SOUTH ATLANTIC OCS AREA LIVING MARINE RESOURCES STUDY

VOLUME I

DISCLAIMER

FINAL REPORT

SOUTH ATLANTIC OCS AREA
LIVING MARINE RESOURCES STUDY

VOLUME I

AN INVESTIGATION OF LIVE BOTTOM HABITATS
SOUTH OF CAPE FEAR, NORTH CAROLINA

Prepared for
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ABSTRACT

Major objectives of this study were to (1) characterize benthic and nektonic communities associated with representative live bottom habitats on the continental shelf of the South Atlantic Bight, and (2) evaluate factors which might influence these communities, particularly the potential for impact by offshore oil and gas activities. Nine live bottom areas assessed during winter and summer of 1980 were located off South Carolina, Georgia and Florida between latitudes 30° and 33°N and in water depths representing inner (19 - 27 m), middle (28 - 55 m), and outer (56 - 100 m) shelf zones. Sampling gears used at each study site included underwater television and still camera systems, fathometers, Niskin bottle casts with reversing thermometers, a transmissometer, scuba, trawl, fish traps, vertical long lines, snapper reels, an epibenthic juvenile fish sled, dredges, a Smith-McIntyre grab, and a suction sampler.

Hydrographic measurements obtained were typical of the South Atlantic Bight. Water temperature was the most variable parameter, particularly at inner shelf sites. Salinity and dissolved oxygen were generally high and water clarity, as measured by the transmissometer, showed no consistent pattern.

Assessment of bottom topography documented differences in relief among study areas, ranging from areas of hard bottom with low rock relief (< 0.5 m) to areas with rock outcroppings of moderate to high relief (0.5 - > 2 m). Live bottom within most study areas was patchy, and all but one area, located in middle shelf waters off northern Florida, had roughly similar proportions of live versus non-live bottom.

Invertebrate communities at all study sites were very diverse relative to sand bottom areas, but algae were generally sparse. No consistent patterns were noted in diversity with respect to depth, latitude, or season. Species composition of invertebrates, on the other hand, changed with depth and, to some extent, with season, but generally not with latitude. Most species collected at the study areas represented Carolinian and Tropical fauna. Invertebrate biomass was generally dominated by sponges; however, the occurrence of large sponges and octocorals decreased with increasing depth.

Community composition of demersal fishes collected at the study areas also varied with depth and season. Highest fish biomass and high concentrations of commercially valuable species were collected at middle shelf sites. Diversity of demersal fish catches was greatest at the outer shelf and was most stable seasonally in this depth zone. Food habits analysis of commercially important species indicated that *Centropristis striata* and *Pagrus pagrus* fed heavily on live bottom fauna, *Rhomboplites aurorubens* fed on invertebrates in the water column, and *Lutjanus campechanus* and *Mycteroperca microlepis* were top carnivores. Two other abundant demersal species, *Calamus leucosteus* and *Stenotomus aculeatus*, ingested a mixture of fauna from sand and live bottom habitats.

Detrimental impacts from offshore drilling operations are dependent on depth, currents, and distance of platforms (or discharge points) from live bottom areas. Negative impacts should be minimized or avoided by restricting platform placement (or discharge of cuttings and drilling muds) to distances of at least 1000 m from live bottom habitat. Positive impacts from drilling and production platforms would result from the creation of artificial reefs which should enhance fish density.

Based on the limited information obtained in the first year of this study, recommended research efforts include increased seasonal sampling and food habits analysis of selected demersal species, recolonization and growth rate studies, and monitoring studies if oil rigs are placed near live bottom habitat.

CHAPTER 1

INTRODUCTION

BACKGROUND

In order to meet the growing demands for petroleum products in the United States, the Department of Energy has accelerated its efforts to locate and extract hydrocarbon resources beneath the ocean floor. The Southeastern Georgia Embayment was opened for exploration by Lease Sale 43 in 1978, and exploration associated with this lease sale has already started. Further, Lease Sales 56 and 78 are scheduled for the South Atlantic Bight in 1981 and 1984, respectively.

Due to distinct geologic and stratigraphic features, outcroppings of sedimentary rock have been associated historically with potential energy reserves. Correspondingly, areas of prime interest resulting from Outer Continental Shelf Lease Sale 43 and areas nominated for Lease Sales 56 and 78 often coincide with the scattered occurrences of biologic assemblages associated with hard bottom locations. These rocky outcroppings are unique areas consisting of very rich and productive infaunal, epifaunal, and demersal assemblages of invertebrate and vertebrate species. For the purpose of this study, hard or "live" bottom areas are defined as areas containing "biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography, or whose lithotope favors the accumulation of turtles, fishes, and other fauna" (U. S. Department of Interior 1981).

Five different types of live bottom areas have already been identified in the South Atlantic Bight. They consist of (1) the shelf break (Eddy et al. 1967, Macintyre and Milliman 1970), (2) a relict lithothamnion reef off North Carolina (Menzies et al. 1966), (3) coral outcroppings (Huntsman and Macintyre 1971), (4) Black Rocks (Pearse and Williams 1951), and (5) Gray's Reef off Georgia (Hunt 1974; U. S. Department of Commerce, Office of Coastal Zone Management 1980). These habitats are interspersed throughout the relatively smooth sand bottom of the South Atlantic continental shelf area and can be separated into three bathymetric zones. The first is a relatively shallow water zone (approximately 19 - 27 m) that exists near shore. Known locally as "black fish banks" (Bearden and McKenzie 1971), this area typifies a number of inshore areas off South Carolina, Georgia, and North Carolina. Further offshore, in waters of approximately 28 - 55 m, occur the so-called "snapper banks" and other reefs of a similar discontinuous nature. The third and deepest zone is found at the edge of the continental shelf in depths of approximately 56 - 100 m. This shelf edge habitat is more or less continuous along the entire shelf off the Florida, Georgia, South Carolina, and North Carolina coasts.

At present, little is known regarding the areal extent or geographical distribution of these biologically important habitats; nor is there a comprehensive understanding of the biological communities which inhabit them. Even at Gray's Reef, which has been studied in greater detail than any other live bottom area on the South Carolina-Georgia Shelf (Hunt 1974), little quantitative data exists on the community structure, population sizes, or species composition of the diverse groups of organisms that inhabit these biologically sensitive areas.

Nevertheless, the importance of live bottom reefs to the commercial and recreational fisheries of the South Atlantic Region has been well documented (Cummins et al. 1962, Menzies et al. 1966, Struhsaker 1969, Bearden and McKenzie 1971, Sekavec and Huntsman 1972, Miller and Richards 1979, Powles and Barans 1980). These fisheries are currently experiencing rapid growth throughout the region. The economic value of these fisheries is difficult to quantify, but the recreational fisheries alone have been conservatively valued in excess of twenty-five million dollars per year in South Carolina and Georgia (D. M. Cupka, pers. comm., S. C. Marine Resources Center, Charleston, S. C., 1981).

Because of (1) their ecological and economic importance, (2) the unknown sensitivity of these habitats to environmental perturbation, and (3) a paucity of information which would allow adequate assessment of potential impacts from energy exploration and development, it is imperative that live bottom areas are studied more thoroughly. A recently completed geophysical study by the U. S. Geological Survey (1979) provides information on the distribution of many hard bottom areas, and Henry et al. (1980) provide some insight on important taxa utilizing these habitats. Results of the South Atlantic Hard Bottom Study (Continental Shelf Associates 1979) have also contributed to the biological understanding of these areas. However, information is still inadequate to determine (1) which live bottom areas are important, (2) what relationships exist between these habitats and adjacent non-live bottom habitats, (3) the importance of spatial and temporal patterns exhibited by live bottom organisms, and (4) the necessity (if any) of lease stipulations relative to these areas. This information must be gathered to properly evaluate these biologically important habitats. In response to this need, the Bureau of Land Management (BLM) developed and funded the present biological study of live bottom habitats entitled the "South Atlantic OCS Area Living Marine Resources Study." For the purpose of this study, the South Atlantic OCS area is that areas bounded by Cape Hatteras on the north and Cape Canaveral on the south and encompassing the continental shelf area within the 19 - 100 m bathymetric zone.

PROJECT ORGANIZATION

When this contract (#AA550-CT9-27) was initiated, the study was constrained to live bottom areas on the continental shelf off South Carolina, Georgia, and northern Florida. The contract was awarded to the South Carolina Marine Resources Research Institute (SC MRRI) as prime contractor and the Georgia Coastal Resources Division (GA CRD) as subcontractor. Approximately midway through the study, the project was expanded to include sites off North Carolina. This smaller study was awarded to Duke University Marine Laboratory (DUML) as a subcontractor to the SC MRRI. Due to differences in the scope of work associated with the Duke University effort, the final report has been divided into three volumes. Information presented in this Volume (I) is restricted to efforts and results associated with the original study areas south of Cape Fear. Volume II contains information related to areas north of Cape Fear, and Volume III provides data appendices related to Volumes I and II.

Project Participants:

<u>South Carolina Marine Resources Research Institute</u> - The Marine Resources Research Institute of the South Carolina Wildlife and Marine Resources Department is located at the South Carolina Marine Resources Center which occupies 30.4 ha (75 acres) adjacent to Charleston Harbor. The Division is broadly charged with the management, development, and proper utilization of the state's coastal resources.

This broad mission is discharged through the Division's two major branches, the Office of Conservation, Management and Marketing and the Marine Resources Research Institute. Collectively, these two branches not only manage the state's marine commercial and recreational fisheries, but also provide the state with a marine research facility capable of technical assistance whenever coastal problems arise.

<u>Georgia Coastal Resources Division</u> - Headquartered in Brunswick, the Coastal Resources Division of the Georgia Department of Natural Resources is responsible for the coastal environment of the six coastal Georgia counties and offshore waters to the two hundred mile fisheries conservation limit. Within this area, the Division carries out their responsibilities through diverse functions in three primary areas: fisheries management, coastal protection, and coastal management.

The Coastal Fisheries Section's primary responsibilities are to conduct studies necessary for management of Georgia's inshore fisheries, to develop stock assessments, and to draft a management plan for finfish and offshore shellfish. The Coastal Protection Section is charged with maintaining the integrity of the state's coastal ecosystems by protecting them from non-essential degradation. The Coastal Management Section works with local governments and other state agencies to evaluate the availability of natural resources to meet development needs of an expanding coastal economy. By providing technical assistance, legislative participation, and citizen input, the coastal management program is designed to coordinate coastal energy development activities and assist local governments in resource management decisions.

Project Management:

Management structure of the South Carolina MRRI and Georgia CRD study participants was designed to integrate personnel from both agencies into a unified team (Figure 1.1). Several senior level personnel on the project also have coastal management responsibilities. Thus, pertinent information resulting from this study is available for their use, even before final publication of the report.

The Project Leader was V. G. Burrell, Jr., Director of the South Carolina Marine Resources Research Institute. The Project Coordinator, R. F. Van Dolah, was primarily responsible for managing and monitoring all phases of the contract. He was assisted by J. V. Miglarese in administering this project. Additional key personnel from SC MRRI are identified in Figure 1.1 as responsible for their respective work elements.

The Georgia subcontractor leader was R. J. Reimold, Director of the Coastal Resources Division, who was responsible for Georgia research efforts

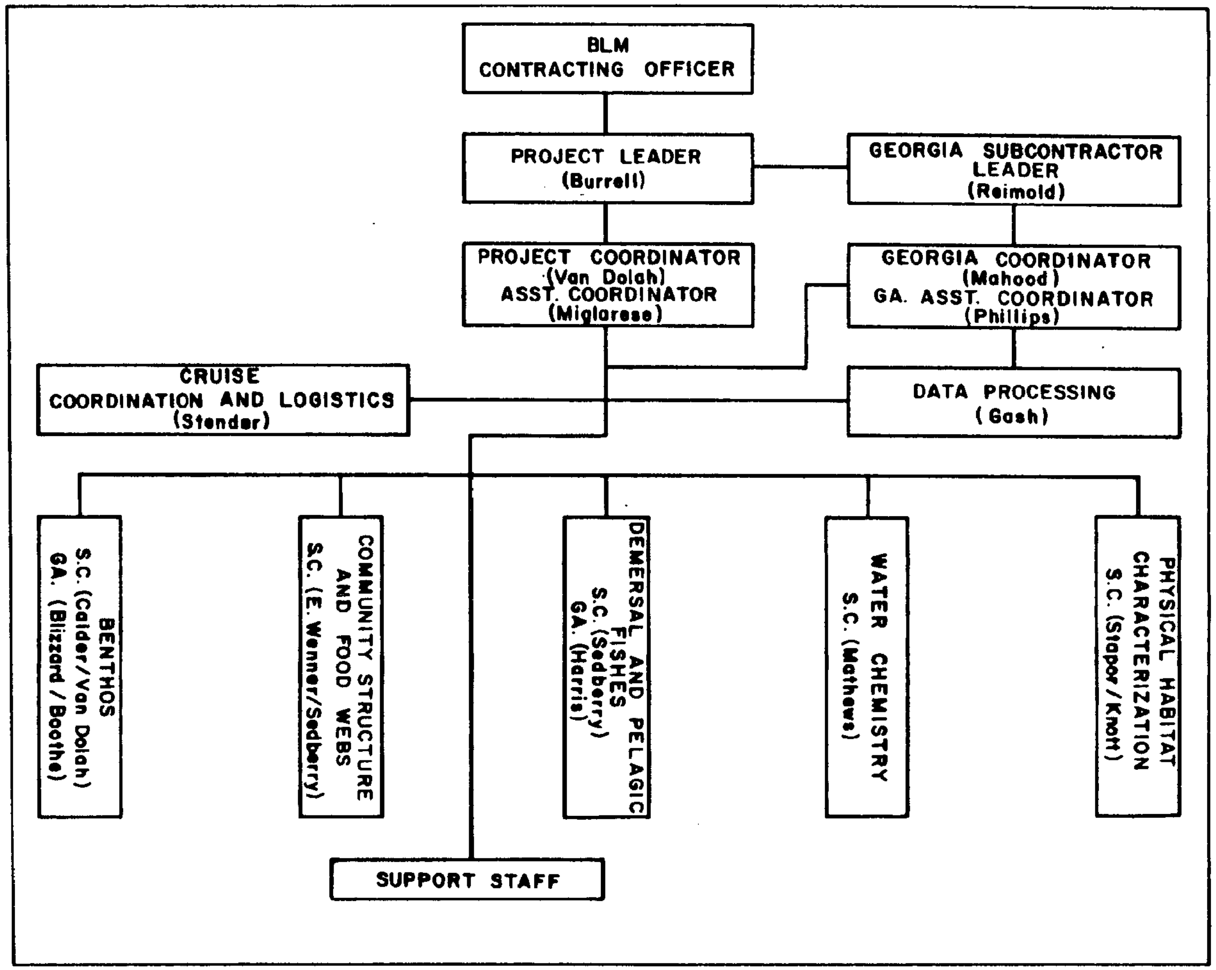


Figure 1.1. General project organization depicting the integrated management structure of South Carolina MRRI and Georgia CRD personnel.

according to contract requirements. R. K. Mahood acted as coordinator for Georgia personnel and was assisted by J. Phillips. Additional key personnel from GA CRD are also identified in Figure 1.1 as responsible for their respective work elements.

See the Acknowledgements section for a complete listing of all project participants and their areas of responsibility.

GENERAL OBJECTIVES AND SCOPE

The primary objective of this study was to characterize invertebrate and nektonic communities associated with representative live bottom habitats on the continental shelf off South Carolina, Georgia, and northern Florida. Factors which might influence community structure such as depth, season, latitude, and bottom relief, were considered in the selection of sites and sampling effort. Bathymetric zonation of communities was evaluated by selecting three sites in each of three different bathymetric zones (19 - 27 m, 28 - 55 m, and 56 - 100 m). The assessment of differences in community structure due to seasonal effects or latitudinal gradients was intended to be a limited effort. Sampling effort was restricted to two seasons (summer, winter) and study areas were confined between 30° and 32°N latitude. Characterization of bottom topography and substrate type was also intended to be a limited effort and sophisticated gears, such as side scan sonar, were not utilized. When possible, study areas within bathymetric zones were selected to provide a range of bottom relief for comparative purposes.

A second objective of this study was to evaluate the potential impacts, both detrimental and beneficial, of oil and gas related activities on live bottom communities. Since live bottom areas in the South Atlantic Bight have not yet been subjected to exploratory activities, this objective is limited to providing hypotheses on potential effects and baseline data on the live bottom communities which might be affected.

CHAPTER 2

SAMPLING APPROACH AND METHODS

INTRODUCTION

Information presented in this chapter is restricted to operations associated with field sampling efforts at the nine southern live bottom study sites. Pertinent data related to all field collections are listed in Appendices 1 and 2. Laboratory methodologies related to the various sampling activities are presented in subject chapters.

LOCATION OF STUDY AREAS

The live bottom sites selected for study (Figure 2.1, Table 2.1) were chosen utilizing information from several preceding research programs. These included the South Atlantic Hard Bottom Study and South Atlantic OCS Area Geology and Geohazards Studies funded by the Bureau of Land Management; the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program funded by the National Marine Fisheries Service; and unpublished data available to South Carolina MRRI and Georgia CRD scientists. Criteria used in selecting representative sites from the known live bottom areas included bathymetric zone, geographical (latitudinal) location, degree of bottom relief, and areal extent.

The three bathymetric zones considered in this study were inner shelf (IS) depths of 19 - 27 m, middle shelf (MS) depths of 28 - 55 m; and outer shelf (OS) depths of 56 - 100 m. Three sites were selected for study in each bathymetric zone (Figure 2.1).

Geographical boundaries for the nine southern sites were initially restricted to the shelf region between 30° and 32°N latitude since this area was of greatest interest to industry based on OCS sale 43. Suitable hard bottom areas in the 19 - 27 m bathymetric zone were not found within the original latitudinal boundaries and required extension of the northern boundary to 33°N latitude.

Within the bathymetric and geographic zones described above, sites were selected to include hard bottom areas with various degrees of rock relief ranging in height from no relief to greater than 2-m relief and ranging in extent of coverage from areas with few outcroppings to areas with a heavy incidence of outcroppings. Additionally, selected sites were restricted to hard bottom areas sufficiently large to ensure that all sampling could be conducted within the designated study area (generally greater than 1 km^2). Physical characteristics of each study site are presented in Chapter 4.

SAMPLING PERIODS

All sites were sampled during winter and summer to obtain information on broad seasonal differences in community structure. Winter samples were collected from 15 January to 26 March 1980, and summer samples were collected

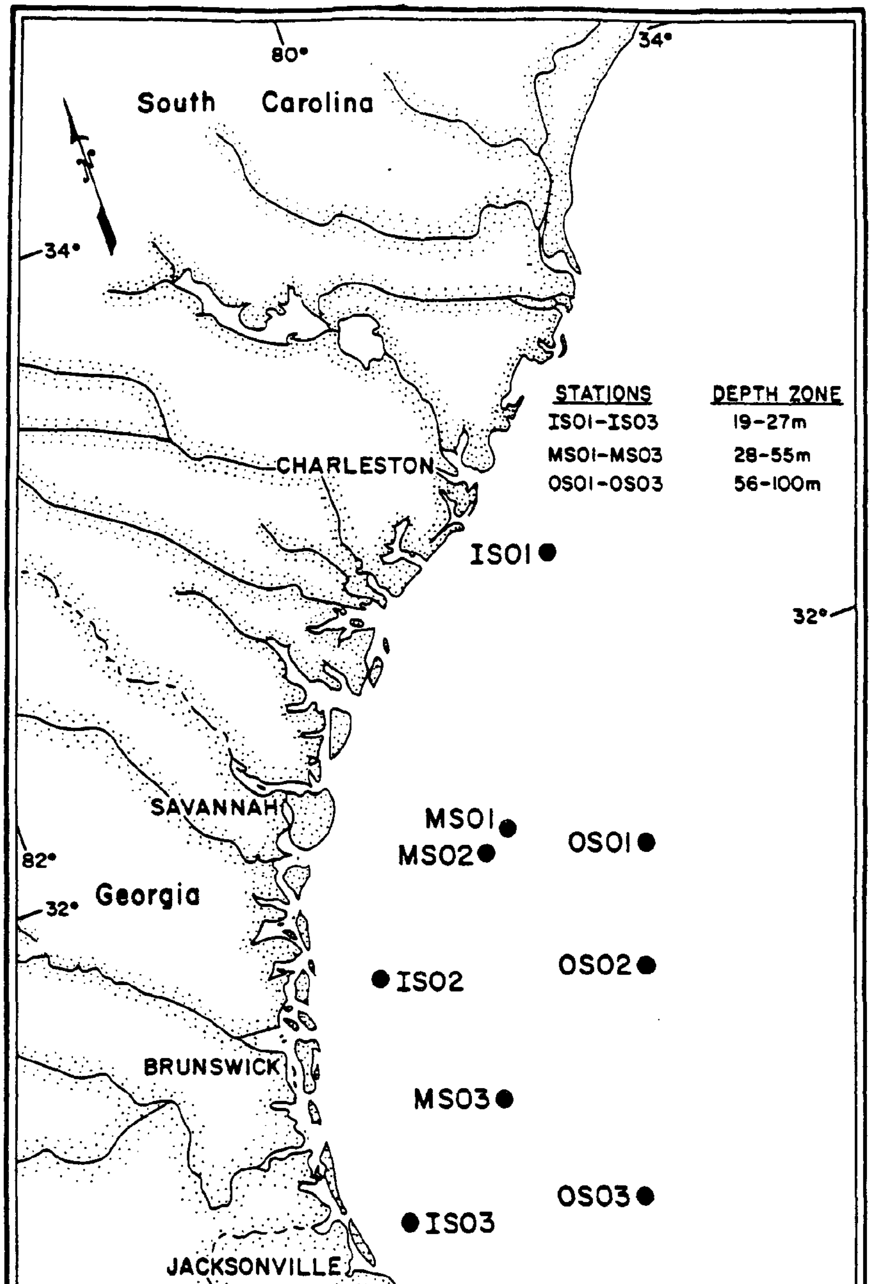


Figure 2.1. Location and depth zones of live bottom stations sampled during winter and summer, 1980.

Table 2.1. Location of the live bottom stations sampled in winter and summer, 1980.

Station	Latitude	Longitude	Lease Block No.
IS01	32°29.7'	79°42.5'	James Island - 446
IS02	31°23.6'	80°53.1'	Brunswick - 596
IS03	30°37.1'	81°10.6'	Jacksonville - 370
MS01	31°44.2'	80°13.4'	Brunswick - 256, 257
MS02	31°41.2'	80°20.9'	Brunswick - 298, 299
MS03	30°54.0'	80°36.3'	Jacksonville - 73
OS01	31°32.0'	79°44.3'	Hoyt Hills - 444, 445
OS02	31°08.1'	79°55.0'	Hoyt Hills - 837
OS03	30°25.7'	80°12.4'	Jacksonville - 565

from 4 August to 18 September 1980. Diver assessment of physical habitat characteristics was conducted only once at each sampling site. However, habitat characterization through television transect analysis included both sampling seasons.

SAMPLING METHODS

Research Vessels and Navigation:

Remote sampling at the study sites was completed using the 32.6-m R/V Dolphin, operated by the South Carolina Wildlife and Marine Resources Department. Diver sampling was conducted either from the 15.8-m R/V Bagby or the 19.8-m R/V Anna, both of which are operated by the Georgia Department of Natural Resources. All three research vessels were positioned at the study sites using Sitex Model Loran C units. These units provided an approximate repositioning accuracy of ± 30 m. To check that the Loran units were functioning properly, disposable pingers (Johnson Lab Inc.) were attached to concrete weights and dropped to the bottom near the center of the study sites. The pingers, operating at 62 KHz, were relocated using a portable hydrophone set (Johnson Lab Inc.) lowered over the side of the research vessel.

Hydrographic and Meteorological Methods:

Prior to any removal sampling, a Niskin bottle cast was conducted at each study site to obtain hydrographic profiles. Parameters measured at 10-m intervals from surface to bottom were temperature, salinity, dissolved oxygen, and water clarity. Temperature was measured with a certified bucket thermometer for surface samples and with reversing thermometers on Niskin bottles for samples taken at subsurface depths. Salinity samples were collected in 250-ml polyethylene bottles for subsequent analysis in the laboratory. Dissolved oxygen samples were collected in 250-ml polyseal bottles and chemically preserved according to the method of Strickland and Parsons (1972) for analysis in the laboratory. Additional dissolved oxygen measurements were collected at sea from each Niskin bottle using a Yellow Springs Instrument Model 51A oxygen meter and probe. Water clarity profiles were obtained using a Martek Model XMS transmissometer. Measurements from the transmissometer were noted at 10-m depth intervals and logged on data forms for later analysis. Niskin bottle and transmissometer casts were conducted once per site visit during each season.

Light penetration was measured once at each station during both seasonal visits with a Secchi disk. All lowerings were conducted at or near local noon.

Weather related observations recorded during sampling included cloud type and percent cover, precipitation, wind speed and direction, barometric pressure, air temperature, and sea state. These observations were generally recorded for each sampling activity and were helpful in assessing the affects of meteorological conditions on sample quality.

Physical Habitat Characterization:

Underwater Television Transects - Before removal sampling, all study sites were reconnoitered through television transect surveys. These surveys were designed to provide information on the physical characteristics of each study site as well as information on the distribution and occurrence of large macrofauna and flora. With respect to physical habitat characterization, television transects were conducted to (1) define boundaries of each study area based on bottom type, (2) evaluate the percentage of different bottom types within study areas, and (3) evaluate the incidence and relief of outcroppings.

Transects were conducted using a Hydro Products television system which consisted of a Model TC-125 SDA television camera, a Model C-105 cable assembly and a ship-mounted Model TP-110 camera power supply unit with remote focusing switch. For low light conditions, a Model LT-7 underwater light assembly and a Model LB-250 gas discharge lamp ballast were used with the camera. A Sony Model SLO-340 videotape recorder and a standard 48 cm (19") black and white television monitor were also connected to the Hydro Products system. A microphone connected to this system permitted simultaneous verbal recordings of Loran C position, time, collection number, and other information on the audio track. The television camera and light assembly were suspended from the research vessel in one of the two frames shown in Figure 2.2, dependent on reconnaissance activity. Generally, the smaller frame (Figure 2.2A) was used for initial reconnaissance activity while the larger frame (Figure 2.2B) was utilized during still camera transects.

Transects were completed while the vessel was underway (approximately 1.8 km hr^{-1}), or by drifting when conditions were favorable. In both situations, the camera frame was suspended approximately one metre above bottom. Reconnaissance transects were initiated considerably outside the proposed area for study. During each transect, bottom type was continuously observed on the television monitor, and was recorded every two minutes in data logs along with simultaneous Loran C bearings. Fathometer tracings were recorded throughout the transect. Together with Loran C positioning, this provided an accurate record of the path and depth profile for each transect. The videotape recorder was activated when an estimate of greater than five percent bottom cover of sessile fauna or rock was detected. Recording continued until six continuous minutes (minimum of 140 m) of sand with less than five percent bottom cover had been observed. Transect paths were selected to minimize overlap and provide adequate assessment of bottom types present. At least three transects were conducted through every study site each season. Analysis of videotapes and fathometer records is described in Chapter 4.

Still Camera Transects - Following television reconnaissance, additional characterization of bottom type and fauna was obtained using an Edgerton 35-mm photographic system. This system consisted of a Benthos Model 372 camera equipped with a Model 380-34 data chamber, a Model 383 high intensity flash unit, and a Model 3940 bottom contact switch for remote tripping. The camera system was suspended from the research vessel in a frame (Figure 2.2B) with the camera in a vertical position. A tripper weight, suspended from the contact switch mounted on the frame, activated the camera upon bottom contact and provided a known unit of measure in each photograph for laboratory analysis (Chapter 5).

Two series of at least 25 color photographs were taken at each study site: one series taken one metre above bottom and the other series taken three metres

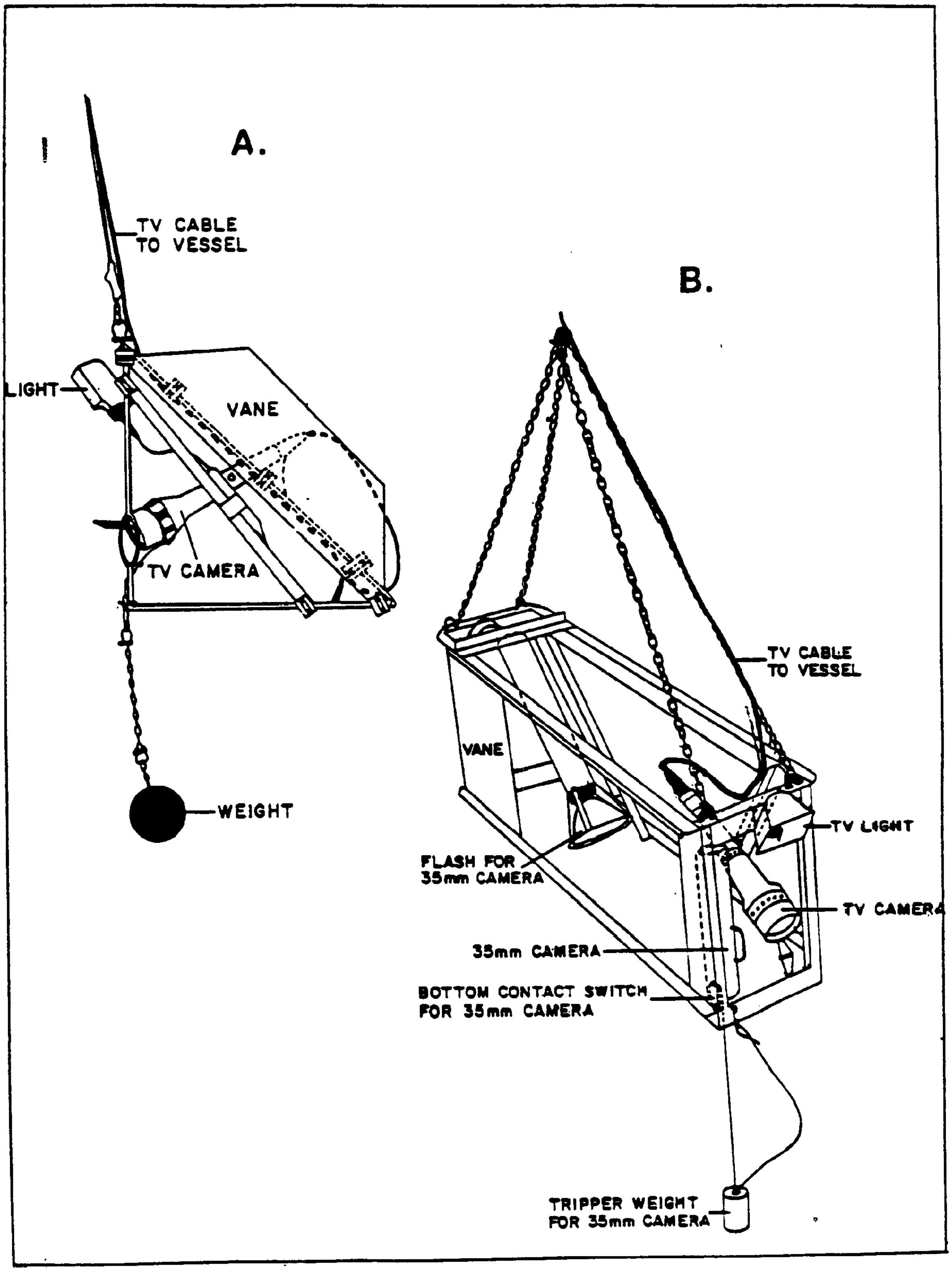


Figure 2.2. Schematic diagrams of two frames (A and B) used for television and still camera transects.

above bottom providing photographic records of 0.5-m^2 and 3.0-m^2 quadrats, respectively. The camera was tripped at constant time intervals along transects across study areas to avoid sampling bias with respect to bottom type and fauna. The television camera was also lowered during still photo transects to monitor bottom type and ensure that quadrats photographed were within study area boundaries as defined by television transect analysis. Although the photographs obtained from these transects were analyzed for bottom type, the primary intent of this effort was to obtain quantitative information on large macrofauna and flora as well as information on smaller biota not detected by television transects and not captured by removal sampling gears.

Diver Surveys - Physical characterization of the live bottom habitats in the 19 - 27 m and 28 - 55 m bathymetric zones was also accomplished by scuba diver surveys of the study sites. On each survey, the dive team located regions of lowest and highest relief and photographed each area utilizing ambient light and a Nikonos underwater camera loaded with black and white film (TRI-X, ASA 400). Scale was provided by using a 3-m aluminum rod or metre stick marked into 0.33 m and 0.50 m increments and held adjacent to the feature that was photographed.

Rock Samples - Attempts were made to collect rocks at all stations for thin section analysis. At stations IS01, IS02, MS02, MS03, and OS01, large rock fragments were obtained in dredge samples described below. Scuba divers collected rocks at stations IS03 and MS02, but no rocks were obtained from stations OS02 and OS03. All rocks were tagged for identification and brought to the laboratory.

Biological Community Characterization:

Trawl Sampling - Trawl sampling for fish consisted of standard tows with a 40/54 fly net. This net has the following overall dimensions: 12.2-m (40 ft) headrope, 16.5-m (54 ft) footrope, 12.8-m (42 ft) vertical height. The net is equipped with steel doors and rubber rollers and has the following stretch-mesh dimensions: 20.3 cm in the wings, 10.2 cm in the body, 4.1 cm in the codend, and 0.6 cm in the codend liner. Six replicate tows, three each day and night, were attempted at all low to moderate relief sites. Trawl tows were directed over live bottom areas as defined by underwater television. An attempt was made to standardize trawl samples by towing the net at 100 RPM (about 6.5 km hr^{-1}) for a distance of five Loran C microsecond units. This resulted in an average trawl distance of about one kilometre.

Upon retrieval, fishes collected in the trawl were sorted to species, counted, weighed, and measured. Large catches of abundant species were subsampled for length measurements and abundance estimates. Lengths, either fork length or total length when appropriate, were measured to the nearest centimetre. Fishes which could not be identified at sea, as well as representative voucher specimens of all fish species, were preserved in 10% seawater formalin. Subsamples of priority and dominant non-priority fish species were saved for stomach contents analysis. Fishes utilized for stomach analysis were individually measured and weighed. Lengths were measured to the nearest millimetre and weight was measured to the nearest gram using an Ohaus Dial-o-Gram balance. Each fish was then dissected and its stomach excised, if not conspicuously empty. Stomachs were individually labeled, wrapped in cheesecloth, and fixed in 10% seawater formalin.

Invertebrates captured by the trawl were sorted into major taxa, weighed, and representative specimens preserved for identification in the laboratory. Squid were counted, weighed, and measured (mantle length).

Baited Fishing Gear - In addition to trawling, baited fishing gears were deployed in an attempt to collect larger predatory fishes for food habits analysis. Baited fishing gears included Antillean S-traps (122 cm x 122 cm x 61 cm), vertical longlines (10 hooks each), and manual snapper reels. These gears were fished simultaneously in two sets at each station; one set at dawn and one at dusk. Each set consisted of two Antillean fish traps and four vertical longlines fished for about one hour, and three snapper reels fished for about 15 min. Additional rectangular Antillean traps (104 cm x 90 cm x 61 cm) were deployed at some stations during the summer in order to determine the most effective trap design.

Fishes captured by baited fishing gears were identified, measured, weighed, and subsampled for stomach analysis in the same manner as described for trawl collections.

Juvenile Fish Sled - Sampling for near bottom larval and juvenile fishes which were unavailable to other fishing gears was accomplished with a specially designed epibenthic fish sled. This sled has a mouth opening of 1 m^2, a 947-μ mesh bag attached to the rear of the sled, and runners which permit the sled to sample 5 cm off the bottom. Although the sled also has a mouth opening mechanism designed to fish only when in contact with the bottom, the door of this mechanism was locked in the open position during most sampling due to sled damage. Two 5-min tows were made per station at night to minimize visual net avoidance.

Television and Still Camera Transects - Transect surveys using the television and still camera surveys were utilized to obtain additional information on fish and invertebrates as noted previously. See previous sections in this chapter for details on field methodology and Chapter 5 for laboratory analysis methodology.

Diver Swimming Transects - To supplement information obtained through television and still camera transects, diver swimming transects were conducted during both winter and summer seasons at the inner and middle shelf stations. These transects were designed to provide estimates of fish populations and additional characterization of the invertebrate community utilizing still photography.

Transects across the dive sites were initiated by locating an area of dense live bottom or ledge and noting a compass reading. From this point, two divers swam side by side, one recording fish species and numbers; the other taking black and white photographs. The photographs were taken in the following manner: At the starting point, four photographs were obtained at 90^{o} angles from each other. The divers then swam 10 kicks along a course dictated by the compass reading, stopped and shot four more photographs in the same manner as before. This procedure was repeated either until the entire roll of film was exposed or until the transect line being followed led the divers off live bottom onto adjacent sand areas. Distances covered by the transects normally ranged between 25 m and 50 m. Random color photographs of representative fauna and flora were also taken along the transect line with a Nikonos 35-mm camera and strobe unit. Film obtained from the transects was placed in canisters, labeled, and later processed into prints or slides for analysis.

Dredge Sampling - In addition to the incidental catch of invertebrates in trawl nets, qualitative samples of macroinvertebrates and algae were collected in dredge tows at each station. Dredge tows are especially useful for documenting the presence of large organisms that are relatively rare; smaller organisms capable of escaping other sampling gears; and encrusting, colonial organisms whose presence is only detected when rocks are examined closely in the laboratory.

Two replicate dredge tows were made in each study area over live bottom, as determined by television reconnaissance. The length of each tow was standardized to approximately 0.1 km using Loran C positioning. This distance was sufficient to obtain an adequate representation of the biological community for comparisons between stations.

With the exception of summer collections at stations OS01 and OS02, all dredge tows were made with a heavy duty rock dredge (Kahlsico No. 215WA420). This dredge has a mouth opening of 60 cm x 37 cm and a collapsible metal ring bag with a minimum mesh opening of 37 mm x 25 mm. Moderate to high relief at offshore stations resulted in the loss of three rock dredges, in spite of the use of a weak link designed to prevent such loss. This resulted in a reevaluation of the requirements for this type of equipment, and led to the replacement of the rock dredge by a heavy duty Cerame-Vivas benthic dredge (mouth opening 90 cm x 37 cm; maximum mesh opening 40 mm x 30 mm).

Samples collected in the dredge were sorted on station to remove non-biological material and to subdivide the catch into its major taxonomic components. Dominant components were weighed separately on spring balances to determine their contribution to the total catch biomass. After the samples were weighed, representative specimens of each taxon collected were placed in labeled containers, preserved in 10% buffered seawater formalin, and brought to the laboratory for identification. Rocks collected in the dredge were also saved.

Suction Sampling - Quantitative suction samples of smaller benthic invertebrates, not adequately sampled by previously described gears, were obtained at inner and middle shelf sites by scuba divers. Using Loran C coordinates of known hard bottom, divers obtained five replicate samples at each station from a suitable area chosen to avoid large patches of sand commonly found at the sites. A disc with five equally spaced radial marks was dropped to the bottom and a 3-m line, fastened to the center of the disc, was then used to place five quadrat boxes (0.1 m^2, 10-cm walls, open on both ends) equidistant from the disc. Exact positioning of the quadrat boxes was accomplished by randomly selecting one of nine possible quadrat areas from a larger grid frame attached to the 3-m line. Fauna within the quadrat was sampled by scraping the area while simultaneously sucking with an airlift device similar to that described by Chess (1979). All suction samples were collected in 1.0-mm mesh bags and brought to the surface for preservation. On deck, each sample was narcotized with magnesium chloride and preserved in

10% seawater formalin. During the winter sampling period, one sample was lost from two stations (MS01, MS02) resulting in only four replicate samples for those stations.

Grab Sampling - At the outer shelf stations (OS01, OS02, and OS03) where water depth precluded the use of the suction device operated by divers, quantitative 0.1 m^2-samples were collected with a modified Smith-McIntyre grab (Kahlsico No. 214WA250). This sampler is a spring loaded grab that is triggered upon contact with the bottom, and has been found to be the most successful of its type for use in open sea conditions on compacted sediments or hard surfaces.

The grab was lowered over live bottom within the study area, as determined by previous television transect records and five replicate samples were obtained. In most instances, numerous attempts were necessary to obtain five adequate samples. This was usually due to failure of the tripping mechanism, or to improper closure of the grab when the jaws were held open by rock or shell fragments.

After retrieval, each sample was placed into a one millimetre sieve and washed to remove the finer sediment. Excess non-biological material was then removed, and the remaining contents were rinsed into labelled containers and preserved in 10% buffered seawater formalin.

CHAPTER 3

HYDROGRAPHY AND WEATHER OBSERVATIONS

INTRODUCTION

The hydrographical and meteorological portions of this study were complementary to the biological sampling, with the hydrographic sampling limited in scope. The primary intent of hydrographic sampling was to provide environmental data at the nine live bottom stations when biological samples were obtained, not to delineate conditions throughout the entire South Atlantic Bight.

Several references are available which contain detailed and comprehensive physical and chemical data for the South Atlantic Bight. Bumpus (1955) described circulation along the continental shelf, utilizing drift bottles. Rao et al. (1971) utilized satellite infrared imagery to locate Gulf Stream meanders and eddies. Mathews and Pashuk (1977) provided large amounts of chemical and physical data with some general current descriptions. Atkinson (1978) published the results of four cruises in the Georgia Bight with abundant physical and chemical data, including limited drift bottle results. Finally, extensive physical and chemical data are available through the South Atlantic OCS Physical Oceanography Study (Science Applications, Inc. 1981). The South Atlantic OCS Study provides good descriptions of large scale current patterns.

Studies off the North Carolina coast that provide similar information on currents as well as physical and chemical parameters include Wells and Gray (1960), Gray and Cerame-Vivas (1963), Stefansson et al. (1971), Blanton (1971) and Schumacher and Korgen (1976).

LABORATORY METHODS

Salinity and dissolved oxygen (DO) samples were returned to the MRRI chemistry laboratory for analysis. Salinity samples were analyzed on a Beckman RS-7B induction salinometer. DO samples were treated with H_2SO_4 and titrated with $Na_2S_2O_3$ in the standard Winkler-Carpenter iodometric method (Strickland and Parsons 1972). Salinity, dissolved oxygen, transmissometry, and temperature data were tabulated for further analysis and interpretation.

RESULTS

Water Temperature:

In general, the winter water temperature followed regular trends, i.e., colder water inshore of the Gulf Stream and limited stratification except at offshore stations (Figure 3.1, Appendix 3). Inshore stations were distinctly colder than those offshore, e.g. 12.28°C (surface) at IS02 vs. 19.95°C (surface) at OS02, and 14.07°C (surface) at IS03 vs. 21.54°C (surface) at OS03 (Figure 3.1). Weak stratification was observed at several stations, with the strongest

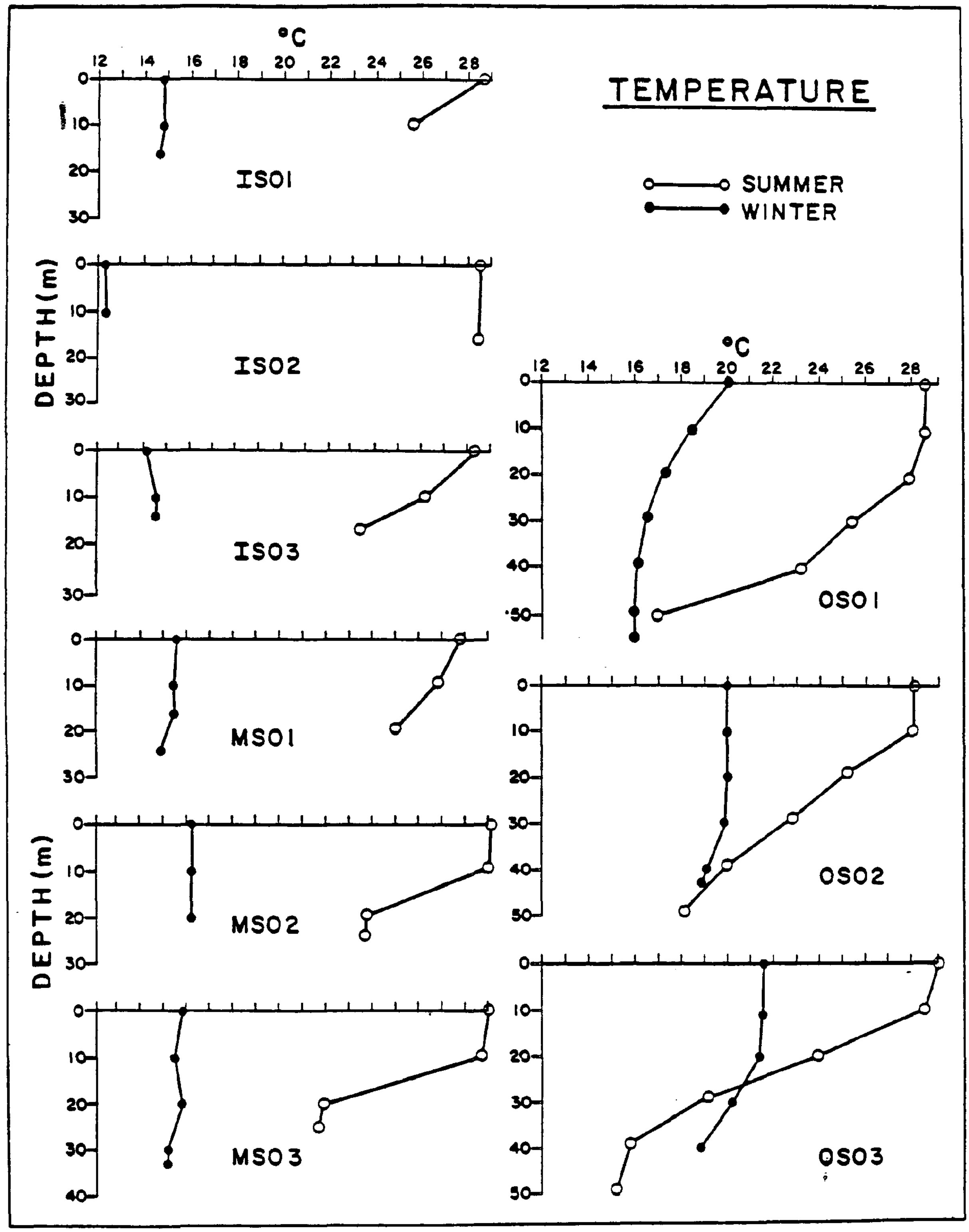


Figure 3.1. Vertical profiles of water temperature (°C) at live bottom stations during winter and summer, 1980.

vertical temperature gradient present at OS01 (0.08°C m^{-1}). At two stations, surface waters were colder than subsurface waters at 10 m. Temperatures at IS03 on the surface and at 10 m were 14.07°C and 14.46°C, respectively, while at OS03 water temperature was 21.54°C at the surface and 21.63°C at 10 m.

Summer water temperatures indicated highly stratified conditions with well defined thermoclines at most stations, e.g., vertical temperature gradients were 0.31°C m^{-1} at IS01, 0.23°C m^{-1} at OS01, and 0.30°C m^{-1} at MS03. Little stratification was evident at IS02, where temperatures ranged from 28.49°C on the surface to 28.40°C at 14 m (Figure 3.1). Differences in summer inshore and offshore temperatures were relatively small, especially when compared to winter temperature variations. All surface water temperatures were in the range of about 27.8° - 29.2°C.

Salinity:

Winter salinities were > 36.0 °/oo, regardless of depth, at all stations except IS02, IS03, and MS03 (Figures 3.2 - 3.4, Appendix 4). The lower salinity water at these three stations may be a reflection of runoff from the Savannah, Altamaha, and other Georgia rivers (see Figure 3.2). Most stations had very low vertical salinity gradients, with typical values being < 0.006 °/oo m^{-1}. The maximum salinity at most stations occurred below the surface (Figures 3.2 - 3.4).

Summer salinities were generally high with no values < 35.0 °/oo. Vertical salinity gradients were relatively low, e.g., 0.047 °/oo m^{-1} (OS03), but somewhat greater than winter values. As in the case of winter salinities, maxima at most stations occurred below the surface (Figures 3.2 - 3.4).

Dissolved Oxygen:

This contract required that all DO concentrations measured by the oxygen meter at sea be confirmed by chemical laboratory analyses. However, due to the time lag between the collection and analysis of DO samples, the titration data proved unreliable. Consequently, DO measurements presented in this chapter represent values obtained with the DO meter.

Winter dissolved oxygen concentrations were all > 4.7 ml l^{-1}, with the majority being > 5.0 ml l^{-1} (Figures 3.2 - 3.4, Appendix 5). Only stations OS02 and OS03 had dissolved oxygen concentrations < 5.0 ml l^{-1} ($\geq$ 40 m depth) (Figure 3.4). The maximum concentration of 6.73 ml l^{-1} occurred at IS02 (surface), which had the coldest water temperature and next to the lowest salinity of any of the winter stations (Figure 3.2). Oxygen maxima occurred at the surface at five stations during the winter cruise, possibly due to wind mixing.

Summer dissolved oxygen concentrations were somewhat lower than winter values due to higher water temperatures, biological activity, and stratification, i.e., little wind mixing. Most concentrations were > 4.0 ml l^{-1}, with only four samples being < 4.0 ml l^{-1} at or near the bottom (Figures 3.2 - 3.4). Few concentrations exceeded 5.0 ml l^{-1}, and these were subsurface measurements in each instance.

Oxygen saturation ranged from 89% - 112% during the winter and 66% - 106% during the summer. Generally, percent saturation was higher on the surface than near the bottom. During the summer cruise the surface saturation was up

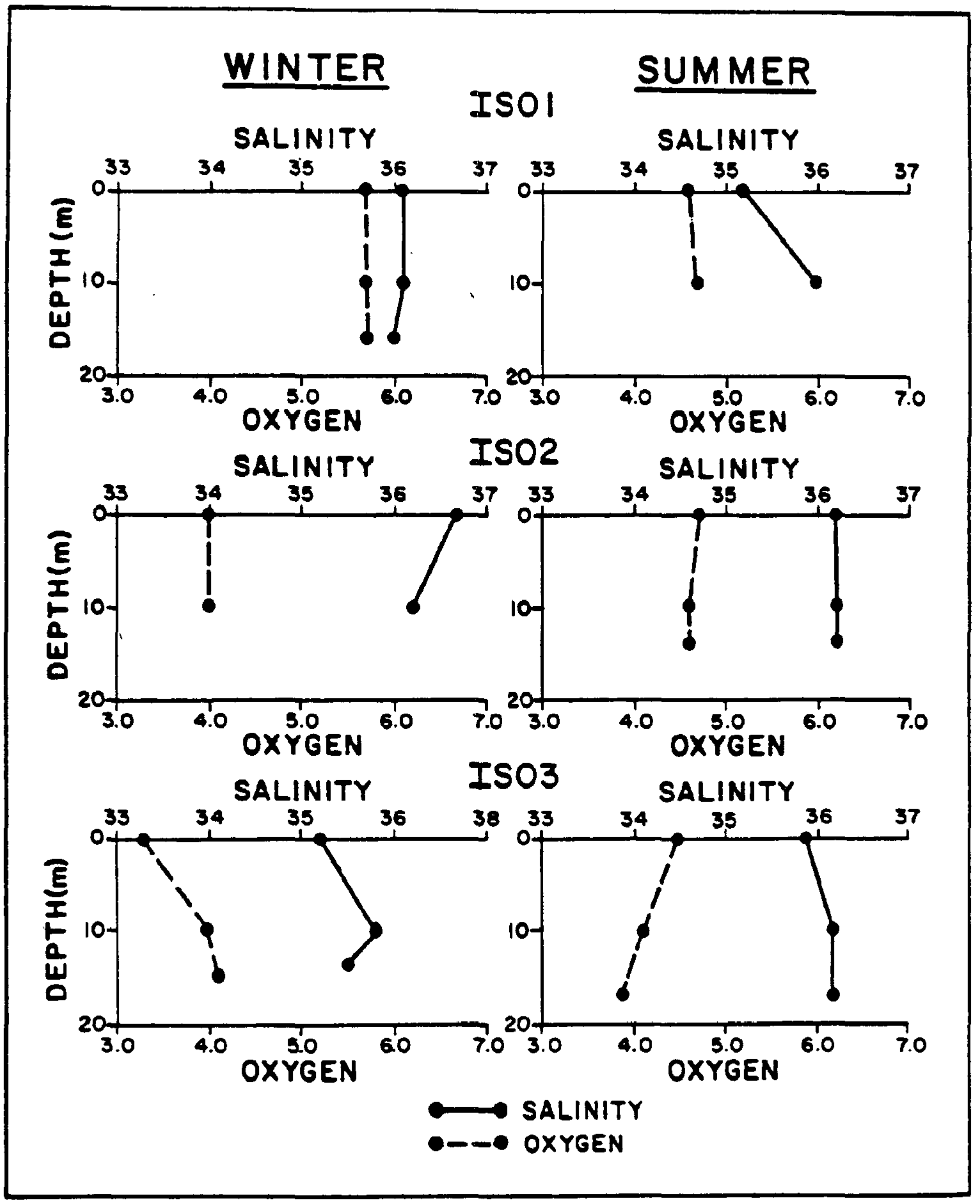


Figure 3.2. Vertical profiles of salinity ($^{o}/oo$) and dissolved oxygen ($ml\ l^{-1}$) at inner shelf stations during winter and summer, 1980.

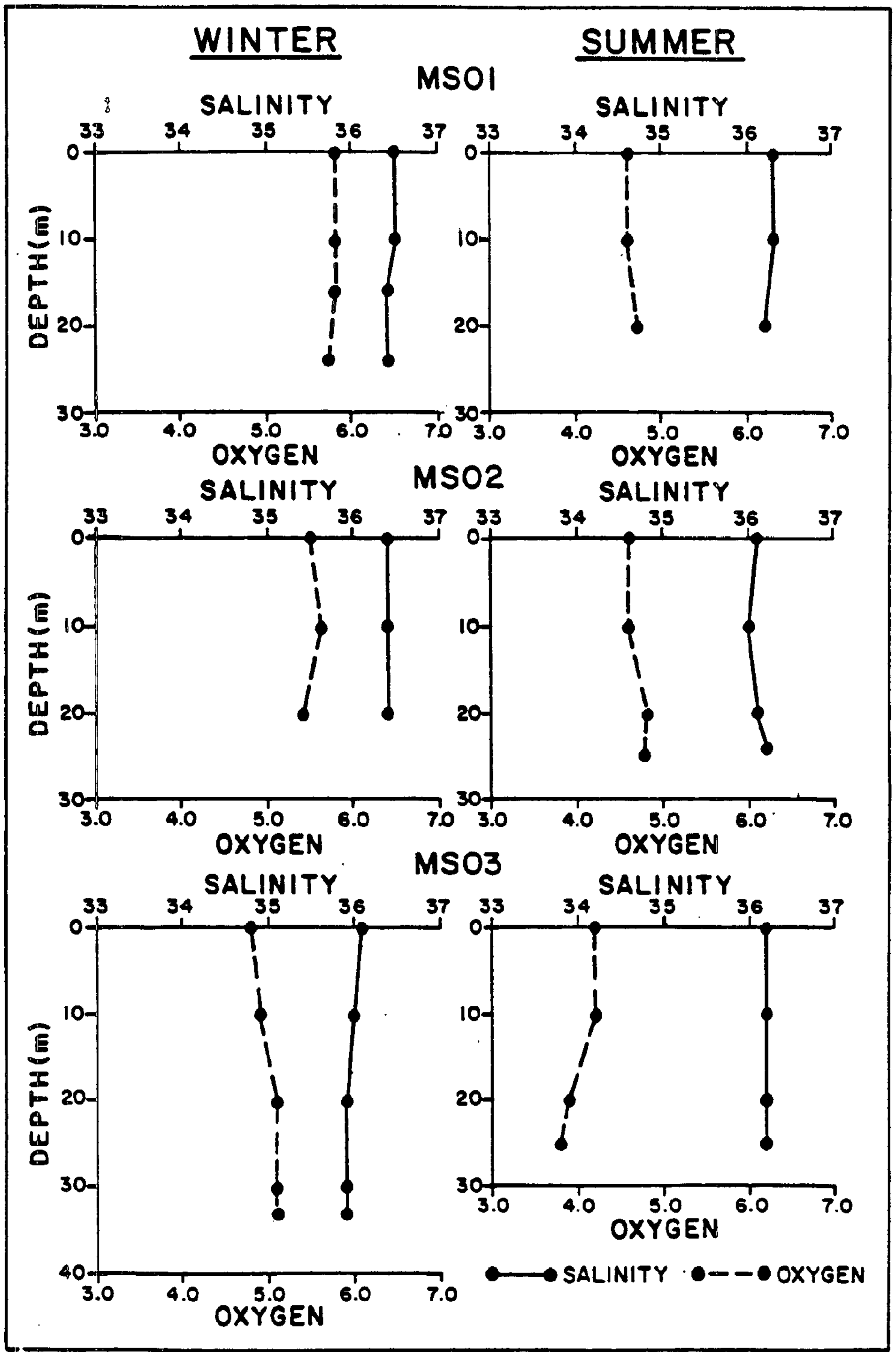


Figure 3.3. Vertical profiles of salinity ($^{o}/oo$) and dissolved oxygen (ml l^{-1}) at middle shelf stations during winter and summer, 1980.

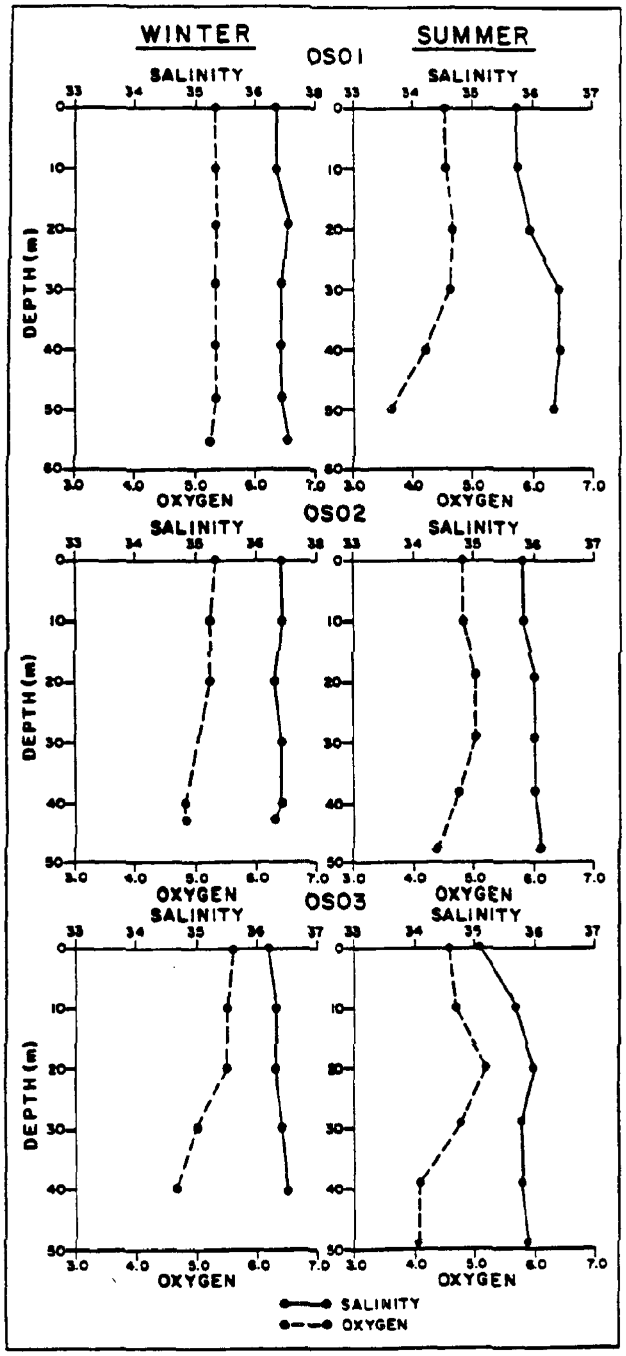


Figure 3.4. Vertical profiles of salinity ($^{0}/oo$) and dissolved oxygen (ml l^{-1}) at outer shelf stations during winter and summer, 1980.

to 35% higher than bottom saturation, primarily at the outer shelf stations. The winter surface saturation was not always greater than bottom saturation and was not more than 22% higher in any case. Both summer and winter oxygen saturations illustrate stratified versus well-mixed conditions. There were, however, no obvious relationships between percent saturation and station location. Representative values are reported in Appendix 5.

Light Transmission:

Light transmission was generally less variable with depth during winter than summer; however, the overall percent transmission was not significantly different for the two seasons, despite some seasonal variations at individual stations (Figure 3.5).

Light transmission was greatest below the surface at six winter stations and five summer stations (Figure 3.5, Appendix 6). The maximum was always found either at the surface or at the greatest sampling depth. The minimum, on the other hand, was at intermediate depths at three winter stations and four summer stations.

Finally, the time of day appeared to have little effect on percent transmission. Daytime measurements were comparable for both the winter and summer cruises.

Light Penetration:

Despite the inaccuracy of Secchi disc measurements, some general trends were detected. Light penetration was greater during summer than during winter, due perhaps to calmer, more highly stratified conditions prevalent during the warm summer months (Appendix 6). Light penetration did not reflect any patterns with respect to depth during either season (Appendix 6).

Meteorological Observations:

The results of meteorological observations are presented in Appendices 1 and 2. Predictably, air temperatures were lower and wind velocities were higher in winter than in summer. However, the short term effects of variations in air temperature, wind velocity and barometric pressure were too subtle to detect in our water column data.

DISCUSSION

Overall, the hydrographic data generated by this study indicate conditions typical of the South Atlantic Bight. Nearshore waters had larger ranges of temperature and salinity than offshore waters, corresponding to seasonal or long term meteorological influences. The offshore stations (OS01, OS02, and OS03) had consistently warmer surface waters (up to $8^{o}C$ in winter) than inshore stations (IS01, IS02, and IS03) (Appendices 3 and 4). While salinity was generally $\geq$ 35.00 $^{o}/oo$, the winter salinities at IS02, IS03, and MS03 were as low as 33.29 $^{o}/oo$, probably due to river runoff. Low salinities in the same area have also been observed by Mathews and Pashuk (1977), Atkinson (1978), and Science Applications, Inc. (1981).

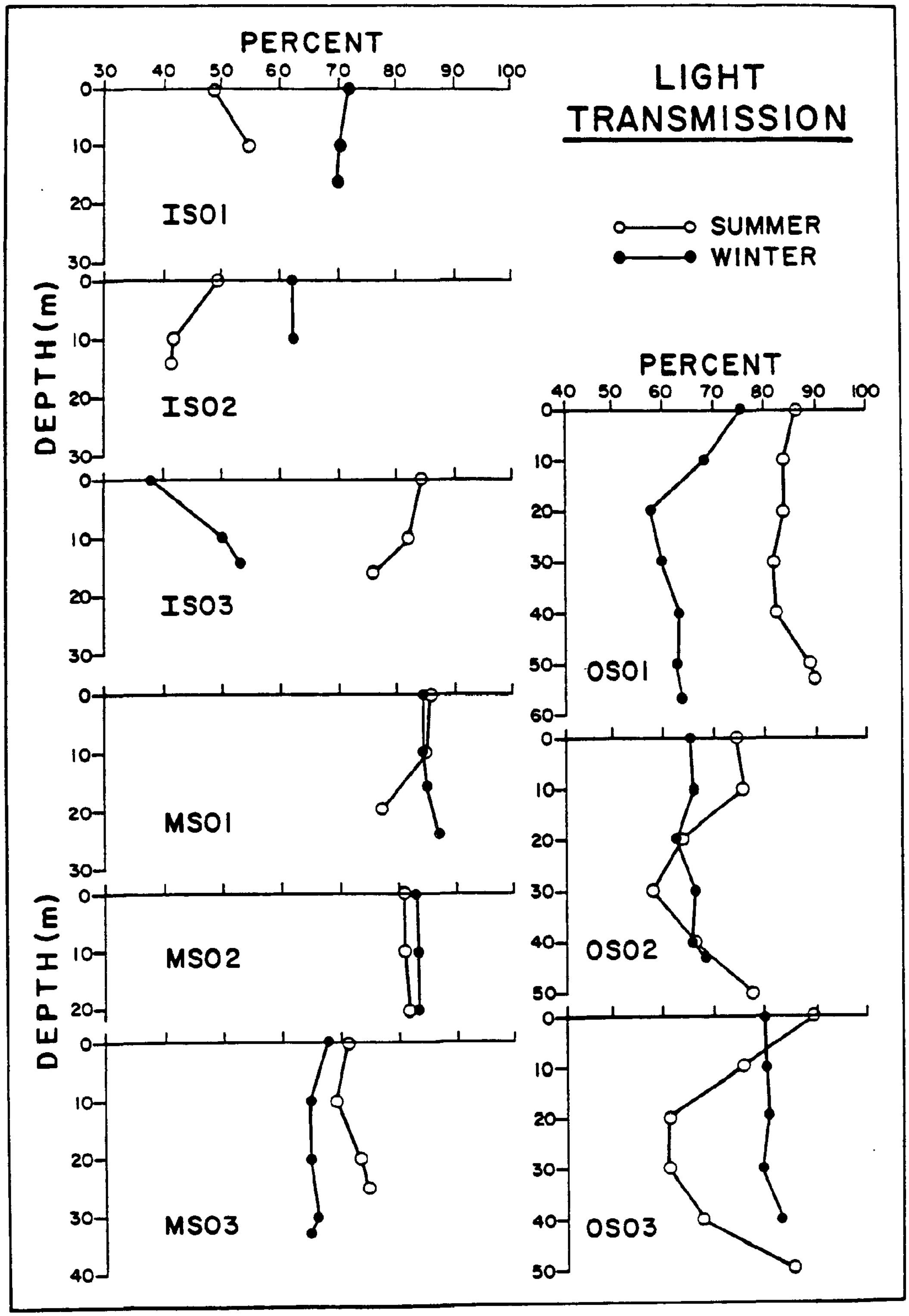


Figure 3.5. Vertical profiles of light transmission at live bottom stations during winter and summer, 1980.

Dissolved oxygen concentrations were, for the most part, near saturation, with some stations having supersaturated concentrations (Appendix 5). The DO concentrations are indicative of conditions commonly found along the shelf, i.e., highly oxygenated waters, unstressed by a high biochemical oxygen demand (BOD) associated with decaying organic matter or some chemical pollutants. Mathews and Pashuk (1977) and Atkinson (1978) recorded DO concentrations in the same range as those reported in this study for the same geographical area. It is not unusual for DO concentrations at the surface or in shallow waters to be affected by localized meteorological influences, such as high winds with concommitant wave action resulting in increased wind mixing of oxygen.

Despite the inherent difficulties in interpreting the transmissometry data, some general relationships are evident. Since the transmissometer has a built-in light source, it measures light transmission through a given path length and not light penetration from the surface. Hence, percent transmission should be independent of depth and time of day, but not of solids, phytoplankters, and other light scattering constituents. Our data, in fact, support these premises since there is no apparent relationship between depth or time of day and percent transmission. Transmission may be reduced by the suspension of bottom sediments due to wind induced turbulence, but this is not supported by our data.

IMPACT/ENHANCEMENT

Due to the limited scope of this study, it is not possible to accurately predict the impacts of drilling for oil or gas relative to hydrography. Some possible effects on the parameters measured, however, include reduced light transmission and DO concentrations due to the suspension of anoxic bottom sediments. Presumably, these effects would be localized or short term due to the relatively strong currents along the coast (Bumpus 1955, Mathews and Pashuk 1977). Additional impacts are difficult to predict, based on our present data base.

CONCLUSIONS

- Overall, the values of hydrographic parameters measured at the live bottom sites during this study were typical of the South Atlantic Bight.

- Salinities were uniformly high ($\geq$ 35.00 ^{o}/oo) at all depths and at all stations except for IS02, IS03, and MS03, which were probably influenced by increased river runoff during winter.

- Temperatures varied predictably, with inner shelf waters exhibiting a wider range than outer shelf waters. A low of 12.28°C was recorded at IS02 during January 1980, while a high of 29.22°C was recorded during August 1980 at OS03.

- Dissolved oxygen concentrations were generally high at all station and depths, ranging from 3.63 ml l^{-1} to 6.73 ml l^{-1} and 66% to 112% saturation.

- Light transmission ranged from 38% to 90% transmission. Secchi disc readings varied from 6.0 m to 31.0 m.

CHAPTER 4

PHYSICAL HABITAT CHARACTERIZATION

INTRODUCTION

Recent oil lease activity in the Georgia Bight has been accompanied by extensive topographical and geological surveys. A variety of geophysical equipment, including precision depth recorders, side scan sonar devices, and subbottom profilers have been used to conduct these investigations (U. S. Geological Survey 1979). These surveys have provided information on the occurrence of potential geological hazards associated with petroleum development, textural characteristics of the bottom sediments, and topographic features of selected areas on the continental shelf. They have also led to the identification of shallow subsurface reflectors (hard bottom) which may or may not be indicative of live bottom. Because hard grounds such as these are often covered by a layer of sand which may prevent accumulation of sessile epifauna, it is often necessary to employ means of detecting live bottom other than geophysical surveys such as those previously described.

A recent report to the Bureau of Land Management (Continental Shelf Associates 1979) has demonstrated the importance of using underwater television to make visual observations of geophysically detected hard bottom. This gear is useful for delineating the discontinuous nature of emergent hard bottom areas and characterizing the types of biological assemblages associated with them. Underwater television also has been used along with side scan sonar to classify the morphology of reefs and hard grounds and to describe the distribution of hard bottom areas in a survey of the Georgia Bight (Henry and Giles 1979, Henry et al. 1980). In addition, this gear has been used to estimate the amount of reef habitat on the continental shelf of the South Atlantic and Gulf of Mexico (Parker et al. in preparation).

Although the primary focus of the present study was on the living resources of live bottom habitats, it was also necessary to describe the physical characteristics of the study sites. These descriptions were based on information obtained through television and still camera transects, fathometer tracings, diver observations, and analysis of rock samples. Underwater television transects were intended to define approximate boundaries of the selected areas, location and extent of outcroppings, and together with still photograph analysis, to provide an estimate of percent cover of sand versus live bottom within the boundaries of the study area. The fathometer was utilized to define the depth range within the study area, and diver observations and rock samples were utilized to assess the degree of habitat complexity and the geological nature of outcroppings.

METHODS OF LABORATORY ANALYSIS

Television Transects:

Television transect videotapes were reviewed in the laboratory to eliminate those which were unsuitable for analysis due to poor visibility. Duration of tape segments to be analyzed was also noted. Analysis of tape segments commenced either at the beginning of the videotape recording for a particular transect or at the Loran C position (recorded on tape) closest to the first evidence of live bottom (> 5% bottom cover of rock or sessile fauna). Analysis ended at the Loran C position immediately following last evidence of live bottom (< 5% bottom cover) or when the videotape recorder was turned off. Absence of live bottom for three consecutive Loran C readings (6 min, minimum of 140 m) was the criterion used for last evidence of live bottom. However, shorter gaps of sand between patches of live bottom were included in the analysis when they occurred.

Attempts were made to select three transects from each study area to provide a total of 60 min of analysis per study area per season. When transects were longer than 20 min, only 20 min were selected for analysis. If transects were shorter than 20 min, more than three transects were analyzed. For most stations, three or more transects were randomly selected from a larger number available for analysis.

Bottom type at each study area was assessed by noting presence or absence of live/hard bottom during 10-sec intervals along the entire length of each transect. Since speed was usually constant during a transect, these time intervals divided each transect into numerous, short, and approximately equal distance intervals. A mean proportional estimate of bottom type was obtained for every study area by determining the number of intervals with different bottom types noted on the transects. The three categories of bottom type that were analyzed included thin sand with hard bottom fauna present, rock outcroppings, and sand with no evidence of hard bottom fauna present. During assessment of bottom type, only the lower middle third of the television monitor was viewed. This restriction reduced variability caused by poor visibility and fluctuations in the distance of the camera above bottom.

Fathometer Readings:

Fathometer tracings obtained during television transects were examined in the laboratory to determine depth extremes within study areas. Minimum and maximum depths were measured on each tracing and tabulated.

Still Camera Transects:

Ektachrome film (ASA 160) exposed during one- and three-metre photographic transects was processed, mounted in slide frames and labelled with collection numbers, slide number, date, and time of exposure. All slides were reviewed to determine suitability for analysis. Slides eliminated from further analysis included: (1) photographs taken prior to the first or following the last evidence of live bottom, (2) photographs in which the bottom or the tripper weight was not visible, and (3) photographs taken unintentionally by inadvertent bouncing of the tripper weight. All remaining photographs collected at a study area were sequentially numbered, and 25 slides from each transect series (1 m and 3 m) were randomly selected for analysis. During quadrat analysis of macrofauna (described in Chapter 5) the bottom type observed in each slide was noted and tabulated.

Rock Analysis:

Rocks were obtained from all study areas except OS02 and OS03, where repeated dredge tows failed to retrieve rocks of sufficient size for analysis.

Rocks collected by divers and dredge tows were brought to the laboratory and subjectively examined to determine degree of rugosity and cribriformity. Sessile fauna having calcareous components were also identified because they contributed heavily to rock surface texture. Rocks were then broken apart to obtain non-eroded pieces for thin section analysis. All thin sections were stained to differentiate calcite and dolomite. Constituents forming each rock specimen were identified through binocular analyses of thin sections. The proportional contribution of each rock constituent was estimated using standardized visual estimate charts (Terry and Chilingar 1955).

RESULTS

Description of the Study Sites:

Observations recorded during videotape interpretation, along with notes made by scuba divers at the inner and middle shelf stations, are summarized in the following site descriptions. The terminology used in describing various degrees of rock relief conforms to the categories defined by Henry and Giles (1979): (1) low relief is less than 0.5 m, (2) moderate relief ranges from 0.5 m to 2 m, and (3) high relief (shelf edge) is greater than 2 m. Maps that accompany these descriptions were compiled using Loran C position plots for television transects and logs maintained during videotaping and subsequent videotape analysis. The boundary shown on each map was determined by connecting the points which designate the approximate location of the first or last evidence of live bottom on the most peripheral television transects. Thus, all or only a portion of a given transect may fall within the boundary of a study area as defined above. The areal extent of each study site was approximated by geometrically determining the area within the boundary, using the scale which accompanies each map.

Inner Shelf Stations - Station IS01 was an extensive 4.5-km^2 area situated approximately 31 km southeast of Charleston, South Carolina in James Island Lease Block 446. Fathometer recordings made during television transects indicated that water depths at this location ranged from 16.5 m to 18.3 m (Table 4.1). This station was characterized by a moderately heavy growth of sessile invertebrates distributed somewhat uniformly over a broad expanse of hardpan overlaid by a thin layer of sand (4 - 8 cm). Bottom topography was rather smooth, with little relief and only occasional cracks or depressions in the substratum. Other than a few small ledges (< 0.5 m), no significant rock outcroppings were observed on videotapes from this station (Figure 4.1).

Station IS02 was a smaller area of dense live bottom, measuring approximately 1.4 km^2 in size. This study site was only one reef patch within the much larger Gray's Reef area described by Hunt (1974). This station was located approximately 32 km due east of Sapelo Island, Georgia, in Brunswick Lease Block 596, where water depths ranged from 16.5 m to 21.5 m (Table 4.1). Bottom topography consisted of numerous rock ledges (Figure 4.2) up to one metre in height, which were covered with a heavy growth of encrusting and sessile invertebrates. The ledges were comparable to those described by Hunt (1974) and were distributed throughout areas of sand which supported thick epifaunal growth, particularly adjacent to the ledges. The density of growth decreased with distance from the ledges, and graded into the sparser growth typical of hardpan areas. Also observed were occasional patches of pure sand that supported no apparent growth, presumably because accumulation of sand was too thick to allow attachment of epifauna to subsurface rock.

Table 4.1. Depths recorded by fathometer during television transects. Mean values represent the average of minimum (or maximum) depths from all transects conducted at each station during both sampling periods.

Station	No. of Transects	Mean Minimum Depth (m)	Mean Maximum Depth (m)	Depth Extremes (m)
IS01	5	17.1	17.5	16.5-18.3
IS02	5	17.0	19.6	16.5-21.5
IS03	4	20.6	21.5	20.1-22.0
MS01	9	30.9	33.0	24.7-34.8
MS02	6	26.2	28.6	23.3-29.3
MS03	2	33.8	36.8	33.8-37.5
OS01	3	59.4	66.2	58.5-66.8
OS02	8	48.9	54.3	46.6-57.6
OS03	2	54.0	61.5	54.0-63.1

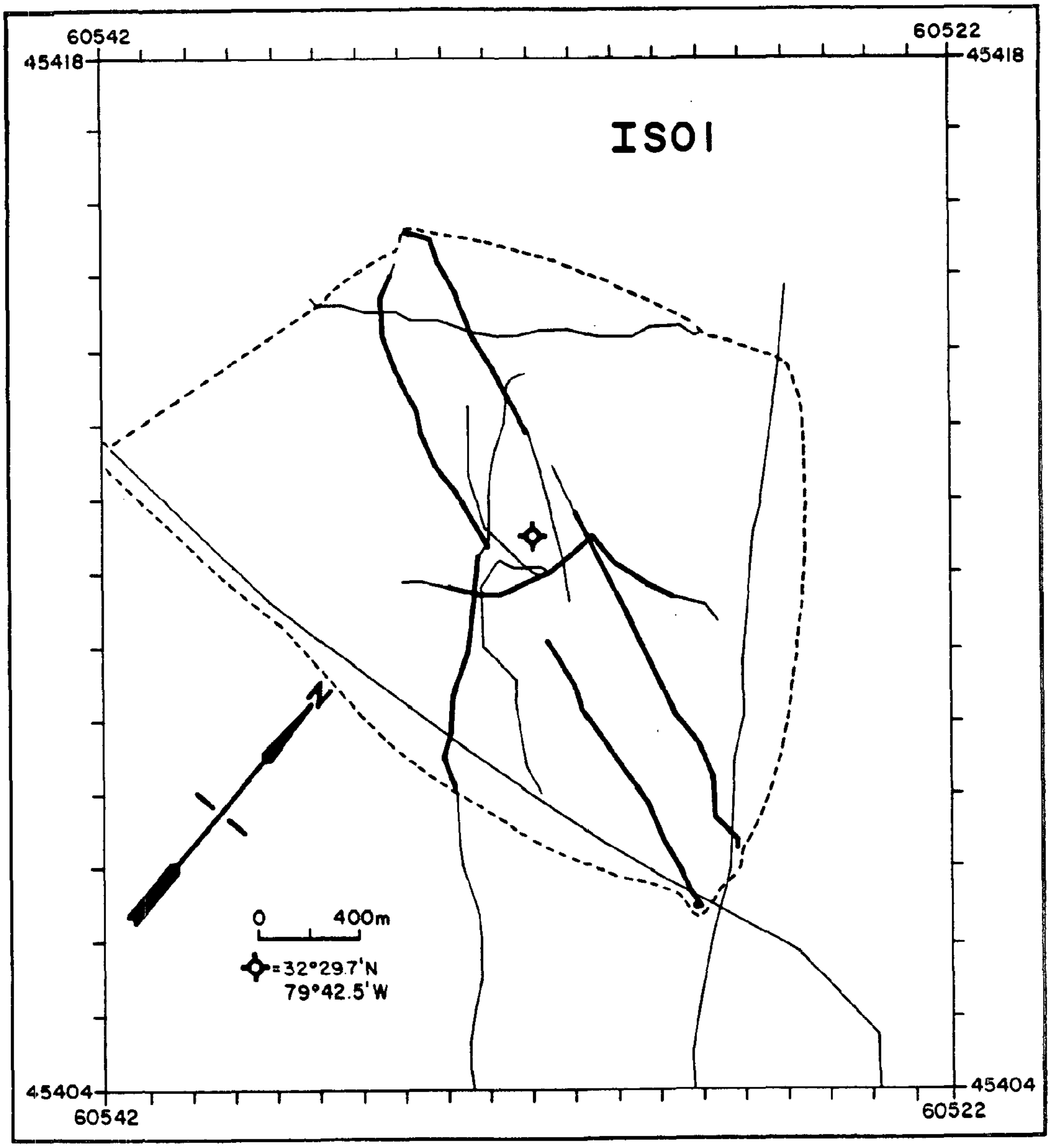


Figure 4.1. Location of television transects at Station IS01. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dot (southeast corner of study area) shows location of rock outcropping on analyzed portions. Corner coordinates are Loran C units.

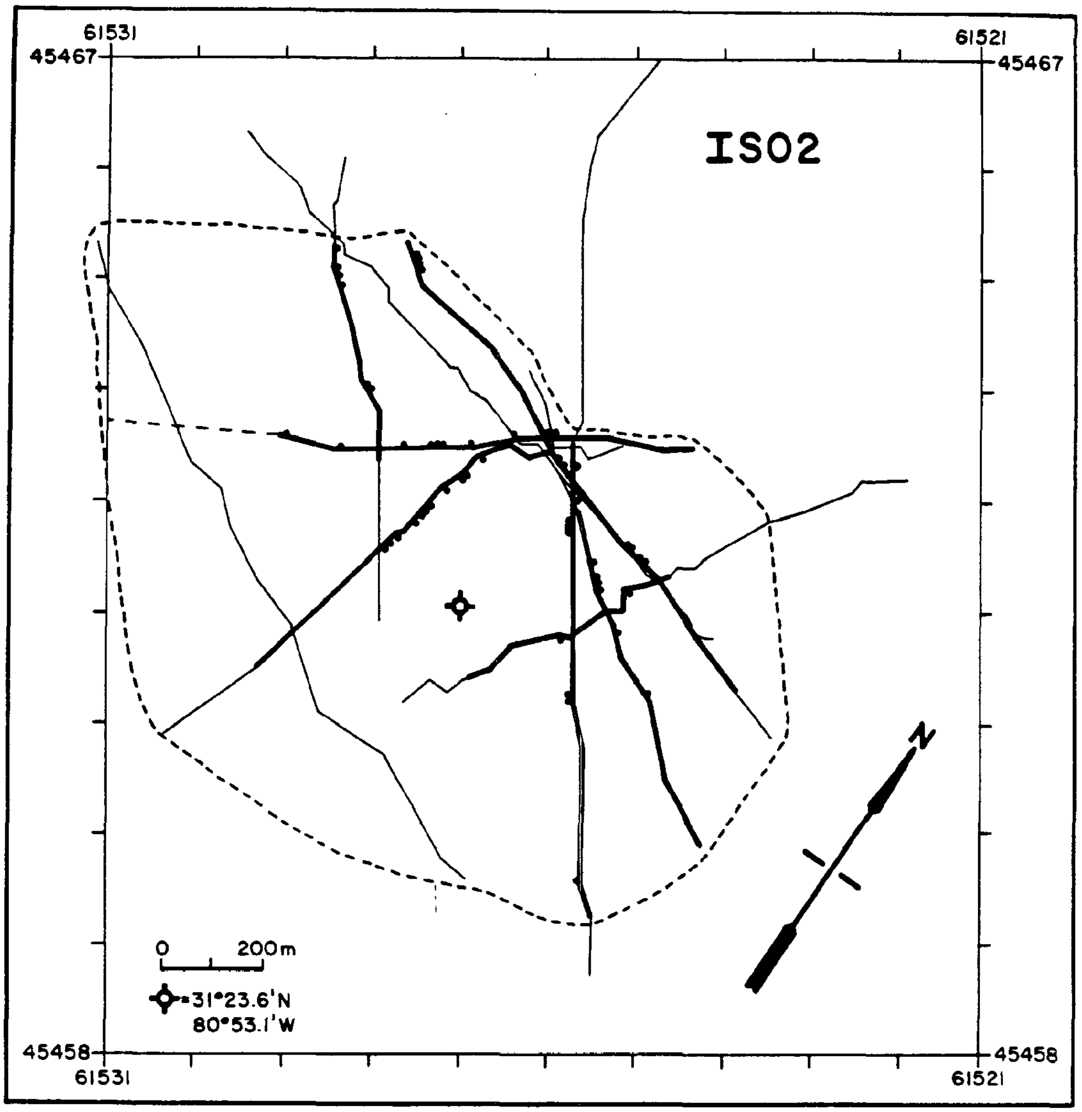


Figure 4.2. Location of television transects at Station IS02. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

Station IS03 was located 30 km east of Amelia Island, Florida in Jacksonville Lease Block 370. Water depths at this site varied from 20.1 m to 22.0 m (Table 4.1), and the areal extent (1.6 km^2) was roughly equivalent to that of IS02. IS03 was an area of patchy live bottom with low relief. The topography of the bottom was quite similar to IS02, although ledges were less frequent (Figure 4.3) and lower than those at IS02. Epifaunal growth, particularly sponges and octocorals, was sometimes heavy and often occurred in areas of hard bottom covered by sand as well as on exposed rock. A larger amount of bare sand was observed at this site than at other inner shelf stations.

