- Stratum 3. medium-fine sand flank and eroded flank
- Stratum 4. shallow swale
- Stratum 5. deep swale

Area E

- Stratum 1. ridge and megaripples
- Stratum 2. medium-fine sand flank
- Stratum 3. shallow and deep swale
- Stratum 4. eroded swale
- Stratum 5. upper and mid-shelf break

Patterns of numerical abundance and biomass dominance were examined to detect faunal changes among strata in each of the two areas on a seasonal basis. Wherever pooled sample size exceeded 30 individuals per area and a minimum of 10 individuals occurred in each of at least two strata, relative abundance of dominant species was compared among strata using analysis of variance (ANOVA) ($\alpha = 0.05$) on log-transformed $[\ln(x + 1)]$ numerical abundance. When ANOVA showed significance, Scheffe's multiple-range test ($\alpha = 0.05$) was used to determine which groups were significantly dissimilar (Guenther 1964).

Similarly, length frequency distributions of dominant species were plotted and analyzed by area and season. Length distributions were compared among strata using ANOVA ($\alpha = 0.05$), and, when variance was significant, Scheffe's test ($\alpha = 0.05$) was used to determine which strata were significantly different.

Basic statistics relating to tow depth, bottom temperature and number of species were computed and analyzed by collection period, stratum, study area, and season. Mean and cumulative species

diversity (H'), richness (D), and evenness (J') were calculated and compared among strata, areas, and seasons (Hurlburt 1971; Pielou 1975).

RESULTS AND DISCUSSION

Hydrography

The seasonal thermal conditions at the sea bottom for each stratum and study area are plotted in Figure 9-21. Bottom temperatures during the fall of 1976 were similar in all strata of areas B and E. During winter (1977), temperatures in area B had dropped to below 5°C while area E remained above 7°C. Spring 1977 temperatures in area B showed little difference from winter conditions while those in area E fell to below 6°C except in stratum 5 (shelf-break) which remained one degree warmer. Temperatures in both areas rose to $10 \pm 0.5^\circ\text{C}$ in summer 1977 except in shelf-break stratum 5 of area E which had already warmed to 11.5°C.

Maximum bottom temperatures occurred in the fall due to turnover resulting from dissipation of the thermocline while minimum temperatures were found in spring when bottom waters were isolated from the effects of vernal warming by the formation of a thermocline. Temperatures in the deeper waters of shelf-break stratum 5 (area E) were influenced by the proximity of Slope Water and its moderating effects (Chapter 10).

In general, temperatures on the sea bottom in the study areas attained their annual maximum and minimum values several months later and out of phase with the usual definition of seasonality based on air temperatures. Since thermal conditions greatly influence the seasonal north-south and onshore-offshore migrations of many fishes, community structure reflected the ambient temperatures at the time of collection. Thus, a typical warm-water faunal assemblage did not occur until fall, whereas cold-water conditions and associated species patterns dominated the study sites at other seasons.

Fish Assemblages

Cluster Analysis

Initial results of normal cluster analysis from all seasonal cruises indicated strong day-night catch differences. Smaller daytime catches resulted from vertical migration or net avoidance by many species. Figures 9-22 through 9-30 indicate that the number of species, numerical abundance, and biomass of night stations exceeded those of day stations. The few exceptions were due to low sampling intensity (e.g., Figures 9-26 and 9-29, BLM-06T, B-area, stratum 4.) In order to eliminate the masking effect (e.g., Figure 9-31) of these

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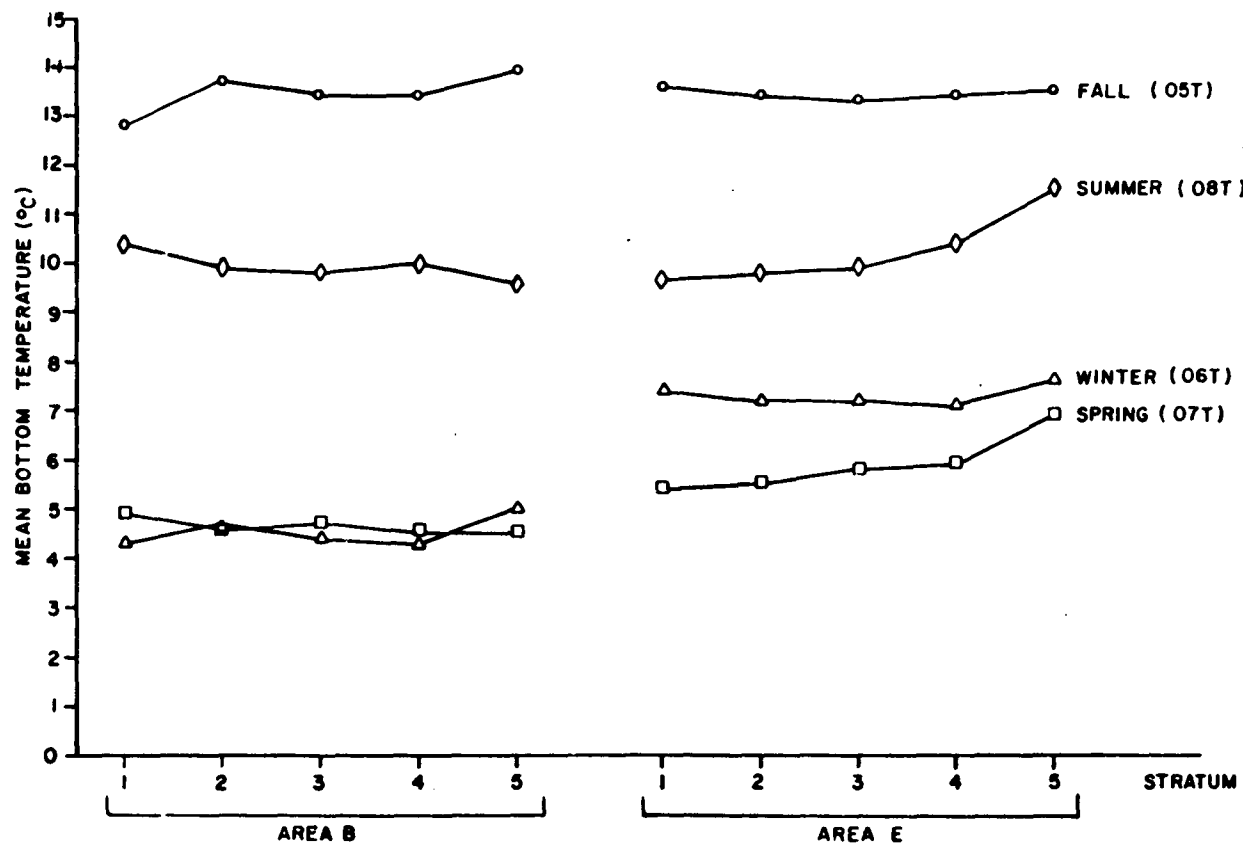


Figure 9-21. Mean bottom temperature ($^{\circ}\text{C}$) by stratum and study area for each seasonal cruise.

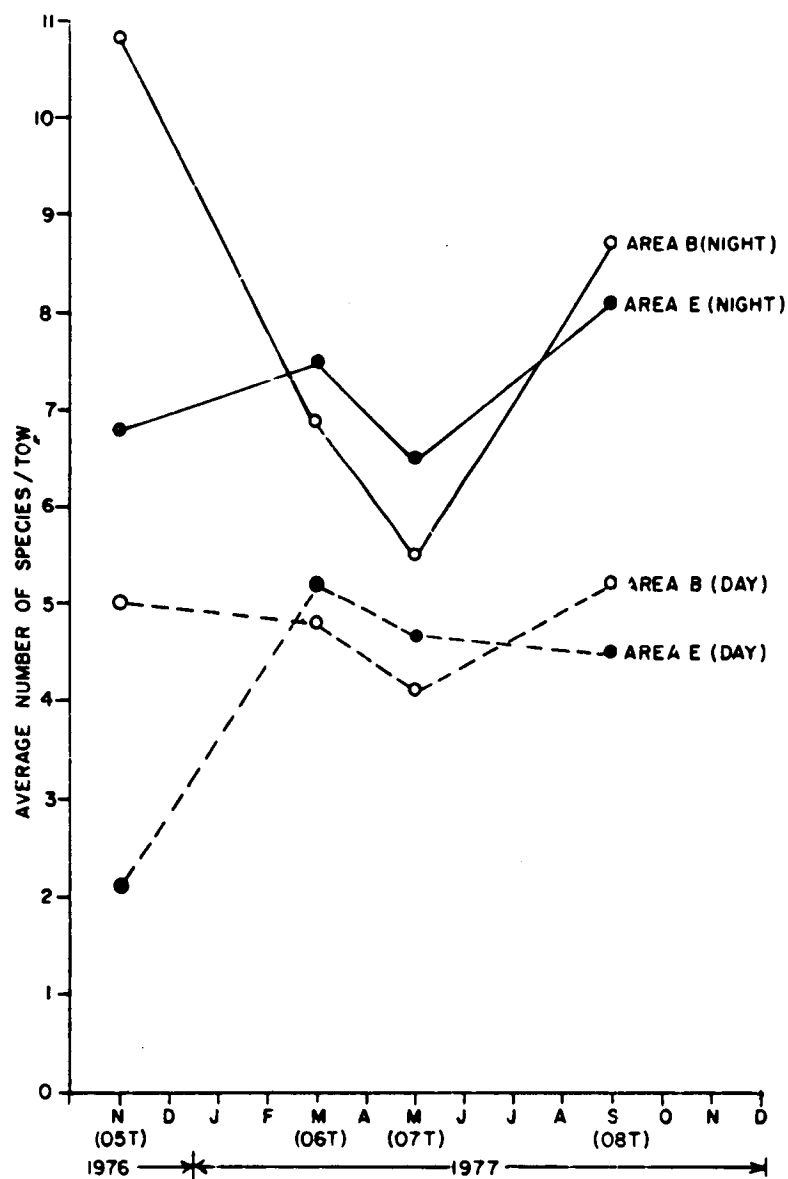


Figure 9-22. Average number of species per tow by seasonal cruise, study area, and period of collection.

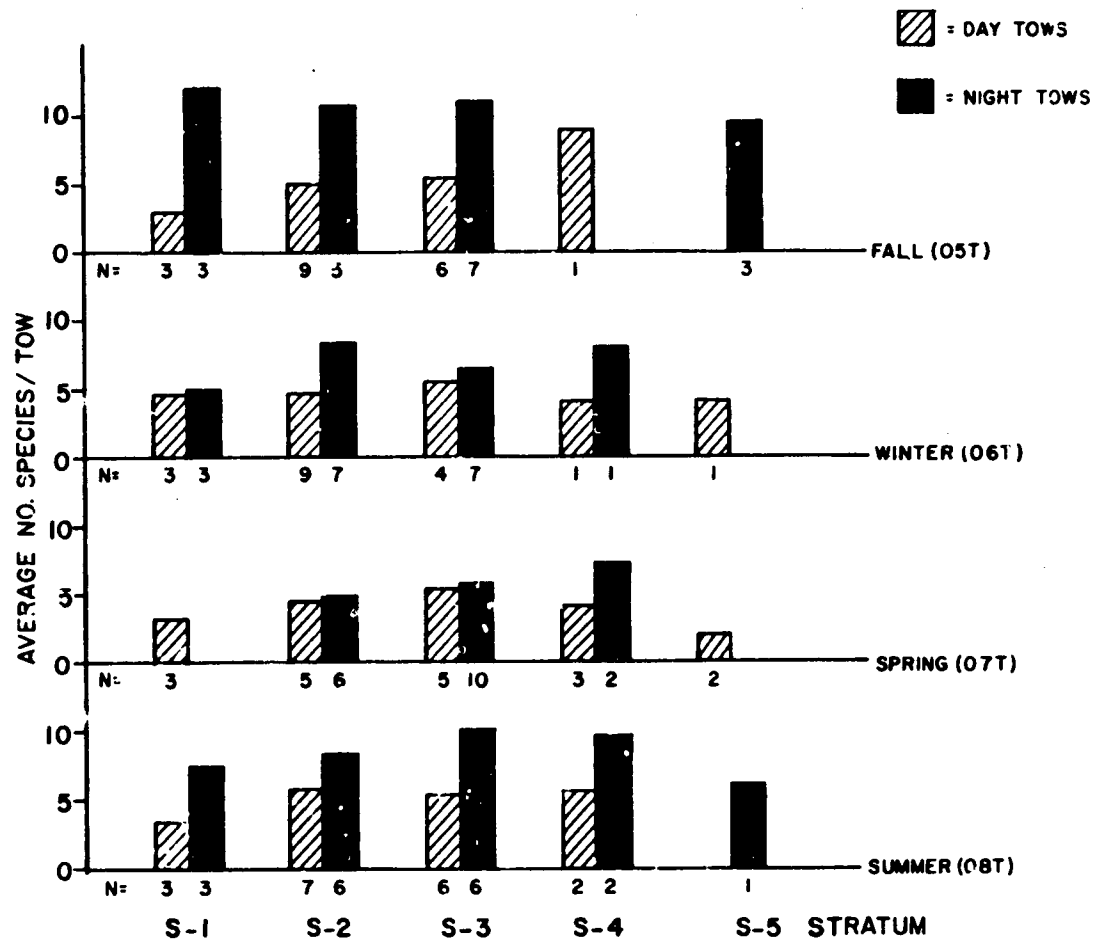


Figure 9-23. Average number of species per tow in Area B by period of collection, stratum, and seasonal cruise. N = number of tows.

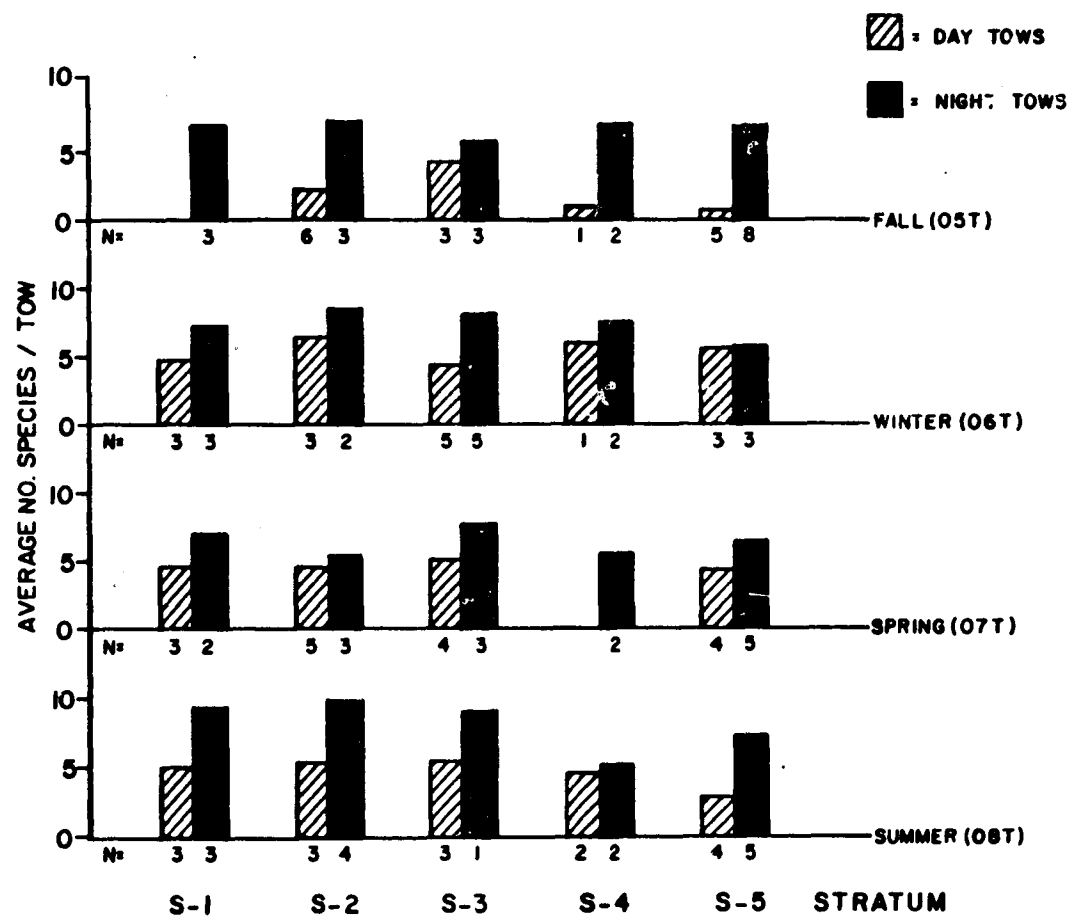


Figure 9-24. Average number of species per tow in Area E by period of collection, stratum, and seasonal cruise. N = number of tows.

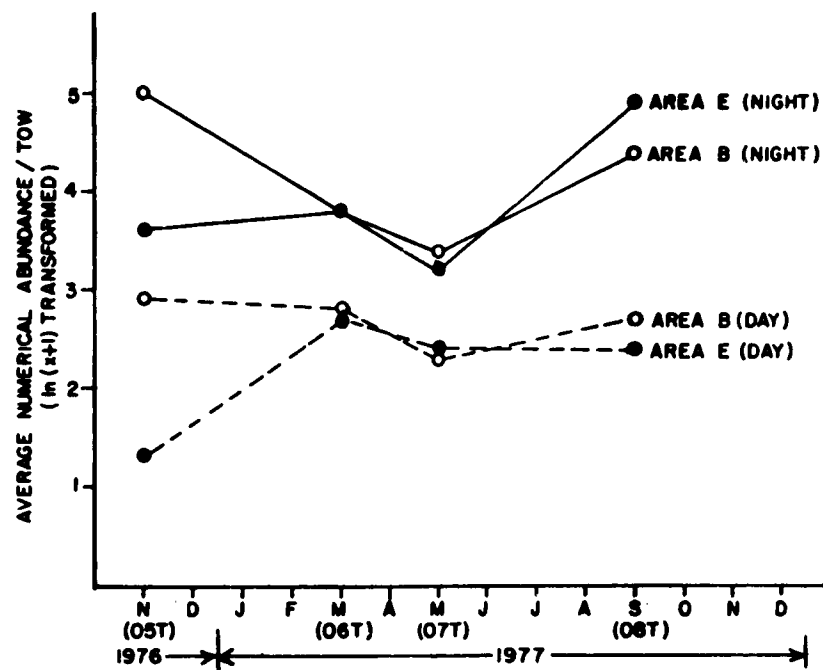


Figure 9-25. Average numerical abundance [$\ln (x+1)$ transformed] per tow by seasonal cruise, study area, and period of collection.

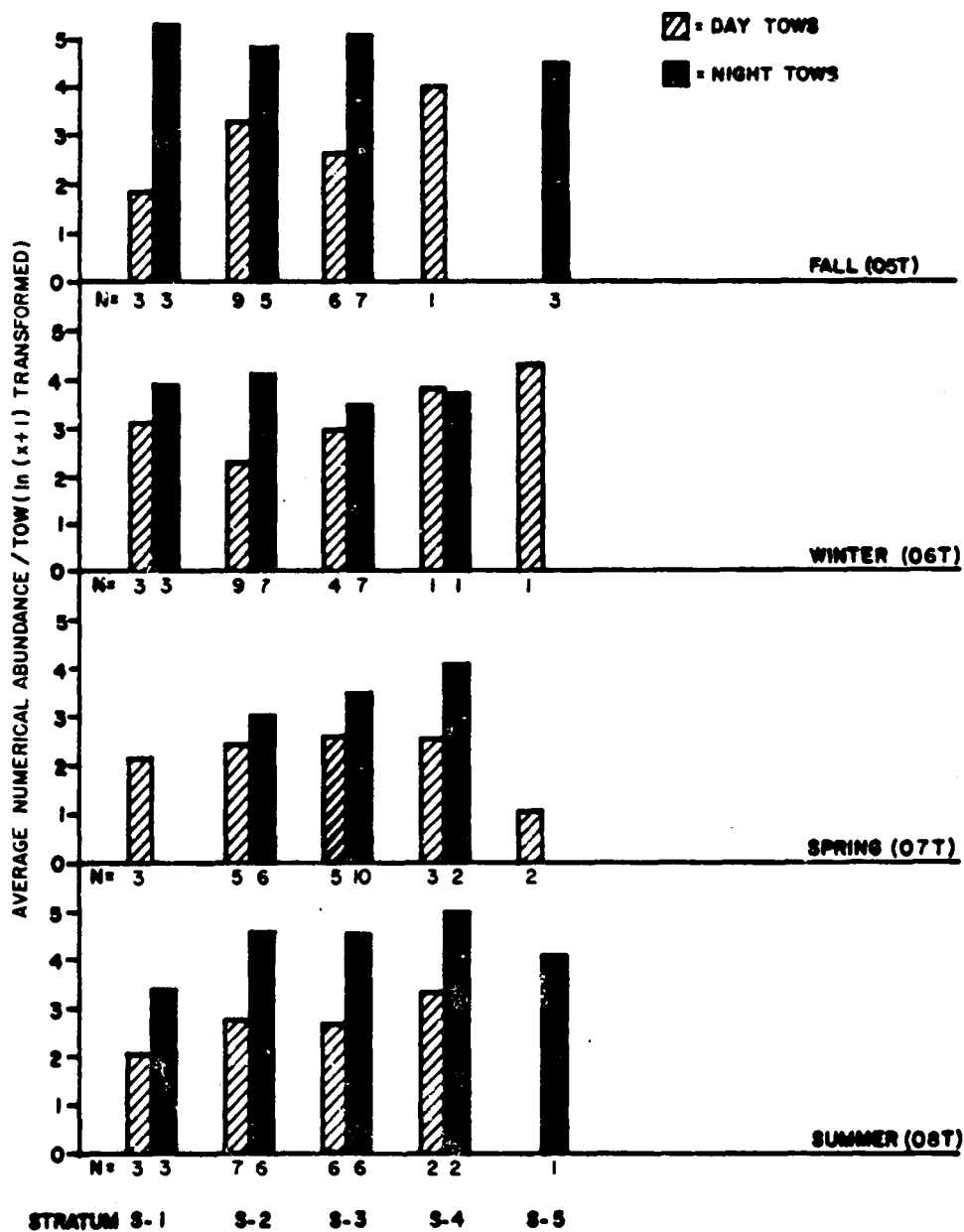


Figure 9-26. Average numerical abundance [$\ln (x+1)$ transformed] per tow in Area B by period of collection, stratum, and seasonal cruise. N = number of tows.

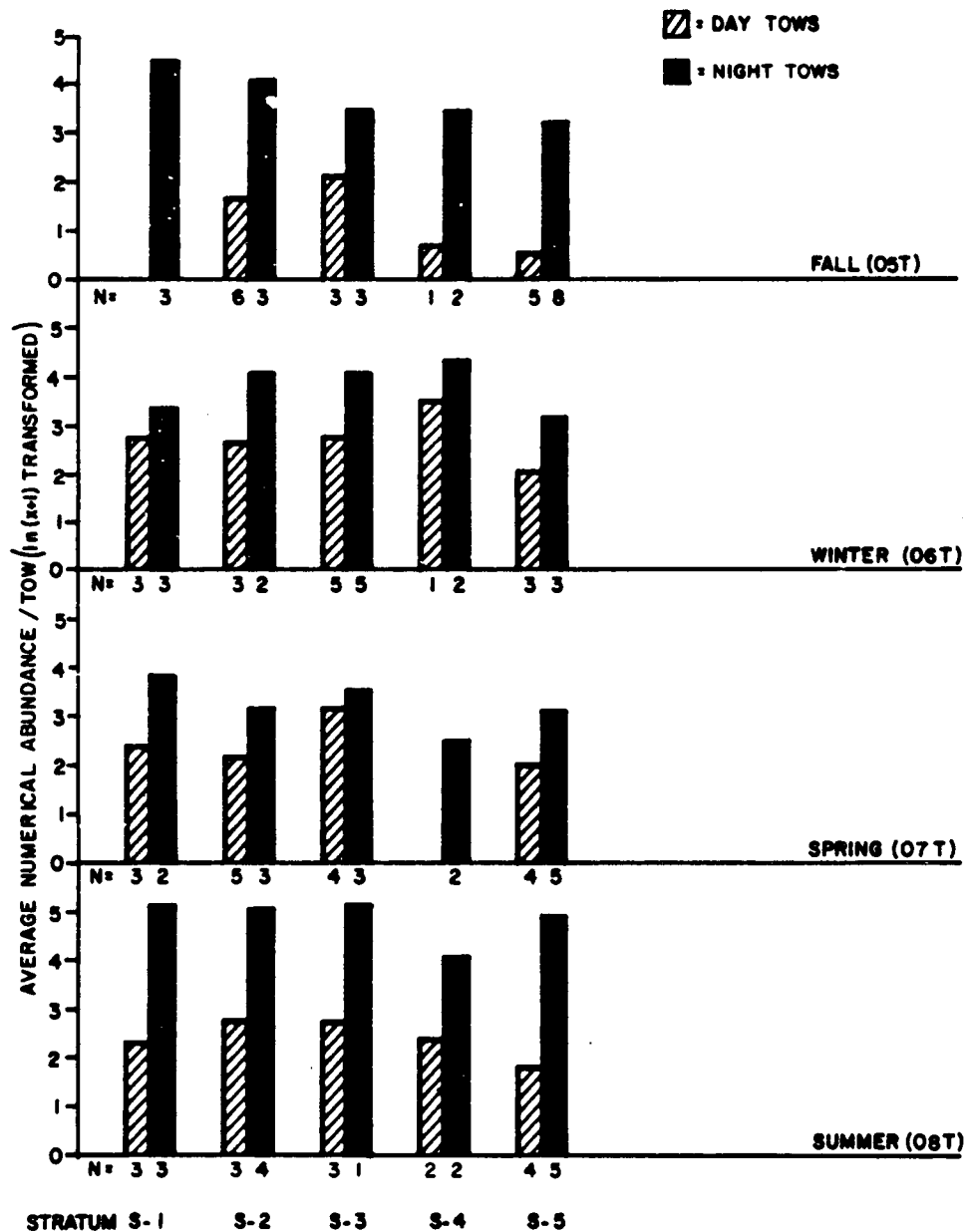


Figure 9-27. Average numerical abundance $[\ln (x+1) \text{ transformed}]$ per tow in Area E by period of collection, stratum, and seasonal cruise. N = number of tows.

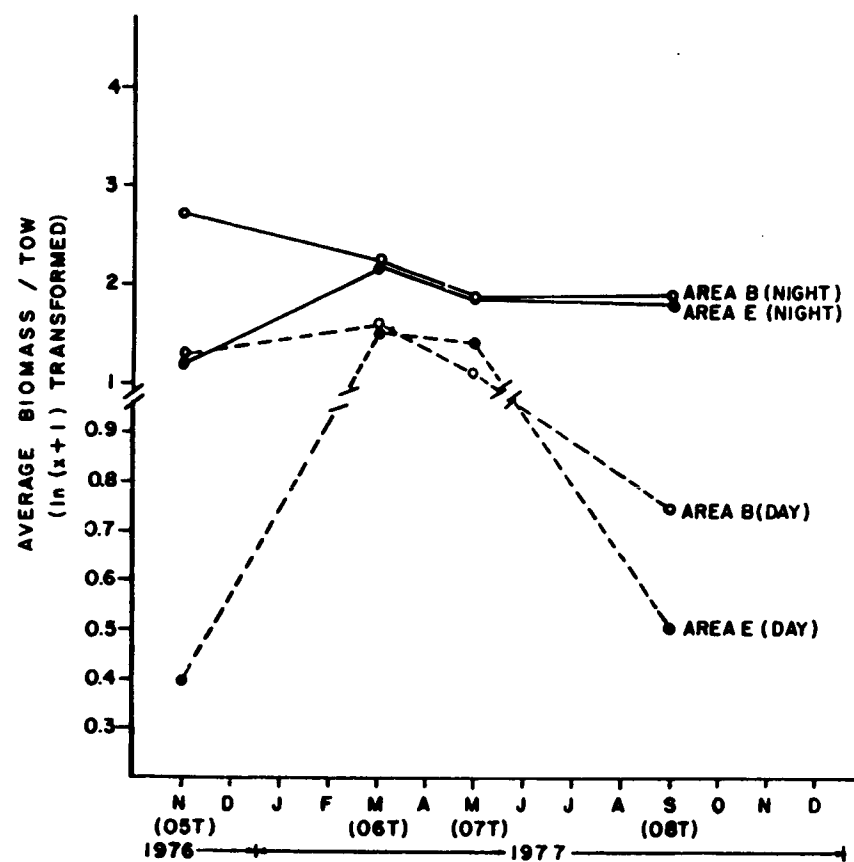


Figure 9-28. Average biomass [$\ln(x+1)$ transformed] per tow by seasonal cruise, study area, and period of collection.

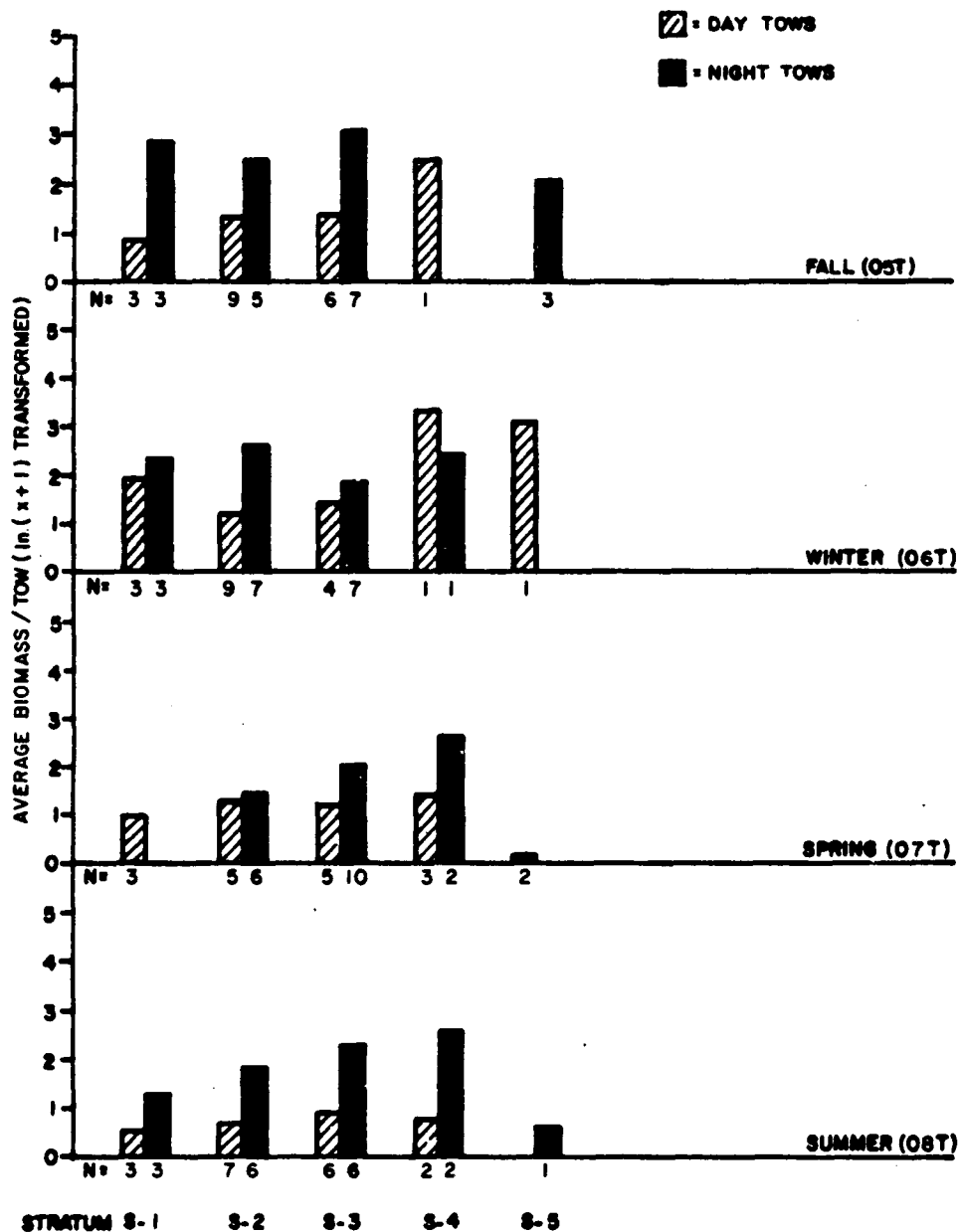


Figure 9-29. Average biomass $[\ln (x+1) \text{ transformed}]$ per tow in Area B by period of collection, stratum, and seasonal cruise. N = number of tows.

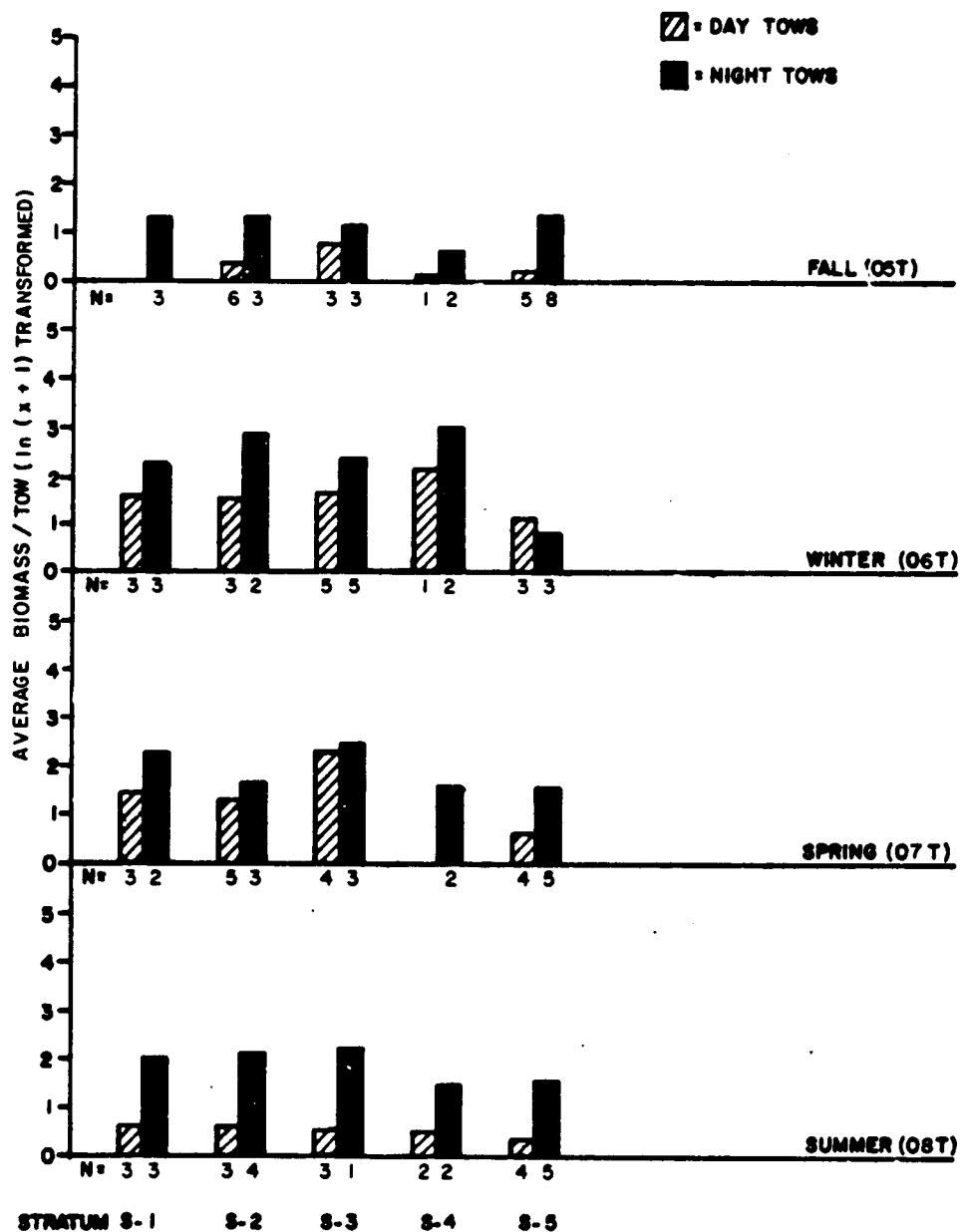


Figure 9-30. Average biomass [$\ln (x+1)$ transformed] per tow in Area E by period of collection, stratum, and seasonal cruise. N = number of tows.

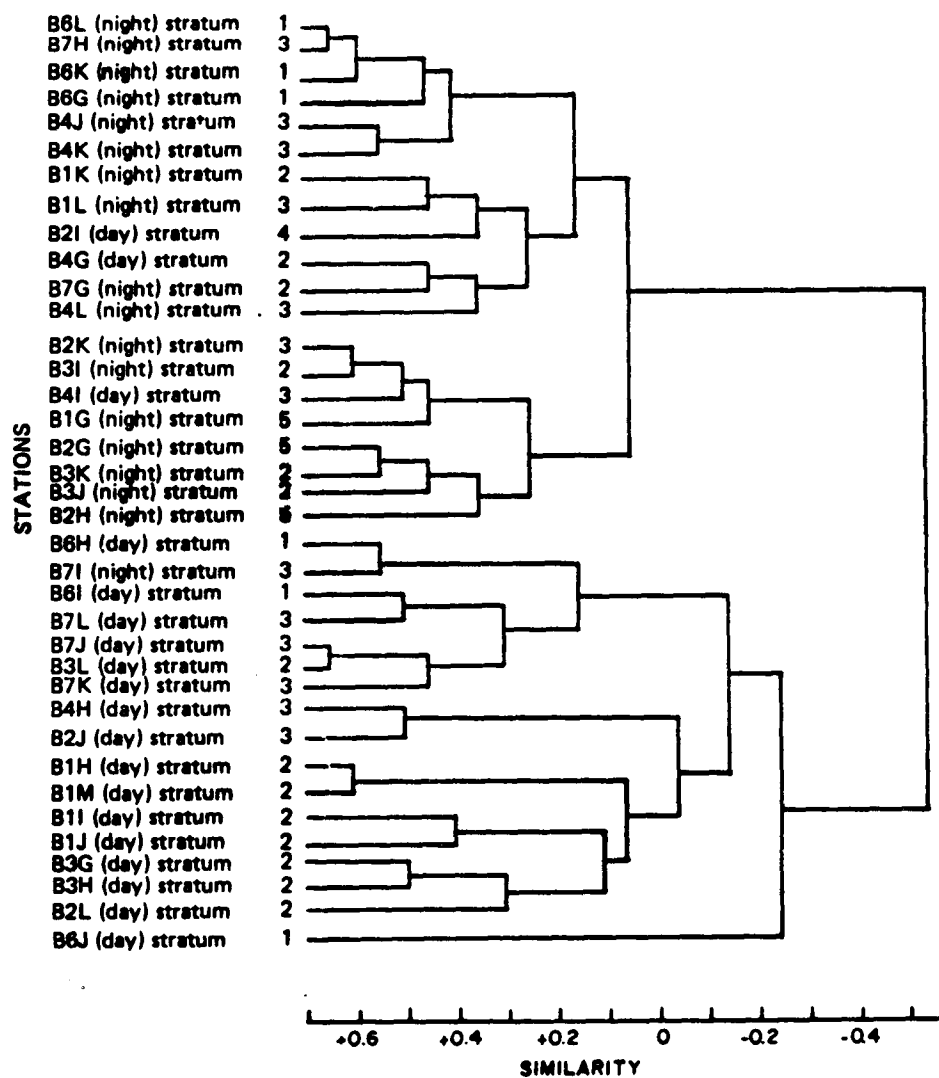


Figure 9-31. Normal (station) cluster for all Area B collections during fall 1976 (BLM05T). Similarity coefficient employed is the Canberra metric with flexible sorting ($\beta = -0.25$). Stations are identified by a three character code in which the first letter represents the study area (B or E), the number represents the a priori stratum (1 through 7), and the last letter represents a specific tow (G through M). The period of collection (day or night) is followed by the a posteriori stratum designation.

large diel fluctuations in abundance, the catch data were separated into day and night collections for further analysis.

Results of cluster analysis on catch data separated by season, study areas and sampling period indicated that the greatest similarities existed among rather than within both the a priori and the a posteriori sampling strata (e.g., Figures 9-32 and 9-33). Station cluster groups formed consisted of stations from various strata with no detectable tendency for stations from the same stratum to align into cohesive aggregates other than those due to chance. This result, based upon the distribution of demersal fishes, differs from that obtained with distribution of benthic organisms described in previous chapters. Several explanations may be offered for this apparent inconsistency.

A primary consideration is the relative mobility of the organisms involved. Fishes in the study area were relatively large and capable of rapid and wide-ranging movements across stratum boundaries. Although fishes may prefer a certain substrate for food availability, etc., they may not necessarily have been bound to a given stratum for an entire 24-hour period.

Another reason for the apparent homogeneity of fish community structure throughout a given study area may be the lack of gross variation in topography, depth, and bottom temperature among strata. Depth and temperature zonation have been shown (Chapter 10) to influence the distribution of fishes, but on a larger scale than that in the current study. Only where sufficient environmental differences exist, as for example between areas B and E in terms of geographic location and prevailing thermal regime during winter and spring, are differences in fish faunal composition detectable by relatively coarse techniques such as an otter trawl survey.

The sampling plan (see Methods) involved three day and three night tows randomly placed in each a priori stratum, i.e., a random stratified design based on depth and substrate type. However, after completion of all field sampling, evaluation of newly acquired sediment and benthic data brought about a re-definition of stratum types into an a posteriori stratification scheme. This resulted in unequal distribution of a limited number of trawl samples across the a posteriori strata and considerably hindered the statistical analysis and comparability of the data collected. The BLM decision to halt all OCS benchmark studies precluded acquisition of a second year of seasonal data from the two study areas. This would have involved a sampling design based upon the new a posteriori stratification scheme, would have allowed a more detailed analysis on a stratum by stratum basis, and would have given some insights on year-to-year variability in the fish populations of the prime lease areas.

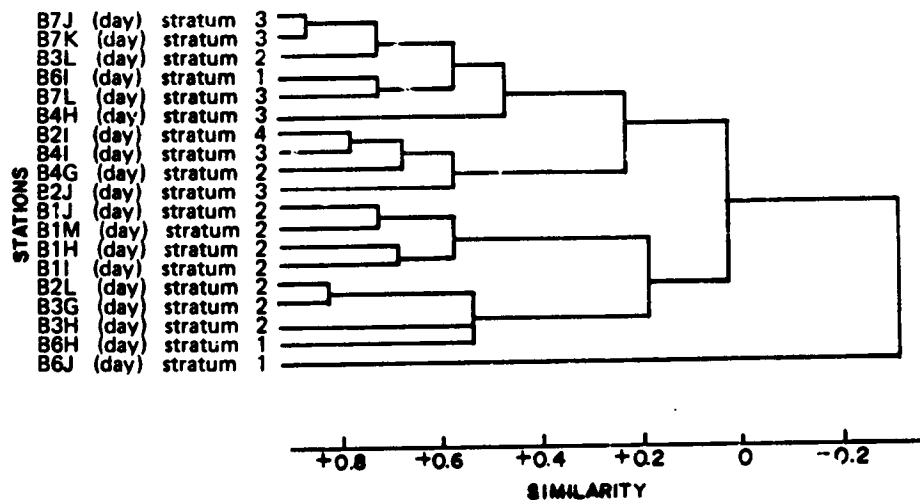
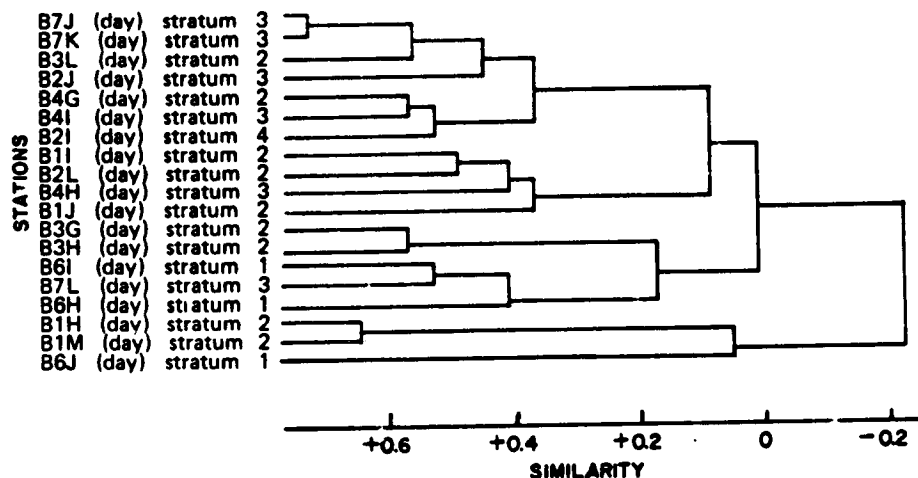


Figure 9-32. Normal (station) cluster for Area B day collections during fall 1976 (BLM05T). Similarity coefficients employed are (top) the Canberra metric with flexible sorting ($\beta = -0.25$) and (bottom) the Bray-Curtis with flexible sorting ($\beta = -0.25$). Stations are identified by a three character code in which the first letter represents the study area (B or E), the number represents the a priori stratum (1 through 7), and the last letter represents a specific tow (G through M). The period of collection (day or night) is followed by the a posteriori stratum designation.

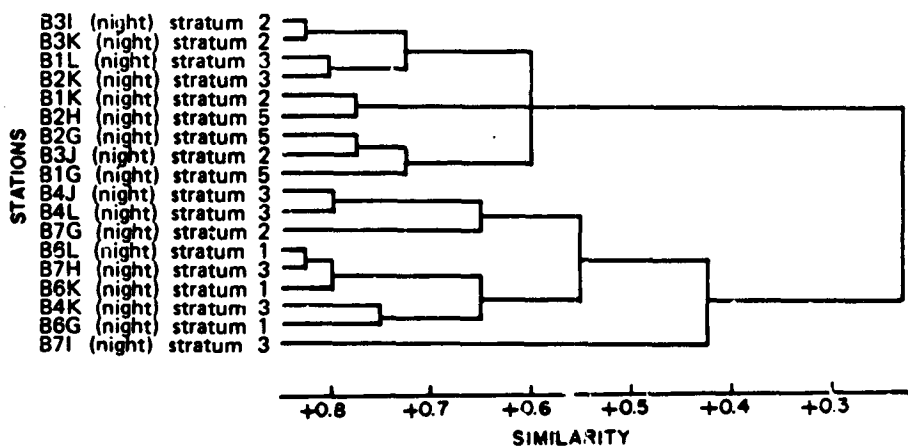
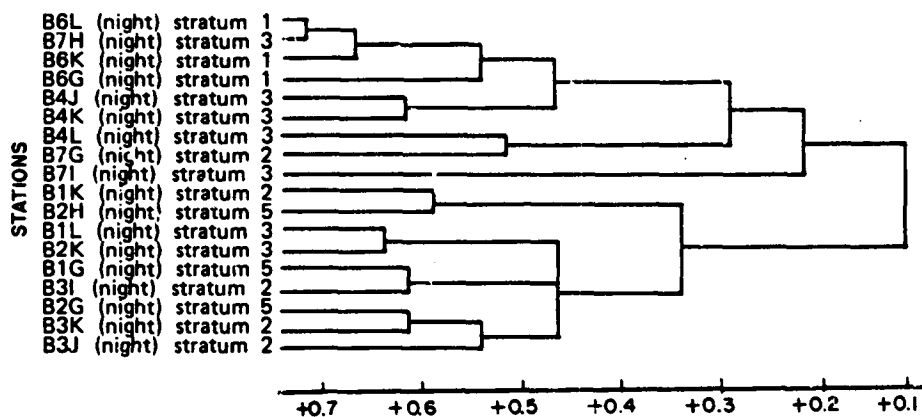


Figure 9-33. Normal (station) cluster for Area B night collections during fall 1976 (BLM05T). Similarity coefficients employed are (top) the Canberra metric with flexible sorting ($\beta = -0.25$) and (bottom) the Bray-Curtis with flexible sorting ($\beta = -0.25$). Stations are identified by a three character code in which the first letter represents the study area (B or E), the number represents the a priori stratum (1 through 7), and the last letter represents a specific tow (G through L). The period of collection (day or night) is followed by the a posteriori stratum designation.

Numerical Abundance and Biomass

A total of 13,430 fishes representing 25 families and 41 species were collected in areas B and E during four seasonal cruises (Table 9-11). Eight species alone accounted for 12,510 individuals or more than 93% of the total number of fishes caught (Table 9-12).

The five most dominant species by numerical abundance and biomass for each season and study area are listed in Tables 9-13 and 9-14. Three boreal species (Urophycis chuss, Merluccius bilinearis, and Raja erinacea) were among the numerically dominant forms in both areas during all seasons. Citharichthys arctifrons, a slope resident, was absent from the numerical dominance listing only in the spring area B collections where it was ranked sixth in abundance. Hippoglossina oblonga, an outer-shelf resident, occurred among the dominant species during winter and spring collections in areas B and E. This species was also present in sizeable numbers during fall, but ranked sixth in abundance in both areas due to the seasonal appearance of large number of Stenotomus chrysops, a warm-temperate form that moved offshore and southward out of the study areas (apparently when water temperatures fell to below 7.5°C [Bigelow and Schroeder 1953b]). Another boreal species, Macrozoarces americanus, occurred among the area B dominants during spring and summer whereas U. regius, a warm-temperate congener of U. chuss, was dominant only for the summer area E collections.

Several other species were taken in significant numbers, but are not ranked among the eight numerically dominant fishes on Table 9-12. Lophius americanus, a boreal species, was common in both study areas and during all seasons (Table 9-11). The 248 individuals taken in the current survey were relatively evenly distributed in terms of area and season of collection. The species is probably resident in both study areas throughout the year.

Paralichthys dentatus, a species with warm-temperate faunal affinity, was seasonally common in the fall (44 specimens) and to a lesser extent in the winter (21 specimens). It was not collected during spring and summer sampling (Table 9-11). This species is known to migrate onshore in the spring and to remain in relatively shallow coastal areas and estuaries throughout the summer. In fall, the species migrates offshore and disperses widely over the continental shelf (Bigelow and Schroeder 1953b). It is probably an important constituent of the benthic fish community in the study areas only during the colder months when onshore temperatures fall below its preferred temperature range. Other warm-temperate species (Centropristis striata, Peprilus triacanthus, Prionotus carolinus) occurred seasonally in the collections, but were not sufficiently abundant to allow interpretation of distributional patterns or importance in the community structure of the study areas. These species represent portions of larger populations whose distribution and migratory movements are more extensively discussed in Chapter 10.

Table 9-11. List of fish species and number captured during four seasonal trawl cruises.

SPECIES	FALL (05T)	WINTER (06T)	SPRING (07T)	SUMMER (08T)
Scyliorhinidae				
<u>Scyliorhinus retifer</u>				1
Carcharhinidae				
<u>Mustelus canis</u>	1			
Squalidae				
<u>Squalus acanthias</u>	11	39	1	1
Rajidae				
<u>Raja erinacea</u>	300	335	386	251
<u>Raja ocellata</u>		1		
Congridae				
<u>Conger oceanicus</u>	10	1		1
Ophichthidae				
<u>Ophichthus cruentifer</u>	42	8	24	40
Clupeidae				
<u>Alosa pseudoharengus</u>		8		
Lophiidae				
<u>Lophius americanus</u>	66	71	52	59
Gadidae				
<u>Enchelyopus cimbrius</u>	1			
<u>Merluccius bilinearis</u>	752	570	163	1308
<u>Physiculus fulvus</u>				1
<u>Urophycis chuss</u>	1125	993	584	838
<u>Urophycis regius</u>	52	2	10	347
<u>Urophycis tenuis</u>		1	1	
Ophidiidae				
<u>Lepophidium cervinum</u>	26		3	45
Zoarcidae				
<u>Macrozoarces americanus</u>	23	46	84	397
Syngnathidae				
<u>Syngnathus fuscus</u>		3		
<u>Hippocampus erectus</u>	1	1	1	

Table 9-11. (Concluded)

SPECIES	FALL (05T)	WINTER (06T)	SPRING (07T)	SUMMER (08T)
Serranidae				
<u>Centropristis striata</u>	19	12	3	
Pomatomidae				
<u>Pomatomus saltatrix</u>	2			
Sparidae				
<u>Stenotomus chrysops</u>	1203	1	6	
Sciaenidae				
<u>Cynoscion regalis</u>	2			
Pholidae				
<u>Pholis gunnellus</u>		3	2	9
Ammodytidae				
<u>Ammodytes dubius</u>				10
Scombridae				
<u>Scomber scombrus</u>		9		
Stromateidae				
<u>Peprilus triacanthus</u>	7	12		11
Triglidae				
<u>Peristedion miniatum</u>				2
<u>Prionotus carolinus</u>	31	16	2	
<u>Prionotus evolans</u>		1		
Cottidae				
<u>Hemitripterus americanus</u>	1			2
<u>Myoxocephalus octodecemspinosus</u>	2			5
Cyclopteridae				
<u>Liparis inquilinus</u>	2	1		38
Bothidae				
<u>Citharichthys arctifrons</u>	528	198	113	1300
<u>Etropus microstomus</u>		2		
<u>Hippoglossina oblonga</u>	232	126	147	90
<u>Paralichthys dentatus</u>	44	21		
<u>Scophthalmus aquosus</u>	4	8	1	6
Pleuronectidae				
<u>Glyptocephalus cynoglossus</u>		1	6	
<u>Limanda ferruginea</u>	6	7	5	70
<u>Pseudopleuronectes americanus</u>	6			8

Table 9-12. Numerical abundance by season of eight dominant species collected during four seasonal cruises. The number enclosed by parentheses represents the percent contribution to the total number of fishes collected during the season indicated.

Species	Fall (05T)	Winter (06T)	Spring (07T)	Summer (08T)	Total Collected	Percent of Grand Total Collected
<u>Urophycis chuss</u>	1125 (25.0)	993 (39.8)	584 (36.6)	838 (17.3)	3540	26.4
<u>Merluccius bilinearis</u>	752 (16.7)	570 (22.8)	163 (10.2)	1308 (27.0)	2793	20.8
<u>Citharichthys arctifrons</u>	528 (11.7)	198 (7.9)	113 (7.1)	1300 (26.9)	2139	15.9
<u>Raja erinacea</u>	300 (6.7)	335 (13.4)	386 (24.2)	251 (5.2)	1272	9.5
<u>Stenotomus chrysops</u>	1203 (26.7)	1 (0.1)	6 (0.4)	- -	1210	9.0
<u>Hippoglossina oblonga</u>	232 (5.2)	126 (5.0)	147 (9.2)	90 (1.9)	595	4.4
<u>Macrozoarces americanus</u>	23 (0.5)	46 (1.8)	84 (5.3)	397 (8.2)	550	4.1
<u>Urophycis regius</u>	52 (1.2)	2 (0.1)	10 (0.6)	347 (7.2)	411	3.1
					12510	93.2

Table 9-13. Rank by numerical abundance of the five most dominant species for each of the two areas and four seasonal cruises.

Cruise and Season	Area	1	%	2	%	3	%	4	%	5	%	Number of Specimens	Number of Species
05T Fall	B	<u>S. chrysops</u>	31	<u>U. chuss</u>	23	<u>M. bilinearis</u>	17	<u>C. arctifrons</u>	8	<u>R. erinacea</u>	8	3362	25
	E	<u>U. chuss</u>	31	<u>C. arctifrons</u>	23	<u>M. bilinearis</u>	15	<u>S. chrysops</u>	13	<u>R. erinacea</u>	3	1137	20
06T Winter	B	<u>M. bilinearis</u>	36	<u>U. chuss</u>	26	<u>R. erinacea</u>	21	<u>H. oblonga</u>	4	<u>C. arctifrons</u>	4	1290	21
	E	<u>U. chuss</u>	55	<u>C. arctifrons</u>	12	<u>M. bilinearis</u>	9	<u>R. erinacea</u>	6	<u>H. oblonga</u>	6	1207	20
07T Spring	B	<u>U. chuss</u>	33	<u>R. erinacea</u>	32	<u>H. oblonga</u>	12	<u>M. bilinearis</u>	8	<u>M. americanus</u>	6	947	13
	E	<u>U. chuss</u>	42	<u>M. bilinearis</u>	13	<u>R. erinacea</u>	13	<u>C. arctifrons</u>	11	<u>H. oblonga</u>	5	647	16
08T Summer	B	<u>M. bilinearis</u>	38	<u>M. americanus</u>	17	<u>U. chuss</u>	17	<u>R. erinacea</u>	9	<u>C. arctifrons</u>	8	2226	19
	E	<u>C. arctifrons</u>	43	<u>M. bilinearis</u>	18	<u>U. chuss</u>	18	<u>U. regius</u>	13	<u>R. erinacea</u>	2	2614	20

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Table 9-14. Rank by biomass (fresh wet weight) of the five most dominant species for each of the two areas and four seasonal cruises.

Cruise and Season	Area	1	%	2	%	3	%	4	%	5	%	Total Biomass (kg)
05T Fall	B	<u>S. chrysops</u>	24	<u>R. erinacea</u>	22	<u>L. americanus</u>	21	<u>S. acanthias</u>	9	<u>H. oblonga</u>	7	376.4
	E	<u>S. chrysops</u>	34	<u>R. erinacea</u>	17	<u>P. dentatus</u>	10	<u>M. bilinearis</u>	10	<u>C. striata</u>	8	60.4
06T Winter	B	<u>M. bilinearis</u>	36	<u>R. erinacea</u>	20	<u>U. chuss</u>	18	<u>L. americanus</u>	16	<u>H. oblonga</u>	2	310.7
	E	<u>U. chuss</u>	50	<u>S. acanthias</u>	14	<u>M. bilinearis</u>	13	<u>R. erinacea</u>	8	<u>L. americanus</u>	6	271.3
07T Spring	B	<u>R. erinacea</u>	40	<u>U. chuss</u>	27	<u>M. bilinearis</u>	10	<u>L. americanus</u>	10	<u>H. oblonga</u>	6	184.6
	E	<u>U. chuss</u>	42	<u>M. bilinearis</u>	19	<u>L. americanus</u>	17	<u>R. erinacea</u>	15	<u>U. regius</u>	2	166.6
08T Summer	B	<u>M. bilinearis</u>	39	<u>R. erinacea</u>	21	<u>L. americanus</u>	12	<u>U. chuss</u>	11	<u>H. oblonga</u>	7	152.8
	E	<u>U. regius</u>	29	<u>M. bilinearis</u>	22	<u>U. chuss</u>	22	<u>L. americanus</u>	8	<u>R. erinacea</u>	8	98.8

Another boreal form, Limanda ferruginea, was common in the summer, particularly in area B where 59 of the total of 70 individuals collected during that season were taken (Table 9-11). The species occurred in lesser numbers in the other three seasonal collections, but again appeared to be more abundant in the northern study area (17 of 18 specimens).

The spiny dogfish, Squalus acanthias, a boreal species of shark, occurred infrequently in the fall, but was common in winter collections (Table 9-11). Only a single specimen was taken during both spring and summer sampling. This species was found to be one of the most dominant species on the Middle Atlantic OCS in our analysis of available historical data (Chapter 10), and its actual abundance in the study areas is probably underestimated in the current survey. The 45' trawl used in our collections was not very efficient in sampling this relatively large and mobile species when compared to the much larger nets used in the trawl surveys which provided the data base for the historical community structure analysis reported in Chapter 10.

Lepophidium cervinum, an outer-shelf resident, was infrequent in both areas during the fall and entirely absent during winter. Three specimens were collected in spring and 45 in summer, in both instances from area E. Relatively little is known about the distribution and habits of this cusk eel, but the species was a significant member of the fish community in the study areas, at least seasonally.

Liparis inquilinus, a cyclopterid fish associated with the sea scallop, Placopecten magellanicus (Able 1973; Able and Musick 1976), was common in those summer and fall collections that also included relatively large catches of this bivalved mollusc. During these seasons, juvenile Liparis were inquiline in the mantle cavity of Placopecten. Fewer specimens were noted in winter and none during spring. The numbers of Liparis collected, as given in Table 9-11, do not reflect actual abundances in the study areas. Only those individuals found free in the trawl catch were counted whereas specimens found within scallops, when these were later opened, could not be attributed to a particular tow and were thus not itemized.

The listing of dominant forms ranked by biomass (Table 9-14) includes some species (Lophius americanus, Squalus acanthias, Centropristis striata, Paralichthys dentatus) which, although present in relatively low abundance, were often represented by individuals of larger size and thus became significant contributors to total biomass. Similarly, abundant species such as Citharichthys arctifrons and Macrozoarces americanus were not included on the biomass dominance list due to their relatively small size. Generally, however, species such as Stenotomus chrysops, Urophycis chuss, Urophycis regius, Merluccius bilinearis, Raja erinacea, and Hippoglossina oblonga which were numerically dominant also formed the majority of dominant species in terms of biomass.

The three most dominant species by numerical abundance as well as the total number of tows, specimens collected, and species for each study area, stratum, and seasonal cruise are given in Table 9-15. Two study areas, each divided into five strata and sampled during four seasonal cruises, allowed 40 possible dominant occurrences for any given species. A brief analysis of the number of occurrences and their distribution by stratum, study area, and season for each dominant species indicates that there were seasonal differences in benthic fish community structure within each area. Furthermore, differences in faunal assemblage were found between the two study areas, whereas few differences were detected among strata within a study area, during each season. This result is similar to the conclusion previously derived from cluster analysis.

Two boreal species, Urophycis chuss and Merluccius bilinearis, were present throughout the year and appeared to be ubiquitous in distribution. They occur on Table 9-15, 34 and 28 times respectively. Although sampling effort was not equally distributed over the two study areas (145 or 54% of all tows were made in area B while 125 or 46% of all tows were made in area E), the 3540 U. chuss collected were remarkably even in their occurrences with 1791 taken from area B and 1749 from area E. M. bilinearis, however, was more abundant in area B from which approximately 70% of all silver hake were collected. This can be seen on Table 9-15 by comparing the number of times M. bilinearis ranks first in dominance in area B to those in area E.

A third boreal form, Raja erinacea, was among the dominants a total of 15 times, but occurred more often in study area B (10 times and 80% of the total collected in all tows) than in area E. This species also appeared to exhibit seasonality in that 14 of the 15 dominant occurrences were in winter and spring. However, this effect is due to displacement of R. erinacea from the dominance table by the large numbers of seasonally migrating fishes present in summer and fall. Table 9-12 shows that R. erinacea was actually a significant member of the fish community throughout the year.

Citharichthys arctifrons, a slope resident, was clearly more abundant in area E where it occurred 12 times among the dominants than in area B where it was among the dominants only twice. This may be attributed to the proximity of area E to the shelf edge and continental slope. Approximately 75% of all C. arctifrons collected were taken in area E and nearly 50% of all fishes collected in shelf-break stratum 5 of area E were members of this species.

A seasonally migrating warm-temperate species, Stenotomus chrysops, appears on the dominance table only for the fall (November 1976) collections. During fall, the species was among the dominants in all five strata of area B from which 87% of all scup were collected, while it was among the dominants in only three strata of area E. A few isolated individuals of this species were taken from area E during winter and spring, possibly because water temperatures

Table 9-15. Rank by numerical abundance of the three most dominant species in areas B and E for each stratum and season.

Area	Stratum	Cruise	Season	Number of Tows	1	%	2	%	3	%	Total Number of Specimens	Total Number of Species
B	1	05T	F	6	<u>S. chrysops</u>	42	<u>M. bilinearis</u>	32	<u>U. chuss</u>	6	658	15
		06T	W	6	<u>M. bilinearis</u>	73	<u>R. erinacea</u>	11	<u>U. chuss</u>	11	258	13
		07T	Sp	3	<u>M. bilinearis</u>	43	<u>R. erinacea</u>	25	<u>U. chuss</u>	25	28	5
		08T	Su	6	<u>M. bilinearis</u>	47	<u>U. chuss</u>	15	<u>M. americanus</u>	14	153	12
	2	05T	F	14	<u>U. chuss</u>	39	<u>M. bilinearis</u>	18	<u>S. chrysops</u>	15	1052	21
		06T	W	16	<u>U. chuss</u>	32	<u>R. erinacea</u>	23	<u>M. bilinearis</u>	20	574	16
		07T	Sp	11	<u>U. chuss</u>	30	<u>R. erinacea</u>	29	<u>H. oblonga</u>	15	223	9
		08T	Su	13	<u>M. bilinearis</u>	31	<u>U. chuss</u>	23	<u>M. americanus</u>	15	926	15
	3	05T	F	13	<u>S. chrysops</u>	40	<u>M. bilinearis</u>	13	<u>C. arctifrons</u>	12	1311	21
		06T	W	11	<u>M. bilinearis</u>	37	<u>R. erinacea</u>	31	<u>U. chuss</u>	15	297	14
		07T	Sp	15	<u>R. erinacea</u>	35	<u>U. chuss</u>	31	<u>H. oblonga</u>	15	495	11
		08T	Su	12	<u>M. bilinearis</u>	48	<u>M. americanus</u>	14	<u>R. erinacea</u>	10	722	15
	4	05T	F	1	<u>S. chrysops</u>	55	<u>P. triacanthus</u>	9	<u>H. oblonga</u>	9	56	9
		06T	W	2	<u>M. bilinearis</u>	55	<u>U. chuss</u>	12	<u>R. erinacea</u>	12	86	8
		07T	Sp	5	<u>U. chuss</u>	41	<u>R. erinacea</u>	28	<u>M. americanus</u>	13	197	8
		08T	Su	4	<u>M. americanus</u>	32	<u>M. bilinearis</u>	25	<u>U. chuss</u>	20	364	12
	5	05T	F	3	<u>U. chuss</u>	60	<u>S. chrysops</u>	23	<u>H. oblonga</u>	7	285	15
		06T	W	1	<u>U. chuss</u>	91	<u>L. americanus</u>	5	<u>M. bilinearis</u>	3	75	4
		07T	Sp	2	<u>R. erinacea</u>	50	<u>L. americanus</u>	25	<u>M. bilinearis</u>	25	4	3
		08T	Su	1	<u>M. bilinearis</u>	74	<u>U. chuss</u>	13	<u>C. arctifrons</u>	5	61	6
E	1	05T	F	3	<u>C. arctifrons</u>	41	<u>U. chuss</u>	36	<u>M. bilinearis</u>	11	485	11
		06T	W	6	<u>U. chuss</u>	55	<u>R. erinacea</u>	11	<u>M. bilinearis</u>	9	172	11
		07T	Sp	5	<u>U. chuss</u>	27	<u>R. erinacea</u>	25	<u>M. bilinearis</u>	20	124	10
		08T	Su	6	<u>C. arctifrons</u>	46	<u>M. bilinearis</u>	28	<u>U. chuss</u>	13	590	14
	2	05T	F	9	<u>U. chuss</u>	44	<u>S. chrysops</u>	21	<u>M. bilinearis</u>	12	215	12
		06T	W	5	<u>U. chuss</u>	46	<u>R. erinacea</u>	15	<u>H. oblonga</u>	9	162	12
		07T	Sp	8	<u>U. chuss</u>	34	<u>R. erinacea</u>	30	<u>M. americanus</u>	9	133	12
		08T	Su	7	<u>C. arctifrons</u>	33	<u>U. chuss</u>	26	<u>M. bilinearis</u>	25	770	15
	3	05T	F	6	<u>S. chrysops</u>	20	<u>M. bilinearis</u>	20	<u>U. chuss</u>	15	154	15
		06T	W	10	<u>U. chuss</u>	66	<u>C. arctifrons</u>	12	<u>M. bilinearis</u>	5	569	16
		07T	Sp	7	<u>U. chuss</u>	65	<u>M. bilinearis</u>	10	<u>C. arctifrons</u>	8	215	12
		08T	Su	4	<u>U. chuss</u>	68	<u>C. arctifrons</u>	14	<u>U. regius</u>	7	222	13
	4	05T	F	3	<u>U. chuss</u>	45	<u>C. arctifrons</u>	22	<u>O. cruentifer</u>	9	65	11
		06T	W	3	<u>U. chuss</u>	59	<u>M. bilinearis</u>	24	<u>H. oblonga</u>	6	186	11
		07T	Sp	2	<u>U. chuss</u>	56	<u>R. erinacea</u>	12	<u>C. arctifrons</u>	12	25	7
		08T	Su	4	<u>U. regius</u>	45	<u>C. arctifrons</u>	32	<u>U. chuss</u>	12	151	9
	5	05T	F	13	<u>M. bilinearis</u>	27	<u>S. chrysops</u>	17	<u>U. chuss</u>	16	218	14
		06T	W	6	<u>C. arctifrons</u>	54	<u>P. triacanthus</u>	8	<u>P. carolinus</u>	7	118	15
		07T	Sp	9	<u>U. chuss</u>	27	<u>C. arctifrons</u>	25	<u>M. bilinearis</u>	14	150	13
		08T	Su	9	<u>C. arctifrons</u>	58	<u>U. regius</u>	25	<u>M. bilinearis</u>	10	881	12

in this more southerly area had not fallen as rapidly as in the northern area B (Figure 9-21). No members of the species were collected during summer when S. chrysops occurred close inshore and in estuaries (Bigelow and Schroeder 1953b), although water temperatures were above 9.5°C in both areas B and E at that time.

The ocean pout, Macrozoarces americanus, is a boreal species which occurred in greatest abundance in the northern area B where it was dominant five times and where about 90% of the total number was collected. Off New England and in waters further north, Macrozoarces is believed to migrate offshore in fall and return inshore in spring, from coastal areas where bottom temperatures may become too low for the species during the winter (Bigelow and Schroeder 1953b; Leim and Scott 1966). Another explanation for the apparent seasonal absence of the species in offshore waters during summer and early fall is offered by Olsen and Merriman (1946) who stated that: "at least part of the ocean pout population in southern New England waters remain in the same general depth zone in which they are taken in winter and spring, but move into rocky areas where their capture by trawl nets is at best fortuitous." In the current study, the greatest seasonal abundance occurred in area B during the summer (Table 9-15) when bottom water temperatures were about 10°C (Figure 9-21). This may be due to a tendency for individuals of this boreal species to move offshore and aggregate in regions with a more suitable temperature regime during the spring and summer months when the maximum upper limit of 62°F (17°C) given for the occurrence of the species by Bigelow and Schroeder (1953b) may well be approached or exceeded in inshore areas.

An outer-shelf resident species, Hippoglossina oblonga, occurred among the dominants a total of six times, being present in both areas during all seasons. Four of the six dominant occurrences were in area B which also accounted for 75% of the total number of individuals collected.

Another warm-temperate form, Urophycis regius, was dominant during the summer in three strata of area E which also provided 93% of the total collected during the four cruises. It occurred in low numbers during fall collections in both areas and was found only as an occasional stray during winter and spring in the area E samples.

Two additional warm-temperate species, Peprilus triacanthus and Prionotus carolinus, occur on the dominance by strata listing (Table 9-15), but are not included in the overall dominance list in Tables 9-12 and 9-13. P. triacanthus occurs twice, once in stratum 4 of area B fall collections which are based on a single tow and once in relatively warm and deep stratum 5 (shelf-break) of area E during winter where P. carolinus also occurred among the dominant species once. P. triacanthus is more pelagic in habit than most other species discussed herein and was probably not sampled adequately by our relatively small 45' trawl. Research with larger nets (see Chapter 10) has shown that P. triacanthus is very abundant in the Middle

Atlantic OCS and co-occurs with other warm-temperate species such as Urophycis regius and Stenotomus chrysops. Therefore, although the patterns of seasonal relative abundance found in the present study are probably representative for the species, its true abundance and relative dominance have been underestimated.

The last two species in the dominance by stratum listing are Lophius americanus, a boreal form, in stratum 5 of area B during winter and spring, and Ophichthus cruentifer, an outer-shelf and upper-slope resident, in stratum 4 of area E during fall. Lophius americanus was found in low numbers throughout the year in both areas and all strata. Its occurrence among the numerically dominant species was undoubtedly a result of low sampling intensity in stratum 5 of area B. Similarly, O. cruentifer was resident in both areas throughout the year, but was probably not adequately sampled by otter trawl since it is a burrowing form (Wenner 1976). Its single dominant occurrence was probably attributable to chance resulting again from low sampling intensity in this stratum.

The three most dominantly ranked species by biomass as well as the total number of tows and total biomass for each study area, stratum, and seasonal cruise are listed in Table 9-16. The ubiquitous presence of Urophycis chuss and Merluccius bilinearis was again reflected in their widespread occurrence among the biomass dominant forms throughout both study areas and during all seasons. Raja erinacea dominated mainly in area B (16 of 22 occurrences) whereas the seasonally restricted, but geographically extensive distribution of Stenotomus chrysops was indicated by its rank among the biomass dominants in all strata of both areas during the fall. Again, the relatively small size of some numerically dominant species accounted for their low representation (e.g., Macrozoarces americanus) or absence (e.g., Citharichthys arctifrons) from the dominance by biomass table, while the larger size of individuals of some species (e.g., Lophius americanus and Squalus acanthias) was responsible for their inclusion among the biomass dominants despite their relatively low numerical abundance.

Whenever sample size was sufficiently large (see Methods), analysis of variance (ANOVA) ($\alpha = 0.05$) and Scheffé's multiple range test ($\alpha = 0.05$) were used to detect differences in numerical abundance of dominant species among strata. Results of this analysis for each study area, period of collection, and seasonal cruise are depicted in Table 9-17.

Urophycis chuss, which was the overall most numerically abundant species collected, accounting for more than one-quarter of all fishes taken during the four seasonal cruises (Table 9-12), also showed the greatest number of significant differences in distribution among strata (Table 9-17). Area B day abundances differed significantly in fall, winter, and summer, although no differences were detected in night collections in the same area. In fall, the largest

Table 9-16. Rank by biomass (fresh wet weight in kg) of the three most dominant species in areas B and E for each stratum and season.

Area	Stratum	Cruise	Season	Number of tows	1	%	2	%	3	%	Total Biomass (kg)
A	1	05T	F	6	<u>R. erinacea</u>	28	<u>S. acanthias</u>	27	<u>S. chrysops</u>	20	58.0
		06T	W	5	<u>M. bilinearis</u>	78	<u>R. erinacea</u>	15	<u>R. ocellata</u>	5	55.7
		07T	Sp	3	<u>M. bilinearis</u>	54	<u>R. erinacea</u>	39	<u>U. chuss</u>	10	5.7
		08T	Su	6	<u>M. bilinearis</u>	66	<u>L. americanus</u>	12	<u>U. chuss</u>	8	11.7
B	2	05T	F	14	<u>R. erinacea</u>	26	<u>L. americanus</u>	21	<u>S. chrysops</u>	16	92.7
		06T	W	16	<u>U. chuss</u>	27	<u>R. erinacea</u>	22	<u>M. bilinearis</u>	21	144.0
		07T	Sp	11	<u>U. chuss</u>	34	<u>R. erinacea</u>	25	<u>L. americanus</u>	15	39.6
		08T	Su	13	<u>M. bilinearis</u>	27	<u>R. erinacea</u>	24	<u>U. chuss</u>	20	43.6
B	3	05T	F	13	<u>S. chrysops</u>	28	<u>L. americanus</u>	23	<u>R. erinacea</u>	22	189.8
		06T	W	11	<u>M. bilinearis</u>	50	<u>R. erinacea</u>	39	<u>U. chuss</u>	3	53.6
		07T	Sp	15	<u>R. erinacea</u>	50	<u>U. chuss</u>	21	<u>L. americanus</u>	12	94.3
		08T	Su	12	<u>M. bilinearis</u>	44	<u>L. americanus</u>	19	<u>R. erinacea</u>	17	69.4
B	4	05T	F	1	<u>S. chrysops</u>	46	<u>L. americanus</u>	19	<u>R. erinacea</u>	11	11.2
		06T	W	2	<u>L. americanus</u>	51	<u>M. bilinearis</u>	35	<u>R. erinacea</u>	7	36.5
		07T	Sp	5	<u>U. chuss</u>	36	<u>R. erinacea</u>	33	<u>M. americanus</u>	20	44.6
		08T	Su	4	<u>M. bilinearis</u>	32	<u>R. erinacea</u>	31	<u>U. chuss</u>	16	27.2
B	5	05T	F	3	<u>L. americanus</u>	48	<u>S. chrysops</u>	24	<u>M. oblonga</u>	10	24.7
		06T	W	1	<u>U. chuss</u>	79	<u>L. americanus</u>	16	<u>M. bilinearis</u>	1	20.9
		07T	Sp	2	<u>M. bilinearis</u>	41	<u>R. erinacea</u>	27	<u>L. americanus</u>	26	0.4
		08T	Su	1	<u>M. bilinearis</u>	27	<u>M. americanus</u>	19	<u>U. chuss</u>	17	0.9
E	1	05T	F	3	<u>S. chrysops</u>	42	<u>R. erinacea</u>	36	<u>P. dentatus</u>	6	7.9
		06T	W	6	<u>U. chuss</u>	41	<u>S. acanthias</u>	28	<u>M. bilinearis</u>	13	53.6
		07T	Sp	5	<u>R. erinacea</u>	29	<u>M. bilinearis</u>	22	<u>U. chuss</u>	21	29.7
		08T	Su	6	<u>M. bilinearis</u>	42	<u>U. chuss</u>	17	<u>R. erinacea</u>	16	22.2
E	2	05T	F	9	<u>S. chrysops</u>	38	<u>G. striata</u>	38	<u>L. americanus</u>	6	11.0
		06T	W	5	<u>U. chuss</u>	33	<u>S. acanthias</u>	21	<u>L. americanus</u>	17	45.8
		07T	Sp	8	<u>R. erinacea</u>	34	<u>U. chuss</u>	33	<u>M. bilinearis</u>	16	29.0
		08T	Su	7	<u>M. bilinearis</u>	31	<u>U. chuss</u>	29	<u>R. erinacea</u>	12	34.7
E	3	05T	F	6	<u>R. erinacea</u>	36	<u>S. chrysops</u>	24	<u>M. oblonga</u>	13	13.5
		06T	W	10	<u>U. chuss</u>	64	<u>S. acanthias</u>	9	<u>M. bilinearis</u>	9	113.5
		07T	Sp	7	<u>U. chuss</u>	60	<u>L. americanus</u>	19	<u>M. bilinearis</u>	13	55.7
		08T	Su	4	<u>U. chuss</u>	74	<u>U. regius</u>	14	<u>M. bilinearis</u>	3	10.5
E	4	05T	F	3	<u>P. dentatus</u>	64	<u>S. chrysops</u>	16	<u>G. oceanicus</u>	7	2.0
		06T	W	3	<u>U. chuss</u>	58	<u>M. bilinearis</u>	27	<u>M. oblonga</u>	4	46.1
		07T	Sp	2	<u>U. chuss</u>	43	<u>L. americanus</u>	31	<u>M. bilinearis</u>	13	7.7
		08T	Su	4	<u>U. regius</u>	70	<u>L. americanus</u>	10	<u>M. bilinearis</u>	9	8.3
E	5	05T	F	13	<u>S. chrysops</u>	37	<u>M. bilinearis</u>	20	<u>U. regius</u>	12	26.0
		06T	W	6	<u>S. acanthias</u>	19	<u>P. dentatus</u>	18	<u>S. scombrus</u>	17	12.3
		07T	Sp	9	<u>U. chuss</u>	36	<u>M. bilinearis</u>	30	<u>L. americanus</u>	13	27.5
		08T	Su	9	<u>U. regius</u>	75	<u>L. americanus</u>	12	<u>M. bilinearis</u>	5	23.1

Table 9-17. Differences in numerical abundance of dominant species among strata grouped by season, period of collection, and study area. Results are based upon analysis of variance (ANOVA) and a posteriori contrasts of mean abundance using Scheffé's multiple-range test ($\alpha = 0.05$). Strata are arranged in order of decreasing mean numerical abundance. Underlined strata are not significantly different.

Species	Study Area	Period of Collection	Cruise and Season			
			05T (Fall)	06T (Winter)	07T (Spring)	08T (Summer)
<u>Urophycis chuss</u>	B	Day	<u>2-4-1-3</u>	<u>5-4-3-2-1</u>	NS	<u>4-2-3-1</u>
<u>Urophycis chuss</u>	B	Night	NS	NS	NS	NS
<u>Urophycis chuss</u>	E	Day	NS	NS	<u>3-1-2-5</u>	<u>3-4-2-1-5</u>
<u>Urophycis chuss</u>	E	Night	<u>1-2-3-4-5</u>	NS	NS	<u>3-2-1-4-5</u>
<u>Merluccius bilinearis</u>	B	Day	NS	<u>4-1-3-5-2</u>	NS	NS
<u>Merluccius bilinearis</u>	B	Night	NS	NS	NS	NS
<u>Merluccius bilinearis</u>	E	Day	NS	NS	NS	NS
<u>Merluccius bilinearis</u>	E	Night	NS	<u>4-3-2-1-5</u>	NS	NS
<u>Citharichthys arctifrons</u>	B	Day	NS	NS	NS	NS
<u>Citharichthys arctifrons</u>	B	Night	NS	<u>2-1-4-3</u>	NS	NS
<u>Citharichthys arctifrons</u>	E	Day	NS	NS	NS	NS
<u>Citharichthys arctifrons</u>	E	Night	NS	NS	NS	NS
<u>Raja erinacea</u>	B	Day	NS	NS	NS	NS
<u>Raja erinacea</u>	B	Night	<u>3-2-1-5</u>	NS	NS	<u>4-3-2-5-1</u>
<u>Raja erinacea</u>	E	Day	NS	NS	<u>1-2-3-5</u>	NS
<u>Raja erinacea</u>	E	Night	<u>1-3-4-2-5</u>	NS	NS	<u>1-2-3-5-4</u>

Table 9-17. (Concluded)

Species	Study Area	Period of Collection	Cruise and Season			
			05T (Fall)	06T (Winter)	07T (Spring)	08T (Summer)
<u>Stenotomus chrysops</u>	B	Day	NS	--	--	--
<u>Stenotomus chrysops</u>	B	Night	NS	--	--	--
<u>Stenotomus chrysops</u>	E	Day	NS	--	--	--
<u>Stenotomus chrysops</u>	E	Night	NS	--	--	--
<u>Hippoglossina oblonga</u>	B	Day	NS	NS	NS	NS
<u>Hippoglossina oblonga</u>	B	Night	NS	NS	NS	NS
<u>Hippoglossina oblonga</u>	E	Day	--	NS	NS	--
<u>Hippoglossina oblonga</u>	E	Night	--	NS	NS	--
<u>Macrozoarces americanus</u>	B	Day	--	NS	NS	NS
<u>Macrozoarces americanus</u>	B	Night	--	NS	<u>4-2-3</u>	NS
<u>Macrozoarces americanus</u>	E	Day	--	--	--	--
<u>Macrozoarces americanus</u>	E	Night	--	--	--	--
<u>Urophycis regius</u>	B	Day	--	--	--	--
<u>Urophycis regius</u>	B	Night	--	--	--	--
<u>Urophycis regius</u>	E	Day	--	--	--	NS
<u>Urophycis regius</u>	E	Night	--	--	--	<u>5-4-3-2-1</u>

NS = no significant differences between strata as based on ANOVA ($\alpha = 0.05$).

concentrations of this species were in stratum 2 (ridge and medium sand flank) whereas lowest abundances were found in strata 1 (terrace) and 3 (medium-fine sand flank and eroded flank). Stratum 5 (deep swale) had the largest number of the species during winter whereas strata 2 and 1 had the lowest abundances. In summer, stratum 4 (shallow swale) had the highest abundance while stratum 1 was lowest. No daytime tows were made in deep swale stratum 5 during fall and summer.

Additional differences in U. chuss abundances were found for area E day stations during spring and summer and area E night stations in fall and summer. During fall, stratum 1 (ridge and megaripples) had the greatest abundances whereas stratum 5 (upper and mid-shelf break) had the lowest concentrations. In spring, stratum 3 (shallow and deep swales) had the greatest abundances whereas the shelf break (stratum 5) had lowest concentrations. This same general pattern, of largest concentrations occurring in the swales (stratum 3) and lowest in the shelf break region (stratum 5) was again found in both day and night collections during the summer cruise.

Significant differences in abundance distribution of Merluccius bilinearis were detected only for the winter cruise (Table 9-17). Area B day stations showed greatest concentrations of the species to occur in strata 4 (shallow swale) and 1 (terrace) while stratum 2 (ridge and medium sand flanks) had the least abundances. In area E collections, highest abundances were found in strata 4 (eroded swale) and 3 (shallow and deep swale) whereas the shelf break (stratum 5) had lowest concentrations.

Abundance distributions of Citharichthys arctifrons were found to be significantly different only in area B night collections during the winter (Table 9-17). Greatest concentrations of the species occurred in stratum 2 (ridge and medium sand flank) whereas stratum 3 (medium-fine sand flank and eroded flank) had the lowest numbers.

Abundance of Raja erinacea were found to be significantly different during fall in area B and E night collections, during spring in area E day collections and during summer in area B and E night collections (Table 9-17). In fall, area B stratum 5 (deep swale) had significantly fewer R. erinacea than the other strata sampled. In area E during the same season, stratum 1 (ridge and megaripples) had the greatest concentration whereas strata 2 and 5 had the lowest abundance. In spring, stratum 1 of area E again had the greatest abundance while strata 3 and 5 were lowest. During summer, area B strata 4, 3, and 2 had significantly greater abundances than strata 5 and 1, whereas area E again showed stratum 1 to have the largest concentration and strata 5 and 4 the lowest. Based on the significant differences detected in area E, R. erinacea appeared to be most abundant in stratum 1 (ridge and megaripples), whereas stratum 5 (shelf break) was consistently among the strata with lowest concentrations of the species.

No significant differences were found for the abundance distributions of Stenotomus chrysops and Hippoglossina oblonga in all cases tested. Macrozoarces americanus showed the greatest concentrations in stratum 4 (shallow swale) of area B during spring, whereas stratum 3 abundances were significantly lower. Lastly, Urophycis regius was found to be more abundant in area E strata 5 and 4 (shelf break and eroded swale) than in stratum 1 (ridge and megaripples) during the summer.

Overall, there were definite seasonal differences in fish community structure both between and within the two study areas. During a given season, differences between study areas exist, but few changes in faunal assemblage were detectable within the areas on a stratum to stratum basis. Shelf-break stratum 5 of area E was a notable exception, probably due to its location near the continental slope, stenothermal environment, and relatively greater depth.

Length Frequencies

The length frequency distributions of selected dominant species were plotted (Figures 9-34 through 9-42) on a seasonal basis. Additionally, when sample size was sufficient (see Methods), analysis of variance (ANOVA) ($\alpha = 0.05$) and Scheffé's multiple range test ($\alpha = 0.05$) were used to detect differences in length frequency distribution of dominant species among strata for each study area and season (Table 9-18).

The length frequency distribution of Urophycis chuss, a boreal species, in area B (Figure 9-34) indicated that juveniles (under 100 mm standard length) dominated the fall collections. Winter and spring distributions showed the progressive growth and mortality of the younger fishes and the movement of adult fishes into the area. By summer, only scattered older individuals remained whereas a new peak at about 40 mm was indicative of recruitment to the population. Area E distributions (Figure 9-35) were similar with the exception that fewer juveniles were present there during winter and spring. The distribution of juvenile U. chuss was associated with that of the sea scallop, Placopecten magellanicus, which serves as a host to the young inquiline members of the species (Musick 1974). This mollusc occurred in variable densities throughout the two study areas (Chapter 6).

Significant differences in distribution (Table 9-18) among area B strata were detected in winter with the largest fishes being concentrated in stratum 5 (deep swales) and during summer where low sampling intensity in strata 4 and 5 and wide distribution of juveniles may have been responsible for the slight significant difference shown. Area E distributions were significantly different during three seasons. In fall, the majority of smaller juveniles ($\bar{x} = 32$ mm) occurred in stratum 1 (ridge and megaripples). During spring, smaller adults formed the major part of fishes collected from the

(TEXT CONTINUES ON PAGE 9-123)

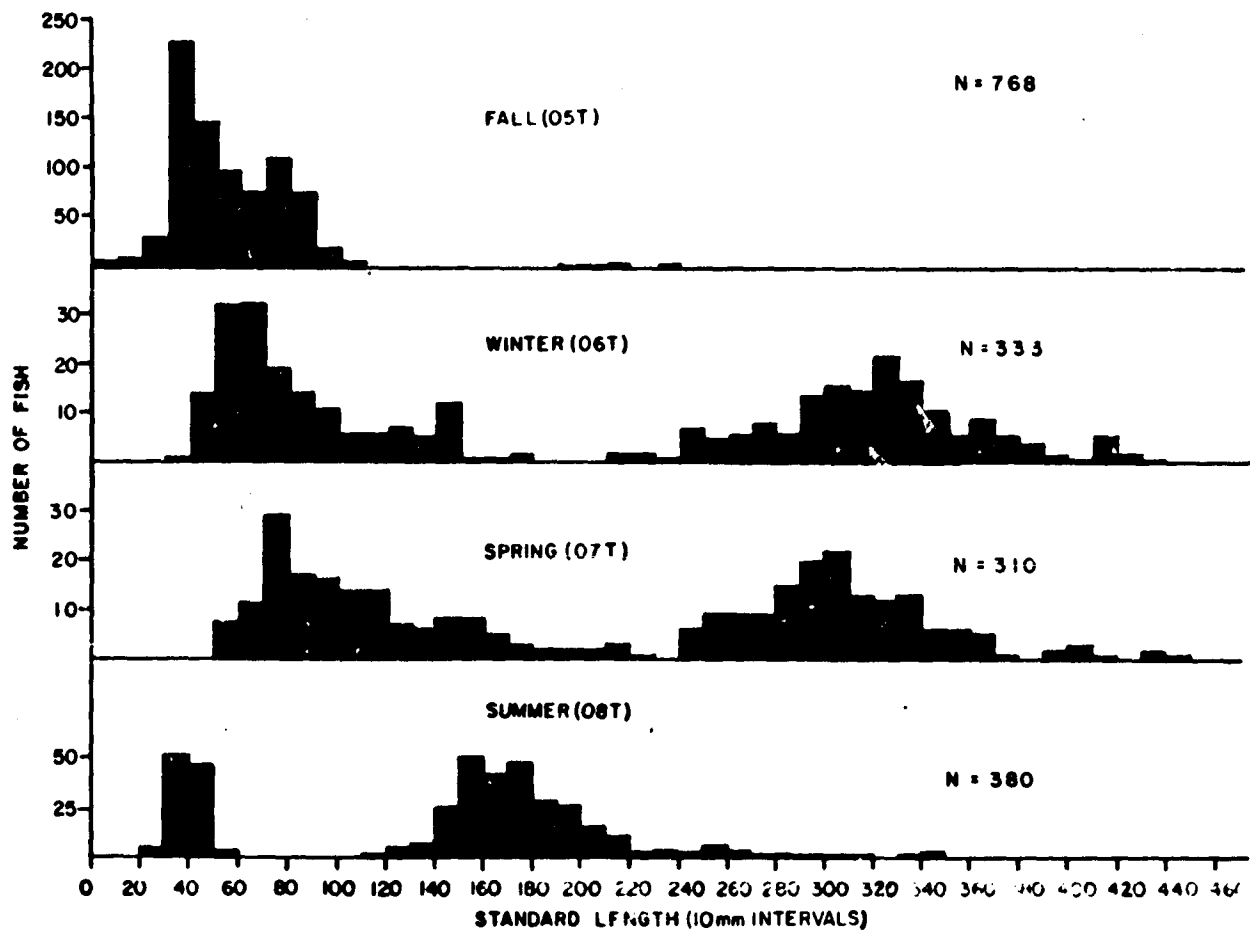


Figure 9-34. Length frequency distributions of *Urophycis chuss* in Area B by seasonal cruise.

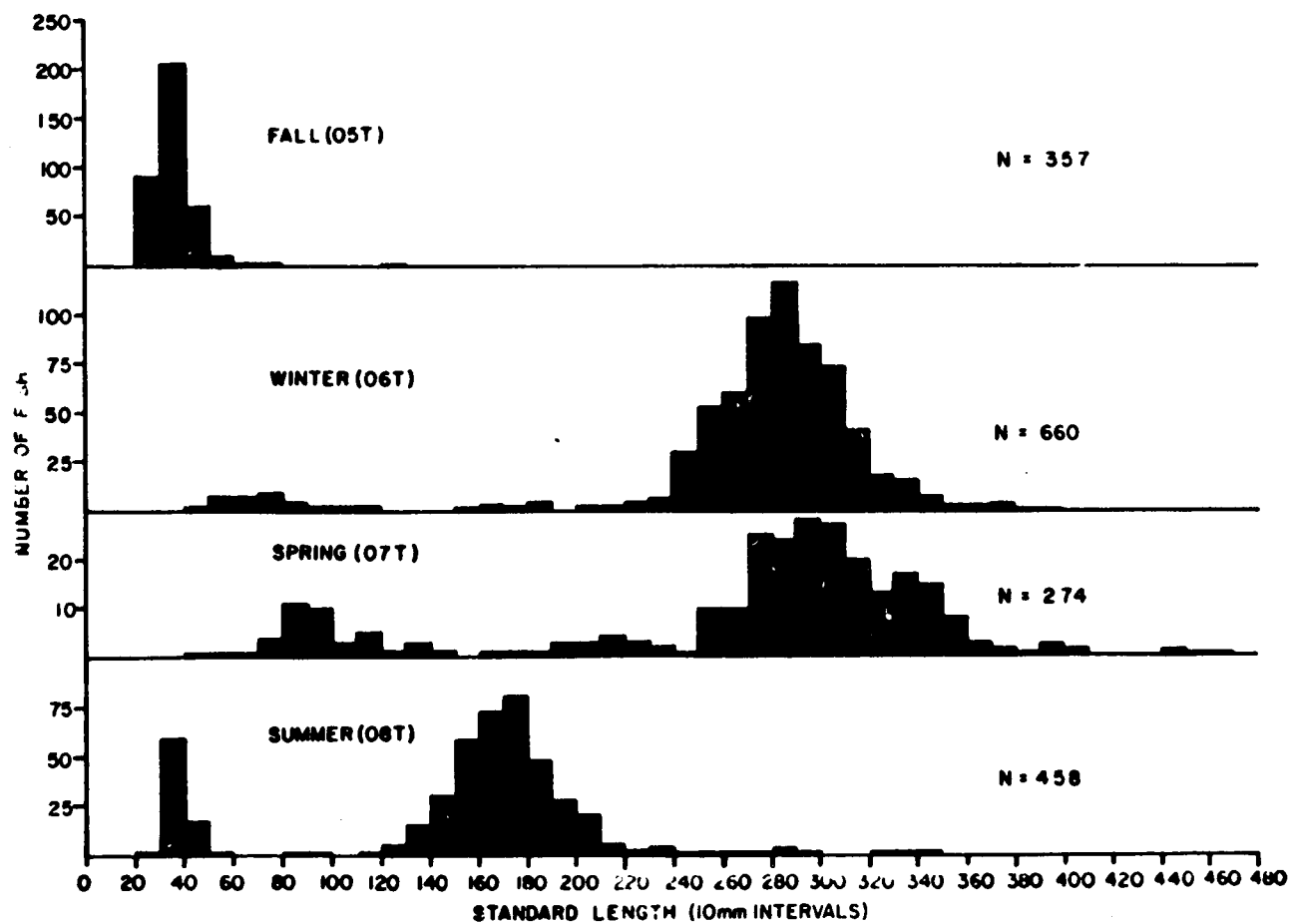


Figure 9-35. Length frequency distributions of *Urophycis chuss* in Area E by seasonal cruise.

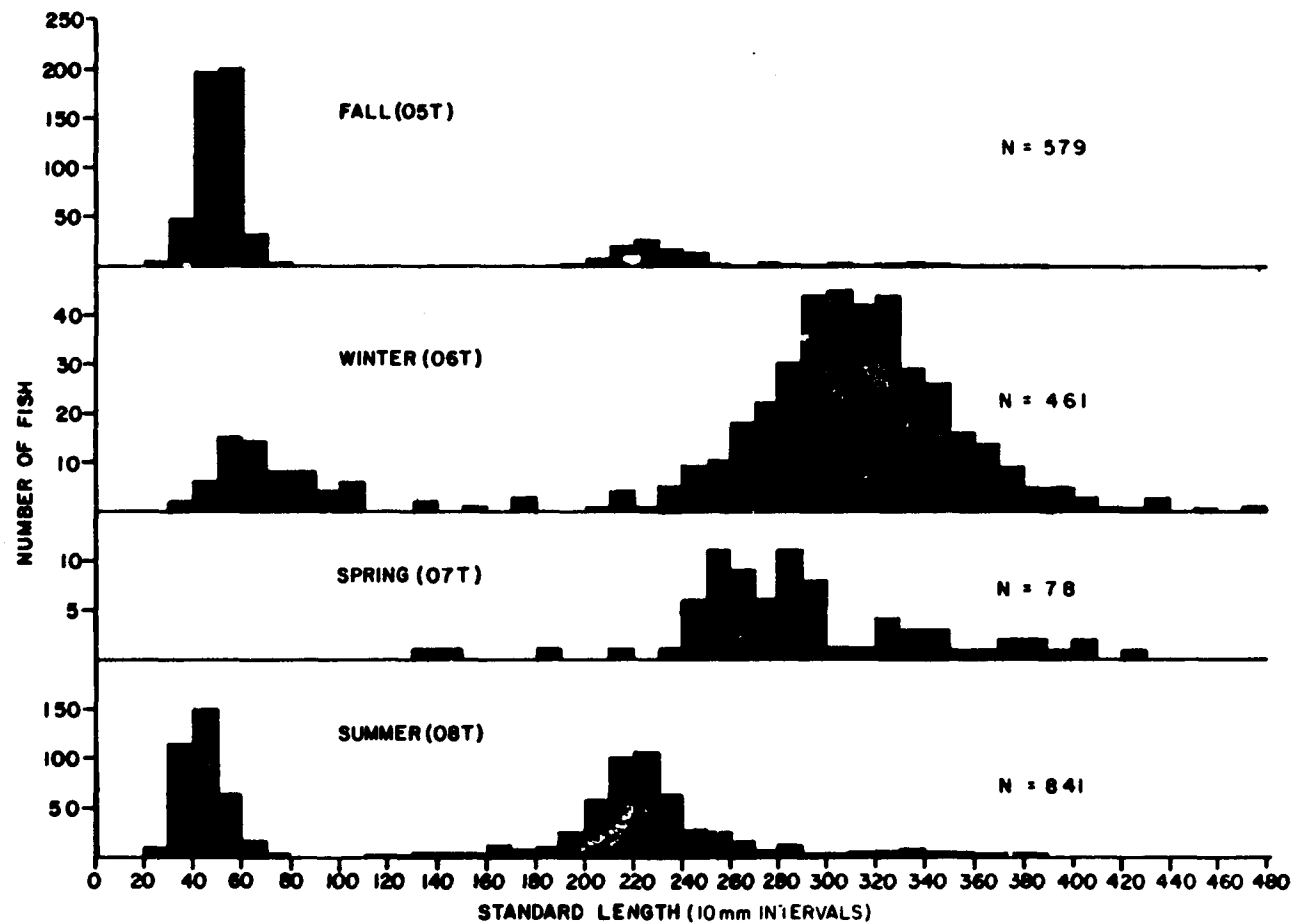


Figure 9-36. Length frequency distributions of Merluccius bilinearis in Area B by seasonal cruise.

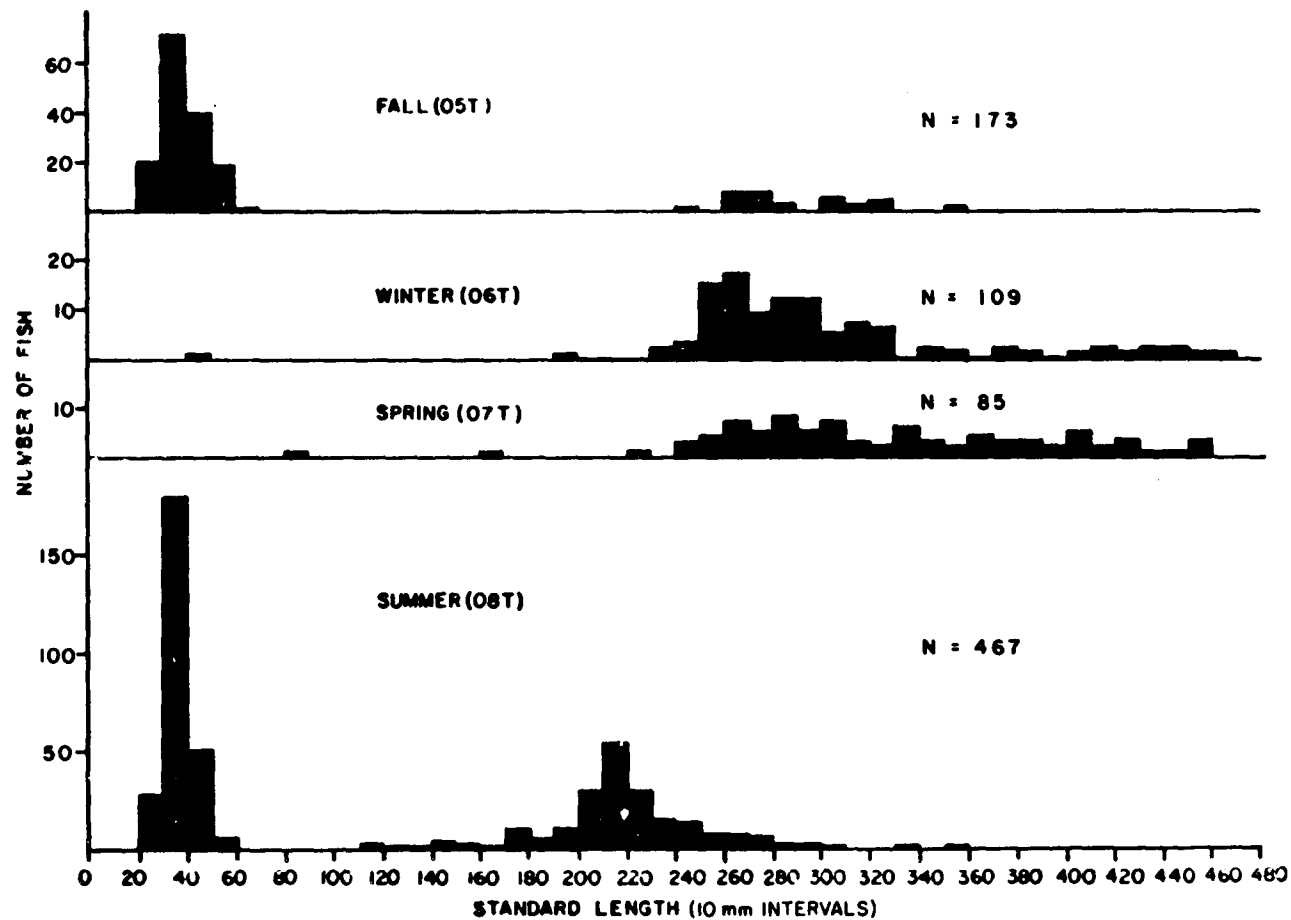


Figure 9-37. Length frequency distributions of *Merluccius bilinearis* in Area E by seasonal cruise.

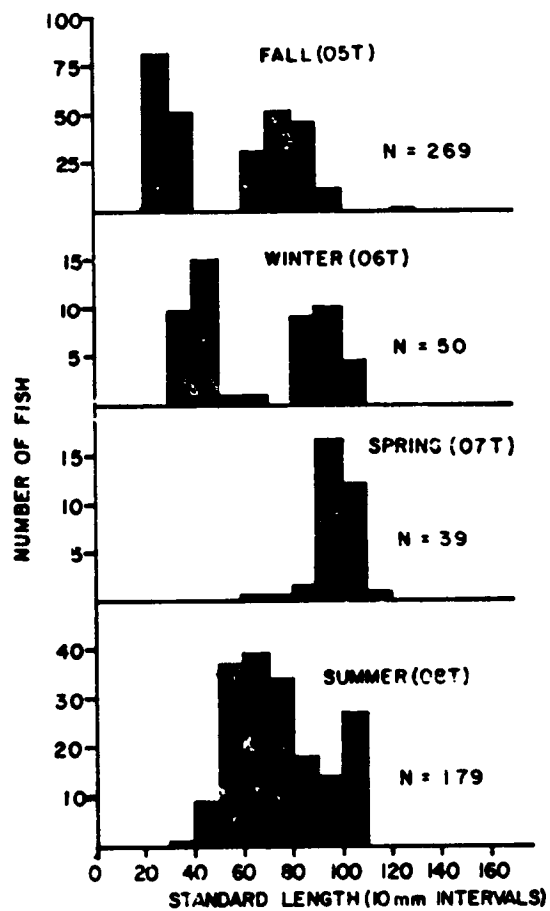


Figure 9-38. Length frequency distributions of Citharichthys arctifrons in Area B by seasonal cruise.

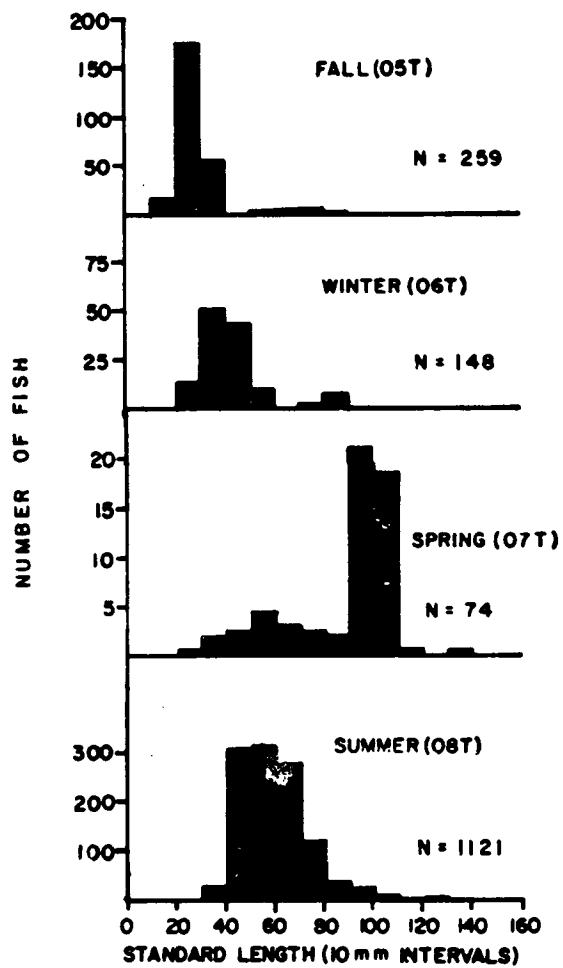


Figure 9-39. Length frequency distributions of *Citharichthys arctifrons* in Area E by seasonal cruise.

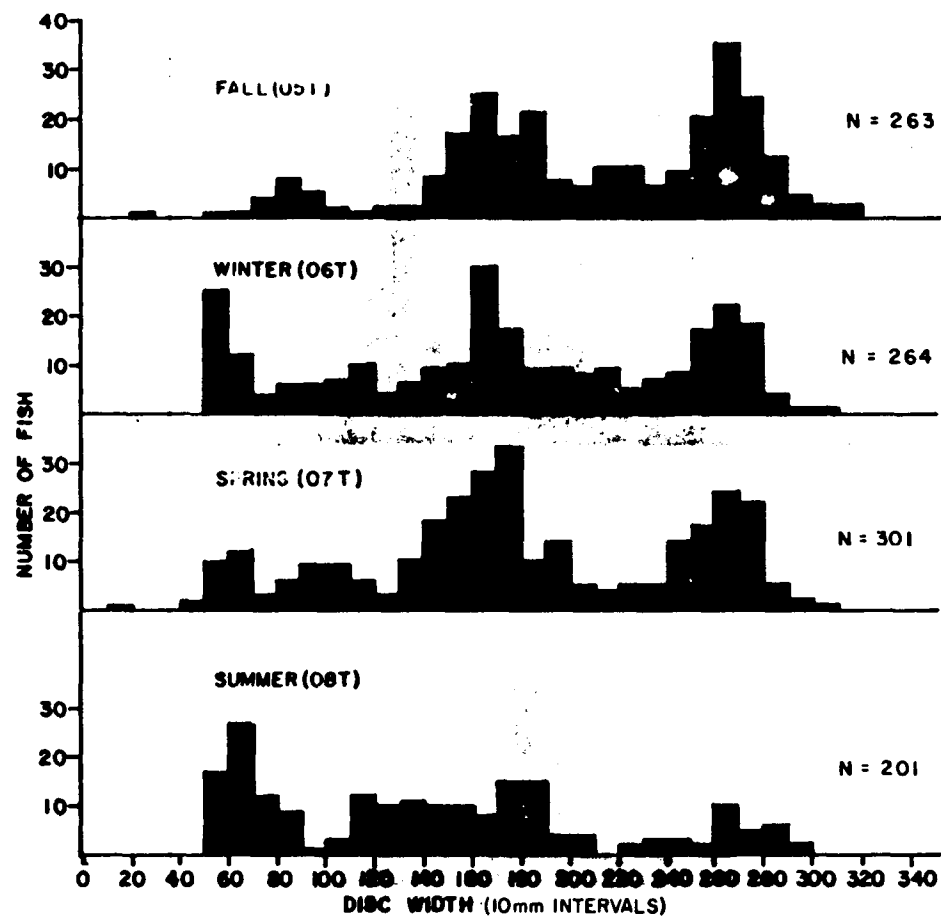


Figure 9-40. Length frequency distributions of *Raja erinacea* in Area B by seasonal cruise.

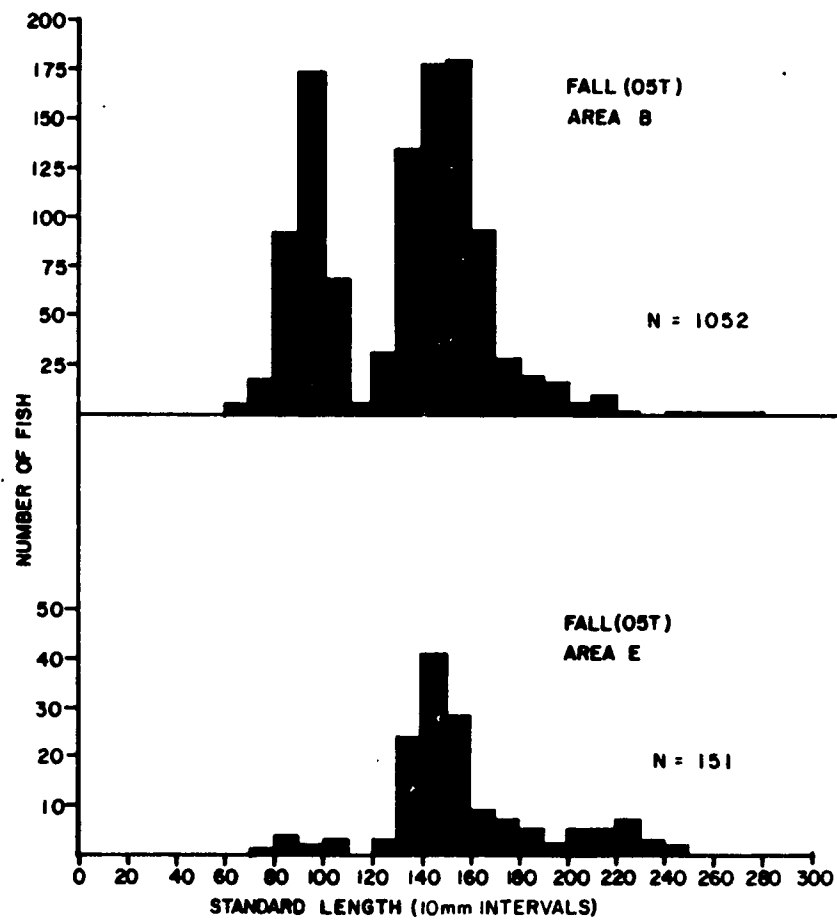


Figure 9-41. Length frequency distributions of Stenotomus chrysops in Areas B and E.

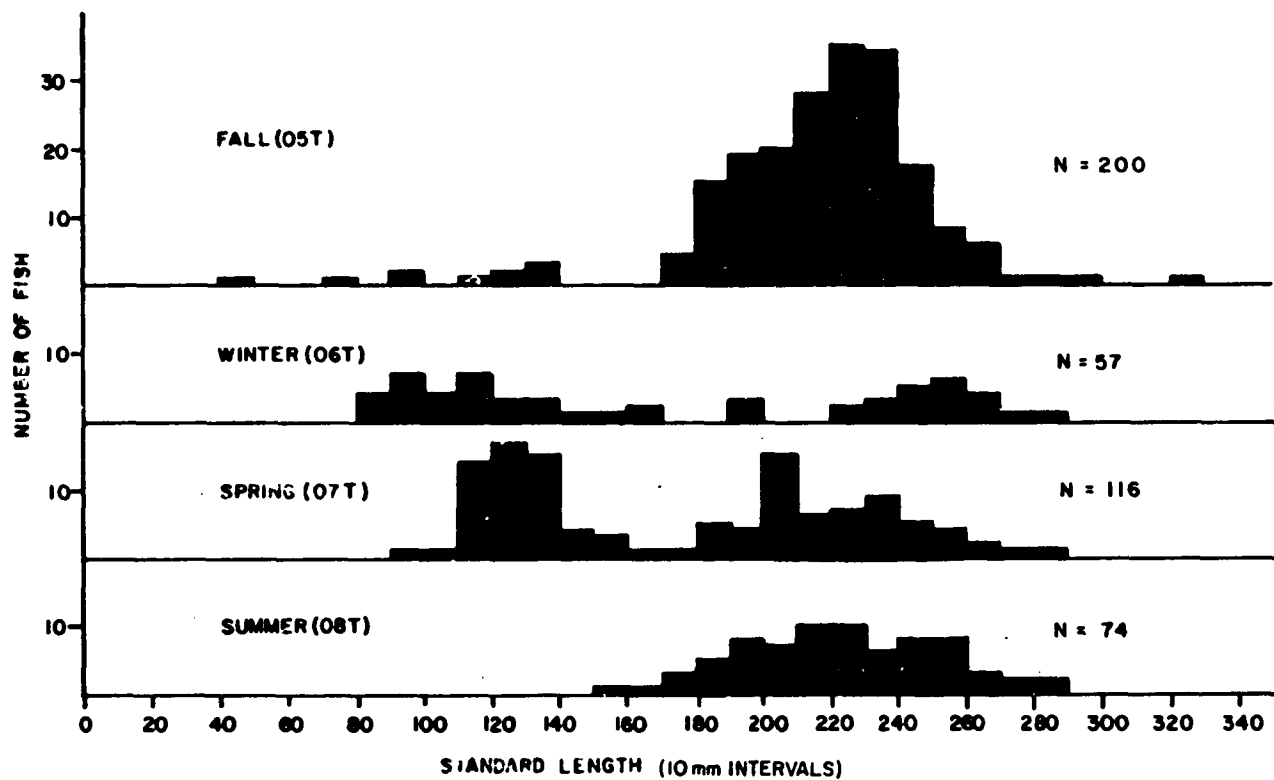


Figure 9-42. Length frequency distributions of Hippoglossina oblonga in Area B by seasonal cruise.

Table 9-18. Differences in length frequency of dominant species among strata grouped by season and study area. Results are based upon analysis of variance (ANOVA) and a posteriori contrasts of mean lengths using Scheffé's multiple range test ($\alpha = 0.05$). Strata are arranged in order of increasing mean length. Underlined strata are not significantly different.

Species	Study Area	Cruise and Season			
		05T (Fall)	06T (Winter)	07T (Spring)	08T (Summer)
<u>Urophycis chuss</u>	B	NS	<u>1-3-4-2-5</u>	NS	<u>5-2-3-1-4</u>
<u>Urophycis chuss</u>	E	<u>1-4-2-5-3</u>	NS	<u>1-2-5-4-3</u>	<u>5-4-1-2-3</u>
<u>Merluccius bilinearis</u>	B	<u>5-1-2-3-4</u>	<u>1-3-2-5-4</u>	NS	<u>5-2-4-3-1</u>
<u>Merluccius bilinearis</u>	E	NS	NS	NS	<u>5-3-2-4-1</u>
<u>Citharichthys arctifrons</u>	B	<u>1-2-3-5</u>	NS	NS	NS
<u>Citharichthys arctifrons</u>	E	<u>3-4-1-2-5</u>	<u>5-3-4-2-1</u>	NS	<u>5-4-2-1-3</u>
<u>Raja erinacea</u>	B	<u>5-2-4-3-1</u>	NS	NS	<u>2-3-1-4</u>
<u>Raja erinacea</u>	E	NS	NS	NS	NS
<u>Stenotomus chrysops</u>	B	<u>1-3-5-2-4</u>	--	--	--
<u>Stenotomus chrysops</u>	E	<u>1-2-3-4-5</u>	--	--	--
<u>Hippoglossina oblonga</u>	B	NS	NS	NS	NS
<u>Hippoglossina oblonga</u>	E	<u>4-1-5-3-2</u>	NS	NS	--
<u>Macrozoarces americanus</u>	B	--	--	<u>3-2-4</u>	NS
<u>Macrozoarces americanus</u>	E	--	--	NS	--
<u>Urophycis regius</u>	B	--	--	--	--
<u>Urophycis regius</u>	E	--	--	--	NS

NS = no significant differences between strata as based on ANOVA ($\alpha = 0.05$).

shallower waters of strata 1 and 2 whereas larger adults tended to be associated with the relatively greater depths of strata 3, 4, and 5. In summer, larger fish ($\bar{x}$ = 160 mm) were concentrated in strata 2 and 3 whereas newly recruited juveniles were widely distributed across all strata, a situation similar to that found for area B summer collections. No significant differences were found in U. chuss distributions within area B during fall and spring or within area E during winter.

The size distribution of Merluccius bilinearis, another boreal form, in areas B and E (Figures 9-36 and 9-37) again showed that juveniles dominated the fall collections whereas adults occurred only occasionally. Winter and spring populations were dominated by adult fishes in both areas with juveniles being present in significant numbers only in the northern site (area B) during winter. Smaller adults and newly recruited juveniles (mode at about 40 mm) dominated both areas in the summer collections.

Area B distributions by strata (Table 9-18) for M. bilinearis differed significantly during three seasons. During fall, low sampling intensity in strata 4 and 5 was partly responsible for their occurrence at extreme positions in the array of strata arranged in order of increasing length. The majority of juveniles were concentrated in strata 1 and 2 (terrace, ridge, and medium sand flank) whereas larger fish preferred the deeper waters of stratum 3. The same trend is supported by winter distributions where stratum 1 (terrace), with an average collection depth of 45 m, had more juveniles whereas larger fish tended to be in the greater depths of strata 2 through 5 (average collection depth 60 m). Summer collections showed the wide dispersion of newly recruited juveniles with some indication, after allowances were made for the low sampling effort of one tow in stratum 5, that larger fishes preferred shallower depths during this season. This same tendency was evident in area E summer distributions where again the deepest stratum (shelf break stratum 5) had the greatest proportion of the widely distributed, newly recruited juveniles, whereas the majority of larger fish were in shallower waters. No significant differences were detected in spring for area B or in fall, winter, and spring for area E.

Length frequency distributions of Citharichthys arcifrons in both study areas (Figures 9-38 and 9-39) showed that newly recruited young-of-the-year fish (standard length of 15-35 mm) were in greatest abundance during fall. This concurs with the late-summer to early fall spawning peak reported for this slope resident species (Leonard 1971). Growth and mortality of young-of-the-year fish were reflected in winter distributions as they were for yearlings, which accounted for the second peak during both seasons, although the latter occurred in lesser abundance during area E fall collections. Spring samples showed strong peaks for yearling fish, whereas young-of-the-year individuals appeared to be considerably less abundant, especially in area B. During summer, the smaller fish reappeared in both areas, but

were particularly numerous in area E, whereas older fish remained in area B and to a lesser extent in area E. Occasional two year old fish were found scattered throughout the seasonal collections, but the maximum length of 150 mm for the species given by Parr (1931) was not exceeded by individuals collected during the current survey.

Area B collections of C. arctifrons showed significant differences in length frequency distributions (Table 9-18) only during fall when smaller fish predominated in strata 1 and 2 (terrace, ridge, and medium sand flank) while larger fish occurred primarily in strata 3 and 5 (medium to fine sand flank, eroded flank and deep swale). This difference was also detected by stomach content analysis (see Section I, Food Habits of Fishes). Stratum 4 was excluded from the rankings since a single tow there yielded no specimens of the species. Area E showed significant differences during three seasons. In fall, larger fish predominated in shelf-break stratum 5 while the young-of-the-year were distributed across all strata. During winter, smaller individuals and greater overall abundances occurred in strata 3 and 5 whereas larger fish in lower numbers predominated in the remaining strata. Summer distributions in area E again showed a tendency for smaller fish to prefer deeper waters (strata 4 and 5) whereas larger individuals predominated in the shallower strata. No significant difference was detected in area E spring distributions.

Length frequency distributions of Raja erinacea during all four seasonal cruises are shown for area B in Figure 9-40. Distributions of this boreal species in area E, although based on smaller overall abundances, were extremely similar and are not shown. Several year classes were represented by peaks during all seasons. The year-round spawning habits of this species were probably responsible for the similarity of length frequency patterns across the seasons. Richards et al. (1963) give November-January and June-July as two periods when egg laying is maximal while March-April and August-October are the periods of lowest egg production. Embryos hatch about 6-8 months after egg cases are laid. This was reflected in length frequency distribution where peaks representing newly recruited individuals (at about 60 mm disc width) occurred in winter (March) and summer (September), in each case about 8 months after a maximal egg-laying period. Such a peak was notably absent in the fall (November) collections which took place 7 months after the March-April minimum egg-laying period. Some evidence for slight inshore movement of the species into shoaler waters during summer (Bigelow and Schroeder 1953a) was provided by the summer distribution pattern which showed a reduction in abundance, especially among the older fishes. Data from Chesapeake Bight (McEachran and Musick 1975) showed that R. erinacea was most abundant there during the winter and that individuals remaining in the region during the summer had moved into deeper waters.

Differences among strata (Table 9-18) were found in area B for the fall and summer collections. In fall, larger R. erinacea occurred

in stratum 1 while smaller individuals were proportionately more abundant in strata 2 and 5. However, low sampling effort in strata 4 and 5 may partly account for these differences. Summer distributions showed that larger individuals predominated in stratum 4 (shallow swale) while smaller fish occurred more often in stratum 2 (ridge and medium sand flank). No significant differences were detected during any season in area E.

Stenotomus chrysops length frequency distributions (Figure 9-41) are shown only for the fall collections in area B and E. This warm-temperate species was virtually absent from the study areas during other seasons. At least two distinct peaks were evident in both areas although overall abundance was considerably higher in area B. The peak representing smaller individuals (at about 90 mm standard length) was less evident in area E whereas the peak at about 150 mm was distinct in both areas. A third peak (at about 220 mm) was more evident in area E. Smith and Norcross (1968) give mean fork lengths of 97.5 and 153.3 mm at the time of first and second annulus formation in Stenotomus. When allowances are made for the standard length measurements taken in the current study, the modes at 90 and 150 mm correspond to one and two year old fish respectively.

Significant differences were found among strata in both areas for the fall S. chrysops collections (Table 9-18). Smaller individuals tended to occur in the shallower strata whereas larger fish were found in deeper waters, especially in shelf-break stratum 5 of area E.

Length frequency distributions of Hippoglossina oblonga, an outer-shelf resident, are given for area B collections during all seasons (Figure 9-42). Area E distributions were similar, but were based on lesser abundances and were not depicted. The smallest juveniles occurred in fall, reflecting the May to mid-July spawning period and three month planktonic existence of larvae given by Bigelow and Schroeder (1953b). Overall abundance was greatest for adults during fall when the species was widely distributed over the shelf (Chapter 10). Winter and spring distributions show decreased abundance for older fish which may have moved further offshore, but increased representation of juveniles which showed the expected progressive growth pattern seen previously for other species. During summer, the juveniles were absent from study area B, whereas adult populations increased, possibly indicating onshore movement from deeper waters.

Significant differences in distribution across strata were detected for H. oblonga only in fall area E collections (Table 9-18). However, the detection of a difference between stratum 4 and the other strata was based on the occurrence of a single juvenile specimen in the former and may thus be an artifact due to sampling variability.

Length frequency distributions for Macrozoarces americanus, a boreal species, and Urophycis regius, a warm-temperate form, are not

presented due to relatively small sample size and restricted seasonal occurrence.

A significant difference among strata was detected for M. americanus distributions during spring in area B (Table 9-18). Larger fish ($\bar{x} = 327$ mm) were found in stratum 4 (shallow swale) whereas those collected in strata 2 and 3 averaged 220 mm in total length. The species was not collected from strata 1 and 5 during that season. No other significant differences were detected for either species in collections sufficiently large enough to be tested.

Diversity Indices

Mean Shannon diversity (H'), richness (D), and evenness (J') were calculated for study areas A and B based on tows pooled by period of collection, stratum, and seasonal cruise (Appendix 9-C). No clear trends were evident from these calculations, possibly due to the confounding effect of unequal sampling effort and diel catch variability as previously discussed under cluster analysis.

Summary of Significant Findings

1. Based on the cluster analysis of data derived from a single year of study (four seasonal cruises), faunal assemblages within each study area were found to be more similar among strata than within strata during any given season. The only stratum to consistently differ from the others was stratum 5 (upper and mid-shelf break) in area E where the greatest depths and least seasonal thermal variation of all strata in both study areas were found. Substrate type or bottom topography appeared to have minimal influence on species distributions within the confines of the two areas. These findings differ from those for sedentary benthic invertebrates, but the difference is not surprising because the fishes are highly mobile and can move from one stratum to another in a relatively short period of time.
2. Five species of demersal fishes were numerically dominant in both study areas throughout the year. Three species (Urophycis chuss, Merluccius bilinearis, and Raja erinacea) were boreal in faunal affinity, one species (Citharichthys arctifrons) was a slope resident and one species (Hippoglossina oblonga) was an outer-shelf resident.
3. Three additional species were numerically dominant on a seasonal basis. Macrozoarces americanus, a boreal form, was most abundant in spring and summer. Two warm-temperate species, Stenotomus chrysops and Urophycis regius, were most numerous in fall and summer respectively.

4. Differences in community structure were detected between the two study areas within a given season, but the most notable differences occurred among seasons and areas. A complex and variable pattern of faunal assemblages characterized each study area due to seasonal onshore-offshore and north-south migrations of various species.
5. Biomass and numerical abundance of some dominant species fluctuated according to the age structure of the populations present in the study areas during any given collection period. Length frequency analysis demonstrated that there was a tendency for the various age groups of certain species to segregate and be more abundant in specific strata. This tendency was also detected in the food habits study (Section I of this chapter). Thus, feeding selectivity may have been one of the factors that controlled the distribution of various sized individuals of the same species across strata.
6. Temperature was undoubtedly the primary environmental factor affecting the structure and distribution of the demersal fish community present within the study areas. The relatively wide annual variation in bottom water temperatures and delayed response of bottom thermal conditions to variation in air temperatures caused by the formation and dissipation of the thermocline was reflected in the seasonal changes in fish community structure.
7. Large diel fluctuations in numbers of species, numerical abundance, and biomass were probably due to vertical migration or net avoidance by many species during daytime collections. This necessitated separation of collections into day and night tows for further analysis, and, in effect, reduced the sample size for comparative purposes. Night tows normally exceeded day tows in number of species, abundance, and biomass and were probably more representative of the actual status and composition of the demersal fish community.
8. Availability of various species of fishes to an otter trawl depends upon the behavioral characteristics of each species as well as the types and configuration of gear used in sampling. Comparability of data obtained with the use of two or more types of gear has been a problem (see Chapter 10). An effort should be made to either standardize the methodology and gear used in collecting or arrive at "catchability coefficients" for various species under a variety of sampling conditions. The 45' trawl used in the current survey probably underestimated the actual abundance of some species (e.g., Squalus acanthias, Peprilus triacanthus) and may have affected their overall dominance ranking. However, relative seasonal abundance patterns were probably not affected.

ACKNOWLEDGEMENTS

Sincere appreciation is due to our colleagues James A. Colvocoresses and George R. Sedberry, and to the other VIMS personnel, both staff and students, who were members of the scientific parties on the four trawl cruises for their assistance during the field collection phase. Additional appreciation is extended to the crews of R/V Cape Henlopen (U. Del.) and R/V James M. Gilliss (U. Miami, Florida) for their aid and cooperation at sea.

We would further like to thank the following VIMS personnel for their help during this study: Joseph G. Loesch and William F. Roller provided valuable advice on statistical matters; William P. Blystone, Jr. assisted with computer programming and data manipulation; Julia F. Millen, Barbara J. Gardner and Carolyn H. Orselli patiently suffered through typing various drafts of the manuscript tables and text; the VIMS Art Department drafted the figures; and Beverly Laird assisted in coordinating and producing this report.

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APPENDIX 9

Appendix 9A. Mean numerical abundance per tow by study area, stratum, and seasonal cruise.

Area and Stratum	Fall	Winter	Spring	Summer	Overall
Area B					
1	109.7	43.0	9.3	25.5	52.2
2	75.1	35.9	20.3	71.2	51.4
3	100.8	27.0	33.0	60.2	55.4
4	56.0	43.0	39.4	91.0	58.6
5	95.0	75.0	2.0	61.0	60.7
Area E					
1	161.7	28.7	24.8	98.3	68.6
2	23.9	32.4	16.6	110.0	44.1
3	25.7	56.9	30.7	55.5	43.0
4	21.7	62.0	12.5	37.7	35.6
5	16.8	19.7	16.7	97.9	36.9

Appendix 9B. Mean biomass (kg wet weight) per tow by study area, stratum, and seasonal cruise.

Area and Stratum	Fall	Winter	Spring	Summer	Overall
Area B					
1	9.7	9.3	1.9	2.0	6.2
2	6.6	9.0	3.6	3.4	5.9
3	14.6	4.9	6.3	5.8	8.0
4	11.2	18.2	8.9	6.8	10.0
5	8.2	20.9	0.2	0.9	6.7
Area E					
1	2.6	8.9	5.9	3.7	5.7
2	1.2	9.2	3.6	5.0	4.2
3	2.3	11.4	8.0	2.6	7.2
4	0.7	15.4	3.9	2.1	5.3
5	2.0	2.1	3.1	2.6	2.4

APPENDIX 9-C

Mean Shannon Diversity (H'), Richness (D), and Evenness (J')
in Study Areas A and B by Period of Collection, Stratum,
and Seasonal Cruise. N = Number of Tows.

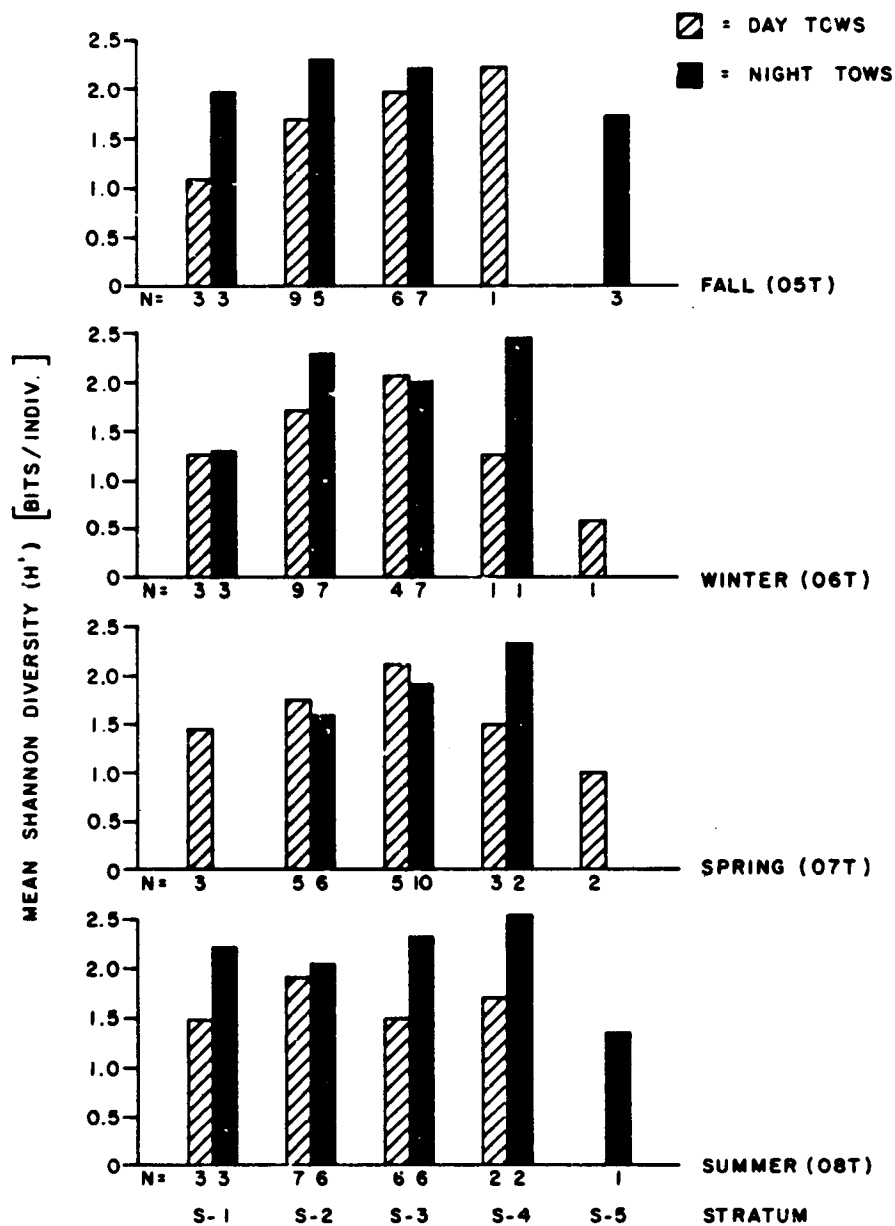


Figure 9-C-1. Mean Shannon diversity (H') in Area B.

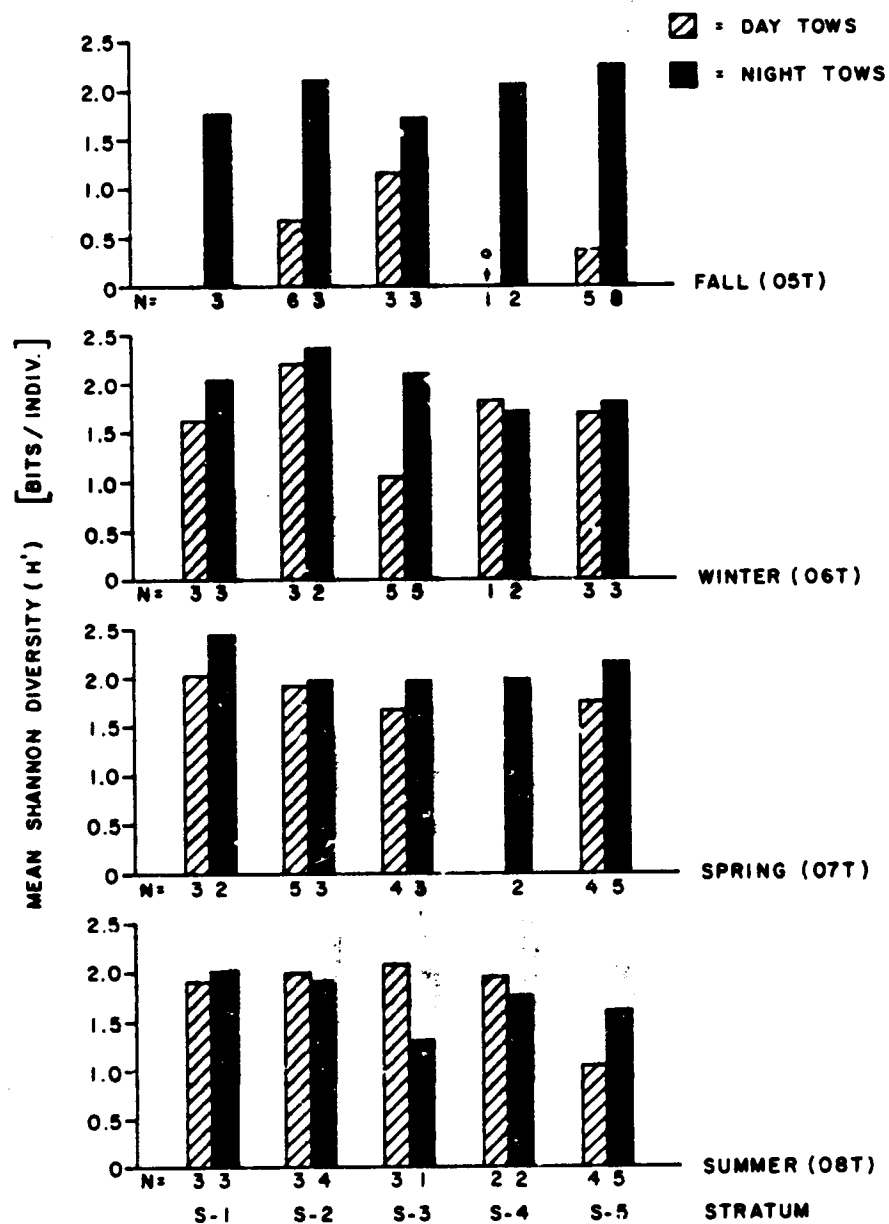


Figure 9-C-2. Mean Shannon diversity (H') in Area E.

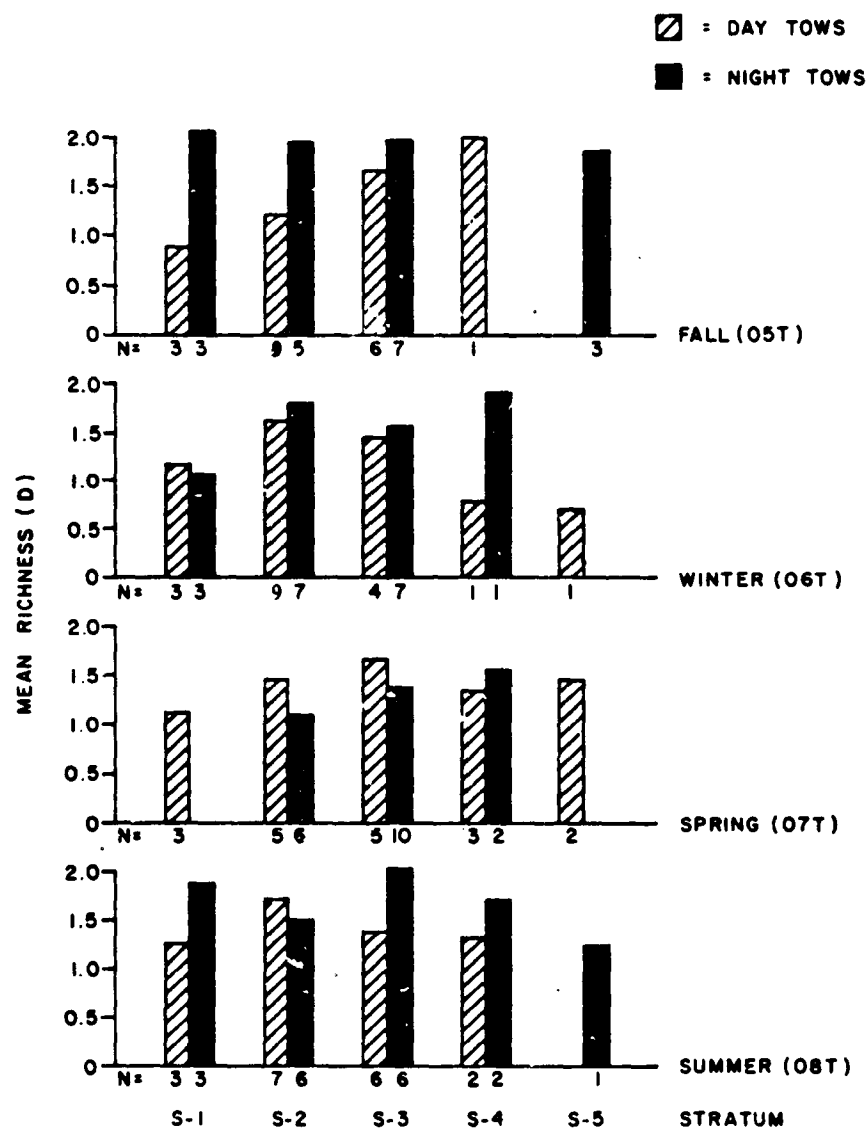


Figure 9-C-3. Mean richness (D) in Area B.

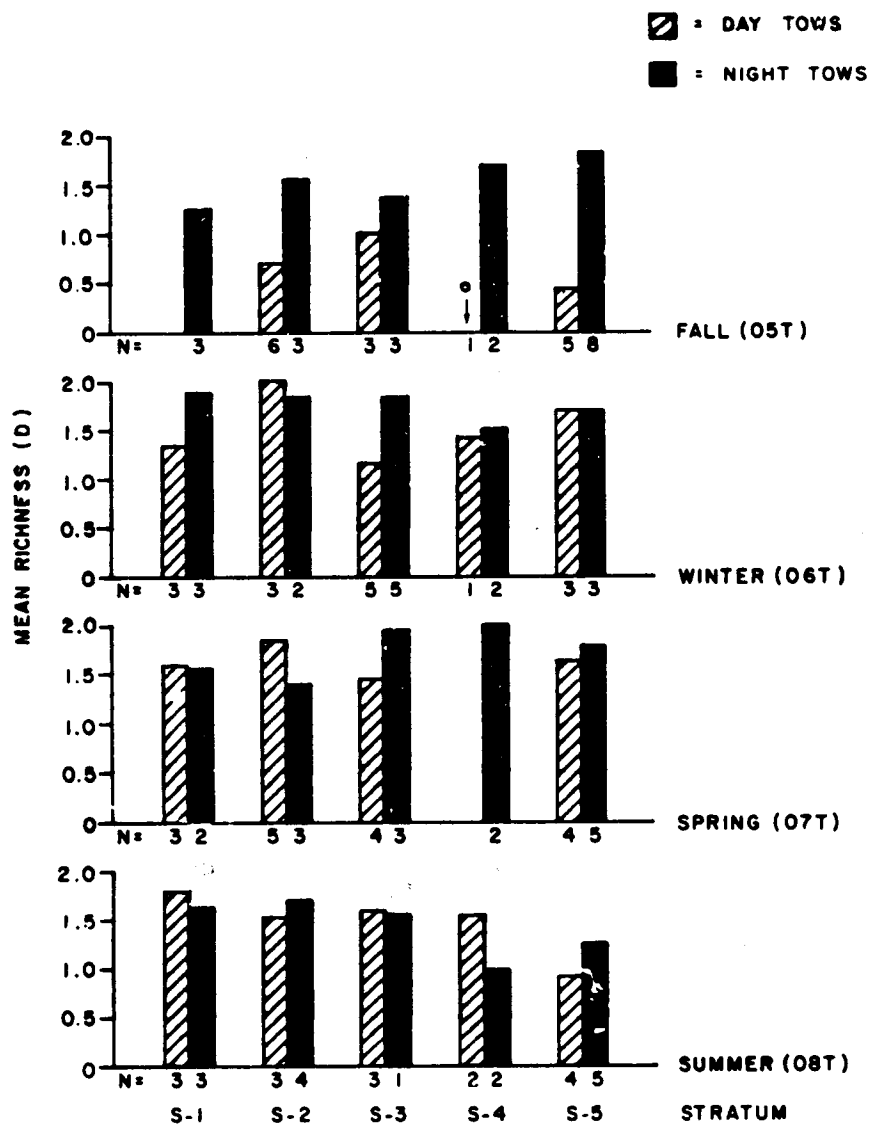


Figure 9-C-4. Mean richness (D) in Area E.

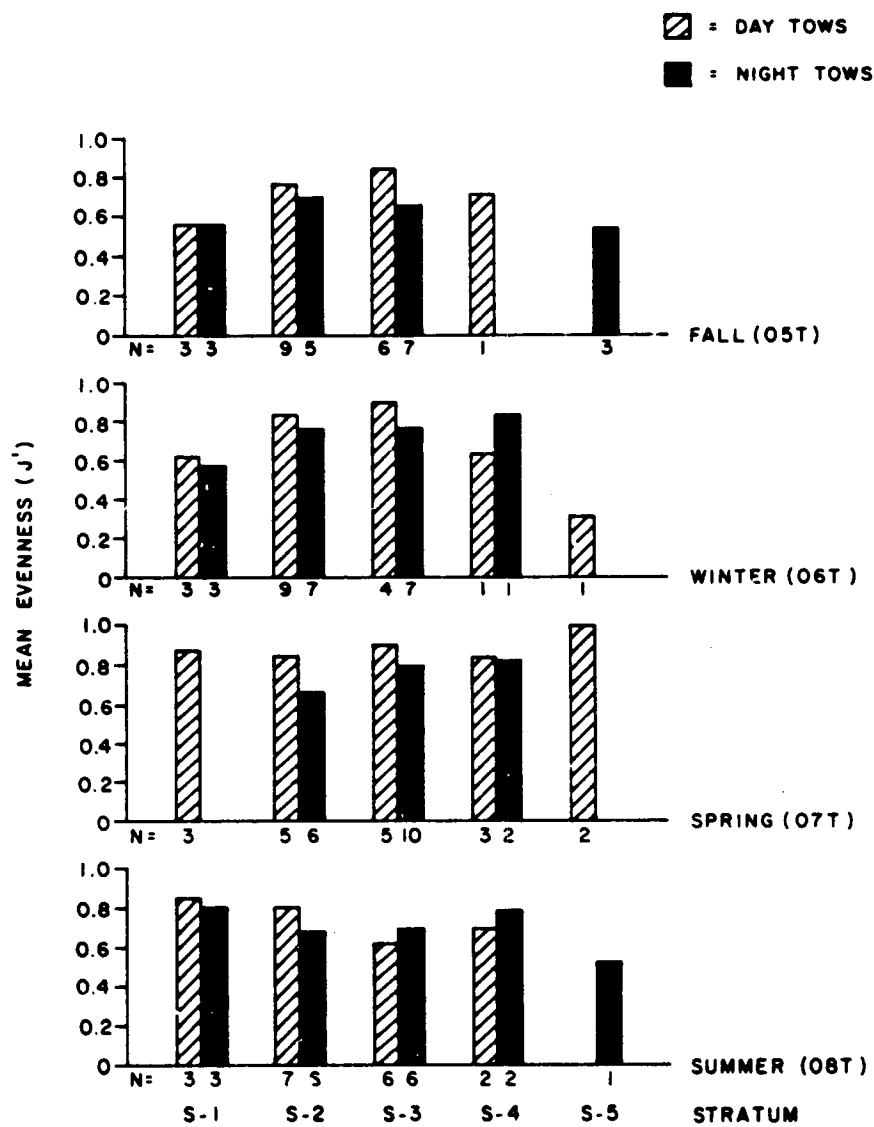


Figure 9-C-5. Mean evenness (J') in Area B.

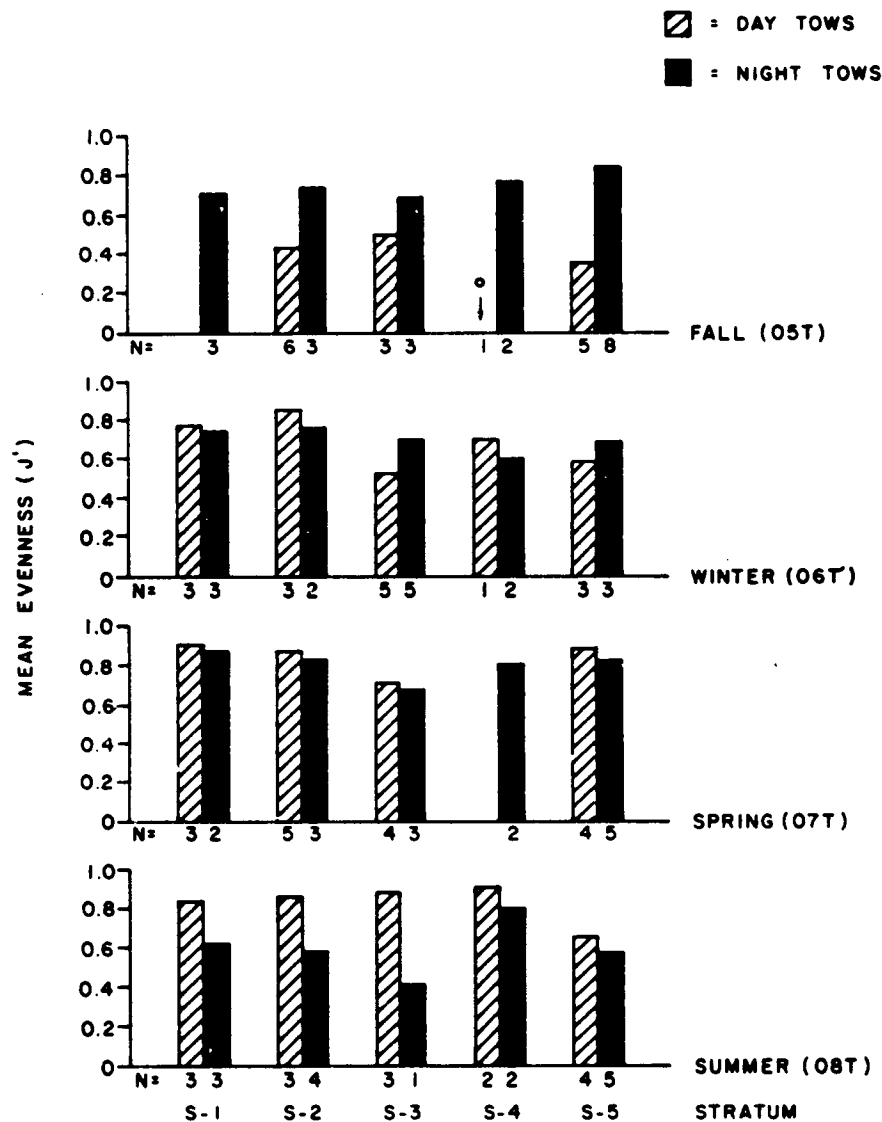


Figure 9-C-6. Mean evenness (J') in Area E.

APPENDIX 9-D

Statistical Data for Trawl Collections Grouped by Seasonal Cruise,
Study Area, Period of Collection, and Stratum

Table 9-D-1. Fall (BLM-05T, November 1976) B-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	9	6	1	0
Depth (m)	$\bar{x}$	42.7	62.4	61.0	68.0	-
	range	42-44	55-75	56-68	-	-
Temperature (°C)	$\bar{x}$	13.0	13.8	13.4	13.4	-
	range	12.8-13.1	12.9-14.2	13.0-13.9	-	-
No. of Species	$\bar{x}$	3.0	5.0	5.3	9.0	-
	σ	2.00	1.66	1.97	-	-
Abundance ln (x+1)	$\bar{x}$	1.87	3.33	2.63	4.04	-
	σ	1.320	0.785	0.656	-	-
Biomass (kg) ln (x+1)	$\bar{x}$	0.88	1.36	1.38	2.50	-
	σ	0.806	0.618	0.629	-	-
Cumulative Diversity (H')		2.01	2.47	2.62	2.22	-
Cumulative Evenness (J')		0.778	0.689	0.758	0.701	-
Cumulative Richness		1.46	1.90	2.20	1.99	-

$\bar{x}$ = mean value

σ = standard deviation

Table 9-D-2. Fall (BLM-05T, November 1976) B-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	5	7	0	3
Depth (m)	$\bar{x}$	41.3	59.0	60.0	-	69.3
	range	39-46	55-61	57-65	-	64-73
Temperature (°C)	$\bar{x}$	12.7	13.7	13.4	-	13.9
	range	12.1-13.4	13.1-13.9	12.9-13.9	-	13.9
No. of Species	$\bar{x}$	12.0	10.6	11.0	-	9.3
	σ	1.00	2.97	2.45	-	0.58
Abundance ln (x+1)	$\bar{x}$	5.32	4.87	5.11	-	4.54
	σ	0.261	0.566	0.363	-	0.274
Biomass (kg) ln (x+1)	$\bar{x}$	2.90	2.51	3.13	-	2.08
	σ	0.191	0.379	0.471	-	0.672
Cumulative Diversity (H')		2.28	2.60	2.73		1.88
Cumulative Evenness (J')		0.583	0.601	0.622	-	0.481
Cumulative Richness		2.17	2.88	2.82	-	2.48

$\bar{x}$ = mean value σ = standard deviation

Table 9-D-3. Fall (BLM-05T, November 1976) E-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		0	6	3	1	5
Depth (m)	$\bar{x}$	-	64.2	71.3	72.0	82.2
	range	-	55-68	69-75	-	77-90
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	-	13.4	13.1	13.2	13.5
	range	-	13.1-13.8	13.0-13.4	-	13.0-14.0
No. of Species	$\bar{x}$	-	2.2	4.3	1.0	0.8
	σ	-	1.60	4.93	-	1.09
Abundance ln (x+1)	$\bar{x}$	-	1.70	2.12	0.69	0.54
	σ	-	0.548	1.517	-	0.763
Biomass (kg) ln (x+1)	$\bar{x}$	-	0.33	0.76	0.09	0.18
	σ	-	0.396	1.145	-	0.059
Cumulative Diversity (H')		-	2.34	3.02	0.0	1.79
Cumulative Evenness (J')		-	0.780	0.841	0.0	0.896
Cumulative Richness		-	2.02	2.86	0.0	1.67

$\bar{x}$ = mean value

σ = standard deviation

Table 9-D-4. Fall (BLM-05T, November 1976) E-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	3	3	2	8
Depth (m)	$\bar{x}$	55.0	62.3	71.7	76.0	84.6
	range	55	61-64	68-78	72-80	77-92
Temperature (°C)	$\bar{x}$	13.6	13.4	13.6	13.5	13.6
	range	13.5-13.7	13.2-13.6	13.4-13.8	13.4-13.7	13.4-13.9
No. of Species	$\bar{x}$	7.0	7.3	5.7	7.0	6.9
	σ	3.61	1.53	2.31	4.24	2.17
Abundance ln (x+1)	$\bar{x}$	4.55	4.11	3.48	3.45	3.20
	σ	1.556	0.234	0.574	0.442	0.607
Biomass (kg) ln (x+1)	$\bar{x}$	1.26	1.29	1.12	0.59	1.30
	σ	0.292	0.152	0.165	0.573	0.571
Cumulative Diversity (H')		1.99	2.37	2.63	2.49	3.02
Cumulative Evenness (J')		0.576	0.714	0.792	0.720	0.793
Cumulative Richness		1.62	1.73	1.93	2.40	2.43

$\bar{x}$ = mean value σ = standard deviation

Table 9-D-5. Winter (BLM-06T, March 1977) B-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	9	4	1	1
Depth (m)	$\bar{x}$	45.7	61.6	58.5	66.0	70.0
	range	43-49	56-66	49-70	-	-
Temperature (°C)	$\bar{x}$	4.5	4.4	4.4	4.2	5.0
	range	4.4-4.5	4.3-4.7	4.2-4.6	-	-
No. of Species	$\bar{x}$	4.7	4.8	5.3	4.0	4.0
	σ	1.53	2.73	1.71	-	-
Abundance ln (x+1)	$\bar{x}$	3.12	2.31	2.94	3.85	4.33
	σ	0.786	0.606	0.490	-	-
Biomass (kg) ln (x+1)	$\bar{x}$	1.93	1.21	1.42	3.31	3.09
	σ	0.618	0.811	0.334	-	-
Cumulative Diversity (H')		1.40	2.74	2.45	1.26	0.58
Cumulative Evenness (J')		0.466	0.793	0.709	0.630	0.288
Cumulative Richness		1.60	2.19	2.28	0.78	0.69

$\bar{x}$ = mean value σ = standard deviation

Table 9-D-6. Winter (BLM-06T, March 1977) B-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	7	7	1	0
Depth (m)	$\bar{x}$	44.0	62.9	62.4	68.0	-
	range	42-46	59-67	58-69	-	-
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	4.2	5.0	4.4	4.4	-
	range	4.1-4.5	4.3-5.7	4.3-4.9	-	-
No. of Species	$\bar{x}$	5.0	8.3	6.3	8.0	-
	σ	1.00	2.29	1.11	-	-
Abundance ln (x+1)	$\bar{x}$	3.88	4.11	3.43	3.71	-
	σ	0.915	0.515	0.292	-	-
Biomass (kg) ln (x+1)	$\bar{x}$	2.36	2.59	1.85	2.40	-
	σ	0.821	0.731	0.361	-	-
Cumulative Diversity (H')		1.32	2.60	2.27	2.45	-
Cumulative Evenness (J')		0.441	0.666	0.655	0.816	-
Cumulative Richness		1.35	2.27	1.86	1.90	-

$\bar{x}$ = mean value σ = standard deviation

Table 9-D-7. Winter (BLM-06T, March 1977) E-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	3	5	1	3
Depth (m)	$\bar{x}$	58.7	64.0	75.8	78.0	83.0
	range	54-67	62-67	72-81	-	82-84
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	7.5	7.2	7.2	7.2	7.4
	range	7.4-7.7	6.6-7.7	6.4-7.9	-	7.2-7.5
No. of Species	$\bar{x}$	4.7	6.3	4.4	6.0	5.7
	σ	1.53	3.21	2.70	-	4.51
Abundance ln (x+1)	$\bar{x}$	2.76	2.68	2.79	3.53	2.09
	σ	0.919	0.166	1.674	-	1.221
Biomass (kg) ln (x+1)	$\bar{x}$	1.58	1.52	1.65	2.17	1.12
	σ	0.901	0.562	1.426	-	0.903
Cumulative Diversity (H')		2.07	2.67	0.96	1.81	3.12
Cumulative Evenness (J')		0.688	0.771	0.319	0.699	0.901
Cumulative Richness		1.70	2.69	1.28	1.43	2.89
$\bar{x}$ = mean value		σ = standard deviation				

Table 9-7-8. Winter (BLM-06T, March 1977) E-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	2	5	2	3
Depth (m)	$\bar{x}$	59.0	67.0	73.2	77.5	83.0
	range	57-63	67	68-77	77-78	82-85
Temperature (°C)	$\bar{x}$	7.3	7.1	7.3	7.0	7.7
	range	7.1-7.8	6.5-7.7	6.7-7.8	7.0	7.2-8.0
No. of Species	$\bar{x}$	7.3	8.5	8.2	7.5	5.7
	σ	2.08	0.71	1.30	3.54	1.53
Abundance ln (x+1)	$\bar{x}$	3.38	4.09	4.07	4.35	3.16
	σ	0.965	0.364	0.564	0.137	0.852
Biomass (kg) ln (x+1)	$\bar{x}$	2.26	2.86	2.34	2.99	0.78
	σ	1.150	0.302	0.689	0.208	0.332
Cumulative Diversity (H')		2.32	2.39	2.29	1.76	1.80
Cumulative Evenness (J')		0.672	0.755	0.574	0.507	0.541
Cumulative Richness		2.12	1.67	2.59	1.99	2.02

 $\bar{x}$ = mean value σ = standard deviation

Table 9-D-9. Spring (BLM-07T, May 1977) E-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	5	5	3	2
Depth (m)	$\bar{x}$	40.7	60.6	54.4	64.3	67.5
	range	37-45	57-65	49-59	62-66	66-69
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	4.9	4.5	4.7	4.4	4.5
	range	4.5-5.1	4.4-4.7	4.4-5.2	4.4-4.5	4.5
No. of Species	$\bar{x}$	3.3	4.4	5.2	4.0	2.0
	σ	1.15	1.14	0.84	1.73	0.0
Abundance ln (x+1)	$\bar{x}$	2.17	2.42	2.61	2.54	1.10
	σ	0.732	0.408	0.400	1.33	0.0
Biomass (kg) ln (x+1)	$\bar{x}$	0.97	1.31	1.23	1.42	0.18
	σ	0.540	0.282	0.359	1.145	0.0
Cumulative Diversity (H')		1.87	2.47	2.57	1.89	1.50
Cumulative Evenness (J')		0.804	0.824	0.858	0.674	0.946
Cumulative Richness		1.20	1.75	1.66	1.48	1.44
$\bar{x}$ = mean value		σ = standard deviation				

Table 9-D-10. Spring (BLM-07T, May 1977) 8-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		0	6	10	2	0
Depth (m)	$\bar{x}$	-	59.7	52.6	66.0	-
	range	-	55-62	40-64	64-68	-
Temperature (°C)	$\bar{x}$	-	4.7	4.7	4.7	-
	range	-	4.5-4.8	4.5-5.2	4.6-4.8	-
No. of Species	$\bar{x}$	-	4.8	5.6	7.0	-
	σ	-	2.40	1.35	1.41	-
Abundance ln (x+1)	$\bar{x}$	-	3.01	3.50	4.09	-
	σ	-	1.201	0.910	0.838	-
Biomass (kg) ln (x+1)	$\bar{x}$	-	1.44	2.02	2.64	-
	σ	-	0.790	0.690	0.724	-
Cumulative Diversity (H')		-	2.39	2.22	2.24	-
Cumulative Evenness (J')		-	0.754	0.669	0.748	-
Cumulative Richness		-	1.56	1.49	1.42	-

$\bar{x}$ = mean value

σ = standard deviation

Table 9-D-11. Spring (BLM-071, May 1977) E-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	5	4	0	4
Depth (m)	$\bar{x}$	56.7	66.0	76.3	-	79.5
	range	51-63	63-68	71-78	-	75-87
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	5.4	5.6	5.8	-	6.2
	range	5.2-5.6	5.3-5.8	5.8	-	5.8-7.3
No. of Species	$\bar{x}$	4.7	4.6	5.3	-	4.3
	σ	0.58	1.34	1.50	-	1.71
Abundance	$\bar{x}$	2.42	2.19	3.18	-	2.06
ln (x+1)	σ	0.419	0.281	0.466	-	0.493
Biomass (kg)	$\bar{x}$	1.42	1.29	2.28	-	0.62
ln (x+1)	σ	0.770	0.145	0.431	-	0.369
Cumulative Diversity (H')		2.56	2.79	1.81	-	2.48
Cumulative Evenness (J')		0.854	0.806	0.544	-	0.781
Cumulative Richness		2.00	2.69	1.96	-	2.35
$\bar{x}$ = mean value σ = standard deviation						

Table 9-D-12. Spring (BLM-07T, May 1977) E-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		2	3	3	2	5
Depth (m)	$\bar{x}$	58.0	57.3	70.0	78.5	78.2
	range	51-65	51-66	65-77	77-80	75-84
Temperature (°C)	$\bar{x}$	5.5	5.4	5.8	5.9	7.5
	range	5.3-5.7	5.1-5.7	5.7-5.8	5.9	5.8-9.8
No. of Species	$\bar{x}$	7.0	5.3	7.7	5.5	6.6
	σ	0.0	1.53	0.58	0.71	2.70
Abundance ln (x+1)	$\bar{x}$	3.84	3.18	3.54	2.51	3.10
	σ	0.046	0.951	0.656	0.612	0.540
Biomass (kg) ln (x+1)	$\bar{x}$	2.27	1.65	2.43	1.54	1.56
	σ	0.058	0.728	0.474	0.404	0.722
Cumulative Diversity (H')		2.50	2.24	1.92	2.05	2.86
Cumulative Evenness (J')		0.889	0.799	0.577	0.731	0.826
Cumulative Richness		1.33	1.33	1.90	1.86	2.09

$\bar{x}$ = mean value σ = standard deviation

Table 9-D-13. Summer (BLM-08T, September 1977) B-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	7	6	2	0
Depth (m)	$\bar{x}$	40.3	62.1	59.8	66.5	-
	range	38-42	60-65	57-69	65-68	-
Temperature ($^{\circ}\text{C}$)	$\bar{x}$	10.6	9.8	9.8	9.8	-
	range	10.1-11.3	9.6-10.3	9.7-10.1	9.8	-
No. of Species	$\bar{x}$	3.3	5.7	5.3	5.5	-
	σ	0.58	2.21	3.14	2.12	-
Abundance ln (x+1)	$\bar{x}$	2.04	2.78	2.72	3.35	-
	σ	0.315	0.863	1.424	0.648	-
Biomass (kg) ln (x+1)	$\bar{x}$	0.50	0.70	0.92	0.78	-
	σ	0.166	0.398	0.821	0.536	-
Cumulative Diversity (H')		1.87	2.36	2.12	2.01	-
Cumulative Evenness (J')		0.722	0.681	0.590	0.716	-
Cumulative Richness		1.64	2.04	2.15	1.46	-
$\bar{x}$ = mean value		σ = standard deviation				

Table 9-D-14. Summer (BLM-08T, September 1977) B-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	6	6	2	1
Depth (m)	$\bar{x}$	44.0	59.2	59.8	65.5	79.0
	range	40-48	53-62	57-66	65-66	-
Temperature (°C)	$\bar{x}$	10.2	10.0	9.8	10.2	9.6
	range	10.0-10.4	9.7-10.2	9.1-10.2	9.9-10.5	-
No. of Species	$\bar{x}$	7.3	8.2	10.0	9.5	6.0
	σ	3.51	2.71	1.67	0.71	-
Abundance ln (x+1)	$\bar{x}$	3.40	4.58	4.51	5.03	4.13
	σ	1.285	1.051	0.259	0.004	-
Biomass (kg) ln (x+1)	$\bar{x}$	1.27	1.82	2.29	2.57	0.64
	σ	0.752	0.603	0.287	0.221	-
Cumulative Diversity (H')		2.47	2.52	2.52	2.59	1.34
Cumulative Evenness (J')		0.715	0.646	0.663	0.750	0.519
Cumulative Richness		2.05	2.10	2.06	1.75	1.22
$\bar{x}$ = mean value		σ = standard deviation				

Table 9-D-15. Summer (BLM-08T, September 1977) E-Area Day Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	3	3	2	4
Depth (m)	$\bar{x}$	57.0	64.3	70.3	74.5	82.0
	range	53-64	57-68	69-71	74-75	73-88
Temperature (°C)	$\bar{x}$	9.6	9.6	9.8	10.3	12.1
	range	9.4-9.8	9.4-9.7	9.6-9.9	10.3	10.6-12.8
No. of Species	$\bar{x}$	5.0	5.3	5.3	4.5	2.8
	σ	1.00	2.52	1.53	0.71	1.71
Abundance ln (x+1)	$\bar{x}$	2.35	2.81	2.77	2.39	1.84
	σ	0.504	0.265	0.415	0.129	1.150
Biomass (kg) ln (x+1)	$\bar{x}$	0.60	0.61	0.52	0.49	0.35
	σ	0.442	0.421	0.394	0.216	0.454
Cumulative Diversity (H')		2.40	2.46	2.41	2.38	2.00
Cumulative Evenness (J')		0.854	0.741	0.761	0.849	0.773
Cumulative Richness		1.75	2.32	2.07	2.00	1.40

$\bar{x}$ = mean value

σ = standard deviation

Table 9-D-16. Summer (BLM-08T, September 1977) E-Area Night Stations.