<u>Middle Shelf Stations</u> - Station MS01 was a small area (0.6 km^2) located 67 km east-southeast of Savannah, Georgia, on the border of Brunswick Lease Blocks 256 and 257. Water depths at this station ranged from 24.7 m to 34.8 m (Table 4.1). Extensive areas of rock outcroppings, as well as hardpan covered by coarse sand, were observed at this site (Figure 4.4). The outcroppings were of moderate relief, approximately one-half to one metre in height. Bottom topography was similar to IS02, with ledges appearing as linear features that occasionally intersected one another, but which were otherwise separated by areas of sand of varying thickness. Much of the sandy area had no epifaunal growth. Conversely, areas of moderate relief were typically covered by a very heavy growth, particularly sponges and octocorals, while epifaunal growth on low relief hardpan was usually sparse.

Station MS02 was situated 63 km southeast of Savannah, Georgia, and 13 km southwest of MS01. In addition to their proximity, MS01 and MS02 were roughly equivalent in size, being about 0.6 km^2. MS02 was located in Brunswick Lease Block 298 and 299, in water depths ranging from 23.3 m to 29.3 m (Table 4.1). Despite their proximity, MS01 and MS02 were dissimilar in that MS02 was characterized by having few distinct ledges (Figure 4.5). It did, however, possess some patchy areas of outcroppings with low, broken relief, where cracks and crevices were numerous. Large expanses of sand-covered hardpan lay between the outcroppings and supported moderate growths of sponges, although most of the biota was concentrated on the outcroppings. A considerable amount of bare sand was interspersed throughout the area.

Station MS03 encompassed an area of 4.7 km^2 and was considerably larger than the other middle shelf stations. It was located 81 km east-southeast of Brunswick, Georgia, in Jacksonville Lease Block 73. Water depths ranged from 33.8 m to 37.5 m (Table 4.1). Analysis of television transects indicated that rocky outcrops were sparse at this station and very patchy within areas of bare sand. A few ledges of low relief were observed (Figure 4.6), some with heavy growth but others were rather bare. Diver observations, however, revealed a bottom topography at MS03 more similar to IS02, with ledges of moderate relief and a flat hardpan plateau. These observations of moderate relief not recorded on videotape indicate that the television transects did not completely census this extensive area.

<u>Outer Shelf Stations</u> - Station OS01 was the smallest study area (0.4 km^2) and was located on the border between Hoyt Hills Lease Blocks 444 and 445, approximately 120 km east-southeast of Savannah, Georgia. Water depths ranged from 58.5 m to 66.8 m (Table 4.1). This site contained a moderate amount of flat exposed rock with sparse epifaunal growth. Relief was generally very low,

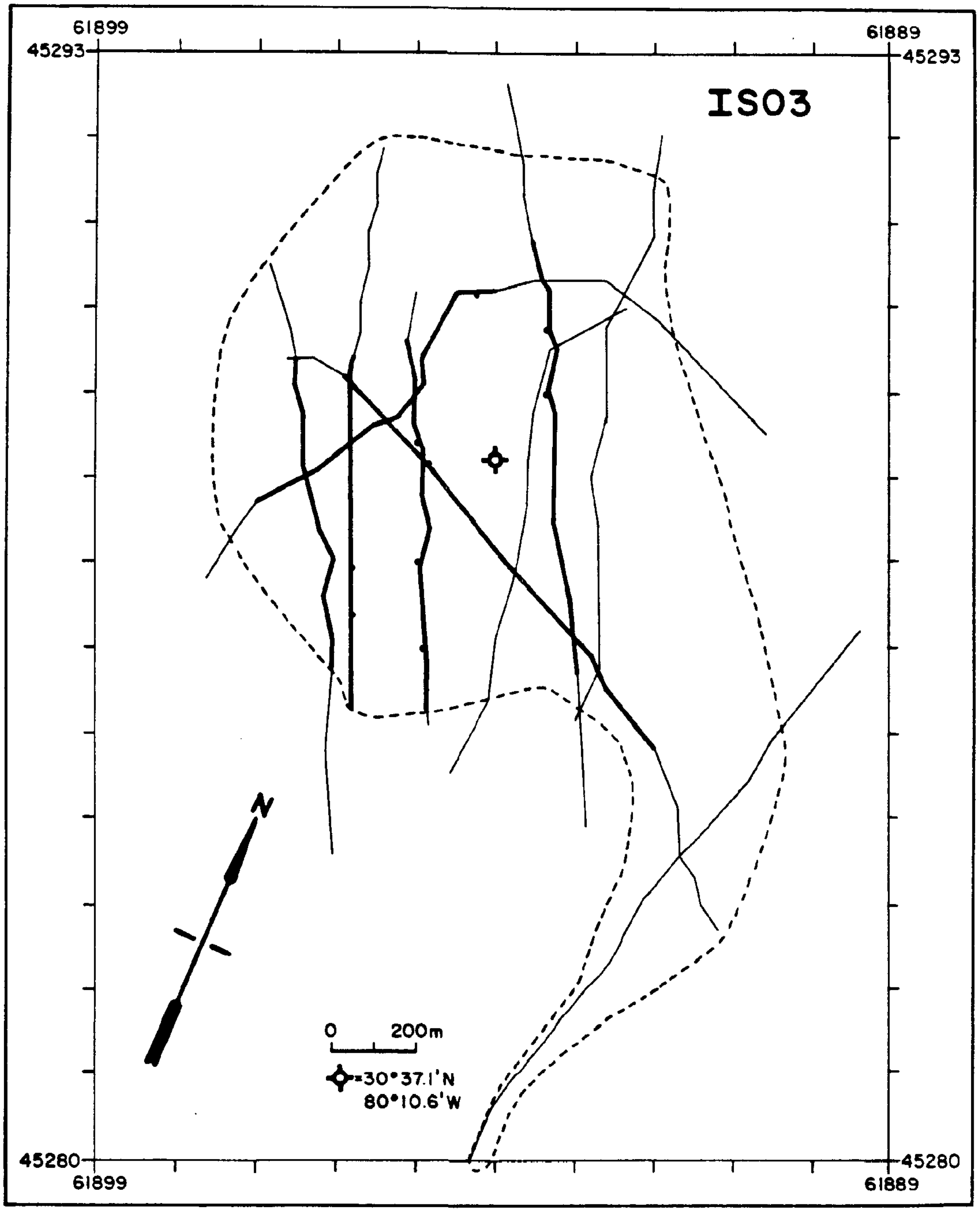


Figure 4.3. Location of television transects at Station IS03. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

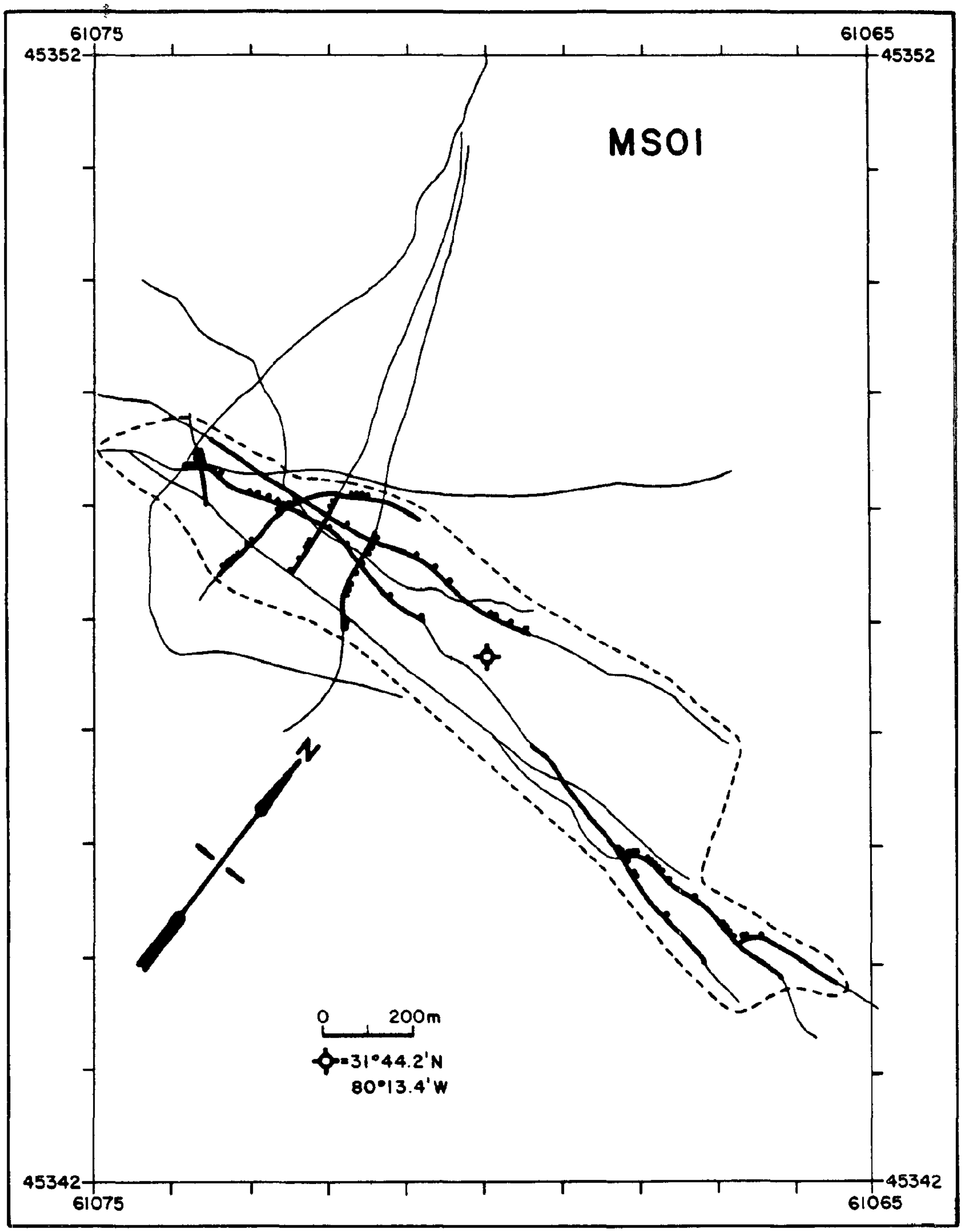


Figure 4.4. Location of television transects at Station MS01. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

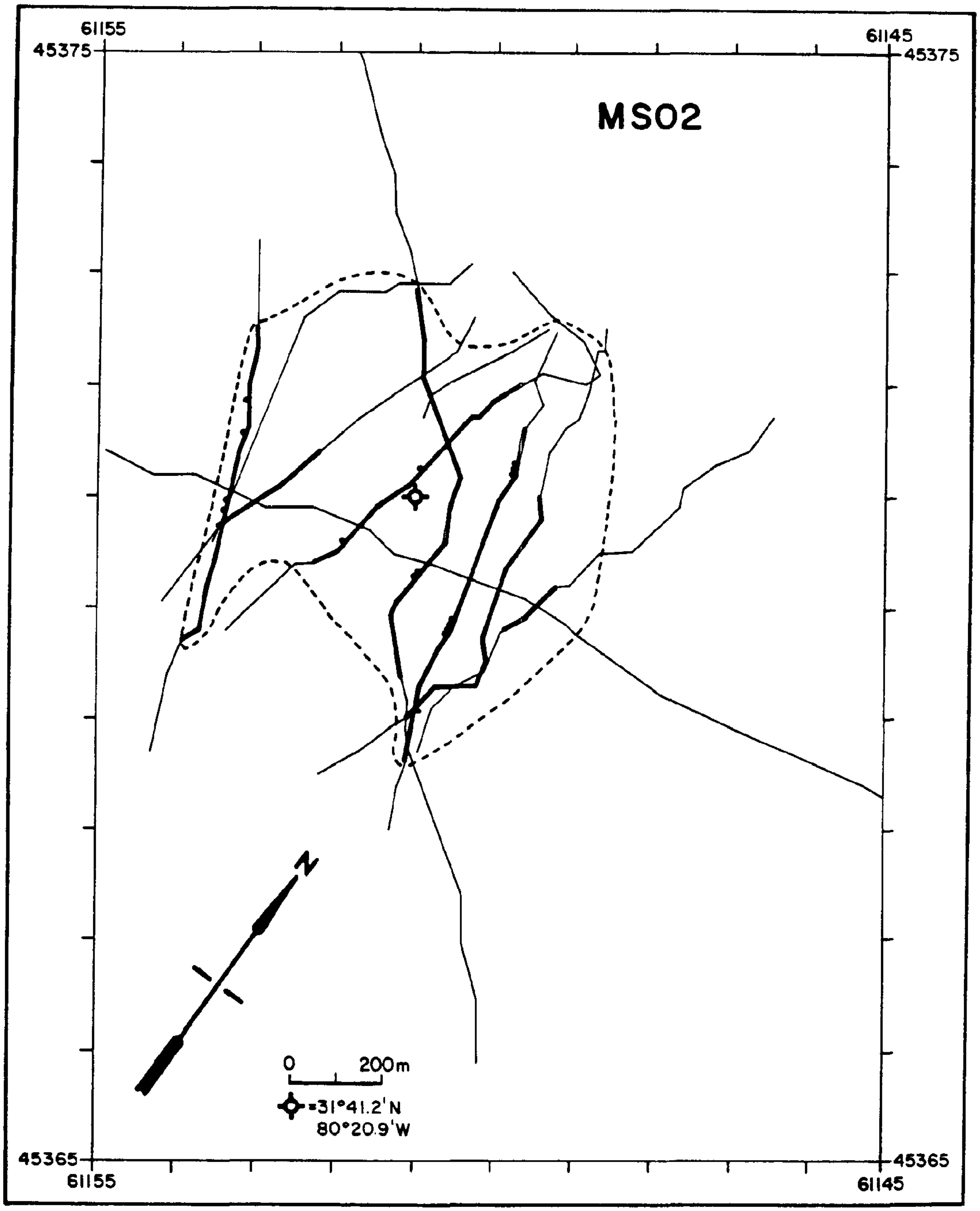


Figure 4.5. Location of television transects at Station MS02. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

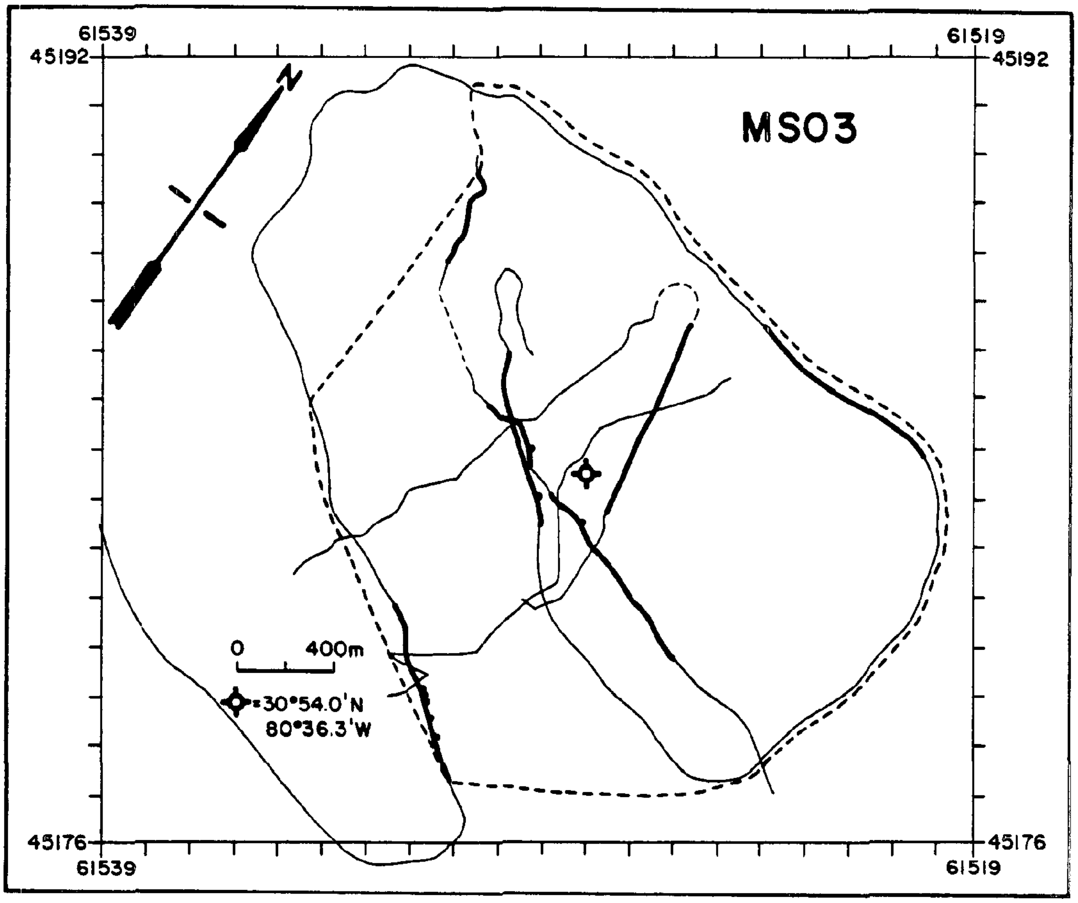


Figure 4.6. Location of television transects at Station MS03. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

with only a few ledges of notable height observed (Figure 4.7). Occasional patches of thin sand contained some epifauna, but this growth was light compared with inner shelf stations.

Station OS02 was a narrow, elongated area of 1.3 km^2, located in Hoyt Hills Lease Block 837, roughly 141 km east of Brunswick, Georgia. Water depths at this site ranged from 46.6 m to 57.6 m (Table 4.1). Television reconnaissance and videotape transects revealed a narrow, concentrated band of ledges with a north-south orientation (Figure 4.8). These ledges were of moderate relief, and large rectangular rocks up to a metre or more in length were common. These rocks supported a light growth of sponges and octocorals, and were interspersed among patches of barren sand.

Station OS03 was similar to OS02 in bottom topography. It was a narrow area of extensive rocky outcroppings which covered 3.3 km^2 (Figure 4.9) in Jacksonville Lease Block 565, approximately 115 km east of Jacksonville, Florida. Water depths ranged from 54.0 m to 63.1 m (Table 4.1). Relief at OS03 was moderate to high (up to 2 m), and many large rectangular blocks like those at OS02 supported moderate growths of sponges. Some rocks were covered by thin sand, but little bare sand was observed. Rock rubble was noted at the foot of some of the larger rock prominences.

Substratum Analysis:

Estimates of the proportion of different bottom types, as determined from videotape analysis, varied considerably among stations and among replicate transects within stations (Figure 4.10). Total estimates of live bottom occurrence for each station included sessile epifauna observed on both rock outcroppings (shaded portions of histograms) and hardpan with a layer of sand (unshaded portions of histograms). Values of the histograms that were less than 100% indicated the presence of sandy areas interspersed among patches of live bottom. Thus, although the percent frequency of live bottom on videotaped transects was generally quite high, the occurrence of actual rock outcroppings was less frequent (Figure 4.10). Emergent rock was uncommon at all inshore stations except IS02 and was also quite infrequent at middle shelf stations except at MS01. Rock outcroppings were uncommon at OS01 as well, but were more frequently encountered at OS02 and OS03 than at all other stations. The relative proportion of emergent rock (Figure 4.10) agreed with the observations made by scuba divers and with the frequency of ledges shown on individual station maps (Figures 4.1 through 4.9).

Live bottom estimates were lowest at MS03, where the mean percent frequency of occurrence was only 45% (Figure 4.10). Estimates for all other stations were considerably higher, with mean values greater than 60%. Heterogeneity of variances at many stations precluded the use of analysis of variance to test for significant differences; however, the non-parametric Kruskal-Wallis test (Sokal and Rohlf 1969) indicated a significant difference in the percentage of live bottom among study areas ($P < 0.001$). Although unequal sample sizes prevented statistical verification, it seems likely that this difference was due to the extremely low values at MS03 (Figure 4.10).

Estimates of the proportion of various bottom types, as determined from still photographs, also showed high variability among stations (Figure 4.10), probably due to the small quadrat size and patchy nature of the bottom. Nevertheless, estimates from both 1-m and 3-m elevations generally agreed with

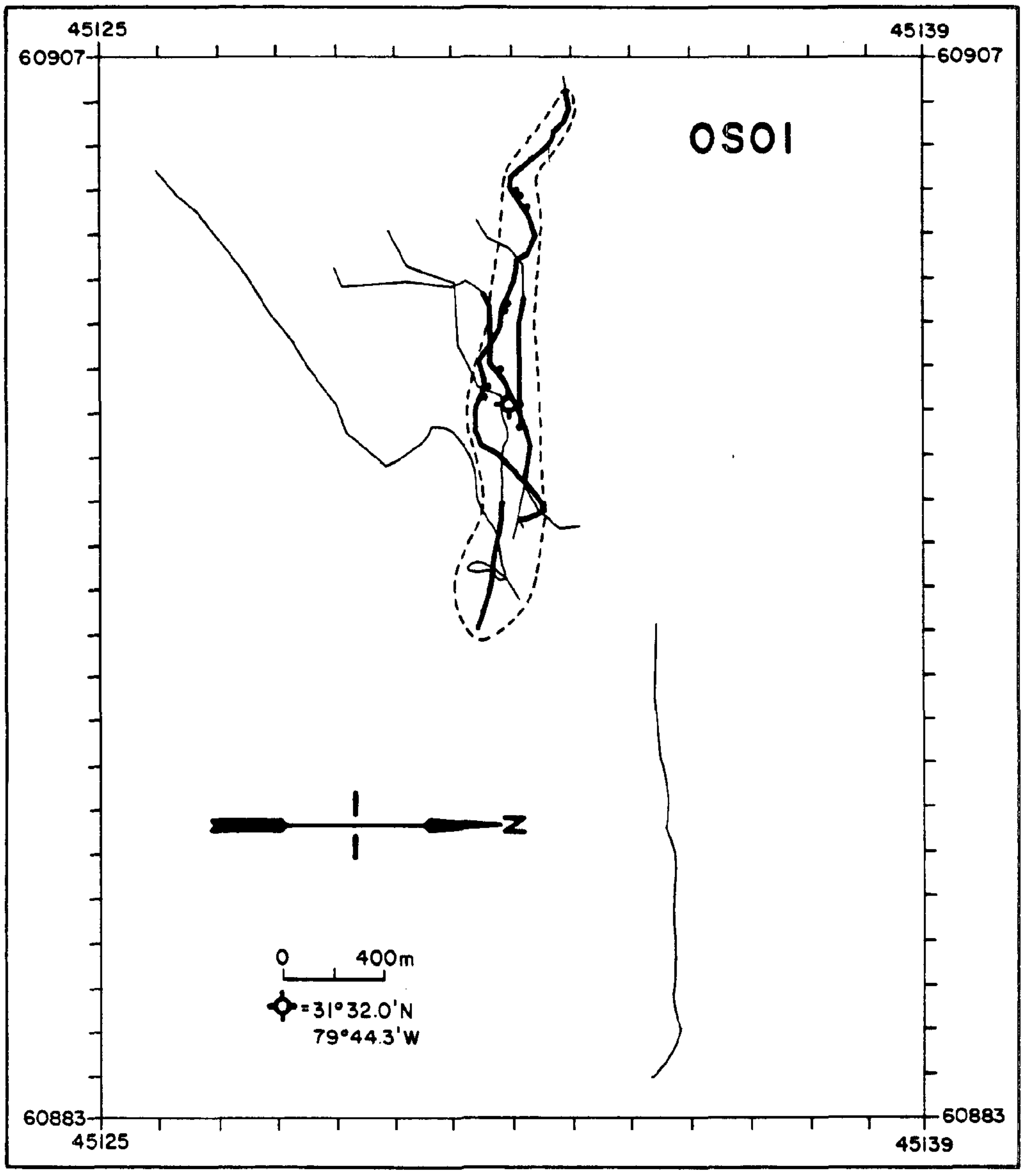


Figure 4.7. Location of television transects at Station OSO1. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

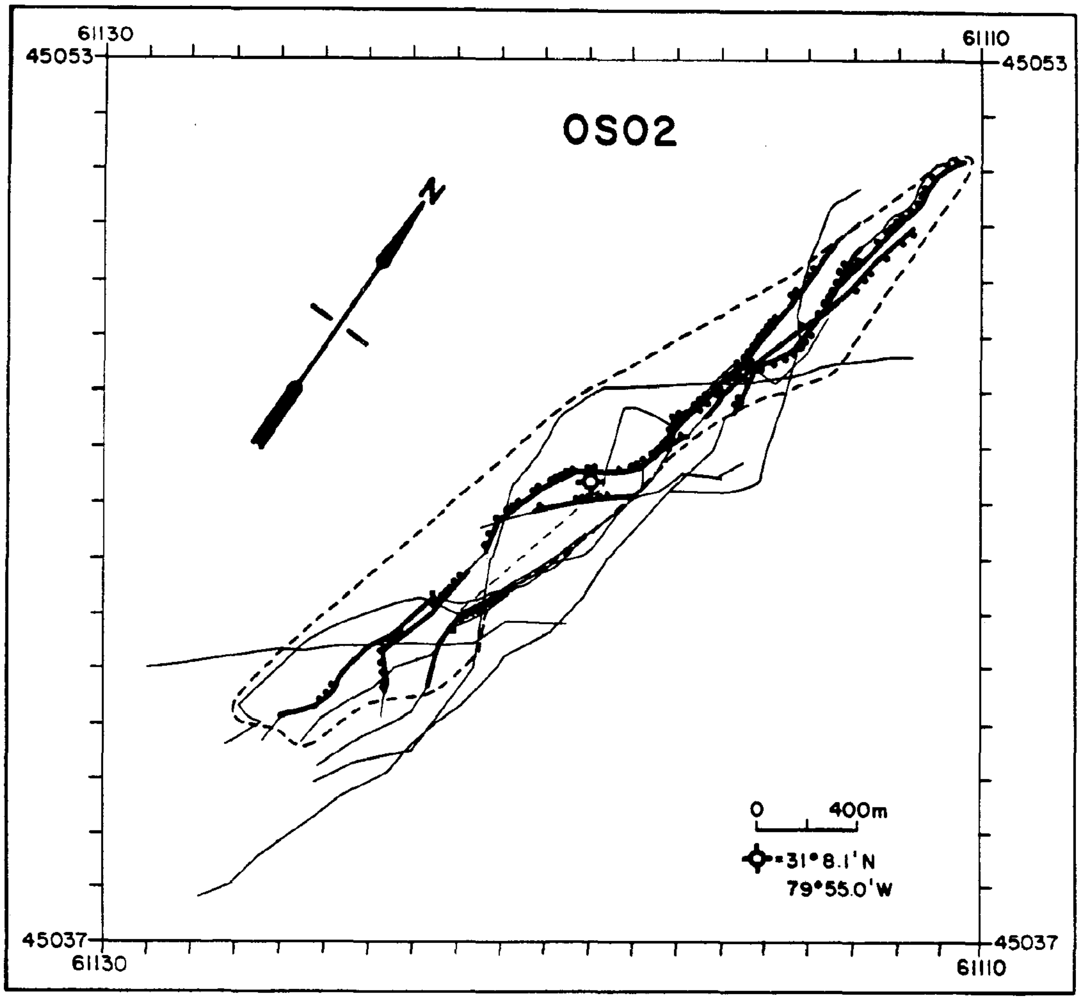


Figure 4.8. Location of television transects at Station OS02. Dashed line represents boundary of study area, heavy segments represents portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

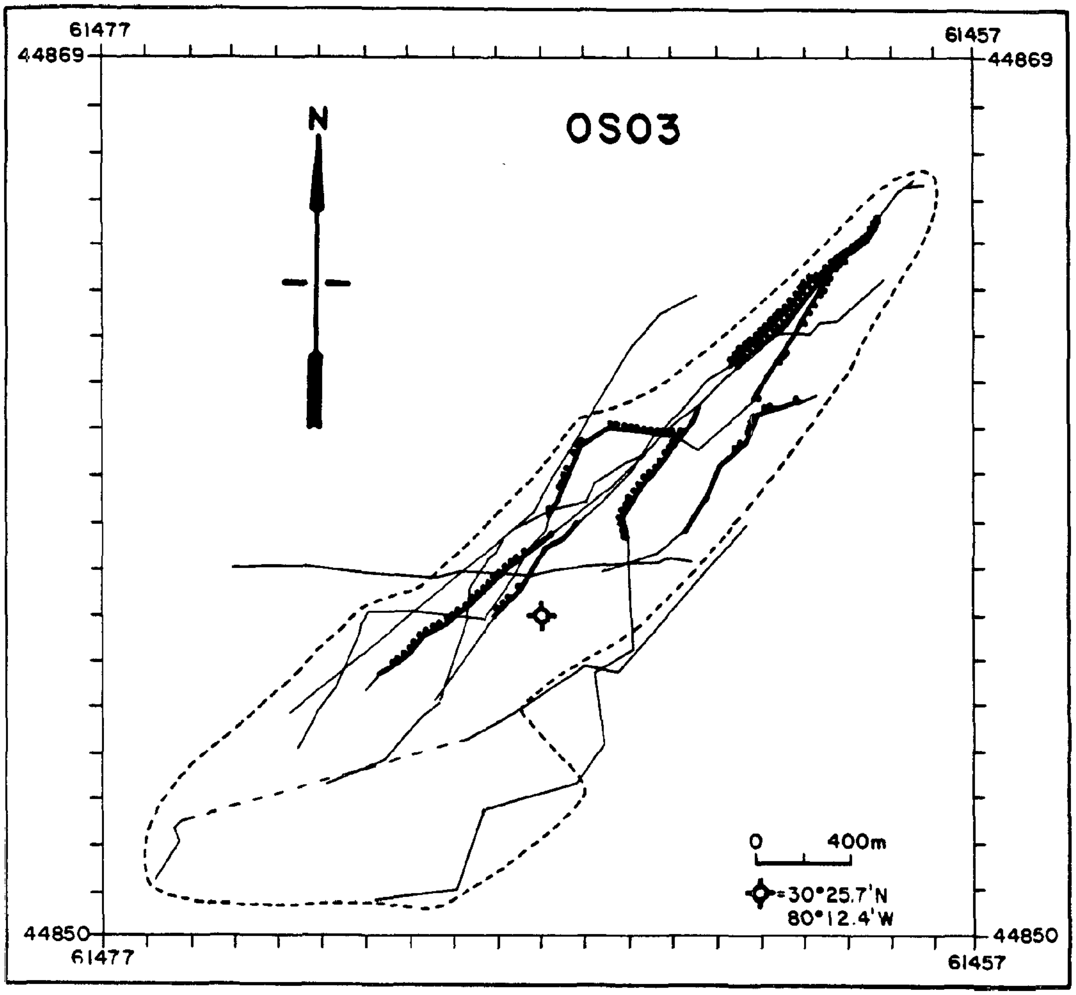


Figure 4.9. Location of television transects at Station OS03. Dashed line represents boundary of study area, heavy segments represent portions of transects used in analysis, and dots show locations of rock outcroppings on analyzed portions. Corner coordinates are Loran C units.

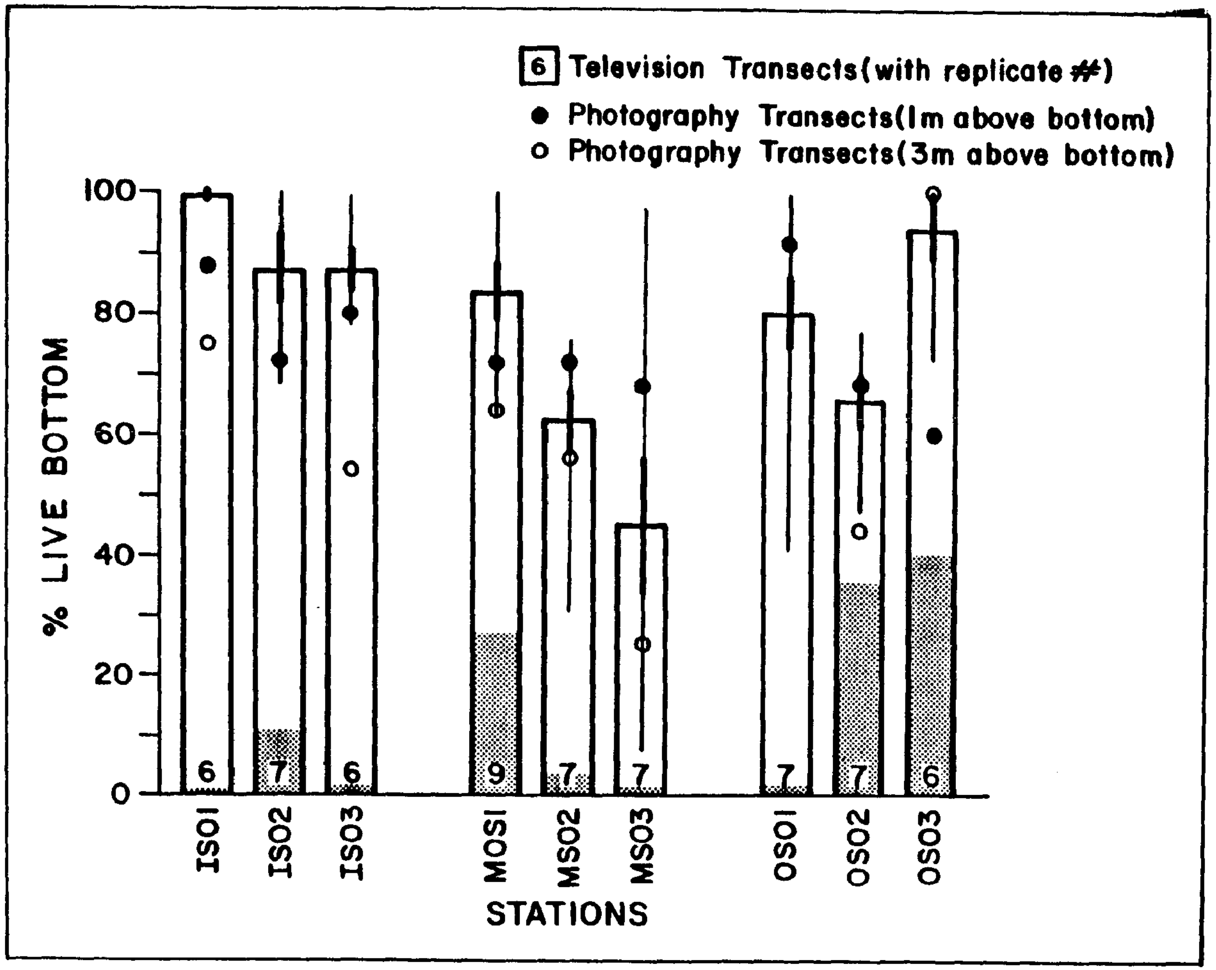


Figure 4.10. Mean percent frequency of live bottom from videotape analysis of the study sites. Heavy vertical lines represent standard error of the mean and thin vertical lines indicate the range. Shaded portions of the histograms represent the mean percent frequency of rock outcroppings. Circles represent the percent frequency of live bottom estimates from still photographs.

those made from television transects, often falling within the range of values from videotape analysis at a given station. Analysis of still photographs indicated that station MS03 had the lowest frequency (25%) of live bottom, although no trends were apparent among the other stations. At stations where photographs were taken at both 1 m and 3 m above bottom, the 1-m photographs usually yielded higher estimates of percent live bottom than did the 3-m photographs. It is likely that this difference is a result of better visual resolution of organisms in the closer photographs.

Rock Analyses:

Thin sections from rock samples contained sandy limestones, with the exception of OS01, which was a quartz sandstone cemented by cryptocrystalline micrete (Table 4.2). These limestones are sandy (Quartzose) biomicrites, according to the classification of Folk (1959).

Notable quantities of the phosphate mineral collophane and phosphorite sand grains were found at IS01 and MS03, respectively (Table 4.2). The collophane of station IS01 was a secondary replacement of the original cryptocrystalline micrite cement. In specimens from MS01 and MS02, this original cryptocrystalline micrite cement has been partially recrystallized to coarser crystalline sparry calcite.

Thin sections were not made on rock specimens from IS02, since photographic details were available for rocks collected by Hunt (1974) in the area of Gray's Reef. All rocks described by Hunt were similar to one another in composition. They were unlike those described in this study, however, in that the sandy biomicrite had been moderately to strongly dolomitized. Table 4.2 includes a summary of the characteristic features of Hunt's specimens.

With the exception of IS01, all specimens contained considerable quantities of fossil fragments, ranging from 20% at MS03 and OS01 to 45% at IS03 (Table 4.2). These fragments were typically composed of mollusk, echinoderm, and foraminiferal material. The only identifiable fossils were contained in the specimen from IS01 which contained fossil valves of Pecten eboreus. These shells are Pliocene to early Pleistocene in age, and are found in the Bears Bluff and Waccamaw formations of coastal South Carolina.

Although the general stratigraphic nature of the exposed bedrock on the continental shelf controls the topographic relief in hard bottom areas, the various encrusting and boring organisms which colonize these exposures modify the relief of the rock surface itself. Several organisms commonly found on the rock samples contributed to the complexity of the microhabitat available to other more motile epifauna. These included the encrusting bryozoans (Trypsostega venusta, Reptadeonella hastingsae, Hippoporina contracta, Turbicellipora dichotoma, Schizoporella floridana, Petraliella bisinuata, Hippaliosina rostrigera, Celleporaria albirostris), mollusk shells (Chama sp., Arca zebra), barnacles (Balanus venustus, B. trigonus), stony corals (Solenastrea hyades, Phyllangia americana, Balanophylla floridana), and the calcareous tubes of serpulid worms. A list of the dominant encrusting species found on rocks from each station is included in Table 4.2. These organisms produced a moderate to high degree of rugosity on all rock samples examined. All rock samples also contained either living specimens of the burrowing mussel Lithophaga sp. or evidence of their boring activity. Burrows were particularly numerous on rocks from IS02, MS02, and MS03, and specimens from those stations showed the greatest degree of porosity.

Table 4.2. Results of thin section analysis and general description of rocks collected by dredges and SCUBA divers at live bottom stations.

Station	Description of Rock	Petrographic Analysis: Terrigenous Constituents	Petrographic Analysis: Allochemical Constituents	Petrographic Analysis: Orthochemical Constituents	Encrusting Fauna	Boring Fauna
IS01	Sandy biomicrite (micrite replaced by collophane)	Quartz sand grains: 40%, poorly sorted, sub-angular, fine sand (1/8-1/4 mm)	Mollusk fragments: 5%, 2mm-20mm in size, replaced by sparry calcite	Micrite: 15%, light to dark brown Collophane: 40%, replaces the micrite	_Chama_ sp. Serpulidae _Solenastrea hyades_ _Trypsostega venusta_ _Reptadeonella hastingsae_	_Lithophaga_ sp.
IS02*	Moderately to strongly dolomitized sandy biomicrite	Quartz sand grains: 22%-35%, poorly sorted, sub-angular to sub-rounded, fine to medium sand	Mollusk and echinoderm fragments: 9%-10% (also some foraminifera, bryozoan, and coral material)	Micrite: 7%-37% Dolomite: 20%-46% appears to have replaced the micrite Phosphatic concretions: 1%-4%	_Chama_ sp. Serpulidae _Phyllangia americana_ _Balanus trigonus_ _Arca zebra_ _Hippoporina contracta_ _Turbicellipora dichotoma_	_Lithophaga_ sp.
IS03	Biomicrite	Quartz sand grains: 5%, well sorted, angular, very fine sand (1/16-1/8 mm)	Fossil fragments: 45%, 2mm-10mm size, partially micritized and replaced by sparry calcite	Micrite: 50%, light to dark brown	_Chama_ sp. Serpulidae _Phyllangia americana_ _Balanus trigonus_ _Balanus venustus_ _Schizoporella_ sp.	_Lithophaga_ sp.
MS01	Sandy biomicrite	Quartz sand grains: 35%, poorly sorted, sub-rounded to sub-angular, fine sand (1/8 - 1/4 mm)	Fossil fragments: 35%, mollusk, echinoderm, and foraminiferal material, 1-5 mm	Micrite: 30%, very light brown, crystalline (< 10 μm, but much greater than cryptocrystalline micrite)	_Chama_ sp. Serpulidae _Balanophylla floridana_ _Balanus_ sp. _Petraliella bisinuata_ _Schizoporella floridana_	_Lithophaga_ sp.
MS02	Sandy biomicrite	Quartz sand grains: 40%, poorly sorted, sub-angular to sub-rounded, fine sand (1/8 - 1/4 mm)	Fossil fragments: 40%, mollusk, echinoderm, and foraminiferal material, 1-5 mm	Micrite: 20%, dark brown, partially recrystallized to fine-grained sparry calcite adjacent to terrigenous and allochemical sand grains	_Chama_ sp. Serpulidae _Balanus_ sp. Coralline algae _Hippaliosina rostrigera_ _Trypsostega venusta_	_Lithophaga_ sp.

Table 4.2 (Continued)

Station	Description of Rock	Petrographic Analysis: Terrigenous Constituents	Petrographic Analysis: Allochemical Constitutents	Petrographic Analysis: Orthochemical Constituents	Encrusting Fauna	Boring Fauna
MS03	Phosphatic sandy biomicrite	Quartz sand grains: 20%, poorly sorted, sub-angular to sub-rounded, fine sand (1/8 - 1/4 mm) Phosphorite sand grains: 10%, well sorted, rounded, very fine sand (1/16 - 1/8 mm)	Fossil fragments: 20%, mollusk, echinoderm, and foraminiferal material, 1-2 mm	Micrite: 50%, dark brown	*Chama* sp. Serpulidae *Balanus* sp. *Trypsostega venusta* *Celleporaria albirostris* *Petraliella bisinuata*	*Lithophaga* sp.
OS01	Quartz sandstone with micrite cement	Quartz sand grains: 65%, very poorly sorted, sub-rounded to sub-angular, coarse to fine sand (1/8 - 1 mm)	Fossil fragments: 20%, mollusk and foraminiferal material, 1-5 mm	Micrite: 15%, dark brown	*Chama* sp. Serpulidae *Balanophylia floridana* Undetermined corals *Balanus* sp. Undetermined bryozoans	*Lithophaga* sp.

*based on thin sections from Gray 1974

Hunt

DISCUSSION

The literature indicates that low relief areas (< 0.5 m profile) typically support sparse to moderate growth of sessile epibenthos (mostly sponges and octocorals), and are widely distributed across the shelf (Henry and Giles 1979, Henry et al. 1980, Powles and Barans 1980). Due to their low relief, these areas are not often detected by fathometer or side scan sonar. Consequently, because television surveys on the shelf have been rather limited, regional distribution of these areas is largely unknown.

Two inshore stations of the present study (IS01 and IS03), one middle shelf station (MS02), and one outer shelf station (OS01) fall into the low relief category. Another middle shelf station (MS03), for which videotape analysis indicated extensive areas of low relief, but where scuba observations revealed at least some local areas of moderate relief, illustrated the overlap of these morphological categories. In fact, all live bottom areas examined in this study exhibited a gradient in the degree of relief which results in some overlap of classification.

All low relief stations showed evidence of a hard substratum in areas where outcroppings were not detected, by the growth of attaching organisms that extended through the layer of sand. Figure 4.11 is a photograph of a typical low relief hard ground obtained by scuba divers. This type of substratum was present at most study sites to varying degrees, but was prevalent at IS01, where the bottom was generally devoid of rock relief. Another example of low relief live bottom, with areas of patchy rock outcroppings less than 0.5 m in height, is shown in Figure 4.12.

Powles and Barans (1980) investigated the groundfish in a hard bottom area encompassing station IS01. They reported a flat, sandy substratum underlain at various depths by rock and described areas of bare sand alternating with areas of thick epifaunal growth. This patchiness was probably attributable to sediment depth, since organisms were found attached in depths of 8 cm and less, but not in sand 15 cm thick. Henry and Giles (1979) have also attributed the unpredictability and patchiness of hard ground distribution to sediment thickness. It is likely that low relief areas are subjected to cyclic covering and uncovering by a layer of sand several centimetres or more in thickness. This temporal variability of low relief live bottom areas may be significant (Powles and Barans 1980).

Moderate relief reefs from 0.5 m to 2 m are common off northern Florida, South Carolina and North Carolina, and occur at inner and middle shelf depths between 15 m and 30 m (Henry and Giles 1979). Although many inshore reefs typically are of low relief (Henry et al. 1980, this study), one notable exception is the 40-km^2 area known as Gray's Reef which encompasses station IS02. Although a maximum relief of 6.6 m has been observed (Hunt 1974), the relief is generally less than 2 m, and it is a characteristic moderate relief reef (Henry et al. 1980). Middle shelf stations MS01 and MS03 were also classified in the moderate relief category, and Figure 4.13 shows a ledge at MS01 that is typical of this category.

A third classification of hard ground, the shelf edge reef, was described by Henry and Giles (1979) as a discontinuous, but generally well defined, high relief ridge or series of ridges at or near the shelf break. This series of ridges extends from Cape Hatteras, North Carolina, to Ft. Lauderdale, Florida (Macintyre and Milliman 1970, Avent et al. 1977) and is characterized by blocky irregular rock outcrops with local relief up to 15 m (Henry et al. 1980). Although relief this great was not detected during videotape analysis, additional videotapes from OS02 and OS03 showed areas of relief considerably

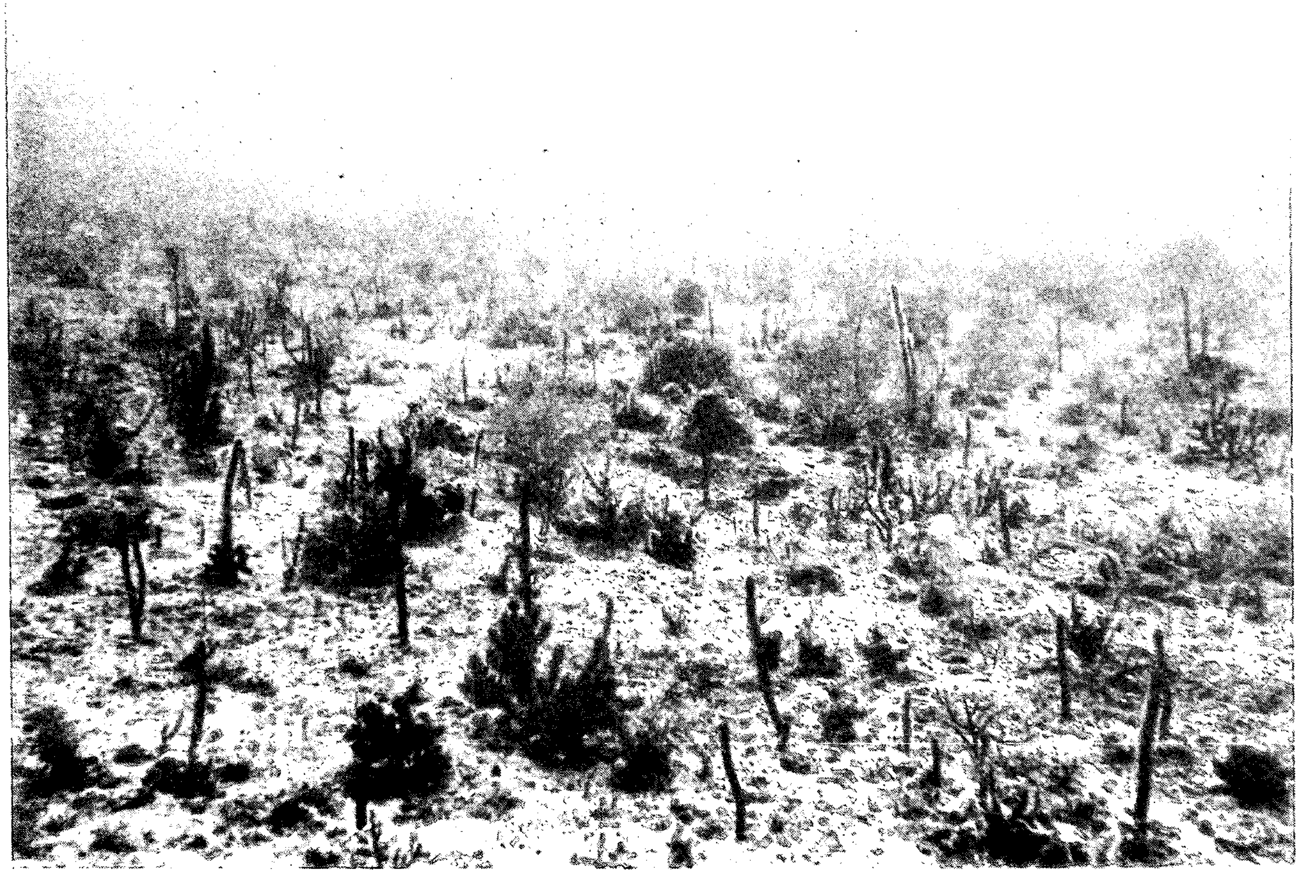


Figure 4.11. A live bottom station with typical low relief hard ground covered by an extensive layer of sand. Finger-like projections are the octocoral _Titanidium frauenfeldii_. The smaller, branching octocorals are probably _Lophogorgia hebes_. The actual distance across the middle of the photograph is about 3.0 - 4.5 m.

Figure 4.12. A live bottom station with patchy outcroppings of low relief. A vase sponge, Ircinia sp., is evident in the lower portion of the upper left-hand corner. The highly branched octocoral Muricea pendula can be seen on the far right, in the middle of the photograph. The actual distance across the middle of the photograph is about 7.6 m.

Figure 4.13. A ledge of moderate relief at a live bottom station. Note the large vase sponge, Ircinia campana, in the upper right-hand portion of the photograph. Length of the stick held by the diver is 1 m.

greater than 2 m. Rocks shown in still photographs at these two stations were similar in shape and size to the blocks described by Henry et al. (1980). Water depths at all outer shelf stations (Table 4.1) were also similar to the 50 - 70 m depths at which Henry and Hoyt (1968) encountered shelf edge reefs.

Stations OS02 and OS03 had numerous ledges and rock outcroppings (Figures 4.8 - 4.10), but relief at OS01 was similar to low relief stations (Figures 4.7 and 4.10). Station OS01 was located landward of what Henry et al. (1980) described as a transitional zone in which no distinct scarp was present. Their records, compiled from fathometer data along the shelf edge, also indicated the presence of a pronounced scarp near OS02 and OS03. Television reconnaissance and videotape made at both of these stations suggest that they lie within narrow, elongated features which may be more extensive than the areas delineated for this study (Figures 4.8 and 4.9).

Estimating the amount of live bottom habitat that occurs on the continental shelf is difficult because of the patchy and discontinuous nature of its distribution. Several studies have attempted to make such assessments of live bottom coverage, but the accuracy of these estimates is uncertain. Henry et al. (1980) estimated the proportion of hard bottom in the Georgia Bight to be 4.3% of the total area surveyed, but they consider this to be an underestimate because an additional 16.2% of shallow acoustic reflector may support undetected low relief hard bottom. Limited television groundtruthing did not confirm this, however. More recent studies by Parker et al. (in preparation) suggest that "rock-coral-sponge" habitat accounts for nearly 30% of the substratum between the 27-m and 101-m isobaths from Cape Fear to Cape Canaveral. This is equivalent to an area of 7403 km^2 of live bottom, as compared with the estimate of 6524 km^2 derived by Barans and Burrell (1976) for the same area, although the latter estimate was based on a more restricted bathymetric zone (19 - 55 m).

Within discrete areas of live bottom, such as our study areas, bottom type is quite variable. The proportion of live bottom within our stations ranged from 25% to 100% of the total area (Figure 4.10). These values may be somewhat inflated, since the presence of even the slightest amount of live bottom within a 10-sec videotape interval qualified that interval as "live"; however, these estimates do document the presence of non-live bottom and the variability between stations. The high variability of our estimates (Figure 4.10) also illustrates the patchiness of the bottom within the study areas.

One apparent trend seen in Figure 4.10 is the greater incidence of emergent rock at the offshore stations OS02 and OS03. This is consistent with the patterns described by Henry and Giles (1979), who suggested that reefs and hard grounds are less common near shore as a result of greater thickness of Quaternary sediments and partial removal of the hard layer by stream channeling during periods of lower sea level. Further offshore the sediment layer thins, allowing increased exposure of underlying hard bottom.

Thin section analysis of rock specimens revealed a strong similarity among inner and middle shelf stations. Reef material from these stations consists of sandy limestones that are classified as sandy biomicrites (Table 4.2). Hunt (1974) found that the reef substrate at Gray's Reef (IS02) consists of an outcropping layer of sandy biomicrite. However, unlike specimens from the present study and others (Continental Shelf Associates 1979), Hunt's specimens were strongly dolomitized following deposition of the rock in a shallow marine environment. Hunt (1974) suggested this layer may be stratigraphically continuous over an extensive area and correlated it with the Duplin Marl of coastal Georgia and northern Florida. Rock samples collected in shallow water near IS01 by Powles and Barans (1980) also consisted of a tightly cemented limestone conglomerate of carbonate shell and quartz sand material.

Petrographic analysis by Continental Shelf Associates (1979) on more than 40 dredge samples from off South Carolina and Georgia have shown that the hard bottom was primarily a recent to sub-recent biostromal reef, somewhat younger than indicated by Hunt (1974). Rock samples from a shelf edge reef lying east of Charleston in 44 - 78 m depths, were predominantly sandstone (Continental Shelf Associates 1979), as was the single specimen from station OS01 (Table 4.2). The lack of rock samples from the other two outer shelf stations, OS02 and OS03, precludes speculation on the significance of the distribution of lithologic types among the study areas.

IMPACT/ENHANCEMENT

Because our assessment of the physical characteristics of each study area was limited, only general statements can be made concerning possible impacts of drilling operations. One potential negative impact would be environmental damage associated with increased sedimentation over hard bottom. However, enhancement of these live bottom areas also could result from the addition of hard platform surfaces.

Increased sedimentation resulting from discharge of drilling muds and cuttings would be less severe where currents are strong enough to disperse these materials over a wide area. For example, effects of drilling activities might be minimal at the shelf edge because of dispersion by the Gulf Stream. Furthermore, greater relief on shelf edge reefs may localize the effects of sedimentation by confining its accumulation to local depressions. Thus, topographic elevations might remain relatively free of sediment, providing clear surfaces for attachment of encrusting organisms that cannot tolerate even thin layers of sediment. Low relief hard grounds might be more susceptible to widespread burial by drilling discharges, unless tidal currents or occasional storm generated wave action were sufficient to disperse those by-products.

Drilling structures present vertical surfaces of solid material and are, therefore, favorable for growth of encrusting epibenthos that require exposed hard surfaces for attachment and growth (i.e., bryozoans, barnacles, some sponges, and tunicates). Growth of such organisms would result in a considerable addition to the fauna in areas where little emergent rock occurs naturally, such as IS01, IS03, MS02, and MS03. At deeper stations, platforms would also foster the growth of shallow water epibenthic organisms which might otherwise be excluded from the deeper bathymetric zones.

CONCLUSIONS

- The distribution of live bottom on the continental shelf of the Georgia Bight is not well known, due to the difficulty of recognizing its presence using standard geophysical techniques and equipment. Remote sensing by underwater television and still camera equipment aids in the assessment of bottom type, and was used in the present study to confirm that all study areas were located over live bottom.

- Inshore stations IS01 and IS03 contained patchy live bottom with low relief (< 0.5 m). At IS01 the rock was typically covered by a layer of sand. Station

IS03 more closely resembled IS02, which was part of an extensive moderate relief area known as Gray's Reef, and was atypical of inshore reefs. Ledges and rock outcrops in this area were higher and more frequent than at the other two stations.

- One middle shelf station, MS02, was classified as a low relief hard ground and possessed only low, rounded outcroppings. At the other middle shelf stations, ledges of moderate relief (0.5 - 1.0 m) were found. At MS01 these ledges were extensive, but they were somewhat localized at MS03.

- Outer shelf stations were located near the continental shelf break, and OS02 and OS03 had numerous ledges with moderate to high relief (> 0.5 m) and outcroppings of large rectangular rocks. These two stations may be a part of a long series of discontinuous scarps that extend along the shelf edge from North Carolina to Florida. OS01 was unlike the other outer stations and had less emergent rock and lower relief.

- The distribution of live bottom within the study sites was extemely patchy. This patchiness is reflected by high variability among estimates of frequency of occurrence of hard bottom, which ranged from 25% to 100%. Analysis of videotapes for bottom type revealed no trends, with respect to depth or latitude, in the proportion of live bottom versus non-live (sand) bottom, and still photograph analysis supported this conclusion. Emergent rock was found at all stations, although it was generally less frequent at inshore stations versus offshore stations, where it accounted for up to 40% of the substratum.

- Rock samples collected at inner and middle shelf stations were of similar composition, consisting of heavily encrusted fragments of sandy biomicrite. The only rock specimen obtained from the outer shelf depth zone was a quartz sandstone rock from OS01. All rocks collected were rugose, heavily encrusted by epifaunal organisms, and showed varying degrees of bioerosion by boring organisms.

- This study has provided only limited information for predicting impacts on the physical characteristics of live bottom habitats. However, it is likely that negative impacts would be related to excessive sedimentation caused by disposing drilling muds and cuttings. One potential benefit of oil platforms would be the additional hard substrate made available by emplacement of these structures, particularly in areas where most hard surfaces are normally covered by a veneer of sand.

CHAPTER 5

BENTHIC COMMUNITY

INTRODUCTION

Marine epifaunal communities associated with intertidal and coastal shallow water hard substrates, such as rocks and shells, have been the subject of intensive theoretical and empirical investigations (see Osman 1977 for review). However, studies concerning epifauna associated with oceanic hard bottom habitats have lagged behind those conducted in the more accessible intertidal zone. This is unfortunate because oceanic hard or live bottom communities are highly diverse and ecologically important to offshore fisheries in the South Atlantic region (Struhsaker 1969, Miller and Richards 1979). One of the primary goals of the current investigation is to characterize the epibenthos from representative live bottom habitats. The information provided herein will serve as a basis for predicting community composition and structure at other live bottom habitats in the South Atlantic and should be useful in management decisions concerning oil and gas exploration on the continental shelf.

Although several previous studies have examined biota associated with live bottom habitats on the South Atlantic continental shelf (Pearse and Williams 1951, Menzies et al. 1966, Macintyre and Pilkey 1969, Macintyre 1970, Huntsman and Macintyre 1971, Cain 1972, Hunt 1974), most have been limited to descriptive lists of fauna present in discrete areas of the shelf or have centered on selected taxonomic groups. A community approach to the study of the hard bottom habitat was not forthcoming until McCloskey's (1970) paper. Later, Schneider (1976) considered spatial and temporal distributions of benthic marine algae from hard bottom areas of the middle and outer continental shelf of North Carolina. More recently, studies by George and Staiger (1978), Henry et al. (1980), and Powles and Barans (1980) have documented the location and extent of some live bottom habitats on the continental shelf and provided generalized characterizations of these sites. In addition, Continental Shelf Associates (1979) compared hard bottom communities present at four sites in different bathymetric zones; however, their assessment of community composition was secondary to the physiographic characterization of these hard bottom sites.

This study provides comprehensive information on the epibenthic communities associated with several hard bottom sites on the shelf between South Carolina and northern Florida. Our goals are to describe the composition of the communities in terms of seasonal, latitudinal, and bathymetric variations; to adequately understand the structure of the community in terms of species abundance and distributional patterns; and to propose hypotheses concerning the effect of physical disturbances on community structure.

METHODS

Laboratory Analysis:

Television Transects - Videotaped segments of television transects used in the bottom type analysis (described in Chapter 4) were also used to estimate the frequency of occurrence of large fauna and flora. Epibenthic taxa analyzed in this effort included the sponges Spheciospongia vesparium, Ircinia campana, and Haliclona oculata; soft corals Leptogorgia spp., Titanideum frauenfeldii, Muricea pendula, Lophogorgia hebes, and Stichopathes sp.; hard corals Oculina spp. and Solenastrea hyades; and algae.

Estimates of frequency of occurrence were obtained for the above species by noting the presence or absence of each species during 10-sec intervals along the transect paths. Assessments made during each interval were restricted to the center third of the television monitor to minimize variability in estimates due to poor water visibility and also, to minimize variability in bottom surface area assessed due to variations in the height of the camera above bottom. When poor visibility made it impossible to accurately determine the presence or absence of a certain species during an interval, the interval was not included in the frequency estimate of that species. Thus, frequency estimates represent the proportion of intervals in which a species was present relative to the total number of intervals analyzed for that species along a transect.

Still Camera Transect Analysis - Selected slides taken 1 m and 3 m above the bottom during still photographic transects (see Chapter 4 for details on selection) were analyzed in the laboratory using different techniques.

Slides obtained from 1 m above bottom were projected onto a screen to provide an image of 0.5-m^2 bottom surface area for quadrat analysis. Quadrat boundaries were drawn on the screen and measurements of real bottom area were derived using known measurements of the tripper weight in each photograph. A 0.5-m^2 quadrat represented the maximum bottom surface area available for analysis. Biota observed in each of the 25 replicate slides was evaluated using the random point count technique described by Bohnsack (1979). Fifty points were selected in each slide from which estimates of percent cover were taken. In some instances, fewer than 50 points were analyzed because of poor visibility and obstruction of bottom by the tripper weight. Identifiable organisms which were observed in the slides, but not under points, were also noted.

Slides obtained from 3 m above bottom were projected onto a screen to provide a quadrat image of 3 m^2, the maximum bottom surface area available for analysis. Since only larger fauna were generally visible in these slides, analysis entailed counting the number of each species observed in the quadrats and tabulating the presence of colonial organisms which could not be counted.

Removal Sampling Gears - In the laboratory, organisms collected in dredge and trawl samples were sorted into the following categories: Algae, Porifera, Hydrozoa, Scleractinia/Octocorallia, Mollusca, Decapoda, Echinodermata, Ascidiacea, and a miscellaneous category for remaining organisms. Selection of these categories was based upon the stated objectives for the trawl and dredge sampling procedure, namely, to characterize the presence of large epifauna and macroalgae. For that reason, several smaller taxa (e.g. Amphipoda, Polychaeta) which were not well sampled by these gears were not sorted from the samples. Except for algae, which was kept in formalin, all specimens were transferred to 70% isopropyl alcohol and identified to the lowest feasible taxonomic level by the appropriate investigator.

Suction and grab samples were obtained to provide quantitative information on smaller epibenthos not sampled in dredge or trawl gears. Rose bengal stain was added to these samples in the laboratory to facilitate sorting of the small organisms from non-biological material. Prior to staining, macroalgae and sponges that were visible without magnification were removed to avoid destroying characteristics important in the identification of these taxa. Following removal of these organisms and staining, the samples were then sorted under illuminated magnifiers into the following categories: Algae, Porifera, Mollusca, a category for "worm-like" organisms (including annelids, sipunculids, echiurids, phoronids, etc.), Decapoda, Arthropoda (excluding Decapoda), Echinodermata, Ascidiacea, and a miscellaneous category. Animals were then distributed for identification and enumeration of all non-colonial taxa. Encrusting fauna such as bryozoans and barnacles, which were assessed in dredge and trawl samples, were not included in the analysis of suction and grab samples. In addition, the abundance of hydroids and colonial corals was not considered because these organisms are not easily quantified by counting.

Representative specimens of all taxa collected were transferred to separate vials and labelled consecutively with a voucher specimen number. A voucher ledger was maintained which included the following information for all specimens: voucher number, species name (or lowest known taxon), family name, number of specimens, latitutde and longitude, depth, bottom temperature, collection gear, date of collection, collection number, and the name of the individual making the identification. When the container was large enough, a permanent label containing this information was included with the specimens. Most specimens, however, were stored in small vials, and the only information included in the vial was species name, voucher number, and collection number.

Data Analysis:

Television Transects - Mean frequency of occurrence estimates for the sponges, corals, and algae were computed from occurrence percentages noted on replicate transects. Because the data were proportional, all percentages (P) were transformed using arcsin $\sqrt{P}$ for a Model I one-way analysis of variance (ANOVA) with stations as treatment groups (Sokal and Rohlf 1969).

Removal Sampling Gears - Qualitative binary data (i.e., species presence or absence) collected by dredge and trawl, and quantitative abundance data collected by suction and Smith-McIntyre grab samplers were converted into a standard data format (Appendix 7) prior to data analysis using computer programs.

Numerical Classification - Numerical classification (cluster analysis) was used to elucidate patterns of similarity among collections and among species for both binary and abundance data. Due to the large number of species represented in collections made by the various sampling devices, it was necessary to reduce data sets which contained > 150 species prior to cluster analysis in order to remain within the computational core and time limits of available computer programs. Data sets were reduced by both elimination of species which were infrequently collected and elimination of these taxa from our data sets of undetermined or questionable identity, unless such species were consistently recognized as being unique. The elimination of these taxa from our data sets was justifiable because "rare" species usually do not have definable distribution patterns and can confuse interpretation of cluster analysis. Analysis of data sets for dredge and trawl collections included only those species represented in three or more samples. Because the large number of species from pooled suction and grab collections exceeded the capability of our computer program, analysis was restricted to those species which occurred in seven or more samples. Following reduction of species, data sets were examined to insure that each collection contained at least two species. Collections which contained only one species were eliminated because they contribute little information to cluster analysis (Boesch 1973) and frequently confuse interpretation.

Both species and collections were classified using clustering methods which are discussed at length by Sneath and Sokal (1973); Clifford and Stephenson (1975); and Boesch (1977). Flexible sorting (Lance and Williams 1967a) was used with a cluster intensity coefficient (β) of -0.25. At this level of β, flexible clustering imposes a bias against an entity or group joining a large group and a bias for entities or small groups to form separate branches of the hierarchy (Williams 1971, Clifford and Stephenson 1975, Boesch 1977). Flexible sorting with β of -0.25 has been satisfactorily used in marine ecology and has become more or less conventional (Clifford and Stephenson 1975).

The clustering algorithms differed according to whether the data were qualitative or quantitative. The Jaccard similarity coefficient was used with binary data and species abundance data were subjected to a square-root transformation and subsequently clustered using the Canberra metric similarity coefficient. Normal and inverse classifications were produced for each data set. The result of normal classification is a dendrogram in which collections are clustered as entities with species presence or transformed abundance as attributes, whereas inverse classification produces a dendrogram in which species are clustered as entities with their presence or transformed abundance in collections as attributes (Williams and Lambert 1961).

The Jaccard similarity coefficient is effective in discriminating distributional relationships among species or collections and is particularly useful when many conjoint presences exist (Clifford and Stephenson 1975, Boesch 1977). This coefficient ranges from zero to one with one expressing maximum similarity or identical entities (species or collections). It is expressed as:

$$\frac{a}{a + b + c}$$

where a is the number of attributes (joint presences) shared by both entities; b is the number of attributes possessed by the first entity but not the second; and c is the number of attributes possessed by the second entity but not the first.

The Canberra metric measure, expressed in terms of dissimilarity, is:

$$D_{jk} = \frac{1}{m} \sum_{i} \frac{|X_{ij} - X_{ik}|}{(X_{ij} + X_{ik})}$$

where D_{jk} is the dissimilarity between entities (species or collections) j and k; m is the total number of attributes (transformed abundance); and X_{ij} and X_{ik} refer to abundance of the i^{th} attribute for entities j and k, respectively (Lance and Williams 1967b). The similarity equivalent of this coefficient is: $S_{jk} = 1 - D_{jk}$, where S_{jk} is the similarity between entities j and k. The Canberra metric coefficient is not greatly influenced by extremely abundant species which might otherwise dominate the coefficient (Clifford and Stephenson 1975). Hence, this coefficient is appropriate for the purpose of identifying assemblages in the live bottom community which contain numerous rare species.

Because the Canberra metric measure is insensitive to large attribute values, it was used with the relatively mild square-root transformation (Clifford and Stephenson 1975).

Following formation of dendrograms resulting from normal and inverse classification, groups with internal resemblance were chosen by a variable "stopping rule" (Boesch 1977) which is based on a priori knowledge of station characteristics and the ecology of component invertebrate species. For some data sets, it was necessary to reallocate misclassified entities from one group to another. The criterion for reallocation involved the computation of average similarity values to determine whether inclusion of reallocated entities improved the average similarity of the group in which it was placed (Boesch 1977).

Nodal Analysis - Nodal analyses (Williams and Lambert 1961, Lambert and Williams 1962) were employed to describe collections at a station in terms of their characteristic species and to describe species groups resulting from inverse cluster analysis in terms of their patterns of occurrence in collections (Boesch 1977). Coincidence was expressed by graded constancy and fidelity values in nodal diagrams. Nodal diagrams were drawn so that the width of rows and columns was proportional to the number of entities in the respective station and species groups.

Constancy expresses the frequency with which species belonging to a particular group are found in collections which represent a given station. It is expressed algebraically as:

$$C_{ij} = \frac{a_{ij}}{(n_i \; n_j)}$$

where a_{ij} is the actual number of occurrences of members of species group i in collection group j, and both n_i and n_j are the numbers of the entities in the respective groups. The constancy index has a value of one when all species in a group occurred in all collections at a station and zero when none of the species in a group occurred in collections at a station.

The fidelity index:

$$F_{ij} = \frac{(a_{ij} \; \Sigma_j \; n_j)}{(n_j \; \Sigma_j \; a_{ij})}$$

uses the same terms as the constancy index to express fidelity of species in group i to collections at station j. It measures the degree to which species are restricted to collections at a station. The fidelity index ranges from values greater than two, suggesting "preference" of species in a group for collections at a station, to less than one, which suggests "avoidance" of stations represented by collections.

Reciprocal Averaging Ordination - Reciprocal averaging, an eigenvector method of indirect ordination (Hill 1973), was used in conjunction with cluster analysis to describe the zonation of live bottom communities based on data from samples collected by dredge, trawl, suction, and grab. This method involved an iterative process in which species scores, weighted by their position along a rough initial gradient, were used to compute sample scores and vice versa.

Reciprocal averaging ordinations were performed on qualitative and quantitative data following reduction and transformation, as previously described for cluster analyses. A further reduction in the number of species to $\leq$ 100 was required to conform with the dimensions of the program utilized (ORDIFLEX, Gauch 1977).

The seven axes extracted by ordination are assigned eigenvalues, expressed as percentages of the total eigenvalue. These percentages indicate the proportion of the total variance in the data set accounted for by each of the seven axes. The collection scores resulting from ordination were ranked and rescaled from zero to 100 and then plotted separately on the first two axes. Species ordinations were less informative than inverse cluster analyses. Consequently, only collection ordinations were included in this report.

Species Diversity - The Shannon index of species diversity (Pielou 1975) and its two components, species richness and evenness, were computed for quantitative collections made with suction and grab samplers. These measures of diversity were also calculated on data from pooled replicates in order to index diversity by station.

The Shannon index (H') is expressed by:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i$$

where s is the number of species and P_i is the proportion of the i^{th} species in a collection. Species richness (SR) was calculated using Margalef's (1958) expression:

$$SR = \frac{(s-1)}{\log_e n}$$

where s is the number of species and n is the number of individuals in a collection. The evenness index (J') was calculated using the following expression from Pielou (1975):

$$J' = \frac{H'}{\log_2 s}$$

Additional sample statistics used to assess differences in community structure among stations included the number of species (s) and number of individuals (n). Both s and n were tabulated for collections made with suction and grab samplers, while only s was tabulated for qualitative collections made by dredge and trawl. The Kruskal-Wallis one-way analysis by ranks (Siegel 1956) was used to determine whether s and n differed significantly between stations.

Dominance diversity curves (Whittaker 1965) were drawn using the rank of each species and its corresponding number of individuals from pooled replicated collections made at each station with suction and grab samplers. The degree of dominance at a station was quantified with the dominance index (DI)(McNaughton 1967):

$$DI = \frac{N_1 + N_2}{N} (100)$$

where N_1 and N_2 are the numbers of individuals for the first and second most abundant species, and N is the total number of individuals for all species at a station.

Species Abundance - An index of relative abundance (Musick and McEachran 1972, Elliott 1977) expressed as:

$$\frac{1}{n}\sum_{1}^{n}\log_e (x + 1)$$

where x is the number of individuals of a given species and n is the number of collections, was used to assess relative abundance of numerically dominant species by station. The data were logarithmically transformed to reduce the variance to mean ratio for number of individuals. Numerically dominant species were chosen arbitrarily as the ten most abundant species from combined data collected with suction and grab samplers during summer and winter. The Mann-Whitney U-test (Siegel 1956) was used to test whether the median abundance of each dominant species differed between winter and summer collections.

Biomass - A Model I single classification analysis of variance (Sokal and Rohlf 1969) was performed on biomass determinations from dredge and trawl collections separately to determine whether biomass from replicated sampling effort differed between stations. Due to non-normality and heterogeneous variances, a logarithmic $[\log_{10} (x + 1)]$ transformation was used prior to the analysis of variance.

Student's t-test (Sokal and Rohlf 1969) was used to determine whether invertebrate biomass differed between winter and summer sampling periods. Because biomass determinations from samples collected by dredge and trawl were not normally distributed and had heterogeneous variances, a logarithmic $[\log_{10} (x + 1)]$ transformation was performed on the data prior to the t-test. The rejection level for the null hypothesis in all statistical tests was $\alpha = 0.05$.

RESULTS

Assessment of Epibenthos by Television Transects:

Analysis of sponge frequency along television transects (Figure 5.1) indicated several differences in the distributions of the three species monitored. The finger sponge *Haliclona oculata* was the most commonly observed sponge at inner shelf sites. The occurrence of this species decreased significantly ($P < 0.002$, ANOVA) with depth, and it was only rarely observed along transects at middle and outer shelf station. The vase sponge *Ircinia campana* was the second most common sponge observed at inner shelf sites, and this species occurred more frequently than the other two species at middle and outer shelf sites. Although the percentage occurrence of *I. campana* varied considerably between stations, no depth related trends were observed, and differences were not highly significant ($P > 0.01$, ANOVA) due to high intra-site variability. The loggerhead sponge *Spheciospongia vesparium* was the largest sponge observed at all stations. This species occurred less frequently than the other two sponges at inner shelf sites and was only slightly more common than *H. oculata* at deeper stations. No significant depth related patterns were detected for *S. vesparium*. Additionally, no

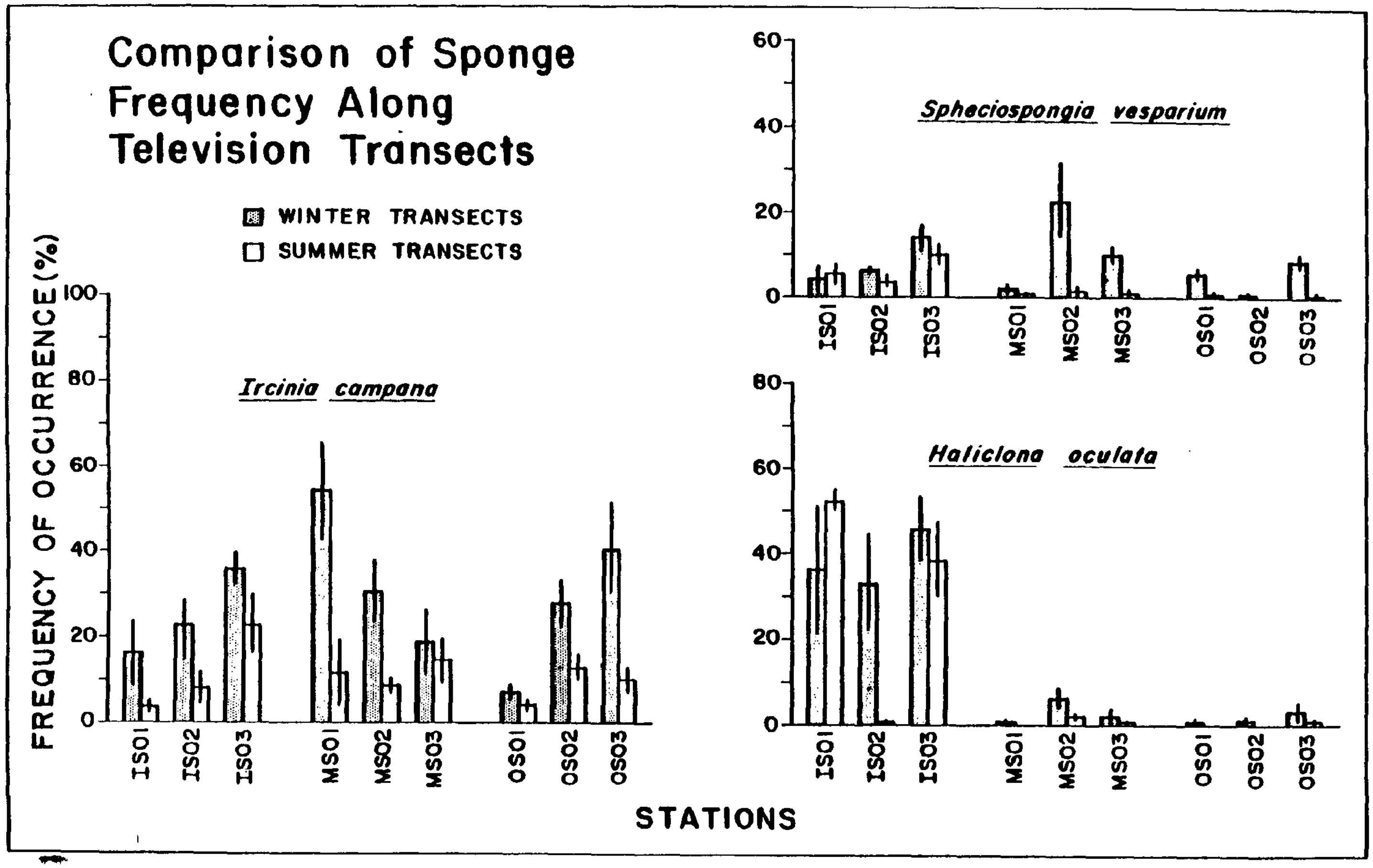


Figure 5.1. Frequency of three sponge species along television transects during winter and summer, 1980. Vertical lines within each bar indicate standard error of the mean.

consistent seasonal or latitudinal patterns were noted for any of the above species, except I. campana which was noted more frequently during winter transects at every station.

Several distributional patterns are apparent from the analysis of octocorals observed along television transects (Figure 5.2). Leptogorgia spp. occurred quite frequently at inner shelf sites during winter but was only observed at one deeper station (MS01) during this season. This genus was observed at some middle and outer shelf stations during summer, but the frequency of occurrence decreased significantly ($P < 0.002$, ANOVA) with increasing depth. Two species of this genus, L. virgulata and L. setacea, were observed on the transects; however, L. virgulata was more common than L. setacea. Data for both species were combined in Figure 5.2 due to the uncertainty of identifications made via television. The most commonly observed octocoral at inner and middle shelf stations was Titanideum frauenfeldii. Frequency of this species differed significantly between sites during both seasons ($P < 0.02$, ANOVA), but consistent depth related trends were not detected. Lophogorgia hebes and Muricea pendula (presented together in Figure 5.2) were often difficult to distinguish on the television. However, casual observations made during analysis of the tapes suggest that L. hebes was more prevalent at inner shelf sites, while M. pendula was more prevalent at middle shelf sites. Neither species was commonly observed at outer shelf sites. Frequency estimates were not significantly different between stations where these species were noted ($P > 0.2$, ANOVA). Consistent seasonal or latitudinal patterns were not detected for any of the above octocoral species.

The antipatharian whip coral, Stichopathes sp., was observed only at outer shelf stations, and frequency of occurrence was low. No seasonal or latitudinal patterns were apparent.

The only stony corals observed on television transects were the branching coral Oculina sp. and the mound coral Solenastrea hyades. Both occurred very infrequently at the study areas (Table 5.1). Highest frequency of occurrence for these species was on the inner shelf in winter. Oculina sp. was not collected at any station on the inner shelf in summer, yet it occurred at all three sites in winter, suggesting that some seasonal pattern may be present. However, any trends are noted cautiously because of the low incidences of these species. Undetermined species of algae were also observed infrequently along transects, except at station IS01 and MS01 during summer (Table 5.1). Algae were not observed at outer shelf stations during this season. No latitudinal trends were noted for stony corals or algae.

Assessment of Epibenthos by Still Camera Transects:

Data from the point count census shown in Table 5.2 represent estimates from only those quadrats which showed evidence of hard bottom. Even so, estimated biota cover observed in these quadrats was quite low at all stations, ranging from 3.7% at MS02 to 19.6% at OS02. However, these percentages may underestimate true biota cover since it was often impossible to ascertain whether biological material was under a particular point. No discernable trends were noted with respect to percentage biota cover and depth or latitude. Proportional estimates of bottom cover attributable to major taxonomic groups are presented in Table 5.2, and Table 5.3 lists all biota identified in the 0.5-m^2 quadrats at each station.

Density estimates of fauna observed in the 3-m^2 quadrats (Table 5.4) were also derived, but only from those quadrats with evidence of hard bottom. Unfortunately, the bottom was not visible in quadrats photographed at IS02

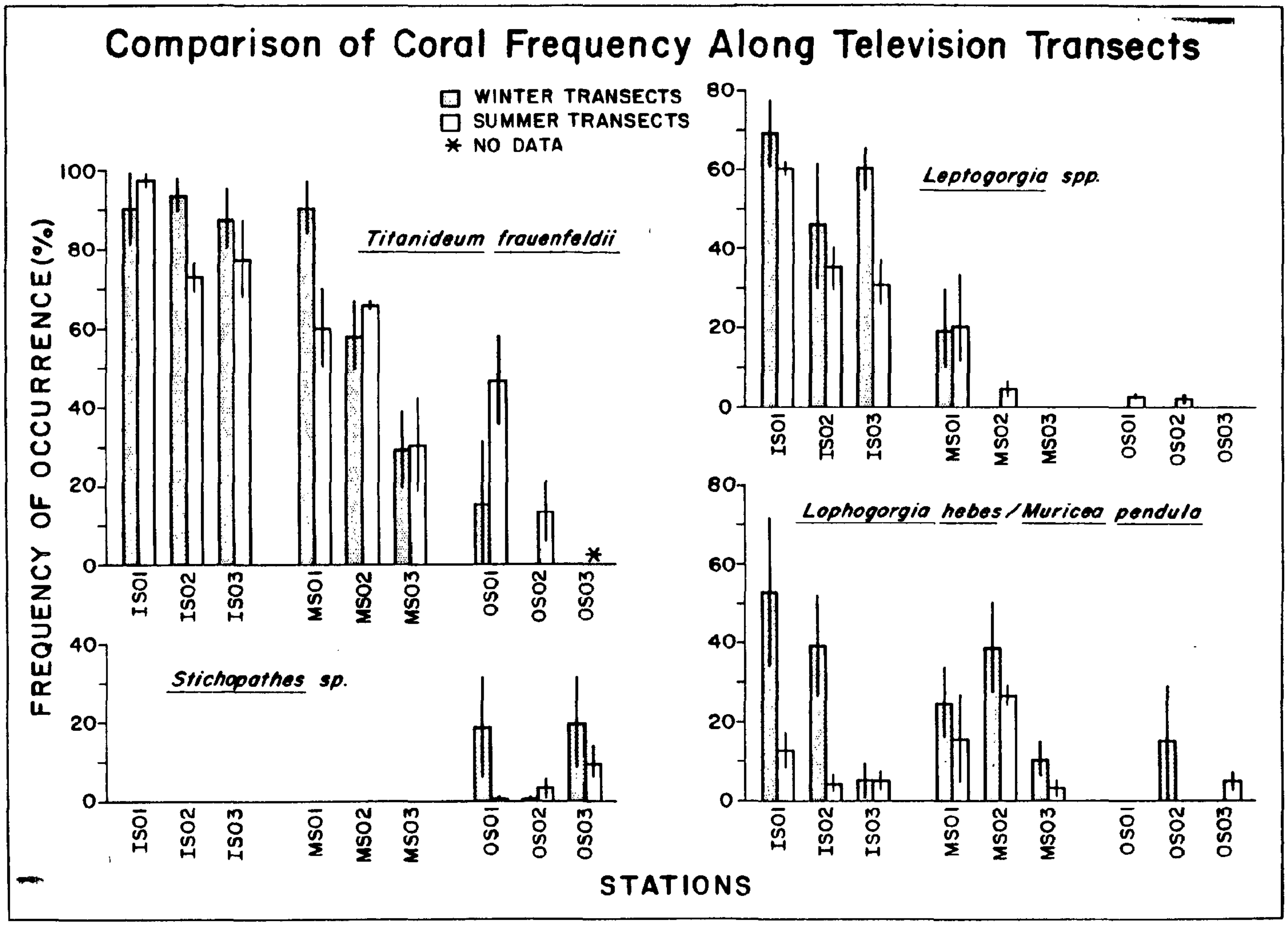


Figure 5.2. Frequency of coral along television transects during winter and summer, 1980. Vertical lines within each bar indicate standard error of the mean.

Table 5.1. Percent frequency of occurrence for the hard corals Oculina sp. and Solenastrea hyades, and for macroalgae (undetermined), based on television transect analysis at live bottom stations. Mean values ($\bar{x}$) and standard error (S.E.) are indicated.

	Oculina sp.				Solenastrea hyades				Algae			
	winter		summer		winter		summer		winter		summer	
Station	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.
IS01	2.6	1.3	0.0	0.0	11.4	7.4	9.0	4.0			69.9	12.8
IS02	1.8	0.7	0.0	0.0	0.5	0.4	0.7	0.3			13.0	4.9
IS03	11.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0			2.4	1.7
MS01	1.3	0.8	0.3	0.3	0.6	0.7	2.8	1.9			24.0	11.4
MS02	4.2	1.9	0.0	0.0	0.0	0.0	1.4	0.3	NO DATA		5.9	3.9
MS03	1.8	0.2	0.2	0.2	0.4	0.5	0.0	0.0			2.1	1.2
OS01	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0
OS02	2.0	0.8	0.6	0.6	0.0	0.0	0.0	0.0			0.0	0.0
OS03	0.0	0.0	0.6	0.6	0.0	0.0	0.3	0.3			0.0	0.0

Table 5.2. **Results from point count analysis of 0.5-m^2 photographic quadrats taken 1 m above bottom showing percent cover of selected taxa.**

Station	No. quadrats analyzed	No. points analyzed	Points with no biota No.	Points with no biota % of total	Points with biota No.	Points with biota % of total	Points with Porifera No.	Points with Porifera % of total	Points with Octocorallia No.	Points with Octocorallia % of total	Points with Scleractinia No.	Points with Scleractinia % of total	Points with Other Inverte-brates & Algae No.	Points with Other Inverte-brates & Algae % of total
IS01	23	1050	980	93.3	70	6.7	19	1.8	11	1.0	3	0.3	37	3.5
IS02	18	859	764	88.9	95	11.1	18	2.1	35	4.1	0	0	42	4.9
IS03	20	928	838	90.1	90	9.7	35	3.8	36	3.9	0	0	19	2.0
MS01	20	923	828	89.7	95	10.3	23	2.5	10	1.1	0	0	62	6.7
MS02	18	869	837	96.3	32	3.7	4	0.5	5	0.6	0	0	23	2.6
MS03	18	853	769	90.2	84	9.8	30	3.5	7	0.8	2	0.2	45	5.3
OS01	23	1104	978	88.6	126	11.4	17	1.5	3	0.2	1	0.1	105	9.5
OS02	17	775	645	83.2	130	16.8	3	0.4	2	0.1	0	0	125	16.1
OS03	15	696	624	89.7	72	10.3	3	0.4	0	0	0	0	69	9.9

Table 5.3. List of taxa identified in 0.5-m^2 photographic quadrats taken 1 m above bottom. x = organisms identified in point-count census, * = organisms noted in quadrats but not included in point-count census.

TAXA	IS01	IS02	IS03	MS01	MS02	MS03	OS01	OS02	OS03
PORIFERA									
Axinellidae undetermined	x	-	-	-	-	-	-	-	-
Chondrilla nucula	-	x	-	-	-	-	-	-	-
Cinachyra alloclada	x	-	x	x	-	x	x	-	-
Cinachyra sp.	-	x	x	-	-	-	-	-	-
Cliona sp.	x	x	x	x	*	x	x	x	x
Haliclona oculata	-	-	x	-	-	-	-	-	-
Homaxinella waltonsmithi	x	-	-	-	-	-	-	-	-
Ircinia campana	x	-	x	x	-	x	-	-	-
Ircinia felix	-	-	-	x	-	-	-	-	-
Ircinia sp.	x	x	-	x	-	x	-	-	-
Porifera undetermined	x	x	x	x	x	x	-	x	*
CNIDARIA									
HYDROZOA									
Aglaophenia sp.	x	-	-	-	-	-	-	x	*
Aglaophenia trifida	-	-	-	*	-	*	-	-	-
Hydrozoa undetermined	-	-	-	*	*	-	*	x	x
Nemertesia sp.	-	-	-	-	-	-	-	*	-
ANTHOZOA									
Antipatharia undetermined	-	-	-	-	-	-	-	-	x
Diodogorgia sp.	-	-	-	-	-	-	-	*	-
Leptogorgia virgulata	x	x	x	-	-	-	-	-	-
Lophogorgia hebes	*	x	x	-	-	*	-	-	-
Muricea pendula	-	-	-	x	-	x	-	-	-
Octocorallia undetermined	-	-	-	x	-	-	x	-	*
Telesto sp.	-	*	-	-	-	-	*	x	-
Titanideum frauenfeldii	x	x	x	x	x	x	*	*	-
Renilla reniformis	x	-	-	-	-	-	-	-	-
Actiniaria undetermined	-	-	-	-	-	-	-	-	x
Caryophyllidae	-	-	-	-	-	x	x	-	*
Balanophyllia floridana	-	-	-	-	-	-	-	*	-
Oculina sp.	x	-	-	-	-	-	-	-	-
ANNELIDA									
Phyllochaetopterus socialis	-	-	-	-	-	-	x	-	x
BRYOZOA									
Amathia sp.	-	-	-	-	-	-	-	x	-
Celleporaria magnifica	*	*	-	-	-	-	-	-	-
ECHINODERMATA									
Arbacia punctulata	x	-	-	-	-	-	-	-	-
Asteroidea undetermined	-	-	-	-	*	-	-	-	-
Astropecten articulatus	-	-	-	-	-	-	*	-	-
Astroporpa annulata	-	-	-	-	-	-	*	-	-
Echinoidea undetermined	-	-	-	-	-	-	-	x	-
Eucidaris tribuloides	-	-	-	-	-	-	-	-	x
Holothuroidea undetermined	-	-	-	-	-	*	*	-	-
Isostichopus badionotus	-	-	-	-	-	x	-	-	-
Lytechinus variegatus	-	*	-	-	-	-	-	-	-
UROCHORDATA									
Ascidiacea undetermined	x	x	-	x	-	*	-	-	-
Clavelina picta	-	-	-	x	-	-	-	-	-
Didemnidae	-	-	-	x	-	-	-	-	-
ALGAE									
Algae undetermined	-	-	-	-	-	-	x	-	-
Coralline algae	x	-	-	-	-	-	-	-	-

Table 5.4. Estimated mean ($\bar{x}$) densities and standard deviation (S.D.) of selected species observed in 3-m^2 photographic quadrats taken 3 m above bottom at inner shelf stations. Additional miscellaneous invertebrate taxa observed in quadrats are also listed.

TAXA	IS01 Quadrats analyzed	IS01 Organisms per quadrat $\bar{x}$	IS01 S.D.	IS02 Quadrats analyzed	IS02 Organisms per quadrat $\bar{x}$	IS02 S.D.	IS03 Quadrats analyzed	IS03 Organisms per quadrat $\bar{x}$	IS03 S.D.
Porifera									
Spheciospongia vesparium	12	.17	.39				13	.15	.38
Ircinia campana	12	0	-				13	.31	.75
Haliclona oculata	12	.25	.62				13	.77	1.48
Anthozoa									
Leptogorgia virgulata	10	.40	.97	NO DATA			10	0	-
Lophogorgia hebes, Muricea pendula	9	0	-				12	0	-
Stichopathes sp.	12	0	-				13	0	-
Oculina sp.	12	0	-				13	0	-
Solenastrea hyades	12	0	-				13	0	-
Echinodermata									
Arbacia sp.	11	0	-				13	.15	.38
Eucidaris tribuloides	12	0	-				13	0	-
Asteroidea undetermined	12	.08	.29				13	.15	.38
Miscellaneous Invertebrate Taxa (not counted)	Clionia sp. Titanideum frauenfeldii						Titanideum frauenfeldii Halichondria sp. Keratosa undetermined Porifera undetermined		

Size of taxa and bottom visibility determined the number of 3-m^2 quadrats analyzed.

Table 5.4 (Continued)

TAXA	MS01 Quadrats analyzed	MS01 Organisms per quadrat $\bar{x}$	MS01 S.D.	MS02 Quadrats analyzed	MS02 Organisms per quadrat $\bar{x}$	MS02 S.D.	MS03 Quadrats analyzed	MS03 Organisms per quadrat $\bar{x}$	MS03 S.D.
Porifera									
Spheciospongia vesparium	14	0	-	14	0	-	6	0	-
Ircinia campana	14	.50	.85	14	.21	.58	6	0	-
Haliclona oculata	14	0	-	14	0	-	6	0	-
Anthozoa									
Leptogorgia virgulata	14	.07	.28	14	0	-	6	0	-
Lophogorgia hebes } *Muricea pendula*	14	.07	.28	14	.57	1.28	6	0	-
Stichopathes sp.	14	0	-	14	0	-	6	0	-
Oculina sp.	13	0	-	14	0	-	6	0	-
Solenastrea hyades	14	0	-	14	0	-	6	0	-
Echinodermata									
Arbacia sp.	14	0	-	14	0	-	6	0	-
Eucidaris tribuloides	14	.07	.28	14	0	-	6	0	-
Asteroidea undetermined	14	0	-	14	0	-	6	0	-

	MS01	MS02	MS03
Miscellaneous Invertebrate Taxa (not counted)	*Clavelina gigantea* *Titanideum frauenfeldii* *Ircinia ramosa* *Filograna implexa* *Cliona* sp. Ascidiacea undetermined Porifera undetermined	*Titanideum frauenfeldii* *Filograna implexa* *Tedania* sp. *Clavelina gigantea* *Cliona* sp. Porifera undetermined	*Titanideum frauenfeldii* *Clavelina gigantea* Porifera undetermined

Size of taxa and bottom visibility determined the number of 3-m^2 quadrats analyzed.

Table 5.4 (Continued)

TAXA	OS01 Quadrats analyzed	OS01 Organisms per quadrat $\bar{x}$	OS01 S.D.	OS02 Quadrats analyzed	OS02 Organisms per quadrat $\bar{x}$	OS02 S.D.	OS03 Quadrats analyzed	OS03 Organisms per quadrat $\bar{x}$	OS03 S.D.
Porifera									
Spheciospongia vesparium				11	0	-	25	0	-
Ircinia campana				11	.27	.90	25	0	-
Haliclona oculata				11	0	-	25	0	-
Anthozoa									
Leptogorgia virgulata	NO DATA			4	0	-	23	0	-
Lophogorgia hebes } *Muricea pendula* }				3	0	-	23	0	-
Stichopathes sp.				3	0	-	24	.04	.20
Oculina sp.				8	0	-	25	0	-
Solenastrea hyades				8	0	-	25	0	-
Echinodermata									
Arbacia sp.				4	0	-	24	0	-
Eucidaris tribuloides				4	0	-	22	.55	.86
Asteroidea undetermined				4	0	-	24	.04	.20
Miscellaneous Invertebrate Taxa (not counted)				*Filograna implexa* *Cliona* sp.			*Filograna implexa* *Cliona* sp. Actiniaria undetermined		

Size of taxa and bottom visibility determined the number of 3-m^2 quadrats analyzed.

and OS01, and bottom visibility was poor at several other stations. This problem, combined with the elimination of sand bottom quadrats, greatly reduced the number of photographs analyzed from all stations except OS03.

Quantitative assessment of the 3-m^2 hard bottom quadrats indicated distributional patterns of the larger fauna which corresponded to qualitative television observations. The sponges S. vesparium and H. oculata were observed only at inner shelf sites and ranged in average density from 0.15 to 0.17 and 0.25 - 0.77 sponges per 3 m^2, respectively. Ircinia campana was observed at all depth zones, but not all stations. When present, average densities of this species ranged from 0.21 to 0.50 sponges per 3 m^2. The larger octocorals L. virgulata, L. hebes, and M. pendula were only observed in quadrats at stations IS01, MS01, and MS02. Average colony densities were low (Table 5.4). Colonies of the smaller octocoral Titanideum frauenfeldii were not counted due to difficulties in accurately assessing densities of this species from 3 m above bottom. Echinoderms counted in quadrats included Arbacia sp., Eucidaris tribuloides, and other undetermined Asteroidea. Arbacia sp. was only noted at IS03; E. tribuloides was observed at MS01 and OS03. A list of miscellaneous colonial invertebrates not counted in quadrats is presented in Table 5.4.

Qualitative Assessment of Epibenthos Captured by Dredge and Trawl Sampling:

Species Composition - A total of 407 and 357 identifiable taxa were collected by dredge and trawl, respectively, during both seasons. A list of the identified taxa, arranged phylogenetically for each station and sampling gear, is given in Appendices 8 and 9. The phyla represented by the greatest number of identified taxa in dredge collections included the Bryozoa (88 taxa) and Cnidaria (85 taxa). Porifera (67 taxa) and Bryozoa (62 taxa) were the most diverse phyla in trawl collections.

Those species which were dominant by virtue of their occurrence in 15 or more dredge collections are listed in Table 5.5. Most of these frequently occurring species were either bryozoans or cnidarians, which reaffirms their general predominance in dredge collections from the live bottom habitats. Cnidarians and bryozoans were also important among the 29 most frequently occurring species in trawl collections (Table 5.6); however, dominants collected by trawl also included several decapod and cirriped crustaceans, as well as echinoderms.

Algae were collected infrequently by both dredge and trawl. During the winter cruise, none were collected by dredge, while Ulva sp. and Cladophora sp. were present in two samples collected by trawl. During the summer, Gracilaria sp., Hymenema sp., and unidentified algae were collected in three dredge samples, while Ulva rotundata and unidentfied algae were collected in two trawl samples. Although Sargassum fluitans and S. natans were collected in winter, and S. fluitans and S. filipendula in summer, these algae are predominantly pelagic and were probably caught at or near the surface. Therefore, we did not consider these species to be part of the epibentic live-bottom community.

Percentage contribution of the major invertebrate groups collected with the dredge did not differ appreciably between inner, middle, and outer shelf stations. During both winter and summer sampling, the Bryozoa and, to a lesser extent, the Cnidaria and Porifera, dominated collections across the shelf in terms of numbers of species (Table 5.7). The Porifera were important in trawl collections only from inner shelf stations, while Cnidaria and Decapoda were important at all stations (Table 5.8). The Bryozoa were not a major

Table 5.5. Invertebrate species represented in 15 or more dredge collections from both winter and summer, 1980.

Species	Number of Occurrences
Halecium sp. (Cnidaria)	15
Lophogorgia hebes (Cnidaria)	15
Hippaliosina rostrigera (Bryozoa)	15
Aetea anguina (Bryozoa)	15
Antropora tincta (Bryozoa)	15
Campanularia hincksii (Cnidaria)	16
Clytia cylindrica (Cnidaria)	16
Dynamena cornicina (Cnidaria)	16
Hebella scandens (Cnidaria)	16
Cribrilaria radiata (Bryozoa)	16
Celleporaria albirostris (Bryozoa)	16
Reptadeonella hastingsae (Bryozoa)	16
Balanus venustus (Cirripedia)	18
Monostaechas quadridens (Cnidaria)	18
Turbicellepora dichotoma (Bryozoa)	22
Kochlorine floridana (Cirripedia)	23
Hippoporina contracta (Bryozoa)	23
Trypsostega venusta (Bryozoa)	23
Balanus trigonus (Cirripedia)	24
Conopea merrilli (Cirripedia)	24
Schizoporella cornuta (Bryozoa)	24
Titanideum frauenfeldii (Cnidaria)	25
Crisia sp. (Bryozoa)	26
Microporella ciliata (Bryozoa)	28

Table 5.6. Invertebrate species represented in 15 or more trawl collections from both winter and summer, 1980.

Species	Number of Occurrences
Cliona caribbaea (Porifera)	15
Metapenaeopsis goodei (Decapoda)	16
Astrophyton muricatum (Echinodermata)	16
Synalpheus townsendi (Decapoda)	18
Balanus venustus (Cirripedia)	18
Clytia fragilis (Cnidaria)	18
Actiniaria (Cnidaria)	18
Obelia dichotoma (Cnidaria)	19
Schizoporella cornuta (Bryozoa)	19
Synalpheus longicarpus (Decapoda)	20
Haliclona oculata (Porifera)	21
Thyroscyphus marginatus (Cnidaria)	21
Tamoya haplonema (Cnidaria)	21
Trachypenaeus constrictus (Decapoda)	23
Turbicellepora dichotoma (Bryozoa)	23
Celleporaria albirostris (Bryozoa)	23
Pilumnus sayi (Decapoda)	24
Lophogorgia hebes (Cnidaria)	24
Ophiothrix angulata (Echinodermata)	25
Monostaechas quadridens (Cnidaria)	29
Microporella ciliata (Bryozoa)	29
Pteria colymbus (Mollusca)	29
Leptogorgia virgulata (Cnidaria)	30
Arbacia punctulata (Echinodermata)	30
Spheciospongia vesparium (Porifera)	32
Conopea merrilli (Cirripedia)	32
Crisia sp. (Bryozoa)	33
Balanus trigonus (Cirripedia)	38
Styela plicata (Ascidacea)	39

Table 5.7. Numbers of species and percent of total numbers for major taxonomic groups represented in dredge collections at each station and sampling period.

Station	Season	Mollusca		Decapoda		Porifera		Cnidaria		Bryozoa		Echino-dermata		Cirripedia		Tunicata		Total
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Number
IS01	Winter	5	(5.9)	4	(4.7)	16	(18.8)	25	(29.4)	19	(22.3)	9	(10.6)	5	(6.0)	2	(2.3)	85
	Summer	2	(3.2)	3	(4.8)	8	(12.7)	14	(22.2)	19	(30.1)	6	(9.5)	5	(7.9)	6	(9.5)	63
IS02	Winter	3	(3.8)	7	(8.9)	19	(24.0)	18	(22.8)	22	(27.8)	5	(6.3)	4	(5.1)	1	(1.3)	79
	Summer	7	(8.4)	4	(4.8)	15	(18.1)	17	(20.5)	23	(27.7)	5	(6.3)	5	(6.0)	7	(8.4)	83
IS03	Winter	4	(6.0)	6	(8.9)	21	(31.3)	10	(14.9)	11	(16.4)	8	(11.9)	5	(7.5)	2	(3.0)	73
	Summer	5	(7.8)	1	(1.6)	20	(31.2)	9	(14.1)	13	(20.3)	6	(9.4)	5	(7.8)	5	(7.8)	70
MS01	Winter	1	(4.0)	0		0		11	(44.0)	8	(32.0)	2	(8.0)	3	(12.0)	0		25
	Summer	1	(1.6)	1	(1.6)	3	(4.9)	27	(42.2)	28	(43.7)	1	(1.6)	2	(3.2)	1	(1.6)	64
MS02	Winter	3	(3.1)	11	(11.2)	9	(9.2)	31	(31.6)	30	(30.6)	8	(8.2)	4	(4.1)	2	(2.0)	98
	Summer	6	(8.7)	1	(1.4)	9	(13.0)	18	(26.1)	20	(29.0)	6	(8.7)	2	(2.9)	7	(10.1)	69
MS03	Winter	1	(1.4)	0		9	(12.7)	21	(29.6)	31	(43.7)	4	(5.6)	3	(4.2)	2	(2.8)	71
	Summer	6	(6.7)	0		11	(12.2)	28	(31.1)	37	(41.1)	3	(3.3)	4	(4.4)	1	(1.1)	90
OS01	Winter	2	(3.1)	2	(3.1)	30	(46.1)	6	(9.2)	17	(26.1)	5	(7.7)	3	(4.6)	0		65
	Summer	3	(2.9)	13	(12.6)	16	(15.5)	24	(23.3)	32	(31.1)	6	(5.8)	4	(3.9)	5	(4.8)	103
OS02	Winter	4	(6.3)	8	(12.7)	3	(4.8)	16	(25.4)	26	(41.3)	4	(6.3)	2	(3.2)	0		63
	Summer	0		0		0		2	(10.0)	17	(85.0)	0		1	(5.0)	0		20
OS03	Winter	24	(12.8)	31	(16.6)	27	(14.4)	36	(19.2)	46	(24.6)	17	(9.1)	4	(2.1)	2	(1.1)	187
	Summer	0		0		0		4	(13.3)	22	(73.3)	1	(3.3)	3	(10.0)	0		30

Table 5.8. Numbers of species and percent of total number for major taxonomic groups represented in trawl collections at each station and sampling period.

Station	Season	Mollusca No.	Mollusca %	Decapoda No.	Decapoda %	Porifera No.	Porifera %	Cnidaria No.	Cnidaria %	Bryozoa No.	Bryozoa %	Echinodermata No.	Echinodermata %	Cirripedia No.	Cirripedia %	Tunicata No.	Tunicata %	Total Number
IS01	Winter	6	(7.7)	16	(20.5)	25	(32.0)	15	(19.2)	1	(1.3)	7	(9.0)	4	(5.1)	4	(5.1)	78
	Summer	2	(3.2)	12	(19.3)	13	(21.0)	14	(22.6)	6	(9.7)	3	(4.8)	4	(6.4)	8	(12.9)	62
IS02	Winter	6	(6.9)	15	(17.2)	16	(18.4)	14	(16.1)	19	(21.8)	7	(8.0)	4	(4.6)	6	(6.9)	87
	Summer	9	(10.7)	20	(23.8)	11	(13.1)	18	(21.4)	7	(8.3)	3	(3.6)	4	(4.8)	12	(14.3)	84
IS03	Winter	4	(6.0)	13	(19.4)	18	(26.9)	13	(19.4)	4	(6.0)	6	(8.9)	5	(7.5)	4	(6.0)	67
	Summer	3	(6.8)	10	(22.7)	10	(22.7)	6	(13.6)	3	(6.8)	3	(6.8)	2	(4.5)	7	(15.9)	44
MS01	Winter	2	(3.6)	20	(35.7)	8	(14.2)	12	(21.4)	8	(14.2)	4	(7.1)	1	(1.8)	1	(1.8)	56
	Summer	2	(2.2)	12	(13.5)	8	(9.0)	25	(28.1)	35	(39.3)	3	(3.4)	3	(3.4)	1	(1.1)	89
MS02	Winter	6	(6.7)	11	(12.3)	11	(12.3)	28	(31.5)	21	(23.6)	4	(4.5)	4	(4.5)	4	(4.5)	89
	Summer	1	(1.5)	9	(13.4)	4	(6.0)	24	(35.8)	23	(34.3)	2	(3.0)	2	(3.0)	2	(3.0)	67
MS03	Winter	3	(4.2)	18	(25.3)	7	(9.8)	17	(23.9)	16	(22.5)	6	(8.4)	2	(2.8)	2	(2.8)	71
	Summer	1	(2.2)	5	(11.1)	5	(11.1)	13	(28.9)	11	(24.4)	6	(13.3)	2	(4.4)	2	(4.4)	45
OS01	Winter	3	(5.9)	14	(27.4)	4	(7.8)	19	(37.2)	6	(11.8)	2	(3.9)	2	(3.9)	1	(2.0)	51
	Summer	7	(5.4)	21	(16.0)	21	(16.0)	26	(20.0)	35	(26.9)	6	(4.6)	7	(5.4)	7	(5.4)	130

constituent of trawl collections from the inner shelf.

The number of identifiable taxa (s) collected at each station also did not show any consistent pattern with regard to depth, although the most diverse assemblages sampled by dredge and trawl were collected on the outer shelf. Among dredge collections, s was greatest at OS03 in winter (Figure 5.3); whereas among trawl collections, the richest assemblage of taxa occurred in summer at OS01, which was the only outer shelf station sampled by trawl (Figure 5.4). Qualitative samples from inner and middle shelf stations did not differ appreciably with respect to species number, regardless of the sampling gear used. The Mann-Whitney U-test indicated that s was not significantly different between winter and summer sampling periods for collections made with either dredge or trawl ($P > 0.05$).

Biomass - Determinations of biomass for individual taxa indicated that the Porifera were dominant at most stations sampled during winter and summer. They constituted 77% of the total invertebrate biomass in winter dredge collections and 66% in summer dredge collections. Among trawl samples, the Porifera accounted for 93% and 84% of the total invertebrate biomass during winter and summer, respectively. For dredge collections, the only exceptions to dominance of biomass by Porifera occurred at stations MS01, OS01, and OS02 during winter; and IS02 and OS02 during summer (Table 5.9). Videotapes and underwater television indicated that station OS02 in summer was characterized by rocks and shells with very little attached epifauna. Porifera dominated by weight in all trawl collections (Table 5.10).

Analysis of variance of logarithmically transformed biomass determinations from replicated dredge samples indicated no significant difference in biomass between stations during winter ($P > 0.25$) or summer ($P > 0.50$). However, there were significant differences between stations in biomass of trawl collections (winter, $P < 0.01$; summer, $P < 0.01$). In winter, average biomass was greatest at station IS03 ($\bar{x} = 105.25$ kg) and lowest at station OS01 ($\bar{x} = 0.73$ kg). In summer, average biomass was highest again at an inner shelf station, IS02 ($\bar{x} = 41.09$ kg) and was lowest at MS02 ($\bar{x} = 1.06$ kg). No significant differences were noted in logarithmically transformed biomass determinations between winter and summer using either dredge ($P > 0.50$, t-test) or trawl data ($P > 0.20$, t-test).

Species Assemblages and Distributional Patterns: Dredge Collections - Normal cluster analysis indicated that stations sampled by dredge were grouped fairly distinctly according to their bathymetric location on the continental shelf. The 19 dredge collections obtained during winter were classified into four station groups (Figure 5.5). These station groups corresponded to inner shelf collections (group 1), middle shelf collections (groups 2 and 3), and outer shelf collections (group 4). Collections from inner and outer shelf stations were strongly similar within their respective station groups; however, collections from middle shelf habitats formed two separate groups, with those from station MS01 differing in species composition from collections at stations MS02 and MS03. An examination of the invertebrate species collected at station MS01 revealed that fewer species were found there than at the other middle shelf stations, probably because of poor collections in both replicate dredge tows. Based on the structural hierarchy of the dendrogram, it is apparent that middle and outer stations were more similar in faunal composition to each other than to inner stations.

Summer dredge collections again grouped into three agglomerations corresponding to inner, middle, and outer shelf stations (Figure 5.6). In

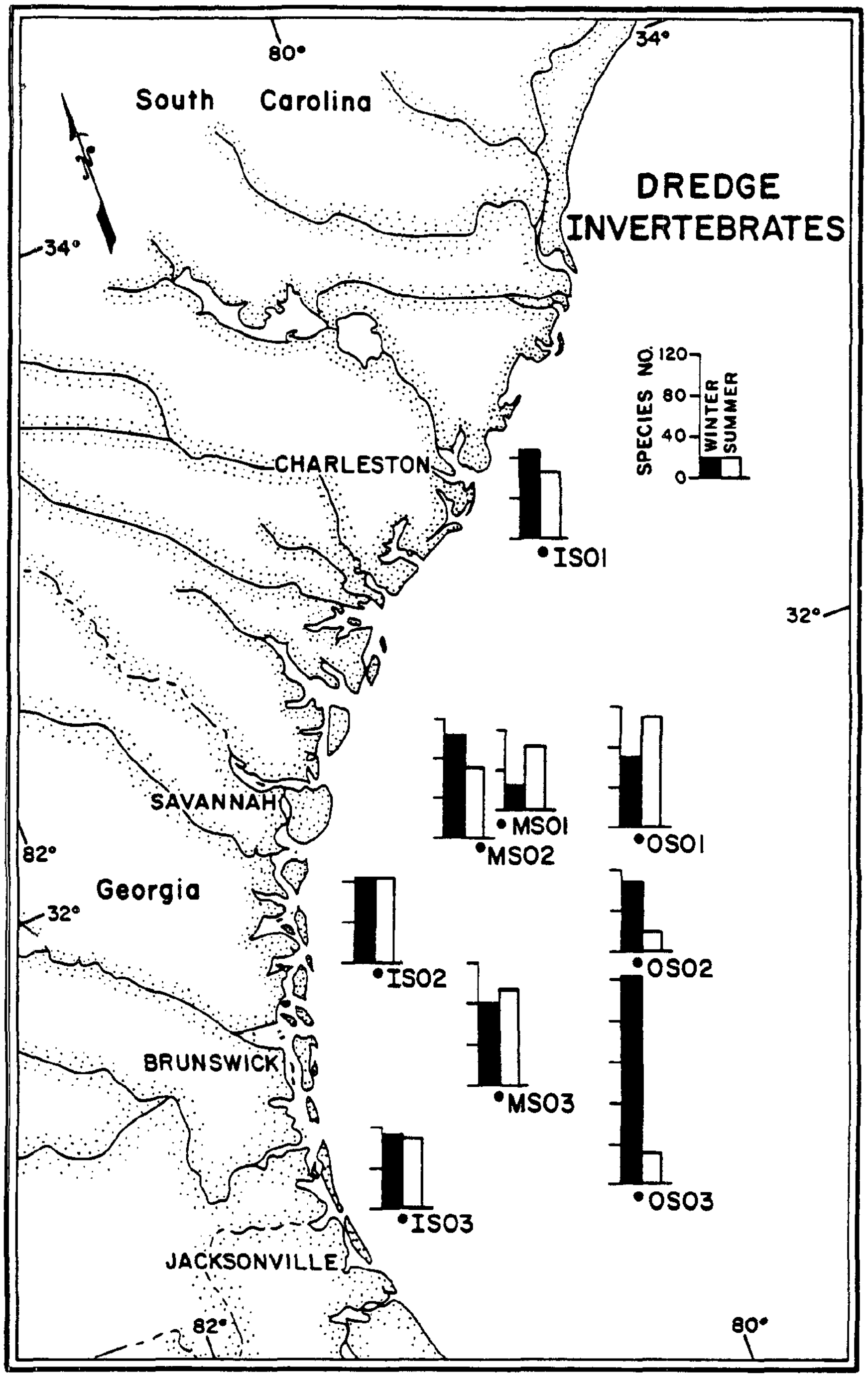


Figure 5.3. Number of species collected at each station by dredge during winter and summer, 1980.

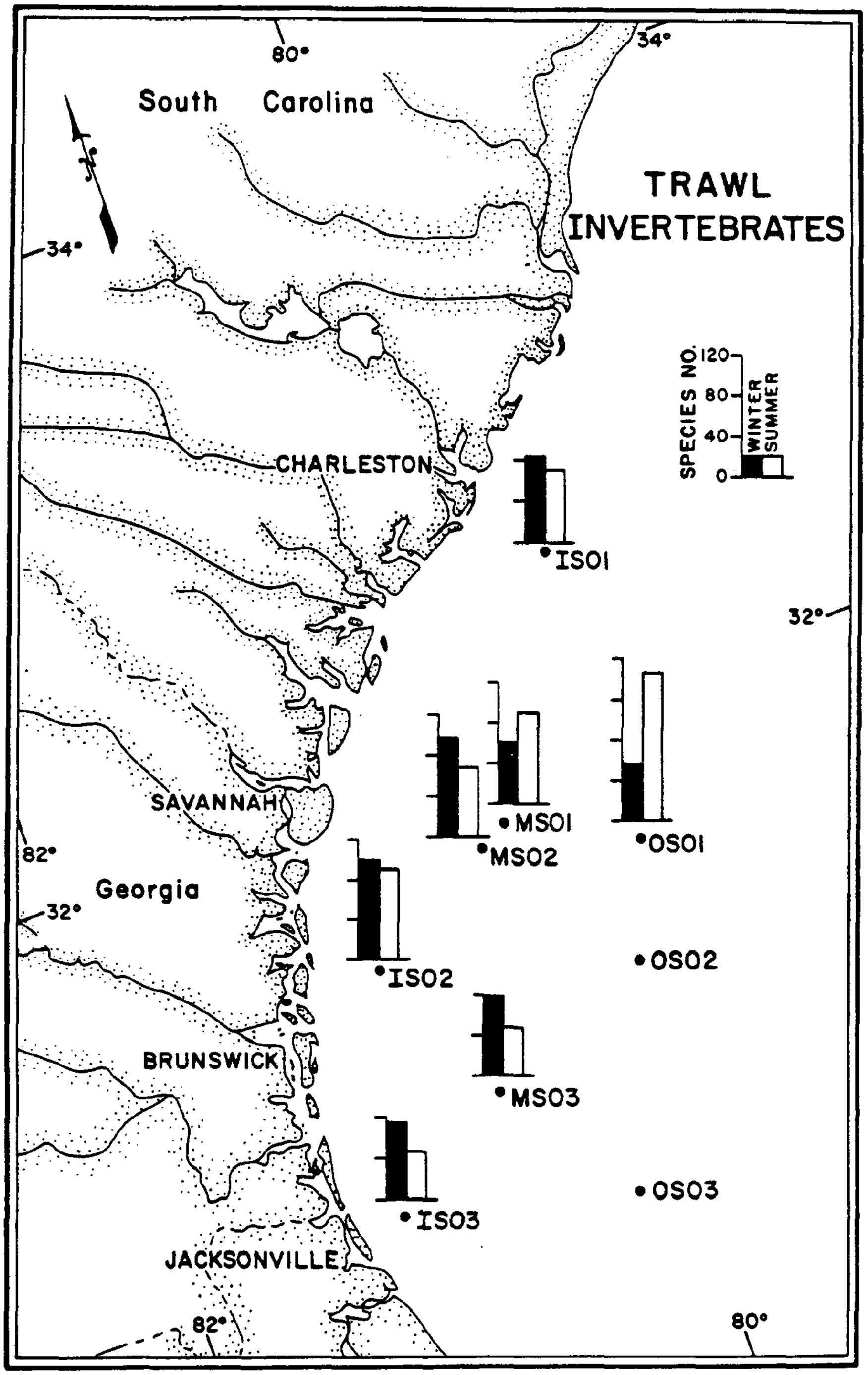


Figure 5.4. Number of species collected by trawl at each station during winter and summer, 1980.

Table 5.9. Percent of the total biomass for major taxonomic groups in dredge collections for each station and sampling period. The mean ($\bar{x}$) and standard deviation (S.D.) of the total biomass, and the number of samples (n) for which biomass measurements were taken, are indicated.

	IS01	IS02	IS03	MS01	MS02	MS03	OS01	OS02	OS03
					WINTER				
Porifera	82%	36%	64%	0%	93%	82%	2%	0%	62%
Anthozoa	5%	13%	12%	10%	3%	0%	2%	0%	0%
Mollusca	2%	4%	5%	0%	0%	0%	70%	0%	28%
Decapoda	0%	0%	0%	0%	0%	0%	0%	0%	2%
Echinodermata	9%	10%	13%	90%	<1%	15%	20%	2%	6%
Ascidiacea	0%	33%	4%	0%	2%	<1%	0%	0%	3%
Other Invertebrata	2%	4%	1%	0%	1%	3%	7%	98%	0%
Total Biomass (kg) $\bar{x}$	8.03	4.28	3.73	0.10	14.85	6.07	0.46	0.92	3.82
S.D.	6.12	1.23	2.93	0.04	24.47	5.72	0.55	1.54	4.66
n	2	2	2	2	3	2	2	3	2
					SUMMER				
Porifera	45%	30%	85%	62%	78%	87%	55%	-	0%
Anthozoa	24%	4%	5%	3%	4%	7%	35%	-	0%
Mollusca	16%	0%	0%	0%	0%	1%	<1%	-	0%
Decapoda	0%	<1%	<1%	13%	<1%	0%	1%	-	0%
Echinodermata	5%	1%	7%	<1%	9%	2%	7%	-	100%
Ascidiacea	7%	65%	3%	10%	2%	0%	0%	-	0%
Other Invertebrata	3%	<1%	<1%	12%	4%	3%	<1%	-	0%
Total Biomass (kg) $\bar{x}$	2.81	12.10	12.36	1.29	5.71	9.66	1.65	-	0.04
S.D.	3.68	16.11	0.17	0.65	7.53	12.22	0.79	-	-
n	2	2	2	3	2	2	2	2	1

Table 5.10. Percent of the total biomass for major taxonomic groups in trawl collections for each station and sampling period. The mean ($\bar{x}$) and standard deviation (S.D.) of the total biomass, and the number of samples (n) for which biomass measurements were taken, are indicated.

		IS01	IS02	IS03	MS01	MS02	MS03	OS01
					WINTER			
Porifera		87%	69%	99%	80%	96%	94%	71%
Anthozoa		2%	2%	<1%	0%	2%	4%	3%
Mollusca		<1%	0%	<1%	0%	<1%	0%	0%
Decapoda		<1%	<1%	<1%	1%	0%	<1%	12%
Echinodermata		3%	<1%	<1%	3%	<1%	<1%	0%
Ascidiacea		6%	27%	<1%	1%	<1%	<1%	0%
Other Invertebrata		2%	2%	<1%	14%	<1%	<1%	14%
Total Biomass (kg)	$\bar{x}$	10.34	26.17	105.25	6.35	31.37	38.37	0.73
	S.D.	6.23	23.48	119.54	9.88	43.64	37.11	1.22
	n	6	6	6	6	6	6	6
					SUMMER			
Porifera		92%	75%	96%	51%	45%	96%	64%
Anthozoa		1%	1%	1%	<1%	16%	0%	1%
Mollusca		<1%	1%	<1%	1%	<1%	0%	<1%
Decapoda		<1%	<1%	<1%	27%	13%	<1%	5%
Echinodermata		<1%	<1%	<1%	1%	16%	<1%	20%
Ascidiacea		6%	18%	2%	4%	5%	<1%	0%
Other Invertebrata		<1%	5%	<1%	16%	5%	3%	10%
Total Biomass (kg)	$\bar{x}$	13.27	41.09	35.54	5.39	1.06	18.60	4.96
	S.D.	12.02	20.69	47.22	4.54	1.31	27.86	3.03
	n	6	6	5	6	6	6	6

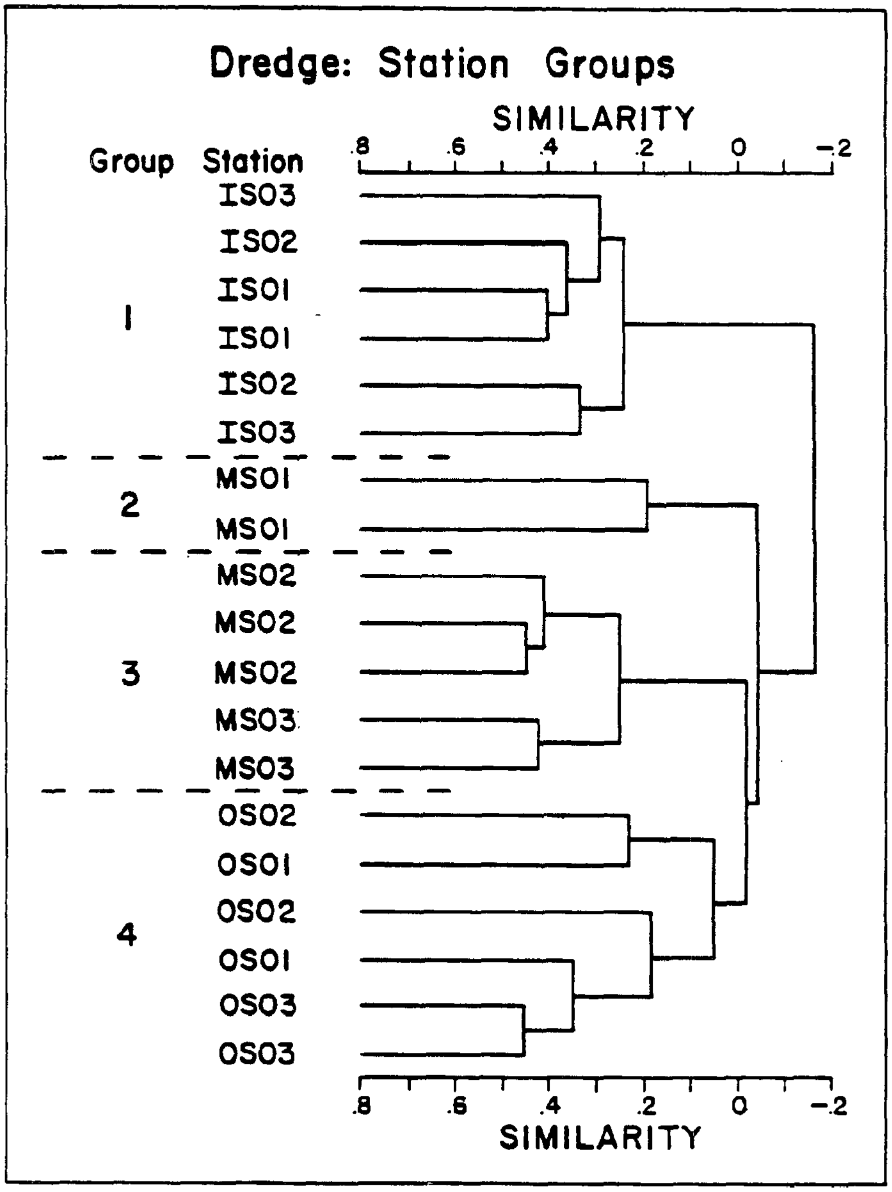


Figure 5.5. Normal cluster dendrogram of winter dredge collections indicating station groups formed using the Jaccard similarity coefficient and flexible sorting.

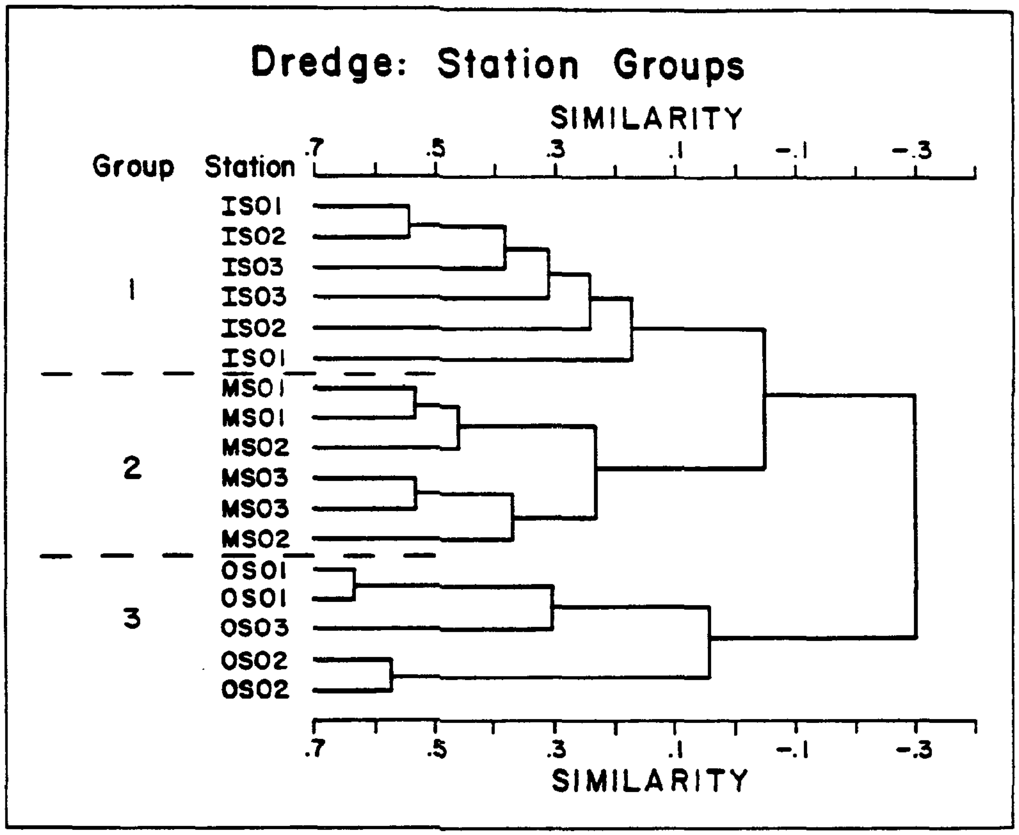


Figure 5.6. Normal cluster dendrogram of summer dredge collections indicating station groups formed using the Jaccard similarity coefficient and flexible sorting.

contrast to the dendrogram generated from winter dredge data, this cluster hierarchy indicated that faunal composition of all collections from the middle shelf were more similar to the inner shelf collections than to those from the outer shelf.

The results of reciprocal averaging ordination basically confirmed the zonation patterns indicated by cluster analysis. For winter data, axis 1, which accounted for 16.57% of the total variance, separated inner shelf (i.e., members of normal cluster group 1) from middle and outer shelf stations (i.e., members of cluster groups 3 and 4, respectively)(Figure 5.7). As in cluster analysis, the greater similarity in faunal composition between middle and outer shelf collections (versus middle and inner shelf collections) is reflected in the greater proximity of the former two groups and in their mutual separation from inner shelf collections on axis 1 (Figure 5.7). Axis 2 accounted for 11.12% of the total variance and separated outer shelf (group 4) collections from middle shelf (groups 2 and 3) collections. Inner shelf collections were generally intermediate in position along axis 2, but they spanned a wide range of values. Unlike cluster analysis, ordination results indicated that collections from MS01 were not sufficiently different from other middle shelf collections to justify separation. This discrepancy in results of the two analyses indicates the greater space dilating properties of clustering techniques such as flexible sorting as compared with reciprocal averaging ordination.

Ordination of summer dredge data indicated a relatively discrete grouping of collections belonging to each of the three shelf areas in ordination space and conformed with the results of normal cluster analysis. Axis 1, which accounted for 19.34% of the total variance, separated outer shelf collections (i.e., members of cluster group 3) from inner and middle shelf collections (i.e., members of cluster groups 1 and 2, respectively)(Figure 5.8). Axis 2, which explained 14.35% of the total variance, was most successful in separating inner shelf collections from middle and outer shelf collections (Figure 5.8). As demonstrated by cluster analysis, the middle shelf samples taken in the summer were more similar to inner shelf than to outer shelf samples.

Inverse cluster analysis of the 122 most frequently occurring species collected in winter dredge samples formed ten species groups (Table 5.11). The distribution of species within these groups was compared in nodal diagrams to determine their relative constancy and fidelity to collections at each station (Figure 5.9).

The hierarchy of species groups formed by inverse analysis and shown in the nodal diagram indicated that species in groups A and B were least similar to other groups in terms of their distributional patterns. These species were primarily associated with collections from the outer continental shelf and exhibited high constancy at those stations. Furthermore, species in these groups were primarily restricted to outer shelf station OS03. Species in groups A and B which were collected only at outer shelf stations during winter included the bryozoans Plagioecia dispar, Floridina antiqua, and Membraniporella aragoi; the hydroids Salacia desmoides, Halecium tenellum, and Dynamena dalmasi; the decapod crustacean Mithrax acuticornis; and the echinoderms Narcissia trigonaria and Astroporpa annulata.

Species in group C were restricted in their distribution and were highly constant only at inner shelf stations. All species in this group, except the tunicate Pyura vittata and the mollusk Simnia acicularis, were collected at all three inner shelf stations.

Other species groups formed by our analysis of winter dredge collections

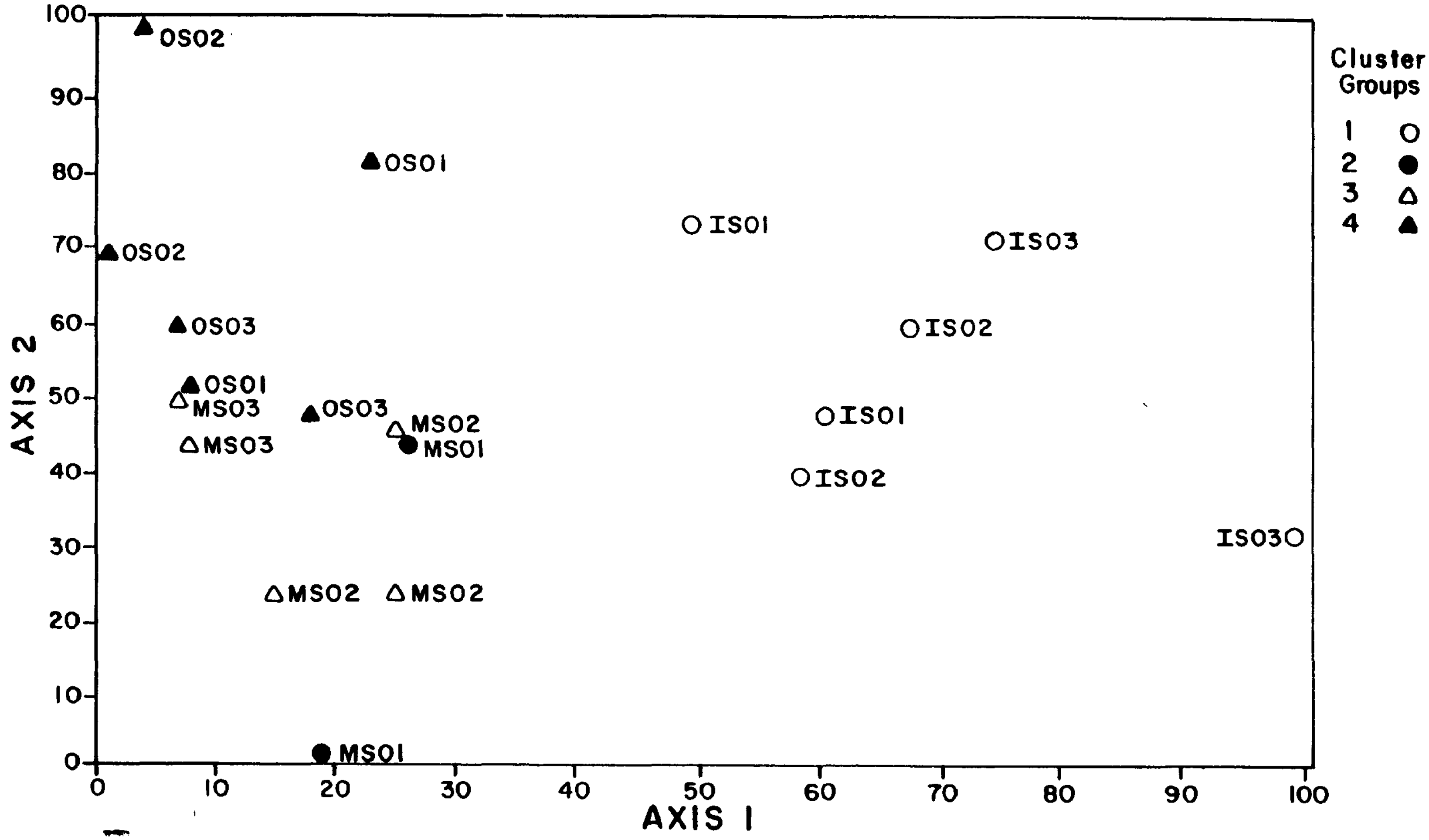


Figure 5.7. Results of reciprocal averaging ordination showing orientation of winter dredge collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

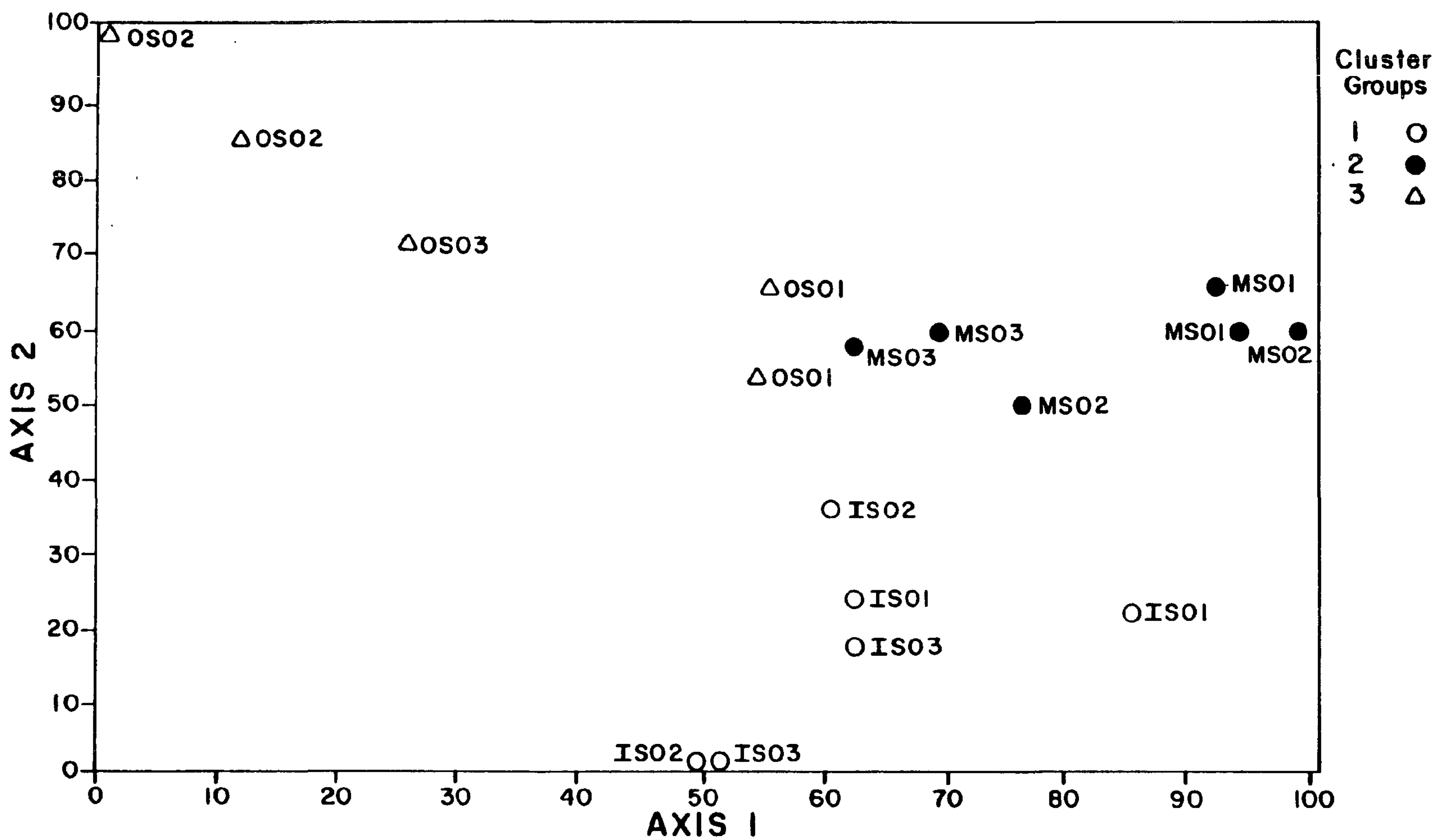


Figure 5.8. Results of reciprocal averaging ordination showing orientation of summer dredge collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

Table 5.11. Species groups resulting from numerical classification of data from samples collected by dredge during winter and summer, 1980. (Ar = Arthropoda; Bry = Bryozoa; Ch = Chordata; Cn = Cnidaria; Ech = Echinodermata; Mo = Mollusca; Po = Porifera).

Winter 1980

Group A

Plagioecia dispar (Bry)
Floridana antiqua (Bry)
Smittipora levinseni (Bry)
Stylopoma informata (Bry)
Cleidochasma porcellanum (Bry)
Cribrilaria floridana (Bry)
Microporella umbracula (Bry)

Group B

Salacia desmoides (Cn)
Mithrax acuticornis (Ar)
Pachycheles rugimanus (Ar)
Halecium tenellum (Cn)
Dynamena dalmasi (Cn)
Narcissia trigonaria (Ech)
Cycloperiella rubra (Bry)
Parasmittina spathulata (Bry)
Stephanoscyphus sp. (Cn)
Astroporpa annulata (Ech)
Membraniporella aragoi (Bry)
Scypha barbadensis (Po)
Ophiostigma isacanthum (Ech)
Eucidaris tribuloides (Ech)
Aglaophenia latecarinata (Cn)
Halopteris sp. (Cn)

Group C

Encope michelini (Ech)
Pyura vittata (Ch)
Simnia acicularis (?) (Mo)
Homaxinella waltonsmithi (Po)
Oculina arbuscula (Cn)
Leptogorgia virgulata (Cn)
Arbacia punctulata (Ech)
Spheciospongia vesparium (Po)
Lytechinus variegatus (Ech)

Group D

Myrastria fibrosa (Po)
Synalpheus minus (Ar)
Cliona caribbaea (Po)
Ircinia ramosa (Po)
Clavelina picta (?) (Ch)

Group E

Haliclona oculata (Po)
Conopea galeata (Ar)
Membranipora tenuis (Bry)
Hadromerida A (Po)
Ciocalapata gibbsi (Po)
Halichondria bowerbanki (Po)
Pilumnus sayi (Ar)
Leodia sexiesperforata (Ech)
Ocnus pygmaeus (Ech)
Balanus venustus (Ar)

Summer 1980

Group A

Eucidaris tribuloides (Ech)
Smittina smittiella (Bry)
Filellum serratum (Cn)
Diaperoecia floridana (Bry)
Smittipora levinseni (Bry)
Cleidochasma porcellanum (Bry)
Poecilosclerida H (Po)
Halecium tenellum (Cn)

Group B

Stylopoma informata (Bry)
Cycloperiella rubra (Bry)
Floridina antiqua (Bry)
Kochlorine floridana (Ar)
Cribrilaria radiata (Bry)
Parasmittina spathulata (Bry)

Group C

Membranipora tenuis (Bry)
Parellisina curvirostris (Bry)
Hippaliosina rostrigera (Bry)
Nolella gigantea (Bry)
Clytia cylindrica (Cn)
Antropora tincta (Bry)
Ircinia strobilina (Po)
Amathia distans (Bry)
Bimeria humilis (Cn)
Amathia alternata (Bry)
Aglaophenia trifida (Cn)
Telesto sanguinea (Cn)

Group D

Hebella venusta (Cn)
Chaperia sp. (Cn)
Aglaophenia allmani (Cn)
Scandia mutabilis (Cn)
Monostaechas quadridens (Cn)
Thyroscyphus marginatus (Cn)
Aglaophenia latecarinata (Cn)
Hebella scandens (Cn)
Aeverrillia setigera (Bry)
Aetea anguina (Bry)
Synthecium tubitheca (Cn)
Nellia tenella (Bry)
Celleporaria magnifica (Bry)
Schizoporella floridana (Bry)
Campanularia hincksii (Cn)
Sertularia marginata (Cn)
Hincksella cylindrica (Cn)
Keratosa D (Po)

Group E

Conopea merrilli (Ar)
Microporella ciliata (Bry)
Titanideum frauenfeldii (Cn)

Table 5.11 (Continued)

Winter 1980

Titanideum frauenfeldii (Cn)
Epizoanthus americanus (Cn)
Telesto fruticulosa (Cn)
Lophogorgia hebes (Cn)
Telesto sanguinea (Cn)
Antropora tincta (Bry)
Thalysias juniperina (Po)
Scrupocellaria regularis (Bry)

Group F

Astropecten duplicatus (Ech)
Nolella gigantea (Bry)
Scandia mutabilis (Cn)
Aplousina gigantea (Bry)
Phylactella aviculifera (Bry)
Cribrilaria radiata (Bry)
Clytia fragilis (Cn)
Hippaliosina rostrigera (Bry)
Reptadeonella hastingsae (Bry)
Sertularia plumulifera (Cn)
Schizoporella cornuta (Bry)
Conopea merrilli (Ar)
Obelia dichotoma (Cn)
Balanus trigonus (Ar)

Group G

Ircinia campana (Po)
Bugula rylandi (Bry)
Hebella venusta (Cn)
Aglaophenia trifida (Cn)
Ectopleura dumortieri (Cn)
Bugula sp. (Bry)
Dynamena cornicina (Cn)
Crisia sp. (Bry)
Parasmittina nitida (Bry)
Aglaophenia sp. (Cn)
Celleporaria magnifica (Bry)
Petraliella bisinuata (Bry)
Monostaechas quadridens (Cn)
Sertularia marginata (Cn)
Bimeria humilis (Cn)
Thesea sp. (Cn)
Schizoporella floridana (Bry)
Parellisina curvirostris (Bry)

Group H

Ircinia felix (Po)
Megalobrachium soriatum (Ar)
Styela plicata (Ch)
Pteria colymbus (Mo)
Sertularella conica (Cn)
Bugula fulva (Bry)
Aplysina fistularis (Po)
Luidia alternata (Ech)

Group I

Kochlorine floridana (Ar)
Hippoporina contracta (Bry)
Dynamena quadridentata (Cn)
Smittina smittiella (Bry)

Summer 1980

Turbicellepora dichotoma (Bry)
Schizoporella cornuta (Bry)
Balanus trigonus (Ar)
Hippoporina contracta (Bry)
Crisia sp. (Bry)
Celleporaria albirostris (Bry)
Arca zebra (Mo)
Ircinia campana (Po)
Thesea sp. (Cn)
Petraliella bisinuata (Bry)
Aplousina gigantea (Bry)
Ctenostomata (Bry)
Reptadeonella hastingsae (Bry)
Trypsostega venusta (Bry)
Stephanoscyphus sp. (Cn)

Group F

Halichondria bowerbanki (Po)
Ophiothrix angulata (Ech)
Spheciospongia vesparium (Po)
Phylactella aviculifera (Bry)
Cribrilaria floridana (Bry)
Homaxinella waltonsmithi (Po)
Scrupocellaria regularis (Bry)
Pilumnus sayi (Ar)
Sertularella gayi (Cn)
Bellulopora bellula (Bry)
Dynamena quadridentata (Cn)

Group G

Epizoanthus americanus (Cn)
Modiolus americanus (Mo)
Arbacia punctulata (Ech)
Distaplia bermudensis (Ch)
Tedania ignis (Po)
Pteria colymbus (Mo)
Eudendrium ramosum (Cn)
Ocnus pygmaeus (Ech)
Molgula occidentalis (Ch)
Styela plicata (Ch)
Leptogorgia virgulata (Cn)
Balanus venustus (Ar)

Group H

Poecilosclerida A (Po)
Microporella umbracula (Bry)
Astropecten duplicatus (Ech)
Dynamena cornicina (Cn)
Lophogorgia hebes (Cn)
Aplysina fistularis (Po)
Luidia alternata (Ech)
Cliona caribbaea (Po)
Astropecten comptus (Ech)
Poecilosclerida B (Po)
Crepidula aculeata (Mo)
Hemectyon pearsei (Po)
Haliclona oculata (Po)
Didemnum candidum (Ch)
Pseudomedaeus agassizii (Ar)
Echinaster serpentarius (Ech)

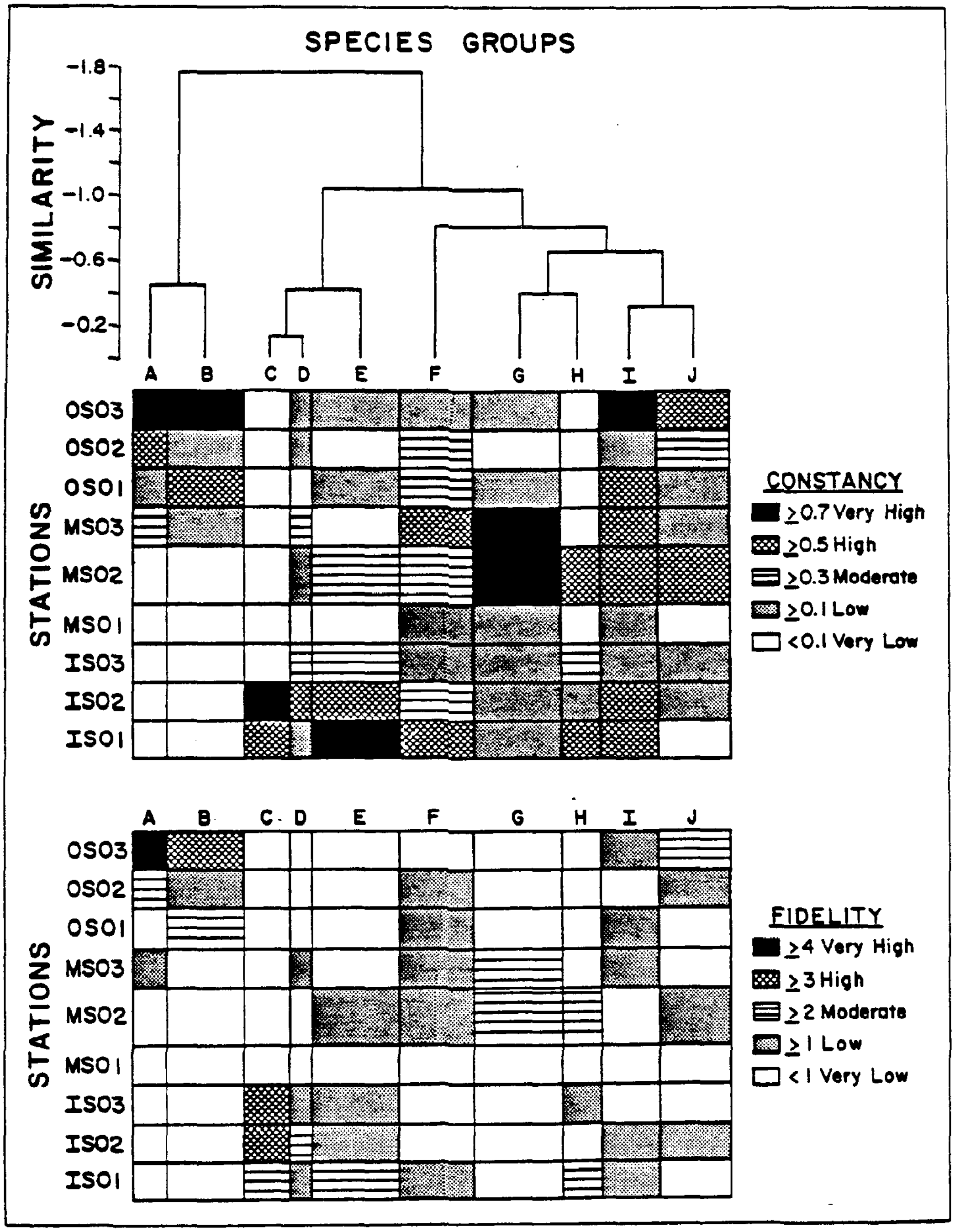


Figure 5.9. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on winter dredge collections.

were fairly ubiquitous in their distribution on the continental shelf, and thus displayed little faithfulness to any station. Species forming groups D and E were most consistently encountered at inner shelf stations but were only moderately faithful there. Groups F and H contained species which were highly constant at both an inner and middle shelf station but were not restricted to either station. Species in group G were very common in collections from MS02 and MS03 but displayed only moderate fidelity to these stations. Species in group I were the most ubiquitous, being consistently encountered at inner, middle, and outer stations. Group J contained species which were also represented at several stations in each depth zone but only displayed high constancy at stations MS02 and OS03.

The inverse cluster analysis of the 101 most frequently occurring species collected in summer dredge sampling yielded 8 species groups (Table 5.11). The nodal constancy and fidelity diagrams (Figure 5.10) indicate that these species assemblages can be described in terms of their constancy and fidelity at inner, middle, and outer shelf live bottom habitats.

Those species which were most characteristic of outer shelf stations were found in group A. Species in this group were highly constant and faithful to stations OS01 and OS03, although they were highly constant at station MS03, also. None of the species in this group was collected at station OS02. Species which comprised group B were collected at all outer shelf stations and displayed very high constancy there. Most species in this group, except the bryozoan Cycloperiella rubra, were also collected at either inner or middle stations where they were common at stations MS03 and IS02. The somewhat ubiquitous distribution of members of this group is reflected by their moderate to low fidelity values for these stations. Species forming group C were also fairly ubiquitous, although they were most commonly encountered in collections from OS01.

Group D consisted of species which were highly constant at middle shelf stations but were only moderately restricted to them. Species in this group which were collected only at middle shelf stations during summer included the hydroids Hebella venusta, Aglaophenia allmani, A. latecarinata, Thyroscyphus marginatus, Synthecium tubitheca, Sertularia marginata, and Hincksella cylindrica; and the bryozoans Chaperia sp. and Nellia tenella. The constituent species of group E were also common at middle shelf stations and were generally much more ubiquitous than any other species group. They were particularly common at stations IS01, IS03, MS01, MS02, MS03, and OS01. Species in group H were infrequently encountered at several stations and displayed high constancy only for station MS02.

Although some constituent species were fairly ubiquitous, members of groups F and G were primarily characteristic of inner shelf stations. Species in these groups which were collected only at inner shelf stations during summer included the sponge Homaxinella waltonsmithi, the bryozoan Scrupocellaria regularis, the cnidarians Epizoanthus americanus and Eudendrium ramosum, the echinodrems Arbacia punctulata and Ocnus pygmaeus, and the mollusk Modiolus americanus.

The seasonal comparison of selected members of species groups is represented by the matrix shown in Figure 5.11. This presentation indicates that most species associations defined by inverse cluster analysis were not consistent between winter and summer. However, several species did occur together in cluster groups formed by analysis of data collected during both sampling periods. Notable co-occurrences during both winter and summer sampling included the ubiquitous bryozoan species Schizoporella cornuta and Reptadeonella hastingsae with the barnacles Conopea merrilli and Balanus

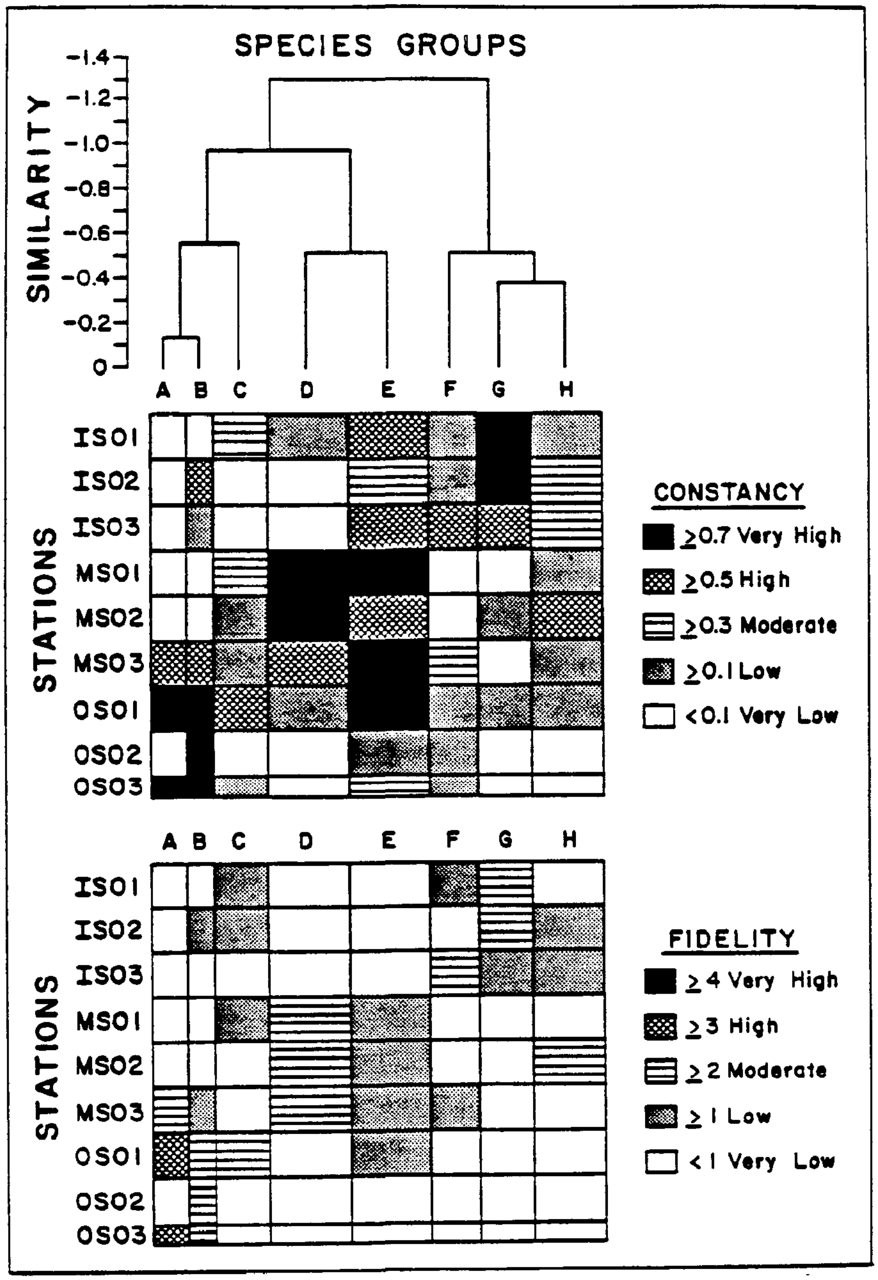


Figure 5.10. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on summer dredge collections.

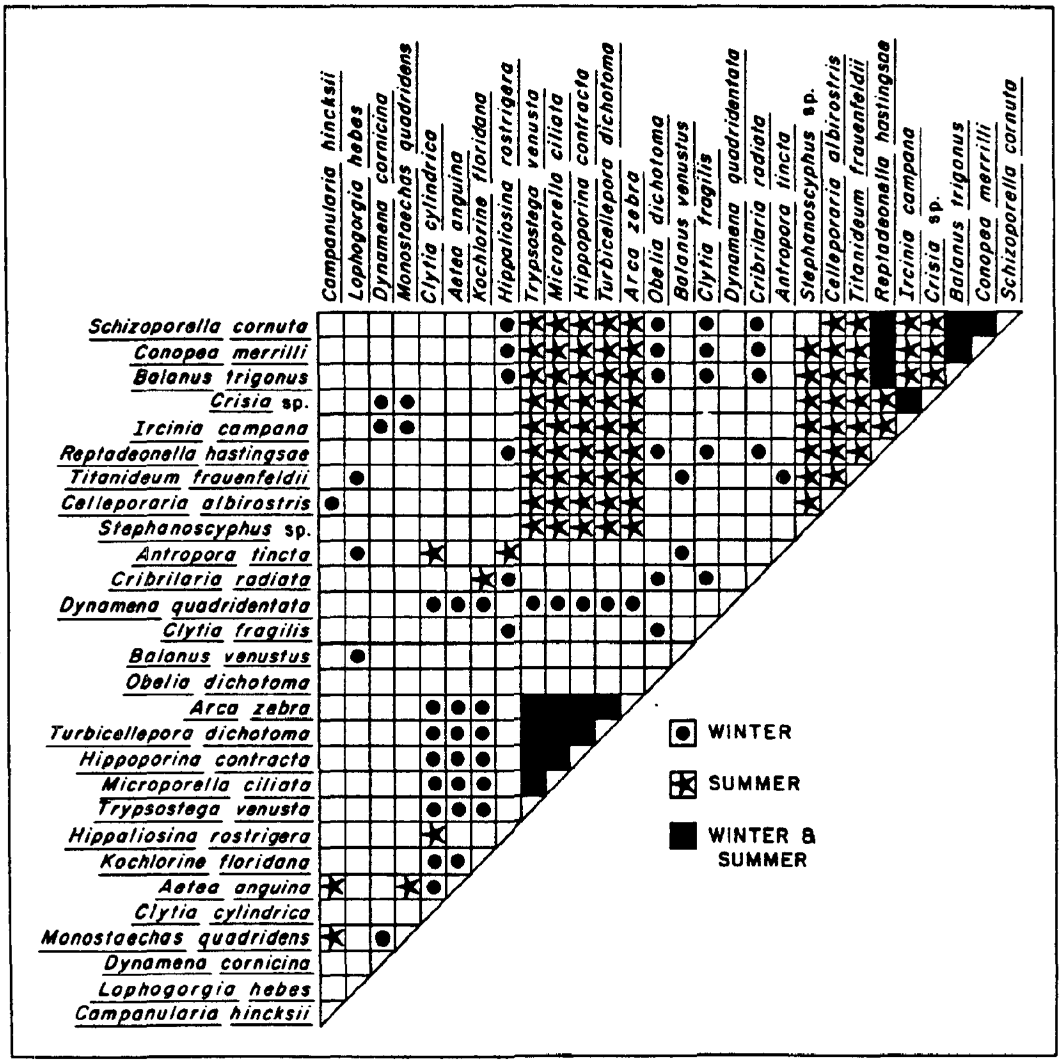


Figure 5.11. Matrix showing co-occurrence of species within the same group formed by inverse cluster analysis of dredge collections from winter sampling only, summer sampling only, or both winter and summer sampling. Species were selected for inclusion in the matrix if they occurred at $\geq$ 50% of the collections from at least six stations sampled by dredge.

trigonus. The bryozoan Crisia sp. and the sponge Ircinia campana, which were also ubiquitous, were classified in the same species group during both seasons. Other winter and summer co-occurrences included the mollusk Arca zebra and the bryozoans Turbicellepora dichotoma, Hippoporina contracta, and Microporella ciliata.

Species Assemblages and Distributional Patterns: Trawl Collections - Normal analysis of the 42 winter trawl collections produced six station groups (Figure 5.12). Groups 1 and 2 consisted of collections made at inner shelf stations; however, the faunal composition at station IS02 was sufficiently different from that of the other inner shelf stations to justify formation of a separate group. Group 3 consisted of collections from middle shelf stations, and its constituent species were similar to those of three collections from station OS01 (group 4). The other collections from station OS01 formed station group 6. These collections were most similar to others taken at middle shelf stations found in group 5. The formation of totally separate groups (4 and 6) containing collections from the outer shelf was due to their having only two species in common. Similarly, not all collections from middle shelf stations shared the same species.

Cluster analysis classified summer trawl collections into four groups (Figure 5.13) which again corresponded, for the most part, to bathymetric location on the continental shelf. Group 1 consisted of collections from OS01. Groups 2 and 3 largely comprised collections from middle shelf stations; however, two collections from station IS03 were apparently more similar in faunal composition to middle shelf samples than to the other inner shelf collections and were also placed in group 3. All of the remaining collections from inner shelf stations composed group 4, which was not similar in faunal composition to any other station group.

Reciprocal averaging ordination of winter trawl collections revealed a more homogeneous zonation pattern across the shelf than did cluster analysis. Axis 1, which accounted for 11.57% of the total eigenvalue, was most successful in separating members of cluster groups 5 and 6 from all other collections (Figure 5.14). These two groups are comprised of middle and outer shelf samples which shared species. Axis 2 explained an additional 8.45% of the total variance. In general, middle and outer shelf stations had intermediate to low scores on axis 2, while inner shelf stations had intermediate to high scores on axis 2. The degree of overlap among members of all cluster groups on axis 2 is considerable, however, suggesting that the faunal assemblages characteristic of each area are more similar to one another than cluster analysis would seem to indicate.

The ordination of summer trawl data indicated several misclassifications of collections by cluster analysis. Axis 1, which explained 15.65% of the total variance, successfully separated inner, middle, and outer shelf collections from one another, with the exception of a single middle shelf sample (MS03). This sample appeared to be more similar in faunal composition to trawl collections from the outer shelf than it was to other middle shelf collections (Figure 5.15). This affiliation is not supported, however, by the results of cluster analysis which grouped this collection with other middle shelf samples in site group 3. The ordination results further indicate that two other collections (both from station IS03) were also misclassified. These samples grouped much more closely in the two dimensional ordination space with members of inner shelf site group 4 than they did with other constituents of site group 3, the group to which these two collections were originally assigned by

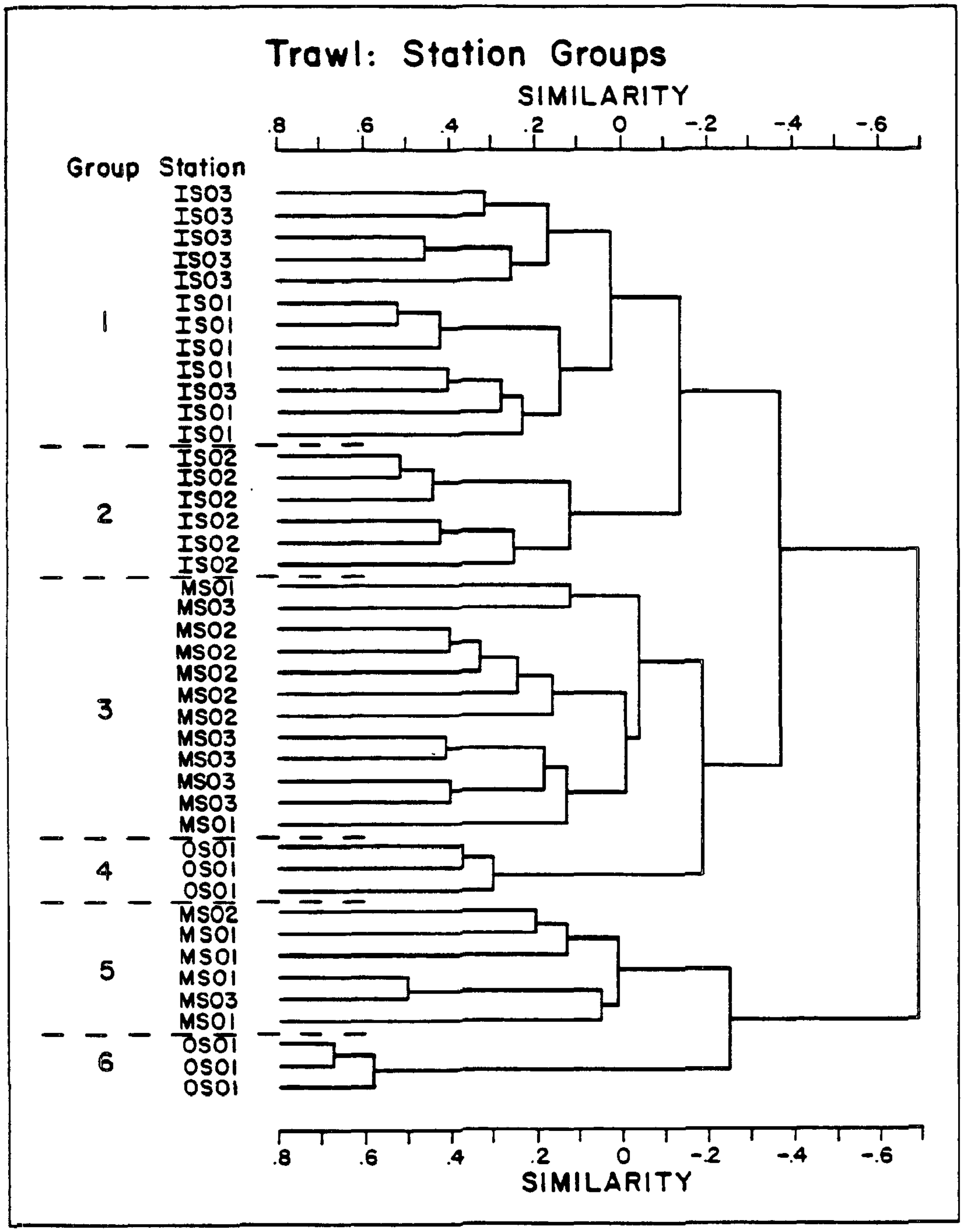


Figure 5.12. Normal cluster dendrogram of winter trawl collections indicating station groups formed using the Jaccard similarity coefficient and flexible sorting.

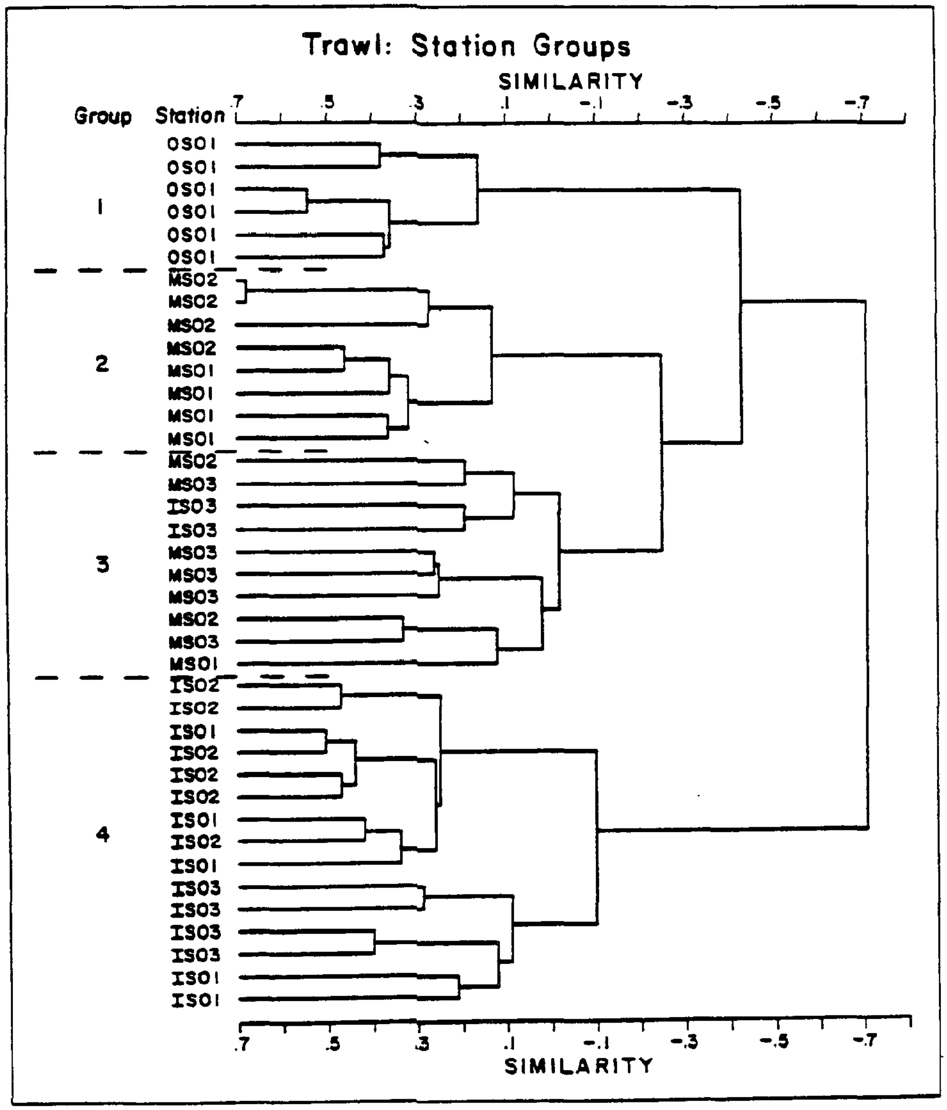


Figure 5.13. Normal cluster dendrogram of summer trawl collections indicating station groups formed using the Jaccard similarity coefficient and flexible sorting.