STRATUM		1	2	3	4	5
No. of Stations		3	4	1	2	5
Depth (m)	$\bar{x}$	54.3	65.5	75.0	76.0	75.2
	range	51-57	64-69	-	75-77	74-77
Temperature (°C)	$\bar{x}$	9.8	9.9	10.3	10.4	11.0
	range	9.6-9.9	9.7-10.2	-	10.3-10.6	10.3-11.6
No. of Species	$\bar{x}$	9.3	9.8	9.0	5.0	7.2
	σ	1.53	1.89	-	1.41	1.09
Abundance ln (x+1)	$\bar{x}$	5.17	5.09	5.16	4.10	4.96
	σ	0.410	0.611	-	0.648	0.607
Biomass (kg) ln (x+1)	$\bar{x}$	2.00	2.09	2.22	1.43	1.54
	σ	0.189	0.538	-	0.562	0.483
Cumulative Diversity (H')		2.03	2.39	1.30	1.82	1.70
Cumulative Evenness (J')		0.550	0.610	0.410	0.702	0.493
Cumulative Richness		1.90	2.13	1.55	1.03	1.48
$\bar{x}$ = mean value		σ = standard deviation				

CHAPTER 10

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CHAPTER 10

HISTORICAL COMMUNITY STRUCTURE ANALYSIS OF FINFISHES

SECTION I: CHESAPEAKE BIGHT

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INTRODUCTION

The Chesapeake Bight includes the continental sea between the offing of Delaware Bay ($38^{\circ}53'N$) and Cape Hatteras, North Carolina ($35^{\circ}13'N$). This region constitutes the southern half of the "Virginian" zoogeographic province (Johnson 1934). Its southern boundary near Cape Hatteras has been shown to be an effective faunal barrier to invertebrates (Cerame-Vivas and Gray 1966). Parr (1933) noted that this area constituted a faunal barrier to coastal fishes during the winter when water temperatures are much lower north of the Cape than to the south. In fact the extreme seasonal variations in temperature in the Chesapeake Bight may be unique. Examination of figures in Walford and Wicklund (1968) shows that coastal sea surface temperature may have an annual range of $25^{\circ}C$, and unpublished VIMS studies show that the annual temperature range may approach $30^{\circ}C$ at the mouth of the Chesapeake Bay in some years.

Just as the seasonal thermal regime at Cape Hatteras may control the emigration and immigration of fishes between Chesapeake Bight and areas to the south, seasonal changes in thermal regime also are closely correlated with geographic and bathymetric migrations of some fishes within the Bight (Musick 1972; Musick and Mercer 1977).

The present paper analyzes seasonal patterns in distribution, abundance, and composition of fish assemblages in the Chesapeake Bight.

METHODS

Sampling

Cruises were conducted by the Virginia Institute of Marine Science (VIMS) in the Chesapeake Bight during the four seasons of 1967 and the winter of 1968 aboard the 88 gross ton side trawler Sea Breeze. The survey area (Figure 10-1), bounded by the 9 and 274 m isobaths, was divided into grids (15' latitude x 15' longitude). Attempts were made to sample each grid once during each seasonal

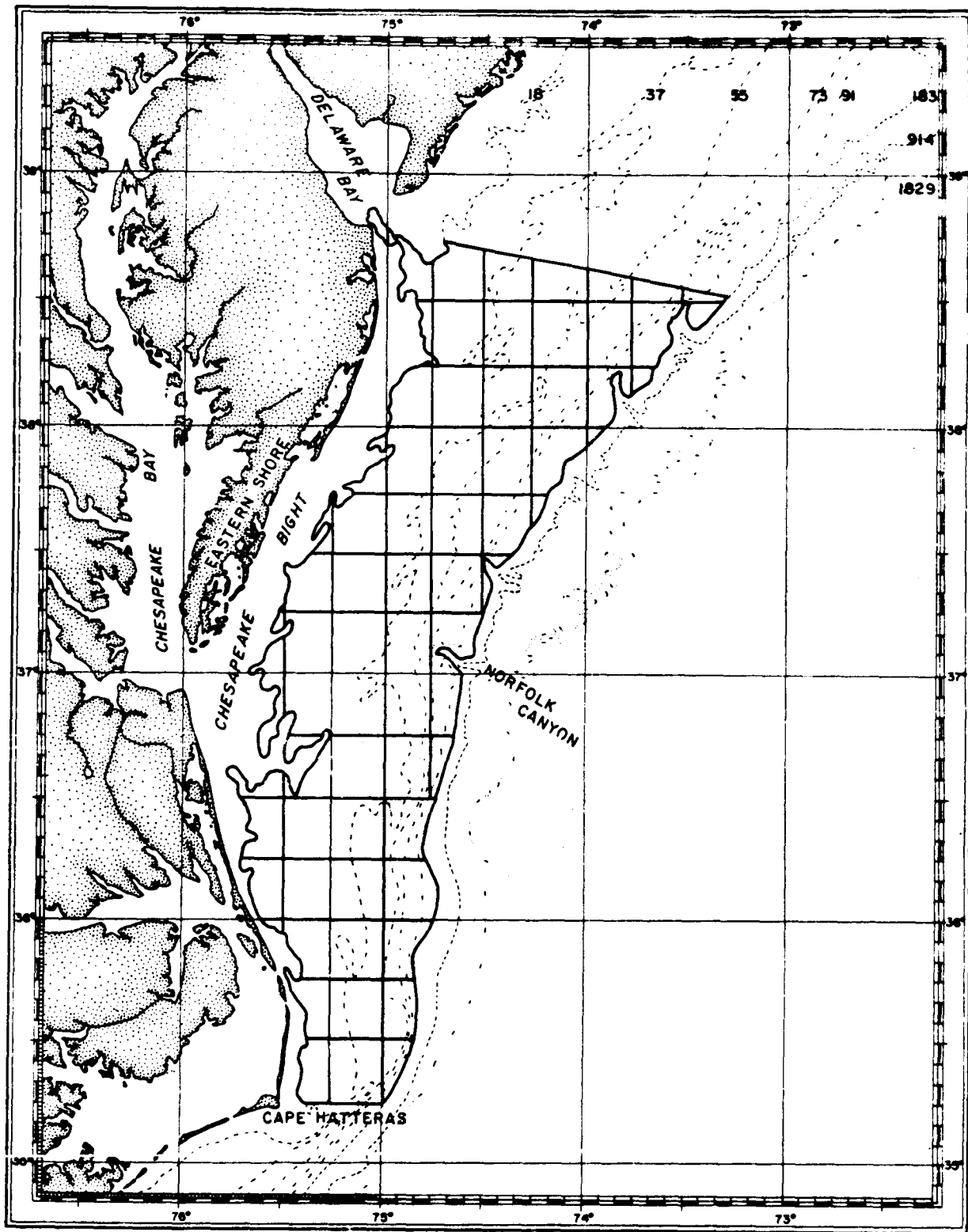


Figure 10-1. Sampling area, Chesapeake Bight, 1967-68. Contour depths in meters.

cruise. At each station a model IV Atlantic Western trawl (16 m head rope, 24 m foot rope; stretch mesh sizes: 200 mm in body, 150 mm extremes, 100 mm cod end) was towed for one hour at a speed of 3 knots. All fish captured were identified, counted, and weighed by species. Very large catches were subsampled of necessity. Most trawls were made during daylight hours, except during winter when short day-length required some night sampling in order to complete synoptic seasonal collections within a reasonable time period. Water temperature and salinity were measured at surface and bottom at each station. Because otter trawls are selective sampling devices, and the relative catchability of different species may vary, abundance and biomass estimates reflect the relative availability of the species to our gear.

Analyses

Clustering

The catch data were analyzed separately for each of the five seasonal cruises. Assemblages of fishes were defined by computing a similarity coefficient, $D(j,k)$, among species and subsequently classifying species into clusters or groups (Sneath and Sokal 1973). Stations were clustered in the same manner, and species and station (site) groups were compared by nodal analysis (Lambert and Williams 1962).

The similarity coefficient used was the Canberra Metric which is particularly effective when the organisms under study are contagiously distributed (W. Stephenson, pers. comm.) as most fishes are. Also, to further reduce the effects of contagion, the numerical abundance data were transformed [$\log_e (x + 1)$] before analysis (Taylor 1953). Species were eliminated from cluster analysis if they occurred at less than five percent of the stations occupied during a sampling period. The Canberra Metric coefficient was defined by Lance and Williams (1967) as:

$$D(j,k) = \frac{1}{m} \sum_i \frac{|x_{ij} - x_{ik}|}{(x_{ij} + x_{ik})}$$

where in species analysis (inverse analysis) X = the number of species j and k at station i , and m = the total number of stations, and in site analysis (normal analysis) X = the number of species i at stations j and k , and m = the total number of species.

The Canberra Metric is a dissimilarity function, but in practice the complement is used to yield a similarity function before clustering (Williams 1971). The clustering strategy used herein was

flexible with $\beta = -0.25$. This is an agglomerative hierarchical procedure which avoids chaining and is space dilating (Clifford and Stephenson 1975).

The choice as to what size cluster might be biologically significant was based on several criteria. Each site cluster should have reflected faunal homogeneity relative to other clusters. Each species cluster should have been distributed consistently among site clusters. Comparison of site clusters with species clusters through nodal analysis suggested whether clusters were excessively divisive or agglomerative, or whether they reflected natural cohesive groups.

Two methods of nodal analysis were performed. The patterns of "constancy" of species belonging to particular species groups in particular site groups were expressed as relative densities of cells of a two-way table (Stephenson et al. 1972). These densities were based on proportions of the number of occurrences of species in the site group to the total number of occurrences (Boesch 1977). Algebraically, this constancy index is:

$$C_{ij} = a_{ij}/(n_i n_j)$$

where a_{ij} is the actual number of occurrences of members of species group i in site group j , and the n_i and n_j are the numbers of entities in the respective groups. The index will take a value of one when all species occur in all collections in the group, and zero when none of the species occur in the collections.

The patterns of "fidelity" of species groups to site groups also were expressed as relative densities of cells of a two-way table. Fidelity is a measure of the degree to which species are limited to site groups. The fidelity index was used as an expression of the constancy of species in a site group compared to the constancy over all sites. The fidelity of species group i in site group j was defined as:

$$F_{ij} = (a_{ij} \sum_j n_j) / (n_j \sum_j a_{ij})$$

This index is unity when the constancy of a species group in a site group is equivalent to its overall constancy, greater than 1 when its constancy in the site group is greater than that overall, and less than 1 when its constancy is less than its overall constancy. A chi-square test was applied to the fidelity value of each cell to determine whether it varied significantly ($\alpha = 0.05$) from 1 (Woolf 1968). Fidelity values significantly greater than 1 indicate a positive association of species in a group with a site group, while values significantly less than 1 suggest a "negative" association. In the present analyses a highly positive (or strong) association was inferred if the number of occurrences of a given species group within

a site group was twice that necessary to produce a fidelity value significantly greater than 1. Conversely, a highly negative association, or avoidance, was assumed when the number of occurrences were less than half that necessary to produce a fidelity value significantly less than 1. All nodal diagrams were drawn with the width of the rows and columns proportional to the number of entities in the respective site and species groups.

Species Dominance

Numerically dominant species have been used to characterize communities by ecologists for many years (Thorson 1957), and changes in dominant species often reflect faunal changes. In the present study, we have compared patterns of species dominance among site groups. A species was considered dominant if it occurred among the five most abundant species in at least 20% of all the stations from a site group. The five most abundant species comprised 90% or more of the total number of individuals at most stations.

Availability: Abundance and Biomass

Estimates of mean log-transformed [$\log_e (x + 1)$] abundance and biomass were computed for each site cluster. Analysis of variance (ANOVA) was then performed among site clusters for each cruise. If ANOVA was significant at the 0.05 level, Scheffe's multiple range test for unequal sample sizes was performed to determine which site groups were different from one another at the same level (Guenther 1964).

Faunal Affinities

The faunal affinities of most species of fishes captured could be determined by examining published records of their usual ranges of occurrence (Bigelow and Schroeder 1953; Leim and Scott 1966; Struhsaker 1969; Musick 1972). Most warm-temperate species had resident populations south of Cape Hatteras in the "Carolinian" faunal province (Hazel 1970), and had their normal northern range limit somewhere within the mid-Atlantic Bight south of Cape Cod. Boreal species had permanent populations north of Cape Cod, and most had their southern range limit somewhere within the mid-Atlantic Bight north of Cape Hatteras. A few boreal species transcended Hatteras through bathymetric submergence. Certain components of the fauna tended to be residents on the inner shelf (Scophthalmus aquosus) or outer shelf (Hippoglossina oblonga). Many species were resident on the shelf edge and upper slope (Musick 1976).

RESULTS AND DISCUSSION

Thermal Regime

The thermal regime at the sea bottom has been plotted for each season in Figure 10-2. The thermal regime was similar in the winter of 1967 and 1968 so only that for 1968 is presented because geographic coverage was more complete in that year. Isotherms were extrapolated from discrete measurements of bottom temperatures at each station. Thermal anomalies caused by temporal temperature changes during a sampling period were omitted from the figures. Because of sampling restrictions imposed on our small vessel by weather, it was virtually impossible to complete our station pattern in less than a month. Thus samples were not entirely synoptic.

In winter (Figure 10-2D), bottom temperatures were less than 2°C inshore. Temperature increased with depth out to the shelf edge where temperatures in excess of 10°C were measured in the relatively stable Slope Water (Iselin 1936; Wright and Parker 1976). The Gulf Stream thermal front was quite obvious northeast of Cape Hatteras with a steep thermal gradient from 10 to 18°C. In spring (Figure 10-2A), vernal warming occurred more rapidly in the shallowest inshore areas with bottom temperatures reaching 12°C. The strong thermal front was again obvious off Cape Hatteras. In summer (Figure 10-2B), inshore bottom temperatures from the Chesapeake Capes south had risen to 20°C or higher resulting in a more gentle thermal gradient between the Gulf Stream and the Virginia coastal water north of Cape Hatteras. Because of strong thermal stratification, bottom water beneath the thermocline between the 35 to 55 m isobaths remained as low as 6°C. At greater depths the bottom temperature increased because of the moderating influence of Slope Water.

In fall (Figure 10-2C), cooling proceeded most rapidly inshore. With cooling surface waters and dissipation of the thermocline, turnover occurred and bottom temperatures at intermediate depths (ca 30-60 m) rose to 10-12°C, the annual maximum there. A strong thermal front was becoming re-established off Cape Hatteras, and there was evidence for the incursion of warm (>14°C) Gulf Stream meanders over the bottom at the shelf edge (ca 180 m isobath) between Hatteras and Norfolk Canyon (37°00'N).

Fish Assemblages

Winter 1967

Cluster Analyses. Five groups of stations were apparent from the cluster (Figure 10-3). Group I comprised stations mostly shoaler than 38 m (Table 10-1); group II, a northern group of stations at intermediate depths (37-51 m); group III, a southern group at

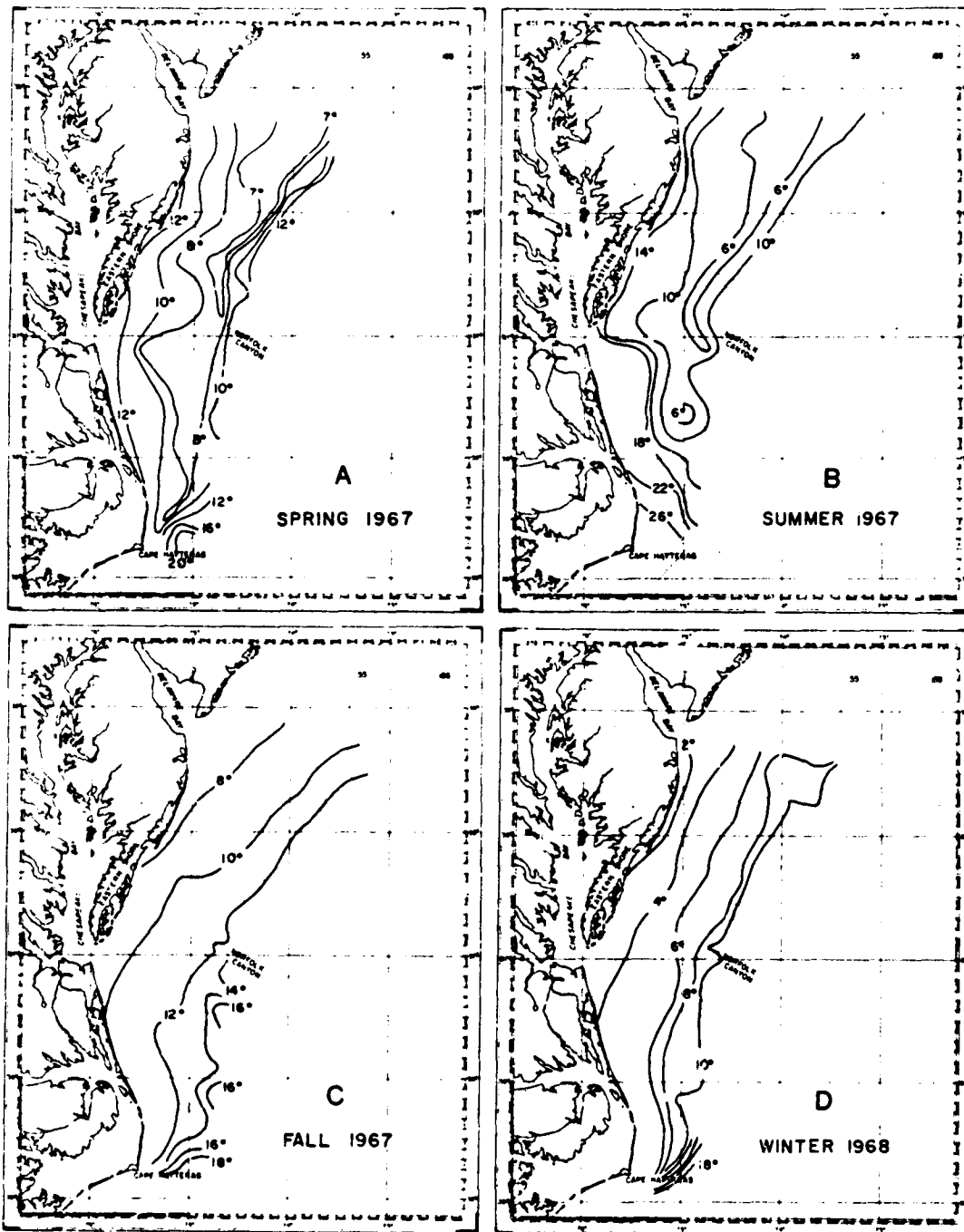


Figure 10-2. Bottom isotherms in Chesapeake Bight A) spring 1967, B) summer 1967, C) fall 1977, and D) winter 1968.

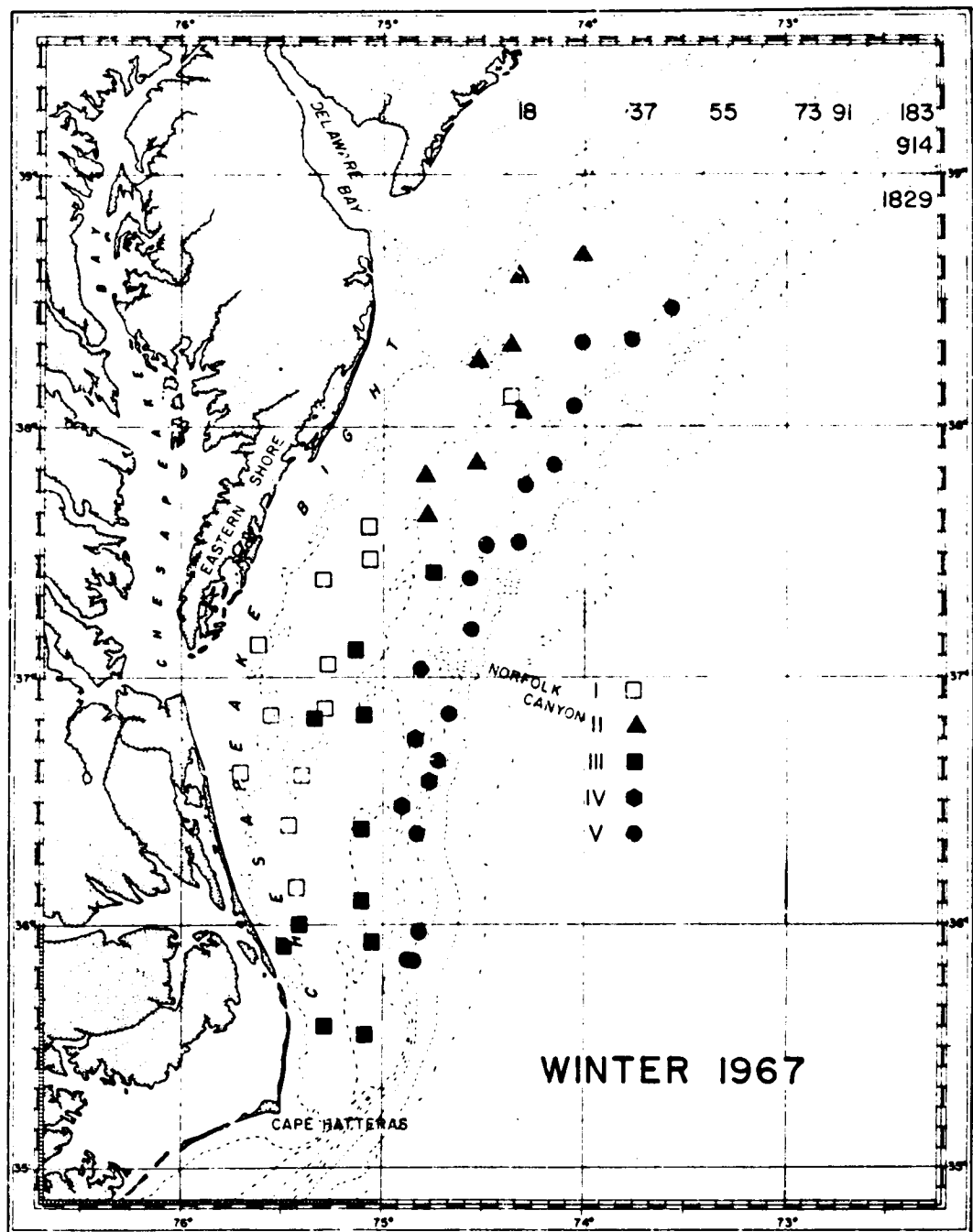


Figure 10-3. Distribution of trawl stations by site group in winter 1967.

Table 10-1. Site group statistics, trawler Sea Breeze, winter 1967.

SITE GROUP		I	II	III	IV	V
No. of Stations		12	8	11	3	17
Abundance ln (x+1)	$\bar{x}$	5.25	6.10	5.82	6.02	6.57
	σ	0.939	0.823	1.058	2.570	0.979
No. of Species	$\bar{x}$	10.1	16.8	9.3	7.7	13.6
	σ	2.15	2.82	3.04	2.52	2.89
Biomass (kg) ln (x+1)	$\bar{x}$	4.98	5.36	6.01	5.43	6.07
	σ	0.785	0.585	1.071	2.028	1.254
Depth (m)	Range	15-38	37-51	20-49	35-79	57-174
	$\bar{x}$	25.1	42.5	31.8	57.9	97.9
Temperature (°C)	Range	4-8	5-7	6-13	6-8	8-12
	$\bar{x}$	5.9	5.6	7.7	7.3	10.2

$\bar{x}$ = mean value

σ = standard deviation

intermediate depths (20-49 m); group IV, an unusually small and geographically restricted group; and group V, an outer shelf group (57-174 m). Seven species clusters were recognized (Table 10-2) ranging in content from 3 (group F) to 8 (group D) species.

Distribution of Fishes. Water temperatures at the inshore site group I and at the northern site group II were low (4-8°C) (Table 10-1), and the species contents of groups found there reflected the thermal regime (Table 10-2). Species group A had high constancy and the only positive fidelity in site group I (Figure 10-4). Species group D had moderate constancy but negative fidelity in site group I. Both these species groups had very high constancy and positive fidelity in site group II. Also species groups B and C exhibited their only positive fidelities to this site group. These species groups had a majority of boreal species (Table 10-2): in group A, 6 of 7 species; B, 3 of 4; C, 3 of 4; D, 5 of 8. Among the dominant species (Table 10-3) at site group I, 5 of 7 had boreal affinities, and at site group II, 8 of 9 dominants had boreal affinities.

Temperatures at the southern mid-shelf stations (site group III) were higher (6-13°C, $\bar{x}$ = 7.7°C). Species groups D and E had high constancy there and E had positive fidelity. Group E comprised 5 species all with warm-temperate affinities. Group D contained 2 warm-temperate species, 1 resident outer-shelf form, and 5 boreal species which were widespread. Species group D had moderate to high constancy in all site groups. Among the dominant species at site group III, 4 of 7 were warm-temperate, 2 were boreal, and 1 was a resident of the inner-shelf.

Temperatures at the shelf edge at site group V were less variable (8-12°C) than at the southern mid-shelf group and higher on the average ($\bar{x}$ = 10.2°C). The ubiquitous species group D had very high constancy there. Also, the warm-temperate group E and group G had moderate constancy at the shelf edge. All three of these species groups had positive fidelity to site group V, as did species in group F. Species group G included 3 warm-temperate species, and 3 species resident on the upper-slope. Group F included 3 boreal species, 2 of which undergo tropical submergence south of New England, becoming resident on the upper-slope (Musick 1974, 1976). Among the dominant species at site group V, 4 of 8 had warm-temperate affinities, 2 had boreal affinities, 1 was an outer-shelf resident, and 1 was a slope resident.

Site group IV had a limited temperature range (6-8°C) and was unique in that no species group had a positive fidelity there. Three boreal, benthopelagic species (Clupea harengus, Scomber scombrus, and Squalus acanthias) were among the dominant species which also included two warm-temperate forms, particularly Prionotus carolinus, which occurred at all stations and accounted for over half of the individuals taken.

Table 10-2. Contents of species groups, trawler Sea Breeze, winter 1967.*

A	B	C
<u>Scophthalmus aquosus</u> IS	<u>Alosa aestivalis</u> WT	<u>Citharichthys arctifrons</u> Si
<u>Alosa pseudoharengus</u> Bo	<u>Clupea harengus harengus</u> Bo	<u>Hemitripterus americanus</u> Bo
<u>Raja erinacea</u> Bo	<u>Scomber scombrus</u> Bo	<u>Gadus morhua</u> Bo
<u>Pseudopleuronectes americanus</u> Bo	<u>Alosa sapidissima</u> Bo	<u>Raja ocellata</u> Bo
<u>Myoxocephalus octodecemspinosus</u> Bo		
<u>Limanda ferruginea</u> Bo		
<u>Macrozoarces americanus</u> Bo		
D	E	F
<u>Lophius americanus</u> Bo	<u>Stenotomus chrysops</u> WT	<u>Conger oceanicus</u> Bo-Sl
<u>Merluccius bilinearis</u> Bo	<u>Peprilus triacanthus</u> WT	<u>Urophycis tenuis</u> Bo-Sl
<u>Hippoglossina oblonga</u> OS	<u>Raja eglanteria</u> WT	<u>Raja laevis</u> Bo-Sl
<u>Glyptocephalus cynoglossus</u> Bo-Sl	<u>Prionotus carolinus</u> WT	
<u>Urophycis chuss</u> Bo	<u>Prionotus evolans</u> WT	
<u>Urophycis regius</u> WT		
<u>Paralichthys dentatus</u> WT		
<u>Squalus acanthias</u> Bo		
	G	
	<u>Squatina dumerili</u> WT	
	<u>Mustelus canis</u> WT	
	<u>Centropristis striata</u> WT	
	<u>Raja garmani</u> Sl	
	<u>Scyliorhinus retifer</u> Sl	
	<u>Zenopsis ocellata</u> Sl	

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl.

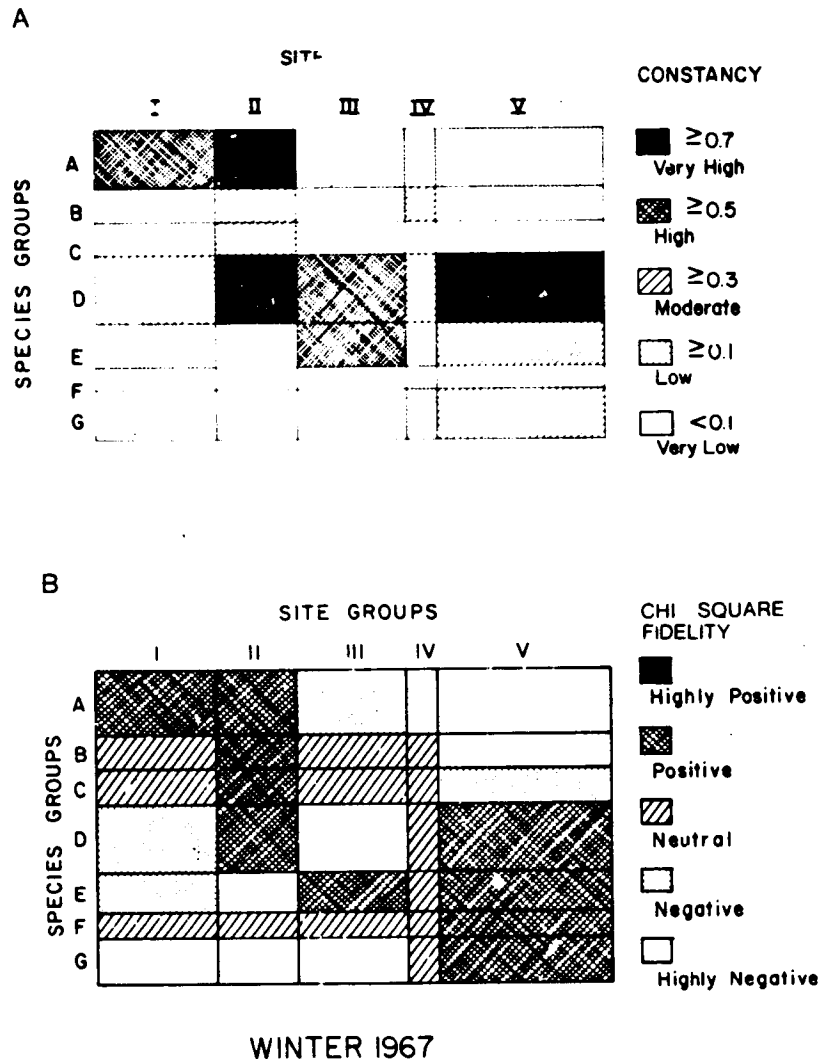


Figure 10-4. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for winter 1967.

Table 10-3. Species dominance, trawler Sea Breeze, winter 1967.

Species	Faunal Affinity*	Species Group	I		II		III		IV		V	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Pseudopleuronectes americanus</u>	Bo	A	58	2.3								
<u>Alosa pseudoharengus</u>	Bo	A	75	21.7	100	8.8						
<u>Myoxocephalus octodecemspinosus</u>	Bo	A			100	6.6						
<u>Limanda ferruginea</u>	Bo	A			100	27.8						
<u>Macrozoarces americanus</u>	Bo	A			88	7.3						
<u>Scophthalmus aquosus</u>	IS	A	100	14.5	88	3.4	71	2.6				
<u>Raja erinacea</u>	Bo	A	92	7.0	100	15.3	36	2.7				
<u>Clupea harengus harengus</u>	Bo	B	33	5.8					67	9.8		
<u>Scomber scombrus</u>	Bo	B			50	4.1			67	3.1		
<u>Peprilus triacanthus</u>	WT	E	25	10.3			55	9.9			65	4.4
<u>Prionotus carolinus</u>	WT	E					45	9.4	100	53.6		
<u>Stenotomus chrysops</u>	WT	E					27	6.5			59	5.6
<u>Squalus acanthias</u>	Bo	D	100	28.8	100	9.4	100	55.4	67	22.1	100	31.9
<u>Merluccius bilinearis</u>	Bo	D			100	4.1					88	3.7
<u>Urophycis regia</u>	WT	D					91	2.9	67	3.0	94	6.3
<u>Hippoglossina oblonga</u>	OS	D									94	12.9
<u>Centropristis striata</u>	WT	G									65	11.2
<u>Raja germani</u>	SI	G									47	4.8

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Availability: Abundance and Biomass. Mean abundance (Table 10-1) increased from a low level inshore (site group I) to an intermediate level on the middle shelf in site groups II, III, and IV, and reached a maximum in the outer shelf site group V. Mean biomass (Table 10-1) patterns were more pronounced, with a direct relationship between biomass and depth. The mean biomass in group V at the shelf edge was almost an order of magnitude higher than that in group I inshore. Also, mean biomass was much higher in the southern mid-shelf group III than that in the northern group II. Although patterns for mean abundance and biomass appeared well-defined, ANOVA was barely significant for abundance, and Scheffe's test failed to detect differences among site groups. Also the ANOVA for biomass was not significant. The absence of statistically significant differences appeared to be caused by the high variability in abundance and biomass within site groups, and to the relatively restricted bathymetric distribution of stations.

Spring 1967

Cluster Analyses. Six clusters of stations were apparent (Figure 10-5). Site group I was distributed across the shelf (out to 55 m) in the south, and then inshore northward. Group II was distributed from about 17 m in the northern part of the study area to deeper areas (40 m) south of Chesapeake Bay. Site group III occupied a narrow bathymetric range on the mid-shelf (Table 10-4) (24-46 m). Site group IV had the most discontinuous distribution, with 5 stations at intermediate depths (26-84 m), one station off the Eastern Shore of Virginia in 15 m, and another station off Cape Hatteras in 27 m. Site group V comprised a northern group of stations on the mid- to outer-shelf (38-93 m). Site group VI included a continuous group of stations along the shelf edge. Seven species clusters were recognized ranging in content from 2 (group A) to 8 (groups C and D) species (Table 10-5).

Distribution of Fishes. Water temperatures at inshore site group I were influenced by vernal warming (8-12°C) (Table 10-4). The fishes present, in turn, reflected the rising water temperatures. Species groups A and C both had high constancy (Figure 10-6A) and positive fidelity (Figure 10-6B) to site group I. Both species in group A had warm-temperate faunal affinities, while species group C was comprised of 1 warm temperate, 5 boreal, and 2 resident species, reflecting the transitional thermal conditions. At site group I, warm-temperate species were much more abundant (7 of 8 dominants in Table 10-6, including 5 species from the ubiquitous group D) than boreal species even though the latter occurred in catches frequently.

Water temperatures at site group II were about 1°C cooler on the average than those at group I, and stations were slightly deeper and more northerly. Constancy and fidelity reflected the offshore and northern movement of boreal species groups. Species group B,

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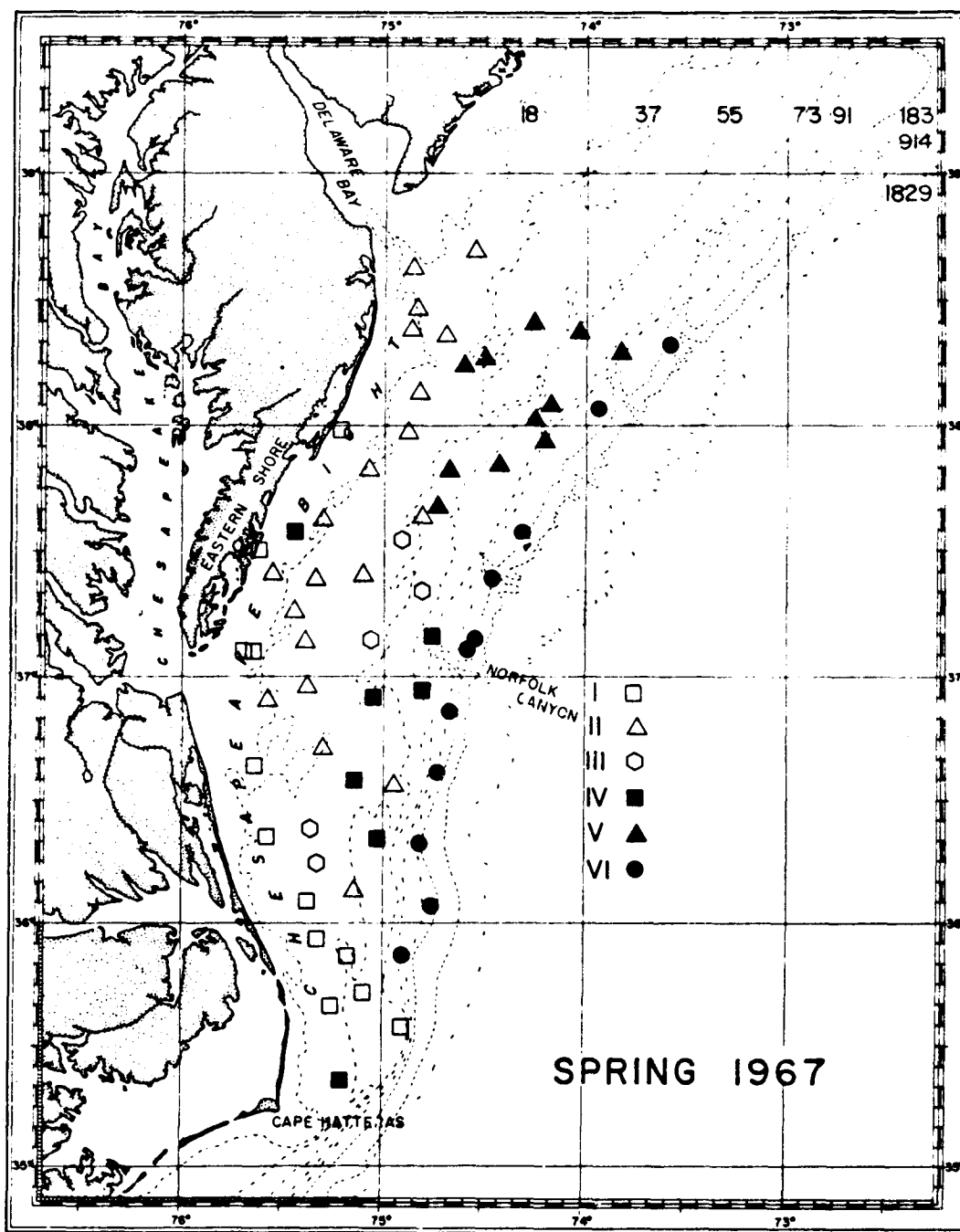


Figure 10-5. Distribution of trawl stations by site groups in spring 1967.

Table 10-4. Site group statistics, trawler Sea Breeze, spring 1967.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		12	20	5	7	11	11
Abundance ln (x+1)	$\bar{x}$	5.19	6.86	4.36	5.55	5.47	6.53
	σ	1.664	0.929	0.837	1.249	0.600	1.613
No. of Species	$\bar{x}$	9.8	14.3	7.0	11.1	12.9	13.1
	σ	2.69	3.08	1.58	2.04	2.17	4.74
Biomass (kg) ln (x+1)	$\bar{x}$	4.61	5.47	3.07	4.28	4.55	4.86
	σ	1.108	0.571	0.252	1.119	0.472	1.475
Depth (m)	Range	9-55	17-40	24-46	15-84	38-93	104-229
	$\bar{x}$	24.1	26.1	32.9	41.3	58.7	148.1
Temperature (°C)	Range	8-12	7-11	7-11	7-20	6-11	9-12
	$\bar{x}$	10.5	9.1	9.2	9.7	7.6	10.7

 $\bar{x}$ = mean value σ = standard deviation

Table 10-5. Contents of species groups, trawler Sea Breeze, spring 1967.*

A	C	D
<u>Cynoscion regalis</u> WT	<u>Raja erinacea</u> Bo	<u>Urophycis regius</u> WT
<u>Raja eglanteria</u> WT	<u>Prionotus carolinus</u> WT	<u>Peprilus triacanthus</u> WT
	<u>Scophthalmus aquosus</u> IS	<u>Sequalus acanthias</u> Bo
	<u>Pseudopleuronectes americanus</u> Bo	<u>Paralichthys dentatus</u> WT
B	<u>Lophius americanus</u> Bo	<u>Centropristis striata</u> WT
	<u>Hippoglossina oblonga</u> OS	<u>Stenotomus chrysops</u> WT
<u>Raja ocellata</u> Bo	<u>Merluccius bilinearis</u> Bo	<u>Prionotus evolans</u> WT
<u>Tautoga onitis</u> Bo	<u>Urophycis chuss</u> BO	<u>Mustelus canis</u> WT
<u>Alosa pseudoharengus</u> Bo		
E	F	G
<u>Scomber scombrus</u> Bo	<u>Limanda ferruginea</u> Bo	<u>Raja garmani</u> S1
<u>Alcea aestivalis</u> WT	<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Helicolenus dactylopterus</u> S1
<u>Clupea harengus harengus</u> Bo	<u>Macrozoarces americanus</u> Bo	<u>Zenopsis ocellata</u> S1
<u>Squatina dumerili</u> WT	<u>Glyptocephalus cynoglossus</u> Bo-S1	<u>Scylliorhinus retifer</u> S1
		<u>Urophycis tenuis</u> Bo-S1
		<u>Peristedion miniatus</u> Bo

*Faunal affinity is designated after each species name: boreal, Bo; warm temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1.

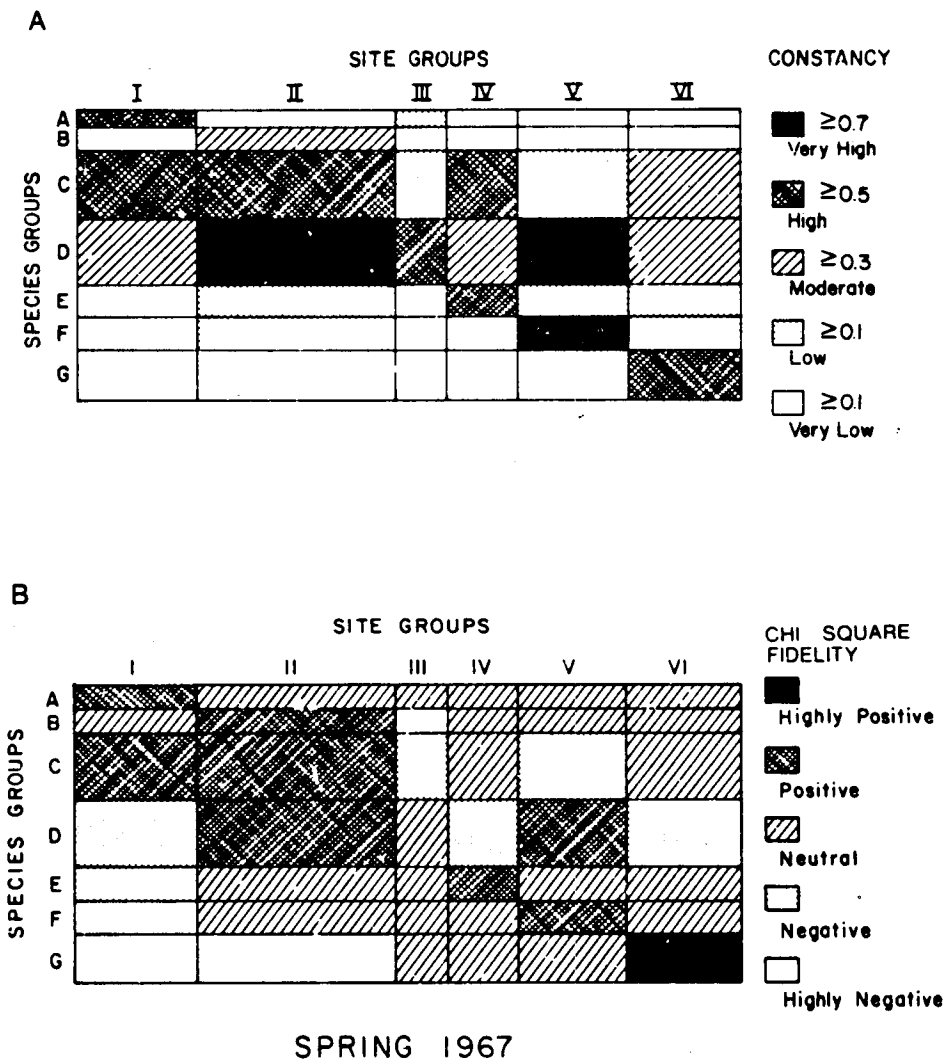


Figure 10-6. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for spring 1967.

Table 10-6. Species dominance, trawler Sea Breeze, spring 1967.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			Z	X	Z	X	Z	X	Z	X	Z	X	Z	X
<u>Raia eglanteria</u>	WT	A	75	11.0										
<u>Prionotus evolans</u>	WT	D	75	7.8										
<u>Mustelus canis</u>	WT	D	75	12.7										
<u>Stenotomus chrysops</u>	WT	D	67	2.4	70	6.2			71	10.2				
<u>Urophycis regius</u>	WT	D	75	12.5									91	16.2
<u>Peprilus triacanthus</u>	WT	D	92	22.9	70	14.2	100	39.4	57	23.1			73	23.0
<u>Centropristis striata</u>	WT	D			95	4.4			86	3.6			45	10.6
<u>Squalus acanthias</u>	Bo	D							71	9.1			27	5.8
<u>Scophthalmus aquosus</u>	IS	C			80	3.4	80	5.8						
<u>Prionotus carolinus</u>	WT	C	33	12.8	95	46.0	80	3.6	86	27.7	100	15.5		
<u>Pseudopleuronectes americanus</u>	Bo	C			80	12.9	60	39.8			55	14.2		
<u>Merluccius bilinearis</u>	Bo	C	50	2.7	85	3.1	40	3.0			91	5.1	100	9.8
<u>Lophius americanus</u>	Bo	C									100	8.3		
<u>Raja erinacea</u>	Bo	C									100	4.7		
<u>Hippoglossina oblonga</u>	OS	C									91	10.6	91	7.2
<u>Urophycis chuss</u>	Bo	C									100	20.4	64	5.2
<u>Scomber scombrus</u>	Bo	E							71	1.9				
<u>Morone saxatilis</u>	WT	E							5	4.4				
<u>Limanda ferruginea</u>	Bo	F									73	5.1		
<u>Macrozoarces americanus</u>	Bo	F									73	5.6		
<u>Glyptocephalus cynoglossus</u>	Bo-SI	F									91	4.0		
<u>Helicolenus dactylopterus</u>	SI	G											64	8.9

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI).

** Z = percent of stations in each site group at which each dominant species occurred.

X = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

including 3 boreal species, was absent or rare elsewhere, and group F, comprising 4 boreal species, occurred at site group II, but was absent inshore at site group I. Species group C (5 of 8 boreal) had high constancy and positive fidelity here as at site group I, but was much more dominant. Also, there was strong evidence for the inshore and northern movement of warm-temperate forms from offshore and southern wintering grounds. Species group D (7 of 8 species, warm-temperate) had very high constancy at site group II. The dominant species also reflected the transitional nature of fish assemblages over the shelf during the spring with 4 warm-temperate species, 2 boreal species, and 1 inner-shelf resident. Site group III differed little from II in thermal regime. Numerical abundance and biomass were much lower at site group III than elsewhere, and the constancy and pattern was similar to those at inshore site groups but very weak. All 5 dominants at group III were also dominant at group II. They included 2 boreal, 2 warm-temperate, and 1 resident species.

Site group IV also had a mixed fauna with high constancy in species group C (5 of 8 boreal) and species group E which also had positive fidelity. Group E contained 3 benthopelagic and 1 demersal species. Pelagic species appear to have been responsible in part for the cluster formation of group IV because 2 of these species (Alosa aestivalis and Scomber scombrus) were also numerical dominants there. Of the other dominants, 4 were warm-temperate in faunal affinity, and one (Squalus acanthias) was a large benthopelagic boreal species. The inclusion of the discontinuous stations at Hatteras and inshore off the Eastern Shore with this offshore site group (Figure 10-5) was due to the high dominance of the same warm-temperate species at these stations. In addition, the Eastern Shore station was made more than a month after the other stations in site group IV during which time elements of the warm-temperate fauna were actively migrating inshore.

Site group V on the northern portion of the outer-shelf had the coldest temperatures encountered during the spring cruise, and 8 boreal species were among the 10 dominants recognized. Likewise, the boreal species group F had very high constancy and high fidelity at site group V. Species group D (7 of 8 warm-temperate) also had very high constancy even though only 1 warm-temperate species was among the dominants. This suggests that warm-temperate species occurred frequently in small numbers. The outer-shelf site group VI located in a seasonally stable area had moderate constancy in species groups C and D, and high constancy and high fidelity in species group G. All 6 members of the last group were outer-shelf or upper-slope residents. Among the dominant species were 1 upper-slope resident, 1 outer-shelf resident, 3 boreal, and 3 warm-temperate species.

Availability: Abundance and Biomass. Abundance (Table 10-4) increased from inshore site group I offshore to group II, then decreased drastically in mid-shelf group III. It then increased to intermediate levels in groups IV and V and reached a secondary maximum in outer-shelf group VI. The ANOVA for abundance was significant and

differences were found between group II and groups I and III respectively. The biomass (Table 10-4) pattern was fairly similar with maxima in groups II and VI and a minimum in mid-shelf group III. The ANOVA for biomass was significant and differences were found between group III and groups II and VI respectively.

Summer 1967

Cluster Analyses. Seven site groups were recognized (Figure 10-7). Site group I extended inshore (<27 m) from the southern extreme of the sampling area north to the Eastern Shore of Maryland. Site group II, another inshore group (<37 m) included stations north of Chesapeake Bay. Site group III was a mid-shelf group (27-38 m) (Table 10-7) extending from the northern-most part of the study area south to the northern side of the Gulf Stream front. Site group IV was a southern mid- to outer-shelf group (27-75 m) restricted to the region of the Gulf Stream front. Site group V was a northern outer-shelf group (35-68 m), site group VI extended along the shelf margin, and site group VII consisted of 1 deep station (190 m) on the continental slope.

Seven species groups were apparent, ranging in content from 3 (group G) to 8 (group D) species (Table 10-8).

Distribution of Fishes. The thermal regime (Table 10-7) of the study area had the greatest range and was most strongly stratified during the summer. Site groups IV and I had the warmest (17-26°C and 11-26°C respectively), group II had intermediate (8-15°C), group III had cooler (6-11°C), and V had the coldest (5-8°C) temperatures. The more stable outer-shelf and slope groups VI and VII had intermediate temperatures.

This strongly defined thermal environment was reflected in the homogeneous faunal affinities of the species groups (Table 10-8). Groups A, B, C, and D each comprised warm-temperate species (group D also included the inshore resident, Scophthalmus aquosus). Groups E and F comprised boreal species (group E also included the outer-shelf resident, Hippoglossina oblonga). Group G included resident upper-slope species.

Warm temperate species were numerically dominant (Table 10-9) at site group I. Of the warm-temperate species groups at site group I, groups A and C had low constancy but positive fidelity, group B had moderate constancy and positive fidelity, and group D had high constancy and positive fidelity (Figure 10-8). At site group IV, species groups D and B had moderate and high constancy, and B had positive fidelity as well. The numerically dominant species were all warm-temperate in affinity (Table 10-9). Both boreal species groups (E and F) had very low constancy at site groups I and IV.

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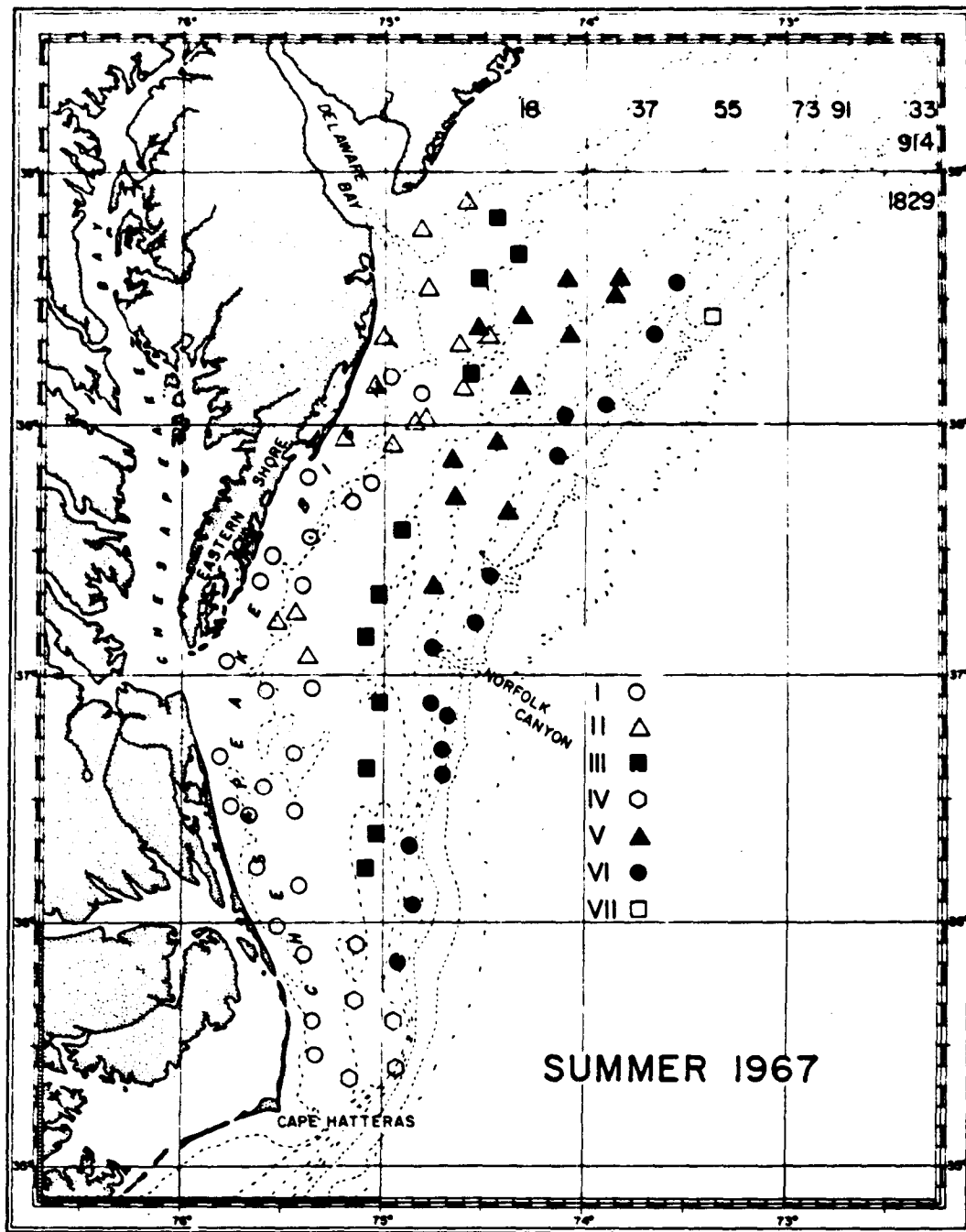


Figure 10-7. Distribution of trawl stations by site group in summer 1967.

Table 10-7. Site group statistics, trawler Sea Breeze, summer 1967.

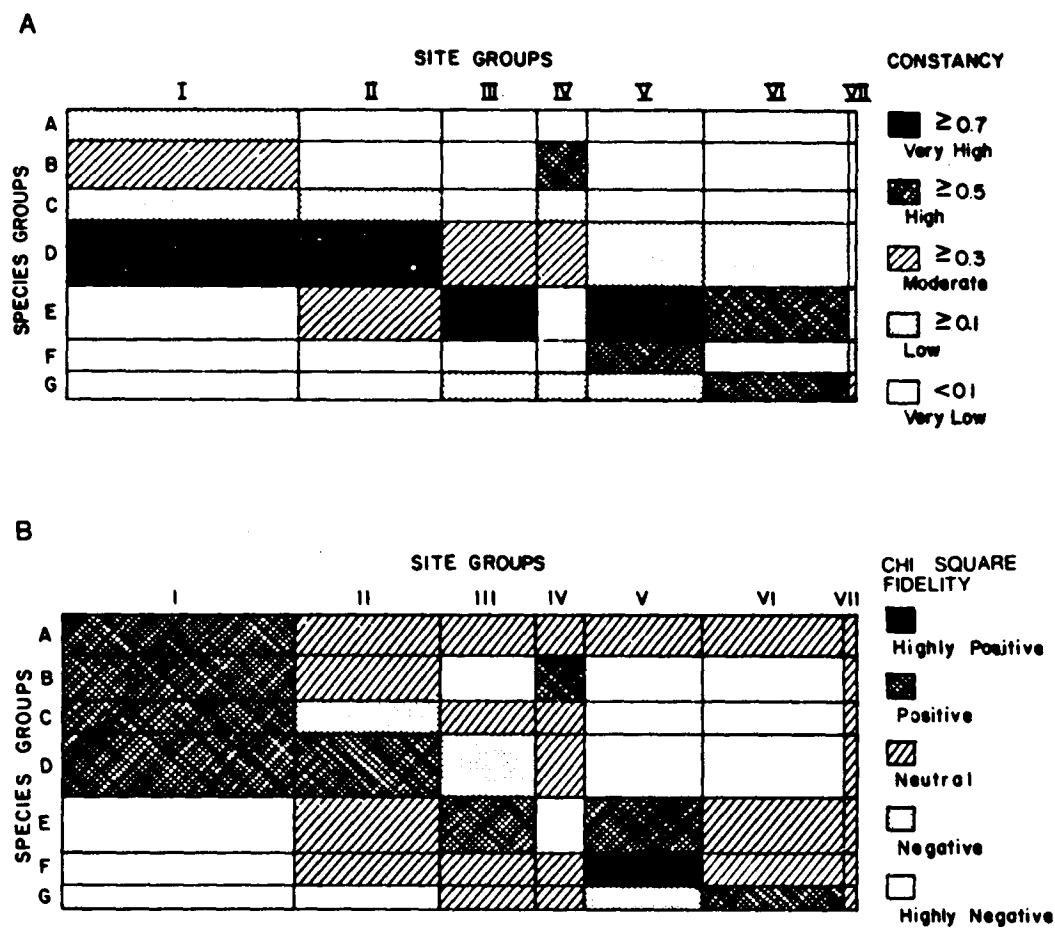
SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		24	15	11	5	12	15	1
Abundance ln (x+1)	$\bar{x}$	6.89	6.90	5.44	3.82	5.18	5.52	2.83
	σ	1.181	1.762	1.479	1.077	0.937	1.498	0
No. of Species	$\bar{x}$	13.1	10.1	9.1	9.2	11.3	7.5	4
	σ	5.11	3.75	1.38	3.27	1.66	2.45	0
Biomass (kg) ln (x+1)	$\bar{x}$	5.34	5.26	3.90	3.14	3.55	3.54	0.34
	σ	0.979	1.660	1.283	2.063	0.834	1.284	0
Depth (m)	Range	11-27	15-37	27-38	27-75	35-68	57-134	190
	$\bar{x}$	19.4	25.5	33.6	42.1	51.4	88.0	
Temperature (°C)	Range	11-26	8-15	6-11	17-26	5-8	6-13	13
	$\bar{x}$	18.8	11.5	7.6	20.6	6.3	10.4	

 $\bar{x}$ = mean value σ = standard deviation

Table 10-8. Contents of species groups, trawler Sea Breeze, summer 1967.*

A	B	C
<u>Dasyatis sayi</u> WT	<u>Astroscopus guttatus</u> WT	<u>Myliobatis freminvillei</u> WT
<u>Cynoscion regalis</u> WT	<u>Stenotomus chrysops</u> WT	<u>Carcharhinus obscurus</u> WT
<u>Orthopristis chrysoptera</u> WT	<u>Sphoeroides maculatus</u> WT	<u>Dasyatis centroura</u> WT
<u>Pomatomus saltatrix</u> WT	<u>Micropogon undulatus</u> WT	<u>Mustelus canis</u> WT
	<u>Squatina dumerili</u> WT	
	<u>Stephanolepis hispidus</u> WT	
D	E	F
<u>Raja eglanteria</u> WT	<u>Hippoglossina oblonga</u> OS	<u>Macrozoarces americanus</u> Bo
<u>Paralichthys dentatus</u> WT	<u>Lophius americanus</u> Bo	<u>Myoxocephalus octodecemspinosus</u> Bo
<u>Prionotus evolans</u> WT	<u>Merluccius bilinearis</u> Bo	<u>Limanda ferruginea</u> Bo
<u>Prionotus carolinus</u> WT	<u>Urophycis chuss</u> Bo	<u>Glyptocephalus cynoglossus</u> Bo-Sl
<u>Centropristis striata</u> WT	<u>Raja erinacea</u> Bo	
<u>Urophycis regius</u> WT	<u>Pseudopleuronectes americanus</u> Bo	
<u>Scophthalmus aquosus</u> IS	<u>Squalus acanthias</u> Bo	
<u>Peprilus triacanthus</u> WT		
	G	
	<u>Citharichthys arctifrons</u> Sl	
	<u>Peristedion miniatum</u> Sl	
	<u>Raja garmani</u> Sl	

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl.



SUMMER 1967

Figure 10-8. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for summer 1967.

Table 10-9. Species dominance, trawler Sea Breeze, summer 1967.

Species	Faunal Affinity	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X
<u>Cynoscion regalis</u>	WT	A	21	3.5												
<u>Prionotus carolinus</u>	WT	D	96	37.9	93	73.0										
<u>Scophthalmus aquosus</u>	IS	D			87	2.3	91	7.6								
<u>Raja esianteria</u>	WT	D	100	11.3					60	7.6						
<u>Peprilus triacanthus</u>	WT	D	79	5.3	33	4.6	64	28.7	80	14.9			53	13.4		
<u>Urophycis regia</u>	WT	D			100	6.8	91	33.5	60	20.4			87	37.8		
<u>Centropristis striata</u>	WT	D							80	5.2						
<u>Microgobius undulatus</u>	WT	B	54	3.0												
<u>Stenotomus chrysops</u>	WT	B	71	30.4					80	19.7						
<u>Squatina dumerilii</u>	WT	B							100	13.1						
<u>Stephanolepis hispidus</u>	WT	B							80	8.2						
<u>Raja erinacea</u>	Bo	E			60	6.9	100	7.6								
<u>Hippoglossina oblonga</u>	OS	E					100	10.2			100	7.8	100	12.4		
<u>Merluccius bilinearis</u>	Bo	E					91	4.2			100	16.1	67	8.4	100	60.0
<u>Pseudopleuronectes americanus</u>	Bo	E									100	12.6				
<u>Squalus acanthias</u>	Bo	E									100	15.3				
<u>Urophycis chuss</u>	Bo	E									100	15.2	53	6.8		
<u>Lophius americanus</u>	Bo	E									100	8.4	87	6.5		
<u>Limanda ferruginea</u>	Bo	F									83	12.0				
<u>Glyptocephalus cynoglossus</u>	Bo-SI	F													100	6.7
<u>Raja germani</u>	SI	G											87	7.9		
<u>Peristedion miniatum</u>	SI	G													100	33.3

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI).

** Z = percent of stations in each site group at which each dominant species occurred.

X = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

At site group II, 3 dominant species had warm-temperate affinities, 1 had boreal affinities, and 1 was an inner-shelf resident. Also at site group II, warm-temperate species group D had very high constancy and the only positive fidelity, and boreal group E had moderate constancy. Site group III, cooler than groups I, IV, or II, but still intermediate overall, was dominated by 2 boreal species, 2 warm-temperate species and 2 residents (*S. aquosus* and *H. oblonga*). Constancy at site group III was moderate in species group D and very high in group E, which also had positive fidelity.

Site group V included the coldest stations sampled and the dominant species there included 6 boreal and 1 resident species. Boreal species groups E and F had very high and high constancy respectively at site group V. Also, group F had high fidelity there and negative or neutral fidelity elsewhere, suggesting that the species contained were more stenothermal and restricted in their distribution within the study area. Group E also had positive fidelity.

The outer-shelf site group VI was dominated by a faunal mixture including 2 warm-temperate species, 3 boreal species, 1 outer-shelf resident, and 1 upper-slope resident. Constancy was high in boreal species group E and upper-slope group G. The latter group also had positive fidelity at site group VI. The continental slope site group VII was dominated by a boreal species, *Merluccius bilinearis* (the slope species *M. albidus* also undoubtedly was present at this station, but was unrecognized by personnel on this cruise and thus was included with the *M. bilinearis* data), an upper-slope species and another boreal species, *Glyptocephalus cynoglossus*. Juveniles of the latter species exhibit latitudinal submergence, and are dominant species on the mid-slope off Virginia (Markle 1975; Musick 1976). Constancy at site group VII was moderate for species group G.

Availability: Abundance and Biomass. Values for abundance and biomass were at a maximum at the inshore site groups I and II (Table 10-7). There was a decrease in abundance and biomass offshore in site group III and a further decrease in the southern group IV. Biomass and abundance increased in northern group V and outer-shelf group VI, and values were about the same order of magnitude as for site group III. The slope site group VII had the lowest values for both abundance and biomass, but was not included in the ANOVA because it included only one station. The ANOVA for abundance was significant with differences between groups II and IV, and between group I and groups IV and V respectively. The ANOVA for biomass was also significant and Scheffe's test found differences between group I and groups IV, V, and VI respectively, and between group II and groups V and VI respectively.

Fall 1967

Cluster Analyses. Six site groups were recognized (Figure 10-9). Site group I was an inshore group (<29 m) north of Chesapeake Bay. Site group II was another inshore group (<33 m), but distributed predominantly from the mouth of Chesapeake Bay south. Site group III included stations mostly from intermediate depths (18-75 m) (Table 10-10) south of Chesapeake Bay. Three disjunct group III stations located in shoal water off the Eastern Shore of Virginia were sampled nearly a month previous to the rest of the stations in the group. The fall was a time of active migration for fishes and the disjunct distribution of these stations, as well as that of the group II station off Delaware Bay, could be attributed directly to temporal changes in fish distribution during the sampling period. Site group IV comprised a group of northern mid- to outer-shelf stations (26-143 m). Site group V included shelf edge stations south of Norfolk Canyon (93-170 m), whereas site group VI included continental slope stations north of the Canyon (168-196 m). Seven species groups were apparent (Table 10-11) ranging in content from 3 (group C) to 11 (group E) species.

Distribution of Fishes. Autumnal cooling was occurring rapidly during the fall 1967 cruise. Temperatures were lowest at the northern inshore site group I (Table 10-10). They remained a bit higher (10-12°C) at the southern inshore site group II. Temperatures at the deeper southern site group III were higher still (11-19°C). The 19°C value for this group was due to one station located off Cape Hatteras at the Gulf Stream front (Figure 10-9). Site group IV had a narrow range of moderate temperatures (9-12°C). The southern shelf edge group V had the highest average temperature (13-16°C, $\bar{x}$ = 14.4°C) and these temperatures probably were due to incursions of the Gulf Stream upon the upper slope. Site group VI had a very narrow range of moderate temperatures (11-12°C) typical for most of the upper slope throughout the year.

Thermal changes (turnover) in the fall occur more rapidly compared to those (warming and stratification) in the spring. Fish movements appeared more concerted and rapid, and the temporal duration of mixed boreal and warm-temperate assemblages was probably shorter because species clusters had more homogeneous affinities (Table 10-11) than for the spring cruise (Table 10-5). Species group A consisted of 3 benthopelagic species, (2 boreal, Clupea harengus and Alosa pseudoharengus; 1 warm-temperate, A. aestivalis) and 1 warm-temperate demersal fish, Bairdiella chrysura. Species group B comprised 6 warm-temperate species. Group C had 3 warm-temperate species, 2 of which (Porichthys porosissimus and Syacium papillosum) do not usually occur north of Cape Hatteras. Species group D comprised 9 boreal, and 1 resident inshore species. Species group E comprised 8 warm-temperate, 2 boreal, and 1 outer-shelf species. Group F

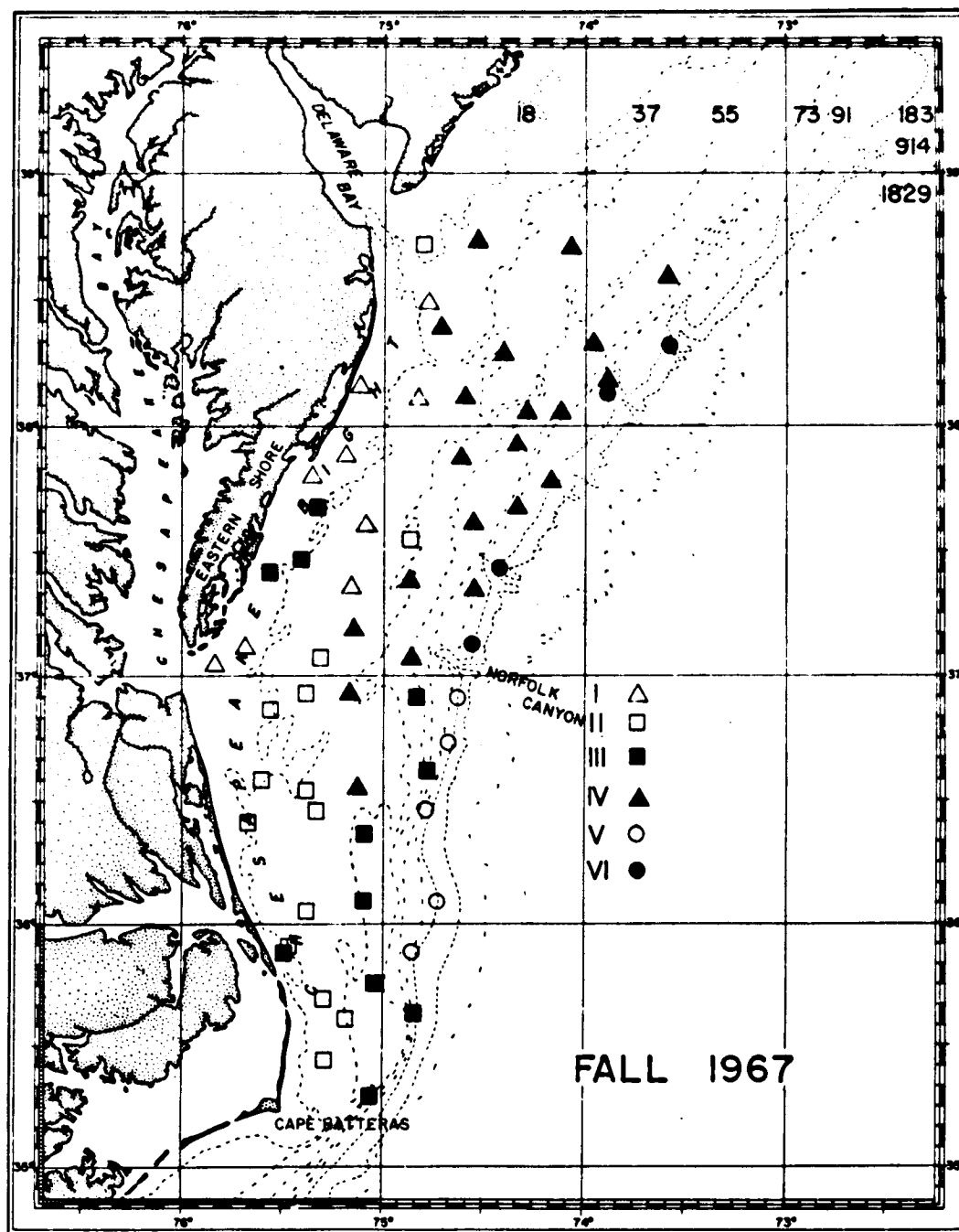


Figure 10-9. Distribution of trawl stations by site group in fall 1967.

Table 10-10. Site group statistics, trawler Sea Breeze, fall 1967.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		9	14	11	21	5	4
Abundance ln (x+1)	$\bar{x}$	5.86	6.13	6.65	7.40	7.17	7.25
	σ	0.437	0.836	1.173	0.853	0.608	0.633
No. of Species	$\bar{x}$	15.8	11.6	13.4	16.0	12.4	15.5
	σ	2.05	2.53	3.64	3.04	2.61	3.87
Biomass (kg) ln (x+1)	$\bar{x}$	5.85	6.15	6.02	6.62	5.79	6.15
	σ	0.619	0.546	1.400	0.777	0.694	0.461
Depth (m)	Range	11-29	15-33	18-75	26-143	93-170	168-196
	$\bar{x}$	18.5	22.6	40.6	58.4	135.3	187.5
Temperature (°C)	Range	7-11	10-12	11-19	9-12	13-16	11-12
	$\bar{x}$	9.2	11.1	13.5	10.7	14.4	11.5

 $\bar{x}$ = mean value σ = standard deviation

Table 10-11. Contents of species groups, trawler Sea Breeze, fall 1967.*

A	B	C
<u>Alosa aestivalis</u> WT	<u>Menticirrhus saxatilis</u> WT	<u>Porichthys porosissimus</u> WT
<u>Alosa pseudoharengus</u> Bo	<u>Sphoeroides maculatus</u> WT	<u>Syacium papillosum</u> WT
<u>Bairdiella chrysura</u> WT	<u>Mustelus canis</u> WT	<u>Dasyatis centroura</u> WT
<u>Clupea harengus harengus</u> Bo	<u>Stephanolepis hispidus</u> WT	
	<u>Squatina dumerili</u> WT	
	<u>Cynoscion regalis</u> WT	
D	E	F
<u>Macrozoarces americanus</u> Bo	<u>Paralichthys dentatus</u> WT	<u>Scyliorhinus retifer</u> S1
<u>Pseudopleuronectes americanus</u> Bo	<u>Raja eglanteria</u> WT	<u>Zenopsis ocellata</u> S1
<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Peprilus triacanthus</u> WT	<u>Raja garmani</u> S1
<u>Scophthalmus aquosus</u> IS	<u>Squalus acanthias</u> Bo	
<u>Raja erinacea</u> Bo	<u>Urophycis regius</u> WT	
<u>Limanda ferruginea</u> Bo	<u>Merluccius bilinearis</u> Bo	G
<u>Lophius americanus</u> Bo	<u>Prionotus carolinus</u> WT	
<u>Urophycis chuss</u> Bo	<u>Prionotus evolans</u> WT	<u>Merluccius albidus</u> S1
<u>Urophycis tenuis</u> Bo-S1	<u>Stenotomus chrysops</u> WT	<u>Glyptocephalus cynoglossus</u> Bo-S1
<u>Scomber scombrus</u> Bo	<u>Centropristis striata</u> WT	<u>Peristedion miniatum</u> S1
	<u>Hippoglossina oblonga</u> OS	<u>Citharichthys arctifrons</u> S1
		<u>Ventrifossa occidentalis</u> S1

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1.

comprised 3 shelf-edge residents, and group G comprised 5 slope residents (including the boreal submergent Glyptocephalus cynoglossus).

At the cold, inshore site group I, 5 boreal species, 2 warm-temperate species, and 1 inshore resident species were numerically dominant (Table 10-12). The mixed species group A had moderate constancy (Figure 10-10A) and high fidelity (Figure 10-10B) to site group I. Boreal species group D had high constancy and positive fidelity to site group I. The ubiquitous warm-temperate species group E also had moderate constancy at group I, but negative fidelity. At the southern inshore site group II, 5 warm-temperate, 2 boreal, and 1 inshore resident species were numerically dominant. The boreal Squalus acanthias and Merluccius bilinearis, the warm-temperate Urophycis regius and Peprilus triacanthus, and the inshore resident Scophthalmus aquosus were dominant at both I and II. Both S. acanthias and M. bilinearis are benthopelagic, highly mobile and more able to move quickly into areas which become thermally suitable. Even though U. regius and P. triacanthus both fit the criteria for warm-temperate species given in the "Methods" section above, they tend to occupy cooler water than most other warm-temperate species. Thus U. regius occupies cooler offshore waters off the Carolinas during the summer and migrates inshore during cooler months (Struhsaker 1969). P. triacanthus is represented by an inshore "warm water" and an offshore "cool water" population south of Cape Hatteras (Horn 1970). The warm-temperate species group E had high constancy at southern group II. Site group III, a southern mid-shelf group, included a station in the Gulf Stream front at Hatteras. Species group C, including species usually restricted to south of Hatteras had positive fidelity to site group III. Warm-temperate groups B and E respectively had moderate and very high constancy and B had positive fidelity as well at site group III. Among the dominant species, 9 were warm-temperate in affinity, 1 was boreal (S. acanthias), and 1 was an inshore resident.

Site group IV, located to the north and on the mid- to outer-shelf with moderate temperatures, had a mixed fauna. Among the dominants, 4 were boreal, 3 were warm-temperate, 1 was an inner-shelf resident, and 1 was an outer-shelf resident. Boreal species group D and warm-temperate group E had moderate and very high constancy respectively, and both groups had positive fidelity at site group IV. Site group V, a southern shelf-edge group was dominated by 3 warm-temperate, 2 boreal, and 1 resident species. Warm-temperate species group E and the upper-slope resident group F had high and very high constancy respectively, and group F had high fidelity at site group V.

The northern upper-slope group VI was dominated by 3 boreal species, 1 outer-shelf resident, and 2 upper-slope residents. Boreal species group D, warm-temperate species group E, and upper-slope resident group F had moderate constancy at site group VI. Upper-slope

Table 10-12. Species dominance, trawler Sea Breeze, fall 1967.

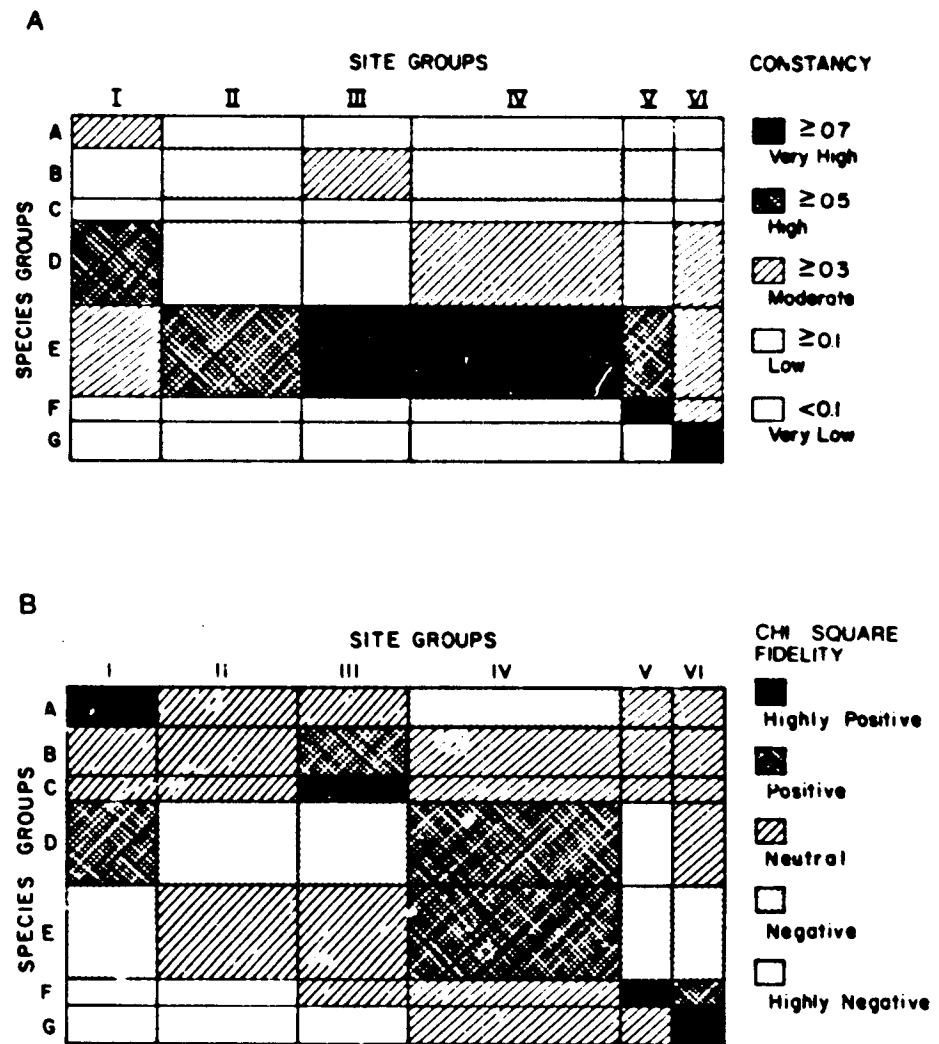
Species	Faunal Affinity *	Species Group	Site Group **											
			I		II		III		IV		V		VI	
			$\bar{f}$	$\bar{x}$	$\bar{f}$	$\bar{x}$	$\bar{f}$	$\bar{x}$	$\bar{f}$	$\bar{x}$	$\bar{f}$	$\bar{x}$	$\bar{f}$	$\bar{x}$
<u>Pseudopleuronectes americanus</u>	Bo	D	89	5.1										
<u>Myoxocephalus octodecemspinosus</u>	Bo	D	89	2.7										
<u>Scophthalmus aquosus</u>	IS	D	100	15.5	86	6.6	45	3.1	48	4.4				
<u>Raia erinacea</u>	Bo	D	67	4.3					71	3.7				
<u>Limanda ferruginea</u>	Bo	D							67	6.2				
<u>Lophius americanus</u>	Bo	D							90	2.7				
<u>Urophycis chuss</u>	Bo	D									40	15.4	100	45.4
<u>Mustelus canis</u>	WT	E					82	2.0						
<u>Prionotus oviformis</u>	WT	E			43	2.5	91	1.5						
<u>Raia glauca</u>	WT	E			93	4.7	66	4.2						
<u>Paralichthys dentatus</u>	WT	E					91	3.8						
<u>Centropristis striata</u>	WT	E					73	4.4						
<u>Urophycis regia</u>	WT	E	100	3.7	93	2.1	73	4.0			100	23.5		
<u>Paralichthys dentatus</u>	WT	E	89	8.4	100	31.1	64	16.9	95	14.8	60	13.3		
<u>Squalus acanthias</u>	Bo	E	89	32.5	100	38.5	64	22.8	100	15.6			100	7.8
<u>Merluccius bilinearis</u>	Bo	E	100	17.5	36	3.1					100	11.5	100	16.4
<u>Prionotus carolinus</u>	WT	E			57	3.6	91	15.9	81	25.5	40	20.4		
<u>Stenotomus chrysops</u>	WT	E					82	5.8	86	9.5				
<u>Hippoglossus oblongus</u>	OS	E							81	6.8	100	9.6	100	4.0
<u>Merluccius albidus</u>	SI	G											100	3.3
<u>Citharichthys arctifrons</u>	OS-SI	G											100	3.0

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI).

** $\bar{f}$ = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.



FALL 1967

Figure 10-10. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for fall 1967.

group G had very high constancy. Species group F had positive and group G had high fidelity to site group VI.

Availability: Abundance and Biomass. Among the northern site groups there was an increase in abundance and biomass from group I to IV, then a slight decrease in groups V and VI (Table 10-10). Among the southern site groups, there was a steady increase in abundance from II to III to V, but there was a slight decrease in biomass. The ANOVA for abundance was significant and group IV was different from groups I and II respectively (Table 10-10). The ANOVA for biomass was not significant.

Winter 1968

Cluster Analyses. Bathymetric coverage of the sampling area was broadest during the winter 1968 cruise. Consequently, more site groups were recognized (9) than for any other cruise (Figure 10-11). Site group I comprised 4 stations in shallow water (≤ 20 m) adjacent to the mouth of the Chesapeake Bay. Site group II consisted of a group of shallow stations (≤ 26 m) north of Chesapeake Bay. Site group III consisted of a group of shallow stations south of Chesapeake Bay, and group IV comprised a mid-shelf group (33-48 m) located mostly to the north of Chesapeake Bay (Table 10-13). Site group V was an odd group of 3 widely scattered stations, and was not considered to be a natural cluster. The 3 stations clustered together because they shared overwhelming dominance of Squalus acanthias or Prionotus evolans, or both and the absence of all but one other species.

The species composition estimates for these three stations were anomalous because they were made by sight with the net at the side of the ship. The catches were not landed because of logistic problems. Thus, the data from these stations will not be discussed further herein.

Site group VI was found on the outer-shelf (42-66 m) in the north. Group VII was widespread with the narrow bathymetric range (70-95 m) north of $37^{\circ}00'N$ and a wider range (26-101 m) to the south. Group VIII included stations along the shelf-edge (77-183 m) from Norfolk Canyon south with the exception of one station to the north which was made more than one month previous to the others in the group. Group IX included upper-slope stations (121-274 m) north of Norfolk Canyon. Six species groups were apparent (Table 10-14) ranging in content from 4 (group E) to 10 (group A) species.

Distribution of Fishes. The direct correlation of temperature with depth typical of winter conditions was reflected by the thermal milieu associated with respective site groups. Group II, the most northern and inshore group, had lowest temperatures ($2-5^{\circ}C$) followed by group I ($3-5^{\circ}C$) off Chesapeake Bay and group III ($4-6^{\circ}C$) to the south (Table 10-13). The northern site groups IV and VI, in

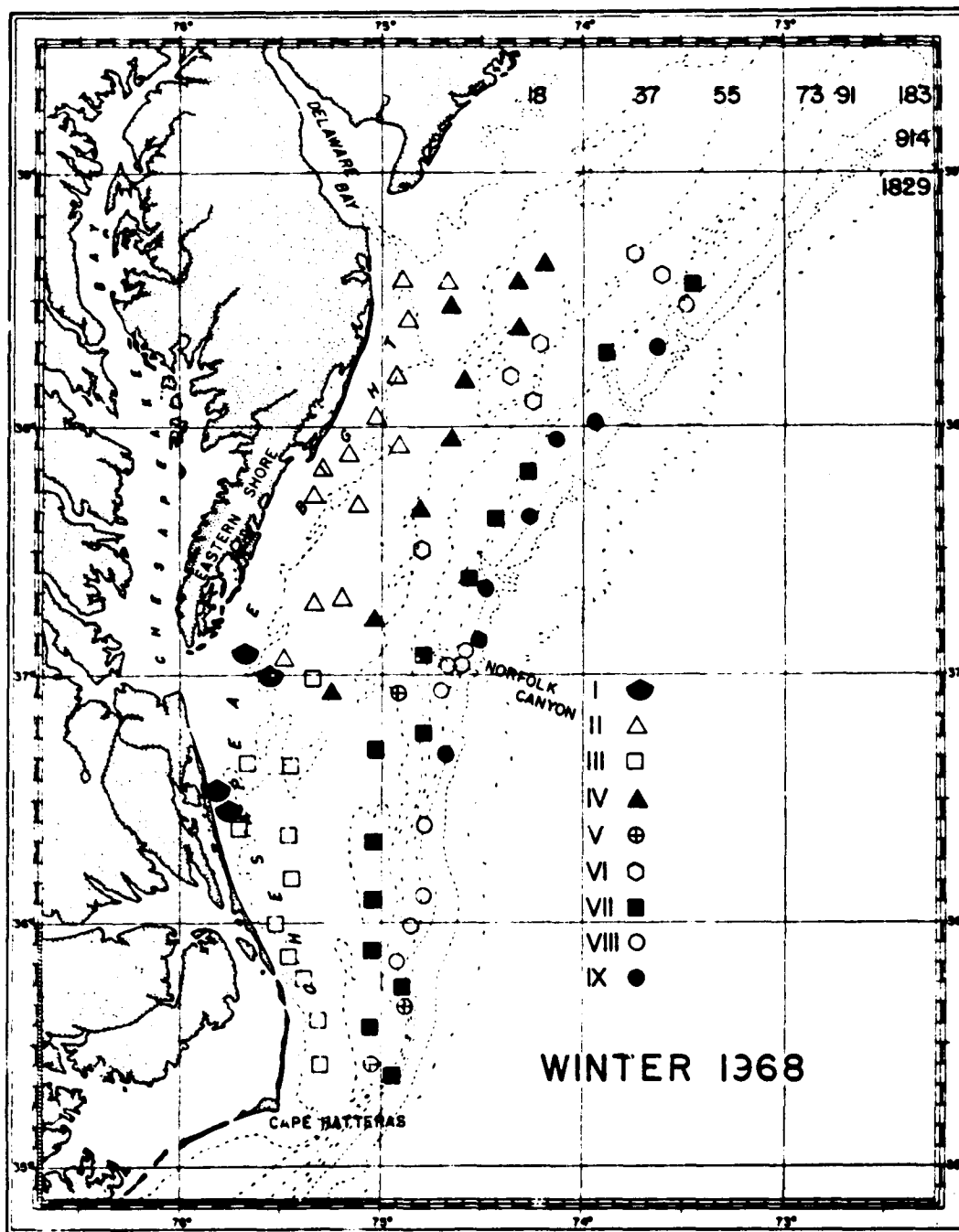


Figure 10-11. Distribution of trawl stations by site group in winter 1968.

Table 10-13. Site group statistics, trawler Sea Breeze, winter 1968.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII	IX
No. of Stations		4	13	11	9	3	6	14	9	7
Abundance ln (x+1)	$\bar{x}$	5.12	4.87	5.07	6.67	7.79	7.50	7.34	7.47	7.24
	σ	1.360	0.712	0.821	0.925	1.574	0.417	0.917	0.911	0.605
No. of Species	$\bar{x}$	7.3	10.8	10.2	17.3	2.3	16.2	13.6	14.0	14.7
	σ	2.06	2.58	2.99	3.67	1.15	2.04	3.65	2.96	2.21
Biomass (kg) ln (x+1)	$\bar{x}$	4.01	4.15	5.00	5.90	7.37	7.75	6.92	6.51	6.26
	σ	1.035	0.763	0.953	0.836	1.940	0.424	1.056	1.149	0.891
Depth (m)	Range	9-20	13-26	15-29	33-48	35-77	42-66	26-101	77-183	121-274
	$\bar{x}$	15.1	19.3	21.4	38.6	50.0	56.4	62.7	117.2	187.6
Temperature (°C)	Range	3-5	2-5	4-6	5-8	7-8	6-8	6-18	8-11	9-11
	$\bar{x}$	4.3	3.5	5.1	5.9	7.3	7.3	9.6	9.7	10.3

$\bar{x}$ = mean value

σ = standard deviation

Table 10-14. Contents of species groups, trawler Sea Breeze, winter 1968.*

A	B	C
<u>Macrozoarces americanus</u> Bo	<u>Hemitripterus americanus</u> Bo	<u>Urophycis regius</u> WT
<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Etropus microstomus</u> IS	<u>Hippoglossina oblonga</u> OS
<u>Limanda ferruginea</u> Bo	<u>Alosa sapidissima</u> Bo	<u>Peprilus triacanthus</u> WT
<u>Raja erinacea</u> Bo	<u>Alosa aestivalis</u> WT	<u>Lophius americanus</u> Bo
<u>Alosa pseudoharengus</u> Bo	<u>Scomber scombrus</u> Bo	<u>Merluccius bilinearis</u> Bo
<u>Clupea harengus harengus</u> Bo	<u>Brevoortia tyrannus</u> WT	<u>Urophycis chuss</u> Bo
<u>Scophthalmus aquosus</u> IS		<u>Squalus acanthias</u> Bo
<u>Gadus morhua</u> Bo		
<u>Raja ocellata</u> Bo		
<u>Pseudopleuronectes americanus</u> Bo		
D	E	F
<u>Centropristis striata</u> WT	<u>Urophycis tenuis</u> Bo-Sl	<u>Scyliorhinus retifer</u> Sl
<u>Paralichthys dentatus</u> WT	<u>Citharichthys arctifrons</u> Sl	<u>Zenopsis ocellata</u> Sl
<u>Stenotomus chrysops</u> WT	<u>Glyptocephalus cynoglossus</u> Bo-Sl	<u>Peristedion miniatum</u> Sl
<u>Raja eglanteria</u> WT	<u>Cynoscion regalis</u> WT	<u>Squatina dumerili</u> WT
<u>Prionotus carolinus</u> WT		<u>Mustelus canis</u> WT
<u>Prionotus evolans</u> WT		<u>Raja garmani</u> Sl
<u>Trachurus lathami</u> WT		<u>Conger oceanicus</u> Bo-Sl

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl.

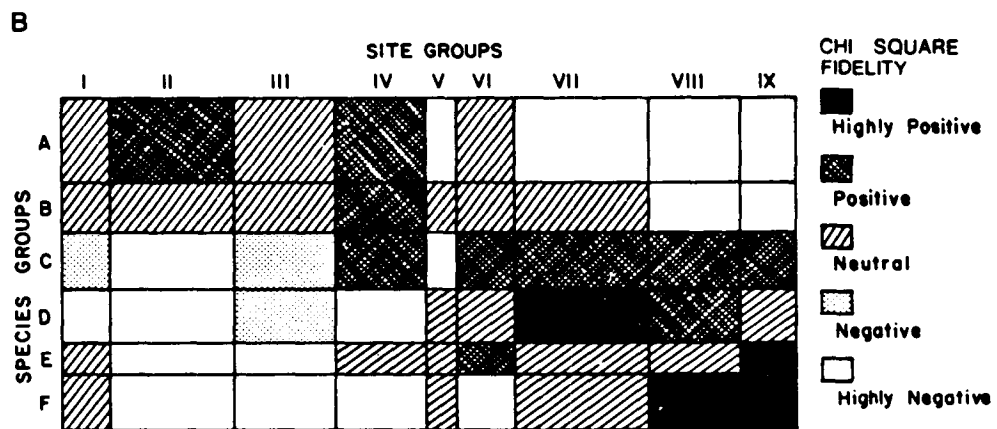
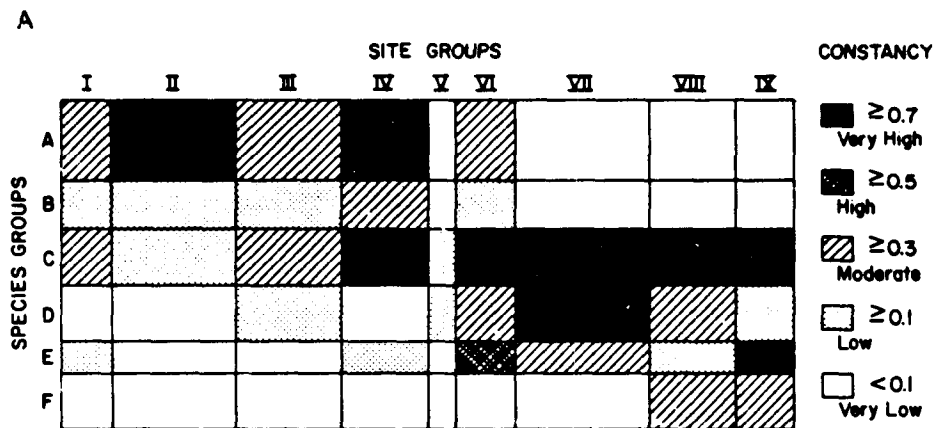
intermediate depths, increased respectively in temperature (5-8°C, $\bar{x}$ = 5.9°C; 6-8°C, $\bar{x}$ = 7.3°C). The wide bathymetric range of group VII in the south was reflected by a wide thermal range (6-18°C) including one station in the Gulf Stream front. However, the mean temperature at VII was 9.6°C and this was more representative of those stations north of Norfolk Canyon. Shelf-edge and upper-slope groups VIII and IX had relatively narrow ranges of moderate temperatures, 8-11°C and 9-11°C respectively.

Most species groups were faunistically homogeneous as would be expected from the relatively stable thermal regime. An exception, group C, comprised 4 boreal species, 2 warm-temperate species (Urophycis regius, Peprilus triacanthus), and 1 outer-shelf resident. As noted above, U. regius and P. triacanthus often clustered with boreal species. Species in this group were widespread over the mid- and outer-shelf (Figure 10-12). Another unusual group was B which included 4 pelagic species, 1 boreal demersal (Hemitripterus americanus), and 1 inshore resident species. Group A comprised 9 boreal and 1 inshore resident species. Group D comprised 7 warm-temperate species. Group E comprised 3 upper-slope residents and 1 warm-temperate species, and group F included 5 upper-slope residents and 2 warm-temperate species.

At the coldest inshore site group II, 7 boreal and 1 inshore resident species were dominant (Table 10-15). The boreal species group A had very high constancy (Figure 10-12A) and positive fidelity there (Figure 10-12B). The Bay mouth site group I was dominated by 4 boreal and 1 resident inshore species, and the boreal species groups A and C had moderate constancy there. Site group III to the south has many of the same boreal dominants as group I, but also included the warm-temperate, pelagic Brevoortia tyrannus.

Progressing offshore north of Chesapeake Bay, site group IV was dominated by 6 boreal and 1 resident species. Boreal species groups A and C both had very high constancy and positive fidelity at group IV. The mixed species group B had moderate constancy and its only positive fidelity at site group IV. Site group VI was dominated by 4 boreal, 1 warm-temperate, and 1 outer-shelf resident species. This site group was bathymetrically and thermally intermediate, and had the greatest mixture of boreal and temperate groups. Boreal groups C and A respectively had very high and moderate constancy, while temperate group D had moderate, and upper-slope group E had high constancy at site group VI.

Site group VII which was geographically extensive, was dominated by 5 warm-temperate species, 3 boreal species, and 1 outer-shelf resident. Boreal group C and warm-temperate group D both had very high constancy at site group VII and positive and high fidelity respectively. Southern shelf-edge group VIII was dominated by 3 boreal, 5 warm-temperate, and 1 outer-shelf resident species. Boreal



WINTER 1968

Figure 10-12. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for winter 1968.

Fig. 11. Nodal A) constancy and B) chi-square test of fidelity in a two-way table of species groups in site groups for winter 1968.

Table 10-15. Species dominance, trawler Sea Breeze, winter 1968.

Species	Faunal Affinity *	Species Group	Site Group**																	
			I		II		III		IV		V		VI		VII		VIII		IX	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Clupea harengus harengus</u>	Bo	A	100	57.9	77	17.6	91	4.2												
<u>Pseudopleuronectes americanus</u>	Bo	A			85	13.6														
<u>Raja ocellata</u>	Bo	A			92	3.9														
<u>Alosa pseudoharengus</u>	Bo	A	100	14.3	69	10.8	91	17.0	100	7.1										
<u>Myoxocephalus octodecemspinosus</u>	Bo	A			85	6.8			100	3.2										
<u>Scophthalmus aquosus</u>	IS	A	100	8.8	100	24.7	91	16.5	100	11.5										
<u>Raja erinacea</u>	Bo	A			62	8.6			89	9.3			100	4.3						
<u>Limanda ferruginea</u>	Bo	A							100	36.2			100	13.1						
<u>Brevoortia tyrannus</u>	WT	B					45	8.6												
<u>Scomber scombrus</u>	Bo	B					18	3.6	56	12.8					43	4.6				
<u>Urophycis chuss</u>	Bo	C	50	6.2							33	0.1	100	12.1	50	2.7	89	3.7	100	19.0
<u>Squalus acanthias</u>	Bo	C	100	7.6	69	3.6	100	37.6	100	10.4	67	61.7	100	56.0	93	29.7	89	25.3	100	28.4
<u>Merluccius bilinearis</u>	Bo	C					64	3.5									100	17.0	100	25.6
<u>Peprilus triacanthus</u>	WT	C									33	2.2			79	15.3	89	9.8		
<u>Hippoglossina oblonga</u>	OS	C											83	2.5	86	5.3	100	4.5	86	6.4
<u>Urophycis regius</u>	WT	C															100	6.9	100	2.3
<u>Prionotus carolinus</u>	WT	D									33	2.6	83	3.2	79	15.1				
<u>Prionotus evolans</u>	WT	D									67	33.4					44	8.4		
<u>Raja salientaria</u>	WT	D													93	2.2				
<u>Stenotomus chrysops</u>	WT	D													79	10.2	22	5.1		
<u>Centropristis striata</u>	WT	D													79	6.2	78	14.0		
<u>Glyptocephalus cynoglossus</u>	Bo-SI	E																	100	5.9
<u>Peristichion miniatum</u>	SI	F																	86	2.2

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

species group C, and warm-temperate species group D respectively had very high and moderate constancy and both had positive fidelity. The slope groups E and F had low and moderate constancy and F had high fidelity at site group VIII.

The deeper, northern group of upper-slope stations (group IX) was dominated by 3 boreal, 1 outer-shelf resident, 1 warm-temperate, and 2 upper-slope species. Boreal species group C and upper-slope group E had very high constancy and slope group F had moderate constancy at site group IX. Furthermore, group C had positive and groups E and F had high fidelity there.

The more extensive sampling in winter 1968 than in 1967 was reflected in the greater number of site groups in 1968. Content of species groups showed many similarities between the two years. Thus in 1967 species groups A and B contained many of the same species included in groups A and B in 1968, and the 1967 group D included many of the species found in group C in 1968. Because of the greater sampling effort in 1968 more species (23) were found to meet the requirements for species dominance than in 1967 (18 species), but all but 2 of the species found to be dominant in 1967 were also dominant in 1968.

Availability: Abundance and Biomass. Among the northern site groups, abundance and biomass were lowest inshore, increased offshore in group IV, reached a maximum in group VI, then decreased offshore in groups VII and IX (Table 10-13). Abundance was similar in shallow groups I, II, and III, but biomass was greater in the southern group III. Among the southern groups, proceeding offshore, abundance and biomass increased offshore to group VII and remained about the same out to group VIII. The ANOVA for abundance was significant and Sheffe's test showed that group I was different from groups VI, VII, and VIII, and that groups II and III were significantly different from groups IV, V, VI, VII, VIII, and IX.

CONCLUSIONS

Cluster analyses suggest that fish assemblages available to otter trawl on the continental shelf in the Chesapeake Bight form a dynamic mosaic of migratory and resident species. Most species on the shelf are migratory, but at least two dominant species are resident, one on the inner-shelf (Scophthalmus aquosus), the other on the outer-shelf (Hippoglossina oblonga). Many species are resident on the shelf-edge and upper-slope. The migratory species show two primary migratory patterns that are related to the faunal affinities of the species and the extreme seasonal thermal variations of the Bight. One group is boreal and migrates south and inshore until vernal warming begins, then migrates offshore and to the north. The larger species or pelagic species with greatest mobility (e.g. Squalus acanthias, Scomber scombrus, Clupea harengus) may emigrate from Chesapeake Bight

altogether during the warmer months to cooler waters off southern New England and in the Gulf of Maine.

The most cryophilic of the boreal group that remain during the summer are restricted to a tongue of cold water on the mid-shelf, sandwiched between a deepening mixed layer inshore, and moderate slope water temperatures offshore. Some boreal species (Urophycis chuss, Merluccius bilinearis) have broader temperature requirements than others. These tend to be found at intermediate temperatures during the entire year at the shelf-edge, and also to occur inshore during the spring and fall. The warm-temperate species migrate inshore and north in spring, stay inshore during the summer (many species moving into estuaries), and migrate offshore and south during the fall. Most species in this group spend the winter at the shelf-edge, but some may migrate south of Cape Hatteras. Most notable in the latter group are the sciaenids (Nesbit and Neville 1935; Joseph 1972) which are subject to large year-class fluctuations and which were uncommon at the time of this study. Also many of the larger species or pelagic species that have high mobility migrate south of Hatteras in winter (Pomatomus saltatrix, Dasyatis sayi, D. centroura, Myliobatis freminvillei, etc.). We suspect that parts of the populations of other species (Centropristis striata, Paralichthys dentatus, Stephanolepis hispidus, Sphoeroides maculatus, and others) also may migrate south of Hatteras in winter, but we have not direct evidence for this.

Assemblages containing mixed boreal and warm-temperate elements are encountered most often in spring when the thermal regime is slowly changing, and least often in the summer when the thermal regime is strongly stratified (both vertically and horizontally). Temperature is probably the most important single environmental parameter controlling distribution of fishes over the continental shelf in Chesapeake Bight. Substrate type does not appear to have a discernible effect on the distribution of migratory species (such an effect may be present on resident species but could not be detected in the present study). The sediment composition in the Chesapeake Bight is quite homogeneous compared to that off New England to the north, or to that off the Carolinas to the south, and consists mostly of sand (Uchupi 1963). Through migration, even stenothermal species are able to maintain themselves within a relatively narrow thermal range thus optimizing biological processes such as growth and reproduction.

Abundance and biomass in summer are highest inshore (<25 m), and in winter are highest offshore (>50 m), with transitional patterns in spring and fall. Highest values are encountered in winter and lowest in summer. These patterns reflect major seasonal changes in availability of demersal fishes in Chesapeake Bight due to migration in summer of abundant boreal species (particularly Squalus acanthias) to the north out of the study area, and of abundant warm-temperate species both to the north and into coastal and estuarine waters too shallow to sample with the large commercial trawler used in this study.

ACKNOWLEDGEMENTS

Analyses of these data were supported by Bureau of Land Management Contract Number AA550-CT6-62, J. A. Musick, principal investigator. The data were originally collected through support by the United States Commercial Fisheries Research and Development Act, Project No. 3-5-D, W. J. Davis, principal investigator. We would like to thank the following people, all presently or formerly associated with the Virginia Institute of Marine Science for their help during this study: J. D. McEachran for aid in preliminary analyses; D. F. Boesch, J. G. Loesch, and R. J. Diaz for invaluable counsel about statistical methods; W. Blystone and R. F. Wojcik for their assistance with computer programming; G. D. Stamper, J. F. Milieu, and C. H. Orselli for typing various drafts of the manuscript; and P. Peoples for drafting the figures.

SECTION II: NMFS GROUND FISH SURVEY

James A. Colvocoresses
John A. Musick

INTRODUCTION

The finfish populations of the Middle-Atlantic outer continental shelf (OCS) constitute an integral part of the marine ecosystem as well as a valuable natural resource. Evaluation of these populations is complicated by the high mobility, seasonality, and natural variability of most fish species in this region. Because of these factors, assessment of the condition or value of the fish stocks in a given area requires a thorough knowledge of the normal variability in that area as well as an understanding of its interrelationships with other areas. Since the variations in abundance of individual species may be large and possibly unrelated, analysis of fish community structure should provide a more valuable tool for habitat assessment than abundance indices for selected species.

Since 1967 the National Marine Fisheries Service has conducted a semi-annual bottom trawl survey of the continental shelf waters from Nova Scotia to Cape Hatteras (Grosslein 1959). This program has produced a data base which offers a unique opportunity for a temporal analysis of the composition and variability of the fish communities in this region. Previous analyses of these surveys has been primarily directed toward population assessment and management of commercially important species (Brown et al. 1976, Brown and Clark 1977). Brown and Clark recognized four sub-areas primarily based on differences in faunal assemblages (Figure 10-13A). Their Middle Atlantic and Southern New England areas are the same as the area extending from Cape Hatteras to Cape Cod included in the present study. This study is aimed at defining temporal patterns in the composition of fish communities present within this area, and how they vary geographically, thermally, and seasonally.

METHODS

Sampling

Groundfish Survey cruises were conducted by the U. S. National Marine Fisheries Service during the fall and spring from fall 1967 through spring 1976, aboard either the RV Albatross IV or RV Delaware II (Table 10-16). In addition a summer cruise was made during 1969. The survey area extended from the 15 fathom (27 m) contour offshore to 200 fathoms (365 m). A stratified random sampling design was utilized, based on depth and geographical zones (Figure 10-13B).

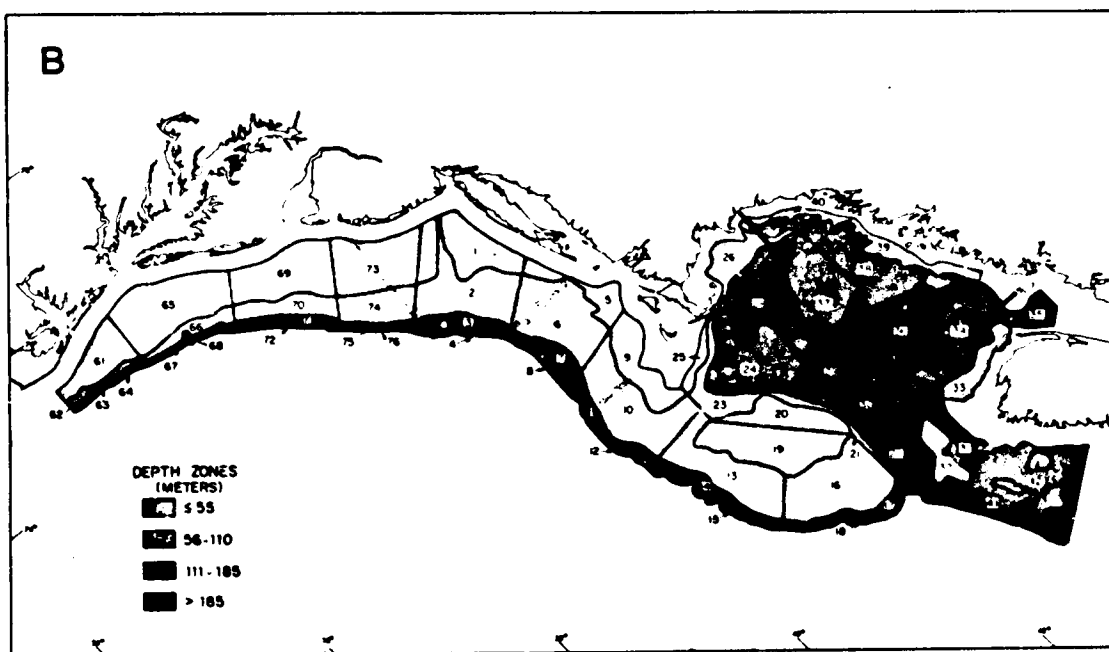
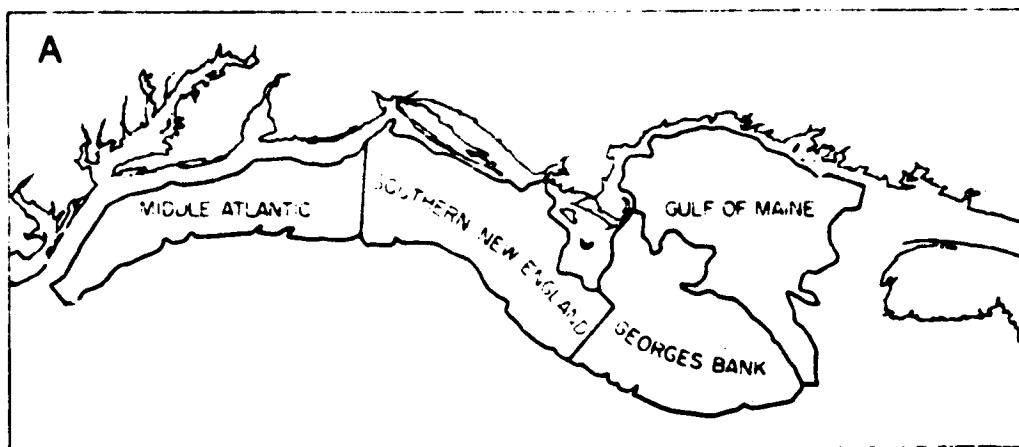


Figure 10-13. Northwest Atlantic area sampled by NMFS Groundfish Survey, A) delineated into major analytical units, and E) delineated into sampling strata.

Table 10-16. NMFS Groundfish Survey Cruises, 1963-1976.

Cruise	Year	Season	Dates	No. Stations in Mid-Atlantic	Vessel(s)	Trawl
67-20,21	1967	Fall	17 Oct - 9 Dec	121	<u>Albatross IV</u>	#36 Yankee
68-3	1968	Spring	4 Mar - 22 Mar	108	"	"
68-17	1968	Fall	10 Oct - 13 Nov	121	"	"
69-2	1969	Spring	5 Mar - 29 Mar	109	"	"
69-8	1969	Summer	14 Jul - 12 Aug	103	"	"
69-11	1969	Fall	8 Oct - 8 Nov	109	"	"
70-3	1970	Spring	25 Mar - 29 Apr	124	"	"
70-6	1970	Fall	3 Sep - 31 Oct	113	"	"
71-1	1971	Spring	9 Mar - 12 Apr	116	"	"
71-6	1971	Fall	29 Sep - 25 Oct	115	"	"
72-2	1972	Spring	8 Mar - 7 Apr	120	"	"
72-8	1972	Fall	28 Sep - 30 Oct	103	"	"
73-3	1973	Spring	16 Mar - 24 Apr	145	<u>Albatross IV & Delaware II</u>	#41 Yankee
73-8	1973	Fall	26 Sep - 11 Oct	103	<u>Albatross IV</u>	#36 Yankee
74-4	1974	Spring	12 Mar - 11 Apr	91	"	#41 Yankee
74-11	1974	Fall	23 Sep - 25 Oct	99	"	#36 Yankee
75-3	1975	Spring	14 Mar - 29 Mar	90	"	#41 Yankee
75-12	1975	Fall	15 Oct - 7 Nov	111	<u>Albatross IV & Delaware II</u>	#36 Yankee
76-2	1976	Spring	4 Mar - 9 Apr	117	<u>Albatross IV & Delaware II</u>	#41 Yankee

Catch data from strata 1-12 and 61-76 were analyzed for the present study. Sampling intensity in each stratum was allocated according to the geographic area of each stratum (2-16 stations per stratum). At each station a tow of 1/2 hour duration at a speed of 3.5 knots was made along the bottom. Most cruises utilized a standard #36 Yankee trawl (18 m headrope, 24 m footrope with 14-18" rollers; stretch mesh sizes: 125 mm in body, 115 mm cod end with 13 mm liner). The spring cruises from 1973-1976 used a modified high-opening #41 Yankee trawl (24 m headrope, 30 m footrope with rollers; same mesh sizes). The catches were identified, counted, and weighed by species. A bathythermograph cast was made at each station. For further details of sample processing, see Grosslein (1969).

Analyses

The catch data were analyzed in the same manner as the Chesapeake Bight cruises (Section I of this chapter).

RESULTS

Thermal Regime

The geographic patterns of bottom water temperatures were variable among years within both of the major sampling seasons, although these differences were minor compared to seasonal variations within a given year. The variability among years within a season can be attributed to three major sources; climatic differences among years, differences in the dates and duration of the sampling periods, and stochastic differences arising from the location of stations and the temporal sequence in which they were done. The rapidly changing nature of environmental conditions during the spring and fall and weather conditions which often inhibited field operations made synoptic sampling during these seasons virtually impossible.

Spring Cruises

The spring cruises commenced between early and late March and were completed by late March to late April. This is the period at which water temperatures in the Middle Atlantic Bight are at a minimum (Walford and Wicklund 1968), and therefore it is more appropriate to consider these cruises as having sampled the late winter distribution of fishes (Musick and Mercer 1977). Bottom temperatures for these cruises ranged from 2-16°C (Appendix 10-A) and mean temperatures for each cruise ranged from 6.7 to 9.7°C (Figure 10-14A). There was a definite trend toward warmer temperatures during the study period which cannot be completely attributed to sampling artifacts. Bottom isotherms extrapolated from the collection data have been plotted for two typical cruises representing the warmer (1976) and cooler (1969) extremes (Figure 10-15). During the 1969 cruise inshore and mid-shelf temperatures were less than 4°C north of Delaware Bay and between 4 and 6°C between Delaware Bay and Cape Hatteras. Temperatures

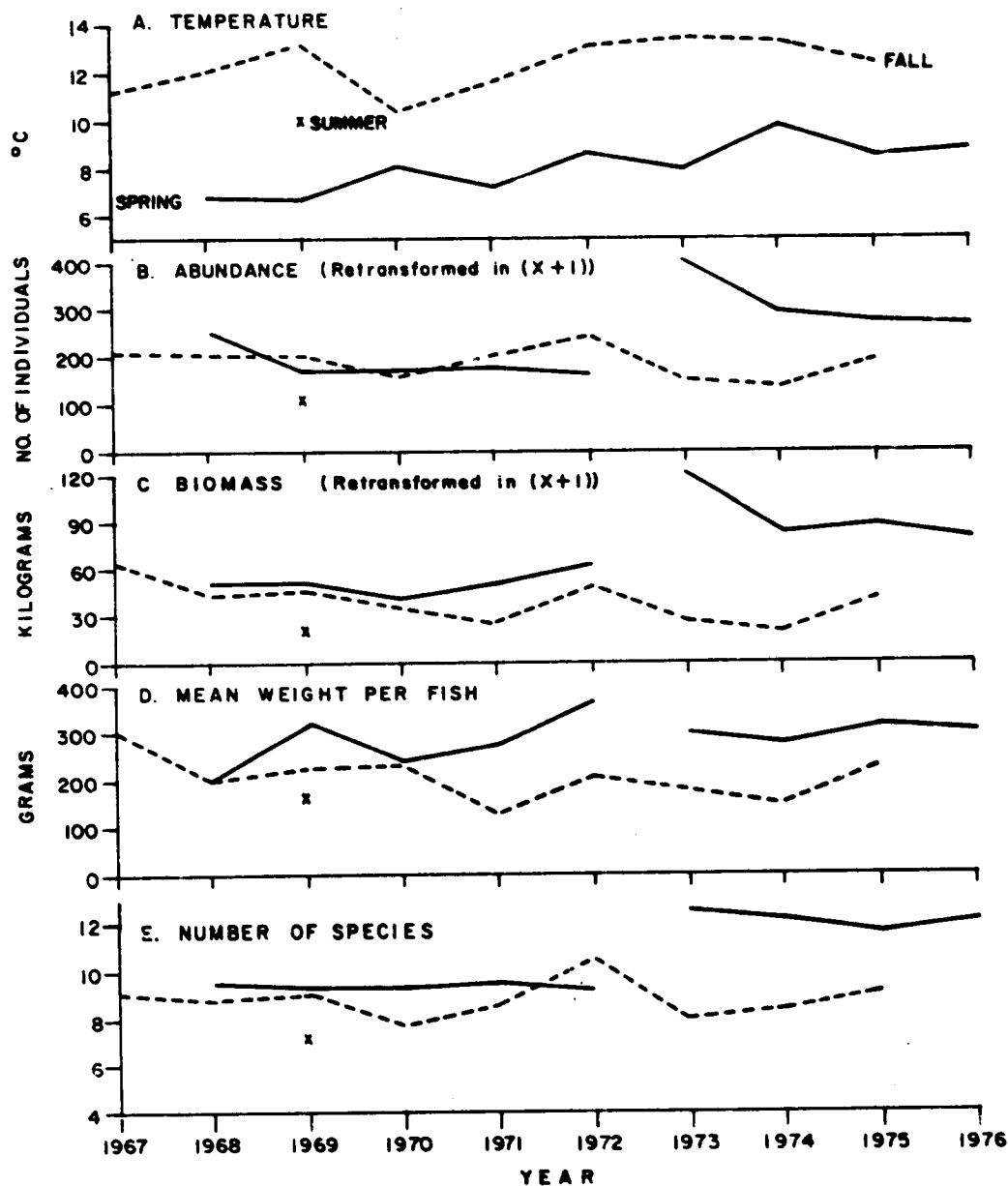


Figure 10-14. Mean A) bottom water temperature, B) retransformed ($\ln(x+1)$) number of individuals (fish), C) retransformed ($\ln(x+1)$) fish biomass, D) average fish size, and E) number of fish species per tow during NMFS Groundfish Surveys, Cape Hatteras to Cape Cod, 1967-1976. Spring cruises after 1972 used a #41 Yankee trawl, all others, a #36 Yankee trawl.

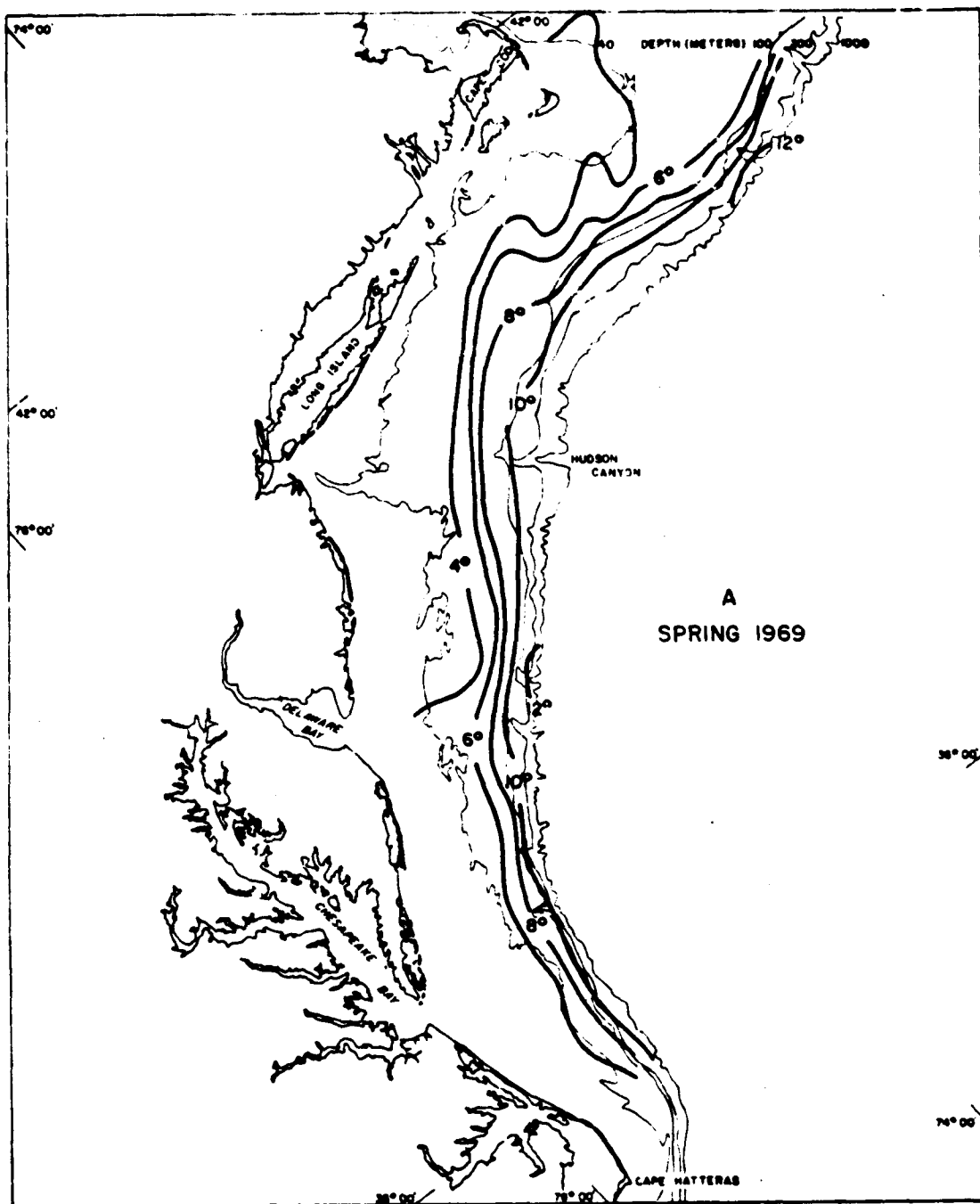


Figure 10-15. Bottom isotherms for spring A) 1969 and B) 1976 extrapolated from NMFS Groundfish Survey cruises.

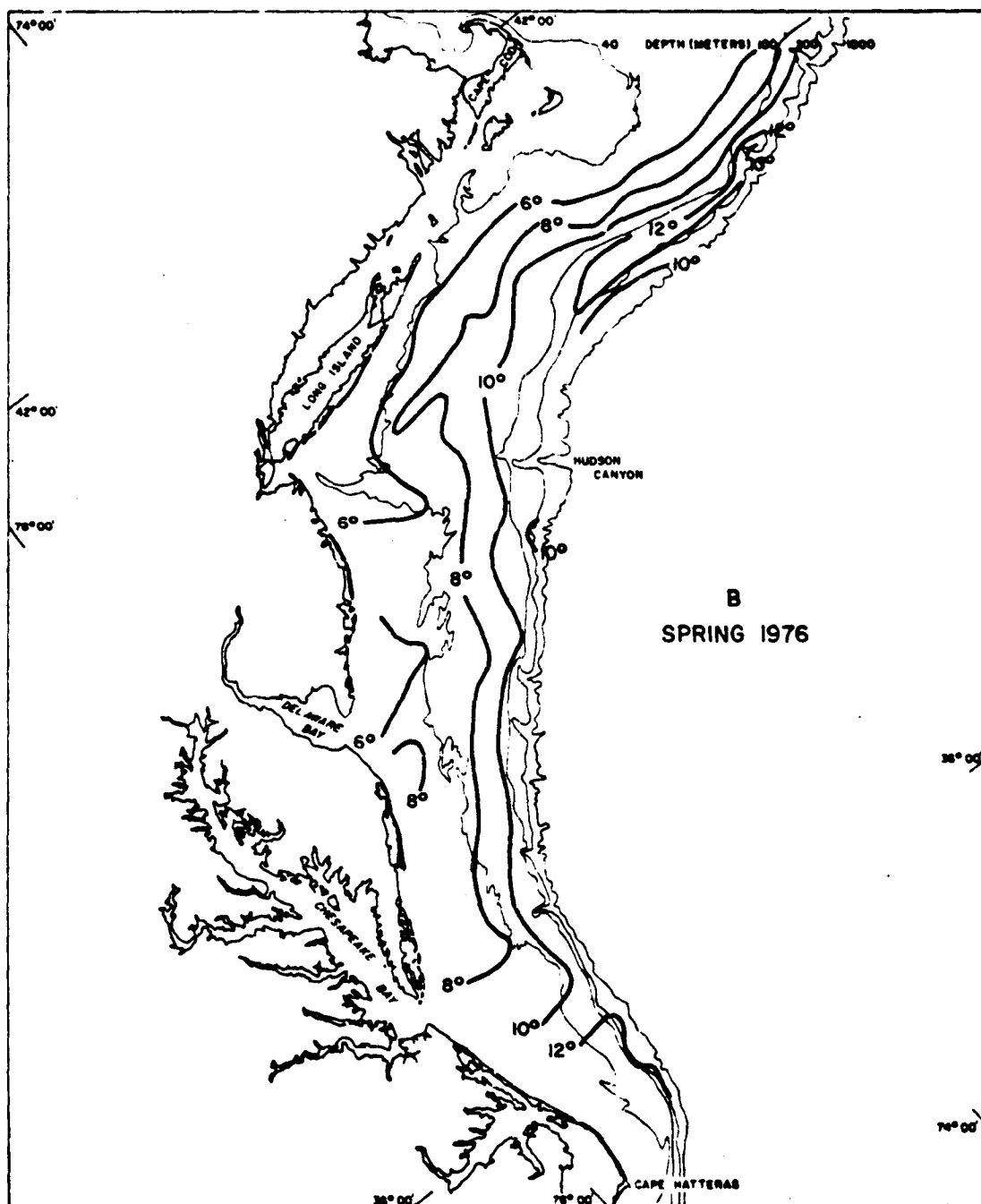


Figure 10-15. (continued)

increased toward the outer shelf, where the 10°C isotherm followed the shelf break, and temperatures greater than 10°C occurred on the slope.

In 1976 temperatures of less than 6°C were encountered only at northern inshore stations. Mid-shelf temperatures north of Chesapeake Bay increased from 6 to 10°C moving offshore, while south of Chesapeake Bay there was a southwardly increasing thermal gradient perpendicular to the shoreline. Outer shelf and slope stations for the entire area ranged from 10-12°C. Bottom temperatures for the other spring cruises exhibited patterns intermediate between these two.

Fall Cruises

Fall sampling cruises were conducted primarily in October. Because of water column turnover this is the time of maximum temperature for middle shelf bottom waters in this region (Bigelow 1933); however, coastal waters undergo rapid cooling during the fall (Parr 1933), initiating migrations for many fishes that spend the summer inshore. Bottom temperatures ranged from 5 to 25°C, with the means for each cruise varying between 10.4 and 13.4°C (Figure 10-14A). There was no pronounced trend in the variation of mean temperature among cruises. Bottom isotherms for a typical warm (1973) and cool (1971) fall sampling period are shown in Figure 10-16. In 1971 a strong thermal gradient was encountered along the mid-shelf from New Jersey to Cape Hatteras. Temperatures ranged from the 22°C inshore down to 10°C at about mid-shelf. A pocket of cooler water (6-9°C) was present offshore of this gradient, extending northward and inshore to occupy most of the mid-shelf off Long Island. Turnover was in progress or just beginning at these cold stations. Temperatures gradually increased offshore and northward from this pocket, exceeding 14°C in shallow areas and ranging between 10 and 13°C along the outer shelf and the mid-shelf above Long Island.

During 1973 bottom water temperatures were considerably less stratified and several degrees warmer throughout most of the study area. Inshore temperatures exceeded 16°C along the entire bight, with temperatures above 18°C occurring only south of Chesapeake Bay. The coolest temperatures were found again on the mid-shelf off New Jersey and Long Island, but the "pocket" was much less clearly defined and was composed of waters between 10 and 12°C, indicating that turnover had already occurred. Temperatures along the outer shelf and the mid-shelf north of Long Island ranged between 12 and 15°C. The other fall cruises showed thermal regimes intermediate to those of 1971 and 1973.

Figure 10-17 shows the isotherms for the 1969 summer cruise. Bottom water temperatures ranged from 6 to 16°C, with a mean of 9.9°C, a value intermediate to that for the fall and spring cruises. The temperature distribution closely resembled that for the fall cruises, with warmest temperatures being found inshore and the coolest waters

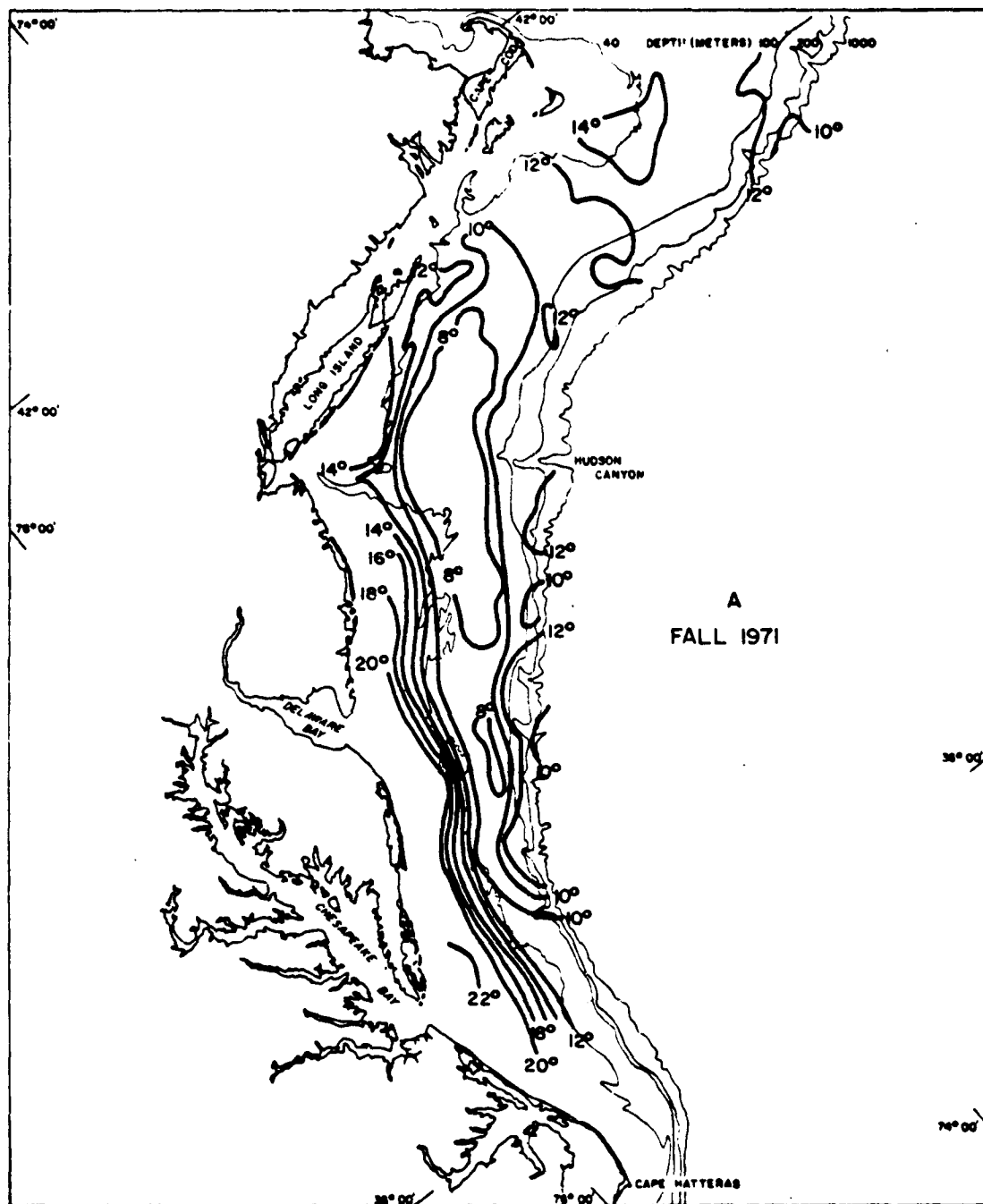


Figure 10-16. Bottom isotherms for fall A) 1971 and B) 1973 extrapolated from NMFS Groundfish Survey cruises.

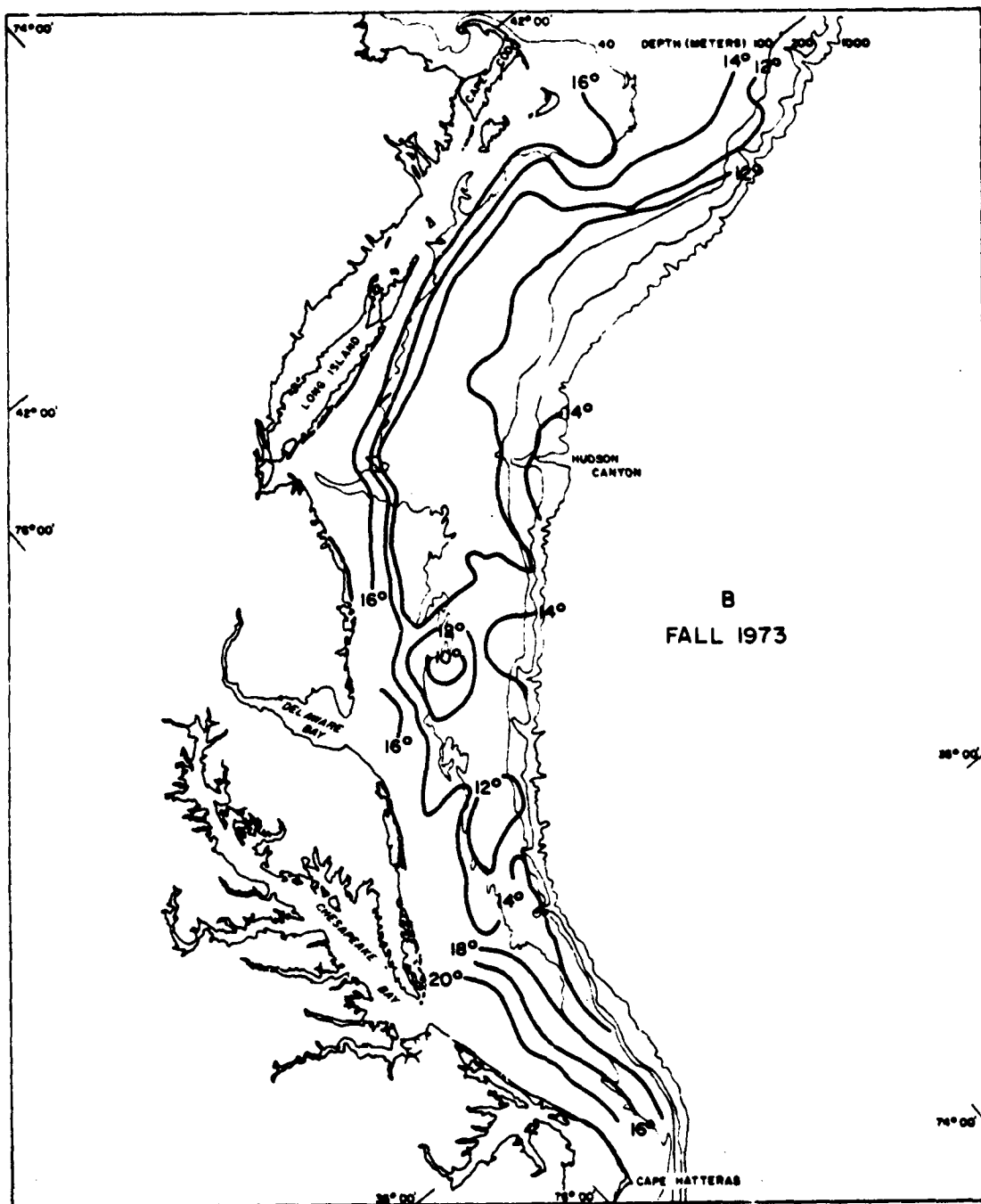


Figure 10-16. (continued)

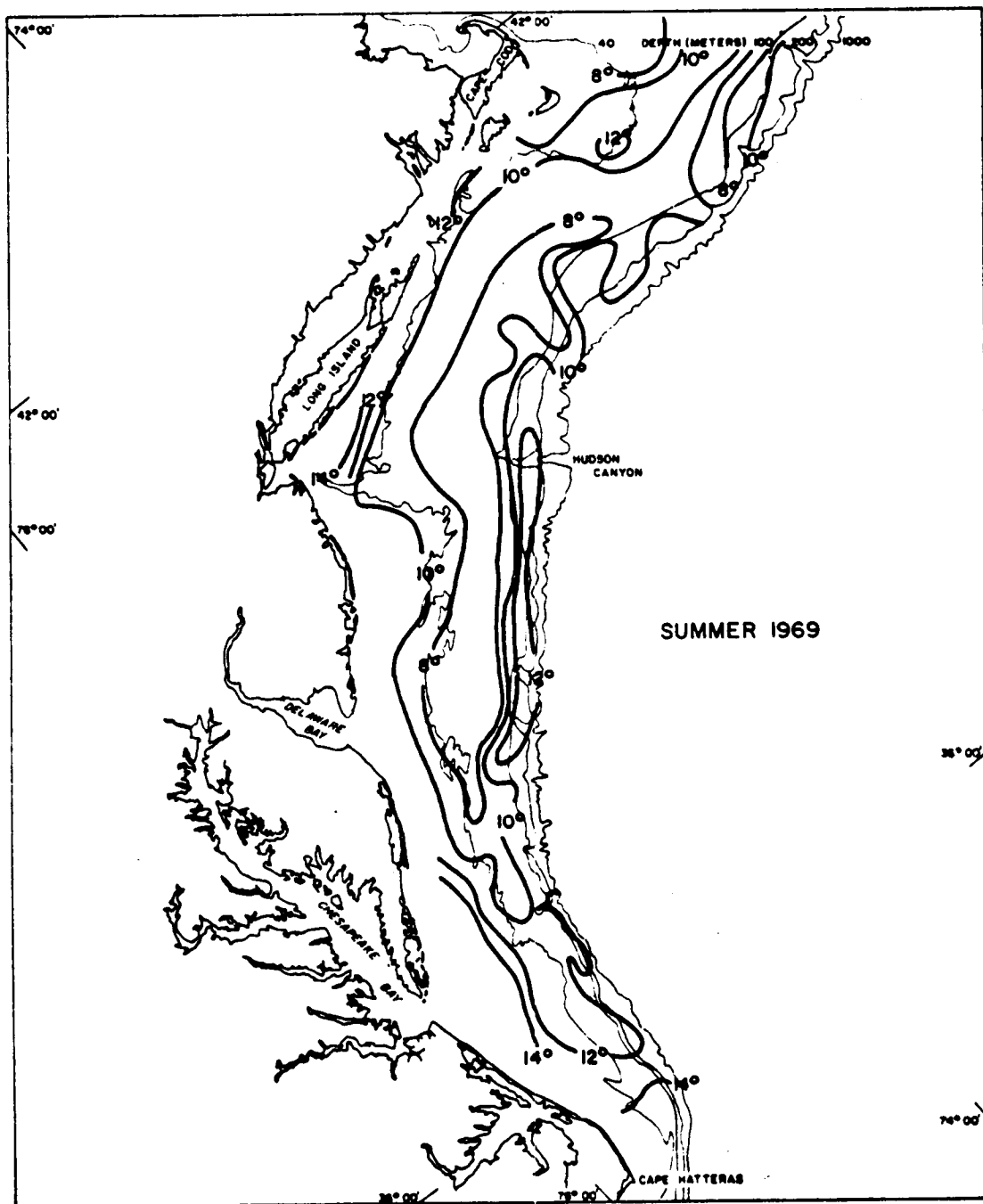


Figure 10-17. Bottom isotherms extrapolated from summer 1969 NMFS Groundfish Survey cruises.

being present on the mid-shelf in the northern portion of the study area.

Fish Assemblages

Spring Cruises

Cluster Analyses. Station groups based on cluster analysis for the nine spring cruises are plotted in Appendix 10-B. Between six and nine station groups were recognized for each cruise. Group size ranged from 3 to 47 stations (Appendix 10-A). Most groups were geographically contiguous. Groups tended to be thermally and bathymetrically restricted (Appendix 10-A). With the exception of the outermost upper slope groups, site groups were not closely comparable from one year to the next. This is understandable considering the differences in sampling, thermal regime, and natural variability of fish populations among years. The groups, however, may be categorized on the basis of bathymetry and temperature.

During all nine cruises there was a group of site clusters of similar depth and temperature regimes which were contained between the shore and approximately the 8°C isotherm (groups I-III in 1968, 1970, and 1972; I-IV in 1969; I-II in 1973-1976). The geographic extent of these groups varied from year to year, but generally covered the inner and mid-shelf out to about 80 m from Cape Cod south to between Delaware Bay and Cape Hatteras, depending upon the southward extent of waters cooler than 8°C. Adjacent to these groups were two other categories of groups; northern outer shelf groups (group V in 1968, 1971, and 1976; VI in 1969; VII in 1970, 1972; III in 1973, IV in 1975) extending from the cold water group to the shelf break (approximately 150 m), and southern groups which occupied the remaining shelf both outward and south of the 8°C isotherm (group IV in 1968, 1971, 1973, 1976; V in 1969; IV, V and VI in 1970; V and VI in 1972, III and IV in 1974; III in 1975). The boundary between these two categories was generally off the New Jersey coast, at which point there was often considerable overlap. The remaining outermost groups were located along the shelf break at depths of 150-350 m.

Between 6 and 9 species clusters ranging in content from 2 to 14 species were recognized for each cruise (Appendix 10-C).

Distribution of fishes. The species groups recognized were extremely homogeneous with respect to faunal affinity (Appendix 10-C). If pelagic and resident species are ignored, 58 of the 70 groups recognized were either exclusively boreal, warm temperate or slope/mesopelagic in their affinities. Only in one case, group F in 1975, was there a substantial degree of co-occurrence of boreal and warm temperate species within a species group, and this can be readily attributed to abbreviated sampling during this cruise in which the southern inshore and mid-shelf strata were either incompletely sampled

or not sampled at all. Had more stations been made in these warmer strata, the three warm temperate species would have undoubtedly formed their own group.

The species groups showed a high degree of repetition, both in terms of composition and distribution, from year to year. One to three groups of boreal affinity (group A in 1968; A and B in 1973-1974; A, B and C in 1970-1972, 1975-1976; A, B and D in 1969) occurred almost exclusively within and had generally positive or high fidelities to the cold water site groups (Appendix 10-D). The most common among these species were Limanda ferruginea, Raja erinacea, and Scophthalmus aquosus (common names given in Appendix 10-F), which occurred within the same group during virtually every cruise. Also exclusive to these groups were the species Gadus morhua, Pseudopleuronectes americanus, Hemitripterus americanus, Hippoglossoides platessoides, Myoxocephalus octodecemspinosus, Macrozoarces americanus, and Raja ocellata, which all occurred commonly in these clusters in varying arrangements. The species Ammodytes dubius, Menidia menidia, Etropus microstomus, and Pollachius virens occurred infrequently but exclusively within these groups, whereas the pelagic species Alosa aestivalis, Alosa pseudoharengus, and Clupea harengus harengus occurred regularly but not exclusively within these groups.

A widespread, common, and usually exclusively boreal group was present during all cruises (group C in 1974; D in 1968, 1970-1973, and 1976; E in 1969; F in 1975). This group generally had moderate or better constancy to all site groups, and with the exception of two small site groups in 1970, did not display highly negative or positive fidelity to any site group (Appendix 10-D). Squalus acanthias and Merluccius bilinearis occurred in this group during every spring cruise, Urophycis chuss in all but one, and Hippoglossina oblonga in 6 of 9 cruises. The pelagic species Scomber scombrus and Alosa pseudoharengus each occurred four times within this assemblage. During the 1975 cruise the warm temperate species Peprilus triacanthus, Paralichthys dentatus, and Prionotus carolinus also occurred within this group, but as mentioned above, had the southern portion of the cruise been completed these species probably would have been sampled adequately enough to form their own group.

One to three warm temperate species clusters were present during each cruise (group C in 1968; G and H in 1969; E and F in 1970-71; F and H in 1972; E, F, and G in 1973; D and E in 1974; E in 1975-1976). These groups occurred across the southern shelf during warmer years and along the outer shelf during all years. Stenotomus chrysops and Centropristis striata were present in these groups during all nine years, Prionotus carolinus during 8 of 9, Peprilus triacanthus and Urophycis regius during 7 of 9, and Paralichthys dentatus and Prionotus evolans during 6 of 9 years. There were no consistent sub-groups when more than one group was recognized. Except for Peprilus triacanthus, which was present twice in the ubiquitous

group, and Urophycis regius, which occurred twice with the mesopelagic/slope group, all these species were found exclusively in these groups.

Those species with mesopelagic or slope affinities were found together in 1 to 3 groups which occurred along the shelf break and upper slope (groups E and F in 1968; I in 1969, 1972-1973; H in 1970; G and H in 1971, 1974; G in 1975; H in 1976). These groups characteristically had highly positive fidelities to the upper slope site groups (Appendix 10-D). Helicolenus dactylopterus was the only species to occur within these groups during all cruises. Merluccius albidus and species of the family Myctophidae appeared in these groups during 7 of 9 cruises. Other species present in the clusters less frequently but occurring exclusively in these groups included Chlorophthalmus agassizi, Maurolicus muelleri, Phycis chesteri, Ceratoscopus maderensis, Argyropelecus aculeatus, Nemichthys scolopaceus, Raja garmani, and Lopholatilus chamaeleonticeps. Also periodically present in, but not exclusive to these groups were the species Peristedion miniatum, Lepophidium cervinum, Urophycis tenuis, and Glyptocephalus cynoglossus. This last group of species was widespread across the outer shelf and upper slope but occurred fairly infrequently, making them difficult to classify. When they were not present in the deep groups they tended to form their own small group (group E in 1968, 1970; F in 1969, 1974; D in 1972, 1975; H in 1973). Occasionally present in these small groups were Lophius americanus and Citharichthys arctifrons, two other species which proved difficult to classify. Lophius occurred commonly throughout most of the study area but in very low abundances in shallow waters, and was variously classified with the ubiquitous, deep, and outer shelf groups. Citharichthys was also widespread but more abundant in warmer outer shelf and upper slope waters and was variously classified with the ubiquitous, outer shelf, and warm temperate groups.

Species dominance by cruise and station group is given in Appendix 10-E. Two species, Merluccius bilinearis and Squalus acanthias, were among the dominants at over 80% of the site groups. In the cold water site groups Limanda ferruginea was the dominant fish taken prior to 1973. During 1973 abundances of Limanda, Merluccius bilinearis, and Raja erinacea were about equal in the cold water groups; after 1973 abundances of M. bilinearis and R. erinacea exceeded those of Limanda. Because of the change in nets commencing in 1973 it is difficult to interpret this change. A relative decline in the population of Limanda may have occurred, or Limanda may have a lower catchability coefficient relative to the other two species when the large net is used.

The site groups southward and offshore of the cold water group were fairly evenly dominated by Squalus acanthias, Merluccius bilinearis, and Peprilus triacanthus. Stenotomus chrysops, and Prionotus carolinus were periodically dominant in the southern portion of this area. Urophycis chuss, Helicolenus dactylopterus, and

myctophids were often abundant along the shelf break and upper slope. There were no noticeable changes in dominance between the earlier cruises and those after 1972 outside of the colder groups.

Availability: Abundance and Biomass. Average total abundance and biomass of fishes fluctuated greatly among site groups and was subject to a high degree of variability (Appendix 10-B). Scheffe's test detected almost no significant differences during the period the smaller net was used (1968-1972), and only a limited number of differences, during the later cruises (Table 10-17). There was no evident pattern to the abundance data. Average biomass tended to be lowest along the shelf break and slope, and reached its highest values on the northern inner and mid-shelf.

Year to year comparisons of abundance and biomass were difficult due to the net differences. Both average abundance and biomass per tow increased sharply with the larger net (Figure 10-14 B & C). The overall average abundance was 1.7 times greater for the period 1973-1976 than 1968-1972, whereas the biomass averaged 1.8 times greater. Because these two values are similar, the two nets may have similar sampling characteristics, but as conversion factors they are probably high; 1973 appears to have been an exceptional year. It is not possible to discuss long-term trends in abundance or biomass of fishes during these cruises without knowing the actual relationships between these nets with respect to catchability of at least the dominant species. The average number of species per tow was consistently about 9 with the smaller net, and then jumped to 12 with the larger net (Figure 10-14D). The number of species was usually significantly higher at the upper slope and cold water site groups (Table 10-17).

Fall Cruises

Cluster analyses. Between six and nine station groups were also recognized from cluster analysis of the fall cruises (Appendix 10-B). Group size ranged from 5 to 27 stations (Appendix 10-A). The groups were not as geographically contiguous or as thermally restricted as during the spring cruises; in fact several of the groups exhibited bottom temperature ranges of 14°C (Appendix 10-A). Considering the asynoptic nature of the sampling, the onset of the rapid autumnal cooling during the later portion of the cruises, and the migratory activity of fishes during the fall, it is not surprising that the site groups are less clearly defined during this period. Again, with the exception of the upper slope groups, site groups were not directly comparable from year to year but could be grouped into categories.

During 7 of the 9 cruises there was a distinct southern inshore site group between shore and about 60 m extending from Cape Hatteras northward to between the northern end of the Delmarva Peninsula and Delaware Bay, depending on the year (group I in 1967-1972, 1975).

Table 10-17. Results of Scheffé's multiple range test for site group abundance, biomass, and number of species. Significant differences at $\alpha = .05$.

Date	Spring			Fall		
	Abundance	Biomass	No. of Species	Abundance	Biomass	No. of Species
1967				III>VI	I,V>VI,VII II,III>V-VI IV>VI	III>I,V-VI II,IV>VI
1968	NSDD*	NSDD	NSDD	NSDD	II,III>VI-VIII IV>V-VI	II,IV>I,III,V-VIII VI>V
1969	NSDD	NSDD	II>IV,V	NSDD	I>VI II>IV-VI III>V,VI	II,III>IV-VI I>IV
1970	NSDD	NSDD	III>I,IV-VI,VIII II>IV,V,III IX>IV	III>IV,V,III	II,III>IV-IX	II>IV,VII,VIII III>I,IV-VIII IX>IV
1971	V>I	V>IV	II,V,VI>I	I,II>IV	II>I,III-VI	I,II>III,IV,VI
1972	NSDD	NSDD	I,II,V,VI,IX>IV II>II,IV-VI,VIII IX>V,VII	III>I,V,VI III,IV>II IV>VI	I,II>VI III,IV>II,V,VI	III>I,II,V,VI IV>II,V
1973	NSDD	III>V,VI	I>II,IV-VI VII>II,IV,V	II,III,V,VI>IV	II>IV,VI III>IV	II,III,V>IV,V I>I
1974	I,III>II	I-IV>V	I,III,V,VI>IV I,IV>II	FNS**	I,III>IV,VI III>V	I,II>V III>V,VI VII>IV-VI
1975	IV>V	II,IV>V,VI III>V	I,IV>III VI>II,III,V	III,IV,VI>II III>V,VII,VIII	I>VII,VIII III,IV>V,VII,VIII	I,III,VI,VII>II,V,VII IV>II
1976	V>IV	III>VI V>I,III,IV,VI	V>III VII>I-IV,VI			

* NSDD - F significant but no specific differences detected.

** FNS - F value not significant

This group was generally contained behind a strong thermal gradient and exhibited the warmest bottom temperatures in the study area. Extending northward from these groups along the inner shelf was a second, colder site group which tended to be constricted toward shore between northern Long Island and Cape Cod (group II in 1969-1974; III in 1975). During 1973 and 1974, when thermal stratification was weaker and inshore water temperatures in the north were higher, there was no distinct break between northern and southern inshore stations groups (groups I and II).

One or two site groups occurred on the northern mid-shelf between 35 and 100 m (groups III and IV in 1967-1968, 1970, 1972; III in 1969, 1971, 1973, 1976; IV in 1974). These groups occupied the coolest shelf waters and were relatively bathymetrically restricted (the 192 m station in group IV in 1970 was anomalous; only two species were taken at that station). The remaining site groups could be classified as outer shelf/shelf break (groups V and VI in 1967, 1974; V, VI, and VII in 1968, 1970; IV and V in 1969, 1971; V in 1972; IV, V, VI in 1973, 1976) or upper slope (highest numbered group for each year). The outer shelf/shelf break groups typically displayed wide depth ranges and temperatures intermediate between the northern mid-shelf and inshore groups. The upper slope groups often had average temperatures lower than those on the mid-shelf but were bathymetrically discrete from the mid-shelf groups.

Between 6 and 11 species clusters, ranging in content from 1 to 9 species, were recognized for each of the fall cruises (Appendix 10-C).

Distribution of fishes. The species groups recognized for the fall cruises were considerably less homogenous with respect to faunal affinity than were the spring species groups, with only about half of the groups composed entirely of species of the same affinity (Appendix 10-C). The species groups were also much more variable with respect to composition and distribution.

One or two groups of warm temperate species were present at the inshore site groups during each cruise (group A in 1967, 1970-1973; A and B in 1968-1969, 1975; A and C in 1974), but the composition of these groups was highly variable. Paralichthys dentatus was the only species to occur within these groups during all nine cruises. Centropomus striatus was present during eight cruises and absent from the cluster during the ninth, whereas Mustelus canis was present in these groups during six cruises in another group twice, and otherwise absent. Prionotus carolinus, Stenotomus chrysops, and Scophthalmus aquosus appeared 6, 4, and 2 times respectively, but were present in other groups during the remaining years. Pomatomus saltatrix was present during four years, in another group once, and otherwise absent, while eight other warm temperate species were exclusive to these groups but appeared three times or less. The boreal species Pseudopleuronectes americanus appeared within these groups once, but in other groups during the remaining eight years. Constancies and

fidelities of these groups were generally higher in the southern portion of the inshore region when the inshore site groups were so divided (Appendix 10-D).

During four years there were one or two species groups of mixed warm temperate and boreal affinity which were distributed along the inshore site groups and out onto the northern mid-shelf (group B in 1967, 1973; C in 1969; B and C in 1972). Stenotomus chrysops and Pseudopleuronectes americanus were present in these groups during all four years; Prionotus carolinus and Scophthalmus aquosus three times each, and Raja erinacea and Mustelus canis twice. Five other species appeared once.

One to four groups of almost exclusively boreal affinity occurred primarily at the northern inshore and mid-shelf site groups during 8 of 9 cruises (groups C-F in 1967; C in 1968, 1971; E in 1969; B and C in 1970; E and F in 1972; B in 1974; C in 1975). Twenty-four species appeared within these groups throughout the study, but only seven reoccurred with any regularity. Raja erinacea was present 7 of 8 times, Limanda ferruginea and Myoxocephalus octodecempinosus 6 times each, and Squalus acanthias 5 times. Hemitripterus americanus, Pseudopleuronectes americanus, and Scophthalmus aquosus each occurred 4 times in these cold water groups.

As during the spring cruises, there was a group (in one case, two groups) of species which occurred throughout most of the study area (group H in 1967; D in 1968-1970, 1972-1974; E in 1971; D and E in 1975). Merluccius bilinearis, Hippoglossina oblonga, and Urophycis chuss were present in this group during all nine cruises. Peprilus triacanthus and Citharichthys arctifrons each appeared during six years, whereas Urophycis regius was present five times. Nine other species occurred in this group three times or less. Constancies of this group were usually lowest at the southern inshore site group and were often accompanied by highly negative fidelities, indicating that while some members of this group occurred in these warmer waters, in general the group avoided this area (Appendix 10-D).

The upper slope groups for the fall cruises were unique in that they were more clearly defined than the corresponding groups for the spring cruises (groups J and K in 1967; G in 1968, 1970; H in 1969, 1972; I in 1971; E in 1973; E and F in 1974; F in 1975). Helicolenus dactylopterus, Merluccius albidus, and myctophids were present in these groups during all nine cruises, and Chlorophthalmus agassizi occurred with them during eight years and was absent from the cluster during the ninth. Eight other slope or mesopelagic species occurred exclusively within these groups but appeared only once or twice. Peristedion miniatum, which appeared 3 times, and Lophius americanus, which was present once, were the only species occurring within these groups that also occurred in other groups.

The remaining groups were generally small and poorly defined geographically. Lophius americanus, Glyptocephalus cynoglossus, Peristedion miniatum, Lepophidum cervinum, and Urophycis tenuis often fell into these groups, but not in any consistent manner. Most of these species occurred sporadically from the mid-shelf offshore.

Merluccius bilinearis, as during the spring, was among the dominant species at over 80% of the site groups. Peprilus triacanthus was dominant at over 75% of the site groups and had the greatest overall abundance (Appendix 10-E). The inshore site groups were usually dominated by Peprilus, Prionotus carolinus, and Stenotomus chrysops. The northern mid-shelf groups showed a trend similar to that observed in the spring; Limanda ferruginea dominated these sites during the earlier cruises and then declined during the later half of the study. Merluccius bilinearis, Peprilus triacanthus, and Squalus acanthias were the other major dominants in this area.

Urophycis regius joined Merluccius bilinearis and Peprilus triacanthus as major dominants on the outer shelf. U. regius was much more abundant during the fall cruises than in the spring, when it seldom occurred among the dominants. The slope sites were regularly dominated by Helicolenus dactylopterus, myctophids, Citharichthys arctifrons, and Merluccius bilinearis. Peprilus and Urophycis regius occasionally reached dominant abundances on the slope.

Availability: Abundance and Biomass. Abundance and biomass estimates for the fall cruises were extremely variable, as in the spring (Appendix 10-B). Scheffé's test detected more significant differences between site groups than for the spring cruises (Table 10-17), but no definite patterns were evident for the abundance data and only a general trend may be noted for the biomass information. During most cruises greater biomass was found at the inshore and northern mid-shelf site groups than along the outer shelf and slope.

Average abundance and biomass per tow for the entire area fluctuated irregularly from year to year (Figure 10-14 B & C). Biomass tended to decline sharply from 1967 to 1974 (as noted by Clark and Brown 1977) although there was a fairly large peak in 1972. Abundances remained much more constant, reflecting a decrease in the average fish size (Figure 10-14D). Average size is a reflection of two factors, age structure within species, and relative abundances of different sized species. The greatest average size occurred in 1967, when the average size of a fish was over twice what it was at its low point in 1971. The influence of specific abundances on this index is discussed below. Biomass and abundance both increased sharply from 1974 to 1975, indicating that the declining trend was either artifact or was reversing. The average number of species per tow averaged about 9 as it had in the spring with the same net, but showed more variability between years (Figure 10-14E) and no consistent pattern between site groups (Table 10-17).

Summer 1969

Cluster analyses. Five station groups were recognized for the summer cruise (Appendix 10-A). These groups can be approximately classified as northern and southern inner shelf, outer shelf, shelf break, and upper slope; although the outer shelf group extended inshore in the vicinity of Hudson Canyon. The inshore groups were confined within the 90 m contour, whereas the other groups had wide bathymetric ranges. The groups showed much less variation in average temperature than during the spring and fall cruises (Appendix 10-B).

Six species groups were recognized, ranging in content from 3 to 8 species (Appendix 10-C).

Distribution of fishes. Only two warm temperate species, Peprilus triacanthus and Urophycis regius, occurred at a sufficient number of stations to be included within the cluster. As a result of this four of the six groups were composed entirely of boreal and resident species. Three of these (groups A, B, and C) occurred primarily within the northern inshore site group. Group B included the more abundant of these species (Limanda ferruginea, Pseudopleuronectes americanus) and also occurred sparsely in the southern inshore and outer shelf groups.

The fourth boreal group (D) occurred primarily at the northern inner shelf and outer shelf groups and was sparsely present at the shelf break and upper slope. Merluccius bilinearis, Melanogrammus aeglefinus, and Urophycis chuss were the most abundant members of this group. Peprilus triacanthus and Urophycis regius were joined by Lepophidium cervinum and Citharichthys arctifrons in a group (E) which occurred throughout the entire study area but was concentrated in the southern inshore, shelf-break and upper slope groups. The last group (F) was composed entirely of slope and mesopelagic species and occurred at the shelf-break and upper slope sites.

Limanda ferruginea was the most abundant fish at the northern inshore site group (Appendix 10-E). Merluccius bilinearis, Melanogrammus aeglefinus, and Urophycis chuss were also major dominants at this site. All of these species except U. chuss were also major dominants at the outer shelf group, where Peprilus triacanthus was the most abundant species. P. triacanthus and Urophycis regius accounted for over 90% of the individuals at the southern inner shelf site group, in roughly equal quantities. These two were joined by the other two members of their group, Lepophidium cervinum and Citharichthys arctifrons, as major dominants at the shelf break. The upper slope site was dominated by U. regius, Maurollicus muelleri, and Helicolenus dactylopterus.

Availability: abundance and Biomass. Average abundances and biomass were lower during the summer cruise than during any of the

fall or spring cruises (Appendix 10-B). Biomass was significantly higher at the northern inner shelf site group; average abundance was also greatest there but was not significantly so. The average number of species per tow was also lower than for any other cruise (Figure 10-14E), and significantly higher at the northern inshore site group.

DISCUSSION

Species Associations

The composition and distribution of fish assemblages in the Middle Atlantic Bight as determined by cluster analyses were largely consistent over the nine year period of this study. Figure 10-18 shows the number of times 37 of the most commonly occurring and dominant species occurred within the same species group during the spring and fall cruises. With the exception of the four widespread pelagic species listed at the top, the species were arranged so as to be closest to those species they occurred with most often in the clusters, i.e. so that the densest cells fell along the diagonal border of the diagram.