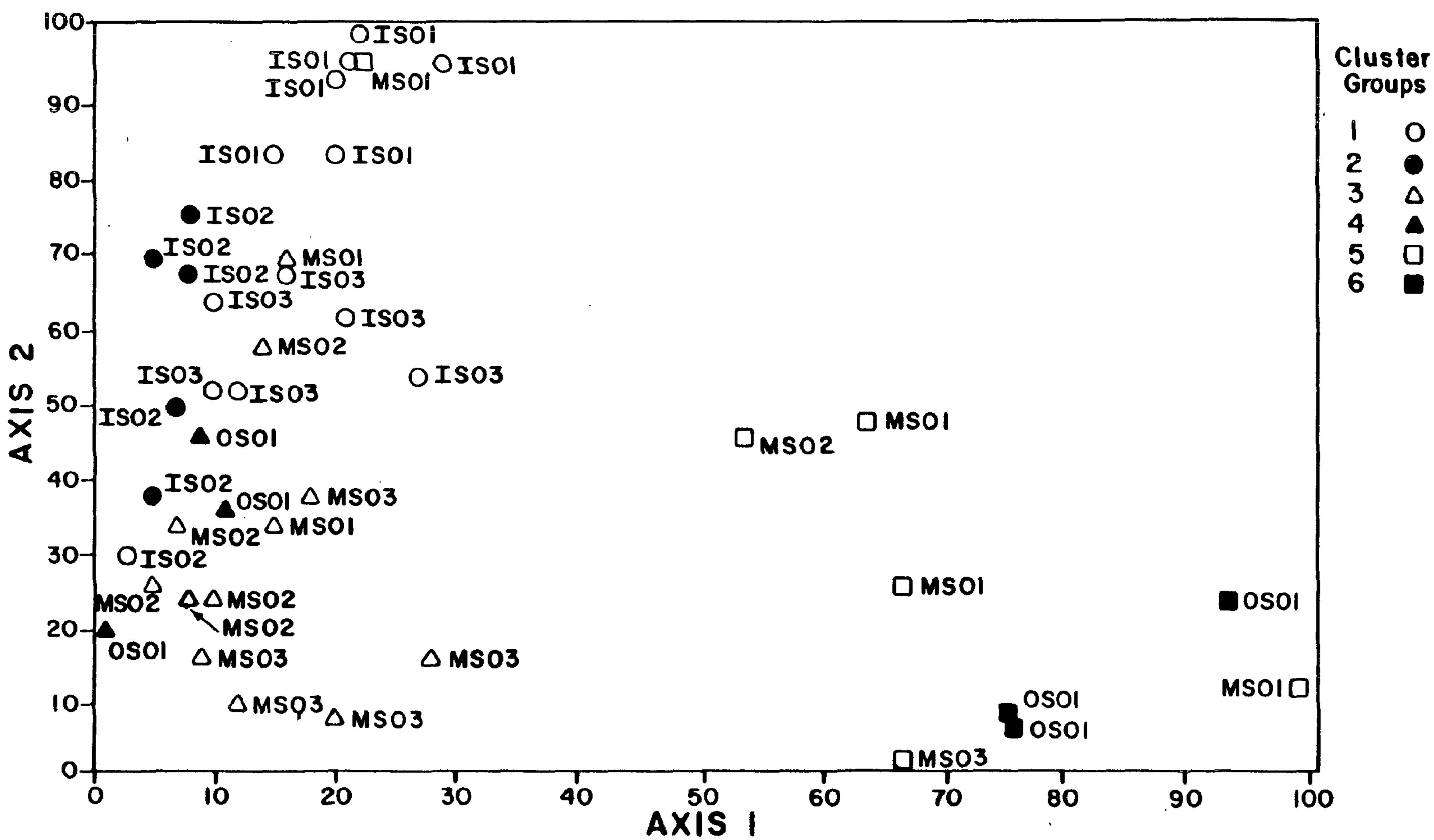


Figure 5.14. Results of reciprocal averaging ordination showing orientation of winter trawl collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

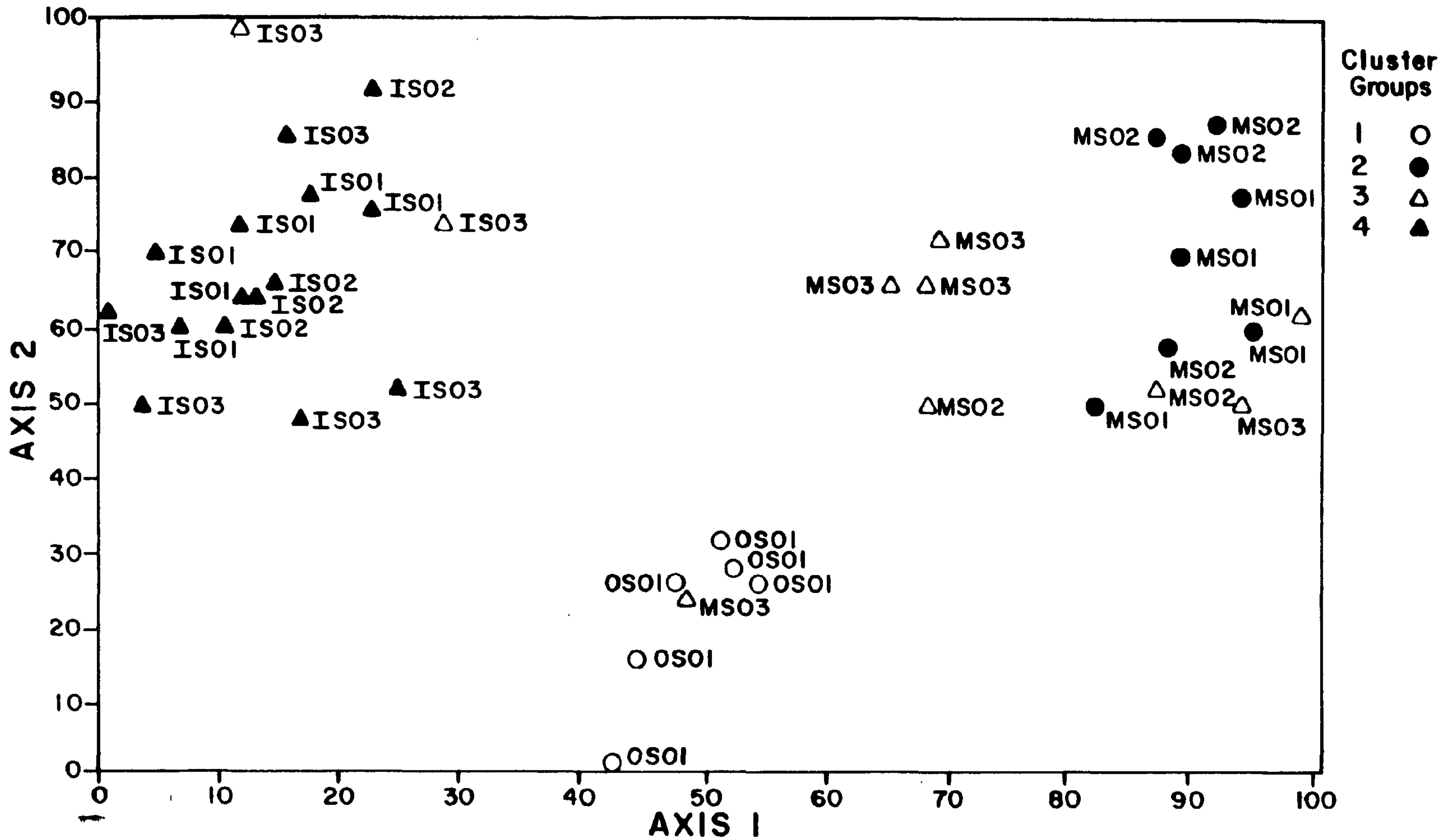


Figure 5.15. Results of reciprocal averaging ordination showing orientation of summer trawl collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

cluster analysis.

Axis 2 explained 8.26% of the total eigenvalue and separated outer shelf collections (site group 1) from inner (group 4) and middle shelf (groups 2 and 3) collections. Some degree of separation existed between the two groups of middle shelf samples along axis 2, but not enough to warrant their being considered representative of very different habitat types.

Nine groups were formed by inverse analysis of the 107 species remaining after reduction of winter trawl data (Table 5.12). The nodal diagram indicates that group A is comprised of an outer shelf assemblage of species which were not very common at any station and were generally restricted to station OS01 (Figure 5.16). As indicated by the cluster hierarchy, species in this group bore little resemblance to members of other groups in terms of their distribution.

Species in group B were characteristic of the inner shelf live bottom habitat, where they were consistently collected at all stations. Although several species in this group were infrequently collected at middle shelf stations MS02 and MS03, the tunicate Clavelina picta, the sponge Homaxinella waltonsmithi, and the octocoral Leptogorgia virgulata were only collected on the inner shelf. Species in groups C and F were also found on the inner shelf where they displayed moderate constancy and high fidelity for stations IS01 and IS02, respectively. Although groups D and E contained species which were somewhat ubiquitous, many such as the echinoderms Lytechinus variegatus and Ocnus pygmaeus, the tunicates Diplosoma macdonaldi and Pyura vittata, and the mollusk Diodora cayenensis were collected only at inner shelf stations. These and other species in the two groups were particularly constant in collections at IS02 where they also displayed moderate to high fidelity.

Groups G, H, and I contained relatively rare species which were not very constant or very faithful at any station. These species displayed their maximum constancy and fidelity at inner and middle shelf stations.

As with the winter trawl data, classification of 113 species from summer collections produced groups which were generally identifiable with live bottom habitats of the inner, middle, and outer continental shelf (Table 5.12 and Figure 5.17). Species in group A were characteristic of the middle shelf live bottom habitat where they were consistently collected and moderately restricted to stations MS01 and MS02. Group B species were fairly ubiquitous but not particularly common or highly faithful among collections at any given station. Species which were restricted to and highly constant in collections from station OS01 formed group C. These included the scyphozoan Stephanocyphus sp., the hydroids Dynamena dalmasi and Sertularella areyi, the octocoral Telesto sanguinea, the barnacle Scalpellum diceratum, the decapods Pachycheles rugimanus and Euchirograpsus americanus, the ascidian Didemnum sp. A, and the echinoderm Astroporpa annulata. Those in group D were also consistently collected at OS01 and were fairly ubiquitous although not as commonly found at other stations on the shelf. Group E species occurred in collections from inner, middle, and outer shelf live bottom habitats but were not common at any station. Species which formed group F were collected at inner and middle shelf live bottom habitats, but they were not particularly constant or faithful in collections from either area. Species in group G were ubiquitous among inner shelf stations but were most frequently collected at station IS02. As indicated by the dendrogram hierarchy of Figure 5.17, assemblages of groups F and G did not resemble those of other species groups.

The composition of most invertebrate assemblages defined by cluster analysis of trawl data changed from one sampling period to the next (Figure 5.18);

Table 5.12. Species groups resulting from numerical classification of data from samples collected by trawl during winter and summer, 1980. (Ar = Arthropoda; Bry = Bryozoa; Ch = Chordata; Cn = Cnidaria; Ech = Echinodermata; Mo = Mollusca; Po = Porifera).

Winter 1980

Group A

- Aglaophenia elongata (Cn)
- Dynamena dalmasi (Cn)
- Cyanea capillata (Cn)
- Renilla reniformis (Cn)
- Mesopenaeus tropicalis (Ar)
- Solenocera atlantidis (Ar)
- Metapenaeopsis goodei (Ar)
- Sicyonia brevirostris (Ar)

Group B

- Clavelina picta (?) (Ch)
- Homaxinella waltonsmithi (Po)
- Styela plicata (Ch)
- Leptogorgia virgulata (Cn)
- Lophogorgia hebes (Cn)
- Spheciospongia vesparium (Po)
- Synalpheus longicarpus (Ar)
- Penaeus duorarum (Ar)
- Trachypenaeus constrictus (Ar)

Group C

- Oculina arbuscula (Cn)
- Asterias sp. A (Ech)
- Tozeuma serratum (Ar)
- Rossia tenera (Mo)
- Aglaophenia rigida (Cn)
- Sertularella conica (Cn)
- Hadromerida B (Po)
- Megalobrachium soriatum (Ar)
- Halicionidae B (Po)
- Sertularia marginata (Cn)
- Amaroucium stellatum (Ch)
- Pandaros acathifolium (Po)
- Dynamena cornicina (Cn)
- Dromidia antillensis (Ar)
- Cinachyra alloclada (Po)
- Octopus sp. (Mo)

Group D

- Turbicellepora dichotoma (Bry)
- Antropora tincta (Bry)
- Balanus trigonus (Ar)
- Balanus venustus (Ar)
- Lytechinus variegatus (Ech)
- Pilumnus pannosus (Ar)
- Ocnus pymaeus (Ech)
- Mithrax pleuracanthus (Ar)
- Diplosoma macdonaldi (Ch)
- Diodora cayenensis (Mo)
- Conopea galeata (Ar)
- Hippoporina contracta (Bry)
- Clytia cylindrica (Cn)

Summer 1980

Group A

- Hebella venusta (Cn)
- Chaperia sp. (Bry)
- Aeverrillia setigera (Bry)
- Aglaophenia trifida (Cn)
- Scandia mutabilis (Cn)
- Aglaophenia latecarinata (Cn)
- Bimeria humilis (Cn)
- Crisia sp. (Bry)
- Thyroscyphus marginatus (Cn)
- Clavelina gigantea (Ch)
- Schizoporella floridana (Bry)
- Aglaophenia allmani (Cn)

Group B

- Hebella scandens (Cn)
- Amathia distans (Bry)
- Bugula rylandi (Bry)
- Synthecium tubitheca (Cn)
- Aetea anguina (Bry)
- Campanularia hincksii (Cn)
- Nellia tenella (Bry)
- Sertularia marginata (Cn)
- Celleporina hassalli (Bry)
- Clytia fragilis (Cn)
- Dynamena quadridentata (Cn)
- Amathia alternata (Bry)
- Titanideum frauenfeldii (Cn)

Group C

- Clytia cylindrica (Cn)
- Celleporaria magnifica (Bry)
- Scalpellum diceratum (Ar)
- Sertularella areyi (Cn)
- Kochlorine floridana (Ar)
- Filellum serratum (Cn)
- Pachycheles rugimanus (Ar)
- Telesto sanguinea (Cn)
- Pseudomedaeus agassizii (Ar)
- Galathea rostrata (Ar)
- Nolella gigantea (Bry)
- Dynamena dalmasi (Cn)
- Keratosa D (Po)
- Didemnum sp. A (Ch)
- Sertularella gayi (Cn)
- Synalpheus townsendi (Ar)
- Xytopsues griseus (Po)
- Sigmadocia caerula (Po)
- Astroporpa annulata (Ech)
- Euchirograpsus americanus (Ar)
- Stephanoscyphus sp. (Cn)

Group D

- Microporella ciliata (Bry)

Table 5.12 (Continued)

Winter 1980

Group E

Microporella ciliata (Bry)
Crisia sp. (Bry)
Monostaechas quadridens (Cn)
Ophiothrix angulata (Ech)
Arbacia punctulata (Ech)
Epizoanthus americanus (Cn)
Telesto fruticulosa (Cn)
Pyura vittata (Ch)
Titanideum frauenfeldii (Cn)

Group F

Kochlorine floridana (Ar)
Ircinia felix (Po)
Bugula grayi (Bry)
Scrupocellaria regularis (Bry)
Celleporaria magnifica (Bry)

Group G

Ircinia ramosa (Po)
Aeverrillia setigera (Bry)
Astrophyton muricatum (Ech)
Aplysina fistularis (Po)
Dynamena quadridentata (Cn)
Stenocionops furcata coelata (Ar)

Group H

Ircinia campana (Po)
Hemectyon pearsei (Po)
Poecilosclerida A (Po)
Haliclona oculata (Po)
Echinaster sp. (Ech)
Tamoya haplonema (Cn)
Pilumnus savi (Ar)
Pteria colymbus (Mo)
Synalpheus townsendi (Ar)
Cliona caribbaea (Po)
Synalpheus minus (Ar)
Pseudomedaeus agassizii (Ar)
Cinachyra keukenthali (Po)
Ircinia strobilina (Po)

Group I

Nellia tenella (Bry)
Bugula fulva (Bry)
Amathia distans (Bry)
Clavelina gigantea (Ch)
Aglaophenia trifida (Cn)
Scandia mutabilis (Cn)
Obelia dichotoma (Cn)
Clytia fragilis (Cn)
Sertularia plumulifera (Cn)
Campanularia hincksii (Cn)
Pilumnus floridanus (Ar)
Pilumnus dasypodus (Ar)
Pagurus carolinensis (Ar)
Celleporaria albirostris (Bry)
Bugula rylandi (Bry)
Schizoporella cornuta (Bry)

Summer 1980

Balanus trigonus (Ar)
Conopea merrilli (Ar)
Turbicellepora dichotoma (Bry)
Schizoporella cornuta (Bry)
Sicyonia brevirostris (Ar)
Solenocera atlantidis (Ar)
Astrophyton muricatum (Ech)
Celleporaria albirostris (Bry)
Metapenaeopsis goodei (Ar)
Petraliella bisinuata (Bry)

Group E

Diplosoma macdonaldi (Ch)
Didemnum candidum (Ch)
Pilumnus floridanus (Ar)
Obelia dichotoma (Cn)
Cinachyra kuekenthali (Po)
Cliona caribbaea (Po)
Eucidaris tribuloides (Ech)
Stylopoma informata (Bry)
Stenocionops furcata coelata (Ar)
Eudendrium tenellum (Cn)
Synalpheus longicarpus (Ar)
Aplysina fistularis (Po)
Paguristes tortugae (Ar)
Ircinia strobilina (Po)
Scyllarides nodifer (Ar)
Sertularella pinnigera (Cn)
Ircinia campana (Po)
Hippaliosina rostrigera (Bry)
Aplousina gigantea (Bry)
Hippoporina contracta (Bry)
Ctenostomata (Bry)
Stomolophus meleagris (Cn)
Holothuria princeps (Ech)
Keratosa C (Po)

Group F

Penaeus duorarum (Ar)
Epizoanthus americanus (Cn)
Turritopsis nutricula (Cn)
Symplegma viride (Ch)
Trachypenaeus constrictus (Ar)
Portunus gibbesii (Ar)
Conopea galeata (Ar)
Antropora tincta (Bry)
Ciocalapata gibbsi (Po)
Sertularella conica (Cn)

Group G

Pilumnus sayi (Ar)
Dromidia antillensis (Ar)
Aplidium constellatum (Ch)
Diodora cayenensis (Mo)
Mithrax pleuracanthus (Ar)
Ocnus pygmaeus (Ech)
Balanus venustus (Ar)
Homaxinella waltonsmithi (Po)
Synalpheus minus (Ar)
Molgula occidentalis (Ch)
Styela plicata (Ch)

Table 5.12 (Continued)

Winter 1980	Summer 1980
Ectopleura dumortieri (Cn)	Leptogorgia virgulata (Cn)
Nolella gigantea (Bry)	Spheciospongia vesparium (Po)
Clathrina coriacea (Po)	Halocordyle disticha (Cn)
Aglaophenia sp. (Cn)	Lophogorgia hebes (Cn)
Hebella venusta (Cn)	Distaplia bermudensis (Ch)
Schizoporella floridana (Bry)	Haliclona oculata (Po)
Thyroscyphus marginatus (Cn)	Pteria colymbus (Mo)
Hebella scandens (Cn)	Arbacia punctulata (Ech)
Conopea merrilli (Ar)	Ophiothrix angulata (Ech)
Muricea pendula (Cn)	Dynamena cornicina (Cn)
Turritopsis nutricula (Cn)	Monostaechas quadridens (Cn)

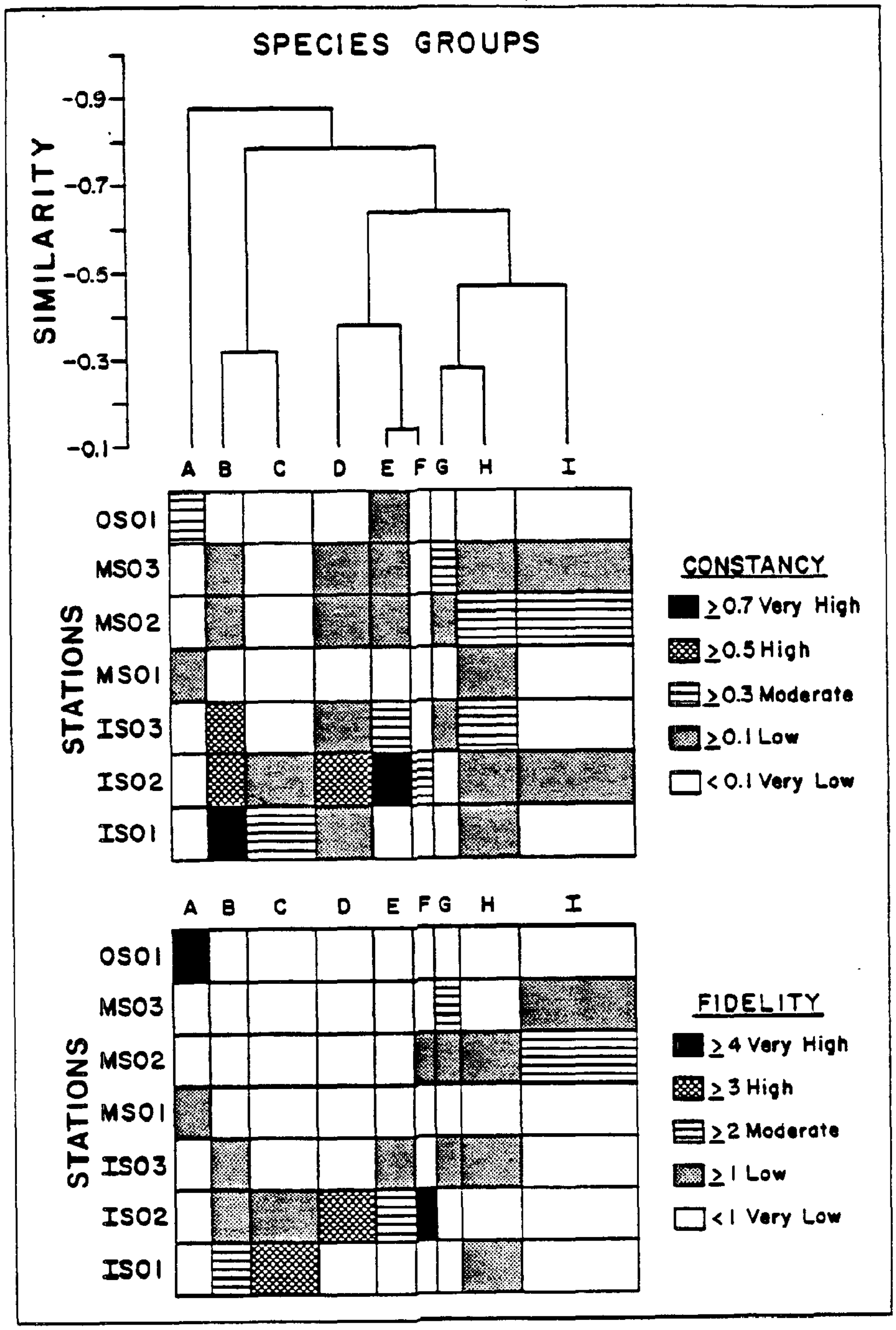


Figure 5.16. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on winter trawl collections.

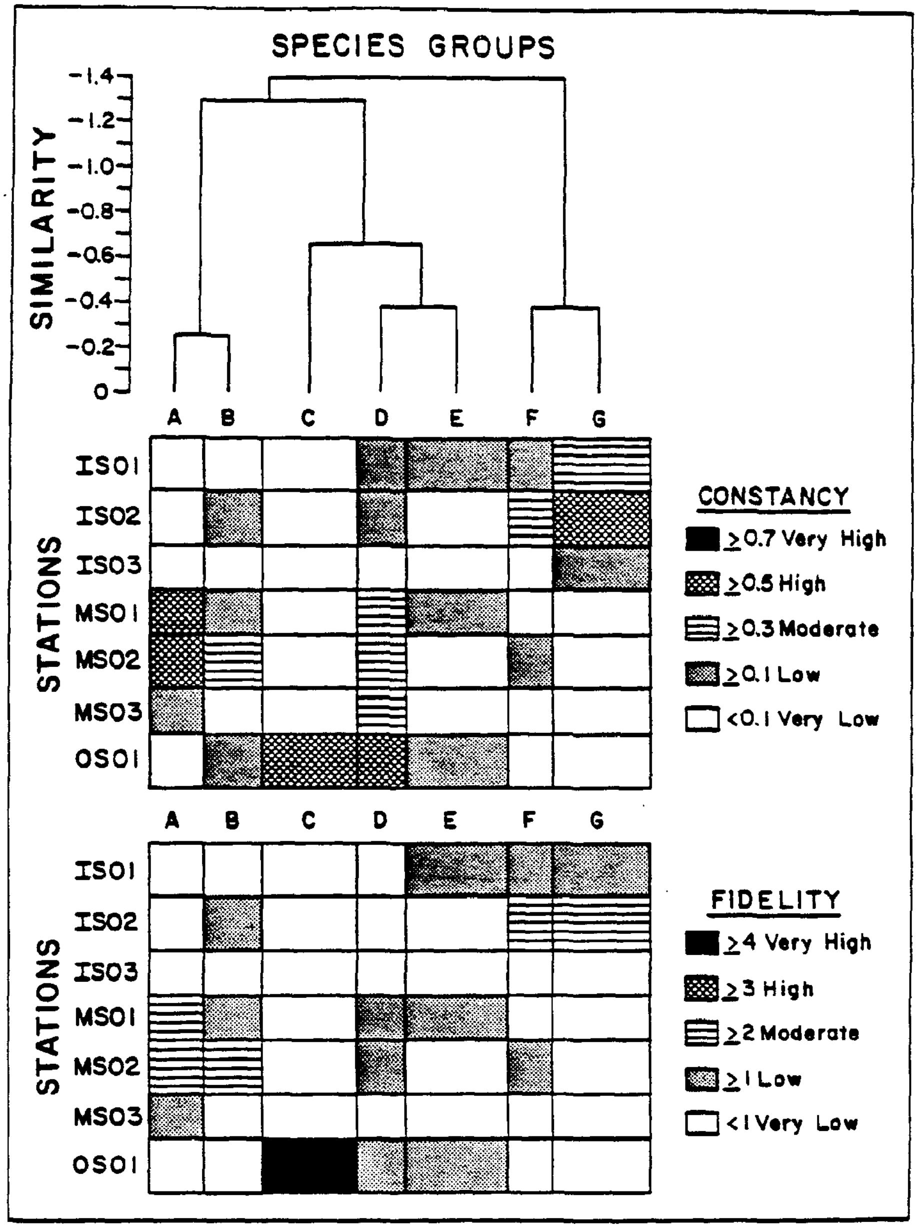


Figure 5.17. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on summer trawl collections.

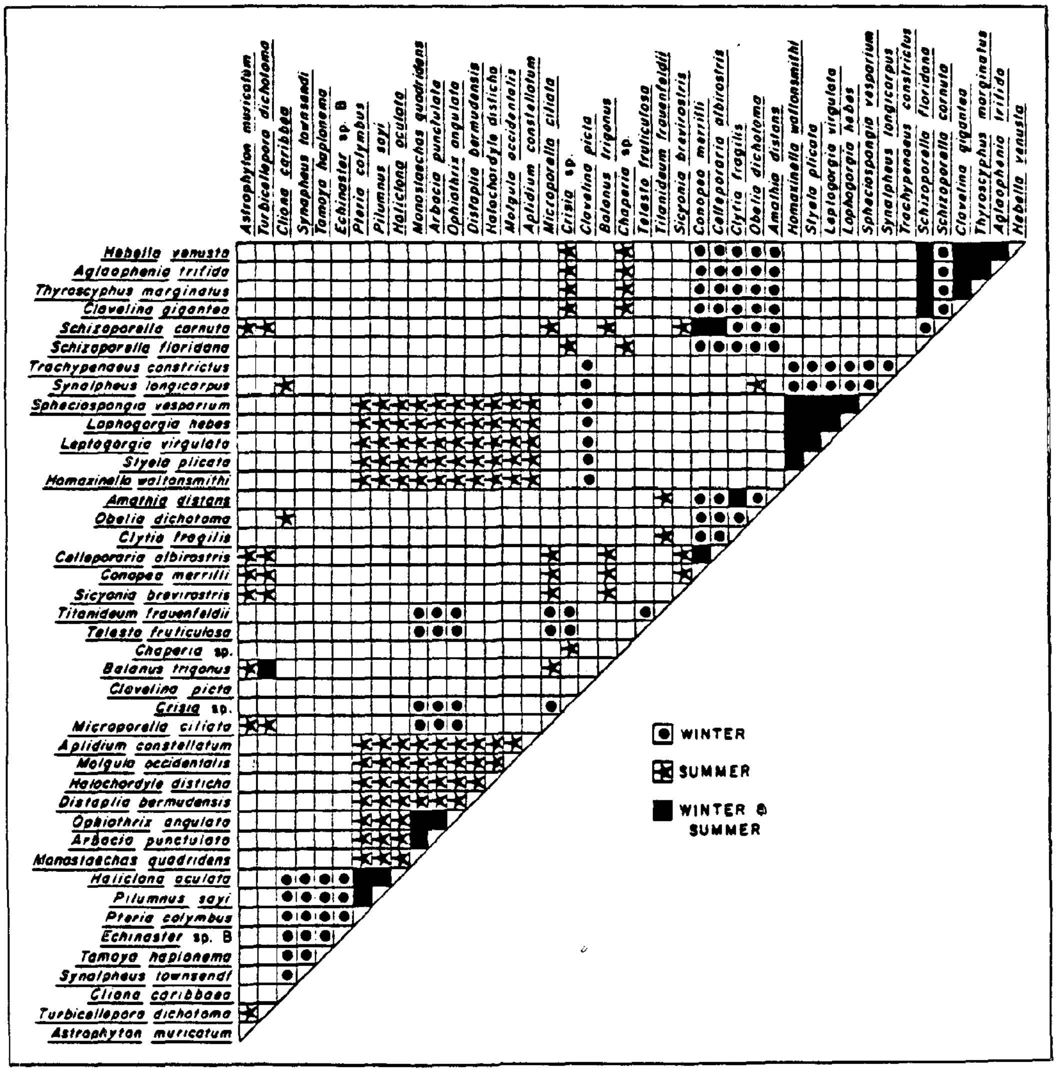


Figure 5.18. Matrix showing co-occurrence of species within the same group formed by inverse cluster analysis of trawl collections from winter sampling only, summer sampling only, or both winter and summer sampling. Species were selected for inclusion in the matrix if they occurred at ≥ 50% of the collections from at least 2 stations sampled by trawl.

however, several recurrent groups of species did occur. The bryozoan Schizoporella floridana; the tunicate Clavelina gigantea; and the cnidarians Thyroscyphus marginatus, Aglaophenia trifida, and Hebella venusta formed a cohesive middle shelf species assemblage during both winter and summer. These species were part of a group which displayed moderate constancy and fidelity for station MS02 in winter, and were quite common at stations MS01 and MS02 in summer. The cnidarian Clytia fragilis and the bryozoan Amathia distans co-occurred with the aforementioned recurrent group in winter samples but were part of a separate group of fairly ubiquitous but uncommon species in the summer.

The bryozoans Schizoporella cornuta and Celleporaria albirostris; and the barnacle Conopea merrilli were also classified in the same group during both seasons. In winter, these species were part of an assemblage that was not very constant or faithful at any station, while in summer, they were classified with species which were ubiquitous yet most frequent at OS01.

A consistently co-occurring group of species from the inner shelf stations included the sponges Spheciospongia vesparium and Homaxinella waltonsmithi, the cnidarians Lophogorgia hebes and Leptogorgia virgulata, and the tunicate Styela plicata. The hydroid Monostaechas quadridens and the echinoderms Ophiothrix angulata and Arbacia punctulata formed another assemblage which was frequently encounted on the inner shelf at station IS02.

The mollusk Pteria colymbus, the sponge Haliclona oculata, and the decapod Pilumnus sayi clustered together during winter and summer. They occurred with species which were not common but which were ubiquitous at inner and middle shelf stations in winter. During summer they clustered with species which frequently occurred in inner shelf collections.

Quantitative Assessment of Benthos Captured by Suction and Grab Samplers:

Species Composition and Abundance - A total of 813 identifiable taxa were collected with suction and grab samplers during winter and summer. This total excludes cnidarian and bryozoan taxa which were not examined. A listing of all taxa collected and ranked by abundance at each station, along with density estimates for each taxon, is presented in Appendices 10 and 11. The phylum Annelida was represented by the greatest number (261) of recognizable species. Annelids also dominated collections in terms of numerical abundance, accounting for ∿ 64.7% of the total of 38,325 invertebrates collected. Mollusca ranked second among the invertebrate phyla with a total of 203 recognizable species; however, with respect to abundance, mollusks accounted for only 4.1% of the total number of individuals. Other groups with fewer numbers of species were Decapoda (97 taxa), Amphipoda (82 taxa), Porifera (61 taxa), other Crustacea (39 taxa), Echinodermata (30 taxa), Ascidacea (15 taxa), Pycnogonida (11 taxa), Sipunculida (8 taxa), and Nemertinea (6 taxa). The phylum Amphipoda was the second most abundant group and comprised ∿ 17.4% of the total number of invertebrates collected.

Macroalgae were collected during our sampling with suction and grab; however, in most instances, only small fragments were collected, and these were generally damaged, making identification impossible. Algae occurred in 11 of the samples collected during winter and in 28 samples collected during summer. The only identifiable taxon collected was Ulva sp. which was present in two collections taken by Smith-McIntyre grab during winter.

The ten numerically dominant invertebrate species from all stations for both sampling periods were the polychaete Filograna implexa (n = 14,914), Phyllochaetopterus socialis (n = 2264), Spiophanes bombyx (n = 751), Exogone dispar (n = 686), and Syllis spongicola (n = 494); the amphipods Photis sp. (n = 647), Podocerus sp. (n = 543), Luconacia incerta (n = 505), and Erichthonius sp. A (n = 492); and the echinoderm Ophiothrix angulata (n = 428). These species accounted for ∿ 56.7% of the entire invertebrate catch from combined winter and summer samples.

The ranking of these numerically dominant species changed considerably from winter to summer, with the exception of the colonial serpulid polychaete Filograna implexa which greatly outnumbered all other invertebrates during both sampling periods (Table 5.13). Differences also existed in dominance between bathymetric zones of the inner, middle, and outer shelf stations (Appendices 10 and 11). Inner shelf stations were dominated in winter by the polychaete Exogone dispar; the amphipods Luconacia incerta, Lembos smithi and Photis sp.; and the echinoderm Ophiothrix angulata. In summer, the polychaete Filograna implexa and the amphipod Ampelisca agassizi constituted a major part of the inner shelf samples. Filograna implexa had the highest density ∿ 788 individuals per 0.10 m^2 at station IS02.

Filograna implexa was overwhelmingly dominant at middle shelf stations during both winter and summer. The maximum winter density for this species was 1197 individuals per 0.10 m^2 at station MS01; however, this was the only middle shelf station at which it was abundant. Maximum density of F. implexa was lower during summer (∿ 424 individuals per 0.10 m^2), and once again the species was most abundant at station MS01. Other dominant winter species from the middle shelf included the polychaete Sabellaria vulgaris vulgaris and the amphipods, Photis sp., Caprella penantis, and Luconacia incerta. Syllis spongicola was abundant in summer collections from middle shelf live bottom habitats.

No species was overwhelmingly dominant in winter at outer shelf stations. In fact, winter collections from the outer shelf were unique in that no species was represented by more than 50 individuals at a station. Consequently, average densities of species did not exceed 10 individuals per 0.10 m^2. This may reflect decreased collecting efficiency by the grab sampler on hard substrates. During summer, Filograna implexa and Phyllochaetopterus socialis accounted for most of the invertebrates collected. These species had respective densities of 733 and 442 individuals per 0.10 m^2 at station OS03. Spiophanes bombyx and Erichthonius sp. A were also important at outer shelf stations, although their abundance was considerably less than F. implexa and P. socialis.

Abundances, expressed as the arithmetic mean of the logarithmically transformed counts, of each of the ten numerically dominant species are shown in Figures 5.19 - 5.28. Filograna implexa was most abundant at stations on the middle shelf, although large numbers of this species were also collected at station OS03 (Figure 5.19). Winter and summer abundances of F. implexa for data from all stations were not significantly different ($P > 0.05$, Mann-Whitney U-test), and we observed no apparent latitudinal trends in abundance. This species occurred in 12% of the suction and grab collections taken during winter and in 31% of those taken during summer.

Phyllochaetopterus socialis, another colonial polychaete, was most abundant at stations IS01 and OS03 (Figure 5.20). There were no significant differences ($P > 0.05$, Mann-Whitney U-test) in abundance between winter and summer collections, although it is noteworthy that P. socialis was collected only at inner shelf stations where it occurred in only 12% of the winter suction samples and 25% of the summer suction and grab samples. No latitudinal

Table 5.13. Numerical ranking of invertebrate species collected by suction and grab samplers. Listing includes only those species represented by >20 individuals. Percents are based on total invertebrate abundance for winter and summer separately. Numerical dominants are indicated by (*).

WINTER			SUMMER		
Species	Total Number	Percent of Total	Species	Total Number	Percent of Total
*Filograna implexa	4818	28.14	*Filograna implexa	10,096	47.70
*Exogone dispar	631	3.69	*Phyllochaetopterus socialis	2227	10.52
*Photis sp.	552	3.22	*Spiophanes bombyx	583	2.75
*Podocerus sp.	520	3.04	*Erichthonius sp. A	464	2.19
*Luconacia incerta	445	2.60	*Syllis spongicola	366	1.79
Erichthonius brasiliensis	358	2.09	Chevalia sp.	241	1.14
*Ophiothrix angulata	333	1.94	Protomedia sp.	212	1.00
Lembos smithi	265	1.55	Ampelisca agassizi	200	0.94
Aspidosiphon spinalis	247	1.44	Melita appendiculata	176	0.83
Caprellidae A	235	1.37	Aspidosiphon spinalis	130	0.61
Ampelisca agassizi	207	1.21	Sabellidae B	120	0.57
Sabellaria vulgaris vulgaris	204	1.19	*Ophiothrix angulata	95	0.45
Caprella penantis	184	1.07	*Photis sp.	95	0.45
Oxyurostylis smithi	182	1.06	Amphipoda E	91	0.43
*Spiophanes bombyx	168	0.98	Pista palmata	88	0.42
Ampharete americana	163	0.95	Unciola laminosa	87	0.41
Owenia fusiformis	161	0.94	Acanthohaustorius millsi	81	0.38
Melita appendiculata	157	0.92	Amphiodia pulchella	79	0.37
Mediomastus californiensis	146	0.85	Ampelisca vadorum	74	0.35
Amphiodia pulchella	138	0.81	Chone americana	70	0.33
*Syllis spongicola	128	0.75	Pagurus hendersoni	61	0.29
Tanaidacea A	126	0.74	*Luconacia incerta	60	0.28
Sabellaria vulgaris beaufortensis	123	0.72	*Exogone dispar	55	0.26
Lumbrineris inflata	116	0.68	Tellina americana	54	0.26
Carpias bermudensis	116	0.68	Gammaropsis sp.	54	0.26
Megalobrachium soriatum	115	0.67	Lumbrineris coccinea	53	0.25
Ampelisca vadorum	109	0.64	Spio pettiboneae	53	0.25
Polycirrus carolinensis	93	0.54	Onuphis nebulosa	51	0.24
Prionospio cristata	91	0.53	Lumbrineris inflata	51	0.24
Chrysopetalidae A	88	0.51	Owenia fusiformis	50	0.24
Syllis gracilis	88	0.51	Chrysopetalidae A	50	0.24
Pista palmata	84	0.49	Pagurus carolinensis	50	0.24
Elasmopus sp. A	81	0.47	Lembos smithi	49	0.23
Lembos unicornis	79	0.46	Axiothella mucosa	48	0.23
Websterinereis tridentata	77	0.45	Megalobrachium soriatum	47	0.22
Loimia medusa	73	0.43	Harmothoe sp. A	46	0.22
Syllis hyalina	69	0.40	Amphipoda G	46	0.22
Unciola laminosa	65	0.38	Nassarius albus	42	0.20
Gammaropsis sp.	57	0.33	Crassinella lunulata	41	0.19
Paracerceis caudata	57	0.33	Scypha barbadensis	41	0.19
Sipunculida A	54	0.32	Eunice vittata	40	0.19
Phtisica marina	53	0.31	Megalomma bioculatum	38	0.18

Table 5.13 (Continued)

WINTER			SUMMER		
Species	Total Number	Percent of Total	Species	Total Number	Percent of Total
Eulalia sanguinea	53	0.31	Nicomache trispinata	38	0.18
Eunice vittata	53	0.31	Amphioplus sp.	38	0.18
Pagurus carolinensis	53	0.31	Paraprionospio pinnata	36	0.17
Ampithoe sp. A	48	0.28	Craniellidae B	36	0.17
Elasmopus sp. B	47	0.27	Syllis hyalina	35	0.17
Mitrella lunata	45	0.26	Ampharete acutifrons	35	0.17
Axiothella mucosa	45	0.26	Phyllodoce longipes	34	0.16
Autolytus sp.	44	0.26	Onuphis pallidula	33	0.16
Ampelisca sp. B	44	0.26	Eulalia sanguinea	33	0.16
Pista quadrilobata	43	0.25	Gouldia cerina	33	0.16
Glycera tesselata	41	0.24	Varicorbula operculata	32	0.15
Sicyonia laevigata	40	0.23	Laonice cirrata	32	0.15
Amphipoda A	39	0.23	Elasmopus sp. A	32	0.15
Pherusa inflata	39	0.23	Lembos unicornis	32	0.15
*Phyllochaetopterus socialis	37	0.22	Lysianopsis alba	31	0.15
Phyllodoce fragilis	36	0.21	Goniadides carolinae	31	0.15
Chone americana	35	0.20	Polycirrus carolinensis	30	0.14
Syllidae A	34	0.20	Ophiostigma sp.	30	0.14
Latreutes parvulus	34	0.20	Ophiophragmus sp.	30	0.14
Odontosyllis fulgurans	33	0.19	Ampelisca sp. B	30	0.14
Maera sp. A	32	0.19	Trichophoxus floridanus	30	0.14
Acanthohaustorius shoemakeri	32	0.19	Alpheus normanni	30	0.14
Euceramus praelongus	32	0.19	Laevicardium pictum	29	0.14
Anachis hotessieriana	31	0.18	Melitidae A	29	0.14
Prionospio cirrifera	31	0.18	Glycera sp. B	29	0.14
Crepidula aculeata	30	0.18	Spiophanes sp. A	28	0.13
Lysianopsis alba	30	0.18	Stenopleustes sp. A	28	0.13
Microdeutopus myersi	29	0.17	Tanaidacea A	28	0.13
Pherusa ehlersi	29	0.17	Nassarina minor	27	0.13
*Erichthonius sp. A	28	0.16	Sipunculida A	26	0.12
Eulalia macroceros	28	0.16	Prionospio sp. B	26	0.12
Crassinella lunulata	28	0.16	Prionospio cristata	26	0.12
Pagurus hendersoni	28	0.16	Ceratonereis mirabilis	25	0.12
Polydora tetrabranchia	27	0.16	Pilumnus floridanus	25	0.12
Syllis alternata	27	0.16	Clathrina coriacea	25	0.12
Laonice cirrata	27	0.16	Chondrilla nucula	24	0.11
Nicomache trispinata	26	0.15	Unciola sp. A	24	0.11
Podarke obscura	25	0.15	Notomastus americanus	24	0.11
Pelia mutica	25	0.15	Websterinereis sp. A	23	0.11
Cerapus tubularis	24	0.14	Pista quadrilobata	23	0.11
Leucothoe spinicarpa	24	0.14	Anoplodactylus petiolatus	23	0.11
Ophiostigma isacanthum	24	0.14	*Podocerus sp.	23	0.11
Cinachyra kuekenthali	22	0.13	Bowmaniella portoricensis	23	0.11
Paguristes tortugae	21	0.12	Phyllocarida	22	0.10

Table 5.13 (Continued)

WINTER			SUMMER		
Species	Total Number	Percent of Total	Species	Total Number	Percent of Total
Botula fusca	21	0.12	Pseudeurythoe ambigua	22	0.10
Phyllodoce longipes	21	0.12	Leucothoe spinicarpa	21	0.10
Spio pettiboneae	21	0.12	Munida irrasa	21	0.10
Streblosoma sp.	21	0.12	Synalpheus townsendi	21	0.10
Onuphis nebulosa	21	0.12			
Malacoceros glutaeus	21	0.12			

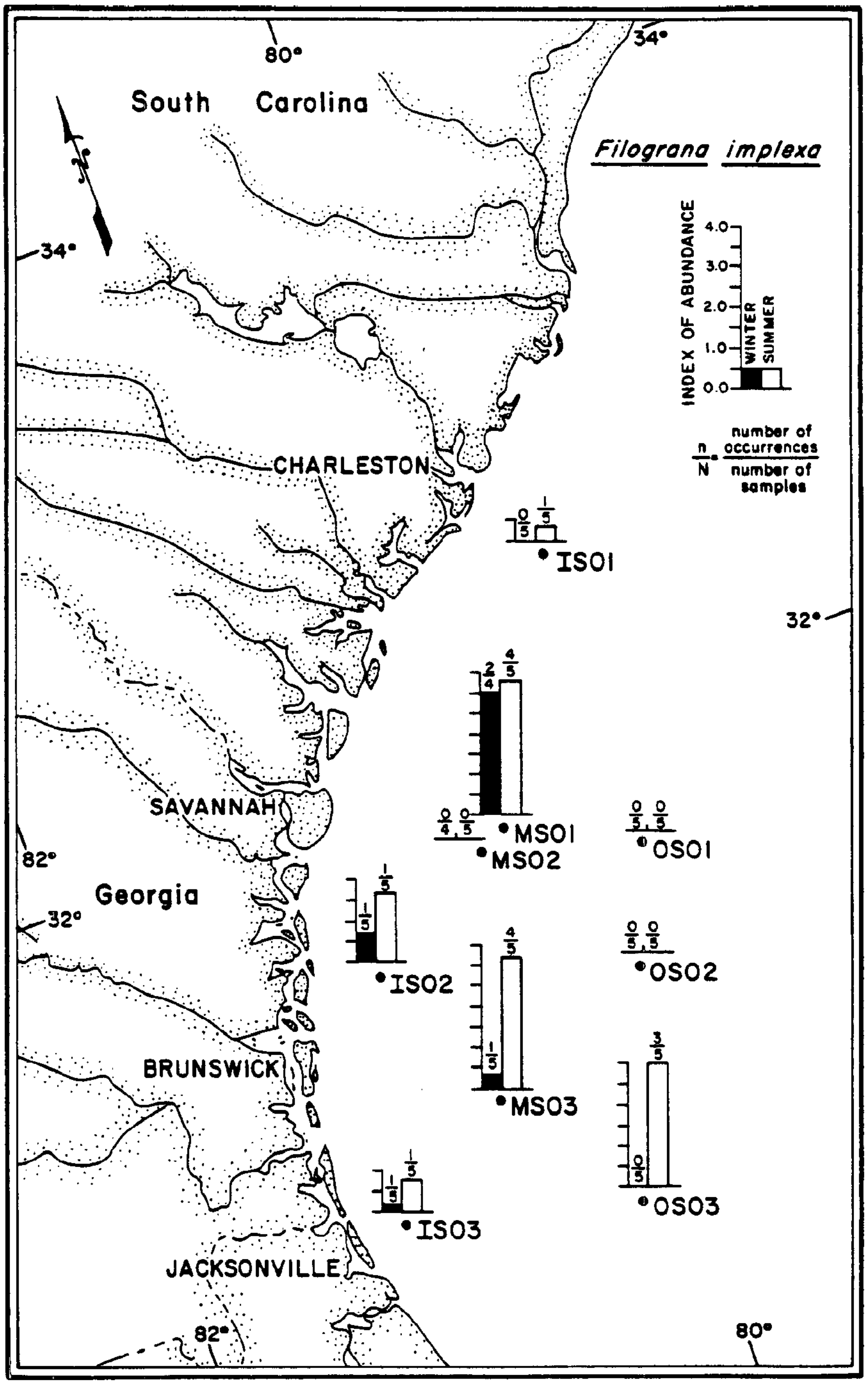


Figure 5.19. Relative abundance of Filograna implexa during winter and summer, 1980.

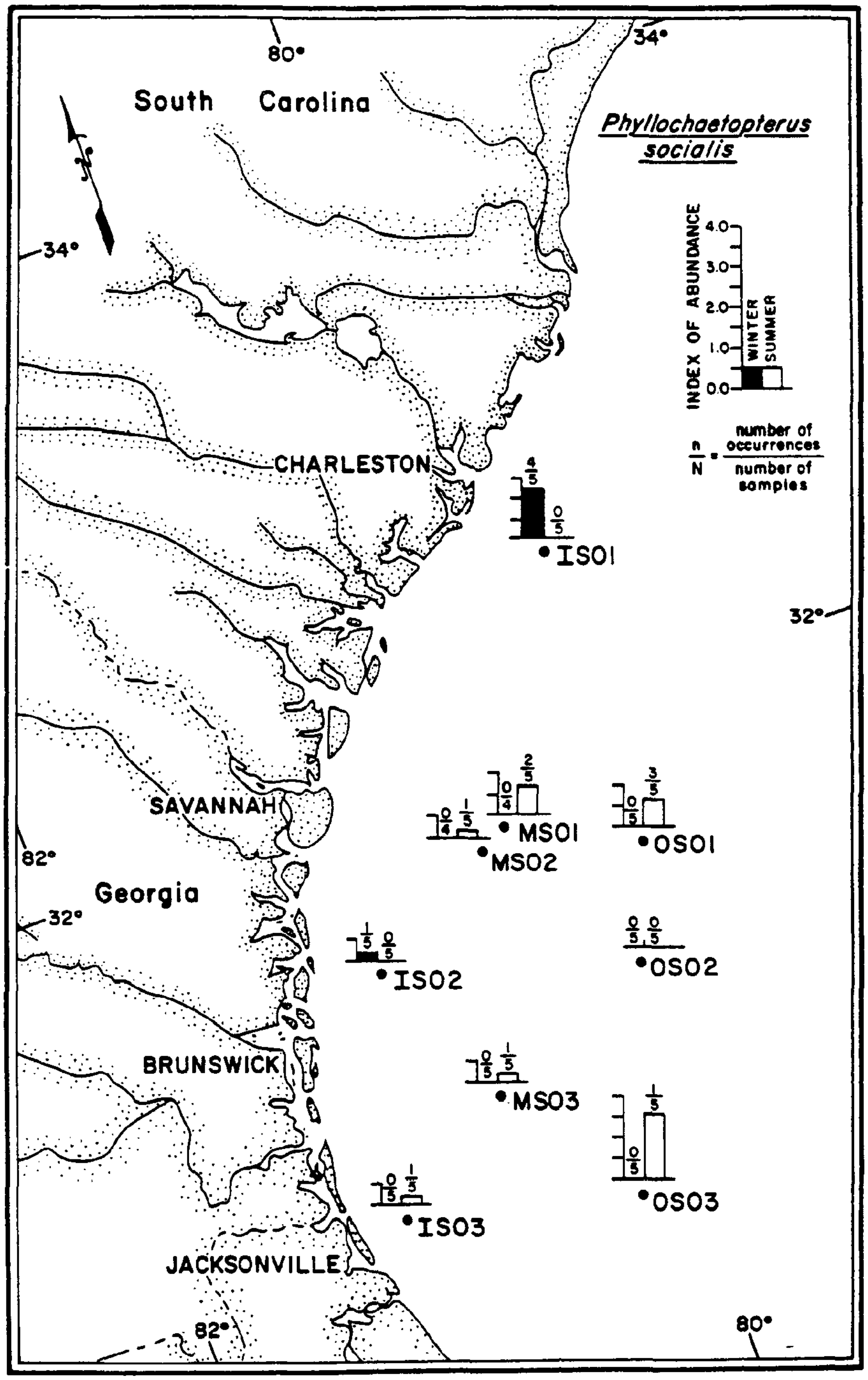


Figure 5.20. Relative abundance of Phyllochaetopterus socialis during winter and summer, 1980.

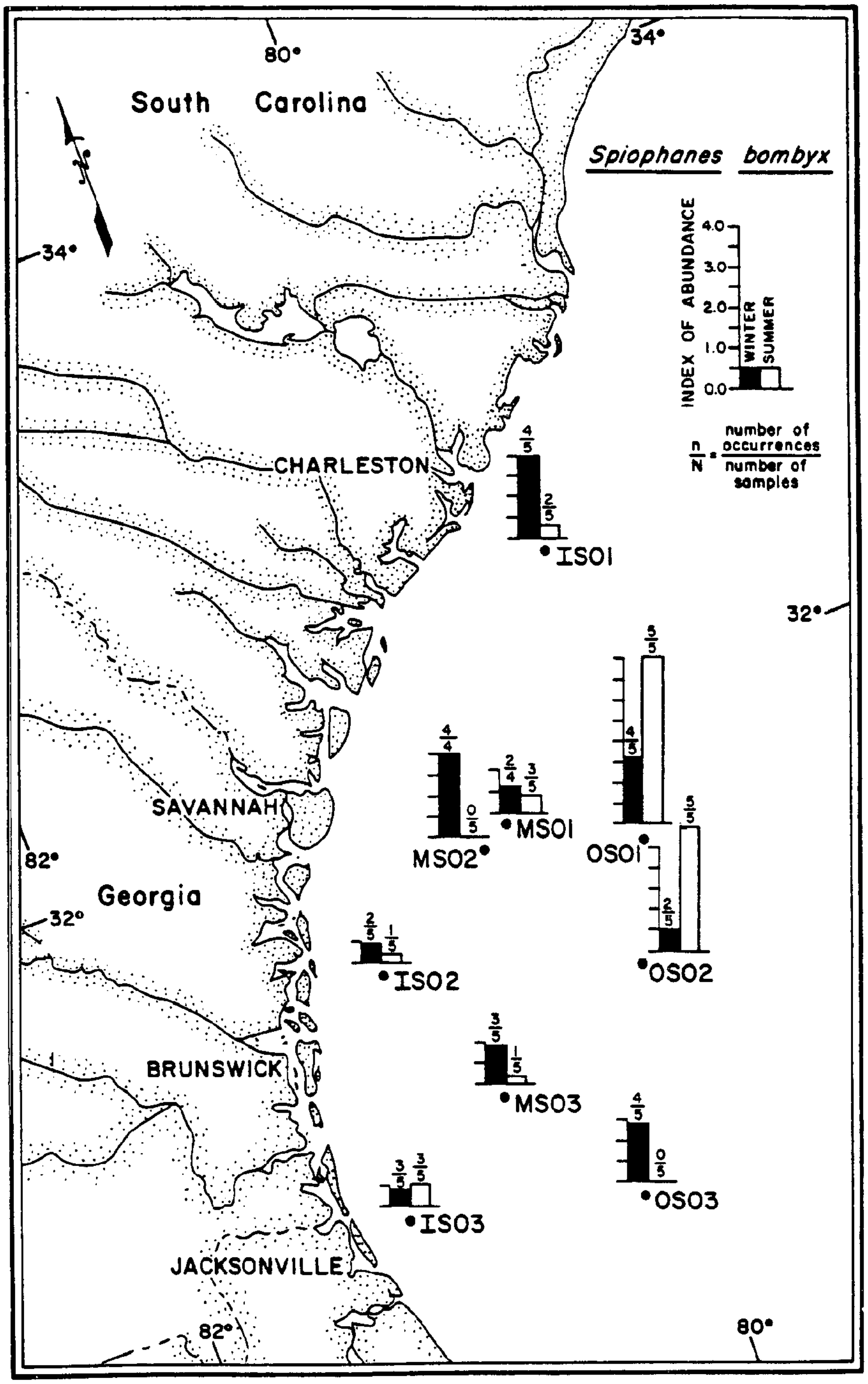


Figure 5.21. Relative abundance of Spiophanes bombyx during winter and summer, 1980.

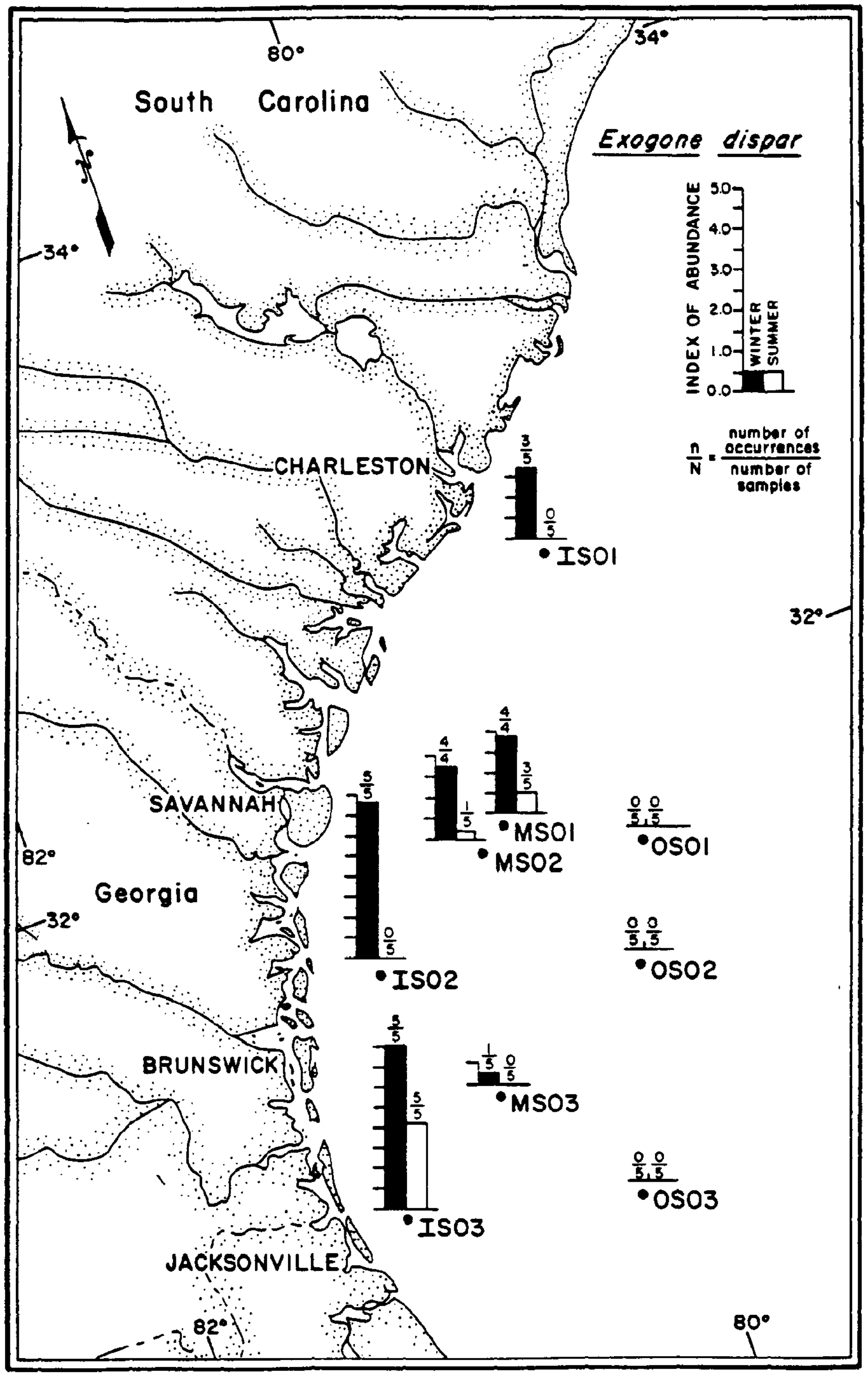


Figure 5.22. Relative abundance of Exogone dispar during winter and summer, 1980.

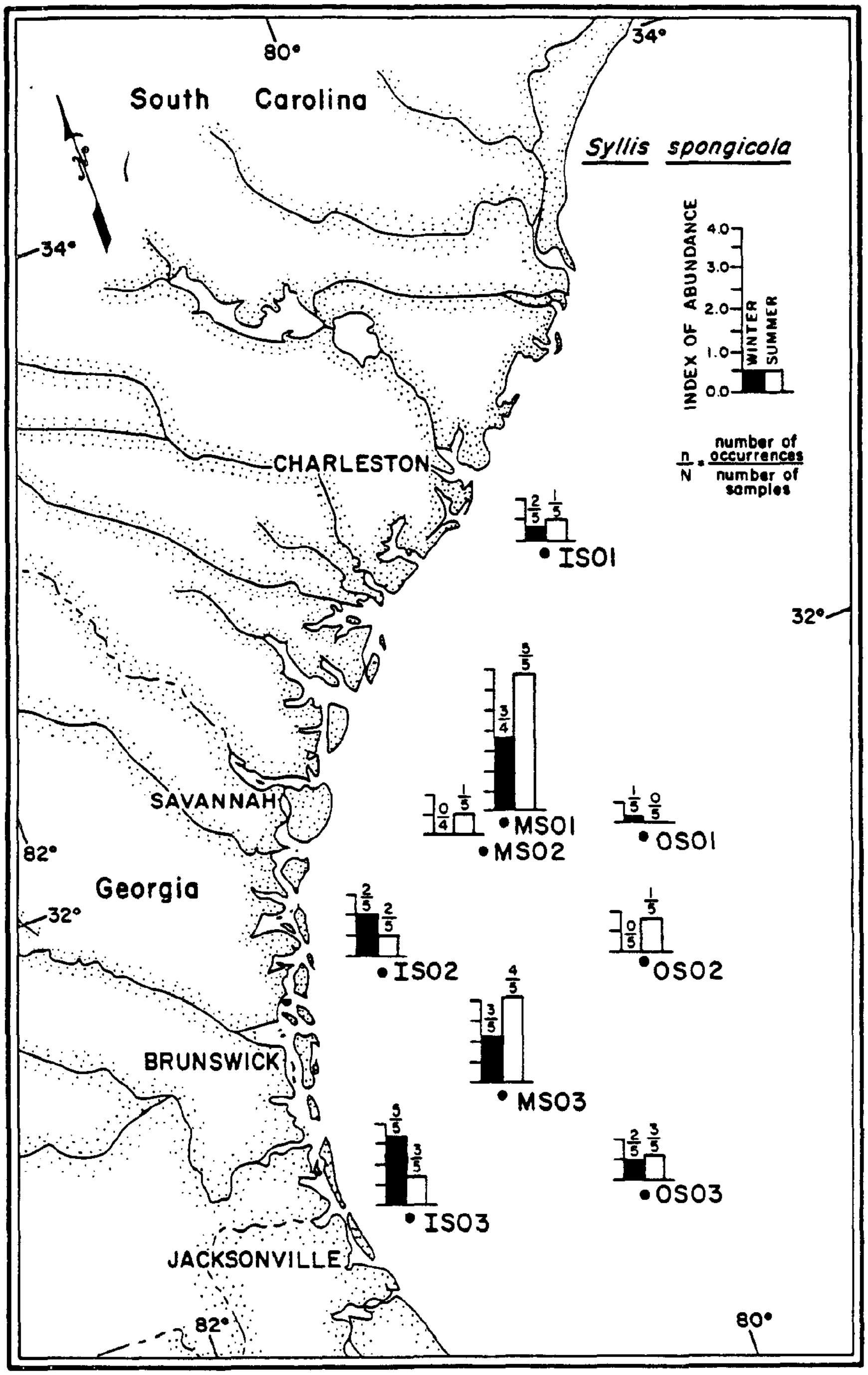


Figure 5.23. Relative abundance of Syllis spongicola during winter and summer, 1980.

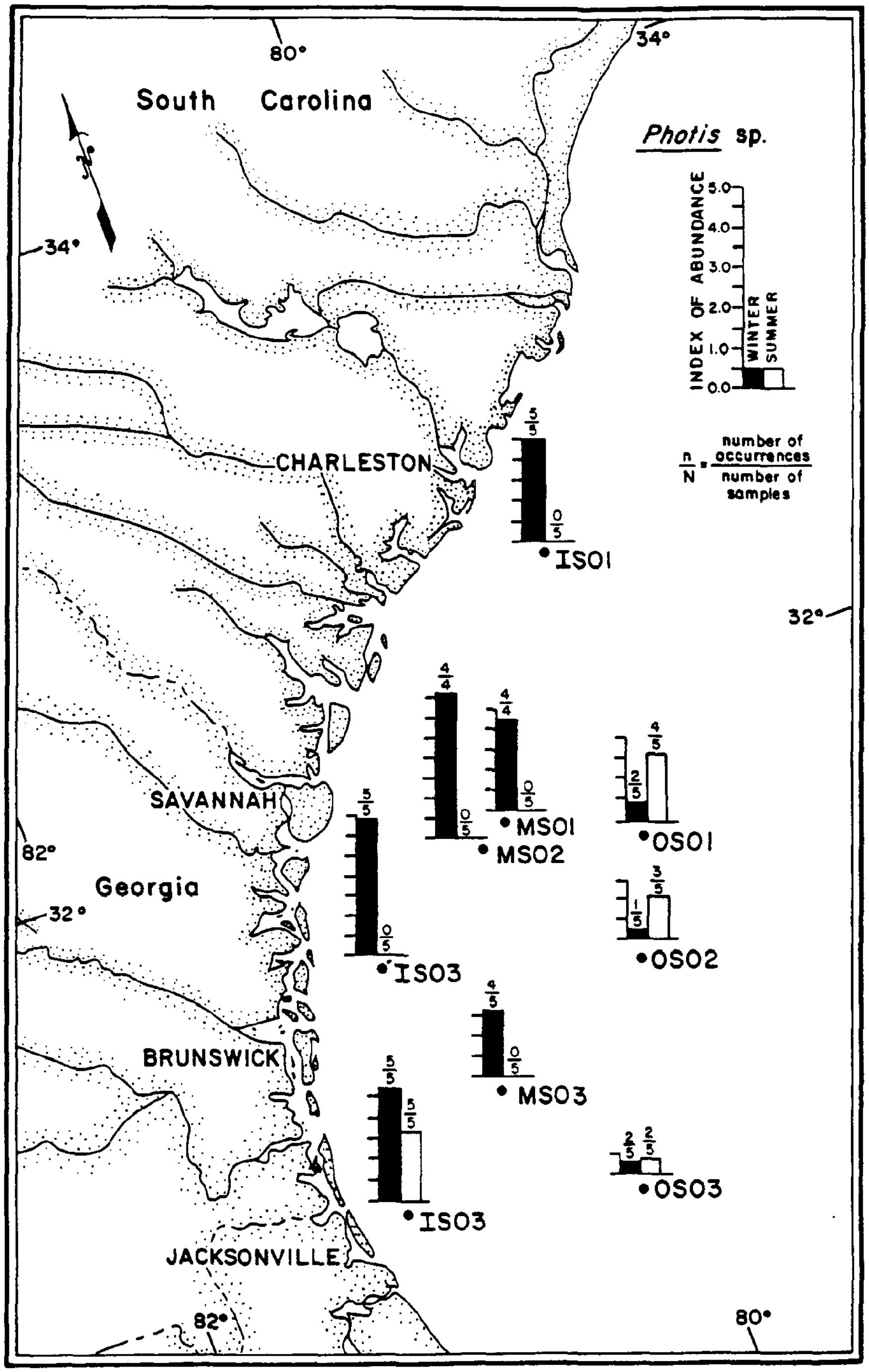


Figure 5.24. Relative abundance of Photis sp. during winter and summer, 1980.

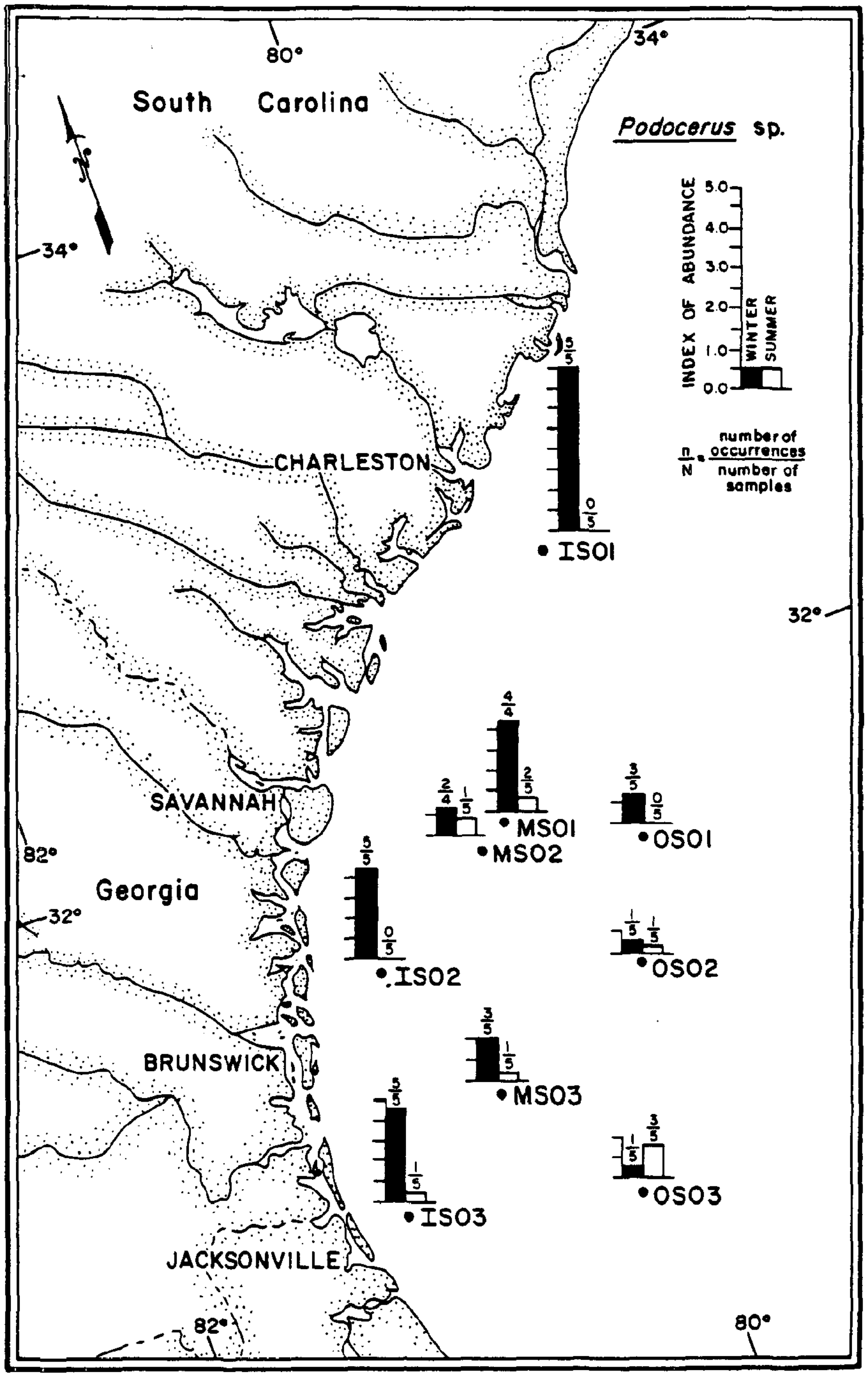


Figure 5.25. Relative abundance of Podocerus sp. during winter and summer, 1980.

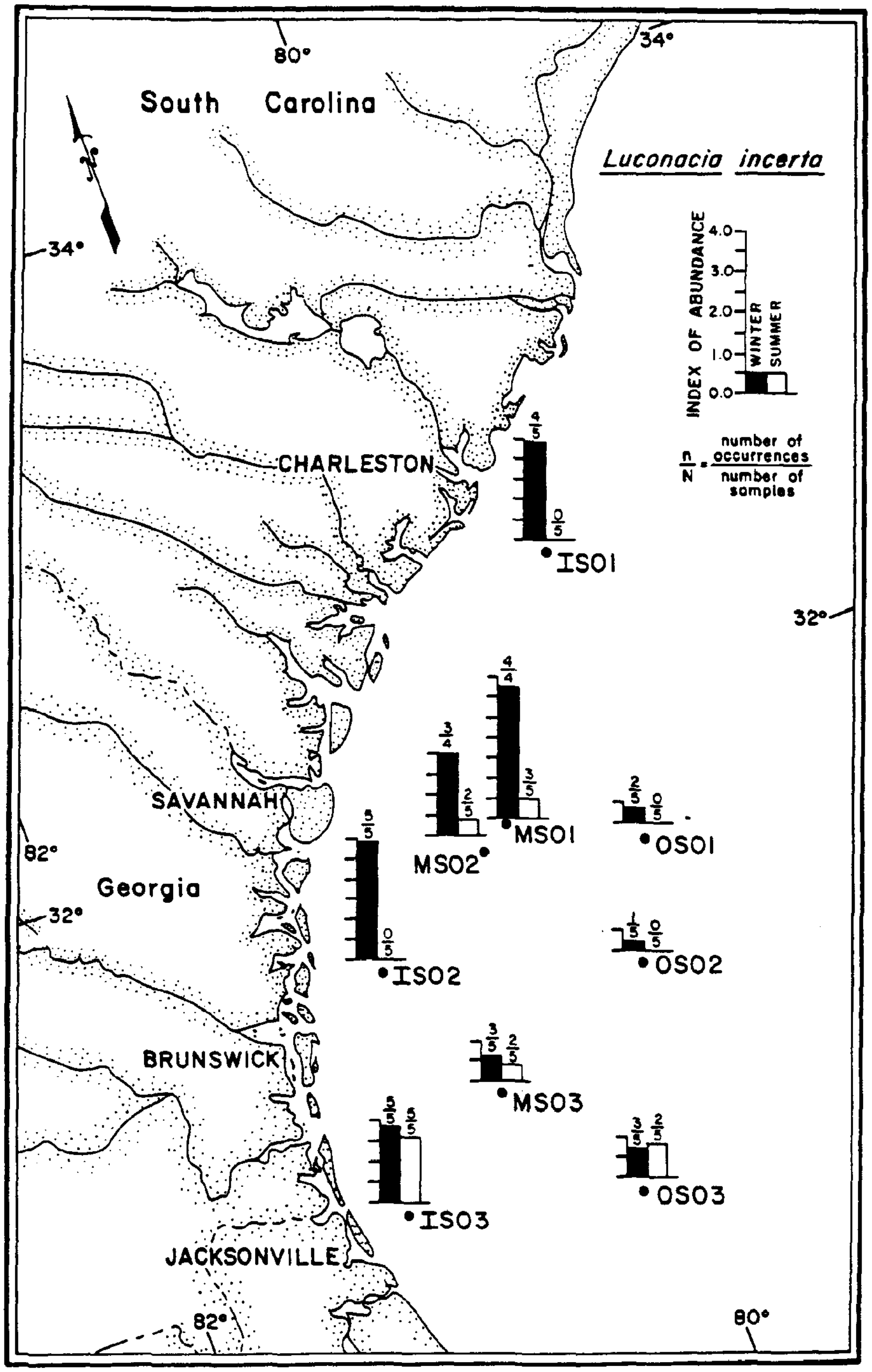


Figure 5.26. Relative abundance of Luconacia incerta during winter and summer, 1980.

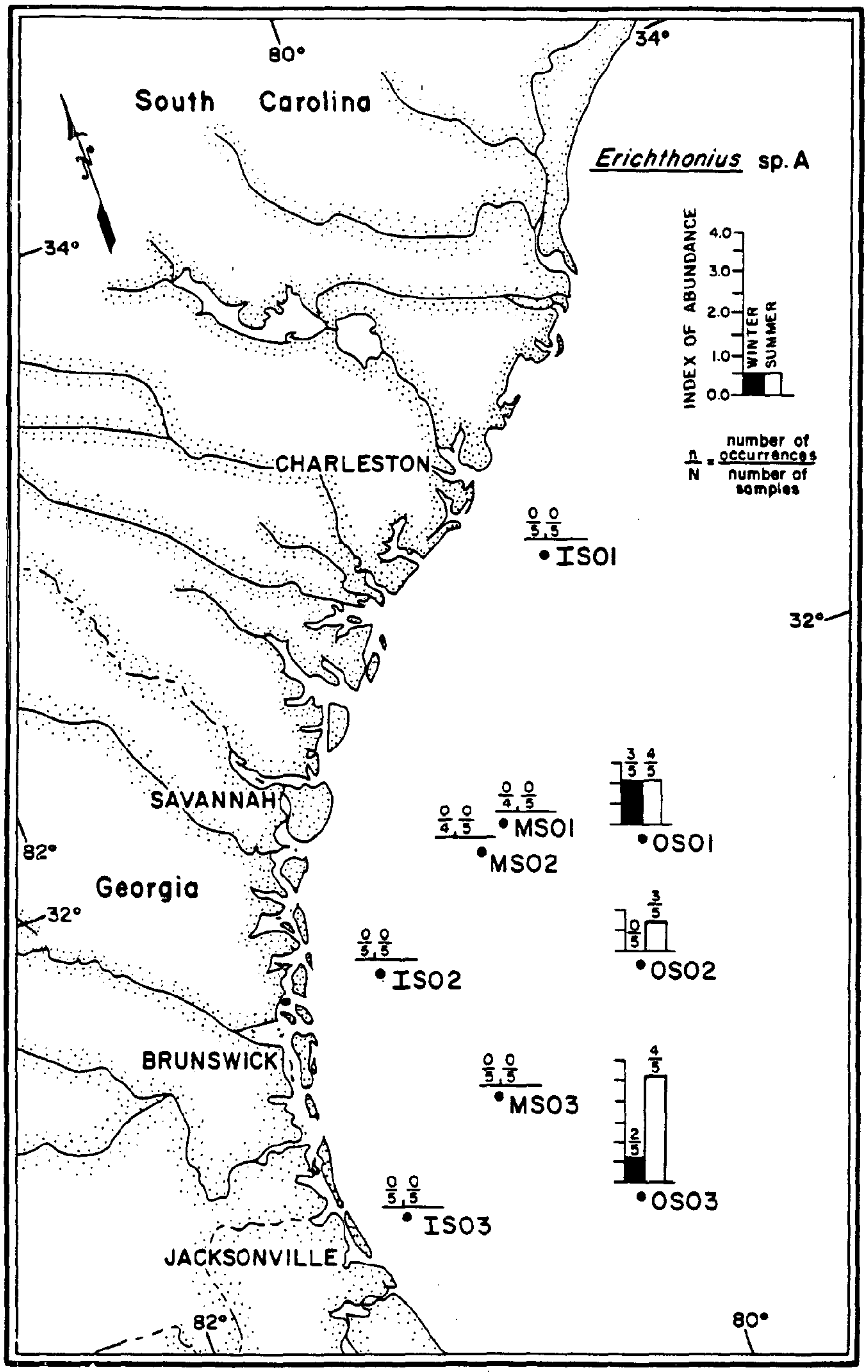


Figure 5.27. Relative abundance of Erichthonius sp. A during winter and summer, 1980.

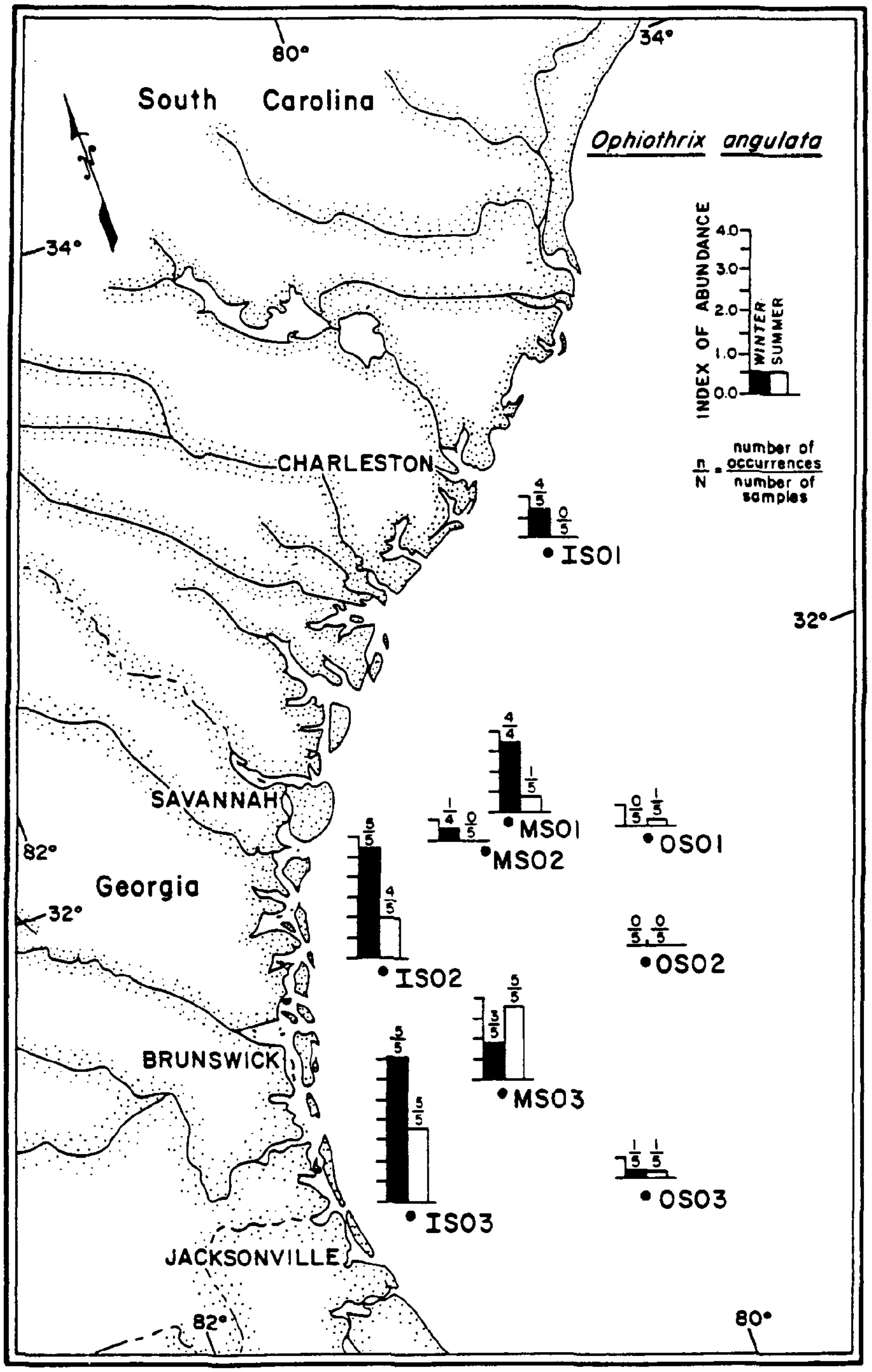


Figure 5.28. Relative abundance of Ophiothrix angulata during winter and summer, 1980.

differences in abundance were noticed.