Four strongly recurrent species groups are evident from this diagram. Myoxocephalus octodecemspinosus, Scophthalmus aquosus, Raja erinacea, and Limanda ferruginea frequently appeared in the same group during both seasons. In the spring they were often joined by Macrozoarces americanus, while Pseudopleuronectes americanus was a common member during the fall cruises. Except for S. aquosus, an inshore resident, all of these species are of boreal faunal affinity and are restricted to cold water (Bigelow and Schroeder 1953; Leim and Scott 1966). During the present study they were found on the inner and mid-shelf in the northern portion of the study area, in the region of lowest water temperatures. Other cold water restricted species which occasionally occurred with this group included Gadus morhua, Hemitripterus americanus, and Raja occellata. These latter species occurred in the clusters predominantly during the spring cruises, where they often formed a separate group with P. americanus which was distributed in the shallower portion of the cold water region.

Prionotus carolinus, Stenotomus chrysops, Paralichthys dentatus, and Centropristes striata, all warm temperate species, were regularly classified in the same group during both seasons. In the spring this group was distributed in the warmer waters on the southern shelf and along the shelf break. P. carolinus was generally found along the entire outer shelf, while the other three species were usually confined to the southern, warmer portion. During the fall this group was distributed primarily on the inner shelf, where they were often joined by Mustelus canis. S. chrysops and P. carolinus occasionally occurred within the same group as the cold water species, reflecting an overlap in distribution on the northern inner shelf.

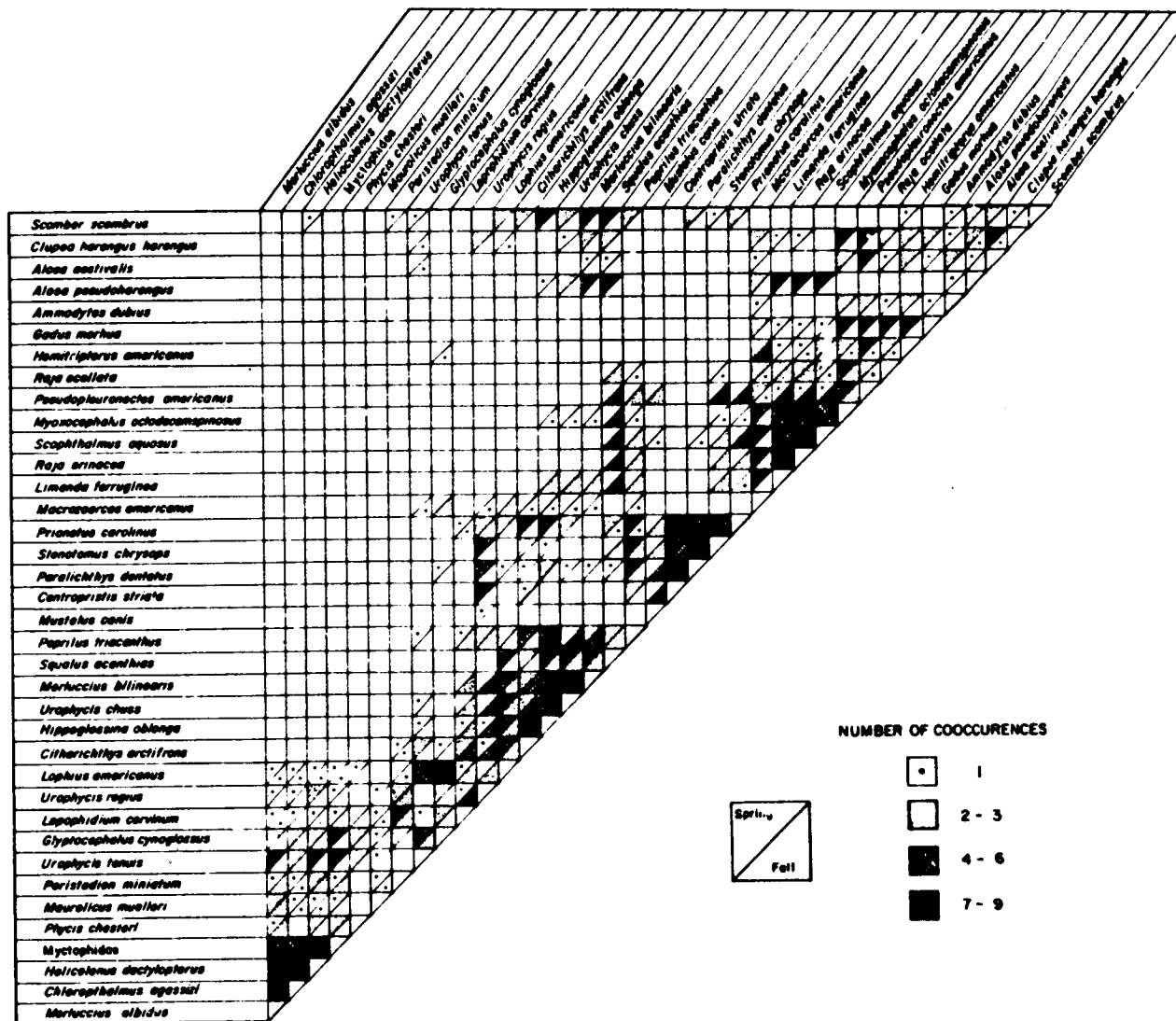


Figure 10-18. Cooccurrences within the same species cluster group for major species.

Merluccius bilinearis and Urophycis chuss were the two most consistently co-occurring species, appearing in the same group in all but one cruise. These two species formed the core of a third species group which was ubiquitous in the spring and nearly so in the fall. Both of these boreal species have broader temperature tolerances than the cold water groups noted above (see Part I this chapter) and were distributed throughout the study area during the spring and everywhere except in the warmest southern inshore waters in the fall. Abundances of these two species were generally greater on the outer shelf and shelf break, and were often in the same species group as Hippoglossina oblonga, an outer shelf resident, and Citharichthys arctifrons, a slope resident which also occurs on the outer shelf (Leonard and Joseph 1973). The latter two species also tended to co-occur with the warm temperate group, particularly Prionotus carolinus, during the spring when the warm water species were largely distributed along the outer shelf. Lophius americanus also commonly occurred in the same group as M. bilinearis and U. chuss, particularly in the spring.

Squalus acanthias and Peprilus triacanthus, two of the most dominant species, showed strong seasonal differences in the groups they clustered with. S. acanthias, a boreal cold water species, was widespread in the spring and occurred in the same ubiquitous group as M. bilinearis and U. chuss. During the fall cruises S. acanthias was restricted to the cooler waters on the northern shelf and generally clustered with the same cold water group as Limanda ferruginea. P. triacanthus generally appeared in the same group as the other warm temperate species in the spring (particularly Prionotus carolinus), when it was distributed along the outer shelf. In the fall P. triacanthus was widespread across the shelf and tended to be more concentrated in the cooler portions of the study area, and usually clustered with the semi-ubiquitous Merluccius bilinearis - Urophycis chuss group or occasionally with the cold water group.

Urophycis regius, another warm temperate species which inhabits cooler waters (Part I of this chapter; Struhsaker 1969), clustered similarly to Peprilus triacanthus, occurring with the warm temperate group in the spring and with the semi-ubiquitous group in the fall. U. regius, however, appeared to have slightly narrower temperature tolerances than P. triacanthus, as it tended to be restricted to the southern portion of the outer shelf in spring and to be more concentrated in deeper, warmer waters in the fall.

The fourth clearly defined recurrent species group was an upper slope group composed of myctophids, Helicolenus dactylopterus, Chlorophthalmus agassizi, and Merluccius albidus, which appeared consistently during both seasons. Glyptocephalus cynoglossus and Urophycis tenuis commonly co-occurred with members of this group during the spring, while in the fall these two species were more widely distributed across the outer shelf and tended to appear in small groups with Lophius americanus. Peristedion miniatum, Maurollicus muelleri, and Phycis chesteri occasionally appeared with the slope group, and

otherwise occurred in other small and variable outer shelf/slope groups. Lepophidium cervinum was in the same group as the slope species once during each season, but was generally either in one of the outer shelf-slope groups or, particularly in the fall, was widely distributed enough to be classified with the semi-ubiquitous group.

The strongest seasonality was displayed by the pelagic species: Scomber scombrus, Clupea harengus harengus, Alosa aestivalis, and Alosa pseudoharengus, which appeared in the clusters almost exclusively during the spring. All four of these species occurred contagiously throughout the study area. Scomber scombrus was the most abundant and usually clustered with the ubiquitous group. The greatest concentrations of S. scombrus occurred along the outer shelf, and as a result S. scombrus occasionally occurred with warm temperate or outer shelf/slope species. C. harengus and the two Alosa species were usually more concentrated on the inner shelf and generally clustered with the cold water group, although they occasionally did appear in the ubiquitous group.

During the summer cruise the cold water species group (dominated by Limanda ferruginea) and the Merluccius bilinearis - Urophycis chuss group persisted with basically the same composition as during the fall and spring cruises. A notable exception was the occurrence of Melanogrammus aeglefinus, a species rare during the other cruises, as a numerically dominant member of the M. bilinearis - U. chuss group. The catches of M. aeglefinus during this cruise were composed almost entirely of young of the year individuals which had probably drifted southwest of their spawning area on George's Bank. As noted above, the geographic distributions of these two species groups were intermediate to those found during the other two seasons but more closely approximated that during the fall, with the Merluccius group avoiding the warmer southern and inshore waters.

Peprilus triacanthus and Urophycis regius were the only truly ubiquitous as well as warm temperate species appearing in the summer cluster. The absence of the warm temperate species group noted during the other cruises (Prionotus carolinus, Stenotomus chrysops, Centropristis striata, Paralichthys dentatus) from the summer cluster is a reflection of the inshore migration of these species during the summer months. The Sea Breeze summer cruise in Chesapeake Bight occupied a number of stations inshore of the present study area and encountered large numbers of these species, particularly P. carolinus and S. chrysops (Part I of this chapter). The summer slope species group appeared with the same composition and distribution as during the other cruises.

Direct comparison of the results of this survey with the Chesapeake Bight study is difficult due to the difference in sampling regimes. The Chesapeake Bight study included a substantial portion of stations made inshore of and to the south of the present study area; conversely a majority of stations made during the cruises discussed here were north of or offshore the previous study area. As a result a greater

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proportion of warm temperate and inshore species appeared in the clusters from the Chesapeake Bight survey and more boreal and slope species are present in the present clusters. In addition, those species common to both analyses were sampled along different portions of their ranges and might therefore be expected to show different associations. Several of the major species associations noted above did, however, occur repeatedly in the Chesapeake Bight study. Merluccius bilinearis, Urophycis chuss, and Hippoglossina oblonga were in the same species group during four of the five cruises; during the fall cruise (which was later in the year than the present fall cruises), U. chuss was restricted to the northern portion of the study area and clustered with the cold water species group. The boreal cold water species Limanda ferruginea, Raja erinacea, Myoxocephalus octodecemspinosus, Pseudopleuronectes americanus, and Macrozoarces americanus all clustered in the same group during the fall and both winter cruises, while they were divided among two groups during the spring and summer. The warm temperate group consisting of Prionotus carolinus, Stenotomus chrysops, Paralichthys dentatus, and Centropristis striata all clustered together during two cruises while three of the four co-occurred during two cruises. The slope group species noted in the present study were not sampled adequately enough to make but isolated appearances in the Chesapeake Bight clusters.

Abundance and Biomass

Clark and Brown (1977), in a previous analysis which included the present data, noted drastic declines in fish biomass on the Northwest Atlantic continental shelf, a change which they related to overfishing. Their data indicated that this change was most severe in the area of the present study, with a 74% decline occurring in the mid-Atlantic study area (southern half of the current study between the periods 1967-68 and 1973-74) and a 52% decline in the Southern New England area (northern half of current study area) between the periods 1963-65 and 1972-74. While the present study verifies their results, it also suggests that the decline may not be as severe as originally indicated or may be reversing.

Clark and Brown utilized data from the fall surveys (as noted above, interpretation of the spring data is made extremely tenuous by the change in nets). Comparison of retransformed average biomass per tow for the periods 1967-1968 and 1973-1974 for both areas combined shows a decline in fish biomass of 57% (Table 10-18) which compares very well to Clark and Brown's figures if allowances are made for the greater biomass in the Southern New England area and the lower biomasses encountered in this area in 1967-68 as compared to 1963-65. In 1975, however, there was a sharp increase in biomass (Figure 10-14C), and if the years 1967-68 are compared to 1975-1976, the decline is only 41%. In addition, Clark and Brown noted that the mid-Atlantic decline was strongly influenced by large catches of searobins in 1967. If these catches are considered anomalous, and the period 1968-1969 is compared

Table 10-18. Changes in average biomass and abundance per tow for fall cruises 1967-1975.

Year	Biomass per tow (kg)		No. Individuals per tow	
1967	64		210	
1968	41		205	
1969	46		201	
1970	36		155	
1971	25		198	
1972	48		238	
1973	26		147	
1974	19		130	
1975	43		187	

	Mean	% Change		Mean	% Change	
1967-68	52.5	-57	-41	207.5	-33	-24
1968-69	43.5			203.0		
1973-74	22.5			138.5		
1974-75	31.0			158.5		

to 1974-75, the decline in biomass is further reduced to 29% and 1975 may be considered an above average year. Analysis of the data from the more recent cruises should greatly clarify this trend.

As noted by Clark and Brown, total fish biomass in this area is largely dependent on one species, Squalus acanthias. S. acanthias accounted for 40% of the total biomass during the fall cruises and over 55% during the spring cruises (Tables 10-19, 10-20). The recovery in biomass in 1975 was largely due to this species. Spring and fall catches of S. acanthias were highly unrelated (Figure 10-19A), indicating the highly migratory nature of this species.

Average total fish abundances remained much more constant than biomass (Figure 10-14B), although there was a 24% decline between the 1967-68 and 1974-75 fall cruises. Peprilus triacanthus was the most abundant species, accounting for over 30% of the individuals in the fall and about 17% in the spring (Tables 10-19, 10-20). P. triacanthus did not, however, exert the same large effect on overall abundance that Squalus acanthias did on biomass; in fact the variation in absolute abundances of P. triacanthus was quite different from the variation in transformed total abundances, reflecting the highly contagious distribution of this species (Figures 10-14B, 10-19B).

In addition to Squalus acanthias and Peprilus triacanthus, four other species made consistent, important contributions to abundance or biomass. Prionotus carolinus was very abundant during the fall 1967 cruise and then declined steadily during the remaining fall cruises (Figure 10-19C). In the spring however, this species showed a marked peak in 1969, declined, and then showed another sharp increase in 1973, after which it declined again. These peaks seem to be related to migratory patterns and resultant availability rather than to yearclass strength because biomass always followed much the same pattern as abundance.

Despite being the most consistently dominant species, Merluccius bilinearis only accounted for about 10% of the individuals and about 3% of the biomass taken, indicating its relatively uniform distribution. Its biomass and abundance followed similar patterns with the exception of fall 1974, when biomass levels were depressed despite relatively high abundances (Figure 10-20A), indicating a much higher proportion of younger fish. The stock did not appear to decline through the study period.

Limanda ferruginea, the most valuable commercial species in the area, as noted above underwent a drastic decline during the study period, although there was an anomalous peak in the fall of 1972 (Figure 10-20B). The decline in yellowtail stocks has been carefully documented to be the result of overfishing (Parrack 1973). Spring and fall catches of this species were more closely related than for any other major species.

Table 10-19. Average abundance and biomass per tow and percentage of total fish catch for major species during spring cruises.

	1968		1969		1970		1971		1972		1973		1974		1975		1976		Total	
	Abundance																			
Species	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	%	
<u>Peprilus triacanthus</u>	95.0	14.7	64.1	15.7	38.4	9.3	37.8	8.3	293.7	50.3	128.0	12.4	33.5	7.3	86.2	19.5	86.2	15.5	17.4	
<u>Prionotus carolinus</u>	42.0	6.5	126.9	31.0	45.2	10.9	11.8	2.6	13.6	2.3	344.9	33.4	45.2	9.9	28.4	6.4	15.5	2.8	14.7	
<u>Squalus acanthias</u>	88.5	13.7	42.8	10.5	35.3	8.6	46.4	10.1	80.8	13.8	144.1	14.0	86.1	18.8	76.8	17.4	44.5	8.0	12.8	
<u>Stenotomus chrysops</u>	133.5	20.7	14.0	3.4	146.0	35.3	170.1	37.1	58.0	9.9	3.6	0.4	39.3	8.6	20.6	4.7	4.2	0.8	11.6	
<u>Merluccius bilinearis</u>	60.0	9.3	27.9	6.8	21.4	5.2	47.3	10.3	18.3	3.1	68.0	6.6	109.0	23.8	113.6	25.7	87.5	15.7	10.1	
<u>Scomber scombrus</u>	79.0	12.3	1.4	0.4	18.2	4.4	18.4	4.0	13.0	2.2	113.1	11.0	9.8	2.1	4.5	1.0	6.7	1.2	5.7	
<u>Limanda ferruginea</u>	36.5	5.7	35.1	8.6	23.9	5.8	22.7	5.0	21.4	3.7	31.9	3.1	8.9	1.9	2.9	0.7	3.1	0.6	3.8	
<u>Urophycis chusa</u>	7.7	1.2	7.9	1.9	8.2	2.0	29.1	6.3	16.4	2.8	32.2	3.1	20.1	4.4	13.8	3.1	20.0	3.6	3.1	
<u>Raja erinacea</u>	4.6	0.7	7.9	1.9	2.8	0.7	9.5	2.1	5.2	0.9	36.4	3.5	11.5	2.5	24.3	5.5	11.7	2.1	2.3	
Total (all species)	607.3		409.4		413.1		458.1		584.0		1032.8		458.8		441.6		557.3			
	Biomass																			
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	%	
<u>Squalus acanthias</u>	89.6	58.2	47.6	44.0	20.3	29.5	92.9	65.1	126.6	72.4	168.8	49.7	135.0	64.0	74.1	55.1	63.4	52.9	55.7	
<u>Prionotus carolinus</u>	6.7	4.3	8.6	7.9	6.8	9.9	1.9	1.3	1.4	0.8	50.1	14.9	3.9	4.2	3.5	2.6	1.4	1.2	6.8	
<u>Scomber scombrus</u>	5.9	3.8	0.2	0.2	4.4	6.5	4.6	3.2	2.9	1.6	36.4	10.7	3.1	1.5	0.9	0.7	1.1	0.9	4.6	
<u>Merluccius bilinearis</u>	7.3	4.7	3.9	3.6	1.8	2.7	5.2	3.6	2.9	1.7	10.1	3.0	8.3	3.9	12.8	9.6	10.3	8.6	3.7	
<u>Limanda ferruginea</u>	8.1	5.3	7.5	6.9	6.1	8.9	5.3	3.7	5.5	3.2	8.3	2.4	2.7	1.9	0.9	0.7	0.9	0.8	3.2	
<u>Raja erinacea</u>	2.5	1.7	4.0	3.7	1.4	2.0	3.4	2.4	2.3	1.3	13.1	3.9	4.3	2.0	10.0	7.5	6.8	4.0	3.1	
<u>Peprilus triacanthus</u>	5.4	3.5	6.2	5.7	1.8	2.7	2.6	1.8	8.8	5.0	9.8	2.9	2.3	1.1	3.9	2.9	2.8	2.4	3.0	
<u>Stenotomus chrysops</u>	4.4	2.9	2.5	2.3	6.9	10.1	7.7	5.4	2.5	1.4	0.9	0.3	3.4	1.6	4.1	3.1	0.6	0.5	2.2	
<u>Urophycis chusa</u>	1.7	1.1	1.8	1.7	1.7	2.4	4.9	3.4	3.5	2.0	5.8	1.7	3.6	1.7	3.1	2.3	5.4	4.5	2.2	
Total (all species)	154.0		108.1		68.9		142.8		175.0		339.7		210.8		134.5		119.6			

Table 10-20. Average abundance and biomass per tow and percentage of total fish catch for major species during fall cruises.

	1967		1968		1969		1970		1971		1972		1973		1974		1975		Total
	Abundance																		
Species	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	%
<u>Peprilus triacanthus</u>	272.9	28.8	131.7	32.3	134.2	17.7	65.9	16.1	302.2	49.2	100.2	24.9	231.1	45.2	140.3	44.4	55.8	16.6	30.5
<u>Etrumeus teres</u>	4.4	0.7	19.4	4.7	61.0	8.1	16.0	38.8	118.0	19.2	1.7	0.4	123.5	24.2	5.9	1.9	42.6	12.7	12.0
<u>Merluccius bilinearis</u>	29.3	4.3	58.2	14.3	33.4	4.4	31.2	7.6	62.0	10.1	67.8	16.8	20.4	4.0	65.1	20.6	43.1	12.8	9.1
<u>Prionotus carolinus</u>	222.4	32.5	45.0	11.0	15.0	2.0	10.9	5.1	10.5	1.7	22.7	5.6	7.1	1.4	6.6	2.1	3.4	1.0	8.4
<u>Stenotomus chrysops</u>	26.6	3.9	12.8	3.1	70.9	9.4	11.7	2.9	8.5	1.4	34.4	8.6	20.9	4.1	8.8	2.8	43.9	13.1	5.3
<u>Limanda ferruginea</u>	31.0	4.5	36.3	8.9	32.4	4.3	25.6	6.2	24.0	3.9	53.3	13.2	5.0	1.0	2.1	0.7	1.0	0.3	4.8
<u>Squalus acanthias</u>	61.8	9.0	28.8	7.0	32.6	4.3	21.6	5.3	6.7	1.1	10.1	2.5	19.0	3.7	4.1	1.3	21.4	6.4	4.8
<u>Urophycis regius</u>	12.0	1.8	23.4	5.7	20.6	2.7	33.3	8.1	17.9	2.9	6.4	1.6	20.9	4.1	12.9	4.1	23.4	7.0	3.9
<u>Urophycis chuss</u>	5.7	0.8	9.9	2.4	12.9	1.7	11.7	2.9	13.5	2.2	24.8	6.2	10.3	2.0	4.4	1.4	14.7	4.4	2.4
Total (all species)	684.9		408.3		757.3		410.8		614.1		402.5		510.9		315.8		336.2		
	Biomass																		
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	%
<u>Squalus acanthias</u>	59.5	43.7	27.3	38.4	57.3	51.8	32.3	48.6	7.8	17.1	18.6	24.9	21.8	37.1	9.5	30.0	34.1	42.3	39.8
<u>Peprilus triacanthus</u>	12.1	8.9	11.0	15.5	10.1	9.2	3.9	5.9	8.5	18.7	3.8	5.0	9.5	16.0	5.9	18.5	3.2	3.9	10.0
<u>Prionotus carolinus</u>	39.0	25.9	5.3	7.4	2.0	1.8	2.5	3.8	1.1	2.4	2.9	3.9	0.8	1.3	0.7	2.3	0.3	0.4	7.9
<u>Limanda ferruginea</u>	6.2	4.6	6.9	9.7	7.7	7.0	6.3	9.5	4.6	10.0	13.6	8.1	1.2	2.1	0.6	2.0	0.2	0.3	7.0
<u>Merluccius bilinearis</u>	3.5	2.6	2.6	3.7	1.3	1.2	1.5	2.3	2.8	6.1	2.6	3.5	1.8	3.0	0.7	2.3	1.9	2.3	2.8
<u>Urophycis chuss</u>	1.2	0.9	2.0	2.9	3.1	2.8	1.8	2.7	2.0	4.5	3.7	4.9	1.5	2.5	0.3	1.0	2.2	2.7	2.6
<u>Etrumeus sadina</u>	0.3	0.2	0.4	0.6	2.2	2.0	4.4	6.6	2.9	6.3	0.1	0.1	3.4	5.8	0.2	0.5	1.6	2.0	2.2
<u>Stenotomus chrysops</u>	1.3	1.0	0.5	0.7	3.2	2.9	0.2	0.4	0.3	0.6	2.1	2.8	0.8	1.4	0.9	3.0	3.0	1.7	1.8
<u>Urophycis regius</u>	0.8	0.6	1.8	2.6	1.3	1.2	1.6	2.5	1.3	2.9	0.5	0.7	1.5	2.5	0.8	2.7	2.2	2.7	1.8
Total (all species)	136.1		71.2		110.5		60.5		47.8		74.9		59.7		31.7		80.5		

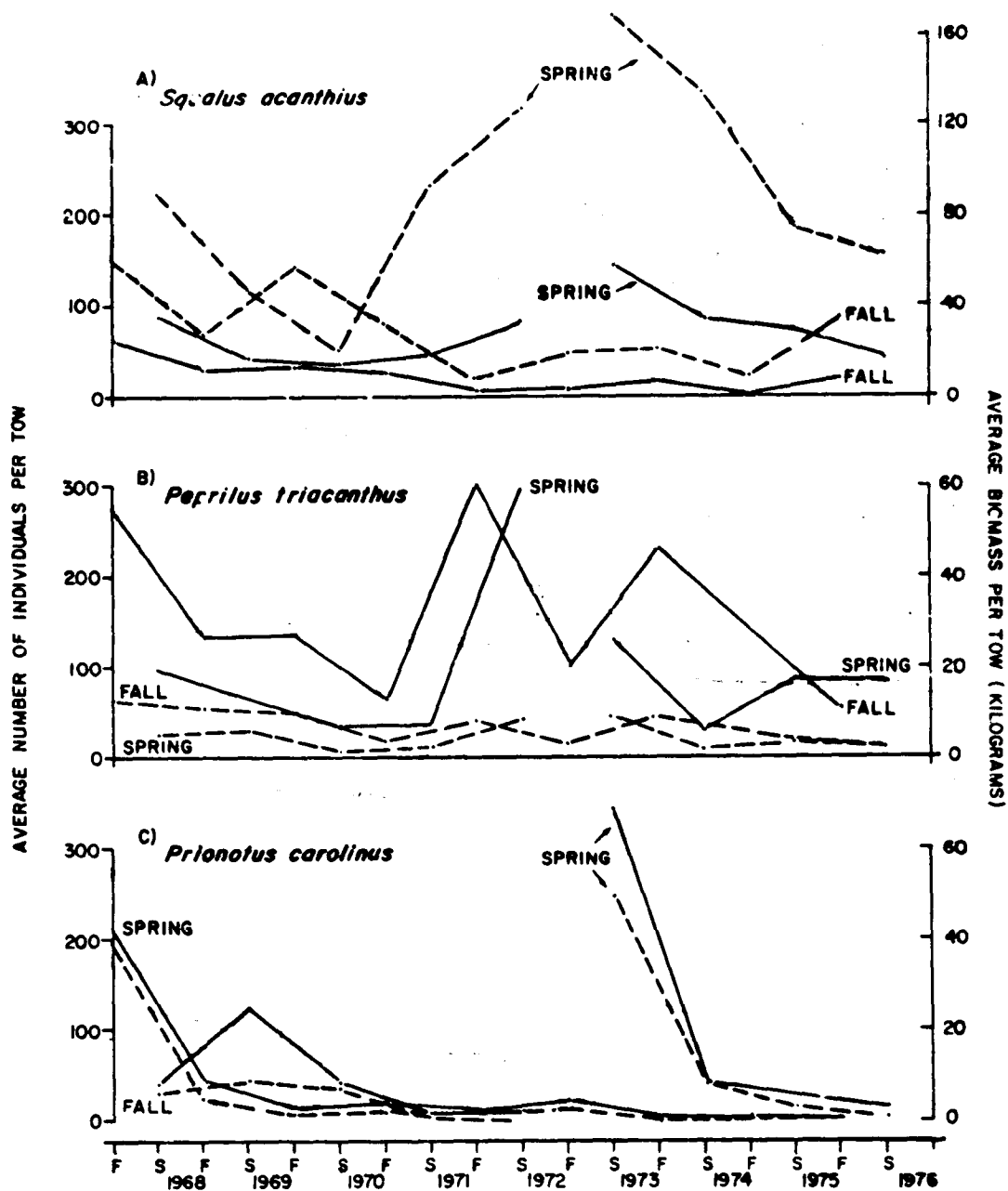


Figure 10-19. Mean number of individuals (—) and biomass (---) per tow of A) *Squalus acanthias*, B) *Peprilus triacanthus*, and C) *Prionotus carolinus* during NMFS Groundfish Surveys, Cape Hatteras to Cape Cod, 1967-76.

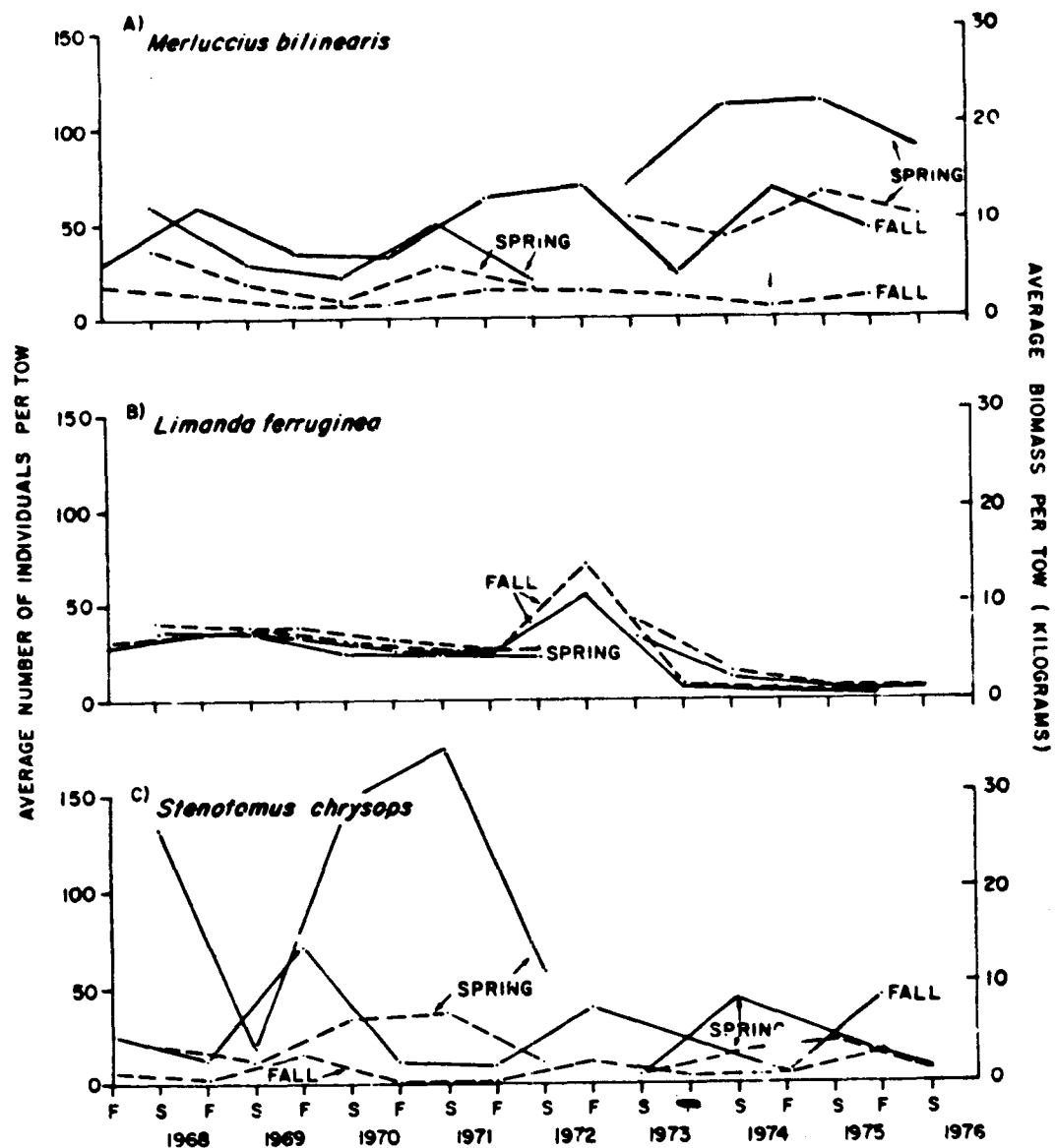


Figure 10-20. Mean number of individuals (—) and biomass (---) per tow of A) *Merluccius bilinearis*, B) *Limanda ferruginea*, and C) *Stenotomus chrysops* during NMFS Groundfish Surveys, Cape Hatteras to Cape Cod, 1967-76.

Stenotomus chrysops, like the other warm temperate species discussed here, was subject to wide fluctuations in abundance, particularly in the spring (Figure 10-20C). As with Prionotus carolinus, these fluctuations seemed more closely related to migration than yearclass strength. Whereas there appears to have been a large decline in the spring abundances of this species, the fall catches have remained relatively stable, suggesting the possibility of two separate stocks.

Dominance

Despite the highly variable abundances of the species involved, there were few major changes in species dominance throughout the study. Merluccius bilinearis, Perprilus triacanthus, and Squalus acanthias were consistently the three most dominant species during both major seasons (Table 10-21). Limanda ferruginea was the only major species to undergo a notable change in dominance, and even that decline was only pronounced during the last two years of the study. Several less abundant cold water species, namely Pseudopleuronectes americanus, Myoxocephalus octodecemspinosus, and Macrozoarces americanus underwent declines in dominance similar to L. ferruginea, but in view of their close association with the yellowtail, it can be assumed that they have been subjected to the same fishing pressure. Concurrent with the declines in dominance of these species was an increase in the dominance of Hippoglossina oblonga. While H. oblonga is generally a deeper living species their ranges do overlap, and the increased abundance of H. oblonga occurred within the range of L. ferruginea. Some degree of replacement seems likely.

The only other notable change in dominance occurred among the pelagic species. Scomber scombrus, Clupea harengus, and Alosa pseudoharengus all showed declines in dominance through the study period. While these species have been subjected to considerable foreign fishing pressure (Brown et al. 1975) their abundances are so variable that the decline may be only apparent.

Summary of Significant Findings

1. Despite large fluctuations in the abundance of individual species, the composition and distribution of fish species associations remained largely consistent over a nine year period on the Middle Atlantic shelf.
2. Four major types of species associations were noted;
 - a. cold water, dominated by Limanda ferruginea,
 - b. warm temperate, dominated by Prionotus carolinus and Stenotomus chrysops,
 - c. ubiquitous throughout the study area, dominated by Merluccius bilinearis and Urophycis chuss, and

d. upper slope, dominated by Helicolenus dactylopterus and myctophids.

Peprilus triacanthus and Squalus acanthias, the two most abundant species in terms of number and biomass respectively, showed seasonal difference in their species associations. P. triacanthus clustered with the warm temperate group in the spring but was ubiquitous in the fall, while S. acanthias was ubiquitous in the spring and clustered with the cold water group in the fall.

3. Distributions of these groups seemed closely related to temperature and depth.
4. Fish biomass appeared to decline during the study period, but apparently stabilized or recovered during the last year of the study. These fluctuations can be largely traced to one species, Squalus acanthias. Individual abundances followed the same pattern but showed less variation.
5. Species dominance remained generally stable throughout the study, with Merluccius bilinearis, Peprilus triacanthus, and Squalus acanthias the principal dominants. Limanda ferruginea showed a sharp decline during the study, presumably due to overfishing.

SECTION III: A SUMMARY OF THE DISTRIBUTION, ABUNDANCE, AND
FOOD HABITS OF DEMERSAL FISHES OF THE MID-ATLANTIC
OUTER CONTINENTAL SHELF--A CONCISE SOURCE DOCUMENT
FOR RESOURCE MANAGERS AND USERS

J. A. Musick

INTRODUCTION

The purpose of this document is to summarize the existing information on the distribution, abundance, and food habits of finfishes in the Middle Atlantic OCS in a concise, easily referable form. The data on which most of this summary has been based were presented and analyzed in Chapter 9 and Sections I and II of Chapter 10 of this report. Information for fishes of the continental slope was drawn from unpublished VIMS data and the literature (Musick 1976; Sedberry and Musick 1978; Haedrich et al. 1976; Schroeder 1955). The format of the present document is arranged so that resource managers and users concerned with OCS development can access accurate information about finfishes with a minimum of time, effort, and expense. Specifically not included in this report is information about the larger sharks, tunas, and billfishes.

RESULTS AND DISCUSSION

Faunal Characteristics

Most fishes of the Middle Atlantic OCS may be placed in one of three categories based on their migratory habits:

1. Fishes that remain on the outer continental shelf or upper slope for the entire year. Species in this category may undertake limited seasonal movements, but these are confined to the outer shelf and upper slope. For certain management purposes such as the monitoring of potential persistent pollutants (i.e., heavy metals) which may be produced on the OCS by oil development, this group of "resident" fishes would be the best to study because they would be chronically exposed, and would not be subject to contamination outside of the OCS (strongly migratory species may be exposed to OCS environmental pollutants only seasonally, and could be exposed to pollutants outside the OCS during the inshore phase of their migratory patterns).

2. Fishes that are boreal (northerly) in their faunal affinity. Most species in this group migrate north and offshore in summer and south and inshore in winter. During years when water temperatures are cooler (usually during severe winters) this group of fishes may migrate further south than during warmer years.

3. Fishes that are warm-temperate (southerly) in their faunal affinity. Most species in this group migrate north and inshore in summer, and south and offshore in winter.

Physiographic and Hydrographic Characteristics

Because the faunal assemblages of fishes in the OCS change seasonally, the faunal composition at any specific point (i.e., lease site) will depend on season, water depth, and temperature. Hydrographic conditions are closely correlated with season and water depth. Consequently, it is possible to construct a chart of the OCS with zones delineated by depth and latitude within which the fish assemblages may be characterized each season. Figure 10-21 includes 12 such zones, 3 of which are inshore (20-40 m depth), 3 of which comprise the middle continental shelf (40-100 m), 3 of which comprise the outer continental shelf (100-200 m), and 3 of which comprise the upper continental slope (200-500 m). The two geographic boundaries between these bathymetric zones (one along a line from Sandy Hook, N.J. to Hudson Canyon, the other along a line from Cape May, N.J. to Baltimore Canyon) are somewhat arbitrary but are located where faunal changes occur most often. If a resource user wishes to determine which species of fishes are dominant at a particular lease site in the OCS, he has only to determine in which zone the lease site is located (by latitude, longitude, and depth). Once he has determined the correct zone the user then may refer to Table 10-22 which lists the dominant fish species present in each zone in each season (common names given later in Table 10-24).

The fish fauna at lease sites on or adjacent to one of the geographic boundary lines (Sandy Hook/Hudson Canyon or Cape May/Baltimore Canyon) will probably include dominant species listed for both bathymetric zones adjacent to the lines. Migration of fishes occurs mostly in spring (April, May, June) and fall (October, November, December). Consequently, because fishes are actively moving during these seasons, the faunal composition at any one point on the OCS will be more variable from year to year in the spring or fall than in the summer (July, August, September) or winter (January, February, March).

Pertinent Characteristics of Dominant Fish Species

Certain information pertinent to environmental assessment and resource utilization is included in Table 10-23 for each dominant fish species:

1. Faunal Affinity: Fishes may be classified as boreal (B), warm-temperate (W.T.), outer shelf resident (R), anadromous (A), or other (O). This information may reflect the migratory pattern of the species in question.

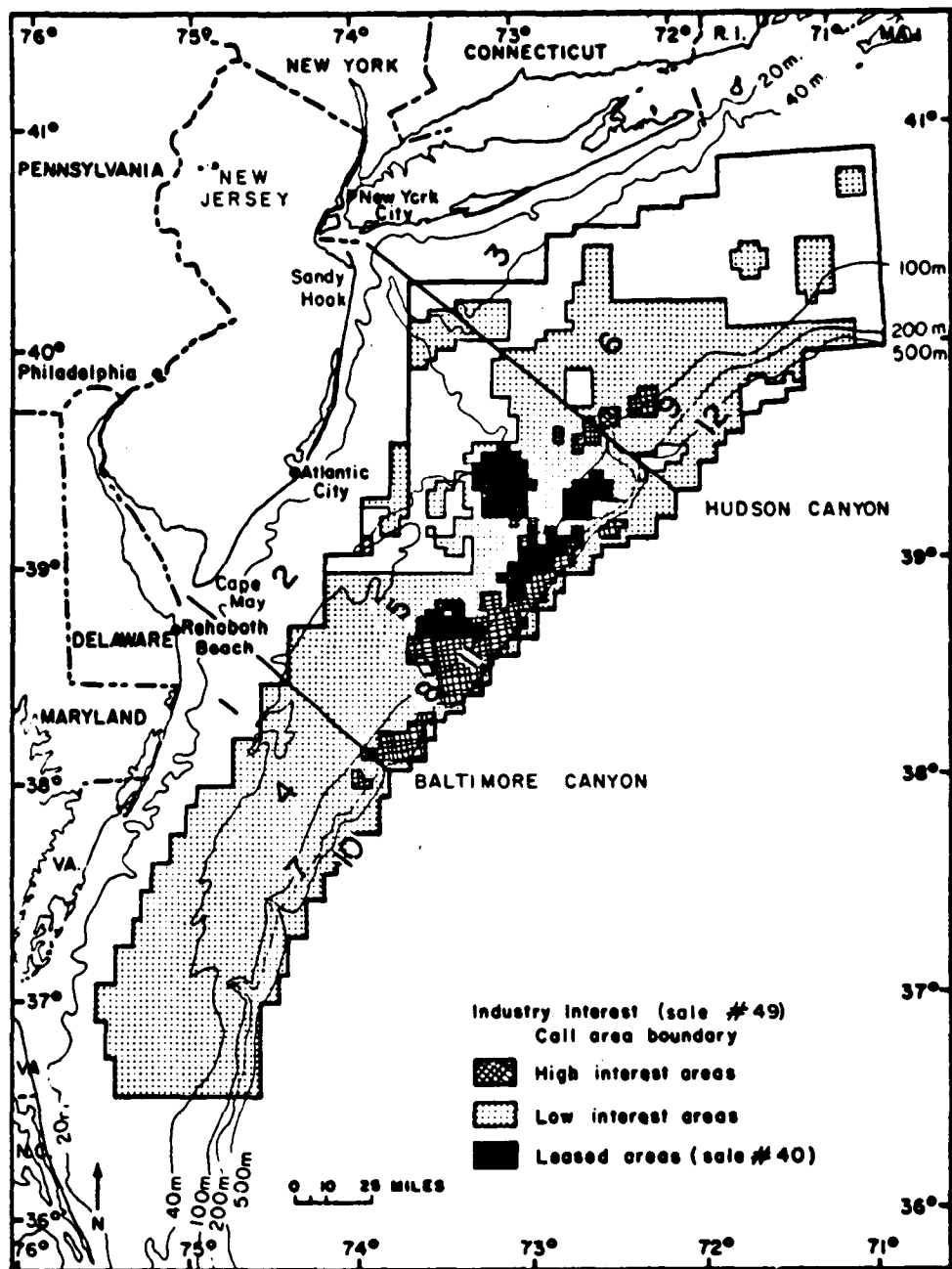


Figure 10-21. Chart of Middle Atlantic continental shelf lease areas divided into 12 zones to permit seasonal characterization of fish assemblages found therein. Zones 1-3 are inshore (20-40 m depth), zones 4-6 are middle continental shelf (40-100 m), zones 7-9 are outer continental shelf (100-200 m), and zones 10-12 are upper continental slope (200-500 m).

10-82

[illegible]

Table 10-23. Pertinent characteristics of dominant fishes of the Middle Atlantic Outer Continental Shelf.

Species	Faunal Affinity	Commercial Importance	Recreational Importance	Trophic Role	Life Style	Early Life History	Spawning Season	Spawning Importance in OCS
<i>Alosa aestivalis</i>	A	I	M	1	P,E	A	Sp	U
<i>Alosa pseudoharengus</i>	A	I	U	1	P,E	A	Sp	U
<i>Ammodytes dubius</i>	B	U	U	1	E	B/P	Wi	I
<i>Brevoortia tyrannus</i>	W.T.	I	U	1	P	P	Fl,Sp	"
<i>Centropristis striata</i>	W.T.	I	I	2	E	P	Su	I
<i>Chlorophthalmus agassizi</i>	R	U	U	1	B	P	"	I
<i>Citharichthys arctifrons</i>	R	U	U	1	B	P	Sp,Su	I
<i>Clupea harengus harengus</i>	B	I	U	1	P	B/P	Fl	M
<i>Coelorhynchus c. carminatus</i>	R	U	U	1	P	"	"	"
<i>Cynoscion regalis</i>	W.T.	I	I	2,3	P	P	Sp,Su	I
<i>Glyptocephalus cynoglossus</i>	B.R.	I	U	1	R	P	Sp,Su	I
<i>Gadus morhua</i>	B	I	I	2,3	E	P	Wi,Sp	I
<i>Helicolenus dactylopterus</i>	R	U	U	1	B	A/P	"	I
<i>Hippoglossina oblonga</i>	R	P	U	1,2	B	P	Sp,Su	I
<i>Lepophidium cervinum</i>	R	U	U	1	B	P	Su	I
<i>Limanda ferruginea</i>	B	I	U	1	B	P	Sp,Su	I
<i>Lophius americanus</i>	R	M	U	2,3	B	P	Sp	I
<i>Lycenchelys verrilli</i>	R	U	U	1	B	B/?	Su	I
<i>Macraroctes americanus</i>	B	M	U	1	B	B	Fl	I
<i>Morone chrysops</i>	R	U	U	1	P	P	Su	I
<i>Merluccius albidus</i>	R	I	U	2,1	E,P	P	Sp,Su	I
<i>Merluccius bilinearis</i>	B	I	I	2,1	E,P	P	Sp,Su	I
<i>Micropogon undulatus</i>	W.T.	I	I	1	E	P	Fl,Wi	I
<i>Mustelus canis</i>	W.T.	P	M	1,2	E	L	Sp,Su	I
Myctophidae	R	U	U	1	P	P	A	I
<i>Myoxocephalus octodecemspinosus</i>	B	U	U	1	B	B/P	Fl,Wi	M
<i>Myxine glutinosa</i>	R	U	U	1	B	B	A	I
<i>Nezumia bairdi</i>	R	U	U	1	E	P	Su	"
<i>Ophichthus cruentifer</i>	R	U	U	1	B	P	Su	I
<i>Paralichthys dentatus</i>	W.T.	I	I	2,1	B	P	Fl	I
<i>Peprilus triacanthus</i>	W.T.	I	U	1	E,P	P	Sp,Su	I
<i>Peristedion miniatum</i>	R	U	U	1	B	P	"	I
<i>Phycis chesteri</i>	R	P	U	1,2	E	P	Fl,Wi	I
<i>Pomatomus saltatrix</i>	W.T.	I	I	2,3	P	P	Sp,Su	I
<i>Prionotus carolinus</i>	W.T.	P	U	1	B	P	Su	I
<i>Pseudopleuronectes americanus</i>	B	I	I	1	B	B/P	Wi,Sp	U
<i>Raja eglanteria</i>	W.T.	P	U	1	B	B	Sp	I
<i>Raja erinacea</i>	B	P	U	1	B	B	A	I
<i>Scomber scombrus</i>	B	I	I	1	P,E	P	Sp,Su	I
<i>Scophthalmus aquosus</i>	O	U	U	1,2	B	P	Wi,Sp	I
<i>Squalus acanthias</i>	B	P	M	2	E	L	A,Wi	I
<i>Stenotomus chrysops</i>	W.T.	I	I	1	E	P	Sp	I
<i>Urophycis chuss</i>	B	I	I	1	E	P	Su	I
<i>Urophycis regius</i>	W.T.	P	U	1,2	E	P	Fl,Wi	I
<i>Urophycis tenuis</i>	B	M	U	1,2	E	P	Fl,Wi	U

Key to Symbols:

Faunal Affinity: A = Anadromous, B = Boreal, W.T. = Warm-temperate, R = Resident, O = Other

Commercial or Recreational Importance: I = Important, M = Marginally Important, U = Unimportant, P = Potentially Important

Trophic Role: 1 = Primary Predator, 2 = Secondary Predator, 3 = Tertiary Predator

Life Style: P = Pelagic, E = Eurybenthic, B = Benthic

Early Life History: A = Anadromous, B = Benthic Eggs and Larvae; B/P = Benthic Eggs/Pelagic Larvae, P = Pelagic Eggs and Larvae, L = Live Bearer

Spawning Season: Sp = Spring, Su = Summer, Fl = Fall, Wi = Winter, A = All Year (aseasonal)

Importance of OCS as Spawning Area: I = Important, M = Marginally Important, U = Unimportant

Table 10-24. Common names of fish species cited in Section III.

Species	Common Name
<u>Alosa aestivalis</u>	blueback herring
<u>Alosa pseudoharengus</u>	alewife
<u>Ammodytes dubius</u>	northern sandlance
<u>Brevoortia tyrannus</u>	menhaden
<u>Centropristis striata</u>	black seabass
<u>Chloropthalmus agassizi</u>	shortnose greeneye
<u>Citharichthys arctifrons</u>	Gulf Stream flounder
<u>Clupea harengus</u>	Atlantic herring
<u>Coelorrhinchus c. carminatus</u>	longnose grenadier
<u>Cynoscion regalis</u>	weakfish
<u>Glyptocephalus cynoglossus</u>	witch flounder
<u>Gadus morhua</u>	Atlantic cod
<u>Helicolenus dactylopterus</u>	blackbelly rosefish
<u>Hippoglossina oblonga</u>	fourspot flounder
<u>Lepophidium cervinum</u>	fawn cusk-eel
<u>Limanda ferruginea</u>	yellowtail flounder
<u>Lophius americanus</u>	goosefish
<u>Lycenchelys verrilli</u>	wolf eelpout
<u>Macrozoarces americanus</u>	ocean pout
<u>Maurolicus muelleri</u>	pearlsides
<u>Merluccius albidus</u>	offshore hake
<u>Merluccius bilinearis</u>	silver hake
<u>Micropogon undulatus</u>	Atlantic croaker
<u>Mustelus canis</u>	smooth dogfish
<u>Myoxocephalus octodecemspinosus</u>	longhorn sculpin
<u>Myxine glutinosa</u>	hagfish
<u>Nezumia bairdi</u>	marlin-spike
<u>Ophichthus cruentifer</u>	snake eel
<u>Paralichthys dentatus</u>	summer flounder
<u>Peprilus triacanthus</u>	butterfish
<u>Peristedion miniatum</u>	armored searobin
<u>Phycis chesteri</u>	longfin hake
<u>Pomatomus saltatrix</u>	bluefish
<u>Prionotus carolinus</u>	northern searobin
<u>Pseudopleuronectes americanus</u>	winter flounder
<u>Raja eglantaria</u>	clearnose skate
<u>Raja erinacea</u>	little skate
<u>Scomber scombrus</u>	Atlantic mackerel
<u>Scophthalmus aquosus</u>	window pane
<u>Squalus acanthias</u>	spiny dogfish
<u>Stenotomus chrysops</u>	scup
<u>Urophycis chuss</u>	red hake
<u>Urophycis regius</u>	spotted hake
<u>Urophycis tenuis</u>	white hake

2. Commercial Fishery Importance: Fishes may be classified as important (I), marginally important (M), unimportant (U), or potentially important (P).

3. Recreational Fishery Importance: Fishes may be classified as important (I), marginally important (M), unimportant (U), or potentially important (P).

4. Trophic Role: All dominant species of fishes examined in the OCS are predators (as opposed to detritivores or omnivores). However, important environmental phenomena such as biomagnification of persistent pollutants may be determined by the level at which a predator operates within the ecosystem. Because of their small size, juveniles of most OCS fishes operate as primary level predators, feeding on herbivores (i.e., zooplankton) or detritivores (i.e., benthic invertebrates). With increased age and growth, many OCS fishes are capable of consuming larger prey and thus operate as secondary or tertiary predators. Many fishes as adults may operate on more than one trophic level. In the tables, fishes may be classified as primary (1), secondary (2), or tertiary (3) predators. The classification applies to adults. Where a species consistently operates at two trophic levels, they are listed by order of relative importance to the species.

5. Life Style: Fishes of the OCS reflect a great diversity in motile ability, and activity pattern. Species may be characterized as benthic (B), those that lie on the bottom most of the time; engyenthic (E), those that hover or swim near the bottom most of the time; pelagic (P), those that hover or swim up in the water column or near the surface most of the time. Some pelagic species occur near the bottom during the day and migrate up into the water column to feed during the night. Such species are designated P, E.

6. Early Life History. Most fishes of the OCS may exhibit one of five basic early life history patterns. Species may be characterized as anadromous (A), those that leave the sea and ascend rivers and streams to spawn; pelagic (P), those that spawn pelagic eggs and have pelagic larvae which live in plankton and/or nekton communities; benthic (B), those that spawn benthic eggs which have direct development, or which hatch into pelagic larvae (B/P); live bearers (L), those that bear fully developed young directly.

7. Spawning Season. Species may be characterized as those that spawn in the Spring (Sp), Summer (Su), Fall (Fl), or Winter (Wi). If a species spawns during more than one season, the more important season is listed first. If a species may spawn at any time during the year, with no seasonal spawning peak, it is designated aseasonal (A).

8. OCS Importance as a Spawning Area: The Middle Atlantic OCS may be important (I), unimportant (U), or marginally important (M) as a spawning area to the fish populations which occur there.

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APPENDIX 10-A

Site Group Statistics, NMFS Groundfish Survey,
Cape Hatteras to Cape Cod, 1967-1976

Table 10-A-1. Cruise 68-3, Spring 1968.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		28	14	10	21	15	13	7
Abundance ln (x+1)	$\bar{x}$	5.44	4.91	6.32	5.42	5.73	5.57	4.44
	σ	0.831	1.103	1.071	1.384	1.598	0.870	1.426
No. of Species	$\bar{x}$	9.3	10.1	9.7	10.2	8.9	10.2	6.7
	σ	2.02	2.54	1.57	1.87	2.84	3.06	1.11
Biomass (kg) ln (x+1)	$\bar{x}$	4.10	3.35	4.36	3.95	4.14	3.64	2.76
	σ	0.713	1.226	0.944	1.358	1.477	0.710	1.619
Depth (m)	Range	26-75	20-84	24-77	55-238	60-201	126-280	152-329
	$\bar{x}$	45.4	50.1	41.1	101.2	135.5	204.6	273.6
Temperature (C)	Range	2-4	2-6	6-8	5-11	4-11	8-10	9-9
	$\bar{x}$	3.0	4.7	6.8	8.6	9.6	9.6	9.0

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-2. Cruise 69-2, Spring 1969.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII
No. of Stations		7	24	13	5	9	24	16	11
Abundance ln (x+1)	$\bar{x}$	5.59	5.39	4.66	3.39	4.21	5.13	4.94	5.26
	σ	0.887	0.794	0.619	0.380	1.002	0.990	1.878	1.345
No. of Species	$\bar{x}$	8.0	11.7	10.4	5.8	6.8	9.7	8.6	7.6
	σ	1.83	2.25	1.86	1.48	2.59	3.34	5.03	1.75
Biomass (kg) kn (x+1)	$\bar{x}$	4.00	4.48	3.43	2.31	3.95	3.94	3.40	3.88
	σ	0.920	0.666	0.671	0.227	1.213	1.126	2.027	1.289
Depth (m)	Range	27-51	22-75	29-77	22-27	26-128	24-329	69-280	128-379
	$\bar{x}$	36.7	49.4	53.7	23.4	67.1	112.0	146.9	265.2
Temperature (°C)	Range	2-4	2-4	3-7	4-5	5-11	4-12	6-13	10-12
	$\bar{x}$	2.9	3.3	4.5	4.6	7.3	8.7	9.6	11.1

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-3. Cruise 70-3, Spring 1970.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII	IX
No. of Stations		10	8	30	7	16	12	19	6	16
Abundance ln (x+1)	$\bar{x}$	4.13	5.48	5.25	4.10	4.56	5.56	5.36	5.80	4.61
	σ	0.854	0.569	0.636	1.291	1.590	1.668	1.371	1.482	0.806
No. of Species	$\bar{x}$	8.0	12.0	11.5	5.0	8.5	7.8	9.1	5.8	10.1
	σ	3.02	1.85	2.24	1.53	2.13	2.08	2.07	2.32	2.89
Biomass (kg) ln (x+1)	$\bar{x}$	3.43	4.70	3.87	2.35	3.09	3.23	3.88	3.11	3.57
	σ	0.973	0.411	0.700	1.396	1.520	1.478	1.221	1.141	1.282
Depth (m)	Range	29-75	35-86	31-101	18-110	29-143	37-126	91-165	66-232	128-329
	$\bar{x}$	44.7	54.3	61.6	49.4	80.3	84.1	128.8	159.5	253.6
Temperature (°C)	Range	5-7	4-5	4-8	7-12	5-12	7-13	5-14	7-16	9-13
	$\bar{x}$	5.9	4.6	5.3	8.7	6.8	9.8	10.6	12.4	11.2

$\bar{x}$ = mean value

σ = standard deviation

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Table 10-A-4. Cruise 71-1, Spring 1971.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		11	29	19	20	21	16
Abundance ln (x+1)	$\bar{x}$	4.30	5.05	4.78	4.73	5.95	5.18
	σ	1.551	0.618	0.953	1.623	1.307	0.975
No. of Species	$\bar{x}$	6.2	10.0	9.2	8.7	10.6	11.0
	σ	1.99	2.66	2.76	3.73	3.20	2.25
Biomass (kg) ln (x+1)	$\bar{x}$	3.20	4.12	3.34	3.23	4.45	4.01
	σ	0.596	0.611	0.970	1.518	1.446	1.295
Depth (m)	Range	18-64	27-80	22-95	20-221	33-214	135-329
	$\bar{x}$	39.2	49.3	59.5	96.4	111.1	265.9
Temperature (°C)	Range	4-9	2-7	4-9	7-12	8-14	6-11
	$\bar{x}$	6.3	3.7	5.7	9.4	10.8	8.7

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-5. Cruise 72-2, Spring 1972.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII	IX
No. of Stations		6	15	18	6	26	11	13	13	12
Abundance ln (x+1)	$\bar{x}$	5.20	4.93	5.31	3.58	5.20	5.16	5.60	4.50	4.68
	σ	0.757	1.084	0.528	0.475	1.710	1.485	0.719	1.196	0.598
No. of Species	$\bar{x}$	10.5	8.8	12.9	3.3	8.0	7.4	10.4	6.9	11.4
	σ	0.54	2.78	1.95	1.03	2.90	2.50	2.72	1.97	2.31
Biomass (kg) ln (x+1)	$\bar{x}$	4.64	3.65	4.70	4.31	4.03	3.51	4.25	3.73	3.61
	σ	0.667	0.740	0.742	0.497	1.044	1.334	0.907	1.193	0.867
Depth (m)	Range	27-44	29-80	35-86	26-46	26-132	33-349	53-161	84-285	88-336
	$\bar{x}$	34.5	42.1	59.1	34.2	74.1	160.6	103.7	170.3	258.9
Temperature (°C)	Range	3-4	4-7	3-9	8-9	5-13	8-13	8-14	8-14	5-13
	$\bar{x}$	3.5	5.5	5.7	8.5	9.9	11.6	10.8	11.2	9.0

$\bar{x}$ = mean value

σ = standard deviation

Table 10-A-6. Cruise 73-3, Spring 1973.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		47	29	27	14	11	3	14
Abundance ln (x+1)	$\bar{x}$	6.06	5.33	6.38	5.95	5.73	5.03	6.26
	σ	0.598	1.014	0.763	1.878	2.112	0.336	1.462
No. of Species	$\bar{x}$	14.6	10.8	12.7	9.9	9.8	9.0	14.0
	σ	1.92	2.71	1.83	3.76	2.09	0.0	3.31
Biomass (kg) ln (x+1)	$\bar{x}$	4.90	4.57	5.15	4.67	3.86	3.15	4.23
	σ	0.635	0.788	0.862	1.273	1.407	0.320	1.049
Depth (m)	Range	26-69	24-75	60-152	48-152	95-179	110-135	188-335
	$\bar{x}$	47.4	42.3	85.7	94.1	141.5	123.7	253.4
Temperature (°C)	Range	3-8	3-9	7-16	7-12	11-14	8-8	10-14
	$\bar{x}$	5.2	6.2	9.7	9.3	12.2	8.0	12.4

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-7. Cruise 74-4, Spring 1974.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		19	12	27	11	10	12
Abundance ln (x+1)	$\bar{x}$	6.18	4.65	5.87	5.44	4.89	5.39
	σ	1.015	0.895	1.050	1.441	0.380	0.661
No. of Species	$\bar{x}$	14.1	10.5	12.2	7.5	12.5	14.5
	σ	2.51	2.39	2.11	3.23	4.47	2.57
Biomass (kg) ln (x+1)	$\bar{x}$	4.74	4.51	4.38	4.58	2.90	4.11
	σ	0.775	0.730	1.080	1.296	0.673	0.603
Depth (m)	Range	22-82	35-82	29-123	27-148	66-300	219-338
	$\bar{x}$	46.6	58.6	82.0	73.4	168.6	277.8
Temperature (°C)	Range	5-8	6-11	7-13	10-14	9-14	8-15
	$\bar{x}$	6.3	7.8	10.2	12.2	12.5	11.0

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-8. Cruise 75-3, Spring 1975.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		19	16	14	12	13	16
Abundance ln (x+1)	$\bar{x}$	5.56	5.67	5.55	6.22	4.57	5.58
	σ	0.998	0.680	1.679	0.852	0.874	0.627
No. of Species	$\bar{x}$	13.2	10.4	7.8	11.8	10.3	15.1
	σ	2.47	1.70	2.42	2.08	3.44	2.87
Biomass (kg) ln (x+1)	$\bar{x}$	4.31	4.79	4.60	5.20	3.27	3.69
	σ	0.624	0.825	1.152	0.845	1.054	0.842
Depth (m)	Range	24-77	38-73	33-115	57-104	66-201	123-302
	$\bar{x}$	42.6	57.0	70.9	86.3	126.5	213.2
Temperature (°C)	Range	3-7	5-8	5-11	7-11	8-12	8-12
	$\bar{x}$	4.8	6.4	8.6	9.5	10.9	10.8

$\bar{x}$ = mean value

σ = standard deviation

Table 10-A-9. Cruise 76-2, Spring 1976.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		10	35	10	14	15	16	17
Abundance ln (x+1)	$\bar{x}$	5.84	5.63	4.99	4.70	6.18	5.25	5.68
	σ	1.849	1.122	0.800	0.906	0.521	1.316	0.753
No. of Species	$\bar{x}$	9.7	12.0	8.1	9.8	13.7	10.8	17.3
	σ	2.62	3.05	2.33	3.14	1.98	3.25	4.97
Biomass (kg) ln (x+1)	$\bar{x}$	3.59	4.27	4.99	3.90	5.27	3.48	4.13
	σ	1.019	0.991	0.941	0.959	0.896	0.924	0.700
Depth (m)	Range	18-58	22-90	41-67	27-120	39-101	53-174	85-341
	$\bar{x}$	28.8	46.1	53.2	62.3	72.5	120.4	244.7
Temperature (°C)	Range	6-10	4-8	7-10	9-14	8-12	8-15	6-12
	$\bar{x}$	7.7	5.7	8.2	11.1	9.7	11.8	10.1

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-10. Cruises 67-20 and 67-21, Fall 1967.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		14	13	23	5	24	25	17
Abundance ln (x+1)	$\bar{x}$	5.58	5.88	6.03	5.15	4.82	4.34	4.63
	σ	1.840	0.630	0.653	0.384	1.034	2.135	1.306
No. of Species	$\bar{x}$	8.3	10.8	12.6	13.0	8.3	5.7	8.7
	σ	3.77	3.51	3.11	0.71	2.64	2.72	1.69
Biomass (kg) ln (x+1)	$\bar{x}$	3.91	4.96	5.12	4.04	3.47	2.01	1.96
	σ	1.400	0.949	0.873	0.746	1.312	1.424	0.655
Depth (m)	Range	22-48	27-49	31-73	38-73	60-219	33-223	93-320
	$\bar{x}$	32.4	37.6	50.7	58.6	99.1	137.8	160.5
Temperature (°C)	Range	10-23	10-15	8-13	6-9	7-12	9-18	9-13
	$\bar{x}$	16.5	12.0	9.8	7.6	9.3	11.5	11.1

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-1¹. Cruise 68-17, Fall 1968.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII
No. of Stations		19	13	14	18	12	27	9	9
Abundance ln (x+1)	$\bar{x}$	4.88	5.88	5.34	6.01	5.20	4.87	4.73	4.35
	σ	1.539	0.488	1.238	0.638	1.755	1.040	1.779	0.646
No. of Species	$\bar{x}$	7.4	13.4	7.1	12.7	4.8	9.0	5.9	7.6
	σ	2.73	2.10	2.16	2.40	1.86	2.94	2.37	3.17
Biomass (kg) ln (x+1)	$\bar{x}$	3.55	4.55	4.25	4.35	2.88	2.53	2.29	2.05
	σ	1.415	0.748	1.548	0.619	1.766	0.872	1.401	0.723
Depth (m)	Range	18-44	27-62	33-57	46-91	16-287	53-315	66-172	203-357
	$\bar{x}$	30.8	39.5	43.4	63.2	95.2	127.4	122.4	300.5
Temperature (°C)	Range	11-21	8-15	8-14	7-15	7-21	7-15	11-15	8-11
	$\bar{x}$	17.7	11.7	10.4	10.1	12.1	11.3	12.8	9.6

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-12. Cruise 69-11, Fall 1969.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		15	15	13	27	21	18
Abundance ln (x+1)	$\bar{x}$	5.05	6.07	5.97	4.62	4.95	4.85
	σ	1.462	0.739	0.661	1.666	1.634	1.778
No. of Species	$\bar{x}$	10.5	13.5	12.4	6.1	7.9	7.7
	σ	3.20	2.53	2.22	2.48	2.50	2.57
Biomass (kg) ln (x+1)	$\bar{x}$	3.65	4.84	4.56	3.31	2.88	2.09
	σ	1.200	1.003	0.643	1.582	1.325	1.152
Depth (m)	Range	24-59	33-80	57-80	37-218	55-196	71-351
	$\bar{x}$	37.1	49.7	66.5	68.5	103.2	226.0
Temperature (°C)	Range	17-21	12-18	10-12	9-18	9-13	10-18
	$\bar{x}$	19.1	14.1	10.8	12.6	11.3	12.1

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-13. Cruise 70-6, Fall 1970.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII	IX
No. of Stations		10	17	21	13	14	11	12	8	7
Abundance ln (x+1)	$\bar{x}$	5.09	4.79	6.00	3.12	4.95	4.23	4.92	3.30	4.18
	σ	1.560	1.170	1.098	1.392	0.725	0.977	2.311	1.489	0.511
No. of Species	$\bar{x}$	6.6	9.9	11.7	3.6	7.6	6.5	4.9	4.0	9.9
	σ	2.99	3.67	2.77	1.76	1.90	2.02	2.47	2.51	2.41
Biomass (kg) ln (x+1)	$\bar{x}$	3.07	4.47	4.46	1.82	2.48	1.52	2.74	1.59	1.84
	σ	1.446	1.325	0.789	1.631	0.801	0.926	1.890	1.744	0.519
Depth (m)	Range	20-40	26-80	33-80	33-192	46-230	86-232	37-274	26-313	199-329
	$\bar{x}$	28.6	46.1	59.9	63.2	85.1	146.4	129.3	134.3	266.3
Temperature (°C)	Range	8-18	7-15	8-13	5-13	6-13	9-13	8-13	8-13	8-11
	$\bar{x}$	12.4	11.9	9.9	7.1	9.4	11.6	11.6	10.0	9.6

$\bar{x}$ = mean value

σ = standard deviation

Table 10-A-14. Cruise 71-6, Fall 1971.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		11	28	28	27	10	11
Abundance ln (x+1)	$\bar{x}$	5.97	5.73	4.59	4.99	5.59	3.72
	σ	1.628	1.401	1.540	1.144	2.436	0.972
No. of Species	$\bar{x}$	7.6	13.2	6.9	8.0	4.9	7.0
	σ	3.29	2.84	3.51	2.34	1.73	3.00
Biomass (kg) ln (x+1)	$\bar{x}$	4.28	3.78	2.58	2.13	2.94	1.17
	σ	0.660	1.116	1.515	1.018	1.817	0.566
Depth (m)	Range	22-123	27-80	31-124	33-315	48-219	274-320
	$\bar{x}$	38.9	47.5	62.8	122.6	106.3	295.7
Temperature (°C)	Range	10-22	6-17	6-22	7-13	12-16	9-13
	$\bar{x}$	17.5	10.7	10.9	10.5	13.0	10.2

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-15. Cruise 72-8, Fall 1972.

SITE GROUP		I	II	III	IV	V	VI
No. of Stations		8	16	25	11	21	22
Abundance ln (x+1)	$\bar{x}$	4.69	3.61	6.35	6.09	4.69	4.28
	σ	1.412	0.819	1.088	0.743	1.434	1.157
No. of Species	$\bar{x}$	8.8	7.7	13.9	13.6	8.0	10.0
	σ	2.86	1.85	3.88	2.76	2.89	4.52
Biomass (kg) ln (x+1)	$\bar{x}$	3.76	2.86	4.81	4.38	2.56	1.72
	σ	1.263	0.957	1.121	0.637	0.897	0.892
Depth (m)	Range	18-38	29-59	40-79	60-88	42-165	119-340
	$\bar{x}$	28.3	37.8	57.2	72.1	102.4	235.9
Temperature (°C)	Range	19-21	12-20	9-18	10-13	9-18	7-13
	$\bar{x}$	20.4	16.4	12.4	11.1	12.4	10.1

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-16. Cruise 73-8, Fall 1973.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		12	23	20	13	8	21	6
Abundance ln (x+1)	$\bar{x}$	4.43	5.14	5.50	2.76	5.48	4.89	4.03
	σ	2.179	1.598	0.937	1.312	2.355	1.176	1.594
No. of Species	$\bar{x}$	6.7	9.9	10.5	3.8	3.6	8.8	7.2
	σ	2.10	3.55	2.83	1.28	1.68	2.22	1.60
Biomass (kg) ln (x+1)	$\bar{x}$	3.17	3.95	3.52	1.64	2.88	2.58	2.36
	σ	1.217	1.368	0.892	0.878	1.715	0.915	0.832
Depth (m)	Range	26-40	26-79	48-101	40-271	80-137	57-320	241-366
	$\bar{x}$	31.4	38.7	73.0	101.0	102.3	151.9	321.5
Temperature (°C)	Range	11-19	10-21	10-14	9-15	11-16	11-16	6-16
	$\bar{x}$	15.6	15.7	11.5	11.5	13.8	13.1	10.7

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-17. Cruise 74-11, Fall 1974.

SITE GROUP		I	II	III	IV	V	VI	VII
No. of Stations		14	12	14	16	18	16	9
Abundance ln (x+1)	$\bar{x}$	4.75	4.47	5.12	4.69	4.77	5.22	4.76
	σ	2.027	0.757	1.155	1.458	1.896	0.660	1.059
No. of Species	$\bar{x}$	8.5	9.8	11.4	8.1	4.1	7.0	13.3
	σ	4.48	2.58	4.21	3.04	1.77	2.12	4.03
Biomass (kg) ln (x+1)	$\bar{x}$	3.50	3.18	3.83	1.99	2.24	2.01	2.44
	σ	1.498	1.124	0.703	0.681	1.355	0.548	0.819
Depth (m)	Range	20-60	27-51	33-77	33-243	33-397	40-146	236-433
	$\bar{x}$	35.7	36.2	57.1	106.6	118.2	98.4	310.9
Temperature (°C)	Range	12-25	10-21	11-16	10-13	9-17	11-18	9-13
	$\bar{x}$	17.2	15.3	12.9	11.1	12.4	13.3	9.8

 $\bar{x}$ = mean value σ = standard deviation

Table 10-A-18. Cruise 75-12, Fall 1975.

SITE GROUP		I	II	III	IV	V	VI	VII	VIII
No. of Stations		6	7	23	18	20	12	10	15
Abundance ln (x+1)	$\bar{x}$	4.71	2.73	5.94	5.59	4.24	5.56	3.96	4.53
	σ	2.283	0.842	0.772	1.090	1.167	0.951	0.889	1.102
No. of Species	$\bar{x}$	12.2	4.1	12.0	9.2	5.6	10.7	4.9	11.6
	σ	8.13	1.77	1.88	2.09	1.87	1.72	1.85	3.97
Biomass (kg) ln (x+1)	$\bar{x}$	4.64	2.62	4.38	4.28	2.66	3.37	2.08	2.43
	σ	1.843	1.388	1.027	1.184	1.147	0.856	1.278	0.952
Depth (m)	Range	26-68	20-82	22-69	42-82	27-144	60-155	29-229	187-338
	$\bar{x}$	35.3	41.7	44.9	59.4	85.3	102.8	111.4	261.2
Temperature (°C)	Range	14-19	12-18	10-16	10-14	10-17	10-12	10-17	7-13
	$\bar{x}$	16.8	15.3	13.6	11.4	12.3	11.4	12.7	10.1

$\bar{x}$ = mean value

σ = standard deviation

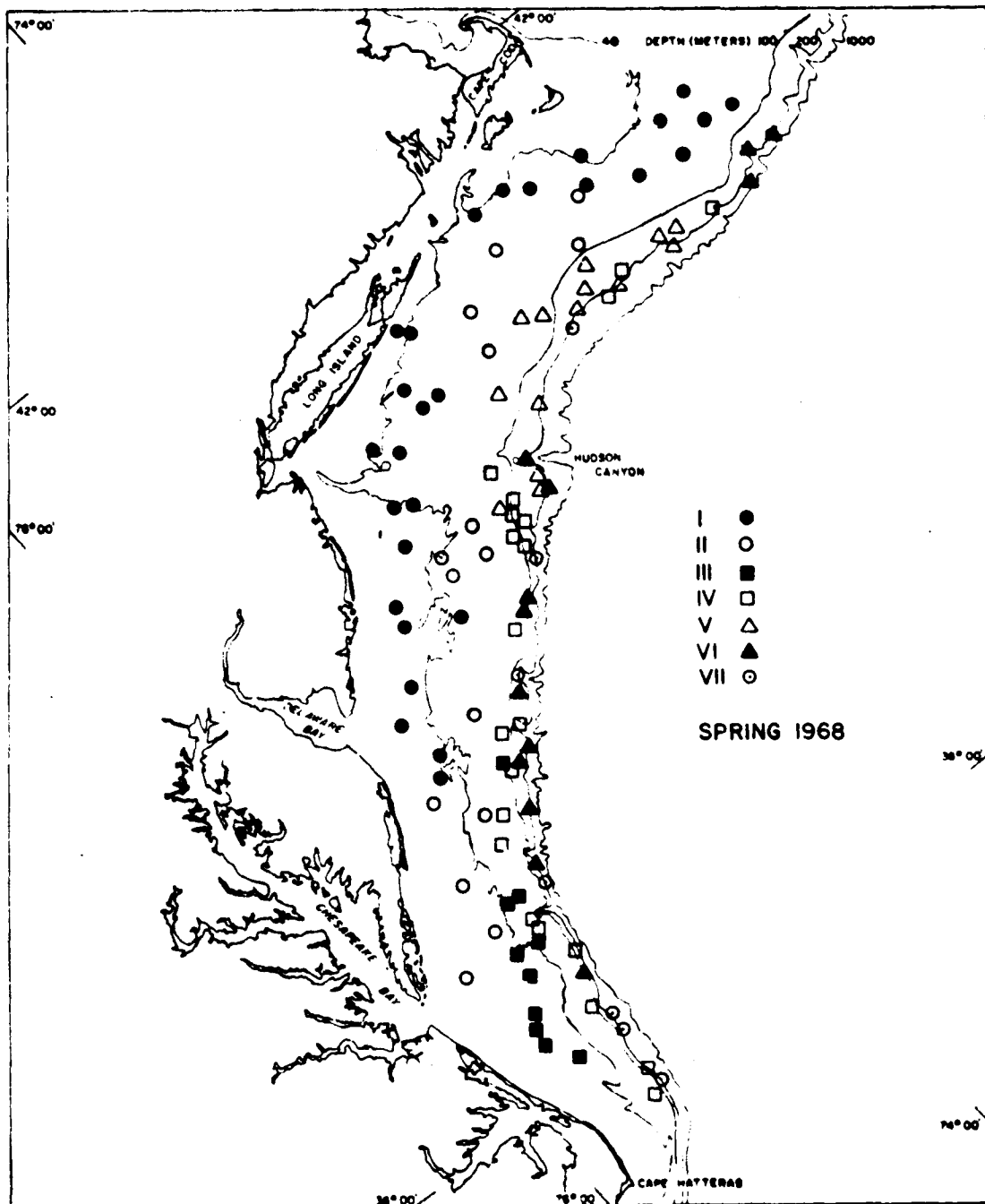
Table 10-A-19. Cruise 69-8, Summer 1969.

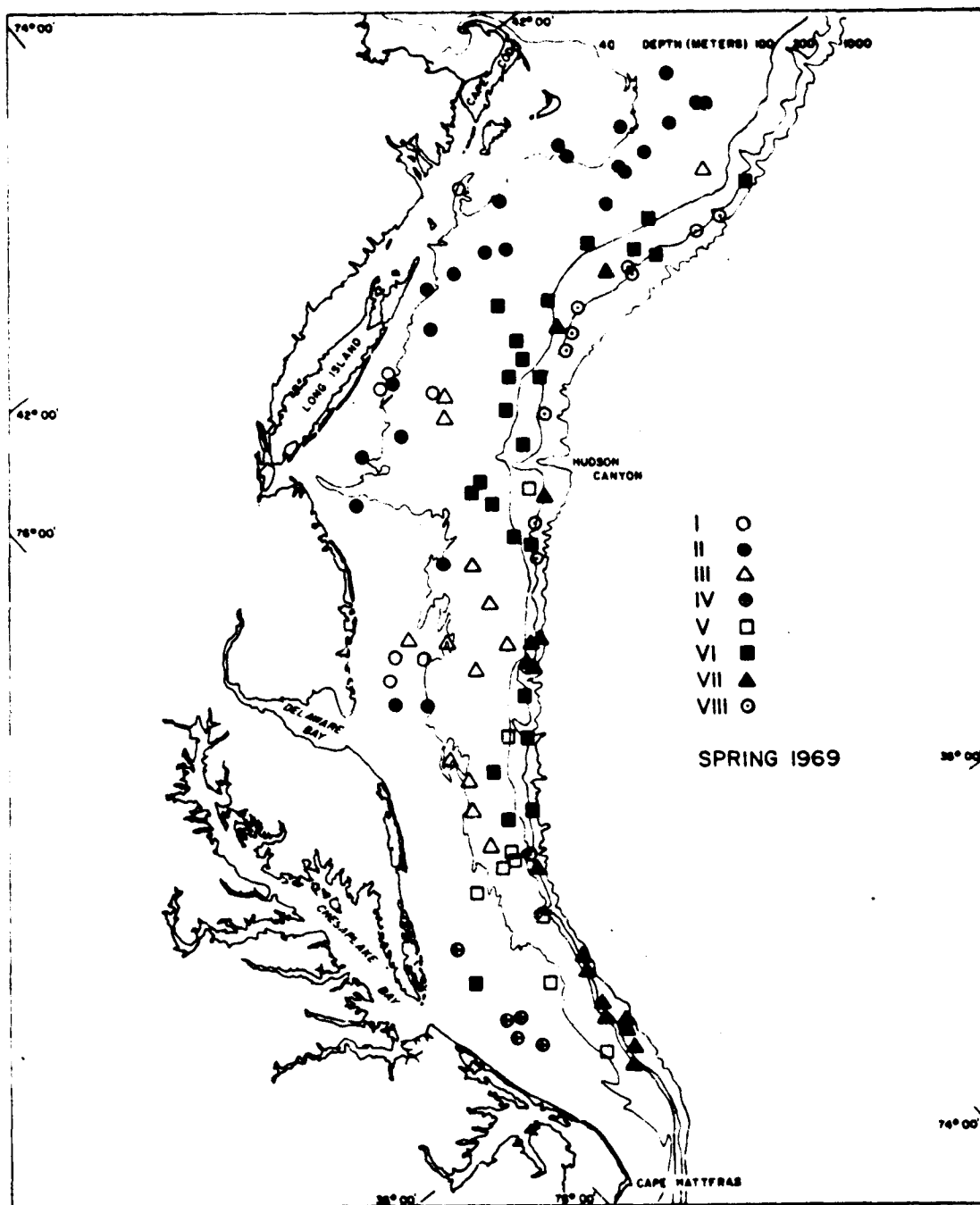
SITE GROUP		I	II	III	IV	V
No. of stations		23	37	15	12	16
Abundance ln (x+1)	$\bar{x}$	5.28	4.35	4.32	4.69	3.64
	σ	0.843	2.224	1.818	1.393	1.539
No. of Species	$\bar{x}$	11.8	5.7	4.0	6.8	7.2
	σ	2.76	2.74	1.96	2.83	3.99
Biomass (kg) ln (x+1)	$\bar{x}$	3.55	2.35	1.77	2.27	1.40
	σ	0.997	1.662	1.547	1.770	0.962
Depth (m)	Range	31-86	27-141	24-88	60-187	66-375
	$\bar{x}$	56.1	67.5	43.3	128.5	235.1
Temperature (°C)	Range	6-13	6-16	7-15	10-14	8-12
	$\bar{x}$	9.0	9.2	11.0	11.9	10.1

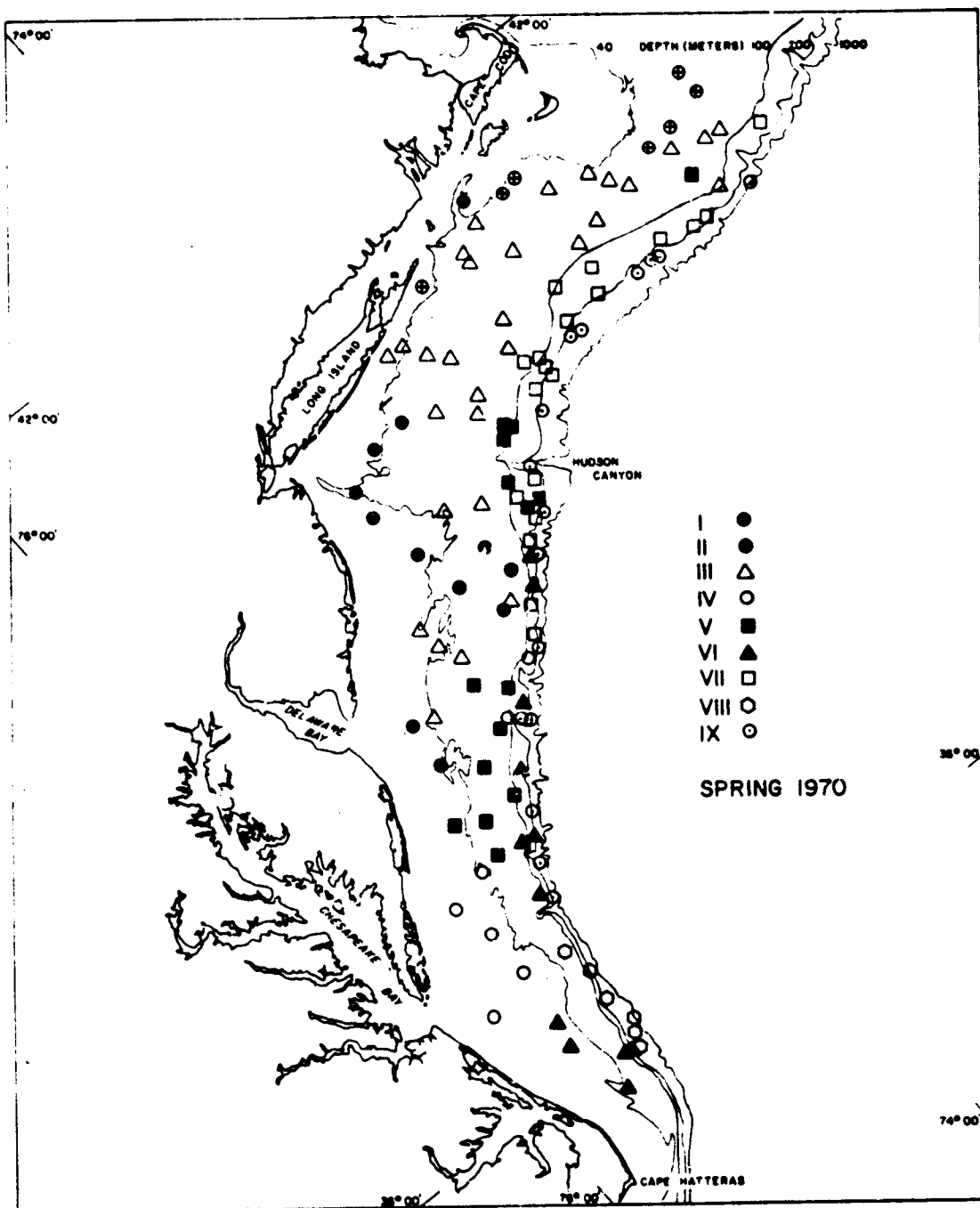
 $\bar{x}$ = mean value σ = standard deviation

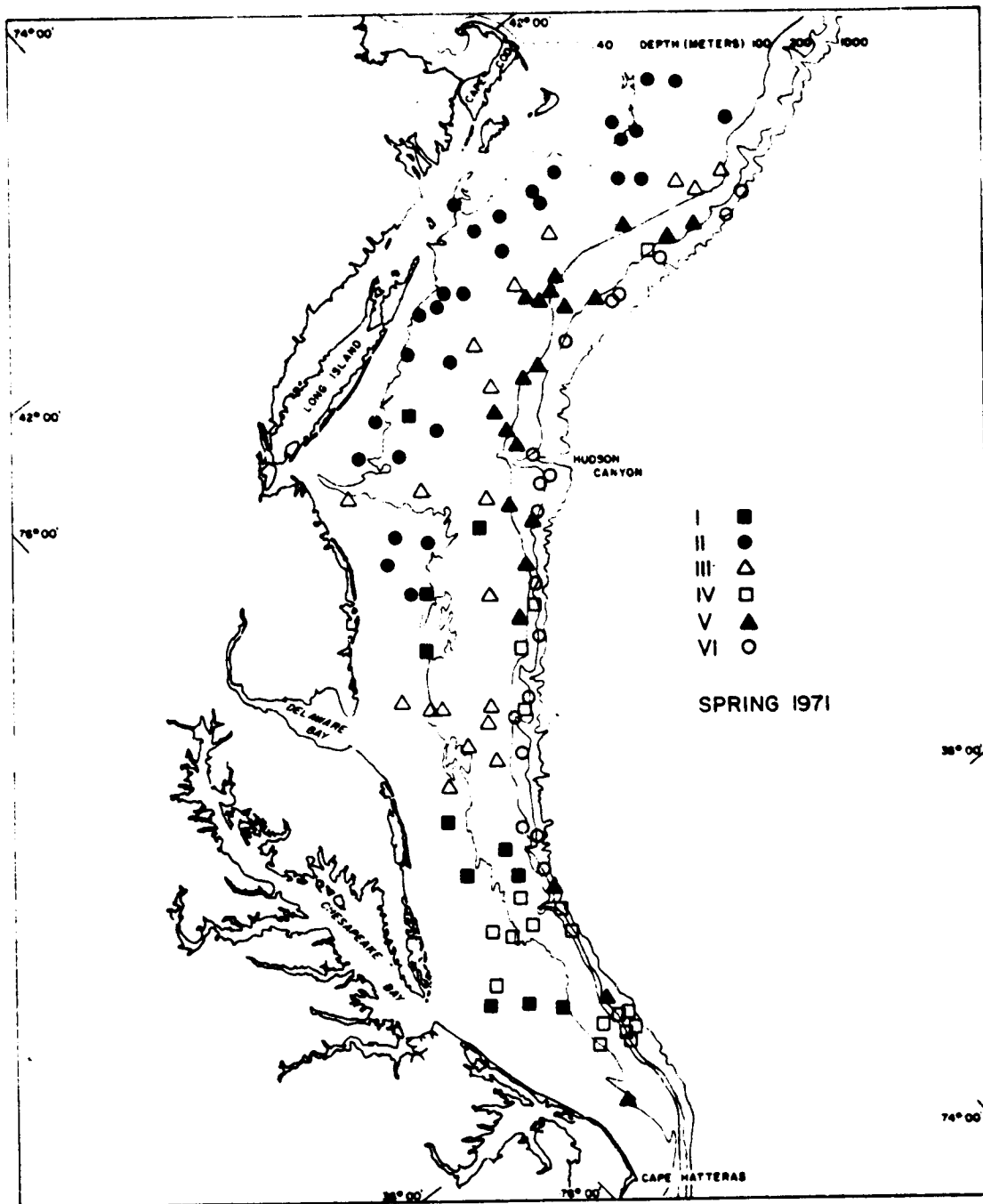
APPENDIX 10-B

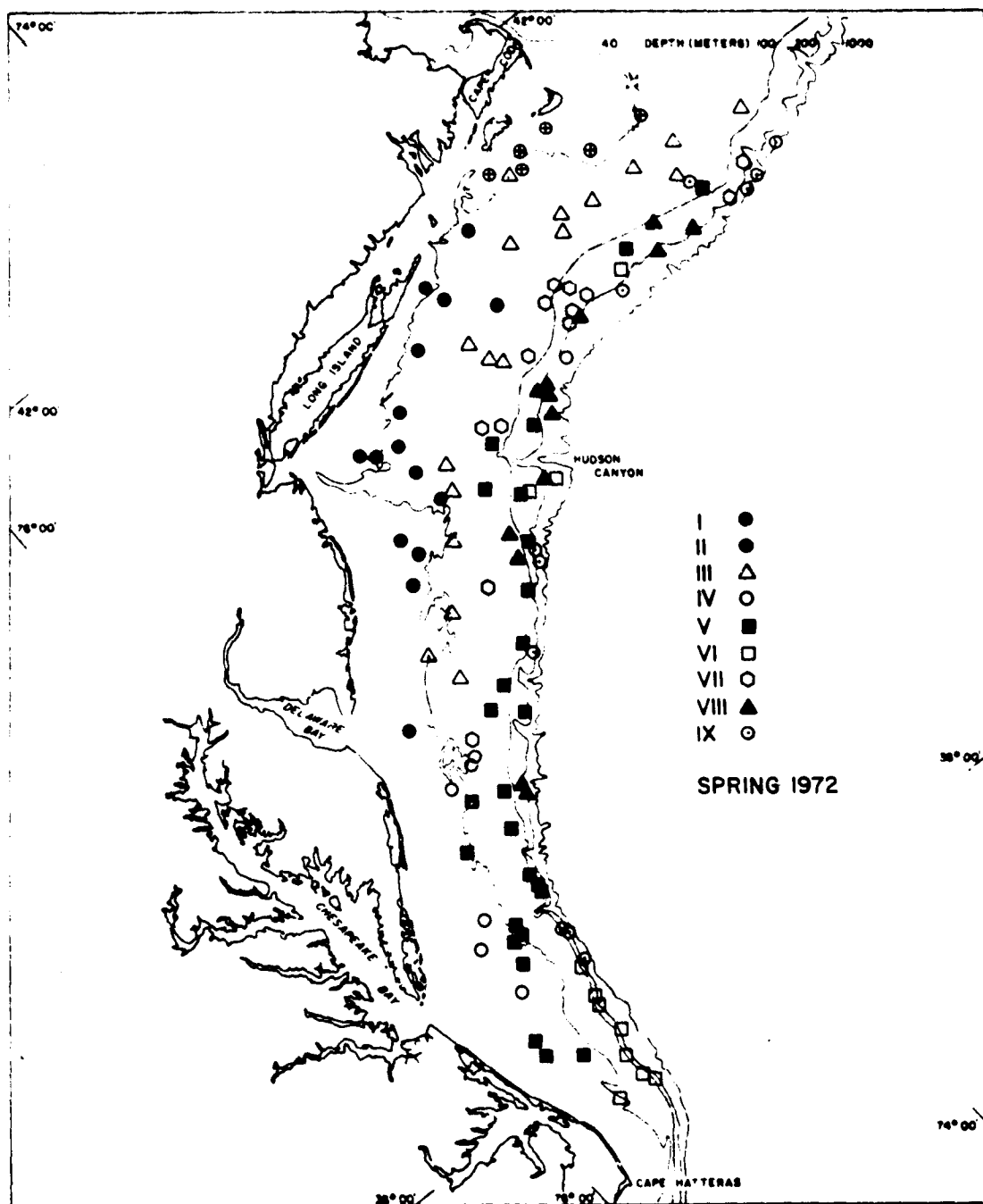
Distribution of Trawl Stations by Site Group Clusters,
NMFS Groundfish Survey, Cape Hatteras to Cape Cod,
1967-1976.

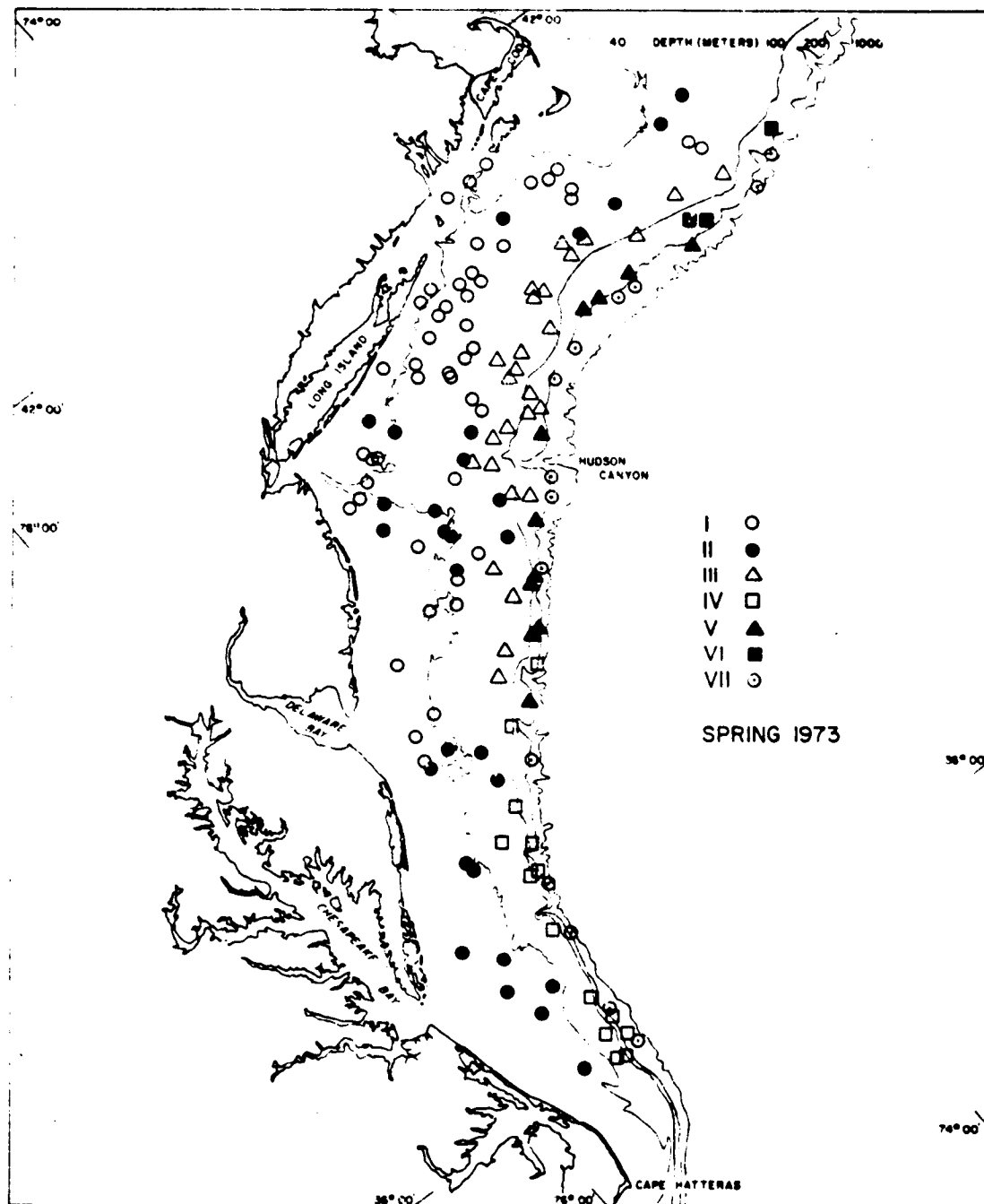


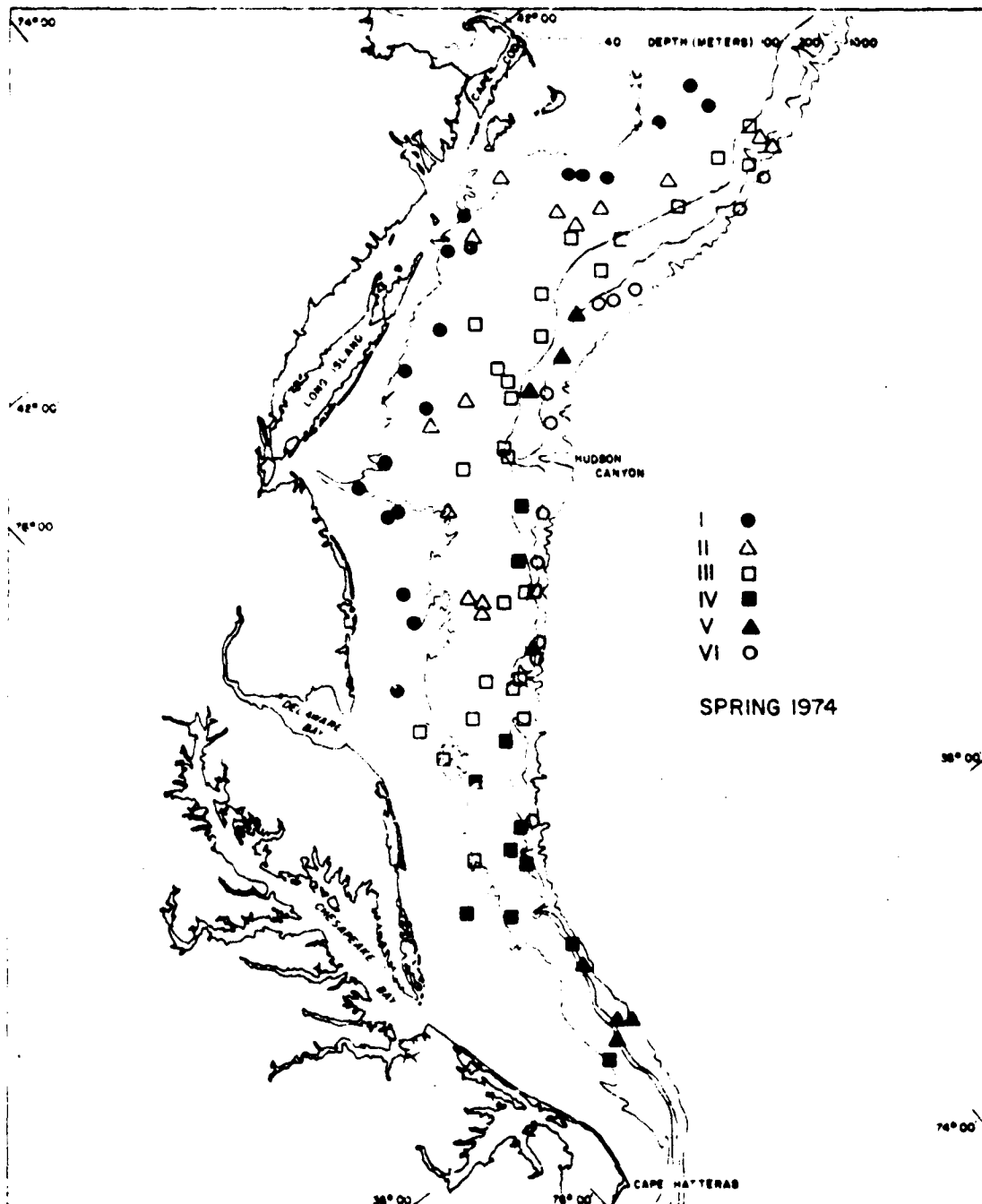


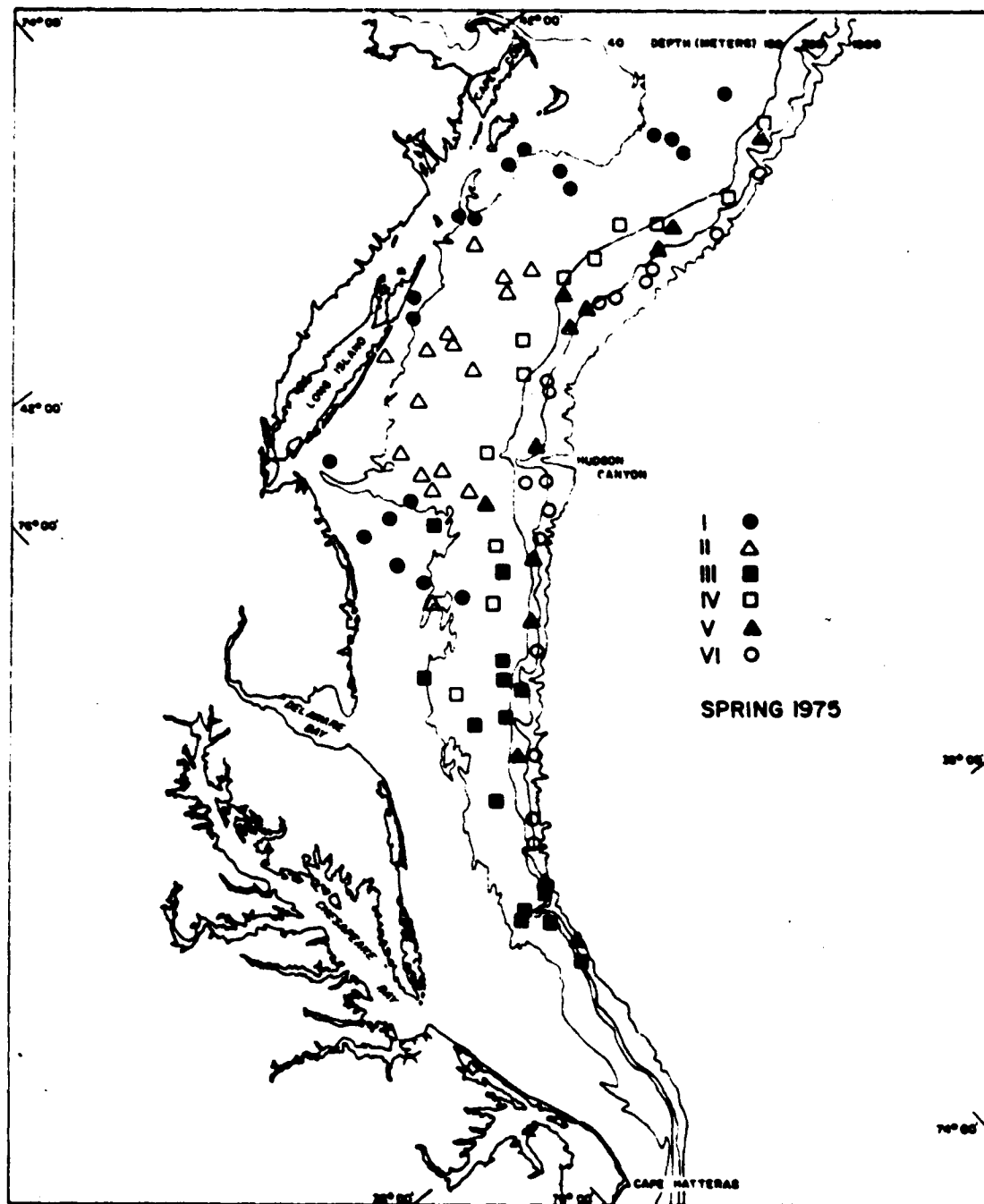


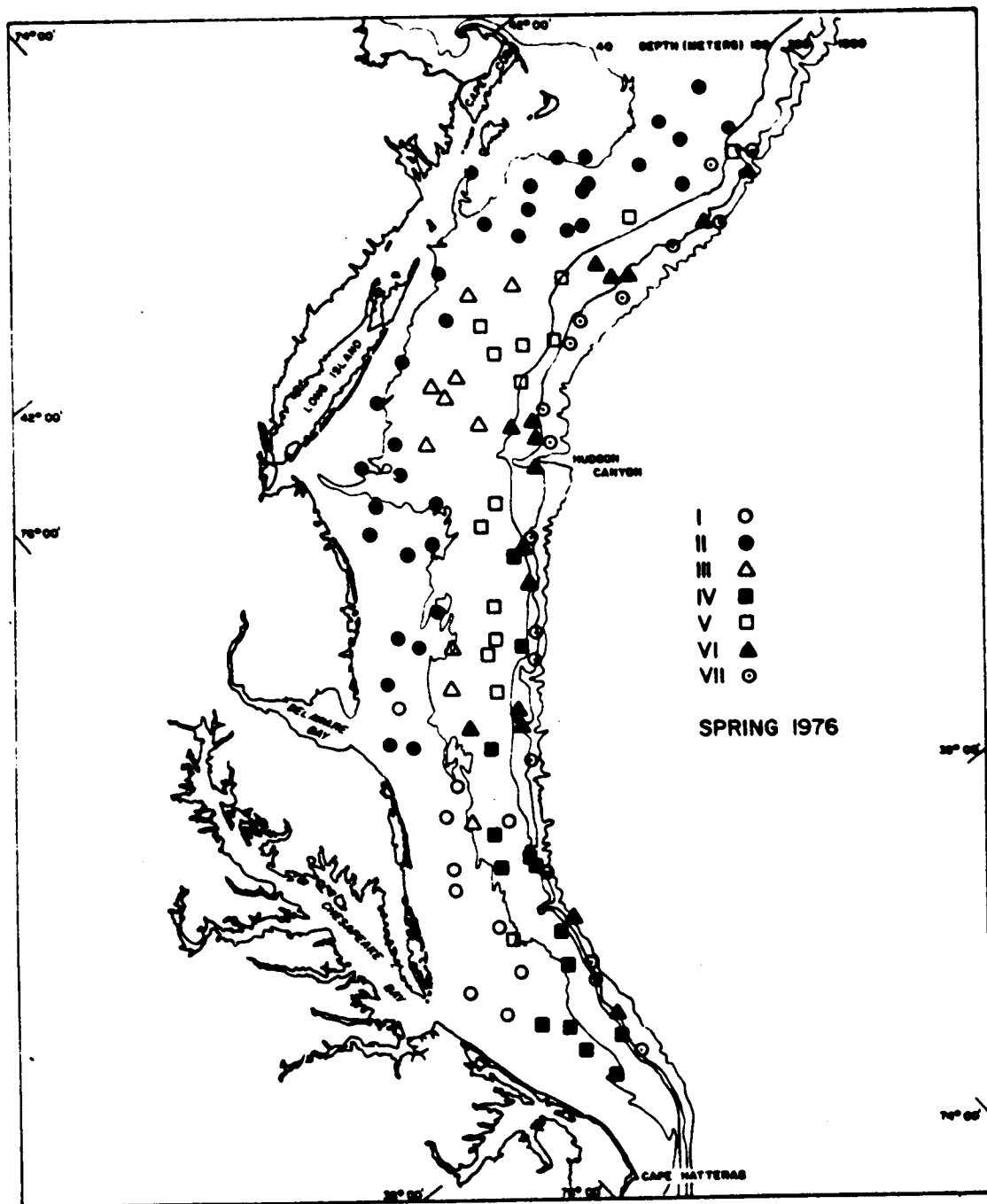


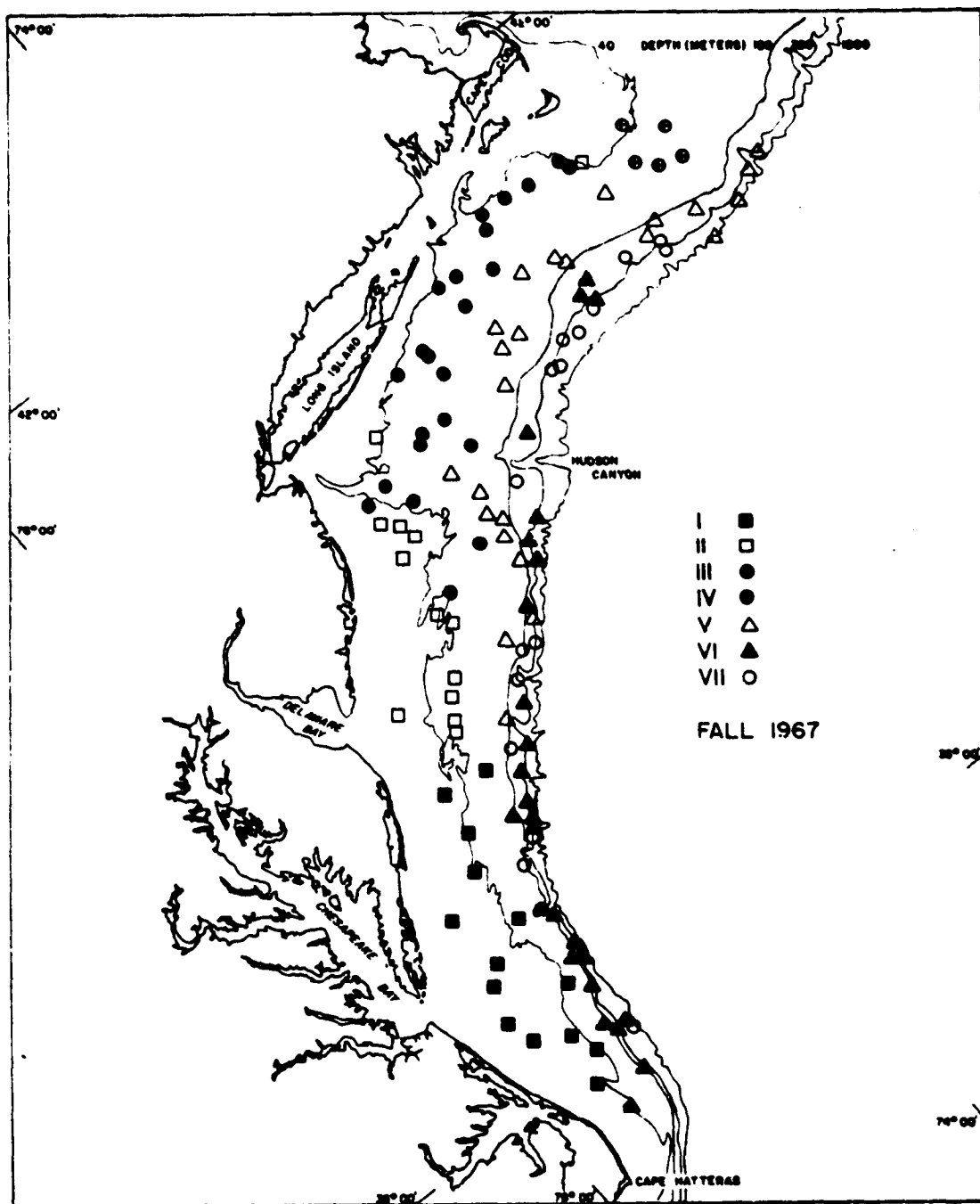


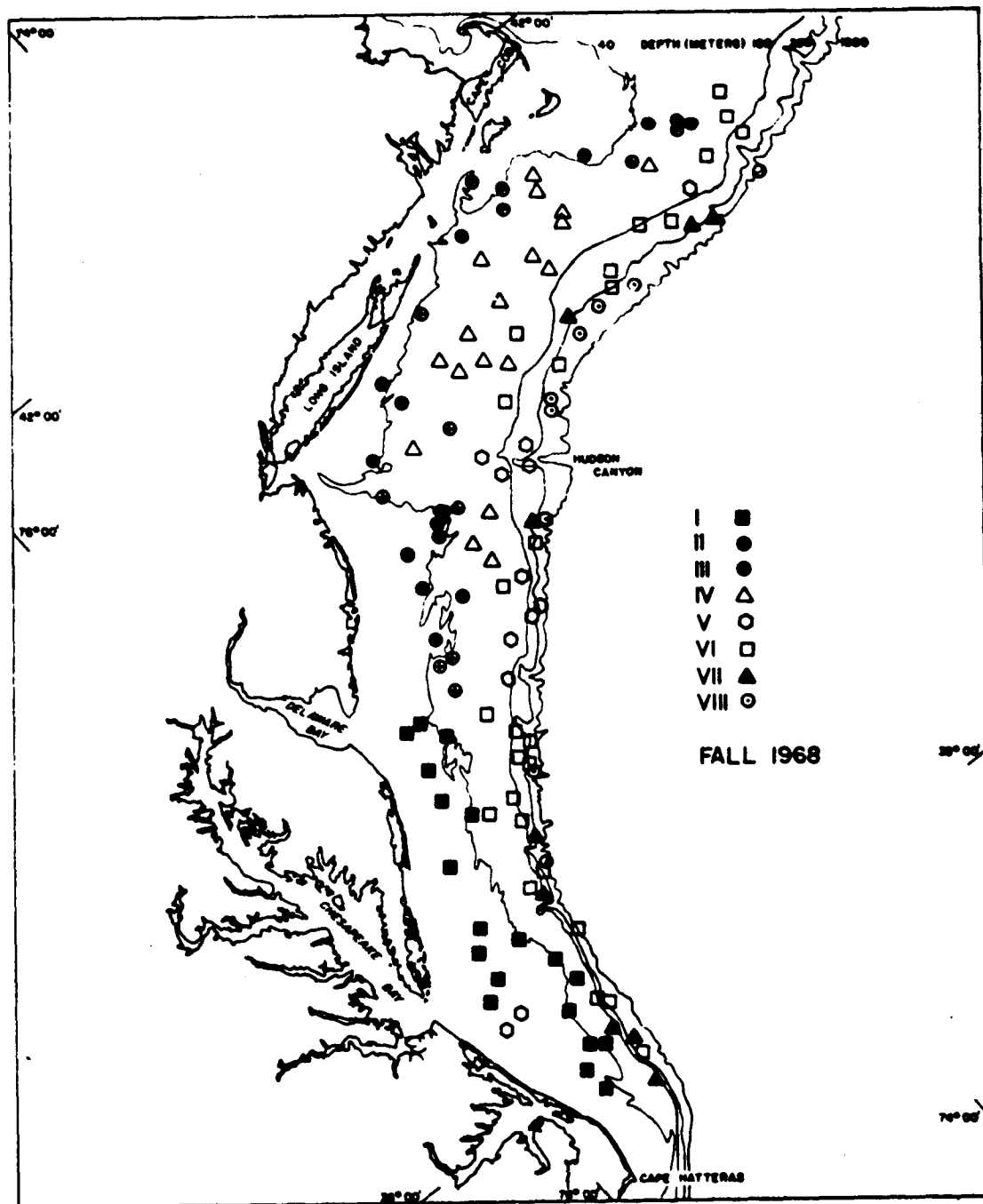


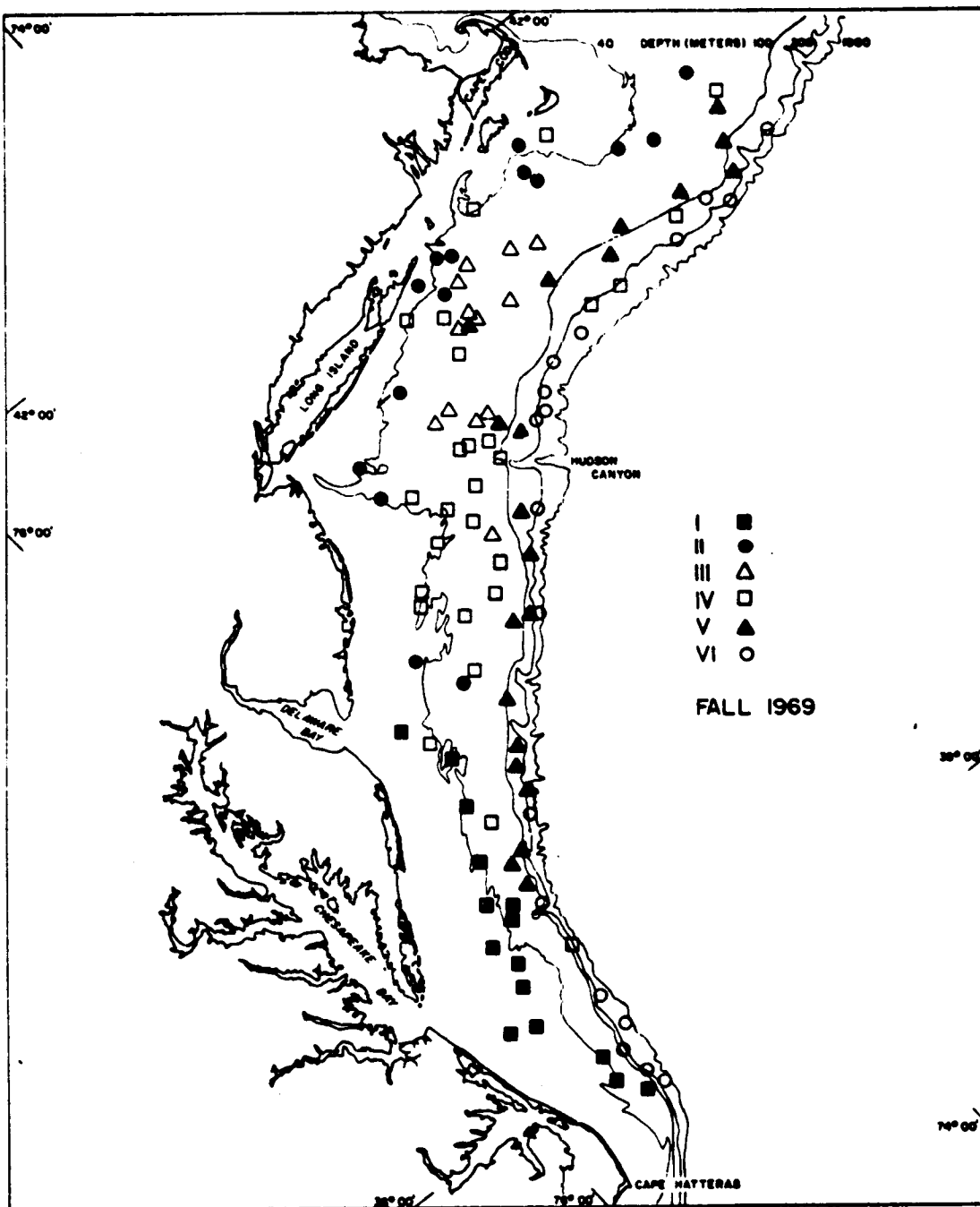


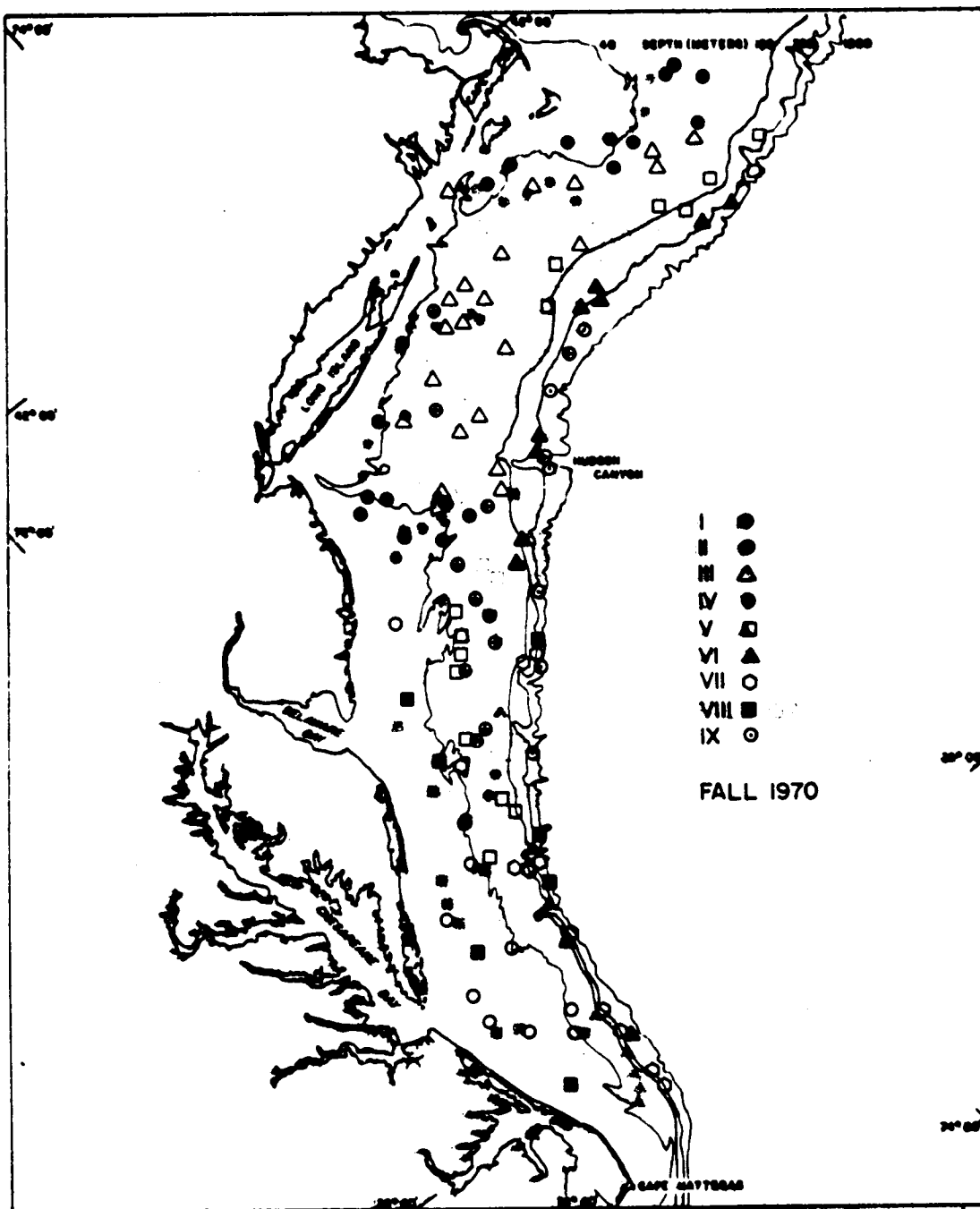


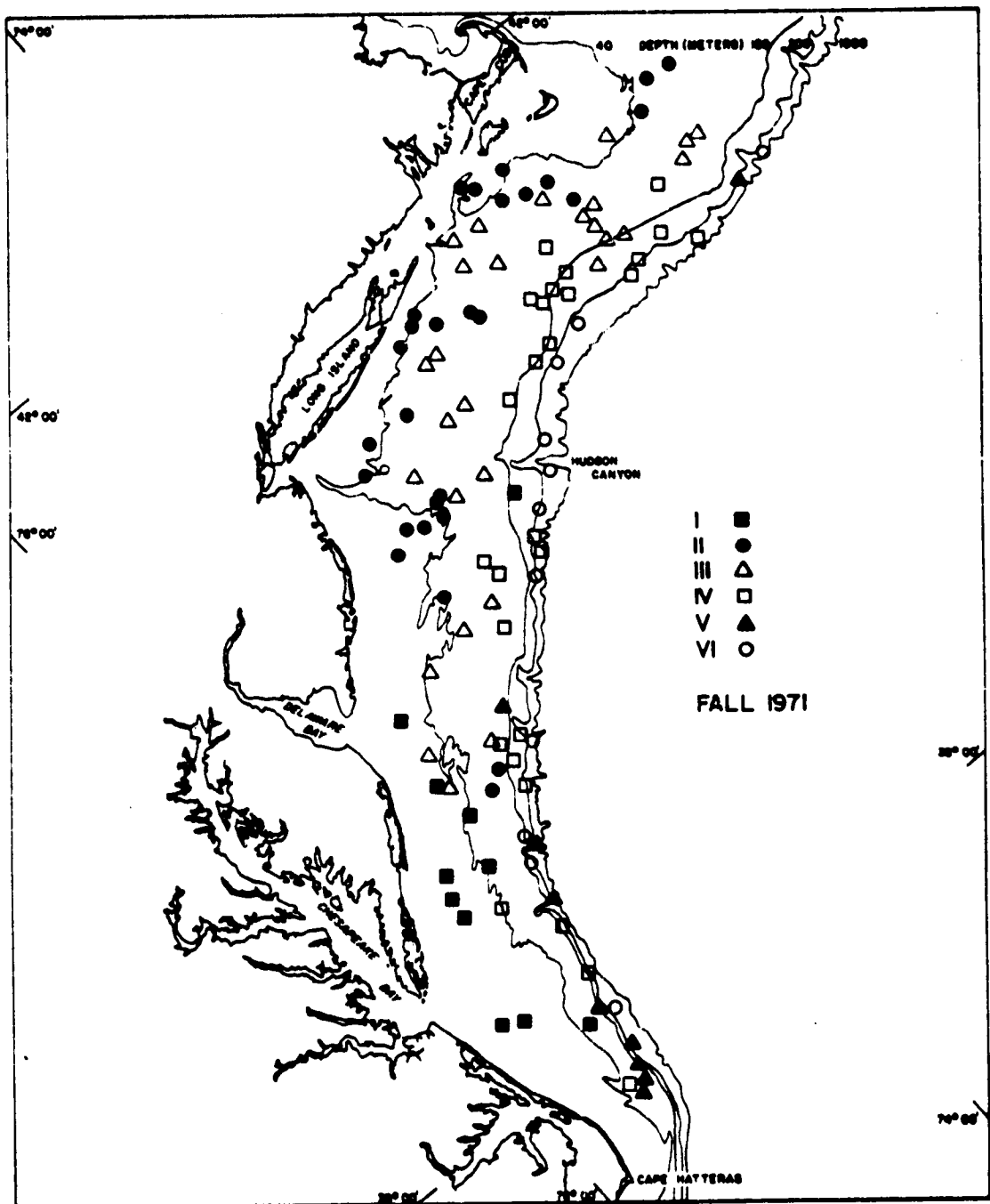


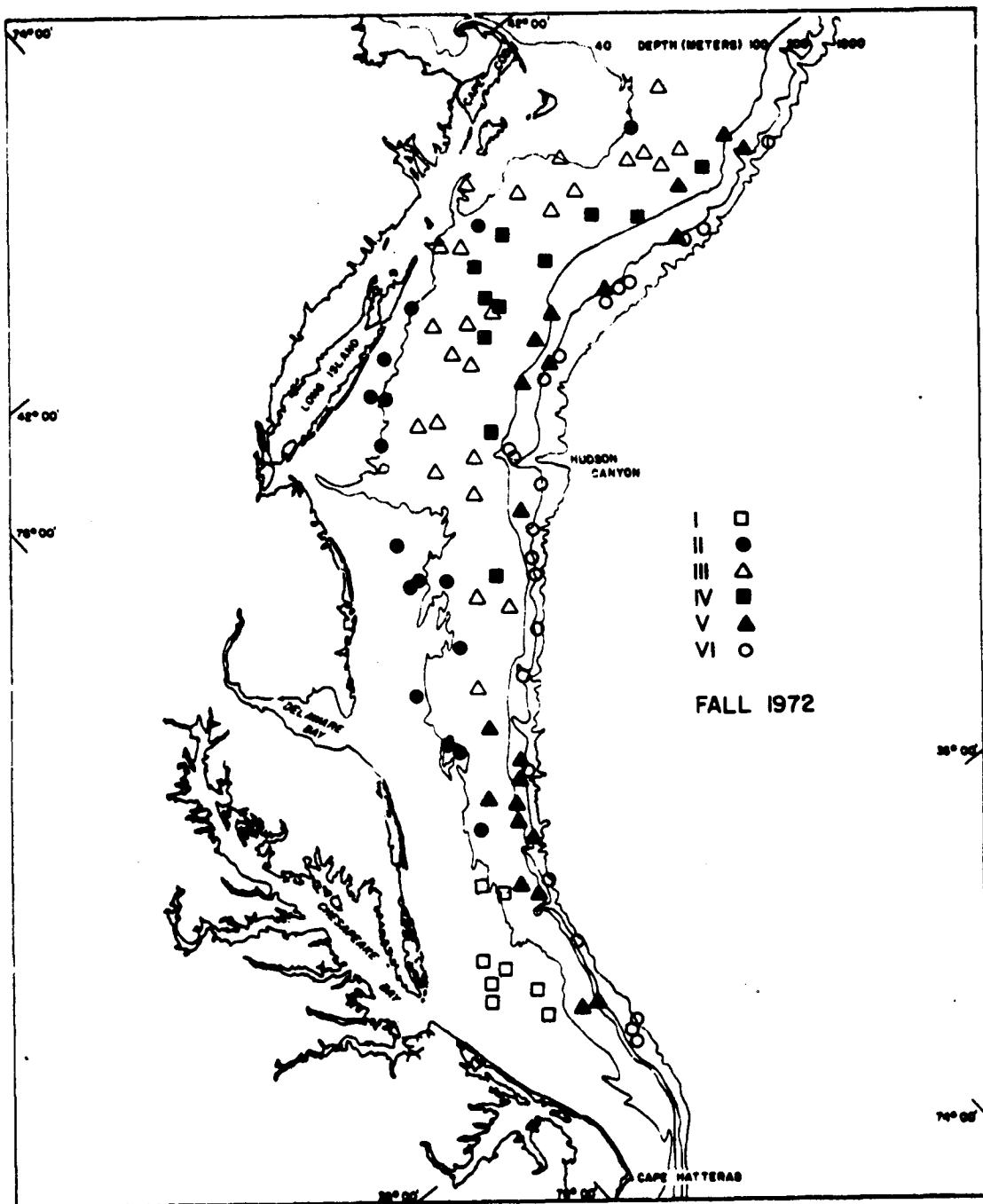


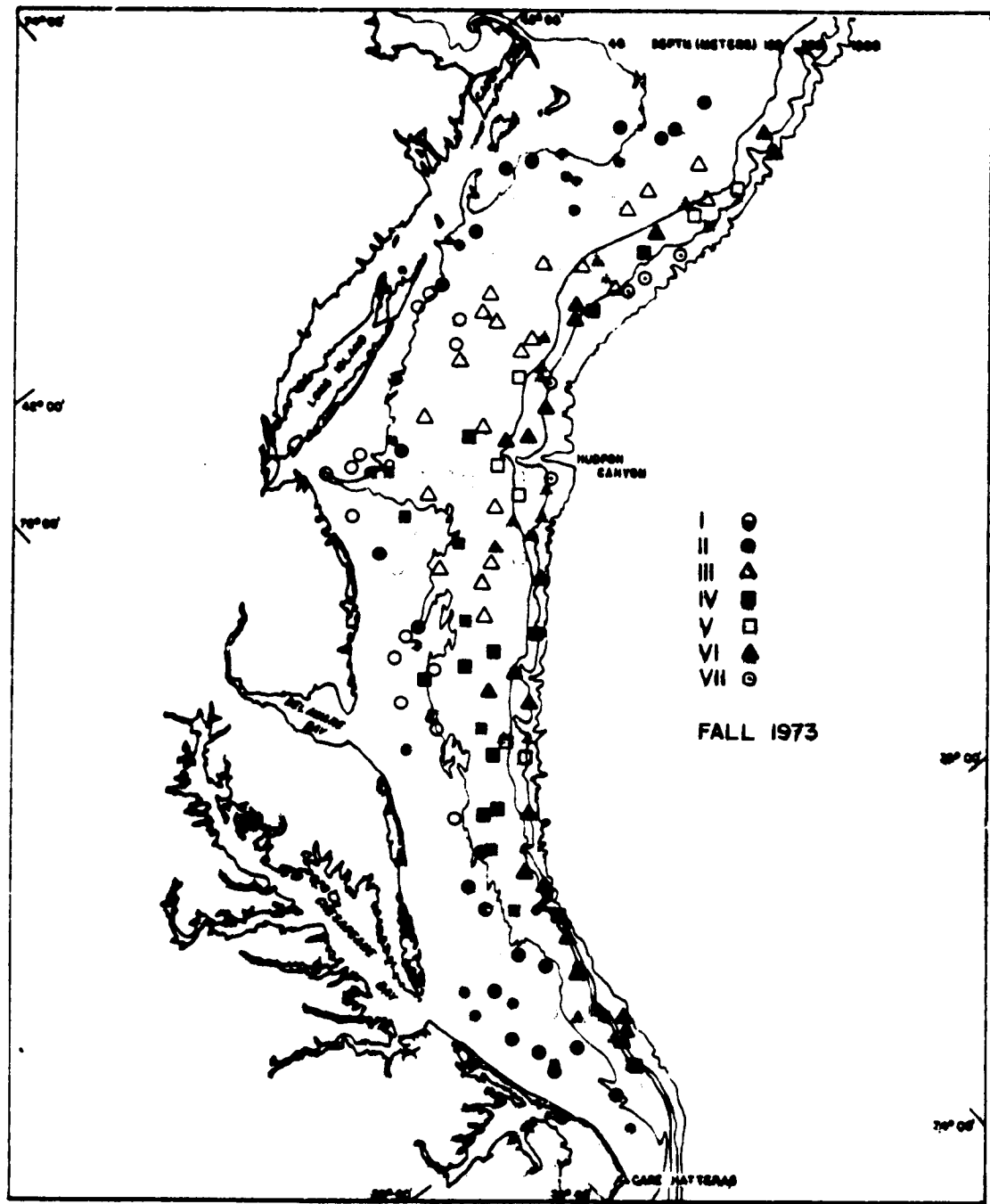


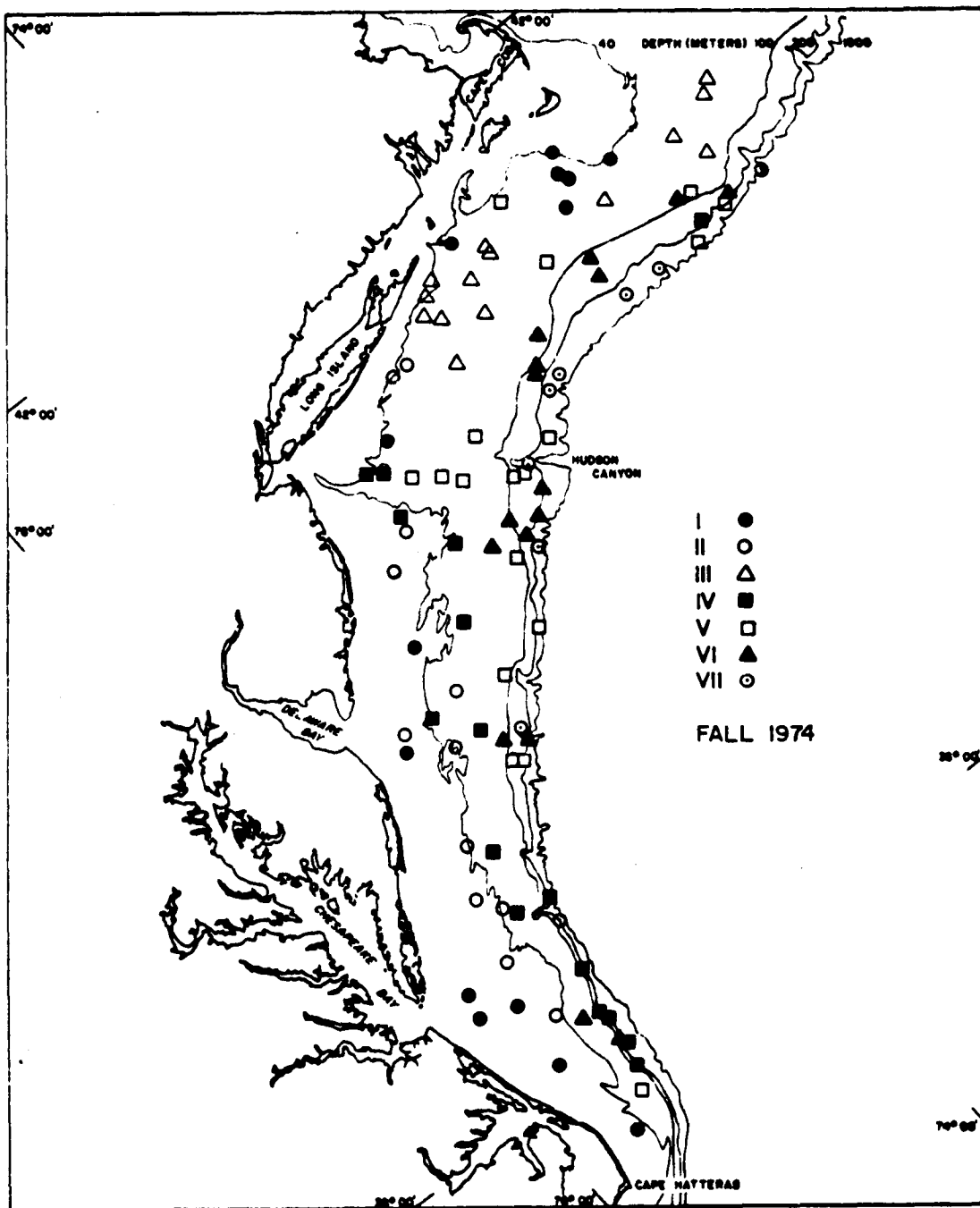


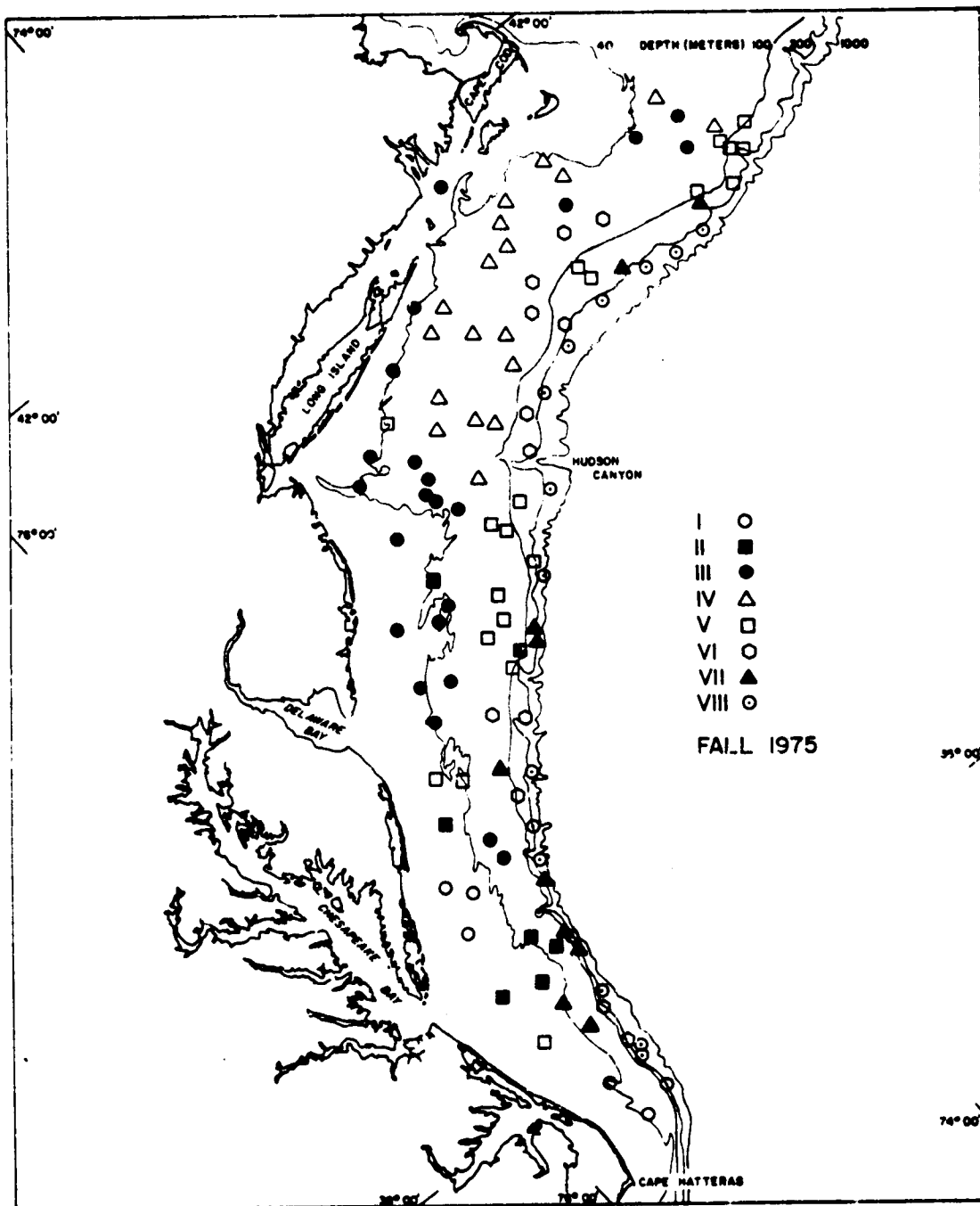


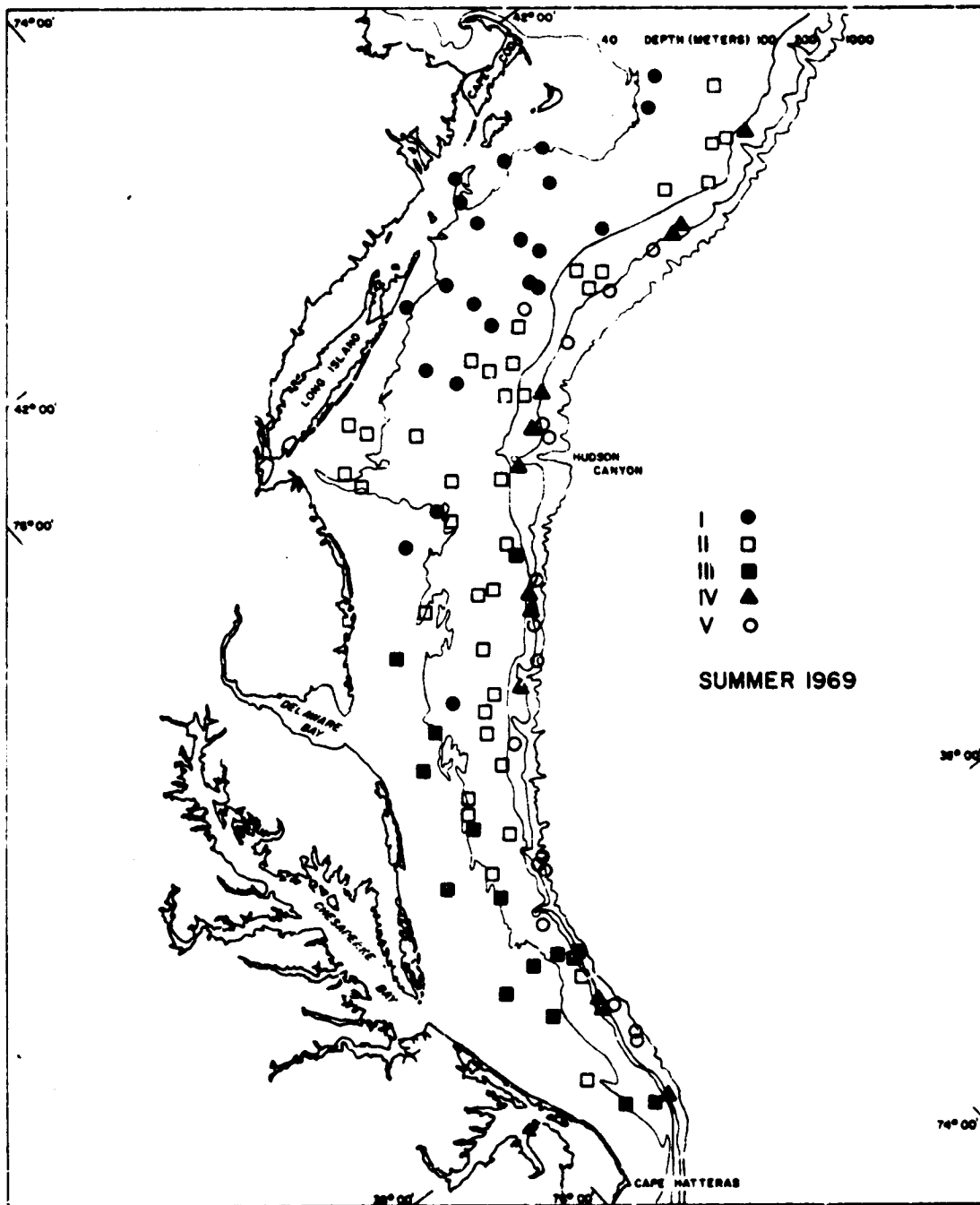












APPENDIX 10-C

**Contents of Species Groups, NMFS Groundfish Survey,
Cape Hatteras to Cape Cod, 1967-1976**

Table 10-C-1. Cruise 68-3, Spring 1968.*

1968.*

A	B	C
<u>Raja erinacea</u> Bo	<u>Squalus acanthias</u> Bo	<u>Paralichthys dentatus</u> WT
<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Merluccius bilinearis</u> Bo	<u>Centropristis striata</u> WT
<u>Limanda ferruginea</u> Bo	<u>Alosa pseudoharengus</u> Bo	<u>Prionotus carolinus</u> WT
<u>Macrozoarces americanus</u> Bo	<u>Alosa aestivalis</u> WT	<u>Stenotomus chrysops</u> WT
<u>Gadus morhua</u> Bo	<u>Scomber scombrus</u> Bo	<u>Urophycis regius</u> WT
<u>Scophthalmus aquosus</u> OS	<u>Clupea harengus harengus</u> Bo	
<u>Pseudopleuronectes americanus</u> Bo		
<u>Raja ocellata</u> Bo		
<u>Hemitripterus americanus</u> Bo		
<u>Hippoglossoides platessoides</u> Bo		
<u>Menidia menidia</u> WT		
D	E	F
<u>Urophycis chuss</u> Bo	<u>Peristedion miniatum</u> Bo	<u>Helicolenus dactylopterus</u> S1
<u>Hippoglossina oblonga</u> OS	<u>Lepophidium cervinum</u> OS	<u>Myctophidae</u> Mp
<u>Peprilus triacanthus</u> WT		<u>Anguilliformes</u>
<u>Urophycis tenuis</u> Bo		
<u>Lophius americanus</u> Bo		
<u>Citharichthys arctifrons</u> S1		
<u>Alosa sapidissima</u> Bo		

*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
 mesopelagic, Mp.

Table 10-C-2. Cruise 69-2, Spring 1969.*

A	B	C
<u>Gadus morhua</u> Bo <u>Pseudopleuronectes americanus</u> Bo <u>Hemitripterus americanus</u> Bo	<u>Melanogrammus aeglefinus</u> Bo <u>Hippoglossoides platessoides</u> Bo	<u>Alosa aestivalis</u> WT <u>Menidia menidia</u> WT
D	E	F
<u>Myoxocephalus octodecemspinosus</u> Bo <u>Limanda ferruginea</u> Bo <u>Macrozoarces americanus</u> Bo <u>Scophthalmus aquosus</u> IS <u>Raja ocellata</u> Bo <u>Raja erinacea</u> Bo	<u>Alosa pseudoharengus</u> Bo <u>Clupea harengus harengus</u> Bo <u>Merluccius bilinearis</u> Bo <u>Squalus acanthias</u> Bo <u>Urophycis chuss</u> Bo	<u>Glyptocephalus cynoglossus</u> Bo-Sl <u>Urophycis tenuis</u> Bo-Sl <u>Lophius americanus</u> Bo
G	H	I
<u>Peprilus triacanthus</u> WT <u>Hippoglossina oblonga</u> OS <u>Prionotus carolinus</u> WT <u>Citharichthys arctifrons</u> Sl <u>Lepophidium cervinum</u> OS	<u>Prionotus evolans</u> WT <u>Centropristis striata</u> WT <u>Stenotomus chrysops</u> WT	<u>Helicolenus dactylopterus</u> Sl <u>Urophycis regius</u> WT <u>Peristedion miniatum</u> Bo <u>Scomber scombrus</u> Bo

*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl;
 mesopelagic, Mp.

Table 10-C-3. Cruise 70-3, Spring 1970.*

A		B		C	
	<u>Gadus morhua</u> Bo		<u>Hemitripterus americanus</u> Bo		<u>Raja erinacea</u> Bo
	<u>Pseudopleuronectes americanus</u> Bo		<u>Scophthalmus aquosus</u> IS		<u>Myoxocephalus octodecemspinosus</u> Bo
			<u>Hippoglossoides platessoides</u> Bo		<u>Clupea harengus harengus</u> Bo
					<u>Limanda ferruginea</u> Bo
					<u>Macrozoarces americanus</u> Bo
D		E		F	
10-132	<u>Merluccius bilinearis</u> Bo		<u>Stenotomus chrysops</u> WT		<u>Lepophidium cervinum</u> OS
	<u>Urophycis chuss</u> Bo		<u>Peprilus triacanthus</u> WT		<u>Citharichthys arctifrons</u> S1
	<u>Squalus acanthias</u> Bo		<u>Prionotus carolinus</u> WT		<u>Urophycis tenuis</u> Bo-S1
	<u>Scomber scombrus</u> Bo				<u>Glyptocephalus cynoglossus</u> Bo-S1
	<u>Hippoglossina oblonga</u> OS				<u>Lophius americanus</u> Bo
	<u>Alosa pseudoharengus</u> Bo				
G		H			
	<u>Centropristis striata</u> WT		Myctophidae Mp		
	<u>Prionotus evolans</u> WT		<u>Chloropthalmus agassizi</u> S1		
	<u>Urophycis regius</u> WT		<u>Helicolenus dactylopterus</u> S1		
			<u>Merluccius albidus</u> S1		

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1; mesopelagic, Mp.

Table 10-C-4. Cruise 71-1, Spring 1971.*

A		B		C	
<u>Clupea harengus harengus</u>	Bo	<u>Gadus morhua</u>	Bo	<u>Raja erinacea</u>	Bo
<u>Alosa aestivalis</u>	WT	<u>Pseudopleuronectes americanus</u>	Bo	<u>Limanda ferruginea</u>	Bo
		<u>Raja ocellata</u>	Bo	<u>Macrozoarces americanus</u>	Bo
		<u>Hemitripterus americanus</u>	Bo	<u>Myoxocephalus octodecemspinosus</u>	Bo
		<u>Hippoglossoides platessoides</u>	Bo	<u>Scophthalmus aquosus</u>	IS
D		E		F	
<u>Squalus acanthias</u>	Bo	<u>Squatina dumerili</u>	WT	<u>Urophycis regius</u>	WT
<u>Merluccius bilinearis</u>	Bo	<u>Centropristis striata</u>	WT	<u>Paralichthys dentatus</u>	WT
<u>Urophycis chuss</u>	Bo			<u>Stenotomus chrysops</u>	WT
<u>Alosa pseudoharengus</u>	Bo			<u>Scomber scombrus</u>	Bo
				<u>Peprilus triacanthus</u>	WT
				<u>Prionotus carolinus</u>	WT
				<u>Hippoglossina oblonga</u>	OS
				<u>Citharichthys arctifrons</u>	Sl
G		H			
<u>Urophycis tenuis</u>	Bo-Sl	<u>Lepophidium cervinum</u>	OS		
<u>Lophius americanus</u>	Bo	<u>Nemichthys scolopaceus</u>	Mp		
<u>Merluccius albidus</u>	Sl	<u>Stomiatoidei</u>	Mp		
<u>Myctophidae</u>	Mp				
<u>Glyptocephalus cynoglossus</u>	Bo-Sl				
<u>Helicolenus dactylopterus</u>	Sl				
<u>Phycis chesteri</u>	Sl				

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl; mesopelagic, Mp.

Table 10-C-5. Cruise 72-2, Spring 1972.*

1972.*

A		B		C	
<u>Alosa aestivalis</u>	WT	<u>Limanda ferruginea</u>	Bo	<u>Hemitripterus americanus</u>	Bo
<u>Clupea harengus harengus</u>	Bo	<u>Macrozoarces americanus</u>	Bo	<u>Gadus morhua</u>	Bo
<u>Pseudopleuronectes americanus</u>	Bo	<u>Raja erinacea</u>	Bo		
<u>Menidia menidia</u>	WT	<u>Scophthalmus aquosus</u>	IS		
		<u>Myoxocephalus octodecemspinosus</u>	Bo		
		<u>Raja ocellata</u>	Bo		
D		E		F	
<u>Lophius americanus</u>	Bo	<u>Squalus acanthias</u>	Bo	<u>Prionotus carolinus</u>	WT
<u>Citharichthys arctifrons</u>	Sl	<u>Merluccius bilinearis</u>	Bo	<u>Peprilus triacanthus</u>	WT
		<u>Hippoglossina oblonga</u>	OS		
		<u>Urophycis chuss</u>	Bo		
G		H		I	
<u>Alosa pseudoharengus</u>	Bo	<u>Urophycis regius</u>	WT	<u>Phycis chesteri</u>	Sl
<u>Scomber scombrus</u>	Bo	<u>Paralichthys dentatus</u>	WT	<u>Myctophidae</u>	Mp
		<u>Stenotomus chrysops</u>	WT	<u>Helicolenus dactylopterus</u>	Sl
		<u>Centropristis striata</u>	WT	<u>Urophycis tenuis</u>	Bo-Sl
		<u>Prionotus evolans</u>	WT	<u>Merluccius albidus</u>	Sl
				<u>Glyptocephalus cynoglossus</u>	Bo-Sl

*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl;
 mesopelagic, Mp.

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Table 10-C-6. Cruise 73-3, Spring 1973.*

A	B	C
<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Raja erinacea</u> Bo	<u>Alosa sapidissima</u> Bo
<u>Macrozoarces americanus</u> Bo	<u>Alosa pseudoharengus</u> Bo	<u>Scomber scombrus</u> Bo
<u>Clupea harengus harengus</u> Bo	<u>Limanda ferruginea</u> Bo	<u>Glyptocephalus cynoglossus</u> Bo-Sl
<u>Gadus morhua</u> Bo	<u>Scophthalmus aquosus</u> IS	
<u>Pseudopleuronectes americanus</u> Bo		
<u>Hemitripterus americanus</u> Bo		
<u>Alosa aestivalis</u> WT		
<u>Ammodytes dubius</u> Bo		
D	E	F
<u>Merluccius bilinearis</u> Bo	<u>Paralichthys dentatus</u> WT	<u>Peprilus triacanthus</u> WT
<u>Urophycis chuss</u> Bo	<u>Urophycis regius</u> WT	<u>Prionotus carolinus</u> WT
<u>Lophius americanus</u> Bo		<u>Citharichthys arctifrons</u> Sl
<u>Squalus acanthias</u> Bo		
<u>Hippoglossina oblonga</u> OS		
G	H	I
<u>Stenotomus chrysops</u> WT	<u>Lepophidium cervinum</u> OS	<u>Merluccius albidus</u> Sl
<u>Centropristis striata</u> WT	<u>Peristedion miniatum</u> Bo	<u>Helicolenus dactylopterus</u> Sl
<u>Prionotus evolans</u> WT		<u>Urophycis tenuis</u> Bo-Sl

*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl;
mesopelagic, Mp.

Table 10-C-7. Cruise 74-4, Spring 1974.*

A

Myoxocephalus octodecemspinosus Bo
Pseudopleuronectes americanus Bo
Alosa aestivalis WT
Clupea harengus harengus Bo
Raja ocellata Bo
Gadus morhus Bo
Ammodytes dubius Bo
Hemitripterus americanus Bo

D

Peprilus triacanthus WT
Paralichthys dentatus WT
Stenotomus chrysops WT
Prionotus carolinus WT
Centropristis striata WT

B

Raja erinacea Bo
Limanda ferruginea Bo
Scophthalmus aquosus IS
Alosa pseudoharengus Bo
Macrozoarces americanus Bo

E

Urophycis regius WT
Prionotus evolans WT
Mustelus canis WT

G

Glyptocephalus cynoglossus Bo-S1
Urophycis tenuis Bo-S1
Chloropthalmus agassizi S1
Merluccius albidus S1
Helicolenus dactylopterus S1
Myctophidae Mp

C

Urophycis chuss Bo
Lophius americanus Bo
Squalus acanthias Bo
Merluccius bilinearis Bo
Hippoglossina oblonga OS
Scomber scombrus Bo

F

Citharichthys arctifrons S1
Lepophidium cervinum OS
Peristedion miniatum Bo

H

Maurollicus muelleri Mp
Ephippidae
Ventrifossa occidentalis S1
Ceratoscopelus maderensis Mp

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*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
 mesopelagic, Mp.

Table 10-C-8. Cruise 75-3, Spring 1975.*

A	B	C
<u>Alosa aestivalis</u> WT <u>Etropus microstomus</u> IS <u>Ammodytes dubius</u> Bo	<u>Myoxocephalus octodecemspinosus</u> Bo <u>Raja ocellata</u> Bo <u>Cidus morhua</u> Bo <u>Clupea harengus harengus</u> Bo <u>Pseudopleuronectes americanus</u> Bo	<u>Scophthalmus aquosus</u> IS <u>Limanda ferruginea</u> Bo <u>Microzoarces americanus</u> Bo <u>Alosa pseudoharengus</u> Bo <u>Raja erinacea</u> Bo
D	F	G
<u>Urophycis tenuis</u> Bo-Sl <u>Alosa sapidissima</u> Bo	<u>Squalus acanthias</u> Bo <u>Merluccius bilinearis</u> Bo <u>Urophycis chuss</u> Bo <u>Hippoglossina oblonga</u> OS <u>Lophius americanus</u> Bo <u>Citharichthys arctifrons</u> Sl <u>Scomber scombrus</u> Bo <u>Peprilus triacanthus</u> WT <u>Paralichthys dentatus</u> WT <u>Prionotus carolinus</u> WT	<u>Lopholatilus chamaelioniceps</u> WT <u>Conger oceanicus</u> Bo-Sl <u>Raja garmani</u> Sl <u>Chlorophthalmus agassizi</u> Sl <u>Merluccius albidus</u> Sl <u>Myctophidae</u> Mp <u>Peristedion miniatum</u> Bo <u>Helicolenus dactylopterus</u> Sl <u>Lepophidium cervinum</u> OS <u>Glyptocephalus cynoglossus</u> Bo-Sl <u>Maurollicus muelleri</u> Mp <u>Argyropelecus aculeatus</u> Mp <u>Urophycis regius</u> WT <u>Nemichthys scolopaceus</u> Mp
E		
<u>Centropristis striata</u> WT <u>Stenotomus chrysops</u> WT <u>Prionotus evolans</u> WT		

*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl;
 mesopelagic, Mp.

Table 10-C-9. Cruise 76-2, Spring 1976.*

A	B	C
<u>Clupea harengus harengus</u> Bo	<u>Gadus morhua</u> Bo	<u>Raja erinacea</u> Bo
<u>Pseudopleuronectes americanus</u> Bo	<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Scophthalmus aquosus</u> IS
<u>Alosa aestivalis</u> WT	<u>Pollachius virens</u> Bo	<u>Limanda ferguginea</u> Bo
<u>Hemitripterus americanus</u> Bo		<u>Macrozoarces americanus</u> Bo
<u>Ammodytes dubius</u> Bo		<u>Alosa pseudoharengus</u> Bo
<u>Etropus microstomus</u> IS		
<u>Scomber scombrus</u> Bo		
D	E	F
<u>Merluccius bilinearis</u> Bo	<u>Urophycis regius</u> WT	Myctophidae Mp
<u>Squalus acanthias</u> Bo	<u>Centropristis striata</u> WT	<u>Merluccius albidus</u> S1
<u>Hippoglossina oblonga</u> OS	<u>Stenotomus chrysops</u> WT	<u>Helicolenus dactylopterus</u> S1
<u>Lophius americanus</u> Bo	<u>Peprilus triacanthus</u> WT	<u>Chlorophthalmus agassizi</u> S1
<u>Urophycis chuss</u> Bo	<u>Paralichthys dentatus</u> WT	<u>Lepophidium cervinum</u> OS
<u>Citharichthys arctifrons</u> S1	<u>Prionotus carolinus</u> WT	<u>Peristedion miniatum</u> Bo
		<u>Maurollicus muelleri</u> Mp
		<u>Polymixia lowei</u> S1
		<u>Glyptocephalus cynoglossus</u> Bo-S1
		<u>Urophycis tenuis</u> Bo-S1
		Cynoglossidae

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1; mesopelagic, Mp.

Table 10-C-10. Cruises 67-20 and 67-21, Fall 1967.*

A	B	C
<u>Mustelus canis</u> WT	<u>Prionotus carolinus</u> WT	<u>Gadus morhua</u> Bo
<u>Paralichthys dentatus</u> WT	<u>Scophthalmus aquosus</u> IS	<u>Pollachius virens</u> Bo
<u>Stephanolepis hispidus</u> WT	<u>Pseudopleuronectes americanus</u> Bo	
<u>Centropristis striata</u> WT	<u>Stenotomus chrysops</u> WT	
D	E	F
<u>Alosa pseudoharengus</u> Bo	<u>Raja erinacea</u> Bo	<u>Squalus acanthias</u> Bo
<u>Clupea harengus harengus</u> Bo	<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Limanda ferrugina</u> Bo
<u>Alosa aestivalis</u> WT	<u>Macrozoarces americanus</u> Bo	
<u>Hippoglossoides platessoides</u> Bo		
G	H	I
<u>Lophius americanus</u> Bo	<u>Merluccius bilinearis</u> Bo	<u>Citharichthys arctifrons</u> S1
<u>Urophycis tenuis</u> Bo-S1	<u>Peprilus triacanthus</u> WT	<u>Lepophidium cervinum</u> OS
	<u>Hippoglossina oblonga</u> OS	<u>Urophycis regius</u> WT
	<u>Urophycis chuss</u> Bo	<u>Peristedion miniatum</u> Bo
J	K	
<u>Zenopsis ocellata</u> S1	<u>Helicolenus dactylopterus</u> S1	
<u>Raja garmani</u> S1	<u>Merluccius albidus</u> S1	
Myctophidae Mp	<u>Maurolicus muelleri</u> Mp	
	<u>Chloropthalmus agassizi</u> S1	

*Faunal affinity is designated after each species name: boreal, Bo;
 warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
 mesopelagic, Mp.

Table 10-C-11. Cruise 68-17, Fall 1968.*

A	B	C
<u>Paralichthys dentatus</u> WT <u>Centropristis striata</u> WT <u>Stenotomus chrysops</u> WT <u>Decapterus macarellus</u> WT	<u>Prionotus carolinus</u> WT <u>Scophthalmus aquosus</u> IS <u>Pseudopleuronectes americanus</u> Bo <u>Mustelus canis</u> WT	<u>Macrozoarces americanus</u> Bo <u>Myoxocephalus octodecemspinosus</u> Bo <u>Raja ocellata</u> Bo <u>Raja erinacea</u> Bo <u>Hemitripterus americanus</u> Bo
D	E	F
<u>Squalus acanthias</u> Bo <u>Limanda ferruginea</u> Bo <u>Merluccius bilinearis</u> Bo <u>Peprilus triacanthus</u> WT <u>Urophycis chuss</u> Bo <u>Hippoglossina oblonga</u> OS	<u>Glyptocephalus cynoglossus</u> Bo-Sl <u>Hippoglossoides platessoides</u> Bo <u>Lophius americanus</u> Bo <u>Urophycis tenuis</u> Bo-Sl <u>Clupea harengus harengus</u> Bo	<u>Lepophidium cervinum</u> OS <u>Citharichthys arctifrons</u> Sl <u>Urophycis regius</u> WT
G		
<u>Myctophidae</u> Mp <u>Helicolenus dactylopterus</u> Sl <u>Merluccius albidus</u> Sl <u>Chloropthalmus agassizi</u> Sl		

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl; mesopelagic, Mp.

Table 10-C-12. Cruise 69-11, Fall 1969.*

A		B		C	
<u>Squatina dumerili</u>	WT	<u>Centropristis striata</u>	WT	<u>Raja erinacea</u>	Bo
<u>Raja eglartheria</u>	WT	<u>Paralichthys dentatus</u>	WT	<u>Pseudopleuronectes americanus</u>	Bo
		<u>Stephanolepis hispidus</u>	WT	<u>Scophthalmus aquosus</u>	IS
		<u>Decapterus macarellus</u>	WT	<u>Prionotus carolinus</u>	WT
		<u>Mustelus canis</u>	WT	<u>Stenotomus chrysops</u>	WT
		<u>Prionotus evolans</u>	WT	<u>Peprilus triacanthus</u>	WT
D		E		F	
<u>Squalus acanthias</u>	Bo	<u>Macrozoarces americanus</u>	Bo	<u>Lophius americanus</u>	Bo
<u>Limanda ferruginea</u>	Bo	<u>Hemitripterus americanus</u>	Bo	<u>Urophycis tenuis</u>	Bo-S1
<u>Myoxocephalus octodecemspinosus</u>	Bo			<u>Glyptocephalus cynoglossus</u>	Bo-S1
<u>Hippoglossina oblonga</u>	OS				
<u>Urophycis chuss</u>	Bo				
<u>Merluccius bilinearis</u>	Bo				
		G		H	
		<u>Citharichthys arctifrons</u>	S1	<u>Chlorophthalmus agassizi</u>	S1
		<u>Lepophidium cervinum</u>	OS	<u>Merluccius albidus</u>	S1
		<u>Urophycis regius</u>	WT	<u>Myctophidae</u>	Mp
				<u>Helicolenus dactylopterus</u>	S1

*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
mesopelagic, Mp.

Table 10-C-13. Cruise 70-6, Fall 1970.*

A	B	C
<u>Prionotus carolinus</u> WT <u>Stenotomus chrysops</u> WT <u>Paralichthys dentatus</u> WT <u>Prionotus evolans</u> WT <u>Centropristis striata</u> WT	<u>Melanogrammus aeglefinus</u> Bo <u>Hemitripterus americanus</u> Bo <u>Alosa sapidissima</u> Bo <u>Alosa pseudoharengus</u> Bo <u>Etrumeus teres</u> WT	<u>Squalus acanthias</u> Bo <u>Limanda ferruginea</u> Bo <u>Myoxocephalus octodecemspinosus</u> Bo <u>Pseudopleuronectes americanus</u> Bo <u>Peprilus triacanthus</u> WT <u>Raja ocellata</u> Bo <u>Scophthalmus aquosus</u> IS <u>Raja erinacea</u> Bo
D	E	F
<u>Urophycis chuss</u> Bo <u>Merluccius bilinearis</u> Bo <u>Hippoglossina oblonga</u> OS <u>Citharichthys arctifrons</u> Sl	<u>Lophius americanus</u> Bo <u>Urophycis tenuis</u> Bo-Sl <u>Macrozoarces americanus</u> Bo <u>Glyptocephalus cynoglossus</u> Bo-Sl	<u>Urophycis regius</u> WT <u>Lepophidium cervinum</u> OS <u>Peristedion miniatum</u> Bo <u>Zenopsis ocellata</u> Sl
G		
<u>Myctophidae</u> Mo <u>Merluccius albidus</u> Sl <u>Chloropthalmus agassizi</u> Sl <u>Helicolenus dactylopterus</u> Sl		

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl; mesopelagic, Mp.

Table 10-C-14. Cruise 71-6, Fall 1971.*

A	B	C
<u>Mustelus canis</u> WT	<u>Etrumeus teres</u> WT	<u>Melanogrammus aeglefinus</u> Bo
<u>Pomatomus saltatrix</u> WT	<u>Scomber scombrus</u> Bo	<u>Myoxocephalus octodecemspinosus</u> Bo
<u>Stenotomus chrysops</u> WT		<u>Scophthalmus aquosus</u> IS
<u>Paralichthys dentatus</u> WT		<u>Pseudopleuronectes americanus</u> Bo
<u>Prionotus carolinus</u> WT		<u>Raja erinacea</u> Bo
<u>Centropristis striata</u> WT		<u>Squalus acanthias</u> Bo
		<u>Limanda ferruginea</u> Bo
D	E	F
<u>Macrozoarces americanus</u> Bo	<u>Urophycis chuss</u> Bo	<u>Lophius americanus</u> Bo
<u>Hemitripterus americanus</u> Bo	<u>Merluccius bilinearis</u> Bo	<u>Glyptocephalus cynoglossus</u> Bo-SI
	<u>Hippoglossina oblonga</u> OS	
	<u>Citharichthys arctifrons</u> SI	
	<u>Peprilus triacanthus</u> WT	
	<u>Urophycis regius</u> WT	
G	H	I
<u>Alosa aestivalis</u> WT	<u>Lepophidium cervinum</u> OS	<u>Helicolenus dactylopterus</u> SI
<u>Alosa sapidissima</u> Bo		<u>Myctophidae</u> Mp
<u>Urophycis tenuis</u> Bo-SI		<u>Chlorophthalmus agassizi</u> SI
		<u>Merluccius albidus</u> SI
		<u>Nezumia bairdii</u> SI

*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, Wt; outer-shelf, OS; inner-shelf, IS; slope, SI;
mesopelagic, Mp.

Table 10-C-15. Cruise 72-8, Fall 1972.*

A

Centropristis striata WT
Raja eglanteria WT
Paralichthys dentatus WT
Dasyatis centroura WT

D

Merluccius bilinearis Bo
Citharichthys arctifrons S1
Lophius americanus Bo
Hippoglossina oblongus Bo
Urophycis chuss Bo
Urophycis regius WT
Peprilus triacanthus WT
Lepophidium cervinum OS

B

Stenotomus chrysops WT
Pseudopleuronectes americanus Bo
Prionotus carolinus WT
Scophthalmus aquosus IS

E

Raja erinacea Bo
Limanda ferruginea Bo
Myoxocephalus octodecemspinosus Bo
Squalus acanthias Bo

G

Raja garmani S1
Peristedion miniatum Bo
Scomber scombrus Bo

C

Mustelus canis WT
Raja ocellata Bo
Pomatomus saltatrix WT
Etrumeus teres WT

F

Hemitripterus americanus Bo
Glyptocephalus cynoglossus Bo-S1
Macrozoarces americanus Bo
Ophichthus cruentifer OS
Urophycis tenuis Bo-S1
Enchelyopus cimbrius S1

H

Merluccius albidus S1
Helicolenus dactylopterus S1
Myctophidae Mp
Chlorophthalmus agassizi S1
Argentina silus S1
Stomiatoides Mp
Nezumia bairdii S1

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*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1; mesopelagic, Mp.

Table 10-C-16. Cruise 73-8, Fall 1973.*

A	B	C
<u>Prionotus carolinus</u> WT	<u>Mustelus canis</u> WT	<u>Squalus acanthias</u> Bo
<u>Scophthalmus aquosus</u> IS	<u>Raja erinacea</u> Bo	<u>Raja ocellata</u> Bo
<u>Paralichthys dentatus</u> WT	<u>Pseudopleuronectes americanus</u> Bo	
<u>Pomatomus saltatrix</u> WT	<u>Stenotomus chrysops</u> WT	
<u>Raja eglanteria</u> WT	<u>Limanda ferruginea</u> Bo	
D	E	
<u>Merluccius bilinearis</u> Bo	<u>Helicolenus dactylopterus</u> S1	
<u>Hippoglossina oblonga</u> OS	<u>Merluccius albidus</u> S1	
<u>Citharichthys arctifrons</u> S1	Myctophidae Mp	
<u>Lophius americanus</u> Bo	<u>Peristedion miniatum</u> Bo	
<u>Urophycis regius</u> WT	<u>Zenopsis ocellata</u> S1	
<u>Peprilus triacanthus</u> WT		
<u>Lepophidium cervinum</u> OS		
<u>Macrozoarces americanus</u> Bo		
<u>Urophycis chuss</u> Bo		

*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
mesopelagic, Mp.

Table 10-C-17. Cruise 74-11, Fall 1974.*

A	B	C
<u>Micropogon undulatus</u> WT	<u>Raja erinacea</u> Bo	<u>Stephanolepis hispidus</u> WT
<u>Squatina dumerili</u> WT	<u>Scophthalmus aquosus</u> IS	<u>Centropristis striata</u> WT
	<u>Pseudopleuronectes americanus</u> Bo	<u>Prionotus carolinus</u> WT
	<u>Squalus acanthias</u> Bo	<u>Stenotomus chrysops</u> WT
	<u>Limanda ferruginea</u> Bo	<u>Paralichthys dentatus</u> WT
	<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Mustelus canis</u> WT
		<u>Pomatomus saltatrix</u> WT
		<u>Etropus microstomus</u> IS
D	E	F
<u>Urophycis regius</u> WT	<u>Helicolenus dactylopterus</u> S1	<u>Phycis chesteri</u> S1
<u>Citharichthys arctifrons</u> S1	<u>Lophius americanus</u> Bo	<u>Merluccius albidus</u> S1
<u>Lepophidium cervinum</u> OS	<u>Chloropthalmus agassizi</u> S1	Macrouridae S1
<u>Merluccius bilinearis</u> Bo	<u>Peristedion miniatum</u> Bo	
<u>Hippoglossina oblonga</u> OS	Myctophidae Mp	
<u>Peprilus triacanthus</u> WT	<u>Argyropelecus aculeatus</u> Mp	
<u>Urophycis chuss</u> Bo		

*Faunal affinity is designated after each species name: boreal, Bo; warm-temperate, WT; outer-shelf, OS; inner shelf, IS; slope, S1; mesopelagic, Mp.

Table 10-C-18. Cruise 75-12, Fall 1975.*

A	B	C
<u>Micropogon undulatus</u> WT	<u>Mustelus canis</u> WT	<u>Raja erinacea</u> Bo
<u>Decapterus punctatus</u> WT	<u>Paralichthys dentatus</u> WT	<u>Pseudopleuronectes americanus</u> Bo
<u>Pomatomus saltatrix</u> WT	<u>Prionotus carolinus</u> WT	<u>Scophthalmus aquosus</u> IS
<u>Carcharhinus milberti</u> WT	<u>Centropristis striata</u> WT	<u>Limanda ferruginea</u> Bo
D	E	F
<u>Squalus acanthias</u> Bo	<u>Merluccius bilinearis</u> Bo	<u>Chloropthalmus agassizi</u> S1
<u>Stenotomus chrysops</u> WT	<u>Hippoglossina oblonga</u> OS	Myctophidae Mp
<u>Peprilus triacanthus</u> WT	<u>Citharichthys arctifrons</u> S1	<u>Peristedion miniatum</u> Bo
	<u>Urophycis chuss</u> Bo	<u>Merluccius albidus</u> S1
	<u>Lophius americanus</u> Bo	<u>Maurollicus muelleri</u> Mp
	<u>Urophycis regius</u> WT	<u>Helicolenus dactylopterus</u> S1
		<u>Lepophidium cervinum</u> OS

*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, S1;
mesopelagic, Mp.

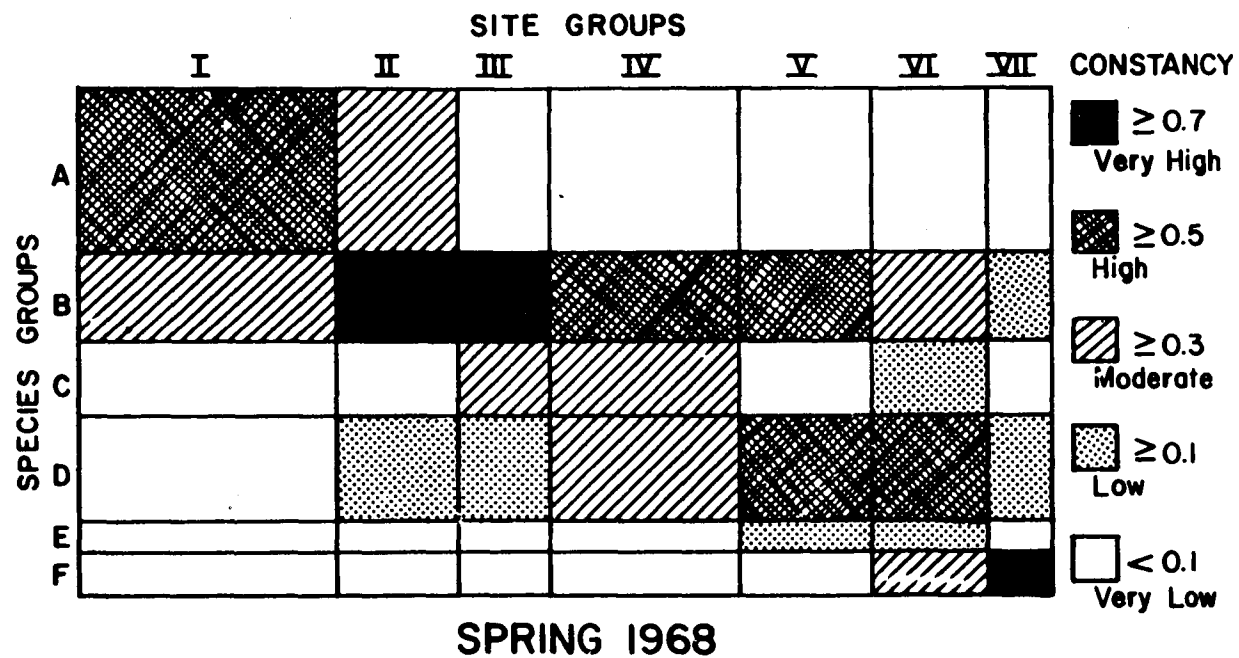
Table 10-C-19. Cruise 69-8, Summer 1969.*

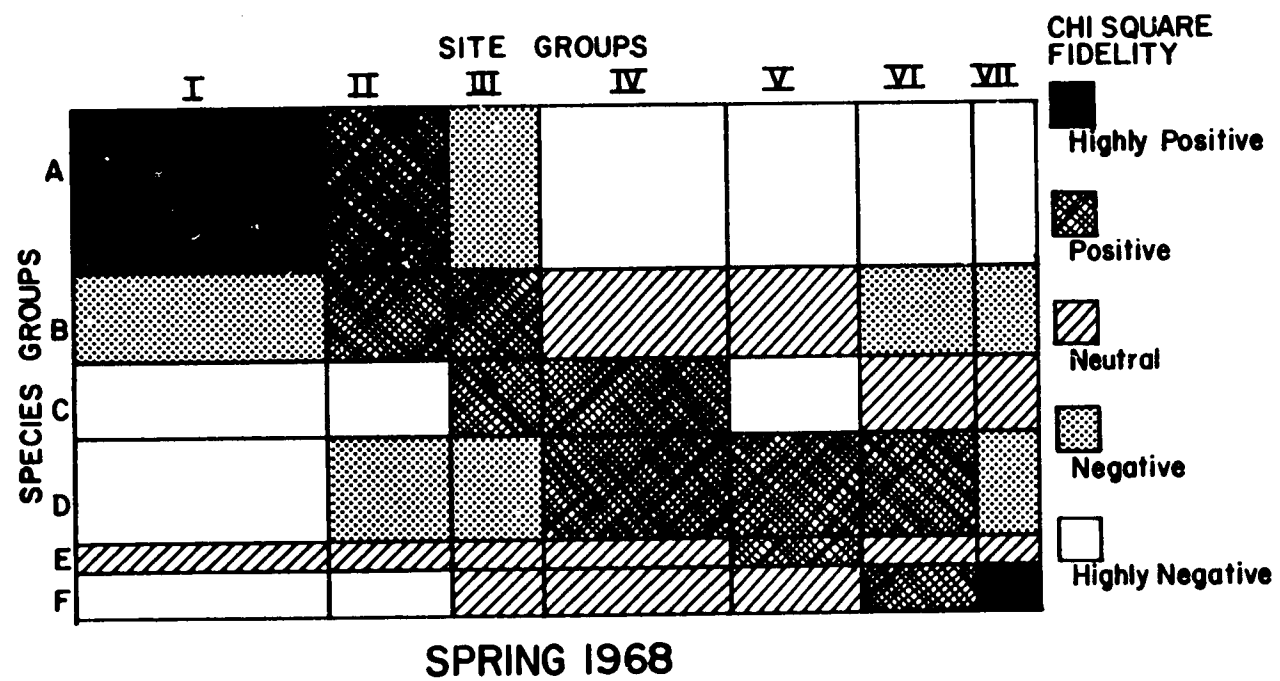
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	A	B	C
	<u>Macrozoarces americanus</u> Bo	<u>Pseudopleuronectes americanus</u> Bo	<u>Alosa pseudoharengus</u> Bo
	<u>Gadus morhua</u> Bo	<u>Limanda ferruginea</u> Bo	<u>Alosa sapidissima</u> Bo
	<u>Hemitripterus americanus</u> Bo	<u>Raja erinacea</u> Bo	<u>Glyptocephalus cynoglossus</u> Bo-Sl
		<u>Scophthalmus aquosus</u> IS	<u>Hippoglossoides platessoides</u> Bo
			<u>Urophycis tenuis</u> Bo-Sl
	D	E	F
	<u>Merluccius bilinearis</u> Bo	<u>Lepophidium cervinum</u> OS	<u>Maurollicus muelleri</u> Mp
	<u>Melanogrammus aeglefinus</u> Bo	<u>Citharichthys arctifrons</u> Sl	Myctophidae Mp
	<u>Urophycis chuss</u> Bo	<u>Peprilus triacanthus</u> WT	<u>Helicolenus dactylopterus</u> Sl
	<u>Myoxocephalus octodecemspinosus</u> Bo	<u>Urophycis regius</u> WT	<u>Ceratoscopelus maderensis</u> Mp
	<u>Hippoglossina oblonga</u> OS		<u>Merluccius albidus</u> Sl
	<u>Lophius americanus</u> Bo		<u>Chloropthalmus agassizi</u> Sl
	<u>Squalus acanthias</u> Bo		
	<u>Scomber scombrus</u> Bo		

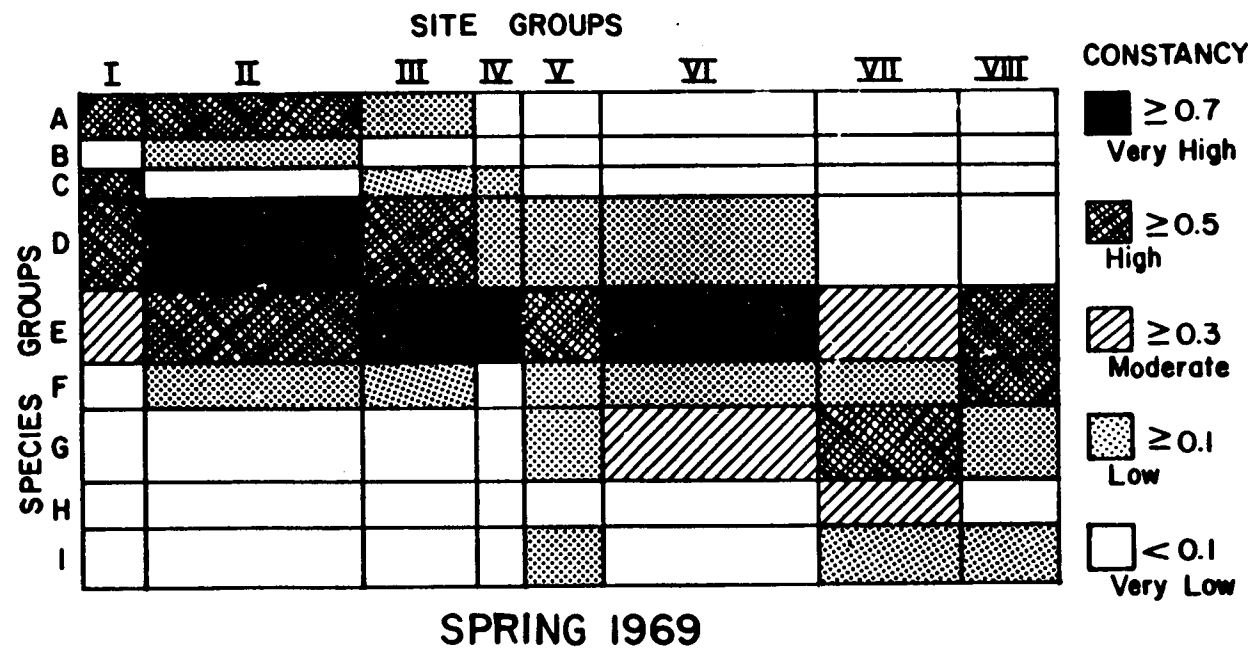
*Faunal affinity is designated after each species name: boreal, Bo;
warm-temperate, WT; outer-shelf, OS; inner-shelf, IS; slope, Sl;
mesopelagic, Mp.

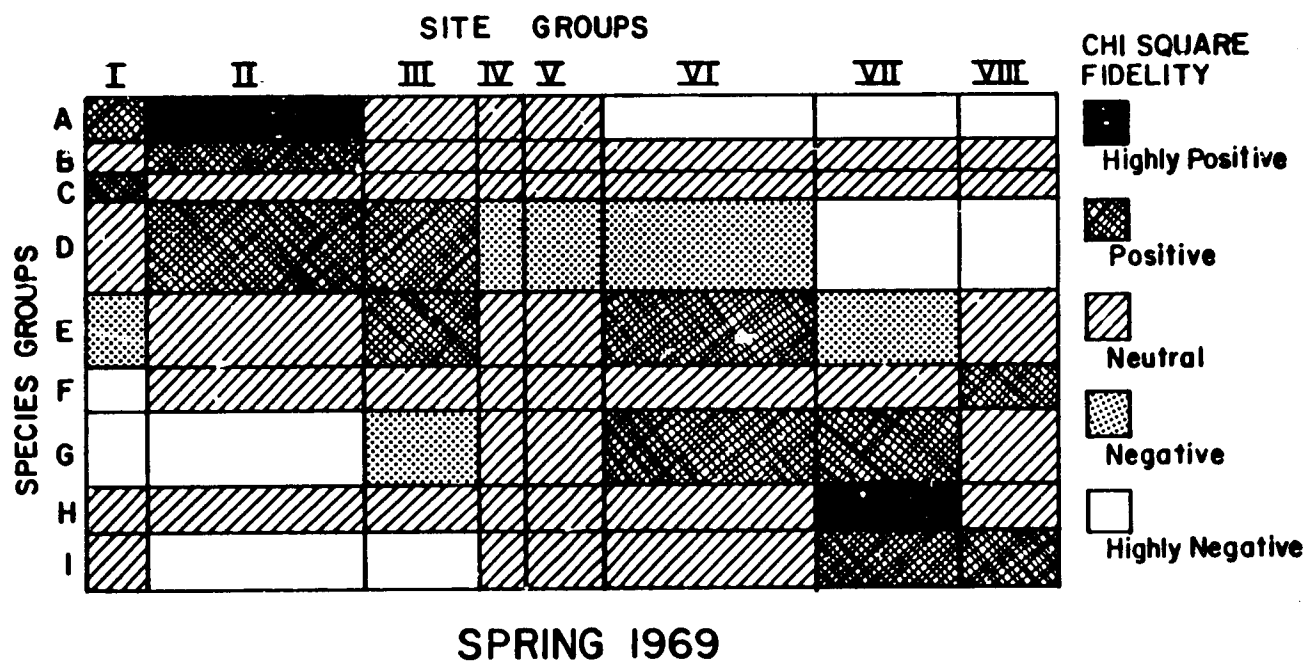
APPENDIX 10-D

Nodal Constancy and Chi-square Test of Fidelity ($\alpha = 0.5$),
NMFS Groundfish Survey, Cape Hatteras to Cape Cod,
1967-1976

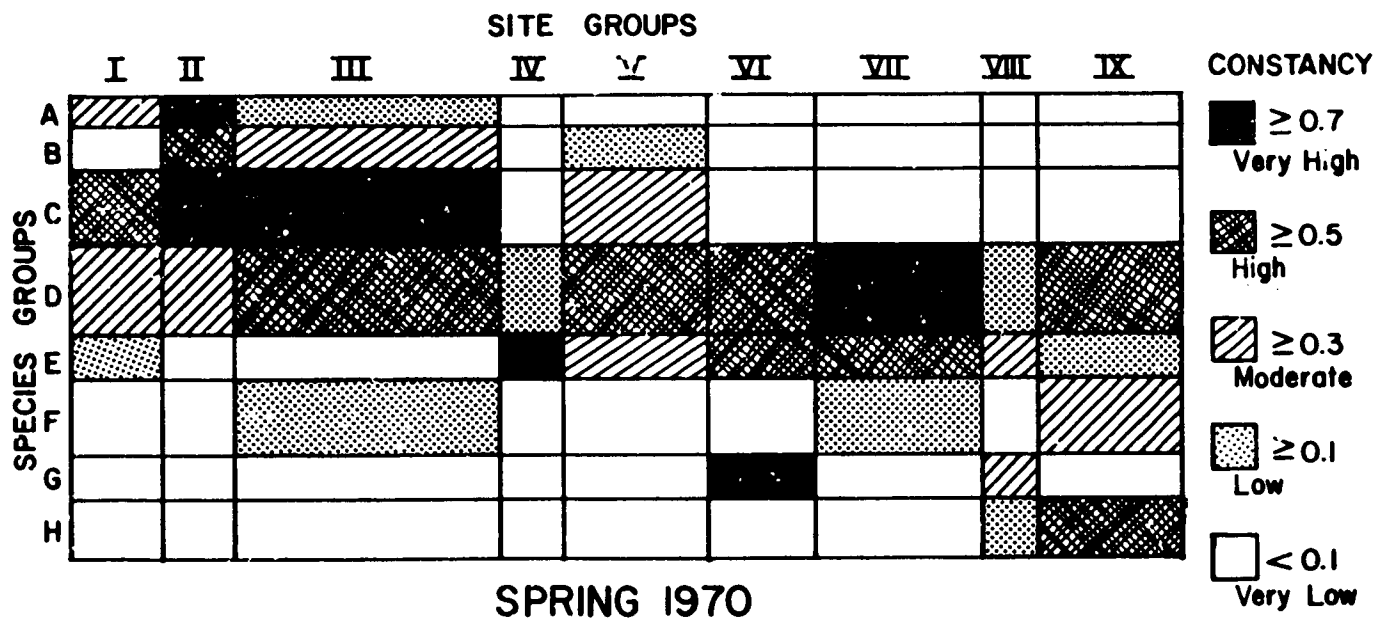


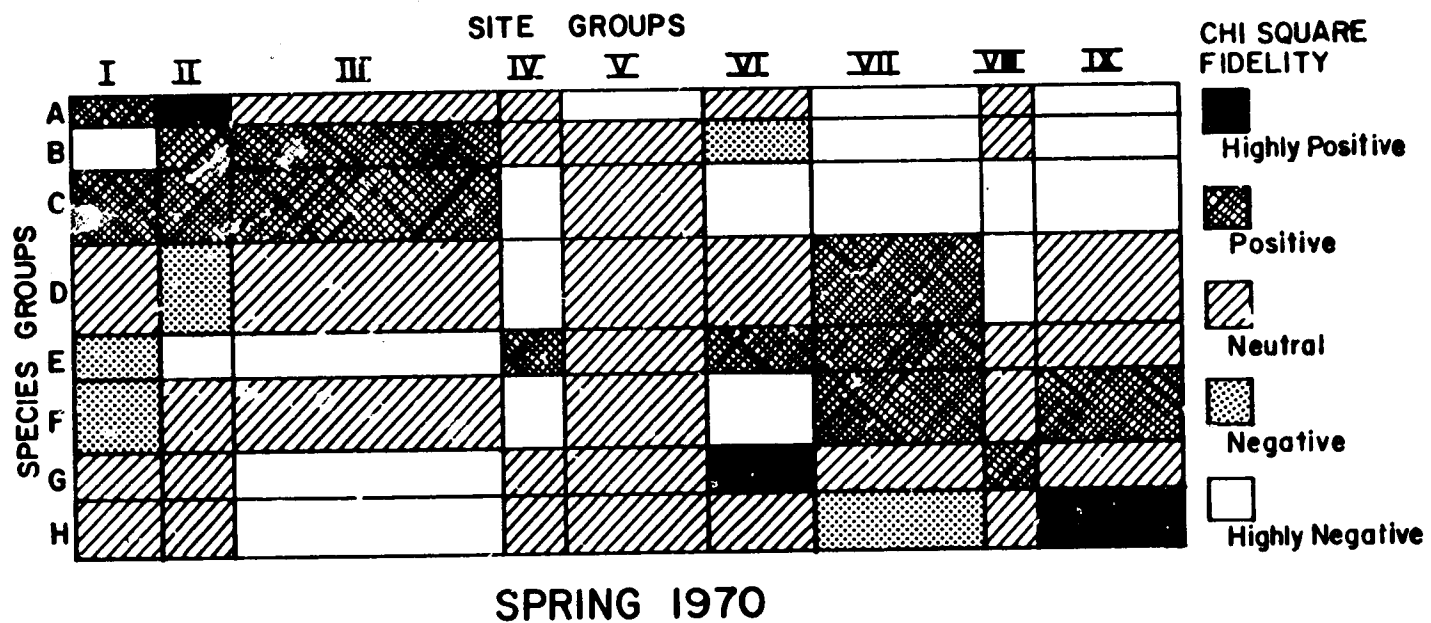


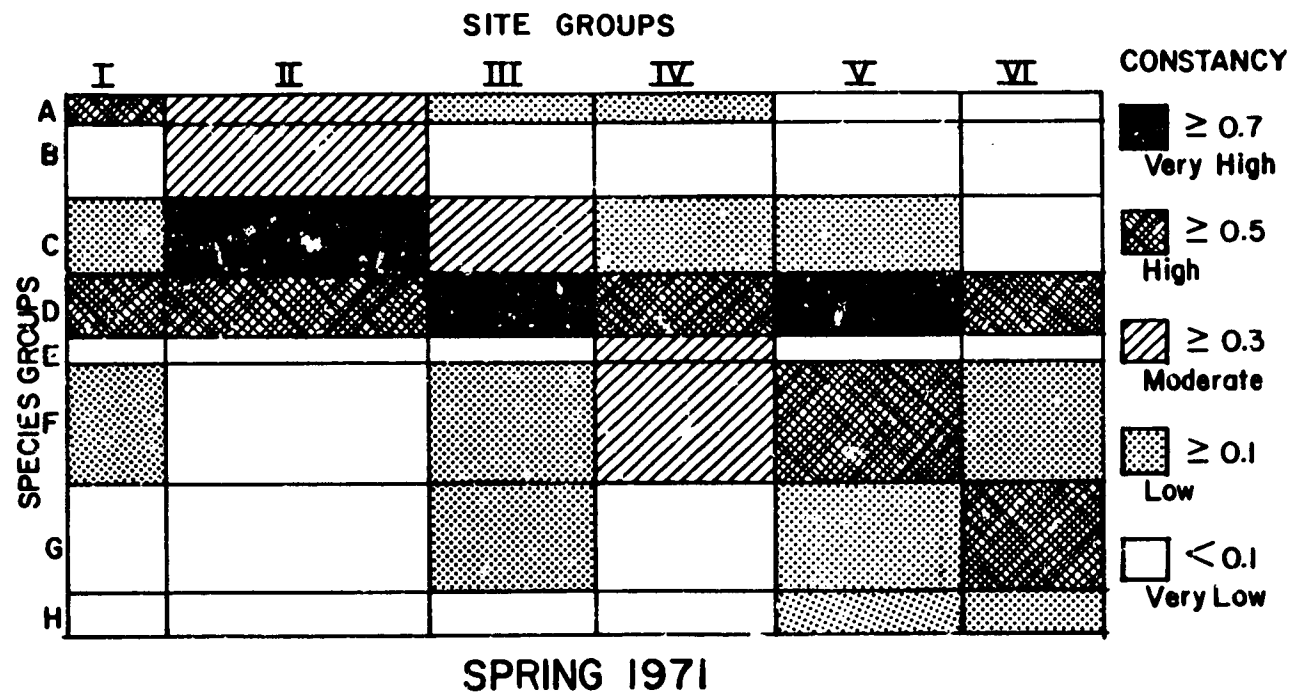


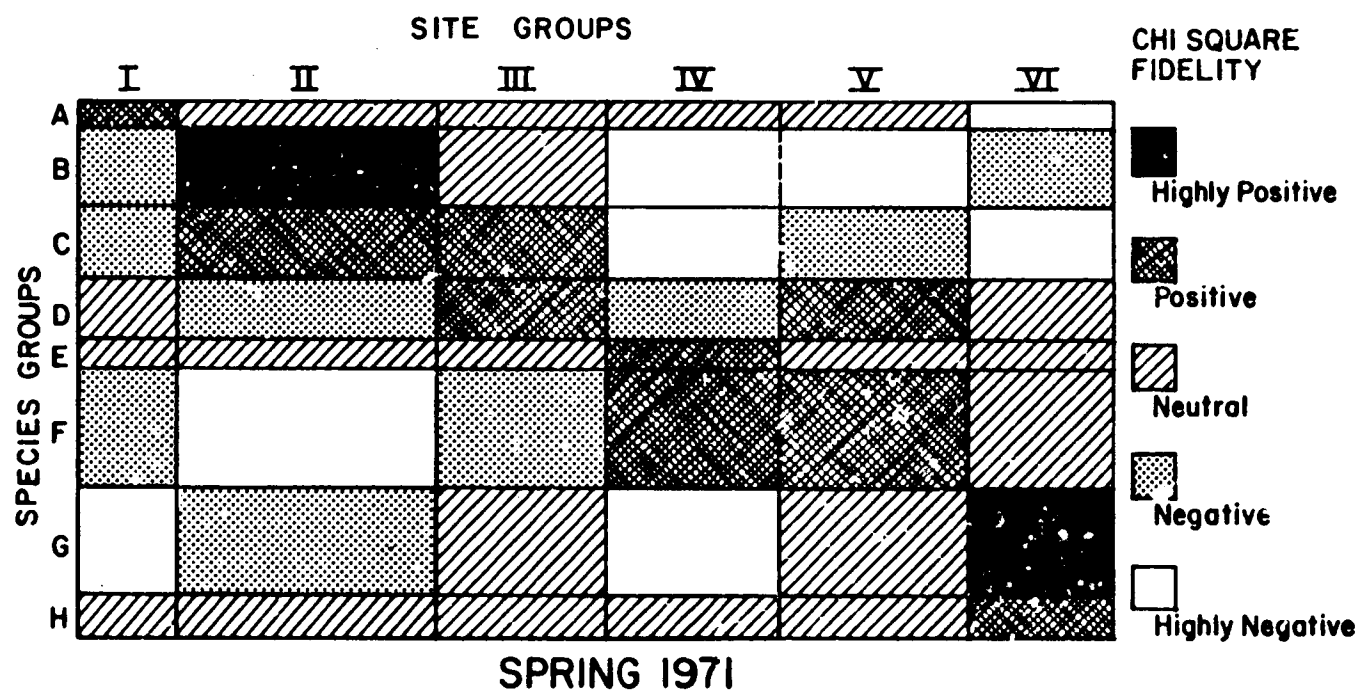


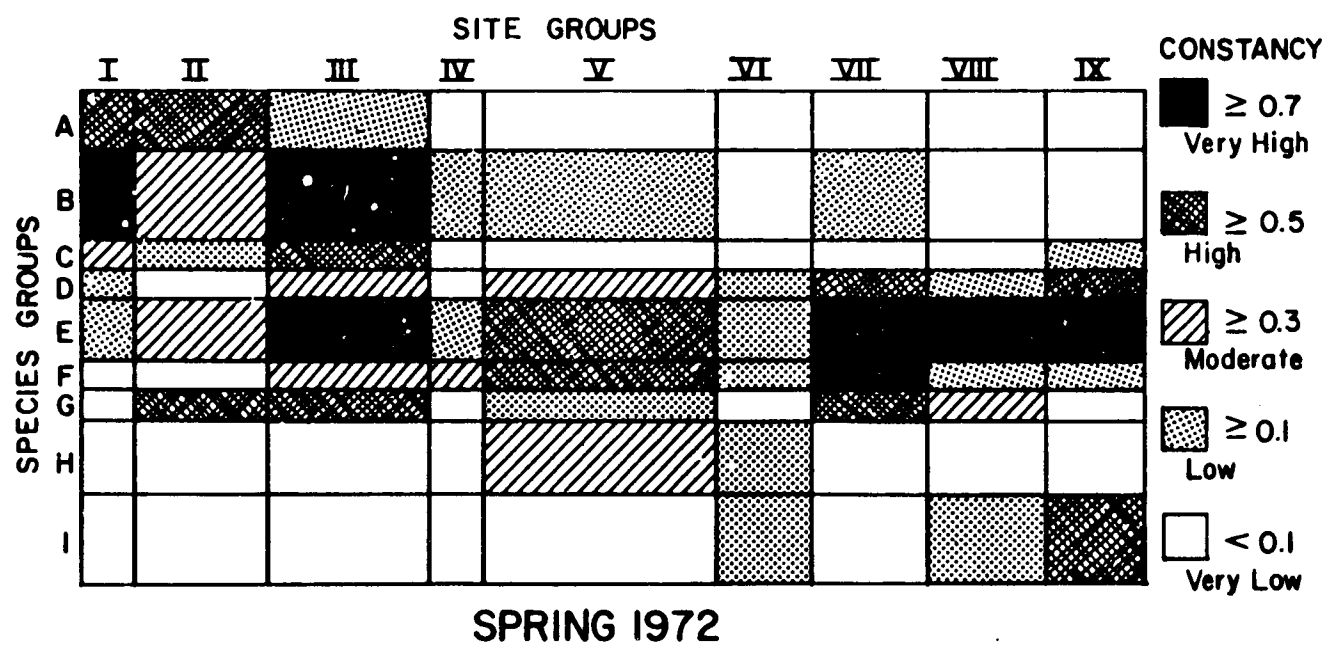
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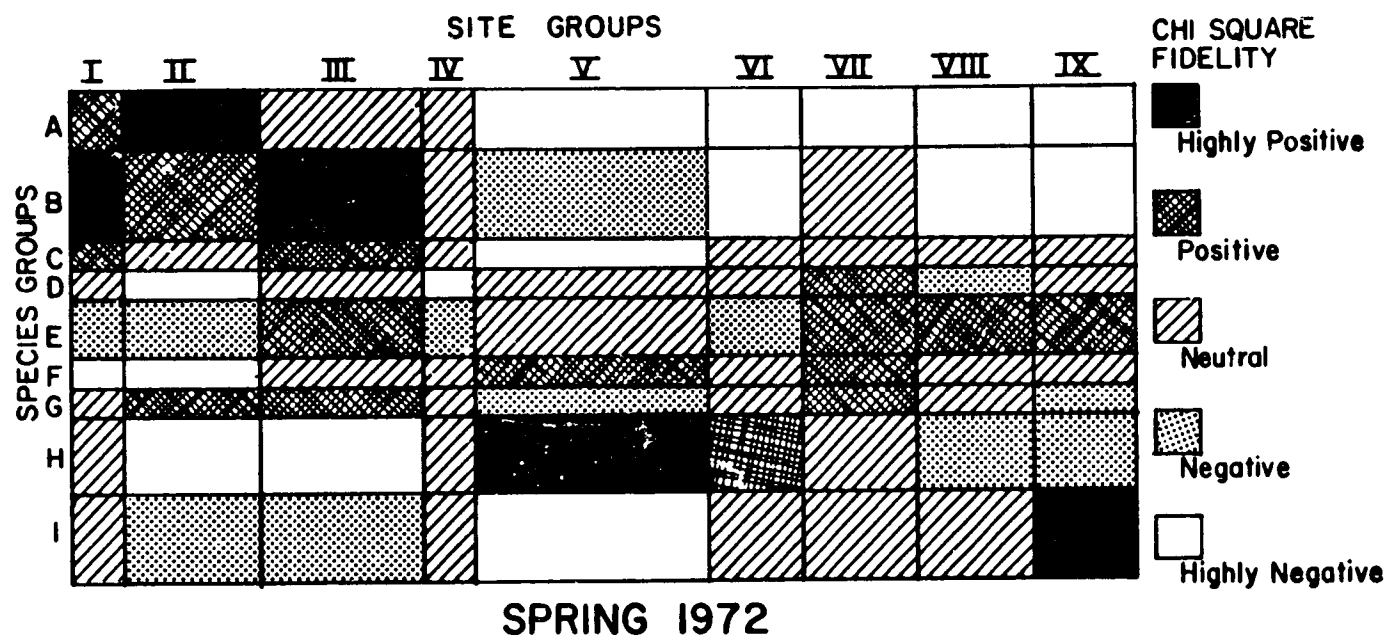




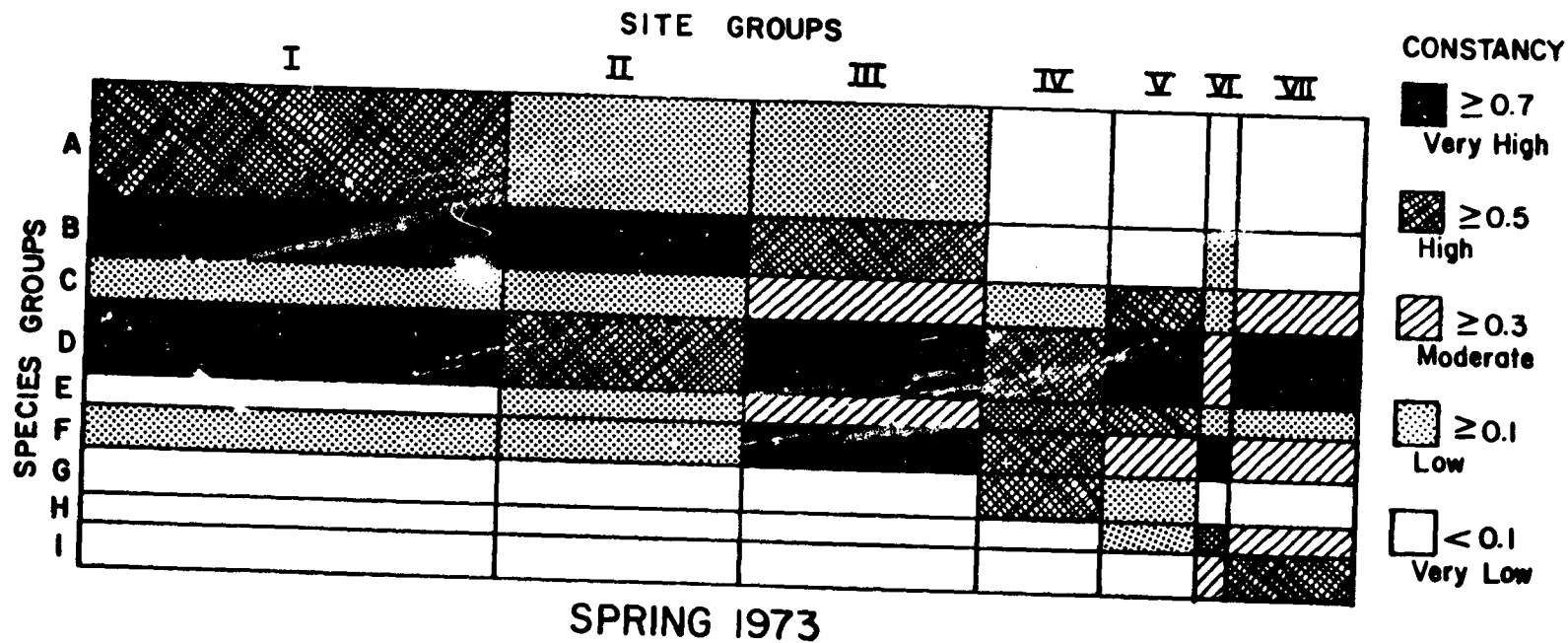




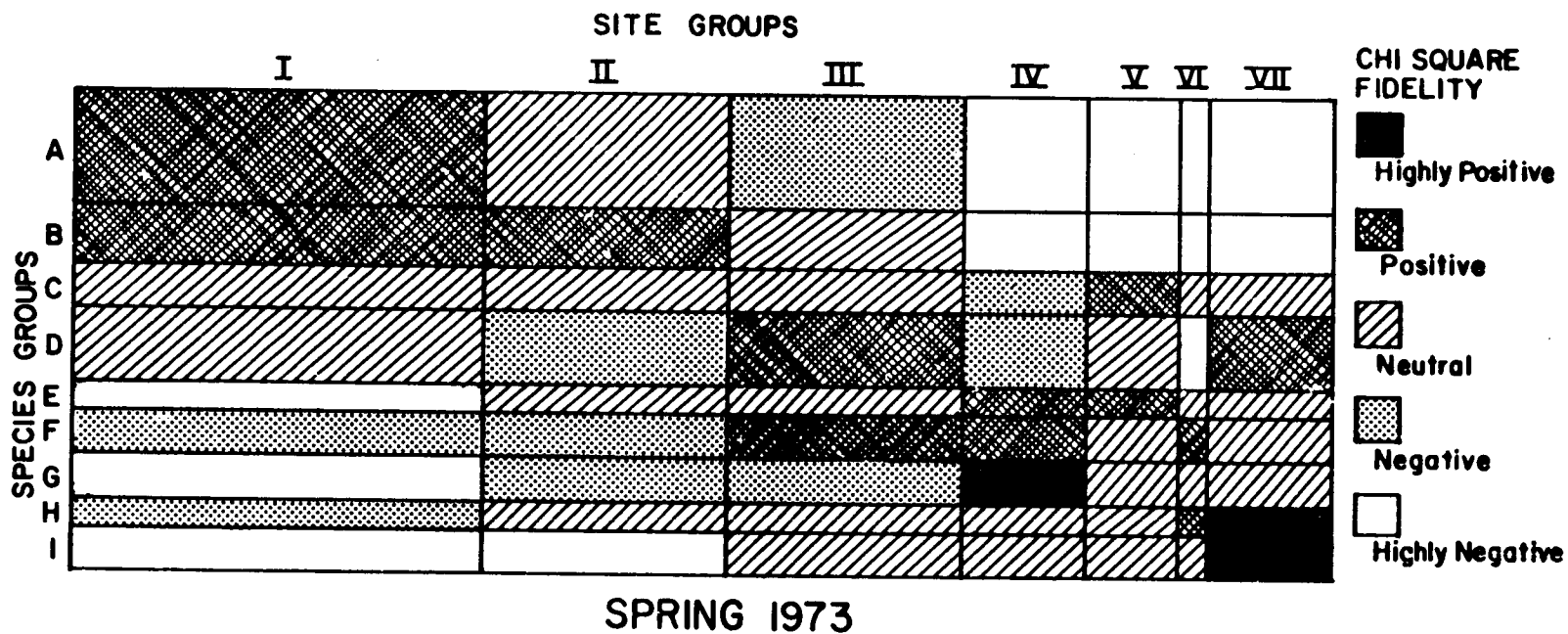


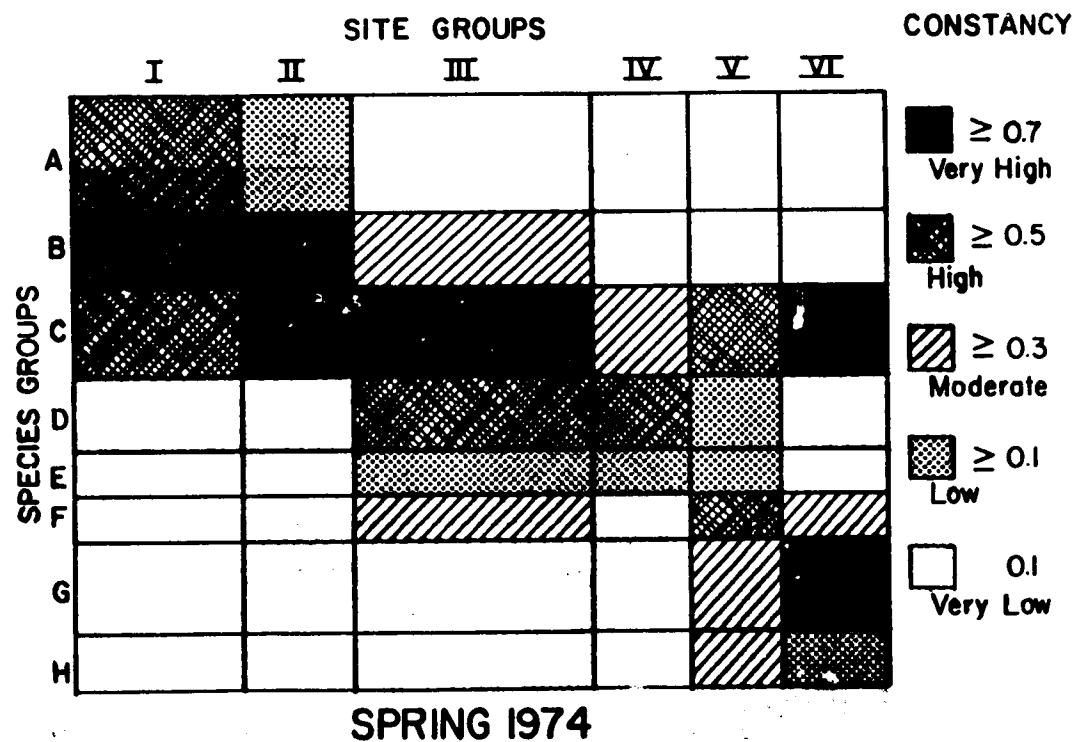


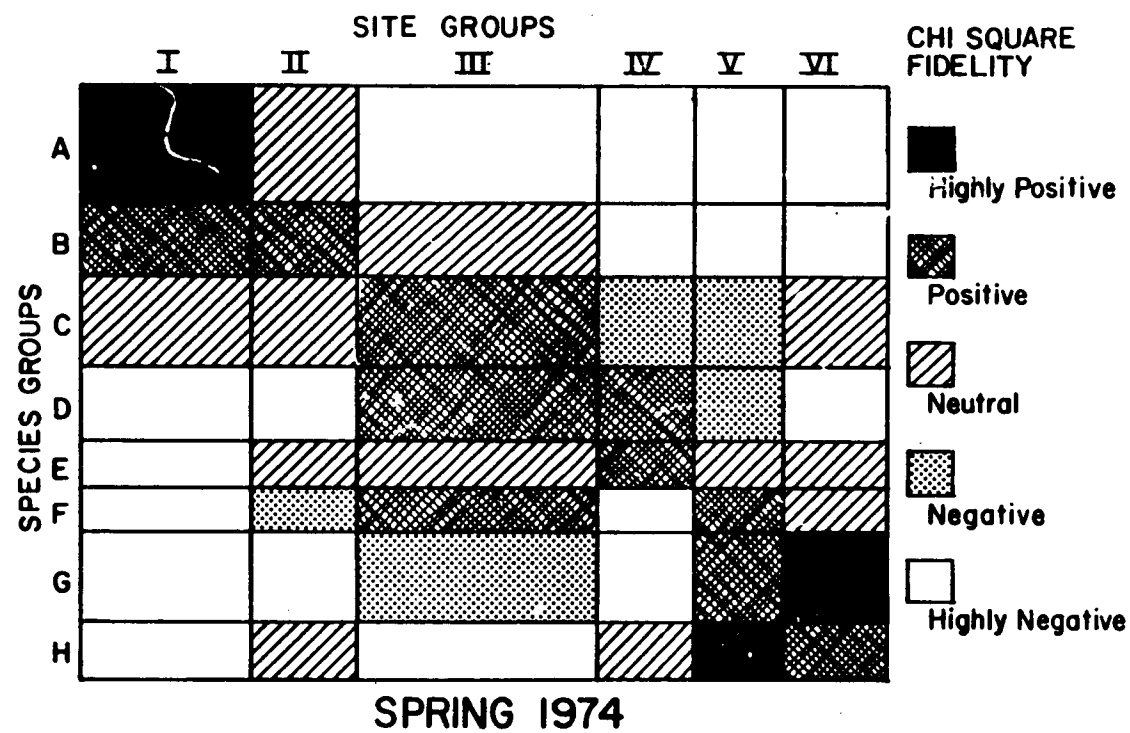
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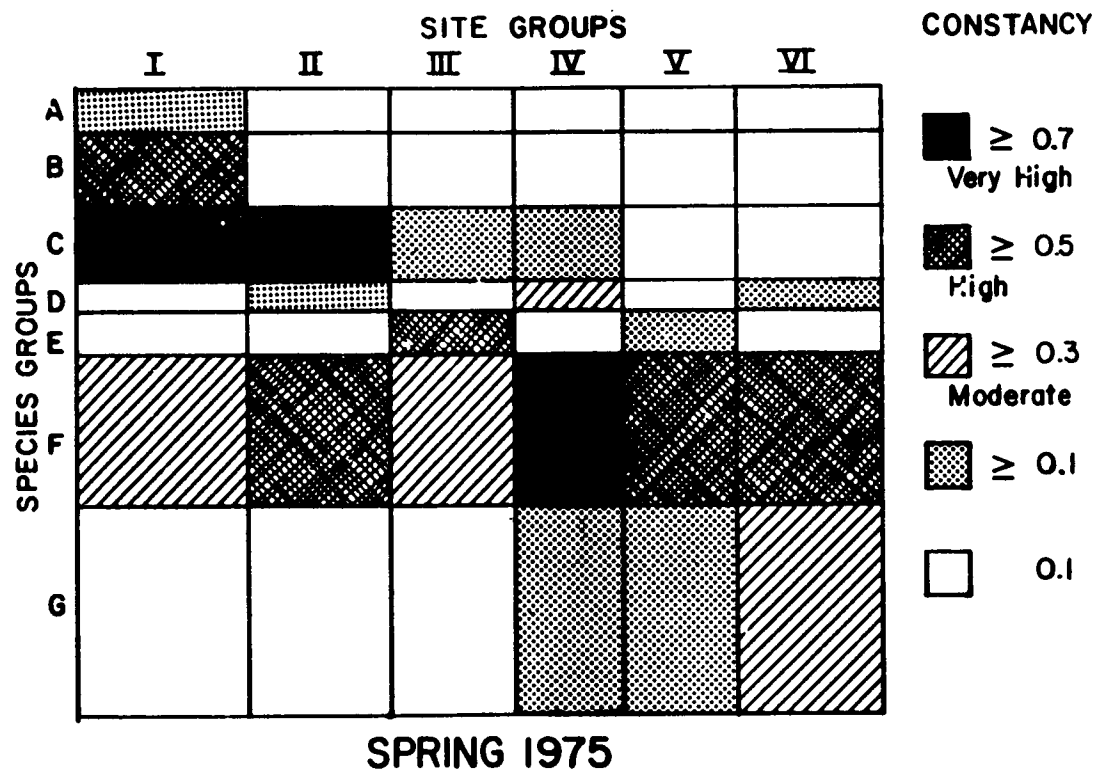


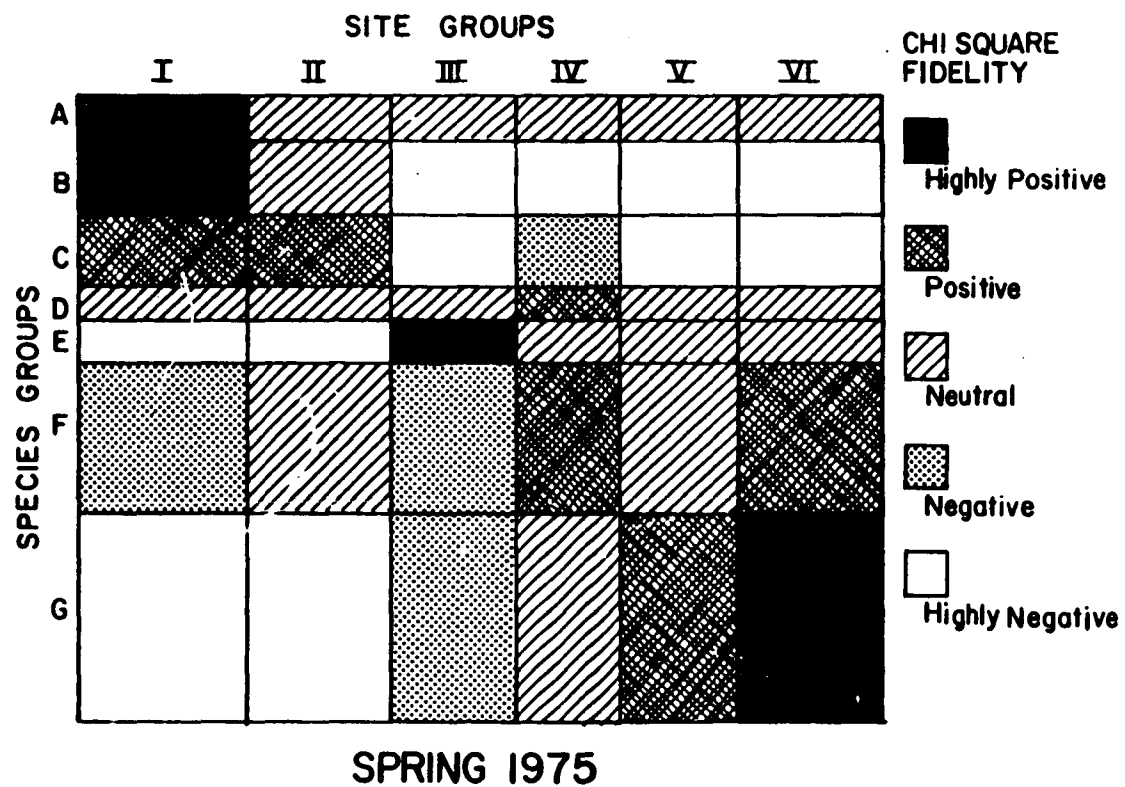
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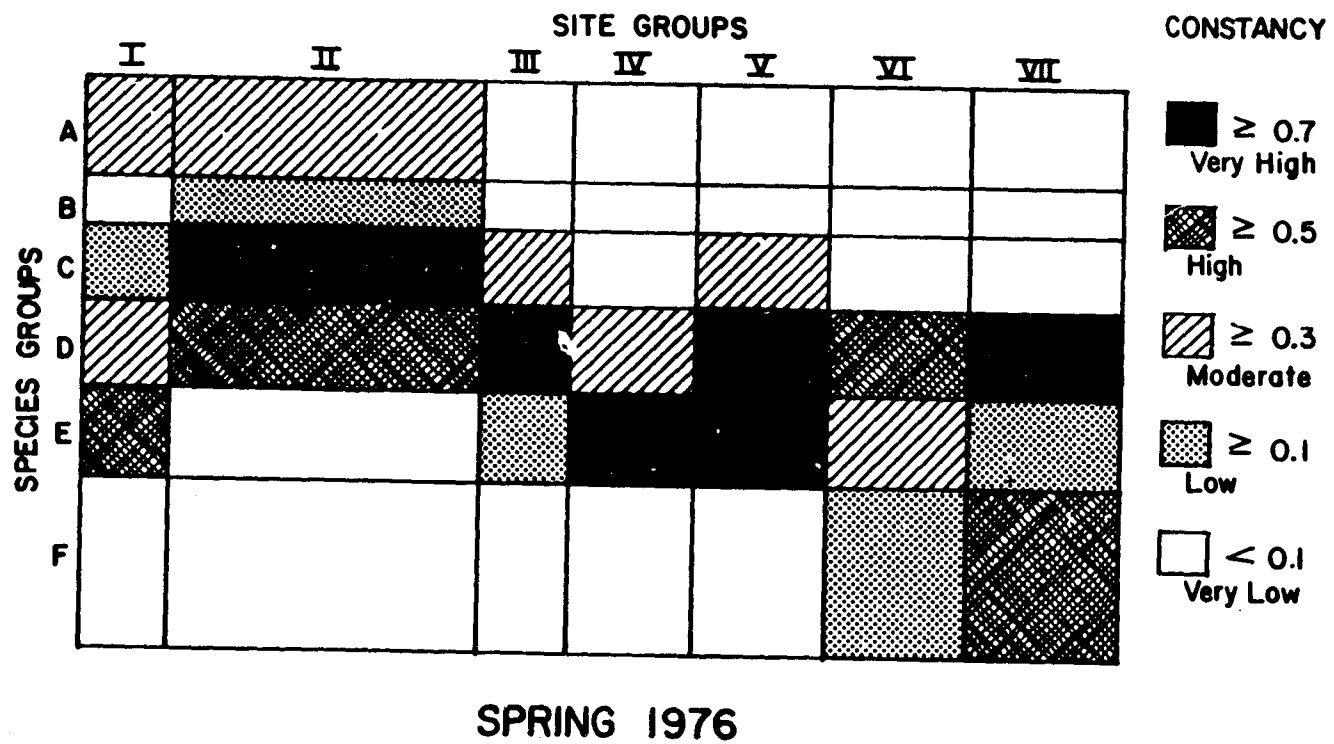


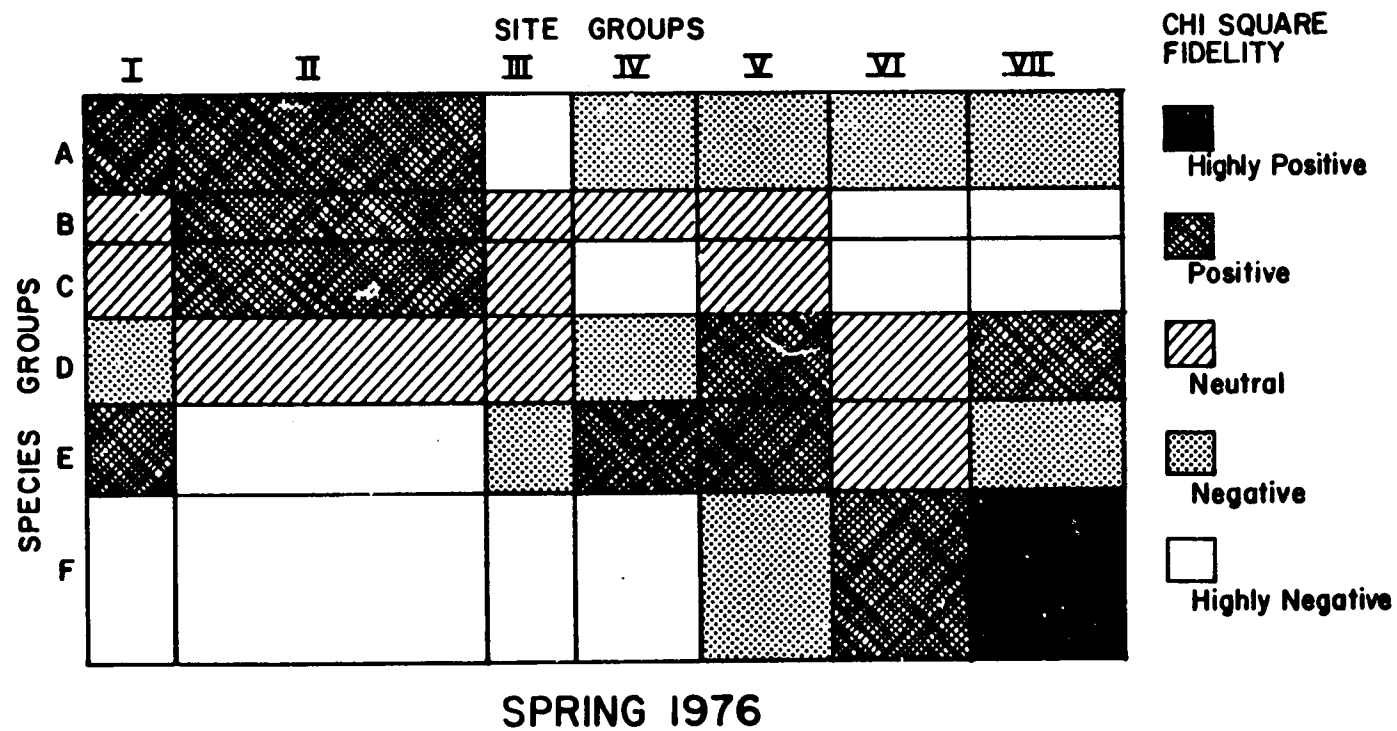


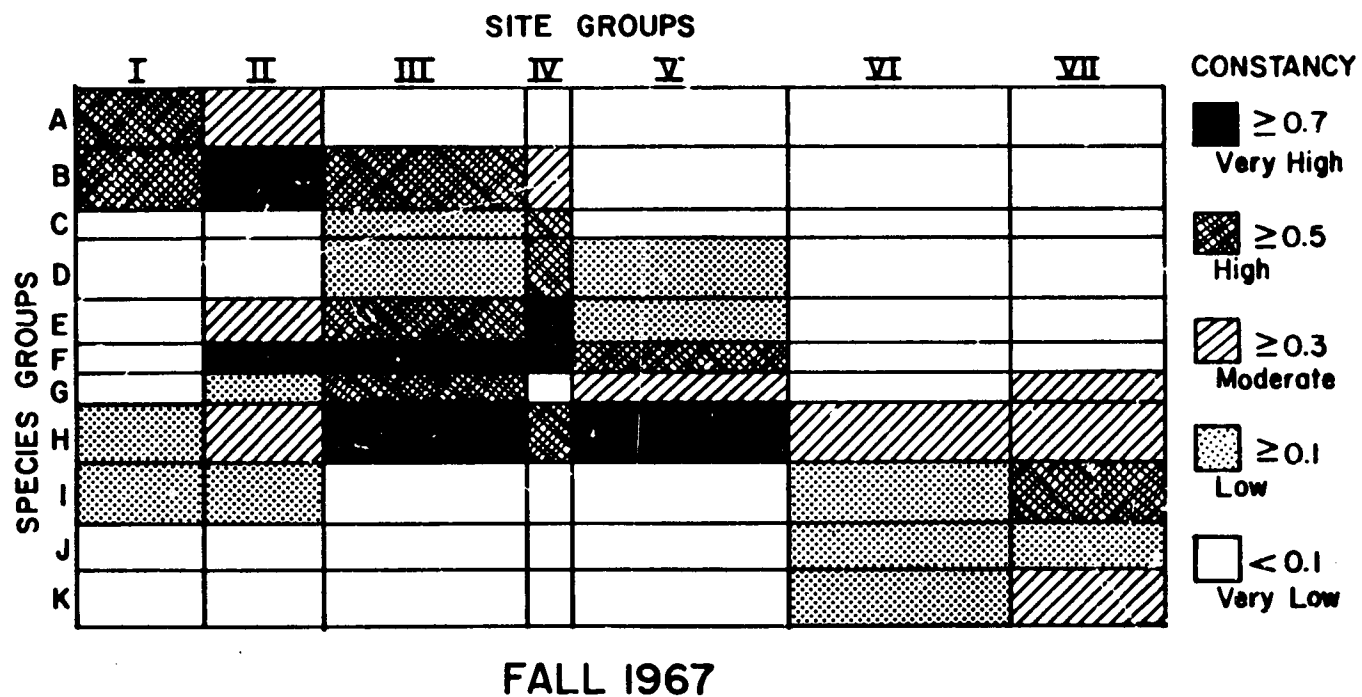




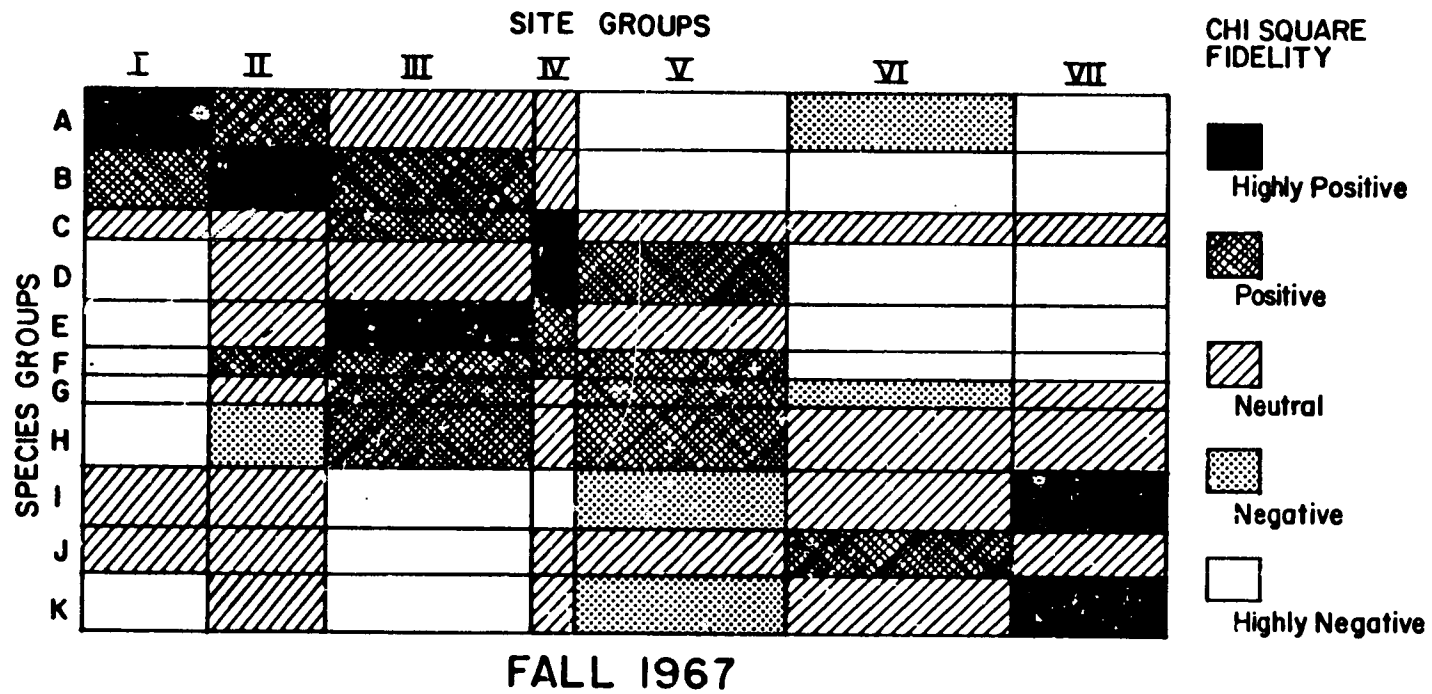
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10-166



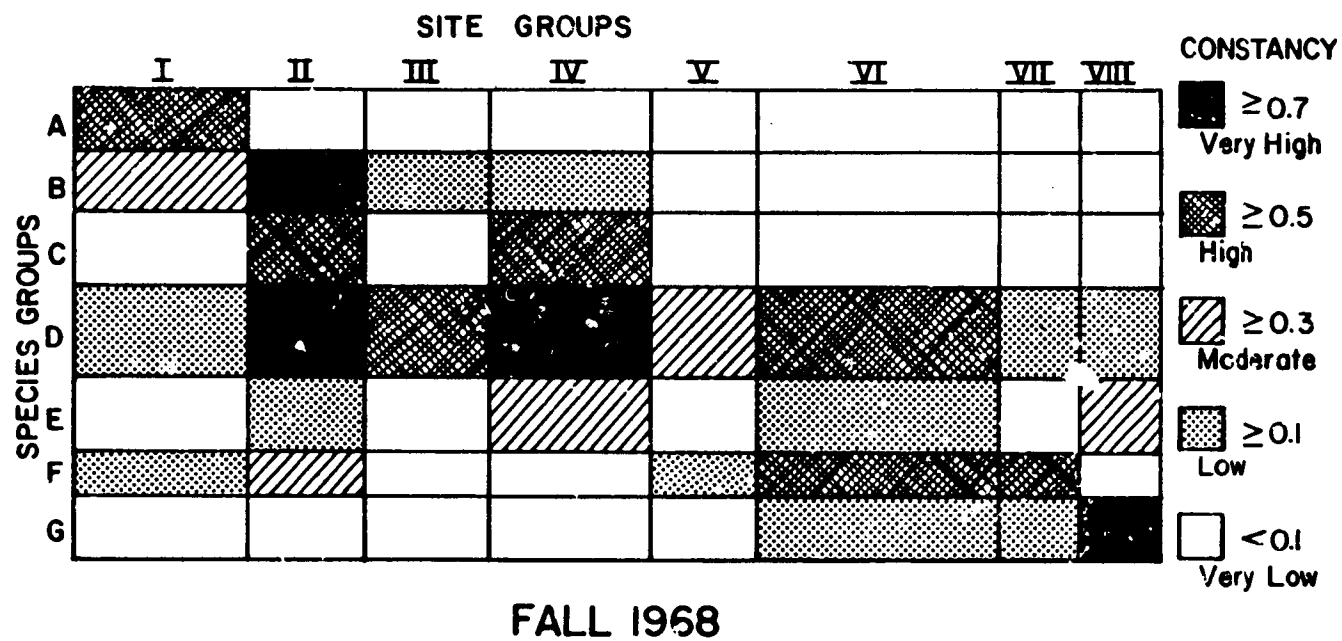




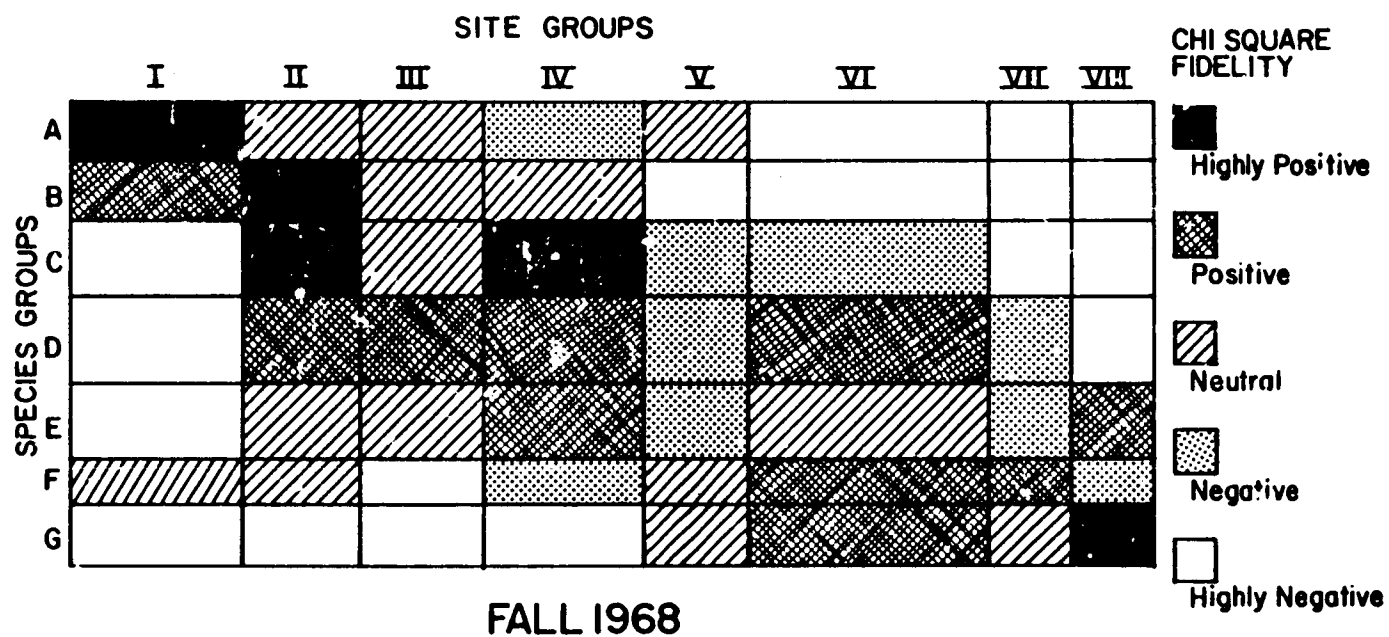
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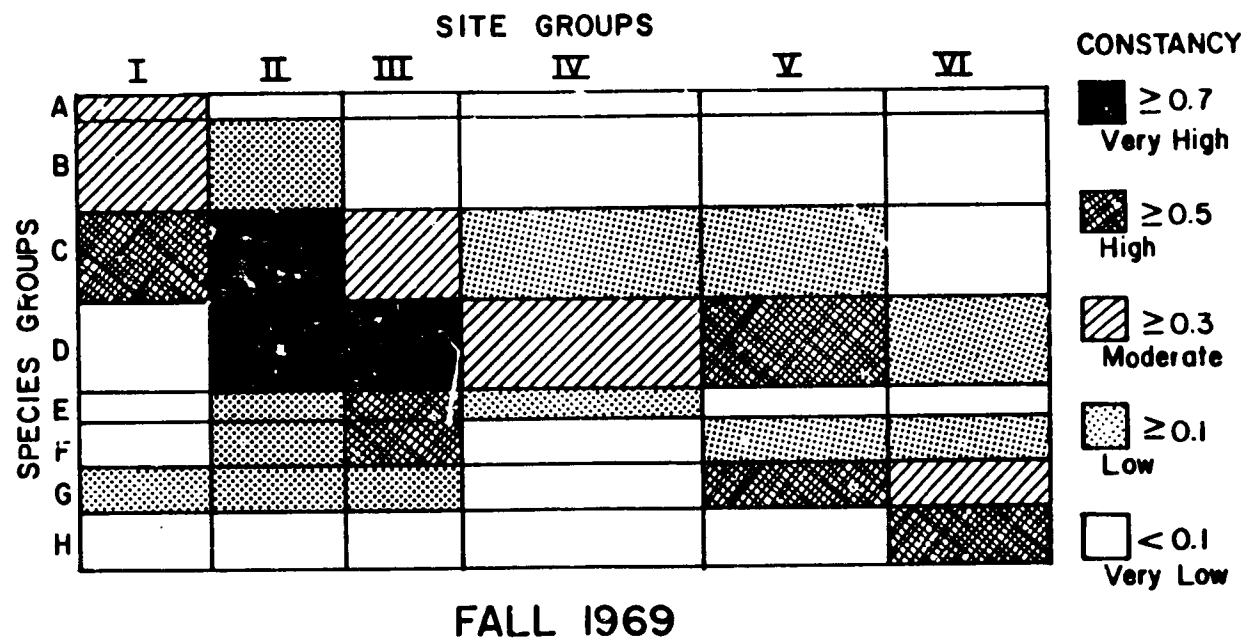


13-170

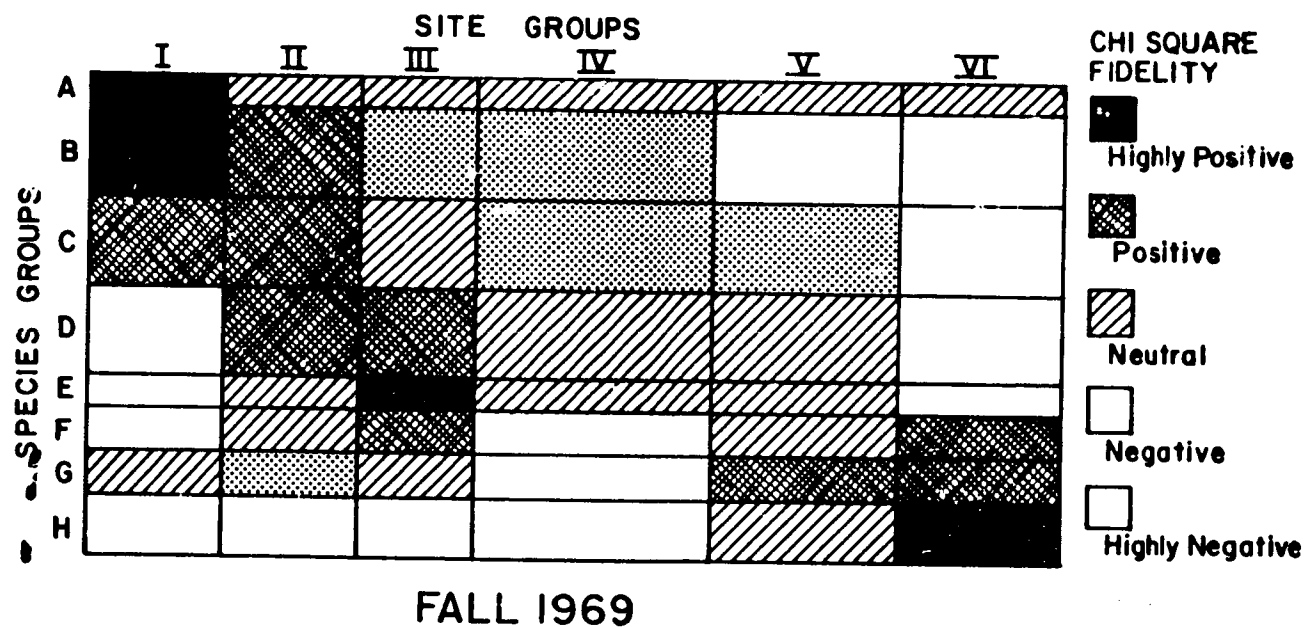


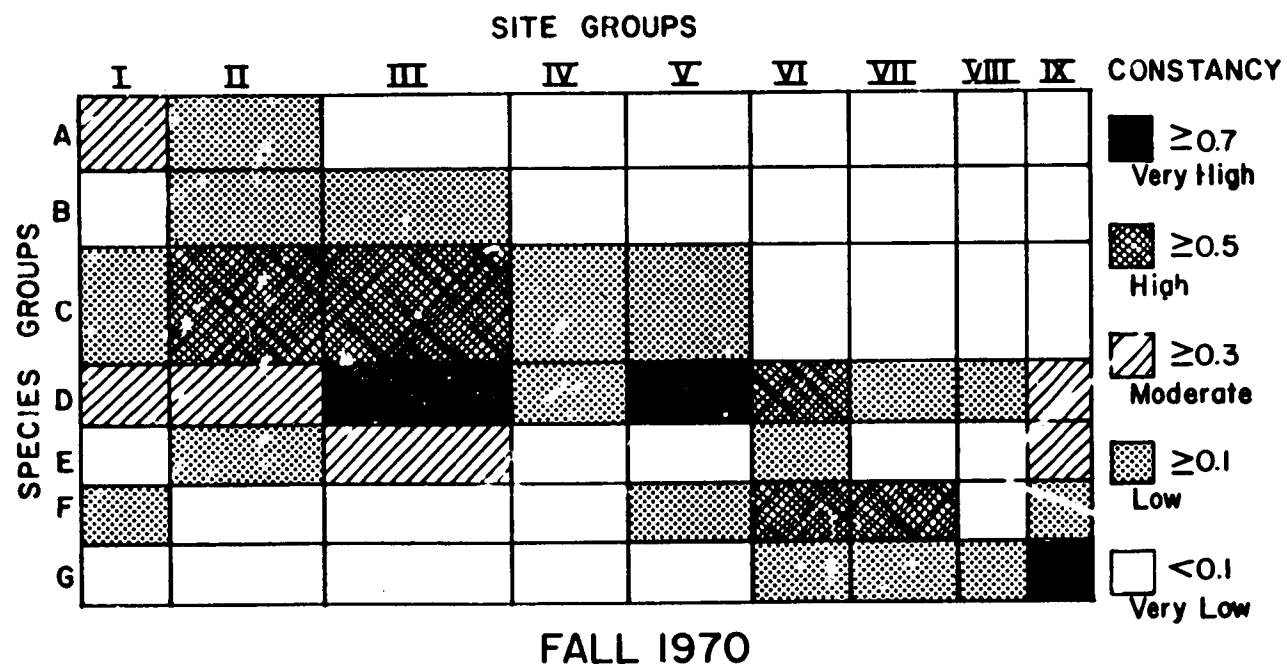
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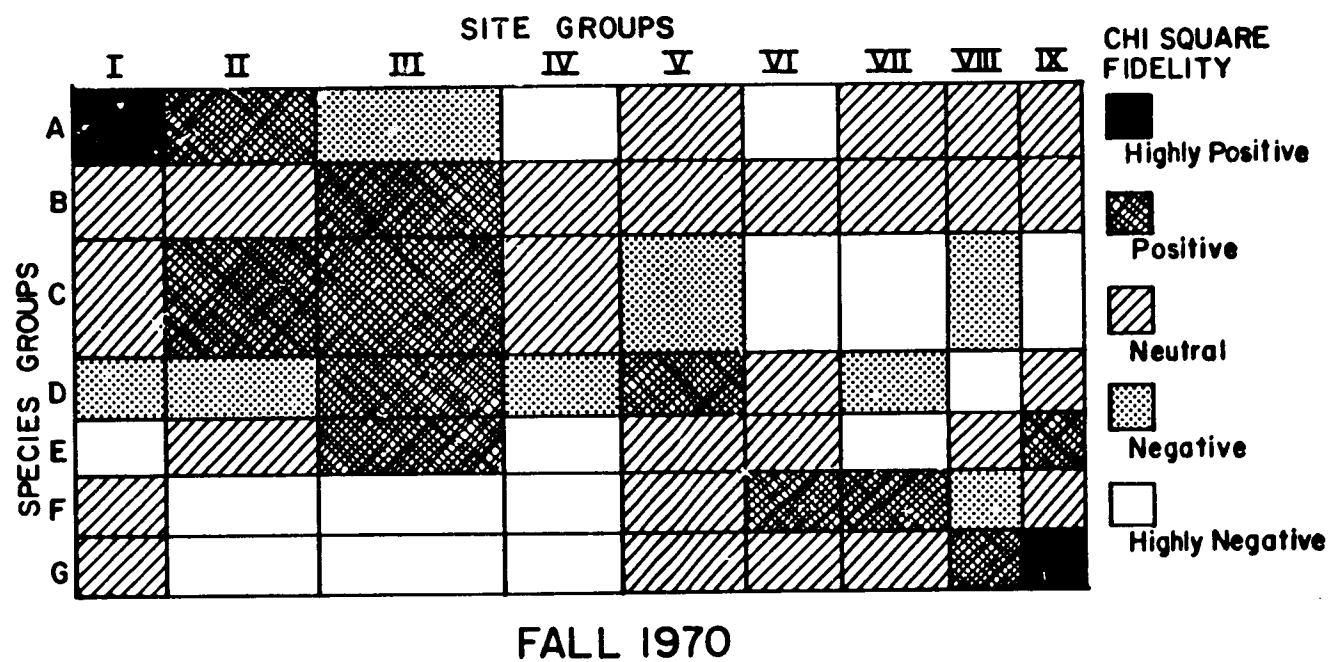


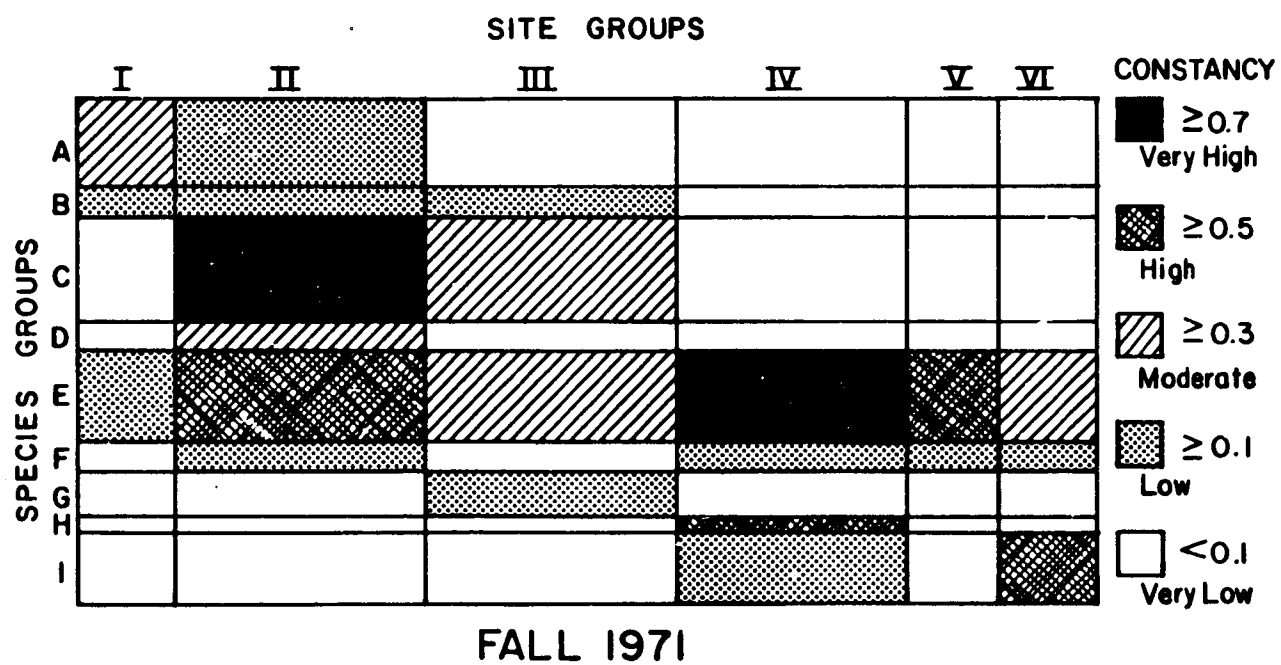
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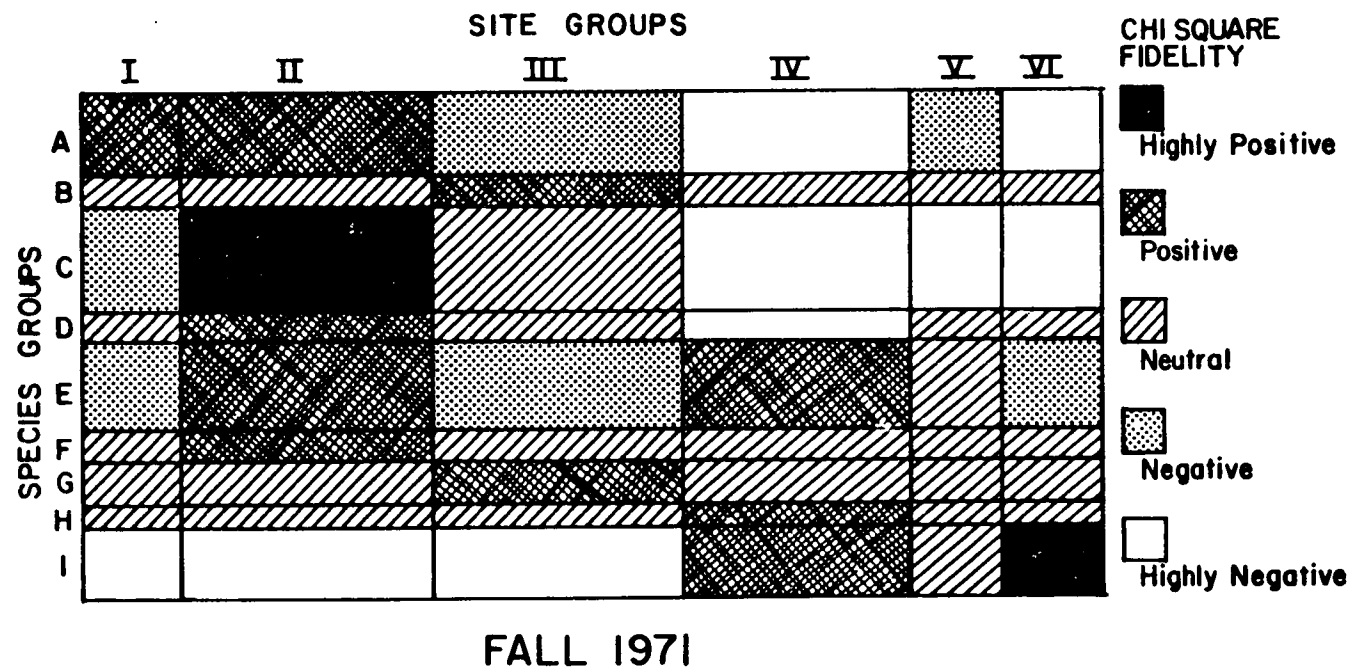


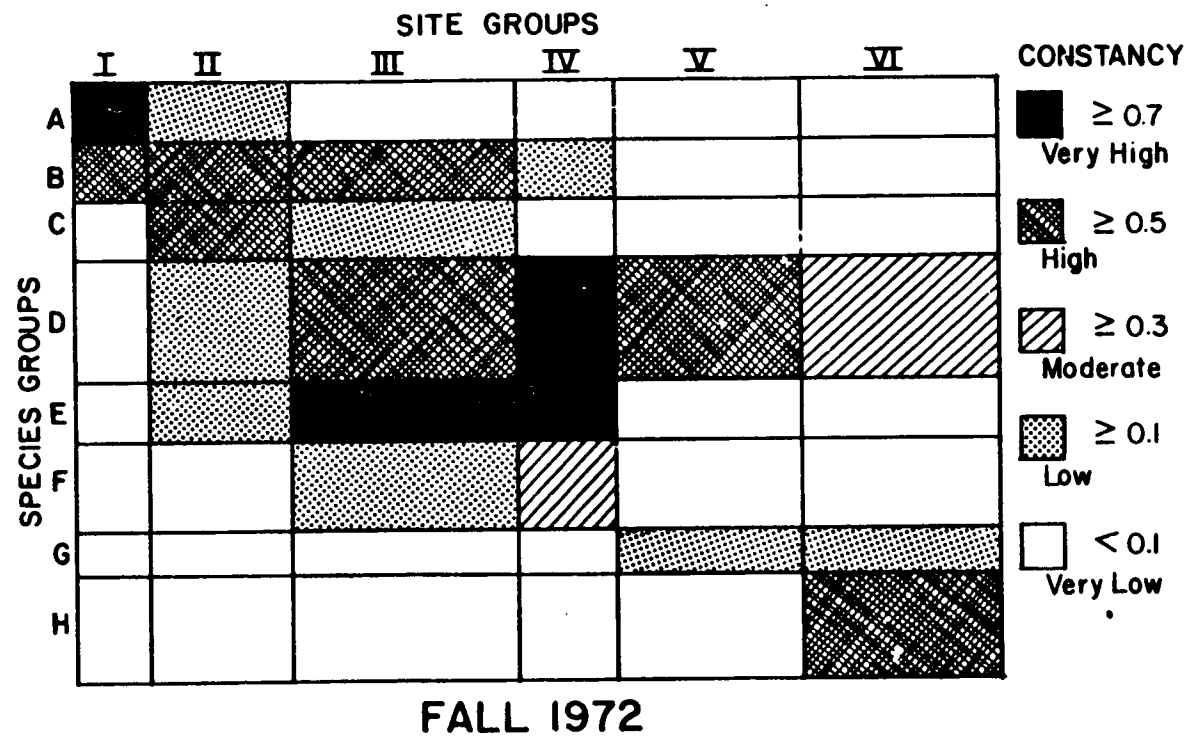
10-175



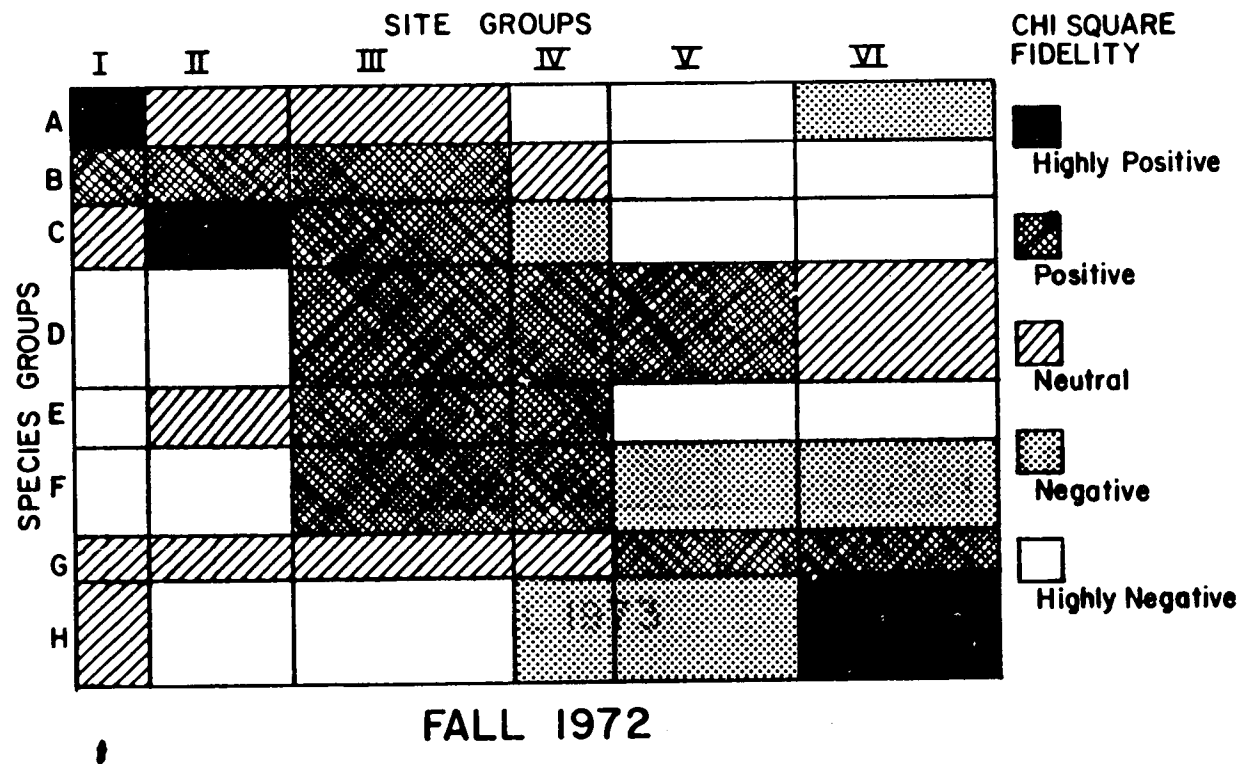


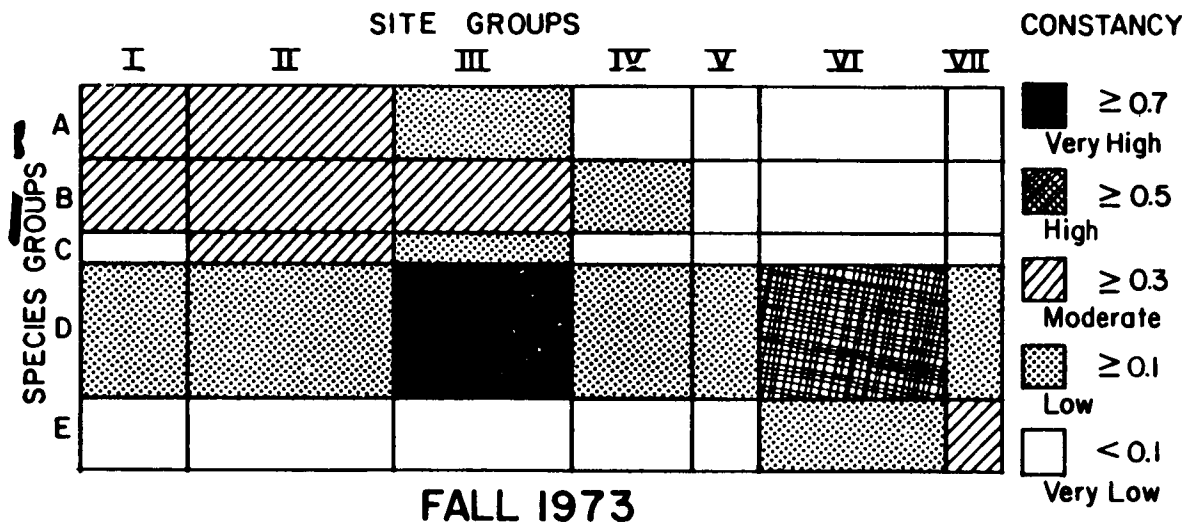
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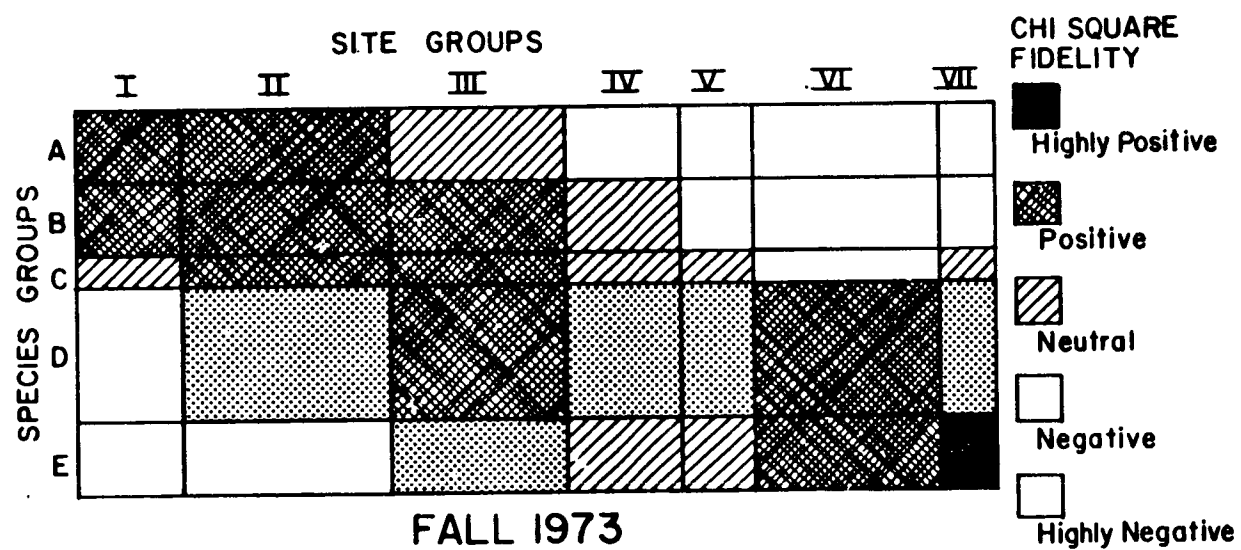


10-179

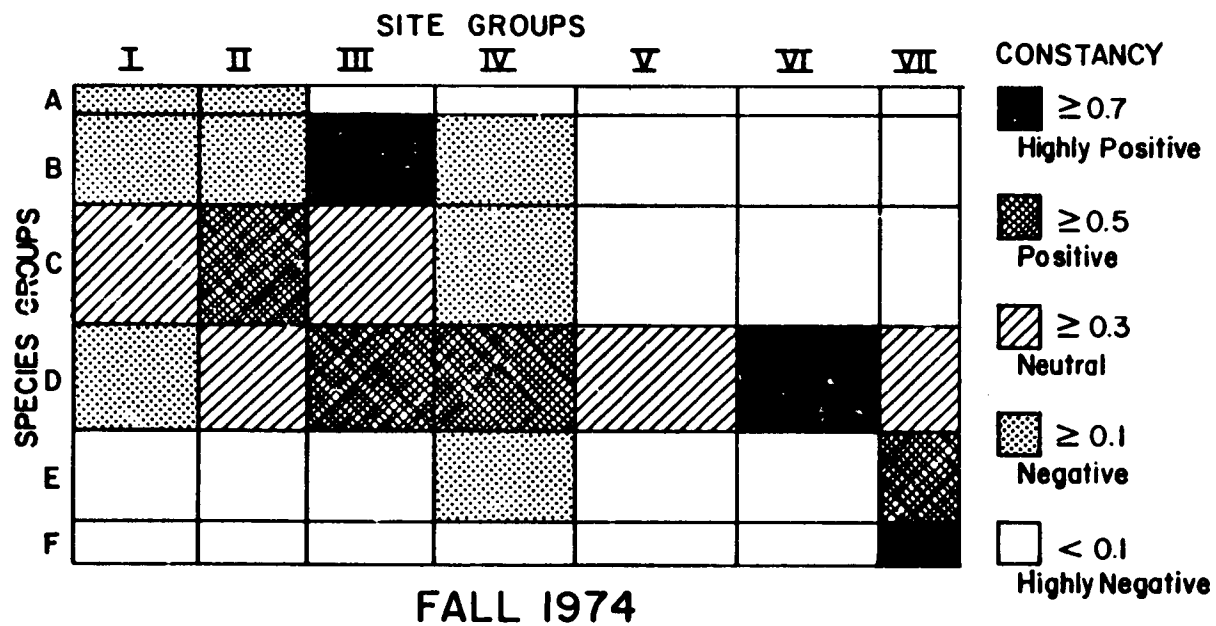




181-01



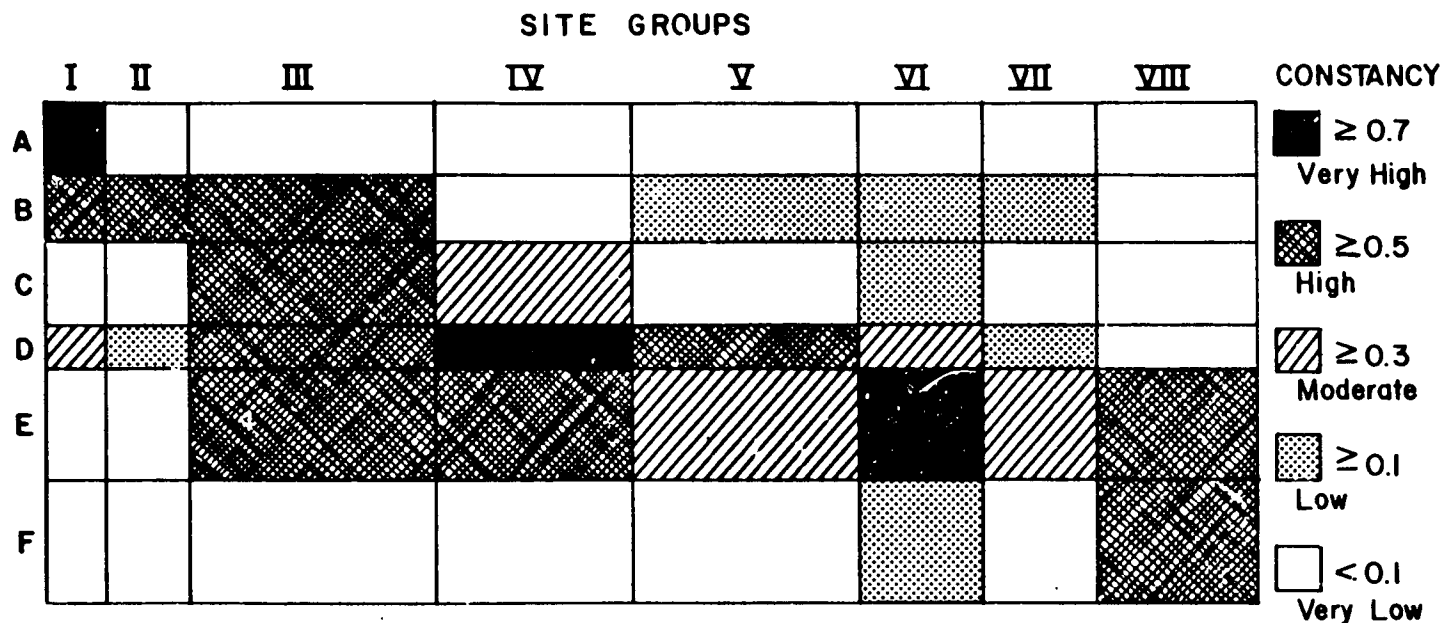
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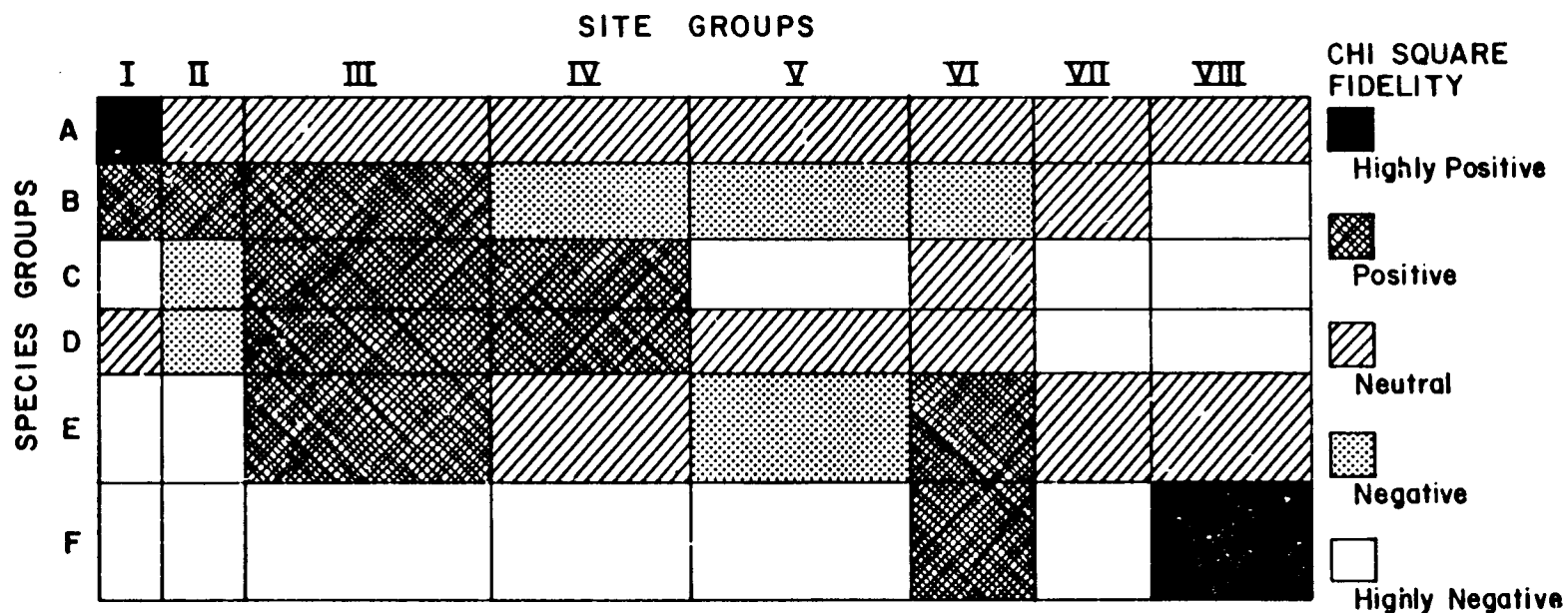
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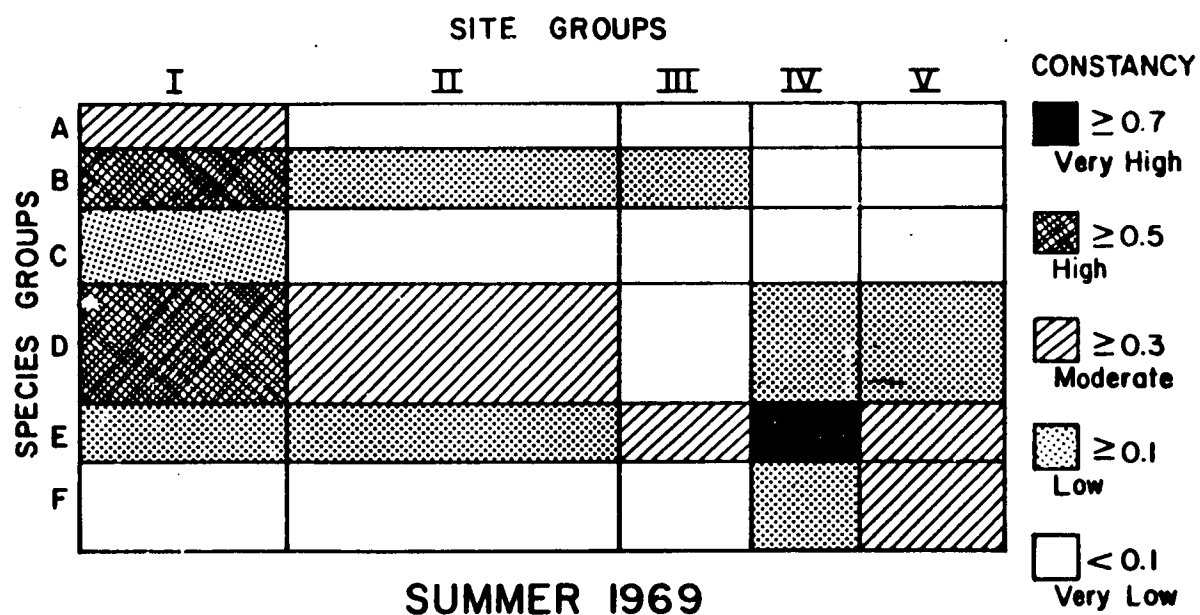
SPECIES GROUPS



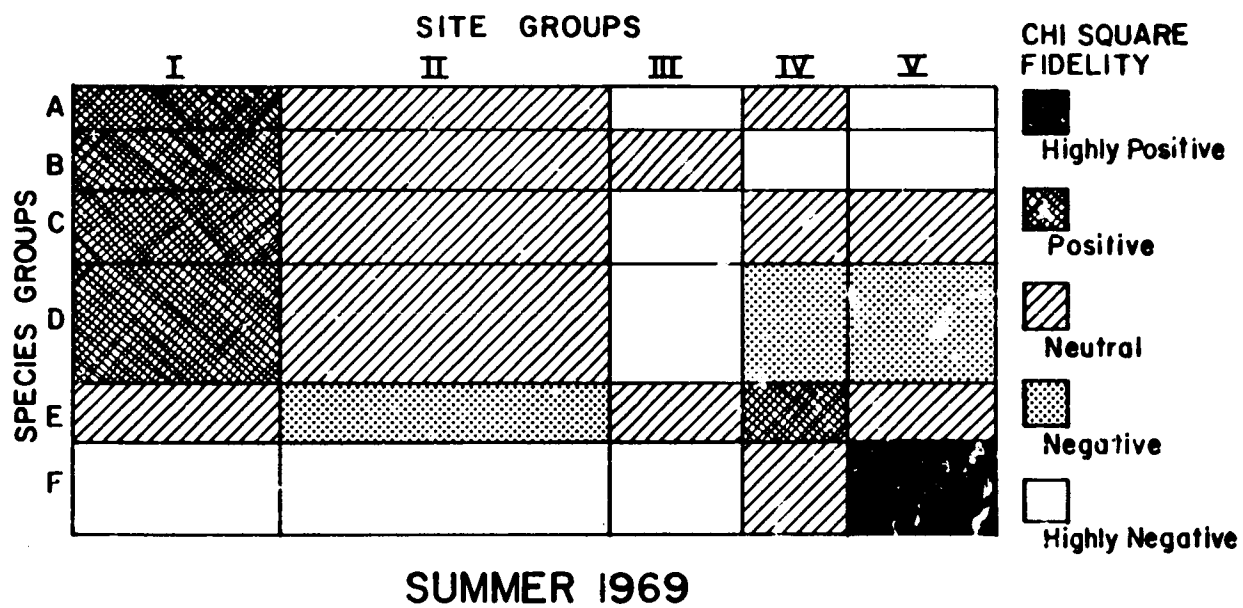
FALL 1975

10-185





10-187



APPENDIX 10-E
Species Dominance, NMFS Groundfish Survey,
Cape Hatteras to Cape Cod, 1967-1976

Table 10-E-1. Cruise 68-3, Spring 1968.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Raja erinacea</u>	Bo	A	79	7.8												
<u>Myoxocephalus octodecemspinosus</u>	Bo	A	96	10.0												
<u>Limanda ferruginea</u>	Bo	A	100	11.9	79	22.2										
<u>Macrozoarces americanus</u>	Bo	A	75	6.1	64	4.1										
<u>Pseudopleuronectes americanus</u>	Bo	A	57	3.6												
<u>Menidia menidia</u>	WT	A			50	3.5										
<u>Squalus acanthias</u>	Bo	B			79	6.3	90	4.4	95	17.9	47	19.1	62	8.1	57	23.1
<u>Merluccius bilinearis</u>	Bo	B	43	4.6	79	6.4	100	5.1	90	28.8	100	34.7	100	37.5	86	12.0
<u>Alosa pseudoharengus</u>	Bc	B	50	3.6	79	5.9	90	6.4	67	6.0	100	9.6				
<u>Alosa aestivalis</u>	WT	B			86	20.5	80	7.5								
<u>Scomber scombrus</u>	Bo	B			50	6.0	100	67.1	48	9.0			23	3.5		
<u>Clupea harengus harengus</u>	Bo	B	64	16.8	86	16.0	100	6.4								
<u>Centropomus striata</u>	WT	C							24	3.6						
<u>Prionotus carolinus</u>	WT	C							57	5.5						
<u>Stenotomus chrysops</u>	WT	C							29	8.8						
<u>Urophycis chuss</u>	Bo	D							57	3.0	73	6.2			57	14.0
<u>Hippoglossina oblonga</u>	OS	D							90	4.0						
<u>Peprilus triacanthus</u>	WT	D							71	8.3	60	16.2	92	34.4		
<u>Lepophidium cervinum</u>	OS	E									33	3.6				
Myctophidae	Mp	F											46	3.5	86	37.6
Anguilliformes		F													71	6.4

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.
 $\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.
 A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-2. Cruise 69-2, Spring 1969.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Pseudopleuronectes americanus</u>	Bo	A			71	3.7										
<u>Myoxocephalus octodecemspinosus</u>	Bo	D	71	7.9	100	14.3	85	4.3								
<u>Limanda ferruginea</u>	Bo	D	100	21.9	100	35.9	100	27.2					50	4.2		
<u>Macrozoarces americanus</u>	Bo	D	86	10.3	88	8.0	62	3.7								
<u>Scophthalmus aquosus</u>	IS	D			75	3.3	62	3.4	80	4.2						
<u>Raja ocellata</u>	Bo	D			83	4.8										
<u>Raja erinacea</u>	Bo	D			100	11.9	62	10.9								
<u>Alosa pseudoharengus</u>	Bo	E	86	33.5	58	3.1	100	21.9	100	35.5	67	6.1	58	6.4		
<u>Clupea harengus harengus</u>	Bo	E	100	19.5	63	5.5	54	6.1	100	14.8	44	9.2				
<u>Merluccius bilinearis</u>	Bo	E					92	6.1	100	31.1			100	30.9	75	12.3
<u>Squalus acanthias</u>	Bo	E					85	10.0	60	4.3	89	46.8	100	30.2	81	17.7
<u>Urophycis chuss</u>	Bo	E											92	7.3		82
<u>Urophycis tenuis</u>	Bo-SI	F														100
<u>Peprilus triacanthus</u>	WT	G													100	33.2
<u>Hippoglossina oblonga</u>	OS	G											75	5.9	56	3.5
<u>Prionotus carolinus</u>	WT	G									44	14.1	38	3.4	44	15.3
<u>Etropus microstomus</u>	SI	G							40	5.2						
<u>Scomber scombrus</u>	Bo	I									11	8.9			50	4.5

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-3. Cruise 70-3, Spring 1970.

Species	Faunal Affinity*	Species Group	Site Group**																	
			I		II		III		IV		V		VI		VII		VIII		IX	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Pseudopleuronectes americanus</u>	Bo	A	40	2.4	88	5.1														
<u>Raja erinacea</u>	Bo	C			63	10.8	77	3.3												
<u>Myoxocephalus octodecemspinosus</u>	Bo	C			100	18.9	67	4.9			25	3.0								
<u>Clupea harengus harengus</u>	Bo	C			50	18.2	90	8.1			50	3.9								
<u>Limanda ferruginea</u>	Bo	C	100	38.4	100	21.4	100	37.7			56	7.3								
<u>Macrozoarces americanus</u>	Bo	C	100	7.7	100	12.5	67	4.5												
<u>Merluccius bilinearis</u>	Bo	D	60	3.0			90	17.3			88	16.7	75	6.7	89	20.1			88	10.6
<u>Urophycis chuss</u>	Bo	D	40	4.5			93	5.8			88	6.5			74	10.0			81	4.3
<u>Squalus acanthias</u>	Bo	D	80	14.8			73	3.0			56	11.5			68	9.3			81	27.4
<u>Scomber scombrus</u>	Bo	D	60	4.8			27	4.4	29	10.3	44	17.6	50	12.3	89	10.6			31	4.2
<u>Hippoglossina oblonga</u>	OS	D									75	4.6								
<u>Alosa pseudoharengus</u>	Bo	D	40	3.0	75	5.4					31	10.3			84	4.9				
<u>Stenotomus chrysops</u>	WT	E							100	59.3			58	19.6	42	4.9				
<u>Peprilus triacanthus</u>	WT	E							57	5.8			58	11.9	79	19.0	100	89.7	38	3.0
<u>Prionotus carolinus</u>	WT	E							71	9.1	50	7.6	83	18.1	58	14.0			31	3.0
<u>Urophycis tenuis</u>	Bo-Sl	F																	50	4.4
<u>Prionotus evolans</u>	WT	G															33	3.5		
<u>Urophycis regius</u>	WT	G											92	20.5			83	6.5		
Myctophidae	Mp	H																	44	7.0
<u>Helicolenus dactylopterus</u>	Sl	H																	100	21.5

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** Σ = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-4. Cruise 71-1, Spring 1971.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			Z	x	Z	x	Z	x	Z	x	Z	x	Z	x
<u>Clupea harengus harengus</u>	Bo	A	64	10.2	55	5.4								
<u>Alosa aestivalis</u>	WT	A	64	13.8										
<u>Pseudopleuronectes americanus</u>	Bo	B			52	4.4								
<u>Raja erinacea</u>	Bo	C			83	14.5	63	5.8	35	3.1				
<u>Limanda ferruginea</u>	Bo	C	45	17.5	97	41.0	84	16.4						
<u>Macrozoarces americanus</u>	Bo	C			83	5.8								
<u>Myoxocephalus octodecemspinosus</u>	Bo	C			72	4.9								
<u>Scophthalmus aquosus</u>	IS	C			59	3.2								
<u>Squalus acanthias</u>	Bo	D	100	15.9	66	3.2	68	5.9	75	12.5	86	22.7	63	13.0
<u>Merluccius bilinearis</u>	Bo	D			66	5.4	100	33.8	90	21.1	90	11.5	100	36.2
<u>Urophycis chuss</u>	Bo	D					95	10.6			86	14.9	100	14.5
<u>Alosa pseudoharengus</u>	Bo	D	82	8.7	52	3.9	100	11.1						
<u>Urophycis regius</u>	WT	F							75	13.4				
<u>Paralichthys dentatus</u>	WT	F							60	2.6				
<u>Stenotomus chrysops</u>	WT	F							40	11.2	33	4.8		
<u>Scomber scombrus</u>	Bo	F	45	13.3			26	8.7	45	2.6	67	10.0	56	4.6
<u>Peprilus triacanthus</u>	WT	F	56	13.9					65	20.3	76	11.9	44	3.7
<u>Prionotus carolinus</u>	WT	F							50	2.4	48	5.5		
<u>Hippoglossina oblonga</u>	OS	F									86	6.1		
<u>Citharichthys arctifrons</u>	Sl	F									71	4.0		
<u>Helicolenus dactylopterus</u>	Sl	G											100	8.6
<u>Phycis chesteri</u>	Sl	G											44	3.2
<u>Stomiatoidei</u>	Mp	H											25	3.8

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** Z = percent of stations in each site group at which each dominant species occurred.
 x = average percent that individuals of each species contributed to stations in each site group.
 A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-5. Cruise 72-2, Spring 1972.

Species	Faunal Affinity*	Species Group	Site Group**																	
			I		II		III		IV		V		VI		VII		VIII		IX	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Alosa aestivalis</u>	WT	A			80	12.6														
<u>Clupea harengus harengus</u>	Bo	A	67	4.7	53	7.2														
<u>Pseudopleuronectes americanus</u>	Bo	A	100	6.8																
<u>Limanda ferruginea</u>	Bo	B	100	19.1	100	35.2	100	29.2	50	6.5										
<u>Macrozoerces americanus</u>	Bo	B	83	7.0	100	5.7	83	4.4												
<u>Raja erinacea</u>	Bo	B	100	13.3			89	7.5												
<u>Scophthalmus aquosus</u>	IS	B	83	4.4			89	9.4												
<u>Myoxocephalus octodecemspinosus</u>	Bo	B	100	24.6			72	3.0												
<u>Raja ocellata</u>	Bo	B	100	8.6																
<u>Squalus acanthias</u>	Bo	E			73	5.7	94	15.6	100	74.1	100	22.5	18	9.1	85	29.1	77	14.8	45	12.3
<u>Merluccius bilinearis</u>	Bo	E					100	14.4			58	6.9	36	6.5	92	10.8	100	29.2	100	30.3
<u>Hippoglossina oblonga</u>	OS	E			20	5.6	72	3.3							92	13.5	69	7.8		
<u>Urophycis chuss</u>	Bo	E			20	5.6	72	3.3							100	12.6	85	8.2	100	20.3
<u>Prionotus carolinus</u>	WT	F									42	4.5	18	7.9						
<u>Peprilus triacanthus</u>	WT	F							67	18.0	73	18.3	36	11.9	92	17.3	54	5.7		
<u>Alosa pseudoharengus</u>	Bo	G			67	10.9														
<u>Scomber scombrus</u>	Bo	G			40	8.2	44	3.9							85	4.1	69	26.6		
<u>Urophycis regius</u>	WT	H									65	8.3	55	10.2						
<u>Stenotomus chrysops</u>	WT	H									38	18.1								
<u>Centropomus striata</u>	WT	H											55	4.9						
<u>Prionotus evolans</u>	WT	H									23	5.2								
<u>Phycis chesteri</u>	Sl	I											18	2.6					36	5.7
Myctophidae	Mp	I											45	21.1						
<u>Helicolenus dactylopterus</u>	Sl	I																	91	11.1
<u>Urophycis tenuis</u>	Bo-Sl	I																	73	2.8
<u>Glyptocephalus cynoglossus</u>	Bo-Sl	I																	73	3.1

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant

Table 10-E-6. Cruise 73-3, Spring 1973.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Clupea harengus harengus</u>	Bo	A	83	6.6	39	9.2										
<u>Ammodytes americanus</u>	Bo	A	26	4.9	43	7.0										
<u>Raja erinacea</u>	Bo	B	100	16.0	89	13.5										
<u>Alosa pseudoharengus</u>	Bo	B	100	13.7	82	6.3	96	12.6								
<u>Limanda ferruginea</u>	Bo	B	100	17.5	57	7.6										
<u>Scophthalmus aquosus</u>	IS	B	96	5.4	86	4.0										
<u>Scomber scombrus</u>	Bo	C									73	11.1				
<u>Merluccius bilinearis</u>	Bo	D	100	16.3	71	10.0	100	11.6			100	8.4			93	36.2
<u>Urophycis chuss</u>	Bo	D					89	10.2			100	5.2			100	8.0
<u>Lophius americanus</u>	Bo	D							79	3.6						
<u>Squalus acanthias</u>	Bo	D	62	4.0	93	17.4	96	25.7	93	22.8	36	8.4			79	18.6
<u>Hippoglossina oblonga</u>	OS	D					96	5.2			91	7.7	100	6.5		
<u>Urophycis regius</u>	WT	E			25	4.5										
<u>Peprilus triacanthus</u>	WT	F			25	4.5	93	17.0	79	13.4	91	49.0	100	69.3	43	11.2
<u>Prionotus carolinus</u>	WT	F					74	9.6	79	28.8						
<u>Citharichthys arctifrons</u>	SI	F											100	10.3		
<u>Stenotomus chrysops</u>	WT	G							100	12.2						
<u>Centropristis striata</u>	WT	G							50	3.9						
<u>Prionotus evolans</u>	WT	G							43	3.9						
<u>Lepophidium cervinum</u>	OS	H											100	7.8		
<u>Merluccius albidus</u>	SI	I													57	8.6
<u>Helicolenus dactylopterus</u>	SI	I													71	6.9

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-7. Cruise 74-4, Spring 1974.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			Z	$\bar{x}$	Z	$\bar{x}$	Z	$\bar{x}$	Z	$\bar{x}$	Z	$\bar{x}$	Z	$\bar{x}$
<u>Clupea harengus harengus</u>	Bo	A	58	5.6	58	8.6								
<u>Raja erinacea</u>	Bo	B	100	7.5	92	11.1								
<u>Limania ferruginea</u>	Bo	B	100	10.1	92	7.0								
<u>Scophthalmus aquosus</u>	IS	B	100	5.6										
<u>Alosa pseudoharengus</u>	Bo	B	79	12.4	67	2.9								
<u>Macrozoarces americanus</u>	Bo	B			58	3.3								
<u>Urophycis chuss</u>	Bo	C	74	3.4	67	8.1	67	2.5					100	25.3
<u>Squalus acanthias</u>	Bo	C	95	8.9	100	26.3	93	27.3	91	22.1				
<u>Merluccius bilinearis</u>	Bo	C	95	32.1	100	12.4	96	18.5			80	8.7	92	30.3
<u>Hippoglossina oblonga</u>	OS	C			83	5.2	89	7.3			40	5.0		
<u>Scorpaenopsis scorpaenoides</u>	Bo	C	85	3.4			63	2.8	18	6.1				
<u>Peprilus triacanthus</u>	WT	D					81	16.5			40	6.8		
<u>Stenotomus chrysops</u>	WT	D							64	26.4				
<u>Prionotus carolinus</u>	WT	D					52	5.9	73	20.2				
<u>Centropristis striata</u>	WT	D							82	6.7				
<u>Urophycis regius</u>	WT	E									40	5.3		
<u>Merluccius setifer</u>	WT	E							27	9.1				
<u>Citharichthys arctifrons</u>	Sl	F					67	5.2			70	10.5		
<u>Lepophidium cervinum</u>	OS	F					29	3.1			80	13.8		
<u>Glyptocephalus cynoglossus</u>	Bo-Sl	G											100	3.4
<u>Chlorophthalmus agassizi</u>	Sl	G											75	6.6
<u>Merluccius albidus</u>	Sl	G											92	8.0
<u>Helicolenus dactylopterus</u>	Sl	G											67	10.1
Myctophidae	Mp	G									30	10.1	58	2.9
<u>Ceratoscopelus maderensis</u>	Mp	H									30	8.1	25	3.0

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** Z = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species group at which each dominant species occurred.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least in at least 20% of all stations included in that site group.

Table 10-E-8. Cruise 75-3, Spring 1975.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Myoxocephalus octodecemspinosus</u>	Bo	B	74	4.4										
<u>Pseudopleuronectes americanus</u>	Bo	B	63	3.0										
<u>Scophthalmus aquosus</u>	IS	C	100	5.7	63	3.3								
<u>Limanda ferruginea</u>	Bo	C	95	3.5	75	2.8								
<u>Alosa pseudoharengus</u>	Bo	C			6	3.2								
<u>Raja erinacea</u>	Bo	C	95	23.3	100	13.0								
<u>Centropristis striata</u>	WT	E					71	8.0						
<u>Stenotomus chrysops</u>	WT	E					26	28.0						
<u>Squalus acanthias</u>	Bo	F	79	2.8	100	24.5	100	24.3	100	39.7	54	8.3		
<u>Merluccius bilinearis</u>	Bo	F	84	41.4	100	41.9	79	2.8	100	24.2	85	11.5	100	22.0
<u>Urophycis chuss</u>	Bo	F							92	7.0			94	11.4
<u>Hippoglossina oblonga</u>	OS	F							100	6.4	85	10.3	88	6.0
<u>Citharichthys arctifrons</u>	Sl	F			50	2.9					54	3.9		
<u>Scomber scombrus</u>	Bo	F	21	2.7									44	5.6
<u>Peprilus triacanthus</u>	WT	F					79	17.8	92	9.4	85	24.9	63	5.5
<u>Paralichthys dentatus</u>	WT	F									54	6.4		
<u>Prionotus carolinus</u>	WT	F					29	7.3	67	3.7				
Myctophidae	Mp	G									23	8.3	81	17.0
<u>Helicolenus dactylopterus</u>	Sl	G											63	4.6
<u>Lepophidium cervinum</u>	OS	G									23	4.1	75	6.2
<u>Maurollicus muelleri</u>	Mp	G											31	5.6
<u>Urophycis regius</u>	WT	G									62	4.4		

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-9. Cruise 76-2, Spring 1976.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	x	%	x	%	x	%	x	%	x	%	x	%	x
<u>Clupea harengus harengus</u>	Bo	A	30	5.6												
<u>Ammodytes dubius</u>	Bo	A	50	14.8	57	23.5										
<u>Scomber scombrus</u>	Bo	A	60	11.3												
<u>Raja erinacea</u>	Bo	C			94	8.7										
<u>Scophthalmus aquosus</u>	IS	C			94	5.7										
<u>Limanda ferruginea</u>	Bo	C			80	6.6										
<u>Macrozoarces americanus</u>	Bo	C			71	2.7										
<u>Alosa pseudoharengus</u>	Bo	C			57	4.1	40	14.3			73	4.6				
<u>Merluccius bilinearis</u>	Bo	D	80	30.7	91	21.3	100	23.1	79	11.2	100	8.8	98	13.1	94	41.0
<u>Squalus scanthias</u>	Bo	D	100	6.3	69	7.3	100	44.1	71	20.9	93	36.8	50	11.8	59	3.6
<u>Hippoglossina oblonga</u>	OS	D					90	4.6			100	8.8	94	10.2	59	3.7
<u>Urophycis chuss</u>	Bo	D			69	5.7					100	3.5			76	3.8
<u>Citharichthys arctifrons</u>	SI	D							21	4.6	93	4.3				
<u>Urophycis regius</u>	WT	E	50	12.7					64	8.0			81	5.4		
<u>Centropristis striata</u>	WT	E							93	14.2						
<u>Stenotomus chrysops</u>	WT	E							86	12.9	60	3.6				
<u>Peprilus triacanthus</u>	WT	E					60	7.0	64	4.7	93	6.0	88	32.2		
<u>Paralichthys dentatus</u>	WT	E							86	4.9						
<u>Prionotus carolinus</u>	WT	E	70	11.6					57	6.4	80	11.9				
Myctophidae	Mp	F											38	8.1	48	4.4
<u>Merluccius albidus</u>	SI	F													76	5.1
<u>Helicolenus dactylopterus</u>	SI	F													88	11.2
<u>Lepophidium cervinum</u>	OS	F									47	3.9			76	4.7
<u>Glyptocephalus cynoglossus</u>	Bo-SI	F													76	4.0

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

x = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 70% of all stations included in that site group.

Table 10-E-10. Cruises 67-20 and 67-21, Fall 1967.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			Z	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z	X
<u>Mustelus canis</u>	WT	A	57	5.4												
<u>Paralichthys dentatus</u>	WT	A	50	3.1												
<u>Prionotus carolinus</u>	WT	B	71	41.1	100	33.6										
<u>Scophthalmus aquosus</u>	IS	B			85	3.4			100	2.4						
<u>Pseudopleuronectes americanus</u>	Bo	E			100	5.5										
<u>Stenotomus chrysops</u>	WT	B	57	26.1	54	3.5	57	2.2								
<u>Alosa pseudoharengus</u>	Bo	D							100	20.4						
<u>Raja erinacea</u>	Bo	E							60	3.9						
<u>Myoxocephalus octodecemspinosus</u>	Bo	E					87	6.0	60	8.0						
<u>Squalus scanthias</u>	Bo	F			92	32.1	100	22.1			83	29.9				
<u>Limanda ferruginea</u>	Bo	F			92	12.2	100	32.8	100	32.5						
<u>Urophycis tenuis</u>	Bo-SI	G									58	3.3				
<u>Merluccius bilinearis</u>	Bo	H					96	9.8	80	7.1	100	20.9	84	37.0	76	18.9
<u>Peprilus triacanthus</u>	WT	H	43	12.2			61	7.8	60	12.1	88	22.3	44	15.9		
<u>Hippoglossina oblonga</u>	OS	H											36	5.4	65	3.0
<u>Urophycis chuss</u>	Bo	H					83	4.2			71	6.9				
<u>Citharichthys arctifrons</u>	SI	I									29	3.6			82	13.7
<u>Lepophidium cervinum</u>	OS	I													71	14.4
<u>Urophycis regius</u>	WT	I	36	3.5									64	16.2	82	9.7
<u>Helicolenus dactylopterus</u>	SI	K													47	5.9
<u>Merluccius albidus</u>	SI	K													41	4.9
<u>Maurolicus muelleri</u>	Mp	K											20	10.0	35	16.3

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** Z = percent of stations in each site group at which each dominant species occurred.

X = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-11. Cruise 68-17, Fall 1968.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Paralichthys dentatus</u>	WT	A	63	4.7												
<u>Centropristis striata</u>	WT	A	68	3.1												
<u>Stenotomus chrysops</u>	WT	A	47	13.0	23	3.2										
<u>Decapterus macarellus</u>	WT	A	47	5.2												
<u>Prionotus carolinus</u>	WI	B	95	49.6	85	10.9										
<u>Scophthalmus aquosus</u>	IS	B			100	7.6										
<u>Pseudopleuronectes americanus</u>	Bo	B			77	5.0	86	2.9								
<u>Myoxocephalus octodecemspinosus</u>	Bo	C			77	2.6										
<u>Squalus acanthias</u>	Bo	D			100	10.7	100	46.1	94	10.1	33	5.2	52	5.4	22	5.9
<u>Limanda ferruginea</u>	Bo	D			92	34.8	100	13.8	100	27.7						
<u>Merluccius bilinearis</u>	Bo	D			100	11.9	86	7.4	100	30.2	67	5.5	93	24.2	67	23.6
<u>Urophycis triacanthus</u>	WT	D	74	7.7			93	10.4	94	11.2	92	14.8	52	8.1	33	2.7
<u>Urophycis chuss</u>	Bo	D							94	8.6			41	8.0		
<u>Lophius americanus</u>	Bo	E														56
<u>Urophycis tenuis</u>	Bo-SI	E														56
<u>Lepophidium cervinum</u>	OS	F													75	2.9
<u>Glyptocephalus arcifrons</u>	SI	F											74	9.0	22	7.9
<u>Urophycis regius</u>	WT	F	42	4.8	69	3.9					25	2.9	70	12.2	54	11.1
Myctophidae	Mp	G														89
<u>Helicolenus dactylopterus</u>	SI	G														100
<u>Merluccius albidus</u>	SI	G														67
<u>Chlorophthalmus agassizi</u>	SI	G														54

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-g-12. Cruise 69-11, Fall 1969.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			%	x	%	x	%	x	%	x	%	x	%	x
<u>Centropristis striata</u>	WT	B	73	4.3										
<u>Paralichthys dentatus</u>	WT	B	67	4.0										
<u>Pseudopleuronectes americanus</u>	Bo	C			80	3.8								
<u>Scophthalmus aquosus</u>	IS	C			93	2.6								
<u>Prionotus carolinus</u>	WT	C	100	25.1	80	8.7			33	5.6				
<u>Stenotomus chrysops</u>	WT	C	93	34.0	60	7.8								
<u>Peprilus triacanthus</u>	WT	C	93	21.8	87	8.0	85	9.0	56	21.1	67	27.4	28	7.1
<u>Squalus acanthias</u>	Bo	D			93	16.8	100	10.5	74	24.5				
<u>Limanda ferruginea</u>	Bo	D			93	19.6	100	23.1	67	15.0	33	3.1		
<u>Myoxocephalus octodecemspinosus</u>	Bo	J			73	4.6	92	5.1						
<u>Hippoglossina oblonga</u>	OS	D									90	3.9		
<u>Urophycis chuss</u>	Bo	E					100	20.0	30	2.2	67	8.2		
<u>Merluccius bilinearis</u>	Bo	D			93	17.2	100	22.5	56	7.9	90	19.5	39	6.0
<u>Lophius americanus</u>	Bo	F											44	2.4
<u>Citharichthys arctifrons</u>	SI	G									67	8.2	56	11.1
<u>Urophycis regia</u>	WT	G									71	19.2	61	13.8
<u>Chlorophthalmus aysiaxi</u>	SI	H											39	6.8
<u>Merluccius albidus</u>	SI	H											33	3.2
Myctophidae	Mp	H											56	11.2
<u>Helicolenus dactylopterus</u>	SI	H											49	4.5

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-13. Cruise 70-6, Fall 1970.

Species	Faunal Affinity*	Species Group	Site Group**																	
			I		II		III		IV		V		VI		VII		VIII		IX	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Prionotus carolinus</u>	WT	A	60	32.2													25	24.0		
<u>Stenotomus chrysops</u>	WT	A			35	5.6														
<u>Centropristis striata</u>	WT	A	40	5.9													13	8.3		
<u>Etrumeus teres</u>	WT	B			24	3.4								25	6.9					
<u>Ugualus acanthias</u>	Bo	C			100	39.8	100	11.8	23	13.8										
<u>Limanda ferruginea</u>	Bo	C			100	21.4	100	27.4	46	10.3										
<u>Myoxocephalus octodecemspinosus</u>	Bo	C			65	3.2	71	2.1												
<u>Pseudopleuronectes americanus</u>	Bo	C			82	4.6			54	3.4										
<u>Peprilus triacanthus</u>	WT	C					76	6.1	54	15.0	36	5.8		33	21.0	63	19.5			
<u>Scophthalmus aquosus</u>	IS	C	90	10.6																
<u>Urophycis chuss</u>	Bo	D					100	12.1			93	14.8								
<u>Merluccius bilinearis</u>	Bo	D	30	3.9	76	12.0	100	18.8	92	51.0	100	31.1	82	26.7	50	10.2	50	8.0	57	19.5
<u>Hippoglossus oblonga</u>	OS	D					76	2.9			86	3.2								
<u>Citharichthys arctifrons</u>	SI	D									100	10.7	100	23.2					57	4.4
<u>Glyptocephalus cynoglossus</u>	Bo-SI	E																	43	3.7
<u>Urophycis regius</u>	WT	F	100	38.8							50	22.3	91	25.9	100	50.5			29	3.8
<u>Lepopidium cervinum</u>	OS	F									43	3.2	91	18.6					29	5.3
Myctophidae	Mp	G																	71	7.3
<u>Merluccius albidus</u>	SI	G																	100	9.4
<u>Chlorophthalmus agassizi</u>	SI	G															38	8.3	57	10.5
<u>Helicolenus dactylopterus</u>	SI	G															35	26.7	100	26.3

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-14. Cruise 71-6, Fall 1971.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Stenotomus chrysops</u>	WT	A	55	8.5	39	4.8								
<u>Paralichthys dentatus</u>	WT	A	64	5.5										
<u>Prionotus carolinus</u>	WT	A	45	18.9	43	3.3	21	2.4						
<u>Etrumeus teres</u>	WT	B	36	32.5	14	4.9	43	6.4						
<u>Myoxocephalus octodecemspinosus</u>	Bo	C			68	3.3								
<u>Scophthalmus aquosus</u>	IS	C			71	3.0								
<u>Pseudopleuronectes americanus</u>	Bo	C			86	3.7								
<u>Raja erinacea</u>	Bo	C			93	8.1								
<u>Squalus acanthias</u>	Bo	C					54	6.9						
<u>Urophycis chuss</u>	Bo	E			93	22.7	64	7.7						
<u>Urophycis chuss</u>	Bo	E			79	10.3	46	3.9	58	5.7				
<u>Merluccius bilinearis</u>	Bo	E			96	14.8	79	15.0	100	32.2	80	9.8		
<u>Hippoglossina oblonga</u>	OS	E			79	3.1								
<u>Citharichthys arctifrons</u>	SI	E							96	9.0			55	14.9
<u>Peprilus triacanthus</u>	WT	E	64	13.5	71	9.3	96	49.0	69	16.1	90	63.5		
<u>Urophycis regius</u>	WT	E	27	13.2					46	10.7	100	23.7	36	2.6
<u>Lepophidium cervinum</u>	SI	H							50	6.1				
<u>Helicolenus dactylopterus</u>	SI	I							42	5.7			82	11.4
Mictophidae	Mp	I							31	9.2			73	18.0
<u>Chloropthalmus agassizi</u>	SI	I											64	13.1
<u>Merluccius albidus</u>	SI	I											73	11.2

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), and slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-15. Cruise 72-B, Fall 1972.

Species	Faunal Affinity*	Species Group	Site Group**											
			I		II		III		IV		V		VI	
			%	x	%	x	%	x	%	x	%	x	%	x
<u>Centropristis striata</u>	WT	A	100	10.1										
<u>Raja eglanteria</u>	WT	A	88	5.5										
<u>Stenotomus chrysops</u>	WT	B	50	43.7	69	14.8	56	7.4						
<u>Pseudopleuronectes americanus</u>	Bo	B			38	4.0	84	3.4						
<u>Prionotus carolinus</u>	WT	B	100	28.7	69	14.4	48	6.1			19	7.6		
<u>Scophthalmus aquosus</u>	IS	B	88	4.7	56	5.8								
<u>Mustelus canis</u>	WT	C			81	9.0								
<u>Raja ocellata</u>	Bo	C			50	7.2								
<u>Etmopterus teres</u>	WT	C			41	7.4								
<u>Merluccius bilinearis</u>	Bo	D					80	15.0	100	34.5	71	8.8	73	6.6
<u>Citharichthys arctifrons</u>	Sl	D					48	3.0	91	9.1	57	5.0	91	11.0
<u>Lophius americanus</u>	Bo	D							100	3.3	86	9.1		
<u>Hippoglossina oblonga</u>	OS	D			25	5.1	92	3.9	91	4.6	67	5.0		
<u>Urophycis chuss</u>	Bo	D					76	4.9	100	26.7	48	7.0		
<u>Urophycis regius</u>	WT	D									76	9.8	27	6.3
<u>Peprilus triacanthus</u>	WT	D			56	10.0	64	14.0			90	36.1		
<u>Lepophidium cervinum</u>	OS	D									38	4.7		
<u>Raja erinacea</u>	Bo	E			69	6.5	92	6.0						
<u>Limanda ferruginea</u>	Bo	E					92	20.5	91	9.4				
<u>Myoxocephalus octodecemspinosus</u>	Bo	E					68	3.7						
<u>Squalus acanthias</u>	Bo	E			25	3.1	76	4.9	73	3.2				
<u>Helicolenus dactylopterus</u>	Sl	H											82	24.2
<u>Merluccius albidus</u>	Sl	H											77	7.9
Myctophidae	Mp	H											77	25.3
<u>Chloropthalmus agassizi</u>	Sl	H											41	4.2

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer shelf resident (OS), slope resident (Sl) and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

x = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-16. Cruise 73-8, Fall 1973.

Species	Faunal Affinity*	Species Group	Site Group										VI		VII	
			I		II		III		IV							
			$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%			$\bar{x}$	%	$\bar{x}$	%
<u>Prionotus carolinus</u>	WT	A	50	1.9	78	23.4										
<u>Scophthalmus aquosus</u>	IS	A			70	4.8										
<u>Musculus canis</u>	WT	H	100	15.7												
<u>Raja erinacea</u>	Bo	B	83	6.2	61	4.7			31	4.2						
<u>Pseudopleuronectes americanus</u>	Bo	B	33	4.9												
<u>Stenotomus chrysops</u>	WT	B	25	2.0	43	14.1										
<u>Limanda ferruginea</u>	Bo	B			30	5.5	45	8.3	15	3.4						
<u>Squalus acanthias</u>	Bo	C			35	7.9	45	7.4								
<u>Merluccius bilinearis</u>	Bo	D					100	24.0	69	24.2	75	9.4	71	8.3	33	3.6
<u>Hippoglossina oblonga</u>	OS	D					100	9.5	31	6.3			76	6.2		
<u>Citharus linguatula</u>	SI	D					80	12.7					90	9.8		
<u>Lophius americanus</u>	Bo	D							100	25.4			76	6.9	83	10.4
<u>Urophycis regia</u>	WT	D			39	6.3			31	11.1	75	7.2	81	16.6		
<u>Peprilus triacanthus</u>	WT	D	92	43.7	78	12.9	75	17.2	15	6.7	100	82.8	62	29.8	50	35.5
<u>Lupophidium cervinum</u>	OS	L											71	6.0		
<u>Urophycis chuss</u>	Bo	D					85	8.9								
<u>Helicolenus dactylopterus</u>	SI	E													100	20.6
<u>Merluccius albidus</u>	SI	E													83	20.0
Myctophidae	Mp	E											43	7.1	33	5.6
<u>Peristedion miniatum</u>	Bo	E							15	3.8						

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

$\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-17. Cruise 74-11, Fall 1974.

Species	Faunal Affinity*	Species Group	Site Group**													
			I		II		III		IV		V		VI		VII	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Micropogon undulatus</u>	WT	A	29	3.8												
<u>Raja erinacea</u>	Bo	B					100	12.3								
<u>Scophthalmus aquosus</u>	IS	B					64	3.1								
<u>Squalus acanthias</u>	Bo	B	43	8.2			71	7.7								
<u>Limanda ferruginea</u>	Bo	B					79	12.7								
<u>Stephanolepis hispidus</u>	WT	C			92	8.2										
<u>Centropristis striata</u>	WT	C			50	6.5										
<u>Prionotus carolinus</u>	WT	C			83	44.1			38	9.6						
<u>Stenotomus chrysops</u>	WT	C	86	29.3												
<u>Paralichthys dentatus</u>	WT	C	86	9.2	75	4.2										
<u>Mustelus canis</u>	WT	C			33	5.3										
<u>Urophycis regius</u>	WT	D			75	2.9			94	29.5			81	10.0		
<u>Citharichthys arctifrons</u>	SI	D							56	5.1			100	18.0	89	12.4
<u>Lepophidium cervinum</u>	OS	D											88	7.4		
<u>Merluccius bilinearis</u>	Bo	D	21	4.0	58	15.6	86	36.4	88	25.1	50	15.7	94	24.9	67	10.2
<u>Hippoglossina oblonga</u>	OS	D					93	7.3	69	6.7	39	4.9				
<u>Peprilus triacanthus</u>	WT	D	86	36.5	33	3.0	21	3.2			94	62.8	100	35.4	56	13.2
<u>Urophycis chuss</u>	Bo	D					57	5.7			28	4.8				
<u>Helicolenus dactylopterus</u>	SI	E									22	3.3			100	21.4
<u>Chloronothus agassizi</u>	SI	E													78	14.1
Myctophidae	Mp	E							31	17.7						
<u>Phycis chesteri</u>	SI	F													56	7.3
<u>Merluccius albidus</u>	SI	F													89	4.9
Macrouridae	SI	F													78	6.2

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (SI), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.
 $\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.
 A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-18. Cruise 75-12, Fall 1975.

Species	Faunal Affinity*	Species Group	Site Group**															
			I		II		III		IV		V		VI		VII		VIII	
			%	x	%	x	%	x	%	x	%	x	%	x	%	x	%	x
<u>Micropogon undulatus</u>	WT	A	100	42.1														
<u>Decapterus punctatus</u>	WT	A	67	15.5														
<u>Mustelus canis</u>	WT	B	67	9.4	43	16.0												
<u>Paralichthys dentatus</u>	WT	B	83	13.3	100	25.1												
<u>Prionotus carolinus</u>	WT	B			86	37.4	78	3.8							30	7.6		
<u>Centropristis striata</u>	WT	B	67	5.2											50	8.3		
<u>Raja erinacea</u>	Bo	C					91	4.4										
<u>Squalus acanthias</u>	Bo	D					70	10.4	100	19.0	35	4.9						
<u>Stenotomus chrysops</u>	WT	D			71	10.9	83	34.8	89	12.3	45	25.4						
<u>Peprilus triacanthus</u>	WT	D	50	6.5			52	2.5	89	43.8	100	38.1	75	6.2	40	10.6		
<u>Merluccius bilinearis</u>	Bo	E			29	8.6	78	19.1	100	14.5	65	7.4	100	19.9	100	34.0	53	9.5
<u>Hippoglossina oblonga</u>	OS	E					96	3.0			50	3.6	92	3.8				
<u>Citharichthys arctifrons</u>	Sl	E					52	6.8			35	5.7	100	18.4			80	13.7
<u>Urophycia chuse</u>	Bo	E					43	4.1	72	4.3			58	14.3			60	6.4
<u>Urophycia regius</u>	WT	E									40	5.4	67	24.3	90	33.3	47	14.7
Myctophidae	Mp	F															47	6.0
<u>Merluccius albidus</u>	Sl	F															73	7.9
<u>Maurolicus muelleri</u>	Mp	F															73	7.1
<u>Helicolenus dactylopterus</u>	Sl	F															93	23.0
<u>Lepophidium cervinum</u>	OS	F											83	4.0				

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.

x = average percent that individuals of each species contributed to stations in each site group.

A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Table 10-E-19. Cruise 69-8, Summer 1969.

Species	Faunal Affinity*	Species Group	Site Group**									
			I		II		III		IV		V	
			%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$
<u>Pseudopleuronectes americanus</u>	Bo	B	57	4.5	35	4.9						
<u>Limanda ferruginea</u>	Bo	B	78	21.0	43	11.0						
<u>Scophthalmus aquosus</u>	IS	B					40	4.7				
<u>Merluccius bilinearis</u>	Bo	D	96	13.7	76	11.4						
<u>Melanogrammus aeglefinus</u>	Bo	D	78	12.6	41	11.1			17	3.9		
<u>Urophycis chuss</u>	Bo	D	91	14.0					17	2.8		
<u>Myoxocephalus octodecemspinosus</u>	Bo	D	74	5.0								
<u>Hippoglossina oblonga</u>	OS	D	70	2.4								
<u>Squalus acanthias</u>	Bo	D	43	2.6	30	5.2						
<u>Scomber scombrus</u>	Bo	D	39	8.7	30	5.8						
<u>Lepophidium cervinum</u>	OS	E							100	26.2	31	2.4
<u>Citharichthys arctifrons</u>	Sl	E			27	2.7			92	20.2	50	7.2
<u>Peprilus triacanthus</u>	WT	E	74	5.6	57	20.7	100	47.2	50	11.2		
<u>Urophycis regius</u>	WT	E			24	9.8	93	44.9	75	27.4	63	20.5
<u>Maurolicus muelleri</u>	Mp	F									44	15.9
Myctophidae	Mp	F									56	8.8
<u>Helicolenus dactylopterus</u>	Sl	F									56	10.6
<u>Merluccius albidus</u>	Sl	F									50	5.4

* Faunal affinity is designated as boreal (Bo), warm-temperate (WT), inner-shelf resident (IS), outer-shelf resident (OS), slope resident (Sl), and mesopelagic (Mp).

** % = percent of stations in each site group at which each dominant species occurred.
 $\bar{x}$ = average percent that individuals of each species contributed to stations in each site group.
 A species was considered to be dominant in a site group if it occurred among the five most abundant species in at least 20% of all stations included in that site group.

Appendix 10-F. List of fish species included in Chapter 10.

Scyliorhinidae

Scyliorhinus retifer (chain dogfish)

Carcharhinidae

Carcharhinus milberti (sandbar shark)

Mustelus canis (smooth dogfish)

Squalidae

Squalus acanthias (spiny dogfish)

Squatinae

Squatina dumerili (Atlantic angel shark)

Rajidae

Raja eglanteria (clearnose skate)

Raja erinacea (little skate)

Raja garmani (rosette skate)

Raja laevis (barndoor skate)

Raja ocellata (winter skate)

Dasyatidae

Dasyatis centroura (rough-tail stingray)

Congridae

Conger oceanicus (conger eel)

Ophichthidae

Ophichthus cruentifer (snake eel)

Nemichthyidae

Nemichthys scolopaceus (slender snipe eel)

Clupeidae

Alosa aestivalis (blueback herring)

Alosa pseudoharengus (alewife)

Alosa sapidissima (American shad)

Brevoortia tyrannus (Atlantic menhaden)

Clupea harengus harengus (Atlantic herring)

Etrumeus teres (round herring)

Argentinidae

Argentina silus (Atlantic argentine)

Maurollicidae

Maurollicus muelleri (pearlsides)

Sternoptychidae

Argyropelecus aculeatus (silver hatchetfish)

Appendix 10-F (continued)

Chlorophthalmidae

Chlorophthalmus agassizi (shortnose greeneye)

Myctophidae

Ceratoscopelus maderensis (lantern fish)

Lophiidae

Lophius americanus (goosefish)

Gadidae

Enchelyopus cimbrius (fourbeard rockling)

Gadus morhua (Atlantic cod)

Melanogrammus aeglefinus (haddock)

Phycis chesteri (longfin hake)

Pollachius virens (pollock)

Urophycis chuss (red hake)

Urophycis regius (spotted hake)

Urophycis tenuis (white hake)

Merlucciidae

Merluccius albidus (offshore hake)

Merluccius bilinearis (silver hake)

Ophidiidae

Lepophidium cervinum (fawn cusk-eel)

Zoarcidae

Macrozoarces americanus (ocean pout)

Macrouridae

Lycenchelys verrilli (wolf eelpout)

Coelorinchus c. carminatus (longnose grenadier)

Nezumia bairdi (marlin-spike)

Ventrifossa occidentalis (American straptail grenadier)

Atherinidae

Menidia menidia (Atlantic silverside)

Polymixiidae

Polymixia lowei (beardfish)

Zeidae

Zenopsis ocellata (American john dory)

Scorpaenidae

Helicolenus dactyloperus (blackbelly rosefish)

Triglidae

Peristedion miniatum (armored searobin)

Appendix 10-F (continued)

Prionotus carolinus (northern searobin)

Prionotus evolans (striped searobin)

Cottidae

Hemitripterus americanus (sea raven)

Myoxocephalus octodecemspinosus (longhorn sculpin)

Serranidae

Centropristis striata (black sea bass)

Branchiostegidae

Lopholatilus chamaeleonticeps (tilefish)

Pomatomidae

Pomatomus saltatrix (bluefish)

Carangidae

Decapterus macarellus (mackerel scad)

Decapterus punctatus (round scad)

Trachurus lathami (rough scad)

Sparidae

Stenotomus chrysops (scup)

Sciaenidae

Bairdiella chrysura (silver perch)

Cynoscion regalis (weakfish)

Menticirrhus saxatilis (northern kingfish)

Micropogon undulatus (croaker)

Labridae

Tautoga onitis (tautog)

Ammodytidae

Ammodytes dubius (northern sand lance)

Scombridae

Scomber scombrus (Atlantic mackerel)

Stromateidae

Peprilus triacanthus (butterfish)

Citharidae

Citharichthys arctifrons (Gulf Stream flounder)

Scophthalmidae

Scophthalmus aquosus (window pane)

Lothidae

Etropus microstomus (smallmouth flounder)

Appendix 10-F (continued)

Hippoglossina oblonga (fourspot flounder)

Paralichthys dentatus (summer flounder)

Syacium papillosum (dusky flounder)

Pleuronectidae

Glyptocephalus cynoglossus (witch flounder)

Hippoglossina platessoides (American plaice)

Limanda ferruginea (yellowtail flounder)

Pseudopleuronectes americanus (winter flounder)

Balistidae

Stephanolepis hispidus (planehead filefish)

Tetraodontidae

Sphoeroides maculatus (northern puffer)

CHAPTER 11

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* Provided on microfiche at the end of Volume II.

CHAPTER 11

BACTERIOLOGY

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with contributions by

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INTRODUCTION

Degradation of Petroleum by Marine Bacteria

A significant activity of bacteria on the Middle Atlantic continental shelf is considered to be that of degradation resulting in regeneration of nutrients essential to biological productivity (Liston 1968). As biogenic hydrocarbons represent a natural substrate for marine bacteria (ca. 10^6 metric tons/year produced by phytoplankton alone), it is not surprising to observe that marine bacterial populations can degrade petroleum hydrocarbons. Unfortunately, petroleum is a substrate of such vast complexity and compositional variation (Kallio 1976), that a complete understanding of its microbiological fate remains obscure.

Despite the awesome task of unraveling the compositional particulars of bacterial petroleum degradation, marine bacterial populations appear to respond to petroleum spillage in a reproducible fashion, i.e., elevated levels of petroleum or derivatives thereof have been observed to result in elevated levels of petroleum-degrading bacteria (ZoBell 1969; Atlas and Bartha 1973b; Walker and Colwell 1973; Seki 1976; Kator and Herwig 1977; Oppenheimer et al. 1977; Walker and Colwell 1977).

Therefore, an important aspect of this study was to determine the seasonal distributions and densities of petroleum-degrading and "total" heterotrophic bacteria in sediments and waters, of the Middle Atlantic continental shelf. This region is now the site of

intensive exploration activities for petroleum deposits. Assessment of bacterial populations prior to production activities would provide for characterization of temporal and spatial variations in density and activity under "oil-free" conditions.

While the ratio of petroleum-degrading to "total" heterotrophic bacteria may be useful in corroborating the occurrence of relatively gross petroleum spillage, this ratio does not yield information on the relative degradation "potential" of bacterial populations toward petroleum. To assess this "potential" of bacterial populations toward various sediment and surface water types, a series of in vitro closed flask "batch" type culture experiments was performed utilizing ambient surface seawater and sediment-seawater homogenates as inocula. Unweathered South Louisiana crude oil was added to these inocula under inorganically enriched and non-enriched regimes.

Changes in populations of "total" heterotrophs and petroleum-degrading bacteria were determined over an extended incubation period at temperatures representative of each biological season. Extent of relative degradation was measured using glass capillary - gas chromatography to determine patterns and absolute amounts of n-paraffins degraded. While cognizant of the uses and limitations inherent in "batch" type culture systems, such studies were expected to provide relative measures of the "potential" for degradation using different inocula and seasonal temperatures.

An experimental degradation technique, designated "continuous-dilution", was tested during this study as an alternative to closed flask experiments. Essentially, a volume of freshly collected seawater, contaminated with a small amount of petroleum, was continually diluted with fresh seawater at ambient seasonal temperatures. This approach attempted to simulate weathering of an oil slick at sea since the slick encounters an ever increasing volume of seawater containing fresh inocula and nutrients.

In addition to experiments and field work dealing with the degradation of petroleum, additional studies were performed to examine some aspects of the effects of petroleum on bacterial growth and chitin utilization. These studies are discussed in the following two sections.

Chitin Degradation in the Presence of Petroleum

Chitin is one of the most ubiquitous biopolymers found in nature and is produced in copious quantities within the marine environment. Johnstone (1908) calculated that copepods alone can produce several billion tons of chitin annually. As this material does not accumulate in marine sediments, mineralization processes involving marine bacteria are effective in recycling chitin carbon and nitrogen in the marine ecosystem (ZoBell and Rittenberg 1938; Hood 1973).

The effects of petroleum on microbial degradation of chitin are unknown. Considering the importance of chitin as a reservoir of carbon and nitrogen in the environment, the increasing incidence of oil spillage in estuarine and coastal waters provides sufficient impetus to examine the effect(s) of oil on chitin degradation. If crude oil becomes a competitive carbon source, or is directly toxic to chitinoclasts, it is possible that a reduction in chitin degradation would occur. Alternately, petroleum could either have no effect or actually enhance the activity of chitinoclastic bacteria through stimulation of the heterotrophic population. ZoBell and Rittenberg (1938) observed that although some bacterial cultures grew on chitin as a sole source of carbon and nitrogen, other cultures required additional forms of carbon or carbon and nitrogen for development of chitinolytic activity. Additionally, complex nutrients such as peptone have been shown to enhance and stimulate chitin decomposition (Chan 1970).

Walker et al. (1975) examined the effects of a petroleum and a fuel oil on populations of lytic groups of estuarine microorganisms in closed flask systems containing water and sediment inocula. Enrichment was not provided in either organic or inorganic form. Relative to non-oiled controls, increases in the viable counts of all lytic forms (including chitinoclasts) during the first three weeks of incubation were observed in petroleum treated flasks. However by "normalizing" counts of chitinoclastic bacteria as a ratio of chitinoclasts to "total number of colonies" (chitinoclasts plus non-chitinoclasts growing on each plate), it was concluded that both petroleum and fuel oil exhibited toxicities towards populations of chitinoclasts. It is difficult to assess the validity of this conclusion with respect to the reported increases in the absolute populations of chitinoclasts (and heterotrophs) in petroleum treated flasks. Furthermore, chitin degradation was never actually measured as substrate loss and the absolute levels of bacteria (and lytic groups) can increase in closed flasks solely because of surface area effects.

Kator (1977) observed that a South Louisiana crude oil did not prevent chitinoclast growth or chitin degradation when mixed cultures of chitinoclasts were grown in a dilute peptone-chitin seawater medium. These experiments were not designed to reflect natural conditions and employed mixed cultures consisting solely of relatively

high levels of chitinoclastic bacteria in a nutrient broth with a relatively large concentration of chitin.

A number of changes were incorporated into second year experiments in order to simulate some aspects of natural systems. Firstly, since peptone at the concentrations employed is an unnaturally rich and energetically preferable substrate relative to chitin or petroleum, peptone-yeast extract concentrations were reduced five-fold for winter, spring and summer experiments. This change was expected to enhance the relative importance of chitin or petroleum as carbon and energy sources. Secondly, mixed chitinoclast isolates were combined with mixed petroleum-degrading cultures as the inocula. This change provided the opportunity to examine the interaction of chitin and petroleum substrates as measured by changes in cell density and substrate utilization. Finally, total heterotrophs were enumerated using the spread plate technique (HM agar) instead of MPN's. Chitinoclast counts could then be directly compared to heterotroph counts eliminating the uncertainty implicit in MPN population estimates.

Growth of Pure Cultures in the Presence of Petroleum

It is widely recognized that genera of marine bacteria can degrade petroleum and contribute to mineralization of hydrocarbons in the marine environment. The abundance of petroleum-degrading bacteria has been shown to be positively correlated with known sources of hydrocarbons and may be a sensitive indicator of hydrocarbon pollution (Atlas and Bartha 1973; Mulkins-Phillips and Stewart 1974; Horowitz and Atlas 1977; and Kator and Herwig 1977). However, possible adverse effects of petroleum hydrocarbons on the metabolic activities of marine bacteria have received infrequent attention despite an abundance of literature dealing with the toxicity of petroleum to metazoans. It has been reported that various petroleum hydrocarbons suppressed marine bacterial chemotactic responses (Mitchell et al. 1972) or were toxic toward ecologically important lytic bacteria (Walker et al. 1975).

The toxicity of petroleum toward phytoplankton has been associated with different fractions of crude or refined oils, i.e., volatile components and water soluble extracts (Pulich et al. 1974; Batterton et al. 1976). Recent investigations revealed that soluble fractions of some fuel and crude oils become increasingly toxic to phytoplankton, yeast, and a variety of invertebrate and vertebrate animals following photo-oxidation (Larson et al. 1976; Lacaze and deNaide 1976; Scheier and Gominger 1976; Larson et al. 1977). The limited number of studies describing the toxic effects of volatile or soluble petroleum hydrocarbons on marine bacteria (Cobet and Guard 1973; Atlas 1975; Calder and Lader 1976; Griffin and Calder 1977) rarely deal with similar studies involving photo-oxidized petroleum. Griffin and Calder (1977) singularly have investigated the effects of

water soluble extracts from selected photo-oxidized crude and fuel oils on the growth of a single marine bacterium.