The infaunal tube building spionid polychaete Spiophanes bombyx was collected at every station during our study. It occurred in 65% of the suction and grab samples in winter and 51% in summer. Abundances were greatest at stations OS01 and OS02 during summer when S. bombyx was collected in all samples at both stations (Figure 5.21). No significant difference between winter and summer abundances of S. bombyx was found ($P > 0.05$, Mann-Whitney U-test).

Exogone dispar, a syllid polychaete, was most abundant at inner shelf stations (Figure 5.22). This species was also collected at stations on the middle shelf but was not found at outer shelf localities. It occurred in 51% of all winter suction and grab collections and 20% of the summer collections. There was no significant difference in the abundance of E. dispar between winter and summer sampling periods ($P > 0.05$, Mann-Whitney U-test), even though the species was collected at twice as many stations during the winter.

Another syllid polychaete, Syllis spongicola, was collected at every station in both seasons (Figure 5.23). It was most frequently encountered in summer when it occurred in 44% of the suction and grab samples. In winter, it was present in 42% of the collections. It was most abundant at stations MS01 and MS03, and least abundant at outer shelf stations. Abundances were not significantly different between winter and summer ($P > 0.05$, Mann-Whitney U-test).

The amphipod Photis sp. was most abundant at inner and middle shelf stations where it was collected almost exclusively during winter (Figure 5.24). It was collected in 74% of the winter suction and grab collections and in 31% of the summer collections. At outer shelf stations, Photis sp. was most abundant in summer; however, no significant difference was noted in the overall abundance of Photis sp. between sampling periods ($P > 0.05$, Mann-Whitney U-test).

Podocerus sp. was ubiquitous on the continental shelf; however, its abundance was greatest at inner shelf stations where it was collected most often during winter (Figure 5.25). It occurred in 67% and 20% of the suction and grab samples collected in winter and summer, respectively. The number of specimens in our samples indicates that Podocerus sp. was significantly more abundant in winter than in summer ($P < 0.05$, Mann-Whitney U-test).

The caprellid amphipod Luconacia incerta was also collected at all stations but was most abundant in inner and middle shelf live bottom areas (Figure 5.26). It was most frequently encountered in winter, when it occurred in 70% of the suction and grab samples, but it was present in only 31% of the summer collections. No significant difference in abundance of L. incerta was noted between winter and summer ($P > 0.05$, Mann-Whitney U-test).

The distribution of Erichthonius sp. A was limited to the outer shelf (Figure 5.27). The abundance of Erichthonius sp. A did not differ significantly between sampling periods ($P > 0.05$, Mann-Whitney U-test). This species was collected in 12% of the suction and grab collections taken in winter and in 24% of those taken in summer.

The ophiuroid, Ophiothrix angulata, was most abundant at stations IS02 and IS03 (Figure 5.28). It was infrequently collected and not very abundant at outer shelf live bottom sites. In winter, O. angulata occurred in 53% of the suction and grab samples and was found in 38% of those taken in summer. No significant difference in abundance was noted between winter and summer ($P > 0.05$, Mann-Whitney U-test).

Community Structure - Community structure measures of Shannon diversity

(H'), evenness (J'), richness (SR), number of species (s) and number of individuals (n) were used primarily to compare faunal assemblages between stations. For completeness and for reference we have also included a listing of these measures for each collection arranged by station and sampling period (Appendices 12 and 13).

The values of H' were generally similar between stations for both sampling periods. Noted exceptions occurred at stations IS02 and IS03 in summer, and station MS01 in both winter and summer (Figure 5.29; Table 5.14), where low H' values were associated with a relatively high abundance of invertebrates and low evenness. Low evenness values were attributed to the overwhelming dominance of inner and middle shelf stations by the colonial polychaete Filograna implexa and of samples from outer shelf station OS03 by F. implexa and Phyllochaetopterus socialis. Furthermore, the substantially lower values of J' at these stations were also a function of the highly contagious distribution of these polychaetes. Most of the other stations had evenness values above 0.60, indicating a fairly even distribution of individuals among species.

The lack of a strong trend between H' and depth was also noted for individual collections (Figure 5.30). It is of interest that H' values for collections from inner and middle shelf depths were less variable (as indicated by the tight clumping of points) than those associated with collections from the outer shelf. The difference in variability between diversity values for these collections probably is related to sampling efficiency of the suction sampler versus that of the grab (see Chapter 8).

Richness corresponded closely to the number of species (Table 5.14). The number of species was found to be significantly different between stations for winter ($P < 0.05$) and summer ($P < 0.05$) by the Kruskal-Wallis test. Lowest values occurred at station OS02 in winter and station IS01 in summer. Otherwise, the richness values were similar between stations and agreed remarkably between sampling periods for a single station.

The number of individuals collected was lowest at stations OS02 and IS01, both of which also had low values of s and SR. Differences in abundance were statistically significant between stations during winter ($P < 0.05$) and summer ($P < 0.05$). No apparent trend in abundance was noted between stations sampled in summer, but fewest individuals were collected at outer shelf stations during winter.

Although H' and its components are important indices for interpreting community structure, they do not fully explain the composition of the community in terms of relative proportions of dominant and rare species. Therefore, we constructed dominance diversity curves for each station based on the numerical relation of individuals to species (Figures 5.31 - 5.39). Results were similar for all stations during both sampling periods in that the majority of species was represented by one or a few individuals. An extension of the dominance diversity curve to the right clearly reflects the presence of many rare species. Species which were represented by one or two individuals accounted for 49% - 71% of all species collected during winter, while the range of percentages in summer was 52% - 79%. In contrast to the large number of rare species, numerically dominant species were few, as expressed by low values (< 40%) of the dominance index (DI). The high values observed at station MS01 and IS02 were in part due to overwhelming dominance by Filograna implexa and Phyllochaetopterus socialis at these stations.

Species Assemblages and Distributional Patterns - Normal cluster analysis of 42 collections taken with suction and grab samplers during winter produced

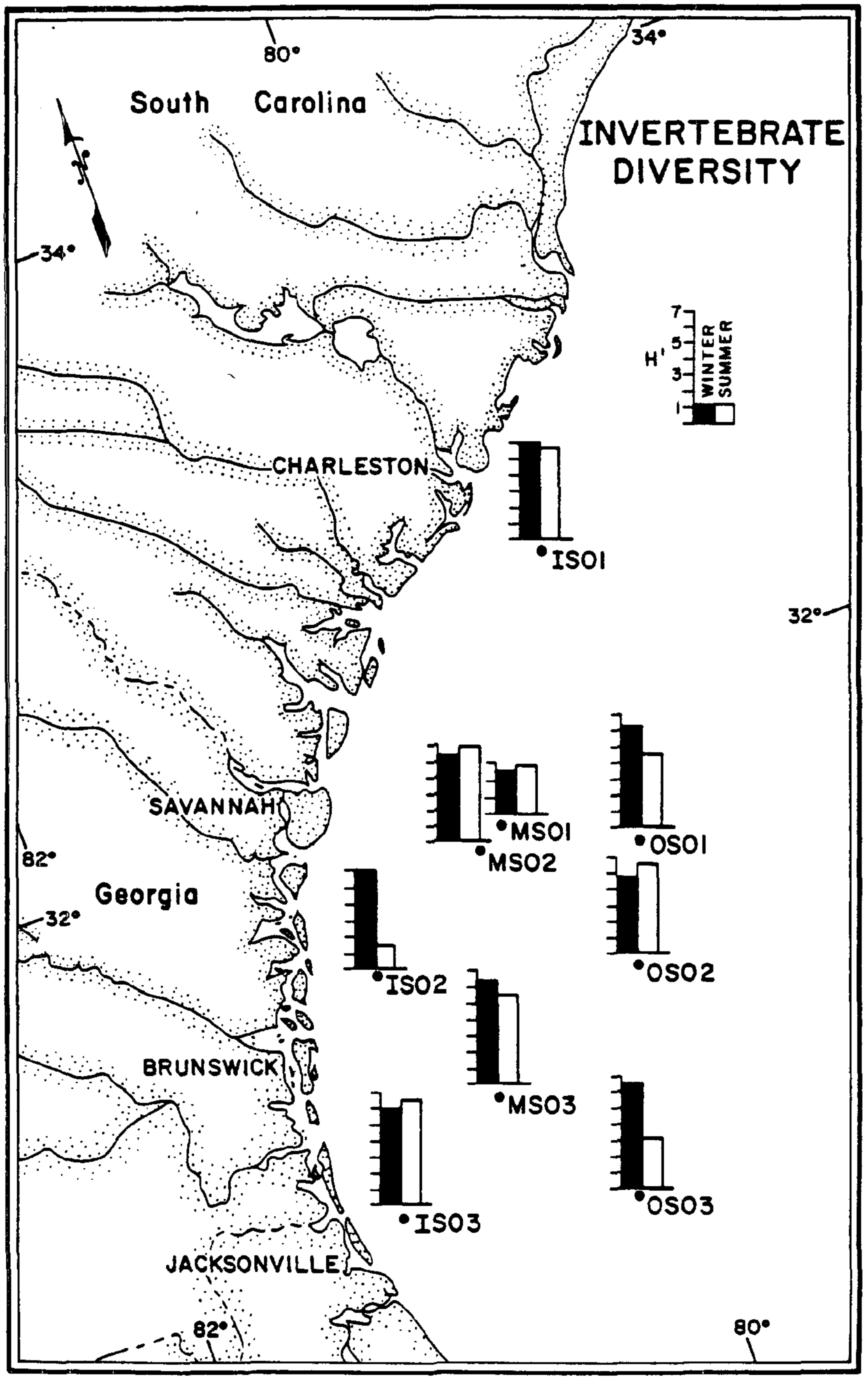


Figure 5.29. Shannon diversity (H') for pooled replicate samples of invertebrates at each station during winter and summer, 1980.

Table 5.14. Community structure values [number of individuals, number of species, Shannon diversity (H'), evenness (J'), and richness (SR)] for pooled replicate samples of invertebrates at each station during winter and summer, 1980.

Station	Season	No. Individuals	No. Species	H'	J'	SR
IS01	winter	1737	243	5.98	0.76	32.44
	summer	222	92	5.74	0.88	16.84
IS02	winter	2250	229	6.05	0.77	29.07
	summer	4526	193	1.43	0.19	22.81
IS03	winter	2874	263	6.11	0.76	32.90
	summer	1368	240	6.63	0.84	33.10
MS01	winter	6528	236	2.56	0.32	26.75
	summer	3180	212	2.99	0.39	26.16
MS02	winter	1202	166	5.62	0.76	23.27
	summer	592	144	5.81	0.81	22.40
MS03	winter	1099	205	6.33	0.82	29.13
	summer	992	193	5.38	0.71	27.83
OS01	winter	425	144	6.21	0.87	23.63
	summer	968	148	4.62	0.64	21.38
OS02	winter	129	48	4.73	0.84	9.67
	summer	1060	157	5.64	0.77	22.39
OS03	winter	616	159	6.39	0.87	24.60
	summer	8257	242	3.10	0.39	26.72

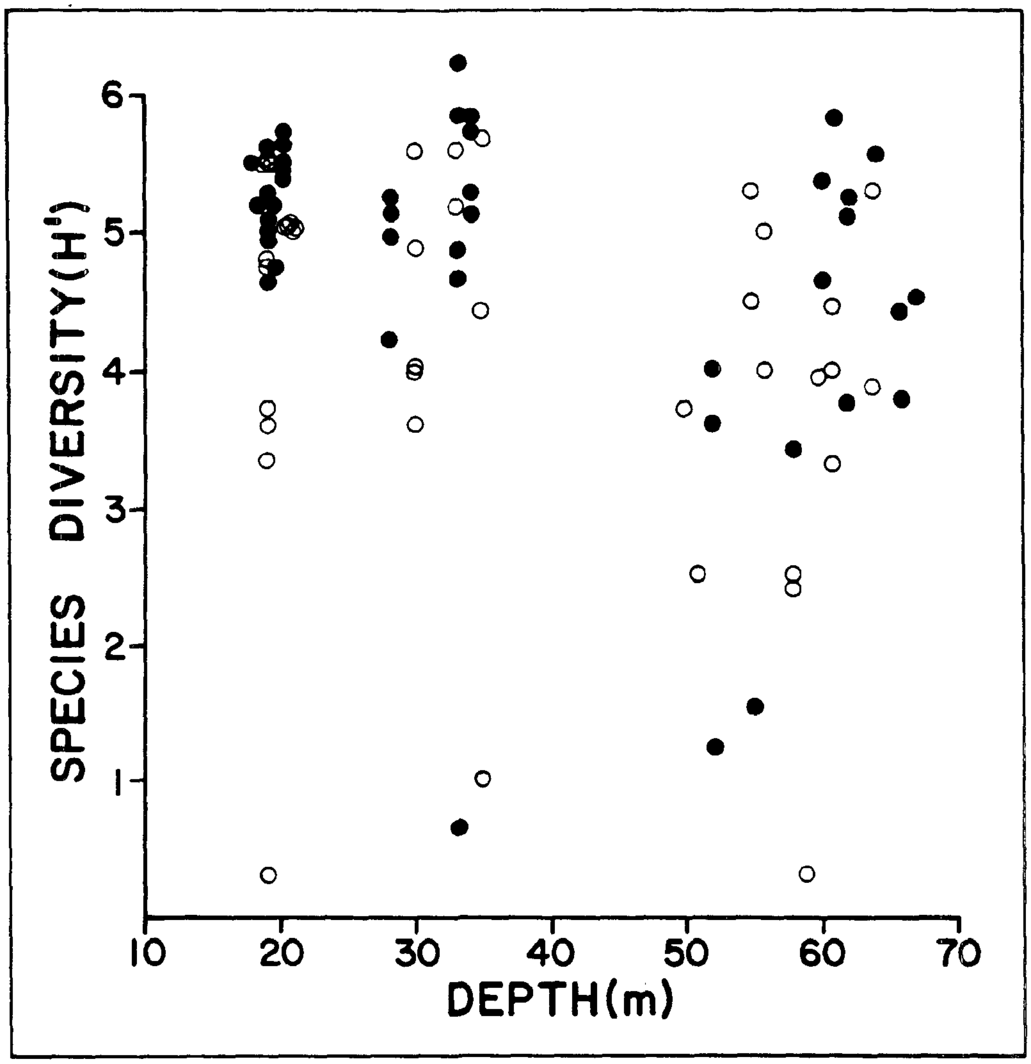


Figure 5.30. Scatterplot showing Shannon diversity (H') in relation to sampling depth. Closed circles represent winter collections, and open circles represent summer collections.

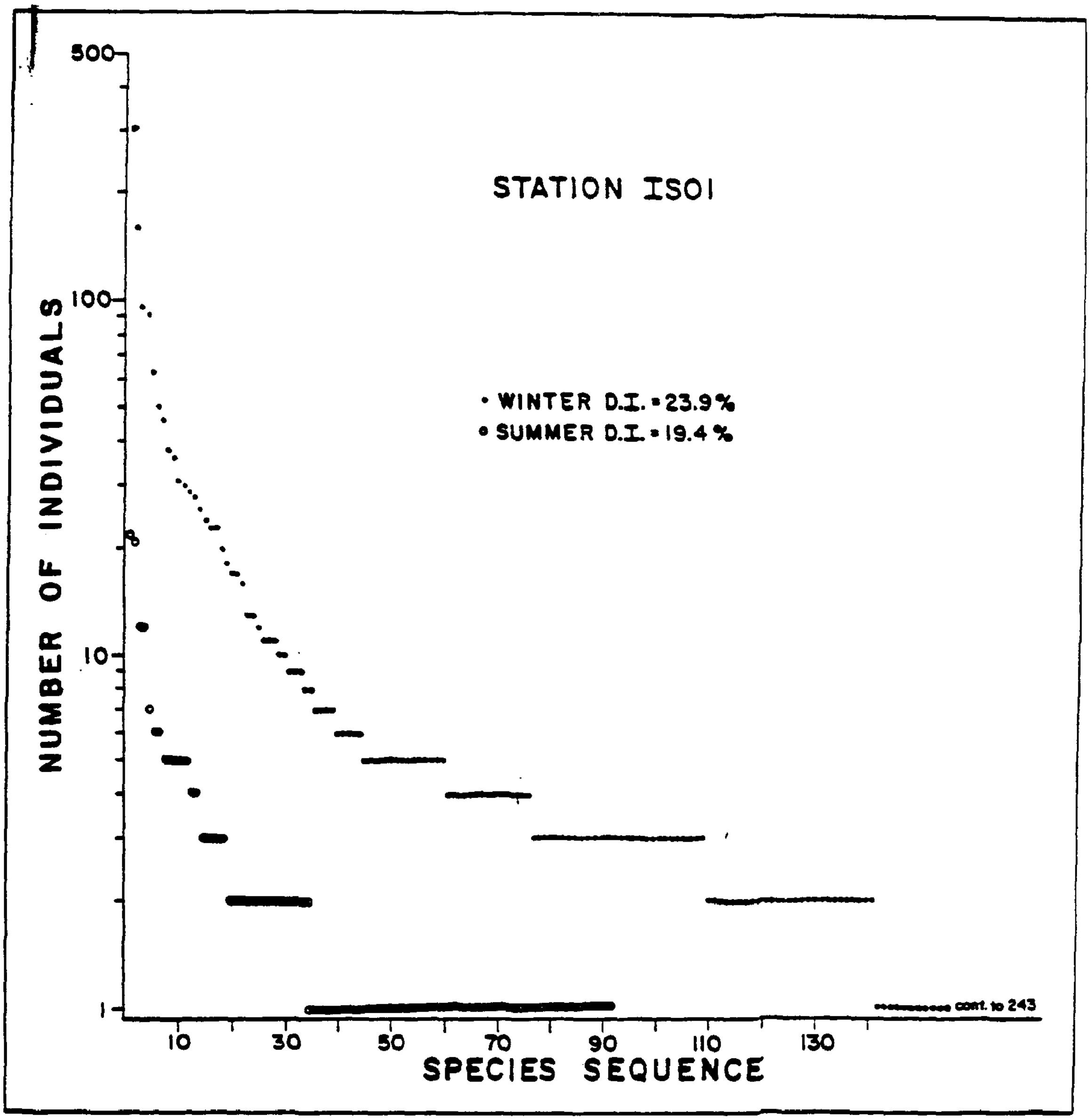


Figure 5.31. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station IS01 during 1980.

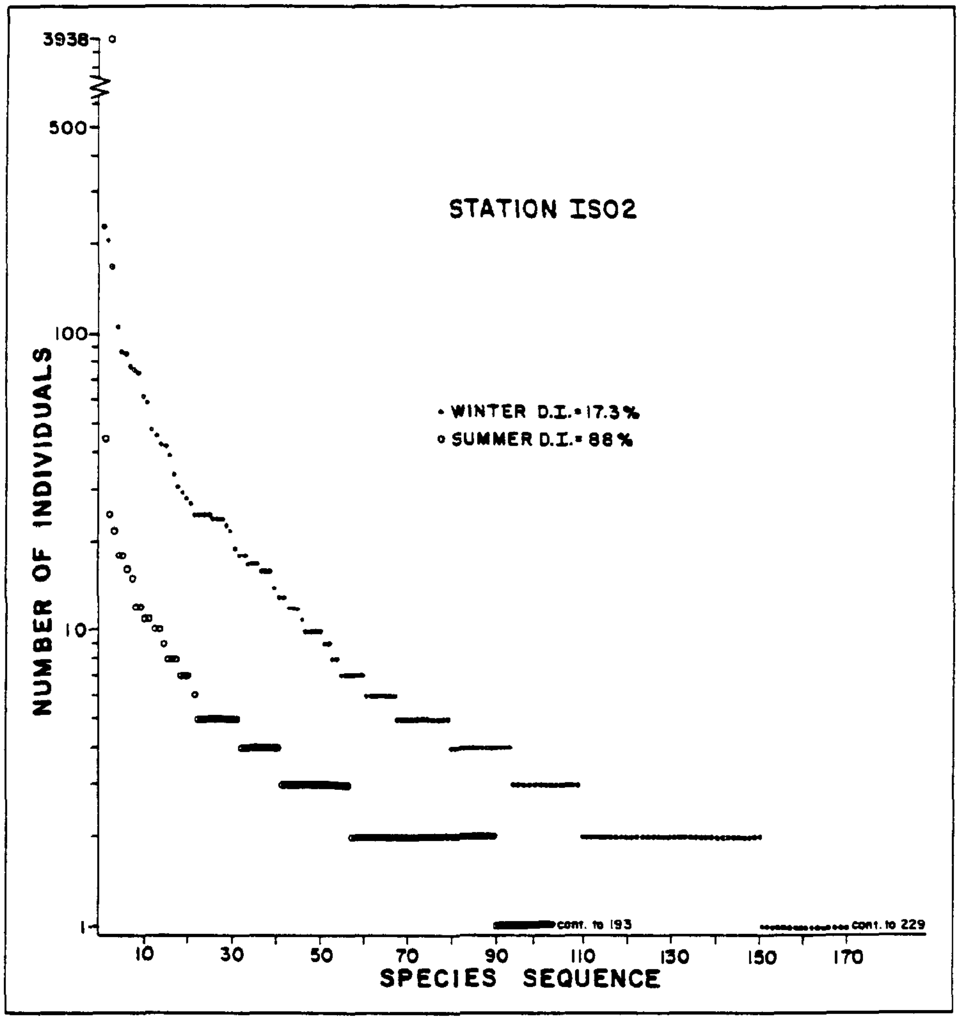


Figure 5.32. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station IS02 during 1980.

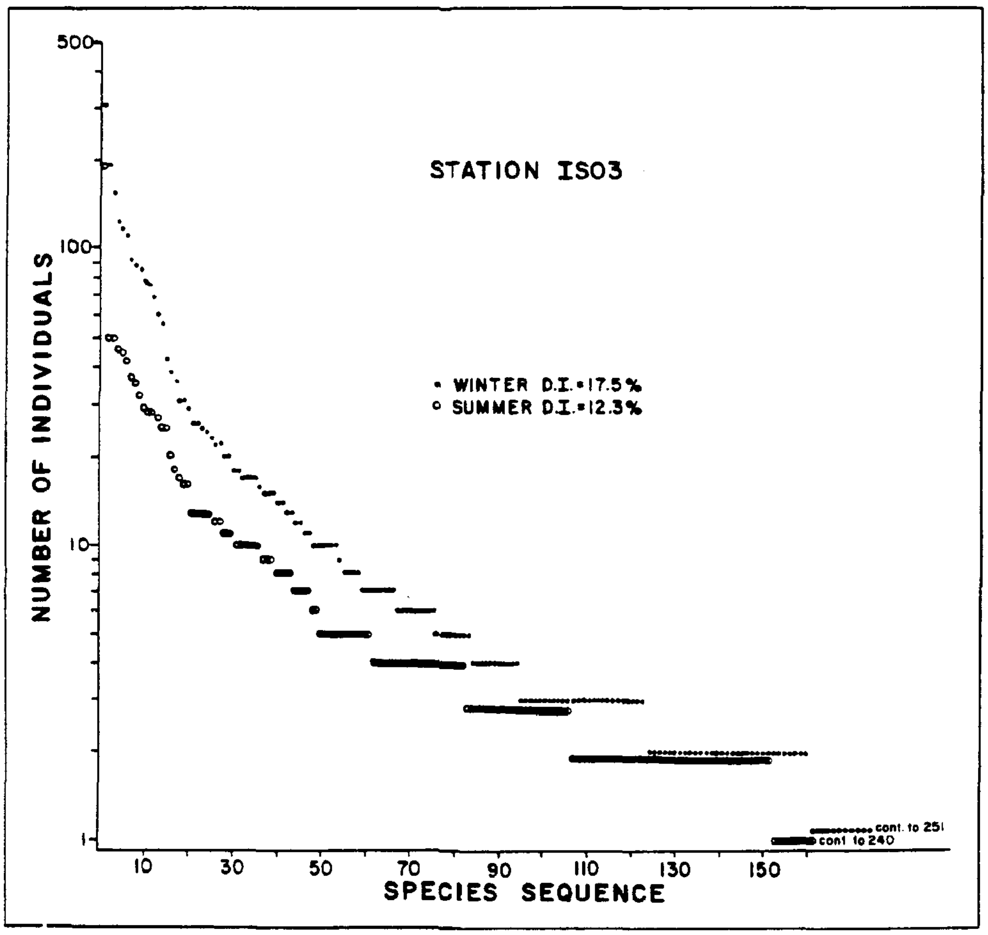


Figure 5.33. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station IS03 during 1980.

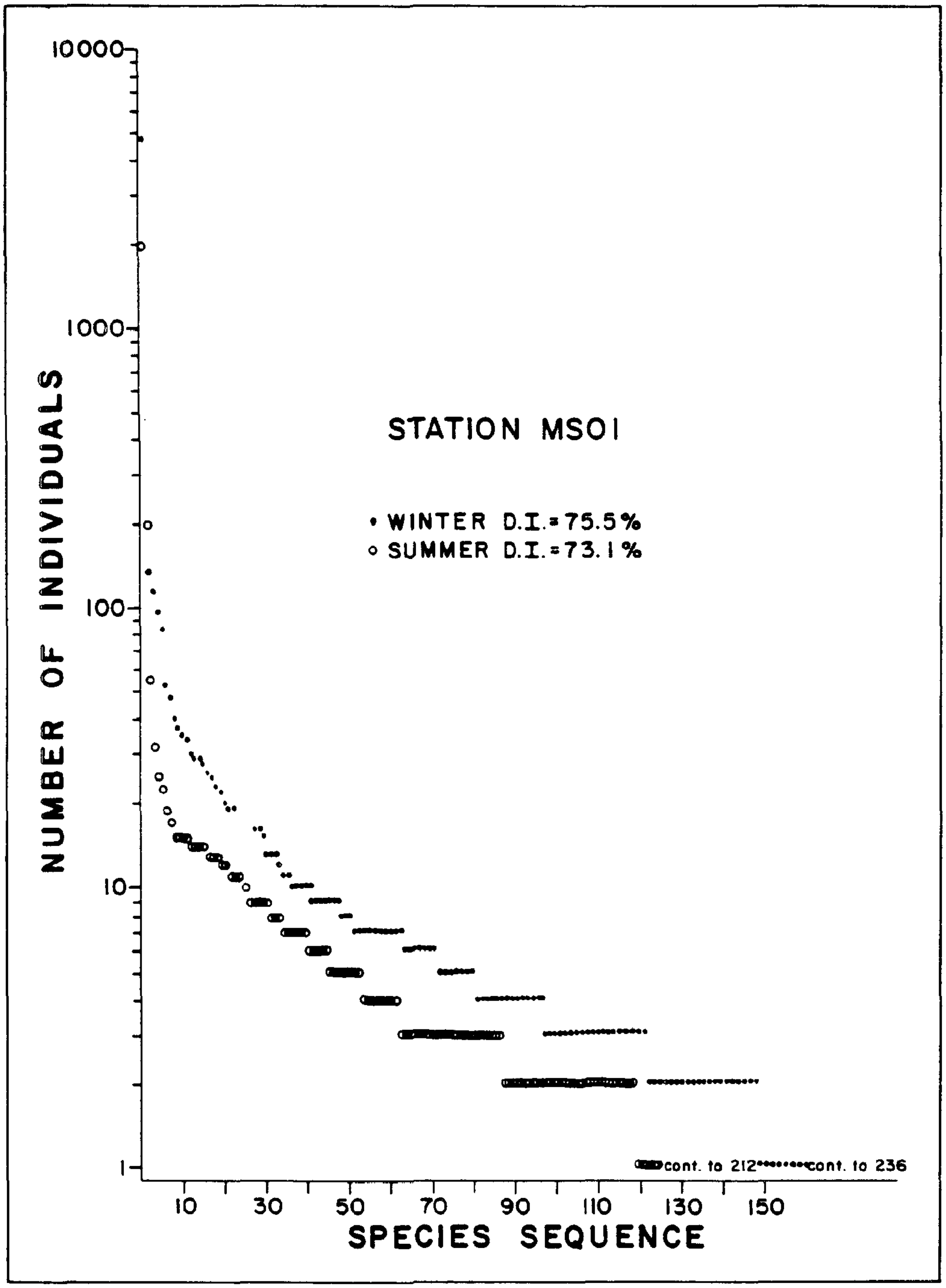


Figure 5.34. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station MS01 during 1980.

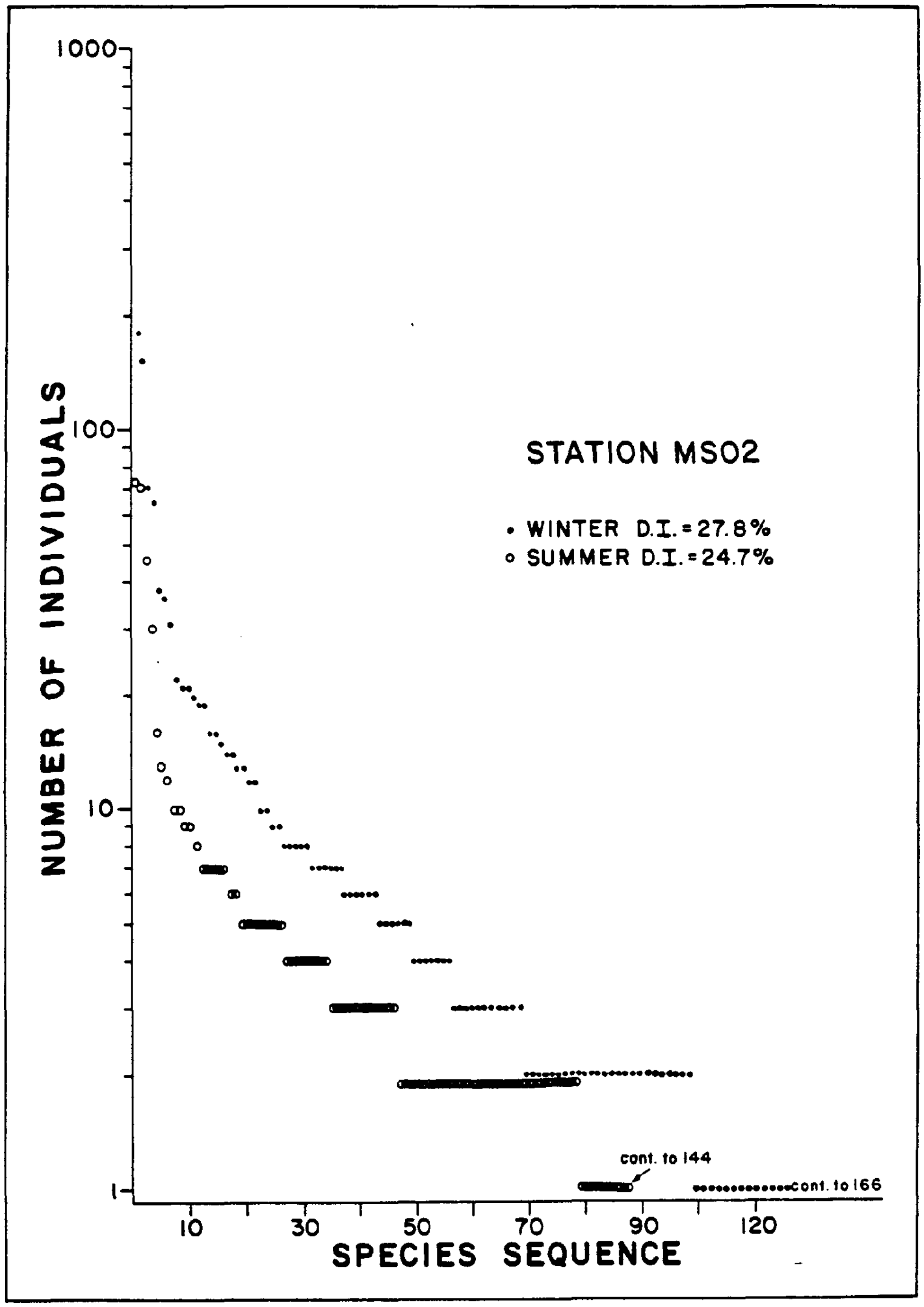


Figure 5.35. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station MS02 during 1980.

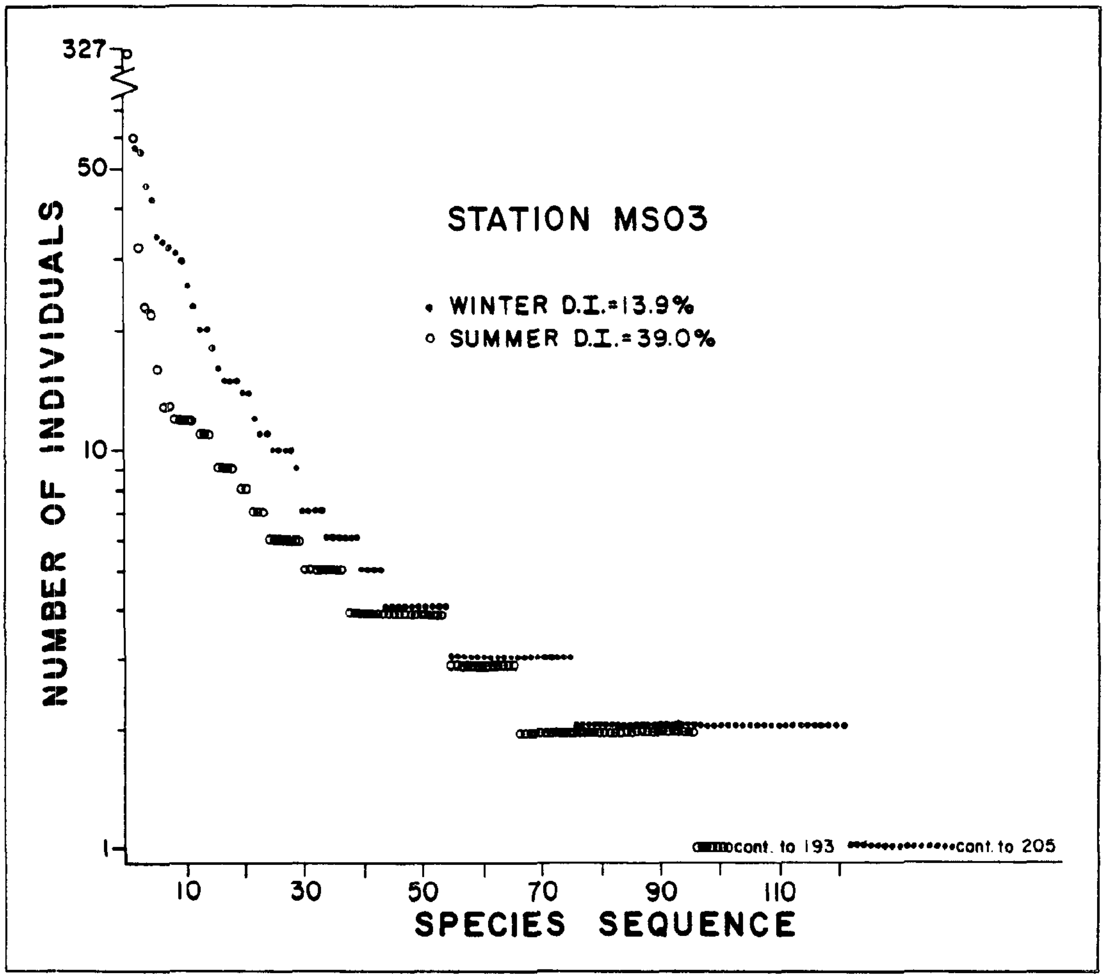


Figure 5.36. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the suction sampler at station MS03 during 1980.

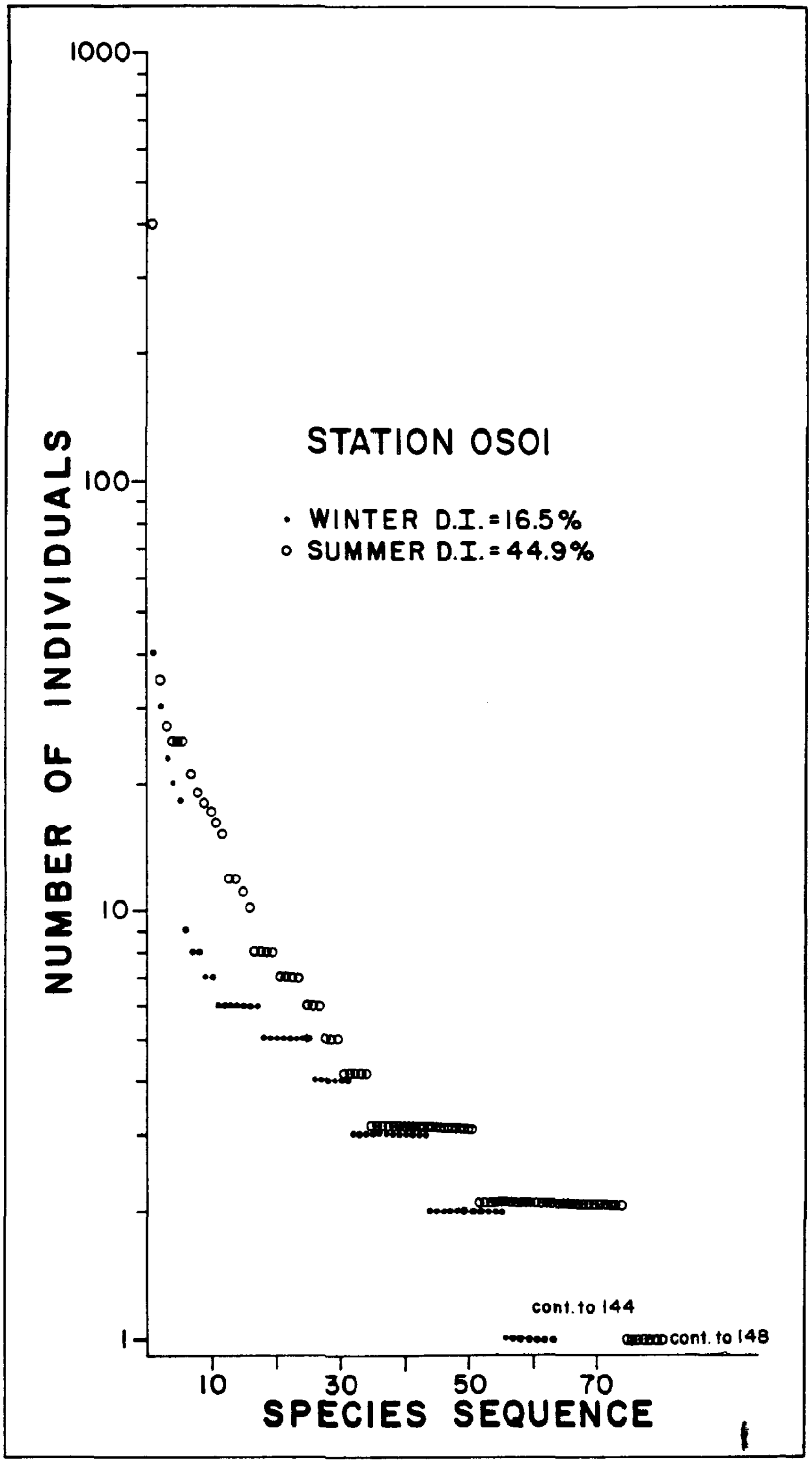


Figure 5.37. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the grab sampler at station OS01 during 1980.

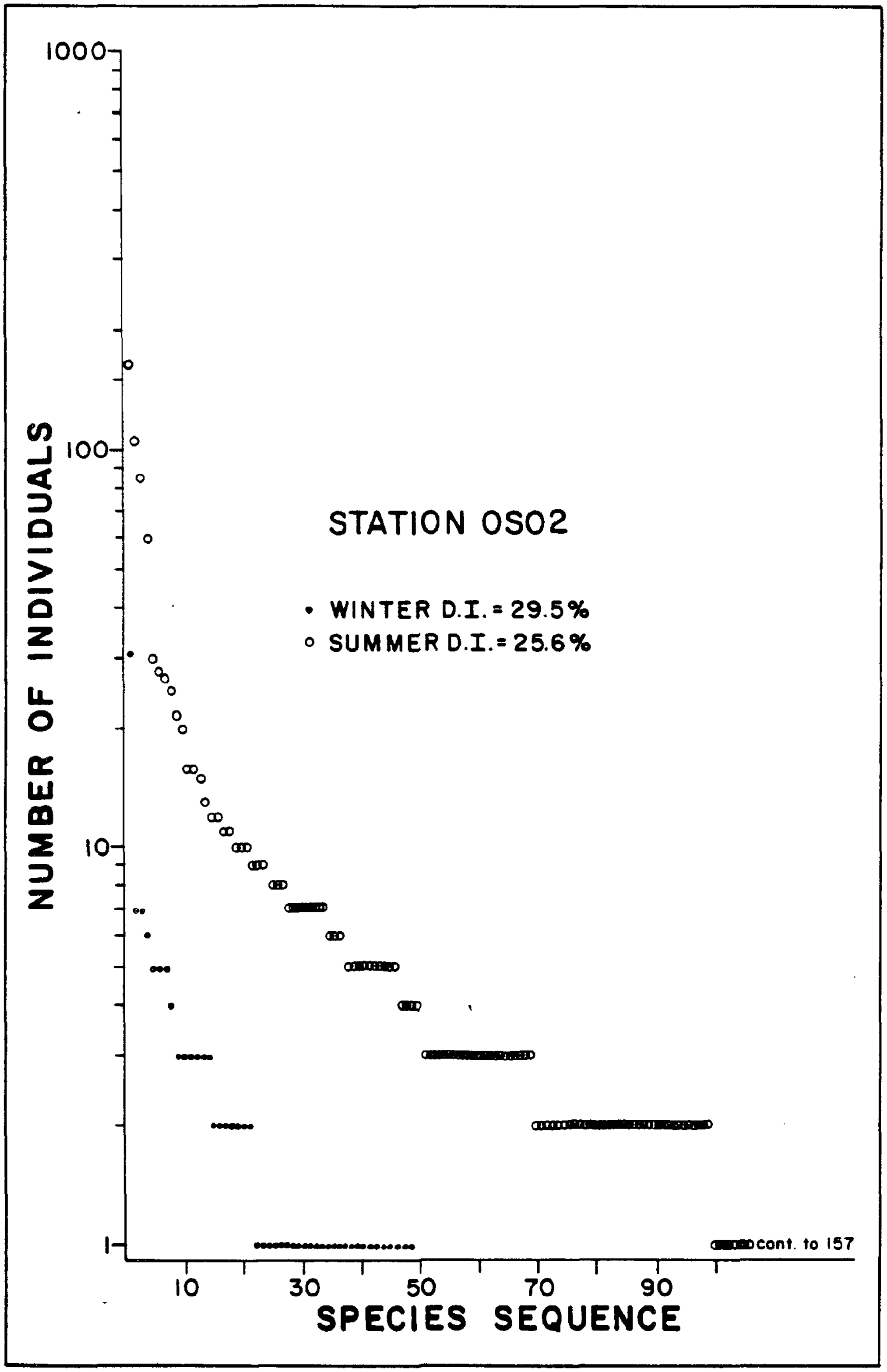


Figure 5.38. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the grab sampler at station OS02 during 1980.

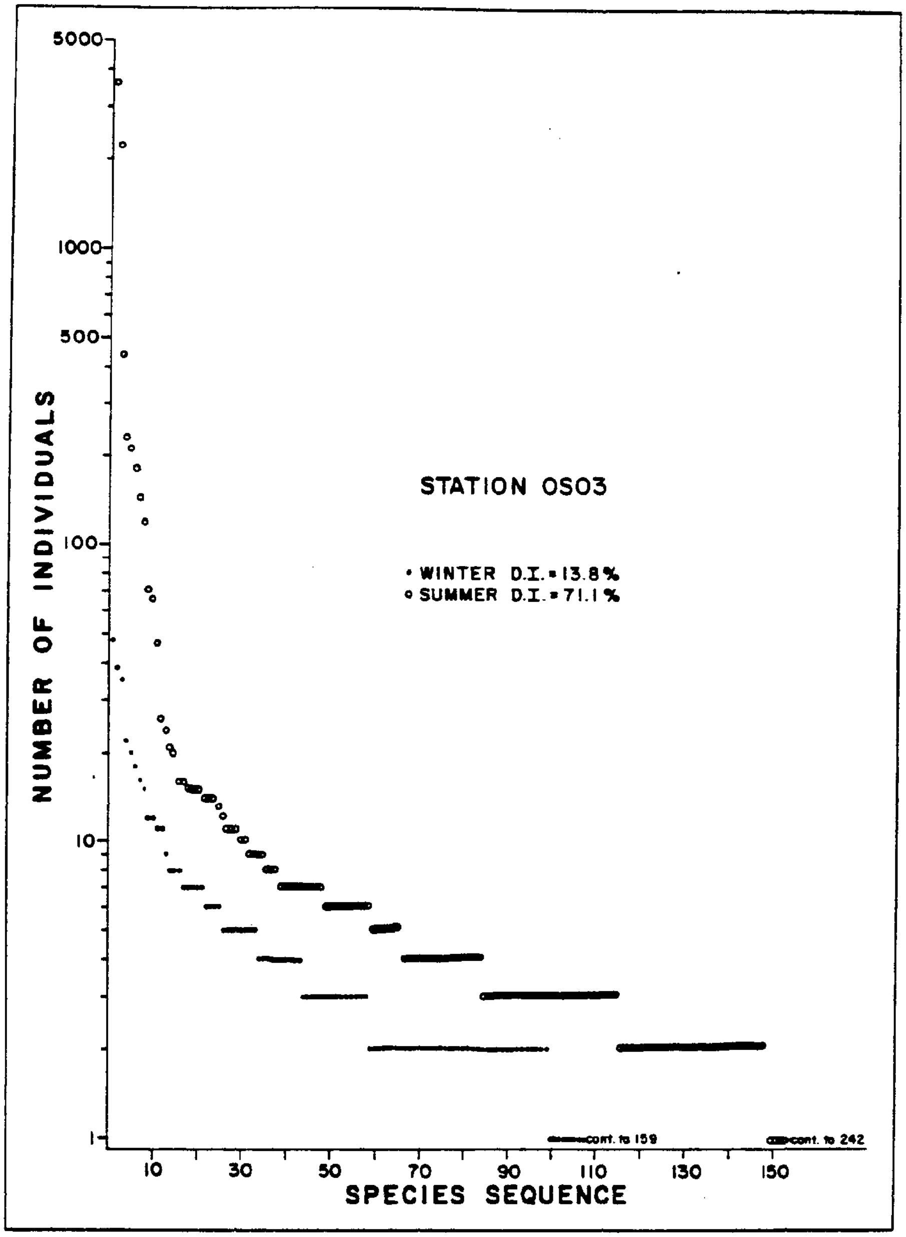


Figure 5.39. Dominance diversity curve and dominance index (D.I.) values for invertebrates collected by the grab sampler at station OS03 during 1980.

5 groups (Figure 5.40). Stations were generally grouped in accordance with their depth zonation on the continental shelf; however, collections from inner and middle shelf live bottom areas formed two groups of collections from each depth zone. Thus, collections from station IS01 were distinct from those taken at stations IS02 and IS03, and the quantitative composition of middle shelf collections in group 3 was different from that of collections in group 4. Outer shelf collections, on the other hand, formed one major agglomeration which was not very similar to other station groups. It is difficult to determine whether outer shelf stations differed from other sites solely because of faunal composition or because of disparate sampling methods between inner, middle, and outer shelf sites. Without using the same gear at all sites, it cannot be conclusively stated whether outer shelf stations have different organisms.

Results of cluster analysis of summer data were not as clear. Classification of the 45 collections formed seven groups which were not all readily explainable in terms of location (Figure 5.41). For example, groups 2, 3, 4, and 7 each consisted of collections from either the inner, middle, or outer shelf live bottom habitats, whereas groups 1, 5, and 6 were composed of collections from more than one area of the shelf. When compared with the relatively high integrity of collections within a site group for the winter data, these results suggest that the quantitative composition of the live bottom community was much more homogeneous across the entire shelf during summer. It further implies that strong zonation of the fauna did not occur at that time.

Ordination of suction and grab collections helped to clarify zonation patterns and pointed out several misclassifications which occurred during cluster analysis. Axes 1 and 2 of the station ordination for winter data together accounted for 26.06% of the total eigenvalue and jointly distinguished outer shelf collections (i.e., members of cluster group 5) from inner and middle shelf collections (Figure 5.42). However, three samples from site group 5 were closer to members of group 4 in the two-dimensional ordination space, suggesting that these seemingly aberrant collections may have been misclassified by the normal cluster analysis. In general, constituents of middle shelf site group 4 had intermediate scores on axis 1, while members of inner and middle shelf site groups 1, 2, and 3 had high scores on axis 1. Axis 2 successfully separated members of inner shelf site group 1 from constituents of groups 2 and 3; however, the overlap among members of the latter two site groups on both axes 1 and 2 suggests that any differences in faunal composition between the two groups may have been exaggerated by cluster analysis.

Ordination of summer data revealed that neither axis 1 nor axis 2 alone was successful in separating all collections taken in any one shelf area from collections taken in other areas. These two axes accounted for 30.89% of the total eigenvalue. The ordination results confirm those of the normal cluster analysis; namely, that strong zonation of the fauna with respect to bathymetry is apparently not as pronounced in the summer as it is in the winter. Certain collection groups defined by cluster analysis retain their integrity in the two-dimensional ordination space, however. Notably, outer shelf site groups 6 and 7 are largely self contained entities in the lower left hand corner of the ordination space (although one collection from site group 7 is distinguished as an "outlier" by its unusually high abundance of the colonial polychaete *Phyllochaetopterus socialis*) (Figure 5.43). Similarly, constituents of inner and middle shelf site group 1 formed a cohesive group in the upper middle portion of the ordination space. Members of all other collection groups (particularly site groups 3 and 5) were widely distributed and showed no apparent

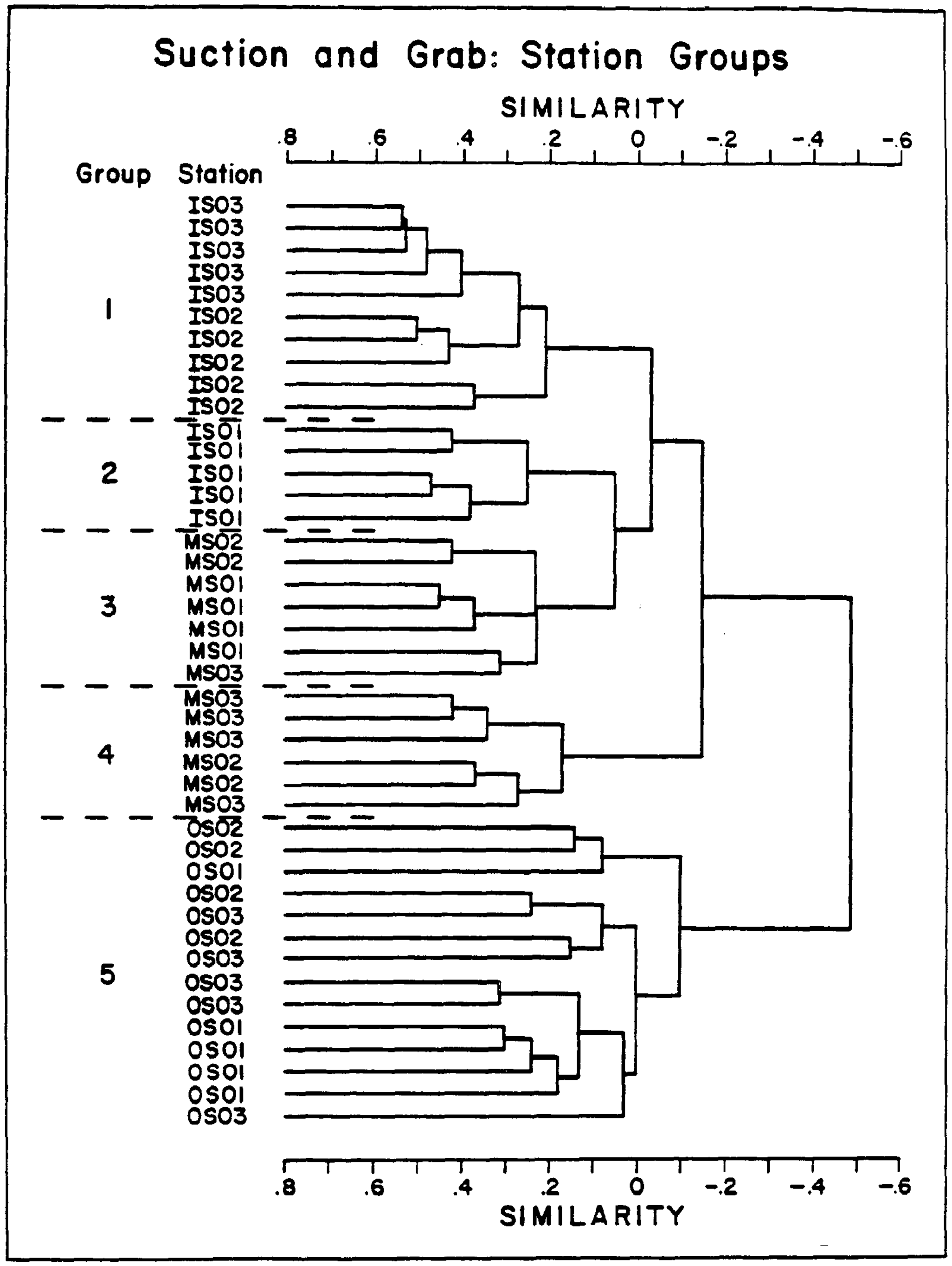


Figure 5.40. Normal cluster dendrogram of winter suction and grab collections indicating station groups formed by a combination of Canberra metric similarity coefficient, square root transformation, and flexible sorting.

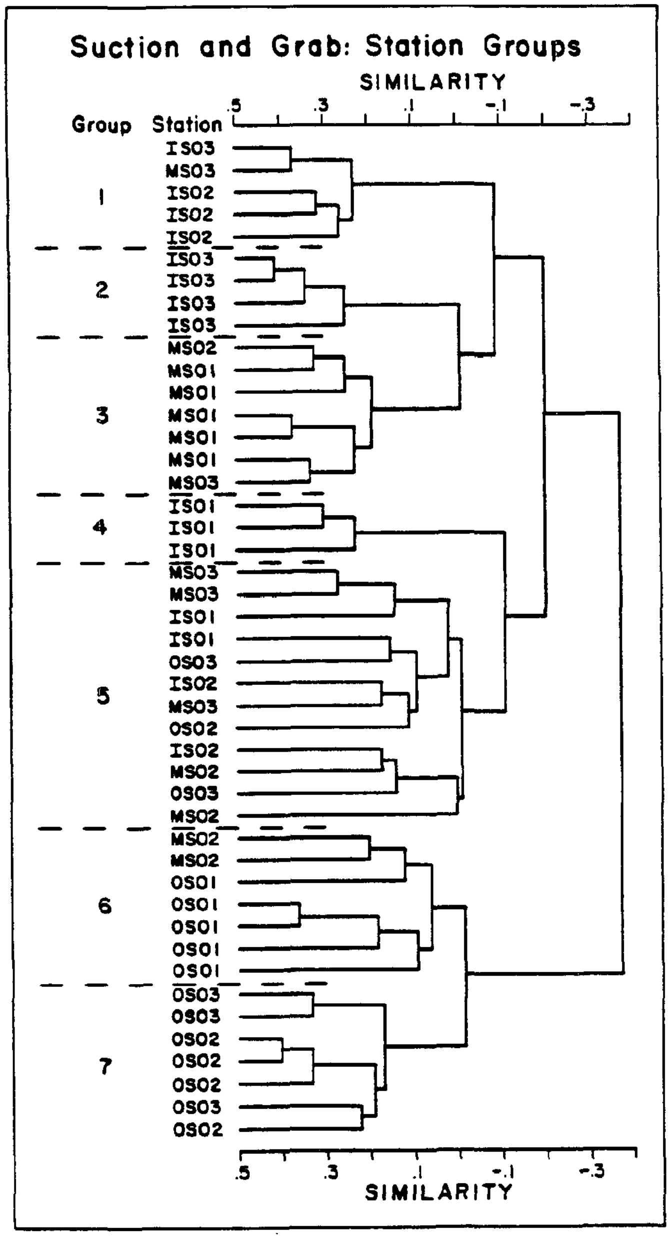


Figure 5.41. Normal cluster dendrogram of summer suction and grab collections indicating station groups formed using the Canberra metric similarity coefficient, square root transformation, and flexible sorting.

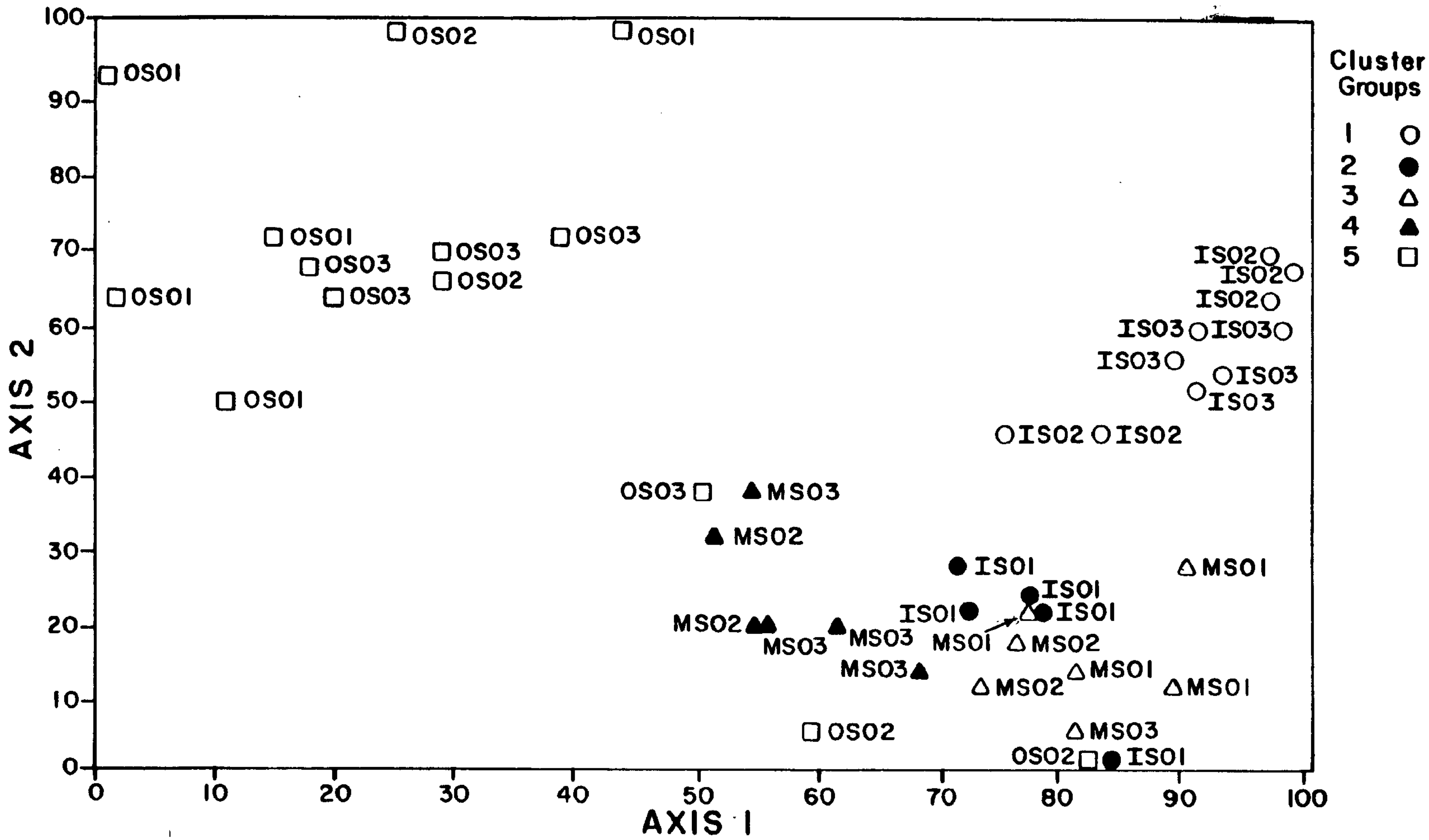


Figure 5.42. Results of reciprocal averaging ordination showing orientation of winter suction and grab collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

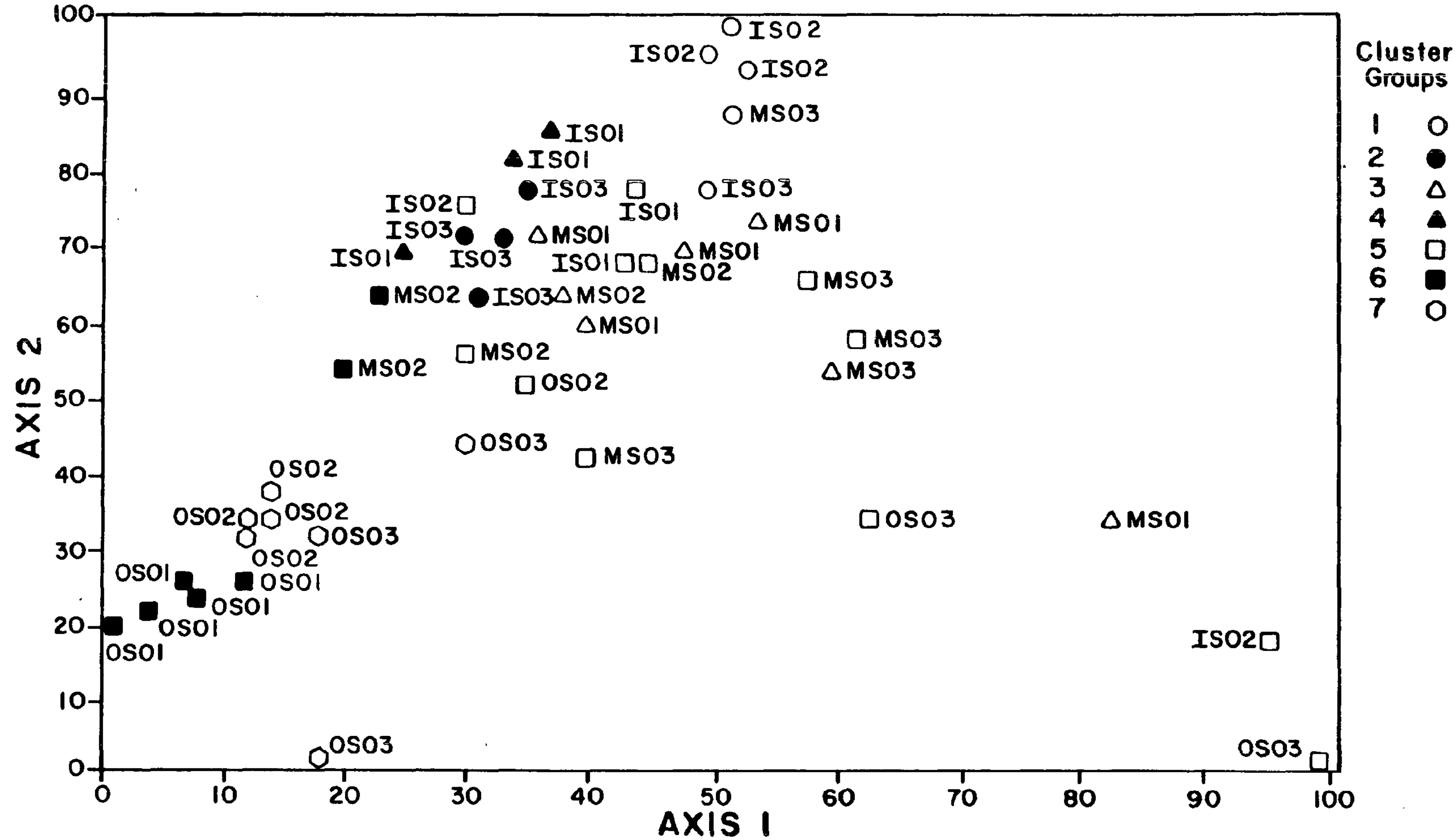


Figure 5.43. Results of reciprocal averaging ordination showing orientation of summer suction and grab collections at stations on axes 1 and 2. Symbols indicate which group these collections were placed into by cluster analysis.

trends with respect to either ordination axis. The most deviant members of collection groups 3 and 5 had the highest scores on axis 1, however, and all were distinguished by large numbers of another colonial polychaete, Filograna implexa.

The classification of 105 species remaining after reduction of winter data produced seven groups (Table 5.15). Nodal constancy and fidelity diagrams (Figure 5.44) revealed that the groupings were interpretable in terms of station location. Species in group A were very highly constant at inner shelf stations IS02 and IS03, and were infrequently collected at MS01. Those species in this group which were entirely restricted to inner shelf stations during winter included the amphipod Amphithoe sp. A and the annelids Eulalia macroceros and Pista quadrilobata.

As indicated by the cluster hierarchy shown in Figure 5.44, species in group B were most similar to those in group A with respect to distribution. Group B species were highly constant in collections from IS02, IS03, and MS01, although they were generally more ubiquitous than group A species, and none were restricted to collections from inner shelf live bottom areas.

Group C species were frequently collected at inner and middle shelf stations. In accordance with their ubiquitous distribution, this group was not faithful to any one station. The numerically dominant amphipods Luconacia incerta and Podocerus sp., polychaetes Spiophanes bombyx and Exogone dispar, and the echinoderm Ophiothrix angulata occurred in this group.

Species in group D were widespread but generally uncommon across the shelf. The only numerical dominant belonging to this group was the syllid polychaete Syllis spongicola.

Group E species were very constant and faithful at station MS01. This group was also encountered at other stations from inner and middle shelf live bottoms but was not very common.

Species in groups F and G were characteristic of the inner shelf live bottom habitat and consistently occurred in collections from stations IS03 and IS01, respectively. These species were not faithful or constant at any other sites where they occurred.

Groups formed by classification of 123 species from summer collections differed from those generated for winter data because of the presence of definite outer shelf assemblages (Table 5.15, Figure 5.45). Otherwise, results from the two seasons were similar with predominantly ubiquitous inner and middle shelf live bottom assemblages represented in collections from both winter and summer.

Species in groups A and B were most consistently collected from outer shelf live bottom areas, especially OS02. Group A species were largely restricted to stations OS02 and OS03 and all members of the group were collected at these stations at least once. Group B species were not restricted in such a manner and displayed only low to moderate constancy for all sites except OS02 where it was consistently collected. Only the amphipods Unciola sp. A and Erichthonius sp. A, and the polychaete Syllis sp. D were limited to outer shelf stations. As indicated by the cluster hierarchy of Figure 5.45, little similarity existed between groups A and B and others formed by cluster analysis.

Ubiquitous shelf species formed groups C and E. Those in group C were generally uncommon and displayed only low to moderate constancy at all sites. The numerically dominant species Spiophanes bombyx and Podocerus sp. were included in group C. Group E contained species which were not consistently encountered anywhere except station IS03.

Table 5.15. Species groups resulting from numerical classification of data from samples collected by suction and grab samplers during winter and summer, 1980. (Am = Amphipoda; Br = Branchiopoda; Cu = Cumacea; D = Decapoda; E = Echinodermata; I = Isopoda; M = Mollusca; My = Mysidacea; P = Polychaete; Po = Porifera; Py = Pycnogonida; Si = Sipunculida; T = Tanaidacea).

Winter 1980

Group A

Ampithoe sp. A (Am)
Eulalia macroceros (P)
Pista quadrilobata (P)
Musculus sp. A (M)
Pherusa ehlersi (P)
Sabellaria vulgaris beaufortensis (P)

Group B

Anachis iontha (M)
Apanthura magnifica (I)
Microdeutopus myersi (Am)
Mitrella lunata (M)
Tellina sp. (M)
Megalobrachium soriatum (D)
Elasmopus sp. A (Am)
Pseudomedaeus agassizii (D)
Lembos unicornis (Am)
Websterinereis tridentata (P)
Pherusa inflata (P)
Lumbrineris inflata (P)
Syllis gracilis (P)
Branchiosyllis oculata (P)
Syllis regulata carolinae (P)
Podarke obscura (P)
Synalpheus townsendi (D)
Odontosyllis fulgurans (P)

Group C

Gammaropsis sp. (Am)
Caprella equilibra (Am)
Melita appendiculata (Am)
Luconacia incerta (Am)
Photis sp. (Am)
Erichthonius brasiliensis (Am)
Podoceros sp. (Am)
Pagurus carolinensis (D)
Paracerceis caudata (I)
Ampelisca agassizii (Am)
Ophiothrix angulata (E)
Aspidosiphon spinalis (Si)
Lembos smithi (Am)
Loimia medusa (P)
Prionospio cristata (P)
Owenia fusiformis (P)
Mediomastus californiensis (P)
Ampelisca vadorum (Am)
Axiothella mucosa (P)
Ampharete americana (P)
Sicyonia laevigata (D)
Exogone dispar (P)
Sabellaria vulgaris vulgaris (P)
Eunice vittata (P)
Oxyurostylis smithi (Cu)
Chrysopetalidae A (P)
Amphiodia pulchella (E)
Polycirrus carolinensis (P)
Eulalia sanguinea (P)

Summer 1980

Group A

Ampelisca sp. B (Am)
Glycera capitata (P)
Syllis cornuta (P)
Chaetozone setosa (P)
Terebellidae C (P)
Polydora caeca (P)

Group B

Onuphis pallidula (P)
Spio pettiboneae (P)
Photis sp. (Am)
Ampelisca vadorum (Am)
Ampharete acutifrons (P)
Phyllodoce longipes (P)
Prionospio sp. B (P)
Unciola sp. A (Am)
Erichthonius sp. A (Am)
Onuphis nebulosa (P)
Accalanthura crenulata (I)
Sthenelais boa (P)
Genocidaris maculata (E)
Syllis sp. D (P)
Glycera sp. B (P)
Armandia maculata (P)
Psammolyce ctenidophora (P)

Group C

Leptochelia sp. (T)
Glycera tesselata (P)
Phtisica marina (Am)
Megalomma bioculatum (P)
Chone americana (P)
Autolytus sp. (P)
Eunice vittata (P)
Chrysopetalidae A (P)
Eulalia sanguinea (P)
Polycirrus carolinensis (P)
Ceratonereis mirabilis (P)
Leptochela papulata (D)
Hydroides sp. A (P)
Pomatoceros americanus (P)
Spiophanes bombyx (P)
Owenia fusiformis (P)
Pagurus hendersoni (D)
Harmothoe sp. A (P)
Melita appendiculata (Am)
Podocerus sp. (Am)
Unciola laminosa (Am)
Erichthonius brasiliensis (Am)
Alpheus normanni (D)

Group D

Lysianopsis alba (Am)
Aspidosiphon misakiensis (Si)
Apanthura magnifica (I)
Tellina sp. (M)

Table 5.15 (Continued)

Winter 1980

Syllis hyalina (P)
Laonice cirrata (P)
Phtisica marina (Am)
Spiophanes bombyx (P)
Glycera tesselata (P)
Pista palmata (P)

Group D

Phyllodoce fragilis (P)
Chrysopetalidae B (P)
Autolytus sp. (P)
Phyllodoce longipes (P)
Anoplodactylus petiolatus (Py)
Lumbrineris impatiens (P)
Paraprionospio pinnata (P)
Spio pettiboneae (P)
Syllis sp. D (P)
Syllis spongicola (P)
Chone americana (P)
Crassinella lunulata (M)

Group E

Cinachyra alloclada (Po)
Caprella penantis (Am)
Megaluropus sp. (Am)
Ophiostigma isacanthum (E)
Bodotriidae B (Cu)
Thor sp. (D)
Syllis alternata (P)
Amphipoda E
Maera sp. A (Am)
Malacoceros glutaeus (P)
Leucothoe spinicarpa (Am)

Group F

Homaxinella waltonsmithi (Po)
Carpias bermudensis (I)
Polycirrus eximius (P)
Protodorvillea kefersteini (P)
Cinachyra keukenthali (Po)
Pelia mutica (D)
Megalomma bioculatum (P)
Tanaidacea A
Strombiformis bilineatus (?) (M)
Arabella mutans (P)
Hydroides sp. A (P)

Group G

Pteria colymbus (M)
Harmothoe sp. A (P)
Inachoides forceps (D)
Unciola laminosa (Am)
Gouldia cerina (M)
Lysianopsis alba (Am)
Pseudeurythoe ambigua (P)
Latreutes parvulus (D)
Gitanopsis sp. (Am)
Leptochela papulata (D)
Bowmaniella portoricensis (My)
Aspidosiphon misakiensis (Si)

Summer 1980

Cinachyra kuekenthali (Po)
Craniellidae B (Po)
Natica pusilla (M)
Corbula dietziana (M)

Group E

Laonice cirrata (P)
Spionidae B (P)
Crassinella lunulata (M)
Prionospio cristata (P)
Gouldia cerina (M)
Goniadides carolinae (P)
Axiothella mucosa (P)

Group F

Bowmaniella portoricensis (My)
Varicorbula operculata (M)
Tellina americana (M)
Laevicardium pictum (M)
Anchialina typica (My)
Thelepus setosus (P)
Phyllochaetopterus socialis (P)
Erycina linella (M)
Tellina sybaritica (M)
Glottidia pyramidata (Br)
Mesochaetopterus sp. (P)
Scolelepis texana (P)
Batrachonotus fragosus (D)
Paraprionospio pinnata (P)
Amphiodia pulchella (E)

Group G

Cinachyra alloclada (Po)
Lima pelucida (M)
Eunice filamentosa (P)
Loimia medusa (P)
Nassarius albus (M)
Pilumnus floridanus (D)
Pherusa inflata (P)
Cumingia coarctata (M)
Exogone dispar (P)
Nicomache trispinata (P)
Anoplodactylus petiolatus (Py)
Syllis alternata (P)
Luconacia incerta (Am)

Group H

Scypha barbadensis (Po)
Clathrina coriacea (Po)
Chione grus (M)
Syllis hyalina (P)
Leucothoe spinicarpa (Am)
Phyllocarida
Thor sp. (D)
Tanaidacea B
Mediomastus californiensis (P)
Lysidice ninetta (P)
Pseudeurythoe ambigua (P)
Anachis hotessieriana (M)
Nassarina minor (M)

Table 5.15 (Continued)

Summer 1980
Filograna implexa (P)
Group I
Phyllodoce fragilis (P)
Syllis gracilis (P)
Podarke obscura (P)
Pagurus carolinensis (D)
Websterinereis sp. A (P)
Lembos unicornis (Am)
Malacoceros glutaeus (P)
Megalobrachium soriatum (D)
Pista quadrilobata (P)
Sipunculida A
Synalpheus townsendi (D)
Lembos smithi (Am)
Elasmopus sp. A (Am)
Paracerceis caudata (I)
Pelia mutica (D)
Aspidosiphon spinalis (Si)
Lumbrineris inflata (P)
Ampelisca agassizi (Am)
Ophiothrix angulata (E)
Syllis spongicola (P)

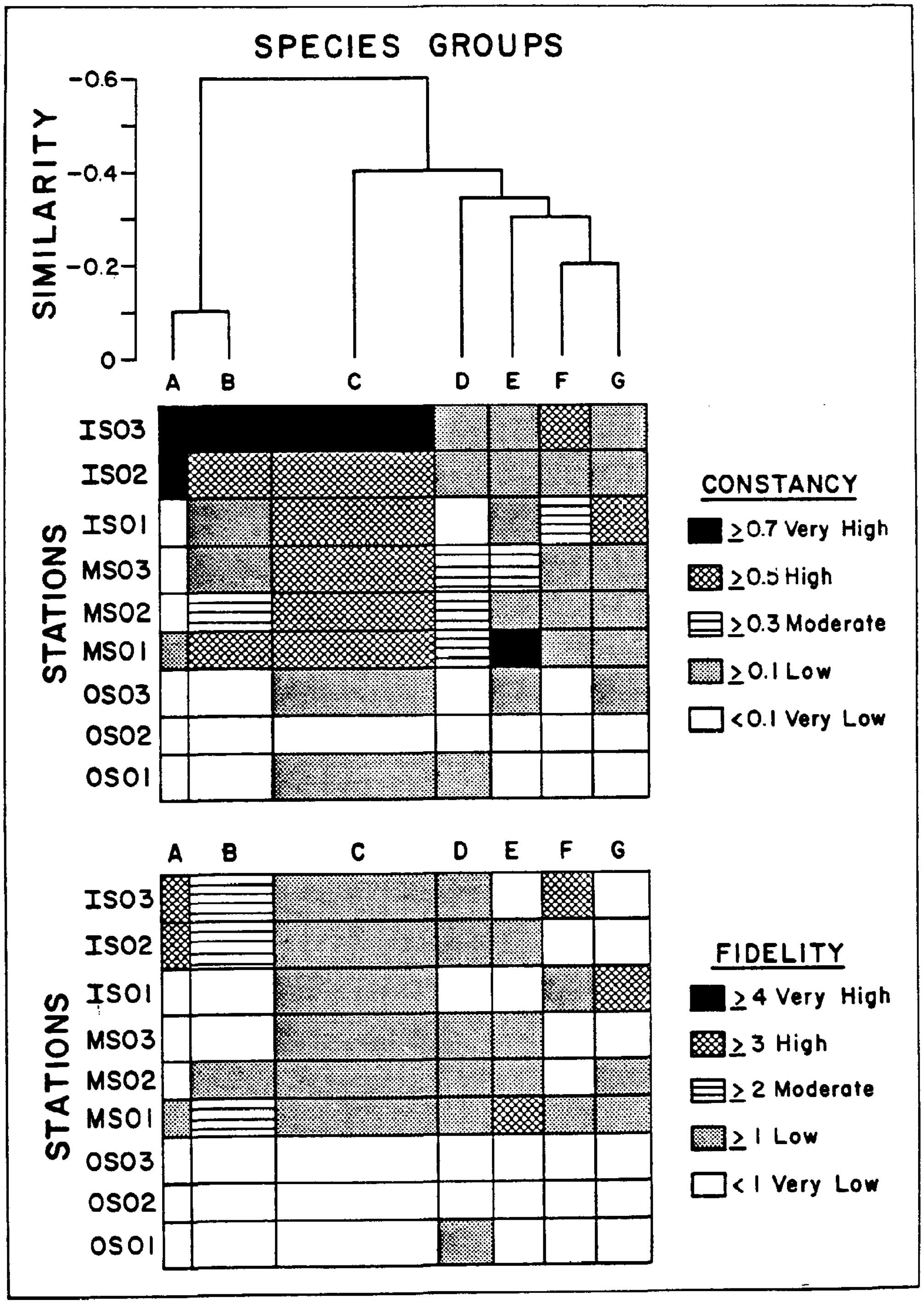


Figure 5.44. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on winter suction and grab collections.

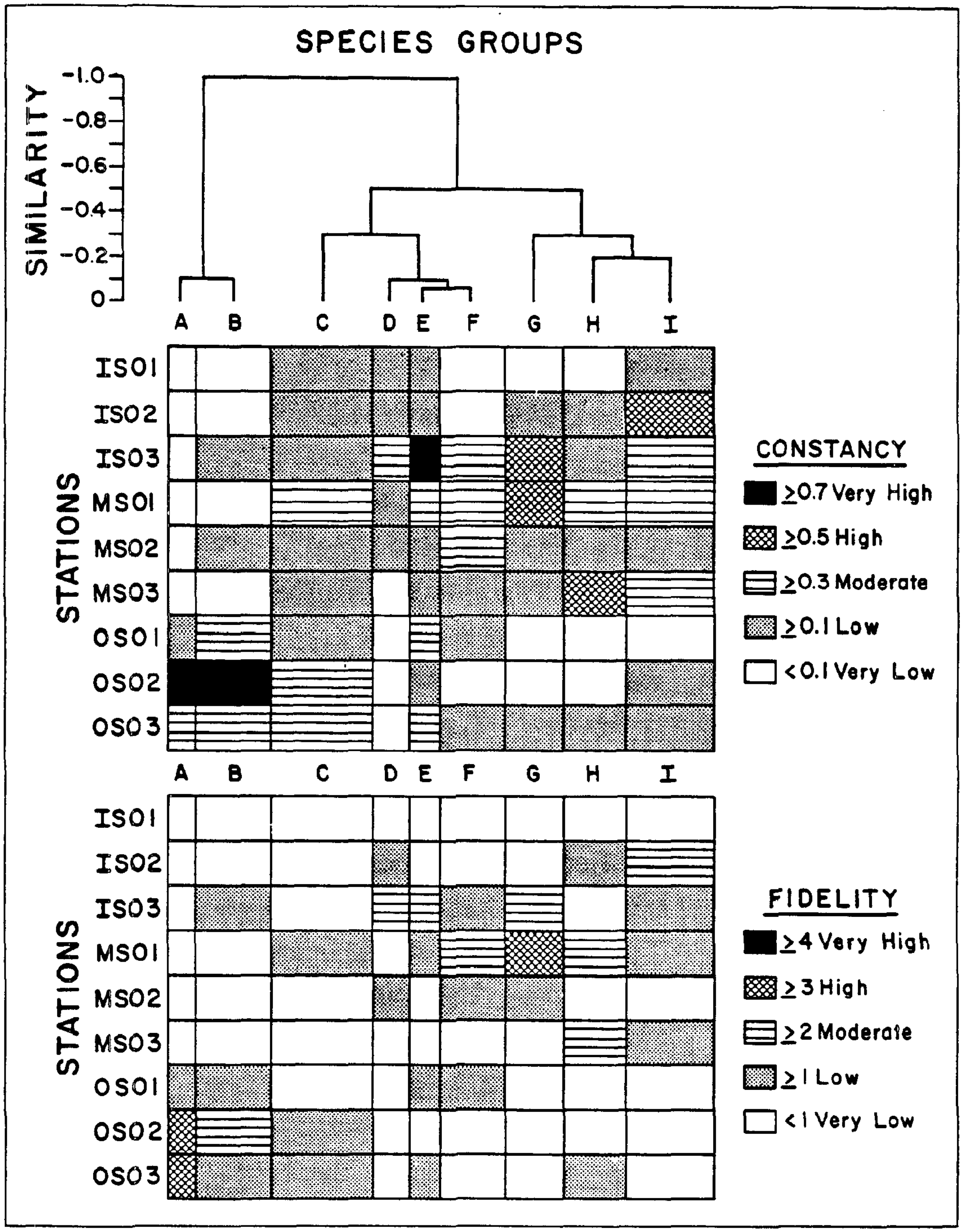


Figure 5.45. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on summer suction and grab collections.

Relatively uncommon and unfaithful species were found in groups D and F. The only numerically important constituent of these groups was Phyllochaetopterus socialis (group F).

The remaining species groups were somewhat ubiquitous but were most common at inner and middle shelf stations. Specifically, species in assemblage G were highly constant at stations IS03 and MS01. They were also highly faithful to MS01. The abundant species Exogone dispar and Luconacia incerta were members of this species group. Those species forming group H were most consistently encountered at station MS03; however, their faithfulness to this station was only moderate. The colonial polychaete Filograna implexa was an important constituent of this group. Species in group I were common at station IS02 but displayed only low to moderate constancy elsewhere. The numerically important species Syllis spongicola and Ophiothrix angulata were members of this group.

A comparison of the associations among selected species from the winter and summer sampling periods is presented in Figure 5.46. Although most species co-occurred only during one season, there were a surprising number of co-occurrences during both seasons. Among these was the association of the annelids Eunice vittata, Chrysopetalidae A, Eulalia sanguinea, Spiophanes bombyx, Polycirrus carolinensis, and Owenia fusiformis; and the amphipods Melita appendiculata and Phtisica marina. These species were ubiquitous during both seasons, although in winter they were most frequently encountered at inner and middle shelf live bottom areas. Another conspicuously recurrent assemblage was composed of the hermit crab Pagurus carolinensis, the amphipods Ampelisca agassizi and Lembos smithi, the isopod Paracerceis caudata, the echinoderm Ophiothrix angulata, and the sipunculid Aspidosiphon spinalis. These species were most constant at inner and middle shelf stations, although they were also collected at sites across the shelf.

DISCUSSION

Diversity of the Live Bottom Communities:

The results of the benthic analysis clearly emphasize the diverse and complex nature of South Atlantic Bight live bottom communities. The number of invertebrate taxa identified in collections from all sampling devices at our study areas totaled 1175. The faunal richness observed in these habitats can be better appreciated when compared with results of other studies; although, few comparable studies of this magnitude have been conducted along the Atlantic coast of the United States. While fully realizing that inequities exist in sampling methodology and extent, as well as in the level of taxonomic identification, we can loosely compare our results with those from other hard bottom studies in the South Atlantic Bight, from sand biotopes in the same area, and from the outer continental shelf region of the Middle Atlantic Bight.