The purpose of this investigation was to describe the effects on bacterial growth of unweathered and weathered South Louisiana crude oil and water soluble fractions thereof, including oil weathered in the laboratory and in natural sunlight. Growth effects were assayed utilizing isolates representative of dominant genera collected from "total" heterotrophic and petroleum-degrading bacterial populations from Middle-Atlantic continental shelf microlayer, surface water, bottom water, and sediment samples.

METHODS AND MATERIALS

Sampling

Microlayer

Surface microlayer samples were obtained under favorable sea conditions from selected stations (Figure 11-1). All samples were collected upwind of the research vessel using a self-propelled inflatable rubber boat. Replicate microlayer samples were obtained using a sterile screen (Nitex monofilament nylon, 6.5 mesh/cm) held in a stainless steel frame to which a handle was attached.

Microlayer samples were collected in replicate by rapidly plunging the screen vertically through the water surface and smoothly raising the screen into the air parallel to the interface. After allowing water coating the frame to drain, the screen sample was collected in a sterile, calibrated test tube using a sterile funnel/support stand configuration and the volume recorded. Mean sample volume for the 40 samples collected during all cruises using the same screen was 12.5 ± 2.2 ml.

Surface (1 m), Thermocline, and Bottom Water

Hydrocasts were performed quarterly at each of the selected stations (Figure 11-1) using Niskin sterile bag samplers. Precautions were taken to prevent contamination by the vessels' bilges etc. Seasonal thermoclines at stations with depths greater than 50 m were located by CTD cast immediately prior to sampling. Bottom water samples were collected 2 m above the sediment. Surface water temperatures were determined at the time of sampling and reversing thermometers were used on bottom samplers to corroborate proper sampler operation.

Hydrocast and microlayer samples were processed for enumeration of heterotrophic and petroleum-degrading marine bacteria immediately

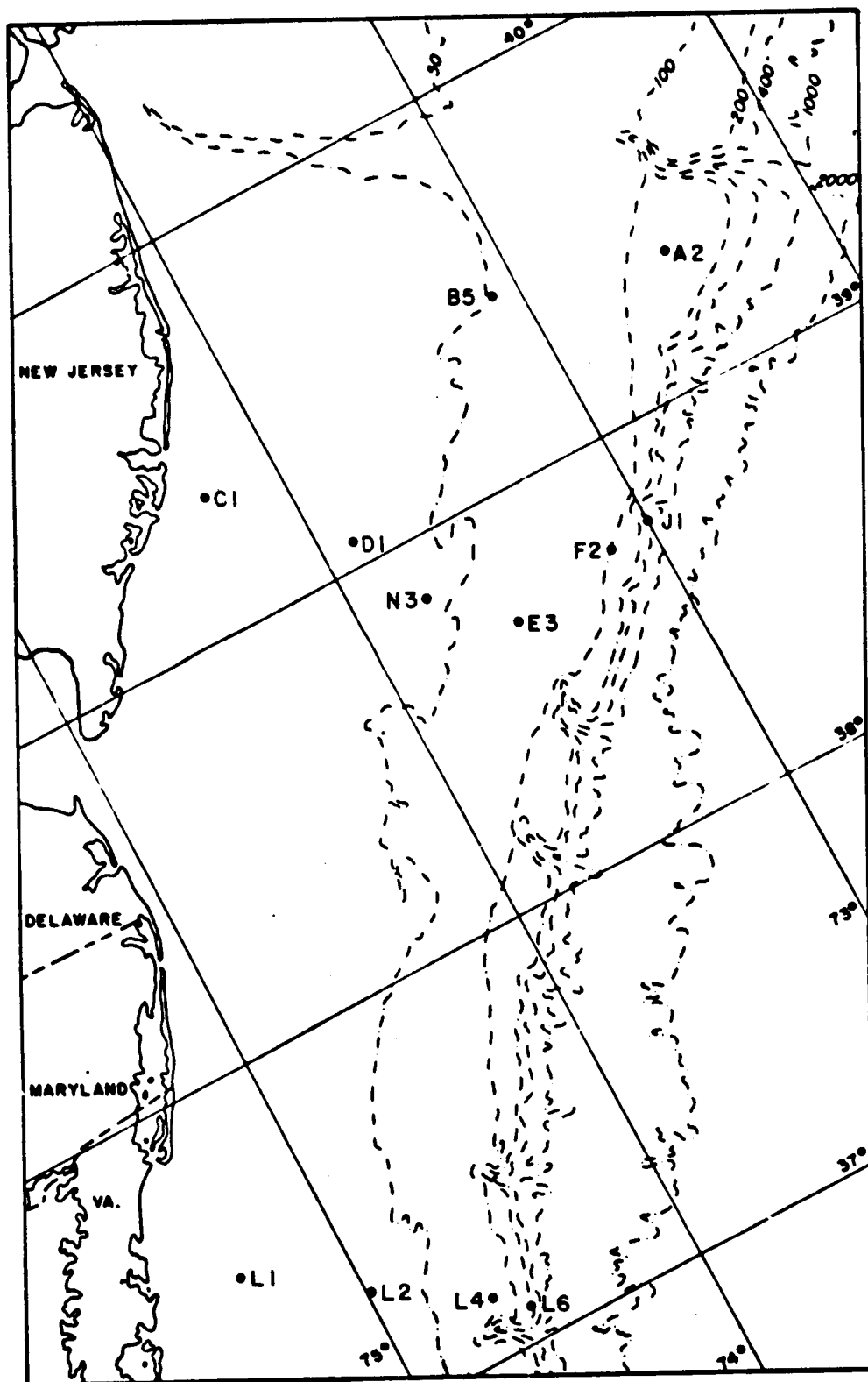


Figure 11-1. Bacteriology water column stations sampled quarterly.

after collection. Appropriate dilutions or concentration on membrane filters were provided prior to enumeration.

Two replicates were removed from each water sample collected for determination of filterable ATP concentration. Replicates (0.5 to 1.0 l) were filtered through 0.45 μ membrane filters. ATP was extracted using boiling Tris buffer (Strickland and Parson 1972). Following extraction samples were frozen for storage at -4°C prior to laboratory assay. Three replicate aliquots were assayed per sample using an ATP photometer (SAI Technology Corporation). Mean ATP concentrations were calculated from standard curves prepared at the time of assay. Miscellaneous samples from selected degradation experiments were assayed for ATP as above.

Sediments

Sediment samples were collected quarterly at cluster stations (Figure 11-2) using a Smith-McIntyre grab. Additional sediment stations (along transects G, H, I, J, K, and L) were sampled only during the summer and winter seasons. Undisturbed central areas of the grab were sampled to obtain an uncontaminated sample using sterile "minicorers", plastic syringes with the luer end removed. "Mini-corers" were pushed into the sediment sample to a depth of about 5-6 cm yielding a sample volume of about 10 ml. Four samples were obtained at each station, two for determination of heterotrophic and petroleum-degrading bacterial populations and two for the determination of the ratio of sediment dry to wet weight. Sediment temperatures were also measured at this time by mercury thermometer and recorded.

Sediment samples for dry weight determinations were immediately frozen for processing at a later date. "Mini-cores" for enumeration were then processed as follows. After weighing the "mini-corer" the sediment sample was extruded into 90 ml of sterile sea water in a Waring blender and homogenized (Stevenson, Millwood, and Hebeler 1974) for one minute. One ml volumes of this homogenate (1:10 dilution of sediment v/v) were diluted by appropriate powers of ten and used to inoculate media for enumeration of heterotrophic and petroleum-degrading marine bacteria.

Enumeration

Inocula from dilution blanks or concentrated seawater samples on membrane filters (1 m and microlayer), sediments, or experimental degradation studies were enumerated for "total" heterotrophic bacteria using a three tube MPN technique (Lewin 1974) in a heterotrophic medium (HM) modified after ZoBell's marine agar (2216). This medium consisted of 1 g/l peptone, 0.5 g/l yeast extract, 0.01 g/l ferric citrate, 0.1 g/l sodium glycerol phosphate, and 1000 ml of aged sea

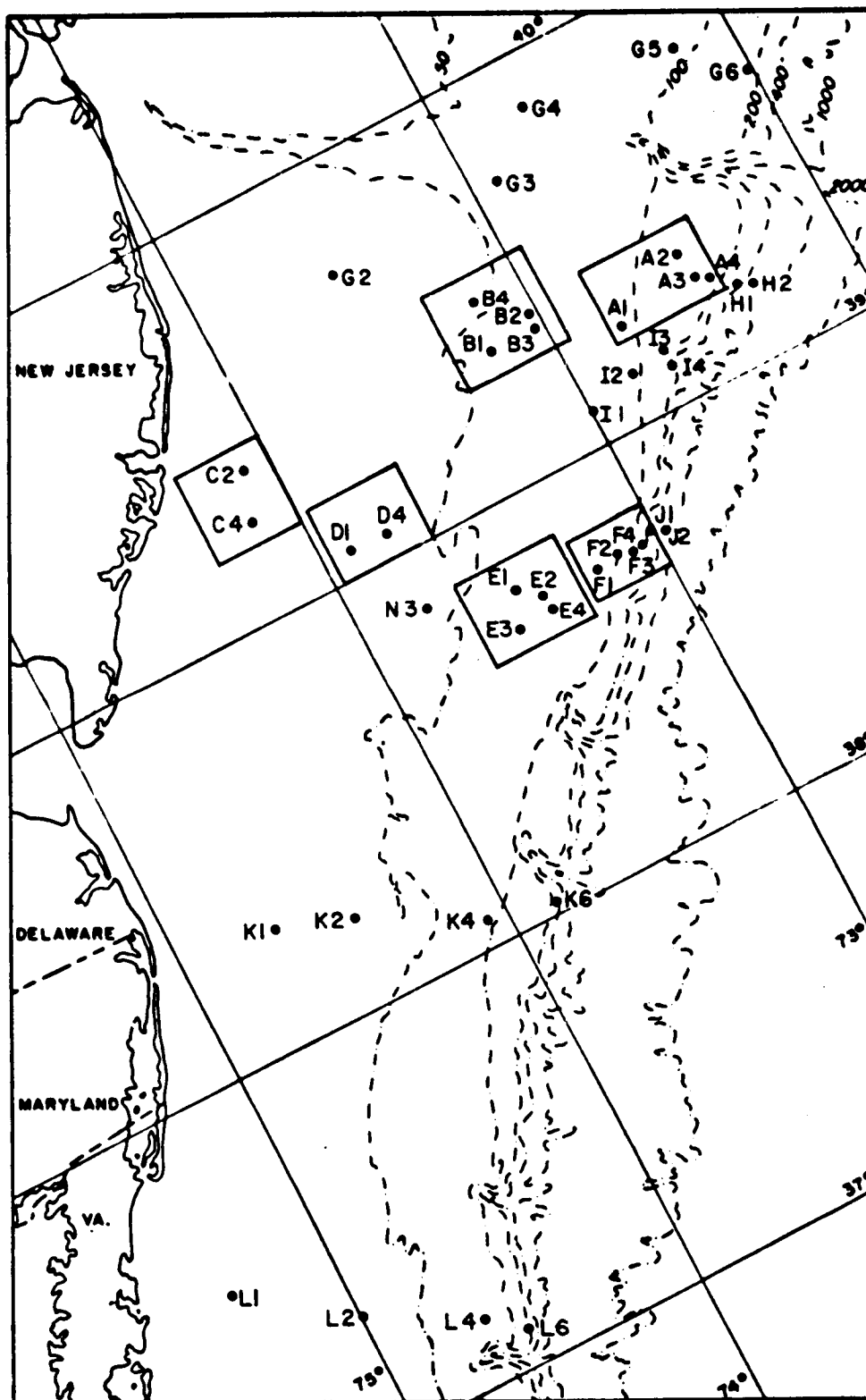


Figure 11-2. Bacteriology cluster stations samples quarterly; stations sampled twice yearly.

water. The final pH of this medium after autoclaving at 121°C for 15 minutes was 7.8. Petroleum-degrading bacteria were enumerated using a three tube MPN technique (Gunkel 1968) employing a minimal salts enriched sea water (ESWB) containing 1 g/l $(\text{NH}_4)_2\text{SO}_4$ and 0.1 g/l K_2HPO_4 in 1000 ml aged sea water to which was added following inoculation, approximately 1% sterile unweathered South Louisiana crude oil as the sole added carbon source. Louisiana crude oil was sterilized by filtration through a polycarbonate membrane, and minimal salts enriched sea water (ESWB) was sterilized by autoclaving at 121°C for 15 minutes yielding a final pH of 7.8.

HM enumeration tubes were incubated at 20-22°C for two weeks and read at weekly intervals. ESWB tubes were incubated at the same temperature on a rotary shaker (140 rpm) for one month and read at bi-weekly intervals. HM tubes were scored positive when turbid; ESWB tubes were scored positive when turbid, if the oil showed obvious signs of degradation with associated cellular debris, or a combination of both. The highest positive dilutions were retained for taxonomic analysis. MPN values were calculated using standard tables (APHA 1975) for three tube MPN distributions. Counts were expressed as bacterial units/ml sea water or bacterial units/g dry sediment. Sediment counts were corrected for dry weight, and a volume/weight conversion of the original 10 ml sediment sample was made.

Isolation of Chitinoclastic Bacteria

Chitinoclastic bacteria were isolated by spread plating appropriate dilutions of water samples (1 m) and sediment homogenates on chitin containing bi-layer plate medium. This medium consisted of a lower layer of HM agar (ca. 20 ml) and a 10 ml chitin-agar overlayer (composed of 30 g/l "dissolved" chitin, 0.5 g/l yeast extract, 15 g/l agar, and 1000 ml aged sea water). Chitin (Calbiochem, unspecified purity from crab-shrimp) was ball milled at 4°C for 48 hours (Hood 1973), "dissolved" in 50% H_2SO_4 , precipitated by the addition of large volumes of distilled water, and neutralized to a pH of 7.0. Chitinolytic bacterial colonies produced clear zones in the surrounding chitin agar.

Taxonomic Analysis of Bacterial Isolates

Isolates were obtained from selected microlayer, surface and bottom water, and sediment stations using the highest positive dilutions of HM and ESWB MPN tubes. Three to five MPN tubes from dilutions were streaked on HM agar plates, the numerically dominant isolates chosen, subcultured to ensure purity, and placed on coded HM agar slants.

Isolates for taxonomic analysis were freshly streaked on HM agar plates to describe colony characteristics. Wet mounts of log phase HM

broth cultures (generally 24 hour cultures) were examined by phase contrast microscopy for motility, size, shape, and cell arrangement. Gram staining was performed using the modification of Hucker (Hucker and Conn 1923).

Biochemical tests relevant to the classification scheme of Shewan (1963) were performed as follows. Oxidase was determined by the method of Kovacs (Kovacs 1956) using 24 or 48 hour HM agar slants or plates depending on isolate growth rate. Isolates were tested for glucose assimilation mode using Liefson's MOF medium (Liefson 1963). Closed or fermentative tubes were first sealed with Vaspar and then over-layered with sterile paraffin oil. Use of Vaspar or paraffin oil alone resulted in frequent false positive fermentative reactions. Growth, gas production, acid, alkaline or "no reaction" were recorded at 1, 7, and 14 day intervals.

Catalase assays (1 drop of 15% H_2O_2 placed directly on 48 hour HM agar colonies) were performed on all gram positive isolates. Isolates were examined for the presence of chitinase by spotting a loopful of a cell suspension on a chitin bi-layer plate followed by examination of the resultant colonies for surrounding zones of hydrolysis or clearing. All isolates were tested for the ability to utilize hexadecane as the sole added carbon source using ESWB and sterile hexadecane. Isolates from ESWB-petroleum tubes were also tested for the ability to utilize Louisiana crude oil.

Antibiotic sensitivity profiles were determined using Sensi-Discs (BBL) for all purified isolates on freshly prepared HM agar spread plates. Chloramphenicol, penicillin, neomycin and C/129 pteridine were used. Pteridine discs were prepared at a concentration of 400 $\mu\text{g}/\text{disc}$. HM agar plates were read at 1, 2, and 7 day intervals for inhibitory response and size of inhibition zone.

Petroleum Degradation Experiments

Petroleum degradation experiments were performed using samples of seawater and sediment as inocula. Samples from surface water (1 m) stations, enumerated quarterly, were used for inocula (Figure 11-1). Seawater collected at each station (as previously described) was used to fill sterile 250 ml Erlenmeyer flasks with 100 ml inocula. At the time of inoculation, water samples were also enumerated for petroleum-degrading and heterotrophic marine bacteria. Replicate flasks for each station were treated as follows: one series was immediately autoclaved providing sterile controls, a second series received inorganic nutrient enrichment (1 mg $(\text{NH}_4)_2\text{SO}_4$ and 0.1 mg K_2HPO_4 as a sterile solution per each flask), and a final series was neither enriched nor autoclaved. All three series of replicate flasks then received 100 ml of membrane sterilized South Louisiana crude oil. An additional control in the form of an inoculated, non-enriched, oil-free flask was included to compensate for surface growth effects.

Sediment inocula were provided from sediment homogenates used for enumeration of heterotrophic and petroleum-degrading marine bacteria at selected benthic stations. Stations from the A, B, C, D, E, and F clusters (Figure 11-2) were examined quarterly. Additional stations from the G, K, and L transects were included during summer and winter. Ten ml volumes of the respective homogenates were added to a series of replicate 250 ml Erlenmeyer flasks containing 100 ml of sterile seawater. Experimental treatment of replicate flasks was the same as described for seawater inocula. Flasks were incubated on a rotary shaker (120 rpm) at temperatures chosen as representative of each shelf season.

At selected intervals a flask from each series of treatments (i.e. sterile control, nutrient enriched, and non-enriched) was harvested. The oil-free control was enumerated and replaced in the incubator. Flasks were described as to the condition of the oil, turbidity, and other manifestations of bacterial degradation. Non-enriched, enriched, and oil-free flasks were enumerated after swirling using a three tube MPN technique for heterotrophs (Lewin 1974) and petroleum-degrading bacteria (Gunkel 1966). After enumeration, growth in enriched and non-enriched flasks was terminated by addition of 10 ml glass-distilled methylene chloride and the flasks sealed to prevent evaporation. Sterile control flasks were not enumerated but were tightly sealed following addition of 10 ml methylene chloride.

Residual crude oil was extracted from flasks following acidification by addition of 4 drops of concentrated HCl and 25 ml methylene chloride. Flask contents were transferred to clean solvent rinsed separatory funnels, shaker, and after phase separation, solvent phases were transferred to a second separatory funnel. Flasks were then rinsed with 25 ml of methylene chloride, and this was added to the aqueous phase in the first separatory funnel. Following phase separation, the organic solvent phases were combined and washed with 50 ml of acidified (pH 4.0) distilled water containing 3% NaCl. The washed solvent phase was dried by passage through pre-washed anhydrous sodium sulfate contained in a glass funnel lined with Whatman #54 hardened paper and collected in a tared pear-shaped flask.

Methylene chloride was removed by aspiration at 40°C using a water bath by monitoring the instant of solvent removal with a McLeod gauge. Residual crude oil extracts were then transferred to vials in 1 ml methylene chloride and stored at 4°C pending further analysis.

Crude oil extracts were fractionated into a saturated paraffin and an aromatic fraction using silica gel column chromatography. Silica gel (60-200 mesh), activated for at least 16 hours at 235°C, was packed in 1 cm diameter glass columns to a height of 17.5 cm and washed with four 10 ml portions of hexane. Extracts, warmed to room temperature, were placed on the column in 1 ml hexane. After addition of 20 ml of hexane to the column, the first 5 ml of hexane eluting

were discarded and the next 16 ml of hexane eluate, containing saturated hydrocarbons, collected (H₂ fraction). Thirty ml of a hexane-benzene solvent mixture (60/40, v/v) were then added to the column and a hexane-benzene eluate (H₃) of 30 ml, containing aromatic hydrocarbons, was collected.

Gas chromatographic analysis of residual oil fractions was performed using a Tracor 560 gas chromatograph equipped with flame ionization detectors and a Grob capillary injector. Samples (2-2.5 µl) were injected, with the split closed on a 20 m x 0.33 mm i.d. glass capillary column coated with 0.2% SE-52 at an initial temperature of 45°C. After 50 seconds the split was opened and the oven temperature programmed to 240°C at 4°/minute with a final hold of 10 minutes. Carrier gas (He) flow rate was adjusted to 2-3 ml/minute. Temperatures of the injector and detector were set at 240° and 325°, respectively.

Chromatograms were evaluated for indications of degradation reflected as loss of specific normal saturated paraffins (nC₁₀ to nC₂₅, inclusive). Identification of n-paraffins was by comparison with retention times of authentic standards. Changes in peak areas were expressed as the ratio of each n-paraffin to the naturally occurring isoprenoid hydrocarbon pristane (2, 6, 10, 14-tetramethylpentadecane). Use of this compound as an internal standard during bacterial utilization of n-paraffins has been demonstrated (Kator 1972). Peak areas were measured by electronic integration. A conservative estimate of the absolute concentration of pristane/unit weight crude oil was determined by the technique of standard addition (McNair and Bonelli 1968). Losses in non-enriched and enriched flasks were corrected for evaporative and procedural losses by comparison with sterile controls.

Continuous Dilution Degradation Experiments

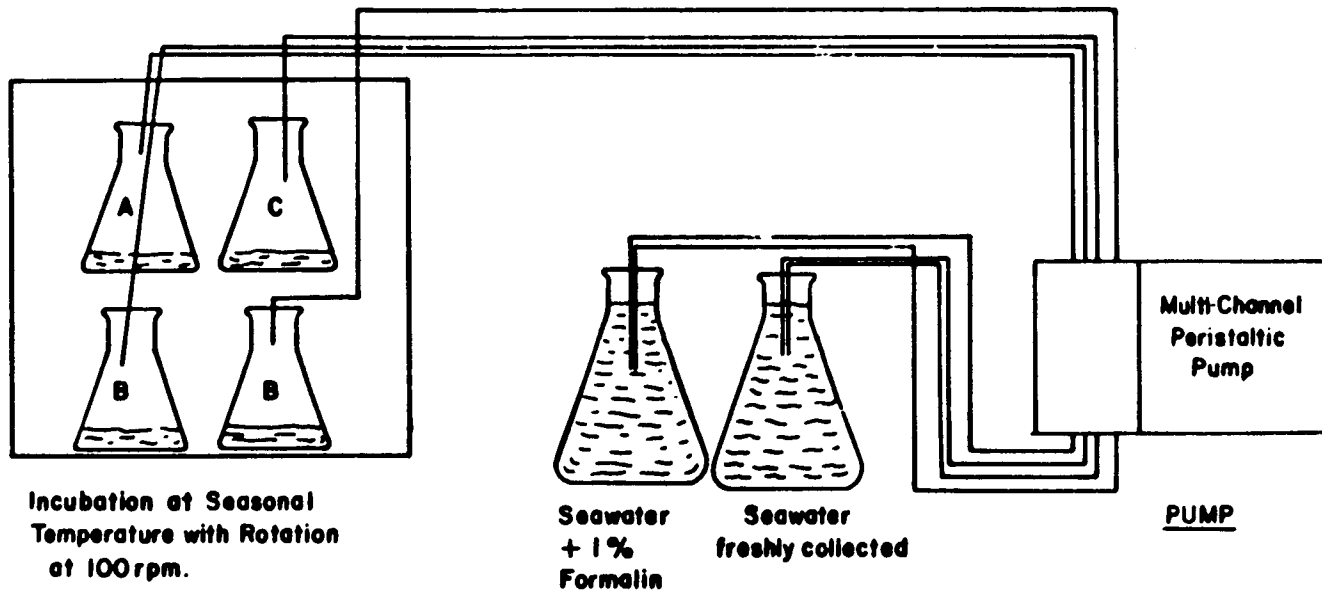
A continuous dilution system was designed to simulate weathering of oil in an "open" system under ambient nutrient conditions (Figure 11-3). Seawater samples (1 m) collected at various stations were used to continually dilute a seawater-oil system. Initially, replicate series of sterile, solvent washed 500 ml Erlenmeyer flasks received each of three different treatments:

Treatment

- A. 50 ml sterile seawater and 0.01 to 0.1% sterile South Louisiana crude oil
- B. 50 ml seawater and 0.01 to 0.1% sterile South Louisiana crude oil
- C. 50 ml seawater

CONTINUOUS DILUTION SYSTEM

INCUBATOR



11-13

Figure 11-3. Schematic of continuous dilution system.

Flasks were incubated in a Lab-Line Orbit Environ-Shaker 18 (Lab-Line Instruments, Inc.) at 100 rpm at selected seasonal temperatures. During the incubation period, flask contents were continually diluted using a Desaga (Brinkmann) peristaltic pump from reservoirs containing either seawater and 1% formalin or freshly collected seawater. At selected harvest intervals four flasks consisting of one from treatment A, two from treatment B, and one from treatment C were harvested for processing. Populations of heterotrophic and petroleum-degrading bacteria were enumerated from one treatment B flask and one treatment C flask. ATP analysis (Strickland and Parsons 1972) was also performed on these flasks. The two remaining flasks (one treatment A and one treatment B) were "pickled" with 10 ml of methylene chloride for analysis of residual petroleum as previously described.

Chitin-Petroleum Degradation Studies

Mixed culture inocula were obtained from four (4) sampling locations during each seasonal cruise. These inocula consisted of 3 dominant chitinoclastic bacterial isolates and either 2 dominant petroleum-degrading isolates (fall) or a natural, petroleum-degrading mixed bacterial population (winter, spring, summer). The four sampling locations consisted of the water column, inner shelf sediments (<50 m), outer shelf sediments (50-100 m), and shelf break sediments (>100 m).

Mixed cultures were maintained on a chitin-peptone-yeast extract seawater broth (CPY-broth). For the fall this medium was composed of 0.1 g/l peptone, 0.1 g/l yeast extract, 0.01 g/l ferric citrate, 0.1 g/l sodium glycerol phosphate, and 1000 ml aged seawater. Winter, spring and summer inocula were maintained on a diluted form of this broth and contained 0.01 g/l peptone, 0.01 g/l yeast extract, 1 g/l ammonium sulfate, 0.1 g/l potassium phosphate and 1000 ml aged seawater. Chitin (Calbiochem, Inc., undefined grade of shrimp-crab chitin), sieved to a size range of 250-500 μ , was added to the media to yield a final concentration of 2 g/l. CPY-broth autoclaved at 121°C for 15 minutes had a final pH of 7.8.

Mixed culture inocula for chitin-petroleum degradation studies were prepared from 18 hour CPY-broth cultures by centrifugation of cells and re-suspension in seawater to an optical density of 0.1 (625 nm). Appropriate dilutions of washed suspensions were used to inoculate 150 ml bottles containing 50 ml CPY-broth. Three series of replicate bottles for each mixed culture were treated as follows: one series received the mixed culture inoculum plus 50 ml sterile Louisiana crude oil (chitin plus oil), the second received the mixed culture inoculum but no petroleum (chitin minus oil), and the third received only 50 ml sterile Louisiana crude oil (sterile control). All bottles were sealed with gauze-cotton plugs to allow for aerobic growth. Initial levels of each inoculum were enumerated for

petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria as described in previous sections.

Following inoculation all bottles were incubated in the dark on a rotary shaker at ambient temperatures (20-22°C). At selected intervals one bottle from each of the three treatments (i.e., chitin plus oil, chitin minus oil, sterile control) for each of the four inocula was randomly selected and inoculated bottles enumerated for the bacterial groups mentioned previously. Methylene chloride was then added to each bottle to terminate bacterial activity.

Recovery of residual chitin and crude oil was achieved by filtration of the spent medium onto tared Whatman #54 hardened filter paper pre-washed with methylene chloride. Residual chitin and petroleum were removed from each bottle using rinses of methylene chloride and water. The filterable material was additionally used with methylene chloride to remove adsorbed petroleum. Following extraction of the filtrate with methylene chloride, the extract was fractionated using silica gel column chromatography and analyzed by glass capillary gas chromatography as previously described. Residual chitin was dried in the presence of desiccant, allowed to equilibrate to room humidity and weighed. Chitin weight losses were expressed as a percentage of the uninoculated sterile controls.

Pure Culture Growth Experiments

Selected bacterial isolates obtained from enumeration of heterotrophic or petroleum-degrading bacteria in microlayer, surface water (1 m), bottom water and sediment samples were utilized to examine the effects of an unweathered petroleum and selected weathered products on growth in a dilute nutrient broth. Isolates were maintained on HM agar and were passed three times in a dilute basal medium (BGM) prior to growth experiments. BGM consisted of 0.006% yeast extract and 0.02% peptone in aged filtered (Whatman #1) seawater diluted with glass distilled water to yield a salinity of 26 ppt. After autoclaving the basal medium at 121°C for 15 minutes, membrane sterilized glucose was added to obtain a concentration of 0.02%. Alternatively, appropriate concentrations of membrane sterilized nutrient solutions were added to autoclaved seawater or membrane sterilized soluble fractions of crude oil with a resultant pH of 7.8.

Weathered crude oil and a water soluble fraction thereof were prepared in the laboratory by addition of 20 ml of unweathered South Louisiana crude to one liter of aged seawater (26 ppt) in a glass carboy containing a teflon stirbar. The bottle was left unsealed in the dark and the contents slowly stirred to avoid breakup of the oil layer for 48 hours at 20°C. After cessation of stirring for 10 minutes a soluble fraction was collected by draining the aqueous layer beneath the quiescent oil followed by collection of the residual weathered crude. Similarly, photo-oxidized crude oil and resulting

soluble fraction were prepared by exposure of an oil-seawater mixture to sunlight for approximately 16-20 hours during a 48 hour period at ambient air temperatures (-1.1 to 38°C). On two occasions the crude oil was weathered in the dark for 48 hours at ambient air temperatures (21-32°C) to compare with oil simultaneously photo-oxidized at the same temperatures. All experiments involving laboratory weathered oil were performed on isolates from the fall cruise while experiments employing photo-oxidized oil occurred during the remaining three seasons of the year. All petroleum substrates were sterilized prior to use by membrane filtration (Nuclepore membrane, 0.4 μ with pre-filter). Photo-oxidized and dark weathered oils were passed through a column of anhydrous Na₂SO₄ to remove residual water prior to sterilization. Nalgene membrane filtration units (0.45 and 0.2 μ) were used to sterilize water soluble extracts.

Immediately prior to growth experiments, isolates were inoculated into BGM and incubated approximately 18 hours at 20°C. Cells were harvested by centrifugation and resuspended in seawater (26 ppt) to an absorbance of 0.1 (625 nm). These suspensions were diluted 100 x and 0.1 ml of the final suspension used to inoculate tubes containing 5 ml BGM and unweathered South Louisiana crude oil (1% w/v); laboratory weathered, photo-oxidized or dark weathered South Louisiana crude oil (1% w/v); the soluble fraction of laboratory weathered South Louisiana crude oil (1% v/v), photo-oxidized or dark weathered South Louisiana crude oil (100% v/v); and no petroleum (control). Additional experiments were conducted to examine the effects of various concentrations of photo-oxidized oil extracts in seawater.

One ml of 100 x BGM was added to 100 ml membrane sterilized soluble fraction in seawater at concentrations of 1, 10, 50% v/v and "undiluted" 100%. A seawater control was provided. Cultures were incubated at 20°C on a New Brunswick Tissue Culture Rollerdrum (10-11 rpm). Growth was measured turbidimetrically at 2-4 hour intervals or longer (for slow growers) during logarithmic growth. Measurements were terminated when absorbance values decreased in all tubes or for as long as 10 days. Replicate experiments were occasionally performed to check on the reproducibility of the results.

Absorbance data were plotted against time on semilog paper. Parameters routinely noted were growth yield, growth rate, and "lag" time. Of these "lag" time proved most useful in quantifying the effects (s) of petroleum on growth. "Lag" time was calculated by extending a straight line along the exponential portion of the growth curve to an absorbance value of 0.1. From this intersection a perpendicular was dropped to the time axis to determine the "lag" time required to reach an absorbance of 0.1. Table 11-1 summarizes the types of experiments performed on 399 bacterial isolates from water and sediment samples.

The Friedman test (Conover 1971) for uniformity was applied to all data except those from experiments with cultures exhibiting

Table 11-1. Number of bacterial isolates examined in pure culture experiments designed to assess the effect of petroleum hydrocarbons on the growth of dominant marine bacteria under laboratory conditions.

Experimental ^a Design	Number of Isolates			Total
	Analyzed	Partial ^b Analysis	Not ^c Analyzed	
1	82	-	4	86
2	196	34	12	242
3	41	-	-	41
4	18	-	1	19
5	11	-	-	11
				<u>399</u>

- ^a 1. control vs. unweathered crude oil vs. laboratory weathered crude oil and soluble fraction thereof
 2. control vs. unweathered crude oil vs. photo-oxidized crude oil and soluble fraction thereof
 3. control vs. unweathered crude oil vs. dark weathered crude oil and soluble fraction thereof vs. photo-oxidized crude oil and soluble fraction thereof
 4. control vs. various concentrations of soluble fraction of photo-oxidized crude oil
 5. confirmation of selected cultures

^b - Simultaneous comparison of control and all other conditions not possible due to oil dispersion or other technical problems within one of the experimental treatments. Resulting data incorporated into histograms but not used in other data analysis

^c - Number of cultures not analyzed due to extensive clumping and settling of growth which prevented interpretation of results

extensive clumping and settling or adherence of oil droplets to the insides of the tubes. In the later case, only data from uncoated oil tubes were included in histogram presentations.

RESULTS

Distribution and Abundance of Heterotrophic and Petroleum-Degrading Bacteria

Sediments

Petroleum-degrading (HC) and heterotrophic (HET) marine bacteria were consistently isolated from Middle Atlantic continental shelf sediments. Bacterial data for all stations and seasons are listed in Tables 11-2 through Tables 11-5. Mean (geometric) values for stations sampled, grouped according to inner shelf (>50 m depth), outer shelf (>50 m depth < 100 m depth) and shelf break-slope (> 100 m depth) stations, are shown in Table 11-6 for season and year of sampling.

Considering variations due to location of stations, season, temperature, textural properties, small scale heterogeneity, sample size and replicates, and precision of the MPN technique, mean viable counts of heterotrophic bacteria were remarkably consistent from season to season within each major shelf location. Small variations in these counts suggested stable sediment populations limited to maximum biomass by complex factors. With respect to heterotrophs, mean viable counts were significantly ($\alpha = 0.05$) larger from inner shelf sediments than either outer shelf or shelf break sediments. Viable counts from shelf break sediments were not significantly ($\alpha = 0.05$) different from outer shelf sediment counts.

Overall geographic patterns of heterotrophic bacterial counts were generally similar from season to season and year to year (Figures 11-4 to 11-7). This similarity was undoubtedly related to the consistency of the sediments with regard to textural properties, terrestrial influences and the effects of season on inner shelf stations. Viable counts of heterotrophic bacteria from sediments sampled quarterly were rather uniform and did not manifest well developed trends with distance from shore. However, certain repetitive maxima and minima usually occurred and could be related to the effects of ridge-swale topography. Similarly, with respect to many outer shelf sediment stations (excluding troughs) comparatively elevated counts were encountered in shelf break stations with the greatest percentages of silt-clay (A and F clusters, New Jersey transect).

Typically, mean viable counts of petroleum-degrading bacteria were 2-4 orders of magnitude smaller than viable counts of heterotrophs. Patterns of viable counts of petroleum-degrading bacteria with distance from shore were more strongly delineated

(TEXT CONTINUES ON PAGE 11-37)

Table 11-2. BLM Microbiology 05B.

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²			
						Heterotrophs (HET)	Petroleum Degradars (HC)	Log HC/HET	
A1	11-15-76	Sed.	91	13.0	13.5	2.2 E 05	1.8 E 03	-2.1	
A2	11-16-76	Sed.	136	13.1	12.5	4.9 E 05	7.8 E 01	-3.8	
		Surface	1			4.6 E 02	6.3 E -01	-2.9	
		Bottom	133			6.3 E 02	1.2 E 00	-2.7	
A3	11-16-76	Sed.	140	14.1	13.0	3.0 E 05	1.0 E 02	-3.5	
A4	11-16-76	Sed.	198	14.0	13.0	6.5 E 04	1.6 E 01	-3.6	
11-19	B1	11-13-76	Sed.	66	11.3	12.7	1.6 E 06	1.5 E 03	-3.0
	B2	11-13-76	Sed.	60	11.4	13.0	2.2 E 05	2.9 E 00	-4.9
	B3	11-14-76	Sed.	74	10.0	11.5	2.5 E 06	5.1 E 01	-4.7
	B4	11-13-76	Sed.	43	12.2	12.3	4.2 E 05	4.8 E 00	-4.9
	B5	11-13-76	Sed.	64	11.3	13.0	6.9 E 06	1.9 E 01	-5.6
		Surface	1			6.3 E 03	4.3 E -01	-4.2	
		Thermo	35			4.4 E 03	1.9 E 00	-3.4	
		Bottom	61			4.6 E 03	4.3 E 00	-3.0	
C1	11-6-76	Sed.	16	11.5	11.5	9.2 E 05	2.9 E 04	-1.5	
		Surface	1			3.9 E 04	6.3 E 02	-1.8	
		Bottom	14			5.4 E 04	2.3 E 02	-2.4	
C2	11-7-76	Sed.	25	12.1	11.7	4.2 E 06	7.7 E 04	-1.7	
C4	11-5-76	Sed.	34	12.1	12.0	2.4 E 06	2.5 E 04	-2.0	
D1	11-7-76	Sed.	31	12.0	12.3	2.9 E 06	3.4 E 03	-2.9	
		Surface	1			1.5 E 04	1.2 E 00	-4.1	
		Bottom	29			2.9 E 04	5.7 E -01	-4.7	
D4	11-7-76	Sed.	50	12.4	12.0	1.5 E 07	1.7 E 03	-3.9	

Table 11-2. (continued)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Heterotrophs (HET)	Petroleum Degradars (HC)	Log $\frac{HC}{HET}$
E1	11-9-76	Sed.	65	12.0	11.8	5.4 E 05	3.4 E 01	-4.2
E2	11-11-76	Sed.	79	13.1	12.4	3.6 E 05	6.4 E 00	-4.7
E3	11-7-76	Sed.	68	13.1	13.0	4.3 E 05	2.2 E 01	-4.3
		Surface	1			1.9 E 03	4.3 E -01	-3.6
		Thermo	25			4.2 E 03	7.6 E -01	-3.7
		Bottom	65			1.5 E 03	3.7 E 00	-2.6
E4	11-11-76	Sed.	81	13.6	13.0	6.7 E 05	3.8 E 01	-4.2
11-20	F1	11-12-76	Sed.	90	13.2	6.3 E 05	5.9 E 02	-3.0
	F2	11-12-76	Sed.	113	12.8	3.1 E 05	1.2 E 02	-3.4
		Surface	1			1.5 E 03	1.9 E 00	-2.9
		Bottom	100			1.4 E 03	3.1 E 01	-1.6
	F3	11-12-76	Sed.	157	13.6	7.2 E 06	6.4 E 02	-4.1
	F4	11-12-76	Sed.	166	14.0	5.6 E 05	7.9 E 00	-4.8
J1	11-12-76	Surface	1	16.1		8.0 E 01	9.3 E -01	-1.9
		Thermo	60			3.0 E 02	2.2 E 00	-2.1
		Bottom	400			1.9 E 02	1.5 E 00	-2.1
L1	11-18-76	Surface	1	11.5		7.4 E 03	6.3 E 00	-3.1
		Bottom	20			1.0 E 04	3.1 E 00	-3.5
L2	11-17-76	Surface	1	12.3		4.1 E 03	2.2 E 00	-3.3
		Bottom	39			4.3 E 03	9.3 E -01	-3.7

Table 11-2. (concluded)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Heterotrophs (HET)	Petroleum Degradars (HC)	Log $\frac{HC}{HET}$
L4	11-17-76	Microlayer				9.6 E 04	1.4 E 03 (s)	-1.8
		Surface	1	12.9		4.6 E 03	9.3 E -01	-3.7
		Bottom	92			1.4 E 03	4.3 E -01	-3.5
L6	11-17-76	Microlayer				1.7 E 05	1.6 E 02 (s)	-3.0
		Surface	1	14.0		2.3 E 03	3.0 E -01	-3.9
		Bottom	267			1.9 E 03	8.4 E -01	-3.3
11-21 N3	11-7-76	Microlayer				8.7 E 05	7.5 E 01 (s)	-4.1
		Surface	1	12.5		1.5 E 04	1.9 E 00	-3.9
		Thermo	35			2.4 E 04	1.3 E 00	-4.3
		Bottom	40			1.5 E 04	5.9 E -01	-4.4

* MPN values are geometric means of two samples. Values followed by (s) are microlayer samples and are expressed as an MPN/m².

Table 11-3. BLM Bacteriology 06B.

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²			
						Petroleum Degradars (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$	
A1	2-12-77	Sed	90	8.2	7.5	8.3 E 00	1.0 E 05	-4.1	
A2	2-12-77	Sed	127		9.0	9.7 E 02	9.8 E 05	-3.0	
A2	2-12-77	Microlayer				2.6 E 02	2.0 E 03 (s)	-0.0	
A2	2-12-77	Surface	1	8.8		2.0 E 00	3.7 E 01	-1.3	
A2	2-12-77	Bottom	125			4.6 E 00	3.1 E 01	-0.8	
A3	2-12-77	Sed	128	10.0	9.0	1.1 E 01	2.4 E 05	-4.3	
A4	2-12-77	Sed	204	9.7	9.0	2.6 E 02	3.7 E 04	-2.2	
11-22	B1	2-11-77	Sed	64	4.8	5.2	3.7 E 01	9.4 E 05	-4.4
	B2	3-8-77	Sed	58	6.3	7.0	3.5 E 00	2.0 E 05	-4.8
	B3	2-11-77	Sed	69	5.7	7.0	7.3 E 01	2.1 E 06	-4.5
	B4	2-11-77	Sed	41	4.3	4.5	2.0 E -01	8.6 E 04	-5.6
	B5	3-8-77	Sed	63	6.3	6.0	2.1 E 02	8.3 E 06	-4.6
	B5	3-8-77	Surface	1	7.0		4.4 E 00	4.6 E 02	-2.0
	B5	3-8-77	Bottom	61			6.3 E 00	2.5 E 02	-1.6
C1	2-14-77	Sed	16		-0.5	1.2 E 01	3.2 E 05	-4.4	
C1	2-14-77	Microlayer				2.4 E 02	6.2 E 06 (s)	-4.4	
C1	2-14-77	Surface	1	-0.5		9.9 E -01	1.2 E 05	-5.1	
C1	2-14-77	Bottom	14			4.8 E -02	4.3 E 04	-5.9	
C2	2-14-77	Sed	26	-0.5	0.5	4.1 E 00	6.0 E 05	-5.2	
C4	2-14-77	Sed	34	-0.5	1.5	4.8 E 03	2.8 E 06	-2.8	
D1	2-8-77	Sed	29		2.9	4.9 E -01	2.0 E 05	-5.6	
D1	2-8-77	Surface	1	2.8		1.5 E 00	4.4 E 03	-3.5	
D1	2-8-77	Bottom	27			5.7 E -01	3.1 E 03	-3.7	
D4	2-8-77	Sed	49	2.8	3.2	7.2 E 03	3.3 E 06	-2.7	

Table 11-3. (continued)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²			
						Petroleum Degraders (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$	
E1	2-9-77	Sed	59	9.0	8.0	7.8 E 01	2.1 E 05	-3.4	
E2	2-9-77	Sed	74	8.3	8.0	1.3 E 02	5.5 E 05	-3.6	
E3	2-9-77	Sed	65		7.4	4.4 E 01	9.6 E 06	-5.3	
E3	2-9-77	Microlayer				1.3 E 02	7.3 E 04 (s)	-2.7	
E3	2-9-77	Surface	1	7.5		1.5 E 00	5.7 E 02	-2.6	
E3	2-9-77	Bottom	63			9.9 E -01	7.3 E 02	-2.9	
E4	2-9-77	Sed	79	9.1	8.5	6.1 E 01	1.1 E 05	-3.3	
11-23	F1	2-9-77	Sed	79	9.8	9.0	9.7 E -01	3.5 E 05	-5.6
	F2	2-10-77	Sed	109		8.5	9.6 E 01	6.0 E 05	-3.8
	F2	2-10-77	Surface	1	7.5		2.2 E 00	2.3 E 02	-2.0
	F2	2-10-77	Bottom	107			2.3 E 00	1.3 E 02	-1.8
	F3	2-10-77	Sed	157	11.3	10.0	2.5 E 01	5.6 E 04	-3.4
	F4	2-10-77	Sed	206	11.2	10.0	1.2 E 03	7.1 E 04	-1.8
G2	2-14-77	Sed	36	0.1	2.3	9.4 E 00	1.6 E 06	-5.2	
G3	3-8-77	Sed	71	6.3	5.0	9.7 E 03	1.2 E 07	-3.1	
G4	3-8-77	Sed	56	4.0	5.0	4.4 E 00	5.7 E 05	-5.1	
G5	3-8-77	Sed	92	5.2	7.0	6.1 E 02	5.5 E 05	-3.0	
G6	3-9-77	Sed	175	6.5	10.0	1.1 E 03	1.7 E 06	-3.2	
H1	3-10-77	Sed	400	7.9	9.0	3.2 E 01	1.5 E 05	-3.7	
H2	3-9-77	Sed	760	11.1	8.0	3.6 E 01	3.2 E 04	-2.9	
I1	2-13-77	Sed	77	8.7	8.0	6.1 E 00	3.1 E 05	-4.7	
I2	2-13-77	Sed	93	9.5	9.0	6.1 E 01	2.7 E 04	-2.6	
I3	2-13-77	Sed	174	10.9	9.0	1.7 E 02	3.9 E 05	-3.3	
I4	3-10-77	Sed	465	6.2	8.0	2.2 E 03	1.1 E 06	-2.7	

Table 11-3. (concluded)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degraders (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
J1	2-10-77	Sed	362		9.0	1.3 E 02	1.1 E 05	-2.9
J1	2-10-77	Microlayer				7.3 E 01	3.7 E 04 (s)	-2.7
J1	2-10-77	Surface	1	10.5		4.3 E -01	4.2 E 02	-3.0
J1	2-10-77	Bottom	357			9.3 E -01	6.3 E 01	-1.8
J2	3-11-77	Sed	740	9.9	8.0	6.9 E 01	2.8 E 05	-3.6
K2	2-16-77	Sed	34	4.2	4.5	3.5 E 00	6.4 E 05	-5.3
K4	2-16-77	Sed	103	11.2	9.5	3.3 E 03	1.2 E 06	-2.6
K5	2-16-77	Sed	152	11.3	10.0	1.3 E 02	2.6 E 05	-3.3
K6	3-12-77	Sed	348	12.0	12.0	3.2 E 00	3.7 E 05	-5.1
L1	2-4-77	Surface	1	4.0		4.3 E -01	2.6 E 04	-4.8
L1	2-4-77	Bottom	22			1.5 E 00	1.6 E 05	-5.0
L2	2-17-77	Sed	47	6.5	7.5	3.1 E 03	2.1 E 06	-2.8
L2	2-4-77	Surface	1	3.0		7.3 E -01	2.1 E 04	-4.5
L2	2-4-77	Bottom	38			6.3 E 00	8.3 E 03	-3.1
L4	3-13-77	Sed	94		13.0	1.9 E -01	9.3 E 05	-6.7
L4	2-5-77	Surface	1	13.0		6.3 E -01	4.1 E 02	-2.8
L4	2-5-77	Thermo	55			1.9 E 00	4.3 E 02	-2.4
L4	2-5-77	Bottom	90			7.3 E -01	6.3 E 02	-2.9
L5	2-16-77	Sed	190	11.6	9.5	1.2 E 02	1.3 E 06	-4.1
L6	3-13-77	Sed	350	12.2	12.0	2.2 E 03	2.1 E 06	-3.0
L6	2-5-77	Surface	1	14.0		6.3 E -01	4.3 E 02	-2.8
L6	2-5-77	Thermo	110			1.9 E 00	4.1 E 02	-2.3
L6	2-5-77	Bottom	400			6.6 E -02	3.1 E 01	-2.7
N3	2-9-77	Surface	1	4.5		6.3 E -01	9.3 E 02	-3.2
N3	2-9-77	Bottom	45			2.3 E 00	6.3 E 02	-2.4

*MPN values are geometric means of two samples. Values followed by (s) are microlayer samples and counts are expressed as MPN/m².

Table 11-4. BLM Microbiology 07B.

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degraders (HC)	Heterotrophs (HFT)	Log $\frac{HC}{HFT}$
A1	6-3-77	Sed.	93	14.3	6.0	5.5 E 02	1.1 E 06	-3.3
A2	6-2-77	Surface	1	15.0		6.3 E -02	2.0 E 03	-4.5
		Thermo	15			7.3 E -03	1.5 E 03	-5.3
		Bottom	128			5.6 E -01	4.6 E 02	-2.9
		Sed.	130		9.8	7.5 E 02	3.3 E 06	-3.6
A3	6-3-77	Sed.	139	10.3	10.0	1.2 E 02	1.5 E 06	-4.1
A4	6-2-77	Sed.	194	14.1	11.0	5.8 E 00	3.8 E 05	-4.8
11-25 B1	6-3-77	Sed.	63	14.2	4.5	3.9 E 01	4.0 E 05	-4.0
B2	6-3-77	Sed.	62	13.8	6.0	1.7 E 01	1.3 E 05	-3.9
B3	6-3-77	Sed.	72	10.3	5.0	1.1 E 02	1.0 E 06	-4.0
B4	6-3-77	Sed.	40	14.1	6.0	3.0 E 01	3.8 E 05	-4.1
B5	6-3-77	Surface	1	14.3		5.7 E -02	3.0 E 02	-3.7
		Thermo	15			6.0 E -02	1.9 E 03	-4.5
		Bottom	65			9.5 E -01	2.5 E 03	-3.4
		Sed.	67			7.1 E 00	2.1 E 05	-4.5
C1	5-30-77	Surface	1	14.0		2.2 E 01	1.4 E 04	-2.8
		Bottom	14			4.3 E 02	6.3 E 04	-2.2
		Sed.	17		10.8	1.2 E 04	1.4 E 07	-3.1
C2	5-30-77	Sed.	26	14.3	7.5	2.3 E 01	2.1 E 06	-5.0
C4	5-31-77	Sed.	34	9.3	7.0	6.9 E 04	1.3 E 07	-2.3
D1	5-31-77	Microlayer				1.1 E 02	1.8 E 03 (s)	-1.2
		Surface	1	14.0		6.3 E -01	4.3 E 03	-3.8
		Bottom	30			9.3 E -01	4.3 E 03	-3.7
		Sed.	31		7.5	0.0 E 00	1.3 E 05	
D4	5-31-77	Sed.	50	13.5	8.0	2.4 E 03	4.1 E 06	-3.2

Table 11-4. (continued)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degradors (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
E1	5-31-77	Sed.	67	14.5	7.0	1.2 E 02	9.5 E 05	-3.9
E2	6-01-77	Sed.	74	11.5	7.3	1.0 E 01	3.3 E 05	-4.5
E3	5-31-77	Microlayer				9.9 E 02	3.3 E 04 (s)	-1.5
		Surface	1	19.0		2.1 E 00	3.1 E 03	-3.2
		Thermo	50			3.1 E 00	4.1 E 03	-3.1
		Bottom	64			2.3 E -01	2.2 E 02	-3.0
		Sed.	66		6.5	0.0 E 00	5.0 E 05	
E4	6-1-77	Sed.	80	19.6	19.0	2.5 E 01	3.3 E 05	-4.1
11-26 F1	6-1-77	Sed.	87	20.3	10.0	2.4 E 00	1.3 E 05	-4.7
F2	6-1-77	Surface	1	21.0		8.0 E -02	7.5 E 02	-4.0
		Thermo	15			4.0 E -02	2.5 E 02	-4.8
		Bottom	107			1.9 E 00	9.9 E 02	-2.7
F2	6-1-77	Sed.	110		13.5	1.6 E 02	3.8 E 05	-3.4
F3	6-1-77	Sed.	152	17.5	11.2	1.0 E 01	1.0 E 06	-5.0
F4	6-1-77	Sed.	183	18.3	13.0	4.1 E 00	1.1 E 06	-5.4
J1	6-3-77	Surface	1	20.5		2.9 E 00	3.1 E 02	-2.0
		Thermo	110			1.2 E 00	1.2 E 03	-3.0
		Bottom	375			6.3 E -01	1.9 E 03	-3.5
L1	6-5-77	Microlayer				6.0 E 02	4.0 E 06 (s)	-3.8
		Surface	1	17.7		4.6 E -01	8.4 E 03	-4.3
		Bottom	20			1.9 E 00	6.3 E 03	-3.5

Table 11-4. (concluded)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degraders (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
L2	6-4-77	Microlayer				1.6 E 02	1.4 E 06	
		Surface	1	18.5		1.3 E -01	6.0 E 03 (s)	-4.8
		Bottom	39			1.7 E 00	2.3 E 03	-3.1
L4	6-4-77	Microlayer				0.0 E 00	8.4 E 04 (s)	
		Surface	1	19.0		1.2 E 00	6.3 E 02	-2.7
		Bottom	92			8.0 E -01	7.3 E 02	-3.0
L6	6-4-77	Microlayer				94. E 00	5.7 E 04 (s)	-3.8
		Surface	1	23.0		5.9 E -01	1.3 E 03	-3.4
		Thermo	20			2.0 E -01	4.3 E 03	-4.3
		Bottom	320			2.1 E 00	6.0 E 02	-2.5
N3	5-31-77	Microlayer				4.1 E 01	5.1 E 04 (s)	-3.1
		Surface	1	15.0		1.5 E 00	9.9 E 02	-2.8
		Thermo	20			1.5 E -01	6.3 E 03	-4.6
		Bottom	46			9.3 E -01	4.3 E 03	-3.7

* MPN values are geometric means of two samples. Values followed by (s) are microlayer samples and counts are expressed as an MPN/m².

Table 11-5. BLM Microbiology 08B.

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degradors (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
A1	8-7-77	Sed	93	23.5	11.0	2.2 E 01	4.6 E 05	-4.3
A2	8-7-77	Microlayer				3.5 E 02	3.1 E 05 (s)	-2.9
		Surface	2	22.5		4.3 E 00	4.3 E 03	-3.0
		Thermo	10			1.4 E 00	8.0 E 03	-3.8
		Bottom	132			9.4 E -01	4.3 E 02	-2.7
		Sed	136		12.5	5.8 E -01	4.4 E 05	-5.9
A3	8-7-77	Sed	140	24.1	12.5	2.9 E 01	6.9 E 05	-4.4
A4	8-7-77	Sed	188	23.7	11.0	4.3 E 01	4.8 E 05	-4.1
B1	8-6-77	Sed	64	23.0	13.0	2.3 E 02	8.6 E 05	-3.6
B2	8-6-77	Sed	62	23.7	15.0	5.3 E 00	1.1 E 05	-4.3
B3	8-7-77	Sed	73	23.6	9.0	4.3 E 01	2.4 E 05	-3.8
B4	8-6-77	Sed	41	23.0	13.0	1.4 E 00	3.4 E 06	-6.4
B5	8-6-77	Microlayer				6.3 E 02	4.6 E 05 (s)	-2.9
		Surface	1	23.9		2.3 E 00	3.1 E 05	-3.1
		Thermo	10			2.2 E -01	1.9 E 05	-4.9
		Bottom	65			4.2 E -01	1.2 E 03	-3.5
		Sed	68		12.0	4.3 E 00	3.8 E 05	-4.9
C1	8-12-77	Surface	1	25.3		12. E 02	1.9 E 05	-3.2
		Bottom	13			4.6 E 01	2.6 E 04	-2.8
		Sed	14		20.0	1.1 E 04	2.5 E 05	-1.4
C2	8-12-77	Sed	25	25.2	16.0	3.6 E 02	4.8 E 05	-3.1
C4	8-12-77	Sed	33	25.2	12.0	1.8 E 04	4.9 E 06	-2.4
D1	8-12-77	Microlayer				4.2 E 03	1.9 E 06 (s)	-2.6
		Surface	1	25.4		1.2 E 01	7.1 E 04	-3.8
		Bottom	30			9.9 E -01	9.3 E 02	-3.0
		Sed	31		14.0	1.9 E 00	1.6 E 04	-3.9

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Table 11-5. (continued)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degradors (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
D4	8-12-77	Sed	49	25.4	9.0	3.4 E 02	1.7 E 06	-3.7
E1	8-11-77	Sed	63	25.5	14.0	1.5 E 02	5.4 E 05	-3.6
E2	8-11-77	Sed	77	24.6	10.0	2.6 E 01	3.4 E 05	-4.1
E3	8-11-77	Microlayer				2.0 E 04	1.2 E 06 (s)	-1.8
		Surface	2	25.0		4.3 E 00	9.9 E 01	-1.4
		Thermo	10			3.1 E -01	2.9 E 02	-3.0
		Bottom	64			4.2 E -01	4.3 E 02	-3.0
		Sed	67		14.0	4.3 E 00	2.3 E 05	-4.7
11-29 E4	8-11-77	Sed	80	24.6	12.0	1.1 E 02	9.5 E 04	-2.9
F1	8-10-77	Sed	82	24.7	14.0	3.9 E 01	2.6 E 04	-2.8
F2	8-11-77	Surface	3	24.4		6.3 E 00	1.4 E 02	-1.3
		Thermo	20			3.1 E -01	1.5 E 02	-2.7
		Bottom	106			3.1 E -01	1.9 E 02	-2.8
		Sed	109		13.0	3.7 E 01	8.6 E 04	-3.4
F3	8-10-77	Sed	162	26.8	13.5	5.6 E -01	4.7 E 04	-4.9
F4	8-10-77	Sed	202	26.6	12.0	1.0 E 01	5.3 E 04	-3.7
G2	8-13-77	Sed	36	24.5	11.0	1.0 E 04	1.4 E 06	-2.1
G3	8-14-77	Sed	74	24.7	10.5	7.6 E 00	4.4 E 05	-4.8
G4	8-14-77	Sed	54	24.2	11.0	7.5 E 00	9.3 E 04	-4.1
G5	8-14-77	Sed	90	24.1	11.0	1.4 E 02	1.4 E 05	-3.0
G6	8-14-77	Sed	185	25.1	12.0	2.1 E 01	1.7 E 05	-3.9
H1	8-8-77	Sed	390	23.8	8.0	8.9 E 00	1.5 E 05	-4.2
H2	8-8-77	Sed	718	23.4	7.0	5.7 E 01	2.4 E 04	-2.6

Table 11-5. (continued)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degraders (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
I1	8-9-77	Sed	75	24.6	10.0	2.9 E 01	1.6 E 05	-3.8
I2	8-9-77	Sed	102	24.3	12.0	2.0 E 00	1.9 E 05	-5.0
I3	8-9-77	Sed	175	23.8	14.0	1.1 E 02	3.5 E 06	-4.5
I4	8-9-77	Sed	445	24.1	8.0	2.6 E 02	3.6 E 05	-3.1
11-30	J1	8-9-77	Microlayer			7.5 E 02	1.0 E 06 (s)	-3.1
			Surface	1	26.4	1.2 E 01	8.4 E 03	-2.8
			Thermo	22		1.3 E 00	4.1 E 02	-2.5
			Bottom	330		4.3 E -01	4.1 E 01	-2.0
			Sed	355	10.5	2.3 E 02	2.4 E 05	-3.0
	J2	8-10-77	Sed	756	26.3	4.4 E 02	8.1 E 04	-2.3
	K2	8-16-77	Sed	42	25.6	1.5 E 02	3.4 E 05	-3.3
	K4	8-16-77	Sed	103	26.1	1.4 E 02	4.4 E 05	-3.5
	K5	8-15-77	Sed	152	26.3	2.5 E 01	8.9 E 04	-3.6
	K6	8-15-77	Sed	345	27.6	4.1 E 01	7.6 E 04	-3.3
	L1	8-4-77	Microlayer			4.2 E 02	1.4 E 06 (s)	-3.5
			Surface	1	24.0	1.4 E 01	1.4 E 04	-3.1
			Bottom	23		7.3 E -01	1.4 E 03	-3.3
	L2	8-4-77	Microlayer			1.0 E 02	1.2 E 06 (s)	-4.1
			Surface	1	25.2	2.1 E 01	5.7 E 03	-2.4
			Bottom	38		4.7 E -01	9.9 E 02	-3.3
			Sed	39	8.5	8.5 E 03	1.9 E 06	-2.4
	L4	8-4-77	Surface	1	25.9	2.3 E 01	9.3 E 03	-2.6
			Thermo	15		2.1 E -01	4.6 E 02	-3.3
			Bottom	95		5.9 E -01	1.5 E 03	-3.4
			Sed	97	16.0	0.0 E 00	2.7 E 06	-

Table 11-5. (concluded)

Station	Date	Sample Type	Sample Depth (m)	Surface Water Temp °C	Sediment Temp °C	MPN Values*/gm dry sediment or ml or meter ²		
						Petroleum Degradars (HC)	Heterotrophs (HET)	Log $\frac{HC}{HET}$
L5	8-5-77	Sed	140	25.7	12.0	1.6 E 01	2.1 E 05	-4.1
L6	8-5-77	Microlayer				2.7 E 02	3.3 E 05 (s)	-3.1
		Surface	1	25.6		4.3 E 00	4.6 E 03	-3.0
		Thermo	25			5.7 E -01	3.1 E 03	-3.7
		Bottom	407			9.3 E -01	4.3 E 02	-2.7
		Sed	410+		10.0	1.2 E 02	5.4 E 05	-3.7
N3	8-12-77	Surface	1	25.5		3.1 E 00	2.6 E 04	-3.9
		Thermo	7			4.6 E -01	2.0 E 03	-3.6
		Bottom	45			4.2 E -01	9.9 E 02	-3.4

*MPN values are geometric means of two samples. Values followed by (s) are microlayer samples and counts are expressed as an MPN/m².

Table 11-6. Geometric means of heterotrophic (HET) and petroleum-degrading (HC) bacterial counts* by season for inner shelf (depth < 50m), outer shelf (depth > 50m < 100m), and shelf break (depth > 100m) sediment stations (1975-1977).

Area	Bacterial Type	Season							
		1975	Fall 1976	1976	Winter 1977	1976	Spring 1977	1976	Summer 1977
Inner shelf	HC	3.4±0.7	4.2±1.1	2.8±0.7	2.0±1.4	3.4±0.8	3.4±1.5	2.4±1.0	2.7±1.6
	HET	5.6±0.5	6.3±0.8	5.7±0.7	5.9±0.6	6.4±0.6	6.5±0.8	6.1±0.6	5.6±0.9
	HC/HET	-2.4±0.8	-2.4±1.0	-3.1±0.7	-4.1±1.3	-3.7±1.0	-3.7±1.2	-4.2±0.9	-2.9±1.0
Outer shelf	HC	2.0±0.5	1.7±1.1	2.0±0.6	1.6±1.1	1.6±0.5	1.5±0.9	1.7±1.1	1.3±1.0
	HET	5.2±0.4	5.8±0.5	5.4±0.6	5.7±0.7	5.6±0.4	5.6±0.5	5.8±0.5	5.5±0.6
	HC/HET	-3.3±0.3	-4.1±1.0	-3.4±0.6	-4.5±0.8	-4.0±0.4	-4.2±0.4	-4.0±1.0	-4.1±1.0
Shelf break	HC	2.3±0.6	1.7±1.0	2.1±0.7	2.2±0.9	1.8±0.7	1.7±1.0	2.3±0.9	0.9±1.2
	HET	4.9±0.4	5.7±0.7	5.8±0.6	5.2±0.6	5.4±0.5	6.0±0.4	5.2±0.5	5.3±0.6
	HC/HET	-2.7±0.3	-3.9±0.5	-3.7±0.4	-3.1±1.0	3.7±0.5	-4.3±0.7	-3.0±0.7	-4.4±0.9

* Log viable bacterial units/g dry sediment

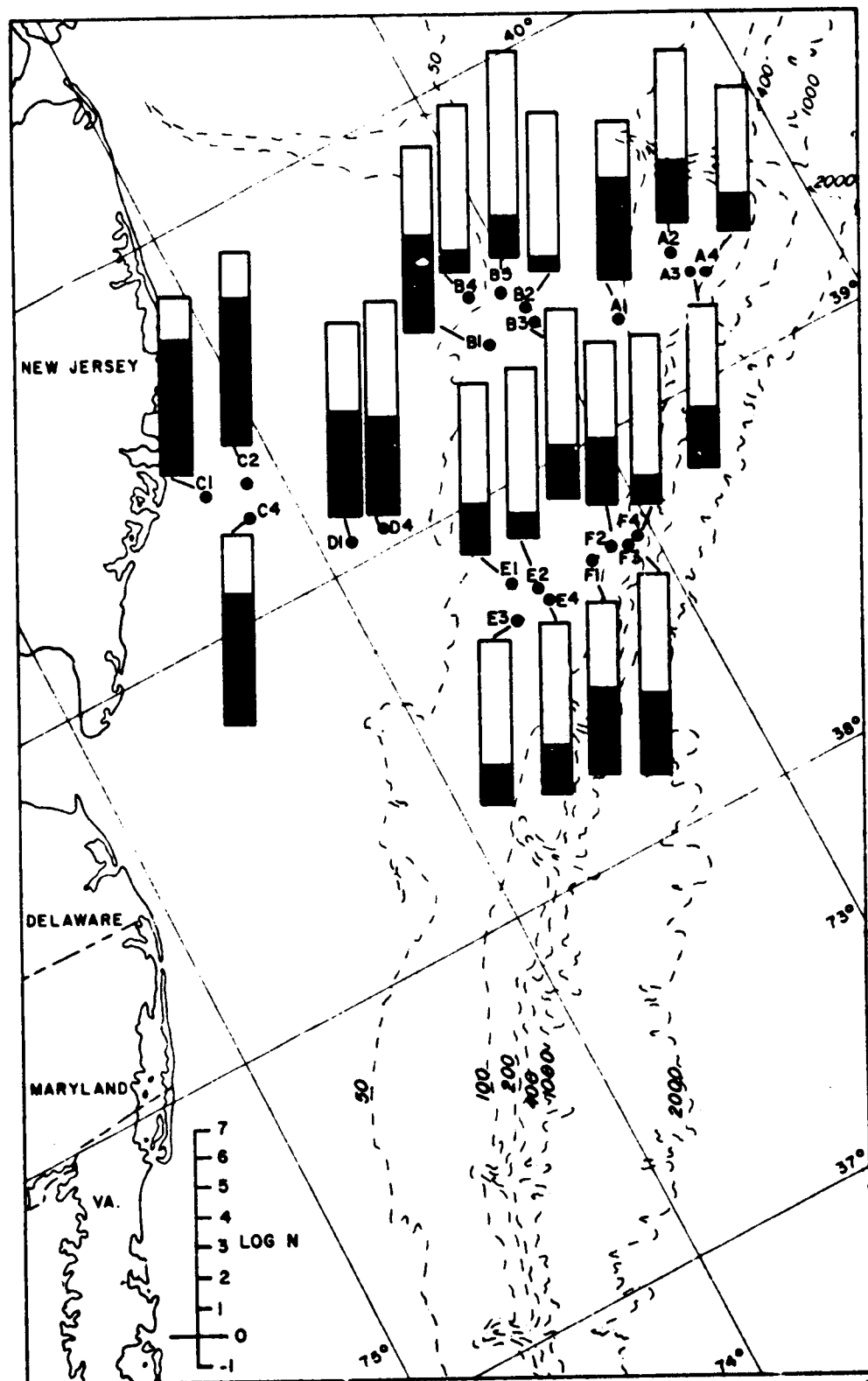


Figure 11-4. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from cluster stations, Fall 1976. N = Bacterial units/g dry sediment. ■ -petroleum-degrading bacteria, □ -heterotrophic bacteria.

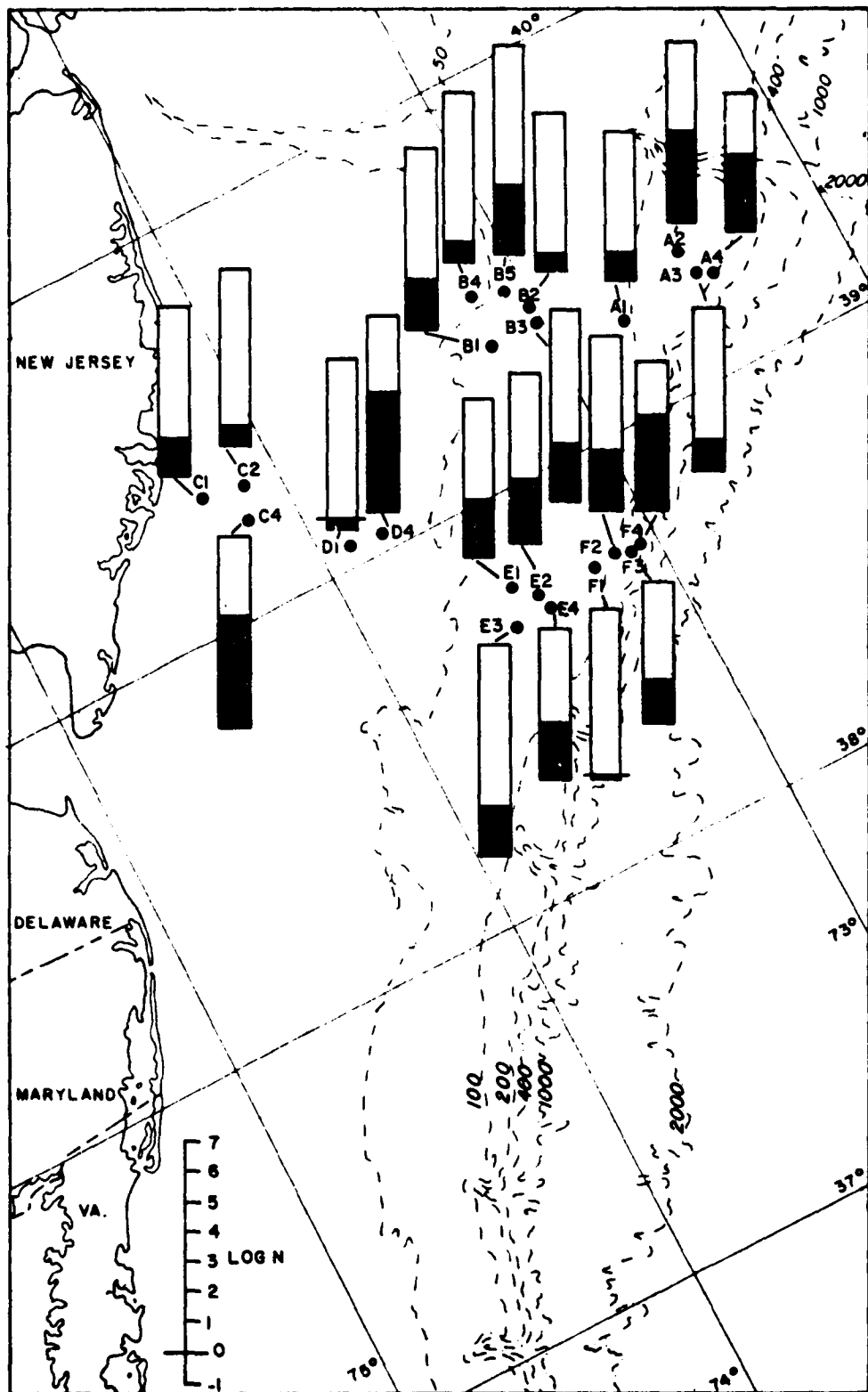


Figure 11-5. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from cluster stations, Winter 1977. N = Bacterial units/g dry sediment. ■ -petroleum-degrading bacteria, □ -heterotrophic bacteria.

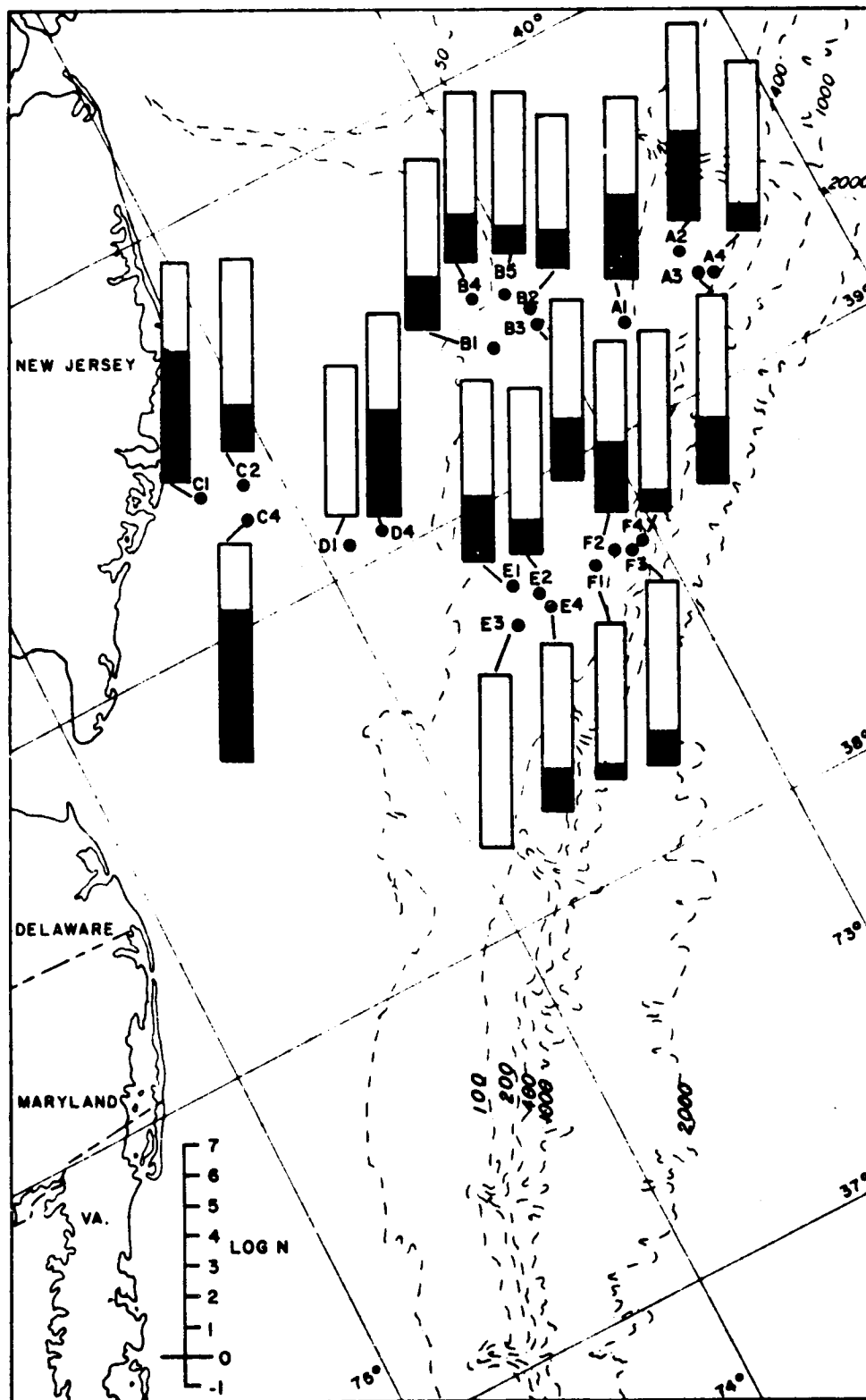


Figure 11-6. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from cluster stations, Spring 1977. N = Bacterial units/g dry sediment. ■ -petroleum-degrading bacteria, □ -heterotrophic bacteria.

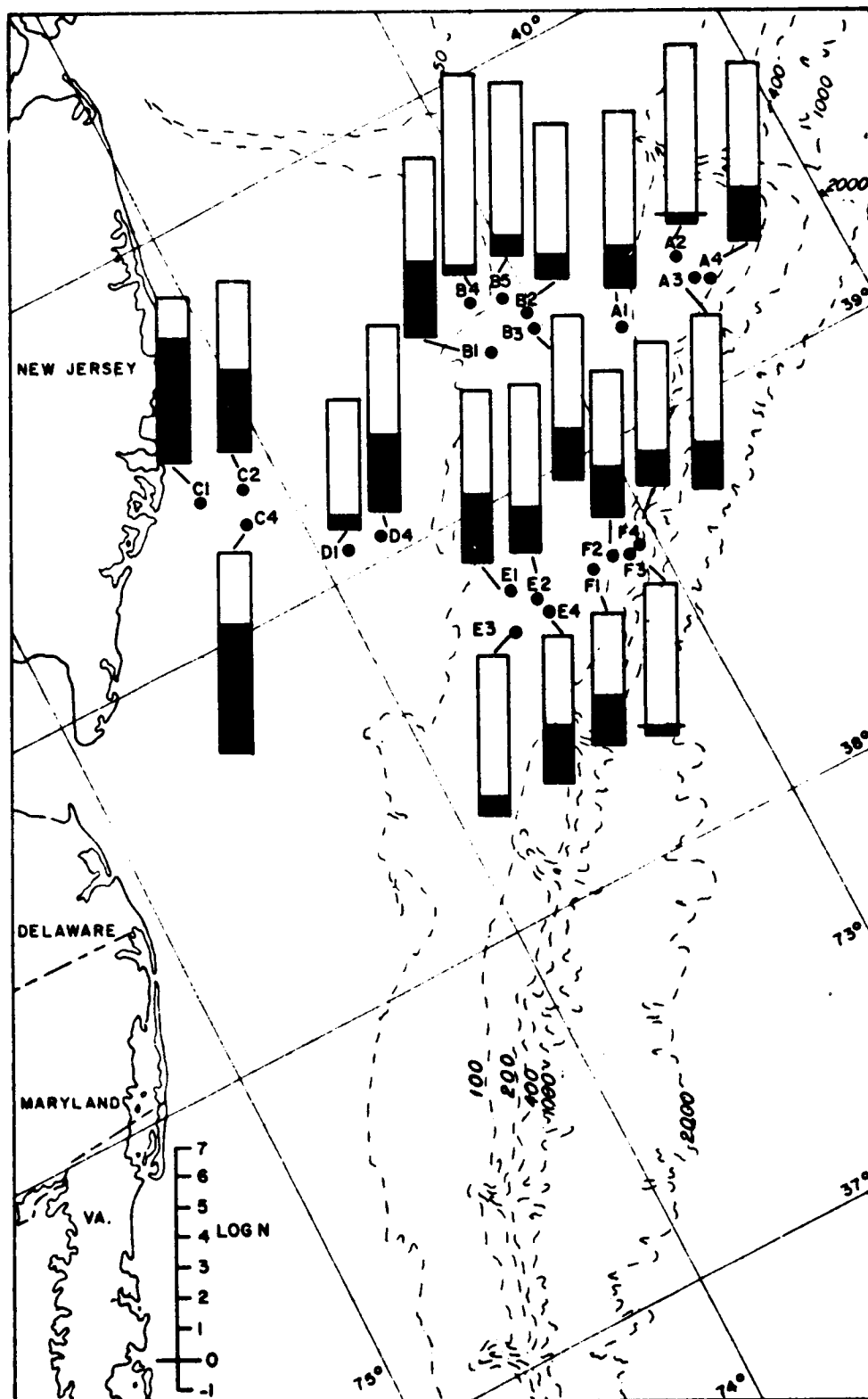


Figure 11-7. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from cluster stations, Summer 1977. N = Bacterial units/g dry sediment. ■-petroleum-degrading bacteria, □-heterotrophic bacteria.

compared with heterotrophs. As can be seen in Figures 11-4 to 11-7, inner shelf sediments usually exhibited the largest mean viable counts. These stations were most directly influenced by terrestrial activities, coastal boundary layer dynamics, and climate. The latter no doubt accounting for the atypically low viable counts during the winter at C1, C2, and D1. Concentrations of inorganic nutrients, organic carbon, and hydrocarbons were frequently elevated in the water column or sediments at these stations. Additionally, patterns of elevated counts in the troughs C4, D4, and B3 were frequently observed (Figures 11-8 to 11-11). Note that the trough-ridge system E1 - E4 did not evidence this effect as strongly as some of the other trough-ridge systems. This observation has been attributed to difficulties in sampling the true ridge sediments at E1. Viable counts of petroleum-degrading bacteria except during the winter, were usually very large at the ridge station C1 owing to its proximity to land. Trough sediments contained greater amounts of silt-clay, organic carbon and when sampled, higher concentrations of saturated hydrocarbons compared with ridges. As with heterotrophic viable counts, relatively elevated counts of petroleum-degrading bacteria were frequently observed at A and F cluster stations.

Outer shelf and shelf break sediment stations sampled quarterly appeared more stable than inner shelf sediments. Bacterial populations from inner shelf sediments should be more susceptible to seasonal effects because of shallow depth, mixing, and terrestrial influences. Viable counts of both petroleum-degrading and heterotrophic bacteria were not uniform over the four biological season from inner shelf sediments. Mean viable counts of petroleum-degrading and heterotrophic bacteria as well as the ratio of petroleum-degrading to heterotrophic bacterial counts were compared statistically using the Mann-Whitney statistic (Conover 1971) for inner shelf vs outer shelf, inner shelf vs shelf break and outer shelf vs shelf break viable counts. For petroleum degrading bacteria the null hypothesis, i.e. that viable counts from inner shelf sediments were greater or equal to viable counts from outer shelf sediments, was accepted ($\alpha = 0.05$, $T = 63$, $T_{critical} = 16$). Outer vs shelf break sediment counts were just at the level of rejection of the null hypothesis ($\alpha = 0.05$, $T = 16$, $T_{critical} = 16$). The null hypothesis was accepted for heterotrophs for inner vs shelf break sediment counts ($\alpha = 0.05$, $T = 54.5$, $T_{critical} = 16$), inner vs outer shelf sediment counts ($\alpha = 0.05$, $T = 53.5$, $T_{critical} = 16$) and outer vs. shelf break sediment counts ($\alpha = 0.05$, $T = 24$, $T_{critical} = 16$). Calculated values of the Mann-Whitney statistic for the ratio of petroleum-degrading to heterotrophic bacteria indicated acceptance of the null hypothesis for inner vs outer shelf sediments ($\alpha = 0.05$, $T = 49.5$, $T_{critical} = 16$), inner vs shelf break sediments ($\alpha = 0.05$, $T = 40.5$, $T_{critical} = 16$), and outer vs shelf break sediments ($\alpha = 0.05$, $T = 21$, $T_{critical} = 16$).

Patterns of bacterial populations from sediment stations sampled twice yearly were not analyzed statistically. However, trends in

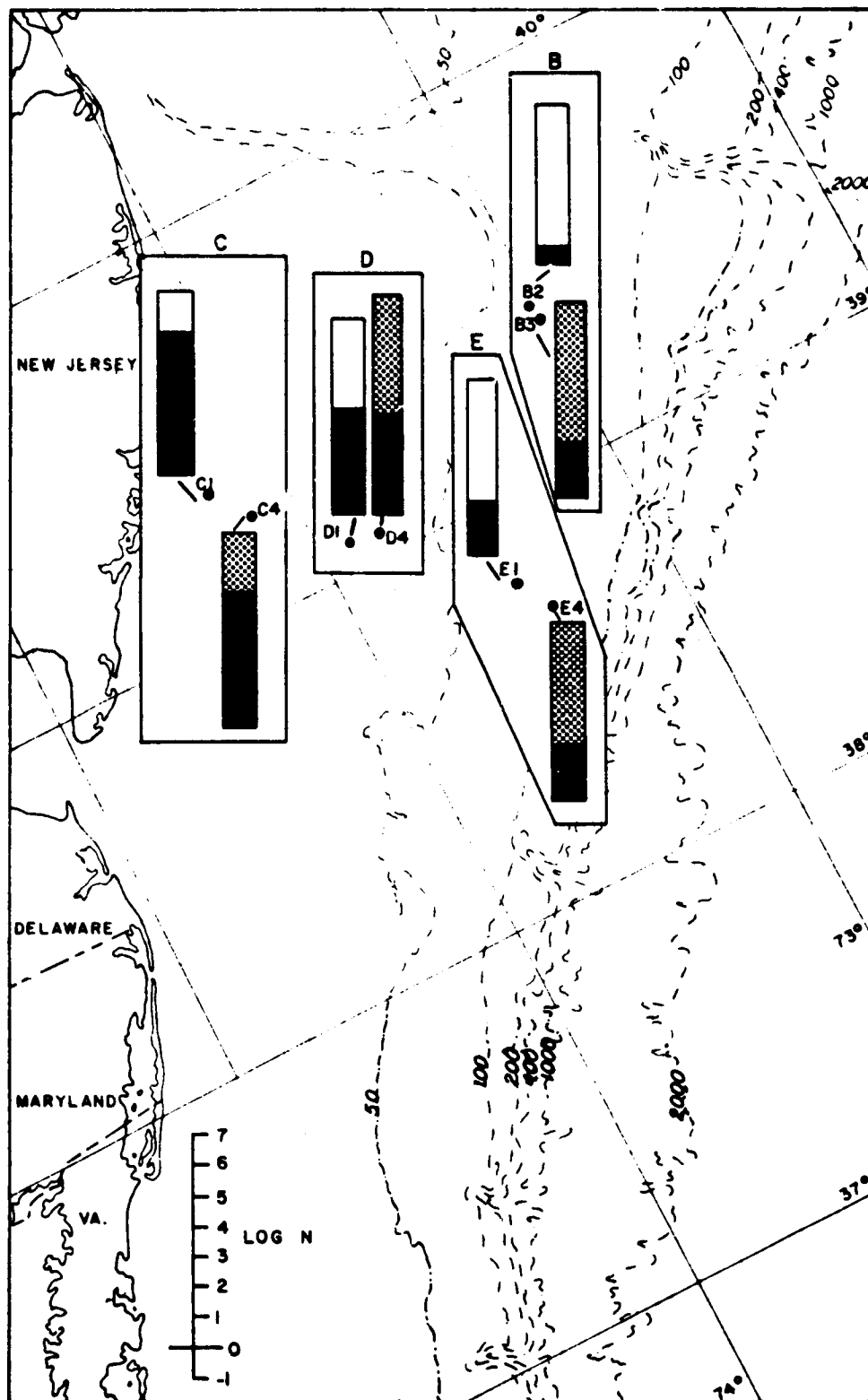


Figure 11-8. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from ridge and swale systems, Fall 1976. N = bacterial units/g dry sediments, -petroleum-degrading bacteria, -heterotrophic bacteria, ridge sediments, -swale sediments. 11-38

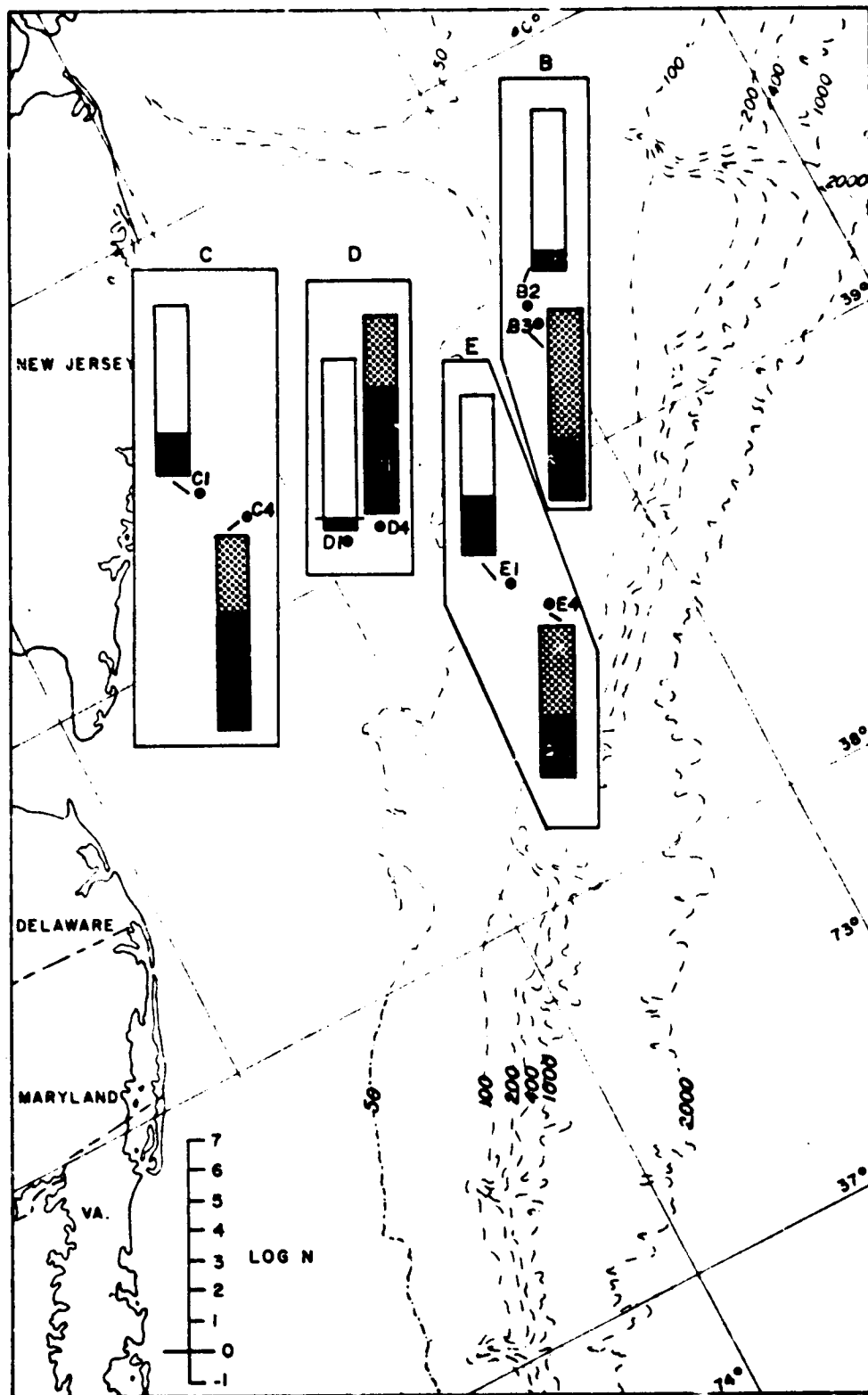


Figure 11-9. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from ridge and swale systems, Winter 1977. N = bacterial units/g dry sediments, ■ -petroleum-degrading bacteria, □ -heterotrophic bacteria, ridge sediments, ▨ -swale sediments.

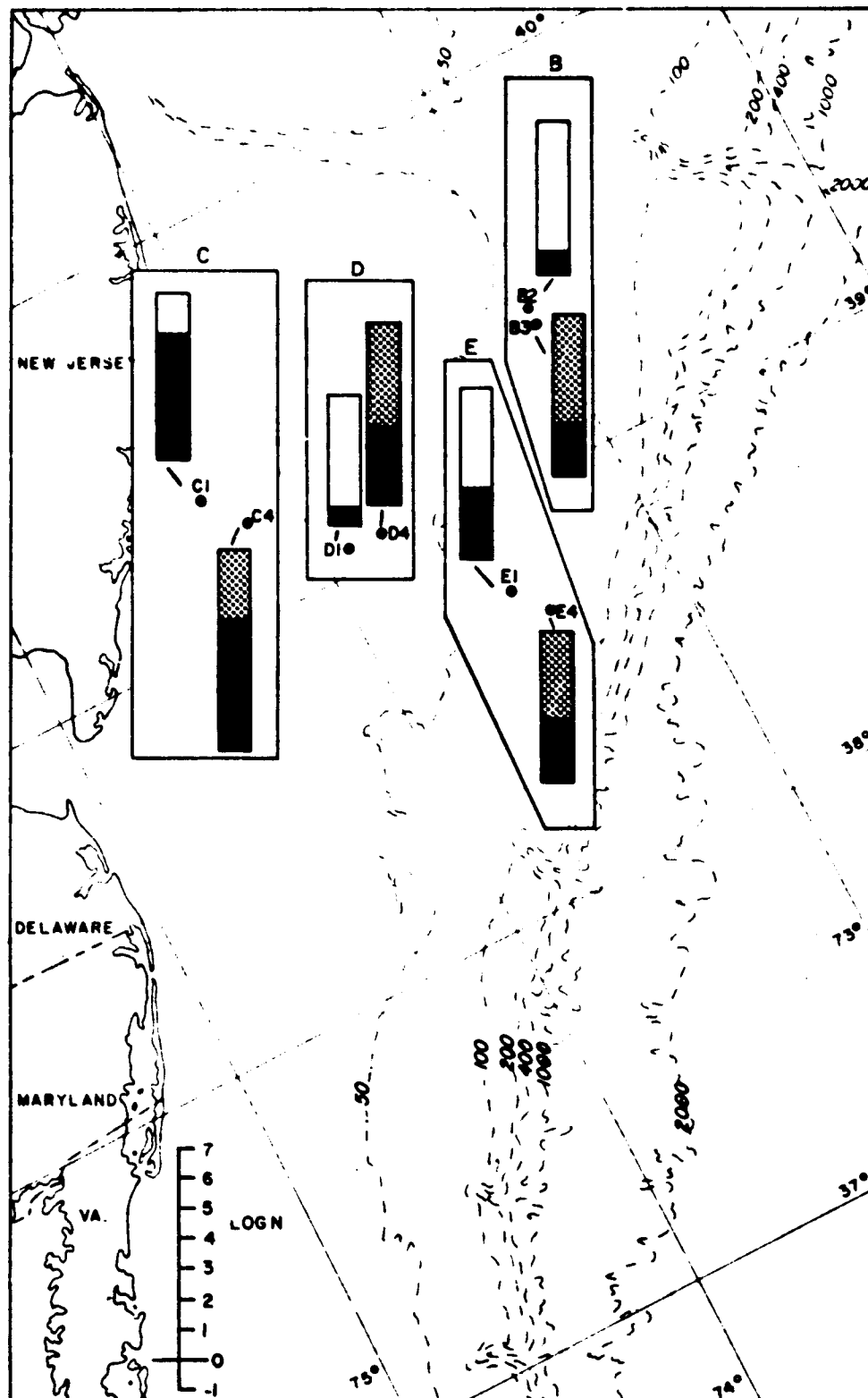


Figure 11-11. Viable counts of petroleum-degrading and heterotrophic marine bacteria in sediments sampled from ridge and swale systems, Summer 1977. N = bacterial units/g dry sediments, -petroleum-degrading bacteria, -heterotrophic bacteria, ridge sediments, -swale sediments. 11-41

counts were generally similar to those observed for the New Jersey transect stations.

Kendall nonparametric correlation coefficients (Conover 1971) were calculated for viable bacterial counts and values of the ratio of petroleum-degrading to total heterotrophic bacteria against % silt-clay, median grain size, total organic carbon, temperature, petroleum-degrading bacteria, and the aforementioned ratio. Results of these calculations are shown in Table 11-7 for each season and inner, outer, and shelf break areas. Overall, significant and consistent correlations with sediment textural properties were not found although values of Tau were usually in the positive direction. While significant correlations were not obtained for temperature, relatively consistent and significant ($\alpha = 0.05$) correlations were calculated for heterotroph counts versus petroleum-degrading bacterial counts during winter and spring but not for the ratio. However, significant and consistent correlations were observed for petroleum-degrading bacteria and the ratio of petroleum-degrading to total heterotrophs. Kendall nonparametric coefficients were also calculated for bacterial counts versus sediment hydrocarbon data. As anticipated on the basis of similar calculations for sediment textural properties, significant correlations were not evident.

If "poor" correlation between bacterial viable count data and various textural parameters was due to a combination of factors among which include small scale heterogeneity of sediment properties and bacterial populations, the precision of the bacterial MPN enumeration procedure, and the fact that neither textural nor chemical properties were determined specifically for bacterial cores, a calculation based on contrasting extreme differences in textural properties might prove more valuable. Therefore, bacterial counts from trough and ridge sediments were compared. Troughs possessed greater amounts of silt-clay and TOC than corresponding ridges. Results using the Mann-Whitney test statistic are shown in Table 11-8 for the years 1975-1977. With the exception of Station C1, the null hypothesis was accepted for all bacterial parameters. Note that calculated T values approach $T_{critical}$ values for the E ridge-swale system, again perhaps a reflection of the station location difficulty previously mentioned. Graphically, the effects of topography can be seen in Figures 11-4 to 11-7. Note that Station C1 generally possessed the highest ratio of petroleum-degrading to heterotrophic bacteria with the exception of winter and that viable HC counts in nearshore troughs during the winter were not diminished as greatly as the ridges.

Ratio of Petroleum-Degrading to "Total" Heterotrophic Bacteria.

Ratios can be readily seen by contrasting the blackened portion of the bar graphs with the total white or shaded area representing total heterotroph levels (Figures 11-4 to 11-7). It is obvious that maximum values were usually found in inner shelf sediments and troughs. Outer shelf sediments (with the exception of troughs) generally possessed values intermediate between inner shelf and shelf break sediments.

Table 11-7. Kendall correlation coefficients for viable bacterial counts from sediments versus selected variables by season.

Area	Bacterial Variable	Variables											
		% Silt-Clay				Medium Grain Size				Total Organic Carbon			
		Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Inner shelf	HC	0.00	0.60	0.40	0.40	-0.20	0.20	0.50	-0.20	-0.20	0.60	0.60	0.40
	HET	0.20	0.80*	0.20	1.00*	0.00	0.40	0.30	0.40	0.40	0.80*	0.40	1.00*
	HC/HET	-0.20	0.60	0.40	0.20	-0.40	0.20	0.50	-0.40	-0.40	0.60	0.60	0.20
Outer shelf	HC	0.55*	0.24	0.27	0.22	0.44*	0.00	0.27	0.44*	0.44*	-0.05	0.38	0.07
	HET	0.27	0.02	0.31	-0.13	0.27	0.18	0.24	-0.20	-0.02	-0.13	0.31	0.09
	HC/HET	0.29	0.47*	0.16	0.16	0.29	0.09	0.16	0.45*	0.40*	0.22	0.20	-0.05
Shelf break & Slope	HC	-0.20	0.20	0.07	-0.07	0.07	0.93	-0.33	0.07	-0.07	0.47	-0.07	-0.07
	HET	0.00	0.07	0.53	0.47	0.07	0.13	-0.27	0.07	-0.07	0.07	0.40	0.46
	HC/HET	-0.07	0.20	0.13	-0.60	0.20	0.67*	-0.40	0.07	0.06	0.47	0.00	-0.60

Area	Bacterial Variable	Variables											
		°C				Petroleum Degrading Bacteria				HC/HET			
		Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Inner shelf	HC	-0.50	0.20	0.10	0.20					0.80*	1.00*	1.00*	0.80*
	HET	0.30	0.40	0.30	-0.40	-0.40	0.80*	1.00*	0.40	-0.60	0.80*	0.80*	0.20
	HC/HET	-0.70*	0.20	0.10	0.40								
Outer shelf	HC	0.13	0.09	-0.27	-0.09					-0.71*	0.40*	0.78*	0.73*
	HET	-0.22	-0.05	-0.24	-0.07	0.29	0.42*	0.60*	-0.04	0.00	-0.18	0.38	-0.31
	HC/HET	0.20	0.33	-0.27	0.00								
Shelf break & Slope	HC	-0.13	0.20	-0.33	-0.40								
	HET	-0.67*	-0.33	-0.53	-0.40					0.33	0.73*	0.66*	0.47
	HC/HET	0.53	0.33	-0.27	-0.13	0.20	0.07	0.27	0.47	-0.47	-0.20	0.07	-0.07

* correlation is significant at $\alpha = 0.05$

Table 11-8. Results of Mann-Whitney statistic T calculated for bacterial counts sampled from ridge and swale stations (1975-1977) - H_0 : Viable bacterial units/g sediment are lower in ridge sediments than swale sediments; H_1 : Viable bacterial units/g sediment are greater in ridge sediments than swale sediments.

Bacterial Viable	Ridge-Swale Stations							
	C1 vs C4		D1 vs D4		B2 vs B3		E1 vs E4	
	1975-76	1976-77	1975-76	1976-77	1975-76	1976-77	1975-76	1976-77
Petroleum- Degrading Bacteria (HC)	T=55 T=48*, $T > T_c$, Reject H_0	T=23 T=48, $T < T_c$, Accept H_0	T=13 T=48, $T < T_c$, Accept H_0	T=8.0 T=48, $T < T_c$, Accept H_0	T=10.5 T=48, $T < T_c$, Accept H_0	T=10.0 T=48, $T < T_c$, Accept H_0	T=46.5 T=48, $T < T_c$, Accept H_0	T=36.0 T=48, $T < T_c$, Accept H_0
Heterotrophic Bacteria (HET)	T=15 T=48, $T < T_c$, Accept H_0	T=12 T=42, $T < T_c$, Accept H_0	T=12 T=48, $T < T_c$, Accept H_0	T=5.5 T=48, $T < T_c$, Accept H_0	T=20 T=48, $T < T_c$, Accept H_0	T=3.0 T=48, $T < T_c$, Accept H_0	T=39.5 T=48, $T < T_c$, Accept H_0	T=47.5 T=48, $T < T_c$, Accept H_0
$\frac{HC}{HET}$	T=56 T=48, $T < T_c$, Reject H_0	T=26 T=48, $T < T_c$, Accept H_0	T=25 T=48, $T < T_c$, Accept H_0	T=14 T=48, $T < T_c$, Accept H_0	T=13 T=48, $T < T_c$, Accept H_0	T=19.5 T=48, $T < T_c$, Accept H_0	T=34 T=48, $T < T_c$, Accept H_0	T=34 T=48, $T < T_c$, Accept H_0

T_c = $T_{critical}$ for $\alpha = 0.05$, H_0 rejected when $T > T_c$, H_0 accepted when $T < T_c$.

Because the values of heterotrophic bacteria usually appeared to approach some limiting and relatively constant (for each station) viable count, it was apparent that the value of the ratio was dependent on the viable count of petroleum-degrading bacteria. This observation was confirmed by the Kendall correlation coefficients for petroleum-degrading bacteria vs. the value of the ratio.

Microlayer

Microlayer samples were collected whenever weather and sea surface conditions were favorable. Seasonally, conditions were usually best during the summer, and to a lesser extent, spring. Fall, winter, and spring cruises were characterized by the frequent passage of fronts with associated high wind speeds and rough surface conditions.

Viable counts of petroleum-degrading and heterotrophic bacteria from microlayer samples are listed in Tables 11-2 through 11-5 and depicted in Figures 11-12 through 11-21. Counts for these figures were normalized on a /ml basis for direct comparison with counts in the bulk subsurface layer. Although the number of data points over the year were relatively small ($n = 11$ and $n = 9$, respectively for New Jersey and "L" transects), concentration effects for heterotrophic bacteria were not evident for either transect. Statistical comparison (Mann-Whitney test; Conover 1971) of viable counts of petroleum-degrading and heterotrophic bacteria from microlayer and bulk subsurface layer samples, failed to reveal significant ($\alpha = .05$) differences in counts for either transect. However, an examination of Figures 11-12 through 11-21 indicated that selected individual stations evidenced substantial enrichment of petroleum-degrading bacteria relative to the bulk subsurface layer (note New Jersey transect, 08B; "L" transect, 05B).

Water Column

Viable counts of petroleum-degrading and heterotrophic bacteria from surface (1 m), selected thermocline and bottom water samples are listed in Tables 11-9 through 11-13. Relevant physical-chemical data are also included for New Jersey and "L" transects. Counts are illustrated as functions of transect and sample type for each season in Figures 11-12 through 11-21.

Heterotrophic bacterial counts in 1 m surface water, thermocline and bottom water New Jersey transect stations generally decreased with distance from land. Occasionally counts at stations E3 (winter, spring) and J1 (spring, summer) would depart from this basic pattern. These departures were usually seen throughout the water column, i.e. at the surface as well as thermocline and bottom water samples.

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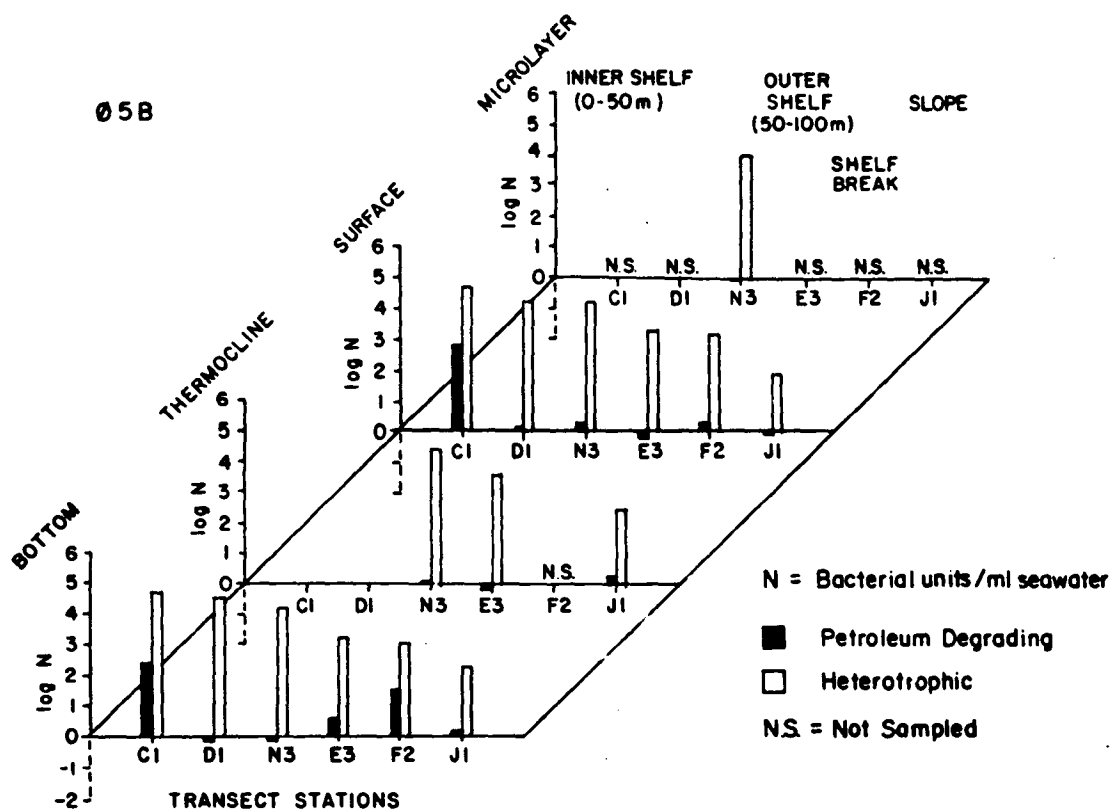


Figure 11-12. Viable counts of petroleum-degrading and heterotrophic marine bacteria from microlayer and water column samples collected at stations along the New Jersey transect, Fall 1976.

Figure 1 Data Summary:

Depth	Station	Petroleum degrading (log N)	Heterotrophic (log N)
Surface	CI	0.2	4.8
	DI	0.1	3.5
	N3	0.1	3.0
	E3	0.1	2.8
	F2	0.2	2.4
	JI	0.1	2.6
	Outer Shelf	0.1	2.8
Thermocline	CI	0.1	3.5
	DI	0.1	3.0
	N3	0.1	2.8
	E3	0.1	2.6
	F2	0.2	2.4
	JI	0.1	2.6
	Outer Shelf	0.1	2.8
Bottom	CI	-1.2	4.5
	DI	-0.2	3.5
	N3	0.2	2.8
	E3	0.1	2.8
	F2	0.2	2.2
	JI	0.1	2.0
	Outer Shelf	0.1	2.8

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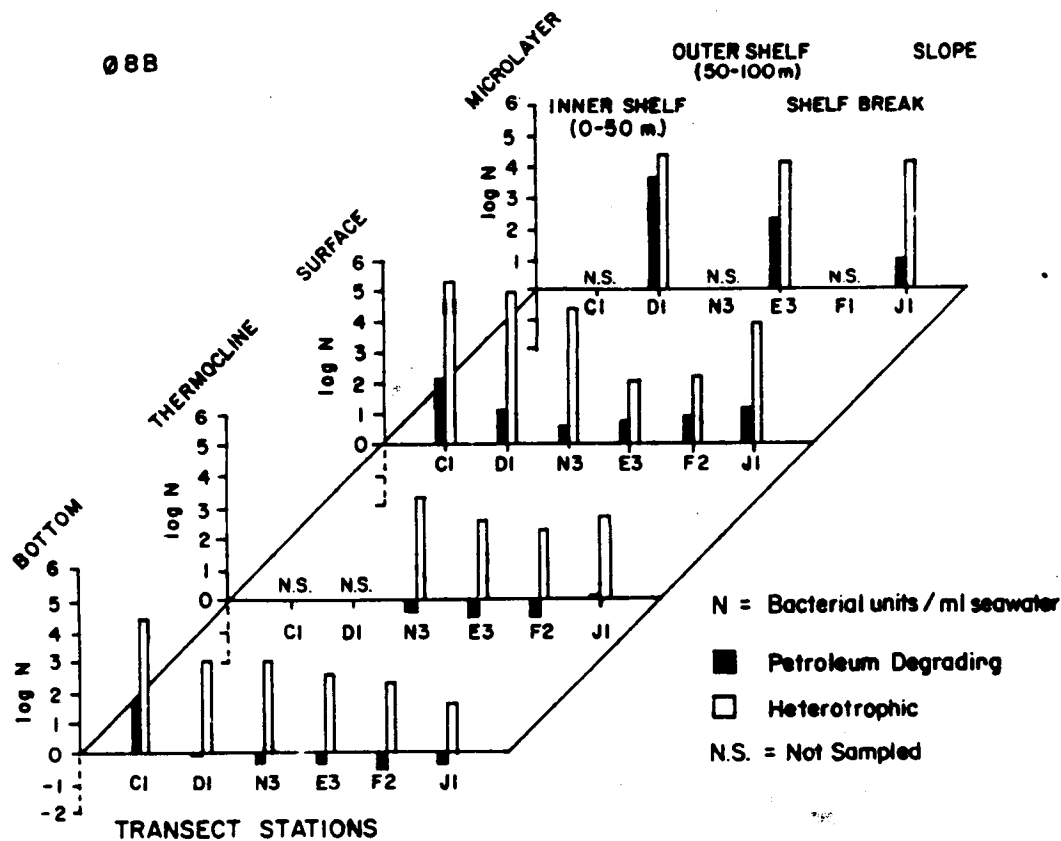


Figure 11-15. Viable counts of petroleum-degrading and heterotrophic marine bacteria from microlayer and water column samples collected at stations along the New Jersey transect, Summer 1977.

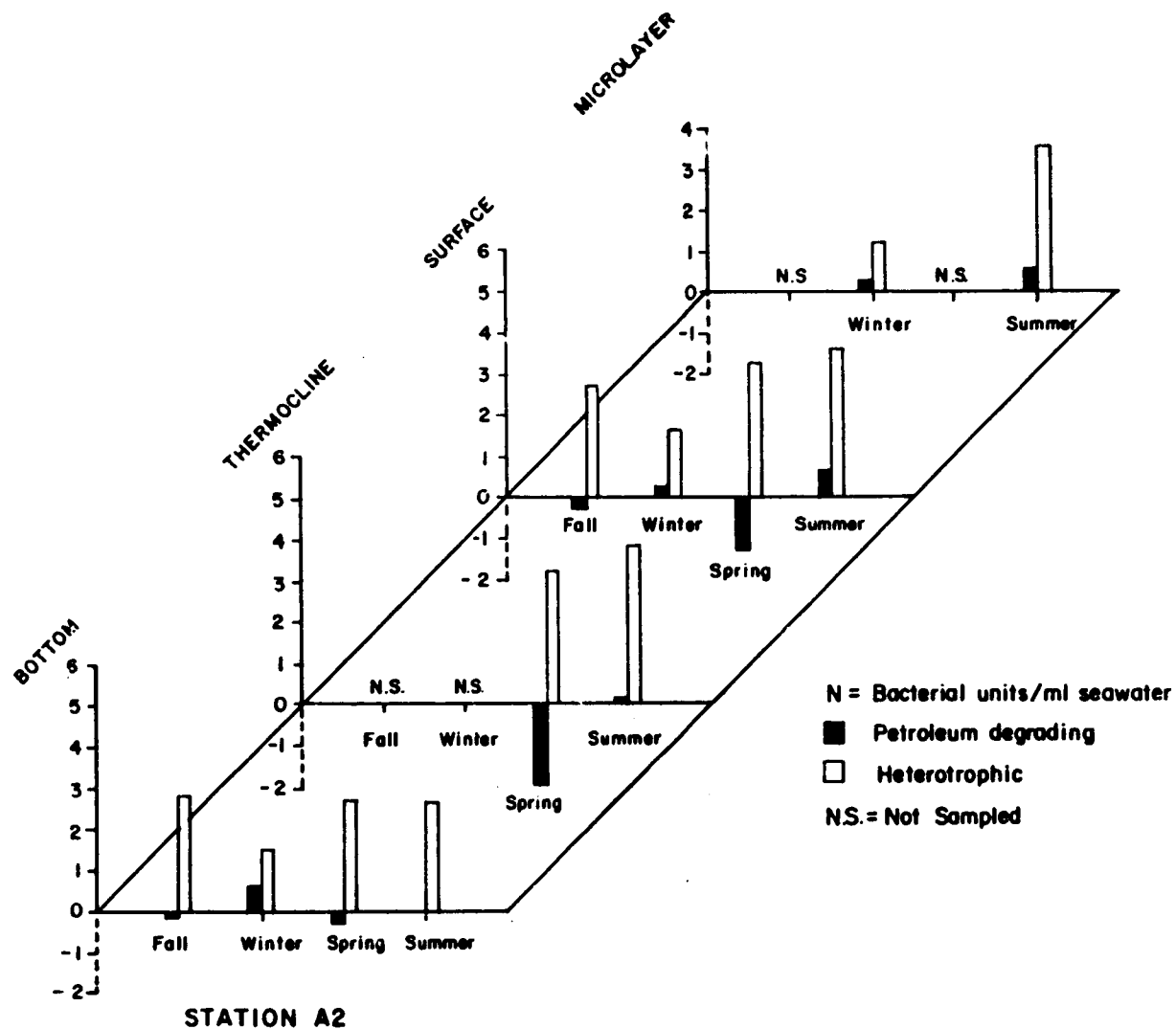


Figure 11-16. Viable counts of petroleum-degrading and heterotrophic marine bacteria collected from microlayer and water column samples at Station A2 during the years 1976-77.

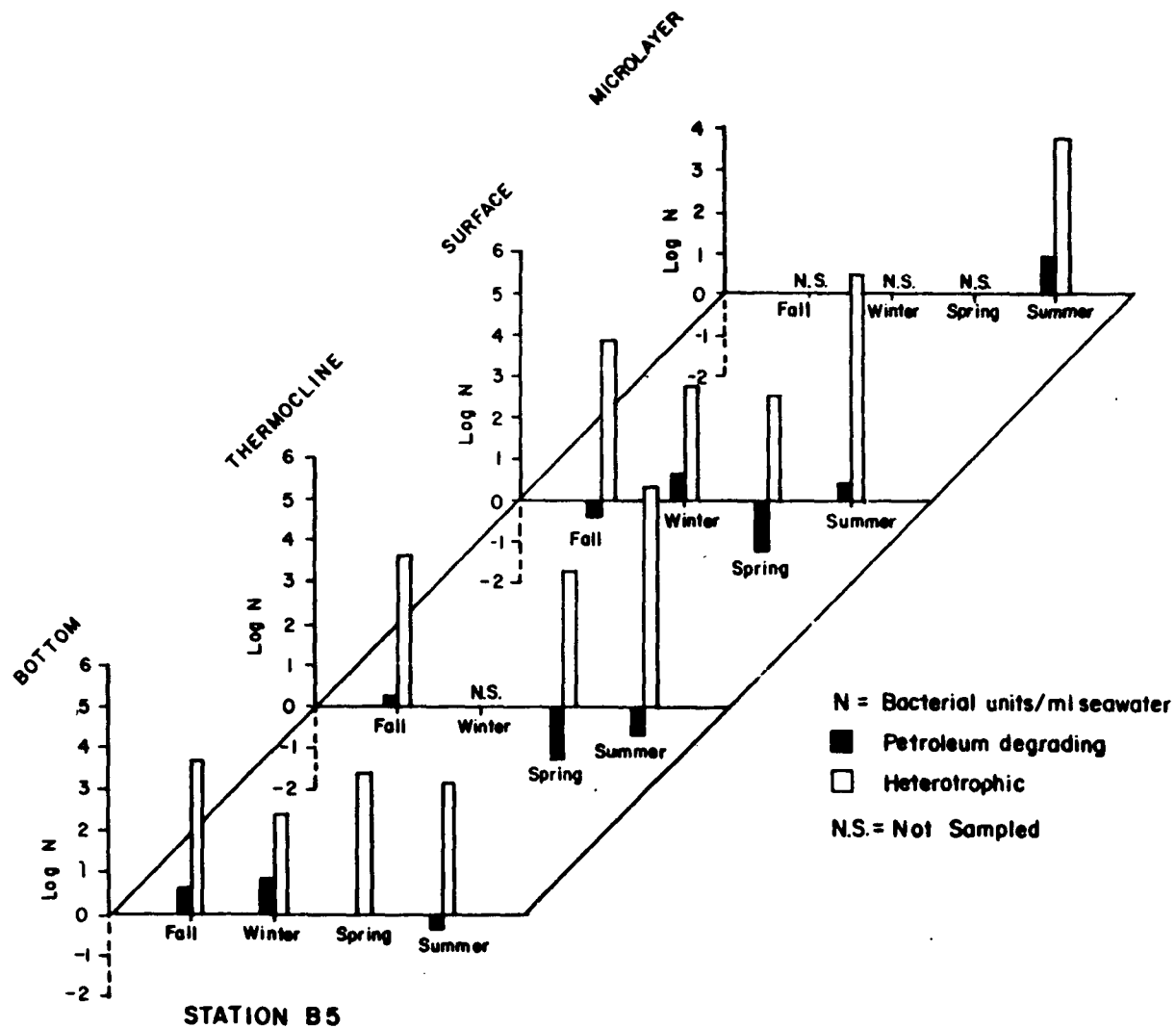


Figure 11-17. Viable counts of petroleum-degrading and heterotrophic marine bacteria collected from microlayer and water column samples at Station B5 during the years 1976-77.

Figure 1 Data Summary:

Depth	Station	Petroleum Degrading (log N)	Heterotrophic (log N)	Notes
Bottom	L1	~0.2	~3.5	
	L2	~0.1	~3.5	
	L4	~0.1	~3.0	
	L6	~0.1	~3.2	
Thermocline	L1	~0.5	~3.8	
	L2	~0.3	~3.5	
	L4	~0.1	~3.5	
	L6	~0.1	~3.2	
Surface	L1	~0.1	~0.1	N.S.
	L2	~0.1	~0.1	N.S.
	L4	~1.2	~3.0	
	L6	~0.2	~3.2	

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Figure 1: Bacterial counts at four transect stations (L1, L2, L4, L6) across three depth profiles (Surface, Thermocline, Bottom).

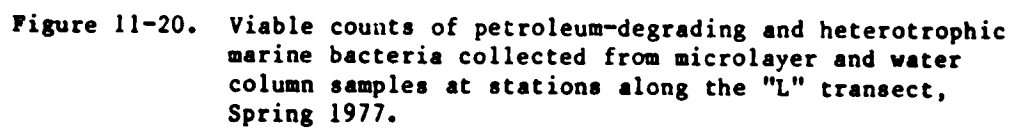
Legend:

- Black bar: Petroleum Degrading
- White bar: Heterotrophic
- N.S.: Not Sampled

Approximate log N values:

Depth Profile	Station	Petroleum Degrading (log N)	Heterotrophic (log N)
SURFACE	L1	-0.5	4.5
	L2	-0.5	4.5
	L4	-0.5	2.5
	L6	-0.5	2.5
THERMOCLINE	L1	-0.5	2.5
	L2	-0.5	2.5
	L4	-0.5	2.5
	L6	-0.5	2.5
BOTTOM	L1	0.5	5.5
	L2	0.5	4.0
	L4	-0.5	3.0
	L6	-1.5	1.5

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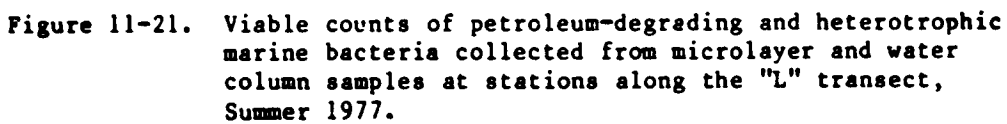


Table 11-9. Bacterial counts and values of selected chemical-physical parameters for 1 m surface water samples along the southern New Jersey transect during 1976-1977.

Station	Log HC	Log HET	Log HC/HET	Temp. (°C)	Sal. (0/00)	NO ₃ (µgat/l)	PO ₄ (µgat/l)	DOC (mg/l)	POC (mg/l)	LOG ATP (ng/l)	ALI* (µg/l)	ARO** (µg/l)
<u>Fall</u> <u>(05B)</u>												
C1	2.8	4.6	-1.8	11.5	31.76	4.01	1.12	4.88	0.27	3.11	1.36	-0.46
D1	0.079	4.2	-4.1	12.3	32.65	0.57	0.76	1.02	0.83	2.83	-0.34	-0.08
N3	0.28	4.2	-3.9	12.6	32.79	0.27	0.40	3.05	0.57	2.59	-0.80	-0.77
E3	-0.37	3.3	-3.6	13.1	33.05	N.A.	N.A.	3.43	0.10	2.67	-0.77	-1.85
F2	0.28	3.2	-2.9	13.0	34.07	0.55	0.26	1.19	0.09	2.59	-0.92	-1.74
J1	-0.032	1.9	-1.9	15.6	35.44	1.64	1.08	7.90	0.10	1.62	-1.64	-1.08
<u>Winter</u> <u>(06B)</u>												
C1	-0.004	5.1	-5.1	0.5	32.51	N.A.	N.A.	5.23	0.24	2.89	-1.33	-1.36
D1	0.18	3.6	-3.5	2.8	34.39	0.80	0.26	3.20	0.19	2.48	N.A.	N.A.
N3	0.18	3.0	-2.6	4.5	N.A.	N.A.	0.52	4.62	0.21	2.57	-0.85	-1.49
E3	-0.20	2.8	-3.2	7.5	35.44	7.73	0.56	4.98	0.17	2.69	-1.02	-2.42
F2	0.34	2.4	-2.0	9.6	35.44	11.60	0.76	8.00	0.14	1.90	-1.40	-1.89
J1	-0.37	2.6	-3.0	10.5	34.83	4.34	1.12	1.95	0.23	2.15	-1.11	-1.46
<u>Spring</u> <u>(07B)</u>												
C1	1.3	4.1	-2.8	14.2	31.93	N.A.	N.A.	3.90	0.34	2.45	-1.04	-1.60
D1	-0.20	3.6	-3.8	13.5	33.23	N.A.	0.18	2.38	0.24	2.43	-1.21	-1.54
N3	0.18	3.0	-2.8	14.3	33.39	N.A.	0.22	2.42	0.19	2.56	-1.34	-1.44
E3	0.32	3.5	-3.2	18.7	35.33	0.10	0.10	3.58	0.22	2.11	-1.44	-1.51
F2	-1.1	2.9	-4.0	20.9	35.58	0.00	0.08	2.28	0.19	2.36	-1.47	-1.30
J1	0.46	3.5	-2.0	20.5	36.03	0.02	0.00	1.85	N.A.	2.04	-1.24	-1.68
<u>Summer</u> <u>(08B)</u>												
C1	2.1	5.3	-3.2	24.3	32.04	0.41	0.28	3.49	0.42	3.08		
D1	1.1	4.9	-3.8	25.4	32.11	0.18	0.04	6.37	0.36	2.78		
N3	0.49	4.4	-3.9	25.7	32.70	N.A.	0.20	6.31	0.25	2.45	N.A.	N.A.
E3	0.63	2.0	-1.4	25.6	32.03	0.13	0.16	6.04	0.35	2.11		
F2	0.80	2.1	-1.3	24.4	32.10	0.07	0.08	3.29	0.26	2.18		
J1	1.1	3.9	-2.8	26.6	35.56	0.81	0.32	4.70	0.22	2.04		

HC = petroleum-degrading bacteria/ml

HET = heterotrophic bacteria/ml

Table 11-10. Bacterial counts and values of selected chemical and physical variables for bottom water samples along the southern New Jersey transect.

Station	Log HC	Log HET	Log HC/HET	Temp. (°C)	Sal. (0/00)	NO ₃ (µgat/l)	PO ₄ (µgat/l)	DOC (mg/l)	POC (mg/l)	LOG ATP (ng/l)	ALI* (µg/l)	ARO** (µg/l)
<u>Fall (05B)</u>												
C1	2.4	4.7	-2.4	11.5	31.78	4.06	1.04	4.22	0.22	3.04	-0.370	-1.410
D1	-0.24	4.5	-4.7	12.3	32.64	0.72	0.84	1.08	0.57	2.89	-0.004	-0.596
N3	-0.23	4.2	-4.4	12.3	32.88	1.22	0.42	5.55	0.54	2.46	0.079	-0.656
E3	0.57	3.2	-2.6	13.4	34.18	8.52	1.36	3.95	0.10	2.38	0.041	-1.638
F2	1.5	3.1	-1.6	12.9	35.50	14.98	1.04	7.92	0.08	1.81	-0.770	-0.538
J1	0.18	2.3	-2.1	9.0	35.19	16.83	1.92	8.40	0.08	0.45	-0.398	-1.886
<u>Winter (06B)</u>												
C1	-1.3	4.6	-5.9	0.6	32.81	N.A.	N.A.	6.22	0.25	2.86	-1.244	-1.699
D1	-0.24	3.5	-3.7	2.6	34.39	1.17	0.34	2.66	0.25	2.71	-1.000	-1.959
N3	0.36	2.8	-2.4	4.5	34.81	4.71	0.56	4.88	N.A.	2.73	-0.721	-1.620
E3	-0.004	2.9	-2.9	7.8	35.47	7.60	0.68	2.37	0.13	2.74	-0.824	-2.244
F2	0.36	2.1	-1.8	8.0	35.31	7.72	0.64	4.77	0.06	2.08	-1.071	-1.149
J1	-0.032	1.8	-1.8	9.1	35.37	18.18	1.00	6.08	0.13	1.41	-0.959	-1.602
<u>Spring (07B)</u>												
C1	2.6	4.8	-2.2	10.0	32.64	0.65	N.A.	6.02	0.43	2.64	-1.252	-1.398
D1	-0.032	3.6	-3.7	6.3	33.77	N.A.	0.42	3.11	0.30	2.26	-1.018	-1.602
N3	-0.032	3.6	-3.7	5.4	33.89	0.18	0.64	4.37	0.22	2.51	-1.237	-1.284
E3	-0.64	2.3	-3.0	4.9	33.97	5.48	0.66	1.73	0.17	2.43	-1.377	-1.538
F2	0.28	3.0	-2.7	12.1	35.22	7.49	0.42	1.76	0.16	1.95	-1.347	-1.770
J1	-0.20	3.3	-3.5	9.5	35.21	12.59	1.02	2.69	0.16	1.51	-1.481	-2.108
<u>Summer (08B)</u>												
C1	1.7	4.4	-2.8	13.6	32.34	1.67	1.64	2.52	0.30	2.70		
D1	-0.004	3.0	-3.0	9.1	33.04	1.74	0.76	4.91	0.39	2.34		
N3	-0.38	3.0	-3.4	8.4	32.86	0.33	0.16	5.47	0.25	1.96		
E3	-0.38	2.6	-3.0	8.9	33.08	1.05	0.24	2.60	0.30	1.77	N.A.	N.A.
F2	-0.51	2.3	-2.8	10.6	34.68	0.04	0.20	5.29	0.22	1.61		
J1	-0.37	1.6	-2.0	7.0	35.08	10.80	0.96	4.14	0.26	0.70		

HC = petroleum-degrading bacteria/ml HET = heterotrophic bacteria/ml

Table 11-11. Bacterial counts and values of selected chemical-physical parameters for 1 m surface water samples along the "L" transect during 1976-1977.

Station	Log HC	Log HET	Log HC/HET	Temp. (°C)	Sal. (0/00)	NO ₃ (µgat/l)	PO ₄ (µgat/l)	DOC (mg/l)	POC (mg/l)	LOG ATP (ng/l)	ALI* (µg/l)	ARO** (µg/l)
<u>Fall (05B)</u>												
L1	0.80	3.9	-3.1	12.2	33.02	0.07	0.46	3.21	0.98	2.52	0.61	-0.27
L2	0.34	3.6	-3.3	12.9	33.88	0.81	0.60	4.25	0.70	2.23	-0.29	-1.41
L4	-0.032	3.7	-3.7	13.9	34.47	1.05	0.34	2.87	0.44	2.15	-0.70	-0.52
L6	-0.52	3.4	-3.9	14.0	N.A.	N.A.	N.A.	2.50	0.57	2.20	-0.10	-0.62
<u>Winter (06B)</u>												
L1	-0.37	4.4	-4.8	3.5	33.74	0.07	0.24	6.10	0.20	2.23	-0.89	-1.24
L2	-0.14	4.3	-4.5	2.9	32.71	0.16	0.08	2.14	0.15	2.36	-0.46	-1.77
L4	-0.20	2.6	-2.8	24.3	36.03	12.33	0.66	1.64	0.20	1.62	-0.82	-1.51
L6	-0.20	2.6	-2.8	14.2	35.94	9.61	0.72	2.97	0.14	1.96	-0.70	-1.55
<u>Spring (07B)</u>												
L1	-0.34	3.9	-4.3	17.7	32.44	0.01	0.18	2.49	0.29	2.53	-0.28	-1.70
L2	-0.89	3.9	-4.8	18.4	33.84	0.12	0.16	3.82	0.30	2.38	-1.22	-2.26
L4	0.035	2.8	-2.7	17.7	34.35	0.15	0.20	2.45	0.25	2.08	0.26	-1.55
L6	-0.23	3.1	-3.4	19.3	34.96	0.24	0.16	2.42	0.22	2.11	-1.31	-1.37
<u>Summer (08B)</u>												
L1	1.1	4.3	-3.1	24.3	32.34	0.14	0.64	5.78	0.22	2.48	N.A.	N.A.
L2	1.3	3.8	-2.4	25.1	32.86	0.10	0.60	4.69	0.48	2.56		
L4	1.4	4.0	-2.6	25.7	33.94	0.16	0.80	4.62	0.24	2.41		
L6	0.63	3.7	-3.0	25.7	34.47	0.33	0.04	4.88	0.25	2.45		

N.A. = Data Not Available HC = petroleum-degrading bacteria/ml

HET = heterotrophic bacteria/ml

*Log Dissolved Aliphatics

**Log Dissolved Aromatics

Table 11-12. Bacterial counts and values of selected chemical-physical parameters for bottom water samples along the "L" transect during 1976-1977.

Station	Log HC	Log HET	Log HC/HET	Temp. (°C)	Sal. (0/00)	NO ₃ (µgat/l)	PO ₄ (µgat/l)	DOC (mg/l)	POC (mg/l)	LOG ATP (ng/l)	ALI* (µg/l)	ARO** (µg/l)
<u>Fall (05B)</u>												
L1	0.49	4.0	-3.5	12.2	33.04	0.15	0.60	6.60	0.93	2.26	0.26	-0.64
L2	-0.032	3.6	-3.7	13.9	34.43	1.07	0.56	3.68	0.69	1.79	-0.27	-1.00
L4	-0.37	3.1	-3.5	13.7	35.42	11.76	0.88	1.85	0.42	2.11	-0.62	-1.19
L6	-0.076	3.3	-3.3	9.4	35.22	23.96	1.80	5.01	0.25	2.46	-0.57	-0.68
<u>Winter (06B)</u>												
L1	0.18	5.2	-5.0	4.3	34.19	0.48	0.20	4.62	0.19	2.70	-0.68	-1.62
L2	0.80	3.9	-3.1	7.8	34.95	7.04	0.64	2.67	0.32	2.67	-0.77	-1.52
L4	-0.14	2.8	-2.9	11.2	35.52	9.61	0.70	5.04	0.15	1.04	-1.25	-1.46
L6	-1.2	1.5	-2.7	6.6	35.10	19.20	1.32	1.42	0.18	0.87	-0.82	-1.59
<u>Spring (07B)</u>												
L1	0.28	3.8	-3.5	10.3	33.40	0.30	0.40	3.65	0.30	2.52	-0.80	-1.39
L2	0.23	3.4	-3.1	7.8	33.99	0.76	0.46	2.59	0.40	2.65	0.77	-1.04
L4	-0.097	2.9	-3.0	7.8	34.56	4.46	0.80	1.33	0.18	2.36	-1.68	-1.92
L6	0.32	2.8	-2.5	10.5	35.32	16.44	1.20	4.37	0.20	1.62	-1.44	-1.74
<u>Summer (08B)</u>												
L1	-0.14	3.1	-3.3	13.2	32.90	0.45	0.32	3.61	0.54	2.62	N.A.	N.A.
L2	-0.33	3.0	-3.3	8.8	33.27	1.60	0.40	7.54	0.48	2.38		
L4	-0.23	3.2	-3.4	13.1	35.24	5.63	0.24	3.88	0.46	1.68		
L6	-0.032	2.6	-2.7	9.0	35.22	11.42	1.04	6.84	0.21	0.95		

HC = petroleum-degrading bacteria/ml HET = heterotrophic bacteria/ml
 *Log Dissolved Aliphatics **Log Dissolved Aromatics

N.A. = Not Available

Table 11-13. Bacterial counts and values of selected chemical-physical parameters for thermocline water samples collected during 1976-1977.

Station	Log HC	Log HET	Log HC/HET	Temp (°C)	Sal. (0/00)	NO ₃ (µgat/l)	PO ₄ (µgat/l)	Log ATP (ng/l)
<u>Fall</u>								
<u>(05B)</u>								
N3	0.11	4.4	-4.3	12.5	N.A.	N.A.	N.A.	2.56
E3	-0.12	3.6	-3.7	12.0	N.A.	N.A.	N.A.	2.79
J1	0.34	2.5	-2.1	15.6	35.43	3.18	0.44	1.38
B5	0.28	3.6	-3.4	11.5	32.81	1.10	0.60	2.48
<u>Winter</u>								
<u>(06B)</u>								
L4	0.28	2.6	-2.4	13.1	35.27	11.20	0.74	1.72
L6	0.28	2.6	-2.3	11.1	35.45	14.80	1.10	2.38
<u>Spring</u>								
<u>(07B)</u>								
N3	-0.82	3.8	-4.6	8.8	33.44	0.03	0.18	2.95
E3	0.49	3.6	-3.1	4.8	33.97	4.61	0.64	1.97
F2	-1.4	2.4	-3.8	20.8	35.57	0.02	0.08	3.18
J1	0.079	3.1	-3.0	14.2	35.62	5.16	0.44	1.26
B5	-1.2	3.3	-4.5	14.0	33.34	0.01	0.20	2.46
A2	-2.1	3.2	-5.3	13.1	34.34	4.20	0.34	2.81
L6	-0.70	3.6	-4.3	19.0	35.28	0.22	0.08	2.26
<u>Summer</u>								
<u>(08B)</u>								
N3	-0.34	3.3	-3.6	25.6	32.33	0.14	0.04	2.32
E3	-0.51	2.5	-3.0	25.0	32.19	0.13	0.12	2.28
F2	-0.51	2.2	-2.7	25.8	34.06	4.60	0.60	2.43
J1	0.11	2.6	-2.5	26.0	35.14	1.26	0.12	2.04
B5	-0.66	5.3	-5.9	23.0	31.98	0.09	0.20	2.41
A2	0.15	3.9	-3.8	22.5	32.07	0.57	0.28	2.30
L4	-0.68	2.7	-3.3	23.9	35.87	0.20	0.04	2.00
L6	-0.24	3.5	-3.7	25.1	35.81	0.86	0.08	2.41

HC = petroleum-degrading bacteria/ml

HET = heterotrophic bacteria/ml

Data from "L" transect stations (Tables 11-11 through 11-12 and Figures 11-18 through 11-21) revealed a somewhat more uniform situation with respect to heterotrophs in that fall and summer counts were relatively constant across the transect. During the winter and spring, tendencies for decrease with distance from land were observed in surface waters. Viable counts of heterotrophic bacteria tended to be at maximum levels closest to land.

Mean (geometric) values of viable bacterial counts for each station (all seasons) and for all transect stations by season are shown in Tables 11-14 through 11-17. Mean values for 1 m surface New Jersey transect stations (all seasons) corroborated the data observed for each seasonal transect during the years 1975-76 and 1976-77. Mean viable counts of heterotrophs were remarkably similar over this two year period. On a seasonal basis (all stations combined), similar patterns of viable counts were observed for both years. Mean viable counts for bottom water samples displayed similar patterns. Mean counts of heterotrophs from "L" transect stations defined more clearly a decrease with distance from land in both surface and bottom water samples. On a seasonal basis, counts were greatest during the summer in surface water samples. Viable counts in bottom waters were usually lowest during the summer.

Viable counts of petroleum-degrading bacteria (HC), both in surface and bottom waters, decreased with distance from land as did heterotroph counts. Station C1, located closest to shore, generally exhibited the largest values of HC. Viable counts usually decreased 1-2 orders of magnitude at the next station (D1). An exception to this pattern were the very low counts of viable HC at C1 observed during the winter seasons.

Other exceptions to the basic pattern of decreasing HC viable counts with distance seaward were noted at Station F2 in both surface and bottom waters (fall and winter), Station E3 in microlayer, surface and thermocline waters (spring), and stations J1 and F2 in surface waters (summer). During certain seasons relatively elevated values of inorganic nutrients, organic carbon and temperature coincided with these increases in viable counts. However, such relationships were not consistent nor did positive correlations with all these parameters occur during the same season (cruise). Salinity data indicated that some count maxima occurred in the vicinity of a highly mobile frontal zone(s) between slope and shelf water types. These data also suggested that North Atlantic central water, rich in mineralized nutrients, upwelled near this convergence giving rise to increased biological productivity.

Note that mean viable counts of HC at C1 and F2 usually possessed the largest standard deviations of the New Jersey transect stations. In the first instance climatic and terrestrial influences resulted in large variations in viable counts; in the later, movement of the

Table 11-14. Geometric mean populations of petroleum-degrading (HC) and heterotrophic (HET) marine bacteria sampled at 1 m below the surface along the southern New Jersey transect (1975-1976).

Log Bacterial Parameter	By Season			
	Fall 1975	Winter 1976	Spring 1976	Summer 1976
HC	-0.1±1.7	0.2±1.1	-0.2±2.6	0.3±1.4
HET	3.0±1.4	2.8±1.2	3.4±1.0	3.5±0.7
HC/HET	-3.1±1.1	-2.6±0.7	-3.6±2.2	-3.2±0.7

	By Station					
	C1	D1	N3	E3	F2	J1
HC	3.0±1.5	-0.2±1.1	-0.5±0.5	-0.8±0.8	-0.1±1.2	-1.1±1.2
HET	4.7±0.3	3.8±0.6	2.8±1.0	2.5±1.0	2.6±0.7	2.6±0.9
HC/HET	-1.7±1.5	-4.0±1.4	-3.3±0.3	-2.8±1.7	-2.7±1.6	-3.7±0.9

Table 11-15. Geometric mean populations of petroleum degrading (HC) and heterotrophic (HET) marine bacteria sampled at 1 m below the surface along the southern New Jersey transect (1976-1977).

Log Bacterial Parameter	By Season			
	Fall 1976	Winter 1977	Spring 1977	Summer 1977
HC	0.5±1.1	0.02±0.3	0.2±0.8	1.0±0.6
HET	3.6±0.9	3.4±1.0	3.3±0.6	3.8±1.4
HC/HET	-3.0±0.9	-3.4±1.1	-3.1±0.8	-1.2±1.1

	By Station					
	C1	D1	N3	E3	F2	J1
HC	1.6±1.1	0.3±0.5	0.2±0.3	0.2±0.4	0.1±0.8	0.3±0.6
HET	4.8±0.6	4.1±0.6	4.1±1.0	2.9±0.7	2.6±0.5	2.7±0.8
HC/HET	-2.3±3.2	-3.8±0.3	-3.7±0.6	-2.7±0.9	-2.0±1.3	-2.1±1.4

Table 11-16. Geometric mean populations of petroleum-degrading (HC) and heterotrophic (HET) marine bacteria sampled at 2 m above bottom along the southern New Jersey transect (1976-1977).

Log Bacterial Parameter	By Season			
	Fall 1976	Winter 1977	Spring 1977	Summer 1977
HC	0.7±1.0	0.3±0.6	0.3±1.1	0.1±0.8
HET	3.7±0.9	3.0±1.0	3.4±0.8	2.8±0.9
HC/HET	-3.1±1.2	-3.3±1.5	-3.1±0.6	-2.7±0.5

	By Station					
	C1	D1	N3	E3	F2	J1
HC	1.3±1.7	-0.1±0.3	-0.1±0.4	-0.1±0.6	0.4±0.8	-0.1±0.2
HET	4.6±0.3	3.6±0.7	3.4±0.6	2.8±0.4	2.8±0.7	2.2±0.7
HC/HET	-3.3±1.7	-3.8±0.8	-3.5±0.8	-2.9±0.6	-2.3±0.6	-2.3±0.7

Table 11-17. Geometric mean populations of petroleum-degrading (HC) and heterotrophic (HET) marine bacteria sampled at 1 m below the surface and 2 m above the bottom along the "L" transect.

Log Bacterial Parameter	By Season			
	Fall 1976	Winter 1977	Spring 1977	Summer 1977
<u>Surface</u>				
HC	0.2±0.5	-0.2±0.3	-0.3±0.5	1.1±0.4
HET	3.6±0.4	3.5±1.0	3.4±0.6	3.9±0.3
HC/HET	-3.5±0.5	-3.7±1.1	-3.8±1.0	-2.8±0.5
<u>Bottom</u>				
HC	0.01±0.3	-0.1±0.8	0.2±0.2	-0.2±0.5
HET	3.4±0.6	3.4±1.5	3.2±0.5	3.0±0.4
HC/HET	-3.5±0.4	-3.4±1.1	-3.0±0.6	-3.2±0.5
	By Station			
	L1	L2	L4	L6
<u>Surface</u>				
HC	0.3±0.8	0.2±0.9	0.3±0.7	-0.1±0.6
HET	4.1±0.4	3.9±0.4	3.3±0.6	3.2±0.4
HC/HET	-3.8±0.9	-3.7±1.1	-3.0±0.5	-3.3±0.6
<u>Bottom</u>				
HC	0.2±0.4	0.2±0.5	-0.2±0.4	-0.2±0.6
HET	4.0±0.9	3.5±0.5	3.0±0.4	2.5±0.7
HC/HET	-3.8±0.8	-3.3±0.3	-3.2±0.7	-2.8±0.5

frontal zone in the vicinity of the shelf break station F2 resulted in greater variations than typically observed at other stations.

With the exception of summer, no obvious differences in mean viable counts or values of the ratio of HC to HET in surface or bottom waters were observed. During summer HC, HET, and HC/HET values appeared to be substantially lower. On an individual station basis, there was a tendency for some stations to exhibit lower mean viable counts of HC and HET in bottom samples. Note, however, that the mean value of HC for Station F2 was greater than either E3 or J1. Values of the ratio tended to be lower in bottom samples.

Mean values for "L" transect stations (on a seasonal basis) were similar with the exception of elevated values in the summer. On an individual station basis mean surface values of HC at Station L6 were similar to those in bottom waters at L4 and L6, suggesting a similarity in water types at these stations.

Statistical analyses for comparison of all HET viable counts for surface, thermocline, and bottom water samples were performed using the Mann-Whitney test statistic (Conover 1971). These calculations indicated no significant ($\alpha = 0.05$) differences between viable surface counts vs bottom counts and thermocline counts vs surface counts for both New Jersey and "L" transect stations during each cruise.

Comparison of viable HC counts using the same test indicated no statistically significant ($\alpha = 0.05$) differences for "L" transect surface vs bottom and surface vs thermocline samples. Comparison of HC counts from New Jersey transect stations indicated that HC surface and HC bottom counts were not significantly ($\alpha = 0.05$) different. However, HC counts from thermocline samples were significantly smaller than viable HC from surface water samples. Assuming we sampled actual thermoclines and based on the small number of samples obtained ($n = 11$), no consistent trapping effects due to the presence of thermocline were reflected in these bacterial counts.

Results of extensive calculations of Kendall nonparametric correlation coefficients (Conover 1971) are presented in Tables 11-18 through 11-19 for both surface and bottom water samples as a function of season. Consistent and significant ($\alpha = 0.05$) correlations were not generally evident for bacterial variables with most chemical and physical properties. Where significant correlations were most frequently observed, these appeared to be related to or functions of distance from land. Thus, significant correlations were frequently observed for heterotrophic bacteria with salinity (negative correlation, as counts decreased salinity increased), temperature (negative correlation, as counts decreased temperature increased). Correlation of ATP with bacterial counts in bottom water samples was more direct than for surface water since the proportion of biomass due to phytoplankton would be much smaller at the bottom. This hypothesis was supported by the greater numbers of significant positive

Table 11-18. Kendall correlation coefficients for viable bacterial counts versus selected variables by season for surface water samples from New Jersey transect stations, 1976-1977.

Bacterial Variable	Variables											
	HC				HET				HC/HET			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
HC	-	-	-	-	0.47	-0.13	0.53	0.53	0.27	0.27	0.67*	0.0
HET	0.47	-0.13	0.53	0.53	-	-	-	-	-0.27	-0.87*	0.20	-0.46
HC/HET	0.27	0.27	0.67*	0.00	-0.27	-0.87*	0.20	-0.46	-	-	-	-
TEMPERATURE				SALINITY				DOC				
HC	-0.53	0.0	-0.07	-0.40	-0.5	-0.07	-0.06	0.0	0.0	0.53	0.47	-0.27
HET	-0.80*	-0.86*	-0.53	-0.33	-0.90*	-0.73*	-0.53	0.07	-0.13	-0.07	0.40	0.20
HC/HET	0.20	0.73*	0.0	-0.20	0.20	0.67*	0.0	-0.33	0.60	0.20	0.13	-0.47
POC				ATP				DISS. ALIPHATICS				
HC	0.07	-0.67*	0.50	0.40	0.27	-0.13	-0.07	0.27	0.27	-0.40	0.47	N.A.
HET	0.47	+0.47	0.90*	0.37	0.73*	0.60	0.13	0.73*	0.80*	0.40	0.80*	N.A.
HC/HET	-0.40	-0.60	0.20	-0.07	-0.13	-0.47	0.00	-0.02	-0.20	-0.20	0.40	N.A.
DISS. AROMATIC				TOT. DISS. HYDRO.				PART. ALIPHATICS				
HC	0.40	-0.40	-0.60	N.A.	0.53	-0.60	-0.06	N.A.	0.53	-0.26	0.06	N.A.
HET	0.40	0.40	-0.67*	N.A.	0.80*	0.20	0.27	N.A.	0.00	-0.07	0.13	N.A.
HC/HET	-0.06	-0.60	-0.53	N.A.	-0.20	-0.40	-0.13	N.A.	0.47	-0.20	-0.27	N.A.

Table 11- 18. (concluded)

Bacterial Variable	Variables											
	PART. AROMATICS				TOT. PART. HYDRO.				NO3			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
HC	-0.8*	0.0	-0.07	N.A.	-0.4	0.27	-0.20	N.A.	-0.10	0.10	N.A.	0.13
HET	-0.4	-0.07	0.40	N.A.	-0.27	-0.33	0.27	N.A.	0.10	-0.40	N.A.	0.20
HC/HET	-0.33	0.20	0.0	N.A.	-0.20	0.47	-0.53	N.A.	0.60	0.20	N.A.	-0.47
PO4												
HC	-0.10	-0.10	-0.20	0.0								
HET	0.30	-0.80*	0.10	0.07								
HC/HET	0.40	0.60	0.0	0.07								

* Correlation significant at $\alpha = 0.05$

N.A. = data not available

Table 11- 19. Kendall correlation coefficients for viable bacterial counts versus selected variables by season for bottom water samples from New Jersey transect stations, 1976-1977.

Bacterial Variable	Variables											
	HC				HET				HC/HET			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
HC	-	-	-	-	-0.07	-0.53	0.53	0.47	0.60	0.60	0.26	0.13
HET	-0.07	-0.53	0.53	0.47	-	-	-	-	-0.47	-0.93*	-0.13	-0.40
HC/HET	0.60	0.60	0.27	0.13	-0.47	-0.93*	-0.13	-0.40	-	-	-	-
TEMPERATURE				SALINITY				DOC				
HC	0.0	0.40	0.53	0.13	0.20	0.40	-0.27	-0.40	0.20	-0.27	0.53	-0.40
HET	-0.13	-0.87*	0.13	0.40	-0.87*	-0.60	-0.67*	-0.93*	-0.60	-0.07	0.93*	-0.13
HC/HET	-0.13	0.80*	0.40	0.20	0.60	0.53	0.13	0.47	0.60	0.0	-0.13	-0.33
POC				ATP				DISS. ALIPHATICS				
HC	-0.40	-0.80*	0.33	0.60	0.07	-0.27	0.27	0.53	-0.33	0.53	0.27	N.A.
HET	-0.67*	0.33	0.60	0.33	0.87*	0.73*	0.40	0.93*	0.20	-0.33	0.40	N.A.
HC/HET	-0.80*	-0.53	-0.07	-0.13	-0.33	-0.67*	0.13	-0.33	-0.73*	0.27	-0.13	N.A.
DISS. AROMATIC				TOT. DISS. HYDRO.				PART. ALIPHATICS				
HC	-0.06	0.27	0.13	N.A.	-0.33	0.93*	0.13	N.A.	0.06	-0.33	0.60	N.A.
HET	0.20	-0.47	0.27	N.A.	0.47	-0.47	0.27	N.A.	-0.06	0.27	0.87*	N.A.
HC/HET	-0.20	0.53	0.0	N.A.	-0.73*	0.53	0.27	N.A.	+0.06	-0.33	-0.07	N.A.

Table 11- 19 . (concluded)

Bacterial Variable	Variables											
	PART. AROMATICS				TOT. PART. HYDRO.				NO3			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
HC	-0.06	-0.33	0.13	N.A.	-0.2	-0.27	0.27	N.A.	0.33	0.10	0.0	0.53
HET	0.47	0.0	0.53	N.A.	0.06	-0.06	0.67*	N.A.	-0.73*	-0.80*	-0.4	0.0
HC/HET	-0.47	-0.06	0.0	N.A.	-0.06	0.0	-0.13	N.A.	0.73*	0.70*	0.20	0.33
	PO4											
HC	0.13	-0.1	-0.6	0.67*								
HET	-0.40	-0.60	-0.2	0.13								
HC/HET	+0.40	0.50	0.0	0.47								

* Correlation significant at $\alpha = 0.05$
N.A. = data not available

correlations of ATP with HET in bottom water samples. ATP is discussed in greater detail in the next section.

ATP Analyses, Field Samples

Samples for ATP determinations were taken from water samples during all seasons (Table 11-20). Concentrations of ATP in surface water (1 m) samples from New Jersey transect stations generally decreased with increased distance from land during all seasons. In contrast, ATP concentrations from "L" transect stations remained relatively uniform over all seasons. ATP levels in bottom water samples decreased with depth. Those stations sampled with thermoclines exhibited thermocline ATP concentrations equivalent to surface water samples. Although ATP concentrations were usually lower in bottom water samples compared to surface samples some differences with season were observed. During the fall and summer, 10 of 12 and 11 of 12 hydrocast stations, respectively, exhibited greater surface water ATP levels than corresponding bottom water samples. However, during the severe winter of 1977, stations located in inner and outer shelf waters manifested higher ATP concentrations in bottom water samples. During the spring, ATP concentrations at these stations began to return to values comparable with those observed in the fall and summer as 7 of 12 stations exhibited higher ATP levels in the surface water.

ATP concentrations and various bacterial parameters were analyzed for correlations using linear regression coefficients and the results summarized in Table 11-21 and Figures 11-22 to 11-29. During three of the four biological seasons, there was a significant positive correlation between ATP concentrations and viable counts of heterotrophic bacteria. A significant correlation was not observed during the spring for either bottom or surface waters. The only other significant positive correlations noted were for viable counts of petroleum-degrading bacteria in the surface water and ATP during the summer and the ratio of petroleum-degrading to heterotrophic bacteria in bottom water samples with ATP during the summer. Therefore, no consistent correlations of microbial biomass as indicated by ATP concentration were observed for viable counts of petroleum-degrading bacteria.

Laboratory Evaluation of Isolates

Isolate Characteristics

Streaked colonies were predominantly translucent to opaque and circular with an entire margin. Most white colonies were low convex to raised while yellow and orange colonies were typically convex to pulmonate. Some colonies were visible after one to three day's incubation; ultimately growing to a diameter of 0.5 - 3.0mm, while

(TEXT CONTINUES ON PAGE 11-31)

Table 11-20 . Concentrations of ATP (ng/l)* in seawater samples collected during BLM05B-08B.

Station Type	Station	Cruise			
		05B	06B	07B	08B
Surface	A2	3.8×10^1	$6.8 \times 10^{1**}$	3.4×10^2	2.2×10^2
	B5	1.6×10^3	$1.9 \times 10^{2**}$	2.5×10^2	2.3×10^3
	C1	1.3×10^2	7.7×10^2	2.8×10^2	1.2×10^2
	D1	6.8×10^2	3.0×10^2	2.7×10^2	6.0×10^2
	E3	4.7×10^2	4.8×10^2	1.3×10^2	1.3×10^2
	F2	3.9×10^2	$8.0 \times 10^{1**}$	2.3×10^2	1.5×10^2
	J1	4.2×10^1	$1.4 \times 10^{2**}$	1.1×10^2	1.1×10^2
	L1	3.3×10^2	1.7×10^2	3.4×10^2	3.0×10^2
	L2	1.7×10^2	$2.3 \times 10^{1**}$	2.4×10^2	3.6×10^2
	L4	1.4×10^2	4.2×10^1	1.2×10^2	2.6×10^2
	L6	1.6×10^2	$9.2 \times 10^{1**}$	1.3×10^2	1.2×10^2
	N3	3.9×10^2	$3.7 \times 10^{2**}$	3.6×10^2	2.8×10^2
Thermocline	A2	N.T.	N.T.	6.4×10^2	2.0×10^2
	B5	3.0×10^2	N.T.	2.9×10^2	2.6×10^2
	C1	N.T.	N.T.	N.T.	N.T.
	D1	N.T.	N.T.	N.T.	N.T.
	E3	6.1×10^2	N.T.	9.3×10^1	1.9×10^2
	F2	N.T.	N.T.	1.5×10^1	2.7×10^2
	J1	2.4×10^1	N.T.	1.8×10^1	1.1×10^2
	L1	N.T.	N.T.	N.T.	N.T.
	L2	N.T.	N.T.	N.T.	N.T.
	L4	N.T.	5.2×10^1	N.T.	1.0×10^2
	L6	N.T.	2.4×10^2	1.8×10^2	2.6×10^2
	N3	3.6×10^2	N.T.	9.0×10^2	2.1×10^2
Bottom	A2	$1.3 \times 10^{1**}$	$6.6 \times 10^{1**}$	6.4×10^2	8.5×10^1
	B5	1.6×10^2	N.S.	1.2×10^2	1.3×10^2
	C1	1.1×10^3	$7.2 \times 10^{2**}$	4.4×10^2	5.0×10^2
	D1	7.7×10^2	5.1×10^2	1.8×10^2	2.2×10^2
	E3	2.4×10^1	$5.5 \times 10^{2**}$	2.7×10^1	5.9×10^1
	F2	$6.5 \times 10^{0**}$	$1.2 \times 10^{1**}$	9.0×10^1	4.1×10^1
	J1	2.8×10^2	$2.6 \times 10^{2**}$	3.2×10^1	5.0×10^0
	L1	1.8×10^2	$5.0 \times 10^{2**}$	3.3×10^2	4.2×10^2
	L2	6.2×10^1	4.7×10^1	4.5×10^2	2.4×10^1
	L4	1.3×10^0	1.1×10^0	2.3×10^1	4.8×10^0
	L6	3.1×10^2	$7.4 \times 10^{2**}$	4.2×10^2	9.0×10^1
	N3	2.9×10^2	$5.4 \times 10^{2**}$	3.2×10^2	9.2×10^1

* - Mean of two replicates

** - One replicate only

N.T.- No thermocline present

N.S.- No sample taken

Table 11-21. Values of linear regression coefficients for ATP levels versus bacterial parameters from seawater samples taken during 05B-08B.

Water Sample	Bacterial Parameter	Season			
		Fall	Winter	Spring	Summer
Surface (1m)	HC	0.5677	0.0786	-0.3350	0.6787*
	HET	0.8047**	0.6489*	0.1008	0.6443*
	HC/HET	-0.0945	-0.5494	-0.5551	-0.4586
Bottom	HC	0.3229	0.2015	0.3000	0.4346
	HET	0.8135**	0.7091*	0.2170	0.7949**
	HC/HET	-0.3865	-0.5084	0.0139	-0.6330*

* Significant at .05

** Significant at .01

HC = petroleum-degrading bacteria

HET = heterotrophic bacteria

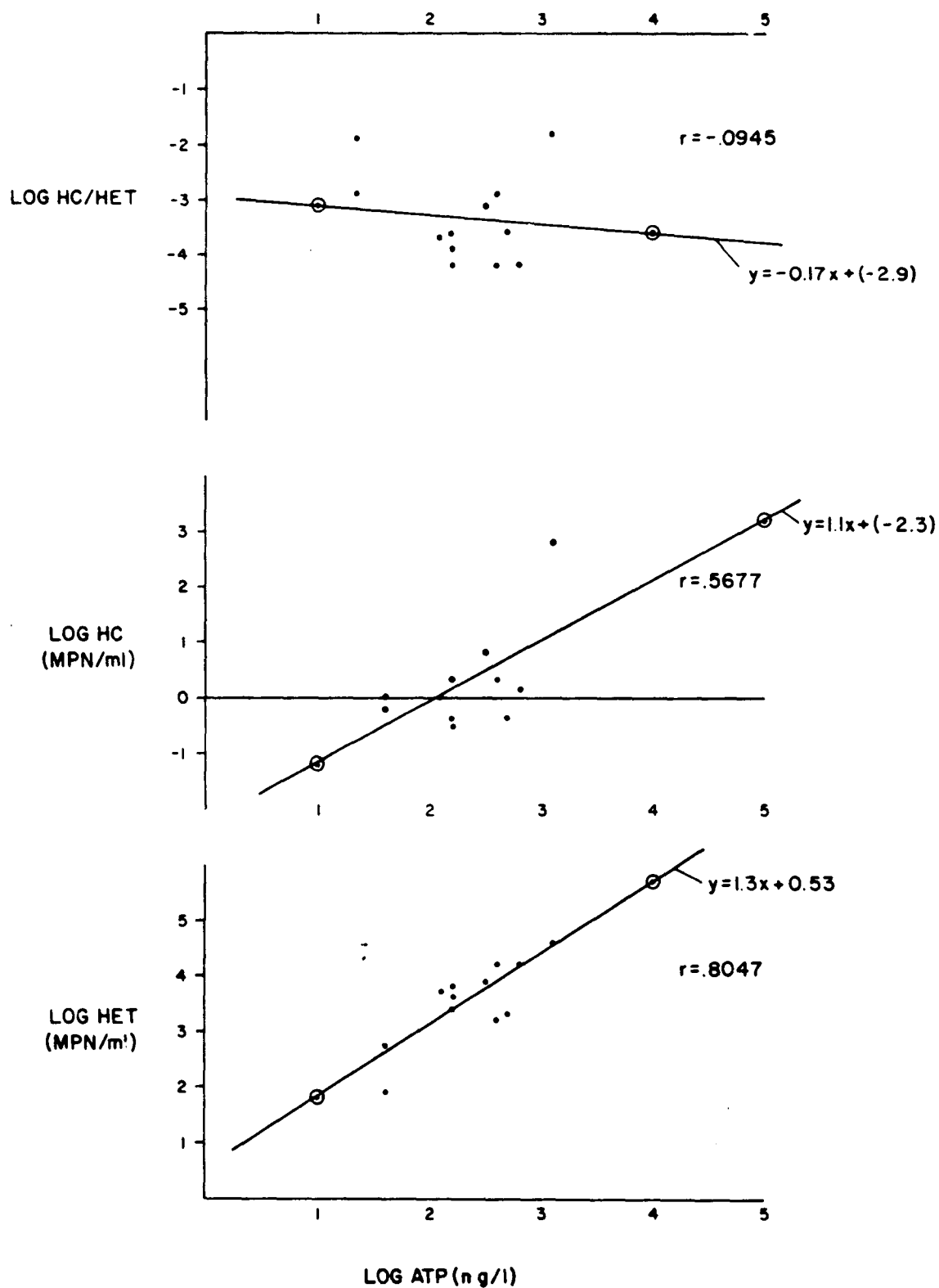


Figure 11-22. Linear regression of bacterial variables against ATP concentrations, surface water, Fall 1976.

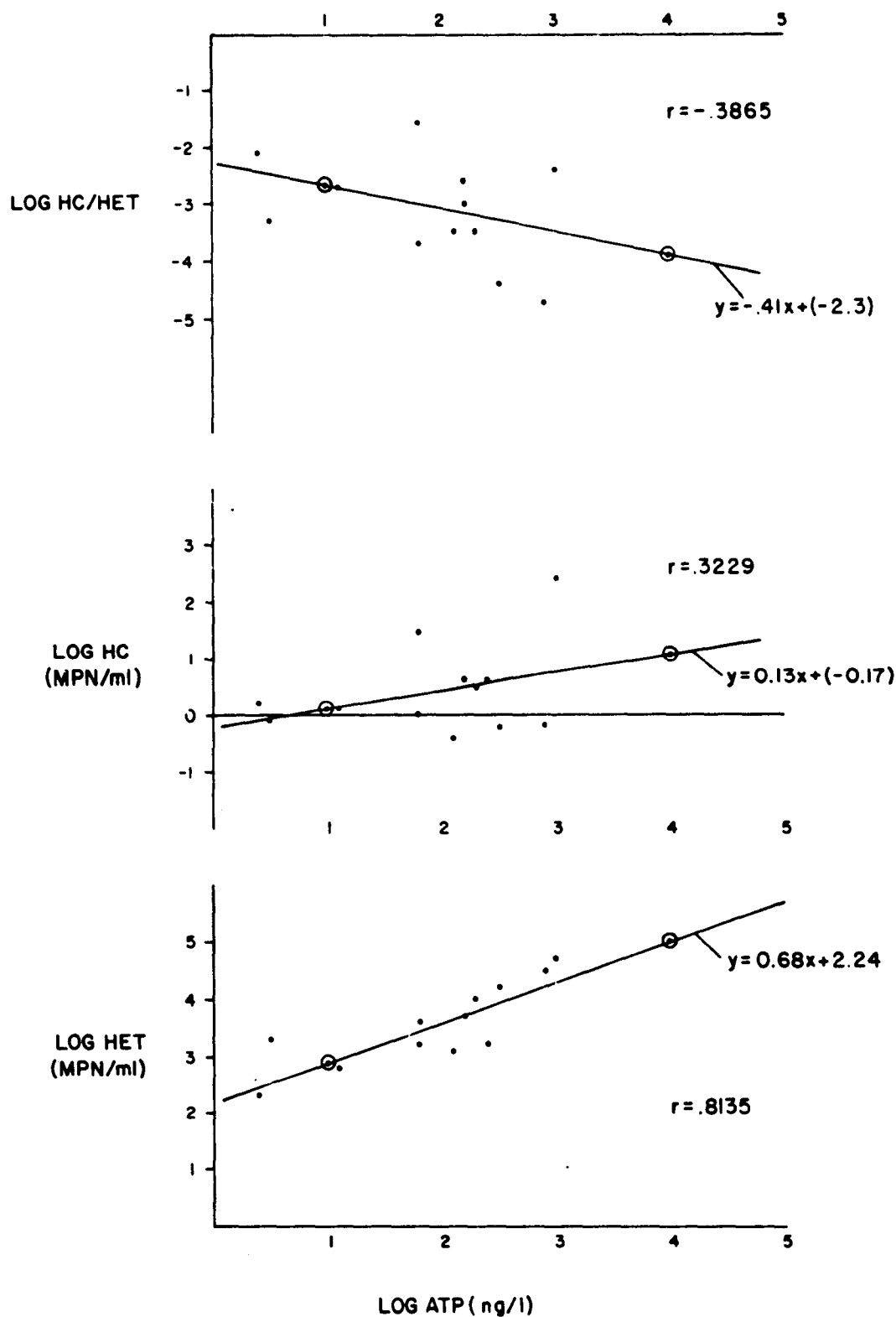


Figure 11-23. Linear regression of bacterial variables against ATP concentrations, bottom water, Fall 1976.