One of the first explorations of hard bottom areas in the South Atlantic Bight was conducted by Pearse and Williams (1951) who collected 240 invertebrate species and 102 species of algae from inshore "Black Rocks" off North Carolina. The taxonomic groups of major importance on these rocks included decapods, mollusks, polychaetes, sponges, and bryozoans. Later Menzies et al. (1966) collected 107 identifiable species by dredge on a lithothamnion "reef" of the outer shelf off North Carolina. Cain (1972) subsequently added 37 more species to this list which was dominated by decapods, hydroids, and gastropods.

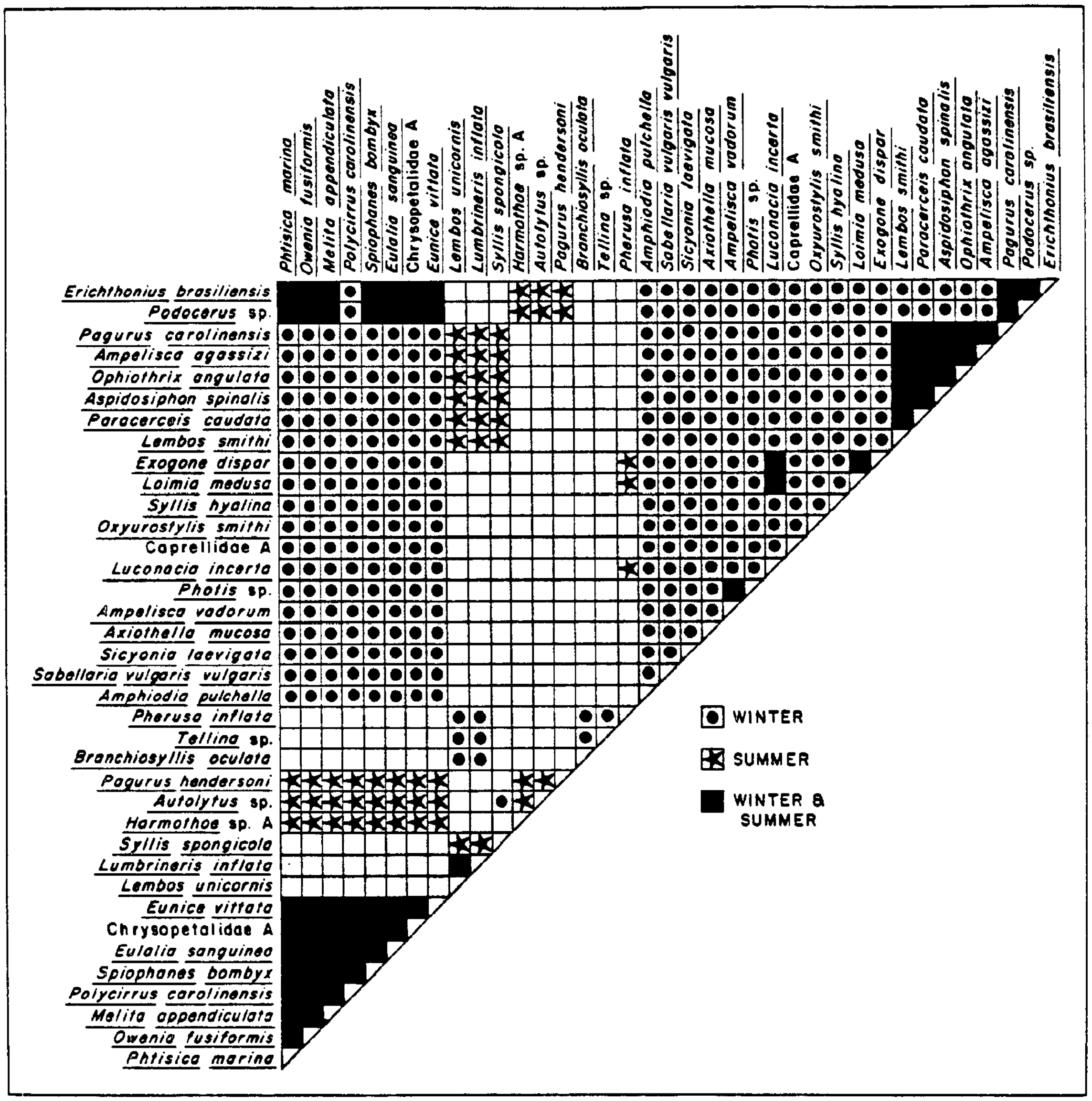


Figure 5.46. Matrix showing co-occurrence of species within the same group formed by inverse cluster analysis of suction and grab collections taken during winter sampling only, summer sampling only, or both winter and summer sampling. Species were selected for inclusion in the matrix if they occurred at $\geq$ 50% of the collections from at least 4 stations sampled by suction and grab.

In a study which demonstrates the complexity of microhabitats found on hard bottoms, McCloskey (1970) collected 56,616 individuals belonging to 309 invertebrate species from eight heads of a scleractinian coral, Oculina arbuscula. Continental Shelf Associates (1979) collected 499 total identifiable taxa in 68 dredge hauls on hard bottom within four lease blocks off Georgia. Frequently occurring taxa associated with hard substrata included the decapod crustaceans, anthozoans, bivalves, bryozoans, and echinoderms. In view of these reports, the present study provides much new information on the importance of the bryozoans, cnidarians, and sponges among the megafauna, and the polychaetes, mollusks, decapod crustaceans, and amphipods among the macrofauna.

Studies by Frankenberg (1971), Day et al. (1971), Frankenberg and Leiper (1977), George and Staiger (1977), and Tenore (1978) on invertebrate fauna from sandy substrates in the South Atlantic Bight illustrate the differences in biomass, faunal composition, and richness between sand and hard bottom habitats. Frankenberg (1971) collected monthly grab samples from a coarse sand bottom area off Georgia in 21-m depth and found a total of 235 species 12 m^{-2} over a 12-month period. In comparison, suction samples taken at our Gray's Reef station (IS02) off Georgia in equivalent depths collected 329 species m^{-2} with only two seasons represented. Day et al. (1971) found diversity was highest at a station off North Carolina which was characterized by lumps of sponges and ascidians. Similarly, George and Staiger (1977) attested to the high invertebrate biomass of one hard bottom area sampled by trawl off Charleston. They found that dominant sand bottom megafauna were holothurians, asteroids, cephalopods, and decapod crustaceans, whereas the high biomass observed at their hard bottom site was due to sponges, tunicates, and soft coral. Tenore (1978) attributed high values for total number and diversity of benthic macroinfauna in the South Atlantic Bight to the occurrence of scattered hard bottom reef communities.

When compared to results obtained by Boesch et al. (1977) for macrofauna in the Middle Atlantic Bight, the South Atlantic Bight fauna appears to be more diverse. Generally, fewer than 60 species were taken in six replicate 0.1 m^2 grab samples from inner or central shelf stations of the Middle Atlantic Bight, and the greatest diversity (up to 141 species) occurred in outer shelf swales (Boesch et al. 1977).

A large number of uncommon or rare species contributed to the high diversity observed during this study. Although others (Day et al. 1971, Davis and Spies 1980) have pointed out that rare species are subject to sampling error and should not be used to describe faunistic patterns, we feel they are an important component of the live bottom biocoenotic complex. In fact, examination of stomach contents of several fish species (see Chapter 7) demonstrated that with few exceptions, species of invertebrates which were not commonly collected by our sampling efforts formed a considerable part of the fishes' diet. Dominance diversity curves, which approximated the lognormal distribution, emphasized the importance of rare species in live bottom communities. Our curves differed from those by Whittaker (1970) for the lognormal distribution of land plants because we collected fewer species with medium abundance and more rare species. The lognormal distribution is appropriate when the number of species is large and the factors determining their relative importance are complex and multiplicative in effect (Whittaker 1965).

The high diversity of live bottom habitats noted in our study is due, in part, to the complexity of bottom types as compared with surrounding sand bottom areas. Substrate composition in all study areas consisted of a mosaic of different microhabitats including rock crevices, bare rock, rock tops with a layer of sand, and sand patches between rocks. The complexity of these habitats allows many similar species to coexist. Microhabitat complexity is further enhanced by the presence of certain organisms which support a variety of other species. This has been demonstrated for the coral Oculina varicosa by McCloskey (1970), and the sabellarid worm Phragmatopoma lapidosa by Gore et al. (1978). In our study, the larger sponges such as Ircinia campana and Spheciospongia vesparium and colonies of the worms Filograna implexa and Phyllochaetopterus socialis appeared to perform a similar function. Sponges are apparently less important at live bottom stations sampled off North Carolina. There, algal species are an important constituent of the community in terms of diversity, abundance, and role as a microhabitat (Vol. II, Chapter 5). In addition, the complexity of live bottom areas, with their component microhabitats, can increase protection afforded to prey species. As Smith (1972) has pointed out, refuges where prey populations can maintain themselves are important in the maintenance of community structure. No doubt, some predators find only limited access to small invertebrates which are sheltered among soft corals, sponges, and polychaete tube mats.

Species diversity is also enhanced through competition among constituent epifaunal species. This can lead to various specializations which allow many species to coexist in a limited space (Menge and Sutherland 1976). Differential growth patterns can also contribute to higher diversity (Jackson 1977). For example, Osman (1977) has noted that bryozoans normally do not overgrow another colony of the same species but, rather, reorient their growth to avoid this. By extending growth upward, many sponges, hydroids, octocorals, and tube building polychaetes are also able to avoid overgrowth by encrusting forms. Additionally, invertebrates such as large sponges reduce intraspecific competition by virtue of their widely spaced distribution. Finally, presence of a variety of sessile invertebrates creates additional habitat and probably reduces competition among epizootic forms. At the moment, information on competition in live bottom habitats is so limited that further investigations concerning growth, succession, and settlement of epifaunal invertebrates appear to be entirely justified.

In shallow water marine communities, predation on competitively dominant species by a single dominant predator allows less competitive species to coexist with other members of the community (Connell 1961a, 1961b; Paine 1966; Dayton 1971, 1975; Porter 1972, 1974) and hence, increases species diversity. In our study, few numerically dominant or common species were consumed by fishes which suggests that predation may not be an important mechanism for explaining the high diversity of live bottom fauna. Although we have not extensively examined trophic level dynamics within the live bottom community, there is currently no evidence which suggests that the species inhabiting these areas are under heavy predation pressure.

Diversity values did not exhibit any discernible patterns with regard to depth or latitude at stations sampled south of Cape Fear. The high number of species collected at outer shelf stations OS03 and OS01 by dredge and trawl was not consistent from one sampling period to the next. Furthermore, not all collections taken within a sampling period at these stations had unusually large numbers of species. Apparently, all hard bottom areas sampled during the current study were sufficiently similar to preclude any obvious differences in diversity between areas. Bottom temperature differences were much more pronounced between winter and summer at the inner shelf stations than at the middle or outer shelf sites (see Chapter 3), but the observed variations in temperature and other hydrographic parameters apparently had little influence on diversity. At stations sampled off North Carolina, the southernmost station in Onslow Bay had higher species diversity than either IS04 or OS04, which were located in more northerly waters (Vol. II, Chapter 5). A comparison of diversity values from summer collections made south of Cape Fear with those made north of Cape Fear (Vol. II, Chapter 5, Table 5.11) indicates higher H', SR, and s values for the more southern stations. This may be attributed to more stable hydrographic conditions of waters south of Cape Fear.

Although the number of invertebrate taxa collected (1175) was high, we believe it may underestimate the actual number of species collected because many organisms were not identifiable due to damage or undetermined taxonomic status (e.g., Actiniaria, Nematoda, Turbellaria, Entoprocta, Ostracoda). In addition, other macrofaunal taxa were undoubtedly missed during sampling due to the physiographic complexity of the habitat.

Community Composition:

Assessment of benthic organisms through television, still camera, and diver observations indicates that megafauna contribute significantly to the physical complexity of hard bottom communities on the South Atlantic continental shelf. This was especially evident at the inner shelf sites due to the relatively high incidence of the octocorals Leptogorgia virgulata and Titanideum frauenfeldii and the finger sponge Haliclona oculata, combined with the presence of other large sponge and octocoral species such as Ircinia campana, Spheciospongia vesparium, and Lophogorgia hebes (Figures 5.1 and 5.2). Because rock outcroppings were scarce at station IS01, these megafaunal species represented the primary source of habitat relief; however, they showed no strong distributional patterns at this site. At the other two inner shelf sites (IS02 and IS03), the distribution of these sponges and octocorals was patchy and restricted to areas of rock relief or areas of rock with a thin sand veneer. Additional taxa which contributed to relief at inner shelf sites, but which occurred only infrequently, included the stony corals Oculina spp. and Solenastrea hyades, and algae.

Although the incidence of some octocorals (Leptogorgia virgulata, Lophogorgia hebes) and sponges (Haliclona oculata) was lower at middle shelf stations (Figures 5.1 and 5.2), physical complexity of the community due to megafaunal species was still very apparent. The sponges, Ircinia campana and Spheciospongia vesparium, were the largest species observed and were most frequently located on or near ledges. Titanideum frauenfeldii was the most frequently occurring octocoral at middle shelf sites, although Muricea pendula, L. hebes, and L. virgulata were also present at one or more of the stations. The relative rarity of T. frauenfeldii and I. campana at MS03 was probably due to the relatively low frequency of hard bottom present at this site (Figure 4.10), rather than to any latitudinal effects. Oculina spp., Solenastrea hyades, and algae were present at most of the middle shelf stations but were infrequent. At station MS04, located north of Cape Fear (Vol. II, Chapter 5), algae were the dominant canopy group; whereas, sponges and octocorals were most important at our middle shelf sites.

At outer shelf sites, the lower incidence of sponges and corals noted on television transects suggests that the physical complexity due to biological communities may be reduced in this depth zone. The most common large sponge, Ircinia campana, was usually observed on the top of rock outcroppings, and the increased frequency of this species at OS02 and OS03 may be correlated with the greater number of outcroppings at those stations. Other large sponges and corals were sparse at outer shelf sites, including an antipatharian (Stichopathes sp.) which was only found at this depth zone and at station OS04 off North Carolina. Sponges were not frequently observed on the outer shelf north of Cape Fear (Vol. II, Chapter 5). Instead, the octocorals Titanideum frauenfeldii and Leptogorgia virgulata were most important at this station.

The bathymetric patterns of sponges and octocorals detected on our television transects have not been well documented in the literature. Prior television reconnaissance of South Atlantic hard bottom areas (Continental Shelf Associates 1979, U. S. Geological Survey 1979, Powles and Barans 1980, MARMAP unpub. data S. C. Marine Resources Center, Charleston) has been used primarily to document the location and extent of hard bottom habitats. Observations on the benthic fauna noted in these reconnaissance efforts are very qualitative and generalized. While our television analysis must also be considered somewhat qualitative due to variations in the height of the television above bottom, our more intensive analysis of the fauna through segmentation of the transects into two-minute intervals provides information useful for predicting megafaunal constituents of hard bottom areas at various depths.

Limited quantitative information obtained through analysis of photographic quadrats (Table 5.4) lends support to the distributional patterns noted previously. However, due to the patchy distribution of these species and the small quadrat size utilized (3 m^2), many more quadrats must be analyzed in this type of assessment before accurate density estimates of megafaunal taxa can be obtained.

Analysis of collections made by dredge and trawl indicated that macroinfaunal assemblages differed according to bathymetric zones. Zonation was most noticeable between assemblages at inner and outer shelf sites. Similar findings were reported for stations sampled off North Carolina (Vol. II, Chapter 5). Although many macrofaunal species were collected at inner shelf sites during both sampling periods, those which were most faithful to these areas included the sponges Spheciospongia vesparium and Homaxinella waltonsmithi; the echinoderms Arbacia punctulata and Ocnus pygmaeus; the octocoral Leptogorgia virgulata; the tunicates Clavelina picta and Styela plicata; and the mollusk Diodora cayenensis. Likewise, outer shelf sites were characterized by the echinoderm Eucidaris tribuloides; several bryozoans, including Smittipora levinseni, Cleidochasma porcellanum, Stylopoma informata, Cycloperiella rubra, Membraniporella aragoi, Floridina antiqua, and Parasmittina spathulata; and the cnidarian Dynamena dalmasi. Middle shelf live bottom areas are apparently transition zones which support species having both inner and outer shelf affinities. Ordination analysis was particularly useful in pointing out the similarity in species composition between middle shelf sites and inner or outer shelf sites. Most species which were consistently collected at middle shelf stations were also collected at inner and outer shelf sites as well; however, the cnidarians Hebella venusta, Aglaophenia allmani, A. latecarinata, Scandia mutabilis, Synthecium tubitheca, Sertularia marginata, Hincksella cylindrica, and Thyroscyphus marginatus; and the bryozoans Chaperia sp., Nellia tenella, and Schizoporella floridana were usually both constant and faithful to middle shelf sites and are representative of live bottom habitats from this area of the shelf. Although many other species were collected at inner, middle, and outer shelf live bottom stations, they tended to be more ubiquitous.

Based on faunal composition, station affiliations among site groups varied with sampling period and with the gear utilized. During winter the greatest differences in faunal composition were between inner shelf stations and all others. Zonation was also evident on the continental shelf in summer when maximum dissimilarity occurred between inner and outer shelf stations.

Multivariate techniques also separated quantitative collections of smaller epibenthic and infaunal organisms, sampled by suction and grab, according to bathymetric zones during winter but not during summer. In winter, outer shelf sites were separated from inner and middle shelf sites, whereas no delineation of areas, based on community composition, was evident during summer. Ordination confirmed the results of normal cluster analysis and was useful in pointing out misclassification of collections by cluster analysis. Most of the species collected by suction and grab samplers were found at stations in all three depth zones; however, a few species such as the annelid *Pista quadrilobata*, the decapod *Pelia mutica*, the sponge *Homaxinella waltonsmithi*, and the mollusk *Pteria colymbus* were both faithful and constant at inner shelf sites. Similarly, the amphipods *Unciola* sp. A and *Erichthonius* sp. A; and the annelids *Syllis* sp. D, *Glycera capitata*, *Syllis cornuta*, and *Spio pettiboneae* were consistently found at outer shelf stations. Analysis of dredge and trawl collections has shown that the middle shelf areas were composed of species with affinities to inner or outer zones. The only species consistently collected at middle shelf sites during both sampling periods were the sponge *Cinachyra alloclada* and the polychaete *Syllis alternata*.

Despite evidence for the existence of faunal zonation patterns related to depth, the point should be made that these apparent trends may actually have been an artifact of sampling methodology which was not consistent over the entire shelf. Thus, grab collections, which were only taken at outer shelf stations and which were restricted to sand or the sand layer on rock, included fewer animals and more infaunal organisms (such as haustoriid amphipods) than did suction samples, which were taken primarily over rock covered by sand.

Zonation patterns observed at live bottom stations during winter and summer may reflect seasonal fluctuations in the occurrence of many epifaunal invertebrates. Periods of dormancy among invertebrates in response to critical environmental conditions are well documented in estuarine and nearshore environments. Dormancy has been reported for sponges (Wells et al. 1964), the entoproct *Barentsia laxa* (Van Dolah et al. 1979), the phoronid *Phoronis hippocepia* (Hyman 1959), and hydroids (Morse 1909, Berrill 1948, Tardent 1963, Hargitt 1900, Calder 1967, 1971). In most instances, the dormancy period was initiated in response to water temperatures. Migration of mobile epifauna in response to temperature may also be a factor in determining zonation patterns. Evidence for this was presented by George and Staiger (1977), who noted dynamic seasonal shifts in populations of epifaunal invertebrates.

Changes in the community structure of live bottom invertebrates, whether effected by dormancy or movement, are apparently influenced by hydrographic conditions in the South Atlantic Bight. The Gulf Stream is an important determinant of hydrographic conditions on the outer shelf and is especially evident in winter. A warm band of water with relatively constant temperature and salinity is present year-round in the open shelf zone at depths of 33 - 40 m; however, inner and outer shelf waters are subject to considerable seasonal fluctuations (Mathews and Pashuk 1977). Cerame-Vivas and Gray (1966) noted that there is commonly a 10^{o} - $12^{o}C$ difference in bottom temperature between the inner and outer North Carolina shelf waters during winter. Coastal and inner shelf waters are influenced by local seasonal weather conditions and run-off. In winter, the warmest water is found just inshore of the shelf break and is bounded on both sides by colder water (Mathews and Pashuk 1977). In summer, water temperatures are much more uniform over the entire width of the shelf encompassing our middle and outer shelf stations. Seasonal changes in water temperature on the inner shelf may have influenced zonation patterns observed by forcing inhabitants of this area to migrate or tolerate cold through dormancy, eurythermy, or other adaptive mechanisms during the winter.

No latitudinal gradients in species assemblages were noted for any of the inner, middle, or outer shelf zones; however, our stations did not encompass a wide latitudinal area. Latitudinal trends may have been more obvious if sampling had included sites further south off Florida, such as the shelf edge prominences sampled by Avent et al. (1977). They found that macrofauna dredged from these prominences exhibited an affinity primarily with the Antillean faunal province. Although a thorough analysis of the zoogeography of the taxa from this study is beyond the scope of this report, it appears that live bottom areas below Cape Fear consist mainly of southern (Carolinean and Caribbean) or widespread species. This conclusion agrees with observations by Cerame-Vivas and Gray (1966) who noted that species found at inner to middle shelf depths south of Cape Hatteras were mainly southern, being found between North Carolina and Florida. Eighty-seven percent of the species in their study from the outer shelf were southern or tropical (Caribbean). At stations IS04 and OS04 sampled off Cape Hatteras, invertebrate assemblages were characteristic of the Virginian Province; however, fauna at station MS04 was typically Carolinean, suggesting that a latitudinal gradient in species assemblages occurs north and south of Cape Hatteras (Vol. II, Chapter 5).

Dominance:

Characteristic species of macrofaunal invertebrates dominated collections in terms of abundance or frequency of occurrence. Although no attempt has been made in our sampling design to directly contrast species composition between live and sand bottom areas, we know that certain taxa such as sponges, cnidarians, and bryozoans are primarily found on hard bottom substrates. Dominant taxa collected off North Carolina included algae, mollusks, decapods, sponges, and echinoderms (Vol. II, Chapter 5). Examination of the species most frequently collected by dredge and trawl at our stations (Tables 5.5 and 5.6) revealed that most are associated primarily with hard substrates such as live bottom or isolated patches of shell. Species frequently occurring and typical of "reef" areas include *Lophogorgia hebes*, *Campanularia hincksii*, *Clytia fragilis*, *Celleporaria albirostris*, *Monostaechas quadridens*, *Turbicellepora dichotoma*, *Titanideum frauenfeldii*, *Crisia* sp., *Thyroscyphus marginatus*, *Spheciospongia vesparium*, *Conopea merrilli*, and *Styela plicata*. In contrast, most of the common motile invertebrates, such as decapod crustaceans, polychaetes, amphipods, and echinoderms, are found on a variety of bottom types.

Most of the numerically dominant taxa collected by suction and grab are also ubiquitous, with some being found from the intertidal zone to deep oceanic water. The colonial serpulid *Filograna implexa* is cosmopolitan in temperate and tropical seas, occurring from the intertidal zone to > 100 m. Its reported mode of reproduction is by transverse fission (Day 1967). This explains the extremely patchy distribution of this species which was abundant in only a few collections. *Phyllochaetopterus socialis*, a chaetopterid polychaete which forms branched colonies, occurs from the intertidal zone to > 100 m throughout the Atlantic Ocean (Day 1973). This species is not exclusively associated with live bottom but is generally found on low relief rock covered by a thin sand veneer (Continental Shelf Associates 1979). Spiophanes bombyx was found by Frankenberg and Leiper (1977) to be a numerically dominant member of the nearshore fine sand habitat. Its dominance in suction and grab collections was primarily a reflection of its occurrence in samples collected either on sand veneer of rocks or from sand patches between rocks. Syllis spongicola occurs in a variety of habitats including those provided by sponges, ascidians, rocks, pilings, clay, sand, silt, and coral. It is found in the intertidal zone and to depths of 400 m (Gardiner 1975). Exogone dispar is also fairly ubiquitous, being found on shell, stone, coral, sand, algal masses, and hydroids. It has the greatest depth range of the numerically abundant polychaetes and is found from low water to 5000 m (Gardiner 1975). The caprellid amphipod Luconacia incerta is widely distributed in temperate and tropical areas of the western North Atlantic where it has been reported on Sargassum, ascidians, and octocorals. The ophiuroid Ophiothrix angulata is not restricted to live bottom areas but is common in a variety of communities (McCloskey 1970). This species was also found to be numerically dominant at stations north of Cape Fear where it was most abundant at IS04 (Vol. II, Chapter 5).

Krebs (1972) and McCloskey (1970) indicate that species which are considered to be dominant should be ecologically constant as well as abundant. Therefore, a representation of dominance based solely on numerical abundance can be misleading, especially since only the smaller macrofauna quantitatively sampled by suction and grab were enumerated in this study. Dominant species which were abundant and frequently encountered during both seasons of sampling included Spiophanes bombyx, Syllis spongicola, Ophiothrix angulata, and Photis sp. The other numerically dominant species were less constant in their occurrence. In particular, the ecological significance of dominance by the colonial species Filograna implexa and Phyllochaetopterus socialis cannot readily be assessed because of their highly contagious distribution. These species are probably important, however, because they provide additional substrate and microhabitats for other species.

Biomass:

Biomass data from the current study can be loosely compared with that reported by George and Staiger (1978) in their study of epifaunal invertebrates collected by trawl from the South Atlantic Bight. During both winter and summer, the biomass of invertebrates from our live bottom trawl collections greatly exceeded the values reported by George and Staiger (1978) from sand habitats; however, at the three "reef-type" stations sampled, they found the biomass of sponges, tunicates, and soft corals to be extremely high. These results contrast with those from stations sampled off North Carolina where scleractinians, mollusks, and algae were dominant (Vol. II, Chapter 5).

Our data indicated no significant difference in biomass between winter and summer (Tables 5.9 and 5.10). This is not surprising considering the sessile nature of most of the major macrofaunal taxa. Any variations which were noted in biomass were probably a result of the patchy distribution of the attached epifauna. Sponges were the main contributors to the large biomass estimates for live bottom areas sampled in this study. Although seasonality is probably exhibited by cnidarians, bryozoans, ascidians, and smaller sponges, the large sponges such as Spheciospongia vesparium and Ircinia campana probably are several years old and do not fluctuate in abundance or biomass as a result of seasonal influences.

No noticeable bathymetric trends in biomass of macrofauna were noted for dredge collections. For trawl collections, we found that biomass was low during both sampling periods at OS01, the only outer shelf station sampled, and at station MS02 during summer. As noted from the analysis of videotapes, the frequency of the large sponges appeared to decrease at the outer shelf stations. Biomass of macroinvertebrates was low at station MS02 during summer because only one small (2.5 kg) S. vesparium was collected. The infrequent capture of sponges at this station during summer was also reflected by their lower frequency of occurrence in television transects in summer.

IMPACT/ENHANCEMENT

The analysis of benthic communities presented in this chapter is primarily intended to provide information on the composition and structure of communities associated with hard bottom habitats in different areas of the South Atlantic Bight. A direct assessment of impacts on these communities from drilling operations is not possible since the study areas have not been influenced by energy related activities. However, several potential impacts should be noted.

The discharge of drilling fluids and cuttings from oil rigs increases sedimentation in the near vicinity of the platform. If this discharge occurred over live bottom, possible consequences for the biota include: (1) smothering of sessile invertebrates, particularly smaller colonies, or inhibition of filter feeding; (2) altered community structure due to decreased hard substrate availability; (3) burial of infauna inhabiting the sand in the vicinity of rock outcroppings; and (4) decreased algal growth due to increased turbidity. Of these consequences, (1) and (2) would probably have the most severe impact on live bottom communities in our study area since sessile fauna (sponges, corals, ascidians, hydroids, bryozoans, etc.) represent the major invertebrate component in terms of biomass, and they are extremely important in providing structurally complex microhabitats for smaller macrofauna. Unfortunately, very little is known concerning the tolerance of sessile fauna to increased sediment load. Thus, it is not possible to predict whether moderate increases in sedimentation, which may not result in burial, would be detrimental to these organisms; nor can we predict the rate of recolonization and recovery to former levels of abundance and biomass for species characteristic of South Atlantic Bight live bottom areas. The smaller sessile biota, such as ascidians, bryozoans, hydroids, small sponges, and some octocorals, may recolonize and grow relatively rapidly as has been observed in other studies (Jackson 1977, Parker et al. 1979, Marine Resources Research Institute 1979); however, larger sponges and octocorals may exhibit comparatively slow growth rates. Data on recolonization and growth rates are sorely needed.

The severity of the impact of discharging drilling muds and cuttings on these habitats is dependent on distance of the drilling operations from live bottom, duration of plume presence, current patterns, water depth, and location of discharge source relative to the bottom. In shallow shelf areas, locating the discharge point ∿ 10 m below the surface, as required by federal regulations (U. S. Department of the Interior 1981), might result in a more severe concentration of sediments in a localized area due to bottom proximity and slower currents, whereas applying this same strategy in deeper shelf waters would largely dilute and disperse the discharge plume over a much greater area.

Negative impacts from plume discharge on smaller infauna and algae might not be as severe as the impacts on sessile colonial invertebrates. Bender et al. (1979) reanalyzed benthic biological data (including macroinfauna) from waters off Louisiana and found no "indication of a stressed environment near or around oil drilling and production platforms." The potential impact on macroalgae is probably minimal since they were generally not prevalent at our study areas.

The detrimental factors related to plume discharge are generally restricted to the vicinity of the discharge point (< 1000 m, Ecomar Inc. 1980). Thus, placement of oil rigs or discharge points at least 1000 m from live bottom areas, combined with the current lease sale stipulations (U. S. Department of the Interior 1981), should lessen or avoid detrimental effects related to drilling muds and cuttings.

Other potential detrimental effects from drilling operations include those related to oil spills or gas leaks. Bright (1977) observed no large scale disturbance on live bottom fauna by methane seeps, suggesting that gas leaks from platform operations may not severely affect live bottom communities. Previous studies on the effects of oil spills have been largely restricted to laboratory toxicity studies and field investigations of infaunal communities, particularly in semi-enclosed intertidal and shallow subtidal areas (Sanders 1978, Thomas 1973, Blumer et al. 1971, Foster et al. 1971, Nicholson and Climberg 1971). At the organismal level, petroleum hydrocarbons have been demonstrated to cause direct lethal toxicity as well as sublethal disruption of physiological and behavioral activities (Moore and Dwyer 1974). At the population and community levels, ecological imbalances may result from the elimination of key species,e.g., predators or grazers (Boesch and Hershner 1974), or from habitat changes effected by alterations in the physical or chemical environment (Moore and Dwyer 1974); however, some studies suggest that infaunal abundances may actually increase in response to low level chronic exposure to petroleum hydrocarbons in the vicinity of a natural oil seep (Spies and Davis 1979, Davis and Spies 1980).

Specific evidence for detrimental effects of oil spills on live bottom communities is sparse; however, Boesch and Hershner (1974) cite one study in which it was observed that some corals, especially "branching varieties," are severely damaged if coated by oil while exposed to air. The implications of this finding for submerged live bottom fauna are unclear, however. It was suggested that individual polyps may be afforded some degree of protection from direct contact with oil by virtue of the copious amounts of mucous they secrete; however, the porous limestone of some scleractinian corals may actually absorb and concentrate oil from the aqueous milieu. Similarly, sponges may have analogous capabilities, although this is purely conjectural.

Whether or not any of these effects impact live bottom communities in the vicinity of an oil spill is currently a moot point in the absence of sufficient information concerning either the fate of oil spills in the open ocean environment or the sensitivity of live bottom fauna to oil contamination. Furthermore, an accurate assessment of the potential impacts from an oil spill would depend upon a consideration of the synergistic or antagonistic effects of water temperature, dissolved oxygen concentration, and life stage of the individual organisms influenced by the spill.

Enhancement effects related to oil platform operations result from the creation of artificial reefs by the addition of hard substrate. Colonization of platforms would probably be rapid, and the subsequent fouling community of invertebrates and algae would, in turn, attract many fish, as noted by others

(U. S. Department of the Interior 1981). Live bottom fauna would contribute to the colonization as a source of recruitment, but distance between live bottom areas and platforms should not be a factor since most sessile biota produce planktonic larvae or spores which are widespread throughout the South Atlantic Bight.

CONCLUSIONS

- A total of 1175 identifiable taxa of invertebrates was collected with all sampling devices during winter and summer. Comparison of number of species with the literature indicates that the live bottom areas studied are more diverse than the surrounding sand biotope. As indicated by dominance diversity curves, a large number of uncommon or rare species contributed to the high diversity of live bottom areas both south and north of Cape Fear, N. C. The values of H', which ranged from 1.43 bits per individual at IS02 in summer to 6.63 bits per individual at IS03 in summer, were generally similar between stations for both sampling periods. Low H' values were associated with high abundance of invertebrates but low evenness. Species richness values were similar between stations and sampling periods, but numbers of species and individuals were different between stations during winter and summer.

- Among macrofauna collected by dredge and trawl, the Bryozoa, Cnidaria, and Porifera were dominant, whereas the Annelida and Mollusca were most important in terms of number of species in collections made by suction and grab. At stations off North Carolina, algae, mollusks, decapods, sponges, and echinoderms were dominant taxa. Composition of the major invertebrate groups represented in dredge collections did not differ appreciably between inner, middle, and outer shelf stations. In collections made by trawl, the Porifera was a dominant component only at inner shelf stations, while the Cnidaria and Bryozoa were important at stations sampled on the middle and outer shelf. Remote sensing of megafauna suggested that frequency of occurrence of the large sponges (especially Haliclona oculata) and octocorals (especially Leptogorgia virgulata) at live bottom sites decreases with increasing depth. Macroalgae were not frequently collected by any sampling gear at stations south of Cape Fear; however, they were very important at mid-shelf depths off North Carolina.

- Biomass determinations of the larger invertebrates collected at most live bottom sites by dredge and trawl showed that sponges were dominant during both winter and summer. Off North Carolina, the biomass of algae, scleractinians, and mollusks exceeded that of other taxa. No difference existed in biomass estimates between winter and summer, but spatial differences in biomass estimates based on trawl collections were present. The low biomass values found at OS01 may reflect decreased occurrence of large sponges at outer shelf stations.

- Species composition was generally distinguishable based on the depth of the live bottom sites examined. Although species assemblages were not always restricted to live bottom sites in particular depth zones, certain species were most consistently collected at inner, middle, or outer shelf stations.

Most species associations varied from one sampling period to the next, suggesting that seasonality may be important. Faunal differences were most evident between inner and outer shelf live bottom communities, while the middle shelf appeared to be an area of transition. This zonation was noted at sites north and south of Cape Fear. Unfortunately, differences in sampling methodology between depth zones limits conclusions which can be made on faunal zonation. No latitudinal gradients in species assemblages were noted for stations south of Cape Fear, possibly due to the narrow range of latitudes included in this study; however, inner and outer shelf stations off North Carolina contained many species characteristic of the Virginian province, indicating penetration of temperate species below Cape Hatteras.

- Numerically dominant invertebrates collected by suction and grab samplers were patchily distributed. Because of the highly contagious distribution of most species, the current number of replicates was inadequate to assess changes in population densities with any degree of confidence. The ranking of numerically dominant species changed considerably from winter to summer, and differences in numerical dominance also existed between bathymetric zones.

- The potential impact of drilling fluids and cuttings from oil rigs would include increased sedimentation in the vicinity of the platform. Other adverse effects from discharge could include altered community structure due to decreased availability of hard substrate, and smothering of sessile invertebrates which represent the major biological component in terms of biomass. Negative impacts from plume discharge on smaller infauna and algae might not be as severe as the potential impacts on sessile colonial invertebrates. Any detrimental effects related to oil and gas activities should be lessened if discharge points are placed at least 1000 m from live bottom areas, and if other current lease stipulations are observed. Enhancement effects related to oil platform operations may result from the addition of hard substrata, which creates artificial reefs.

CHAPTER 6

NEKTONIC COMMUNITY

INTRODUCTION

At present there is little quantitative data on distribution and abundance of demersal fishes associated with live bottom in the South Atlantic Bight. In an extensive study of shelf fishes of the Bight, Struhsaker (1969) reported the results of exploratory groundfish trawling and described live bottom and its associated fish fauna. Although the National Marine Fisheries Service (NMFS) Marine Resources Monitoring and Assessment Program (MARMAP) has conducted extensive groundfish monitoring with trawl collections (Wenner et al. 1980), published reports have been limited to coastal, open shelf, shelf edge, and lower shelf habitats. George and Staiger (1978) described fish assemblages in the Bight from trawl collections, but most collections were over areas of sand bottom on the open shelf. Miller and Richards (1979) examined trawl logs from several exploratory fishing vessels and categorized live bottom areas based on depth, thermal stability, and indicator reef species; however, they provided little quantitative data on abundance of these and other live bottom species. Powles and Barans (1980) tested the effectiveness of trawls, traps, diver observations, and underwater television as sampling methods for live bottom fishes and gave biomass estimates for some species. The purpose of the present study is to provide quantitative and qualitative data on the distribution, abundance, diversity, and community structure of demersal fishes from several live bottom areas in the South Atlantic Bight and to examine seasonal, latitudinal, and depth related patterns in these parameters.

METHODS

Laboratory Analysis:

Trawl Collections - Fishes preserved from trawl collections (Chapter 2) were washed in tap water and transferred to 50% isopropanol. All unknown specimens were identified and added to data forms for computer entry. Voucher specimens were catalogued for all species collected.

Underwater Television Transects - Videotapes from underwater television transects were analyzed in a manner similar to that utilized for invertebrates (Chapter 5). An attempt was made to analyze 60 minutes of videotape at each trawlable site by selecting three 20-min transects which were independent in space and time. At high relief sites which could not be trawled, six 20-min transects, three day and three night, were analyzed. Lengths of transects (m) were measured between start and end Loran C coordinates.

Procedures for fish enumeration were as follows: One observer viewed the tapes and counted fish seen on the entire monitor screen for every ten-second interval of tape. A second observer then viewed the same tape and made counts. For time intervals in which the two observers could not agree on the number of fish seen, an average of the two counts was used. For large schools of fish which were impossible to count, the count was recorded as 100 fish for the ten-second interval in which they occurred. The tape was then viewed a third time by both observers in an attempt to identify fishes which had been counted but not identified during earlier viewings. These attempts were rarely successful. Fish counts were summarized as numbers per 100 m of transect and numbers per hour of videotape. Fish density (number of individuals per hectare) was calculated by multiplying the transect length by the estimated horizontal field of view, estimated to be 3.4 m, based on measurements made in a swimming pool.

Diver Observations - Abundance of fishes in diver hand held still camera photographs was calculated as total number per stop. A stop consisted of 4 photographs taken at right angles to each other (see Chapter 2). Abundance of fishes seen on swimming transects was calculated as total number per minute of observation.

Baited Fishing Gear - Longlines, snapper reels (hook and line), and traps were deployed primarily to capture large predatory species, which were rarely captured by trawl, for food habits analysis (Chapter 7). In addition, these gears provided some qualitative information on demersal fish distribution, and the data from these gears were summarized.

Juvenile Fish Sled - All larval and juvenile fish specimens were removed from each epibenthic sled sample and identified to the lowest taxon possible. Larvae of most species remain undescribed, and thus larval specimens were frequently not identifiable beyond the generic or even family level. Specific identification of undescribed larvae was sometimes possible using fin ray counts, if full meristic complements were developed.

For each sample, number of individuals per taxon and their minimum and maximum sizes were recorded. Voucher specimens for each taxon were labeled, preserved in 5% buffered formulin, catalogued, and stored in a dark room to preserve pigment characters useful in identification.

Data Analysis:

Biomass - Fish biomass was calculated as mean catch per tow for the replicate trawls done on each station. Because previous investigations (Taylor 1953, Struhsaker 1969) have shown that trawl catches are usually distributed as a negative binomial, a $\log_e (x + 1)$ transformation was made on the data (Elliott 1977). Mean biomass estimates per tow were calculated for each station from transformed values following the methodology of Bliss (1967):

$$E(\bar{y}_h) = \exp(\bar{y}_h + S_h^2/2) - 1$$

where $E(\bar{y}_h)$ is the estimated (retransformed) mean catch per tow at the h^{th} station; $\bar{y}_h$ and S_h^2, expressed in logarithmic units, are the mean biomass per tow and its variance for the h^{th} station. Biomass was also calculated as kg of fish ha^{-1} of area swept by the trawl. Area swept by the trawl (a) was determined for each collection by the following equation modified from Klima (1976):

$$a = \frac{D(0.6H)}{10{,}000\ m^2\ ha^{-1}}$$

where D = bottom distance in metres covered by the trawl, as calculated from start and end Loran C coordinates, and H is the trawl headrope length in metres. The constant 0.6 designates an effective horizontal trawl opening of about 60% of the headrope length as used by Roe (1969) and established by Wathne (1959).

The average swept area of our trawl for all stations was estimated to be 4.3 ha tow^{-1}. Because large elasmobranchs such as Dasyatis spp. and Ginglymostoma cirratum, and large catches of schooling pelagic fishes, such as Decapterus punctatus, contribute significantly to the variance in trawl catches, biomass was calculated on demersal teleosts alone as well as on total nekton (all fishes and squid).

Abundance - An index of relative abundance (Musick and McEachran 1972) was calculated by station for each dominant species and for total demersal teleosts as follows:

$$\text{Index of Relative Abundance} = \frac{1}{n} \Sigma \log_e (x + 1)$$

where n is the number of trawls at a station and x is the number of individuals in each tow at that station. This index was calculated for the ten species which were most abundant over all stations and seasons. Abundance was also calculated for several non-dominant species which were considered priority species because of their commercial and recreational importance.

Numerical Classification - Numerical classification techniques were used to compare the similarity between trawl collections (normal analysis) and to elucidate species assemblages (inverse analysis). To reduce the effect of contagion generally present in trawl collections (Taylor 1953), the data were transformed $[\log_{10} (x + 1)]$ before analysis. To prevent the chance occurrence of rare species from confusing the results, only species that occurred in three or more trawl collections were included in the analysis. Similarity between collections and between the distribution of species was measured using 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 is expressed as:

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

where S_{jk} is the similarity between entities j and k, x_{ji} is the abundance of the i^{th} attribute for entity j, and x_{ki} is the abundance of the i^{th} attribute for entity k. In normal analysis (clustering by collection), x is the abundance of species i in collections j and k. In inverse analysis (clustering by species), x is the abundance of species j and k in collection i. Similarity matrices produced by this measure were expressed in the form of dendrograms generated using a flexible sorting strategy (Lance and Williams 1967a, Clifford and Stephenson 1975), with $\beta = -0.25$.

Subsequent to cluster analysis, species groups were chosen from the inverse classification by utilizing a variable stopping rule (Boesch 1977). Nodal analysis was then used to determine the constancy and fidelity of each species group to the seven trawlable stations. Constancy is a measure of the frequency of occurrence of a species group among all samples at a station, and fidelity is an expression of the constancy of a species group to collections at one station over all collections at all stations (Boesch 1977). Constancy is equal to 1 when all species in a group occur in all collections at a station and zero when no species in a group occur in any collections at a station. Fidelity is equal to 1 when the constancy of a species group at a station is equal to its overall constancy, greater than 1 when constancy at a station is greater than its overall constancy, and less than 1 when its constancy at a station is less than its overall constancy (Boesch 1977). Constancy and fidelity were compared between species groups and collections from fixed stations for each season.

Dominance and Diversity - The fish community of each station was characterized by its numerically dominant species from trawl catches. Dominant species were considered to be the ten most abundant species at each station. The degree of community dominance by abundant species at each station was expressed in dominance diversity curves (Whittaker 1965) and by a dominance index (McNaughton 1967) expressed as follows:

$$DI = \frac{n_1 + n_2}{N} (100)$$

where n_1 and n_2 are the numbers of individuals of the first and second most abundant species, and N is the total number of individuals.

After removal of pelagic fishes and squids, diversity was calculated for demersal fishes for each tow and for pooled collections at each site by H' and its components, species richness and evenness, J'(Pielou 1975). Diversity indices were also calculated for collections pooled by day or night for each site. Collections were pooled in order to more accurately assess diversity at each site based on repeated sampling of the community.

RESULTS

Quantitative Assessment of Fish Captured by Trawl:

Species Composition and Abundance - A total of 62,840 fishes representing 54 families, 98 genera, and 128 species were taken in 83 trawl collections during both seasons. Of these, 50,771 belonged to the demersal fish community and the remaining pelagics were mainly carangids and clupeids (Appendix 14). Of the demersal fishes, ten species made up 94.2% of the total number of individuals and the two most abundant species, *Stenotomus aculeatus* (30,714 individuals) and *Haemulon aurolineatum* (8916 individuals) made up 78.1% of the total. Other abundant species were *Rhomboplites aurorubens* (4748), *Equetus lanceolatus* (761), *Centropristis striata* (582), *Prionotus carolinus* (484), *Calamus leucosteus* (475), *Equetus umbrosus* (458), *Urophycis regia* (374) and *Monacanthus hispidus* (335). *Stenotomus aculeatus*, *H. aurolineatum*, and *R. aurorubens* were the most abundant species in both winter and summer; however, other dominant species varied in community ranking seasonally (Table 6.1). Major seasonal differences included increased abundance of *C. striata* during the summer and the appearance in summer of large numbers of *Apogon pseudomaculatus*, which were absent in winter. *Equetus lanceolatus*, which was very abundant in winter, was rarely captured in the summer. *Urophycis regia* was common in winter but was not collected in summer.

Ranking of dominant species changed not only seasonally, but also by station within a season (Tables 6.2 and 6.3). The southern porgy, *Stenotomus aculeatus*, was generally more abundant in summer than in winter (Figure 6.1) and was the most abundant species at all stations, except OS01, in summer.

Table 6.1. Ten most abundant demersal fish species in winter and summer 1980, all stations combined. n = number of occurrences in 42 trawls in winter and number of occurrences in 41 trawls in summer.

Species	Total Number	Percent of Total	n
	WINTER		
Stenotomus aculeatus	12281	52.0	33
Haemulon aurolineatum	4516	19.1	11
Rhomboplites aurorubens	3540	15.0	19
Equetus lanceolatus	738	3.1	10
Urophycis regia	374	1.6	14
Lagodon rhomboides	275	1.2	10
Calamus leucosteus	265	1.1	23
Equetus umbrosus	222	0.9	11
Prionotus carolinus	166	0.7	5
Diplectrum formosum	133	0.6	22
	SUMMER		
Stenotomus aculeatus	18433	67.8	37
Haemulon aurolineatum	4400	16.2	31
Rhomboplites aurorubens	1208	4.4	24
Centropristis striata	462	1.7	26
Prionotus carolinus	318	1.2	10
Apogon pseudomaculatus	312	1.2	17
Monacanthus hispidus	261	1.0	25
Equetus umbrosus	236	0.9	17
Calamus leucosteus	210	0.8	25
Centropristis ocyurus	154	0.6	21

Table 6.2. Ten most abundant demersal fish species, in winter 1980, by station. n = number of occurrences in six replicate trawls.

Station	Species	Total Number	Percent of Total at Station	n
IS01	Urophycis regia	319	40.1	3
	Stenotomus aculeatus	177	22.3	5
	Prionotus carolinus	164	20.6	3
	Prionotus sp.	23	2.9	1
	Centropristis striata	22	2.8	3
	Syacium papillosum	19	2.4	3
	Urophycis sp.	13	1.6	1
	Centropristis ocyurus	10	1.3	3
	Synodus foetens	6	0.8	4
	Ophidion holbrooki	4	0.5	2
IS02	Stenotomus aculeatus	174	45.8	5
	Lagodon rhomboides	78	20.5	1
	Centropristis striata	22	5.8	4
	Equetus umbrosus	20	5.3	2
	Urophycis regia	17	4.5	2
	Calamus leucosteus	17	4.5	3
	Urophycis sp.	11	2.9	2
	Syacium papillosum	8	2.1	2
	Synodus foetens	6	1.6	4
	Ophidion holbrooki	3	0.8	2
IS03	Haemulon aurolineatum	1530	43.2	3
	Rhomboplites aurorubens	934	26.4	3
	Stenotomus aculeatus	472	13.3	6
	Equetus umbrosus	175	5.0	3
	Lagodon rhomboides	168	4.8	5
	Synodus foetens	35	1.0	6
	Orthopristis chrysoptera	30	0.8	3
	Centropristis striata	29	0.8	4
	Calamus leucosteus	24	0.7	3
	Ophidion holbrooki	22	0.6	3

Table 6.2 (Continued)

Station	Species	Total Number	Percent of Total at Station	n
MS01	Stenotomus aculeatus	1163	53.3	2
	Haemulon aurolineatum	859	39.4	2
	Calamus leucosteus	56	2.6	3
	Synodus foetens	15	0.7	6
	Diplectrum formosum	12	0.6	3
	Lutjanus campechanus	8	0.4	1
	Equetus umbrosus	8	0.4	1
	Syacium papillosum	8	0.4	3
	Aluterus schoepfi	8	0.4	3
	Rhomboplites aurorubens	6	0.3	4
MS02	Stenotomus aculeatus	9559	89.4	6
	Equetus lanceolatus	621	5.8	4
	Rhomboplites aurorubens	138	1.3	3
	Calamus leucosteus	89	0.8	6
	Centropristis striata	38	0.4	5
	Monacanthus hispidis	33	0.3	5
	Diplectrum formosum	32	0.3	6
	Aluterus schoepfi	31	0.3	4
	Lactophrys quadricornis	24	0.2	5
	Pagrus pagrus	18	0.2	5
MS03	Rhomboplites aurorubens	2449	42.2	6
	Haemulon aurolineatum	2127	36.6	6
	Stenotomus aculeatus	735	12.6	6
	Equetus lanceolatus	115	2.0	4
	Diplectrum formosum	70	1.2	6
	Calamus leucosteus	53	0.9	5
	Lagodon rhomboides	28	0.5	3
	Monacanthus hispidis	28	0.5	5
	Centropristis ocyurus	27	0.5	4
	Mullus auratus	21	0.4	1

Table 6.2 (Continued)

Station	Species	Total Number	Percent of Total at Station	n
OS01	*Pagrus pagrus*	63	30.9	1
	Synodus poeyi	38	18.6	3
	Calamus leucosteus	26	12.8	3
	Syacium papillosum	22	10.8	3
	Urophycis regia	18	8.8	3
	Rhomboplites aurorubens	13	6.4	3
	Centropristis ocyurus	5	2.4	3
	Synodus foetens	3	1.5	1
	Equetus (= *Pareques*) sp. nov.	3	1.5	2
	Serranus phoebe	2	1.0	2

Table 6.3. Ten most abundant demersal fish species, in summer 1980, by station. n = number of occurrences in six replicate trawls (five at IS03).

Station	Species	Total Number	Percent of Total at Station	n
IS01	*Stenotomus aculeatus*	2942	71.2	6
	Haemulon aurolineatum	435	10.5	6
	Centropristis striata	194	4.7	6
	Monacanthus hispidus	141	3.4	6
	Prionotus carolinus	120	2.9	4
	Porichthys plectrodon	60	1.4	3
	Diplectrum formosum	51	1.2	3
	Calamus leucosteus	38	0.9	5
	Centropristis ocyurus	30	0.7	3
	Apogon pseudomaculatus	25	0.6	3
IS02	*Stenotomus aculeatus*	2721	53.4	6
	Haemulon aurolineatum	1587	31.2	4
	Prionotus carolinus	187	3.7	3
	Centropristis striata	161	3.2	5
	Apogon pseudomaculatus	59	1.2	3
	Syacium papillosum	57	1.1	3
	Monacanthus hispidus	40	0.8	5
	Diplectrum formosum	40	0.8	3
	Porichthys plectrodon	33	0.6	3
	Scorpaena brasiliensis	26	0.5	3
IS03	*Stenotomus aculeatus*	1730	58.2	5
	Haemulon aurolineatum	921	31.0	4
	Centropristis striata	60	2.0	4
	Calamus leucosteus	33	1.1	2
	Monacanthus hispidus	32	1.1	4
	Equetus umbrosus	30	1.0	2
	Lagodon rhomboides	20	0.7	4
	Porichthys plectrodon	20	0.7	1
	Rhomboplites aurorubens	15	0.5	2
	Orthopristis chrysoptera	14	0.5	2

Table 6.3 (Continued)

Station	Species	Total Number	Percent of Total at Station	n
MS01	*Stenotomus aculeatus*	1443	46.9	6
	Haemulon aurolineatum	799	26.0	5
	Rhomboplites aurorubens	399	13.0	6
	Apogon pseudomaculatus	163	5.3	3
	Centropristis ocyurus	48	1.6	3
	Ophidion holbrooki	48	1.6	2
	Calamus leucosteus	31	1.0	5
	Diplectrum formosum	26	0.8	5
	Monacanthus hispidus	19	0.6	3
	Aluterus schoepfi	11	0.4	3
MS02	*Stenotomus aculeatus*	8580	88.1	6
	Haemulon aurolineatum	479	4.9	6
	Rhomboplites aurorubens	460	4.7	6
	Calamus leucosteus	52	0.5	6
	Centropristis striata	33	0.3	5
	Apogon pseudomaculatus	18	0.2	3
	Monacanthus hispidus	18	0.2	5
	Ophidion holbrooki	14	0.1	3
	Priacanthus arenatus	10	0.1	4
	Prionotus carolinus	10	0.1	2
MS03	*Stenotomus aculeatus*	1015	62.2	6
	Rhomboplites aurorubens	192	11.8	5
	Haemulon aurolineatum	179	11.0	6
	Apogon pseudomaculatus	38	2.3	3
	Equetus umbrosus	26	1.6	3
	Aluterus schoepfi	24	1.5	4
	Centropristis ocyurus	16	1.0	4
	Porichthys plectrodon	16	1.0	3
	Equetus lanceolatus	15	0.9	2
	Ophidion holbrooki	13	0.8	3

Table 6.3 (Continued)

Station	Species	Total Number	Percent of Total at Station	n
OS01	*Equetus umbrosus*	145	27.6	3
	Rhomboplites aurorubens	141	26.9	4
	Calamus leucosteus	53	10.1	4
	Serranus phoebe	52	9.9	4
	Centropristis ocyurus	22	4.2	3
	Equetus (= *Pareques*) sp. nov.	17	3.2	3
	Pagrus pagrus	14	2.7	5
	Synodus poeyi	13	2.5	3
	Scorpaena calcarata	10	1.9	3
	Apogon pseudomaculatus	9	1.7	2

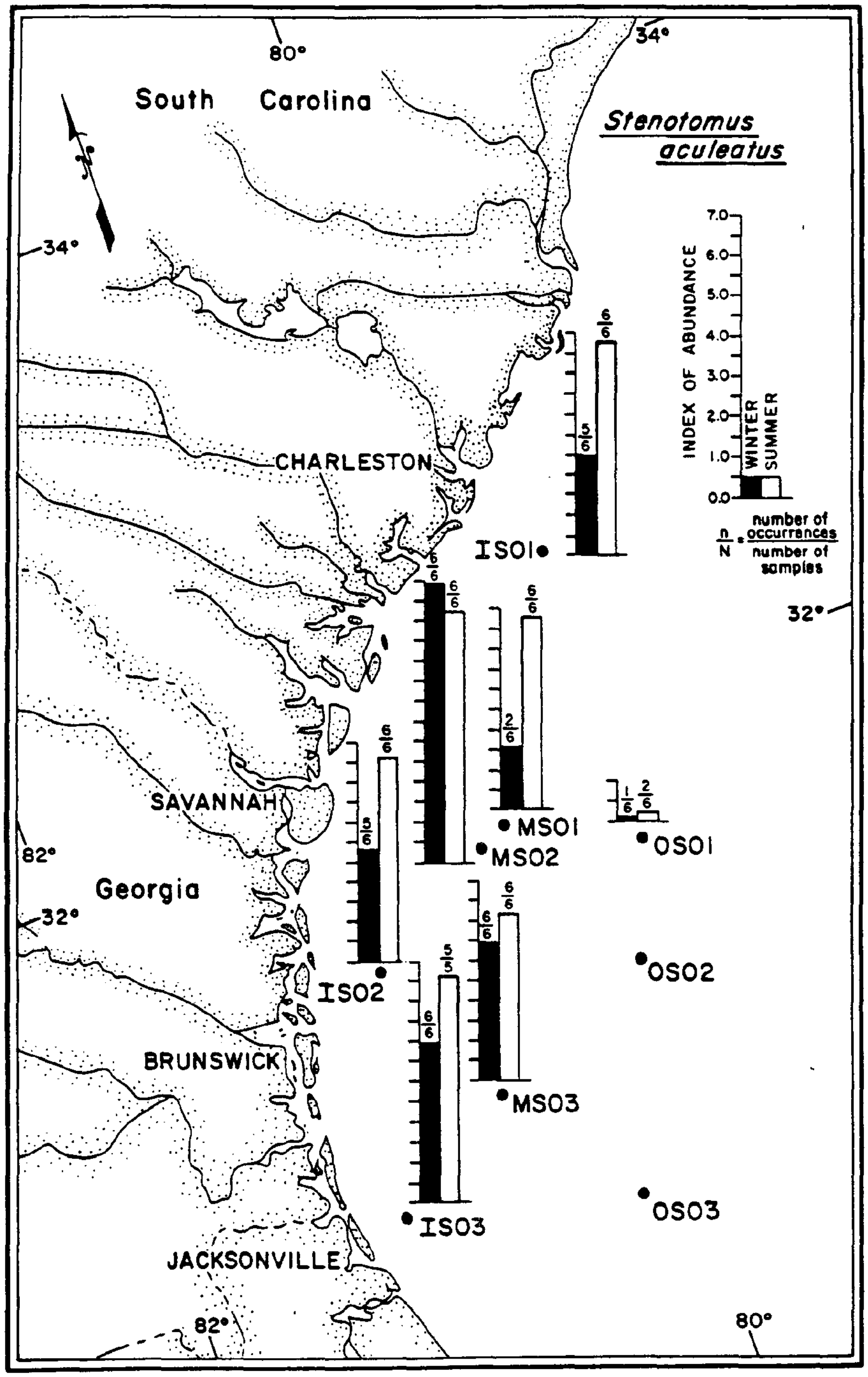


Figure 6.1. Relative abundance of Stenotomus aculeatus during winter and summer, 1980.

In winter, S. aculeatus was one of the three most abundant species at all stations except OS01. Southern porgy were most abundant at MS02 and least abundant at OS01. Most individuals were captured during the day in both winter and summer (Table 6.4).

Tomtate, Haemulon aurolineatum, were more abundant during summer rather than winter at all stations except MS03 (Figure 6.2). In winter, H. aurolineatum was taken only at IS03, MS01, and MS03 with peak abundance at MS03. Tomtate were absent at MS02 in winter but were abundant there during the summer. In summer, tomtate were abundant at all stations except OS01 and were the second most abundant species at most other stations (Table 6.3). Most individuals were captured at night in both winter and summer (Table 6.4).

Vermilion snapper, Rhomboplites aurorubens, a priority species, were most abundant at middle shelf stations with no apparent seasonal pattern (Figure 6.3). They were generally not abundant at inner shelf stations, with the exception of IS03, where they were the second most abundant species in winter (Table 6.2). Rhomboplites aurorubens was the most abundant species at MS03 in winter and was the second most abundant species collected at that site in summer. This species was common at OS01, especially in summer. Vermilion snapper were equally abundant in day and night trawls in winter but were more abundant in day trawls in summer (Table 6.4).

Jackknife fish, Equetus lanceolatus, were common only at middle shelf stations (Figure 6.4). In winter, they were abundant at MS02 and MS03, and a few were taken at IS03. In summer, a few were taken at inner and middle shelf stations. None were taken at OS01 during either season. In winter, most jack-knife fish were captured during the day; however, the few that were taken during summer were all caught at night.

Black sea bass, Centropristis striata, a priority species, were caught in the trawl at all stations except OS01 during winter and summer (Figure 6.5). Catches at inner shelf stations were consistently higher during summer, but not at middle shelf stations. Overall, abundance for this species was highest at inner shelf stations during summer. Abundance was also high at MS02 during both seasons. Most black sea bass were caught at night.

Northern searobin, Prionotus carolinus, were most abundant at the two northern inner shelf stations (Figure 6.6) and were frequently a dominant species (Tables 6.2 and 6.3). No clear seasonal abundance pattern was evident. Northern searobin were common at IS02 in summer, although they were not taken there in winter. All but one specimen were caught at night.

Whitebone porgy, Calamus leucosteus, were caught at all stations and, with the exception of IS01 in winter, were collected at each station during both seasons (Figure 6.7). Abundance was highest at middle shelf stations, especially in winter. Whitebone porgy were more abundant in day trawls.

The cubbyu, Equetus umbrosus, was occasionally captured at all trawlable stations and was sometimes a dominant species (Figure 6.8). Although it was not captured during winter at the outer shelf station, it was the most abundant species there in summer. All specimens of this species were captured at night.

Spotted hake, Urophycis regia, were only collected in winter and were most abundant on the inner shelf, especially at IS01 (Figure 6.9) where it dominated the catch. All but one specimen were taken at night.

Planehead filefish, Monacanthus hispidus, were collected at all stations except OS01 and were occasionally abundant (Figure 6.10). At inner shelf

Table 6.4. Abundance of dominant and priority species by season and light phase. n/N represents the ratio of the number of occurrences of each species (n) to the total number of collections (N).

	Total Number				Mean Number per Tow				n/N			
	Winter		Summer		Winter		Summer		Winter		Summer	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Stenotomus aculeatus	8670	3611	11689	6744	412.86	171.95	556.62	337.20	14/21	19/21	18/21	19/20
Haemulon aurolineatum	2068	2448	1107	3293	98.48	116.57	52.71	164.65	3/21	8/21	14/21	17/20
Rhomboplites aurorubens	1849	1691	880	328	88.05	80.52	41.90	16.40	5/21	14/21	10/21	14/20
Equetus lanceolatus	723	15	0	23	34.43	0.71	0.00	1.15	3/21	7/21	0/21	9/20
Centropristis striata	16	104	23	439	0.76	4.95	1.10	21.95	7/21	15/21	10/21	16/20
Prionotus carolinus	0	166	1	317	0.00	7.90	0.05	15.85	0/21	5/21	1/21	9/20
Calamus leucosteus	215	50	158	52	10.24	2.38	7.52	2.60	14/21	9/21	13/21	12/20
Equetus umbrosus	0	222	0	236	0.00	10.57	0.00	11.80	0/21	11/21	0/21	17/20
Urophycis regia	1	373	0	0	0.05	17.76	0.00	0.00	1/21	13/21	0/21	0/20
Monacanthus hispidus	17	57	15	246	0.81	2.71	0.71	12.30	6/21	13/21	10/21	15/20
Lutjanus campechanus	19	5	1	8	0.90	0.24	0.05	0.40	4/21	3/21	1/21	5/20
Mycteroperca microlepis	2	0	2	1	0.10	0.00	0.10	0.05	2/21	0/21	2/21	1/20
Pagrus pagrus	89	5	18	10	4.24	0.24	0.86	0.50	6/21	2/21	5/21	3/20

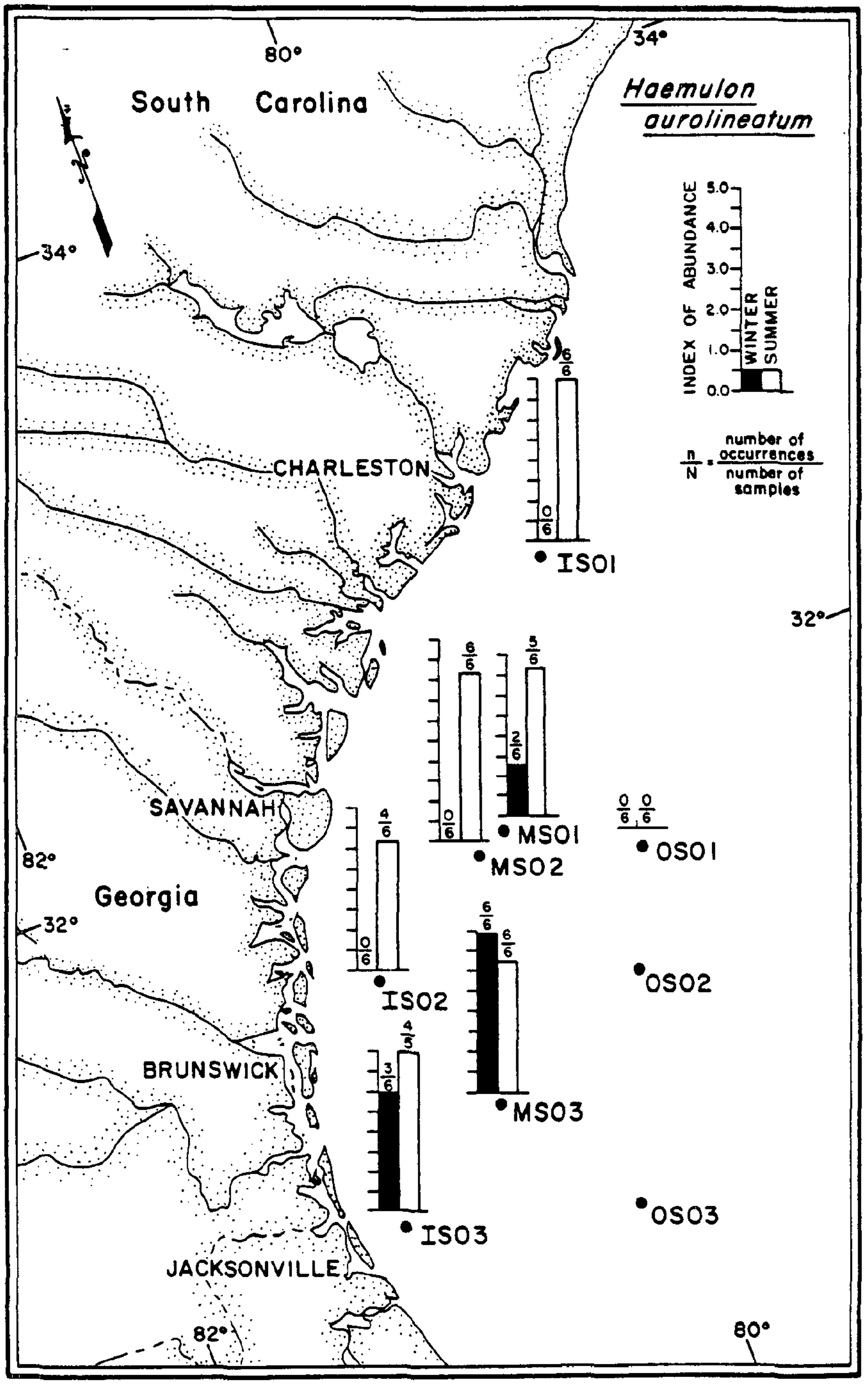


Figure 6.2. Relative abundance of Haemulon aurolineatum during winter and summer, 1980.

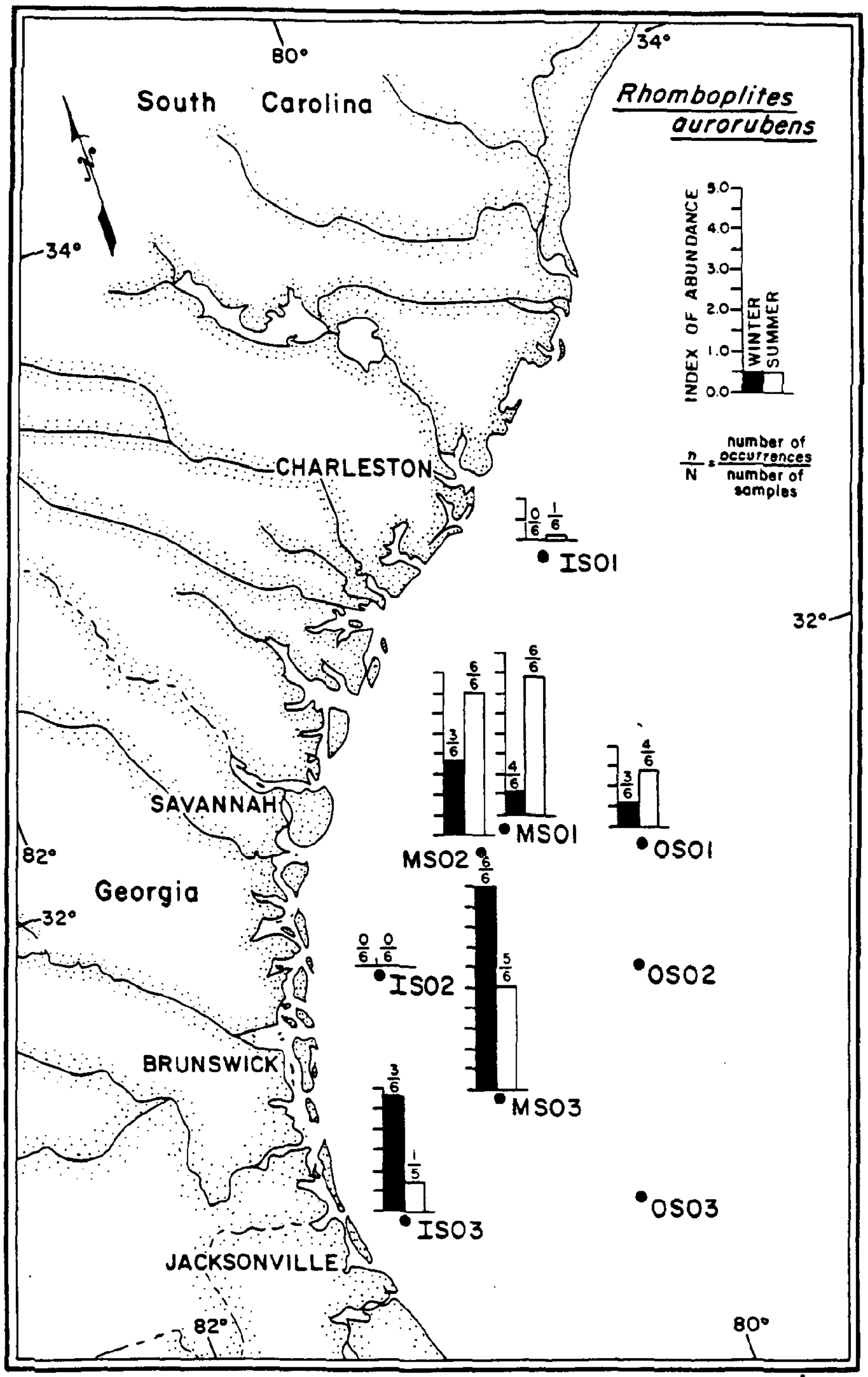


Figure 6.3. Relative abundance of Rhomboplites aurorubens during winter and summer, 1980.

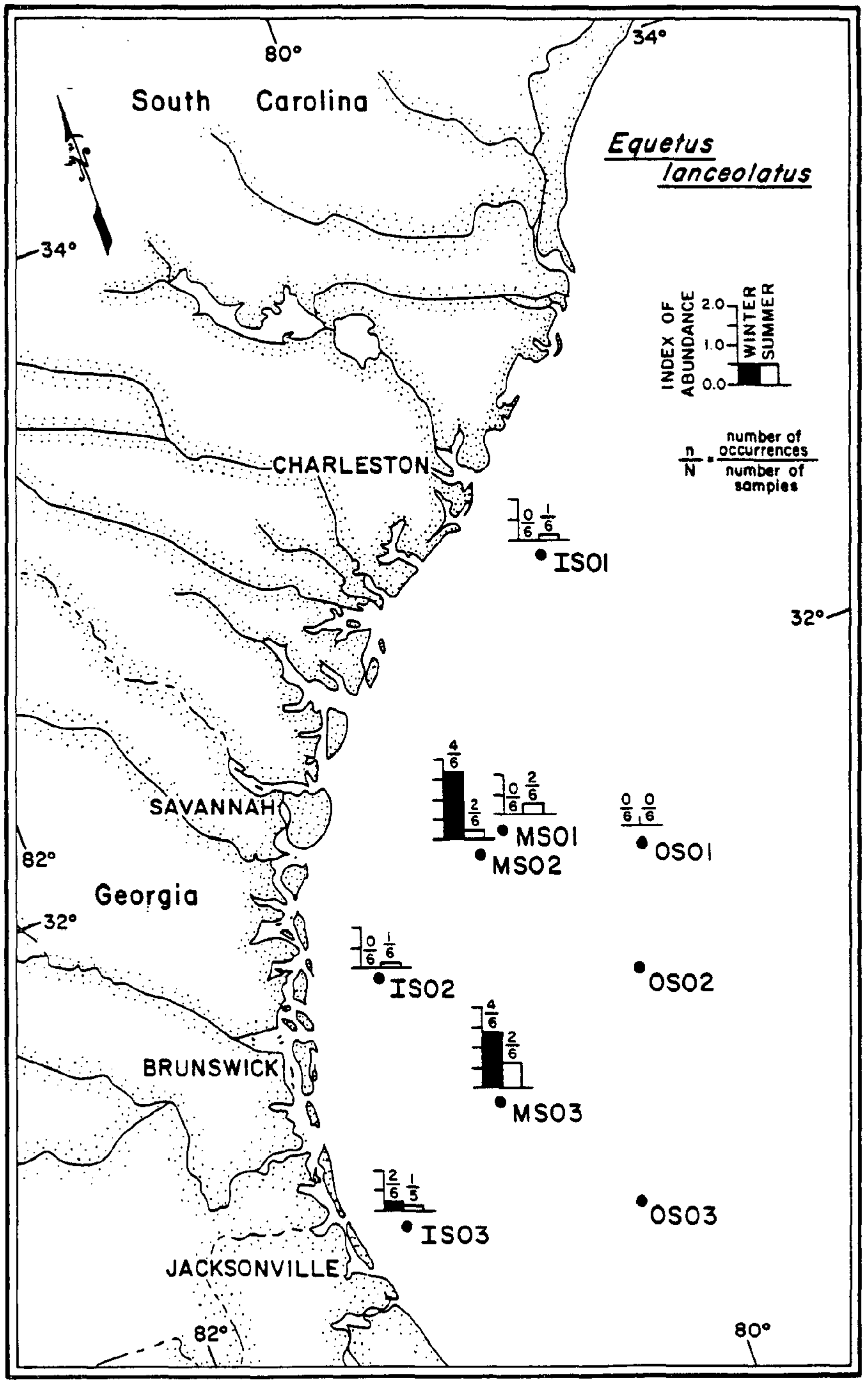


Figure 6.4. Relative abundance of Equetus lanceolatus during winter and summer, 1980.

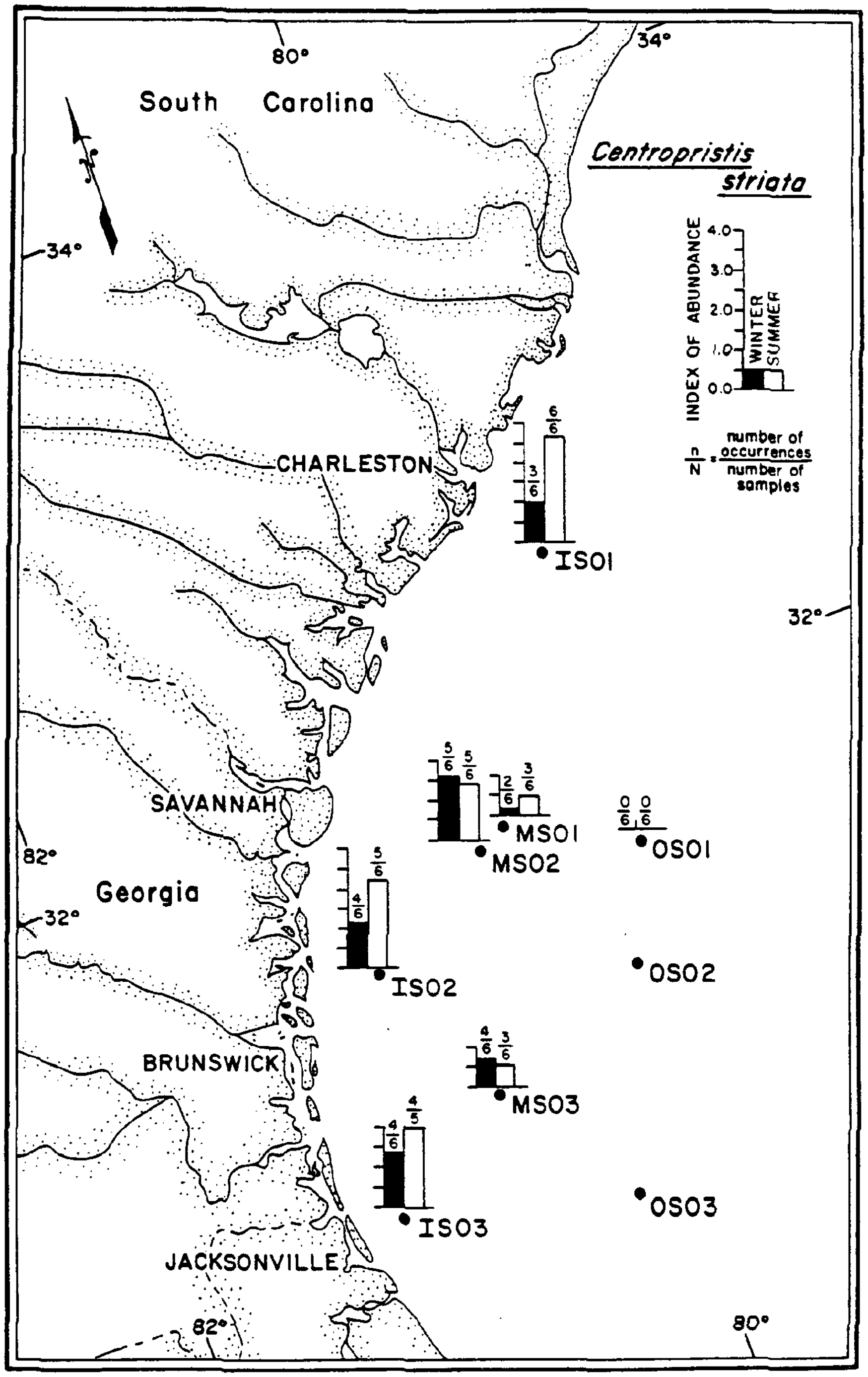


Figure 6.5. Relative abundance of Centropristis striata during winter and summer, 1980.

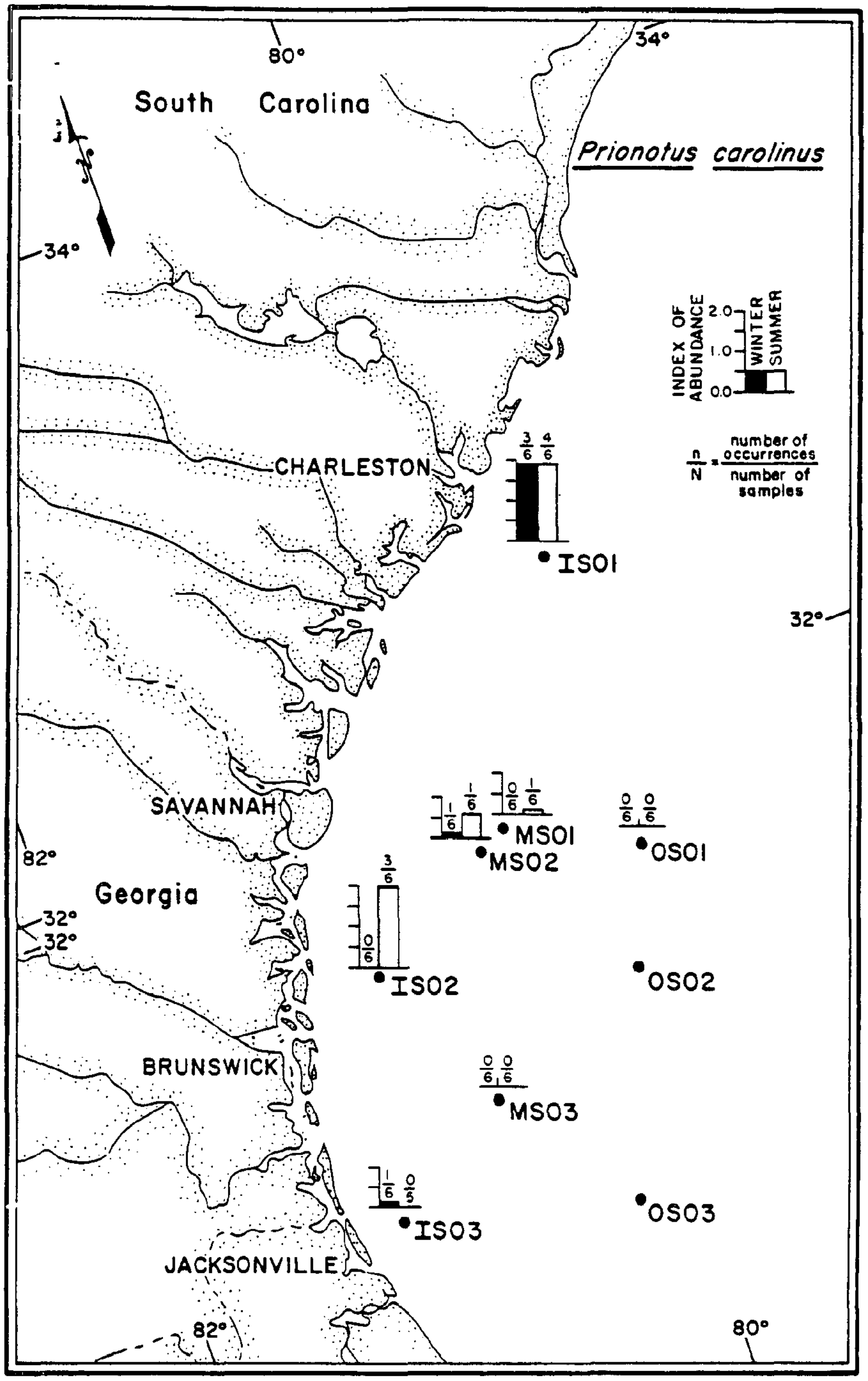


Figure 6.6. Relative abundance of Prionotus carolinus during winter and summer, 1980.

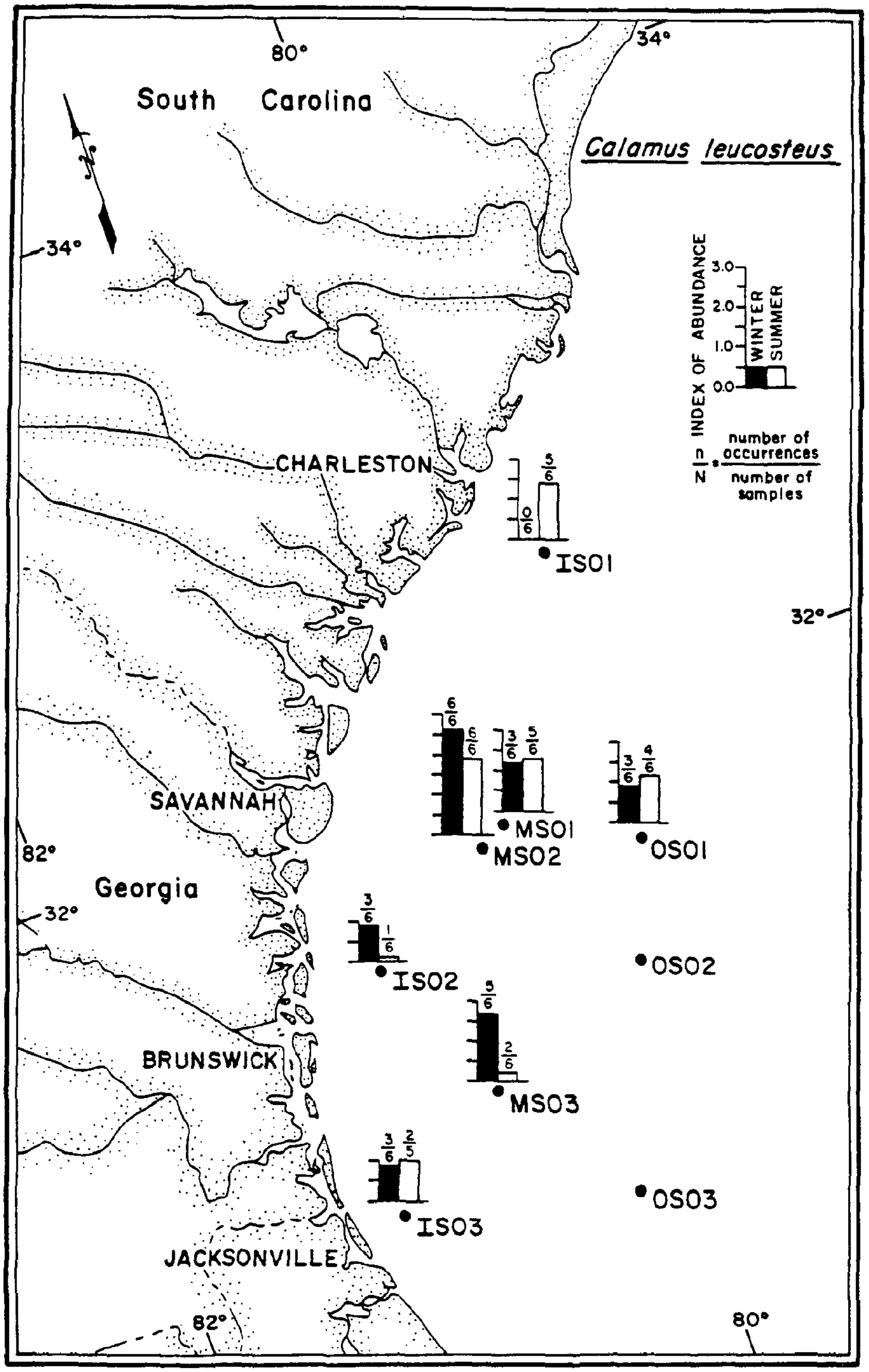


Figure 6.7. Relative abundance of Calamus leucosteus during winter and summer, 1980.