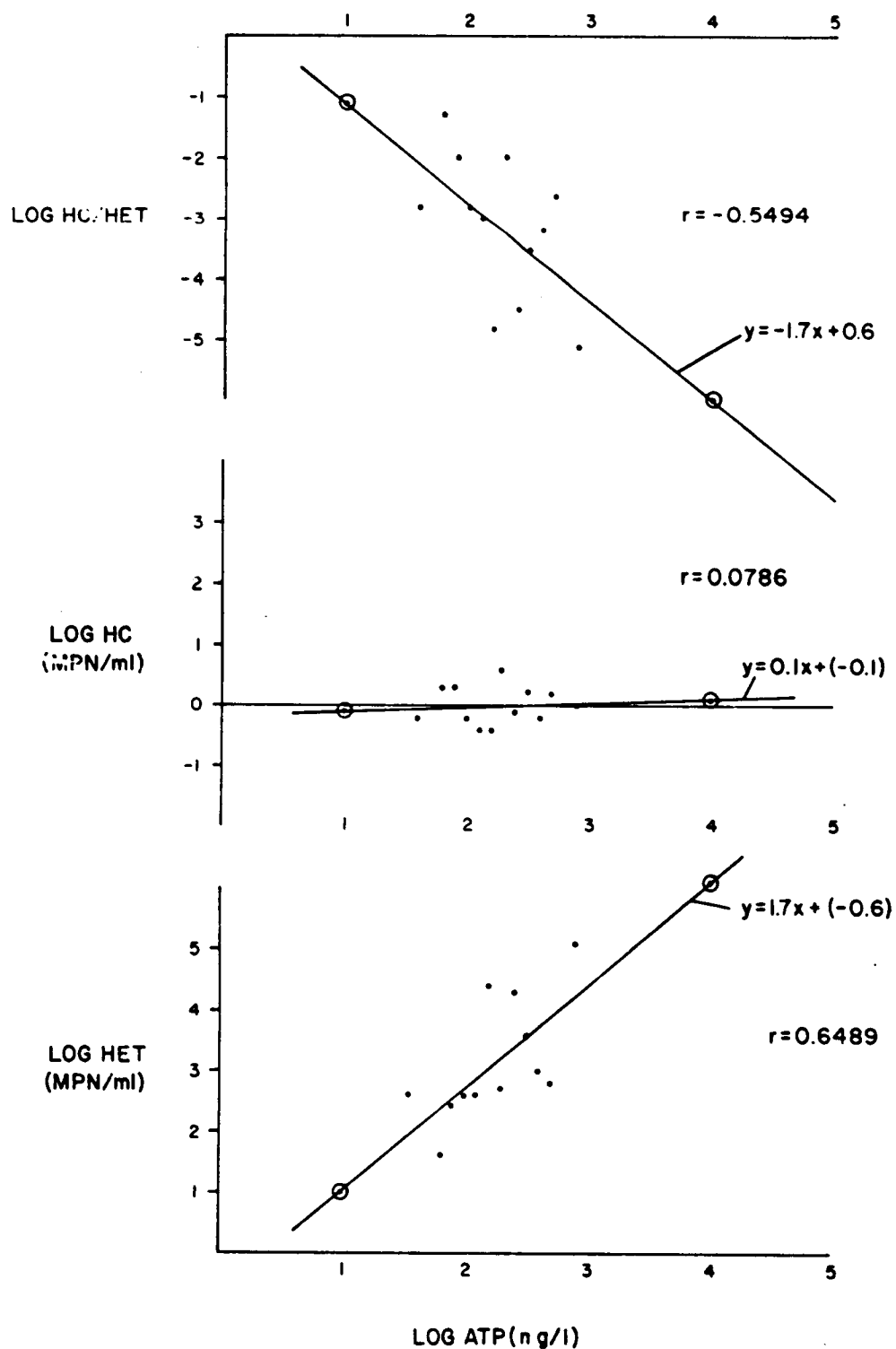


Figure 11-24. Linear regression of bacterial variables against ATP concentrations, surface water, Winter 1977.

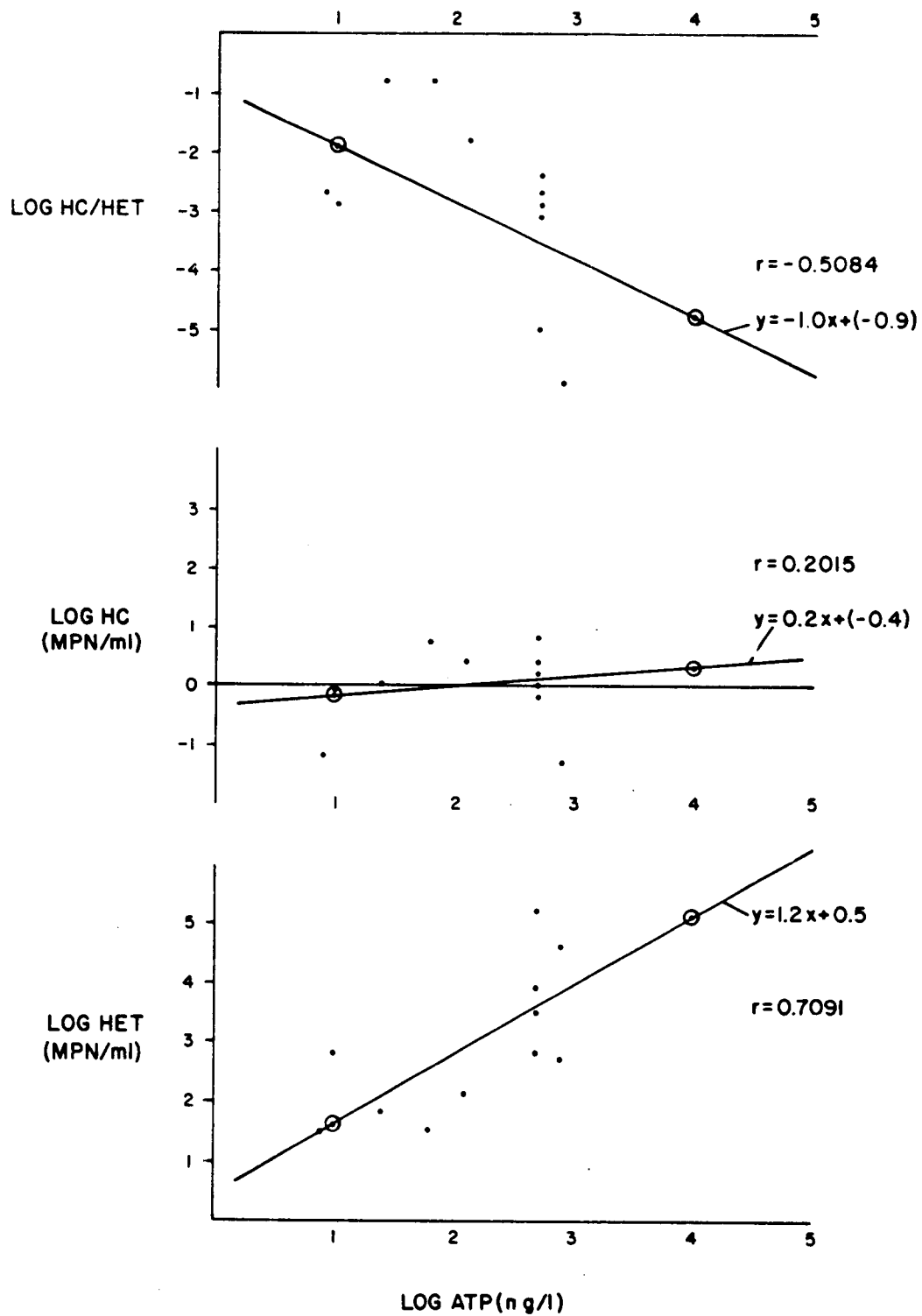


Figure 11-25. Linear regression of bacterial variables against ATP concentrations, bottom water, Winter 1977.

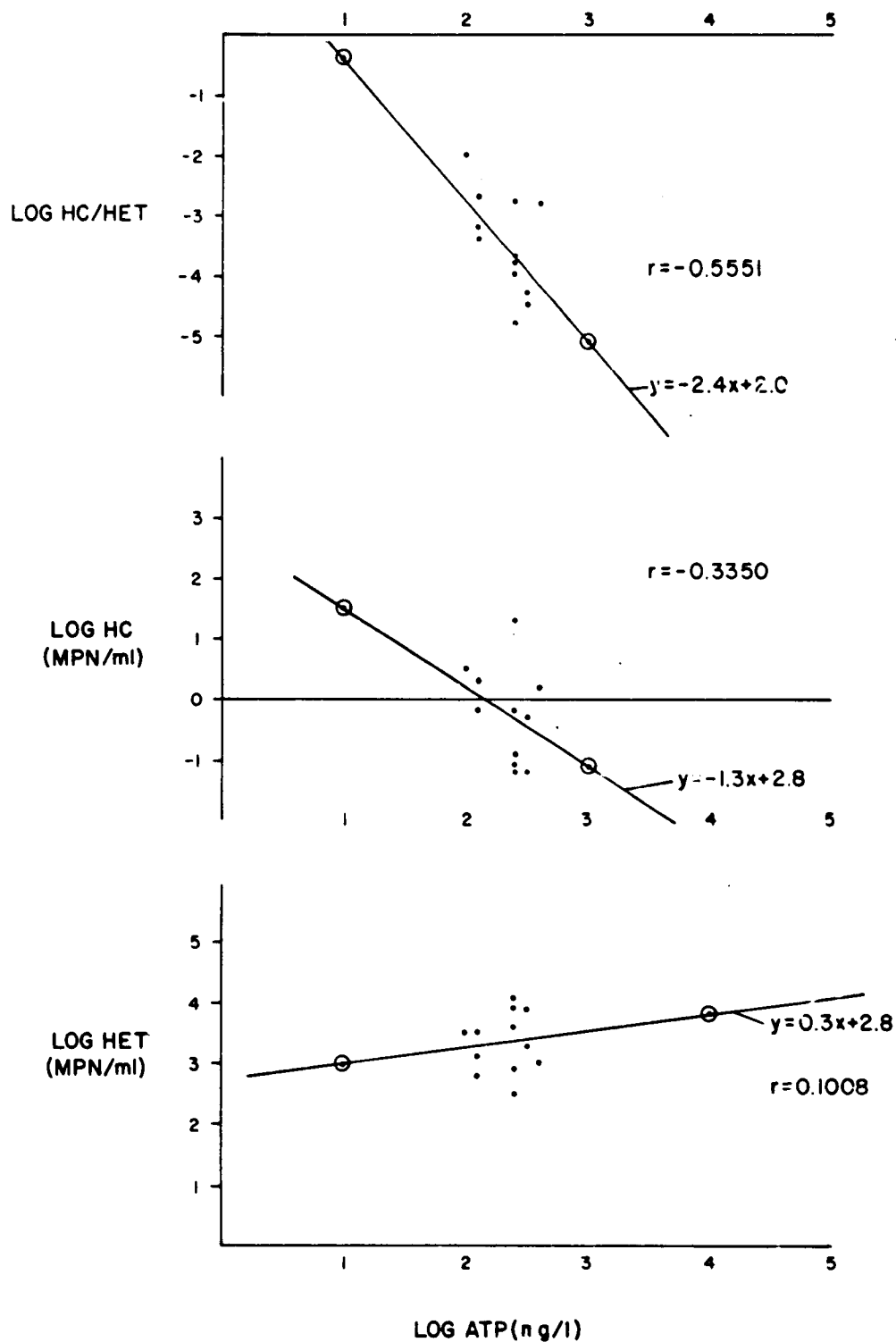


Figure 11-26. Linear regression of bacterial variables against ATP concentrations, surface water, Spring 1977.

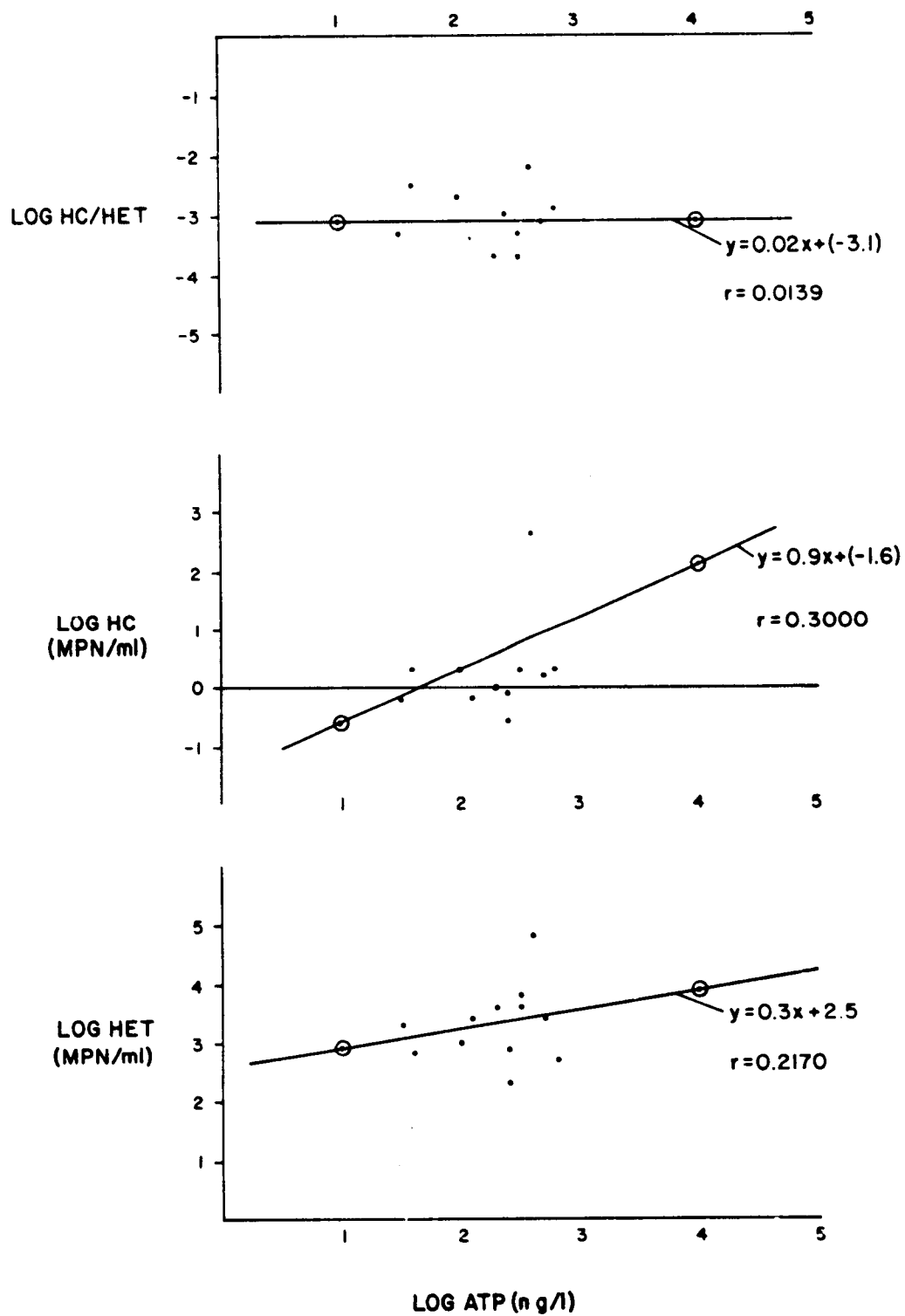


Figure 11-27. Linear regression of bacterial variables against ATP concentrations, bottom water, Spring 1977.

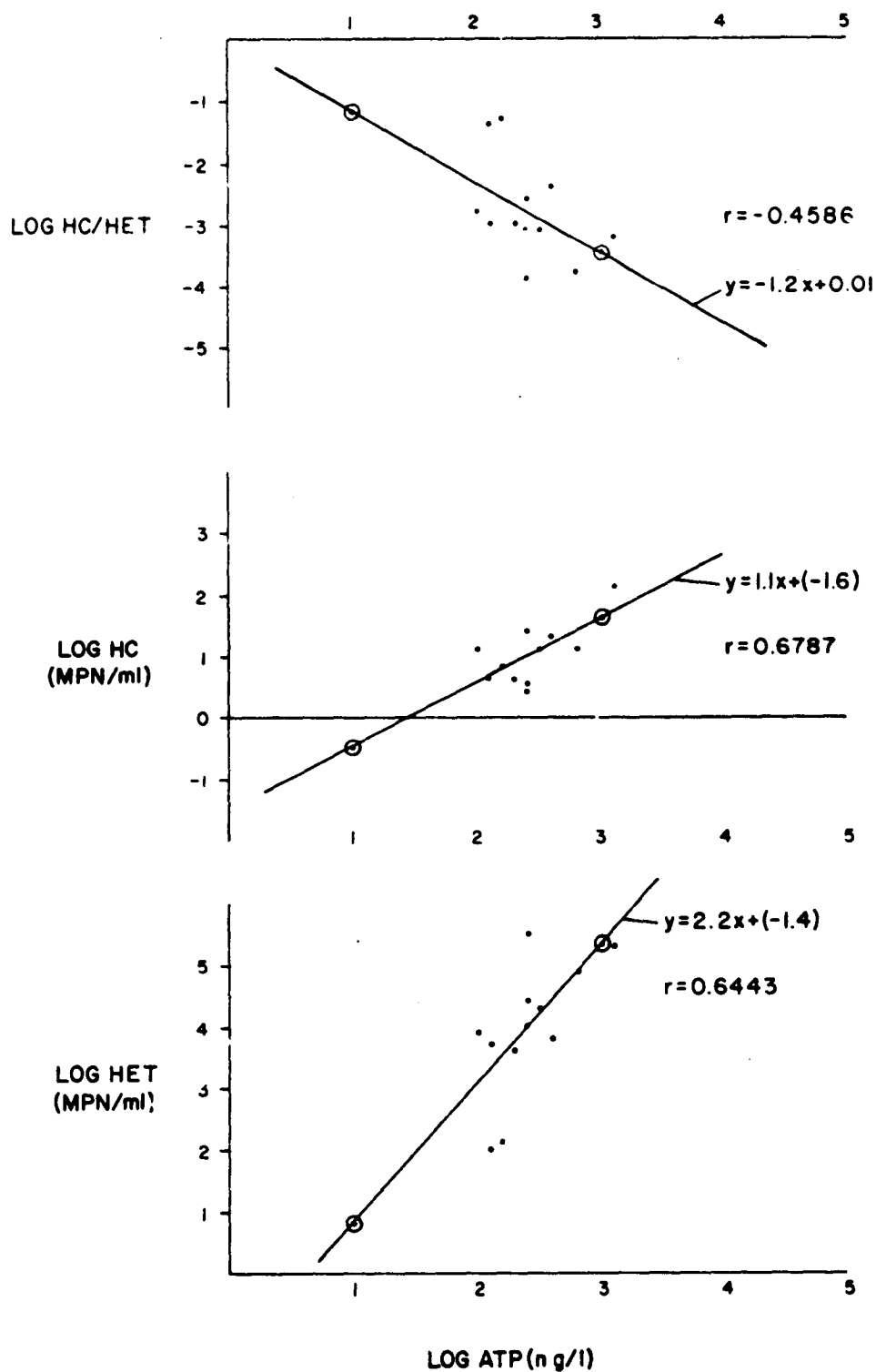


Figure 11-28. Linear regression of bacterial variables against ATP concentrations, surface water, Summer 1977.

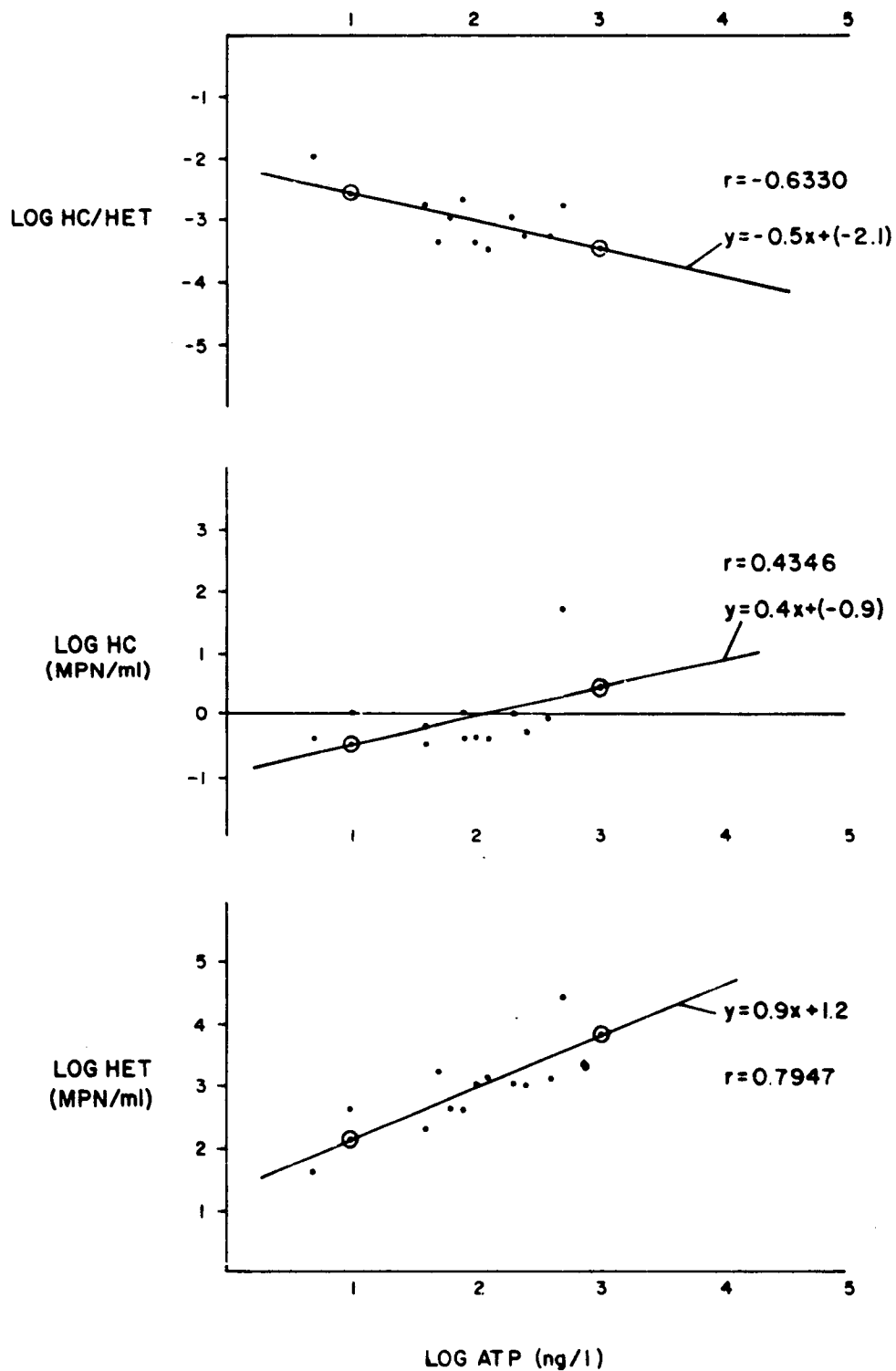


Figure 11-29. Linear regression of bacterial variables against ATP concentrations, bottom water, summer 1977.

other isolates required two weeks to reach a colony diameter of 0.01 mm. Therefore, isolate selection and purification were performed at two week intervals.

The percentage of isolates which produced pigment varied with sample type and season. Approximately twice as many pigmented isolates were obtained from HM tubes (34%) compared with ESWB plus petroleum tubes (18%). Pigmented isolates comprised 30, 30, 31, and 43% of the primary microlayer, water (surface and bottom), and sediment HM tube isolates, respectively.

Isolate mortality was a function of season, colony, size, pigment production, and colony opacity. Approximately 20% of HM and 6% of ESWB plus petroleum tube isolates from fall, spring, and summer cruises were lost prior to completion of taxonomic evaluations. Mortalities for winter were 37% and 9% for HM and ESWB plus petroleum medium isolates, respectively. Each isolate was transferred at least four times during taxonomic evaluation and often colony size would decrease with each successive transfer. Isolate mortality was related directly to decrease in colony size. Common micro-colonies (<0.5 mm diameter) were usually non-viable after several transfers.

Dominant pigmented isolates identified belonged to the genera Flavobacterium (87% of the pigmented HM isolates, 51% of ESWB plus petroleum medium pigmented isolates) and Pseudomonas (13% of the pigmented HM isolates, 49% of the ESWB plus petroleum medium pigmented isolates). Pseudomonas isolates typically formed translucent green-yellow colonies while Flavobacterium isolates produced predominantly opaque yellow-orange colonies on HM agar. Translucent colonies were typically rapid growers with high survival percentages. Presumptive Flavobacterium, generally pigmented and opaque, tended to grow slowly with an observed mortality of approximately 50%. More than 70% of these isolates from winter HM tubes, classified as presumptive Flavobacterium, were lost. In contrast, pigmented isolates from ESWB plus petroleum tubes exhibited relatively low mortality (ca. 6%). Obviously, isolate mortality cannot be overlooked in any assessment of the spatial or temporal dominance of bacterial genera in the original samples.

Taxonomic Evaluation

Approximately 828 isolates were processed for taxonomic identification. Table 11-22 is a list of dominant genera to which isolates were assigned and the observed characteristics of each genus. Figure 11-30 presents the determinative scheme used for the identification of these genera as modified after Shewan (1963). In addition to this information the following comments are in order.

The proposed genus Alteromonas which Baumann et al. (1972) differentiated solely on the basis of % moles G plus C from

Table 11-22. Observed characteristics of important genera used in identification of dominant isolates from microlayer, water, and sediment samples (05B-08B).

Genera	Group	No. Isolates	gram stain	motile	pigmentation	Kovacs oxidase	chitin hydrolyzed	Glucose			Penicillin (G) 2 i.u.	Chloramphenicol 30 µg	Neomycin 30 µg	Pteridine 400 µg
								acid aerobic	acid anaerobic	alkaline				
<u>Acinetobacter</u> : coccoid to short rods	A	5	-	-	-	-	-	1	-	2	+	+	+	+
<u>Aeromonas</u> : rods	A	17	-	16	7	+	12	+	+	-	+	+	+	-
<u>Alcaligenes</u> : coccoid to variable length rods	A	20	-	+	-	+	-	+	-	-	+	+	+	+
	B	52	-	+	-	+	-	-	-	-	+	+	+	+
	C	9	-	+	-	+	-	-	-	+	+	+	+	+
	D	13	-	-	-	+	-	+	-	-	+	+	+	+
	E	52	-	-	-	+	-	-	-	-	+	+	+	+
	F	13	-	-	-	+	-	-	-	+	+	+	+	+
<u>Flavobacterium</u> : coccoid variable length rods	A	98	-	1	+	+	-	35	6	6	+	+	+	+
	B	16	-	-	+	+	1	3	-	1	+	+	+	+
	C	17	-	-	+	+	1	1	1	4	+	+	+	+
	D	18	-	-	+	+	-	3	-	11	+	+	+	+
<u>Moraxella</u> : coccoid to short rods	A	8	-	-	-	+	-	-	-	5	+	+	+	+
<u>Pseudomonas</u> : coccoid to variable length rods	A	27	-	+	5	+	7	+	-	-	+	+	+	+
	B	140	-	+	10	139	59	+	-	-	+	+	+	+
	C	71	-	+	2	+	11	+	-	-	+	+	+	+
	D	15	-	+	1	+	2	-	-	+	+	+	+	+
	E	18	-	+	-	+	-	-	-	+	+	+	+	+
	F	27	-	+	4	+	6	-	-	-	+	+	+	+
	G	33	-	+	4	32	4	-	-	-	+	+	+	+
<u>Vibrio</u> : short rods to longer curved rods, occasional spheroplasts	A	118	-	116	1	+	106	+	+	-	+	+	+	+
	B	19	-	+	2	+	16	+	+	-	+	+	+	+
	C	3	-	+	-	+	-	+	+	-	+	+	+	+
<u>Other</u> : rods and cocci	A	9	+	-	4	-	-	+	3	-	+	+	+	+

Key: + or - indicates character exhibited by 100% of isolates.

Antibiotic and Pteridine inhibition zones (radius of clear zone measured from edge of sensitivity disc (mm)):

	-	*	+
Penicillin (G)	0	1-10	>10
Chloramphenicol	0	1-5	>5
Neomycin	0	1-4	>4
Pteridine	0	1-3	>3

Pseudomonas [groups III and IV of Shewan (1963)] was not recognized for this study. A workable scheme for the differentiation of Alteromonas using selected conventional tests was just recently published (Lee, et al. 1977) and therefore impossible to incorporate in this study. Finally, oxidase negative isolates exhibiting characteristics similar to Pseudomonas, but which fell into Shewan's (1963) "Paracolon" group, were classified as presumptive Pseudomonas sp.

Genera assigned to numerically dominant isolates from microlayer, surface, and bottom waters and sediment samples are listed according to station and sample type for each cruise, and by season for each station and sample type (Appendix 1). Results have been further consolidated to indicate numerically dominant genera isolated as functions of sample type, season, ridge vs. swale, shelf location and transect (Tables 11-23 to 11-31).

Greater than 90% of the isolates identified from both HM and ESWB plus petroleum medium were assigned to the genera Alcaligenes, Flavobacterium, Pseudomonas, and Vibrio. Considering all HM isolates, sample types, and seasons, Flavobacterium sp. was the most frequently isolated genus. Pseudomonas sp. and Alcaligenes sp. were secondary in total numbers of isolates. In contrast to isolates from HM, approximately one half of the isolates from ESWB plus petroleum medium were identified as Pseudomonas sp. The remaining isolates were numerically dominated by Vibrio sp. and Alcaligenes sp. In strong contrast to HM, Flavobacterium isolates from ESWB plus petroleum medium exhibited the smallest percentages of the dominant genera.

Heterotrophic isolates from microlayer and 1 m surface water samples were numerically dominated by Pseudomonas isolates, with Alcaligenes and Vibrio being numerically equivalent but smaller. On a station by station basis, genera most frequently isolated from microlayer samples were also the most frequent in 1 m bulk-subsurface water samples. Compared to microlayer samples, Flavobacterium was more frequently isolated from surface and bottom waters and dominated HM isolates obtained from sediments. Pseudomonas was the most frequently isolated genus from ESWB plus petroleum medium regardless of sample type. Pseudomonas clearly dominated isolates obtained from microlayer samples. With the exception of sediment samples, Vibrio was the next most frequently isolated genus from ESWB plus petroleum medium. Alcaligenes tended to occur more frequently in ESWB plus petroleum enumeration media from bottom waters and sediments.

Vibrio was isolated during all seasons but tended to be somewhat more abundant during the spring or summer in both ESWB plus petroleum and HM enumeration tubes. Isolation of Alcaligenes appeared greater during the fall from HM and ESWB plus petroleum medium in samples from bottom waters and sediment. Isolation frequency for the remaining genera did not appear to be correlated with season. Frequency of isolation as a function of season for genera sampled along the

(TEXT CONTINUES ON PAGE 11-95)

Table 11-23 Dominant genera of marine bacteria isolated from selected stations on HM (Heterotroph Medium) and ESWB + Petroleum Medium. Results are shown as functions of sample type and season.

Cruise:	Medium								Totals	
	HM				ESWB + PETROLEUM				HM	ESWB + Petroleum
	Micro-layer	Surface Water	Bottom Water	Sediment	Micro-layer	Surface Water	Bottom Water	Sediment		
FALL:										
<u>Acinetobacter</u>	—	2	—	2	—	—	1	1	4	2
<u>Aeromonas</u>	—	1	—	1	—	1	1	1	2	3
<u>Alcaligenes</u>	2	4	13	11	1	8	15	18	30	42
<u>Brevibacterium</u>	—	—	—	—	—	—	1	1	0	2
<u>Flavobacterium</u>	3	7	12	17	—	5	1	4	39	10
<u>Moraxella</u>	—	3	—	1	—	2	3	1	4	6
<u>Pseudomonas</u>	1	12	7	5	5	18	10	14	25	47
<u>Staphylococcus</u>	—	—	—	—	—	—	—	—	0	0
<u>Vibrio</u>	—	2	6	2	—	8	8	5	10	21
TOTAL ISOLATES									114	133
WINTER:										
<u>Acinetobacter</u>	—	—	—	2	—	—	—	—	2	0
<u>Aeromonas</u>	—	1	—	—	—	1	—	—	1	1
<u>Alcaligenes</u>	3	5	6	8	2	2	3	6	22	13
<u>Brevibacterium</u>	1	—	—	—	—	—	—	—	1	0
<u>Flavobacterium</u>	—	7	6	14	—	3	3	3	27	9
<u>Moraxella</u>	—	2	1	2	1	—	—	1	5	2
<u>Pseudomonas</u>	3	10	7	8	5	11	16	21	28	53
<u>Staphylococcus</u>	—	—	—	—	—	—	—	—	0	0
<u>Vibrio</u>	1	4	9	3	—	7	3	1	17	11
TOTAL ISOLATES									103	89

Table 11-23. (concluded)

Cruise: Genera	Medium								Totals	
	HM				ESWB + PETROLEUM					
	Micro-layer	Surface Water	Bottom Water	Sediment	Micro-layer	Surface Water	Bottom Water	Sediment	HM	ESWB + Petroleum
SPRING:										
<u>Acinetobacter</u>	—	—	—	—	—	—	—	—	0	0
<u>Aeromonas</u>	—	—	—	1	—	—	2	—	1	2
<u>Alcaligenes</u>	2	2	7	4	—	3	2	8	15	13
<u>Brevibacterium</u>	—	—	—	—1	—	—	—	—	1	0
<u>Flavobacterium</u>	1	7	4	22	1	2	—	4	34	7
<u>Moraxella</u>	—	2	—	—	—	1	—	1	2	2
<u>Pseudomonas</u>	7	8	8	2	7	15	12	14	25	48
<u>Staphylococcus</u>	—	1	—	—	1	—	—	—	1	1
<u>Vibrio</u>	3	6	4	2	3	5	8	3	15	19
TOTAL ISOLATES									94	92

SUMMER:										
<u>Acinetobacter</u>	—	—	—	—	—	1	—	—	0	1
<u>Aeromonas</u>	1	1	—	—	2	2	1	—	2	5
<u>Alcaligenes</u>	3	4	7	10	—	1	3	4	24	8
<u>Brevibacterium</u>	—	2	—	—	—	—	—	—	2	0
<u>Flavobacterium</u>	1	4	6	14	2	—	—	—	25	2
<u>Moraxella</u>	1	2	1	1	1	0	0	2	5	3
<u>Pseudomonas</u>	5	8	3	6	11	12	14	20	22	57
<u>Staphylococcus</u>	—	1	—	—	—	—	—	—	1	0
<u>Vibrio</u>	6	4	10	5	4	7	8	6	25	25
TOTAL ISOLATES									106	101

Table 11-24. Percentage frequency of occurrence of numerically dominant genera of marine bacteria isolated from highest positive dilutions of HM (Heterotroph Medium) and ESWB + Petroleum enumeration tubes. Values are for all sample types obtained during a given biological season.

Genera	HM ("Total Heterotrophs")					ESWB + Petroleum (Petroleum-Degraders)				
	Season				All Seasons $\bar{x}$	Season				All Seasons $\bar{x}$
	Fall	Winter	Spring	Summer		Fall	Winter	Spring	Summer	
<u>Acinetobacter</u>	3.5	1.9	0.0	0.0	1.4	1.5	0.0	0.0	1.0	0.6
<u>Aeromonas</u>	1.8	1.0	1.1	1.9	1.5	2.3	1.1	2.2	5.0	2.7
<u>Alcaligenes</u>	26.3	21.4	16.0	22.6	21.6	31.6	14.6	14.1	7.9	17.1
<u>Brevibacterium</u>	0.0	1.0	1.1	1.9	1.0	1.5	0.0	0.0	0.0	0.4
<u>Flavobacterium</u>	34.2	26.2	36.2	23.6	30.1	7.5	10.1	7.6	2.0	6.8
<u>Moraxella</u>	3.5	4.9	2.1	4.7	3.8	4.5	2.2	2.2	3.0	3.0
<u>Pseudomonas</u>	21.9	27.2	26.6	20.8	24.1	35.3	59.6	52.2	56.4	50.9
<u>Staphylococcus</u>	0.0	0.0	1.1	0.9	0.5	0.0	0.0	1.1	0.0	0.3
<u>Vibrio</u>	8.8	16.5	16.0	23.6	16.2	15.8	12.4	20.7	24.8	18.4

Table 11- 25. Number of isolates belonging to numerically dominant genera as functions of enumeration medium, season, and sample type for all taxonomy stations sampled during 1976-1977.

Dominant Genera	Medium											
	HM (Heterotrophic Medium)						ESWB + Petroleum Medium					
	Fall 1976	Winter 1977	Spring 1977	Summer 1977	TOTAL	% of all Isolates	Fall 1976	Winter 1977	Spring 1977	Summer 1977	TOTAL	% of all Isolates
	MICROLAYER						MICROLAYER					
<u>Alcaligenes</u> sp.	2	3	2	3	10	24	1	2	0	0	3	7
<u>Flavobacterium</u> sp.	3	0	1	1	5	12	0	0	1	2	3	7
<u>Pseudomonas</u> sp.	1	3	7	5	16	39	5	5	7	11	28	68
<u>Vibrio</u> sp.	0	1	3	6	10	24	0	0	3	4	7	17
					41	100					41	100
	SURFACE WATER						SURFACE WATER					
<u>Alcaligenes</u> sp.	4	5	2	4	15	16	8	2	3	1	14	13
<u>Flavobacterium</u> sp.	7	7	7	4	25	27	5	3	2	0	10	9
<u>Pseudomonas</u> sp.	12	10	8	8	38	40	18	11	15	12	56	52
<u>Vibrio</u> sp.	2	4	6	4	16	17	8	7	5	7	27	25
					94	100					107	99
	BOTTOM WATER						BOTTOM WATER					
<u>Alcaligenes</u> sp.	13	6	7	7	33	29	15	3	2	3	23	22
<u>Flavobacterium</u> sp.	12	6	4	6	28	24	1	3	0	0	4	4
<u>Pseudomonas</u> sp.	7	7	8	3	25	22	10	16	12	14	52	49
<u>Vibrio</u> sp.	6	9	4	10	29	25	8	3	8	8	27	25
					115	100					106	100
	SEDIMENT						SEDIMENT					
<u>Alcaligenes</u> sp.	11	8	4	10	33	25	18	6	8	4	36	27
<u>Flavobacterium</u> sp.	17	14	22	14	67	50	4	3	4	0	11	8
<u>Pseudomonas</u> sp.	5	8	2	6	21	16	14	21	14	20	69	53
<u>Vibrio</u> sp.	2	3	2	5	12	90	5	1	3	6	15	11
					133	100					131	99

Table 11-26. Dominant bacterial genera isolated from highest dilution positive petroleum degradation MPN tubes from sediment samples collected quarterly (BLM05B-08B). Dashes indicate no viable isolates.

Station	Seasonal Frequency	Fall	Winter	Spring	Summer
Inner Shelf Sediment Stations	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	3/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	--
	3/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	--
	1/4	--	--	<u>Moraxella osloensis</u>	--
	2/4	<u>Vibrio</u> sp.	--	--	<u>Vibrio</u> sp.
	1/4	<u>Brevibacterium</u> sp.	--	--	--
Outer Shelf Sediment Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	4/4	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.
	2/4	<u>Flavobacterium</u> sp.	--	<u>Flavobacterium</u> sp.	--
	1/4	<u>Acinetobacter</u> sp.	--	--	--
	1/4	<u>Aeromonas</u> sp.	--	--	--
Shelf Break Sediment Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	1/4	--	--	--	<u>Moraxella osloensis</u>
	2/4	--	--	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.
	1/4	--	--	<u>Flavobacterium</u> sp.	--

Table 11-27. Dominant bacterial genera isolated from highest dilution positive heterotrophic MPN tubes from sediment samples collected quarterly (ELM05B-08B). Dashes indicate no viable isolates.

Station	Seasonal Frequency	Fall	Winter	Spring	Summer
Inner Shelf Sediment Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.
	3/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	--	<u>Pseudomonas</u> sp.
	1/4	<u>Acinetobacter</u> sp.	--	--	--
Outer Shelf Sediment Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.
	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	4/4	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.
	2/4	<u>Acinetobacter</u> sp.	<u>Acinetobacter</u> sp.	--	--
Shelf Break Sediment Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.
	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	3/4	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	--	<u>Vibrio</u> sp.
	1/4	--	<u>Acinetobacter</u> sp.	--	--
	1/4	<u>Aeromonas</u> sp.	--	--	--
	1/4	--	--	<u>Brevibacterium</u> sp.	--
	1/4	--	--	--	--

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Table 11-28. Dominant bacterial genera isolated from highest dilution positive petroleum degradation MPN tubes from sediment samples collected quarterly (BLM05B-08B). Dashes indicate no viable isolates.

Station	Seasonal Frequency	Fall	Winter	Spring	Summer
Sediment Ridge Stations	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	3/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	--
	3/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	--
	3/4	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	<u>Vibrio</u> sp.	--
	1/4	<u>Brevibacterium</u> sp.	--	--	--
Sediment Swale Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.
	2/4	<u>Vibrio</u> sp.	--	--	<u>Vibrio</u> sp.
	1/4	<u>Acinetobacter</u> sp.	--	--	--
	1/4	--	<u>Flavobacterium</u> sp.	--	--
	1/4	--	--	<u>Moraxella osloensis</u>	--

Table 11-29. Dominant bacterial genera isolated from highest dilution positive heterotrophic MPN tubes from sediment samples collected quarterly (BLM05B-08B). Dashes indicate no viable isolates.

Station	Seasonal Frequency	Fall	Winter	Spring	Summer
Sediment Ridge Stations	4/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.
	4/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.
	2/4	<u>Pseudomonas</u> sp.	--	--	<u>Pseudomonas</u> sp.
	1/4	<u>Acinetobacter</u> sp.	--	--	--
Sediment Swale Stations	4/4	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.	<u>Flavobacterium</u> sp.
	3/4	<u>Alcaligenes</u> sp.	<u>Alcaligenes</u> sp.	--	<u>Alcaligenes</u> sp.
	2/4	--	<u>Pseudomonas</u> sp.	<u>Pseudomonas</u> sp.	--
	2/4	--	<u>Vibrio</u> sp.	--	<u>Vibrio</u> sp.

Table 11-30. Frequency of isolation of numerically dominant marine bacteria from HM and ESWB-Petroleum MPN enumeration tubes from stations sampled along the southern New Jersey transect. Frequency of isolation expressed as a fraction of the four biological seasons sampled during 1976-1977.

Sample Type: Dominant Genera Isolated	Station											
	C1		D1		N3		E3		F2		J1	
	HM	ESWB	HM	ESWB	HM	ESWB	HM	ESWB	HM	ESWB	HM	ESWB
SURFACE WATER:												
<u>Acinetobacter</u> sp.	1/4	1/4	-	-	-	-	-	-	-	-	-	-
<u>Aeromonas</u> sp.	-	1/4	-	-	1/4	-	1/4	-	-	1/4	-	-
<u>Alcaligenes</u> sp.	3/4	2/4	1/4	1/4	-	3/4	2/4	1/4	1/4	1/4	-	1/4
<u>Brevibacterium</u> sp.	1/4	-	-	-	-	-	-	-	-	-	-	-
<u>Flavobacterium</u> sp.	3/4	2/4	3/4	1/4	2/4	-	1/4	1/4	3/4	1/4	2/4	1/4
<u>Moraxella osloensis</u>	-	-	-	-	-	-	-	-	-	1/4	-	-
<u>Pseudomonas</u> sp.	1/4	2/4	1/4	1/4	1/4	4/4	2/4	4/4	4/4	3/4	3/4	4/4
<u>Staphylococcus</u> sp.	-	1/4	-	-	1/4	-	-	-	-	-	1/4	-
<u>Vibrio</u> sp.	1/4	1/4	2/4	4/4	2/4	-	2/4	1/4	1/4	3/4	-	3/4
BOTTOM WATER:												
<u>Acinetobacter</u> sp.	-	-	-	-	-	-	-	-	-	-	-	1/4
<u>Aeromonas</u> sp.	-	-	-	-	-	-	-	-	-	1/4	-	2/4
<u>Alcaligenes</u> sp.	3/4	1/4	3/4	1/4	2/4	1/4	2/4	1/4	4/4	3/4	1/4	1/4
<u>Brevibacterium</u> sp.	-	-	-	-	-	-	-	-	-	-	-	1/4
<u>Flavobacterium</u> sp.	3/4	1/4	1/4	-	1/4	-	2/4	-	1/4	-	2/4	-
<u>Moraxella osloensis</u>	-	-	-	-	-	-	-	-	-	-	-	-
<u>Pseudomonas</u> sp.	-	1/4	1/4	3/4	2/4	3/4	3/4	4/4	2/4	4/4	1/4	4/4
<u>Vibrio</u> sp.	2/4	4/4	1/4	2/4	1/4	3/4	1/4	3/4	3/4	2/4	2/4	1/4
SEDIMENT:												
<u>Acinetobacter</u> sp.	-	-	1/4	-	NOT SAMPLED		1/4	-	-	-	NOT SAMPLED	
<u>Aeromonas</u> sp.	-	-	-	-			-	1/4	1/4	-		
<u>Alcaligenes</u> sp.	2/4	2/4	3/4	1/4			2/4	1/4	2/4	1/4		
<u>Brevibacterium</u> sp.	-	1/4	-	-			-	-	-	-		
<u>Flavobacterium</u> sp.	3/4	3/4	3/4	3/4			4/4	1/4	3/4	-		
<u>Moraxella osloensis</u>	-	-	-	-			-	-	-	1/4		
<u>Pseudomonas</u> sp.	2/4	3/4	1/4	3/4			2/4	2/4	2/4	3/4		
<u>Vibrio</u> sp.	-	1/4	-	-			1/4	1/4	1/4	1/4		

Table 11-31. Frequency of isolation of numerically dominant marine bacteria from HM and ESWB-Petroleum MPN enumeration tubes from stations sampled along the "L" transect. Frequency of isolation expressed as a fraction of the four biological seasons sampled during 1976-1977.

Sample Type: Dominant Genera Isolated	Station							
	L1		L2		L4		L6	
	HM	ESWB	HM	ESWB	HM	ESWB	HM	ESWB
SURFACE WATER:								
<u>Acinetobacter</u> sp.	-	--	--	-	1/4	-	-	-
<u>Aeromonas</u> sp.	1/4	1/4	-	-	-	-	-	-
<u>Alcaligenes</u> sp.	2/4	-	1/4	-	1/4	-	1/4	1/4
<u>Brevibacterium</u> sp.	-	-	-	-	-	-	-	-
<u>Flavobacterium</u> sp.	2/4	2/4	2/4	-	-	-	-	-
<u>Moraxella osloensis</u>	2/4	-	-	-	1/4	1/4	-	-
<u>Pseudomonas</u> sp.	-	2/4	3/4	4/4	2/4	3/4	4/4	2/4
<u>Vibrio</u> sp.	-	1/4	1/4	-	-	3/4	1/4	3/4
BOTTOM WATER:								
<u>Acinetobacter</u> sp.	-	-	-	-	-	-	-	-
<u>Aeromonas</u> sp.	-	1/4	-	-	-	-	-	-
<u>Alcaligenes</u> sp.	-	1/4	2/4	1/4	1/4	1/4	1/4	1/4
<u>Brevibacterium</u> sp.	-	-	-	-	-	-	-	-
<u>Flavobacterium</u> sp.	1/4	1/4	2/4	-	1/4	2/4	3/4	-
<u>Moraxella osloensis</u>	-	-	-	-	-	-	-	-
<u>Pseudomonas</u> sp.	2/4	2/4	1/4	4/4	3/4	3/4	2/4	4/4
<u>Vibrio</u> sp.	1/4	-	3/4	1/4	2/4	1/4	1/4	2/4

Southern New Jersey and "L" transects are shown in Tables 11-30 and 11-31. Generally these data reproduced the same trends described for all stations. For those genera isolated at least three out of four seasons, Flavobacterium occurred more frequently in HM enumeration tubes than from ESWB plus petroleum tubes. Similarly Pseudomonas and Vibrio were isolated more frequently from ESWB plus petroleum than HM tubes.

No obvious patterns were noted when taxonomic data were examined to determine if frequency of occurrence could be related to sample type or location on the shelf. However, the data suggested that Alcaligenes and Flavobacterium were more frequently isolated (3 out of 4 seasons), in surface and bottom water samples collected from stations located within the inner shelf area compared with slope stations. Finally comparison of dominant genera isolated from the topographically contrasting ridge-swale systems failed to reveal either differences in dominant genera composition or variation in dominance with season (Tables 11-28 and 11-29).

Hexadecane and Petroleum Utilization in Pure Culture

Purified isolates were examined for the ability to utilize hexadecane as the sole added carbon source in ESWB. In addition, isolates originally obtained from ESWB plus petroleum medium were similarly tested using South Louisiana crude oil. Results of these assays are presented in Tables 11-32 to 11-37 for dominant isolates as functions of genus, season and sample type.

Approximately 10% of the identified isolates from ESWB plus petroleum tubes utilized sterile hexadecane in contrast to 3% of the isolates obtained from HM. Percentages of ESWB plus petroleum isolates utilizing hexadecane varied from 7 to 17% on a seasonal basis with the largest proportion expressed with summer isolates. Because percentages of isolates from HM were uniformly low (ca. 3%), seasonal variations were not evident.

ESWB plus petroleum medium isolates from microlayer and surface water samples manifested the highest percentages of hexadecane and petroleum utilization. Isolates from bottom water and sediments exhibited lower percentages of confirmation, respectively.

Genera producing confirming reactions in hexadecane and South Louisiana crude oil are shown in Tables 11-32 to 11-34. Significantly, the dominant genera Flavobacterium and Alcaligenes exhibited very low confirming percentages using both HM and ESWB plus petroleum medium isolates, although confirming percentages tended to be greater in the latter medium. Pseudomonas and Vibrio exhibited the largest confirming percentages of the seasonally dominant genera. Genera such as Acinetobacter, Aeromonas, and Brevibacterium yielded very high confirmation percentages from both HM and ESWB plus

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Table 11-32. Proportion of isolates identified from ESWB + petroleum tubes (all samples) by genera able to grow on hexadecane in pure culture.

Genus	Season				Percentage Confirming
	Fall	Winter	Spring	Summer	
<u>Acinetobacter</u> sp.	0/2	-	-	1/1	33.3 (n=3)
<u>Aeromonas</u> sp.	0/3	0/1	0/2	1/5	9.1 (n=11)
<u>Alcaligenes</u> sp.	1/42	0/13	0/13	0/8	1.3 (n=76)
<u>Brevibacterium</u> sp.	0/2	-	-	-	0 (n=2)
<u>Flavobacterium</u> sp	1/10	0/9	0/7	0/2	3.6 (n=28)
<u>Moraxella osloensis</u>	0/2	-	0/2	0/1	0 (n=5)
<u>Pseudomonas</u> sp.	7/47	6/53	6/49	12/57	15.0 (n=206)
<u>Staphylococcus</u> sp.	-	-	0/1	-	0 (n=1)
<u>Vibrio</u> sp.	2/21	0/11	1/19	3/25	7.9 (n=76)
Percentage of Total Isolates Identified Confirming as Hydrocarbon-Degrading	9	7	8	17	10

Table 11-33. Proportion of isolates identified from HM tubes (all samples)
by genera able to grow on hexadecane in pure culture.

Genus	Season				Percentage Confirming
	Fall	Winter	Spring	Summer	
<u>Acinetobacter</u> sp.	0/4	1/2	-	-	16.7 (n=6)
<u>Aeromonas</u> sp.	0/2	0/1	0/1	1/2	16.7 (n=6)
<u>Alcaligenes</u> sp.	0/30	1/22	0/15	0/24	1.1 (n=91)
<u>Brevibacterium</u> sp.	-	0/1	0/1	0/2	0 (n=4)
<u>Flavobacterium</u> sp.	0/39	0/27	0/34	0/25	0 (n=125)
<u>Moraxella osloensis</u>	0/2	0/1	-	-	0 (n=3)
<u>Pseudomonas</u> sp.	0/25	1/28	0/24	2/22	3.0 (n=99)
<u>Staphylococcus</u> sp.	-	-	0/1	0/1	0 (n=2)
<u>Vibrio</u> sp.	1/10	2/17	1/15	3/25	10.4 (n=67)
Percentage of Total Isolates Identified Confirming as Hydrocarbon-Degrading	1	5	1	6	3

Table 11-34. Proportion of isolates identified from ESWB + petroleum tubes (all samples) by genera able to grow on South Louisiana crude oil in pure culture.

Genus	Season				Percentage Confirming
	Fall	Winter	Spring	Summer	
<u>Acinetobacter</u> sp.	1/2	-	-	1/1	66.7 (n=3)
<u>Aeromonas</u> sp.	2/3	0/1	0/2	0/5	18.2 (n=11)
<u>Alcaligenes</u> sp.	2/42	0/13	1/13	0/8	3.9 (n=76)
<u>Brevibacterium</u> sp.	2/2	-	-	-	100 (n=2)
<u>Flavobacterium</u> sp.	2/10	1/9	0/7	0/2	10.7 (n=28)
<u>Moraxella osloensis</u>	0/2	-	0/2	0/1	0 (n=5)
<u>Pseudomonas</u> sp.	19/47	7/53	8/49	16/57	24.3 (n=206)
<u>Staphylococcus</u> sp.	-	-	0/1	-	0 (n=1)
<u>Vibrio</u> sp.	7/21	4/11	2/19	5/25	23.7 (n=76)
Percentage of Total Isolates Identified Confirming as Petroleum-Degrading	27	14	12	22	20

Table 11-35. Proportions of selected dominant isolates from ESWB + petroleum tubes able to grow in pure culture on hexadecane as a function of sample type (05-08B).

Sample Type	Season				Mean Proportion
	Fall	Winter	Spring	Summer	
Microlayer	6/19	1/28	0/23	14/52	16/100
Surface Water	21/91	12/102	11/87	13/80	16/100
Bottom Water	14/90	10/92	2/78	15/78	12/100
Sediment	12/112	6/109	5/91	15/83	10/100

Table 11-36. Proportions of selected dominant isolates from HM tubes able to grow in pure culture on hexadecane as a function of sample type (05-08B).

Sample Type	Season				Mean Proportion
	Fall	Winter	Spring	Summer	
Microlayer	0/15	2/18	0/40	1/44	3/100
Surface Water	0/66	3/72	2/67	1/64	2/100
Bottom Water	0/69	4/80	3/72	3/73	3/100
Sediment	2/71	4/78	1/91	2/71	3/100

Table 11- 37. Proportions of selected dominant isolates from ESWB + petroleum tubes able to grow in pure culture on South Louisiana crude oil as a function of sample type (05-08B).

Sample Type	Season				Mean Proportion
	Fall	Winter	Spring	Summer	
Microlayer	9/19	4/28	1/23	14/52	23/100
Surface Water	35/91	21/102	13/87	18/80	24/100
Bottom Water	28/90	17/92	2/78	16/78	18/100
Sediment	23/112	5/109	7/91	19/83	14/100

petroleum medium, but this was a reflection of the very small numbers of isolates obtained over the four biological seasons. Interestingly, a greater proportion of isolates from ESWB plus petroleum tubes could utilize petroleum as compared with hexadecane.

Petroleum Degradation Experiments

Closed Flask Experiments

Water Inocula, Enumeration. Viable count data from closed flask petroleum degradation studies utilizing seawater inocula are summarized in Appendix 2 and Figures 11-31 through 11-42. On the basis of field observations, average seasonal incubation temperatures were chosen as follows: fall, 15°C; winter, 5°C; spring, 15°C; summer, 20°C. Stations were grouped for the purposes of analysis into a New Jersey transect and an "L" transect. Similar trends in viable counts during incubation were observed for both transects and all stations. During all seasons and within all experimental treatments, viable counts of heterotrophic bacteria (HET) and petroleum-degrading bacteria (HC) increased above ambient (inoculum) levels. Viable counts of HET in nutrient enriched flasks were greater than those in either inoculated or oil-free control flasks. Essentially equivalent HET viable counts were exhibited by inoculated and oil-free control flasks over the duration of the incubation period. Seasonally, within all experimental treatments, a slower rate of increase in HET viable counts was observed during the winter. Although winter HET viable counts in inoculated and oil-free control flasks eventually reached maximum values similar to other seasons, HET counts in enriched flasks did not. Thus, maximum HET counts for inoculated and oil-free control flasks were about 5×10^5 bacterial units/ml seawater during all seasons. In contrast, maximum viable counts of HET in enriched flasks during fall, spring and summer ranged from 5×10^6 to 1×10^7 bacterial units/ml but were 1×10^6 bacterial units/ml in the winter.

HC viable counts were affected by season within all experimental treatments. During the winter the incubation period required to reach maximum viable counts was the longest of all seasons. In enriched flasks, the greatest rate of increase to maximum count values occurred during the summer. Absolute values of HC viable counts were always greatest in enriched flasks. Maximum viable counts were essentially equivalent in both inoculated and oil-free control flasks. During winter, maximum HC viable counts in enriched flasks were lower than all other seasons. Thus, HC viable counts using New Jersey transect inocula reached maxima of about $1-5 \times 10^4$ bacterial units/ml seawater in inoculated and oil-free control flasks for all seasons, about 5×10^5 bacterial units/ml seawater in enriched flasks during the winter, and about 1×10^6 to 5×10^6 bacterial units/ml seawater in enriched flasks for all other seasons.

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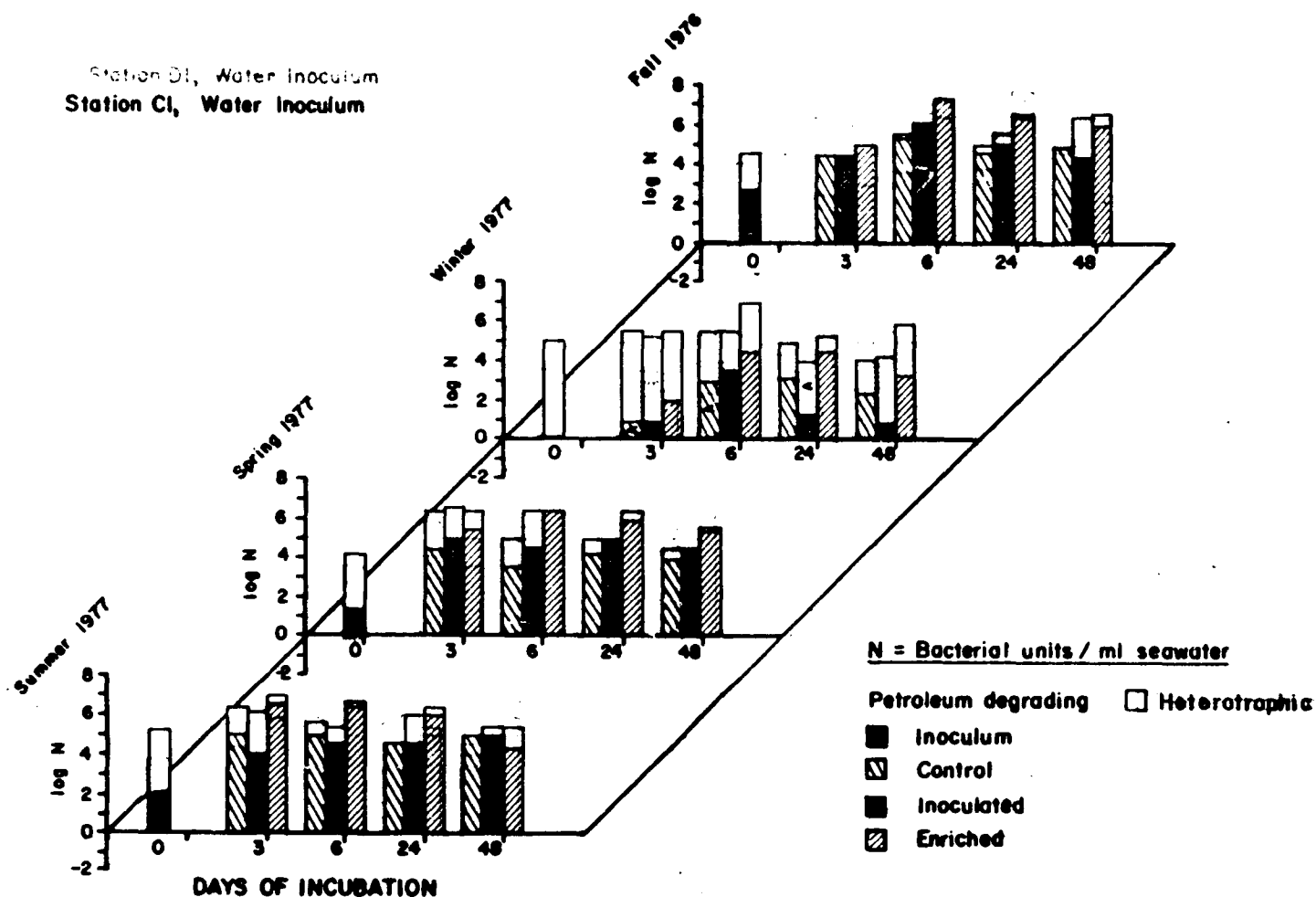


Figure 11-31. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

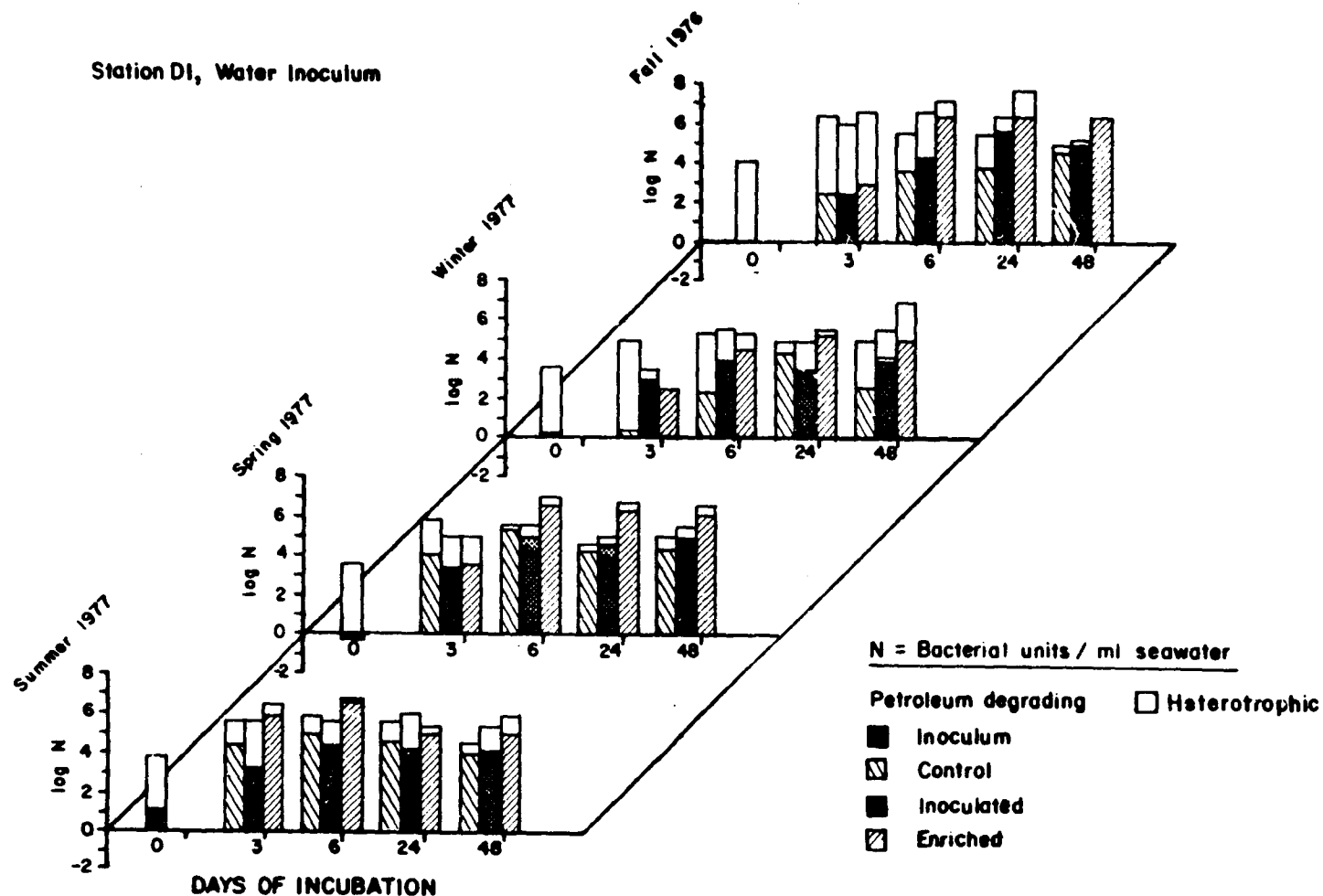


Figure 11-32. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

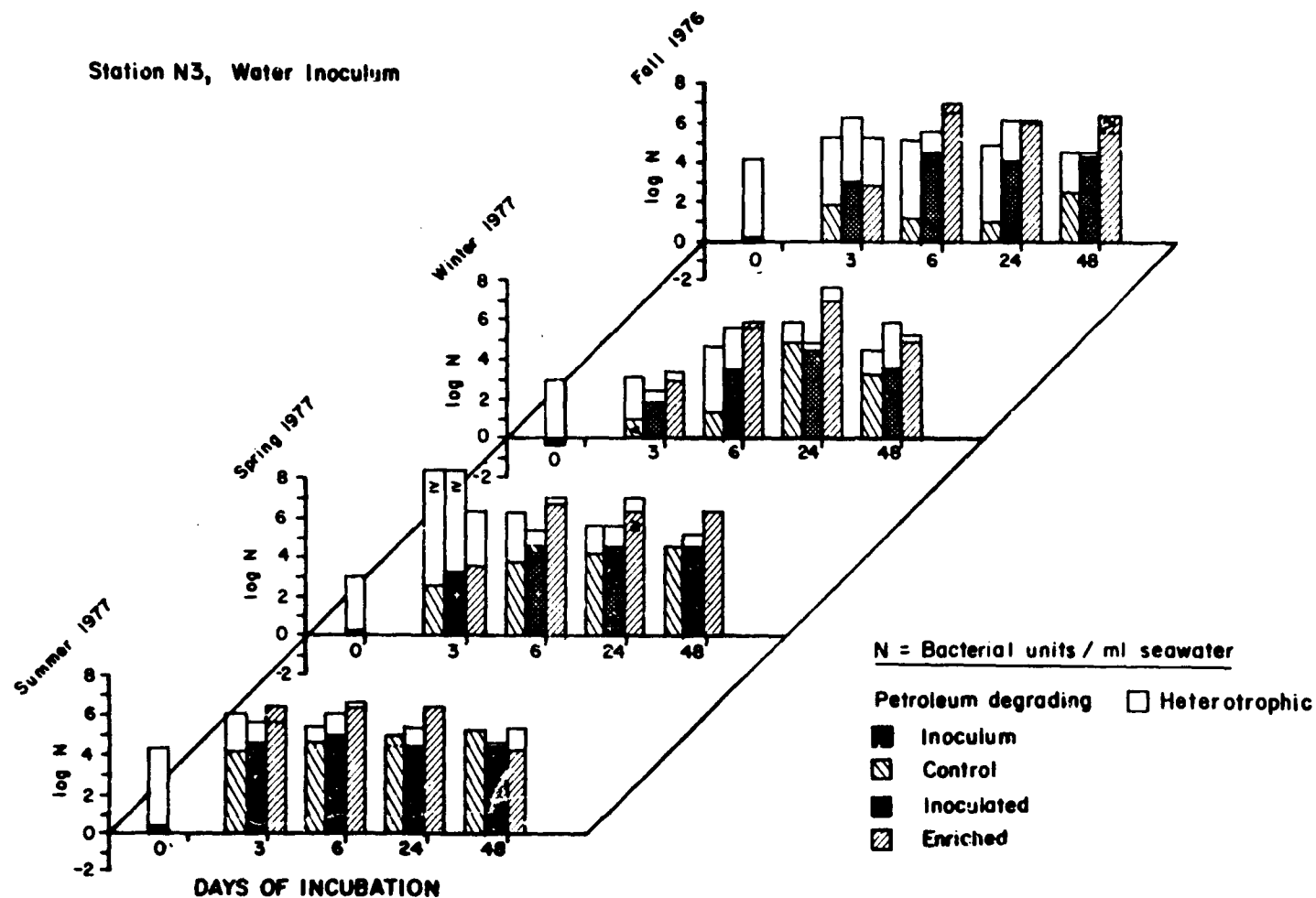


Figure 11-33. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

Station E3, Water Inoculum

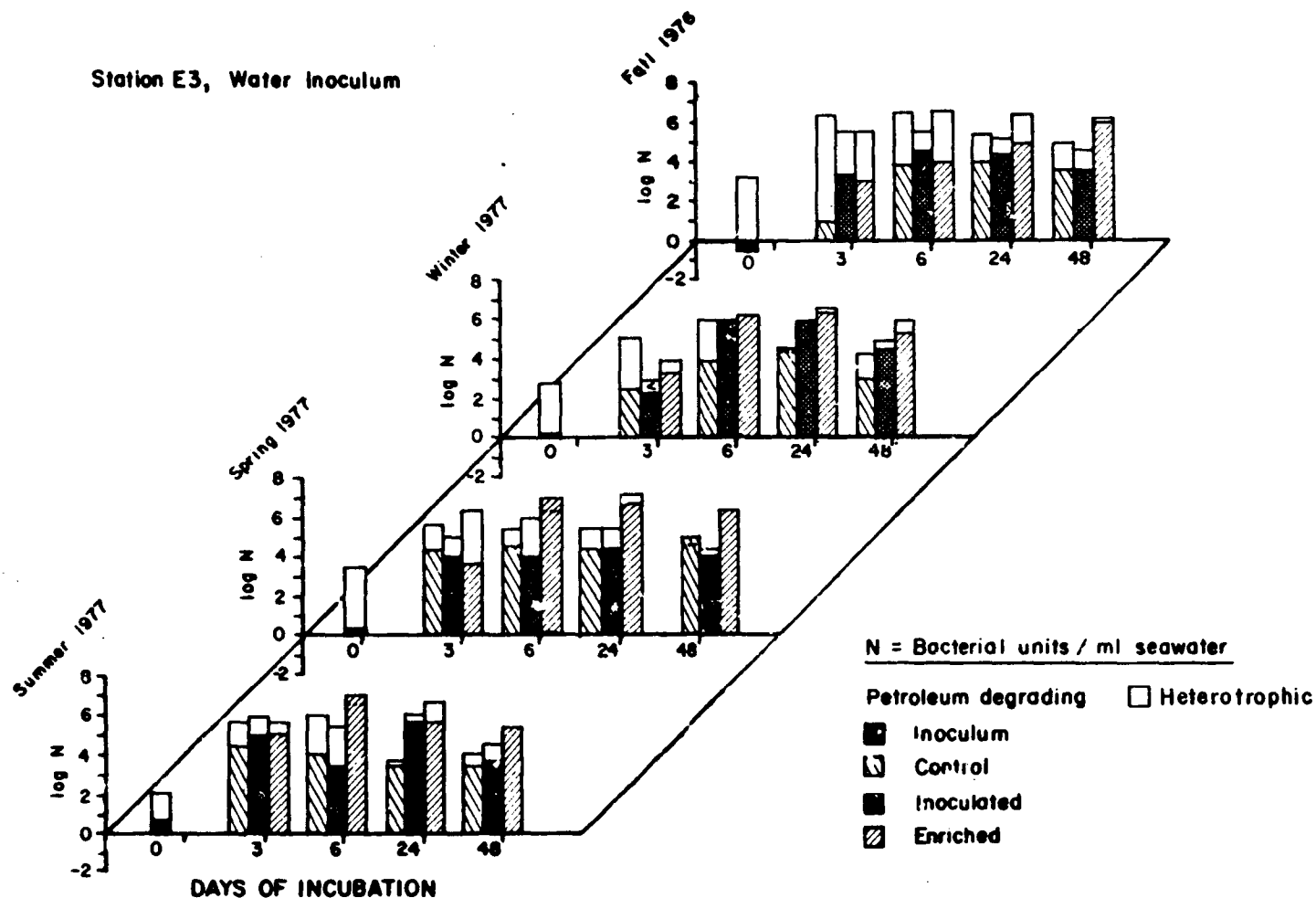


Figure 11-34. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

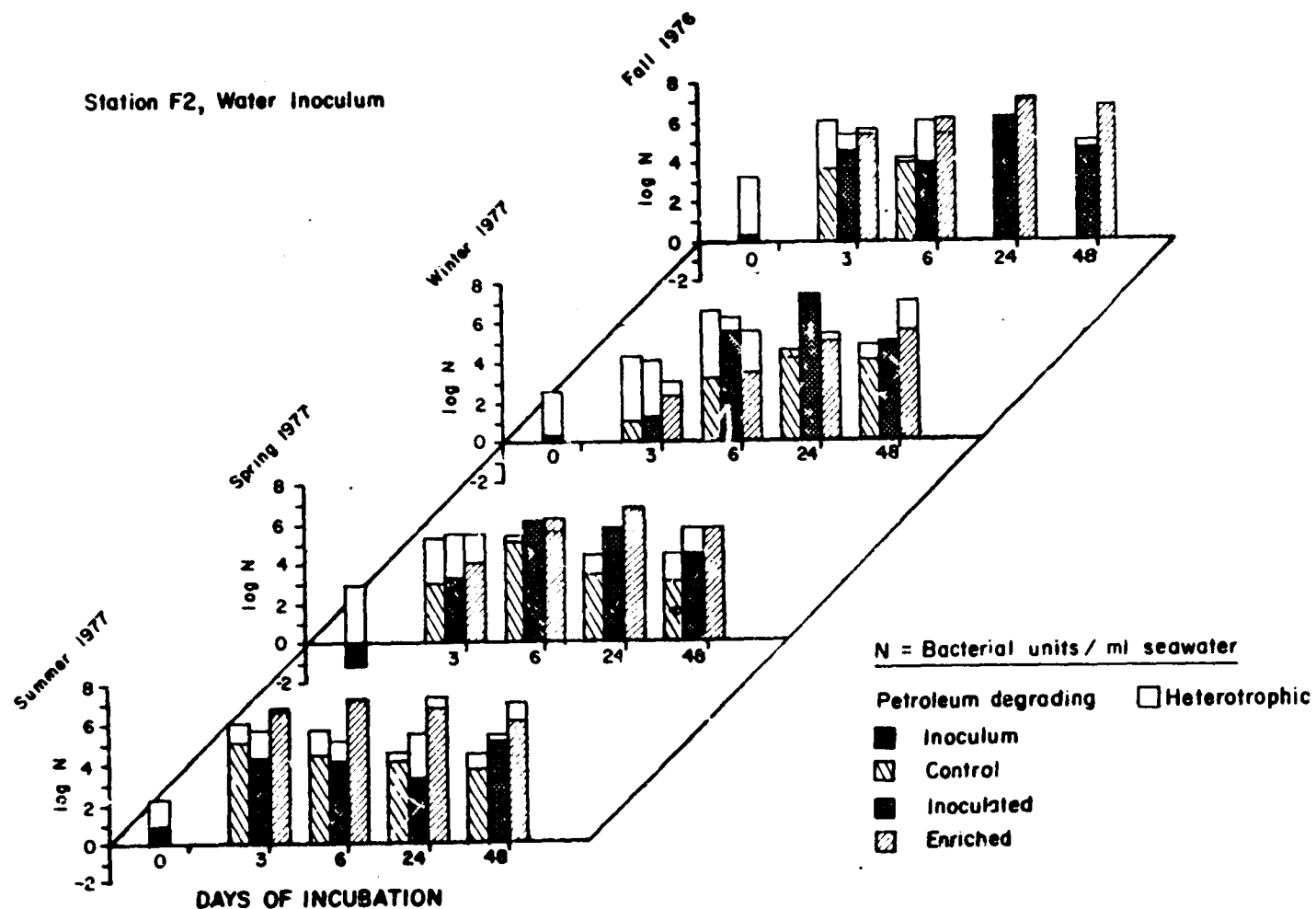


Figure 11-35. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

Station J1, Water Inoculum

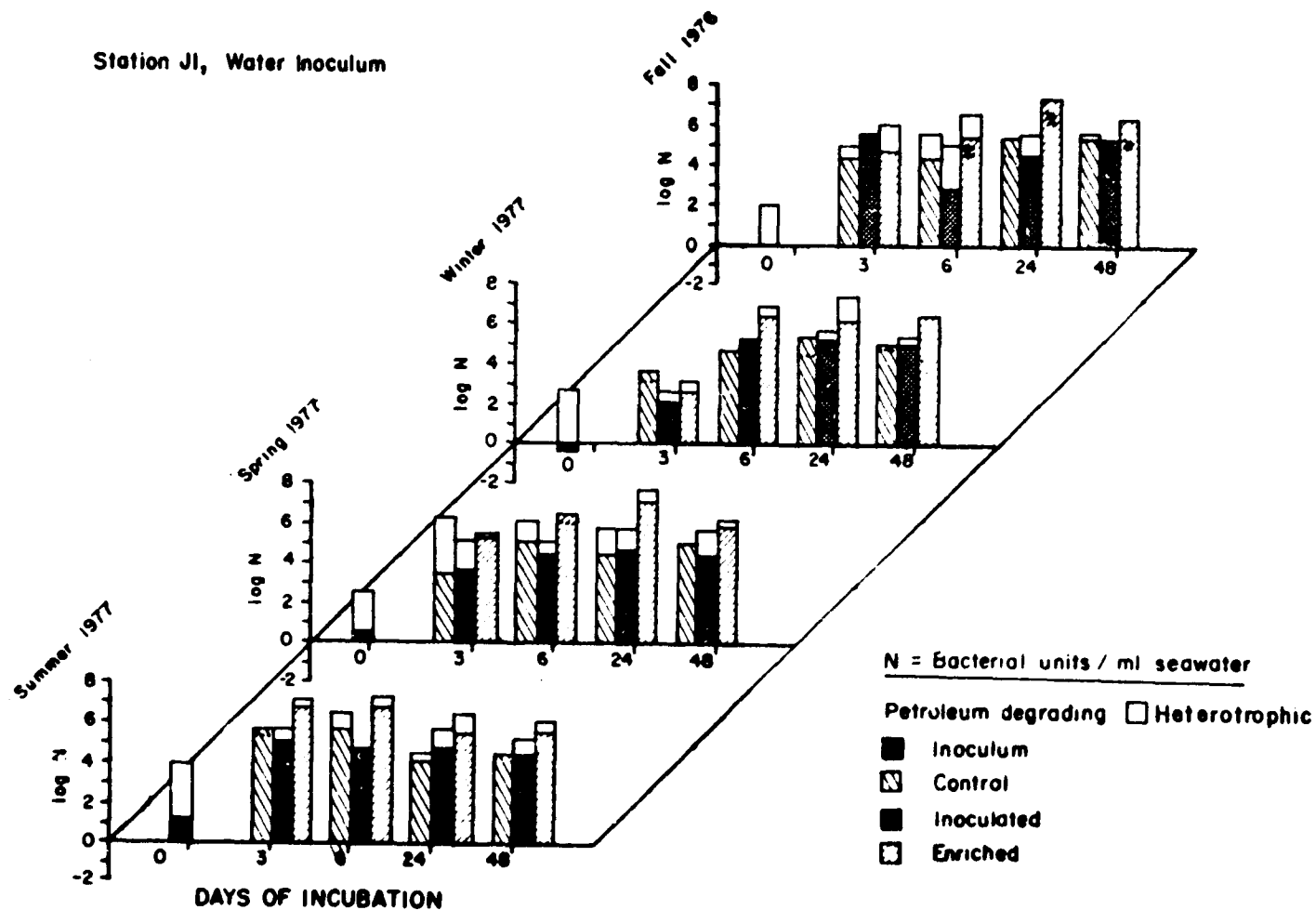


Figure 11-36. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

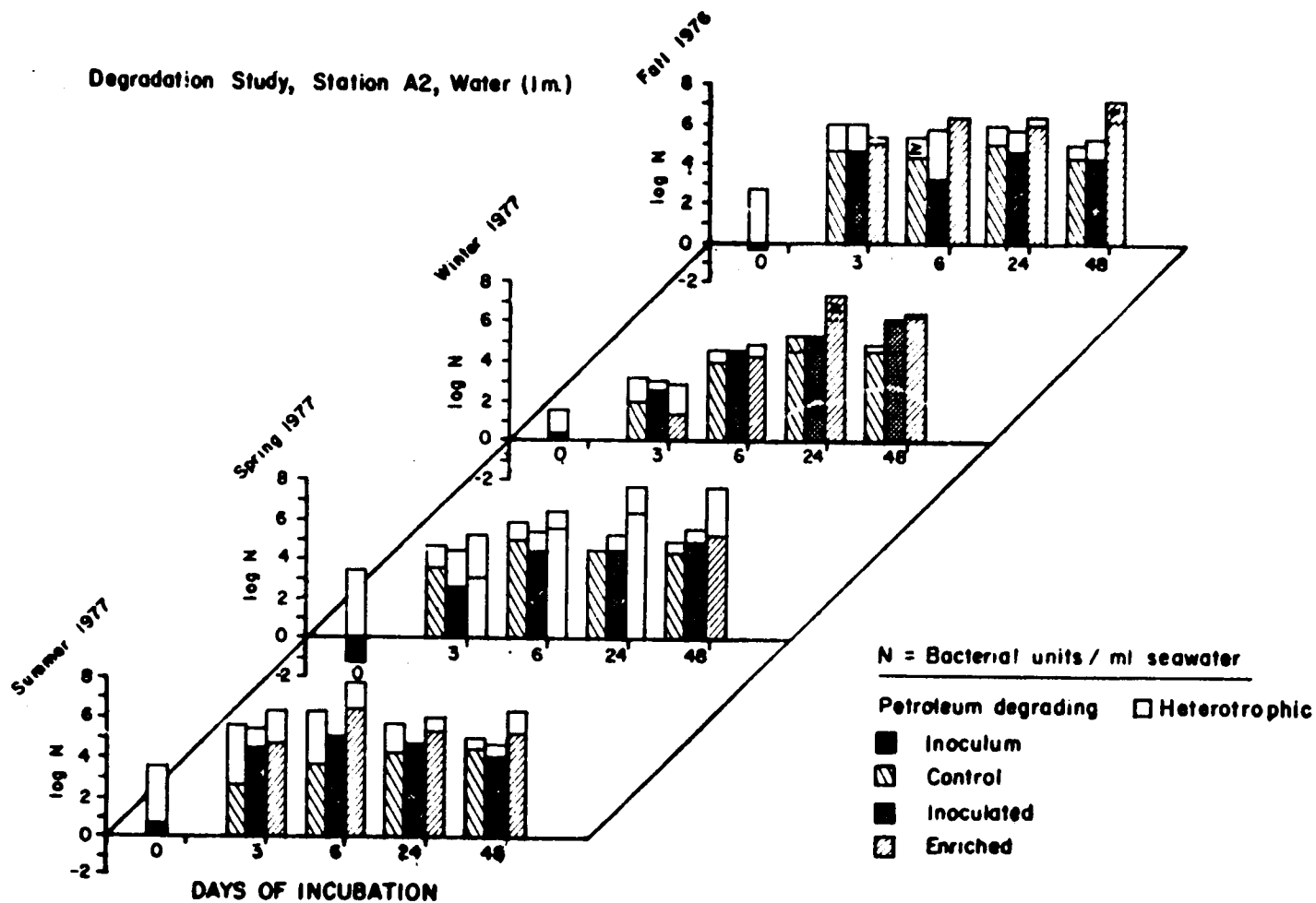


Figure 11-37. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

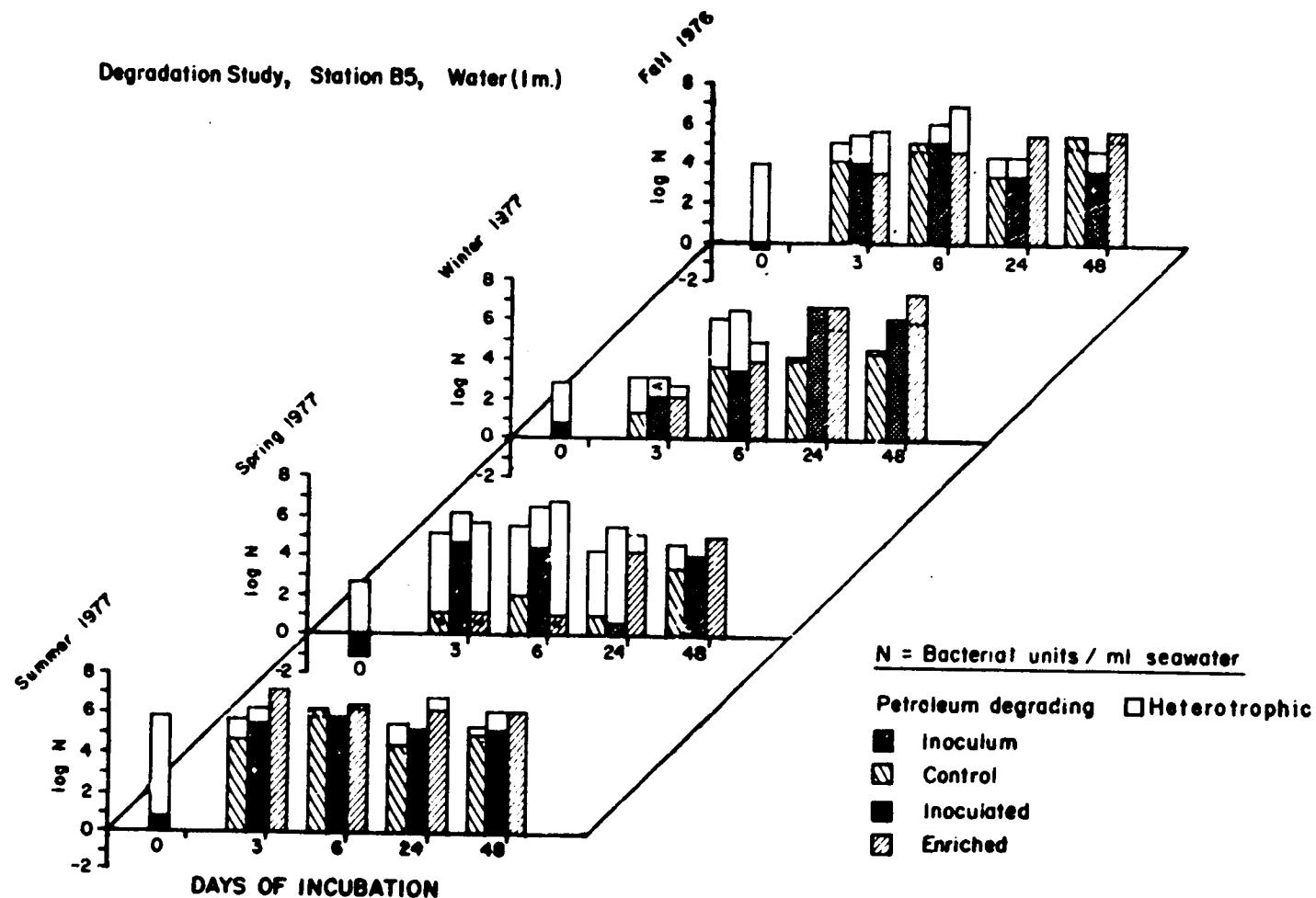


Figure 11-38. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.



Figure 11-39. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

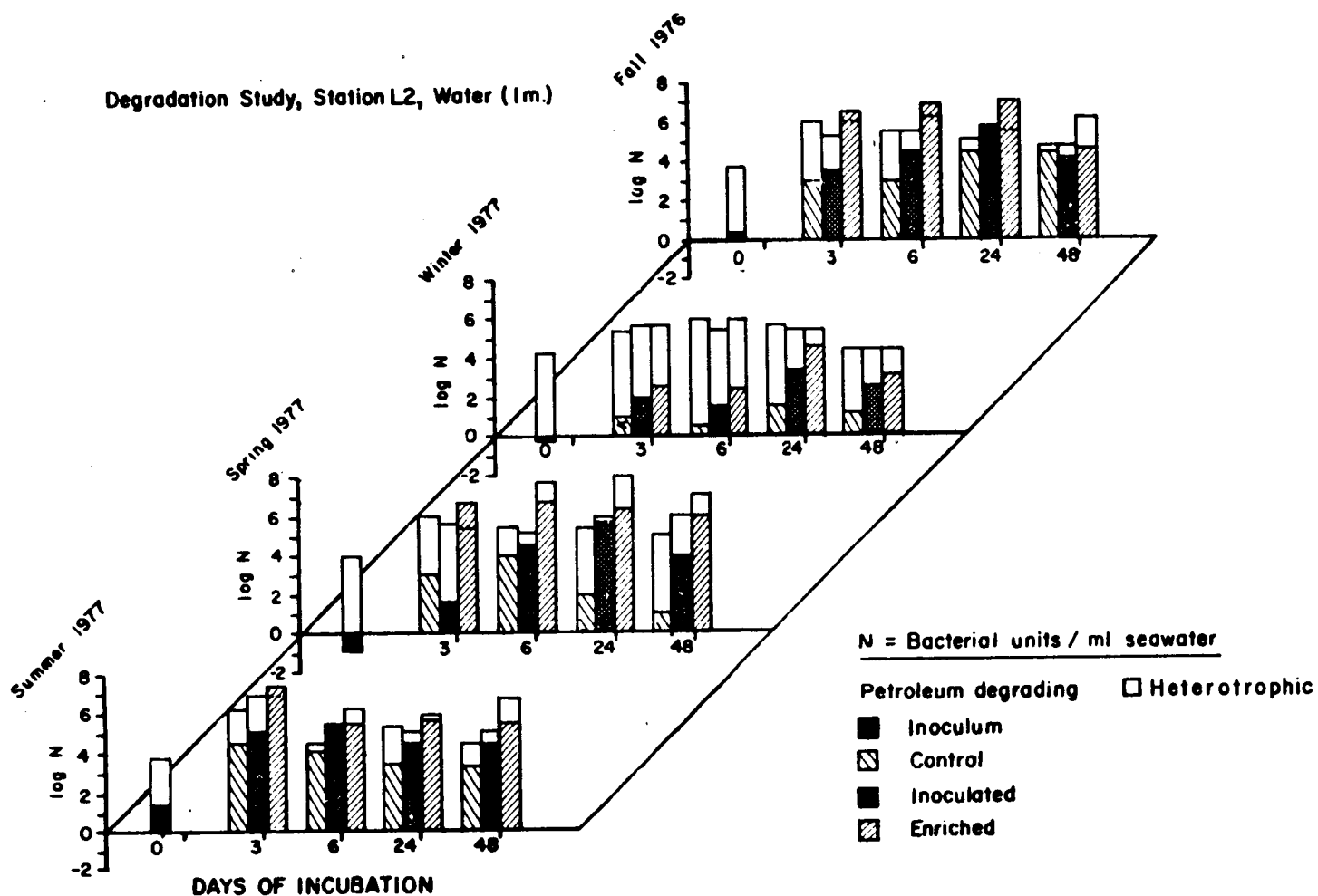


Figure 11-40. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

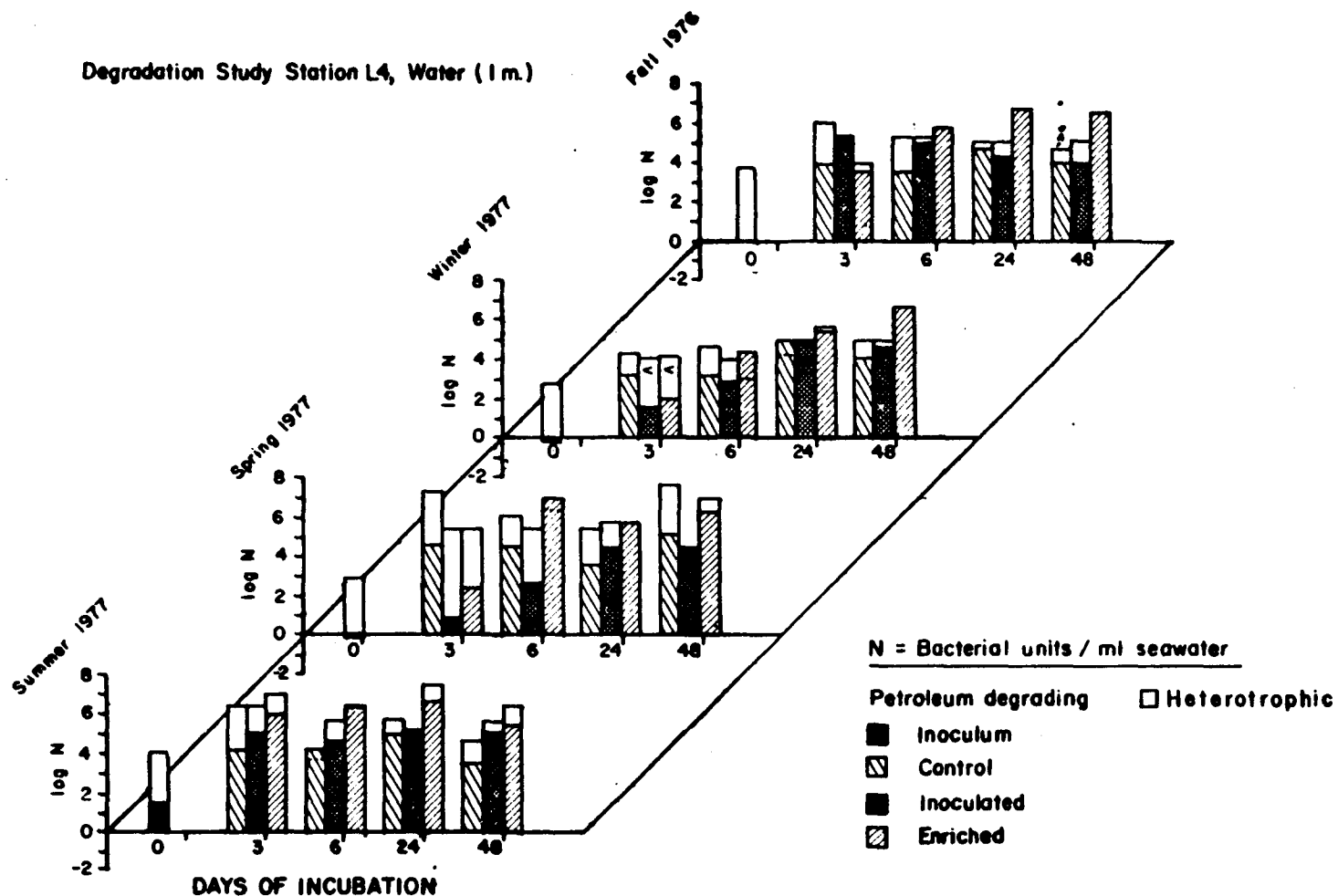


Figure 11-41. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

Degradation Study, Station L6, Water (Im.)

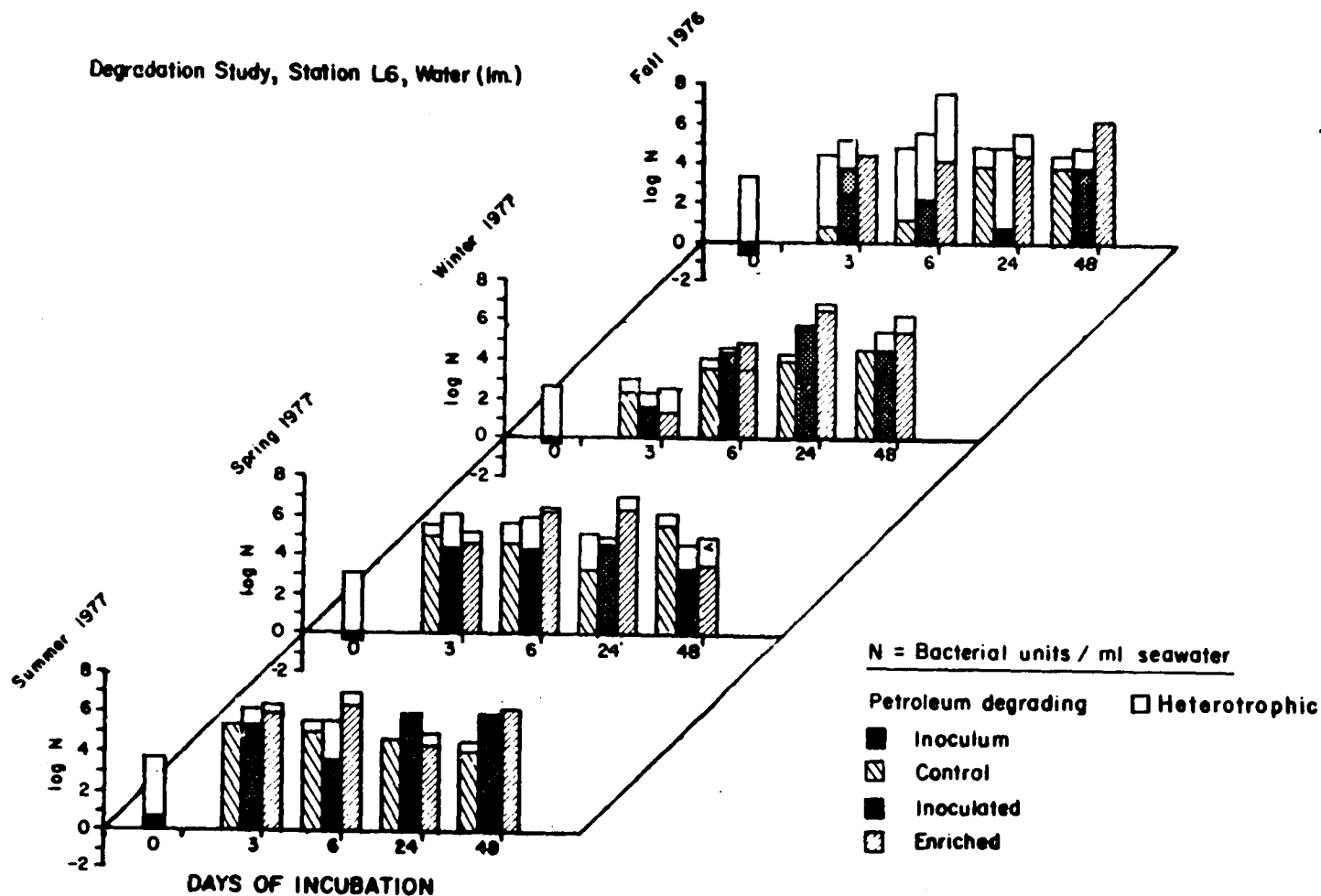


Figure 11-42. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: Control, seawater + inoculum; Inoculated, seawater + inoculum + petroleum; Enriched, seawater + inoculum + petroleum + inorganic nutrients.

Values of the ratio of HC to HET did not vary in consistent patterns or direction. Often low viable HC counts would yield relatively large ratios while conversely, high viable HC counts could yield small ratios.

Water Inocula, Analysis of Residual Petroleum. Results from gas chromatographic analysis of residual normal paraffins (nC_{10} - nC_{25}) are presented in Tables 11-38 through 11-41. Significant degradation was noted only in nutrient enriched flasks. Seasonal differences in the maximum amounts of n-paraffins degraded for all stations were observed with the maximum in the fall and the minimum in the winter. The absolute difference in n-paraffins degraded between these two seasons was approximately 25%. Spring and fall seasons exhibited essentially similar amounts of degradation. Summer, despite the highest incubation temperature (20°C), exhibited degradation comparable with winter. On an individual station basis, station location seemed to be more influential than season since individual stations generally exhibited results independent of season, e.g., the amounts of n-paraffins degraded were generally greater for inshore stations than for offshore stations. These results are similar to those obtained from first year experimental studies.

Patterns of n-paraffin degradation were similar for all flasks regardless of the inoculum source. Shorter chain length n-paraffins were first degraded followed by those with longer chain lengths while branched paraffins only were degraded after n-paraffins were no longer resolvable from the baseline envelope.

Two methods were used to evaluate the rates of n-paraffin degradation. In the first, the weights of residual n-paraffins (μg) were simply plotted against time over the incubation period (Figures 11-43 through 11-48). Rates (μg n-paraffins lost/day) were found to be non-linear with time. Maximum rates generally occurred within 3 to 6 days of incubation during all seasons except the winter. After six days degradation continued at a slower rate. During the winter, flasks incubated at 5°C exhibited a marked lag prior to expression of the maximum rates of degradation. Maximum winter rates of degradation usually occurred between 6 and 24 days of incubation. This lag was characteristic of all stations along the New Jersey and "L" transects during the winter. Comparisons with first year data from New Jersey transect degradation experiments yielded comparable results except during the spring (03B). During this season maximum rates of degradation occurred after a greater incubation interval than for the spring of 1977.

The other method used to compare rates of degradation was the D_{50} measurement (Table 11-42). D_{50} was defined as the days of incubation required for degradation of 50% of the n-paraffins selected (nC_{10} - nC_{25}). Values of D_{50} were smallest during the fall (most rapid degradation) and greatest in the winter and summer. During the fall, 10 of 12 station (both New Jersey and "L" transects) reached D_{50}

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Table 11-38. Change in summation of weights (μg) of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flask with seawater collected during BLM05B. % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
C1	Inoculated	0.0	(0.0)	0.0	(0.0)	302.3	(6.9)	9.7	(0.0)
	Enriched	0.0	(0.0)	130.9	(3.1)	1300.2	(29.2)	2585.2	(61.4)
D1	Inoculated	0.0	(0.0)	302.1	(6.7)	129.3	(2.9)	442.	(10.5)
	Enriched	0.0	(0.0)	600.2	(13.3)	2644.4	(58.7)	2672.9	(63.3)
E3	Inoculated	0.0	(0.0)	309.8	(6.0)	241.9	(5.2)	301.9	(6.9)
	Enriched	498.7	(13.5)	634.8	(12.4)	1563.5	(33.9)	2250.9	(51.2)
F2	Inoculated	0.0	(0.0)	219.8	(4.9)	31.8	(1.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	1110.6	(24.9)	1002.6	(23.9)	3442.8	(68.8)
J1	Inoculated	255.5	(5.5)	0.0	(0.0)	231.1	(5.6)	0.0	(0.0)
	Enriched	0.0	(0.0)	540.8	(11.6)	116.0	(2.8)	1116.9	(25.8)
N3	Inoculated	0.0	(0.0)	0.0	(0.0)	71.6	(1.7)	105.1	(2.4)
	Enriched	0.0	(0.0)	988.4	(21.7)	2535.9	(59.8)	3161.1	(72.1)
A2	Inoculated	0.0	(0.0)	38.5	(0.9)	0.0	(0.0)	394.7	(9.6)
	Enriched	0.0	(0.0)	1001.2	(24.5)	2306.3	(54.6)	1676.1	(40.8)
B5	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	65.6	(1.5)
	Enriched	0.0	(0.0)	1129.2	(24.6)	1859.5	(43.7)	1915.3	(45.2)
L1	Inoculated	31.9	(0.9)	0.0	(0.0)	361.2	(8.4)	0.0	(0.0)
	Enriched	238.4	(5.8)	957.3	(22.0)	2404.2	(55.9)	2879.1	(68.1)
L2	Inoculated	222.9	(5.3)	456.6	(10.4)	0.0	(0.0)	47.8	(1.1)
	Enriched	167.9	(4.1)	664.8	(15.2)	753.1	(19.9)	2835.3	(67.0)

Table 11-38. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
L4	Inoculated	0.0	(0.0)	60.5	(1.4)	183.6	(4.4)	0.0	(0.0)
	Enriched	321.7	(7.4)	913.8	(21.2)	1892.1	(45.6)	2171.6	(59.4)
L6	Inoculated	0.0	(0.0)	282.0	(6.4)	56.6	(1.4)	0.0	(0.0)
	Enriched	562.8	(15.6)	210.2	(4.8)	2096.9	(50.9)	2484.0	(66.3)

a) % weight loss = 100 $\left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{control flask}} \right) \right]$

- b) Inoculated = seawater + sterile oil
 Enriched = seawater + sterile oil + nutrient amendment

Table 11-39. Change in summation of weights (μg) of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flasks with seawater collected during BLM06B, % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
C1	Inoculated	61.4	(1.5)	216.3	(4.8)	118.	(2.6)	147.0	(3.6)
	Enriched	0.0	(0.0)	123.7	(2.8)	0.0	(0.0)	2202.1	(53.2)
D1	Inoculated	294.9	(6.8)	30.0	(0.7)	354.8	(8.0)	175.6	(4.0)
	Enriched	154.8	(3.6)	100.0	(2.2)	1022.5	(23.1)	1051.5	(24.0)
E3	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	373.0	(8.2)
	Enriched	193.4	(4.2)	163.7	(4.5)	647.2	(15.5)	1539.3	(33.9)
F2	Inoculated	0.0	(0.0)	0.0	(0.0)	291.0	(6.5)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	1579.4	(35.1)	1384.3	(30.7)
J1	Inoculated	0.0	(0.0)	303.2	(7.4)	91.9	(2.1)	320.4	(8.6)
	Enriched	0.0	(0.0)	0.0	(0.0)	1531.4	(34.9)	1362.0	(36.4)
N3	Inoculated	371.7	(7.3)	0.0	(0.0)	232.1	(5.2)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	1156.5	(25.8)	1031.5	(25.7)
A2	Inoculated	0.0	(0.0)	0.0	(0.0)	318.9	(7.1)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	448.0	(10.0)	771.4	(19.5)
B5	Inoculated	0.0	(0.0)	367.7	(9.3)	0.0	(0.0)	258.5	(6.5)
	Enriched	0.0	(0.0)	0.0	(0.0)	1345.8	(32.9)	0.0	(0.0)
L1	Inoculated	0.0	(0.0)	0.0	(0.0)	444.5	(10.0)	59.0	(1.3)
	Enriched	0.0	(0.0)	0.0	(0.0)	1279.5	(28.8)	2377.1	(43.7)
L2	Inoculated	0.0	(0.0)	98.9	(2.2)	205.7	(5.1)	71.8	(1.7)
	Enriched	58.4	(1.4)	0.0	(0.0)	681.5	(16.8)	1399.0	(33.6)

Table 11-39. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
L4	Inoculated	0.0	(0.0)	0.0	(0.0)	476.4	(10.3)	360.9	(8.9)
	Enriched	52.2	(1.2)	0.0	(0.0)	1025.8	(22.2)	1142.9	(28.1)
L6	Inoculated	0.0	(0.0)	358.9	(9.0)	0.0	(0.0)	230.7	(5.3)
	Enriched	0.0	(0.0)	184.0	(4.5)	757.0	(21.6)	1545.4	(35.3)

a) % weight loss = $100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{ treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{ control flask}} \right) \right]$

b) Inoculated = seawater + sterile oil

Enriched = seawater + sterile + nutrient amendment

Table 11-40. Change in summation of weights (μg) of crude oil n-paraffins ($\text{nC}_{10} - \text{nC}_{25}$) during incubation in closed flasks with seawater collected during BLM07B, % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
C1	Inoculated	0.0	(0.0)	296.5	(6.4)	139.3	(2.8)	0.0	(0.0)
	Enriched	68.0	(1.7)	1221.3	(26.3)	2439.0	(49.1)	2221.5	(54.5)
D1	Inoculated	0.0	(0.0)	158.6	(3.5)	217.8	(4.6)	125.5	(3.1)
	Enriched	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
E ²	Inoculated	0.0	(0.0)	0.0	(0.0)	25.5	(0.6)	0.0	(0.0)
	Enriched	0.0	(0.0)	71.8	(1.7)	1890.3	(43.8)	1979.4	(50.7)
F2	Inoculated	0.0	(0.0)	246.5	(5.4)	129.6	(2.8)	0.0	(0.0)
	Enriched	289.1	(7.0)	37.1	(0.8)	1839.8	(39.5)	1276.0	(28.3)
J1	Inoculated	299.9	(6.9)	0.0	(0.0)	263.8	(6.8)	0.0	(0.0)
	Enriched	231.7	(5.3)	764.3	(16.6)	411.4	(10.6)	2082.6	(54.1)
N3	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	360.6	(8.0)
	Enriched	172.6	(4.0)	431.9	(9.8)	1361.4	(30.2)	N.S.	N.S.
A2	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	438.2	(11.1)
	Enriched	91.3	(2.2)	993.1	(24.2)	1226.3	(36.0)	2187.1	(55.4)
B5	Inoculated	145.1	(3.3)	0.0	(0.0)	0.0	(0.0)	248.2	(5.9)
	Enriched	0.0	(0.0)	41.7	(1.0)	607.5	(15.6)	422.4	(10.0)
L1	Inoculated	0.0	(0.0)	193.0	(4.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	1033.7	(21.6)	1217.4	(33.6)	2733.8	(70.9)
L2	Inoculated	0.0	(0.0)	169.6	(3.5)	451.9	(11.1)	0.0	(0.0)
	Enriched	453.5	(11.0)	1560.1	(32.5)	2116.7	(52.3)	3463.8	(76.6)

Table 11-40. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
L4	Inoculated	0.0	(0.0)	0.0	(0.0)	179.4	(4.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	1773.8	(44.3)	1503.5	(33.3)	1246.7	(32.4)
L6	Inoculated	0.0	(0.0)	0.0	(0.0)	110.8	(2.7)	0.0	(0.0)
	Enriched	0.0	(0.0)	481.1	(13.9)	345.9	(8.4)	1600.2	(43.4)

a) % weight loss = $100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{control flask}} \right) \right]$

b) Inoculated = seawater + sterile oil

Enriched = seawater + sterile oil + nutrient amendment

N.S. - No Sample

Table 11-41. Change in summation of weights (μg) of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flask with seawater collected during BLM08B. % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
C1	Inoculated	0.0	(0.0)	64.0	(1.4)	269.4	(6.1)	0.0	(0.0)
	Enriched	0.0	(0.0)	831.2	(17.7)	1875.9	(42.2)	1275.3	(27.4)
D1	Inoculated	287.7	(6.4)	16.6	(0.0)	0.0	(0.0)	229.8	(5.1)
	Enriched	588.8	(13.1)	909.9	(20.4)	1067.6	(25.7)	1826.0	(40.4)
E3	Inoculated	176.5	(4.0)	0.0	(0.0)	0.0	(0.0)	107.9	(2.3)
	Enriched	0.0	(0.0)	488.3	(11.0)	42.9	(1.0)	594.5	(14.2)
F2	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	258.1	(5.6)
	Enriched	73.8	(1.8)	0.0	(0.0)	1120.4	(26.2)	926.3	(20.0)
J1	Inoculated	0.0	(0.0)	122.8	(2.9)	318.9	(7.2)	213.1	(5.1)
	Enriched	211.7	(5.1)	89.7	(2.1)	1155.3	(26.2)	752.9	(17.9)
N3	Inoculated	148.0	(3.5)	0.0	(0.0)	0.0	(0.0)	123.0	(2.9)
	Enriched	343.7	(7.8)	557.7	(15.9)	2179.0	(54.6)	3021.1	(70.1)
A2	Inoculated	433.6	(9.2)	0.0	(0.0)	365.8	(8.6)	0.0	(0.0)
	Enriched	882.8	(18.8)	718.6	(18.1)	1563.4	(37.1)	315.3	(8.2)
B5	Inoculated	0.0	(0.0)	57.1	(1.4)	101.2	(2.5)	318.9	(7.7)
	Enriched	1146.5	(28.0)	991.7	(24.3)	1536.5	(38.4)	1860.5	(45.1)
L1	Inoculated	0.0	(0.0)	57.2	(1.4)	109.3	(2.6)	625.5	(14.3)
	Enriched	826.3	(20.5)	616.1	(14.9)	699.3	(16.7)	2088.1	(47.8)
L2	Inoculated	210.6	(5.0)	0.0	(0.0)	162.2	(4.1)	0.0	(0.0)
	Enriched	990.1	(23.4)	509.8	(12.6)	687.2	(17.4)	740.0	(17.6)

Table 11-41. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
L4	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	232.0	(5.9)	769.8	(19.2)	1563.3	(42.5)	743.3	(18.3)
L6	Inoculated	177.7	(4.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	758.2	(17.3)	646.8	(16.1)	828.3	(20.8)	1342.2	(34.2)

a) % weight loss = $100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10} - \text{nC}_{25}, \text{control flask}} \right) \right]$

b) Inoculated = seawater + sterile oil

Enriched = seawater + sterile oil + nutrient amendment

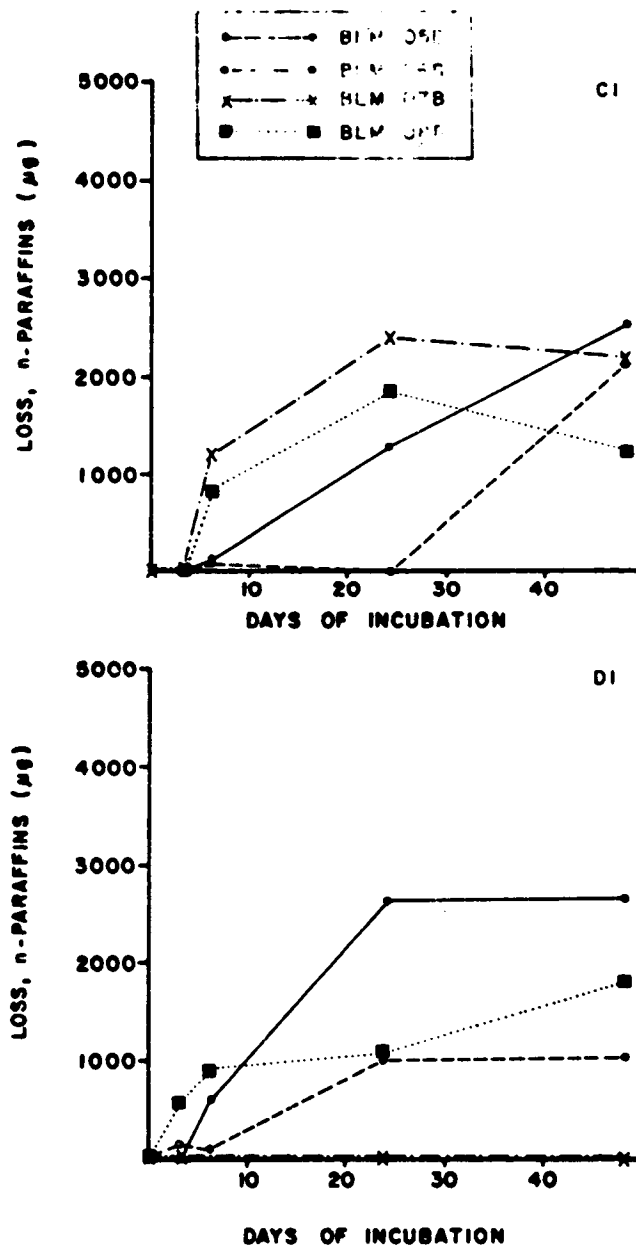


Figure 11-43. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

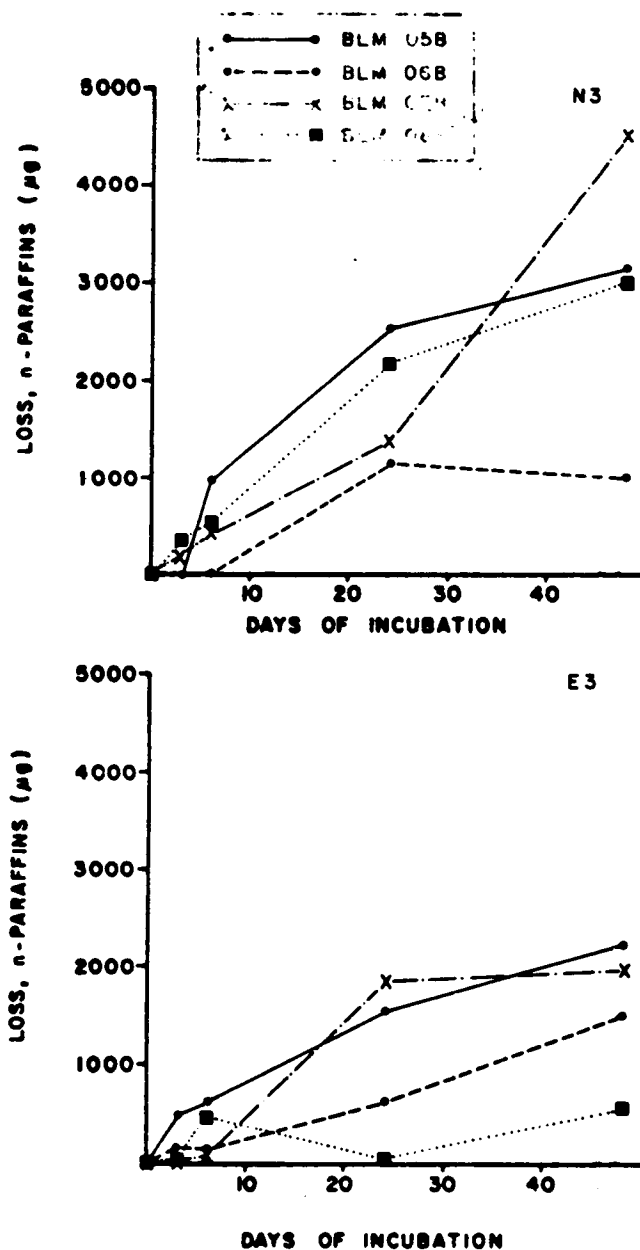


Figure 11-44. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins C}_{10} - \text{C}_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

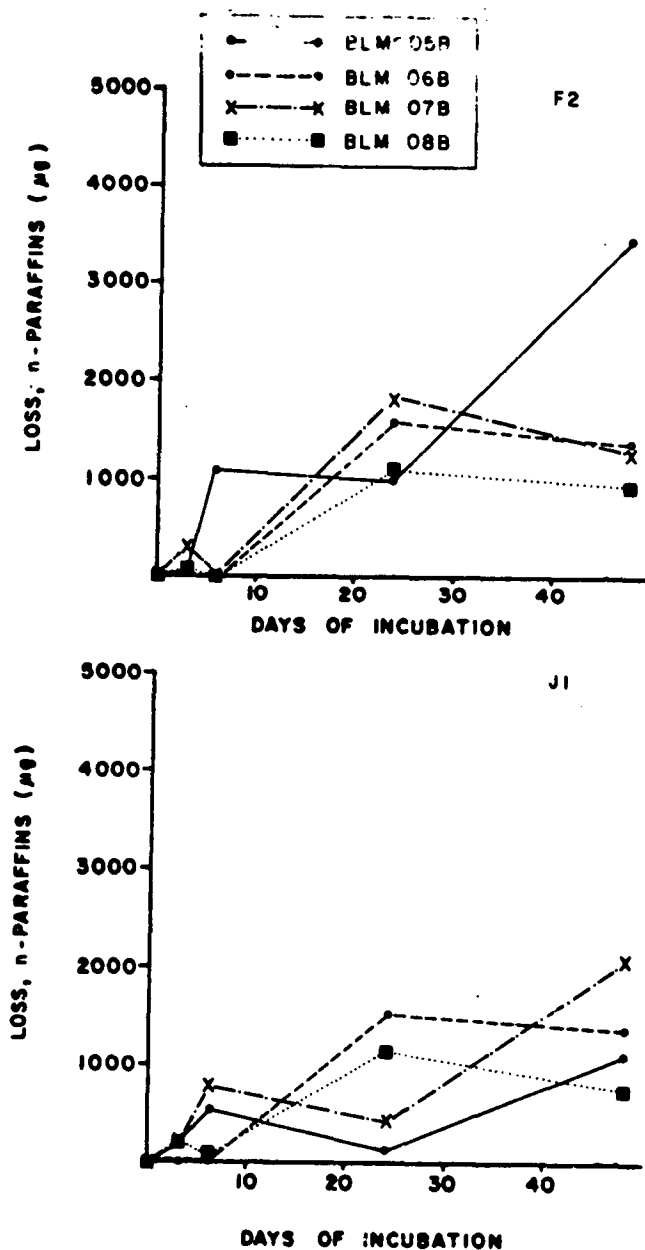


Figure 11-45. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins C}_{10} - \text{C}_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

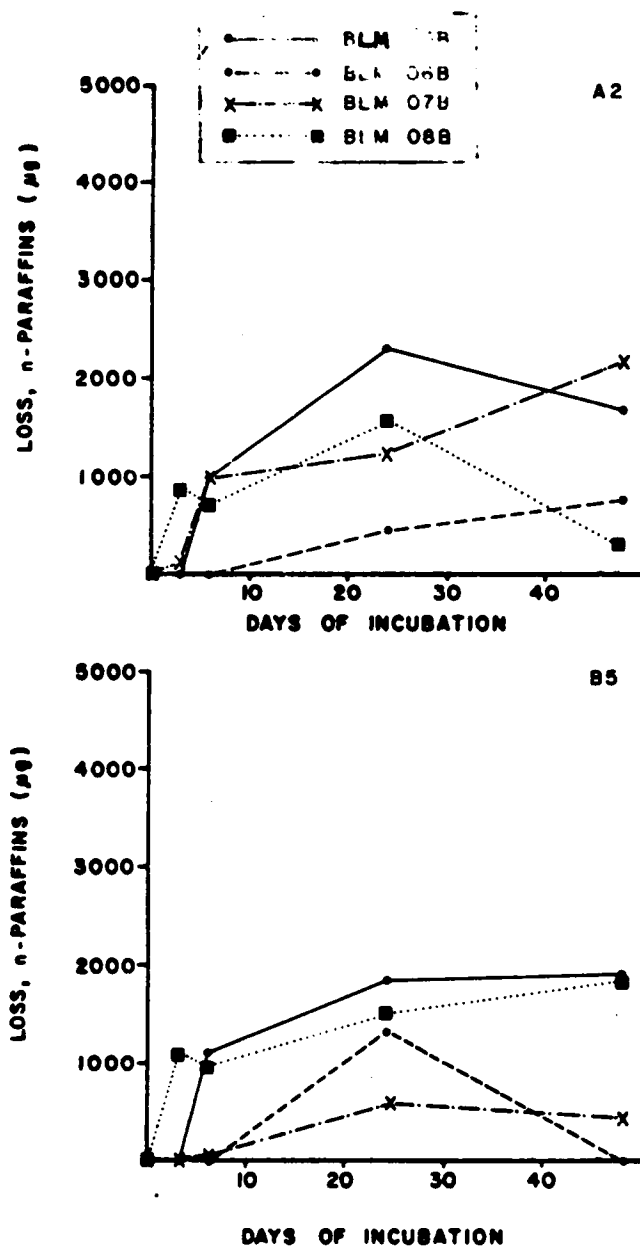


Figure 11-46. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

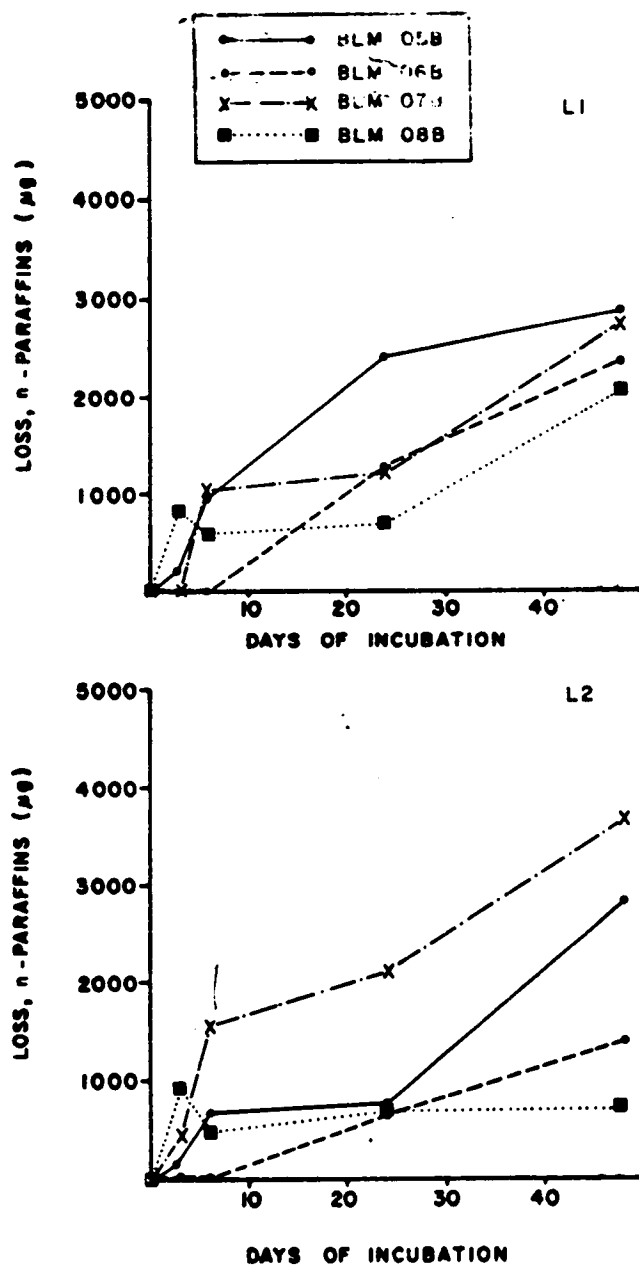


Figure 11-47. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins C}_{10}\text{-C}_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

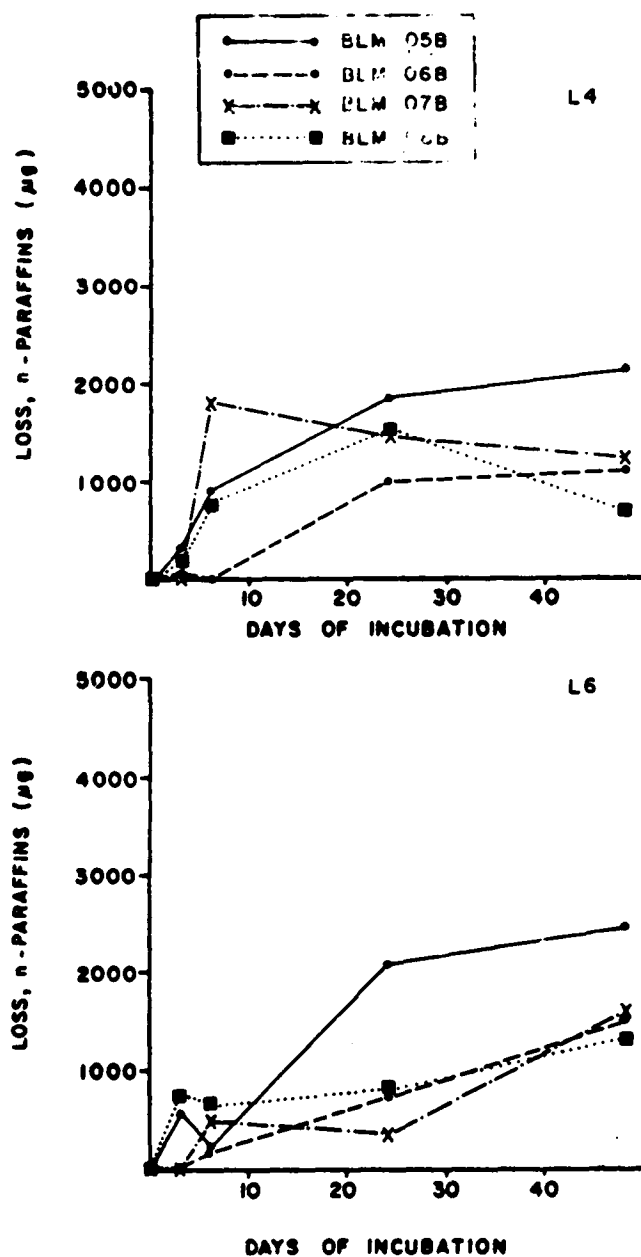


Figure 11-48. n-Paraffin losses in closed flasks containing seawater from selected stations treated with South Louisiana crude oil and receiving inorganic nutrient salts amendment loss = $\Sigma(\mu\text{g n-paraffins } C_{10}-C_{25})$, sterile control flask, $\Sigma(\mu\text{g n-paraffins } C_{10} - C_{25})$ enriched flask. Seasons: 05B = Fall 1976, 06B = Winter 1977, 07B = Spring 1977, 08B = Summer 1977.

Table 11-42. Days of incubation required for degradation^a of 50% (D₅₀)^b of n-paraffins (nC₁₀ - nC₂₅) in closed flasks from petroleum degradation experiments using seawater inocula collected during BLM 05B-08B.

Station	Treatment ^c	Cruise			
		05B	06B	07B	08B
C1	I	NR	NR	NR	NR
	E	48	48	48	NR
D1	I	NR	NR	NR	NR
	E	24	NR	NR	NR
N3	I	NR	NR	NR	NR
	E	24	NR	48	24
E3	I	NR	NR	NR	NR
	E	48	NR	48	NR
F2	I	NR	NR	NR	NR
	E	48	NR	NR	NR
J1	I	NR	NR	NR	NR
	E	NR	NR	48	NR
A2	I	NR	NR	NR	NR
	E	24	NR	48	NR
B5	I	NR	NR	NR	NR
	E	NR	NR	NR	NR
L1	I	NR	NR	NR	NR
	E	24	NR	48	NR
L2	I	NR	NR	NR	NR
	E	48	NR	24	NR
L4	I	NR	NR	NR	NR
	E	48	NR	NR	NR
L6	I	NR	NR	NR	NR
	E	24	NR	NR	NR

a - Degradation based on weight loss in treated flask as compared to control

b - D₅₀ = Incubation period during which degradation was first observed to be 50% or more when compared to control

c - I = seawater plus sterile oil

E = Seawater plus sterile oil plus nutrient amendment

NR - The amount of degradation never reaching the 50% level

levels, as opposed to only 1 of 12 in both summer and winter seasons. On an individual station basis, both C1 and N3 reached D₅₀ levels in 3 of the 4 seasons while B5 never exhibited 50% degradation of n-paraffins.

Compared to first year New Jersey transect degradation experiments, second year D₅₀ values were also smallest during the fall and largest during the summer. Station C1 also exhibited the largest and most consistent degradation potential and Station J1 the lowest over the two year period. During the first year, Station F2 manifested a degradation potential close to that of Station C1. However, in the second year only Station N3 possessed a degradation potential similar to C1.

Comparison of the New Jersey and "L" transects indicated similar results for patterns, rates, and extent of degradation. A decrease in the amount of degradation with distance from land was observed for all seasons but the fall. During the fall the amounts of degradation were rather uniform for stations comprising the "L" transect. As described for the New Jersey transect, similar seasonal patterns were observed with the fall having the greatest degradation and the winter the least.

Rates of degradation were generally directly related to viable counts of HC and the value of the ratio of HC to HET in flasks treated with nutrient enrichment. Thus, significant degradation was associated with levels of HC elevated above those in oil-free controls. Usually, elevated HC viable counts were observed during the incubation interval prior to detection of measurable degradation. However, increases in viable counts of HC above oil-free control values certainly suggests response to petroleum as a substrate. Values of the ratio of HC to HET did not necessarily increase with increased degradation during incubation although in some cases parallel responses were noted.

Water Inocula, Taxonomy. Preliminary analysis of taxonomic data from New Jersey transect degradation experiments indicated that dominant bacterial genera changed during incubation. The initial inocula were dominated by approximately equivalent proportions of four genera during all seasons. These genera were Alcaligenes, Flavobacterium, Pseudomonas, and Vibrio. Depending on genus, these genera were isolated at various incubation intervals with increasing or decreasing frequencies. In general, the proportion of all isolates obtained from HM that were Alcaligenes and Pseudomonas increased as incubation progressed while Flavobacterium and Vibrio decreased. Heterotroph isolates from enriched flasks possessed higher percentages of Pseudomonas than Alcaligenes at 48 days while the reverse was true for oil-free and inoculated flasks. The percentage of isolates that were Pseudomonas increased with time for all treatments using ESWB plus petroleum medium while Vibrio decreased and Alcaligenes remained constant. Flavobacterium populations in enriched flasks initially

decreased and then increased. Preliminary examination of the relationships of the four dominant genera to the amount of degradation over time suggested increases in Pseudomonas frequency of isolation paralleled increased degradation while the increase in Flavobacterium isolation frequency took place after significant degradation had occurred.

Sediment Inocula, Enumeration. Results of these experiments are summarized in Appendix 2 and Figures 11-49 through 11-60. Stations were selected and grouped into ridges and troughs for examination of seasonal and geographic trends. Geometric means of viable counts were calculated for all ridge and all swale stations as functions of incubation interval.

During incubation, mean viable counts of heterotrophs from ridge inocula tended to increase for all treatments and all seasons except winter. Enriched flasks during this season possessed the lowest viable counts of all seasons. The strong seasonal influence of winter on viable heterotroph counts was especially evident with nearshore ridge stations C1 and D1. Rates of increase of viable heterotroph counts were lower during the winter for ridge stations. Mean viable heterotroph counts using trough inocula increased slightly during all seasons and for all treatments. These increases were slightly greater than initial values for all seasons except winter. During winter increases in the relatively low initial mean viable counts resulted in a larger absolute viable count difference. However, there were virtually no differences in the mean maximum viable counts ultimately reached for any season or treatment using trough inocula.

Contrasting ridges vs. troughs, maximum mean viable counts reached in spring and summer (all treatments) and winter (enriched flasks only) were greater for troughs. During the fall, there was no difference in mean heterotroph counts when ridges and swales were compared.

Mean viable counts of petroleum-degrading bacteria increased during incubation for all seasons and for all treatments using inocula from ridge stations. Extent of increase varied with season and sometimes with treatment. During the winter and spring only small increases were observed. These increases were about equal for all treatments. Viable counts of petroleum-degraders in enriched flasks were greater in the fall than in either inoculated or oil-free control flasks. Petroleum-degrader viable counts during the summer were greater in flasks with oil than in oil-free control flasks. Similarly, during all seasons and with all treatments, trough stations exhibited increases in mean viable counts. During the fall, flasks enriched with inorganic nutrients exhibited a mean viable count of greater magnitude than either inoculated or oil-free control flasks. During the winter increases in the mean viable count of petroleum-degrading bacteria from enriched flasks were less than in the fall and about the same as those noted in the oil-free control and

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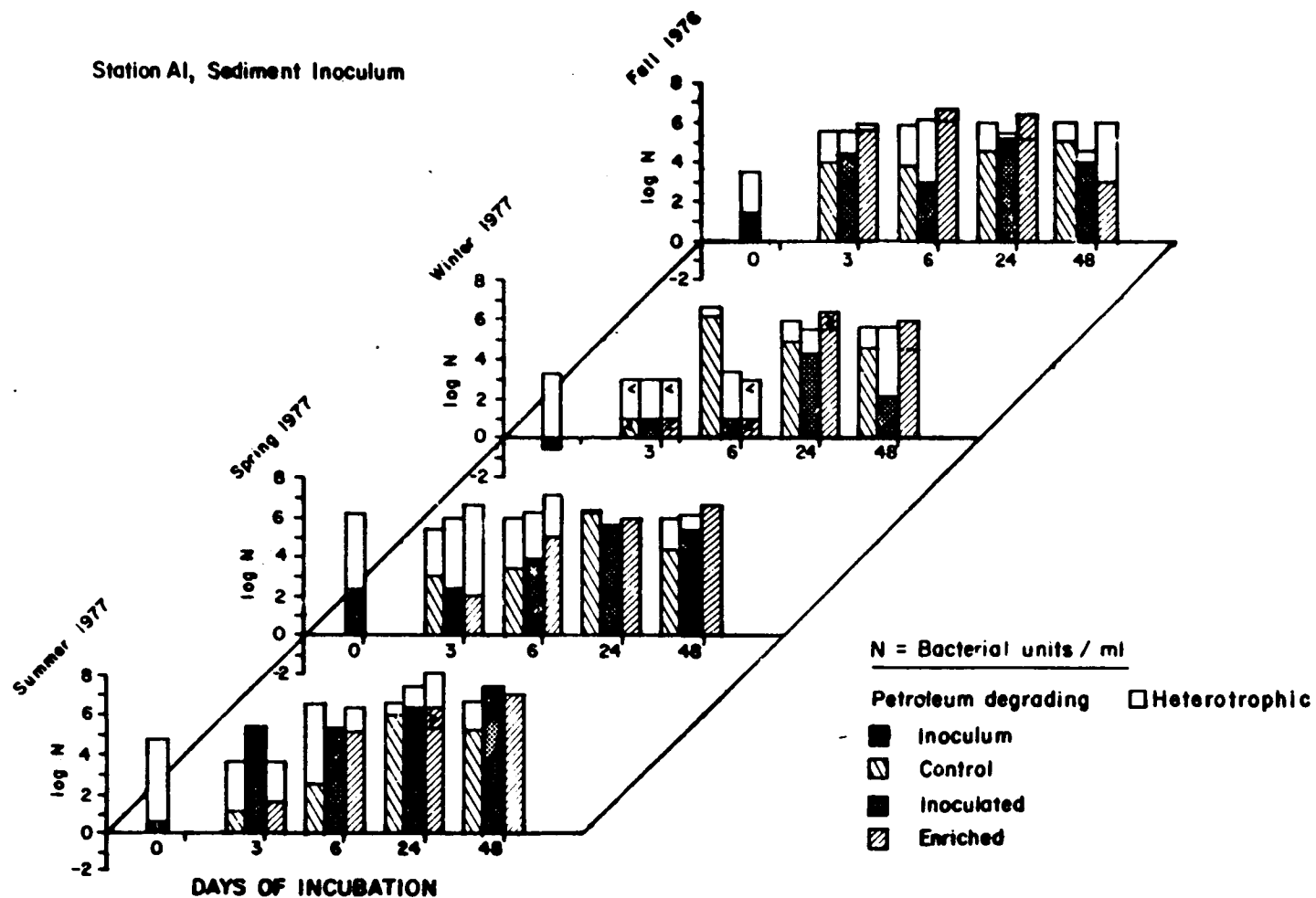


Figure 11-49. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

Station A4, Sediment Inoculum

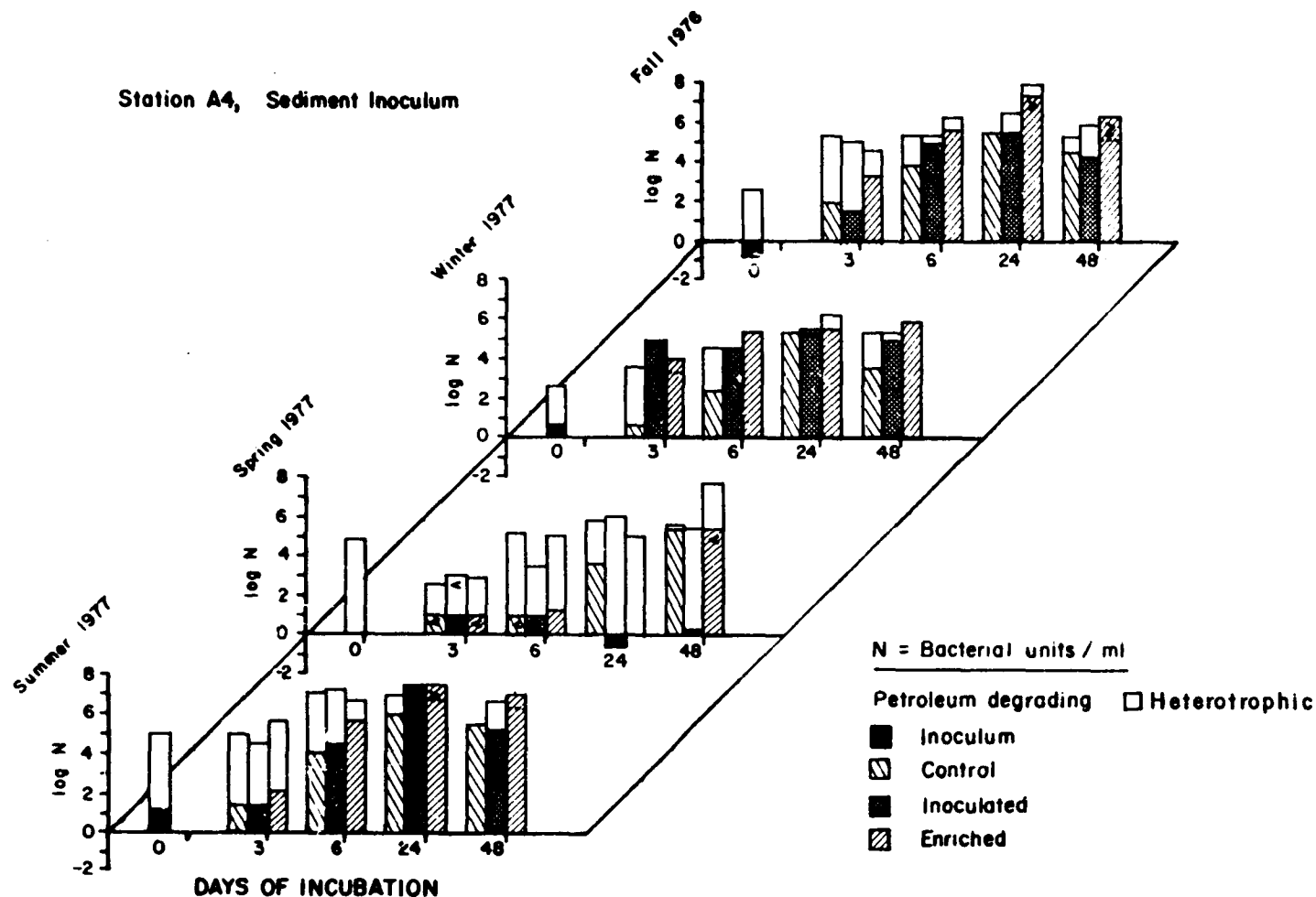


Figure 11-50. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

Station B2, Sediment Inoculum

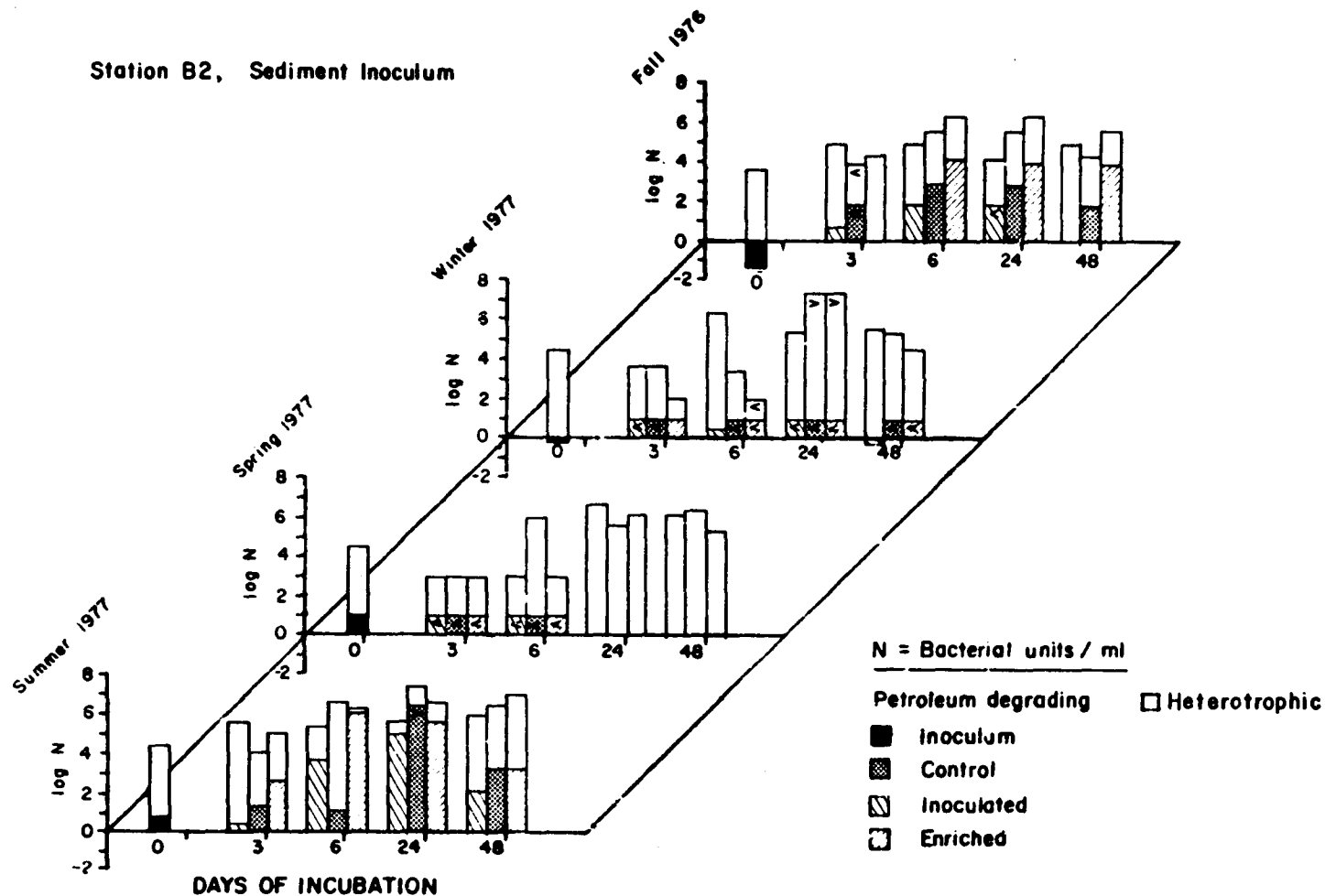


Figure 11-51.

Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

Station B3, Sediment Inoculum

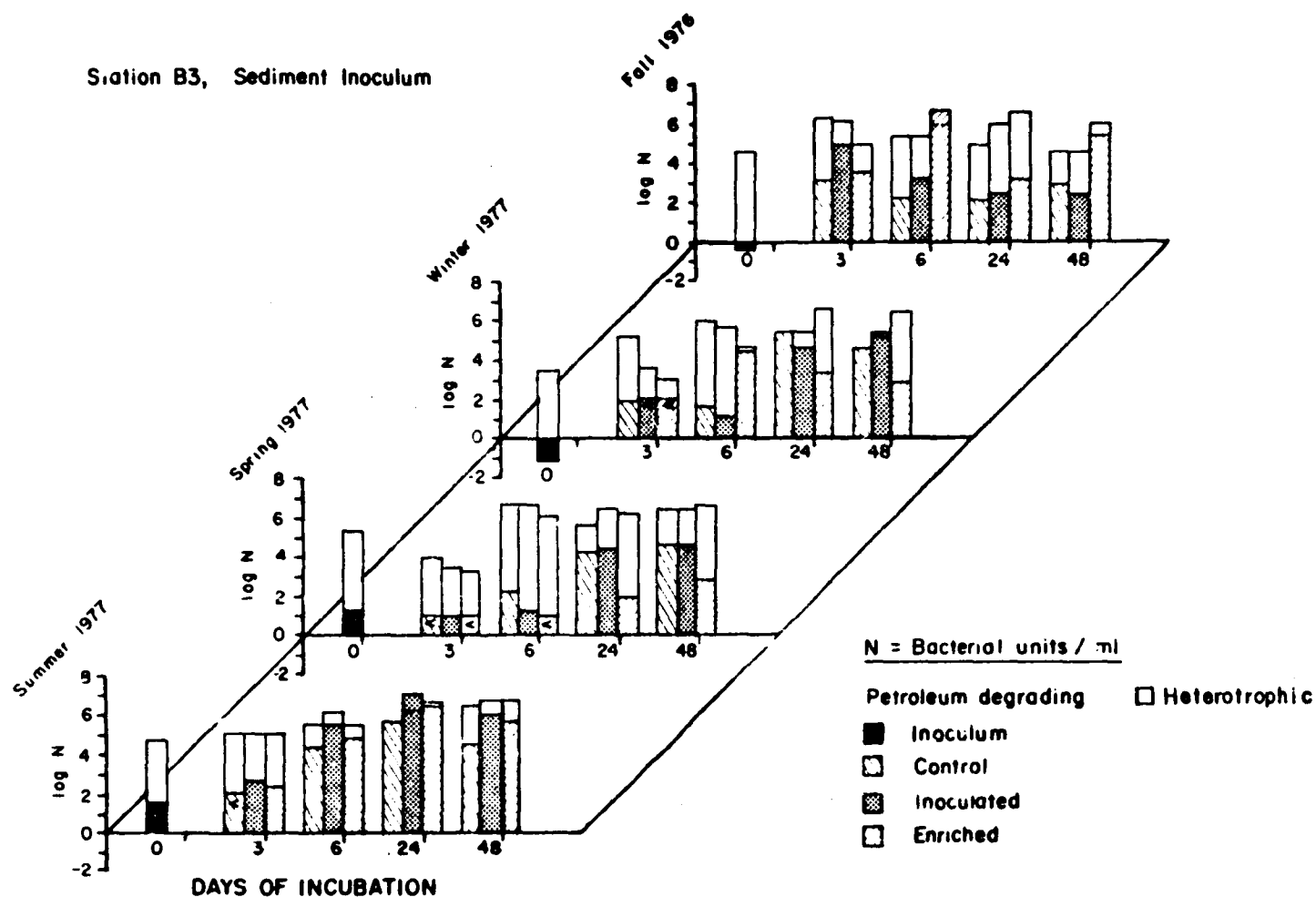


Figure 11-52. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

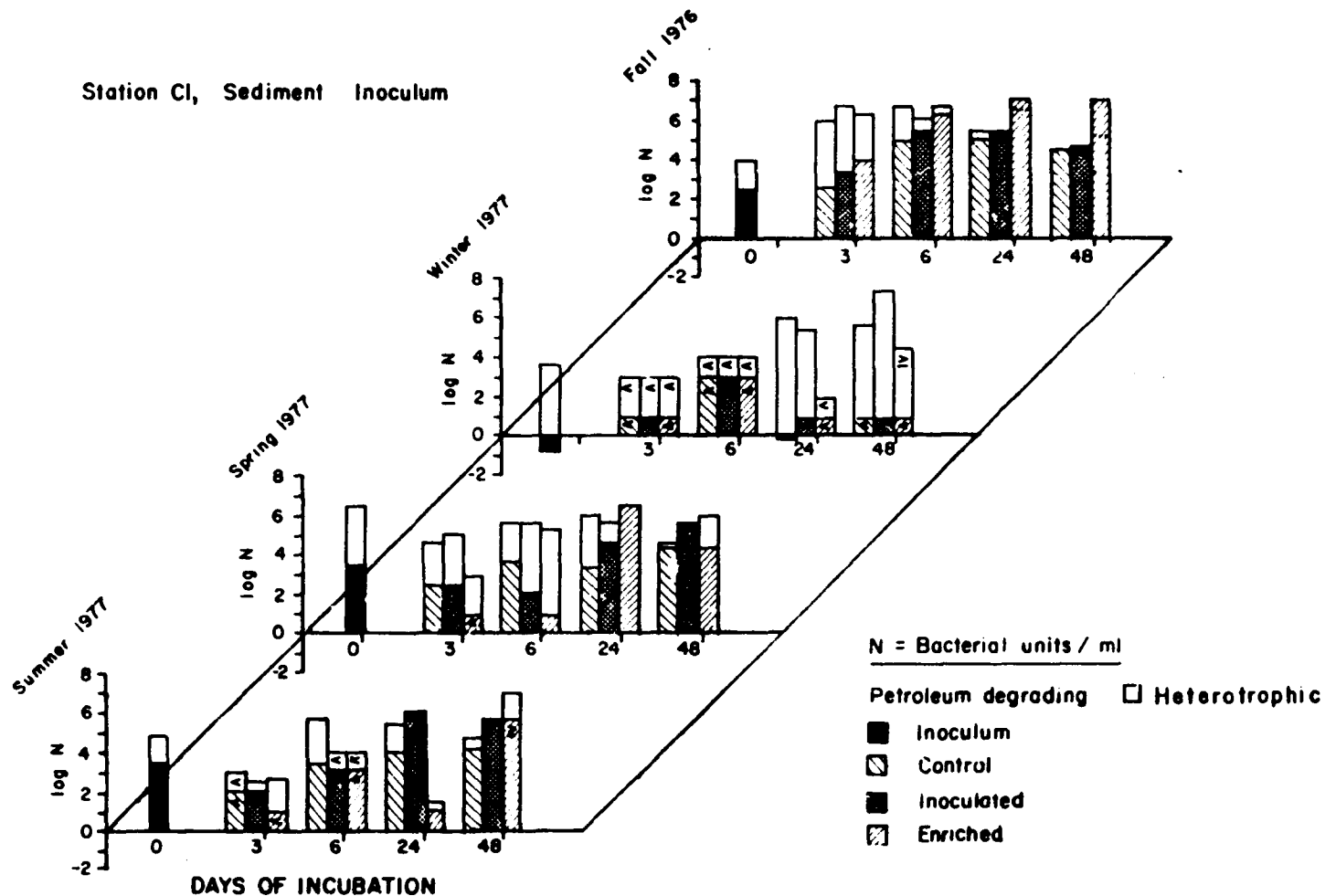


Figure 11-53. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

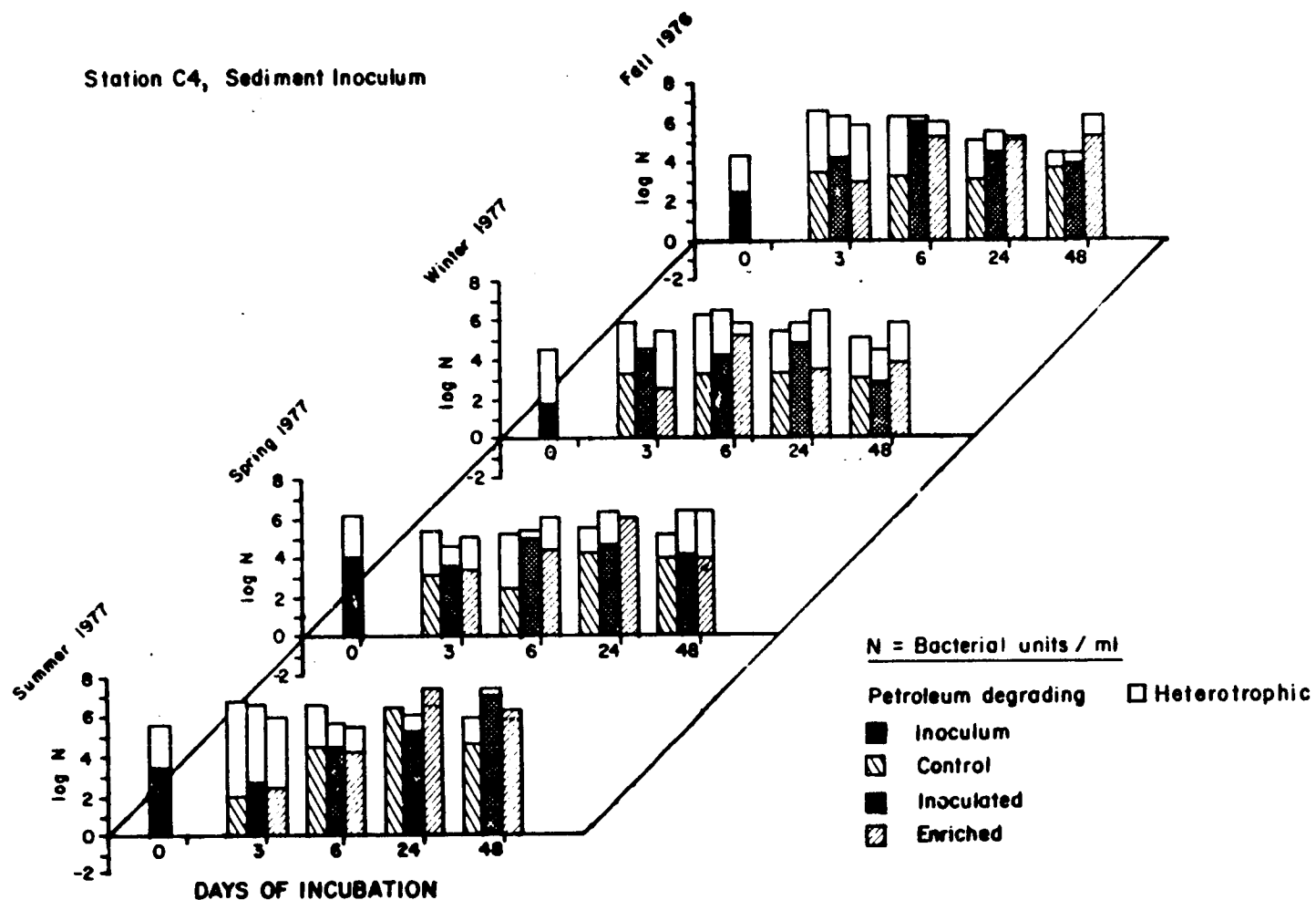


Figure 11-54. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

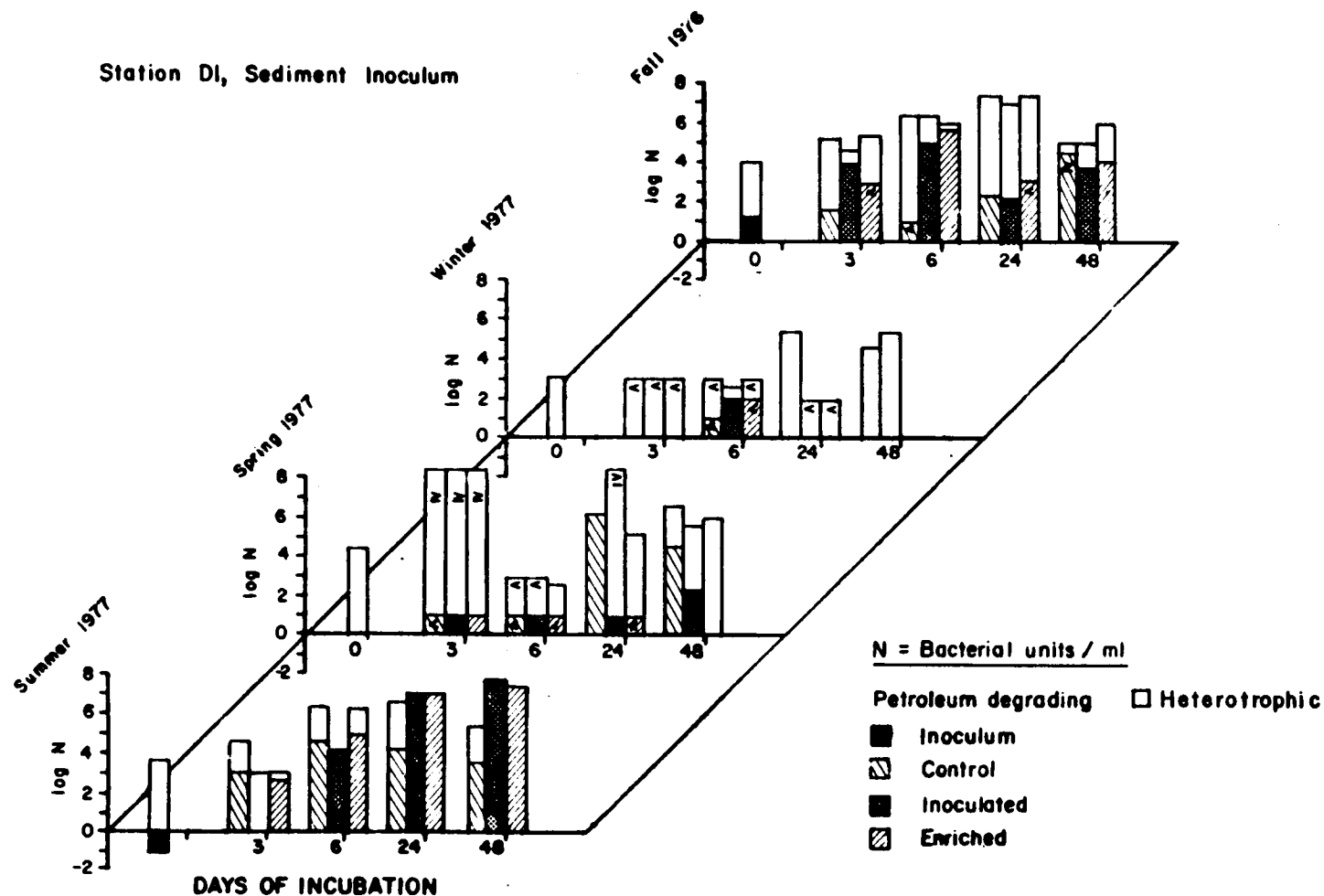


Figure 11-55. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

Station D4, Sediment Inoculum

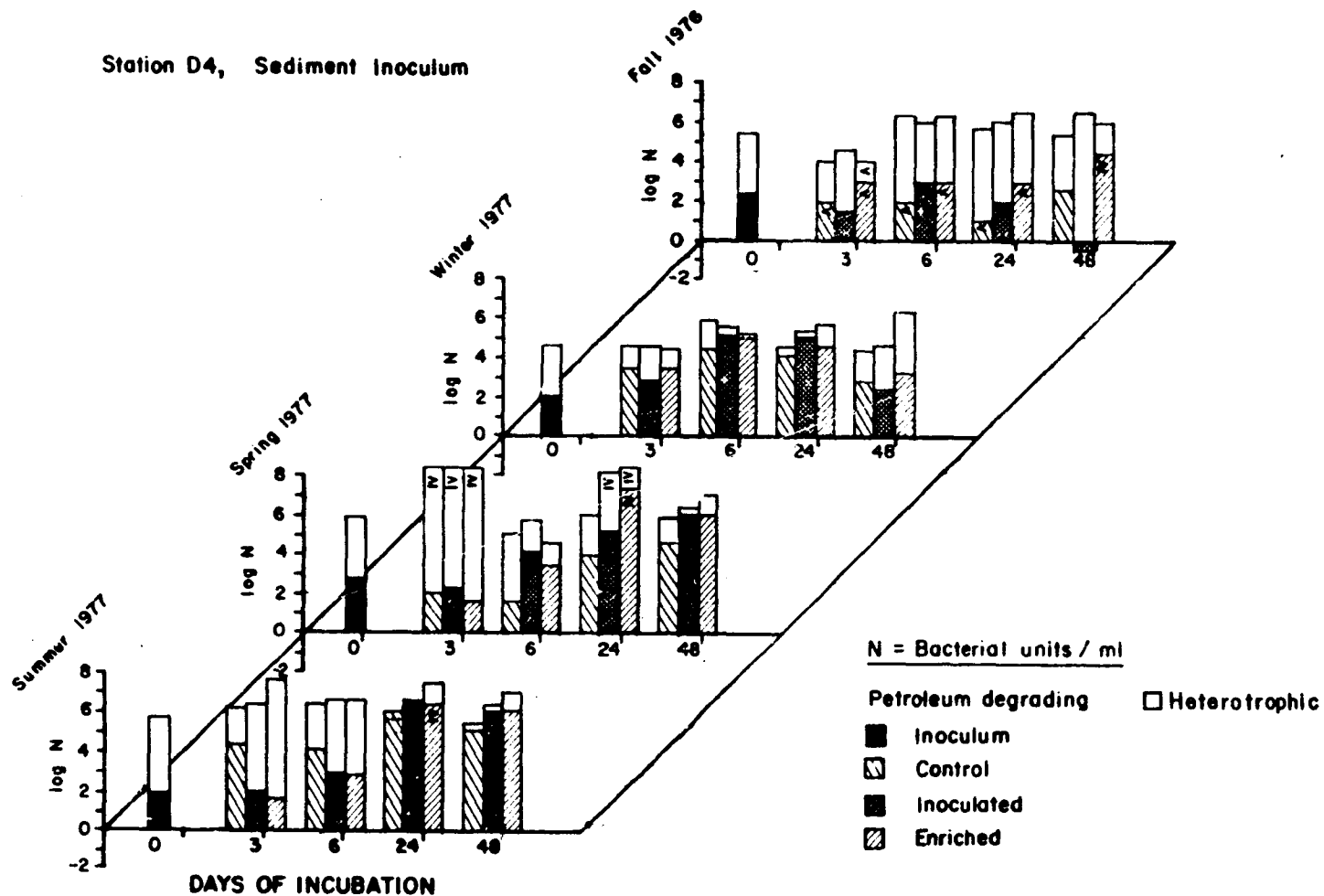


Figure 11-56. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

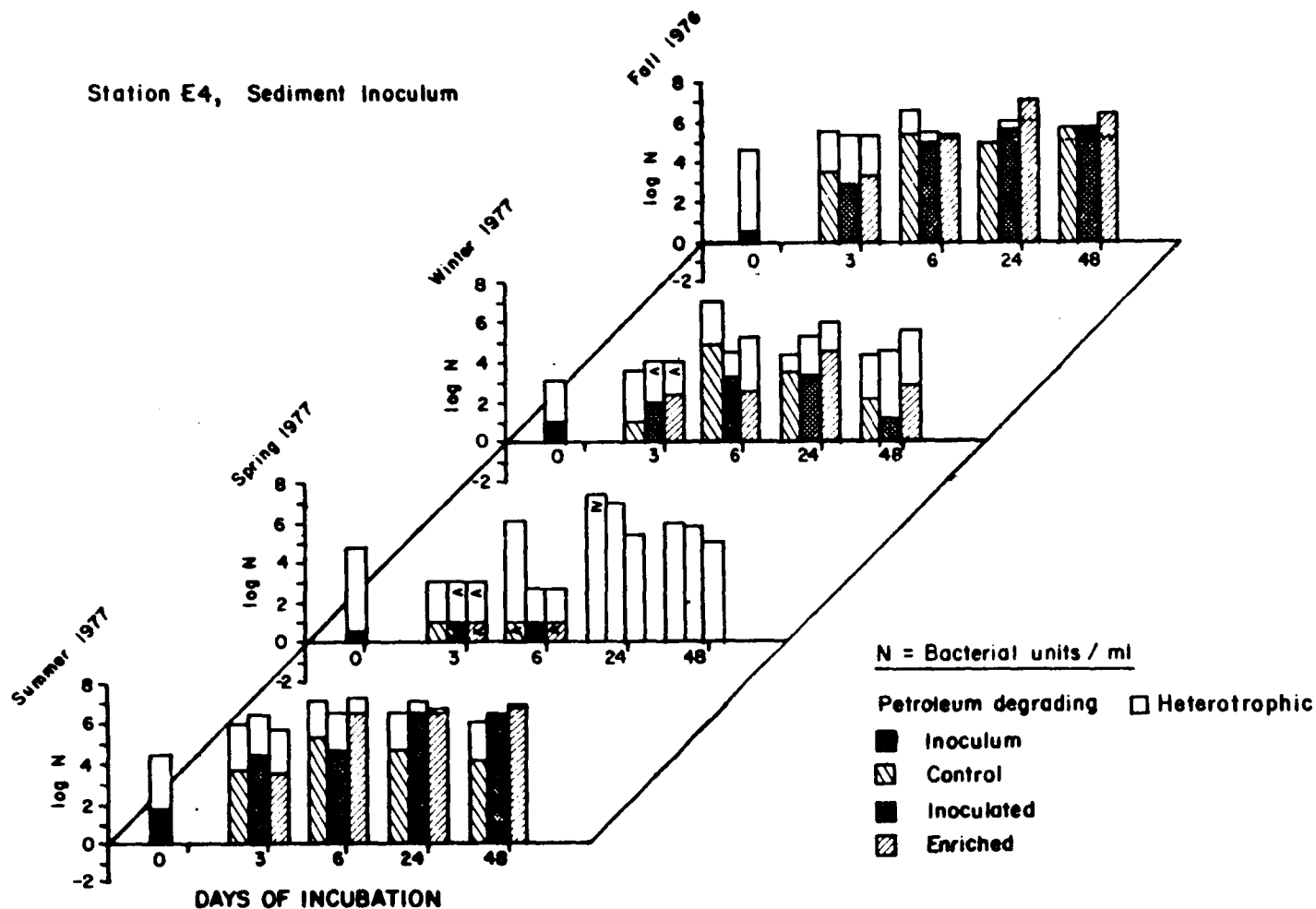


Figure 11-58. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

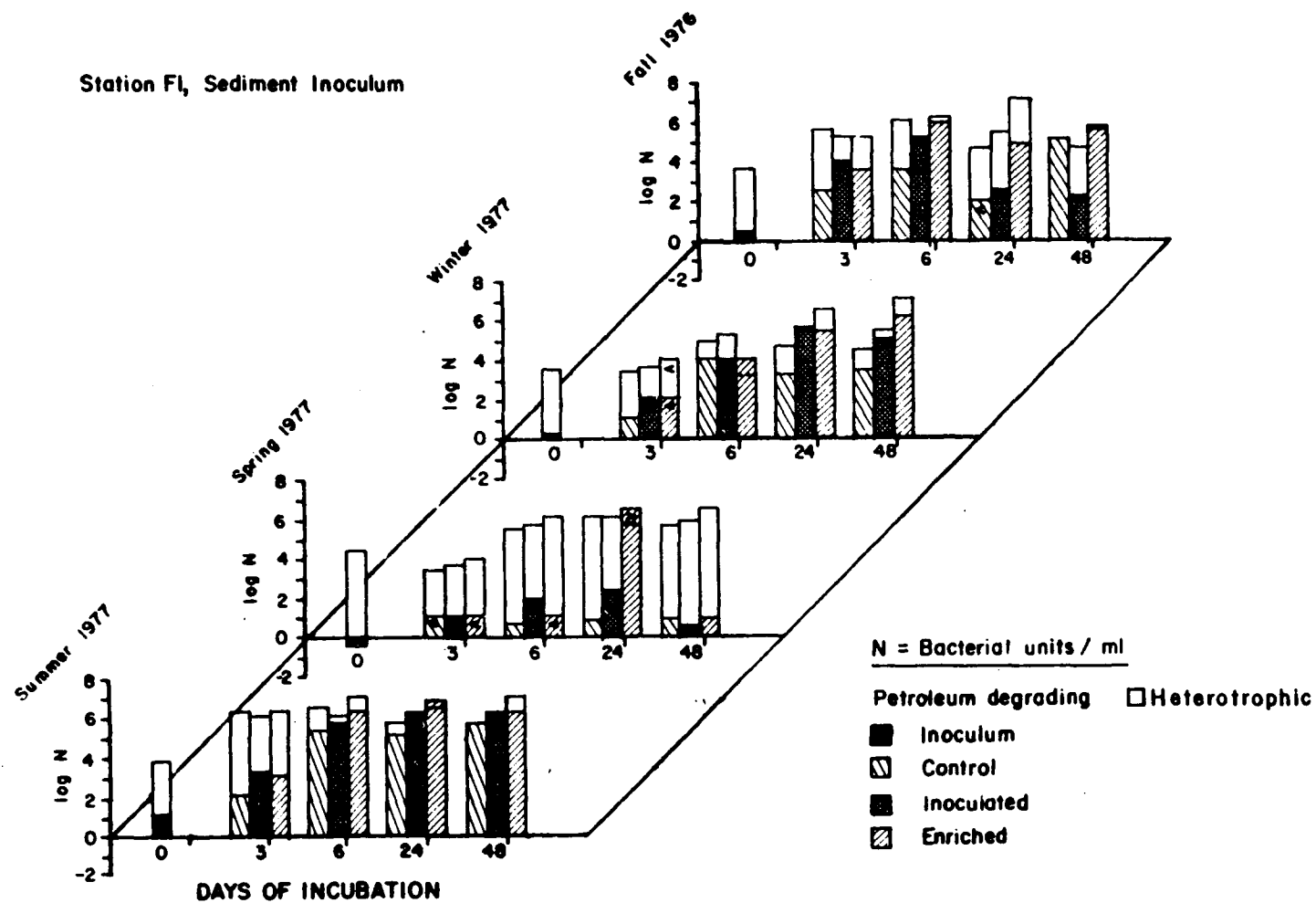


Figure 11-59. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum +

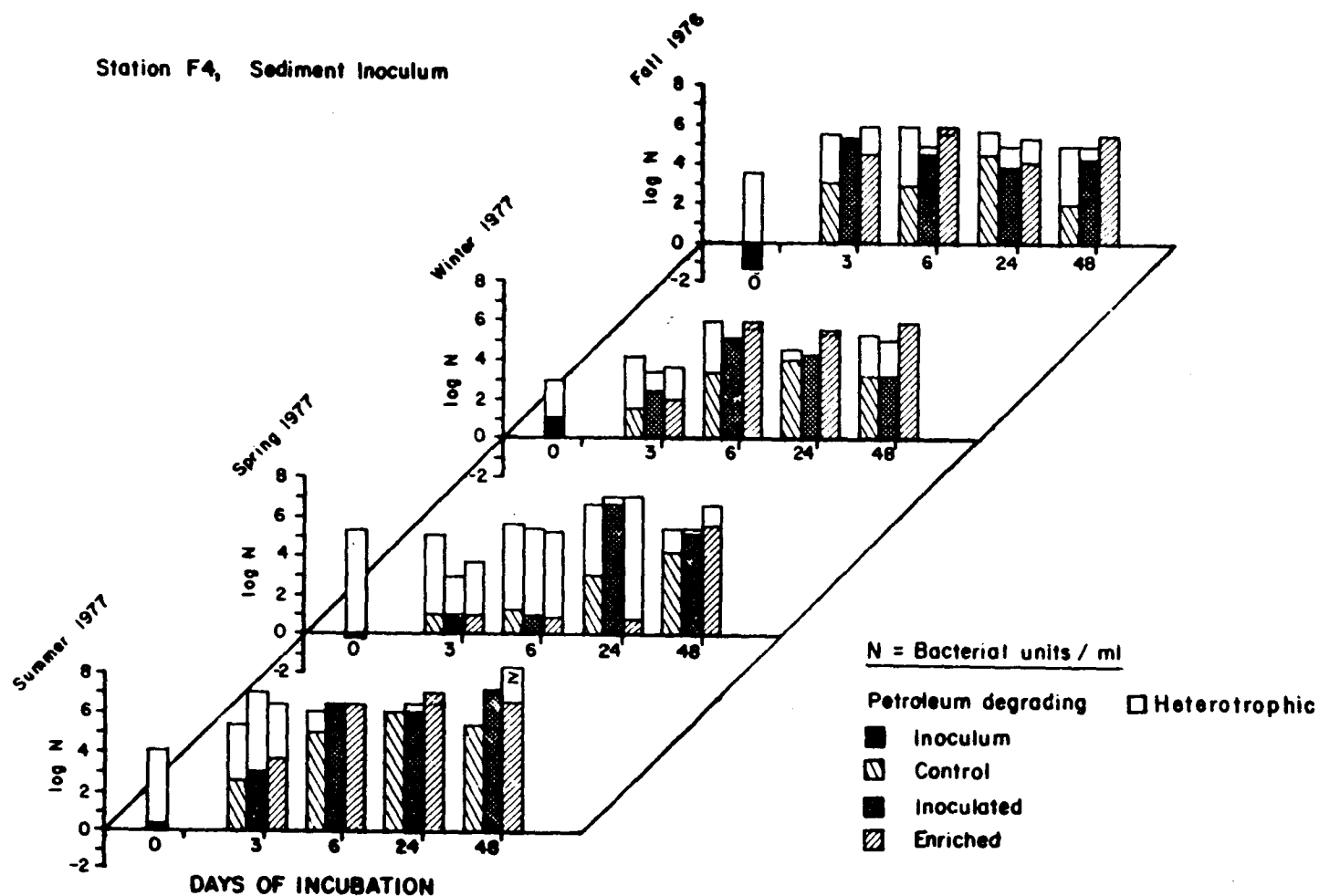


Figure 11-60. Viable counts of petroleum-degrading and heterotrophic marine bacteria during incubation in closed flasks treated as follows: control, sterile seawater + sediment homogenate inoculum; Inoculated, sterile seawater + sediment homogenate inoculum + petroleum; Enriched, sterile seawater + sediment homogenate inoculum + petroleum + inorganic nutrient amendment.

inoculated flasks. On an individual station basis, occasionally during the winter petroleum degrading bacteria were not detected at some stations.