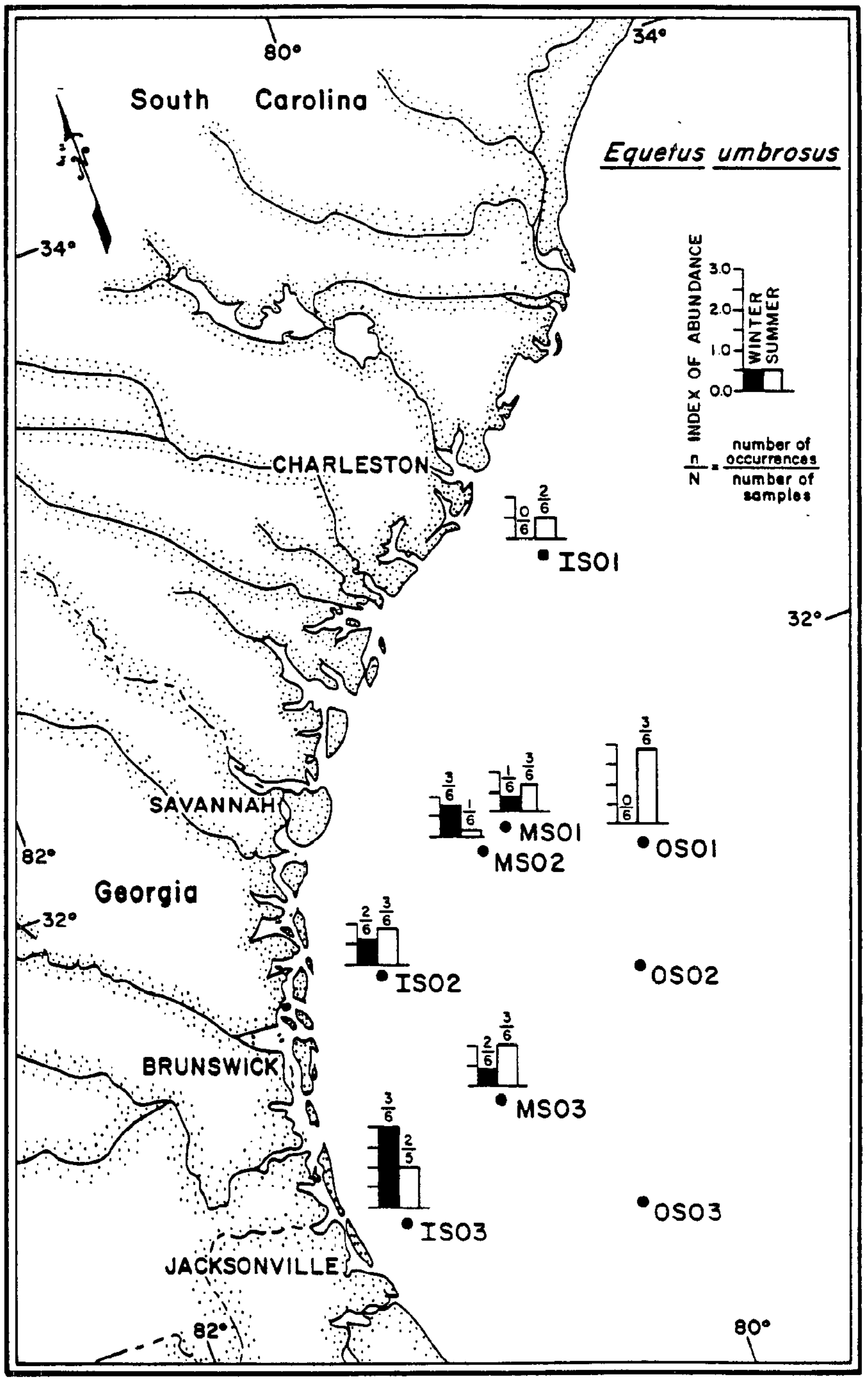


Figure 6.8. Relative abundance of Equetus umbrosus during winter and summer, 1980.

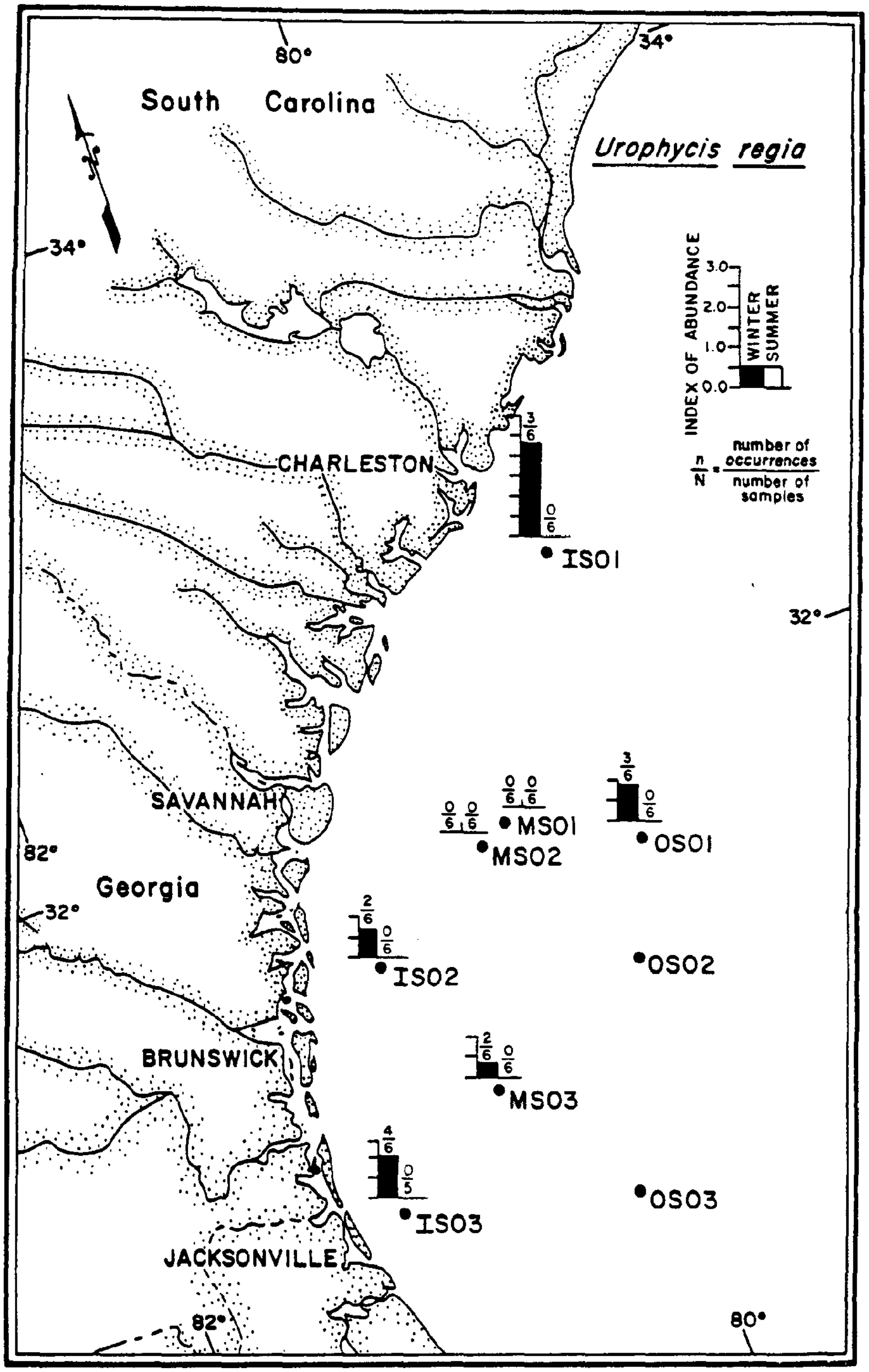


Figure 6.9. Relative abundance of Urophycis regia during winter and summer, 1980.

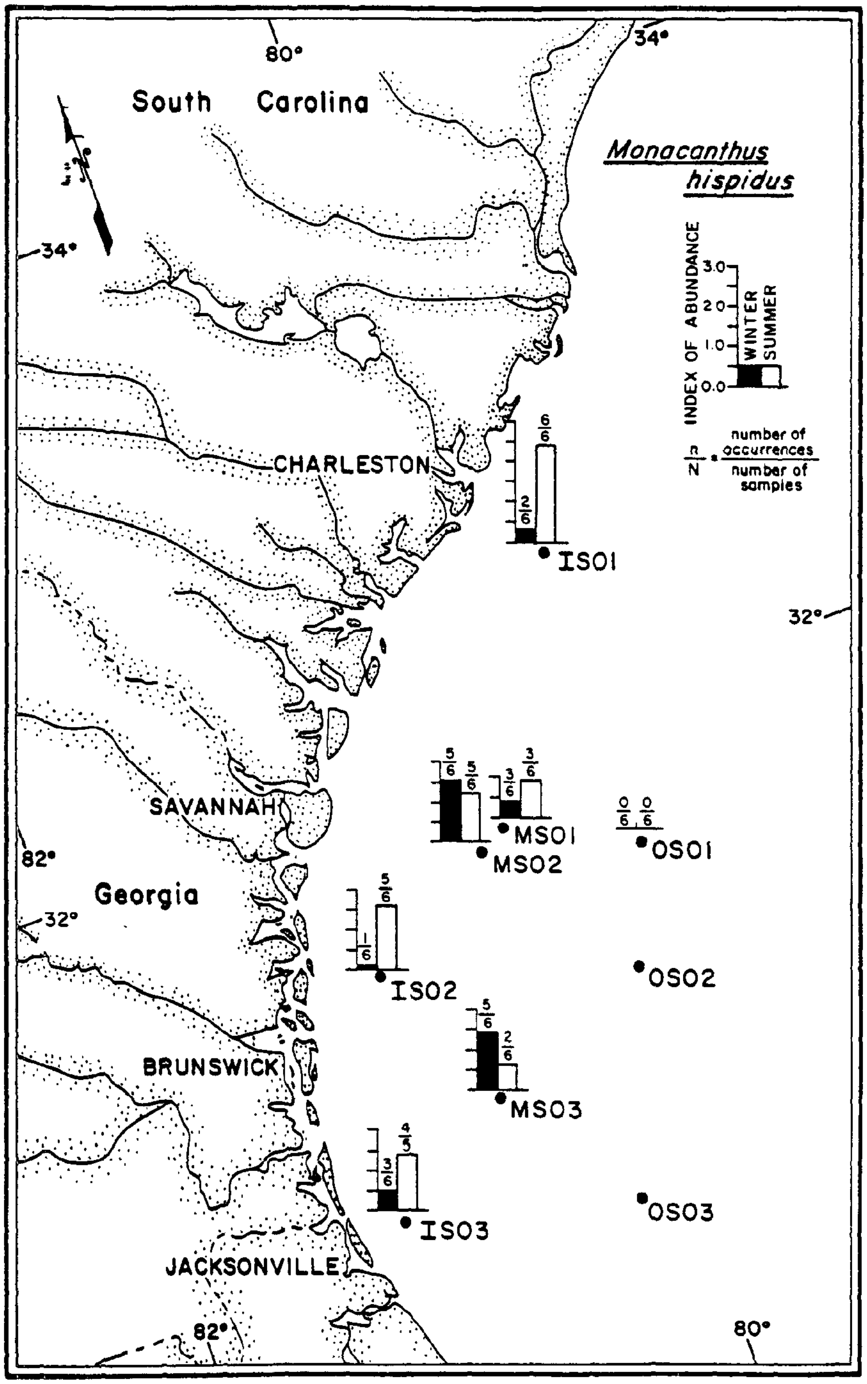


Figure 6.10. Relative abundance of Monacanthus hispidus during winter and summer, 1980.

stations, abundance was much higher in summer than in winter; however, this was not true at middle shelf stations. Most specimens of M. hispidus were taken at night.

In addition to the dominant species discussed above, the index of relative abundance was calculated for other species which were not numerically dominant, but were commercially or recreationally important and of interest in terms of impact or enhancement by oil development. These included the red snapper, Lutjanus campechanus; the gag, Mycteroperca microlepis; and the red porgy, Pagrus pagrus.

Red snapper and gag were taken primarily at middle shelf stations (Figures 6.11 and 6.12). These were infrequently caught by the trawl. Compared to diver observations and television transects, the 40/54 fly net grossly underestimated the abundance of all large snappers and groupers. Sample sizes were too small to determine seasonal or geographical patterns of abundance for these two species.

Red porgy were common at middle and outer shelf stations (Figure 6.13). In winter, P. pagrus was the most abundant species at OS01 and was a dominant species at MS02. In summer, red porgy were dominant only at OS01. None were caught at inner shelf stations. Most red porgy were taken during the day.

Other non-dominant species demonstrated seasonal or diel abundance patterns. All Apogon pseudomaculatus (312 individuals) were captured at all stations, except IS03, in night trawls and only during the summer. All Ophidion spp. were captured at night. Most Centropristis ocyurus (96.5%), Syacium papillosum (96.9%), and Scorpaena spp.(98.2%) were captured at night, whereas most Holacanthus bermudensis (74.2%) and Mullus auratus (95.7%), were trawled during the day. Most Lagodon rhomboides (88.4%) were captured during winter, and 85.4% of these were taken at night.

At inner shelf stations, overall fish abundance was highest in summer when inshore waters warmed up (> 22°C). Increased abundance in summer was particularly pronounced at IS01 and IS02 (Figure 6.14 and Tables 6.5 and 6.6). Station IS03 had a smaller seasonal difference in fish abundance, and differences in temperature were not as great (Chapter 3). Little seasonal difference in the index of relative abundance was evident for demersal teleosts at MS02 and MS03; however, seasonal differences present at MS01 were similar in magnitude to the two northernmost inner shelf stations. Station MS01 had the greatest seasonal temperature difference of any middle shelf station. Lowest overall fish abundance was at OS01.

Biomass - Biomass estimates are presented in Table 6.7 for demersal teleost fishes and Table 6.8 for total nekton, i.e. pelagic and demersal fishes, including elasmobranchs, and squid. Mean biomass per tow for all stations was 44.052 kg (demersal teleosts) and 60.011 kg (total) in winter and 30.974 kg (demersal teleosts) and 46.580 kg (total) in summer. In winter, transformed mean catch per tow values were significantly different between stations for demersal teleosts alone ($P < 0.005$ ANOVA) and for total nekton ($P < 0.05$ ANOVA). In summer, however, there was no significant difference between stations for either demersal teleost biomass ($P > 0.50$ ANOVA) or total nekton biomass ($P > 0.50$ ANOVA). For both seasons combined, biomass in kg ha^{-1} was highest at middle shelf depths and lowest at the outer shelf station.

Diversity - Diversity varied latitudinally, bathymetrically, seasonally,

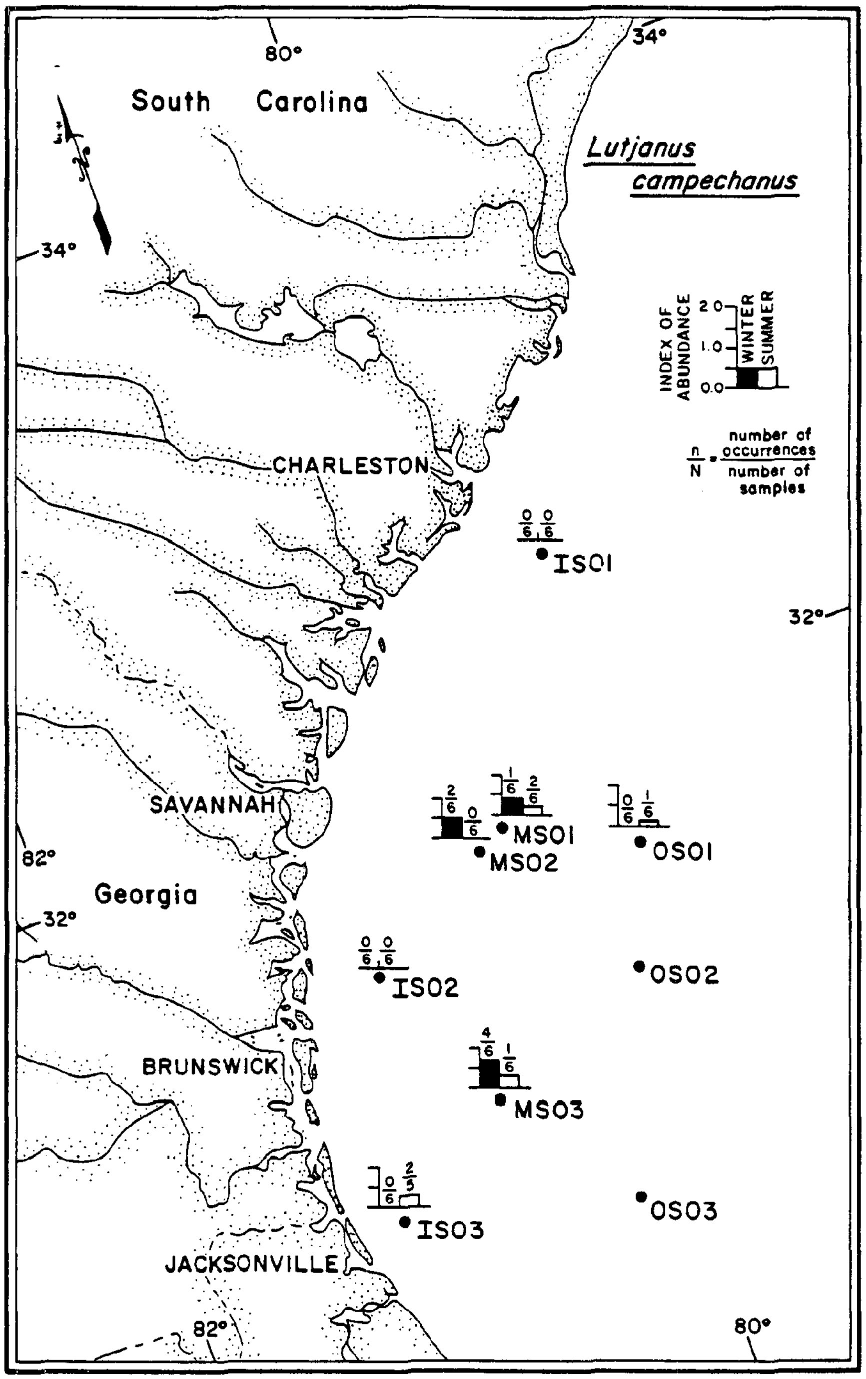


Figure 6.11. Relative abundance of Lutjanus campechanus during winter and summer, 1980.

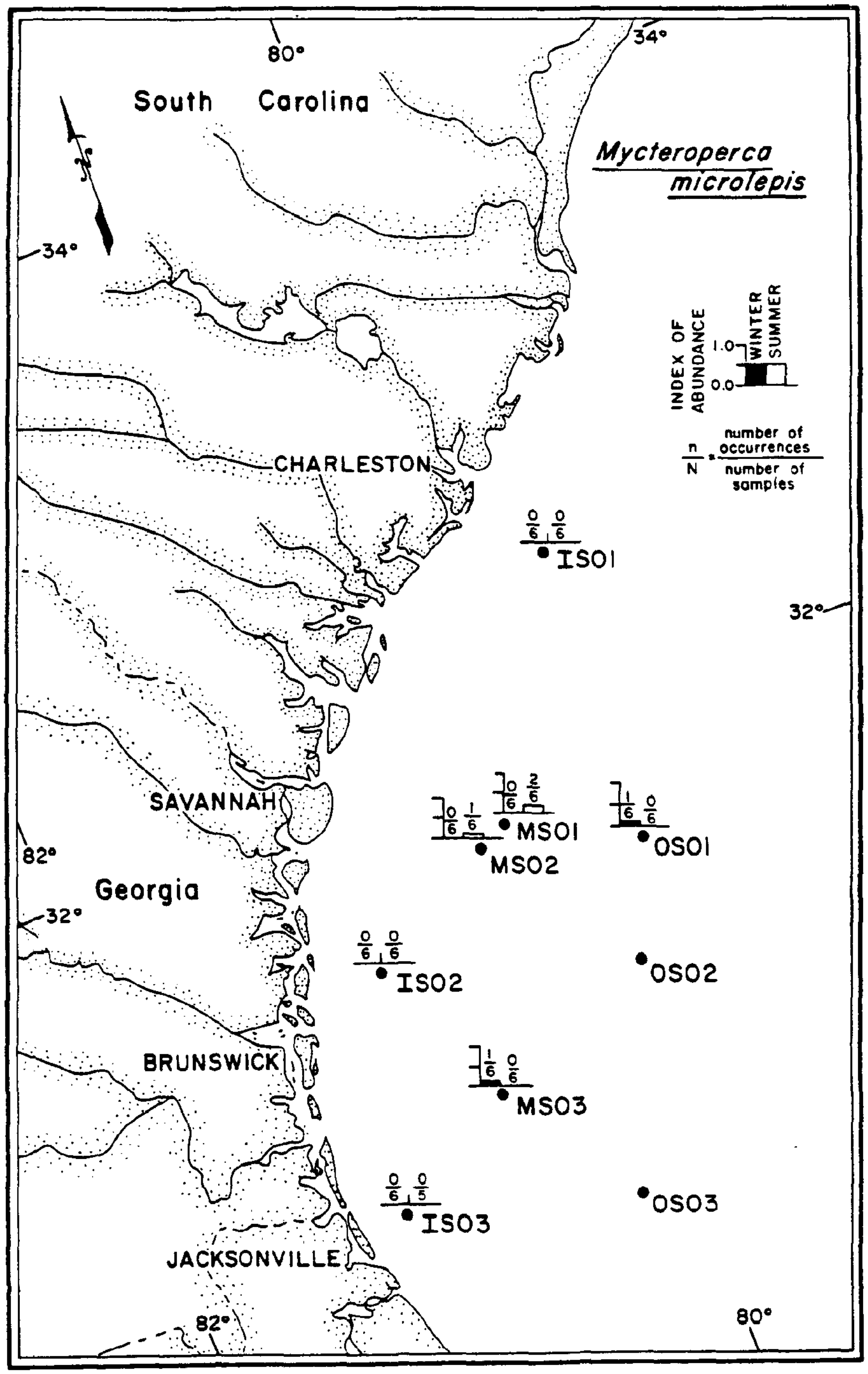


Figure 6.12. Relative abundance of Mycteroperca microlepis during winter and summer, 1980.

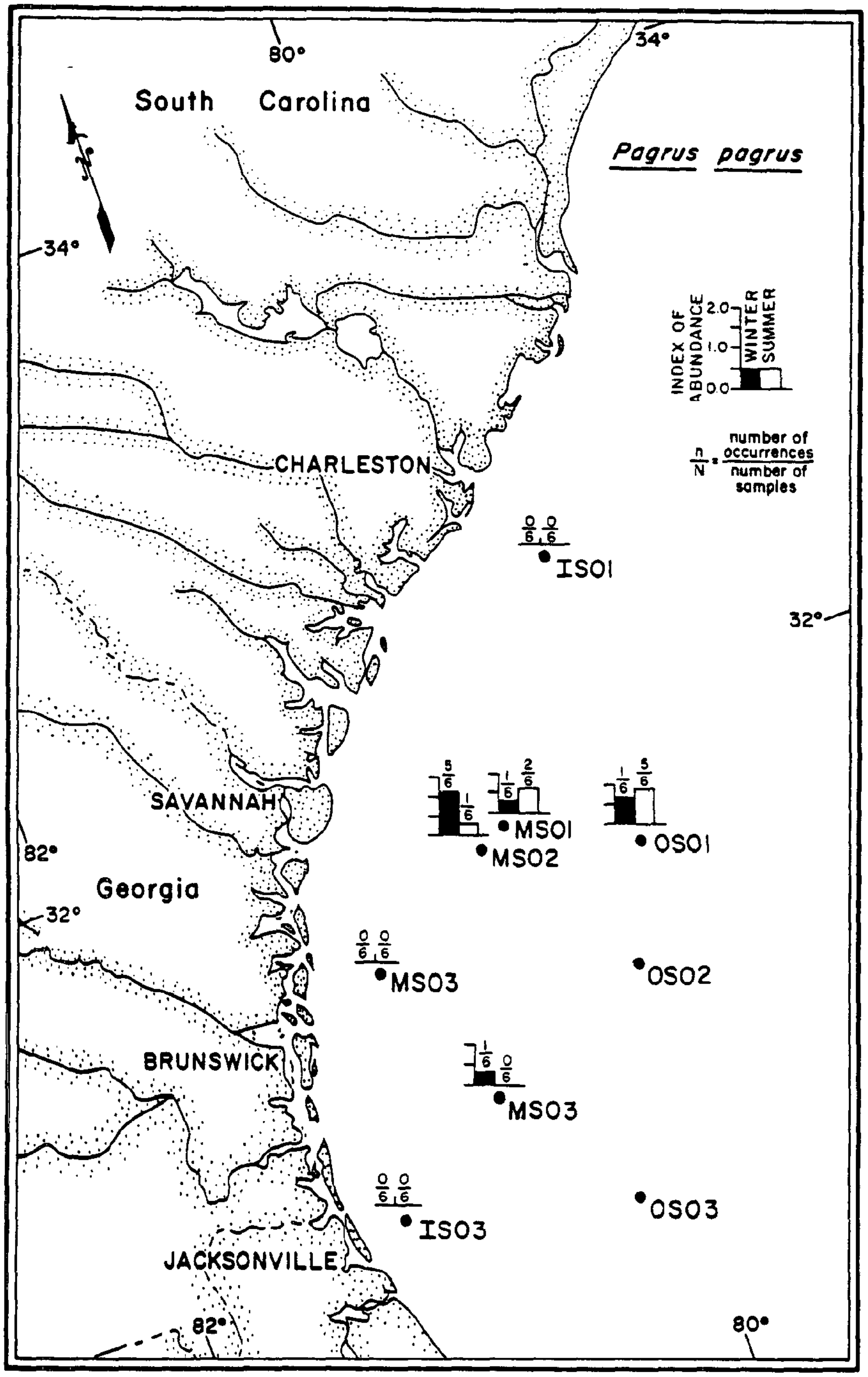


Figure 6.13. Relative abundance of Pagrus pagrus during winter and summer, 1980.

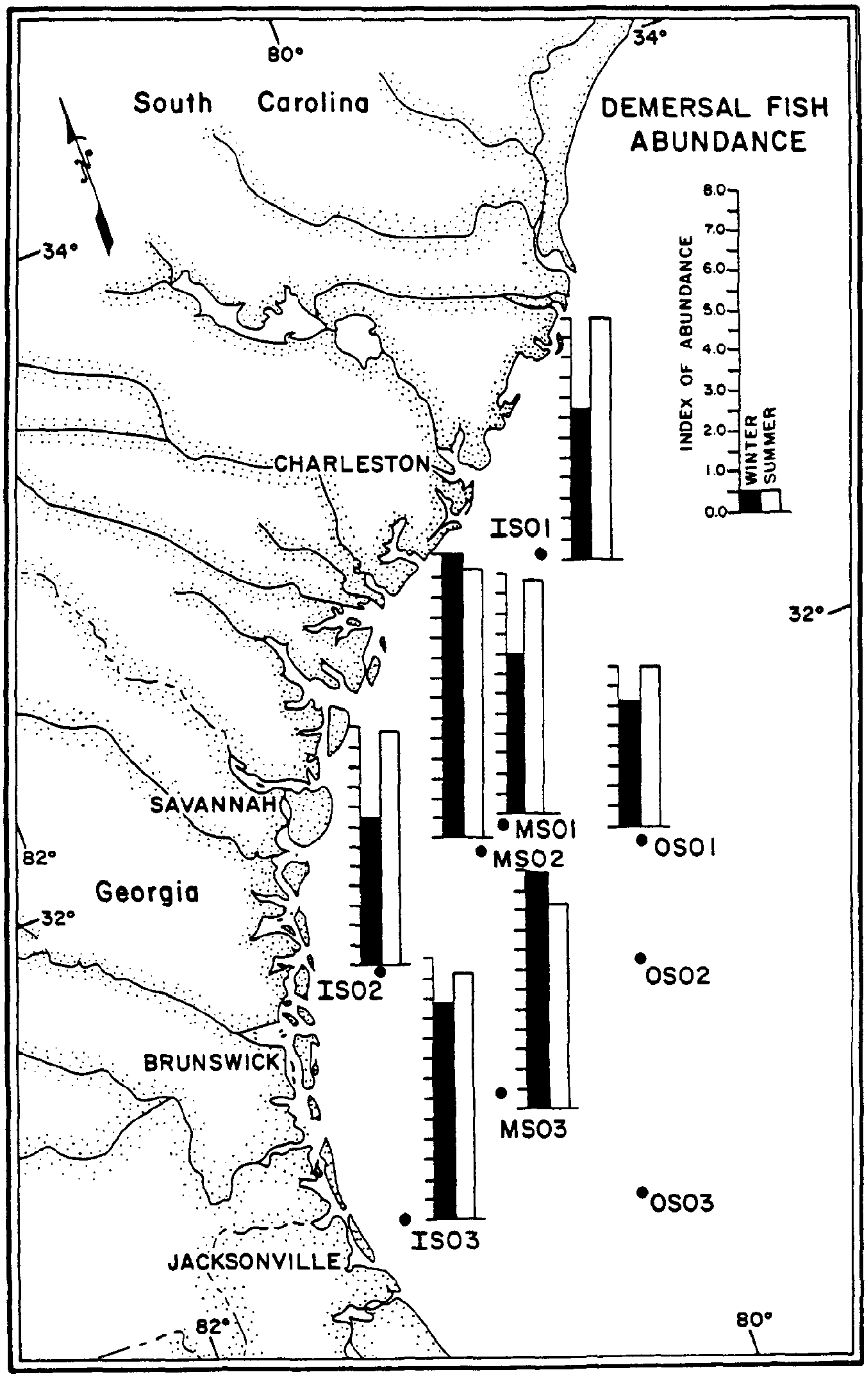


Figure 6.14. Relative abundance of demersal teleosts collected during winter and summer, 1980.

Table 6.5. Abundance estimates for trawl-caught demersal teleosts during winter and summer, 1980.

Station	Mean catch per tow untransformed		Mean catch per tow transformed		Estimated (retransformed) mean catch per tow		Number of individuals ha^{-1} of swept area	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
IS01	132.0	688.5	3.7	6.0	673.1	913.4	174.8	1000.7
IS02	63.3	848.7	3.7	5.9	79.6	1872.5	81.3	1132.2
IS03	587.8	594.0	5.4	6.1	1252.5	675.3	858.2	926.9
MS01	363.3	513.0	4.0	5.8	1105.1	1069.8	472.4	657.3
MS02	1780.5	1623.7	7.1	6.7	1775.0	1946.1	2031.1	2358.2
MS03	967.7	271.7	6.0	5.2	1559.6	332.9	1253.4	435.0
OS01	33.7	87.5	3.1	4.0	45.2	108.7	48.6	141.6

Table 6.6. Abundance estimates for trawl-caught nekton (pelagic and demersal fishes and squids) during winter and summer, 1980.

Station	Mean catch per tow untransformed		Mean catch per tow transformed		Estimated (retransformed) mean catch per tow		Number of individuals ha^{-1} of swept area	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
IS01	262.2	740.5	5.5	6.2	264.1	837.4	374.1	1076.3
IS02	81.2	884.2	4.1	6.1	88.3	1394.3	104.2	1179.6
IS03	739.0	925.4	6.3	6.4	852.8	1134.1	1078.9	1444.0
MS01	425.5	645.2	5.2	6.0	645.7	1388.8	553.2	826.6
MS02	1808.2	2087.3	7.1	6.9	1811.1	2718.8	2062.7	3031.6
MS03	1015.7	311.2	6.1	5.5	1613.8	361.1	1315.6	498.2
OS01	849.7	87.8	5.2	4.0	754.7	109.3	1226.0	142.1

Table 6.7. Biomass estimates for trawl-caught demersal teleosts during winter and summer, 1980.

	Mean catch (kg) per tow untransformed		Mean catch (kg) per tow transformed		Estimated (retransformed) mean catch (kg) per tow		Biomass (kg ha^{-1} of swept area)	
Station	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
IS01	2.483	39.559	1.062	3.202	2.782	48.653	3.288	54.497
IS02	6.957	28.984	1.818	2.767	7.390	45.754	8.929	38.667
IS03	44.382	31.433	3.206	3.133	69.085	40.994	65.283	49.049
MS01	26.108	32.101	2.030	3.076	65.489	50.754	33.949	41.129
MS02	147.269	47.822	4.708	3.550	149.693	53.437	168.000	69.456
MS03	70.196	21.922	3.572	2.929	89.044	23.925	90.926	35.100
OS01	10.972	15.076	2.013	2.474	14.232	18.738	15.831	24.397

Table 6.8. Biomass estimates for trawl-caught nekton (pelagic and demersal fishes and squids) during winter and summer, 1980.

Station	Mean catch (kg) per tow untransformed		Mean catch (kg) per tow transformed		Estimated (retransformed) mean catch (kg) per tow		Biomass (kg ha^{-1} of swept area)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
IS01	8.519	40.122	1.963	3.251	8.886	47.958	11.279	58.316
IS02	7.181	59.441	1.856	3.090	7.629	93.380	9.216	79.300
IS03	68.529	80.289	4.054	3.549	76.718	114.478	100.050	125.288
MS01	28.893	33.767	2.444	3.125	53.570	54.257	37.566	43.264
MS02	161.724	49.209	4.788	3.590	165.672	54.662	184.489	71.471
MS03	81.304	52.432	3.663	3.280	98.455	56.399	105.314	83.953
OS01	63.926	16.416	3.214	2.516	59.878	20.603	92.240	26.566

and with light phase (Figure 6.15 and 6.16). The most apparent pattern was the increased diversity of collections made at night (Figure 6.15). At every station, night trawls had higher H' diversity values than day trawls. (See Appendices 15 and 16 for diversity values for individual trawl collections.) Between seasons, diversity was higher at inner shelf stations during winter (Figure 6.16). Since species richness varied little seasonally at IS01 and IS03 (Figure 6.17), increased diversity at these stations in winter is due to the lack of dominance of the community by a few species (Figure 6.18). Species richness at IS02 was actually much greater in summer, but the dominance of the community by S. aculeatus and H. aurolineatum (Table 6.3) resulted in a lower H' diversity. Diversity at middle shelf stations was equal to or lower than inner shelf stations. Diversity at MS02 was especially low, in spite of high species richness. Large numbers of S. aculeatus dominated at that station (Figure 6.19) during both winter (Table 6.2) and summer (Table 6.3). Unlike inner shelf stations, diversity at middle shelf stations was higher during summer when the two most abundant species were not as dominant (Figure 6.19), and species richness increased (Figure 6.17). Station OS01 had the highest diversity of any station during both seasons. Although species richness was comparable to other stations with low H' diversity (e.g. MS02), very abundant dominant species were absent from OS01.

Dominance diversity curves for inner shelf stations indicated dominance of the community by one or two species and the increased value of the dominance index in summer (Figure 6.18). Middle shelf stations in summer demonstrated a lower abundance of the most abundant species and/or the increased abundances of other species (Figure 6.19). These trends were associated with a decreased dominance index and a concomitant increased H' diversity. Diversity was higher at OS01 in summer, even though the dominance index (Figure 6.19) indicated increased community dominance in summer. Abundances of all species were low at OS01, however, and dominance index values were also low relative to other stations.

In general, dominance diversity curves indicated that inner and middle shelf live bottom fish communities were dominated by a few abundant species. Several species of intermediate abundance were also present. An obvious feature was the large number of rare species, many of which were represented by a single specimen.

Cluster analysis - Normal cluster analysis demonstrated the importance of light phase in determining the community composition of trawl collections (Figures 6.20 and 6.21). The broad grouping of collections by light phase resulted in no clear grouping of collections with respect to depth or latitudinal zones, and most groups contained collections from more than one station, especially in winter. Grouping of stations by light phase was more pronounced in summer. At that time, collections were grouped primarily by time period (day versus night), but were also more clearly grouped by depth zone within each light phase.

Because normal cluster analysis resulted in grouping of collections from different stations, and because of the interest in describing faunal affinities of species groups with regard to our selected study areas, site groups as defined by normal analysis were not used in normal-inverse comparisons by nodal analysis. Instead, species groups as defined by inverse analysis were compared to each station. Fidelity and constancy comparisons were made between species groups and each station; and between species groups and day

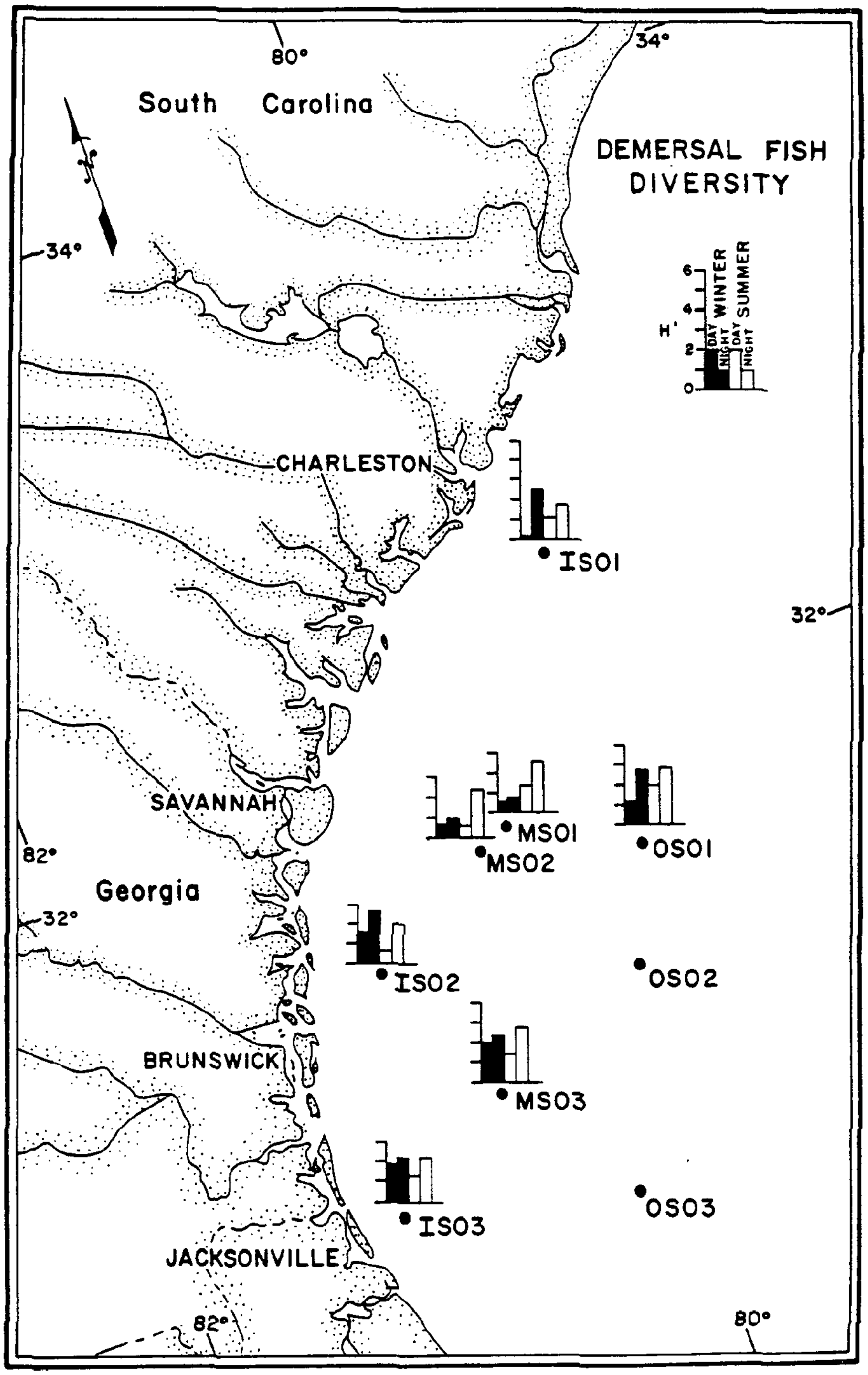


Figure 6.15. Shannon diversity (H') for pooled replicate samples,of demersal fishes at each station, by light phase and season.

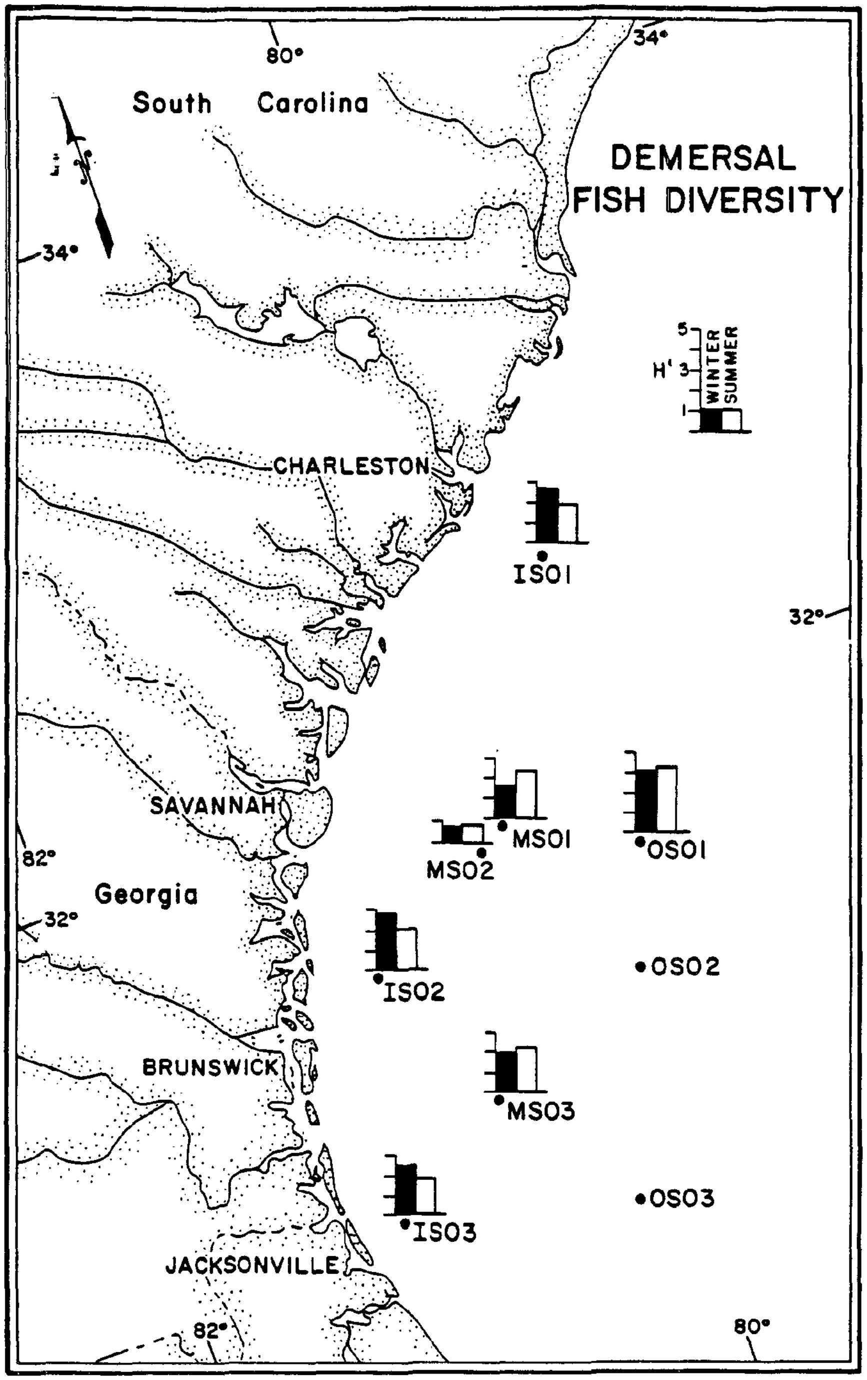


Figure 6.16. Shannon diversity (H') for pooled replicate samples of demersal fishes at each station during winter and summer, 1980.

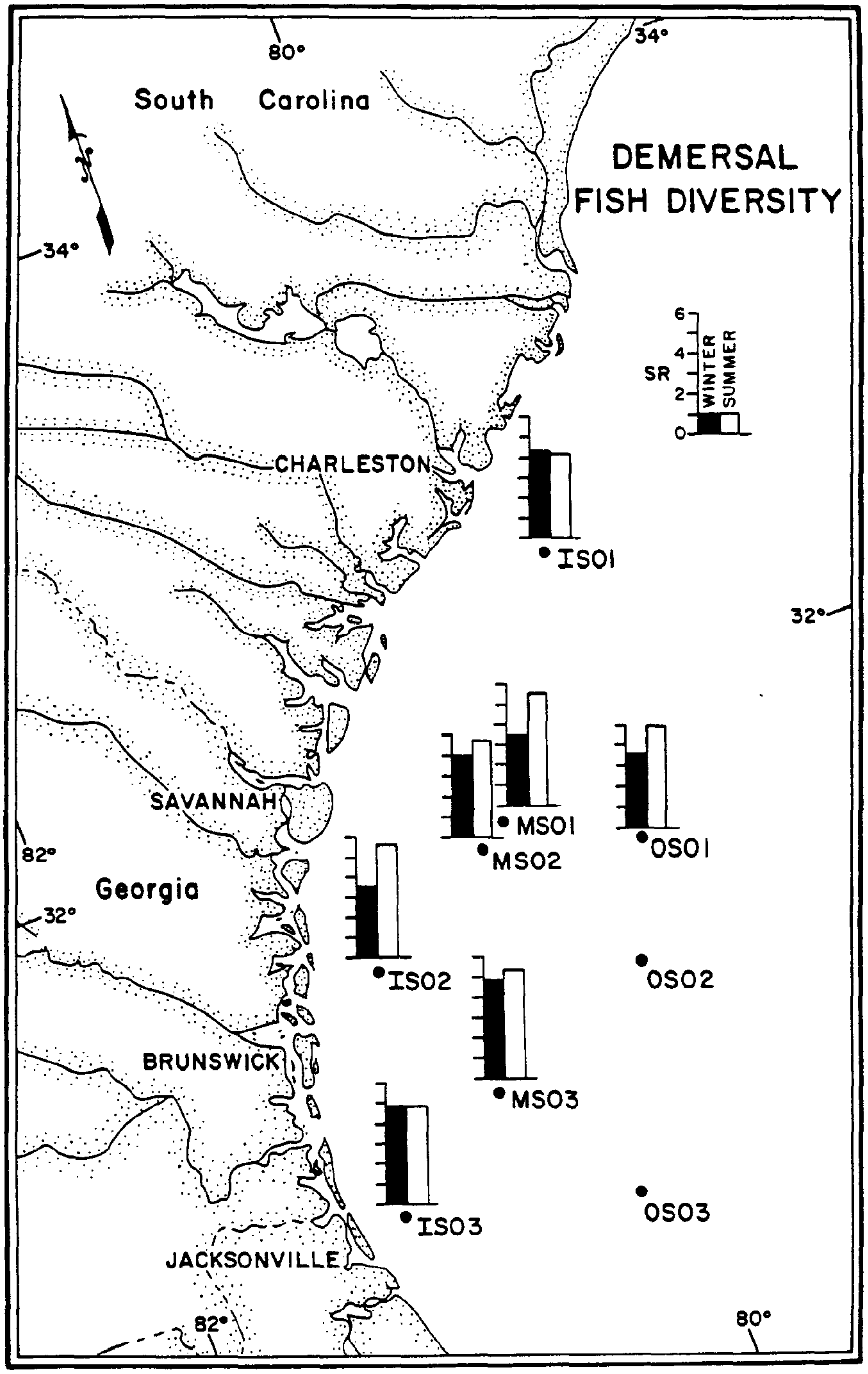


Figure 6.17. Species richness (SR) for pooled replicate samples of demersal fishes at each station during winter and summer, 1980.

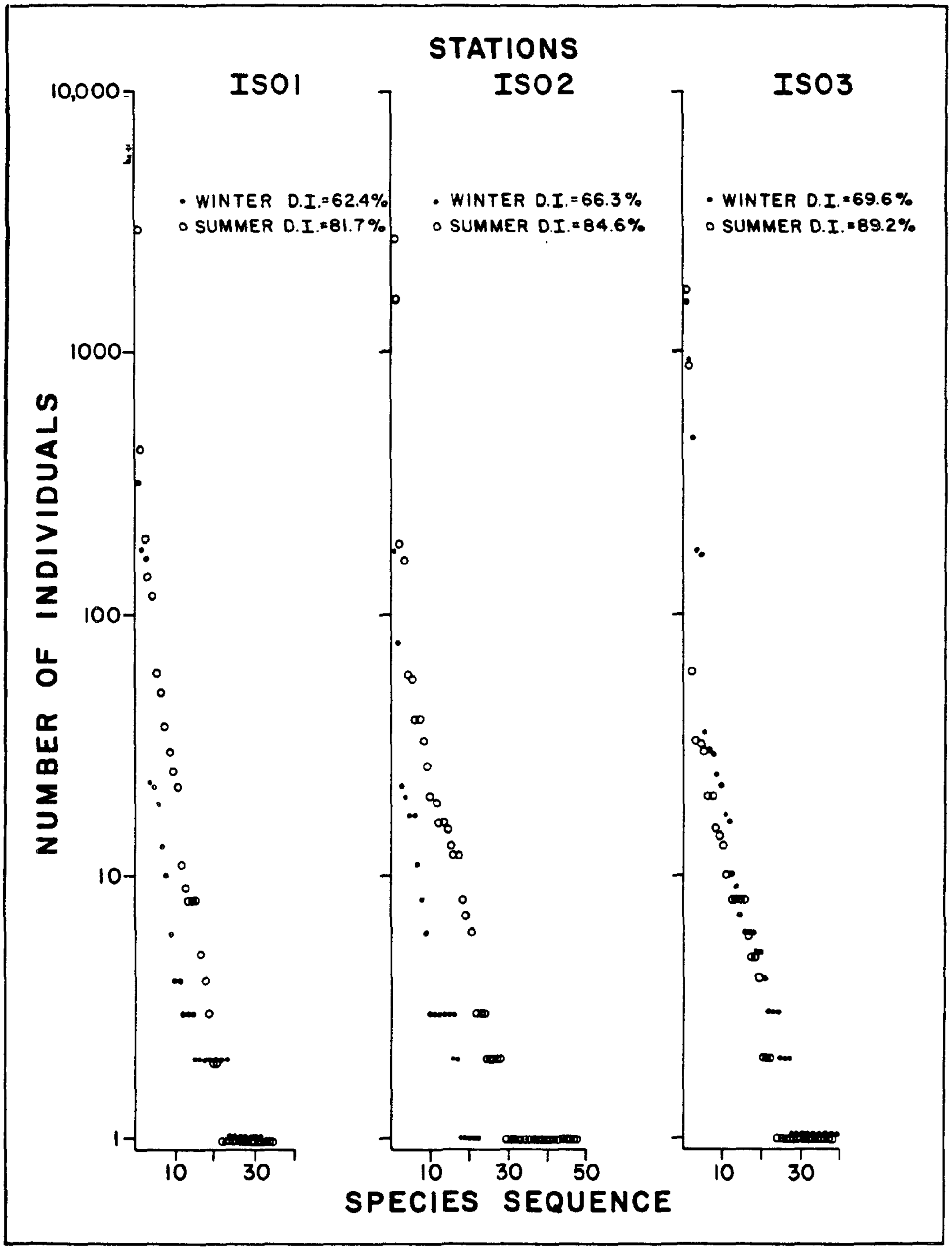


Figure 6.18. Dominance diversity curves and dominance index (D.I.) values for demersal fishes collected at inner shelf stations during 1980 sampling.

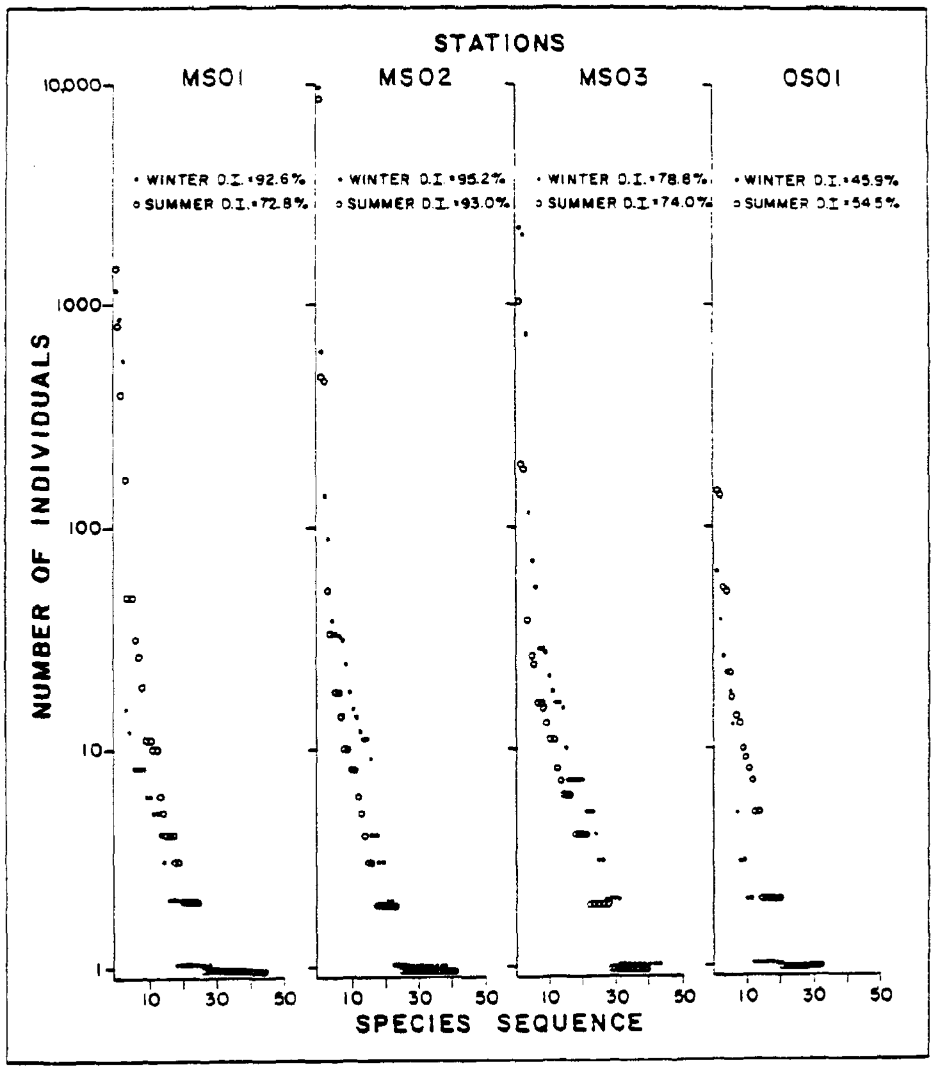


Figure 6.19. Dominance diversity curves and dominance index (D.I.) values for demersal fishes collected at middle and outer shelf stations during 1980 sampling.

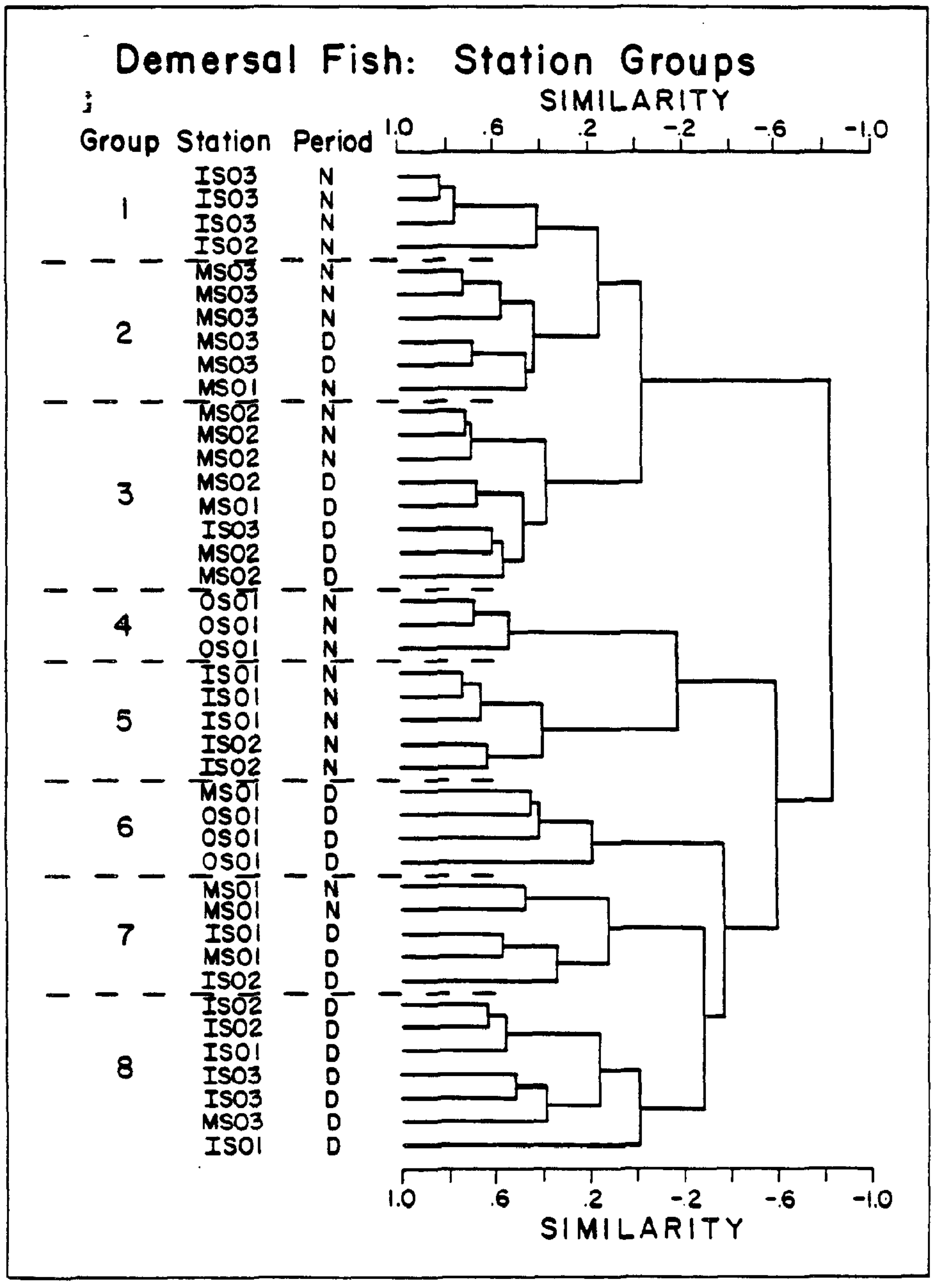


Figure 6.20. Normal cluster dendrogram of winter trawl collections of demersal fishes. D = day trawls and N = night trawls.

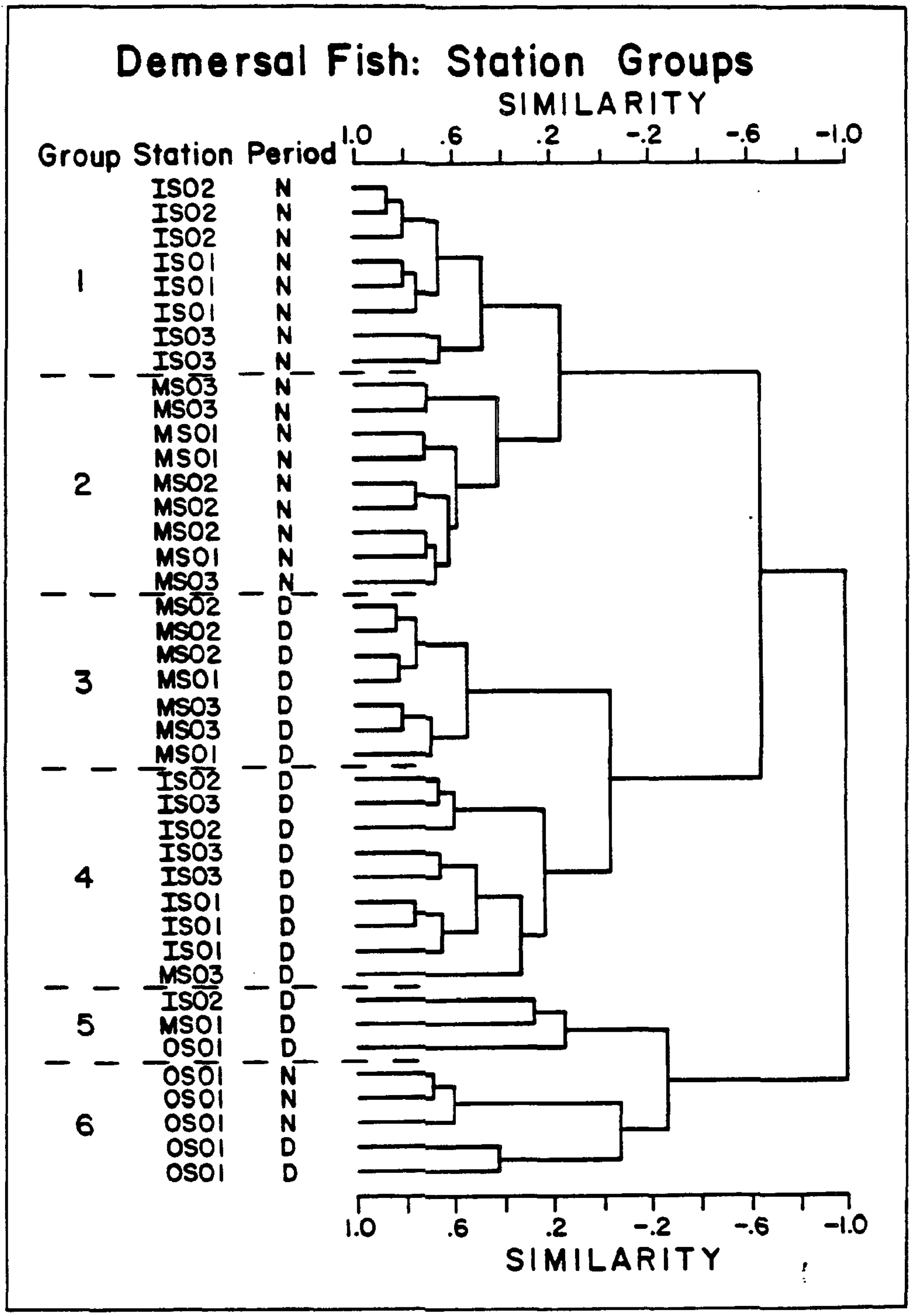


Figure 6.21. Normal cluster dendrogram of summer trawl collections of demersal fishes. D = day trawls and N = night trawls.

and night collections at each station, because normal analysis indicated distinct differences in day and night trawl collections.

Winter inverse and nodal analysis indicated that several species frequently co-occurred within a particular depth zone or during a particular light phase. Species groups B, H, and I (Figure 6.22) were more faithful to inner shelf stations (Figure 6.23). These species were rare and common live bottom (C. ocellatus, A. probatocephalus, C. striata, E. umbrosus), coastal, or open shelf species (Prionotus spp., Urophycis sp., O. chrysoptera) which frequently occur inshore [habitat information from Struhsaker (1969)].

Several species groups (Groups C-E) demonstrated moderate to high constancy and fidelity to middle shelf stations in winter. These groups comprised common to abundant live bottom species (E. lanceolatus, H. aurolineatum, S. aculeatus), including priority species of commercial importance (L. campechanus, P. pagrus, R. aurorubens). Other species which were ubiquitous across the shelf (Groups G and J) were more frequent (higher in constancy) at middle shelf stations.

Only species Group F demonstrated much faithfulness to OS01 in winter. It was composed of deep-living sand bottom species.

Several species were more frequent in night trawls (Groups A, G, H) in winter (Figure 6.24). These groups consisted of both live bottom and open shelf species.

In summer, some species groups (Groups A-C) were high in constancy at inner shelf stations, while several groups (Groups G-J) rarely occurred at those depths (Figures 6.25 and 6.26). Three groups (Groups E-G) demonstrated more than low fidelity to inner shelf stations, and, as in winter, these groups consisted of inshore live bottom and open shelf species.

Two species groups were faithful to middle shelf depths (Groups H and J) in summer. These groups included two priority species, L. campechanus and M. microlepis. As in winter, several species (Group C), including the priority species R. aurorubens, that were ubiquitous across the shelf were more frequent at middle shelf depths.

Species Group D was highly faithful to OS01 in summer. This group included species which were taken only at OS01 [Equetus (= Pareques) sp. nov., C. sedentarius] or which were more abundant at that station (P. pagrus, Echiodon sp. nov., P. salmonicolor). Pagrus pagrus, a priority species, was more frequent at OS01 in summer but more frequent on the middle shelf in winter.

Several species forming Groups A, B, F, and G were more frequently caught in night trawls in summer (Figure 6.27). These groups included species which were also more frequent in night trawls in winter (e.g. O. holbrooki, Scorpaena spp.), as well as species which were only abundant during summer and were more abundant at night (e.g. A. pseudomaculatus, P. plectrodon).

Several species co-occurred in the same depth zone in both winter and summer, whereas other species apparently moved inshore or offshore. Thus, L. rhomboides and O. chrysoptera co-occurred in the same species group which was faithful to inner shelf stations in both winter and summer. The priority species L. campechanus co-occurred in the same group with H. bermudensis in both winter and summer, and these species were most frequent at middle shelf stations during both seasons. Many species were ubiquitous across the shelf (e.g. R. aurorubens, H. aurolineatum) but were more abundant on the middle

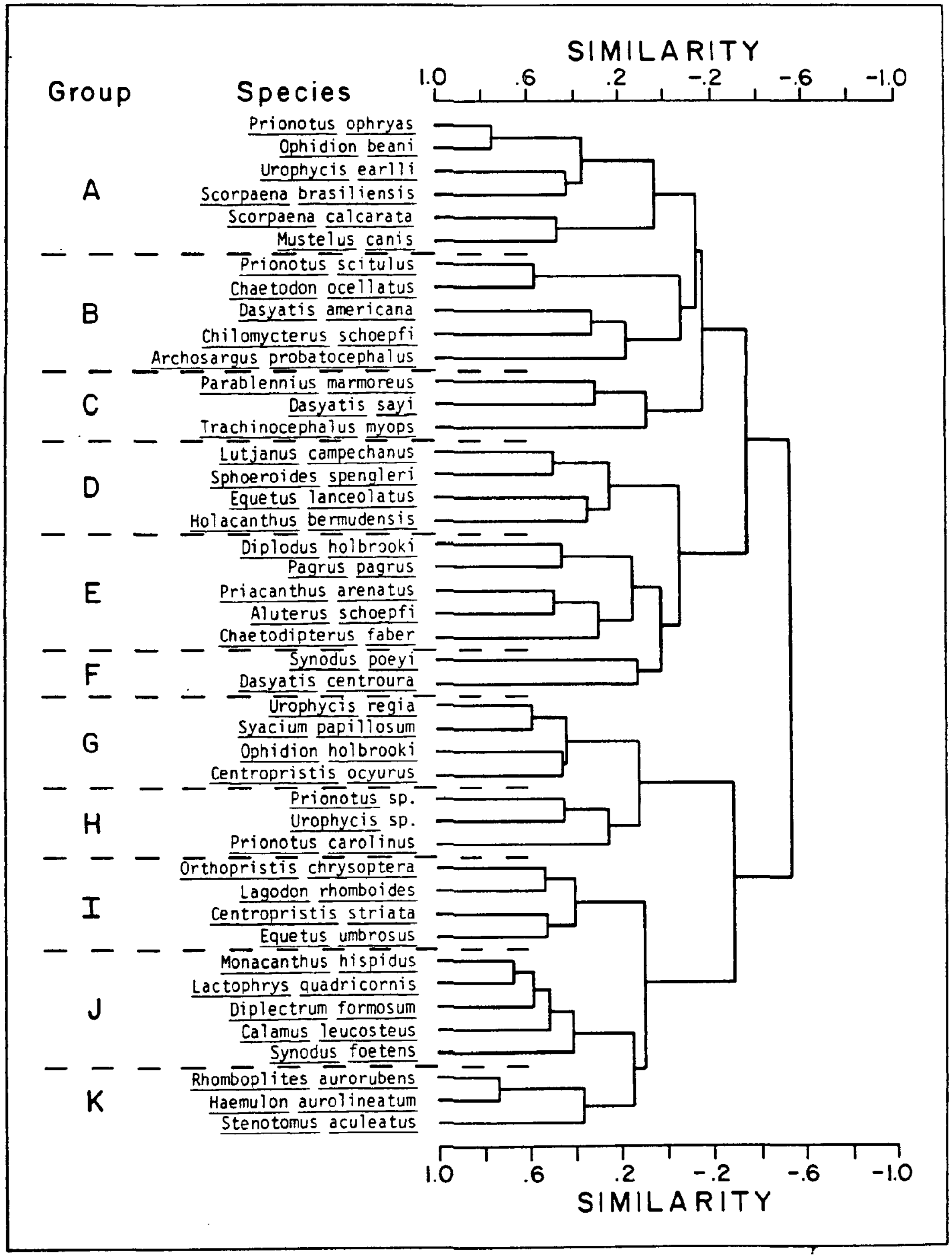


Figure 6.22. Inverse cluster dendrogram of winter trawl collections of demersal fishes.

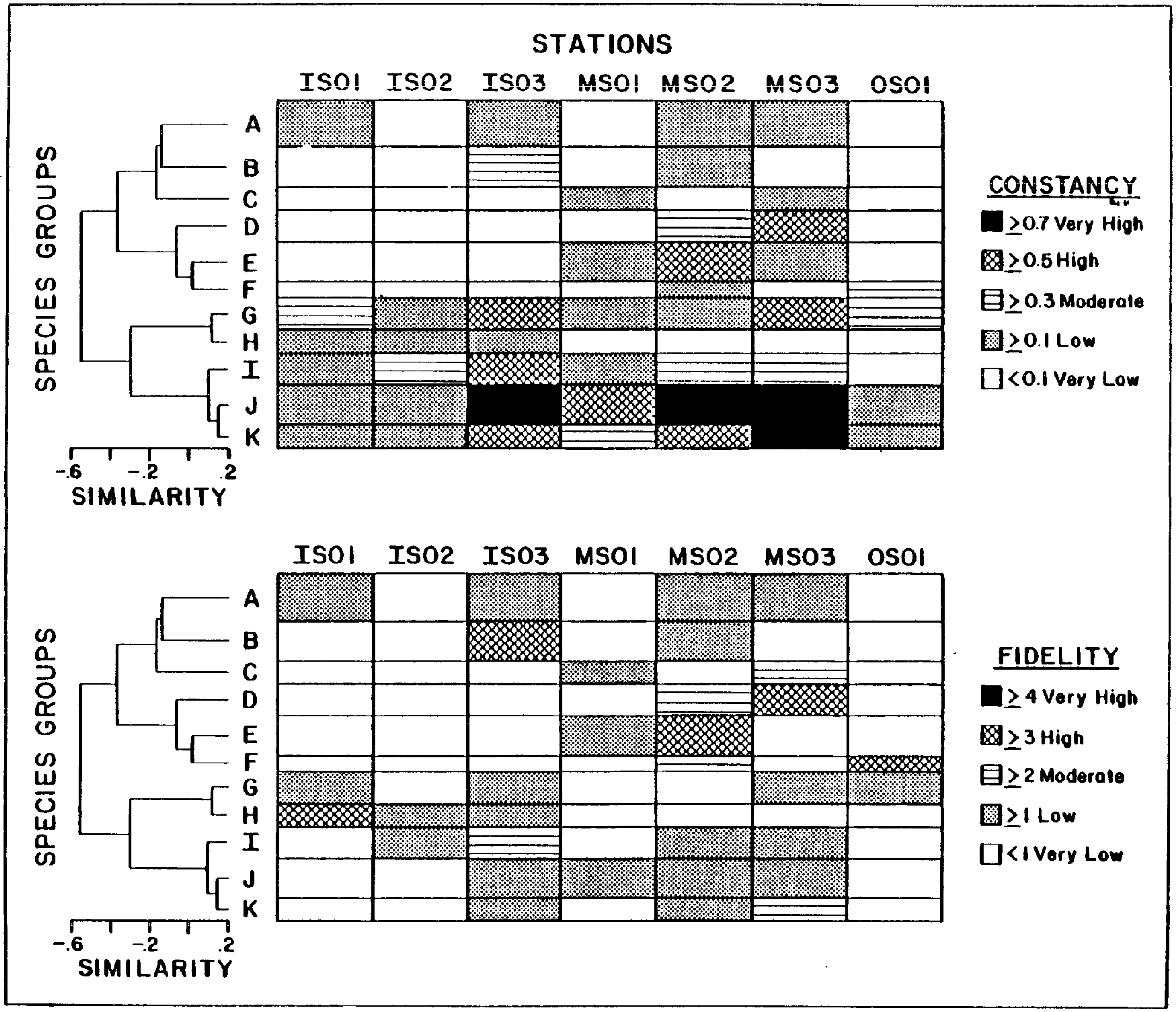


Figure 6.23. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on winter collections of demersal fishes.

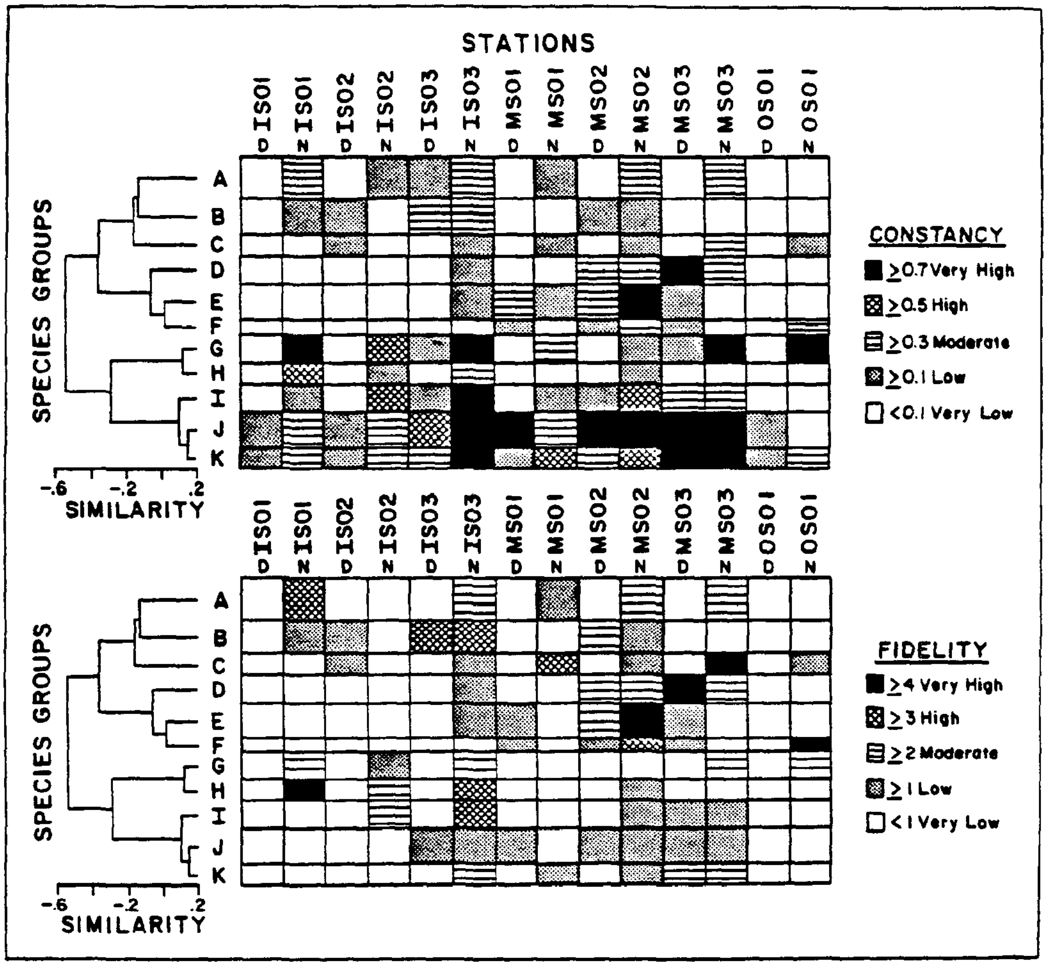


Figure 6.24. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on winter collection of demersal fishes. Stations are separated into day and night collections.

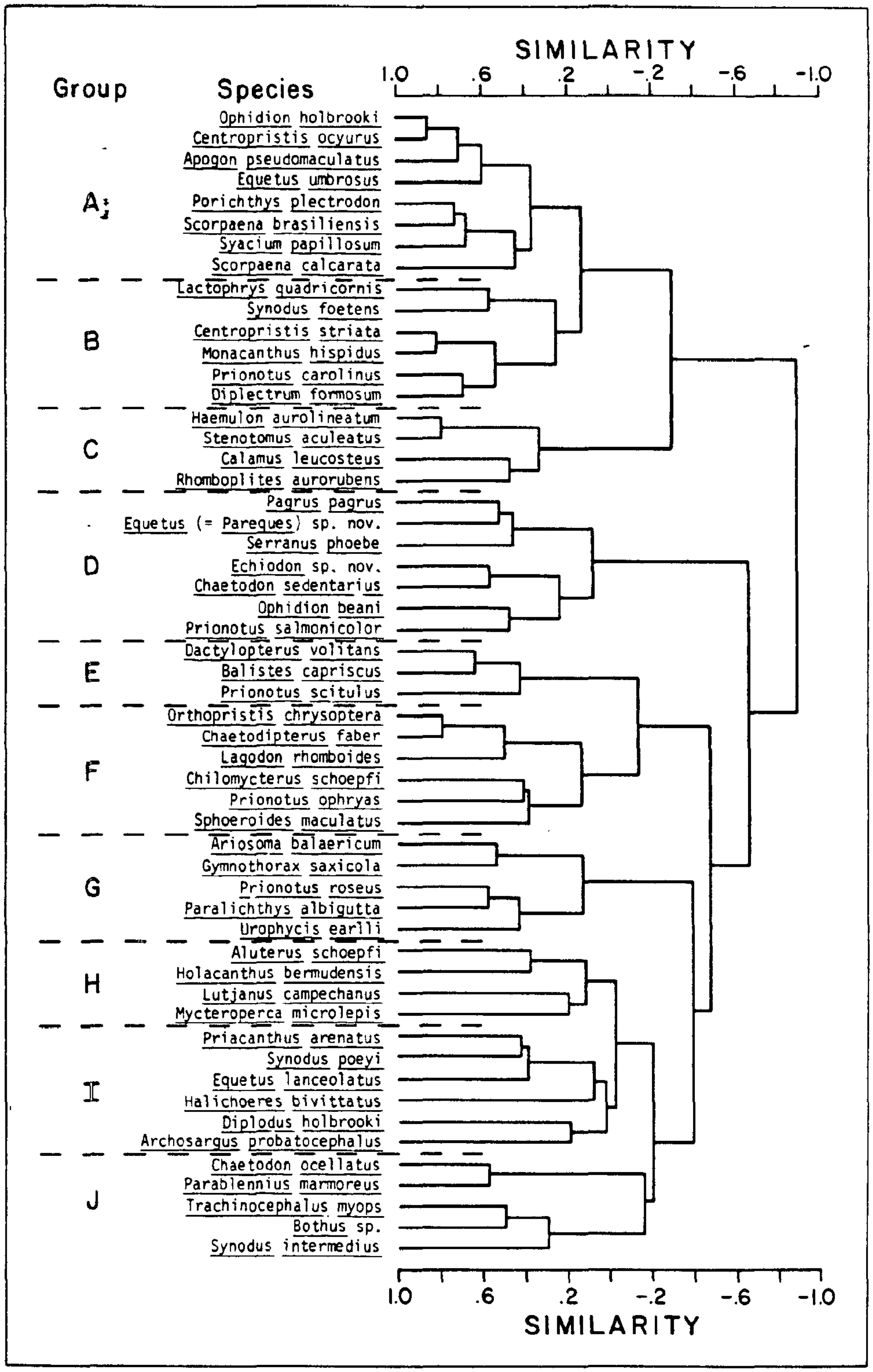


Figure 6.25. Inverse cluster dendrogram of summer trawl collections of demersal fishes.

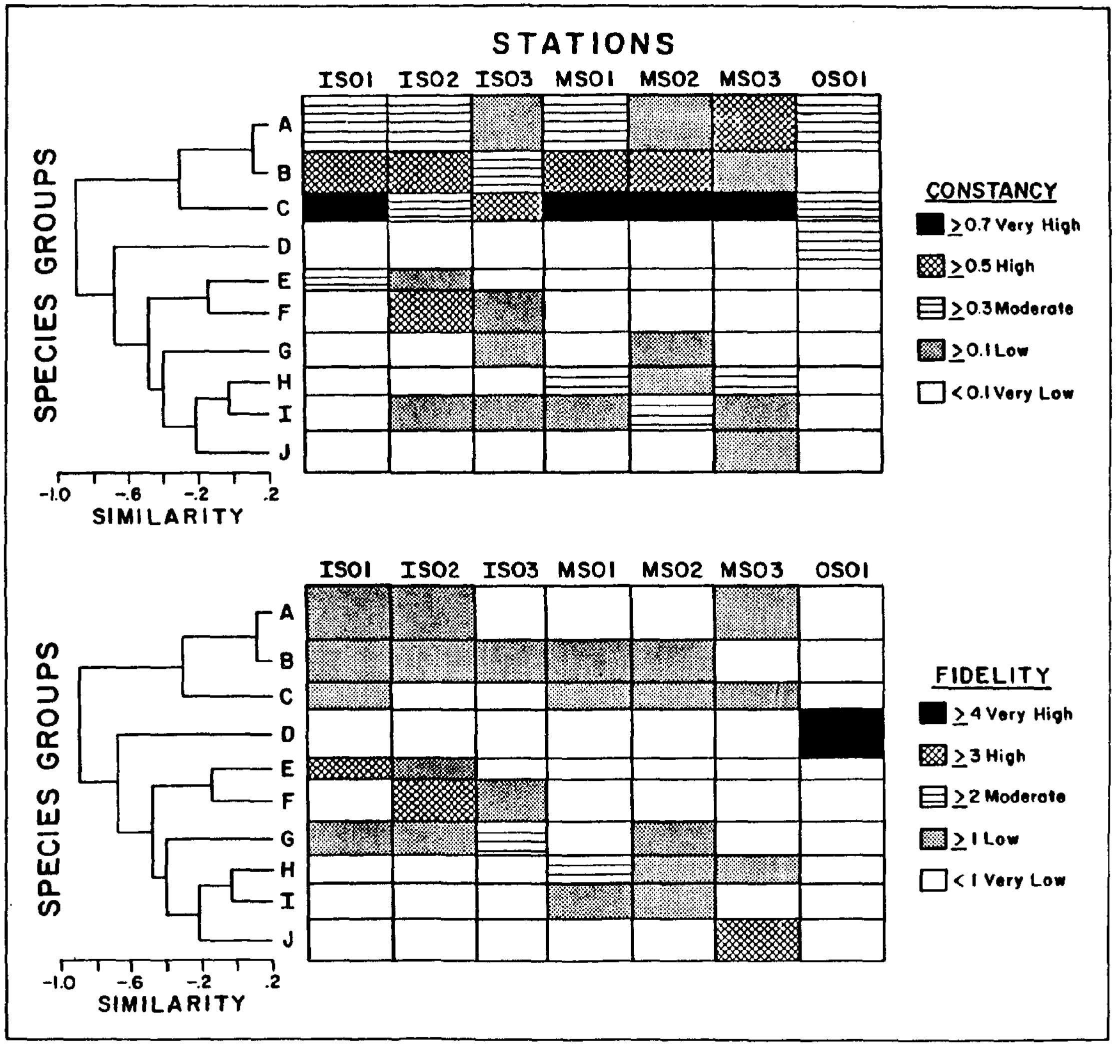


Figure 6.26. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on summer collections of demersal fishes.