In the spring maximum mean viable counts of petroleum-degrading bacteria reached were lower than corresponding means for the fall and winter. Examination of individual trough and ridge stations indicated some stations with very low or undetectable levels of petroleum-degrading bacteria. Mean viable counts of petroleum-degrading bacteria increased the most during the summer with enriched and inoculated flasks maintaining populations greater than in oil-free flasks. Viable counts were greater using trough inocula rather than ridge inocula in three of the four biological seasons. Only during the fall were counts comparable.

Sediment Inocula, Analysis of Residual Petroleum. Results of gas chromatographic analyses of residual petroleum using sediment inocula are summarized in Tables 11-43 through 11-46. Patterns of n-paraffin degradation similar to water inocula were also observed with sediment inocula. On a seasonal basis, degradation was least during the winter and greatest during the summer. In several instances, flasks without nutrient amendments exhibited significant n-paraffin degradation during the summer. An examination of the physical-chemical parameters of these sediments failed to provide an explanation for this apparent source of nutrients.

D₅₀ values for sediment inocula are presented in Tables 11-47 and 11-48. Rates of degradation, during the summer as characterized by the D₅₀ were greater than for all other seasons. With the exception of two stations, the D₅₀ level of degradation was never reached for the remaining seasons.

Grouping the stations on the basis of ridge and swale topography it appeared that degradation using ridge inocula was usually less extensive than for trough inocula. This observation was statistically confirmed using the Mann-Whitney test statistic (Conover 1971) for both non-enriched inoculated and enriched experimental treatments (Table 11-49).

Continuous Dilution Experiments

Results of enumerations of viable counts of petroleum-degrading and "total" heterotrophic bacteria are illustrated in Figure 11-61. Despite the continuous addition of freshly collected inocula from a variety of surface water stations, trends in viable counts were demonstrated. Both viable counts of heterotrophic and petroleum-degrading bacteria increased above initial levels following inoculation in both oil-free and oil-treated flasks. After this increase, viable counts of petroleum-degrading bacteria were generally lower in oil-free flasks at termination of the incubation period.

(TEXT CONTINUES ON PAGE 11-159)

Table 11- 43. Change in summation of weights (μg) of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flasks with sediment inocula collected during BLM05B. % weight loss in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
A1	Inoculated	65.6	(1.5)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	62.5	(1.4)	0.0	(0.0)	561.5	(15.2)	421.1	(11.0)
A4	Inoculated	76.5	(2.0)	0.0	(0.0)	372.2	(8.9)	151.1	(3.5)
	Enriched	623.2	(16.0)	624.0	(14.8)	1599.3	(38.2)	1156.5	(26.4)
B2	Inoculated	343.2	(9.0)	0.0	(0.0)	0.0	(0.0)	79.1	(2.0)
	Enriched	0.0	(0.0)	100.2	(2.7)	1023.7	(23.9)	1828.0	(46.6)
B3	Inoculated	223.9	(5.3)	0.0	(0.0)	0.0	(0.0)	278.6	(6.7)
	Enriched	0.0	(0.0)	122.3	(2.8)	361.8	(9.5)	1345.2	(32.4)
C1	Inoculated	0.0	(0.0)	183.7	(4.1)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	686.7	(15.3)	337.8	(9.5)	103.4	(2.5)
C4	Inoculated	0.0	(0.0)	394.7	(9.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	774.1	(19.8)	319.0	(8.0)
D1	Inoculated	318.1	(7.1)	0.0	(0.0)	210.1	(5.3)	0.0	(0.0)
	Enriched	648.1	(14.6)	800.5	(20.4)	1381.4	(34.7)	1526.0	(37.8)
D4	Inoculated	23.8	(0.6)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	470.1	(11.7)	199.0	(4.8)	0.0	(0.0)	0.0	(0.0)
E1	Inoculated	0.0	(0.0)	193.5	(4.4)	440.4	(10.5)	0.0	(0.0)
	Enriched	242.1	(5.6)	0.0	(0.0)	437.8	(10.5)	924.3	(25.1)
E4	Inoculated	0.0	(0.0)	N.S	-	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	399.2	(10.6)	1098.0	(27.8)

Table 11-43 . (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
F1	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	1288.2	(28.4)	818.7	(20.6)
F4	Inoculated	136.4	(3.0)	0.0	(0.0)	147.4	(3.8)	0.0	(0.0)
	Enriched	322.3	(7.1)	0.0	(0.0)	882.0	(22.9)	627.2	(16.7)

$$^a \text{ \% weight loss} = 100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ control flask}} \right) \right]$$

^b Inoculated = sea water + sterile oil
 Enriched = sea water + sterile oil + nutrient amendment

N.S. = no sample

Table 11-44 . Change in summation of weights (μg) of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flasks using sediment inocula collected during BLM06B. ^a% weight loss in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
A1	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	309.1	(7.9)
	Enriched	0.0	(0.0)	0.0	(0.0)	471.8	(10.5)	0.0	(0.0)
A4	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	117.1	(2.9)	0.0	(0.0)	722.2	(19.7)	311.2	(8.9)
B2	Inoculated	0.0	(0.0)	0.0	(0.0)	N.S.	-	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	N.S.	-	0.0	(0.0)
B3	Inoculated	0.0	(0.0)	252.7	(7.2)	254.4	(5.9)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	375.8	(8.7)	0.0	(0.0)
C1	Inoculated	0.0	(0.0)	0.0	(0.0)	179.7	(4.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	116.4	(2.8)	219.5	(4.8)	324.3	(7.8)
C4	Inoculated	0.0	(0.0)	0.0	(0.0)	28.0	(0.1)	206.7	(4.7)
	Enriched	0.0	(0.0)	0.0	(0.0)	572.5	(15.9)	1336.2	(30.3)
D1	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	459.7	(10.1)	0.0	(0.0)
D4	Inoculated	0.0	(0.0)	0.0	(0.0)	208.4	(4.9)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	525.4	(12.3)	0.0	(0.0)
E1	Inoculated	185.0	(5.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	197.7	(5.4)	0.0	(0.0)	454.7	(12.6)	199.3	(6.0)
E4	Inoculated	0.0	(0.0)	284.6	(6.5)	0.0	(0.0)	0.0	(0.0)
	Enriched	0.0	(0.0)	559.1	(12.8)	273.3	(6.7)	494.7	(17.3)

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Table 11- 44. (continued)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, µg	% Loss	Loss, µg	% Loss	Loss, µg	% Loss	Loss, µg	% Loss
11-148	F1 Inoculated	0.0	(0.0)	286.8	(6.4)	128.5	(3.2)	0.0	(0.0)
	F1 Enriched	0.0	(0.0)	413.6	(9.2)	1240.8	(30.9)	891.0	(25.4)
	F4 Inoculated	0.0	(0.0)	0.0	(0.0)	107.0	(2.6)	121.3	(2.8)
	F4 Enriched	396.1	(10.9)	0.0	(0.0)	631.1	(13.9)	606.2	(14.0)
	G2 Inoculated	399.5	(9.1)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	G2 Enriched	0.0	(0.0)	0.0	(0.0)	1218.1	(28.2)	0.0	(0.0)
	G4 Inoculated	0.0	(0.0)	175.8	(4.6)	N.S.	-	0.0	(0.0)
	G4 Enriched	0.0	(0.0)	117.5	(3.0)	N.S.	-	961.0	(23.0)
	G6 Inoculated	0.0	(0.0)	30.5	(0.7)	469.2	(3.2)	0.0	(0.0)
	G6 Enriched	0.0	(0.0)	101.1	(2.3)	1559.2	(37.1)	0.0	(0.0)
	K2 Inoculated	279.3	(7.2)	404.3	(9.2)	0.0	(0.0)	0.0	(0.0)
	K2 Enriched	281.6	(7.2)	192.5	(4.4)	151.7	(3.2)	187.4	(4.5)
	K4 Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	K4 Enriched	494.3	(11.5)	N.S.	-	764.3	(19.1)	412.3	(10.1)
	K6 Inoculated	0.0	(0.0)	122.0	(2.8)	223.0	(5.7)	0.0	(0.0)
	K6 Enriched	0.0	(0.0)	364.7	(8.3)	479.2	(12.2)	967.7	(30.3)
	L2 Inoculated	155.8	(3.8)	322.3	(8.7)	481.6	(12.2)	594.7	(18.6)
	L2 Enriched	318.7	(7.7)	572.0	(15.4)	873.3	(23.4)	2241.5	(60.0)
	L4 Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	237.3	(7.1)
	L4 Enriched	0.0	(0.0)	130.2	(3.5)	205.4	(5.6)	0.0	(0.0)

Table 11-44 . (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
L6	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	336.5	(8.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	461.7	(11.5)	688.9	(16.5)

^a % weight loss = $100 \left[1 - \frac{(\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{treated flask})}{(\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{control flask})} \right]$

^b Inoculated = sea water + sterile oil
 Enriched = sea water + sterile oil + nutrient amendment

N.S. = not sampled

Table 11-45 . Change in summation of weights (μg) of crude oil n-paraffins ($\text{nC}_{10}-\text{nC}_{25}$) during incubation in closed flasks with sediment inocula collected during BLM07B. % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
11-150	A1 Inoculated	0.0	(0.0)	414.5	(9.2)	0.0	(0.0)	0.0	(0.0)
	A1 Enriched	80.0	(2.1)	435.3	(9.7)	1195.0	(31.1)	1188.5	(32.1)
	A4 Inoculated	154.9	(4.2)	0.0	(0.0)	0.0	(0.0)	61.6	(1.4)
	A4 Enriched	559.0	(15.2)	0.0	(0.0)	0.0	(0.0)	1612.3	(37.1)
	B2 Inoculated	0.0	(0.0)	0.0	(0.0)	61.6	(1.6)	0.0	(0.0)
	B2 Enriched	0.0	(0.0)	0.0	(0.0)	398.9	(10.3)	0.0	(0.0)
	B3 Inoculated	115.9	(3.2)	0.0	(0.0)	0.0	(0.0)	322.2	(10.2)
	B3 Enriched	73.8	(2.0)	0.0	(0.0)	1208.6	(29.8)	1513.9	(47.8)
	C1 Inoculated	17.5	(0.5)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	C1 Enriched	78.5	(2.6)	0.0	(0.0)	666.4	(15.0)	577.2	(16.7)
	C4 Inoculated	215.6	(5.8)	0.0	(0.0)	278.0	(6.5)	0.0	(0.0)
	C4 Enriched	0.0	(0.0)	208.7	(5.0)	1219.7	(28.4)	387.0	(12.1)
	D1 Inoculated	252.8	(6.6)	0.0	(0.0)	133.0	(3.1)	0.0	(0.0)
	D1 Enriched	0.0	(0.0)	0.0	(0.0)	216.1	(5.0)	0.0	(0.0)
	D4 Inoculated	0.0	(0.0)	0.0	(0.0)	389.8	(9.3)	377.2	(10.6)
	D4 Enriched	131.7	(3.4)	14.2	(0.0)	743.8	(17.8)	932.4	(26.2)
	E1 Inoculated	0.0	(0.0)	234.2	(5.7)	609.0	(14.6)	181.6	(5.8)
	E1 Enriched	0.0	(0.0)	527.6	(12.9)	1319.0	(31.6)	1190.9	(38.0)
	E4 Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	E4 Enriched	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)

Table 11- 45. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
F1	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	260.6	(7.3)	0.0	(0.0)	466.7	(10.1)	0.0	(0.0)
F4	Inoculated	0.0	(0.0)	170.0	(3.8)	0.0	(0.0)	0.0	(0.0)
		0.0	(0.0)	111.9	(2.5)	0.0	(0.0)	0.0	(0.0)

$$^a \text{ \% weight loss} = 100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ control flask}} \right) \right]$$

^b Inoculated = sea water + sterile oil
 Enriched = sea water + sterile oil + nutrient amendment

Table 11-46 . Change in summation of crude oil n-paraffins (nC_{10} - nC_{25}) during incubation in closed flasks using sediment inocula collected during BLM08B. % weight loss^a in parentheses.

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
A1	Inoculated	0.0	(0.0)	0.0	(0.0)	2813.0	(72.3)	234.2	(6.1)
	Enriched	568.0	(14.0)	157.6	(4.4)	3047.5	(78.4)	3274.6	(86.3)
A4	Inoculated	380.7	(10.0)	0.0	(0.0)	990.9	(24.0)	1550.4	(36.8)
	Enriched	138.9	(3.7)	899.3	(19.9)	1669.5	(40.5)	1012.7	(24.0)
B2	Inoculated	0.0	(0.0)	71.8	(1.9)	435.7	(10.0)	281.4	(6.5)
	Enriched	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	645.9	(15.0)
B3	Inoculated	0.0	(0.0)	1280.3	(30.7)	2316.5	(63.6)	3553.7	(85.2)
	Enriched	0.0	(0.0)	2330.0	(55.8)	2989.8	(82.0)	3134.7	(75.2)
C1	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	132.1	(3.4)
	Enriched	0.0	(0.0)	160.8	(4.2)	0.0	(0.0)	1608	(41.7)
C4	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	209.7	(5.8)
	Enriched	0.0	(0.0)	0.0	(0.0)	553.4	(15.7)	844.4	(23.3)
D1	Inoculated	0.0	(0.0)	0.0	(0.0)	1090.3	(24.7)	2328.5	(56.4)
	Enriched	0.0	(0.0)	0.0	(0.0)	2928.0	(66.3)	2294.9	(55.7)
D4	Inoculated	0.0	(0.0)	237.2	(6.1)	309.9	(7.3)	0.0	(0.0)
	Enriched	135.3	(3.2)	0.0	(0.0)	1543.1	(36.6)	1328.1	(36.6)
E1	Inoculated	334.0	(7.8)	0.0	(0.0)	0.0	(0.0)	304.0	(6.8)
	Enriched	0.0	(0.0)	158.2	(3.4)	0.0	(0.0)	1255.9	(28.3)
E4	Inoculated	0.0	(0.0)	152.9	(3.8)	104.2	(2.6)	260.8	(6.2)
	Enriched	387.0	(10.2)	0.0	(0.0)	418.8	(10.4)	139.2	(3.3)

Table 11- 46. (continued)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
F1	Inoculated	0.0	(0.0)	0.0	(0.0)	387.7	(8.5)	0.0	(0.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	901.0	(19.8)	334.6	(8.6)
F4	Inoculated	360.5	(7.1)	80.8	(1.9)	921.3	(24.3)	2567.7	(61.9)
	Enriched	444.3	(10.4)	0.0	(0.0)	3574.3	(90.8)	3619.2	(87.3)
G2	Inoculated	387.5	(10.1)	0.0	(0.0)	89.1	(2.3)	121.4	(2.8)
	Enriched	146.1	(3.4)	0.0	(0.0)	0.0	(0.0)	1184.3	(27.0)
G4	Inoculated	0.0	(0.0)	336.7	(8.5)	286.5	(7.5)	124.2	(2.9)
	Enriched	0.0	(0.0)	0.0	(0.0)	112.7	(3.0)	664.6	(15.4)
G6	Inoculated	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	238.2	(6.0)
	Enriched	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	471.8	(11.9)
K2	Inoculated	141.7	(3.8)	363.5	(9.1)	326.0	(7.9)	351.5	(9.4)
	Enriched	0.0	(0.0)	0.0	(0.0)	1888.3	(45.9)	1344.8	(36.0)
K4	Inoculated	0.0	(0.0)	0.0	(0.0)	366.6	(9.9)	0.0	(0.0)
	Enriched	244.2	(5.6)	0.0	(0.0)	743.6	(19.8)	521.0	(13.4)
K6	Inoculated	313.2	(8.2)	274.7	(6.4)	432.0	(9.8)	178.6	(4.4)
	Enriched	6.6	(0.0)	69.4	(1.6)	936.3	(21.3)	494.2	(12.3)
L2	Inoculated	142.8	(3.4)	0.0	(0.0)	1686.6	(39.4)	750.2	(18.8)
	Enriched	358.4	(9.0)	0.0	(0.0)	1366.4	(31.9)	1640.0	(41.2)
L4	Inoculated	230.0	(5.9)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
	Enriched	532.4	(13.6)	0.0	(0.0)	642.4	(16.1)	357.3	(9.4)

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Table 11- 46. (concluded)

Station	Treatment ^b	Days of Incubation							
		3		6		24		48	
		Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss	Loss, μg	% Loss
L6	Inoculated	0.0	(0.0)	1052.9	(24.4)	3730.1	(86.8)	3866.5	(84.6)
	Enriched	0.0	(0.0)	641.5	(14.9)	3588.5	(83.5)	3692.8	(80.8)

$$^a \text{ \% weight loss} = 100 \left[1 - \left(\frac{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ treated flask}}{\sum \mu\text{g n-paraffins, nC}_{10}\text{-nC}_{25}, \text{ control flask}} \right) \right]$$

- ^b Inoculated = sea water + sterile oil
 Enriched = sea water + sterile oil + nutrient amendment

Table 11-47. Days of incubation required for degradation^a of 50% of n-alkanes (nC₁₀ - nC₂₅) in closed flasks from petroleum degradation experiments using sediment inocula from stations sampled quarterly.

Station	Treatment ^b	Cruise			
		BLM05B	BLM06B	BLM07B	BLM08B
A1	inoculated	NR	NR	NR	24
	enriched	NR	NR	NR	24
A4	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
B2	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
B3	inoculated	NR	NR	NR	24
	enriched	NR	NR	NR	6
C1	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
C4	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
D1	inoculated	NR	NR	NR	48
	enriched	NR	NR	NR	24
D4	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
E1	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
E4	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
F1	inoculated	NR	NR	NR	NR
	enriched	NR	NR	NR	NR
F4	inoculated	NR	NR	NR	48
	enriched	NR	NR	NR	24

a weight loss of treated flasks compared to sterile control

b inoculated = seawater + oil

enriched = seawater + oil + nutrient amendment

NR degradation never reached 50%

Table 11-48. Days of incubation required for degradation^a of 50% of n-alkanes (nC₁₀ - nC₂₅) in closed flasks from petroleum degradation experiments using sediment inocula from stations sampled twice a year.

Station	Treatment ^b	Cruise			
		BLM05B	BLM06B	BLM07B	BLM08B
L2	inoculated	NS	NR	NS	NR
	enriched	NS	48	NS	NR
L4	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
L6	inoculated	NS	NR	NS	24
	enriched	NS	NR	NS	24
G2	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
G4	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
G6	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
K2	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
K4	inoculated	NS	NR	NS	NR
	enriched	NS	NR	NS	NR
K6	inoculated	NS	NR	NS	NR
	enriched	NS	48	NS	NR

a weight loss of treated flasks compared to sterile control

b inoculated = seawater + oil

enriched = seawater + oil + nutrient amendment

NS not sampled

NR degradation never reached 50%

Table 11-49. Results of Mann-Whitney U Statistic T applied to maximum amount of n-paraffin degradation in flasks using sediment inocula from ridge and swale stations (05B - 08B).

H_0 : Degradation using Ridge Inocula $\leq$ Degradation using Trough Inocula

H_1 : Degradation using Ridge Inocula $>$ Degradation using Trough Inocula

Treatments	Stations (Ridge - Swale)			
	C1 - C4	D1 - D4	B2 - B3	E1 - E4
Enriched Flasks	$T = 4 < T_c$ accept H_0	$T = 10 < T_c$ accept H_0	$T = 4 < T_c$ accept H_0	$T = 10 < T_c$ accept H_0
Non-enriched Flasks (inoculated)	$T = 4 < T_c$ accept H_0	$T = 7 < T_c$ accept H_0	$T = 2 < T_c$ accept H_0	$T = 12 < T_c$ accept H_0

$T_c = T \text{ critical} = 14 \quad \alpha = 0.05$

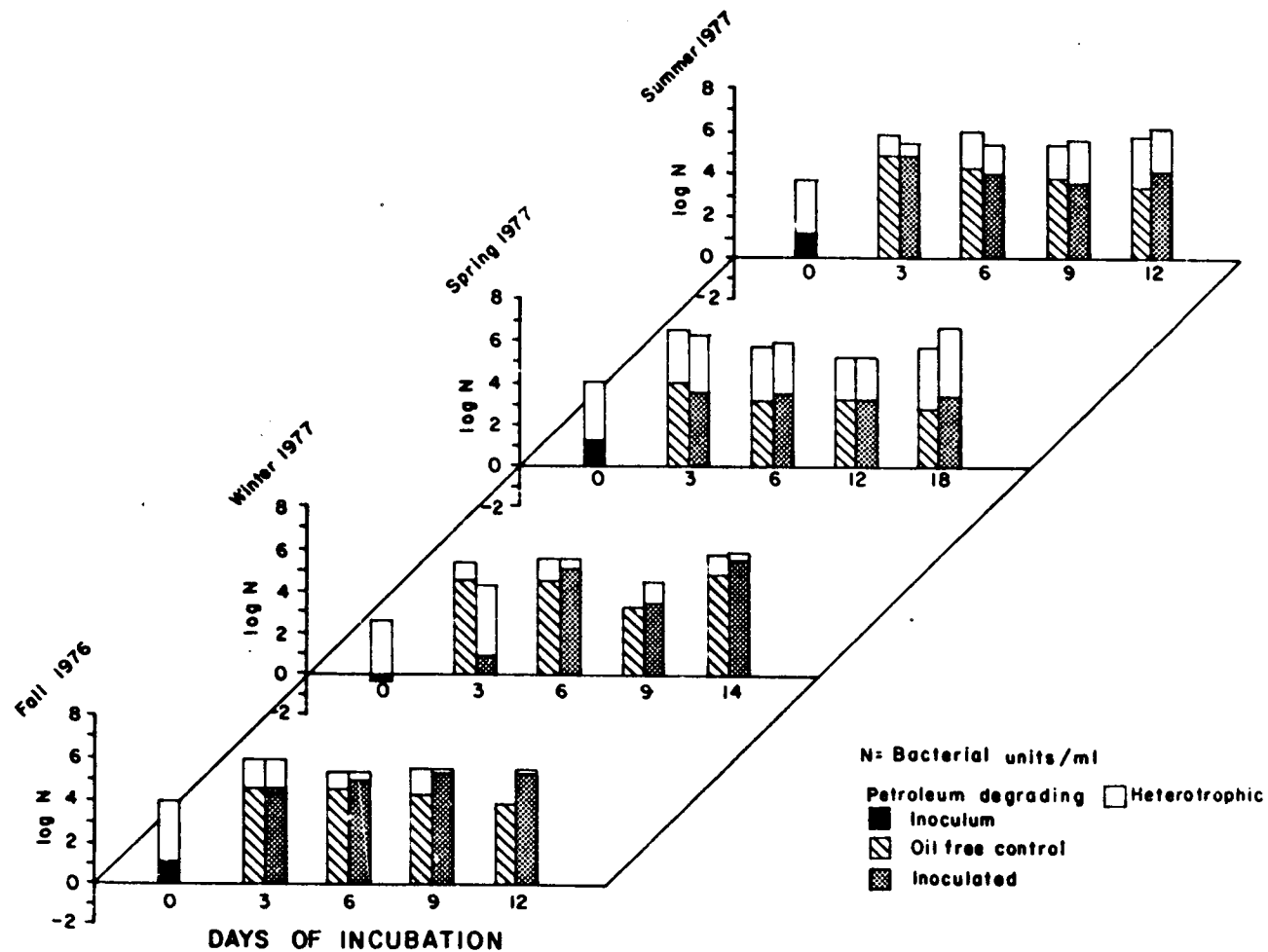


Figure 11-61. Viable counts of petroleum degrading and heterotrophic marine bacteria during incubation under conditions of continuous dilution and treated as follows: oil-free control, sterile seawater; inoculated, seawater + petroleum.

Overall, heterotrophic viable counts and counts of petroleum-degrading bacteria for some incubation intervals tended to be lower in the winter (5°C). Viable counts of heterotrophic bacteria usually remained at elevated levels in both oil-free and oil-treated flasks. It is important to note that the continuous addition of fresh inocula and surface growth effects would be expected to obscure substrate related population responses in oil-treated flasks.

During the fall, 0.1% (v/v) of sterile South Louisiana crude oil was added to each of the oil-treated flasks. Analysis of residual petroleum after the indicated incubation intervals revealed that significant n-paraffin degradation could not be detected. During the winter, spring and summer seasons, 0.01% (v/v) sterile petroleum was used as the initial substrate concentration. Again, significant n-paraffin degradation could not be detected. Attempts to quantify bacterial n-paraffin degradation were not successful apparently because bacterial degradative losses were equal to or less than evaporative losses.

Chitin-Petroleum Degradation Studies

Field Enumeration

Results of chitinoclast enumerations at selected sediment and surface water (1 m) stations are shown in Table 11-50. In general, levels of chitinoclasts were greater in trough sediments than ridge sediments from the B, C, and D clusters. A strong temperature (seasonal) effect on chitinoclast levels from nearshore (1 m) water samples was observed.

Chitin-Petroleum Degradation Experiments

Weight losses of filterable chitin and viable counts of heterotrophic, chitinoclastic, and petroleum-degrading marine bacteria are listed in Tables 11-51 through 11-54 and depicted in Figures 11-62 through 11-85. Results from the fall (05B) experiment were similar to those obtained during 01-04B in that most chitin degradation occurred within the first two weeks of incubation. This period coincided with maximum viable counts of chitinoclasts. Petroleum did not significantly affect either viable chitinoclast counts or the amount of chitin hydrolyzed. Analysis of residual petroleum using gas chromatography revealed that removal of n-paraffins to baseline levels had occurred during the first two weeks of incubation (Table 11-55).

During the winter experiment (06B, Figures 11-64 to 11-65 and 11-74 to 11-77), the presence of petroleum appeared to affect both viable chitinoclast counts and chitin loss. In oil-free flasks, chitinoclast levels generally reached maximum values within 2 weeks. In the presence of petroleum, chitinoclast counts usually did not

(TEXT CONTINUES ON PAGE 11-194)

Table 11-50. Viable counts of chitinoclastic marine bacteria obtained from sediment and 1m surface water samples.

Sample	Station	Winter, 06B	Spring, 07B	Summer, 08B
Sediment	A1	1.7×10^{2a} (2.2) ^b	2.8×10^4 (4.4)	5.3×10^3 (3.6)
	A4	7.3×10^2 (2.9)	2.0×10^3 (3.3)	1.7×10^4 (4.0)
	B2	2.1×10^1 (1.3)	2.6×10^2 (2.4)	3.9×10^3 (3.6)
	B3	1.7×10^3 (3.2)	4.7×10^3 (3.7)	1.6×10^3 (3.2)
	C1	1.3×10^2 (2.1)	3.9×10^4 (4.6)	6.4×10^2 (2.8)
	C4	3.1×10^3 (3.5)	2.0×10^4 (4.3)	2.9×10^5 (5.5)
	D1	2.3×10^1 (1.4)	4.2×10^2 (2.6)	2.7×10^1 (1.4)
	D4	3.6×10^4 (4.6)	5.2×10^3 (3.7)	1.4×10^3 (3.1)
	E1	1.1×10^4 (4.0)	7.4×10^2 (2.9)	2.6×10^3 (3.4)
	E4	4.9×10^3 (3.7)	7.0×10^2 (2.8)	6.9×10^3 (3.8)
	F1	5.8×10^3 (3.8)	1.0×10^3 (3.0)	7.6×10^3 (3.9)
	F4	3.8×10^3 (3.6)	2.2×10^3 (3.3)	1.7×10^3 (3.2)
	K2	1.4×10^3 (3.1)	N.S.	5.5×10^3 (3.7)
	K4	4.1×10^3 (3.6)	N.S.	9.1×10^3 (4.0)
	K5	1.1×10^4 (4.0)	N.S.	9.4×10^2 (3.0)
	K6	7.3×10^3 (3.9)	N.S.	1.2×10^4 (4.1)
Water	A2	6.7×10^0 (8.3×10^{-1})	1.0×10^1 (1.0)	7.3×10^1 (1.9)
	B5	6.7×10^0 (8.3×10^{-1})	2.3×10^1 (1.4)	1.4×10^2 (2.1)
	C1	1.3×10^1 (1.1)	2.7×10^1 (1.4)	2.3×10^2 (2.4)
	D1	3.3×10^0 (5.2×10^{-1})	<3.3 ($<5.2 \times 10^{-1}$)	2.8×10^2 (2.4)
	E3	1.0×10^1 (1.0)	6.5×10^1 (1.8)	7.4×10^1 (1.9)
	F2	3.3×10^0 (5.2×10^{-1})	5.6×10^1 (1.7)	1.3×10^2 (2.1)
	K2	3.3×10^0 (5.2×10^{-1})	N.S.	3.7×10^2 (2.6)
	K4	1.3×10^1 (1.1)	N.S.	4.5×10^1 (1.7)
	K5	6.7×10^0 (8.2×10^{-1})	N.S.	4.2×10^1 (1.6)
	K6	1.0×10^1 (1.0)	N.S.	8.0×10^1 (1.9)

^a 1st column = cells/ml H₂O or gm dry sediment, values are means of 3 replicate determinations.

^b log count

N.S. = Not sampled

Table 11-51. 05B - Changes in bacterial populations and weights of filterable chitin in flasks containing either chitin or chitin plus Louisiana crude oil and inoculated with mixed cultures from the sources indicated.

Incubation Period	Inoculum Type	Heterotrophs	Chitinoclasts	Petroleum Oxidizers
Initial	H ₂ O	1.6x10 ⁶ (6.2)	8.6x10 ⁵ (5.9)	3.0x10 ⁴ (4.5)
	Inner Shelf Sed.	3.2x10 ⁶ (6.5)	1.9x10 ⁶ (6.3)	4.6x10 ² (2.7)
	Outer Shelf Sed.	2.1x10 ⁵ (6.3)	2.1x10 ⁶ (6.3)	4.6x10 ⁴ (4.7)
	Shelf Break Sed.	2.0x10 ⁶ (6.3)	1.8x10 ⁶ (6.3)	4.6x10 ⁴ (4.7)
2 wk	H ₂ O + Oil	2.7x10 ⁸ (8.4)	1.3x10 ⁸ (8.1)	>2.4x10 ⁸ (>8.4)
	H ₂ O - Oil	4.9x10 ⁸ (8.7)	1.8x10 ⁸ (8.1)	4.6x10 ⁶ (6.6)
	Inner + Oil	9.7x10 ⁸ (9.0)	8.3x10 ⁸ (8.9)	>2.4x10 ⁸ (>8.4)
	Inner - Oil	1.0x10 ⁹ (9.0)	1.2x10 ⁹ (9.1)	9.3x10 ⁶ (7.0)
	Outer + Oil	3.7x10 ⁸ (8.6)	1.4x10 ⁸ (8.2)	4.6x10 ⁷ (7.7)
	Outer - Oil	2.1x10 ⁸ (8.3)	1.8x10 ⁸ (8.2)	9.3x10 ⁶ (7.0)
	Shelf Break + Oil	3.1x10 ⁸ (8.5)	3.0x10 ⁸ (8.5)	4.6x10 ⁷ (7.7)
	Shelf Break - Oil	1.2x10 ⁹ (9.1)	6.5x10 ⁸ (8.8)	2.4x10 ⁷ (7.4)
5 wk	H ₂ O + Oil	1.2x10 ⁸ (8.1)	1.6x10 ⁸ (8.2)	2.4x10 ⁷ (7.4)
	H ₂ O - Oil	1.4x10 ⁸ (8.1)	9.6x10 ⁷ (8.0)	4.6x10 ⁷ (7.7)
	Inner + Oil	4.8x10 ⁷ (7.7)	6.6x10 ⁷ (7.8)	9.3x10 ⁶ (7.0)
	Inner - Oil	7.1x10 ⁷ (7.9)	9.2x10 ⁷ (8.0)	2.4x10 ⁷ (7.4)
	Outer + Oil	1.6x10 ⁸ (8.2)	1.4x10 ⁸ (8.2)	4.6x10 ⁷ (7.7)
	Outer - Oil	1.6x10 ⁸ (8.2)	1.0x10 ⁸ (8.0)	2.4x10 ⁷ (7.4)
	Shelf Break + Oil	5.8x10 ⁷ (7.8)	5.1x10 ⁷ (7.7)	4.3x10 ⁶ (6.6)
	Shelf Break - Oil	1.1x10 ⁸ (8.0)	3.0x10 ⁷ (7.5)	2.4x10 ⁷ (7.4)
11 wk	H ₂ O + Oil	2.4x10 ⁷ (7.4)	2.3x10 ⁷ (7.4)	9.3x10 ⁵ (6.0)
	H ₂ O - Oil	8.0x10 ⁷ (7.9)	4.5x10 ⁷ (7.6)	9.3x10 ⁷ (8.0)
	Inner + Oil	9.0x10 ⁶ (7.0)	5.6x10 ⁶ (6.7)	9.3x10 ⁶ (7.0)
	Inner - Oil	3.5x10 ⁷ (7.5)	2.5x10 ⁷ (7.4)	2.3x10 ⁷ (7.4)
	Outer + Oil	1.6x10 ⁷ (7.2)	1.4x10 ⁷ (7.1)	2.3x10 ⁷ (7.4)
	Outer - Oil	4.1x10 ⁷ (7.6)	2.6x10 ⁷ (7.4)	9.3x10 ⁷ (8.0)
	Shelf Break + Oil	2.7x10 ⁷ (7.4)	1.1x10 ⁷ (7.0)	9.3x10 ⁷ (8.0)
	Shelf Break - Oil	5.2x10 ⁷ (7.7)	3.3x10 ⁷ (7.5)	4.3x10 ⁷ (7.6)

Table 11-51. (concluded).

Filterable Chitin Loss, mg					
H ₂ O	+ Oil	- Oil	Outer Shelf	+ Oil	- Oil
2 wk	53.9	45.3	2 wk	69.6	70.5
5 wk	74.8	79.3	5 wk	85.3	84.7
11 wk	91.4	93.8	11 wk	94.8	95.0
Inner Shelf	+ Oil	- Oil	Shelf Break	+ Oil	- Oil
2 wk	83.4	76.8	2 wk	65.3	77.9
5 wk	89.3	92.4	5 wk	90.0	89.3
11 wk	98.0	97.2	11 wk	93.5	93.6

Table 11-52. 06B - Changes in bacterial populations and weights of filterable chitin in flasks containing either chitin or chitin plus Louisiana crude oil and inoculated with mixed cultures from the sources indicated.

Incubation Period	Inoculum Type	Heterotrophs	Chitinoclasts	Petroleum Oxidizers
Initial	H ₂ O	2.6x10 ⁵ (5.4)	2.0x10 ⁵ (5.3)	1.9x10 ³ (3.3)
	Inner Shelf Sed.	2.7x10 ⁵ (5.4)	2.0x10 ⁵ (5.3)	8.6x10 ² (2.9)
	Outer Shelf Sed.	2.0x10 ⁵ (5.3)	6.0x10 ⁴ (4.8)	4.6x10 ² (2.7)
	Shelf Break Sed.	2.9x10 ⁵ (5.5)	9.0x10 ⁴ (5.0)	4.2x10 ² (2.6)
2 wk	H ₂ O + Oil	5.1x10 ⁸ (8.7)	4.7x10 ⁷ (7.7)	2.4x10 ⁸ (8.4)
	H ₂ O - Oil	8.5x10 ⁸ (8.9)	4.8x10 ⁸ (8.7)	7.5x10 ⁵ (5.9)
	Inner + Oil	1.5x10 ⁸ (8.2)	1.1x10 ⁸ (8.0)	4.6x10 ⁸ (8.7)
	Inner - Oil	7.1x10 ⁸ (8.9)	4.9x10 ⁸ (8.7)	4.3x10 ⁵ (5.6)
	Outer + Oil	1.2x10 ⁸ (8.1)	7.9x10 ⁷ (7.9)	1.5x10 ⁸ (8.2)
	Outer - Oil	6.3x10 ⁸ (8.8)	4.2x10 ⁸ (8.6)	9.3x10 ⁵ (6.0)
	Shelf Break + Oil	7.1x10 ⁸ (8.9)	2.8x10 ⁸ (8.4)	1.1x10 ⁹ (9.0)
	Shelf Break - Oil	6.7x10 ⁸ (8.8)	3.8x10 ⁸ (8.6)	7.5x10 ⁵ (5.9)
6 wk	H ₂ O + Oil	5.4x10 ⁸ (8.7)	1.8x10 ⁸ (8.3)	2.4x10 ⁸ (8.4)
	H ₂ O - Oil	2.7x10 ⁷ (7.4)	2.2x10 ⁷ (7.3)	2.3x10 ⁵ (5.4)
	Inner + Oil	1.9x10 ⁸ (8.3)	1.4x10 ⁸ (8.1)	2.4x10 ⁸ (8.4)
	Inner - Oil	6.7x10 ⁷ (7.8)	6.9x10 ⁷ (7.8)	4.3x10 ⁶ (6.6)
	Outer + Oil	2.7x10 ⁸ (8.4)	1.0x10 ⁸ (8.0)	2.4x10 ⁸ (8.4)
	Outer - Oil	7.6x10 ⁷ (7.9)	6.0x10 ⁷ (7.8)	9.3x10 ⁶ (7.0)
	Shelf Break + Oil	8.7x10 ⁸ (8.9)	3.1x10 ⁸ (8.5)	4.6x10 ⁸ (8.7)
	Shelf Break - Oil	2.2x10 ⁷ (7.3)	1.9x10 ⁷ (7.3)	2.3x10 ⁶ (6.4)
11 wk	H ₂ O + Oil	2.6x10 ⁷ (7.4)	1.5x10 ⁶ (6.2)	1.5x10 ⁷ (7.2)
	H ₂ O - Oil	2.3x10 ⁷ (7.4)	1.3x10 ⁷ (7.1)	2.3x10 ⁶ (6.4)
	Inner + Oil	2.5x10 ⁷ (7.4)	7.5x10 ⁶ (6.9)	2.3x10 ⁷ (7.4)
	Inner - Oil	1.1x10 ⁷ (7.0)	8.6x10 ⁶ (6.9)	2.3x10 ⁶ (6.4)
	Outer + Oil	3.2x10 ⁷ (7.5)	6.6x10 ⁶ (6.8)	2.3x10 ⁷ (7.4)
	Outer - Oil	1.6x10 ⁷ (7.2)	9.5x10 ⁶ (7.0)	4.3x10 ⁶ (6.6)
	Shelf Break + Oil	2.6x10 ⁷ (7.4)	8.8x10 ⁶ (6.9)	9.3x10 ⁶ (7.0)
	Shelf Break - Oil	1.2x10 ⁷ (7.1)	8.0x10 ⁶ (6.9)	9.3x10 ⁶ (7.0)

Table 11-52. (concluded).

Filterable Chitin Loss, mg							
	Incubation	+ Oil	- Oil		Incubation	+ Oil	- Oil
H ₂ O	2 wk •	18.2	51.0	Outer Shelf	2 wk	20.3	41.8
	6 wk	63.2	75.9		6 wk	84.1	93.4
	11 wk	83.2	86.2		11 wk	87.9	84.2
Inner Shelf	2 wk	16.7	41.1	Shelf Break	2 wk	33.1	42.3
	6 wk	77.3	74.1		6 wk	80.0	89.9
	11 wk	89.3	80.7		11 wk	89.3	90.8

Table 11-53. 07B - Changes in bacterial populations and weights of filterable chitin in flasks containing either chitin or chitin plus Louisiana crude oil and inoculated with mixed cultures from the sources indicated.

Incubation Period	Inoculum Type	Heterotrophs	Chitinoclasts	Petroleum Oxidizers
Initial	H ₂ O	2.6x10 ⁴ (4.4)	3.4x10 ⁴ (4.5)	.9 (-.04)
	Inner Shelf Sed.	2.8x10 ⁵ (5.4)	2.4x10 ⁵ (5.4)	.9 (-.04)
	Outer Shelf Sed.	3.2x10 ⁵ (5.5)	2.7x10 ⁵ (5.4)	4.2 (.6)
	Shelf Break Sed.	2.7x10 ⁵ (5.4)	2.8x10 ⁵ (5.4)	8.6 (.9)
2 wk	H ₂ O + Oil	1.2x10 ⁹ (9.1)	1.4x10 ⁸ (8.1)	1.1x10 ⁹ (9.0)
	H ₂ O - Oil	1.2x10 ⁸ (8.1)	1.3x10 ⁸ (8.1)	4.3x10 ⁶ (6.6)
	Inner + Oil	1.3x10 ⁹ (9.1)	8.1x10 ⁷ (7.9)	>2.4x10 ⁹ (>9.4)
	Inner - Oil	8.4x10 ⁷ (7.9)	8.4x10 ⁷ (7.9)	1.5x10 ⁷ (7.2)
	Outer + Oil	9.1x10 ⁸ (9.0)	1.0x10 ⁸ (8.0)	1.1x10 ⁹ (9.0)
	Outer - Oil	7.4x10 ⁷ (7.9)	6.2x10 ⁷ (7.8)	9.3x10 ⁶ (7.0)
	Shelf Break + Oil	1.1x10 ⁹ (9.0)	4.9x10 ⁷ (7.7)	>2.4x10 ⁹ (>9.4)
	Shelf Break - Oil	2.5x10 ⁸ (8.4)	2.1x10 ⁸ (8.3)	7.5x10 ⁶ (6.9)
4 wk	H ₂ O + Oil	3.6x10 ⁸ (8.6)	5.6x10 ⁷ (7.7)	2.1x10 ⁸ (8.3)
	H ₂ O - Oil	3.2x10 ⁷ (7.5)	2.3x10 ⁷ (7.4)	9.3x10 ⁶ (7.0)
	Inner + Oil	2.1x10 ⁸ (8.3)	3.0x10 ⁷ (7.5)	2.4x10 ⁹ (9.4)
	Inner - Oil	5.2x10 ⁷ (7.7)	1.8x10 ⁷ (7.3)	4.6x10 ⁷ (7.7)
	Outer + Oil	4.2x10 ⁸ (8.6)	3.8x10 ⁷ (7.6)	4.6x10 ⁸ (8.7)
	Outer - Oil	6.0x10 ⁷ (7.8)	2.3x10 ⁷ (7.4)	1.5x10 ⁷ (7.2)
	Shelf Break + Oil	3.3x10 ⁸ (8.5)	4.7x10 ⁷ (7.7)	2.4x10 ⁸ (8.4)
	Shelf Break - Oil	5.4x10 ⁷ (7.7)	2.7x10 ⁷ (7.4)	2.4x10 ⁷ (7.4)
6 wk	H ₂ O + Oil	1.2x10 ⁸ (8.1)	3.7x10 ⁷ (7.6)	4.3x10 ⁷ (7.6)
	H ₂ O - Oil	8.3x10 ⁷ (7.9)	4.8x10 ⁷ (7.7)	1.5x10 ⁷ (7.2)
	Inner + Oil	1.9x10 ⁸ (8.3)	1.2x10 ⁷ (7.1)	1.1x10 ⁹ (9.0)
	Inner - Oil	4.3x10 ⁷ (7.6)	7.4x10 ⁶ (6.9)	2.4x10 ⁷ (7.4)
	Outer + Oil	1.1x10 ⁸ (8.0)	2.0x10 ⁷ (7.3)	7.5x10 ⁷ (7.9)
	Outer - Oil	4.6x10 ⁷ (7.7)	1.4x10 ⁷ (7.1)	9.3x10 ⁶ (7.0)
	Shelf Break + Oil	7.8x10 ⁷ (7.9)	7.8x10 ⁶ (6.9)	9.3x10 ⁷ (8.0)
	Shelf Break - Oil	5.3x10 ⁷ (7.7)	2.8x10 ⁷ (7.4)	4.6x10 ⁷ (7.7)

Table 11-53. (concluded).

Filterable Chitin Loss, mg							
	Incubation	+ Oil	- Oil		Incubation	+ Oil	- Oil
H ₂ O	2 wk	80.0	70.0	Outer Shelf	2 wk	74.4	79.0
	4 wk	76.9	80.0		4 wk	86.4	88.5
	6 wk	86.3	89.5		6 wk	96.8	99.2
Inner Shelf	2 wk	76.5	84.6	Shelf Break	2 wk	76.8	84.6
	4 wk	89.2	88.8		4 wk	89.1	90.9
	6 wk	89.7	81.0		6 wk	98.5	98.4

Table 11-54 08B - Changes in bacterial populations and weights of filterable chitin in flasks containing either chitin or chitin plus Louisiana crude oil and inoculated with mixed cultures from the sources indicated.

Incubation Period	Inoculum Type	Heterotrophs	Chitinoclasts	Petroleum Oxidizers
Initial	H ₂ O	2.4x10 ⁵ (5.4)	2.0x10 ⁵ (5.3)	4.6x10 ³ (3.7)
	Inner Shelf Sed.	3.0x10 ⁵ (5.5)	3.0x10 ⁵ (5.5)	8.6x10 ² (2.9)
	Outer Shelf Sed.	3.6x10 ⁵ (5.6)	4.6x10 ⁵ (5.7)	8.6x10 ² (2.9)
	Shelf Break Sed.	6.8x10 ⁵ (5.8)	6.8x10 ⁵ (5.8)	1.9x10 ³ (3.3)
2 wk	H ₂ O + Oil	7.7x10 ⁸ (8.9)	2.1x10 ⁸ (8.3)	2.4x10 ⁹ (9.4)
	H ₂ O - Oil	7.6x10 ⁸ (8.9)	8.2x10 ⁸ (8.9)	4.3x10 ⁶ (6.6)
	Inner + Oil	1.6x10 ⁹ (9.2)	7.0x10 ⁸ (8.8)	9.3x10 ⁸ (9.0)
	Inner - Oil	1.2x10 ⁹ (9.1)	1.3x10 ⁹ (9.1)	4.3x10 ⁶ (6.6)
	Outer + Oil	5.6x10 ⁸ (8.7)	2.7x10 ⁸ (8.4)	4.3x10 ⁸ (8.6)
	Outer - Oil	1.5x10 ⁹ (9.2)	2.0x10 ⁹ (9.3)	1.5x10 ⁷ (7.2)
	Shelf Break + Oil	7.5x10 ⁸ (8.9)	4.8x10 ⁸ (8.7)	4.3x10 ⁸ (8.6)
	Shelf Break - Oil	9.2x10 ⁸ (9.0)	1.2x10 ⁹ (9.1)	4.3x10 ⁶ (6.6)
5 wk	H ₂ O + Oil	3.4x10 ⁸ (8.5)	9.2x10 ⁷ (8.0)	2.3x10 ⁸ (8.4)
	H ₂ O - Oil	8.0x10 ⁷ (7.9)	6.1x10 ⁷ (7.8)	9.3x10 ⁶ (7.0)
	Inner + Oil	3.5x10 ⁸ (8.5)	2.2x10 ⁸ (8.3)	2.9x10 ⁸ (8.5)
	Inner - Oil	1.8x10 ⁸ (8.3)	2.5x10 ⁸ (8.4)	7.5x10 ⁶ (6.9)
	Outer + Oil	2.4x10 ⁸ (8.4)	1.1x10 ⁸ (8.0)	2.3x10 ⁸ (8.4)
	Outer - Oil	5.0x10 ⁷ (7.7)	3.3x10 ⁷ (7.5)	9.3x10 ⁷ (8.0)
	Shelf Break + Oil	2.5x10 ⁸ (8.4)	1.4x10 ⁸ (8.1)	1.5x10 ⁸ (8.2)
	Shelf Break - Oil	2.5x10 ⁸ (8.4)	2.2x10 ⁸ (8.3)	4.3x10 ⁷ (7.6)
9 wk	H ₂ O + Oil	6.6x10 ⁷ (7.8)	4.9x10 ⁶ (6.7)	4.3x10 ⁷ (7.6)
	H ₂ O - Oil	4.3x10 ⁷ (7.6)	4.3x10 ⁶ (6.6)	4.3x10 ⁶ (6.6)
	Inner + Oil	9.1x10 ⁷ (8.7)	3.2x10 ⁷ (7.5)	4.3x10 ⁷ (7.6)
	Inner - Oil	9.1x10 ⁷ (8.0)	5.1x10 ⁷ (7.7)	9.3x10 ⁶ (7.0)
	Outer + Oil	8.9x10 ⁷ (7.9)	4.0x10 ⁷ (7.6)	4.3x10 ⁷ (7.6)
	Outer - Oil	4.7x10 ⁷ (7.7)	2.0x10 ⁷ (7.3)	4.3x10 ⁷ (7.6)
	Shelf Break + Oil	4.4x10 ⁷ (7.6)	2.4x10 ⁷ (7.4)	9.3x10 ⁶ (7.0)
	Shelf Break - Oil	7.0x10 ⁷ (7.8)	6.4x10 ⁷ (7.8)	2.3x10 ⁶ (6.4)

Table 11-54. (concluded).

Filterable Chitin Loss, mg							
	Incubation	+ Oil	- Oil		Incubation	+ Oil	- Oil
H ₂ O	2 wk	67.9	68.1	Outer Shelf	2 wk	62.4	76.8
	5 wk	83.1	83.3		5 wk	84.5	85.7
	9 wk	84.8	83.7		9 wk	84.2	82.1
Inner Shelf	2 wk	77.9	86.2	Shelf Break	2 wk	75.4	72.5
	5 wk	86.2	86.6		5 wk	86.3	84.9
	9 wk	86.3	86.6		9 wk	84.4	84.8

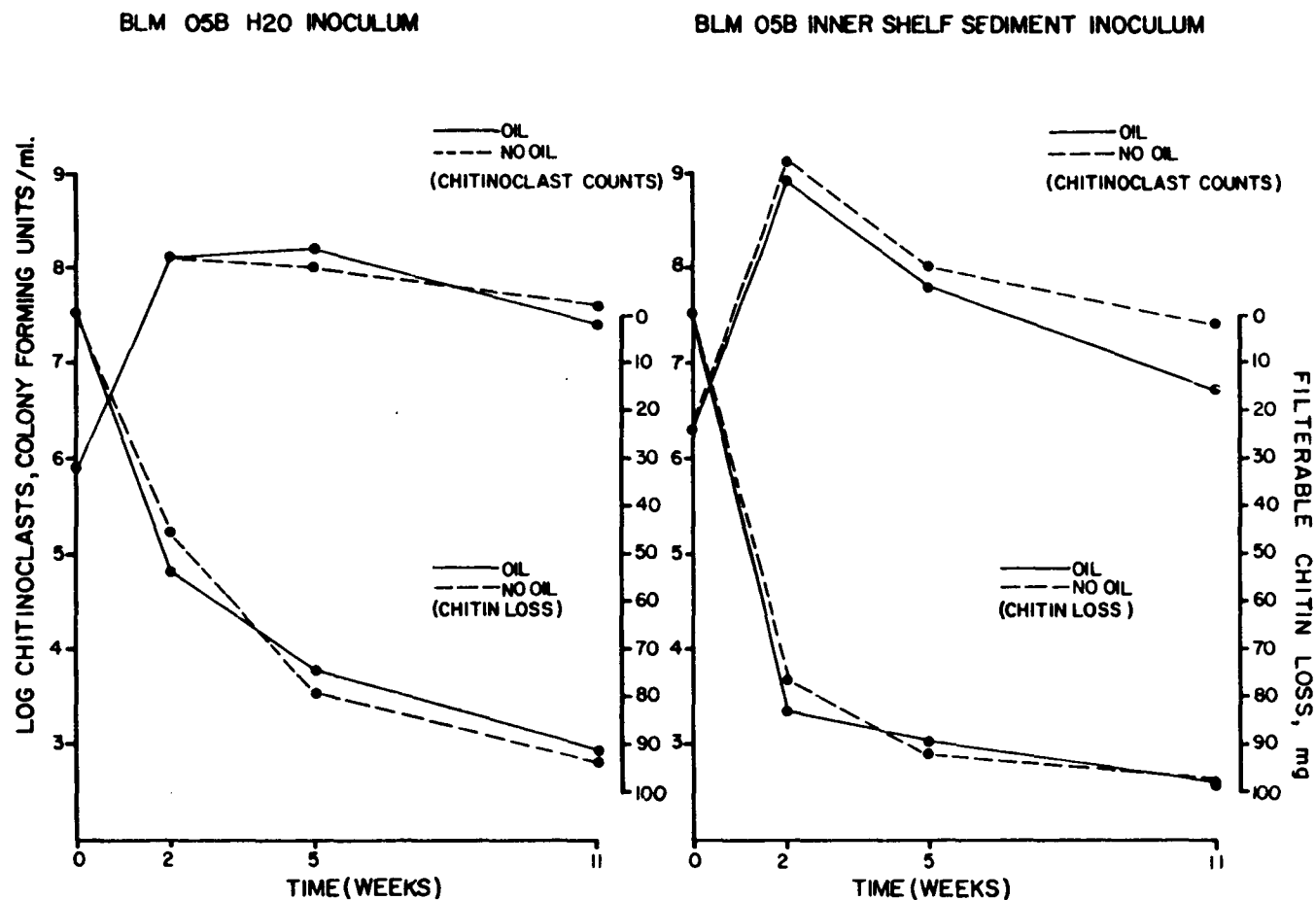


Figure 11-62. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

11-170

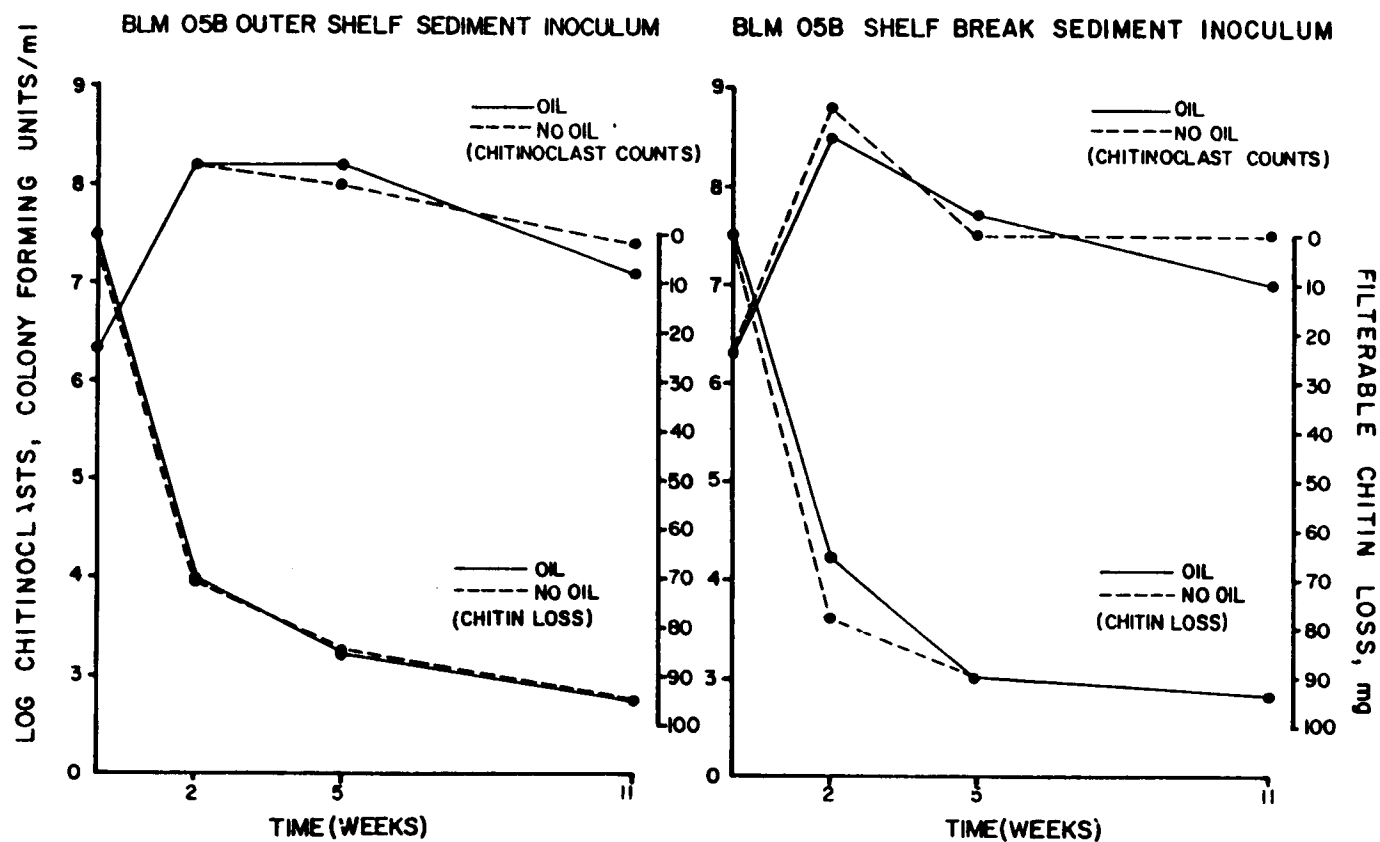
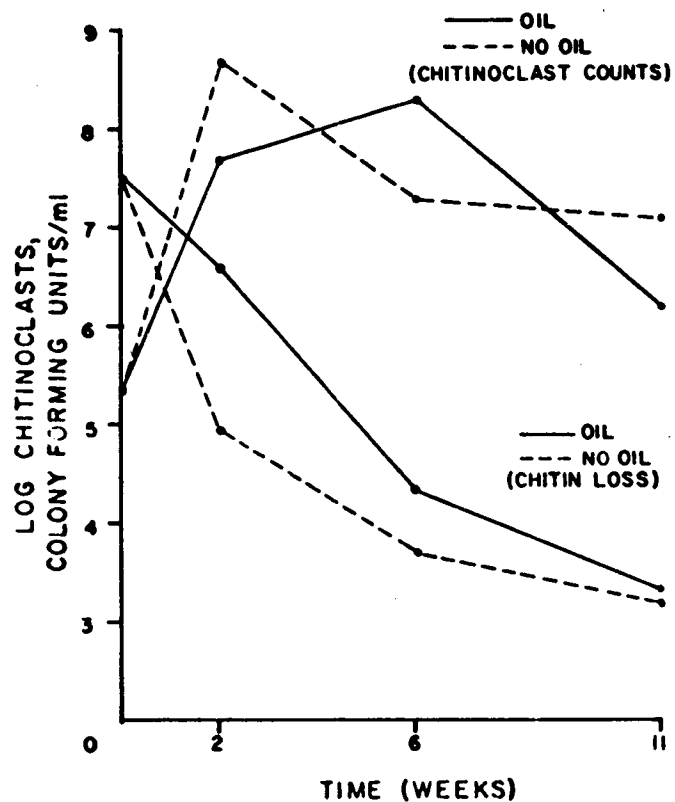


Figure 11-63. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

11-171

BLM 06B H2O INOCULUM



BLM 06B INNER SHELF SEDIMENT INOCULUM

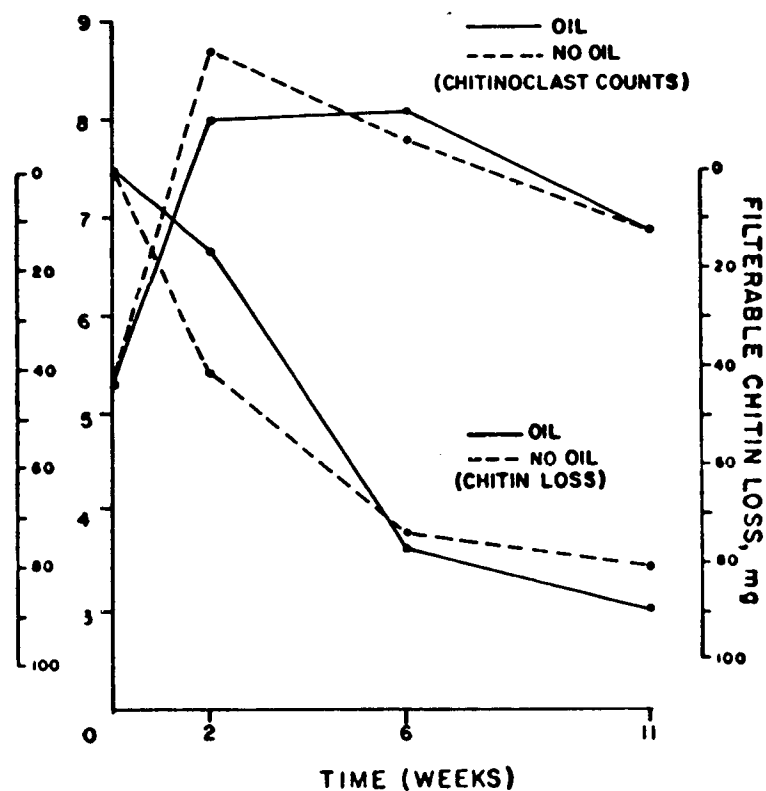


Figure 11-64. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

BLM 06B OUTER SHELF SEDIMENT INOCULUM

BLM 06B SHELF BREAK SEDIMENT INOCULUM

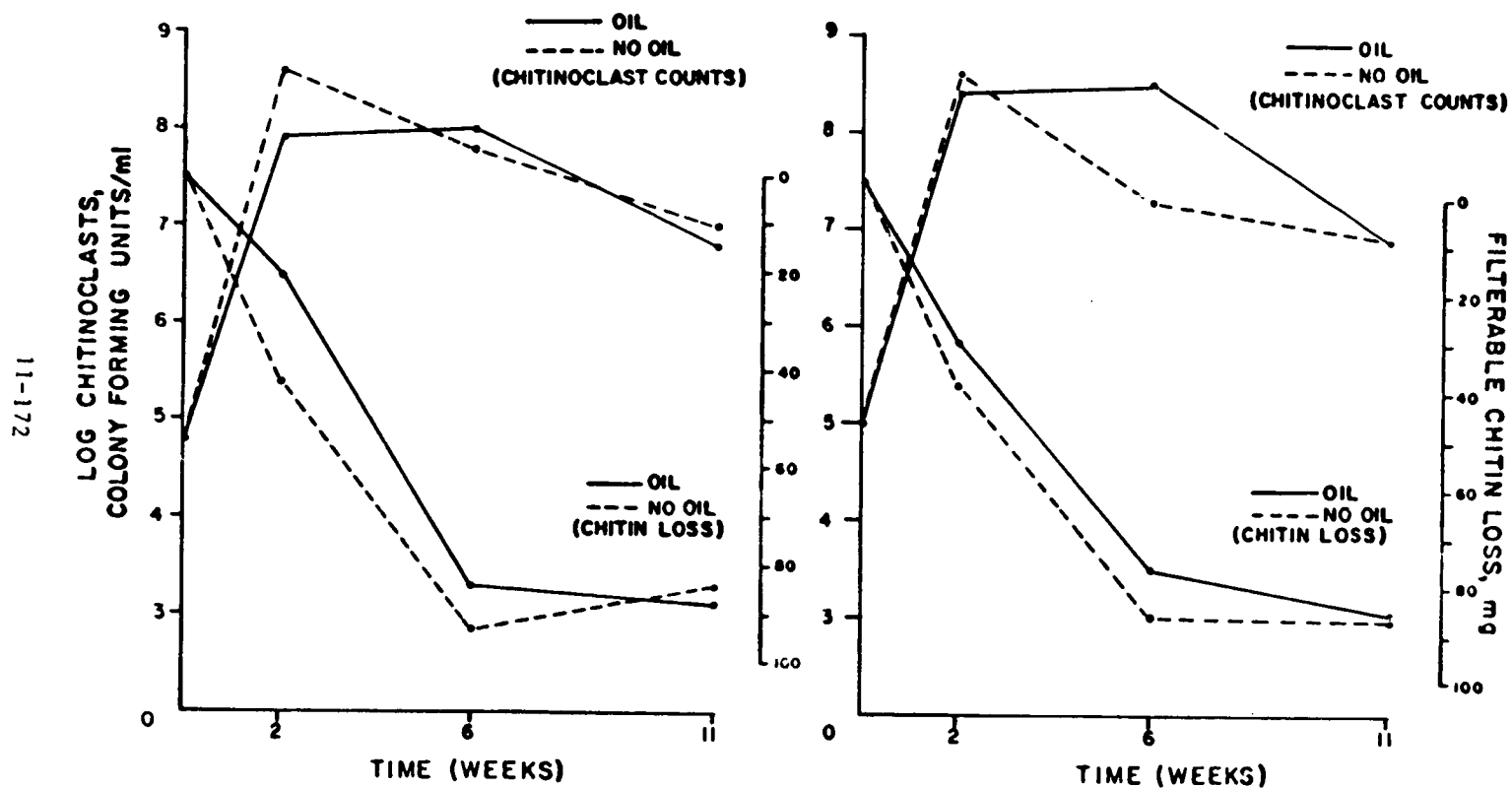


Figure 11-65. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

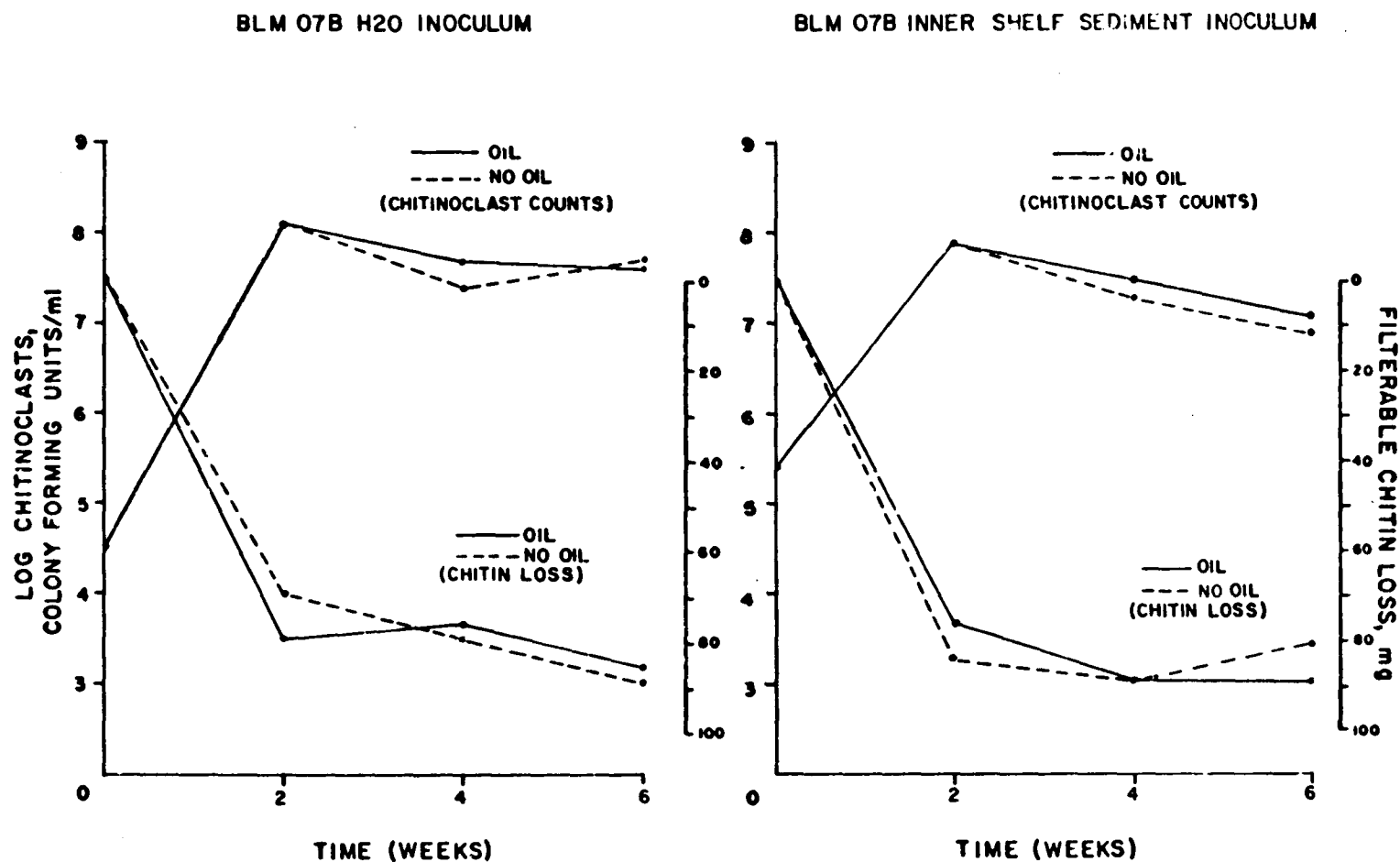


Figure 11-66. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

BLM 07B OUTER SHELF SEDIMENT INOCULUM

BLM 07B SHELF BREAK SEDIMENT INOCULUM

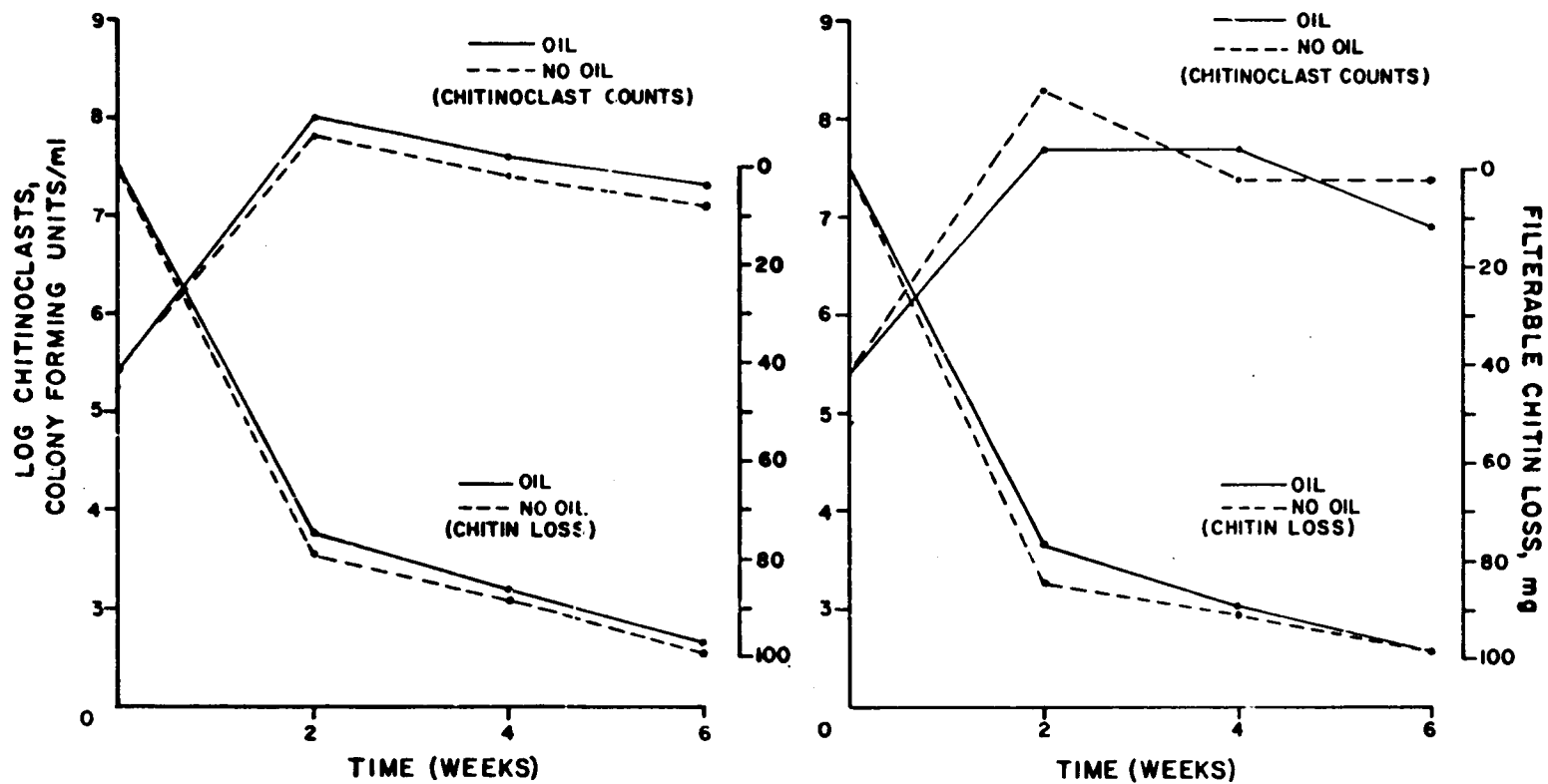
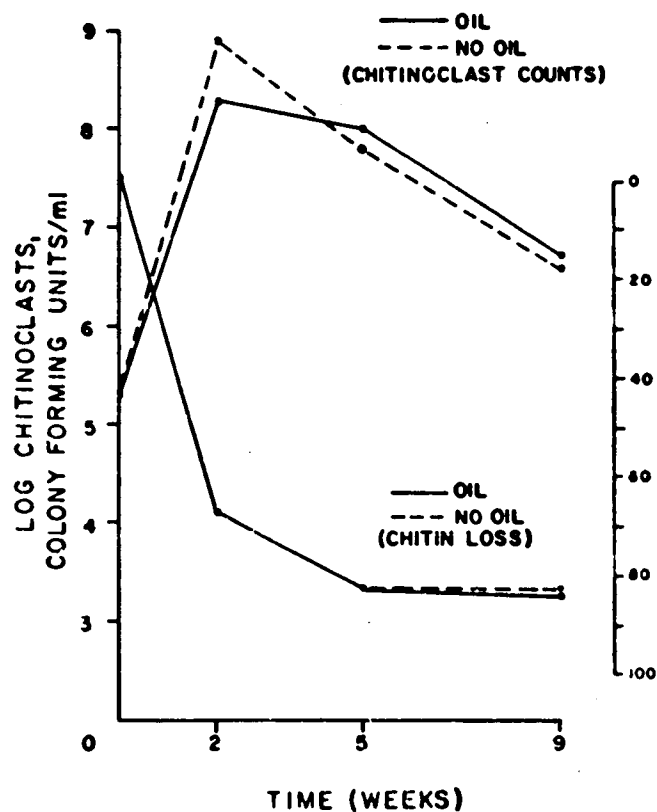


Figure 11-67. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

11-175

BLM 08B H2O INOCULUM



BLM 08B INNER SHELF SEDIMENT INOCULUM

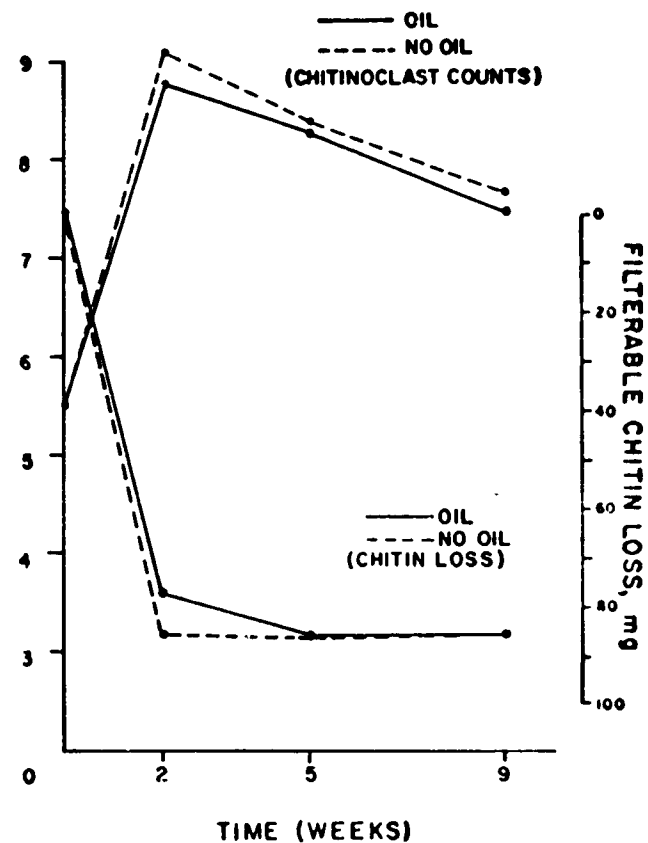
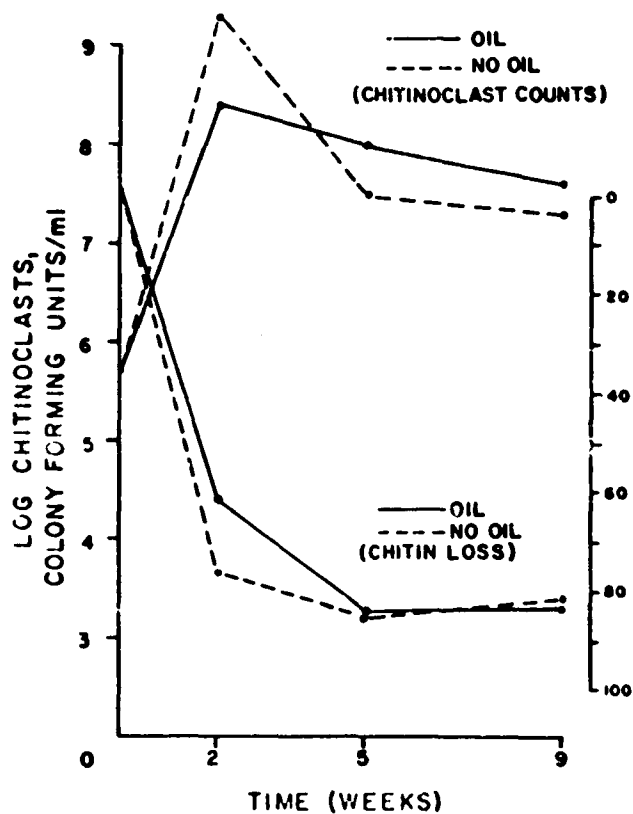


Figure 11-68. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

11-176

BLM 08B OUTER SHELF SEDIMENT INOCULUM



BLM 08B SHELF BREAK SEDIMENT INOCULUM

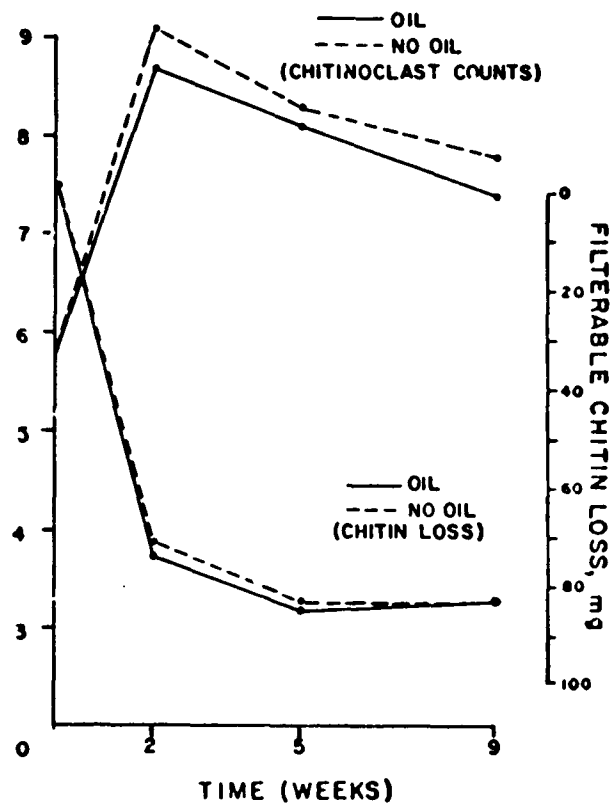


Figure 11-69. Change in amount of filterable chitin and viable counts of chitinoclastic marine bacteria in a dilute seawater-peptone-yeast extract broth with and without unweathered South Louisiana crude oil.

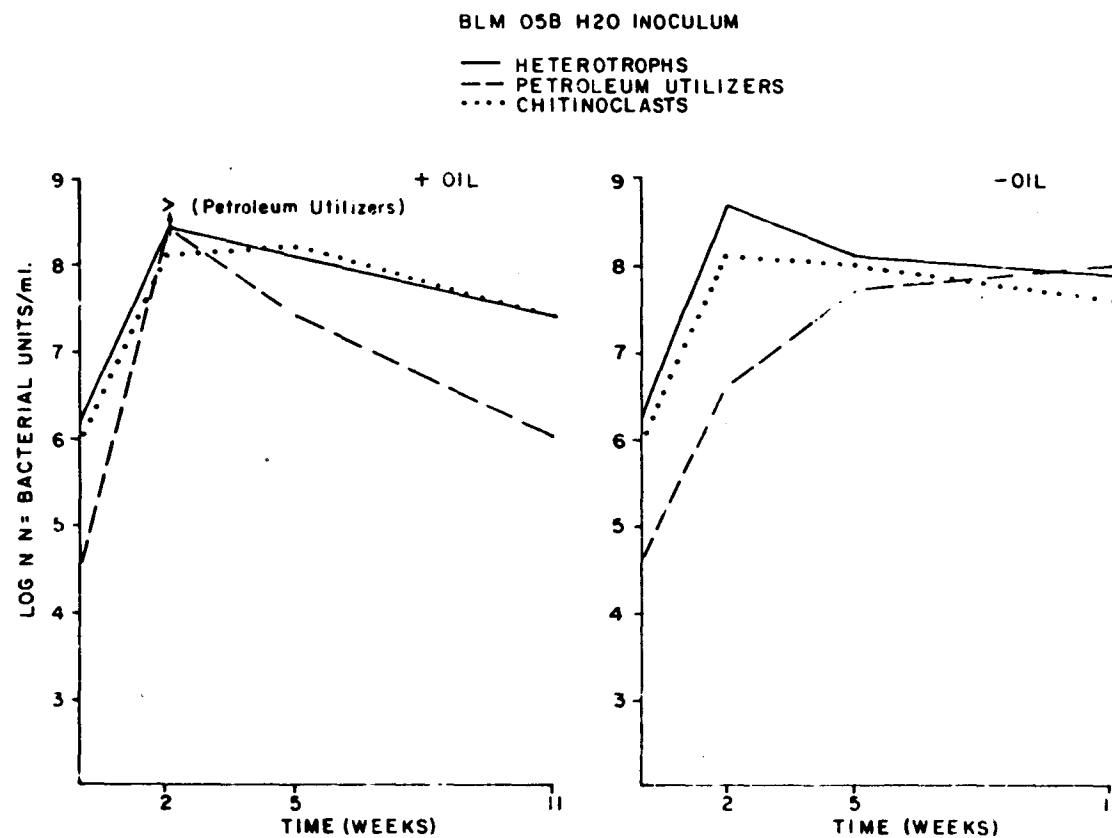


Figure 11-70. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 05B = Fall 1976.

11-179

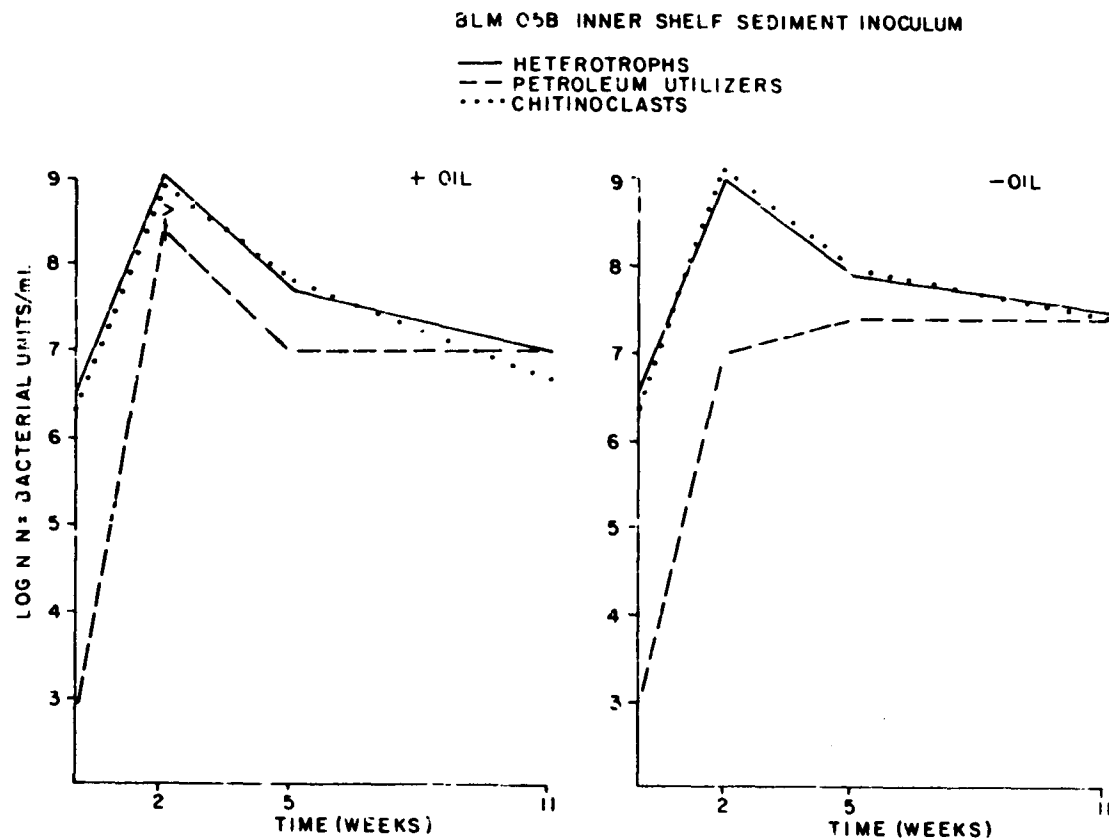


Figure 11-71. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 05B = Fall 1975.

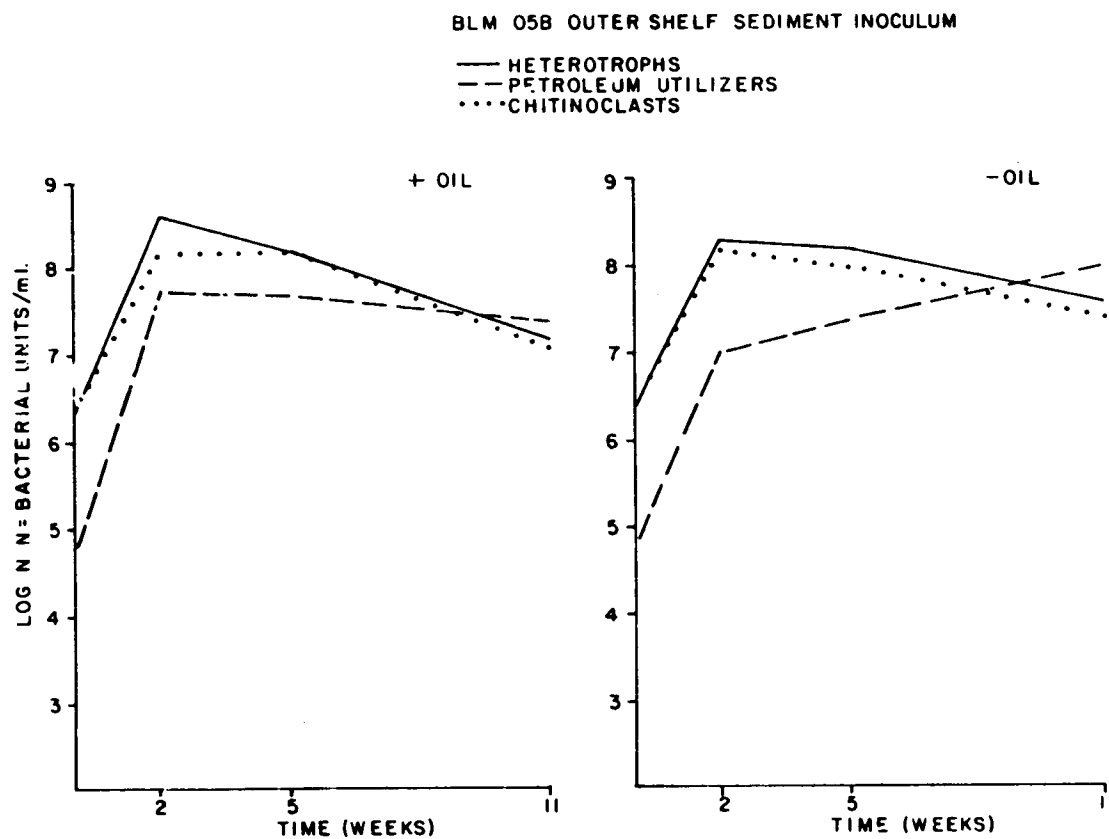


Figure 11-72. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 05B = Fall 1976.

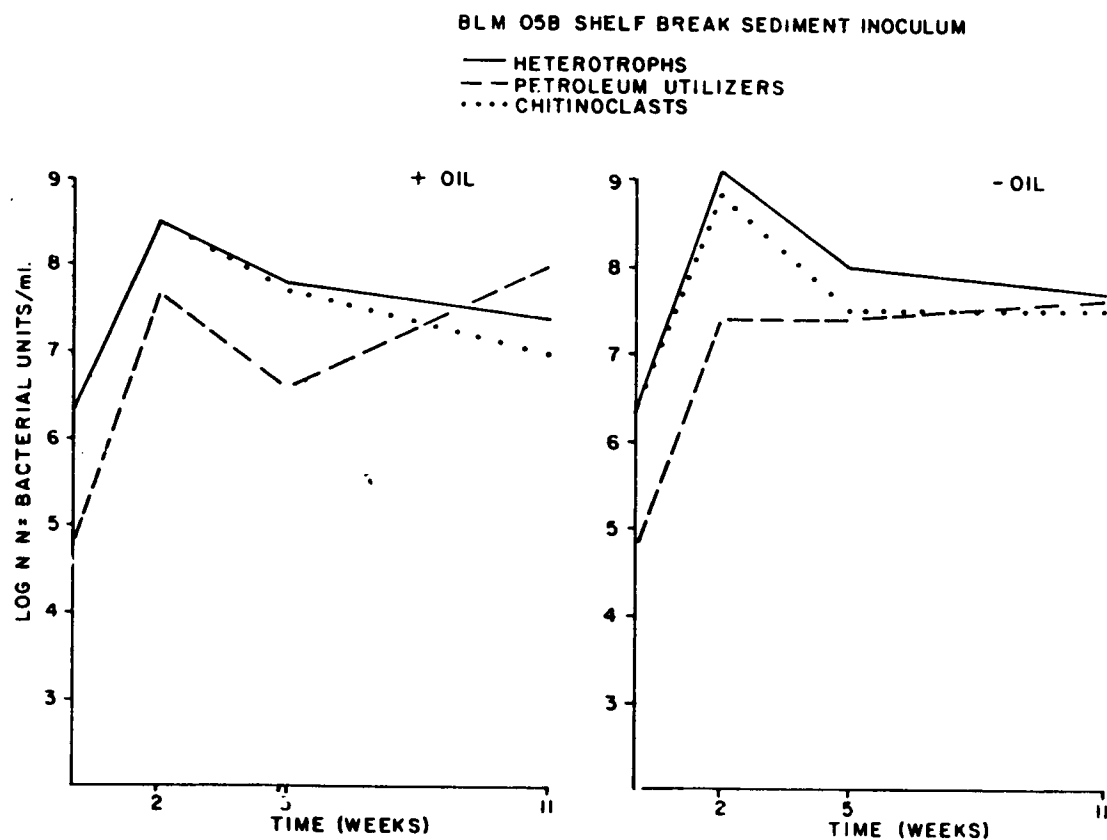


Figure 11-73. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 05B = Fall 1976.

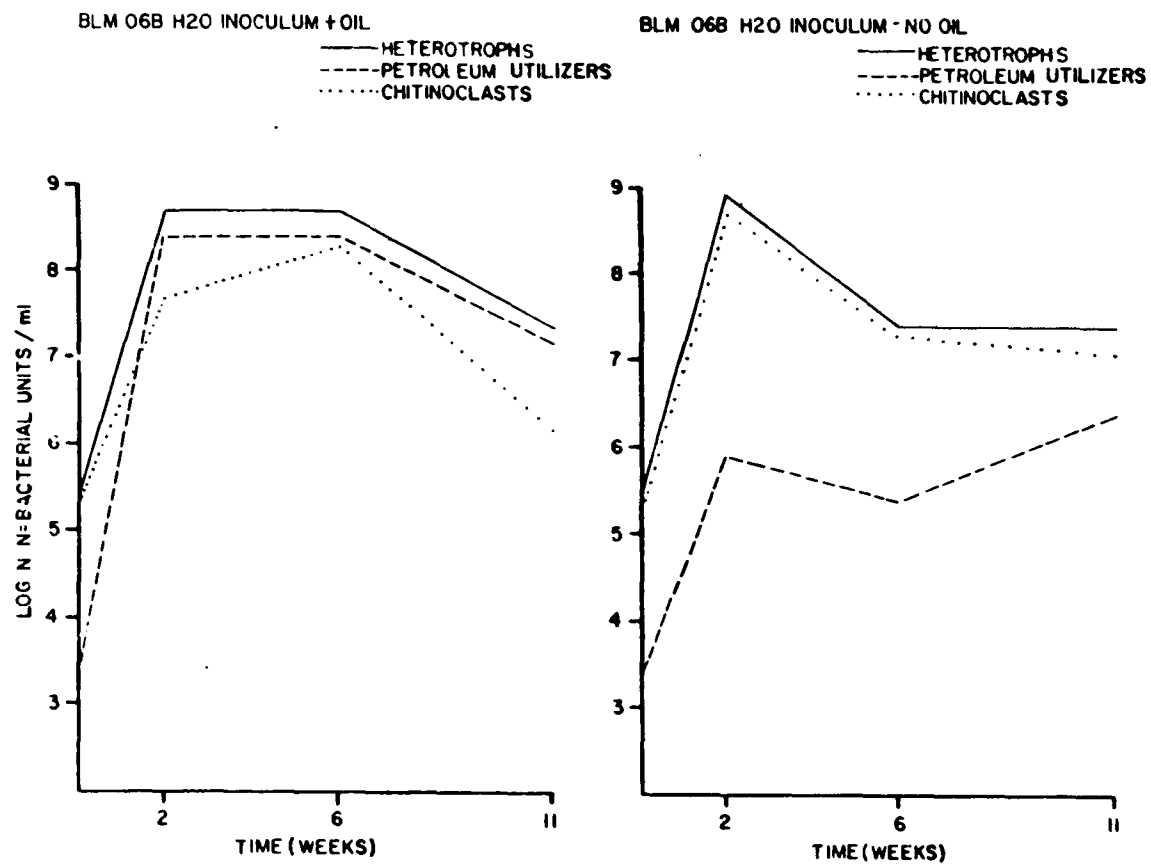


Figure 11-74. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 06B = Winter 1977.

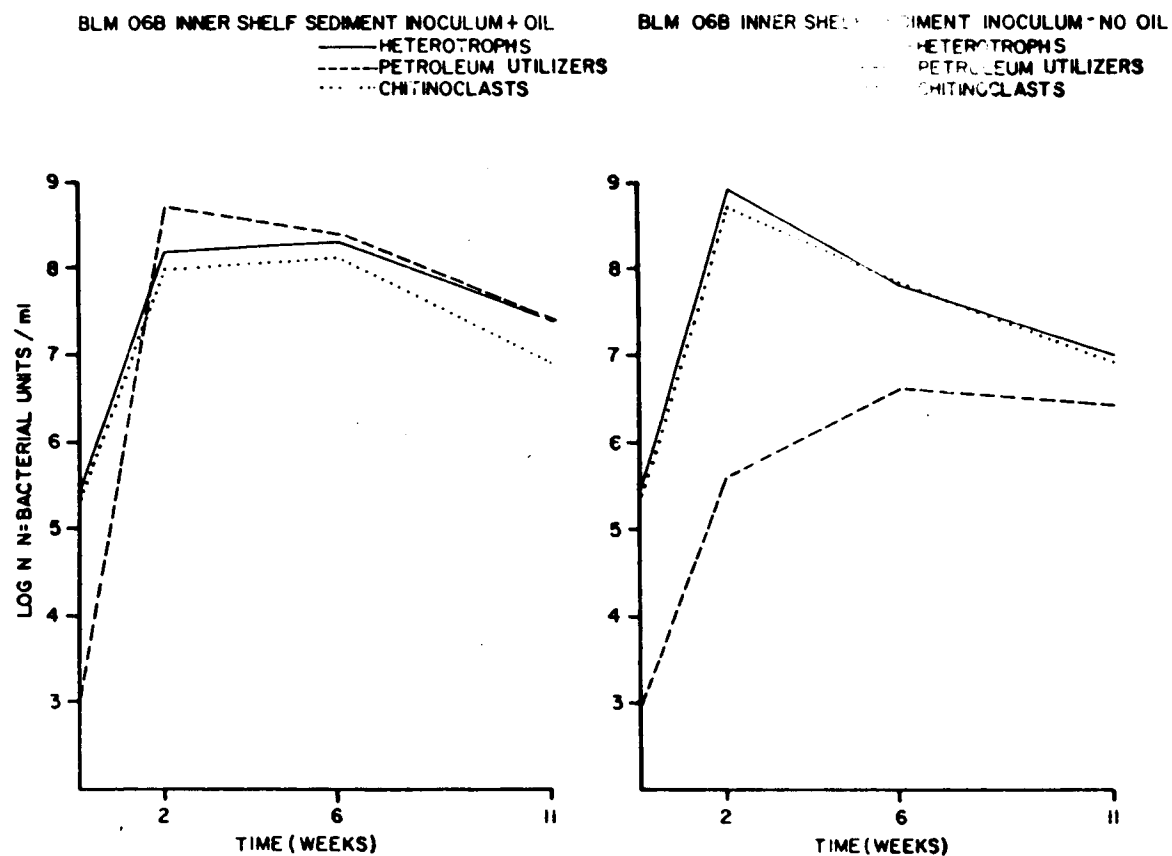


Figure 11-75. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 06B = Winter 1977.

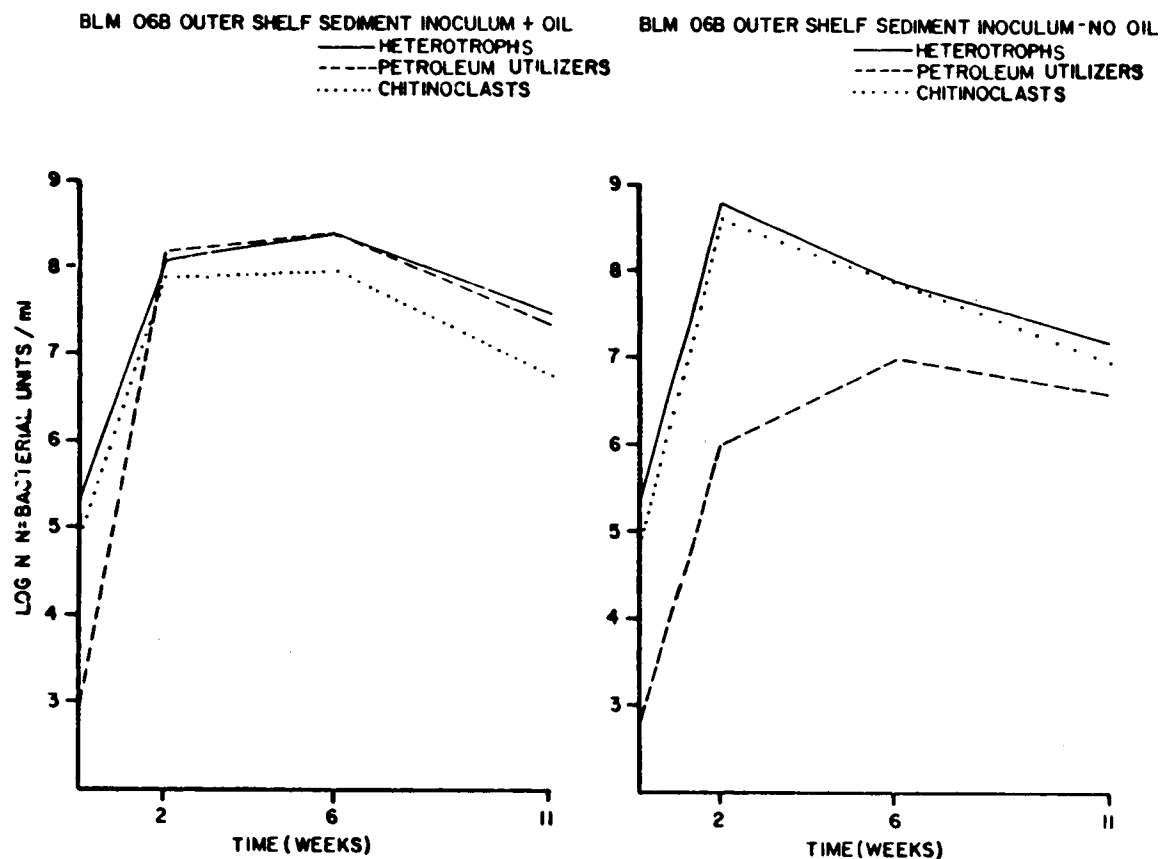


Figure 11-76. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 06B = Winter 1977.

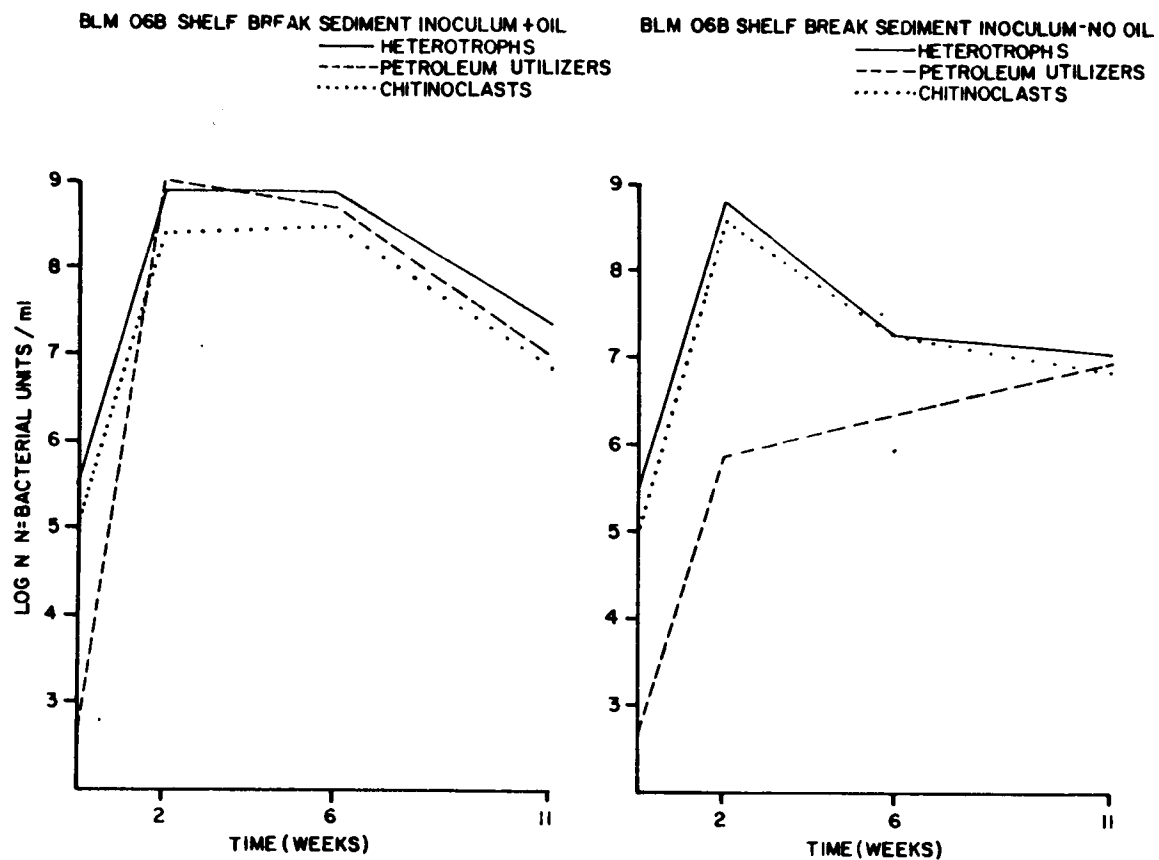


Figure 11-77. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 06B = Winter 1977.

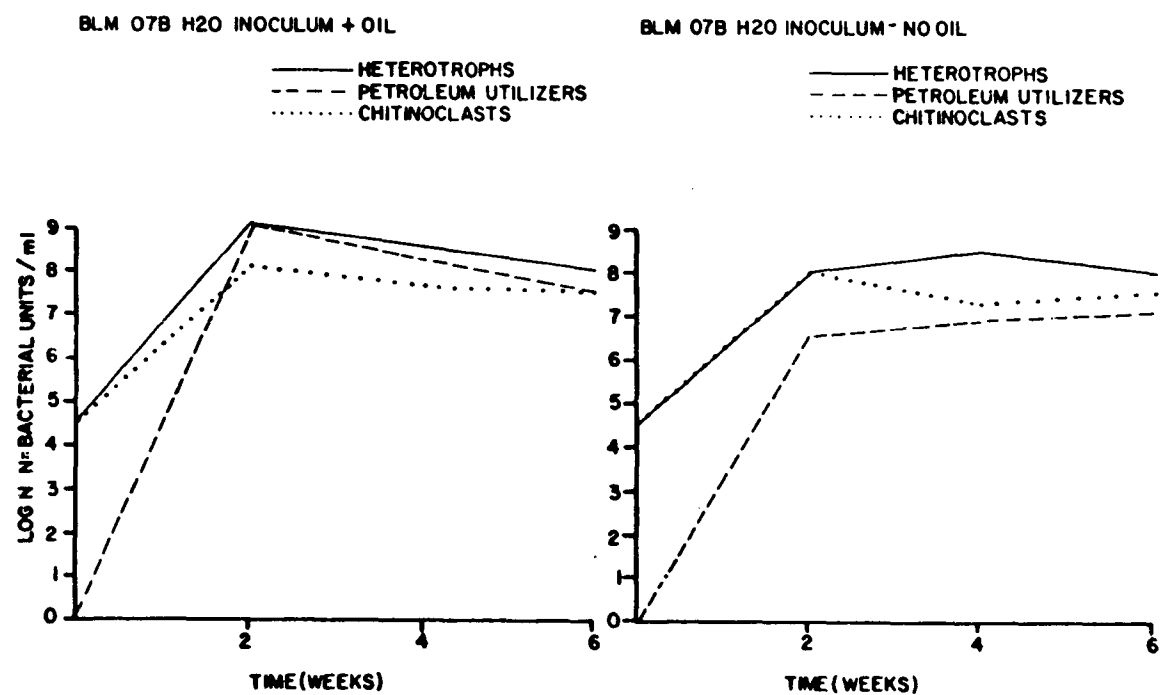


Figure 11-78. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 07B = Spring 1977.

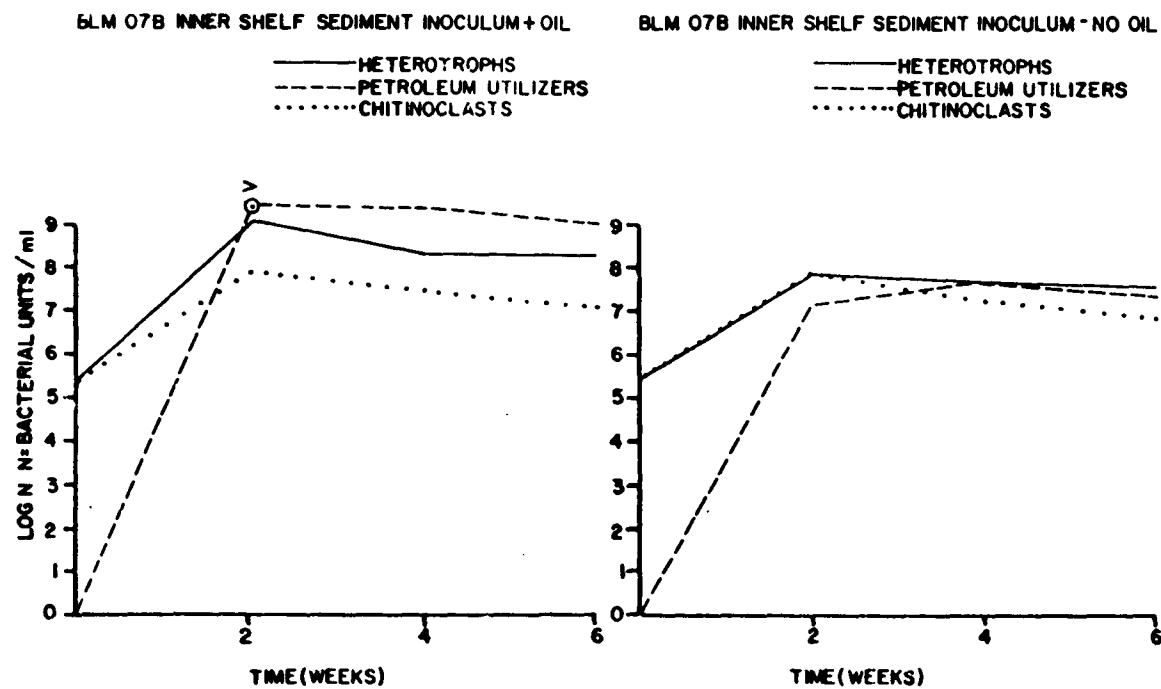


Figure 11-79. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 07B = Spring 1977.

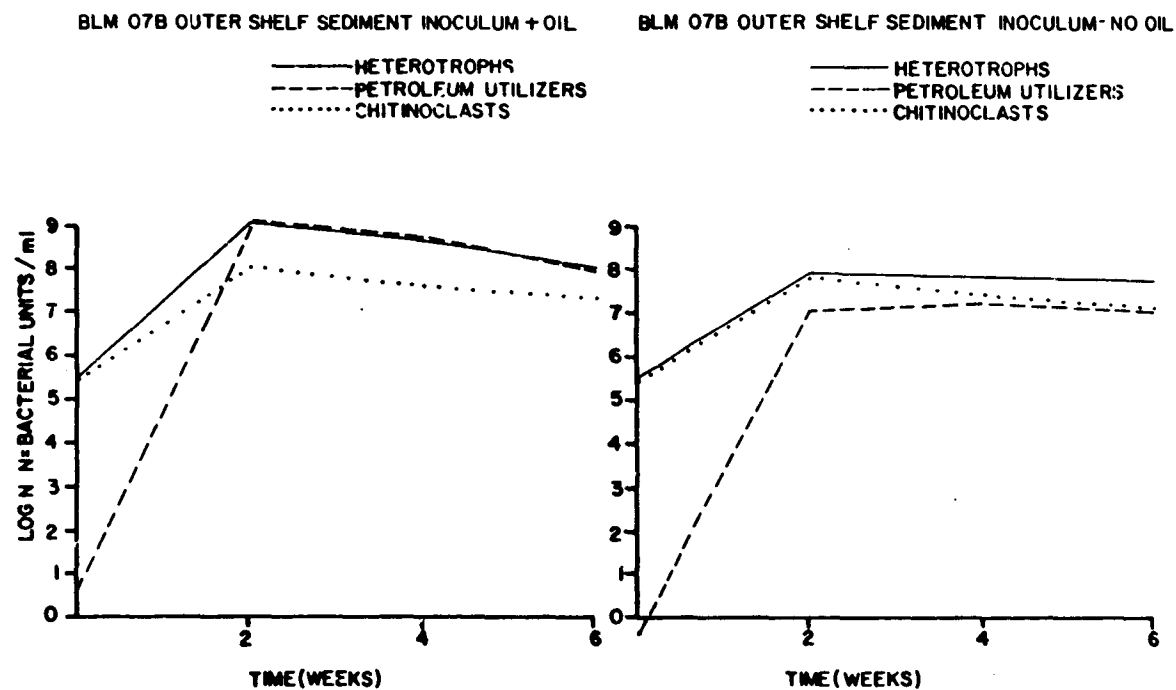


Figure 11-80. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 07B = Spring 1977.

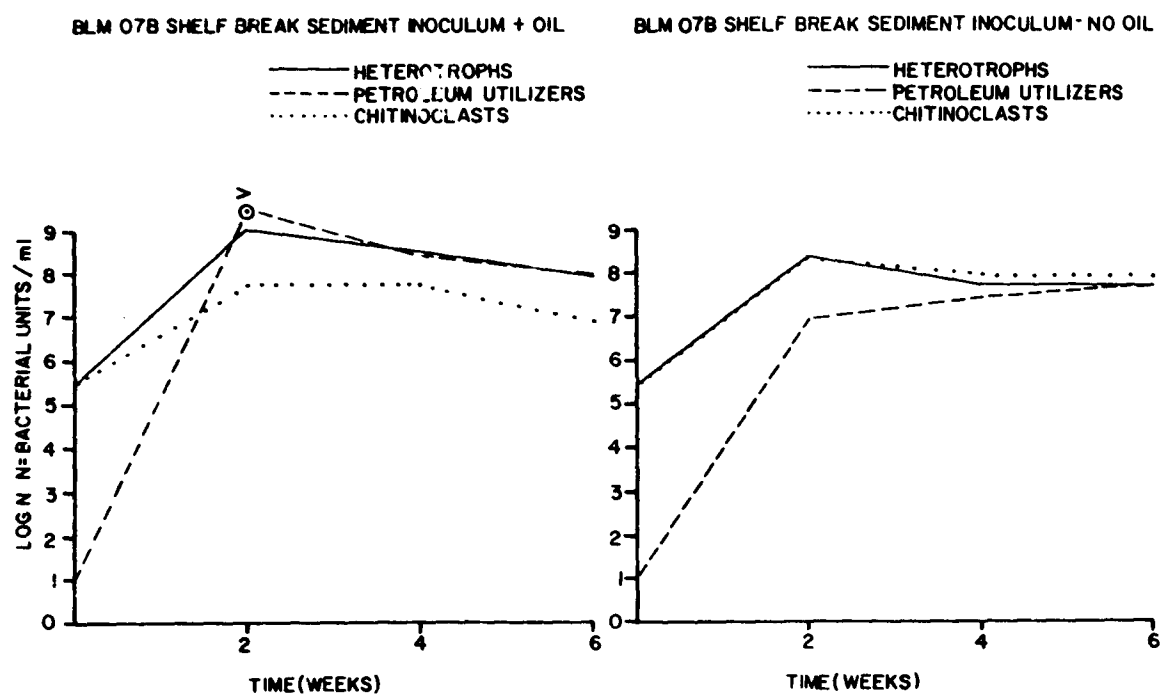


Figure 11-81. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 07B = Spring 1977.

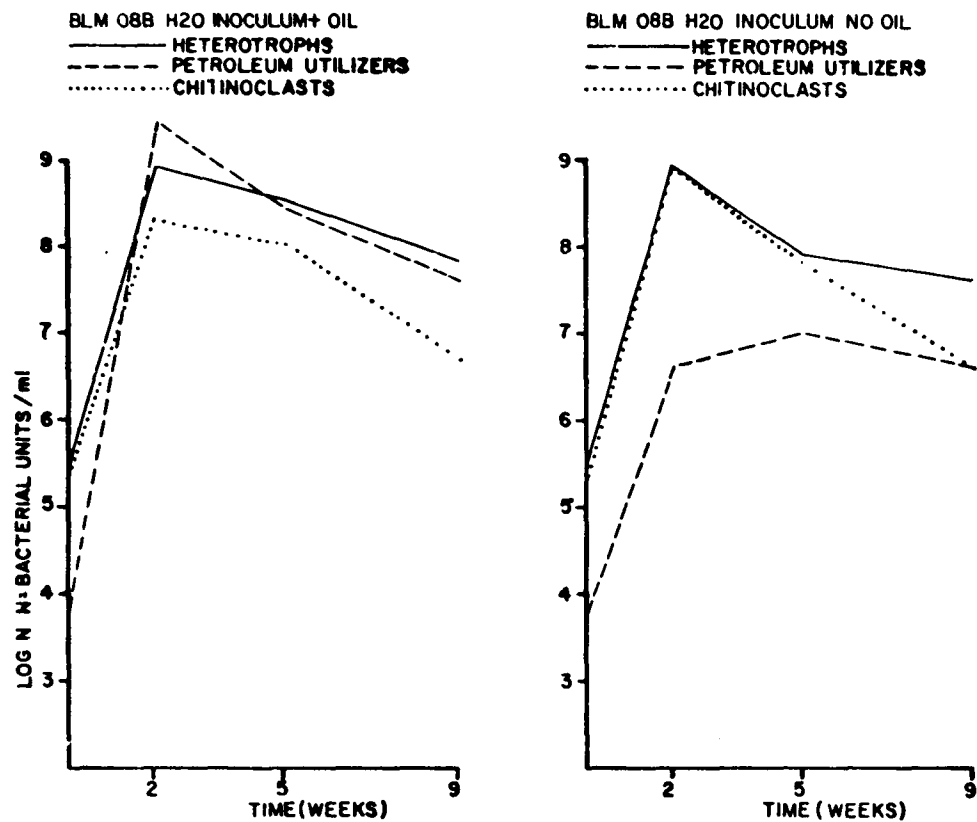


Figure 11-82. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 08B = Summer 1977.

061-11

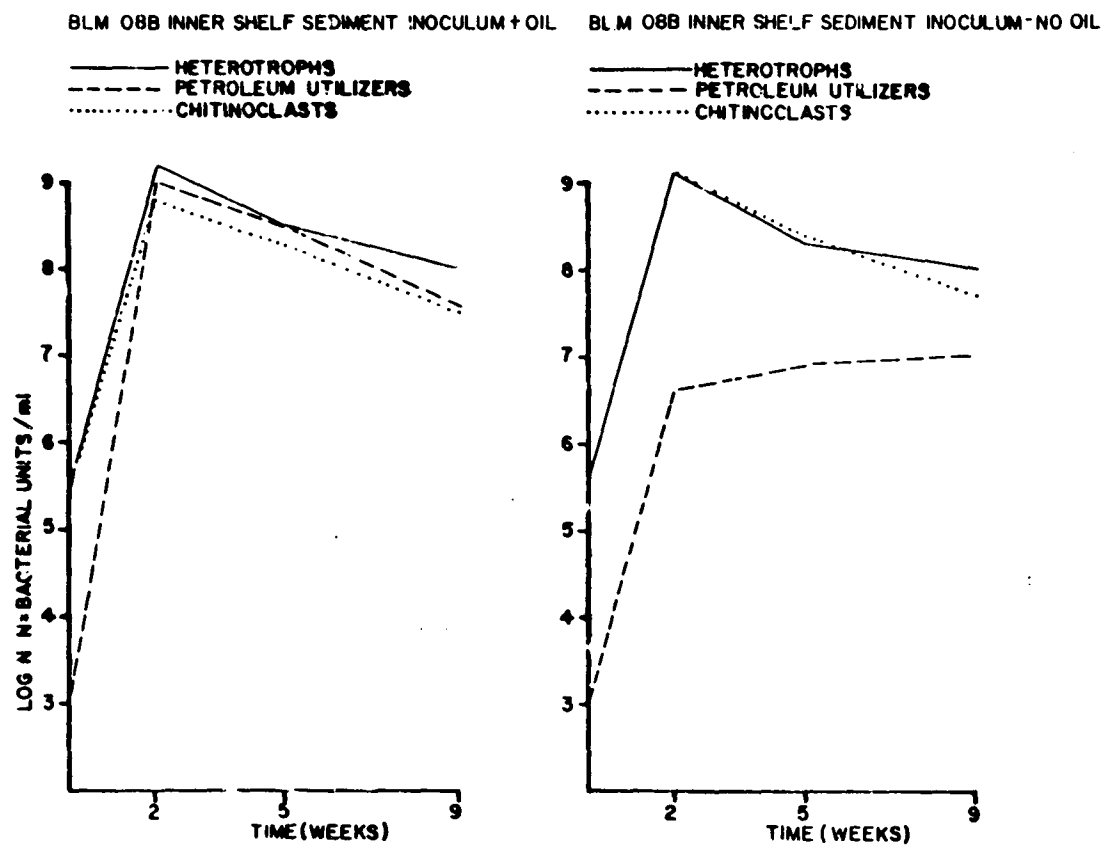


Figure 11-83. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 08B = Summer 1977.

11-191

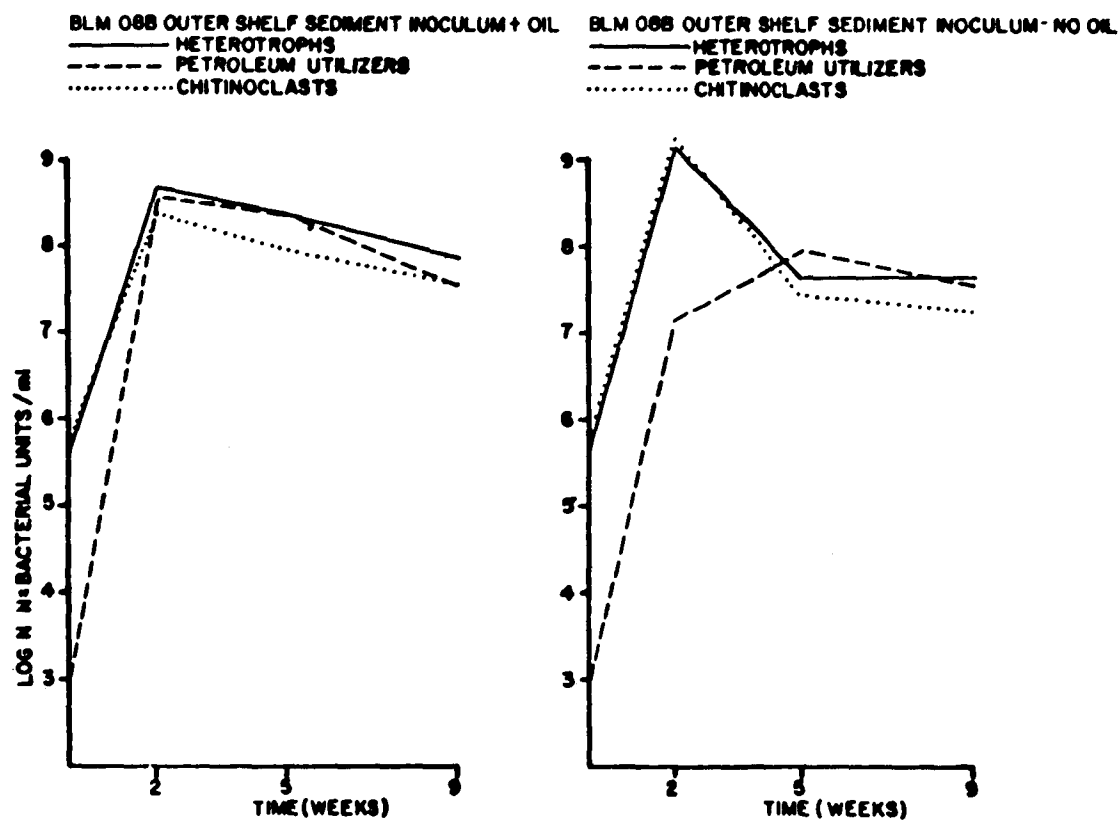


Figure 11-84. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 088 = Summer 1977.

11-192

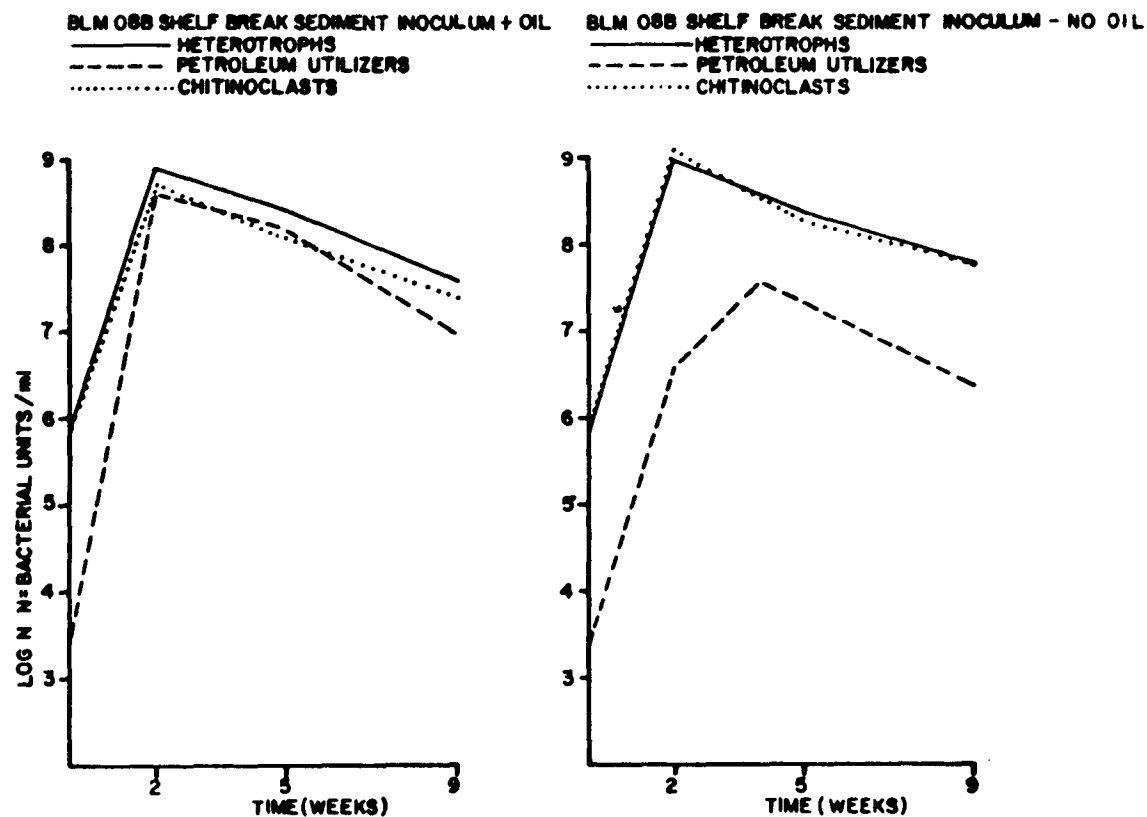


Figure 11-85. Viable counts of petroleum-degrading, heterotrophic, and chitinoclastic marine bacteria in closed flasks under the experimental conditions described. 08B = Summer 1977.

Table 11-55. Change in summation weights (μg) of crude oil n-paraffins (nC_{13} - nC_{25}) and % loss of crude oil during incubation in closed flasks with mixed cultures of chitinoclasts and hydrocarbon utilizers.

Inoculum	$\Sigma(\mu\text{g})$	% Loss	$\Sigma(\mu\text{g})$	% Loss	$\Sigma(\mu\text{g})$	% Loss	
FALL (05B)	2 weeks		5 weeks		11 weeks		**
Control	1621.8		1753.7		1483.4		$\bar{y} = 1619.6$ S.D. = 135.2
Water	0.0	100.0	0.0	100.0	0.0	100.0	S.D./ $\bar{y} = 8.3\%$
Inner Shelf	0.0	100.0	0.0	100.0	0.0	100.0	
Outer Shelf	0.0	100.0	0.0	100.0	0.0	100.0	
Shelf Break	0.0	100.0	0.0	100.0	0.0	100.0	
WINTER (06B)	2 weeks		6 weeks		11 weeks		**
Control	1307.1		1534.1		1261.2		$\bar{y} = 1420.6$ S.D. = 160.5
Water	0.0	100.0*	0.0	100.0*	0.0	100.0*	S.D./ $\bar{y} = 11.3\%$
Inner Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Outer Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Shelf Break	0.0	100.0*	0.0	100.0*	0.0	100.0*	
SPRING (07B)	2 weeks		4 weeks		6 weeks		**
Control	1616.7		1617.3		1785.0		$\bar{y} = 1673.0$ S.D. = 97.0
Water	0.0	100.0*	0.0	100.0*	0.0	100.0*	S.D./ $\bar{y} = 5.8\%$
Inner Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Outer Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Shelf Break	0.0	100.0*	0.0	100.0*	0.0	100.0*	
SUMMER (08B)	2 weeks		5 weeks		9 weeks		**
Control	1777.8		1615.8		1729.2		$\bar{y} = 1707.6$ S.D. = 83.1
Water	0.0	100.0*	0.0	100.0*	0.0	100.0*	S.D./ $\bar{y} = 4.9\%$
Inner Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Outer Shelf	0.0	100.0*	0.0	100.0*	0.0	100.0*	
Shelf Break	0.0	100.0*	0.0	100.0*	0.0	100.0*	

* Pristane, phytane, and other unidentified branched compounds also degraded.

** Mean control value for entire incubation period.

reach maximum values before six weeks. Counts of petroleum-degraders and chitinoclasts reached plateau values within 2 weeks with little change for 4 weeks. In contrast, chitinoclast counts in oil-free flasks rapidly increased to maximum values within 2 weeks followed by a gradual decay over the next 9 weeks. Petroleum-degraders increased several orders of magnitude within 2 weeks but generally continued to increase to maximum values during 6-11 weeks when chitinoclast counts were declining. This response suggested a diauxie-like growth phenomenon as the petroleum-degrading bacteria could have been growing on lipoidal metabolic products produced by chitinoclasts. Rates of chitin degradation were greater in the oil-free flasks during the initial two week period (Table 11-52) and were reflective of viable counts. However, total chitin losses at the termination of the incubation period were similar in oil-treated and oil-free flasks.

Similar patterns of viable counts and chitin loss data were observed for the spring shelf break (Figure 11-67) and summer inner and outer shelf (Figures 11-68 and 11-69) sediment inocula. Count data from the remaining experiments did not reveal as marked or consistent differences between oil-free and oil-treated flasks.

Results of analyses of residual petroleum from winter, spring, and summer experiments are shown in Table 11-56. Note that the summation weights of (n-paraffins nC_{13} - nC_{25}), and in some cases also isoprenoids, were reduced to baseline within 2 weeks of incubation. Coincident with this period the greatest losses in filterable chitin also occurred. Non-parametric analysis of chitin loss data in oil-free and oil-treated flasks indicated chitin losses were not significantly different ($\alpha = 0.05$) for 1st and 2nd incubation intervals with the exception of the winter experiment (first incubation interval, Table 11-56).

Pure Culture - Petroleum Growth Studies

Results of experiments to examine the effects of unweathered (1% w/v), laboratory weathered (1% w/v) and a water soluble fraction (1% v/v) of South Louisiana crude oil on the growth of selected marine bacterial isolates are summarized in Table 11-57. Representative growth curves for the dominant genera are shown in Figures 11-86 through 11-94. In the absence of petroleum hydrocarbons, Vibrio and Pseudomonas characteristically exhibited the shortest lag times (9 and 13 hours, respectively) as expressed by optical density plots. Contrastingly, "lag" times exhibited by Alcaligenes and Flavobacterium were considerably longer (26 and 39 hours, respectively). Of the four major genera, Vibrio exhibited the smallest deviation from the median "lag" time value whereas Pseudomonas, Alcaligenes and Flavobacterium showed increasingly larger deviations.

A non-parametric statistical test (Friedman test, Conover 1971) was used to corroborate the non-uniformity of "lag" time values

(TEXT CONTINUES ON PAGE 11-205)

Table 11-56 . Results of Mann-Whitney Statistic to test
 H_0 : chitin loss in oil treated flasks
equal to loss in oil-free flasks
 H_1 : chitin loss in oil treated flasks are
not equal to loss in oil-free flasks.
For all seasons and treatments
 $T_{critical} = 14$ $\alpha = 0.05$.

Season	Incubation Intervals	
	First	Second
Winter	T=16 H_0 Rejected	T=10 H_0 Accepted
Spring	T=11 H_0 Accepted	T=9 H_0 Accepted
Summer	T=11 H_0 Accepted	T=9 H_0 Accepted

Table 11-57. Effects of unweathered, laboratory weathered and a soluble fraction of South Louisiana crude oil on the median "lag" times of isolates from representative genera of marine bacteria from Middle Atlantic continental shelf water and sediment samples.

Genus	Isolates Examined	Median "lag" time (hours)			
		Control	Soluble Fraction	Unweathered Oil	Weathered Oil
<u>Alcaligenes</u>	23	26	25	29	27
<u>Flavobacterium</u>	18	39	40	52	50
<u>Pseudomonas</u>	16	13	13	15	15
<u>Vibrio</u>	13	9	9	9.5	9

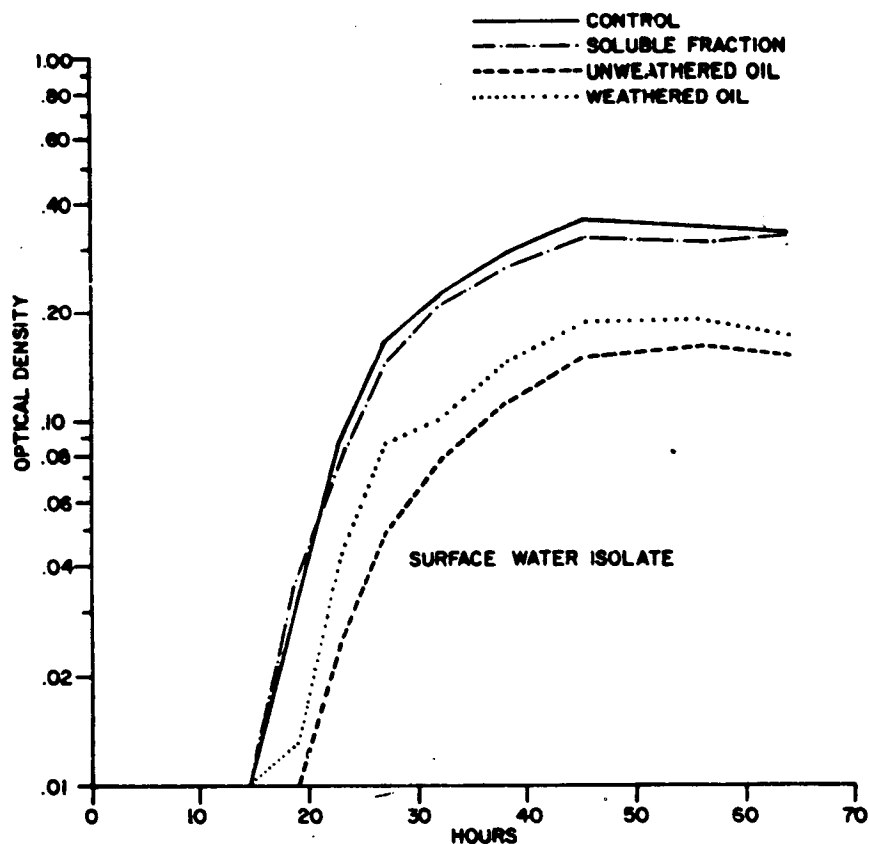


Figure 11-86. Representative growth curves for *Alcaligenes* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

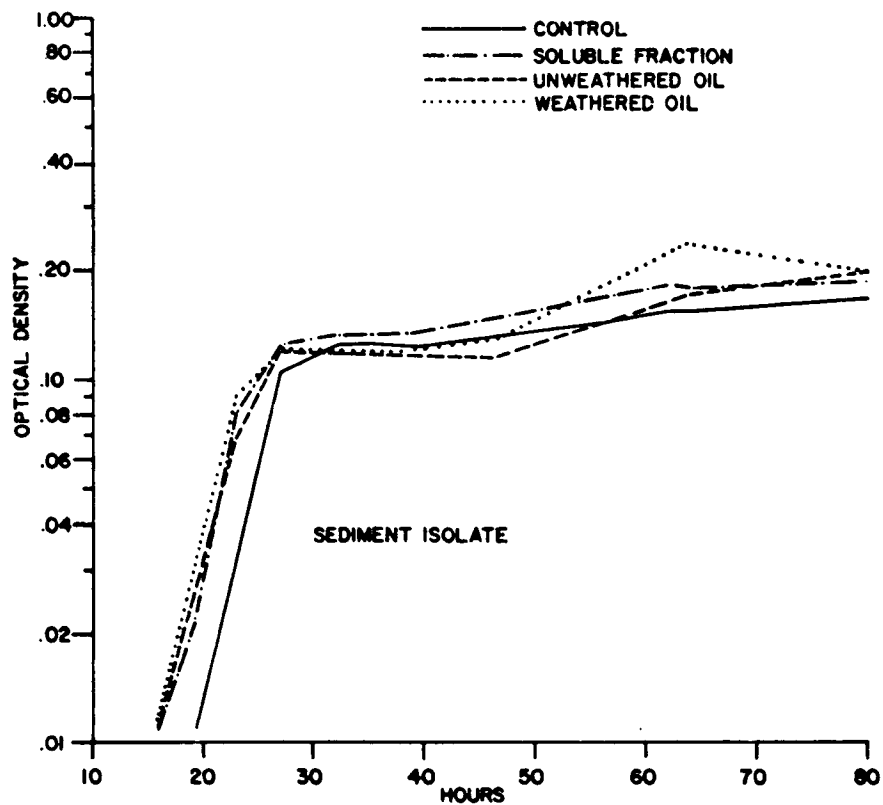


Figure 11-87. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

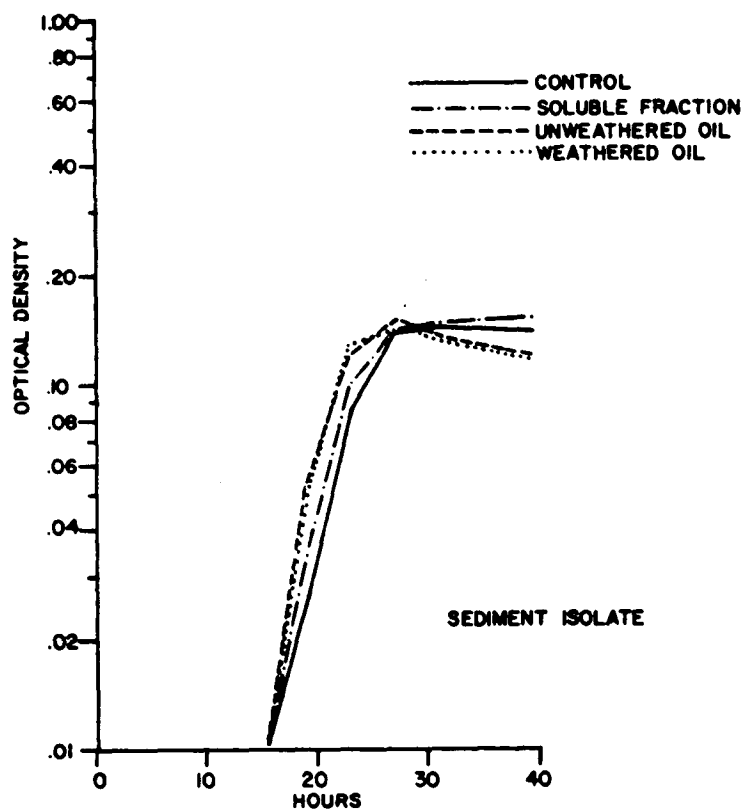


Figure 11-88. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

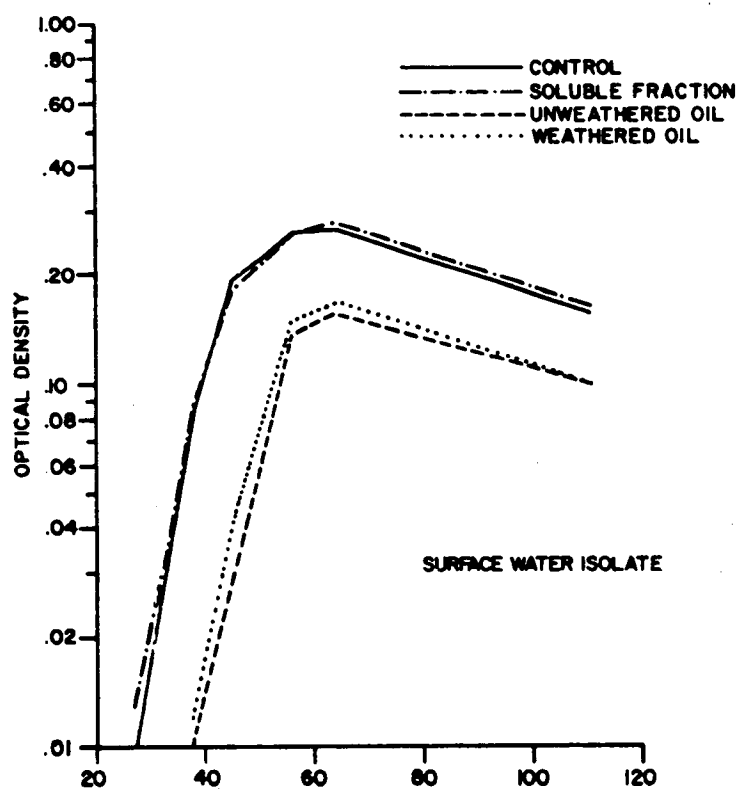


Figure 11-89. Representative growth curves for Flavobacterium sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

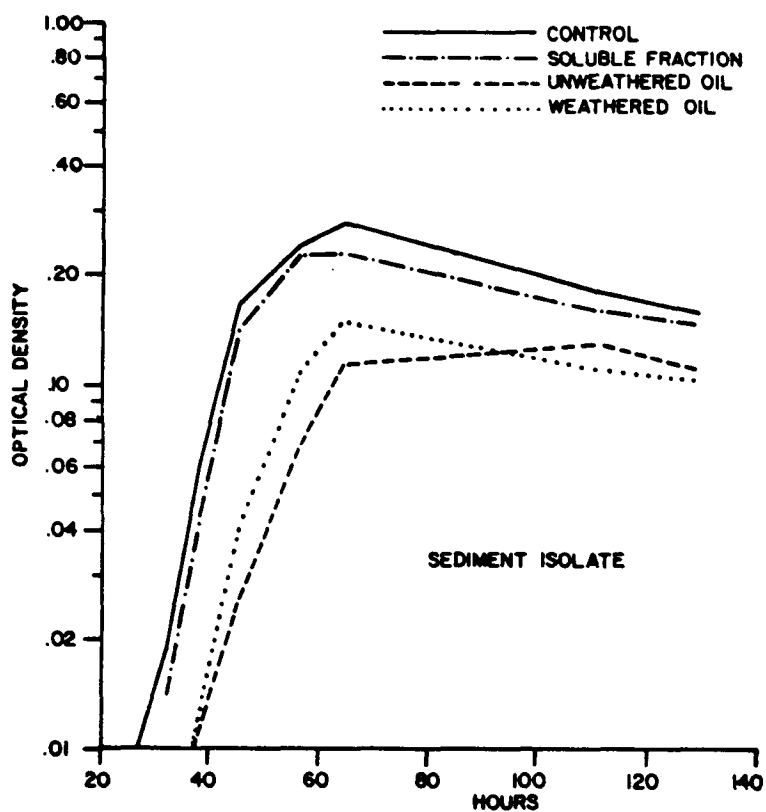


Figure 11-90. Representative growth curves for Flavobacterium sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

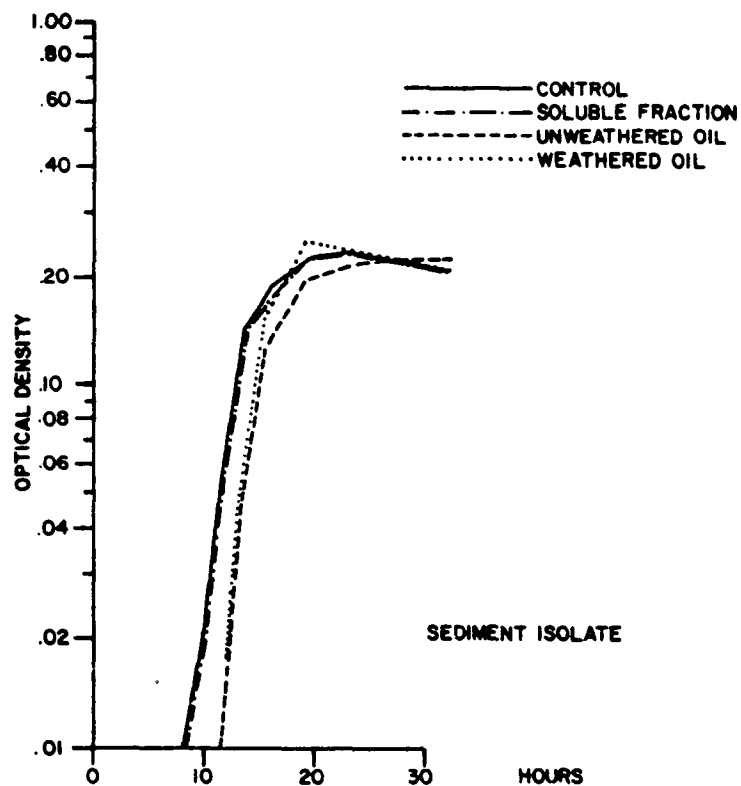


Figure 11-91. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

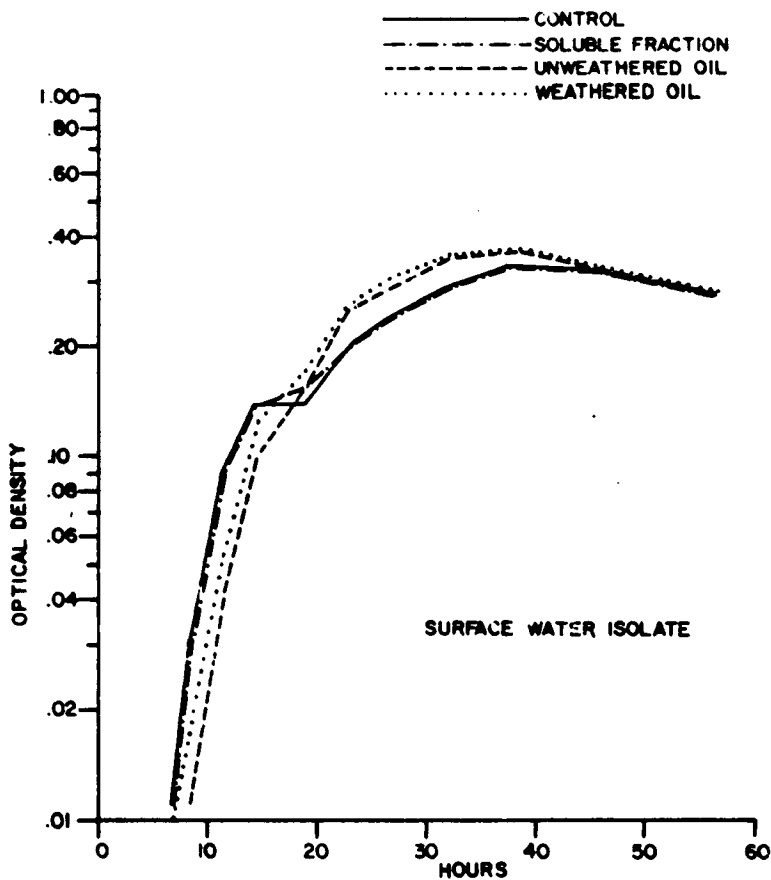


Figure 11-92. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

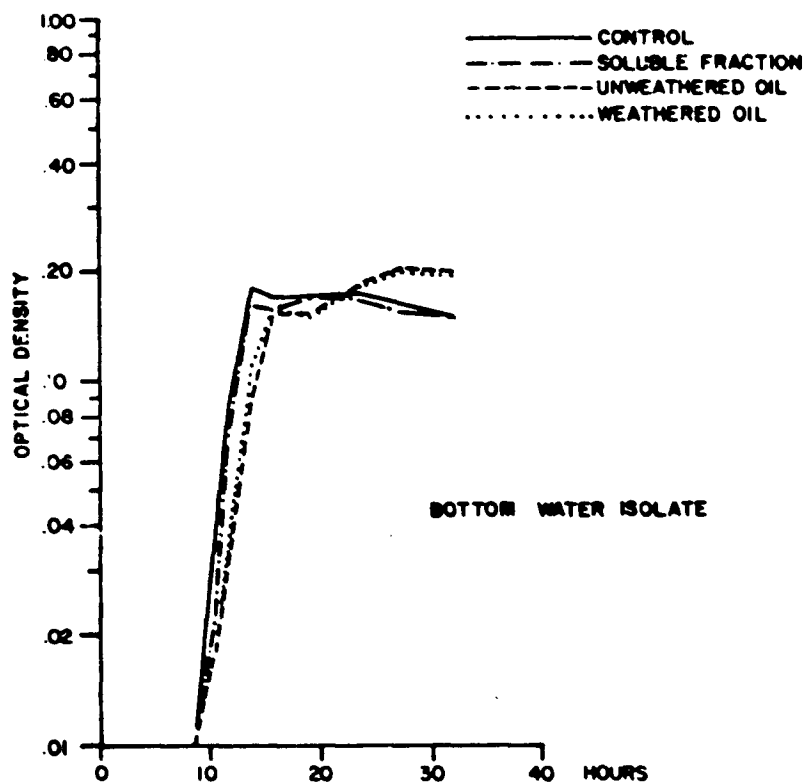


Figure 11-93. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

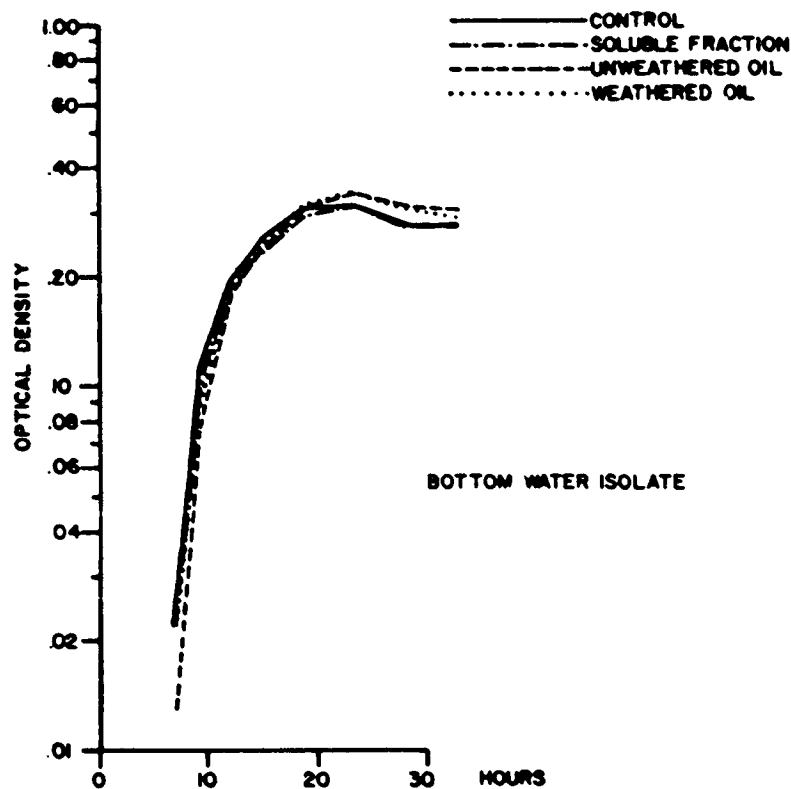


Figure 11-94. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) a soluble fraction of South Louisiana crude oil (ca. 1%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) laboratory weathered South Louisiana crude oil (ca. 1%).

comparing all experimental treatments. Test results indicated that "lag" time values were not uniform for all treatments and the null hypothesis, i.e., "lag" time values under all growth conditions were the same was rejected for Pseudomonas and Flavobacterium ($\alpha = 0.01$) and rejected for all generic groups ($\alpha = 0.05$) (Table 11-58). Water soluble extracts of crude oil at the concentration employed had relatively little affect on growth for the majority of isolates. "Lag" time values for Vibrio were slightly increased in the presence of unweathered crude oil whereas Pseudomonas exhibited somewhat longer "lag" periods in the presence of both unweathered and weathered oil (Table 11-57). Flavobacterium lag times were more extended with median "lag" value increases of 10-12 hours in the presence of crude oil. Considering all isolates identified as Alcaligenes, unweathered oil was less inhibitory than weathered oil. Subdividing these isolates according to isolation medium, i.e., HM or ESWB plus petroleum, revealed somewhat different susceptibility responses. Median "lag" time values of 28, 27, 40 and 37 hours (control, soluble fraction, unweathered and weathered oil respectively) were observed for HM isolates as opposed to corresponding values of 26, 25, 26 and 26 hours for ESWB plus petroleum isolates. Subdivision of the three remaining genera is not presented because the numbers of isolates were small and were not evenly represented from HM and ESWB plus petroleum media.

Susceptibilities of isolates from HM and ESWB plus petroleum enumeration media as a function of degree of "lag" effect for isolates from microlayer, surface water (1 meter), bottom water, and sediment samples are shown in Table 11-59. HM isolates from all sample sources were most strongly affected by unweathered and weathered crude oil with the majority of isolates exhibiting "lag" time increases of four or more hours relative to controls. In contrast, ESWB plus petroleum isolates were least affected with the majority of isolates showing no or insignificant growth effects. No pattern could be established with respect to sample source and occurrence of adverse growth responses in the presence of petroleum. The relative abundances of generic types comprising the HM and ESWB plus petroleum isolates are shown in Table 11-60. Although the numbers of respective isolates were small, 60% of the HM isolates were comprised of Alcaligenes and Flavobacterium, whereas Pseudomonas and Vibrio constituted 51% of the ESWB plus petroleum isolates.

The extent of effect as reflected by "lag" time length appeared similar for unweathered and laboratory weathered oil. A four hour or longer delay in "lag" time was noted for 45.1% of all isolates in the presence of unweathered oil while 46.4% of the cultures were similarly affected by weathered oil (Table 11-59). Approximately 6-11% of all isolates examined were stimulated by the presence of petroleum hydrocarbons with decreases in median "lag" time of 2-3 hours. The majority of isolates exhibiting decreased "lag" intervals were obtained from ESWB media.

Table 11-58. Friedman T statistic calculated for "lag" times exhibited by pure isolates of indicated genera grown in a dilute seawater-peptone medium and this medium containing either unweathered South Louisiana crude oil (1%), or laboratory weathered South Louisiana crude oil (1%) or a soluble fraction of South Louisiana crude oil (1%).

Genus	Number of Isolates Examined	Calculated T Value ^a	Critical T Value		H ₀ : All Treatments Have Identical Effects	
			$\alpha = 0.01$	$\alpha = 0.05$	$\alpha = 0.01$	$\alpha = 0.05$
<u>Alcaligenes</u>	23	11.14	11.3	7.8	Accepted	Rejected
<u>Flavobacterium</u>	18	41.35	11.3	7.8	Rejected	Rejected
<u>Pseudomonas</u>	16	32.21	11.3	7.8	Rejected	Rejected
<u>Vibrio</u>	13	7.87	11.3	7.8	Accepted	Rejected

^aFriedman nonparametric test statistic (Practical Nonparametric Statistics, W.J. Conover, John Wiley and Sons, Inc., 1971).

Table 11-59. Percentages of cultures affected (relative to a non-oil treated control) and degree of effect of unweathered and laboratory weathered South Louisiana crude oil and the water soluble fraction thereof on growth of bacterial isolates from heterotroph (HM) and petroleum-degrading (ESWB) enumeration media from microlayer, surface water (1 meter), bottom water and sediment samples. Legend: (+)=enhancement, >1 hr. decrease in "lag" time; (0)=no effect, <1 hr. difference in "lag" time; (-)=1 to 3 hr. increase in "lag" time; (--)=4-10 hr. increase in "lag" time; (---)=>10 hr. increase in "lag" time or no growth.

Culture Origin	No. Cultures Examined	% of cultures affected and degree of effect in growth media containing:														
		Soluble Fraction (1%)					Unweathered Oil (1%)					Weathered Oil (1%)				
		+	0	-	--	---	+	0	-	--	---	+	0	-	--	---
Microlayer (HM medium)	3		33.3	66.7					66.7	33.3				66.7	33.3	
Surface Water (HM medium)	12	8.3	83.3	8.3			16.7	16.7	25	41.7		16.7	25	41.7	16.7	
Surface Water (ESWB medium)	13	7.7	92.3				53.8	30.8	15.4			53.8	30.8	15.4		
Bottom Water (HM medium)	14		100				7.1	14.3	35.7	42.9		7.1	7.1	50		35.7
Bottom Water (ESWB medium)	11	18.2	81.8				18.2	27.3	36.4	18.2	18.2	27.3	36.4	9.1	9.1	
Sediment (HM medium)	14		78.6	21.4			21.4	7.1	14.3	57.1		7.1	21.4	35.7		35.7
Sediment (ESWB medium)	15	33.3	66.7				20	26.7	46.7	6.7		20	33.3	33.3	13.3	

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Table 11-59. (Concluded)

Culture Origin	No. Cultures Examined	% of cultures affected and degree of effect in growth media containing:														
		Soluble Fraction (1%)					Unweathered Oil (1%)					Weathered Oil (1%)				
		+	0	-	--	---	+	0	-	--	---	+	0	-	--	---
TOTALS																
HM medium	43	2.3	83.7	14	0	0	0	14	11.6	27.9	46.5	0	9.3	16.3	44.2	30.2
ESWB																
medium	39	20.5	79.5	0	0	0	12.8	35.9	38.5	7.7	5.1	12.8	38.5	33.3	12.8	2.6
HM & ESWB																
media	82	11	81.7	7.3	0	0	6.1	24.4	24.4	18.3	26.8	6.1	23.2	24.4	29.3	17.1

Table 11-60. Relative abundance of dominant genera as a function of sample type and enumeration media used for pure culture growth experiments involving unweathered and laboratory weathered South Louisiana crude oil and the soluble fraction thereof.

Genus	Sample Type							
	Microlayer		Surface (lm)		Bottom		Sediment	
	HC ^a	Het ^b	HC	Het	HC	Het	HC	Het
<u>Acinetobacter</u>				1/12				1/14
<u>Aeromonas</u>				1/12				
<u>Alcaligenes</u>		1/3	4/13	2/12	2/11	3/14	8/15	3/14
<u>Flavobacterium</u>		2/3	1/13	4/12		4/14		7/14
<u>Pseudomonas</u>			3/13	3/12	3/11	2/14	5/15	
<u>Vibrio</u>			4/13		4/11	2/14	1/15	2/14
Misc. isolates			1/13	1/12	2/11	3/14	1/15	1/14

^aESWB-Medium for enumeration of petroleum-degrading bacteria.

^bHM-Medium for enumeration of heterotrophic bacteria.

Results of experiments to investigate the effects of photo-oxidized South Louisiana crude oil (1% w/v), the resulting soluble fraction (100% v/v), and unweathered crude oil (1% w/v) on bacterial growth are presented in Table 11-61. Representative growth curves for the dominant genera are shown in Figures 11-95 through 11-114. Distribution of "lag" times for all isolates of a given genus for each treatment are shown as histograms in Figures 11-115 through 11-118.

"Lag" time values in the absence of petroleum hydrocarbons (Table 11-61) were similar to those observed for isolates obtained during the fall cruise (Table 11-57). Vibrio and Pseudomonas exhibited the shortest "lag" times while those of Alcaligenes and Flavobacterium were considerably longer and exhibited more variation around the median value.

Application of the Friedman test (Conover 1971) confirmed that growth under all conditions was not uniform (Table 11-62). The null hypothesis of uniformity was rejected ($\alpha = 0.01$) for all four dominant genera. There was little difference in the effect of unweathered versus photo-oxidized crude oil on lag time with the exception of Alcaligenes which was more sensitive to photo-oxidized oil (Table 11-61). Alcaligenes was extremely sensitive to the presence of the soluble fraction of photo-oxidized oil. The remaining genera also exhibited significant "lag" time delays in the presence of this soluble extract with Vibrio being the least affected. With the exception of Flavobacterium which was represented almost exclusively by heterotrophic isolates, the data were divided for analysis according to isolate enumeration medium, i.e., HM or ESWB plus petroleum (Table 11-63). ESWB plus petroleum isolates exhibited shorter "lag" times than HM isolates. Subdivision of the data revealed that HM isolates of the genera Alcaligenes and Pseudomonas were significantly ($\alpha = 0.01$) more susceptible to the presence of photo-oxidized oil extracts than the same genera isolated from ESWB plus petroleum medium (Table 11-64).

The degree of effect of petroleum on HM and ESWB plus petroleum isolates from microlayer, surface water (1 meter), bottom water and sediment are shown in Table 11-65. Degree of sensitivity of isolates did not appear to be related to sample source but rather to the medium employed for sample enumeration. Overall, the number of isolates exhibiting a four hour or greater delay in "lag" time was the same, ca. 38%, in the presence of unweathered and photo-oxidized crude oil. As previously noted with isolates from fall samples, HM isolates were more sensitive to crude oil with ca. 50% of the isolates exhibiting "lag" time increases of four or more hours as compared to ca. 25% of the ESWB plus petroleum isolates. Likewise, ca. 80% of HM isolates and ca. 32% of ESWB plus petroleum isolates were susceptible to the effects of soluble extracts of photo-oxidized oil. The relative abundance of the dominant genera in various sample types is shown in Table 11-66. Alcaligenes and Flavobacterium were more frequently

(TEXT CONTINUES ON PAGE 11-241)

Table 11-61. Effects of unweathered, photo-oxidized and a soluble fraction of photo-oxidized South Louisiana crude oil on the median "lag" times of isolates from representative genera of marine bacteria from Middle Atlantic continental shelf water and sediment samples.

Genus	Isolates Examined	Median "lag" time (hours)			
		Control	Photo-oxidized Soluble fraction	Unweath- ered oil	Photo- oxidized oil
<u>Alcaligenes</u>	29	29	NG ¹	33	40
<u>Flavobacterium</u>	26	45	92	69	66
<u>Pseudomonas</u>	99	14	22	16	18
<u>Vibrio</u>	58	11	13	12	11.5

¹NG = No growth

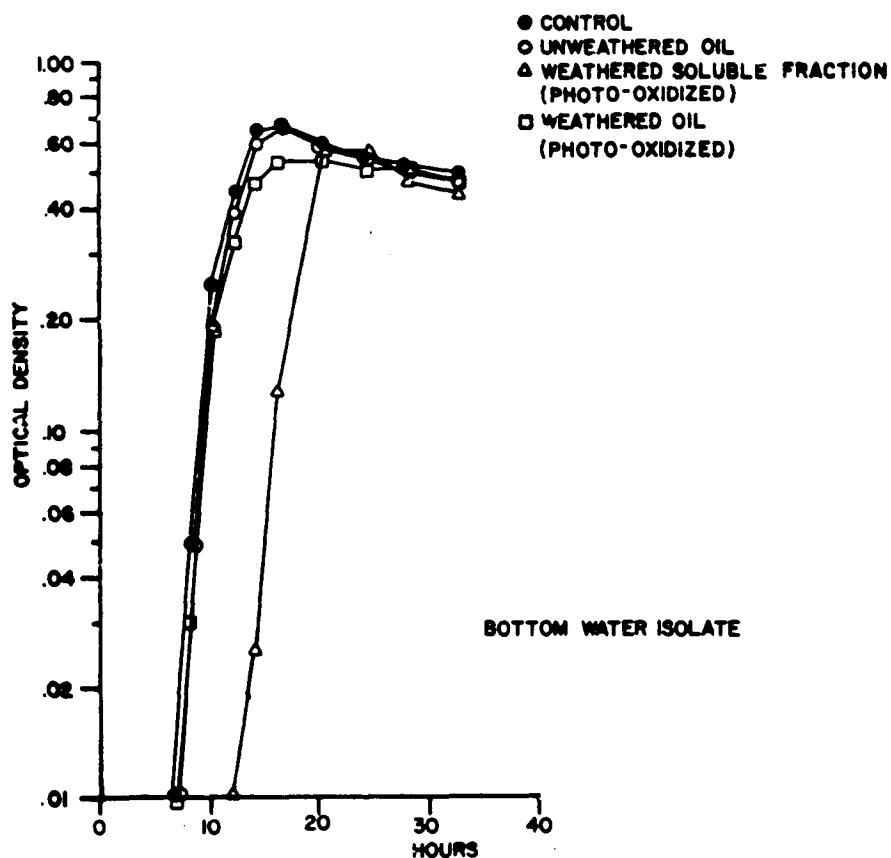


Figure 11-95. Representative growth curves for *Aeromonas* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

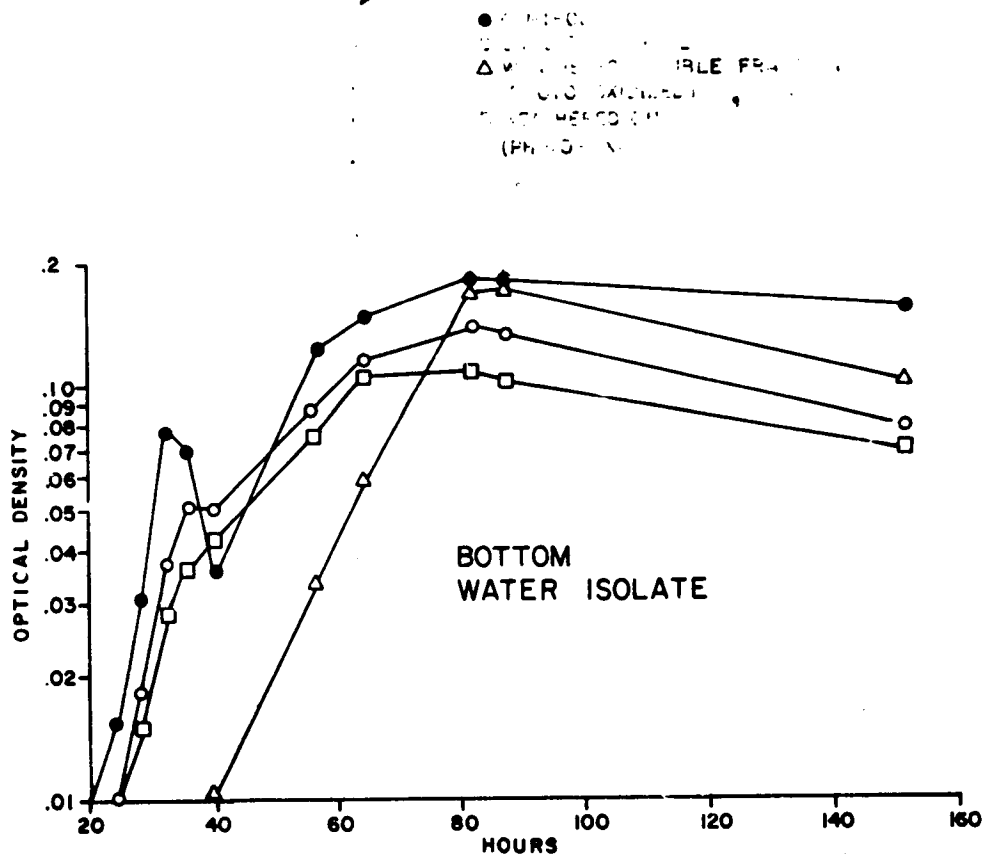


Figure 11-96. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

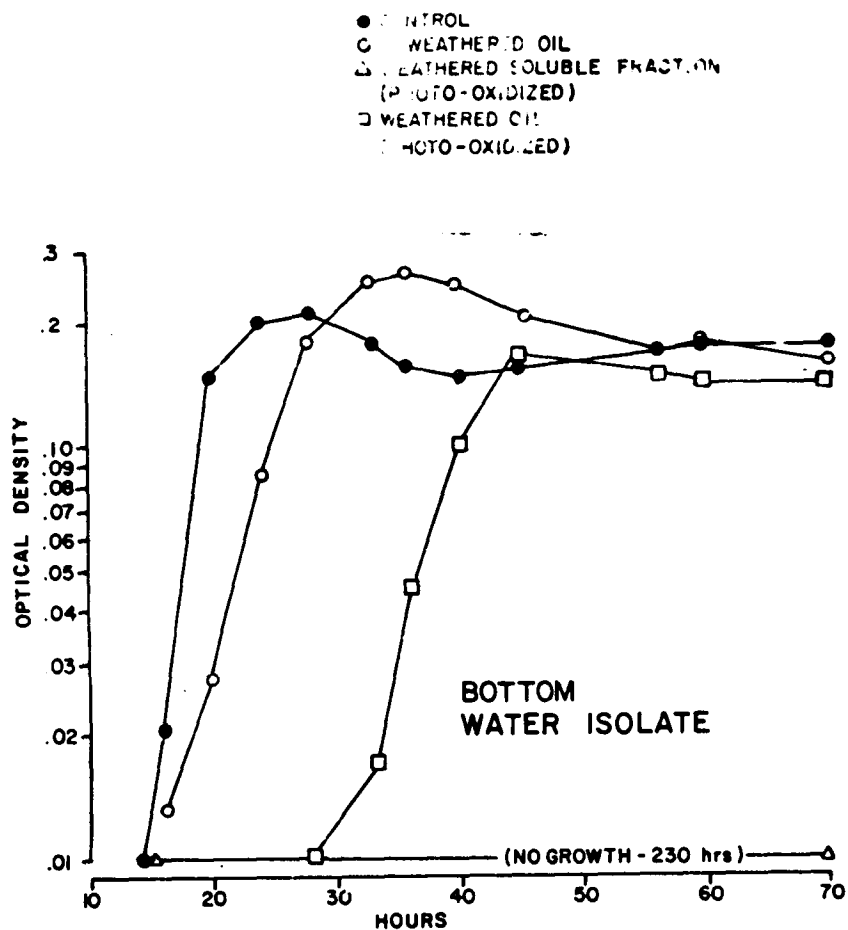


Figure 11-97. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

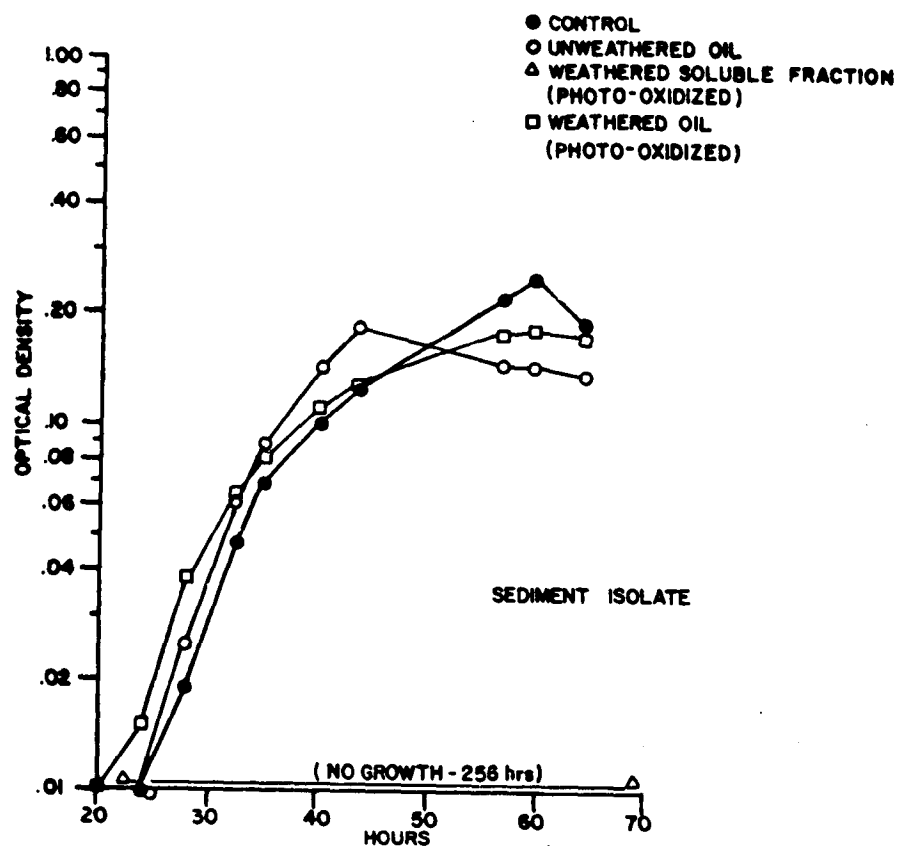


Figure 11-98. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

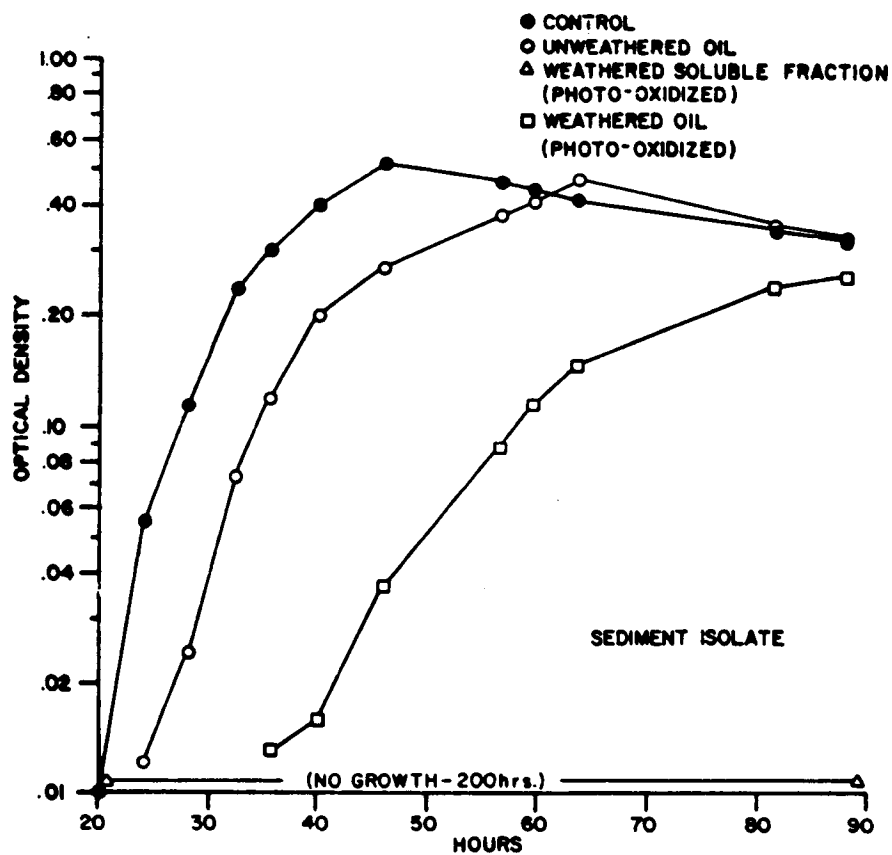


Figure 11-99. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

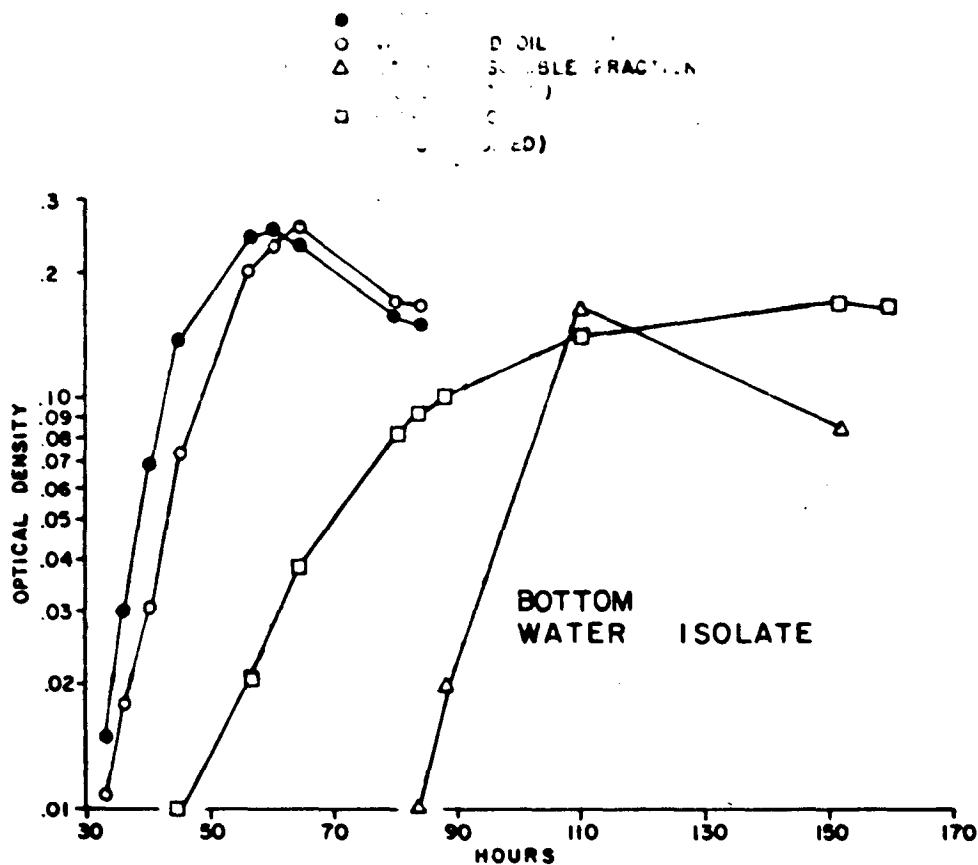


Figure 11-100. Representative growth curves for *Flavobacterium* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

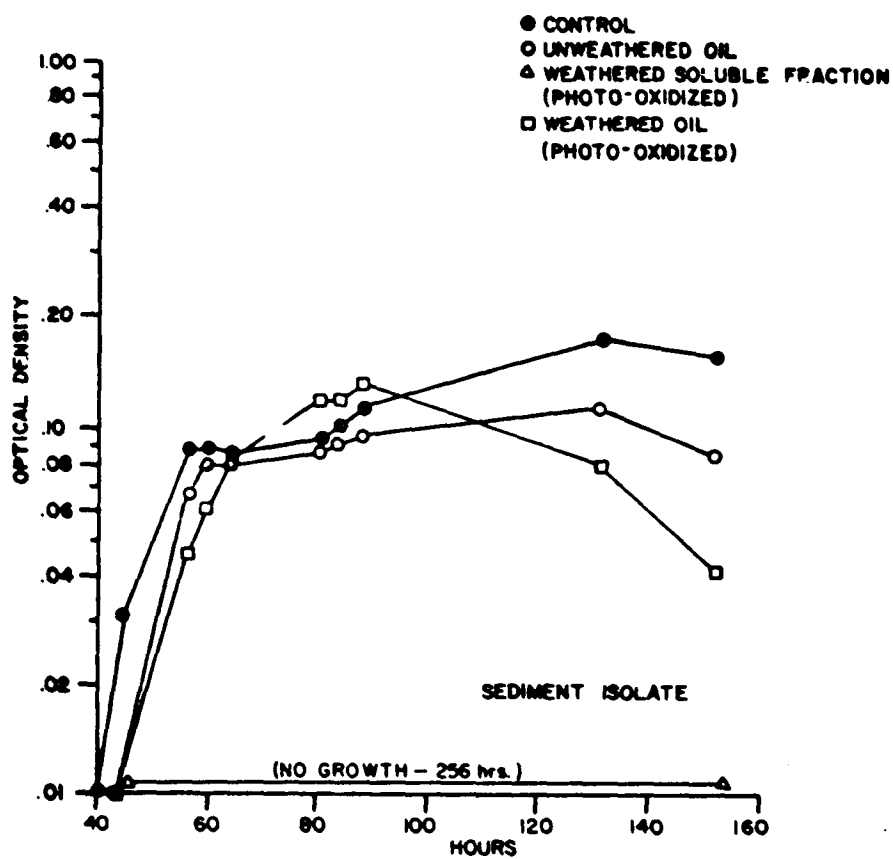


Figure 11-101. Representative growth curves for Flavobacterium sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

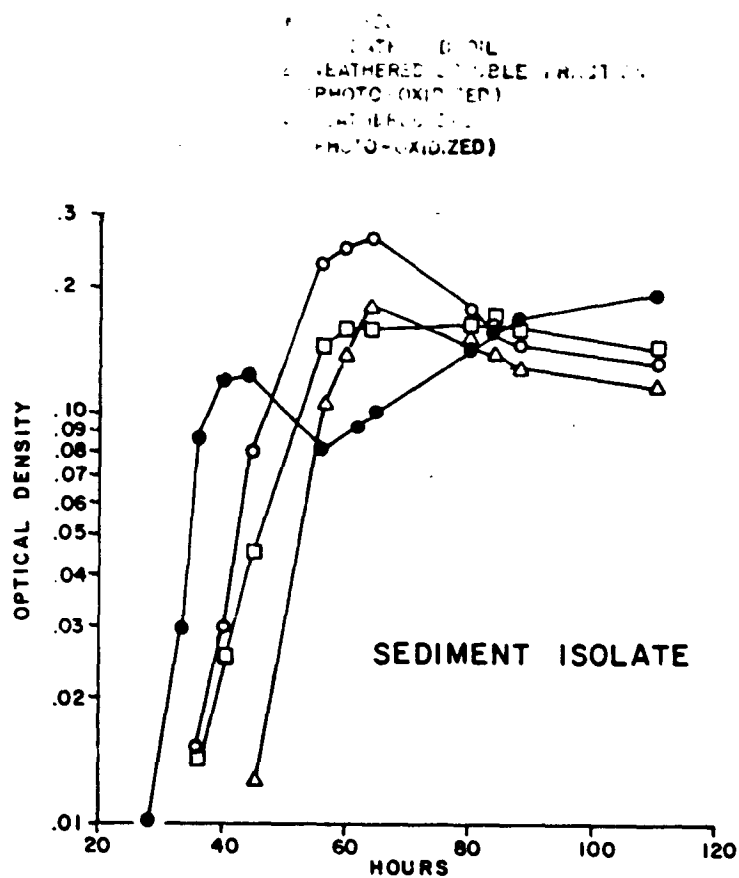


Figure 11-102. Representative growth curves for Flavobacterium sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

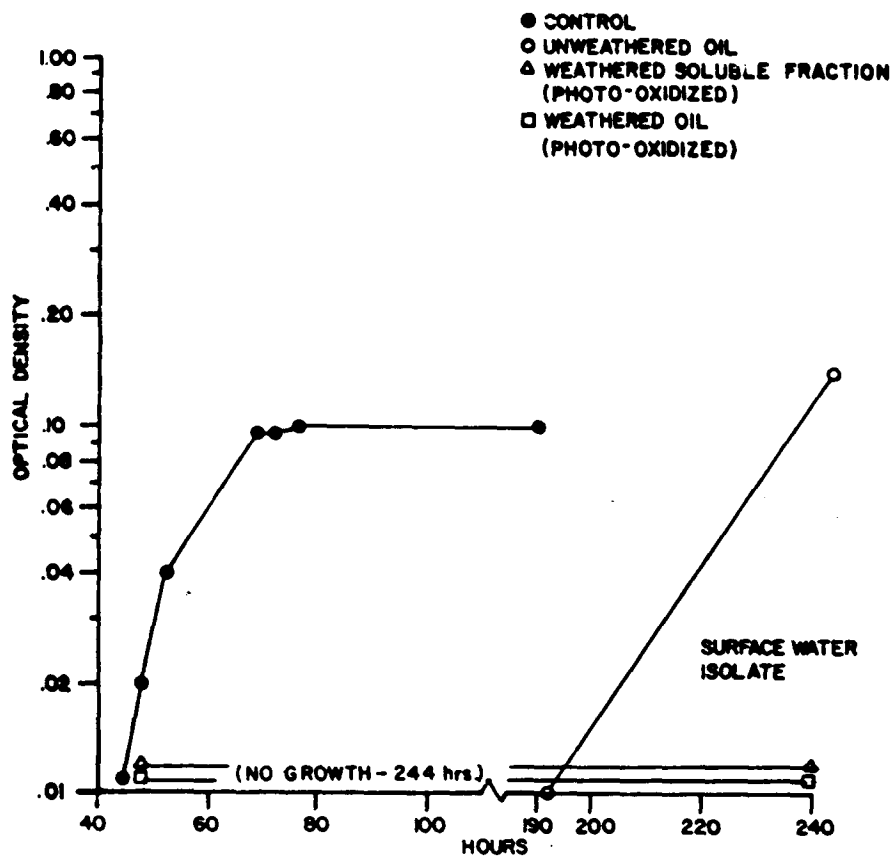


Figure 11-103. Representative growth curves for *Flavobacterium* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

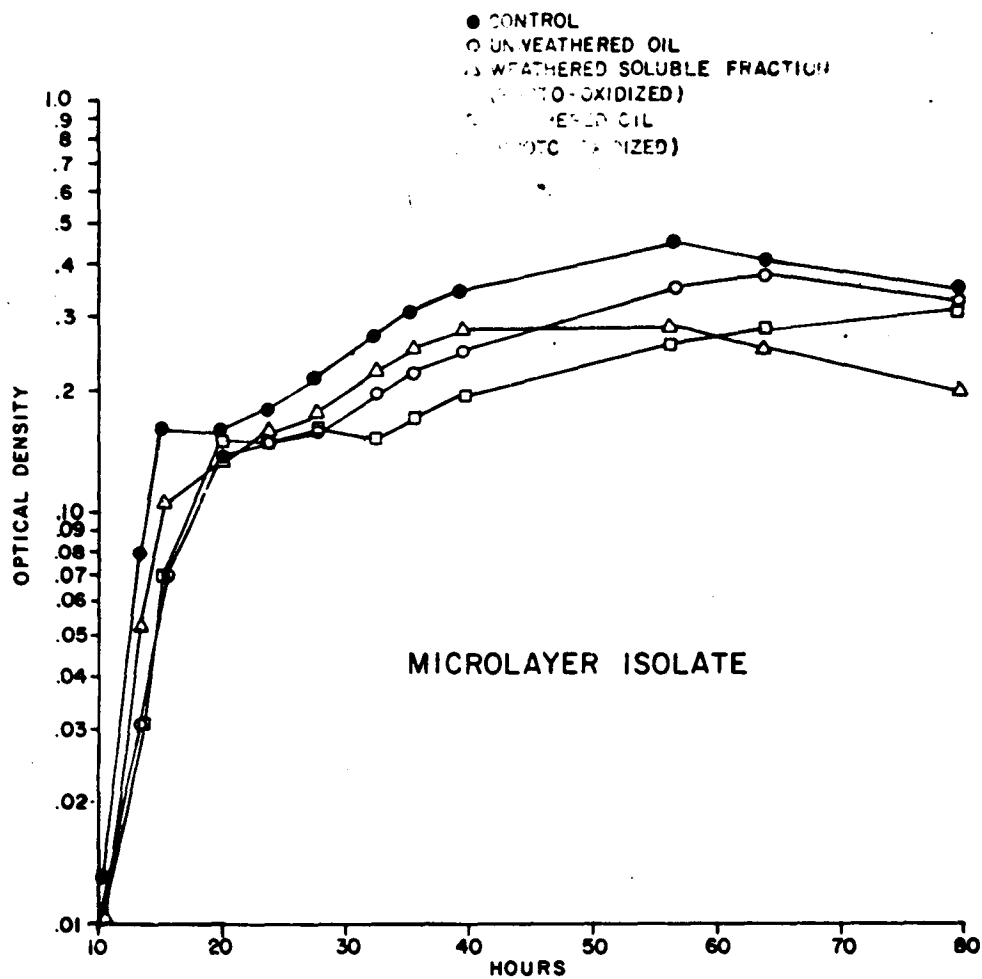


Figure 11-104. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

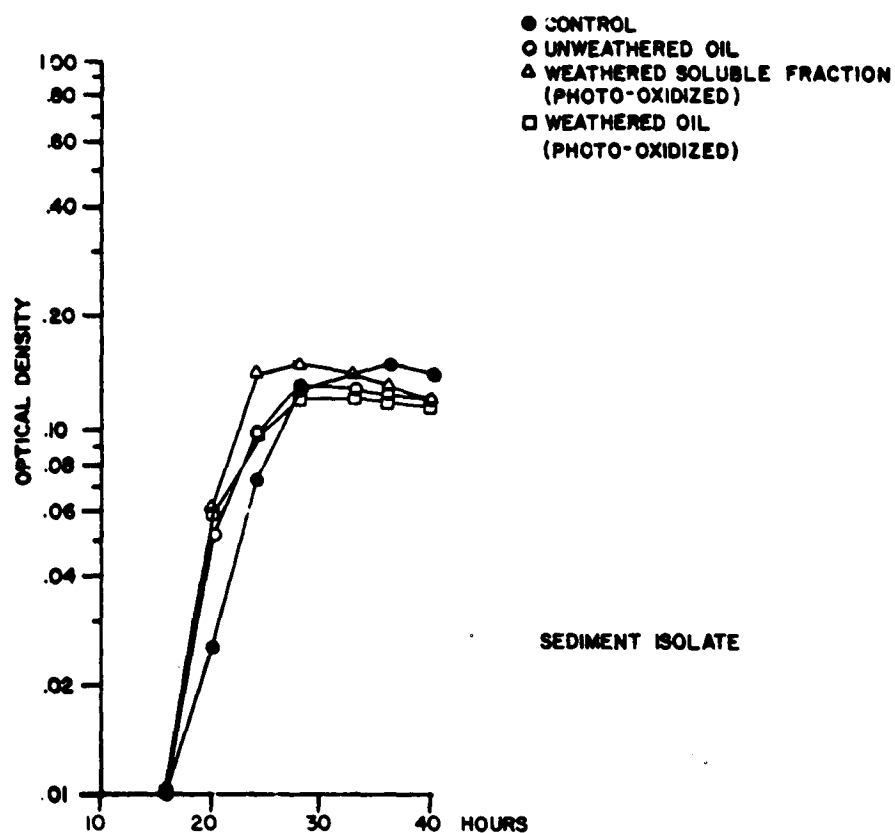


Figure 11-105. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

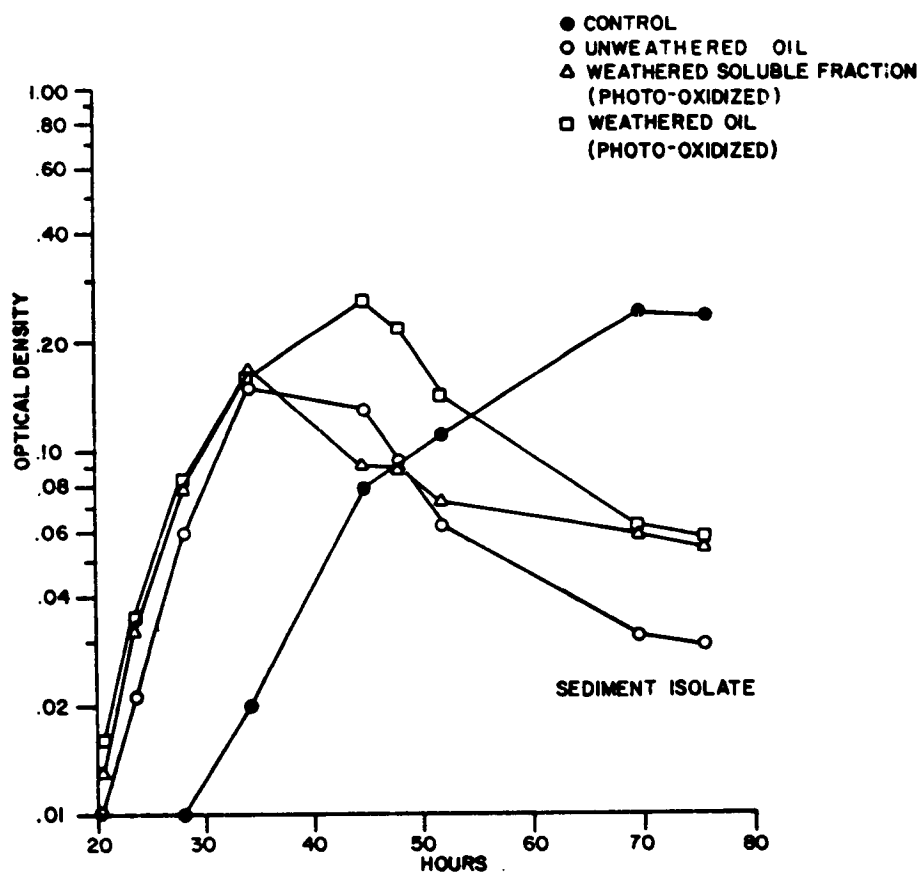


Figure 11-106. Representative growth curves for Pseudomonas sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

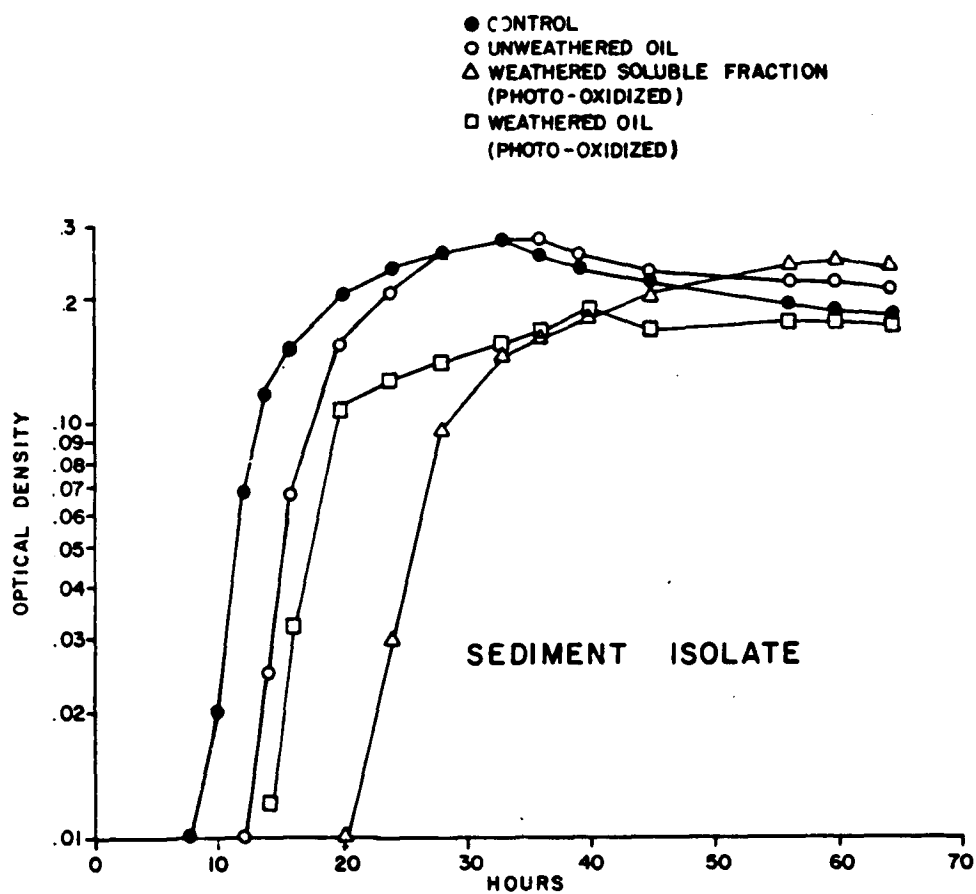


Figure 11-107. Representative growth curves for Pseudomonas sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

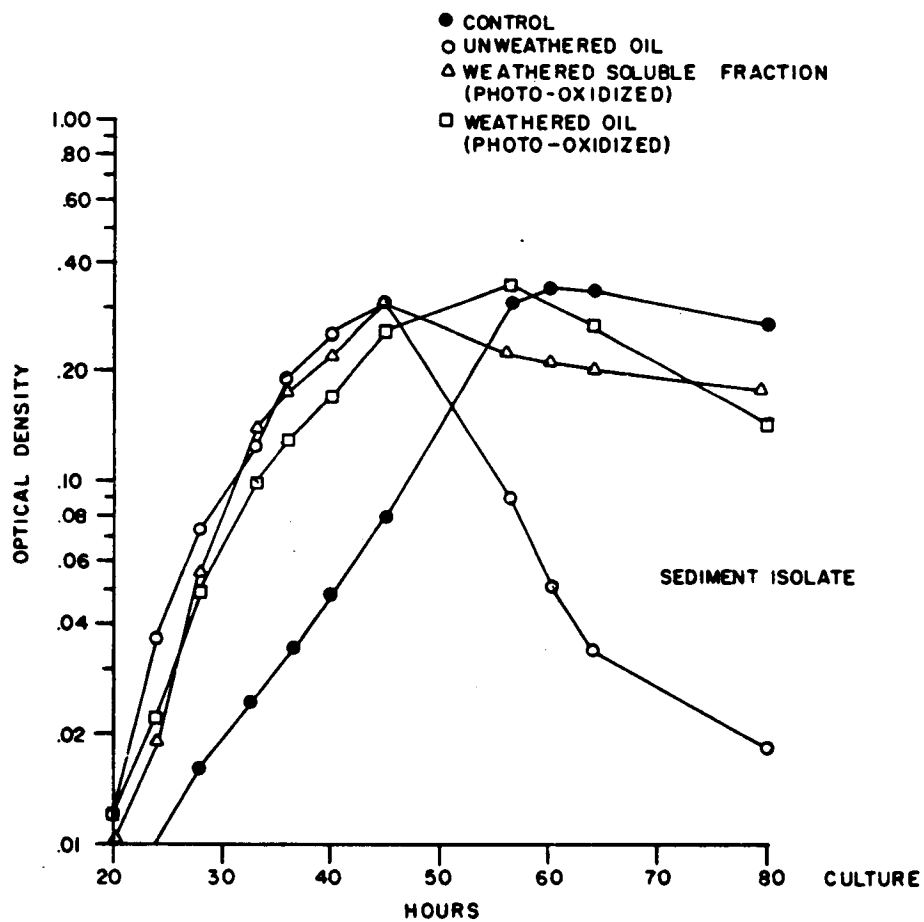


Figure 11-108. Representative growth curves for Pseudomonas sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

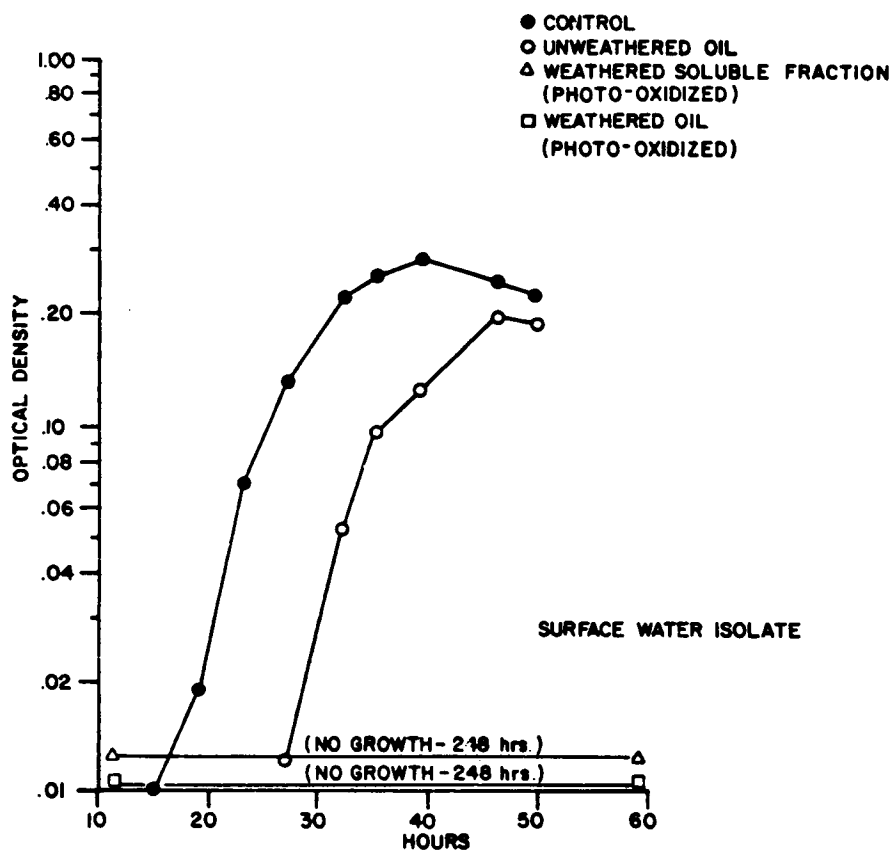


Figure 11-109. Representative growth curves for Pseudomonas sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

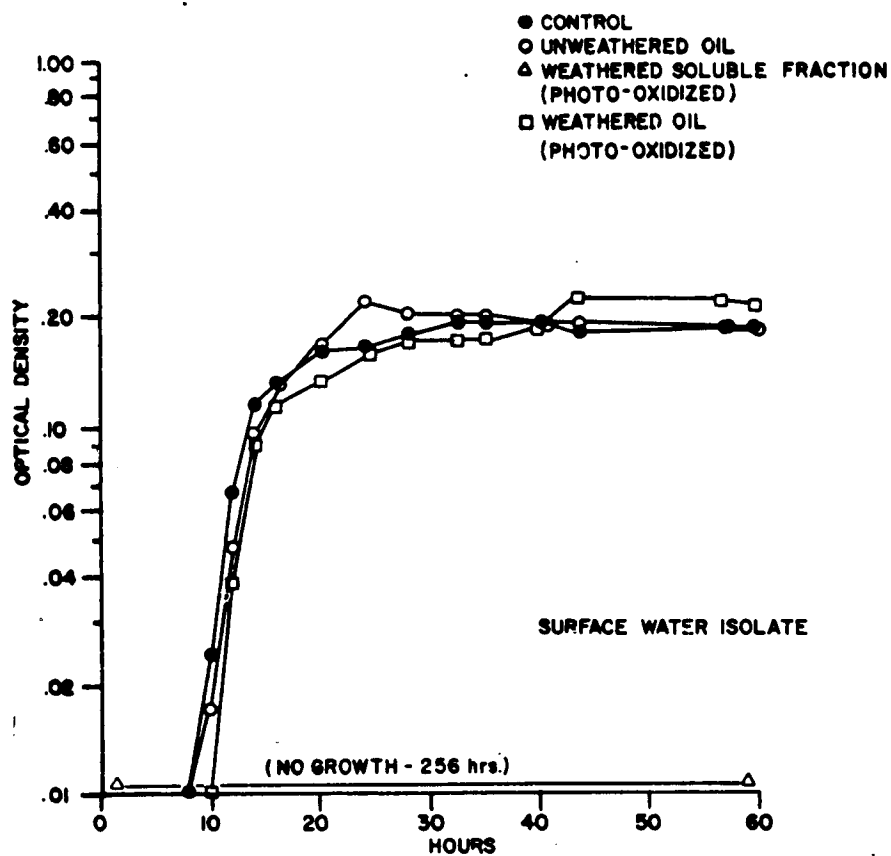


Figure 11-110. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

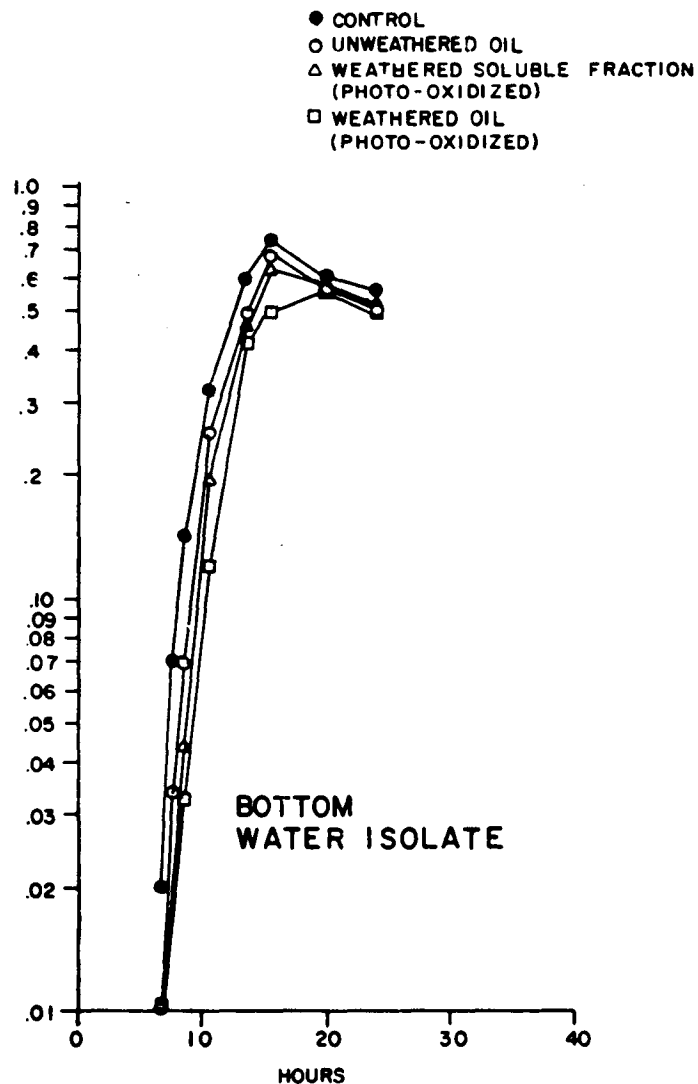


Figure 11-111. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

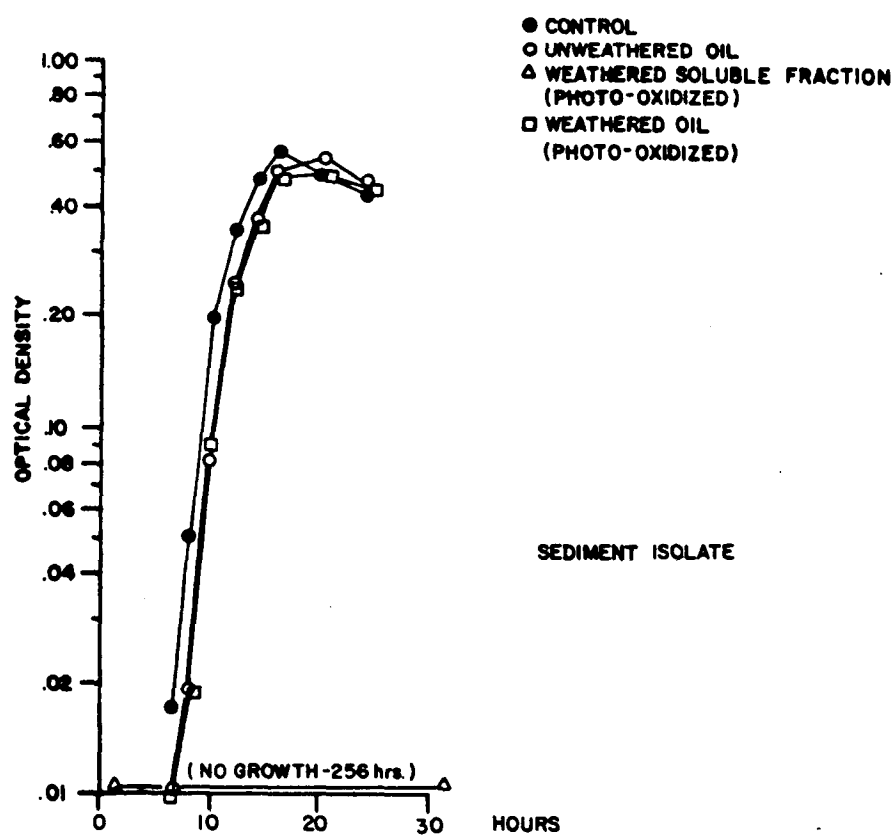


Figure 11-112. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

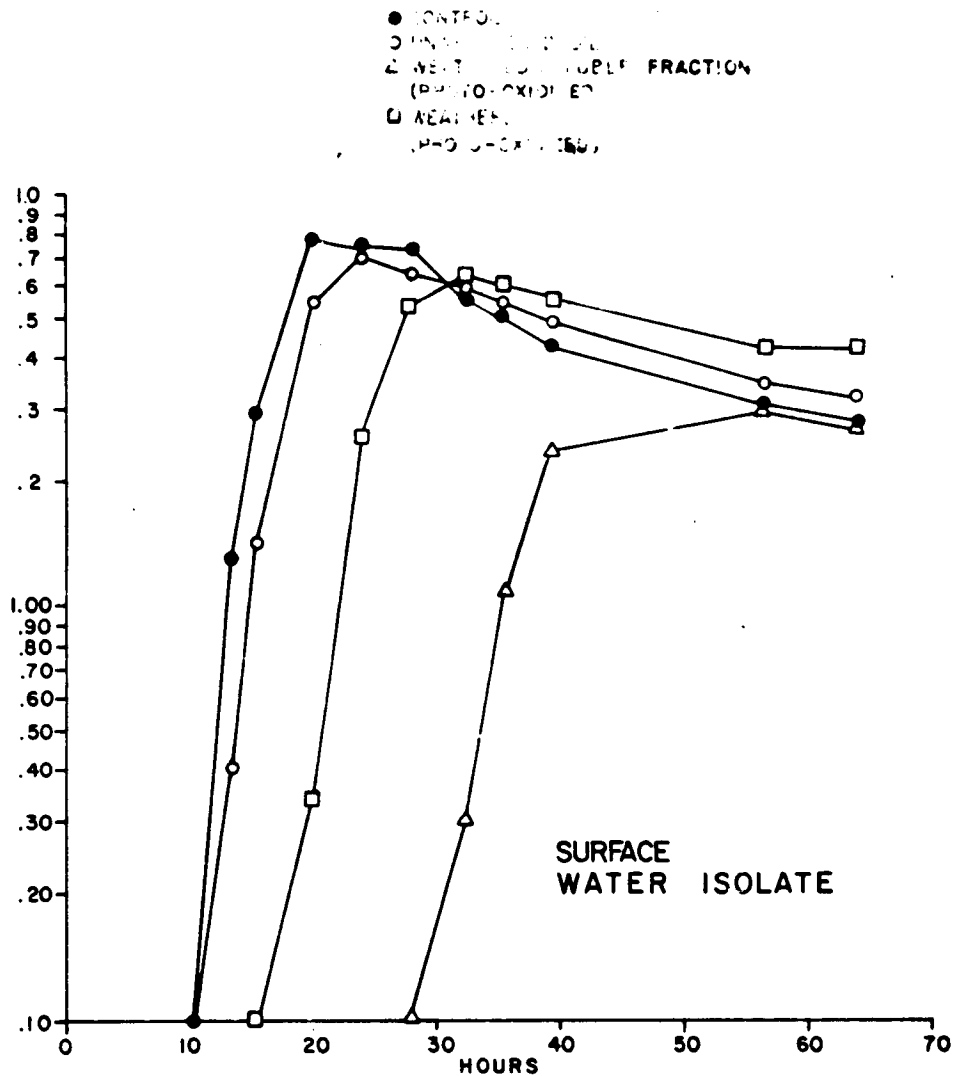


Figure 11-113. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

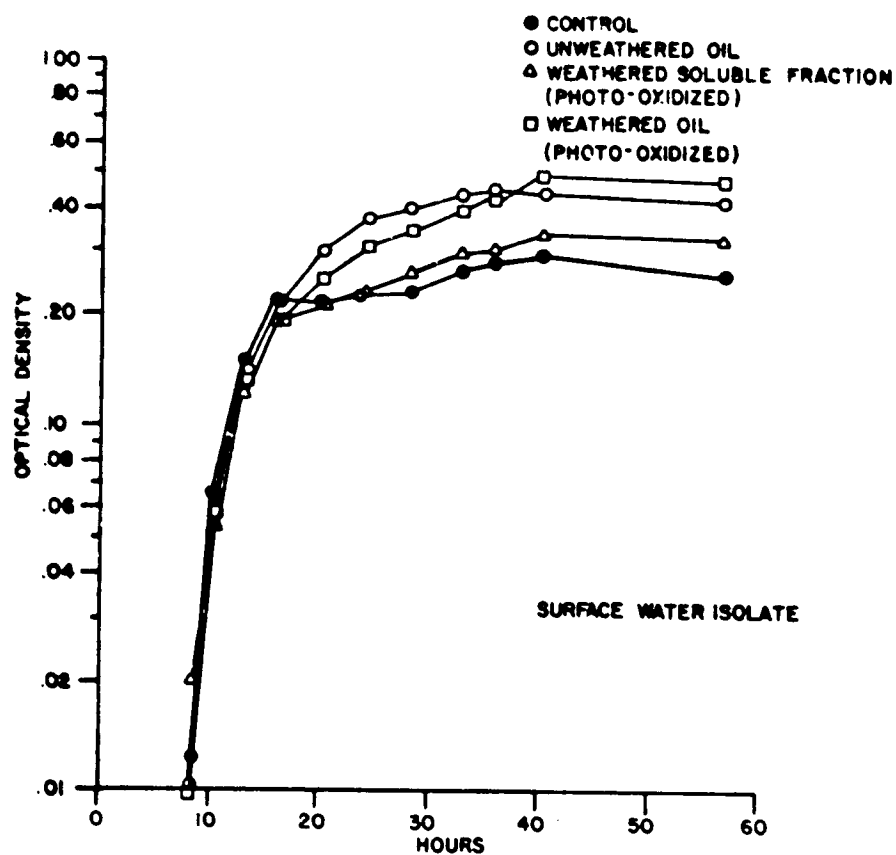


Figure 11-114. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth containing (a) a soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%), or (b) unweathered South Louisiana crude oil (ca. 1%), or (c) photo-oxidized South Louisiana crude oil (ca. 1%).

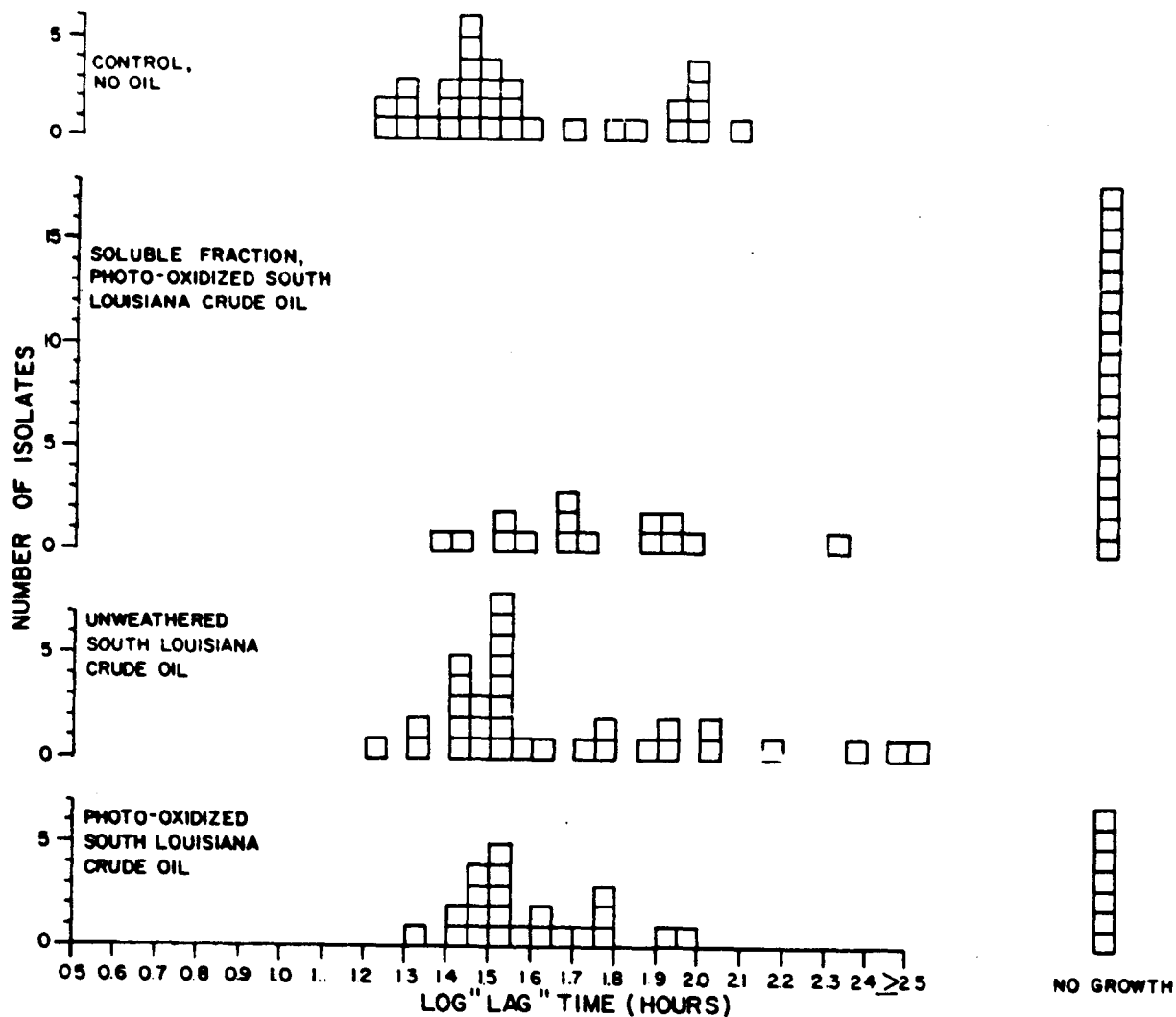


Figure 11-115. Effect of unweathered South Louisiana crude oil, photo-oxidized South Louisiana crude oil, and a soluble fraction of photo-oxidized South Louisiana crude oil on the growth ("lag time") of *Alcaligenes* sp. in a dilute glucose-peptone seawater broth.

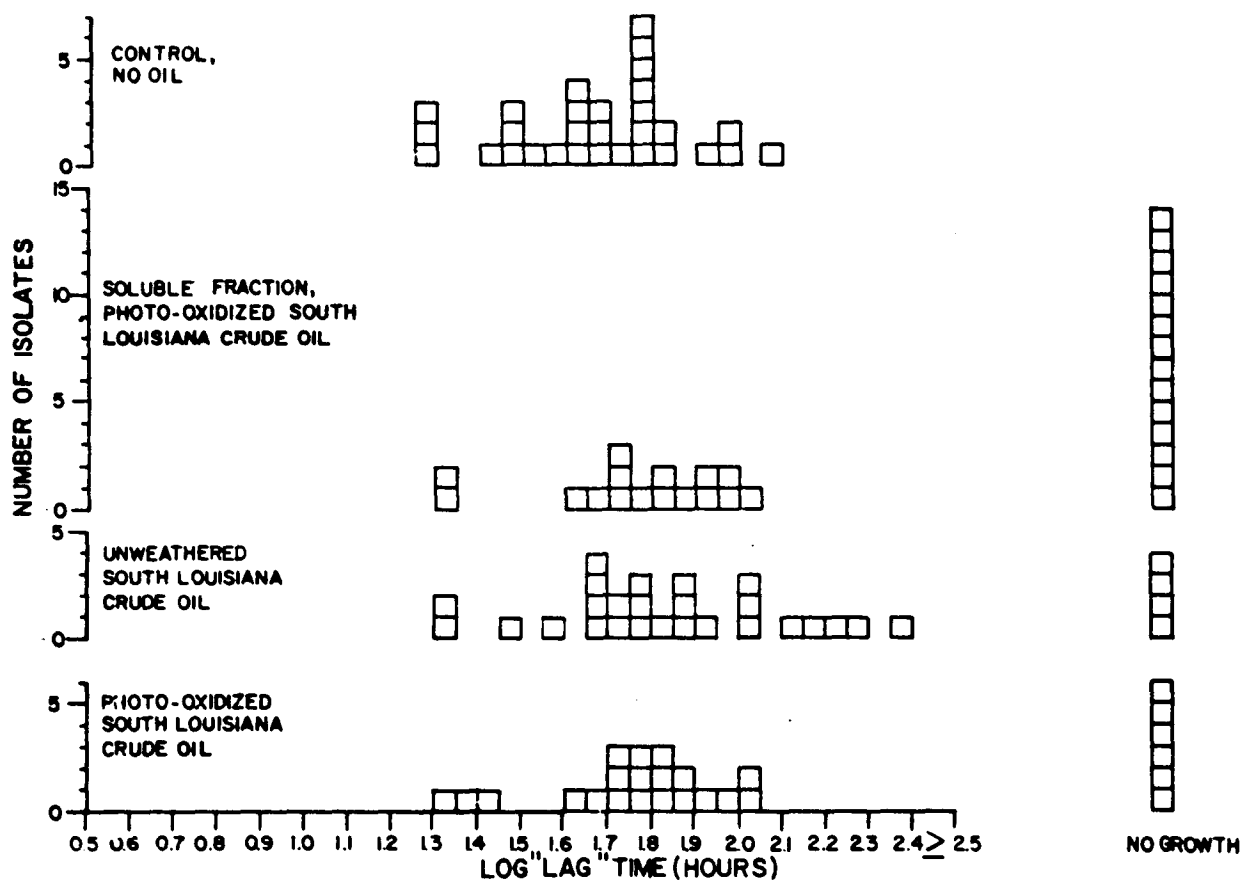
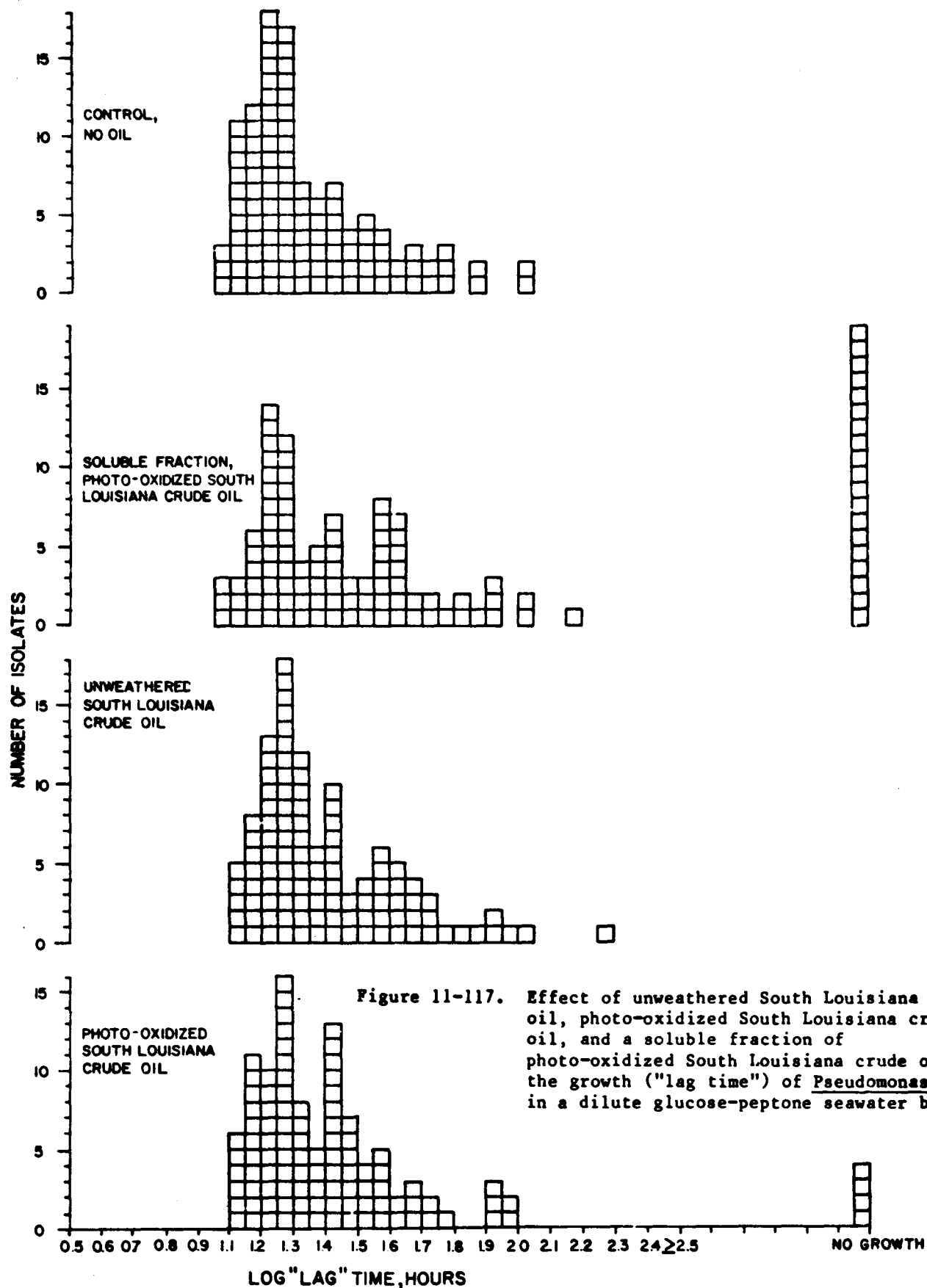


Figure 11-116. Effect of unweathered South Louisiana crude oil, photo-oxidized South Louisiana crude oil, and a soluble fraction of photo-oxidized South Louisiana crude oil on the growth ("lag time") of *Flavobacterium* sp. in a dilute glucose-peptone seawater broth.



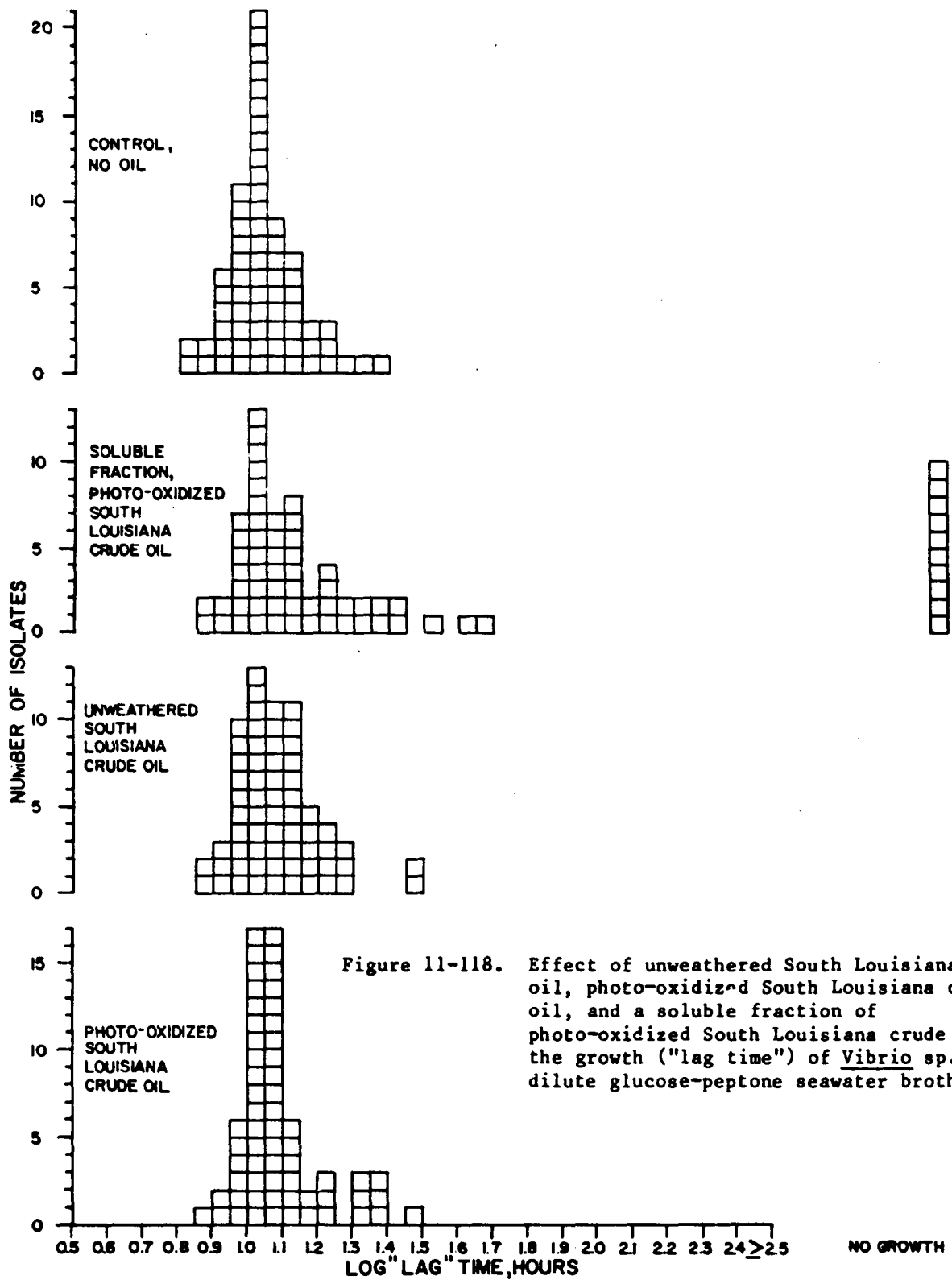


Figure 11-118. Effect of unweathered South Louisiana crude oil, photo-oxidized South Louisiana crude oil, and a soluble fraction of photo-oxidized South Louisiana crude oil on the growth ("lag time") of *Vibrio* sp. in a dilute glucose-peptone seawater broth.

Table 11-62. Friedman T statistic calculated for "lag" times exhibited by pure isolates of indicated genera grown in a dilute seawater-peptone medium and this medium containing either unweathered South Louisiana crude oil (1%), or photo-oxidized South Louisiana crude oil (1%), or a soluble fraction of photo-oxidized South Louisiana crude oil (100%).

Genus	Number of Isolates Examined	Calculated T Value	Critical T Value $\alpha = 0.01$	H ₀ : all treatments Have identical effects
<u>Alcaligenes</u>	20	47.03	11.3	Rejected
<u>Flavobacterium</u>	26	47.42	11.3	Rejected
<u>Pseudomonas</u>	99	86.65	11.3	Rejected
<u>Vibrio</u>	58	77.12	11.3	Rejected

*Friedman nonparametric test statistic (Practical Nonparametric Statistics, W.J. Conover, John Wiley and Sons, Inc. 1971).

Table 11-63. Effects of unweathered, photo-oxidized and a soluble fraction of photo-oxidized crude oil on the median "lag" times of the heterotrophic (HET) and petroleum-degrading (HC) bacteria representing dominant genera of marine bacteria.

Genus	Number Isolates Examined	Median "lag" time (hours)			
		Control	Photo-oxidized soluble fraction	Unweathered oil	Photo-oxidized oil
<u>Alcaligenes</u>					
HET	17	32	NG	35	86
HC	12	27.5	62	32	37.5
<u>Pseudomonas</u>					
HET	31	18	112	23.5	23
HC	68	13	15.5	15	15
<u>Vibrio</u>					
HET	27	11.5	17	12.5	12
HC	31	10.5	11	11.5	11

NG = No Growth

Table 11-64 . Friedman T statistic calculated for "lag" times exhibited by heterotrophic and petroleum-degrading bacterial isolates grown in pure culture in a dilute sea water peptone medium and this medium containing either unweathered South Louisiana crude oil (1%) or photo-oxidized South Louisiana crude oil (1%) or a soluble fraction of photo-oxidized South Louisiana crude oil (100%).

Genus	Number of Isolates Examined	Calculated T Value ^a	Critical T Value ($\alpha = 0.01$)	H ₀ : All Treatments Have Identical Effects
<u>Alcaligenes</u>				
HET	17	37.77	11.3	Rejected
HC	12	11.61		
<u>Pseudomonas</u>				
HET	31	54.75	11.3	Rejected
HC	68	44.66		
<u>Vibrio</u>				
HET	27	48.76	11.3	Rejected
HC	31	31.21		

^aFriedman nonparametric test statistic (Practical Nonparametric Statistics, W. J. Conover, John Wiley and Sons, Inc., 1971).

Table 11- 65. Percentages of cultures affected (relative to a non-oil treated control) and degree of effect of unweathered and photo-oxidized South Louisiana crude oil and the water soluble fraction of photo-oxidized South Louisiana crude oil on growth of bacterial isolates from heterotroph (HM) and petroleum-degrading (ESWB) enumeration media from microlayer, surface water (1 meter), bottom water and sediment samples. Legend: (+)=enhancement, >1 hr. decrease in "lag" time; (0)=no effect, <1 hr. difference in "lag" time; (-)=1 to 3 hr. increase in "lag" time; (--)=4-10 hr. increase in "lag" time; (---)=>10 hr. increase in "lag" time or no growth.

Culture Origin	No. Cultures Examined	% of cultures affected and degree of effect in growth media containing:														
		Photo-oxidized Soluble Fraction (100%)					Unweathered Oil (1%)					Photo-oxidized Weathered Oil (1%)				
		+	0	-	--	---	+	0	-	--	---	+	0	-	--	---
Microlayer (HM medium)	15	0	0	26.7	20	53.3	0	0	53.3	26.7	20	0	6.7	46.7	26.7	20
Microlayer (ESWB medium)	11	9.1	45.5	27.3	9.1	9.1	0	27.3	54.5	18.2	0	0	18.2	54.5	27.3	0
Surface Water (HM medium)	29	0	3.4	17.2	13.8	65.5	0	20.7	37.9	20.7	20.7	0	31.0	27.6	13.8	27.6
Surface Water (ESWB medium)	35	5.7	34.3	31.4	8.6	20	5.7	22.9	48.6	17.1	5.7	57	25.7	37.1	20	11.4
Bottom Water (HM medium)	31	3.2	12.9	6.5	6.5	71	3.2	16.1	25.8	29	25.8	3.2	19.4	12.9	32.3	32.3
Bottom Water (ESWB medium)	34	0	32.4	35.3	14.7	17.6	0	29.4	52.9	14.7	2.9	0	44.1	35.3	11.8	8.8

Table 11-65. (Concluded)

Culture Origin	No. Cultures Examined	% of cultures affected and degree of effect in growth media containing:														
		Photo-oxidized Soluble Fraction (100%)					Unweathered Oil (1%)					Photo-oxidized Weathered Oil (1%)				
		+	0	-	--	---	+	0	-	--	---	+	0	-	--	---
Sediment (HM medium)	35	2.9	2.9	8.6	8.6	77.1	8.6	5.7	22.9	31.4	31.4	8.6	11.4	20	20	40
Sediment (ESWB medium)	47	14.9	21.3	25.5	10.6	27.7	12.8	23.4	29.8	23.4	10.6	10.6	31.9	36.2	8.5	12.8
TOTALS																
HM medium	110	1.8	5.5	12.7	10.9	69.1	3.6	11.8	31.8	27.3	25.5	3.6	18.2	23.6	22.7	31.8
ESWB medium	127	7.9	29.9	29.9	11	21.3	6.3	25.2	43.3	18.9	6.3	5.5	32.3	37.8	14.2	10.2
HM & ESWB media	237	5.1	18.6	21.9	11	43.5	5.1	19	38	22.8	15.2	4.6	25.7	31.2	18.1	20.3

Table 11-66. Relative abundance of dominant genera as a function of sample type and enumeration media used for pure culture growth experiments involving unweathered and photo-oxidized South Louisiana Crude Oil and the soluble fraction thereof.

Genus	Sample Type							
	Microlayer		Surface (1m)		Bottom		Sediment	
	HC ^a	Het ^b	HC	Het	HC	Het	HC	Het
<u>Aeromonas</u>		1/15	1/35		1/34			1/35
<u>Alcaligenes</u>		2/15	3/35	1/29	4/34	7/31	5/47	7/35
<u>Brevibacterium</u>								1/35
<u>Flavobacterium</u>			1/35	5/29	1/34	5/31	3/47	11/35
<u>Pseudomonas</u>	7/11	6/15	14/35	11/29	18/34		29/47	7/35
<u>Vibrio</u>	2/11	4/15	13/35	7/29	9/34	7/31	7/47	4/35
Misc. isolates	2/11	2/15	3/35	5/29	1/34	12/31	3/47	4/35

^aESWB-Medium for enumeration of petroleum-degrading bacteria.

^bHBM-Medium for enumeration of heterotrophic bacteria.

isolated from HM than ESWB plus petroleum media whereas Pseudomonas and Vibrio dominated ESWB plus petroleum isolates.

Two experiments were performed to simultaneously compare the effects on bacterial growth of unweathered Louisiana crude oil (1% w/v), weathered Louisiana crude oil (1% w/v) and its resulting soluble fraction (100% v/v) which had been weathered either in the dark or in full sunlight at ambient temperatures. Less than 10% of the isolates were significantly affected (≥ 4 hour "lag" delay) in the presence of "dark" soluble fraction (Table 11-67). In contrast, 59% of the isolates exposed to the soluble fraction from photo-oxidized oil were affected. Similarly, percentages of isolates affected by "dark" and photo-oxidized oil were 27 and 54 respectively, while unweathered crude oil produced "lag" delays in 41% of isolates examined. These results are pictorially summarized in Figure 11-119. Representative growth curves are shown in Figures 11-120 through 11-124.

Growth effects of various concentrations of soluble extracts from oil photo-oxidized in the summer are shown in Table 11-68 and Figures 11-125 through 11-130. The degree of toxicity and "lag" delay was directly related to the concentration employed. Growth limiting effects were evident at 10% (v/v) for most isolates studied with the exception of Vibrio. Also included in Table 11-68 are "lag" time values obtained when the same isolates were examined using photo-oxidized fractions prepared during the spring. Photo-oxidation was apparently more effective during the summer as evidence by larger "lag" time delays.

DISCUSSION

Distribution and Abundance of Petroleum-Degrading and Heterotrophic Bacteria

Sediments

Populations of heterotrophic bacteria in Middle Atlantic continental shelf sediments sampled quarterly were rather uniform in numbers with mean values (all stations) which did not vary appreciably with season. Variations in numbers as a function of station could be related to the sediment textural property % silt-clay and indirectly, to topographic features. Populations of petroleum-degrading bacteria, a sub-set of the heterotrophic bacterial population, tended to respond more distinctly to known pollutant inputs, textural and topographic features than heterotrophic populations. Thus, although heterotrophic bacterial numbers were somewhat higher in sediments from the station closest to Atlantic City, in troughs or those with higher percentages of silt-clay, populations of petroleum-degrading bacteria strongly increased at these same stations. This "enrichment" was also manifested as an increase in the ratio of petroleum-degrading to heterotrophic bacteria (HC/HET).

(TEXT CONTINUES ON PAGE 11-257)

Table 11-67. Comparison of effects of unweathered South Louisiana crude oil (1%), dark weathered South Louisiana crude oil (1%) and soluble fraction (100%), and photo-oxidized South Louisiana crude oil (1%) and soluble fraction (100%) on the growth of selected bacterial isolates relative to a non-oil treated control. Legend: (+)=enhancement, >1 hr. decrease in "lag" time; (0)=no effect, <1 hr. difference in "lag" time; (-)=1 to 3 hr. increase in "lag" time; (--)=4 to 10 hr. increase in "lag" time; (---)=>10 hr. increase in "lag" time; (NG)=no growth.

Taxonomic Group	Number of Cultures Examined	Degree of Effect	Number of isolates affected in growth media containing:				
			Soluble Fraction		Weathered Oil		Unweathered Oil
			Dark	Photo-oxidized	Dark	Photo-oxidized	
Alcaligenes	3	+	1				
		0	1	1	1	1	1
		-	1		1		1
		--			1	1	1
		---		2			
		NG				1	
Flavobacterium	4	+	1				
		0	2	1	1		0
		-		2	2	1	1
		--				2	2
		---	1		1		1
		NG		1		1	
Pseudomonas	20	+	2	1			
		0	15	4	4	5	3
		-	2	4	11	4	9
		--		2	2	7	5
		---	1	8	3	3	3
		NG		1		1	
Vibrio	8	+					
		0	6	3	5	4	6
		-	2		3	3	1
		--		2		1	1
		---		1			
		NG		2			

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Table 11-67. (concluded)

Taxonomic Group	Number of Cultures Examined	Degree of Effect	Number of isolates affected in growth media containing:				
			Soluble Fraction		Weathered Oil		Unweathered Oil
			Dark	Photo-oxidized	Dark	Photo-oxidized	
Unidentified	6	+	1				
		0	1		1		
		-	2	1	1		2
		--		1	3	2	2
		---	2	3		2	1
		NG		1	1	1	1
			Percent of Total Number Cultures				
	41	+	12.2	2.4	0	0	0
		0	61	22	29.3	24.4	24.4
		-	17.1	17.1	43.9	22	34.1
		--	0	12.2	14.6	31.7	26.8
		---	9.8	34.1	9.8	12.2	12.2
		NG	0	12.2	2.4	9.8	2.4

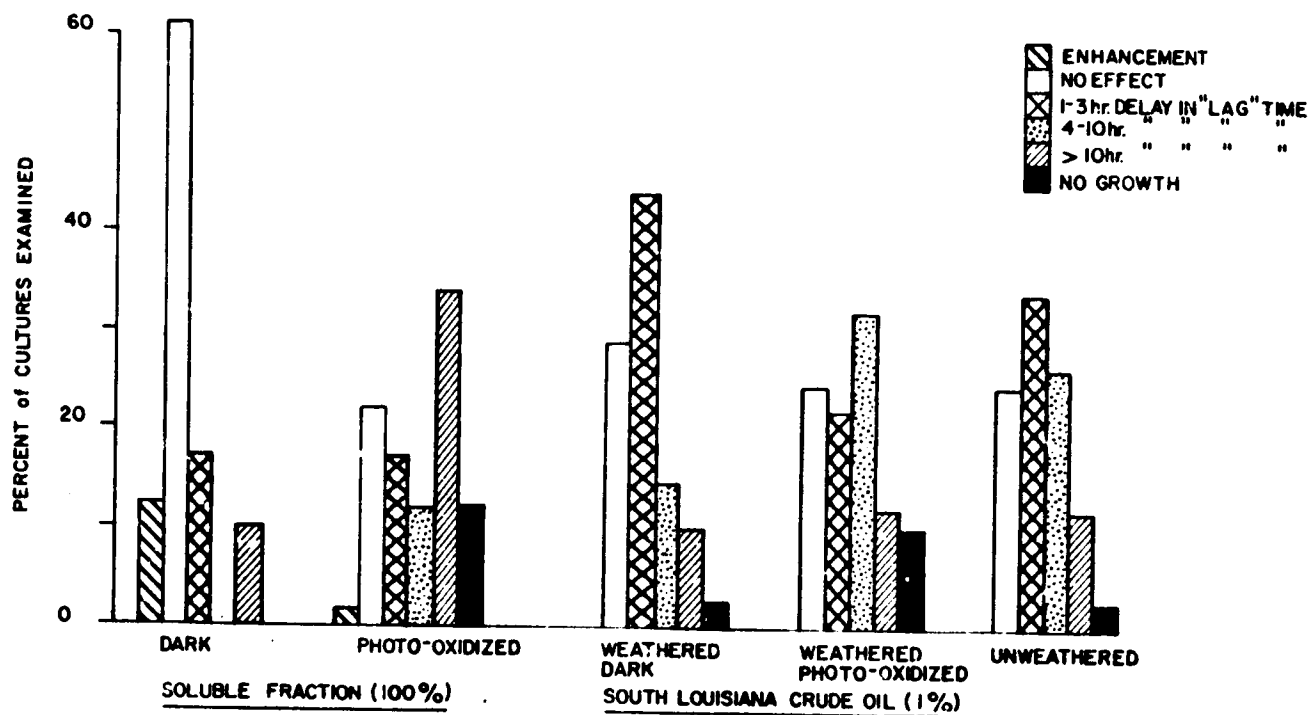


Figure 11-119. Percent of cultures affected (relative to an oil-free control) and the degree of effect of unweathered South Louisiana crude oil (1%), dark weathered South Louisiana crude oil (1%), and soluble fraction (100%), and photo-oxidized South Louisiana crude oil (1%) and soluble fraction (100%) on selected bacterial isolates.

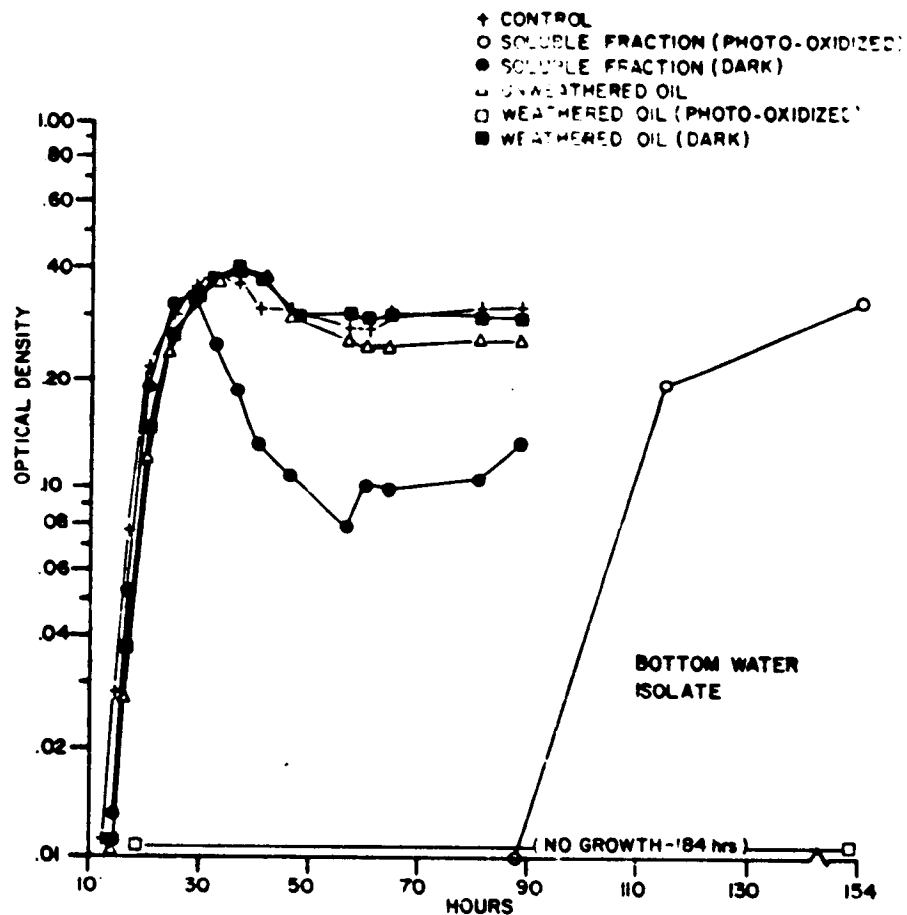


Figure 11-120. Representative growth curves for *Alcaligenes* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) soluble fraction of dark-weathered or (b) soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%); (c) dark weathered or (d) photo-oxidized South Louisiana crude oil (ca. 1%); or (e) unweathered South Louisiana crude oil (ca. 1%).

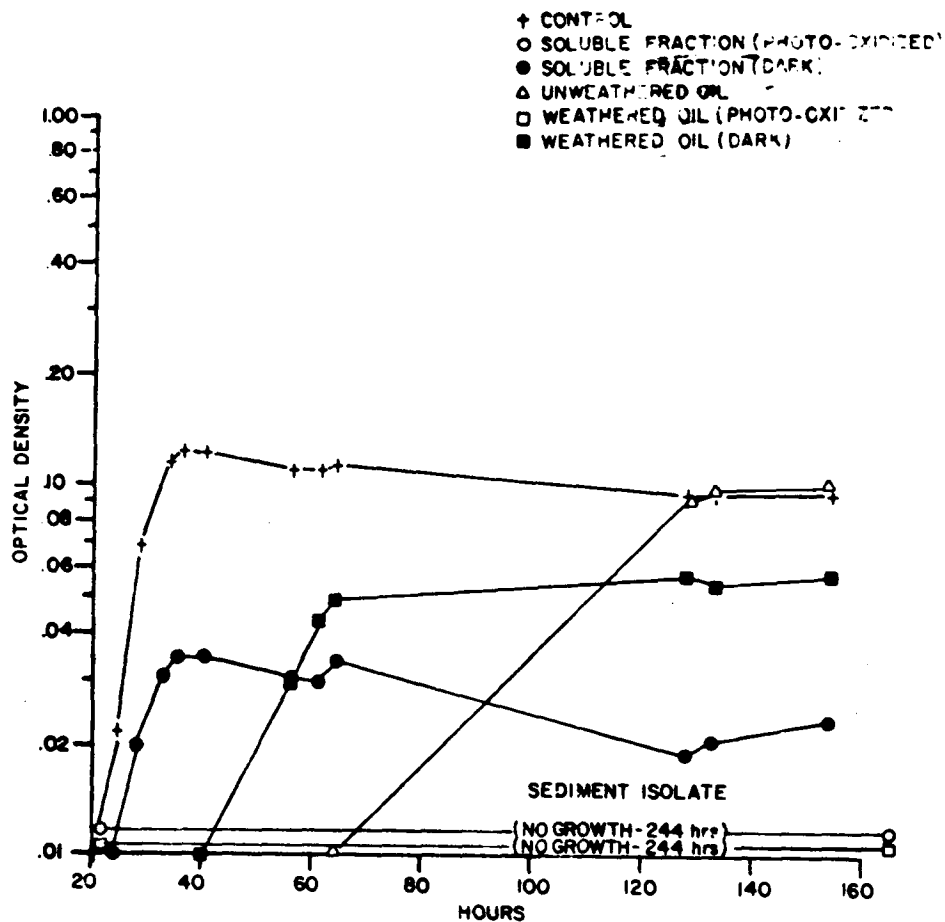


Figure 11-121. Representative growth curves for *Flavobacterium* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) soluble fraction of dark-weathered or (b) soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%); (c) dark weathered or (d) photo-oxidized South Louisiana crude oil (ca. 1%); or (e) unweathered South Louisiana crude oil (ca. 1%).

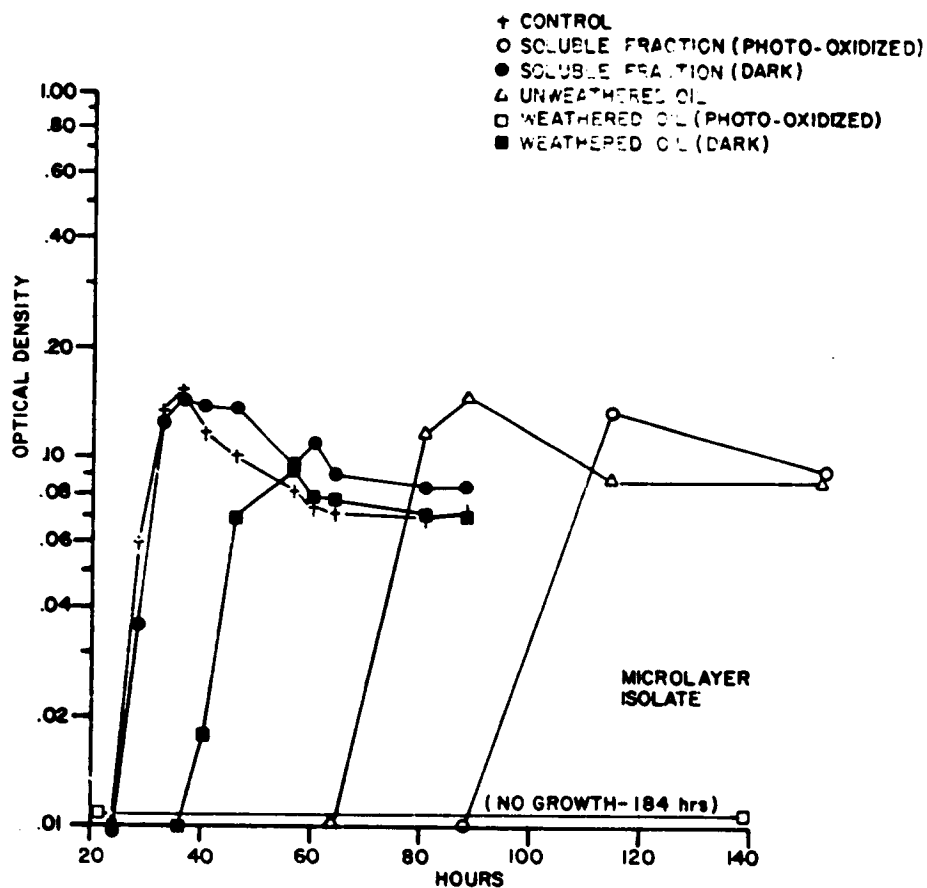


Figure 11-122. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) soluble fraction of dark-weathered or (b) soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%); (c) dark weathered or (d) photo-oxidized South Louisiana crude oil (ca. 1%); or (e) unweathered South Louisiana crude oil (ca. 1%).

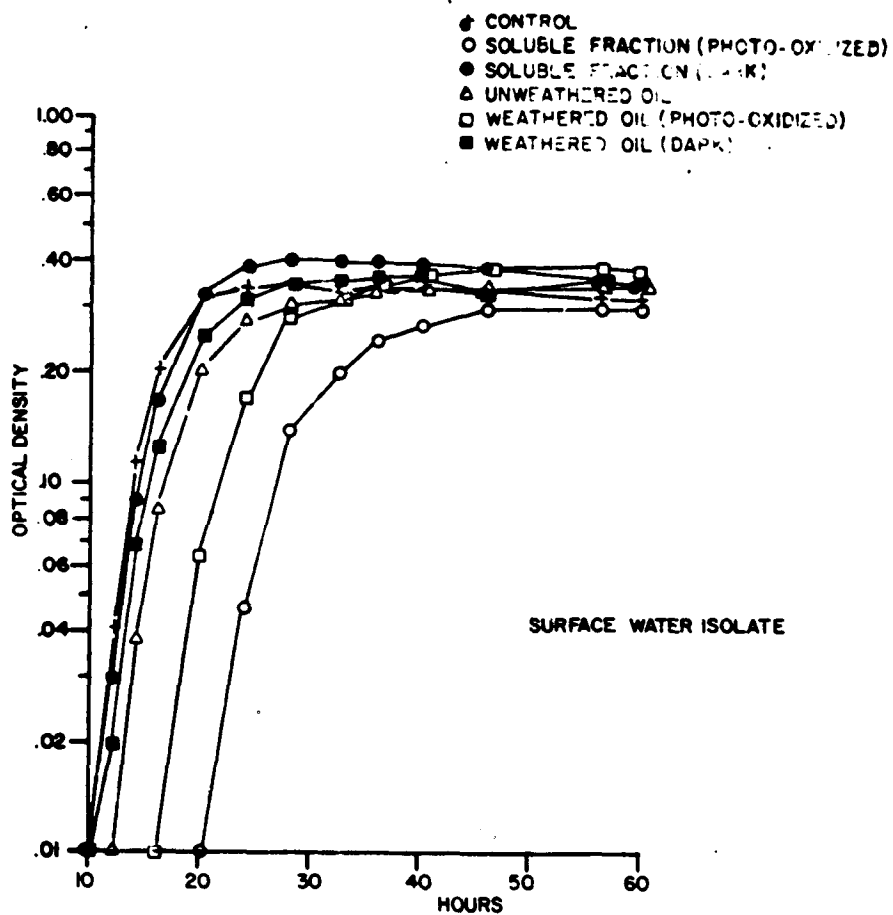


Figure 11-123. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) soluble fraction of dark-weathered or (b) soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%); (c) dark weathered or (d) photo-oxidized South Louisiana crude oil (ca. 1%); or (e) unweathered South Louisiana crude oil (ca. 1%).

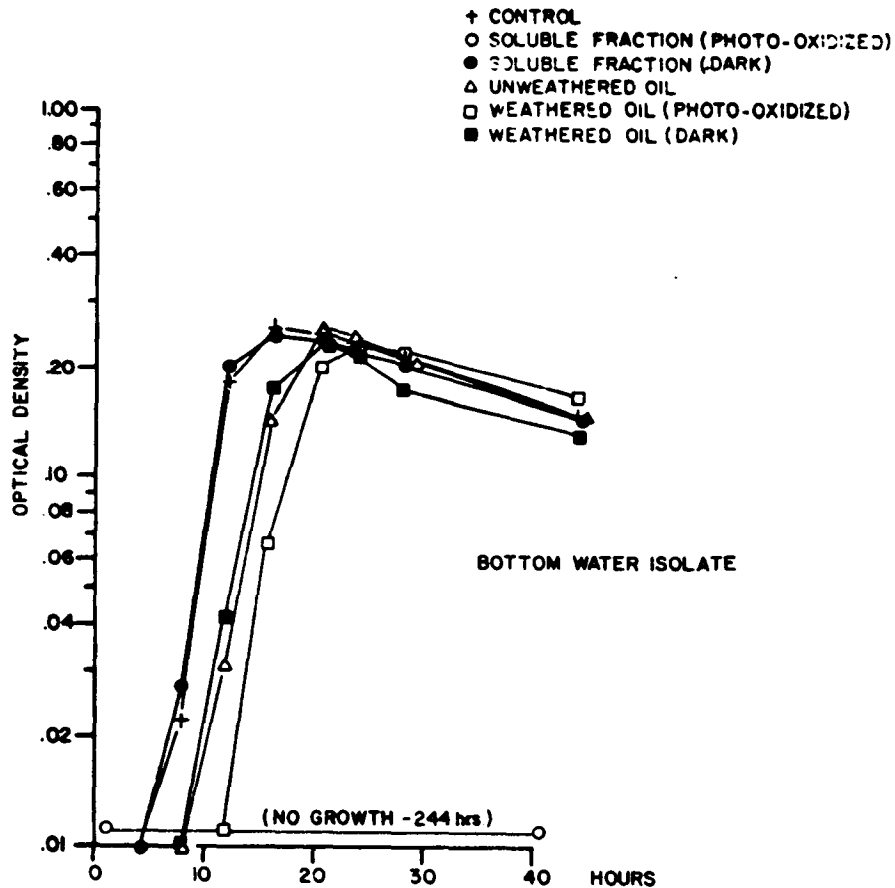


Figure 11-124. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing (a) soluble fraction of dark-weathered or (b) soluble fraction of photo-oxidized South Louisiana crude oil (ca. 100%); (c) dark weathered or (d) photo-oxidized South Louisiana crude oil (ca. 1%); or (e) unweathered South Louisiana crude oil (ca. 1%).

Table 11-68 . Effects of the soluble fraction of South Louisiana crude oil photo-oxidized in the spring and summer on the growth of selected marine bacteria in a dilute sea water-peptone medium.¹

Taxonomic Group	"Lag" Time (hrs)						
	Spring		Summer				
	Control	Soluble Fraction 100%	Control	Soluble Fraction			
				1%	10%	50%	100%
<u>Acinetobacter</u>							
5005	50	86	52	56	61	83	NG ²
<u>Alcaligenes</u>							
5037	20	NG	20	20	NG	NG	NG
5093	49	87	58	60	62	112	NG
5162	19	NG	21	23	53	NG	NG
5380	30	52	30	30	32	38	NG
<u>Flavobacterium</u>							
5004	62	NG	68	70	168	NG	NG
5318	64	88	68	70	74	NG	NG
<u>Pseudomonas</u>							
5010	15	24	15	15	23	NG	NG
5041	13	28	16	18	36	180	NG
5083	17	NG	17	19	38	NG	NG
5262	14	20	16	16	20	NG	NG
5301	46	20	30	28	26	32	136
5309	47	30	30	28	28	32	212
5572	19	28	19	20	21	105	NG
<u>Vibrio</u>							
5022	16	20	19	20	21	24	34
5374	12	13	15	15	15	23	63
5449	13	35	13	13	15	NG	NG
5516	8	10	9	9	9	16	NG

¹ Spring-experiments conducted from May 3 to June 7, 1977
 Summer-experiments conducted July 27, 1977

² NG-no growth

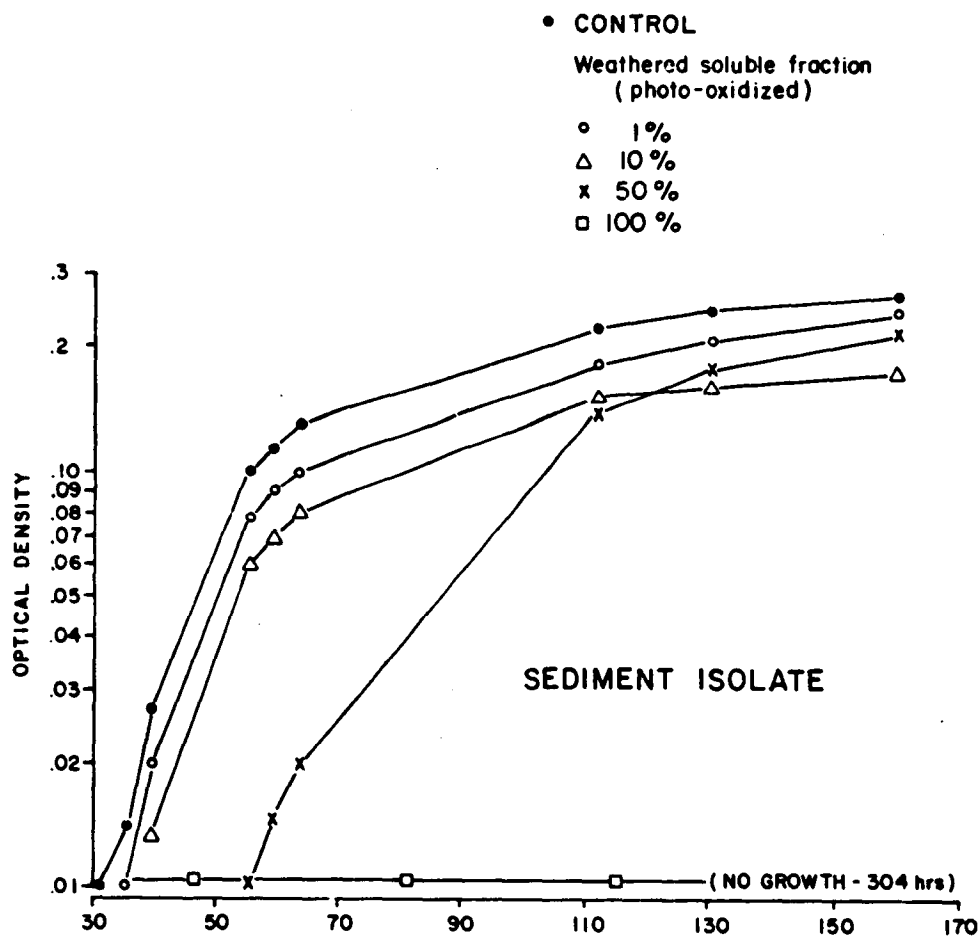


Figure 11-125. Representative growth curves for Acinetobacter sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

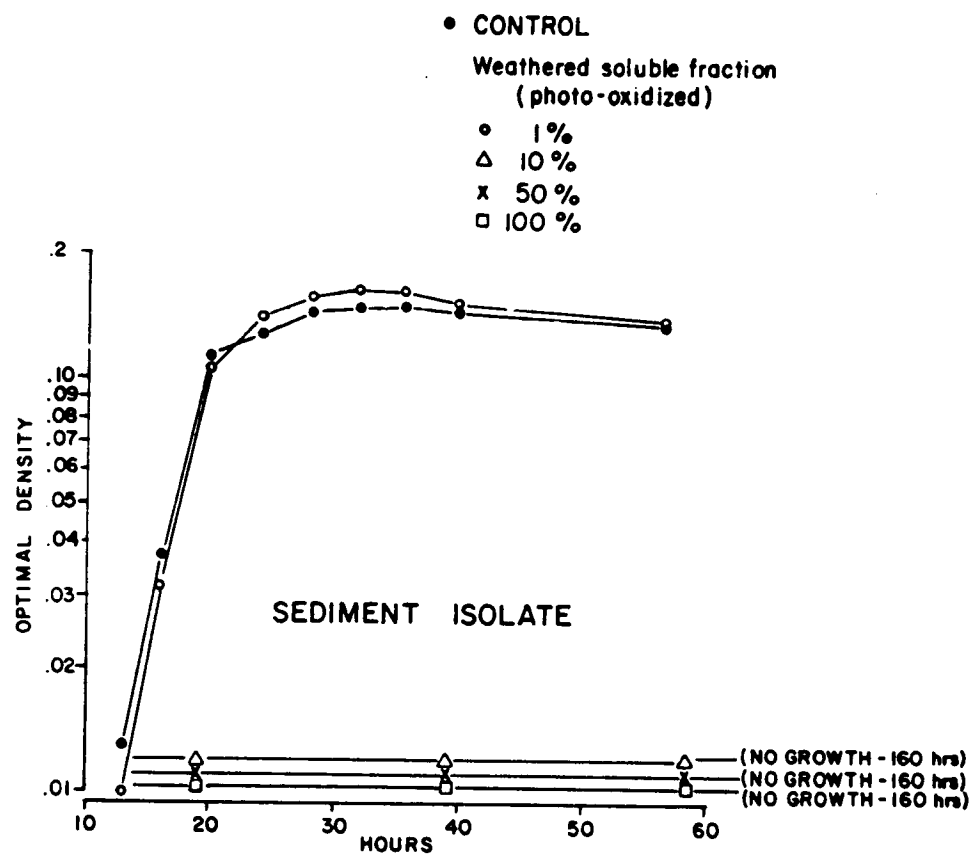


Figure 11-126. Representative growth curves for Alcaligenes sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

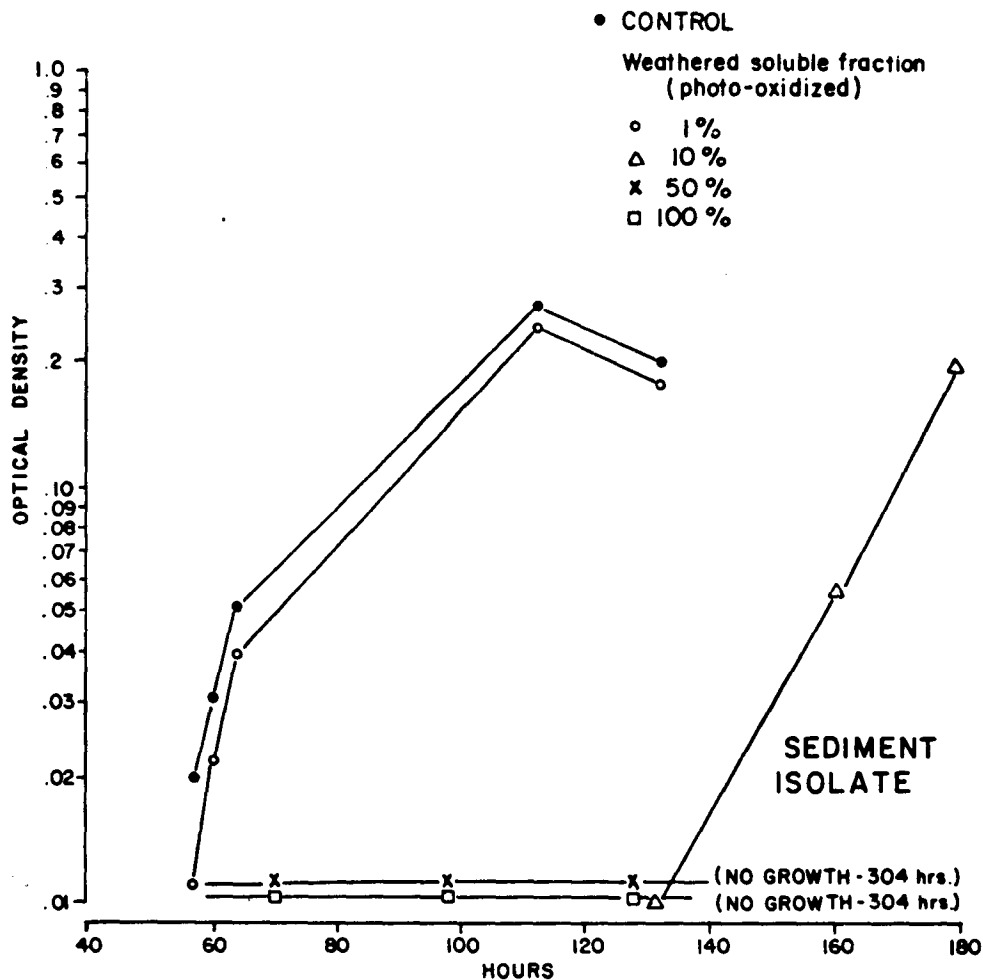


Figure 11-127. Representative growth curves for Flavobacterium sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

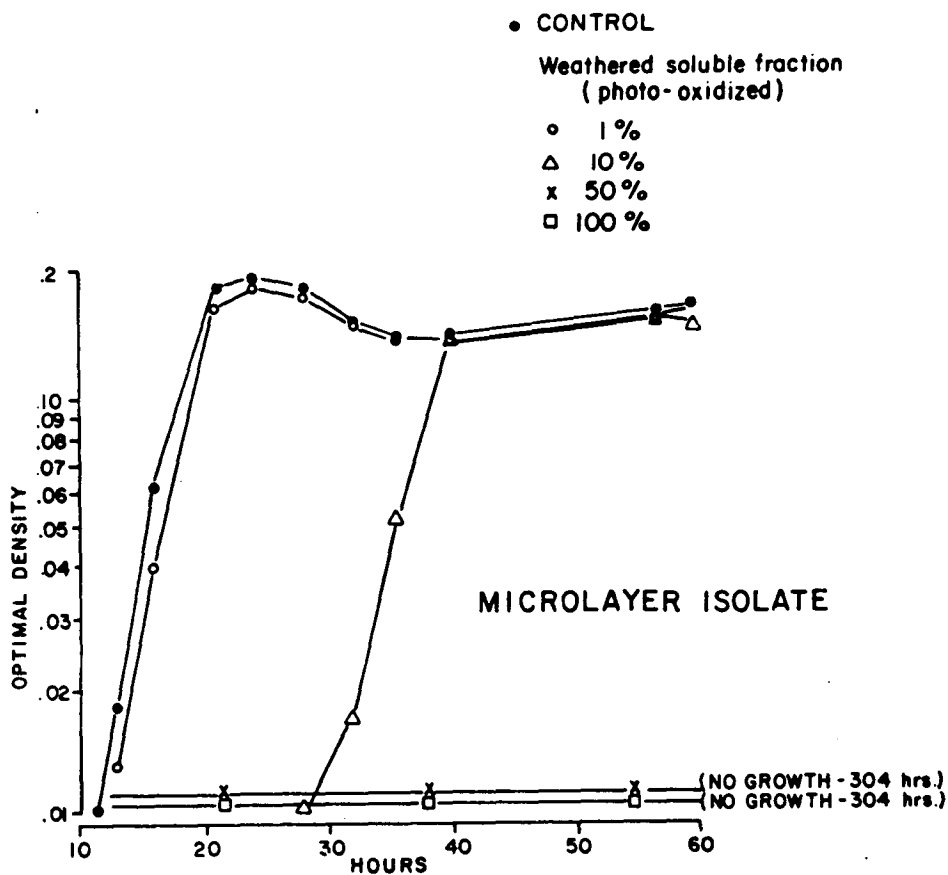


Figure 11-128. Representative growth curves for Pseudomonas sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

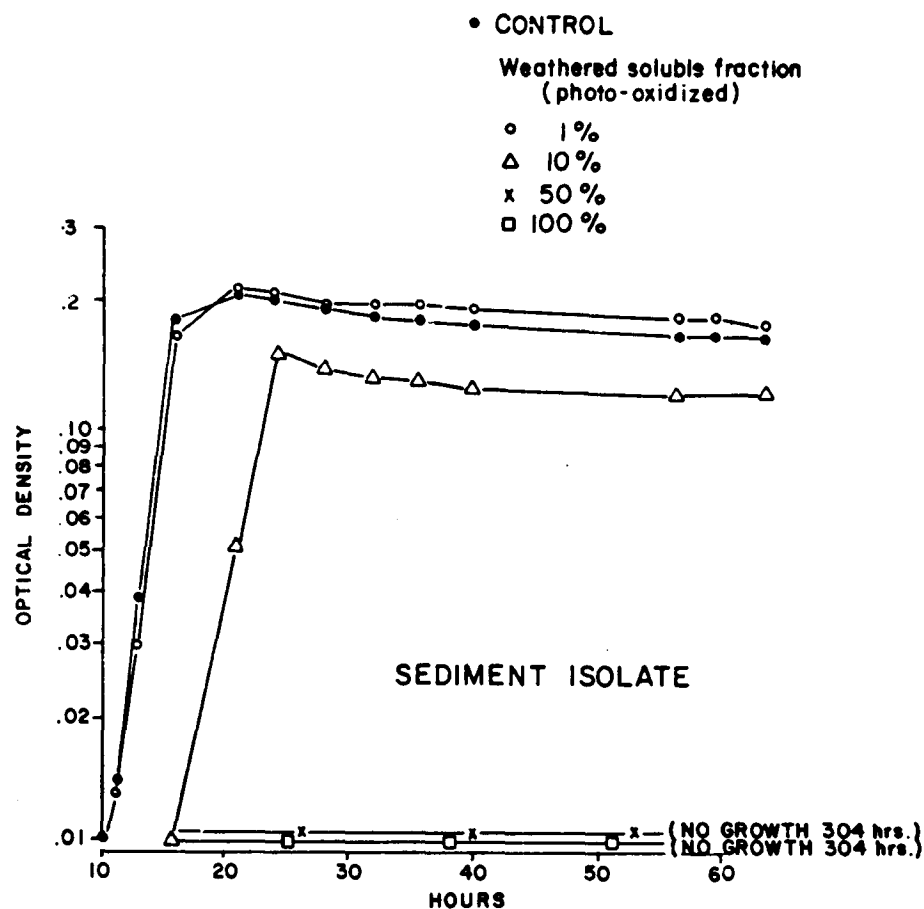


Figure 11-129. Representative growth curves for *Pseudomonas* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

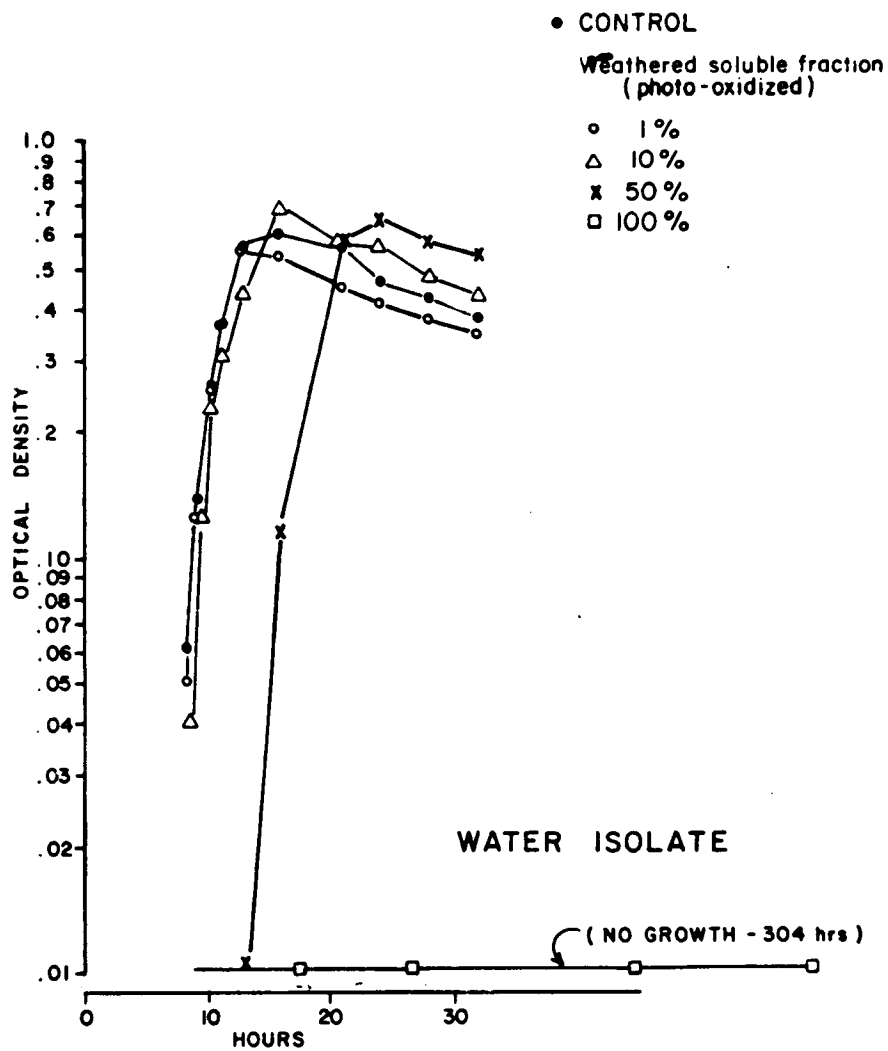


Figure 11-130. Representative growth curves for *Vibrio* sp. in a dilute peptone-seawater broth, and in a dilute peptone-seawater broth containing various concentrations of a soluble fraction of photo-oxidized South Louisiana crude oil.

Observations of elevated levels of petroleum-degrading bacteria in the vicinities of pollutant hydrocarbons have been made (Atlas and Bartha 1973b; Mulkins-Phillips and Stewart 1974; Seki 1976; Walker and Colwell 1977). Walker and Colwell (1977) stress the usefulness of the ratio of petroleum-degrading bacteria to heterotrophs in detecting petroleum pollution. Others (Atlas and Bartha 1973b; Seki 1976) have reported that elevated levels of petroleum-degrading bacteria are themselves indicative of the presence of petroleum. Our data suggest that both approaches yield similar information, provided background data on the natural levels of petroleum-degrading bacteria in non-polluted waters are known. Thus, while the numbers of petroleum degrading bacteria decreased moving offshore from Atlantic City, elevated values occurred in troughs and other stations with high amounts of silt-clay. Elevated levels were also expressed as an increase in the value of the ratio. However, values of the ratio were never as large as those found nearest Atlantic City. These observations underline the importance of knowing where a sample of sediment came from with respect to topographic features, textural composition, as well as sampling reference locations free of suspected petroleum pollution.

Sediments rich in silt-clay may stimulate bacterial diagenetic activities because of surface effects (Zobell 1946b). Similarly, the hydrodynamics of sediments accumulating silts may favor deposition of highly surface active particulates which already contain or scavenge hydrophobic substances from the water column. Finally, the benthic communities in sediments containing high concentrations of silt-clay may contribute lipoidal material which tends to be metabolized slowly because of the fine particulates and produces sustained elevated levels of petroleum-degrading bacteria.

Attempts to statistically correlate bacterial sediment populations with various physical or chemical parameters failed to yield consistent results. Kendall non-parametric correlation coefficients, calculated by ranking mutually independent variables, were particularly sensitive to small variations in viable bacterial counts which are commonly observed in field samples. The occurrence of variations in bacterial population distributions in water or sediments has been addressed frequently (Zobell and Feltham 1934; Ashby and Rhodes-Roberts 1976). Attempts to reduce this variation usually rely on increasing the numbers or size of replicate samples, an approach which becomes prohibitive with large scale surveys. Despite this problem, standard deviations for heterotroph mean counts of all Middle Atlantic shelf sediments sampled were about ± 0.6 log units. Considering the inherent variability of the MPN technique and that of sediment population distributions, this deviation is remarkably small. Liston (1968) observed a similar value of ± 0.5 log units for what he considered bacterial populations from stable shelf environments.

Variations related to technique and bacterial distributions were not the only possible sources of variability. As previously mentioned, despite the high overall correlation between silt-clay and organic carbon, correlations between these parameters with the replicates at any one station were generally poor. Significant ($p < 0.05$) correlations were found at less than 10% of the stations. Thus, variations in sediment properties, small but insignificant variations in bacterial populations, and the variability inherent in the MPN technique, precluded consistent correlation at significant values between bacterial populations and selected parameters.

Assuming that bacterial populations in Middle Atlantic continental shelf sediments should be inversely related to grain size distribution (ZoBell 1946b), percent clay-silt, in these relatively uniform sandy sediments, should be directly related to bacterial numbers. When stations were segregated by grossly different amounts of silt-clay, i.e. ridges vs swales, significant ($p < 0.05$) "correlations" of bacterial populations with % silt-clay were observed. Dale (1974) observed extraordinarily high correlation coefficients between bacterial populations from intertidal sediments and textural properties. However, he was working with a relatively simple system where tidal current energy produced a gradient of sediment characteristics.

In future surveys correlation of bacterial populations and physical-chemical parameters might be improved by analyzing replicates from the bacteriological grab using the "mini corer" to obtain similar penetration and sample size. Dilution of the upper, most active sediment layer, by varying amounts of sediments below, is also a source of variability for textural and chemical analyses.

Considering the absence of consistent and significant correlation of bacterial levels with other sediment-related properties, it is not surprising that a similar situation existed for aliphatic hydrocarbon concentrations. Aliphatic hydrocarbon concentrations in sediments were usually reported at concentrations at least 1000x smaller than corresponding total organic carbon values. It is plausible that we could not detect the response of bacterial populations to this small amount of hydrocarbon material using our methodologies. It is more likely that elevated bacterial counts or enrichment of petroleum-degrading bacteria are only indirectly related to ambient hydrocarbon levels which are in turn a reflection of overall biological activities affected by topography, sedimentation, and granulometric properties. Thus, we find elevated levels of petroleum-degrading bacteria in troughs which are also zones of heightened biological activity and relatively large amounts of clay-silt. Reports of other workers attempting to correlate bacterial parameters with sediment hydrocarbons (Walker and Colwell 1976; Buckley, Jones and Pfaender 1976) are difficult to compare and interpret due to differences in the levels of hydrocarbons involved and the incompatibility of analytical methods for hydrocarbon determination. It must be stated that at the

1

levels of hydrocarbons encountered in BLM sediments, significant correlations of bacterial parameters with sediment hydrocarbons were not observed.

Water Column

Bacterial viable count data suggested that the hydrodynamics of the slope and shelf water types strongly influenced the distribution, abundance, and activities of bacterial populations. A discussion of the seasonal water type composition from New Jersey transect stations as related to bacterial viable count data follows:

Water samples from the coastal boundary layer or coastal water type (cw) usually exhibited maximum viable counts of petroleum-degrading bacteria except during the winter. At this time, severe low temperatures depressed viable counts and activity. Coastal water traveled southward from north of Long Island past New York harbor and would be expected to contain compounds released through terrestrial and maritime activities. Thus, IOC, selected inorganics, and hydrocarbons were at maximum levels at C1 for several seasons compared with other inner shelf stations.

Departures from the pattern of reduction in viable bacterial counts with distance from land were frequently observed over the period 1975-77. During the fall, 1976, although coastal water extended seaward to Station E3, viable counts decreased with distance from land in surface and bottom waters. However, where the water type characterized as shelf-slope was found at depth, counts tended to rise. It is possible that upwelling existed between N3 and E3 giving rise to the elevated count in the surface water at N3. Shelf-slope (SS) water exhibited a somewhat higher C/N ratio (TOC/Total N) than slope water (SW). Slope water, perhaps at times composed of North Atlantic central water, was rich in inorganic N and P with a characteristic C/N ratio of less than 0.6. At Station F2, SS and SW were both present and this was reflected in elevated values of HC. A highly mobile frontal zone between these water types (SS and SW) was frequently observed in the vicinity of Station F2 with associated upwelling of nutrient rich slope water. Whether or not relative increases in HC counts (and to a lesser extent HET) were due to the availability of inorganic nutrients or heightened biological activity is not known. Unfortunately, primary productivity data were not collected as part of this program. Bacterial populations are known to respond to local concentrations of phytoplankton or zooplankton. However, ATP values were not elevated significantly at F2 relative to E3 or J1 to justify the latter hypothesis.

During the winter viable counts of HC were drastically reduced at Station C1. SS water was present at D1 and N3 but bacterial counts were still relatively low because of very low surface water temperatures. Thus, although the C/N ratio was rather low at these SS

water stations, the prohibitive temperatures prevented viable counts from reaching high values associated with SS water. Counts dropped at E3 but increased at F2. Although all surface stations exhibited similar low C/N ratios, the increase in viable count only occurred at F2, again suggesting something other than simply the availability of inorganic nutrients as a dominant factor in controlling bacterial densities.

Source and history of water types thus appeared to affect measured viable counts. During the spring of 1977 eddies from the Gulf Stream were present along the New Jersey transect. At Station E3 many water types were present including shelf-Gulf Stream, shelf-slope and CW apparently being pulled seaward by the clockwise motion of the eddy. At this time Station F2 was located in the vicinity of Gulf stream eddy "P" and exhibited very low surface viable counts of HC and low counts of HET. Counts increased on extended seaward movement of surface coastal water while shelf water or shelf-slope water may be brought shoreward. It is of interest to hypothesize that planktonic forms of marine animals may "utilize" these water type movements for transport. Because it appeared that bacterial counts were not always related clearly to increases in temperature, TOC, or inorganic nutrients, it is suggested that viable counts at certain stations were reflections of heightened biological activity. An example of such activity would be localized phytoplankton blooms due to upwelling of nutrient rich subsurface water. Thus, although nutrient levels in bottom waters at Stations J1 and F2 were the highest of all stations in SW, extremely low viable counts of HC were recorded.

Differences in ATP concentrations and calculated biomass carbon values were noted between New Jersey and "L" transect stations. These differences appeared to reflect variations in water types along the transects. The "L" transect was dominated by surface runoff from Delaware Bay and this water type generally extended uniformly seaward. New Jersey transect hydrography was more complex with coastal water, shelf water, shelf-slope water, slope water and eddies from the Gulf Stream present as previously discussed.

Observations of decreasing ATP concentrations with depth have been previously reported for waters off the coasts of southern California (Holm-Hansen 1969; 1973), the Hawaiian Islands (Holm-Hansen, 1973), and North Carolina (Hobbie et al. 1972). Relatively greater concentrations of ATP in bottom water samples during the winter (1977) were probably related to the severe surface winter temperature regime.

The absence of consistent significant correlations of viable counts of petroleum-degrading bacteria with ATP concentrations was not unexpected considering the extremely low levels of hydrocarbons measured in Middle Atlantic continental shelf water and the respective precision of the bacterial enumeration and analytical hydrocarbon techniques. The hypothesis that petroleum-degrading bacteria counts

would be related to overall biological activity as reflected in ATP concentrations (biomass) would therefore appear unsupported by this evidence. Moreover, since measurements of primary production and phytoplankton biomass were not included as part of this research program, no direct correlation was possible.

Heterotrophic bacterial populations from Middle Atlantic shelf microlayer samples were not consistently enriched relative to the levels in bulk-subsurface water (1 m) samples. This observation contrasts with those of Sieburth (1963) and Tsyban (1971) who reported enrichment of heterotrophs in the microlayer as a fairly consistent observation. However, it would appear that the relative ability to detect enrichment would be a function of the difference between bacterial populations in the microlayer and bulk-subsurface water. Thus, Sieburth (1963) was able to detect enrichment in the microlayer because bacterial populations in the bulk-subsurface water were very low (mean = 8 organisms/ml). In contrast, bacterial numbers in waters farthest from the shelf (J1) exhibited a mean value of 1100 bacterial units/ml. Obviously it becomes difficult to detect enrichment in the microlayer when bacterial levels in the bulk-subsurface water are at similar values.

In contrast to heterotrophic bacteria, sporadic enrichment of petroleum-degrading bacteria was observed in selected microlayer samples. This observation is a logical one since it is known that lipoidal substances, such as hydrocarbons, accumulate in a patchy distribution at the air-water interface (Dietz and Lafond 1950; Garrett 1967; Jarvis et al. 1967; Seba and Corcoran 1969; Parker and Barsom 1970; Duce et al. 1972) and petroleum-degrading bacteria would be capable of degrading such substrates. Enrichment of petroleum-degrading bacteria was also manifested by elevation of the ratio HC/HET relative to the subsurface layer.

Genera observed in microlayer samples supported Sieburth's (1963) contention that Pseudomonas sp. dominated. We also observed that Pseudomonas isolates in the microlayer exhibited the highest proportion of isolates confirmed as petroleum-degraders in pure culture.

Laboratory Evaluation of Isolates

Isolate Characteristics

The majority of gram-negative isolates were identifiable at the generic level using a determinative scheme modified after Shewan (1965). However, difficulties were frequently encountered with isolates assigned to the genera Alcaligenes (Achromobacter) and Flavobacterium as well as certain immotile, non-pigmented strains.

Isolates assigned to the genus Alcaligenes were motile to immotile, non-fermentative, non-pigmented rods, very sensitive to penicillin(G), incapable of degrading chitin and relatively inactive with respect to selected carbohydrates and biopolymers. Shewan (1963) did not report motile marine Achromobacter but some motile species were included in the genera (Breed et al. 1957; Shewan 1963). All isolates conforming to the Achromobacter group of Shewan (1963) have been given the designation Alcaligenes in this report. Similar generic descriptions for both Alcaligenes and Achromobacter has led to the proposal to abandon the designation Achromobacter (Buchanan and Gibbons 1974). Mode of flagellation has been used to assign gram negative aerobic marine bacteria to the genus Alcaligenes (Baumann et al. 1972). However, this property has been shown to vary with culture technique and growth phase (Buchanan and Gibbons 1974; Aragno et al. 1977). In addition, problems with unequivocal interpretation of Leifson preparations frequently require confirmation using transmission electron microscopy. The prohibitive nature of flagella staining and confirmation for the large numbers of isolates processed during this study, precluded the use of mode of flagellation as a diagnostic test.

Non-fermentative isolates which were motile and weakly or insensitive to penicillin(G) were classified as Pseudomonas. These organisms tended to grow rapidly, were active with respect to selected carbohydrates and biopolymers, and were achromatic or produced a diffusible green-yellow pigment.

Identification of immotile, non-fermentative, and non-pigmented isolates still remains a problem. Shewan (1963) placed all penicillin (G) sensitive isolates in the genus Achromobacter (Alcaligenes). Others have placed similar isolates in the genera Acinetobacter and/or Moraxella (Lewis 1973; Buchanan and Gibbons 1974). Kovacs' oxidase negative, penicillin(G) resistant strains have been considered as Acinetobacter (Baumann et al. 1968b; Pagel and Seyfried 1976). Oxidase positive strains have been placed in the genus Moraxella (Baumann et al. 1968a; Buchanan and Gibbons 1974). However, all but one species of Moraxella (M. osloensis), are highly sensitive to penicillin (G), and their extremely fastidious nutritional requirements eliminated them from consideration due to isolation and cultivation methods employed (Baumann et al. 1968a,b). Therefore, isolates which were oxidase positive and weakly sensitive or insensitive to penicillin(G) were considered presumptive Moraxella osloensis. Non-motile, penicillin(G) sensitive isolates with relatively inert biochemical tendencies and characteristics similar to motile Alcaligenes were designated as such.

Differentiation of non-motile Flavobacterium from Cytophaga is a major unresolved taxonomic problem (Mitchell et al. 1969; Hayes 1977), and a reliable differentiation scheme is presently unavailable.

Seasonal and Spatial Variations in Bacterial Genera

In general, frequency of occurrence for dominant genera did not appear to be related to season. However, trends toward increased frequency of isolation for Vibrio from ESWB plus petroleum medium in the fall were suggested. Isolates from microlayer and surface waters, areas most immediately affected by seasonal changes, did not evidence significant variations in generic composition during the four biological seasons. Isolate mortality, cultivation selectivity and conditions, and the relatively few microlayer samples obtained must be taken into consideration in assessing the influence of season on bacterial populations.

The (selective) compositional stability of bacterial populations as determined by viable counts, i.e., numerical dominance by representatives of the genera Alcaligenes, Vibrio, Pseudomonas, and Flavobacterium, has been reported elsewhere in various parts of the world for estuarine and oceanic waters (Sieburth 1967; Liston 1968; Ezura et al. 1974). Murchelano and Brown (1970) reported similar dominance by these genera but also observed a seasonal variation in the frequency of occurrence of Flavobacterium and Pseudomonas for a single station sampled over a yearly interval. Previous data collected on the bacterial populations of the sediments and waters of the Middle Atlantic continental shelf (Kator 1977) revealed no significant variation in the frequency of occurrence of dominant genera by season over a large sampling area. Sieburth (1967) noted that although temperature selected for bacterial "thermal type", temperature did not appear to affect the generic composition of the dominant isolates. It can therefore be concluded that although rates of growth and mineralization would be expected to vary with season, the metabolic "potential" of the selected viable count population remains stable if one considers generic capabilities.

Isolates with the highest frequencies of occurrence were different when HM and ESWB plus petroleum medium were compared. Pseudomonas dominated HM tubes from microlayer and surface water samples while Flavobacterium was the most frequently detected genus in HM tubes from sediment samples. In comparison, Pseudomonas was dominant in ESWB plus petroleum tubes where Flavobacterium infrequently occurred. Vibrio also tended to appear at high frequencies in ESWB plus petroleum tubes. These differences reflected the selectivity of the ESWB plus petroleum medium for petroleum-degrading genera and agree with pure culture hexadecane-petroleum confirmation experiments which indicated that Pseudomonas and Vibrio possessed the highest confirmation percentages among the dominant genera isolated from ESWB tubes. Earlier observations (Kator 1977) were consistent with these findings with the exception of dominance by Alcaligenes in HM tubes. This dominance was probably an artifact owing to the relatively high mortality of presumptive Flavobacterium previously noted. Occurrence at relatively high frequencies of Alcaligenes in ESWB plus petroleum types from

sediment and water samples and the very low confirmation percentages for hexadecane-petroleum utilization for this genus, indicated populations of Alcaligenes in ESWB plus petroleum tubes were mutualistic with respect to petroleum degradation.

Variations in generic composition with geographic station location, depth in the water column, presence in sediments, or topography (ridge-swale system) were not evident. Bacterial genera dominant offshore also dominated inshore when frequencies of occurrence were compared.

Petroleum Degradation Experiments

The ratio of petroleum-degrading (HC) to heterotrophic (HET) bacterial counts has been suggested for use as an indicator of petroleum pollution (Walker and Colwell 1976). Results from closed-flask degradation experiments performed during this study have indicated that although values of the ratio generally tended to increase with petroleum treatment, these values did not always change in the directions predicted. Thus, it was not unusual to observe that samples exhibiting low viable counts of both HC and HET would possess ratios of higher value than samples with considerably greater viable HC counts. Similarly, values of the ratio were sometimes greater in oil-free controls when compared with oil-treated flasks even though the absolute viable counts of HC were larger in the latter. Since viable counts of both HC and HET contributed to the value of the ratio and change in one count was apparently not always related to change in the other, often values of the ratio would not reflect observed increases in viable counts of HC responding to treatment with petroleum.

Increases in viable counts of HC and HET were observed for all closed flask treatments, during all seasons, and with both water and sediment inocula. Differences in viable counts due to treatment were observed as nutrient enriched flasks maintained greater populations of HC and HET than those in both oil-free and oil-treated inoculated flasks. Seasonal effects were superimposed on these observations with smaller viable count increases detected in enriched flasks incubated at winter temperatures (5°C).

During all seasons viable counts of HC and HET in oil-free and inoculated flasks were essentially equivalent. This may have been due to surface adsorption or the "bottle" effect. Significantly greater HC viable counts observed in enriched flasks were directly related to degradation of petroleum under nutrient enriched conditions. The relatively smaller viable count increases in enriched flasks during the winter was probably the result of minimal metabolic uptake and maximum oil viscosity at the winter incubation temperature (5°C).

Results of gas chromatographic quantification of n-paraffin losses agreed well with increases in viable counts of HC. Decreased amounts of degradation as well as a lag in the maximum rates of degradation during the winter corresponded with similar decreases in the maximum values of HC and HET viable counts reached as well as the lag observed with these populations. While realizing the limitations of applying data from closed flask laboratory studies for predictions in the natural environment, these data suggested that the lowest seasonal rates of petroleum degradation would occur during the winter. Based on two years of closed flask degradation studies, bacterial degradation of n-paraffins was always greatest in the fall with spring, summer, and winter manifesting decreasing degradation capacity, respectively.

Since the low water temperatures characteristic of the winter resulted in decreased degradation, presumably greater degradation would be predicted at higher incubation temperatures. This hypothesis appeared to be correct with one important exception. Although degradation was more extensive during the fall (15°C) and spring (15°C) compared with the winter, degradation during the summer (20°C) was only approximately equivalent to that of the winter despite larger initial rates of n-paraffin loss and viable HC counts at 20°C. One plausible explanation for these observations relates to the fact that evaporative losses at summer incubation temperatures were the largest for all seasons. Therefore, even though n-paraffin degradation may have been most extensive during the summer, evaporative losses which resulted in the largest seasonal decreases in control summation weights, produced an apparently lowered degradation capacity.

Analysis of degradation experiments employing sediment inocula indicated trough station inocula exhibited significantly greater degradation than ridge station inocula. As with water station inocula, season affected degradation potentials. Very low inshore winter water temperatures associated with the severe winter of 1977 depressed the degradation of both ridge and swale sediments and greatly reduced the HC viable count in selected inshore sediment inocula. Furthermore, HC populations during spring at these stations appeared slow to recover from the severe winter and therefore spring rates were somewhat less than expected. Subsequently, degradation rates during the summer were at their greatest values with sediment inocula. Possibly, the effects of evaporation on quantifying degradation noted for water inocula were lessened with sediment inocula owing to the observable adsorption of oil to sediment particles. Based on laboratory experiments with sediment inocula, it appeared that oil polluting sediments during the winter and spring (especially during an atypically cold winter) may not be degraded until summer. Inshore surface waters and troughs consistently exhibited the greatest degradation potentials during all seasons compared with offshore waters. Finally, regardless of inoculum source, degradation of petroleum is possible by indigenous microbiota,

given adequate inorganic nutrient enrichment and favorable temperature regimes, during any season.

Results obtained in developing a new experimental technique to assess petroleum degradation under conditions of continuous dilution with ambient seawater were disappointing. Significant degradation was not observed for any season. However, these preliminary experiments revealed deficiencies in our experimental techniques which will yield significant improvements. Experiments performed using 0.01% (v/v) petroleum were complicated in our experiment by evaporative losses that could not be separated from biodegradation at this low substrate concentration. This phenomenon was also observed using 0.1% (v/v) petroleum. Use of a pre-weathered petroleum and larger incubation intervals would undoubtedly facilitate detection of petroleum degradation. The longest incubation interval occurred during the winter (18 days) simply because of severe weather conditions. As indicated for closed flask experiments, this interval was not adequate for detection of degradation at 5°C. Additionally, difficulties with certain components of our experimental system were experienced. These included problems associated with running a slow speed multi-channel peristaltic pump at sea under conditions of poor electrical power regulation, excessive vibration and imprecise flow rate regulation.

Chitin - Petroleum Degradation Studies

Results of the fall (05B) chitin-petroleum degradation experiment revealed that using a somewhat rich organic medium, South Louisiana crude oil did not significantly affect the ultimate amounts of chitin hydrolyzed. Furthermore, viable counts of chitinoclasts did not differ markedly in oil treated and oil-free flasks. However, an examination of each incubation period by harvest interval revealed that petroleum-degrading bacteria tended to be lower in oil-free flasks during the first two weeks of incubation. This period was followed by an increase in counts of petroleum-degraders coincident with the relative decline of chitinoclasts and decrease in amount of chitin hydrolyzed. These observations suggested that the increase in petroleum-degraders under oil-free conditions was in response to degradation products and/or cellular lipids produced by chitinoclasts.

Peptone and yeast extract concentrations were reduced for the winter, spring and summer experiments to increase the relative importance of chitin and petroleum as selective substrates. Using winter isolates, chitin degradation was significantly slower during the initial weeks of incubation in oil-treated flasks with viable chitinoclast counts lower in the presence of oil. Levels of petroleum-degrading bacteria were consistently greater (2-3 log units) in oil treated flasks. Changes in levels of chitinoclasts and petroleum degrading bacteria in oil-free flasks suggested a diauxie-like growth phenomenon. Pronounced differences in chitin loss and cell counts during the winter season may indicate that the

dominant isolates used were compositionally different from those of the other seasons. Although all isolates were selected on the basis of viability and numerical dominance under standardized mesophilic cultivation conditions, and all experiments were conducted at 20°C, some seasonally dependent factor may have been operating to affect the composition of the dominant chitinoclast microbiota sampled.

Total heterotroph counts were similar in both oil-free and oil-treated flasks and appeared to have reached some limiting value within 2 weeks. In the presence of petroleum total heterotrophs were composed of rather high levels of both chitinoclasts and petroleum-degraders, while in oil-free flasks, chitinoclasts clearly dominated the heterotrophic population. Petroleum-degrading bacteria were usually numerically dominant in oil-treated flasks. Similar patterns of change in cell populations occurred to varying degrees in oil-free flasks in the spring and summer experiments.

Considering all experiments, the ultimate amounts of chitin degraded under oil-free and oil-treated conditions over the entire incubation period were not significantly different. These observations suggested that although chitin degradation sometimes occurred at a lesser rate in the presence of oil, neither South Louisiana crude oil nor its degradation products were toxic toward chitinoclasts under the experimental conditions employed. Walker et al. (1975) concluded that South Louisiana crude oil was toxic to chitinoclasts because the percentage of chitinoclasts to total heterotrophs was reduced in the presence of oil even though the absolute values of chitinoclasts and heterotrophs had increased. It seemed logical that when oil was introduced into the chitin-free system, selective enrichment of petroleum degraders occurred resulting in an increase in the total heterotroph population. However, since chitin was not provided as a substrate, chitinoclasts would not be expected to demonstrate a proportionate increase. Thus, if for the winter experiments chitinoclast levels alone had been monitored for two weeks of incubation, it could be concluded that petroleum inhibited chitinoclast populations when compared to the oil-free flasks. However, by simultaneous enumeration of "total" heterotrophic, petroleum-degrading and chitinoclastic bacterial populations and measurement of substrate utilization, it was evident that South Louisiana crude oil was not detrimental to chitinoclast activity. The presence of oil simply produced a shift in the relative proportions of chitinoclasts and petroleum-degrading bacteria in the "total" heterotrophic population.

In conclusion, it appears that under the experimental conditions employed for these experiments, South Louisiana crude oil was not toxic toward populations of chitinoclastic marine bacteria.

Pure Culture - Petroleum Growth Studies

Bacterial growth responses in a dilute glucose medium to unweathered and laboratory weathered crude oil and resulting soluble fractions expressed as "lag" times were similar to those previously observed (Kator 1977). Isolates most sensitive to the presence of petroleum belonged to genera which possessed characteristically longer "lag" times. The occurrence of lengthened lag periods in the presence of toxic compounds is in agreement with classical descriptions of bacterial growth curves. Similarly, while toxic compounds have been recognized to increase the duration of the lag phase, subsequent logarithmic growth occurs at rates similar to untreated cells (Lamanna et al. 1973). Reasons for lengthening of the lag period may be due to increased permeability characteristic of the lag phase, hence easier ease of penetration by toxic lipid-soluble hydrocarbons; time required for synthesis of detoxifying systems, or partial mortality of the inoculum.

It is possible that the "lag" times observed would have been even more pronounced in less concentrated glucose medium. Griffin and Calder (1977) reported that the degree of oil toxicity increased as nutrient concentrations were decreased and suggested that dissolved petroleum hydrocarbons would be even more toxic in relatively organic carbon poor natural waters.

Occasionally isolates from genera with relatively short "lag" times, i.e., Vibrio and Pseudomonas, would be markedly or totally inhibited by the presence of photo-oxidized crude oil and/or the resulting soluble fraction. In addition, some isolates manifested petroleum sensitivities unlike those of the majority of isolates belonging to a given genus. Cobet and Guard (1973) showed that some members of a specific genus could utilize an added petroleum hydrocarbon for growth whereas others of the same genera were adversely affected. Their data also showed that various petroleum compounds possessed different toxicities both within and across generic boundaries. Since in the present and aforementioned studies species identification was not performed, it is not known to what degree this would explain the observed variations. A range of sensitivities at the generic level was not unreasonable with respect to photo-oxidized hydrocarbons due to uncontrolled intensity and duration of illumination as well as temperatures inherent in environmental weathering. Greater variation in "lag" times in the absence of oil was observed within Alcaligenes and Flavobacterium genera than for the other taxonomic groups. "Lag" time variation may have been a function of the taxonomic heterogeneity within these genera (Shewan 1963; Baumann et al. 1972) or due to the tendencies of some cultures within these genera to produce "rope" like or stringy cell masses and to clump. Despite heterogeneity of "lag" time within genera, it was usually possible to identify the genus of an unknown isolate by its characteristic "lag" time and response to unweathered or laboratory weathered crude oil.

With respect to oil treatment it appeared that petroleum weathered in the dark at moderate environmental temperatures (21-32°C) was less inhibitory than unweathered oil and suggests removal of toxic components through evaporation. Elimination of the inhibitory effects of crude and fuel oils on a marine bacterium and micro-algae following evaporation have been reported (Atlas 1975; Batterton et al. 1976). The relative toxicity of photo-oxidized crude oil was more difficult to evaluate when compared only to unweathered oil due to the varying intensities of natural sunlight and temperature. However, comparison of growth effects observed in experiments conducted two weeks apart indicated that photo-oxidized oil was more toxic than the "dark" control but less inhibitory than unweathered oil. These results suggest that removal of toxic volatile components during weathering was offset by the formation of toxic photo-oxidation products. Non-photo-oxidized soluble fractions showed little, if any, significant adverse effects at either 1 or 100% (v/v) concentrations although similar extracts (86.5% v/v) have been reported as toxic for one bacterium studied (Griffin and Calder 1977). These same investigators reported that the absolute toxicities of photo-oxidized soluble fractions of crude and refined oils were generally higher than non-illuminated extracts. The present study showed marked inhibitory effects on bacterial isolates, including even those with short "lag" times, when exposed to photo-oxidized water soluble extracts.

Specific mechanisms underlying petroleum toxicity towards marine bacteria do not appear to be available in the literature. Some isolates were unaffected or slightly suppressed while others were totally inhibited. Growth effects were most frequently observed as increases in "lag" times although decreases in growth rate and "yield" were infrequently noted. Based on these observations it would appear that the observed growth responses to the presence of petroleum hydrocarbons may be due to at least several mechanisms. Griffin and Calder (1977) have suggested that oil toxicants act on the cell membrane by either inhibiting substrate uptake or increasing leakage of metabolites which is congruent with the observation that protection against toxicant oils can be afforded by increasing organic nutrient levels. It could also be hypothesized that the extended lag phase was related to induction of mixed function oxidase systems for hydrocarbon detoxification. Hydroperoxides, carbonyl compounds, acids, and phenols formed during photo-oxidation of a #2 fuel oil were shown to be toxic to yeast (Larson et al. 1966 and 1977). Similar oxygenated compounds were probably formed during our studies. It is reported that certain cell constituents, i.e., nucleic acids, enzymes, polypeptides, proteins, and carbohydrates are damaged or degraded by photo-sensitized oxidative reactions (Foote 1968; Spikes and MacKnight 1970). Exposure of bacteria to photo-oxidized petroleum compounds may result in similar types of cell damage.

The results of pure culture experiments demonstrated that a significant proportion of the heterotrophic bacterial isolates were adversely affected by the presence of petroleum hydrocarbons. One-half to three-fourths of the HM isolates examined were strongly inhibited by unweathered, laboratory-weathered oil, and photo-oxidized crude oil whereas one-fourth or fewer ESWB isolates were likewise suppressed. Similar disparate sensitivities were noted with photo-oxidized soluble extracts. To extrapolate results observed under laboratory conditions to the marine environment is difficult. However, various crude and refined oils have been demonstrated to inhibit uptake and mineralization of d-glucose¹⁴C by heterotrophic bacteria under controlled in situ conditions (Hodson et al. 1977). Our results support the proposition of Atlas (1976) that: "Changes in the microbial communities following oil spillages reflect in part the toxic effects of petroleum components and in part the ability of some micro-organisms to degrade oil". Indeed, research performed on the species composition of indigenous microbial populations in a salt marsh following a controlled oil spill indicated a rapid enrichment in the numbers of *Pseudomonas* in the marsh (Kator and Herwig 1977). Further research is needed to describe successive changes in sensitive and resistant bacterial populations following spillage of oil and the effects of these changes on the mineralization activities of the microbial community.

Summary of Significant Findings

1. Petroleum-degrading and heterotrophic marine bacteria were consistently isolated over a two year period from Middle Atlantic Continental Shelf sediments. Mean viable counts of heterotrophic bacteria were remarkably consistent from season to season within each major shelf location. Mean viable counts of heterotrophs from inner shelf sediments were significantly ($\alpha = 0.05$) larger than counts from outer shelf or shelf-break sediments. Mean viable counts of heterotrophic bacteria from shelf-break sediments were not significantly ($\alpha = 0.05$) different from those in outer shelf sediments. Overall patterns of heterotrophic bacterial counts were generally similar from season to season and year to year. Moreover, repetition of certain viable count maxima and minima were observed and related to the ridge-swale topography of the inner and outer shelf. Stations with higher percentages of silt-clay exhibited comparatively elevated counts relative to those with no silt-clay. Mean viable counts (all stations) tended to be somewhat larger during the fall and summer compared with the remaining seasons.
2. Mean viable counts of petroleum-degrading bacteria in sediments were generally 2-4 orders of magnitude smaller than viable counts of heterotrophs. Patterns of change in viable counts of petroleum-degrading bacteria with distance from shore were easily observed when compared with heterotrophs. Inner shelf sediments

exhibited the largest viable counts of petroleum-degrading bacteria. Elevated counts in the troughs C4, D4, and B3 were frequently observed. Statistically, viable counts of petroleum-degrading bacteria and the ratio of petroleum-degrading to heterotrophic bacteria from inner shelf sediments were significantly ($\alpha = 0.05$) greater than viable counts from outer shelf or shelf-break sediments. Seasonally, viable counts as well as values of the ratio tended to be greater during the fall and summer compared with the remaining seasons.

3. Kendall nonparametric correlation coefficients calculated for viable bacterial counts in sediments versus selected granulometric properties such as % silt-clay, median grain size, and in addition, TOC and temperature were not significant ($\alpha = 0.05$) for most seasons and shelf areas. Significant ($\alpha = 0.05$) correlations were only observed for viable counts of petroleum-degrading bacteria with the ratio of petroleum-degrading to heterotrophic bacteria.
4. Kendall nonparametric correlation coefficients calculated for viable bacterial counts versus sediment aliphatic and aromatic hydrocarbon concentrations were neither significant ($\alpha = 0.05$) nor consistent in direction.
5. Comparison of viable bacterial counts from trough and ridge sediments using a nonparametric test statistic indicated that petroleum-degrading and heterotrophic bacterial counts and values of the ratio of petroleum-degrading to heterotrophic bacteria from trough sediments were consistently and significantly ($\alpha = 0.05$) greater than or equal to similar counts and values from ridge sediments.
6. Maximum values of the ratio of petroleum-degrading to heterotrophic bacteria were always encountered in inner shelf sediments and troughs. Outer shelf sediments usually exhibited intermediate values compared with inner shelf and shelf-break sediments. Values of the ratio were shown dependent on the number of viable petroleum-degrading bacteria since heterotrophic counts were rather constant for most stations.
7. Microlayer samples collected over 8 biological seasons failed to reveal significant ($\alpha = 0.05$) enrichment of heterotrophic bacteria relative to the bulk subsurface layer. Although individual samples from selected microlayer stations indicated enrichment of petroleum-degrading bacteria, statistical analysis of all stations sampled failed to reveal significant ($\alpha = 0.05$) enrichment. Microlayer samples were dominated by the genus Pseudomonas, with Alcaligenes and Vibrio numerically equivalent but detected less frequently.

8. Heterotrophic bacterial counts in 1 m surface, thermocline, and bottom New Jersey transect water column stations generally decreased with distance from land. Viable counts of petroleum-degrading bacteria also decreased with distance from land. Station C1, located in the coastal boundary layer, generally exhibited the largest viable counts of petroleum-degrading bacteria. Exceptions to the basic pattern of decreasing count with distance from shore occurred at certain stations over the two year period. Most frequent among those stations exhibiting relatively elevated viable counts was F2. This station, located at the shelf break (100 m), was generally close to the highly mobile frontal zone between slope and shelf water types. Hydrodynamic survey data indicated that upwelling of nutrient rich slope water occurred in this region but consistent correlations of bacterial counts with inorganic nutrients, dissolved organic carbon, particular organic carbon, and dissolved hydrocarbons were not found. Seasonal differences in viable bacterial counts along the New Jersey transect were related to climate and the complex hydrography of shelf-slope water types.
9. Statistical analyses of viable heterotroph counts from surface, thermocline, and bottom water samples indicated no significant ($\alpha = 0.05$) differences in counts for surface and bottom water samples. However, comparison of viable counts from surface water vs. thermocline samples indicated that viable counts of petroleum-degrading bacteria were significantly ($\alpha = 0.05$) smaller than counts in surface waters.
10. Extensive calculations of Kendall nonparametric correlation coefficients indicated a lack of consistent and significant relationships between bacterial data and most physical-chemical parameters measured in the water column. When significant correlation coefficients were obtained, these appeared to be related to distance from land, e.g., heterotroph viable counts correlated significantly ($\alpha = 0.05$) in a negative direction with salinity and temperature. Heterotroph counts (but not petroleum-degrading bacterial counts) frequently correlated significantly ($\alpha = 0.05$) with ATP concentrations in both surface and bottom waters.
11. ATP concentrations in water samples generally decreased with depth and distance from land. During the severe winter of 1977, ATP levels in surface waters of some inner and outer shelf stations fell below corresponding bottom water values. During the spring and summer seasons ATP concentrations in surface waters indicated return to pre-winter levels.

12. More than 90% of the numerically dominant isolates identified from both HM and ESWB + petroleum enumeration tubes were assigned to the major genera Alcaligenes, Flavobacterium, Pseudomonas and Vibrio. Flavobacterium was the most frequently isolated genus from HM tubes with Alcaligenes and Pseudomonas secondary in total numbers of isolates. In contrast to isolates obtained from HM tubes, those from ESWB + petroleum tubes were overwhelmingly dominated by Pseudomonas. Flavobacterium was the least frequently isolated major genus from ESWB + petroleum enumeration medium.
13. Pseudomonas was the most frequently isolated genus from microlayer samples. In contrast, Flavobacterium was more frequently isolated from the bulk subsurface layer (1 m) and bottom water compared with Pseudomonas. Vibrio was isolated during all seasons but tended to occur at a higher frequency during the spring and summer seasons. Isolation of Alcaligenes from samples of bottom water and sediments appeared greater during the fall. No differences in the patterns or frequencies of detection for major genera existed when New Jersey and "L" transects were compared. Frequencies of occurrence for dominant genera in sediments were similar for all shelf locations. Similarly, analysis of genera isolated from topographic extremes, i.e., ridges vs. swale, did not reveal significant differences in frequencies of occurrence.
14. Analysis of isolates examined for utilization of petroleum and hexadecane in pure culture indicated 10% of ESWB + petroleum derived isolates utilized sterile hexadecane whereas only 3% of HM derived isolates utilized this substrate. ESWB + petroleum isolates from microlayer and bulk subsurface (1 m) water samples exhibited the highest percentages of hexadecane and petroleum utilization compared with bottom water and sediment isolates. Genera confirming for the ability to degrade hexadecane and petroleum in pure culture included Pseudomonas and Vibrio. Both Alcaligenes and Flavobacterium, genera numerically dominant in HM and enumeration tubes, exhibited very low confirming percentages.
15. Closed flask petroleum degradation experiments demonstrated consistent and significant responses of bacterial populations to crude oil addition. Viable counts of heterotrophs and petroleum-degrading bacteria from surface water inocula increased during incubation intervals for all treatments. Increases of viable counts in nutrient enriched flasks were larger than those in either oil-free or inoculated flasks. Viable count changes in the latter flasks were approximately equivalent. Rates of increase in viable counts for all treatments were smallest during the winter (5°C).

16. With respect to surface water inocula, significant degradation of n-paraffins occurred only in flasks enriched with inorganic nutrients. Seasonally, degradation was minimal in the winter and maximum in the fall. Regardless of location of the inoculum source, patterns of n-paraffin degradation were similar for all transect stations.
17. Although viable counts of petroleum-degrading bacteria to heterotrophs generally increased in response to petroleum under enriched conditions, similar changes in values of the ratio were also observed in inoculated (non-enriched) and control (oil-free) flasks. Therefore, values of the ratio could not be consistently used to predict the presence (degradation) of petroleum in closed flask systems. Under enriched conditions values of petroleum-degrading bacteria when elevated above the "baseline" levels in control and inoculated flasks proved a more reliable index of the presence (degradation) of petroleum than the ratio.
18. Populations of heterotrophic and petroleum-degrading bacteria increased in closed flask systems following inoculation with sediment homogenates from ridge and swale sediments. Greater increases in viable counts of petroleum degrading and heterotrophic bacteria were observed in flasks inoculated with homogenates from trough sediments under both enriched and non-enriched conditions. Patterns of n-paraffin degradation were similar to those observed with surface water inocula although maximum degradation occurred in the summer. Degradation was always more extensive in enriched flasks. However, during the summer non-enriched flasks at several stations exhibited significant degradation. Degradation was more extensive using inocula from trough sediments compared with inocula from ridge sediments.
19. Unweathered South Louisiana crude oil (0.1% v/v) and its degradation products were not toxic towards mixed cultures of chitinoclasts as measured by chitin degradation in a dilute peptone-yeast-extract broth.
20. Metabolic byproducts and/or lipoidal cell components produced by chitinoclast populations in the absence of petroleum, resulted in a substantial elevation in the numbers of hydrocarbon-degrading bacteria in closed flask systems.
21. Pure cultures of bacterial isolates from sediment, water and microlayer samples were grown in a dilute peptone-glucose-yeast extract medium in the absence and presence of unweathered and weathered South Louisiana crude oil. Weathered oil consisted of oil weathered in the laboratory under light-free conditions or outdoors either shielded or exposed to ambient sunlight.

- a. Isolates least affected by the presence of petroleum belonged to genera which possessed characteristically the shortest generation times in the control medium.
- b. Alcaligenes and Flavobacterium, which were among the dominant genera isolated from field samples, exhibited extended "lag" times in the presence of unweathered and both types of weathered crude oil. Overall, heterotrophic isolates were most frequently sensitive to petroleum and inhibited to a greater degree than isolates obtained from ESWB + petroleum medium.
- c. Marked differences in the toxicities of unweathered and weathered oils were not apparent. Significant toxicity effects were observed for 45% and 46% of the fall isolates in the presence of unweathered and laboratory weathered oils respectively. Exposure to either photo-oxidized weathered oil or unweathered oil similarly affected 38% of isolates collected during the winter, spring and summer. However, weathering effects with respect to photo-oxidized oil may be obscured due to varying intensities of natural sunlight and temperature. The soluble fraction of crude oil increased dramatically in toxicity following weathering in the presence of sunlight as opposed to oil simultaneously weathered at the same environmental temperature but shielded from light rays.
- d. Results suggested that following an oil spill the species composition of bacterial populations may change in response to the toxic effects of crude oil upon susceptible bacteria followed by enrichment of petroleum-degrading bacteria or other resistant strains.

ACKNOWLEDGEMENTS

I gratefully acknowledge the following individuals whose devotion of time and effort to this project was outstanding: Lex Macculbin (petroleum-degradation studies), Martha Rhodes (pure culture growth studies), and Darbie Lister (chitin-petroleum degradation studies).

I also wish to extend my appreciation to Steven Blanton and Charles Booth for their outstanding technical assistance. Acknowledgement is also extended to Addie Lessard and Carol Rideout for their participation in the taxonomy portion of this project.

Final thanks are extended to Jane Wingrove and Dana McGinnis for preparation of media and for help with all the "little" things I never had time for.

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