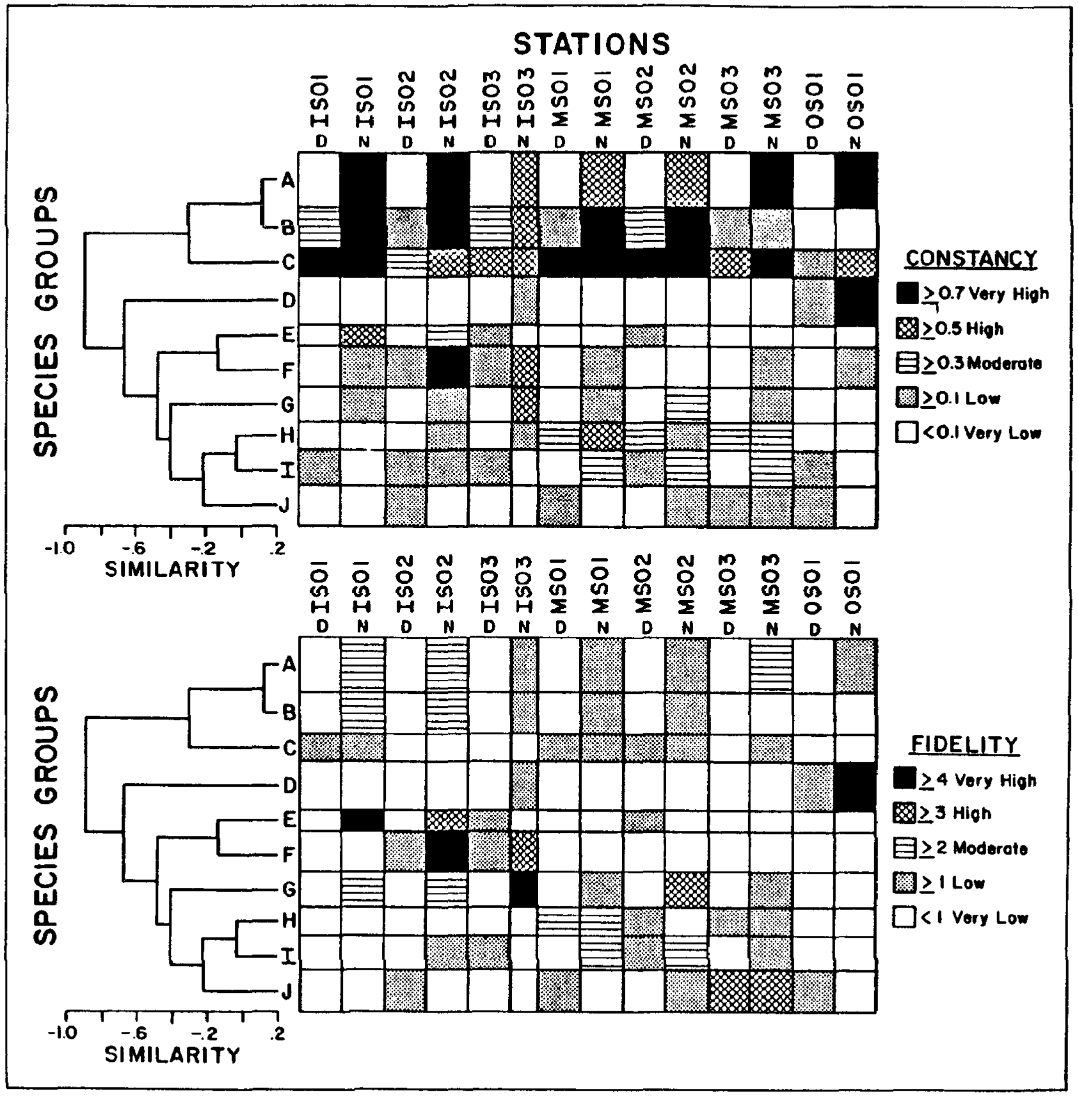


Figure 6.27. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on summer collections of demersal fishes. -Stations are separated into day and night collections.

shelf and demonstrated higher constancy at middle shelf stations during both seasons. The associations and fidelity patterns of some species varied seasonally, perhaps due to migratory movement. Pagrus pagrus, for example, was most faithful to MS02 in winter but was included in a group which was highly faithful to OS01 in summer.

Fishes Observed or Collected by Other Gear:

Underwater Television - Approximately 40 species of fish could be identified on the videotapes (Tables 6.9 and 6.10). With the exception of Sphyraena barracuda and Mycteroperca phenax, which were frequently observed by divers, all species were caught by other removal gears, and most were taken by trawl. Underwater television estimates of abundance were generally higher than trawl estimates (Table 6.11).

Videotape analysis showed differences in fish abundance among the three depth zones. Tomtate (Haemulon aurolineatum) was the most abundant species seen and was most abundant at middle shelf stations, especially MS01. Black sea bass (Centropristis striata) were also commonly observed in all three depth zones and were most abundant on the middle shelf. Red snapper (Lutjanus campechanus) were occasionally seen in all three depth zones, and gag (Mycteroperca microlepis), red porgy (Pagrus pagrus), and greater amberjack (Seriola dumerili) were commonly observed at middle and outer shelf stations.

Underwater television was particularly useful for assessing species composition and abundance at those outer shelf stations which could not be trawled. Based on videotapes, the outer shelf is dominated by yellowtail reeffish (Chromis enchrysurus), red porgy (P. pagrus), blackbar drum [Equetus (= Pareques) sp. nov.], gag (Mycteroperca microlepis), and other large groupers (Mycteroperca spp., Serranidae).

With the exception of MS03, OS01, and OS03, fish density (numbers of individuals per hectare of transect) was lower at all stations in winter. In winter, few fish were recorded on videotape at inner shelf stations, particularly IS01. Density varied widely from station to station at middle shelf depths and was lowest at MS02 and highest at MS03. Stations OS01 and OS02 had similar fish densities, but OS03, a very high relief station, had higher fish densities which were comparable to MS01.

In summer, underwater television transects indicated higher fish density, as compared to winter observations, at all inner shelf stations. Density again varied widely from station to station on the middle shelf and, in contrast to winter television transects, was highest at MS01 and lowest at MS03. Density of fishes at OS01 was similar to winter observations, but many more fish were observed in summer than in winter at OS02, whereas fewer fish were seen at OS03 in summer.

Diver Photographs and Swimming Transects - Results from analysis of the hand held camera photographs were of limited value due to poor visibility in many photographs and limited bottom time on some dives, but the photographs do provide some useful comparison data.

Photographic fish counts indicated increased fish abundance in summer (Table 6.12) as was noted also in trawl collections and television transects at comparable stations, particularly IS01. No Centropristis striata were

Table 6.9. Abundance of fishes counted at each station on videotape transects during winter, 1980.

Species	Station								
	IS01	IS02	IS03	MS01	MS02	MS03	OS01	OS02	OS03
Aluterus spp.	-	1	-	3	-	-	-	1	-
Anguilliformes	-	-	-	-	1	-	-	-	-
Archosargus probatocephalus	1	36	2	-	-	-	1	1	-
Balistes capriscus	-	-	-	-	-	-	1	1	2
Balistidae	-	-	-	2	-	-	-	-	-
Calamus leucosteus?	-	-	-	-	2	-	-	-	-
Centropristis ocyurus	-	-	-	1	-	1	-	9	-
Centropristis ocyurus?	-	-	-	-	-	-	3	-	2
Centropristis spp.	-	-	-	-	-	-	-	-	3
Centropristis sp.?	-	-	-	-	-	-	-	-	3
Centropristis striata	22	32	-	99	1	8	5	8	-
Chaetodon spp.	-	-	-	-	-	-	-	7	-
Chromis enchrysurus	-	-	-	2	-	-	-	3	125
Dasyatis sabina	-	-	-	-	-	-	-	1	-
Dasyatis sp.	-	-	-	-	-	-	1	1	-
Decapterus punctatus?	-	-	9	-	-	-	33	-	-
Diplectrum formosum	-	-	-	-	5	-	-	-	-
Diplectrum formosum?	-	-	-	1	1	-	-	-	1
Diplodus holbrooki	-	-	-	3	1	-	2	-	-
Equetus lanceolatus	-	-	-	-	2	-	-	-	-
Equetus spp.	-	-	-	-	-	-	-	29	-
Equetus (= *Pareques*) sp. nov.	-	-	-	-	-	-	1	2	4
Equetus (= *Pareques*) sp. nov.?	-	-	-	-	-	-	3	-	-
Equetus umbrosus	-	-	-	61	-	-	-	-	-
Fistularia tabacaria	-	-	-	-	-	-	-	-	2
Haemulon aurolineatum	-	-	-	800	-	-	-	-	-
Haemulon plumieri	-	-	-	1	-	-	-	-	-
Holacanthus bermudensis	-	-	-	5	-	5	-	2	8
Lactophrys quadricornis	-	-	-	-	1	-	-	-	-
Lutjanus campechanus	-	-	1	-	-	-	-	-	-
Lutjanus campechanus?	-	-	-	-	-	-	-	-	1
Muraenidae	-	-	-	-	1	-	-	-	-
Mycteroperca microlepis	-	-	-	12	-	-	-	7	4
Mycteroperca microlepis?	-	-	-	-	-	-	-	-	1
Mycteroperca sp.?	-	-	-	-	-	-	-	1	-
Pagrus pagrus	-	-	-	24	-	3	3	3	46
Pagrus pagrus?	-	-	-	-	1	1	-	2	-
Priacanthus spp.	-	-	-	-	-	-	9	1	-
Prionotus sp.	-	-	-	1	-	-	-	-	-
Rhomboplites aurorubens	-	-	-	-	-	-	-	1	-
Rhomboplites aurorubens?	-	-	-	-	-	2000	4	36	675
Scorpaena spp.	-	-	1	-	-	-	-	-	-
Seriola dumerili	-	-	-	-	5	1	-	2	3
Serranidae (Grouper)	-	-	-	10	-	-	1	2	25

Table 6.9 (Continued)

Species	Station								
	ISO1	ISO2	ISO3	MSO1	MSO2	MSO3	OSO1	OSO2	OSO3
Serranidae?	-	-	-	-	-	-	-	2	-
Sparidae	-	-	-	-	11	-	2	5	-
<u>Stenotomus aculeatus</u>	-	-	14	-	4	-	-	-	-
<u>*Stenotomus aculeatus*?</u>	-	-	15	-	-	-	-	-	-
Unknown demersal	12	20	40	42	61	42	107	497	2874
Total	35	89	82	1067	97	2061	175	624	3779
Total number of transects:	3	4	3	6	4	3	4	6	6
Total hrs. of analyzed videotape:	0.97	0.81	0.95	0.74	0.63	0.70	0.76	1.24	1.91
Total length of transects (m):	3012	2637	2833	1733	2070	2157	1838	5244	5991
Number of fish per transect	11.7	22.3	27.3	177.8	24.2	687.0	43.8	104.0	629.8
Number of fish per hr of videotape	36.1	110.1	86.1	1444.1	153.2	2956.0	230.5	503.7	1983.1
Number of fish per 100 m of transect	1.2	3.4	2.9	61.6	4.7	95.6	9.5	11.9	63.1
Number of fish per ha of transect	34.2	99.3	85.1	1810.9	137.8	2810.3	280.0	350.0	1855.2

Table 6.10. Abundance of fishes counted at each station on videotape transects during summer, 1980.

Species	Station								
	IS01	IS02	IS03	MS01	MS02	MS03	OS01	OS02	OS03
Anguilliformes	1	-	2	-	-	-	-	3	1
Archosargus probatocephalus	-	4	7	-	-	-	-	-	-
Bothidae	-	-	-	-	-	1	-	-	-
Calamus leucosteus	-	-	-	-	1	-	-	-	-
Calamus leucosteus?	2	-	-	4	-	-	-	-	-
Carangidae	2	-	-	-	-	-	-	-	-
Carcharhinus sp.	-	-	-	-	1	-	-	-	-
Centropristis ocyurus	-	-	-	-	-	-	-	1	6
Centropristis striata	8	7	18	75	27	16	1	10	2
Chaetodipterus faber	-	28	-	-	-	-	-	-	-
Chaetodon ocellatus	-	-	-	-	-	1	-	-	-
Chaetodon sedentarius	-	-	-	-	-	-	-	-	1
Chaetodon spp.	-	-	-	4	-	2	3	21	5
Chromis enchrysurus	-	-	-	10	2	-	23	103	57
Dasyatis centroura	-	-	-	-	1	-	-	2	-
Dasyatis sp.	1	-	-	-	-	-	-	-	-
Echeneidae	-	-	-	-	1	-	-	-	-
Equetus lanceolatus	-	-	-	-	-	1	-	-	-
Equetus (= Pareques) sp. nov.	-	-	-	-	-	-	-	4	2
Equetus umbrosus	-	-	-	-	25	-	-	-	-
Gymnothorax sp.	-	-	-	-	1	-	-	-	-
Haemulon aurolineatum	-	139	36	8295	4177	8	-	18	1
Halichoeres sp.	-	-	-	1	-	-	-	-	-
Holacanthus bermudensis	-	-	-	12	4	1	1	2	7
Lutjanus campechanus	-	-	-	-	2	-	1	1	-
Lutjanus campechanus?	-	-	-	-	-	1	-	-	-
Muraenidae	-	-	-	-	-	-	-	-	1
Mycteroperca microlepis	-	-	-	16	8	-	2	6	3
Mycteroperca microlepis?	-	-	-	-	-	-	-	2	-
Mycteroperca sp.	-	-	-	-	-	-	1	-	-
Pagrus pagrus	-	-	-	1	4	2	3	18	1
Priacanthidae	-	-	-	3	-	-	1	10	1
Priacanthidae?	-	-	-	-	-	1	-	-	-
Prionotus spp.	2	-	-	-	-	-	-	-	-
Prionotus sp.?	-	-	-	-	-	-	-	1	-
Scomberomorus spp.	2	-	-	-	-	-	-	-	-
Seriola dumerili	-	-	-	40	185	2	-	3	1
Serranidae (Grouper)	-	-	-	-	-	-	-	52	1
Serranus phoebe	-	-	-	-	-	-	-	1	1
Sphoeroides spengleri?	-	-	-	-	-	1	-	-	-
Sphyraena barracuda	-	34	-	-	-	-	-	-	-
Sphyraena barracuda?	-	-	-	-	-	-	1	-	-
Stenotomus aculeatus	64	-	15	5	78	1	-	-	-

Table 6.10 (Continued)

Species	Station								
	IS01	IS02	IS03	MS01	MS02	MS03	OS01	OS02	OS03
<u>Stenotomus aculeatus?</u>	-	-	2	-	-	-	-	-	-
<u>Synodus</u> spp.	1	-	1	-	1	4	-	-	-
Unknown demersal	2050	387	454	3793	176	228	132	1537	232
Total	2133	599	536	12259	4696	270	169	1777	323
Total number of transects:	3	3	3	3	3	4	3	6	6
Total hrs. of analyzed videotape:	0.89	0.97	0.99	1.02	1.01	1.02	1.01	1.92	2.00
Total length of transects (m):	2978	2400	2533	2164	2278	2472	2032	5580	5112
Number of fish per transect:	683.3	199.7	178.7	4086.3	1565.3	67.5	56.3	296.2	53.8
Number of fish per hr of videotape:	2299.1	619.7	537.5	11960.0	4670.0	263.4	166.7	923.1	161.3
Number of fish per 100 m of transect:	68.8	25.0	21.2	566.6	206.1	10.9	8.3	31.8	6.3
Number of fish per ha of transect:	2106.6	734.1	622.4	16661.7	6063.1	321.2	244.6	936.6	185.8

Table 6.11. Abundance estimates (number of individuals ha^{-1}) of selected species, based on television and trawl analysis.

Species	Inner Shelf				Middle Shelf				Outer Shelf			
	Winter		Summer		Winter		Summer		Winter		Summer	
	TV	Trawl	TV	Trawl	TV	Trawl	TV	Trawl	TV	Trawl	TV	Trawl
Archosargus probatocephalus	13.52	0.98	4.09	0.85	0.00	0.90	0.00	0.16	1.60	0.00	0.00	0.00
Centropristis striata	18.72	5.48	12.27	35.08	53.30	3.24	50.20	3.74	20.80	0.00	18.82	0.00
Holacanthus bermudensis	0.00	0.00	0.00	0.00	4.93	0.76	7.23	1.51	16.00	0.00	14.47	0.27
Lutjanus campechanus	0.35	0.00	0.00	0.17	0.00	1.65	0.85	0.48	0.00	0.00	2.89	0.27
Mycteroperca microlepis	0.00	0.00	0.00	0.00	5.92	0.07	10.21	0.24	17.60	0.24	15.92	0.00
Seriola dumerili	0.00	0.00	0.00	0.17	2.96	0.00	96.56	0.08	8.00	0.48	5.79	0.27

Table 6.12. Abundance of fishes seen in photographs taken by divers using the still camera during winter and summer, 1980.

Species	IS01		IS02		IS03		MS01		MS02		MS03	
	w	s	w	s	w	s	w	s	w	s	w	s
<u>Archosargus</u> <u>probatocephalus</u>			16			1						2
<u>Centropristis</u> spp.												2
<u>Centropristis</u> <u>striata</u>		109	79			4	1		20	13		
<u>Decapterus</u> <u>punctatus</u>		22										
Engraulidae												1105
<u>Haemulon</u> <u>aurolineatum</u>		34				210						
<u>Haemulon</u> <u>plumieri</u>										1		2
<u>Halichoeres</u> spp.										16		
<u>Holacanthus</u> <u>bermudensis</u>									2	1		13
<u>Lutjanus</u> <u>campechanus</u>												7
<u>Mycteroperca</u> <u>microlepis</u>						1			5			8
<u>Mycteroperca</u> <u>phenax</u>												20
<u>Mycteroperca</u> spp.						1		12		1		7
<u>Pagrus</u> <u>pagrus</u>						3				15		31
<u>Pomacentrus</u> <u>leucostictus</u>												27
<u>Seriola</u> <u>dumerili</u>							1					
Sparidae		4	19						8			1
<u>Stenotomus</u> spp.		20										
Unidentified		14	27			30	2	34	2	7		
Total	0	203	141	-	-	250	4	46	37	54	*	1225
Number of stops	9	9	8	-	-	7	3	3	8	7	*	9
Number of fish per stops	0.0	22.6	17.6	-	-	35.7	1.3	15.3	4.6	7.7	*	136.1

- = photographs unreadable
* = no photographs taken

photographed and few were captured by trawl at IS01 in winter. In summer, however, C. striata was abundant in diver photographs and in trawl collections. Archosargus probatocephalus were commonly seen in photographs at IS02 in winter and were also commonly seen in videotapes at that time, but few were captured by trawl. Also noteworthy was the abundance of groupers (Mycteroperca spp.). Few of these large groupers were captured by any fishing gear, but they were commonly seen in photographs and on videotapes, especially at middle shelf stations.

Because transect length and visibility varied, results of the diver swimming transects are not quantitative, but are useful for making qualitative comparisons with other gears. The most noticeable differences in the fish community as seen by divers were the number of large predatory fishes observed (Table 6.13). Divers observed more large groupers (Mycteroperca spp.) than were captured or observed on videotapes or photographs. Particularly surprising was the number of M. phenax seen at MS01 and MS03 in summer. This species was not captured by any fishing gear. Lutjanus campechanus was also commonly seen at MS03, even though few were captured there by removal gears. Archosargus probatocephalus was abundant at IS02, but few were captured by trawl.

Baited Fishing Gear - Fifteen species of fishes were captured on the vertical longlines. Centropristis striata was the most abundant and frequently collected species (Table 6.14), and was taken at every station except OS01 and OS03. This species dominated collections at the inner shelf stations. Pagrus pagrus, another priority species, was only taken at middle and outer shelf stations, a distribution pattern also noted in trawl catches. One L. campechanus and two R. aurorubens were taken at outer shelf stations.

Longline catches were generally low and averaged 1.1 fish per hour of fishing time. Longlines did not catch many large predatory fishes they were deployed to catch, and all species collected were also captured by trawl.

Snapper reels were more selective than longlines, and only eight species of fish were taken with this gear (Table 6.15). Centropristis striata and Pagrus pagrus were the most abundant species caught. Centropristis striata was most abundant at inner and middle shelf stations, and P. pagrus and C. ocyurus were most abundant at middle and outer shelf stations, a pattern reflected in collections by other gears.

Snapper reels caught more fish per hour of effort than did vertical longlines. Average catch per hour of fishing was 4.2 fish. Snapper reels caught priority species (C. striata, P. pagrus, R. aurorubens) which were also commonly taken in trawls. They were, however, effective in catching P. pagrus at outer shelf stations which could not be trawled. Snapper reels did not catch any large predatory priority species.

Antillean S-traps caught 10 species of fish, three of which were priority species (Table 6.16). As with other baited gear, C. striata and P. pagrus were the dominant species caught, with C. striata dominating catches at inner and middle shelf stations, and P. pagrus dominating catches at middle and outer shelf stations. Dominant and priority species captured were also taken by trawl; however, the traps caught many specimens of priority species at outer shelf stations which could not be trawled. In addition, one specimen of Corniger spinosus, a rare species not taken by other gears, was captured in an Antillean S-trap. Antillean S-traps were the most efficient baited gear deployed, with an average catch of 5.5 fish per hour.

Table 6.13. Abundance of fishes seen by divers along swimming transects during winter and summer, 1980.

Species	IS01 w	IS01 s	IS02 w	IS02 s	IS03 w	IS03 s	MS01 w	MS01 s	MS02 w	MS02 s	MS03 w	MS03 s
Acanthurus chirurgus	-	-	-	-	-	-	-	-	-	-	-	1
Aetobatus narinari	-	-	-	-	-	1	-	-	-	-	-	-
Aluterus schoepfi	-	-	-	-	-	-	-	3	-	-	-	12
Apogon pseudomaculatus	-	-	-	15	-	1	-	-	-	-	-	15
Archosargus probatocephalus	-	3	56	25	-	20	1	6	-	-	-	8
Balistidae	-	-	-	-	-	-	-	-	1	12	-	-
Blenniidae	1	-	-	-	-	-	-	-	-	3	-	15
Calamus spp.	-	2	5	30	-	200	-	-	-	10	-	-
Caranx ruber	-	-	-	-	-	-	-	-	-	-	-	60
Centropristis philadelphicus	-	-	-	-	-	-	1	-	-	-	-	-
Centropristis spp.	-	2	-	-	-	-	-	1	-	-	12	4
Centropristis striata	2	130	325	100	25	30	12	30	150	86	10	-
Chaetodipterus faber	-	-	-	35	-	-	-	25	-	-	-	-
Chaetodon ocellatus	-	-	-	-	-	-	-	-	-	1	-	5
Chaetodon sp.	-	-	-	-	-	-	-	-	1	-	-	-
Chromis sp.	-	-	-	-	-	-	1	-	-	-	-	-
Chromis cyaneus	-	-	-	-	-	-	-	-	-	-	-	1
Decapterus spp.	-	30	-	-	-	10	-	-	-	-	-	-
Diplectrum formosum	-	-	-	4	-	-	-	-	-	-	-	-
Diplodus holbrooki	-	-	1	2	-	-	-	-	-	-	-	-
Engraulidae	-	-	-	-	-	-	-	-	-	-	-	999
Equetus lanceolatus	-	-	1	-	-	-	-	-	-	-	-	-
Equetus punctatus	-	-	-	4	-	5	-	-	-	-	-	-
Equetus umbrosus	-	-	3	100	-	100	8	-	-	50	-	44
Gymnothorax spp.	-	1	-	-	-	1	-	-	-	-	-	-
Haemulon aurolineatum	-	100	-	150	-	200	-	-	-	100	-	-
Haemulon plumieri	-	-	-	-	-	-	-	-	-	1	-	3
Halichoeres bivittatus	-	-	-	5	-	-	-	-	-	-	-	-
Holacanthus bermudensis	-	-	1	3	-	10	15	6	1	2	-	24
Labridae	-	-	-	25	-	-	-	-	-	-	-	31
Lutjanus campechanus	-	-	-	-	-	-	-	1	-	9	1	63
Mycteroperca microlepis	-	-	4	8	-	5	1	6	20	20	-	20
Mycteroperca phenax	-	-	-	2	-	-	7	26	-	-	-	34
Opsanus spp.	2	-	-	-	-	-	-	-	-	-	-	-
Opsanus tau	-	2	-	3	-	30	-	-	-	2	-	-
Pagrus pagrus	-	-	137	-	-	-	25	6	20	60	3	52
Pomacentrus leucostictus	-	1	-	-	-	1	-	12	-	24	-	75
Pomacentrus variabilis	-	-	-	-	-	-	-	1	-	1	-	-
Pristigenys alta	-	-	-	-	-	-	-	-	-	1	-	-
Remora remora	-	-	-	-	-	2	-	-	-	-	-	-
Rypticus maculatus	-	-	-	-	-	2	-	-	-	-	-	-
Scomberomorus cavalla	-	-	-	-	-	-	-	-	-	2	-	-
Seriola dumerili	-	-	-	1	-	-	20	6	-	30	-	1
Serranus subligarius	-	1	-	30	-	5	-	-	-	-	-	3
Sphyraena barracuda	-	-	-	20	-	1	-	6	-	-	-	-
Stenotomus spp.	-	100	-	15	-	-	-	25	-	-	-	-
Synodontidae	-	-	-	-	-	-	-	-	-	-	1	-
Synodus foetens	-	1	-	-	-	-	-	-	-	-	-	-
Urophycis spp.	-	-	-	-	-	15	-	-	-	-	-	-
Total	5	372	533	577	25	639	91	160	193	414	27	1470
Transect duration (min)	20	16	18	28	17	20	17	14	20	23	15	16
Number of fish observed per min	0.2	23.3	29.6	20.6	1.5	32.0	5.4	11.4	9.6	18.0	1.8	91.8

Table 6.14. Abundance of fish species caught on vertical longlines during winter and summer, 1980. n = number of lines which caught fish and N = number of lines deployed.

	Station																	
	IS01		IS02		IS03		MS01		MS02		MS03		OS01		OS02		OS03	
Species	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s
Calamus leucosteus													1					
Centropristis ocyurus											2		1	1				
Centropristis striata	6	4	7	3	8	5	3	4	11	7	2					2		
Diplectrum formosum					1													
Haemulon aurolineatum							1											
Haemulon plumieri										1								
Lutjanus campechanus														1				
Mustelus canis	7						3		1									
Ophichthus ocellatus			1									1						
Opsanus pardus											1							
Pagrus pagrus									5		3	1	1	3		5	1	
Paralichthys albigutta		1																
Rhizoprionodon terraenovae		2		1						1						1		
Rhomboplites aurorubens															1		1	
Seriola dumerili													1			1		
n/N	8/8	5/8	4/8	4/8	6/8	4/8	6/8	3/8	6/8	5/8	5/8	2/8	3/8	4/8	1/6	4/8	2/8	0/2
Total number of fish	13	7	8	4	9	5	7	4	17	9	8	2	4	5	1	9	2	0
Catch per line (n)	1.7	1.4	2.0	1.0	1.5	1.3	1.2	1.3	2.8	1.8	1.6	1.0	1.3	1.3	1	2.2	1	0.0
Total soak time (hrs) of n lines	10.6	7.4	5.3	6.1	6.6	4.0	9.7	3.3	8.1	5.9	7.3	2.2	5.7	4.8	1.4	5.0	3.0	0.0
Catch per hr of n lines	1.2	1.0	1.5	0.7	1.4	1.3	0.7	1.2	2.1	1.5	1.1	0.9	0.7	1.0	0.7	1.8	0.7	0.0

Table 6.15. Abundance of fish species caught on snapper reels during winter and summer, 1980. n = number of reels which caught fish and N = number of reels fished.

	Station																	
	IS01		IS02		IS03		MS01		MS02		MS03		OS01		OS02		OS03	
Species	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s
Centropristis ocyurus							1	3			2	4		2			7	
Centropristis striata		8	12	4	1	7	3	2	4	8	9	1			1			
Diplectrum formosum											1	1						
Haemulon aurolineatum								1										
Opsanus pardus															1			
Pagrus pagrus										2	3	2	1		2		12	
Rhizoprionodon terraenovae													1					
Rhomboplites aurorubens																	1	
n/N	0/6	5/6	3/6	3/6	1/6	5/6	3/6	3/6	2/6	5/6	6/6	4/6	2/6	2/6	3/6	0/6	4/6	0/3
Total number of fish	0	8	12	4	1	7	4	6	4	10	15	8	2	2	4	0	20	0
Catch per reel (n)	0.0	1.6	4.0	1.3	1.0	1.4	1.3	2.0	2.0	2.0	2.5	2.0	1.0	1.0	1.3	0.0	5.0	0.0
Total soak time (hrs) of n reels	0.0	1.4	2.0	0.8	0.2	1.2	2.6	0.8	1.0	1.2	4.0	1.0	1.4	0.6	1.3	0.0	2.6	0.0
Catch per hr of n reels	0.0	5.8	6.0	5.0	4.0	6.1	1.5	8.0	4.0	8.0	3.8	8.0	1.5	3.5	3.2	0.0	7.7	0.0

Table 6.16. Abundance of fish species caught in Antillean S-traps during winter and summer, 1980. n = number of traps which caught fish and N = number of traps deployed and recovered.

	Station																	
	IS01		IS02		IS03		MS01		MS02		MS03		OS01		OS02		OS03	
Species	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s	w	s
Centropristis ocyurus					1		2				20	5	1		9	2	8	17
Centropristis striata	2	22		2	12	4	16		27	1	48	17			2	3		
Corniger spinosus																1		
Diplectrum formosum					1													
Epinephelus drummondhayi																1		
Haemulon aurolineatum		3				1		8				2						
Opsanus sp.											1							
Pagrus pagrus								1	6		30	6	1	3	18	1	52	10
Rhomboplites aurorubens															1		2	
Stenotomus aculeatus							1		3		2							
n/N	2/4	4/4	0/4	1/4	3/4	2/4	4/4	3/4	2/4	1/4	4/4	4/4	2/4	1/4	3/4	2/4	3/4	1/1
Total number of fish	2	25	0	2	14	5	19	9	36	1	101	30	2	3	30	8	62	27
Catch per trap (n)	1.0	6.2	0.0	2.0	4.7	2.5	4.8	3.0	18.0	1.0	25.2	7.5	1.0	3.0	10.0	4.0	20.7	27.0
Total soak time (hrs) of n traps	2.1	4.0	0.0	0.8	3.1	1.4	7.0	2.6	4.1	0.8	4.8	3.5	2.5	1.6	5.4	2.0	3.5	5.1
Catch per hr of n traps	1.0	6.2	0.0	2.5	4.5	3.6	2.7	3.4	8.7	1.2	21.2	8.6	0.8	1.9	5.5	3.9	17.6	5.3

Rectangular Antillean traps were less efficient than S-traps. Average catch was 3.5 fish per hour (Table 6.17). Centropristis striata was the dominant species collected and was most abundant at inner shelf stations. Other priority species captured were L. campechanus and P. pagrus. These species were also captured by trawl at those stations.

Assessment of Larval and Juvenile Fishes:

A total of 8717 larval and juvenile fishes, representing 119 taxa, were collected in 36 epibenthic sled tows. Of the 119 taxa, 43 represented species, 40 represented genera, 34 represented families, and two represented subfamilies. Seventy percent of the specimens were accounted for by one collection of 5490 specimens of the clupeid Etrumeus teres at OS02, in winter. The other tow taken at this station in winter contained 943 specimens, 779 of which were E. teres. Of the remaining samples, none contained over 160 specimens and only three had more than 100. Twenty-five (69%) of the 36 samples contained fewer than 50 specimens and 10 (28%) had fewer than 15. Only one sample contained no fish (MS01, winter).

Overall taxon composition and abundance by station and season are given in Appendix 17. Abundance is indicated by numbers of individuals per station. Although flow meter readings were recorded for each tow, values showed unreasonable variability, and thus standardized catch figures based on volume of water filtered were not calculated. Since all tows were of five minutes duration on the bottom, catches were assumed to be comparable.

The five most abundant families of larval and juvenile fishes at each station are listed for winter in Table 6.18 and for summer in Table 6.19. Striking seasonal differences in family composition at each station probably reflect differences in spawning times of various species. Sciaenids (primarily Leiostomus xanthurus and Micropogonias undulatus), for instance, occurred at all stations during winter. This family was among the five most abundant families at every station except OS02 and OS03 and was the most abundant family at all three inshore stations. Spot and croaker are known to be winter spawners and were absent from all summer samples. Other families represented only in winter samples included Sparidae, Gadidae, Scophthalmidae, and Uranoscopidae. Families among the five most abundant at summer stations but which were absent or rare in winter samples include Engraulidae, Carangidae, Labridae, Chaetodontidae, Priacanthidae, Apogonidae, Scombridae, Gempylidae, Batrachoididae, Dactyloscopidae, Callionymidae, Carapidae, Antennariidae, and Cynoglossidae. A few families (Bothidae, Clupeidae, Gobiidae, and Serranidae) ranked among the most abundant at several stations in both winter and summer.

Specimens ranged in size from 2 mm to 78 mm SL (Tables 6.20 and 6.21). Mean minimum and maximum lengths were 9.1 mm and 11.1 mm, respectively. As indicated by the average size and general morphology of the majority of specimens, the epibenthic sled collected primarily larval and postlarval forms. Only a few fully transformed juveniles were taken.

Diversity, as indicated by number of taxa, was considerably higher in summer than in winter at inner and middle shelf stations (Tables 6.22 and 6.23). Mean number of taxa per tow at inner and middle shelf stations during summer was 13 and 15, respectively, versus means of five in both depth zones during winter. Seasonal diversity differences were not observed for outer shelf stations OS01 and OS03 where mean number of taxa per tow was 11 in winter and in summer. The highest diversity in both winter and summer occurred at OS02.

Table 6.17. Abundance of fish species caught in rectangular Antillean traps during summer, 1980. n = number of traps which caught fish, and N = number of traps deployed and recovered.

	Station					
Species	IS01	IS02	IS03	MS01	MS02	MS03
Centropristis ocyurus						3
Centropristis striata	11	6				11
Haemulon aurolineatum	2		1			
Lutjanus campechanus						1
Pagrus pagrus						2
n/N	2/2	2/4	1/2	0/2	0/2	2/2
Total number of fish	13	6	1	0	0	17
Catch per trap (n)	6.5	3.0	1.0	0.0	0.0	8.5
Total soak time(hrs) of n traps	2.3	1.6	0.7	0.0	0.0	1.7
Catch per hr of n traps	5.7	3.8	1.4	0.0	0.0	10.1

Table 6.18. Five most abundant families of larval and juvenile fishes collected by fish sled at each station during winter, 1980.

Station	Family	Total Number	Percent of Total at Station
IS01	1) Sciaenidae	11	36.7
	2) Bothidae	8	26.7
	3) Sparidae	3	10.0
	4) Gadidae	2	6.7
	Triglidae	2	6.7
	Clupeidae	2	6.7
	5) Gobiidae	1	3.3
	Gobiosocidae	1	3.3
IS02	1) Sciaenidae	96	76.2
	2) Bothidae	24	19.1
	3) Gadidae	3	2.4
	4) Gobiidae	2	1.6
	5) Sparidae	1	0.8
IS03	1) Sciaenidae	19	90.5
	2) Gobiidae	1	4.8
MS01	1) Bothidae	1	20.0
	Sciaenidae	1	20.0
	Stromateidae	1	20.0
	Serranidae	1	20.0
	Synodontidae	1	20.0
MS02	1) Bothidae	8	44.5
	2) Sciaenidae	5	27.8
	3) Clupeidae	4	22.2
	4) Synodontidae	1	5.6
MS03	1) Clupeidae	21	38.9
	2) Bothidae	15	27.8
	3) Sciaenidae	6	11.1
	4) Synodontidae	5	9.3
	5) Serranidae	3	5.5

Table 6.18 (Continued)

Station	Family	Total Number	Percent of Total at Station
OS01	1) Clupeidae	87	64.0
	2) Sciaenidae	17	12.5
	3) Bothidae	14	10.3
	4) Gobiidae	5	3.7
	5) Serranidae	4	2.9
OS02	1) Clupeidae	6598	94.5
	2) Bothidae	308	4.2
	3) Stromateidae	75	1.1
	4) Ophidiidae	69	0.9
	5) Serranidae	34	0.5
OS03	1) Clupeidae	54	52.9
	2) Synodontidae	7	6.9
	Stromateidae	7	6.9
	3) Myctophidae	5	5.0
	4) Serranidae	3	3.0
	5) Triglidae	3	2.9

Table 6.19. Five most abundant families of larval and juvenile fishes collected by fish sled at each station during summer, 1980.

Station	Family	Total Number	Percent of Total at Station
IS01	1) Engraulidae	50	51.6
	2) Batrachoididae	12	12.4
	3) Ophidiidae	7	7.2
	4) Dactyloscopidae	5	5.2
	Synodontidae	5	5.2
	5) Gobiidae	4	4.1
	Cynoglossidae	4	4.1
IS02	1) Clupeidae	32	17.2
	2) Batrachoididae	29	15.5
	3) Gobiidae	26	13.9
	4) Engraulidae	18	9.6
	5) Carangidae	14	7.5
IS03	1) Gobiidae	8	17.8
	2) Engraulidae	7	15.6
	3) Serranidae	5	11.1
	4) Callionymidae	4	8.9
	5) Clupeidae	4	8.8
MS01	1) Cynoglossidae	23	29.5
	2) Serranidae	14	18.0
	3) Gobiidae	11	14.1
	4) Callionymidae	8	10.3
	5) Clupeidae	4	5.1
	Carangidae	4	5.1
MS02	1) Bothidae	15	22.1
	2) Ophidiidae	11	16.2
	3) Engraulidae	7	10.3
	4) Labridae	6	8.8
	5) Synodontidae	5	7.4

Table 6.19 (Continued)

Station	Family	Total Number	Percent of Total at Station
MS03	1) Clupeidae	170	59.0
	2) Cynoglossidae	28	9.7
	3) Callionymidae	23	8.0
	4) Bothidae	19	6.8
	5) Carangidae	14	4.8
OS01	1) Bothidae	5	20.0
	2) Apogonidae	4	16.0
	Scombridae	4	16.0
	3) Gobiidae	2	8.0
	Cynoglossidae	2	8.0
	4) Clupeidae	1	4.0
	Labridae	1	4.0
	Stromateidae	1	4.0
	Priacanthidae	1	4.0
	Chaetodontidae	1	4.0
	Gempylidae	1	4.0
	Serranidae	1	4.0
	Carapidae	1	4.0
OS02	1) Myctophidae	7	12.7
	2) Clupeidae	6	10.9
	3) Antennariidae	4	7.3
	4) Carangidae	4	7.2
	5) Bothidae	3	5.4
	Serranidae	3	5.4
	Engraulidae	3	5.4
	Scombridae	3	5.4
OS03	1) Bothidae	22	33.4
	2) Myctophidae	12	18.2
	3) Gobiidae	7	10.6
	4) Engraulidae	4	6.1
	5) Gonostomatidae	4	6.0

Table 6.20. Average ($\bar{x}$) minimum and maximum values and range of standard length (SL) for larval and juvenile fishes collected in winter, 1980.

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Congridae	13.5	13.5	6-21
Ophichthidae	9.0	44.0	6-59
Etrumeus teres	7.3	19.6	4-24
Sardinella aurita	10.0	17.0	10-17
Sardinella spp.	8.0	13.5	7-14
Brevoortia spp.	8.2	12.5	5-13
Synodontidae	7.6	9.7	3-15
Aulopidae	11.0	11.0	11
Myctophidae	4.7	5.7	4-6
Diaphus spp.	6.0	6.5	4-8
Lampadena sp.	4.0	4.0	4
Myctophum spp.	7.0	9.5	6-12
Myctophinae	7.0	8.0	7-8
Gobiesox strumosus	11.0	11.0	11
Bregmacerotidae	7.5	12.5	7-15
Bregmaceros spp.	6.0	29.0	6-29
Urophycis regia	15.0	18.3	4-28
Urophycis spp.	11.3	11.7	3-27
Ophidiidae	12.4	16.0	3-24
Carapidae	30.0	30.0	30
Echiodon spp.	84.0	84.0	84
Syngnathus spp.	21.7	29.7	11-35
Scorpaenidae	5.0	5.0	4-6
Triglidae	4.8	6.0	4-7
Prionotus carolinus	30.0	42.0	30-42
Centropristis ocyurus	8.8	11.4	3-13
Centropristis spp.	4.0	5.0	4-5
Serranus spp.	4.0	5.0	4-5
Diplectrum spp.	7.0	9.0	4-13
Serraninae	6.0	6.7	3-9
Hemanthias spp.	4.7	5.0	4-6
Pomatomus saltatrix	8.0	8.0	8

Table 6.20 (Continued)

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Carangidae	4.0	5.0	4-7
Coryphaena spp.	6.0	6.0	6
Gerreidae	7.0	7.0	5-9
Haemulidae	6.0	6.0	6
Sparidae	6.0	7.2	4-10
Pagrus pagrus	4.0	7.0	4-7
Stenotomus spp.	16.5	16.5	16-17
Leiostomus xanthurus	5.4	8.0	1-13
Micropogonias undulatus	6.2	6.8	4-10
Larimus fasciatus	3.0	3.0	3
Labridae	4.0	11.0	4-11
Scaridae	7.5	10.5	6-11
Uranoscopidae	4.0	4.3	3-6
Callionymidae	5.0	6.0	4-8
Gobiidae	7.4	10.8	4-17
Gobiosoma ginsburgi	18.0	18.0	18
Trichiurus lepturus	10.0	10.0	8-12
Cubiceps pauciradiatus	5.0	8.0	5-8
Psenes spp.	5.0	5.0	5
Peprilus spp.	4.2	5.5	3-7
Ariomma spp.	4.0	4.0	4
Hyperoglyphe spp.	4.0	9.0	4-9
Scophthalmus aquosus	5.2	7.8	3-11
Etropus rimosus	6.2	10.2	4-14
Etropus spp.	4.5	15.2	3-30
Citharichthys arctifrons	15.0	15.0	15
Citharichthys spp.	6.6	11.2	3-14
Cyclopsetta fimbriata	4.5	4.5	3-6
Paralichthys spp.	7.0	8.0	6-10
Bothus spp.	14.7	15.7	11-19
Soleidae	4.0	4.0	4
Symphurus spp.	4.5	7.0	4-10

Table 6.20 (Continued)

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Monacanthus spp.	4.0	4.0	4
Tetraodontidae	2.0	2.0	2
Other fish larvae	3.3	4.0	3-4
Disintegrated fish - unidentifiable	3.0	6.0	3-6

Table 6.21. Average ($\bar{x}$) minimum and maximum values and range of standard length (SL) for larval and juvenile fishes collected in summer, 1980.

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Nessorhamphus spp.	7.0	8.0	7-8
Congridae	6.0	6.0	6
Ophichthidae	44.7	44.7	8-78
Clupeidae	9.0	9.0	9
Sardinella aurita	7.2	11.2	5-19
Engraulidae	7.2	15.2	5-30
Gonostomatidae	10.5	10.5	8-13
Cyclothone spp.	6.0	6.0	6
Maurolicus spp.	5.0	7.0	5-7
Vinciguerria spp.	13.0	13.0	13
Synodontidae	9.0	18.0	5-34
Synodus poeyi	26.0	26.0	26
Myctophidae	5.0	8.5	4-10
Porichthys plectrodon	17.0	22.8	17-26
Antennariidae	3.0	3.0	3
Bregmaceros spp.	4.0	4.0	4
Ophidiidae	11.8	19.4	4-37
Lepophidium spp.	35.7	35.7	26-55
Carapus bermudensis	22.0	22.0	22
Echiodon spp.	73.0	73.0	73
Exocoetidae	13.0	13.0	3-30
Hippocampus erectus	6.0	6.0	6
Scorpaenidae	3.7	4.7	2-6
Triglidae	4.2	5.2	3-8
Prionotus spp.	3.0	6.0	3-6
Serraniculus pumilio	3.0	6.0	3-6
Serranus phoebe	17.0	17.0	17
Serranus spp.	4.0	4.0	4
Diplectrum spp.	7.7	9.4	3-12
Serraninae	3.5	4.5	3-8
Anthias spp.	6.0	6.0	6
Priacanthidae	3.0	3.0	3

Table 6.21 (Continued)

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Apogonidae	12.0	12.0	5-19
Apogon quadrisquamatus	10.0	10.0	10
Apogon aurolineatus	13.5	13.5	13-14
Apogon pseudomaculatus	25.7	30.7	21-35
Pomatomus saltatrix	4.0	4.0	4
Carangidae	3.0	3.7	2-5
Decapterus punctatus	14.5	15.0	3-30
Decapterus spp.	4.0	4.0	4
Selene setapinnis	3.0	3.0	3
Seriola spp.	3.0	3.0	3
Lutjanidae	3.0	3.0	3
Rhomboplites aurorubens	10.0	10.0	8-12
Gerreidae	10.5	10.5	10-11
Haemulidae	5.5	6.0	5-7
Holacanthus spp.	4.0	4.0	4
Chromis enchrysurus	29.0	29.0	29
Labridae	7.4	8.4	5-12
Halichoeres bivittatus	29.0	29.0	29
Scaridae	9.0	9.0	9
Opistognathidae	5.0	5.0	5
Dactyloscopus spp.	10.0	10.0	10
Blenniidae	5.0	5.0	5
Hypleurochilus geminatus	11.4	12.4	6-19
Clinidae	5.0	9.5	5-10
Callionymidae	3.3	5.0	3-9
Gobiidae	7.5	11.6	4-21
Evermannichthys spongicola	12.0	17.0	12-17
Lythrypnus phorellus	11.0	11.0	11
Gempylidae	8.0	8.0	8
Scombridae	5.0	5.0	5
Euthynnus alletteratus	5.4	6.2	4-9
Scomberomorus cavalla	7.0	7.0	7

Table 6.21 (Continued)

Taxa	$\bar{x}$ minimum length (mm SL)	$\bar{x}$ maximum length (mm SL)	Range (mm SL)
Euthynnus pelamis	5.0	5.0	5
Auxis spp.	6.0	6.0	6
Cubiceps pauciradiatus	6.0	6.0	6
Psenes pellucidus	5.0	5.0	5
Ariomma spp.	4.5	4.5	4-5
Etropus crossotus	3.0	5.0	3-5
Etropus spp.	7.6	9.9	3-14
Citharichthys spilopterus	7.0	7.0	7
Citharichthys gymnorhinus	11.0	11.0	11
Citharichthys spp.	7.8	9.7	4-15
Cyclopsetta fimbriata	4.0	4.0	4
Bothus spp.	11.2	13.2	4-20
Syacium spp.	4.2	6.5	3-10
Soleidae	5.0	5.0	5
Symphurus spp.	5.8	10.5	3-17
Monacanthus hispidus	12.0	14.0	6-20
Monacanthus spp.	3.0	3.0	3
Aluterus spp.	9.0	9.0	9
Sphoeroides spp.	3.0	3.0	3
Other fish larvae	3.5	3.5	3-4
Disintegrated fish - unidentifiable	-	-	-

Table 6.22. Number of individuals and number of taxa of larval and juvenile fishes in fish sled collections, winter 1980.

Station	Collection Number	Number Individuals	Number Taxa
IS01	800066	26	9
	800067	4	3
IS02	800142	79	5
	800143	47	8
IS03	800102	14	3
	800103	7	3
MS01	800227	5	5
MS02	800188	5	1
	800189	13	5
MS03	800403	8	4
	800404	46	9
OS01	800315	70	9
	800316	66	11
OS02	800330	943	40
	800331	6373	47
OS03	800382	67	16
	800383	35	8

Table 6.23. Numbers of individuals and number of taxa of larval and juvenile fishes in fish sled collections, summer 1980.

Station	Collection Number	Number Individuals	Number Taxa
IS01	800471	58	14
	800472	39	9
IS02	800511	81	16
	800512	106	19
IS03	800534	23	13
	800535	22	9
MS01	800624	44	12
	800625	34	11
MS02	800557	31	17
	800558	37	14
MS03	800646	157	21
	800647	131	13
OS01	800764	8	6
	800765	17	12
OS02	800726	12	7
	800727	43	25
OS03	800671	31	15
	800672	35	13

Numbers of taxa taken in the two tows at OS02 in winter (40 and 47) were more than twice those taken at any other station in winter or summer.

A major objective of the epibenthic fish sled sampling was to determine how extensively live bottom habitats may be used as nursery grounds by fishes designated as priority species due to their commercial importance. Of the seven priority species, only two (R. aurorubens and P. pagrus) were represented in sled samples and these by only two specimens each (Figure 6.28).

DISCUSSION

Intensive studies directed at live bottom fish assessment have not been published. Published trawl studies have dealt with open shelf sand bottom habitat or on the results of exploratory fishing not specifically directed at live bottom. Species composition, abundance, and distribution patterns of the dominant demersal fishes reported herein are consistent with those reported in the available literature (Struhsaker 1969, Miller and Richards 1979, Wenner et al. 1980). Comparison with open shelf studies shows greater abundance, biomass, and diversity of fishes in live bottom habitats.

The dominant species Stenotomus aculeatus, Haemulon aurolineatum, and Calamus leucosteus are ubiquitous species which are found in a wide range of habitats but which are more abundant on and near live bottom (Struhsaker 1969, Waltz et al. in preparation, Manooch and Barans in preparation). For example, total catch of S. aculeatus in six trawls at MS02, a live bottom area, exceeded total catch in 40 trawls in similar depths and season over the open shelf (Wenner et al. 1980). Calamus leucosteus was also much more abundant than reported from sand bottom trawls. The occurrence of H. aurolineatum over sand bottom (Wenner et al. 1980) may be related to feeding behavior, since many haemulids, including H. aurolineatum, are known to forage at night over sand flats, returning to the reef during the day (Randall 1963, Collette and Talbot 1972, Parrish and Zimmerman 1977).

The most noteworthy difference in abundance of dominant species between the North Carolina live bottom site and those areas trawled off of South Carolina and Georgia, is the differing abundance of vermilion snapper (Rhomboplites aurorubens). This priority species was a dominant species at all three middle shelf stations off South Carolina and Georgia in summer. Trawl collections at those three stations produced a mean of 350 individuals per station. In contrast, only two individuals were caught in the trawl at the middle shelf station off North Carolina. Grimes et al. (1977) noted that vermilion snapper appeared to increase in abundance from northern Onslow Bay, North Carolina south to South Carolina waters.

Biomass estimates from trawl catches indicate that biomass of demersal teleosts and total nekton is much higher on live bottom than on the open shelf. Wenner et al. (1980) reported mean values of 12.372 and 3.070 kg ha^{-1} for total nektonic and demersal teleost biomass, respectively, from 70 trawls over sand bottom in the South Atlantic Bight (9 - 366 m depth in summer). Mean biomass from summer trawls in the present study was 46.580 and 30.974 kg ha^{-1} for total nekton and demersal teleosts, respectively. Biomass estimates from live bottom collections off North Carolina were slightly higher - 58.354 and 35.237 kg ha^{-1}. (See Volume II, Chapter Six.) Powles and Barans (1980) reported fish biomass of 27.3 kg ha^{-1} on live bottom, based on their largest

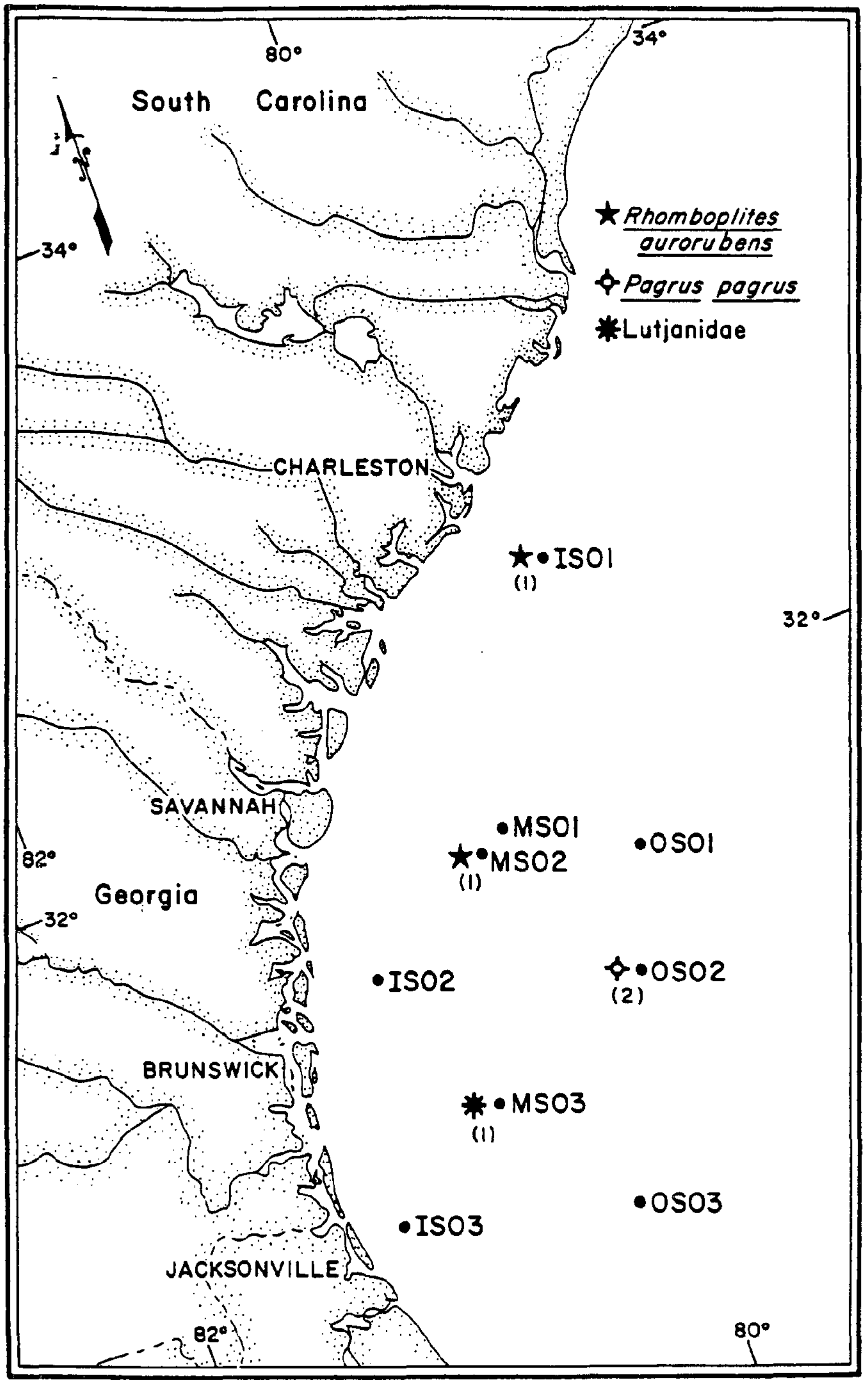


Figure 6.28. Collection locations for larval and juvenile priority fish species captured by fish sled.

trawl catches. Fish biomass estimated from trawl collections on live bottom areas in the South Atlantic Bight is considerably less than the 490 kg ha^{-1} estimated by Bardach (1959) or 446 kg ha^{-1} estimated by Odum and Odum (1955) for tropical reefs in the western Atlantic (Bermuda) and central Pacific, respectively. Biomass on artificial reefs in the tropical western Atlantic has been estimated at 680 kg ha^{-1} in the Florida Keys and 6980 kg ha^{-1} in the Virgin Islands (Stone et al. 1979). The biomass estimates calculated from trawl catches should be considered minimum estimates because vulnerability and availability of the fishes captured are unknown (Edwards 1968). The estimates obtained from natural reefs and artificial reefs in the tropics are from visual counts in clear water, or from poison collections, and this could account for part of the higher biomass estimated by those authors. Bardach (1959) compared his reef fish biomass estimates to estimates from New England and the northeast Atlantic and concluded that higher temperatures and increased surface area provided by reefs accounted for higher biomass. The lower relief, cooler and more variable temperature, and the patchy nature of live bottom areas in the South Atlantic Bight could also account for the lower biomass estimates in the present study, compared to tropical reefs.

The significant differences in biomass between stations in winter were due to the very low biomass of demersal teleosts at IS01 and IS02 and the high biomass at MS02. As inner shelf waters warmed during summer, biomass at IS01 and IS02 increased as fishes apparently moved into these areas from warmer offshore waters, and there was no significant difference between stations in summer.

Middle shelf live bottom areas supported the greatest biomass (kg ha^{-1}) of demersal teleosts. Miller and Richards (1979) noted similar conclusions and attributed the high productivity of these depths to seasonal thermal stability.

Diversity values for demersal fishes were low relative to invertebrate diversity (Chapter 5) due to the lower species richness and the numerical dominance of the community by a few species. Diversity values for the live bottom site off North Carolina (middle shelf) were similar to values at comparable depths off South Carolina and Georgia. Wenner et al. (1980) reported similar ranges of H' for individual trawl collections over sand bottom in the South Atlantic Bight in the same depths, with maximum values being higher at their inner and middle shelf sites but slightly lower at outer shelf sites. Foell and Musick (1979) reported a lower range of diversity values for trawl collections at depths of 39 - 73 m in the Middle Atlantic Bight. The higher diversity of demersal shelf fishes in the South Atlantic Bight (versus the outer shelf north of Cape Hatteras) is due to increased species richness. Whereas Foell and Musick (1979) reported 41 species in 264 trawl collections over four seasons, the 83 collections over two seasons in the present study produced 128 species. Wenner et al. (1980) collected 152 demersal species on the open shelf and slope in summer; however, their stations included a broader latitudinal and depth range in the South Atlantic Bight.

The most noteworthy pattern in diversity at all live bottom sites, including the site off North Carolina, was the increased diversity of collections made at night. Differences in diversity between light phases, depth zones, and between seasons within a depth zone appeared to be related to changes in community dominance or, alternatively, to changes in species richness. Thus, although species richness remained the same or increased at inner shelf stations in summer, H' diversity decreased because of the dominance of the community by one or two species. Community dominance did not increase as much in summer at middle shelf sites, and diversity increased at those depths in summer because of increased species richness. Community dominance was low during both seasons at OS01, and increased species richness during summer resulted in a higher H' diversity. Increased H' diversity values in trawl collections made at night were also related to increased species richness.

Several fish species demonstrated marked diel differences in abundance in trawl catches. Although this could be due to visual net avoidance, there is some evidence for real changes in the live bottom fish community between day and night. All Apogon pseudomaculatus were trawled at night. This is a nocturnal species with well developed vision for feeding at night (Livingston 1971) and could probably visually avoid the trawl during day or night. Members of the genus Apogon are known to hide in crevices during the day and to forage in the water column over and at the edges of reefs at night (Hobson 1965, Livingston 1971, Collette and Talbot 1972, Luckhurst and Luckhurst 1978). This behavior would make them susceptible to capture only at night. Equetus umbrosus was also captured exclusively at night. Although no habitat information is available for this species, closely related Equetus acuminatus and Equetus (= Pareques) viola are known to remain under ledges and in caves during the day, emerging into the open at night (Longley and Hildebrand 1941, Hobson 1965). Equetus umbrosus apparently has a similar behavior pattern and is captured at night when it comes out to feed. Several other species appeared to be nocturnally active and thus vulnerable to the trawl at night (e.g. Group A, Figures 6.24 and 6.27). Space is considered to be the limiting resource on tropical reefs, and diel changes in space utilization by coral reef fishes have been proposed as a mechanism for allowing a diverse community to occupy the same limited habitat (Smith and Tyler 1972, Luckhurst and Luckhurst 1978). Space is probably also a limiting resource on live bottom areas, and diel movements into and out of the reef may be a mechanism for partitioning this resource.

Some species (e.g. P. carolinus and U. regia) generally associated with other habitats such as sand or mud, were abundant in night tows over live bottom. These species may move into reef areas to rest or feed at night. More extensive food habits studies are needed to fully understand these diel abundance patterns.

The results of cluster analysis indicate that the demersal fish fauna of live bottoms on the shelf consists of an inner shelf component, a shelf break component, and a middle shelf component composed of unique species plus species shared with the inner shelf and shelf break. The inner shelf is the most unstable thermally and is characterized by the greatest fluctuation in community composition and overall abundance. Many species found at inner shelf stations were not faithful during both seasons, and dominant species changed dramatically. This was particularly true at the two northernmost inner shelf stations, which had the widest seasonal temperature difference (11°C at IS01 and 16.1°C at IS02). In winter, these stations were characterized by few fishes and by temperate species (e.g. Urophycis regia) which moved offshore to cooler water in summer. In summer, warm temperate and subtropical species invaded these area (e.g. Haemulon aurolineatum, Apogon pseudomaculatus, Monacanthus hispidus), and these two stations were similar in faunal composition to middle shelf stations. Station IS03 had fewer seasonal differences in species composition and abundance. This is probably due to its more southerly position and its lower seasonal temperature difference (9°C).

Miller and Richards (1979) suggested that the middle shelf (18 - 55 m) in the South Atlantic Bight is the most thermally stable zone. They reported subtropical fish species in this zone with a center of distribution and maximum abundance of commercial species at 33 - 40 m. In the present study, fish abundance was also higher at middle shelf sites and did not vary as much between seasons as did inner shelf sites. Nodal analysis indicated a high affinity of dominant subtropical species (e.g. *Lutjanus campechanus*, *Equetus lanceolatus*, *Holacanthus bermudensis*, *Mycteroperca microlepis*) for middle shelf stations. With the exception of *Centropristis striata*, all priority (i.e. commercially important) species were more abundant in trawl catches at middle shelf depths. Most species faithful to middle shelf stations were faithful in both winter and summer. Species that changed fidelity seasonally either moved to or from shallow or deeper water as suggested by Miller and Richards (1979). Thus, *Pagrus pagrus* was in a species group which was highly faithful to MS02 in winter, but belonged to a group highly faithful to OS01 in summer.

Outer shelf hard bottom areas are characterized by unstable temperatures due to cold water intrusions (Miller and Richards 1979). No species in the group faithful to OS01 in winter were included in the group faithful to that station in summer, indicating the thermal instability of that station. The present study indicates four major species assemblages at the outer shelf station: (1) ubiquitous species that range across the shelf (*Rhomboplites aurorubens*, *Calamus leucosteus*), (2) temperate species that move in from deeper water in winter (*Urophycis regia*), (3) subtropical species that invade these depths from shallower water in summer (*Equetus umbrosus*), and (4) species which have their major abundances at these depths year-round [*Equetus* (= *Pareques*) sp. nov., *Serranus phoebe*, *Chaetodon aya*, *Chaetodon sedentarius*]. Miller and Richards (1979) noted similar results.

Species composition of the fish fauna as seen by the television camera differed from that captured by the trawl. One reason for this is the inability to accurately identify many fishes on the television monitor, whereas most fishes captured by trawl were identified to species. Many of the unidentified fishes on videotapes are probably species commonly caught in the trawl (e.g. *S. aculeatus*, *H. aurolineatum*, *R. aurorubens*). In addition, the narrow field of view of the camera (approximately 3.4 m) records fewer of the most abundant species captured by the trawl. Another reason for the faunal difference in trawl collections versus television observations is that many fishes seen on videotapes, particularly large species, may avoid the trawl. Abundance of red snapper, groupers, sheepshead,black sea bass, and greater amberjack was greater, based on videotape analysis, than trawl collections indicated. For example, large amberjacks (*Seriola dumerili*) were rarely taken by trawl at any station, and only one was taken at middle shelf depths in the summer (< 1 individual ha^{-1} of swept area). In contrast, videotape analysis indicated a density of 96.6 individuals ha^{-1} at the same stations. Differences in abundance estimates for these fishes (Table 6.11) between television (and diver observations) and trawl collections are probably due to the ability of these large fishes to avoid the trawl.

Estimates of overall fish abundance also differed between trawl samples, television transects, and diver observations, with no consistent pattern to the differences. Uzmann et al. (1977) and Powles and Barans (1980) reported estimates of fish density obtained from underwater television that were generally higher than those obtained by trawl, and this was generally true in the present study.

Baited fishing gear has only limited utility as a method of assessing fish abundance, but the present data provides useful comparisons with other studies. Vertical longlines deployed in the Virgin Islands caught a maximum of 0.04 fish per hook per minute (Olsen et al. 1974). Maximum catches in the present study were considerably lower, 0.004 fish per hook per minute. Powles and Barans (1980) reported catches in summer of from 3.0 (day) to 20.0 (night) fish hr^{-1} for Antillean S-traps on the South Atlantic Bight middle shelf. In the present study, summer catches at middle shelf stations were lower (1.2 - 8.6 fish hr^{-1}), although comparable catches were made in winter (2.7 - 21.2 fish hr^{-1}). Maximum catches for Antillean S-traps and rectangular Antillean traps were 21.2 and 5.7 fish hr^{-1}, respectively. Antillean S-traps were more effective at catching fish than the rectangular design traps.

The low abundance or absence of priority species in fish sled samples was most likely due to (1) sampling periods not coinciding with known spawning periods of these species, (2) avoidance of the sled by postlarvae and juveniles or (3) the possibility that larvae and juveniles of priority species are not associated with live bottom habitat. For example, no Centropristis larvae which could be positively identified as C. striata were caught by the sled. The absence of C. striata from winter and summer samples is not surprising because C. striata spawns from March to May off the Carolinas (Cupka et al. 1973, Mercer 1978), with a peak in April. Thus, few if any larvae would have been present before completion of the winter sampling in mid-March. Furthermore, Kendall (1972) suggested that C. striata larvae are pelagic until approximately 13 mm. Even specimens spawned in late February would probably not have reached that size and thus would not have been available to the epibenthic sled. Individuals spawned as late as May or June would have grown large enough (at least 30 mm) to easily avoid the sled by early August, when summer sampling began. April - May sampling would be necessary to verify the use of live bottom habitat by young C. striata. However, if Kendall's (1972) estimate of the size at settling is correct, avoidance of the sled even by newly settled individuals is likely.

Only two Pagrus pagrus larvae (4 - 7 mm) were taken in the sled. This is particularly surprising in light of Ranzi's (1969) observation that these larvae occur in the deep plankton until they reach about 10 mm, at which time they apparently migrate to the surface. The small, deep-living individuals may not actually be bottom associated, but water column samplers seem to be no more efficient at capturing Pagrus larvae. Of approximately 100,000 fish larvae collected during two years of seasonal sampling with neuston and bongo nets throughout the South Atlantic Bight (Powles 1977), only 14 specimens were identified as P. pagrus; all were taken with the neuston net at the surface, and the majority were larger than 10 mm.

Ripe females of P. pagrus have been collected off North Carolina from January through April in depths from 21 to 100 m. Peak spawning (based on capture of ripe individuals) was reported to occur from March through April off North Carolina (Manooch 1976) and probably occurs about a month earlier off South Carolina (W. A. Roumillat, pers, comm., S. C. Marine Resources Center, Charleston; 1981). Thus, larvae should have been relatively abundant during at least the latter part of the winter sampling period. In light of the abundance of adult P. pagrus throughout the Bight, the rarity of its larvae remains an enigma. There is no indication from epibenthic sled sampling that larval or postlarval P. pagrus are preferentially associated with live bottom areas.

First year juvenile P. pagrus may inhabit live bottom areas, but this question cannot be answered with the present sampling gear. Ranzi (1969) indicated that settling occurs at lengths above 20 mm, again a size not likely to be sampled by the sled. The largest collection of juvenile P. pagrus taken in seven years of MARMAP trawl sampling off the Southeast United States (44 specimens, 42 - 59 mm SL) was taken in relatively shallow water (9 - 20 m) over flat sand bottom.

Two specimens of vermilion snapper, Rhomboplites aurorubens, were taken in the epibentic sled during the summer sampling period; a 12 mm specimen at IS01 and an 8 mm specimen at MS02. These samples were taken during what is probably a period of peak abundance of R. aurorubens larvae (August - September) (Grimes 1976, LaRoche 1977, Powles 1977). The capture of only two specimens suggests that vermilion snapper larvae and postlarvae are not significantly concentrated near the bottom in live bottom areas. LaRoche (1977) found specimens as large as 14 mm in the water column.

No Lutjanus campechanus larvae were taken in the epibenthic sled, despite the fact that summer samples were taken well within the suspected spawning period and probably near peak activity (Beaumariage and Bulloch 1976, G. D. Johnson, pers. comm., S. C. Marine Resources Center, Charleston, 1981). If young red snapper preferentially inhabit live bottom areas, residence apparently begins above sizes at which avoidance of the sled is possible. Because larvae of this species have only recently been described (Collins et al. 1980) records from previous surveys are nonexistent.

No larval, postlarval, or juvenile groupers (Mycteroperca microlepis, M. phenax, or Epinephelus niveatus) were collected by the epibenthic sled. Gag and scamp, M. microlepis and M. phenax, spawn from January to April with peak spawning off the Carolinas from February to April, and snowy grouper spawn in late summer and early fall (McErlean 1963, Presley 1970, unpubl. MARMAP data, S. C. Marine Resources Center, Charleston, 1979 - 1981). Larval gag remain planktonic and enter estuaries where juveniles spend 6 to 8 months of their first year. Consequently, their absence from sled samples is not surprising. Juvenile scamp and snowy grouper, however, have been collected on live bottom (unpubl. MARMAP data, S. C. Marine Resources Center, Charleston, 1979 - 1981; H. R. Beatty, pers. comm., S. C. Marine Resources Center, Charleston, 1981). Their absence from epibenthic sled samples is most likely a reflection of their large size at settling and their cryptic habits.

Increased larval fish diversity in epibenthic sled collections in summer is clearly attributable to the spring-summer peak in spawning for most fishes in the area. Fahay (1975) noted a similar summer increase in larval fish diversity in surface towed metre net collections.

Hydrographic conditions at OS02 in winter and the exceptionally high diversity of larval fishes there are characteristic of Gulf Stream waters. This increased diversity is attributable to northward transport of larvae from more southern areas where spawning seasons of a more diverse fauna are generally protracted, and to the occurrence of deep water pelagic species such as gonostomatids, myctophids and deep sea eels. The striking influence of Gulf Stream intrusions on taxon composition at OS02 points out the ephemeral nature of the ichthyoplankton community even near the bottom. A significant portion of larvae sampled by the epibenthic sled may be transitory and not directly tied to the live bottom habitat.

IMPACT/ENHANCEMENT

Potential impact to fish populations in live bottom habitats might result from the drilling process and from oil spills. Discharge of drill cuttings and drilling mud, and drilling itself may cause destruction of habitat and smothering mortality of benthic epifauna. Although fishes are highly mobile and may avoid localized areas of disturbance, many reef fishes (e.g., Rhomboplites aurorubens, Lutjanus campechanus, many pomacentrids, chaetodontids, and various groupers) are sedentary in habit and do not move off their home reef (Bardach 1958, Randall 1962, Smith and Tyler 1973, Gladfelter and Gladfelter 1978, Luckhurst and Luckhurst 1978, Fable 1980). Also, many live bottom fishes feed directly on live bottom associated epifauna and would be adversely affected by any resultant lowered food density. (See Chapter 7 for a more detailed discussion.)

Acute effects of oil spills could result in direct physical harm to fishes, such as coating of gill membranes and sensory structures, which could lead to immediate mortality (Heitz et al. 1974, Corner et al. 1976). Fish eggs, larvae, and juveniles are particularly susceptible to the more volatile components of crude oil (Corner et al. 1976, Sharp et al. 1979). Because the early life history stages of many species (e.g., P. pagrus) frequently occur in the upper water column and are often found at the surface, they would be readily exposed to the more toxic, volatile components of a spill.

Sublethal effects due to chronic exposure to oil pollution include increased oxygen consumption (Thomas and Rice 1979), reduced development rates (Sharp et al. 1979), and interference with sensory initiated behavior such as feeding (see Chapter 7) and reproduction (Corner et al. 1976). Oil spills can also reduce the commercial value of a fishery without direct mortality to the fish by imparting unpleasant odors and flavors to fish flesh, thereby making commercial species unsalable (Johannes 1975, Corner et al. 1976).

Petroleum spills and drilling operations may also adversely affect fishes by introducing toxic concentrations of trace metals into the environment. Because trace metals naturally occur in very low concentrations in seawater and carbonate sediments associated with live bottom, introduction of these substances through oil development would expose fishes to much higher concentrations than they are normally accustomed (Johannes 1975, Bryan 1976). These high concentrations of trace metals can be directly lethal to fishes, especially larval stages (Waldichuk 1974), and sublethal effects can also be deleterious. For example, high concentrations of trace metals, such as zinc, damage gill structures in fishes (Waldichuk 1974, Hughes 1976). Sublethal concentrations of mercury and cadmium reduce fecundity of female fishes and fertility of spermatozoa in males (Waldichuk 1974). Additionally, through bioaccumulation and food web magnification, top level predators of commercial importance can become tainted and thus unmarketable.

Another potential disturbance to fish populations is the noise resulting from drilling and production. Noise produced from such activities could frighten fish away from areas where platforms are located; however, there is little evidence to indicate this would happen. Numerous investigators have attempted to scare fish using sounds, but with little success. Generally, the fish are initially startled but rapidly become accustomed to noise, including sounds of very high amplitude (Hawkins 1973).

Higher ambient noise conditions caused by petroleum production can raise the response threshold level to specific sounds to which fishes normally react (Hawkins 1973). Many species of fishes associated with live bottom produce their own species specific sounds (e.g., sciaenids, haemulids, batrachoidids, labrids, scarids). In many families of fishes (e.g., Batrachoididae, Gadidae, Brotulidae, Ophidiidae, Macrouridae, Sciaenidae) the sounds produced and the structures associated with sound production are sexually dimorphic and are used in courtship and reproduction (Hawkins 1973, Fine 1975). Noise caused by oil production activity might inhibit reproduction in those species by raising the threshold level of response to reproductive sounds to a point above the sound producing ability of the fish. Further studies are needed to determine the effect of the frequency and amplitude of sounds produced by petroleum production on behavior in fishes.

Inner shelf stations vary seasonally in fish species composition and abundance, but support large populations of fishes in summer, including recreationally (and easily accessible to sportfishermen) and commercially important species (e.g., black sea bass, sheepshead). Because some of the fishes of these areas apparently move offshore during winter, they may be able to avoid local disturbances and could return to a disturbed area the next season if the environment recovered. Middle shelf stations have more environmental stability and support greater concentrations of commercially valuable fish (red porgy, red snapper, gag, scamp, whitebone porgy). Because of this stability, disturbance in the form of drilling and oil spills might have a greater effect on fish community structure of these areas. The middle shelf is also the most likely area for gas and oil development on the shelf off Georgia and South Carolina based on the past lease sale, and particular care should be taken in developing these areas. The outer continental shelf and shelf break support populations of red snapper, grouper (various species), and tilefish which are currently exploited commercially. Adverse effects of oil development could have an economic impact on these fisheries.

There is some evidence that oil development may enhance finfish populations on the South Atlantic Bight shelf. Drilling platforms could provide additional living space and food for some species in the form of attached epifauna. These resources, especially suitable living space, may be limited on the South Atlantic shelf, and, in this respect, drilling platforms could function as artificial reefs. In addition, pelagic "baitfish" are known to be attracted to artificial structures for behavioral reasons (Klima and Wickham 1971) and would provide additional food for large predatory species.

CONCLUSIONS

- Most demersal shelf fishes demonstrated large seasonal differences in abundance at each station, but especially at inner and outer shelf stations. This is most likely due to the thermal instability of inner and outer shelf waters. All priority species except black sea bass (*Centropristis striata*) were most abundant at middle shelf stations. *Centropristis striata* was most abundant at inner shelf stations.

- Diversity (H') values for demersal fishes ranged from 0.8 (MS02, winter) to 3.2 (OS01, summer) and are comparable to values reported for similar depths from sand bottom in the South Atlantic Bight and live bottom off of North Carolina. Diversity was higher at night versus day and was higher in winter than summer at inner and outer shelf stations, but lower in winter at middle shelf stations. Species richness was higher in summer than in winter at most stations, but H' diversity patterns appeared to be more closely related to community dominance.

- Mean biomass per tow for all stations combined was greater in summer than in winter. There were no significant differences in mean biomass per tow between stations in summer. In winter, middle shelf stations had significantly greater biomass than inner or outer shelf stations. Biomass estimates from the live bottom areas studied were considerably higher than those estimates given in the literature for sand bottom areas in the South Atlantic Bight. Estimated biomass of fishes from the live bottom site off North Carolina was slightly higher than that estimated from sites off South Carolina and Georgia.

- Cluster analysis demonstrated striking differences in community composition between day and night tows. Also evident were seasonal changes in species composition at inner and outer shelf stations, and greater seasonal community stability on the middle shelf.

- Underwater television and diver observations provided useful complementary data to trawl collections, and documented the abundance of snappers, groupers, and other larger fishes at middle shelf stations. Underwater television was also useful for assessing species composition and abundance of fishes at stations which could not be trawled.

- Baited fishing gears were not as effective as the trawl in catching priority fish species. These gears confirmed distribution and abundance patterns of priority species as evaluated from trawl catches. They also were useful in confirming the presence of priority species at stations which could not be trawled. Antillean S-traps yielded the greatest number of individuals per hour of fishing.

- The larval and juvenile fish sled did not collect many priority fishes, and was not useful in assessing the importance of live bottom as spawning and nursery areas for those species. The sled most effectively samples larval and postlarval fishes, rather than juveniles.

- The offshore oil drilling process and possible oil spills may cause localized areas of reduced fish abundance. Because the middle shelf has the highest biomass and abundance of fishes, including many economically valuable species, particular care should be taken in developing middle shelf live bottom areas.

- Drilling rigs and production platforms may provide additional food and shelter for fishes through the creation of artificial reefs, and this could increase fish production in the South Atlantic Bight.

CHAPTER 7

FOOD HABITS OF FISHES

INTRODUCTION

Live bottom areas support a greater abundance, diversity, and biomass of fishes than adjacent areas of the open shelf (see Chapter 6). Many economically important fishes are found associated with live bottom habitats and currently support active commercial and recreational fisheries in the South Atlantic Bight. The dependence of these economically important fishes on live bottom for food and shelter is poorly understood. Although food habits information is available for some species of fishes associated with live bottom (Bradley and Bryan 1975, Manooch 1977, Grimes 1979, Link 1980), those studies have not examined the importance of live bottom habitat as feeding grounds for fishes, nor have they examined diet overlap of the species studied with other fishes in the community.

The purpose of this chapter is to describe the seasonal food habits of seven priority and ecologically dominant live bottom fish species, to evaluate dependence on live bottom as feeding grounds by these species, and to relate the food habits of these species to prey and predator community structure.

METHODS

Laboratory Analysis:

Initially, seven fish species were proposed as priority species for study: *Centropristis striata*, *Epinephelus niveatus*, *Lutjanus campechanus*, *Mycteroperca microlepis*, *M. phenax*, *Pagrus pagrus*, and *Rhomboplites aurorubens*. *Epinephelus niveatus* and *M. phenax* were not collected by any sampling gear and were not included in the analysis. Two additional species were substituted. *Stenotomus aculeatus* was chosen because it was the most abundant species collected (Chapter 6). *Calamus leucosteus* was also chosen because of its abundance over live bottoms (Chapter 6) and importance in the trawl fishery (Waltz et al. in preparation), and for comparison with other dominant sparids, *P. pagrus* and *S. aculeatus*.

Fixed stomachs were washed in tap water and transferred to 50% isopropanol in the laboratory. Attempts were made to examine at least 10 stomachs per station per season for each priority species, 5 from day trawls and 5 from night trawls. When sufficient numbers were not available in trawl collections, stomachs were also utilized from collections made with other gears (traps, longlines, snapper reels). Stomachs analyzed were randomly selected from those preserved when more than 10 stomachs were available. Stomach contents were sorted to the lowest possible taxon and counted. Colonial forms and fragments of animals were counted as one organism, unless abundance could be estimated by counting pairs of eyes (crustaceans), otoliths (fishes), or other parts. Any prey items (i.e., fish or cephalopod remains) that might have been bait on passive fishing gears were not included in the analysis. Volume displacement of food items was measured using a graduated cylinder, or estimated by using a 0.1-cm^2 grid (Windell 1971).

Data Analysis:

Methods of food habits quantification are variously biased (Hynes 1950, Pinkas et al. 1971, Windell 1971); therefore, the relative contribution of different food items to the total diet of each species was determined using three methods: (1) the number of stomachs in which a food item occurred was expressed as a percent frequency occurrence (F), i.e., a percentage of the total number of stomachs containing food; (2) the number of individuals of each type of food was expressed as percent numerical abundance (N), i.e., a percentage of the total number of food items from all stomachs; and (3) the volume displacement of a food item was expressed as percent volume displacement (V), i.e., a percentage of the total volume of food from all stomachs. From these, 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 N, V, and F are the numerical, volumetric, and frequency percentages as defined above. This index has proven useful in evaluating the relative importance of different food items found in fish stomachs (Pinkas et al. 1971, McEachran et al. 1976, Sedberry 1980), and was used in the present study to describe the food habits of each species and determine seasonal differences in the relative importance of food items.

Similarity in diet between predators was measured using the Bray-Curtis measure (Bray and Curtis 1957), expressed as:

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

where S_{jk} is the similarity between the predators j and k; X_{ji} is the abundance of the i^{th} prey taxon (the lowest level to which the prey was identified) for predator j; and X_{ki} is the abundance of the i^{th} prey taxon for predator k. Because sample sizes were unequal, abundance of prey items was standardized as percent numerical abundance for each predator (Clifford and Stephenson 1975, Boesch 1977). Similarity values were presented in trellis diagrams.

Overlap in diet among all predators was also measured using numerical classification techniques (cluster analysis) for comparison with other studies which have used this technique. Each predator was treated as a collection, and all predators were subjected to normal cluster analysis based on the Bray-Curtis similarity measure as defined above. Similarity among groups of predators was expressed in the form of dendrograms generated using flexible sorting with $\beta = -.025$ (Lance and Williams 1967a, Clifford and Stephenson 1975).

To determine the dependence of priority species on live bottom organisms for food, percent volume of prey species consumed by each predator was separated into habitat components (live bottom, sand bottom, or water column), based on information from the literature. Percent volume was used because it is a closer estimate of energy content than frequency or number.

RESULTS

Of the 790 stomachs from seven fish species examined, 509 (39.2%) contained food. Results from the analysis of these stomachs are presented below in individual species accounts.

Centropristis striata:

The contents of 250 black sea bass stomachs examined varied with season. During winter, amphipods were the most abundant prey, especially *Erichthonius brasiliensis* and caprellids (Figure 7.1 and Table 7.1). Fishes and decapods were most important volumetrically. Brachyurans, particularly *Pilumnus sayi*, were the most important decapods. Most fish remains were impossible to identify, but *Sardinella aurita* was an important species.

Summer food habits differed from winter primarily in the reduced importance of amphipods as prey. Caprellid amphipods, which were abundant in the diet in winter, were not consumed in summer. *Pilummus sayi* was still the most important decapod, and many planktonic *Lucifer faxoni* were also consumed. Several fish species were important in the diet in summer. Most were small juveniles which were also abundant in trawl catches in the summer. Ascidians, ophiuroids, polychaetes, and other taxa were also consumed.

Pagrus pagrus:

The contents of 183 stomachs of red porgy varied little between seasons at the higher taxonomic levels, and fishes, decapods, and polychaetes were the most important foods during both seasons (Figure 7.2). Amphipods and anthozoans (Actiniaria) were of lesser importance. Numerous other taxa were infrequently consumed (Table 7.2).

Although relative abundance of higher taxa was similar seasonally, the species consumed varied between winter and summer. Clupeids and seahorses (*Hippocampus* sp.) were the most important fish in winter but were not consumed in summer. Several brachyuran species were consumed in winter, but crabs were infrequent decapods in the diet in summer.

Rhomboplites aurorubens:

Contents of vermilion snapper stomachs (N = 142) varied greatly with season (Figure 7.3). In winter, several taxa were important in the diet. Cumaceans, ostracods, and amphipods were the most important higher taxa, and decapods and fishes were volumetrically important. *Oxyurostylis smithi*, the most important prey species (Table 7.3), is a sand dwelling cumacean. Cumaceans are known to swarm in the water column at night (Anger and Valentin 1976), and *R. aurorubens* may have fed on them at that time. Ostracoda A, the second most important prey species, is a planktonic form. *Promysis atlantica* and *Phtisica marina*, like *O. smithi*, are partially planktonic. Other planktonic prey included calanoid copepods and decapod larvae.

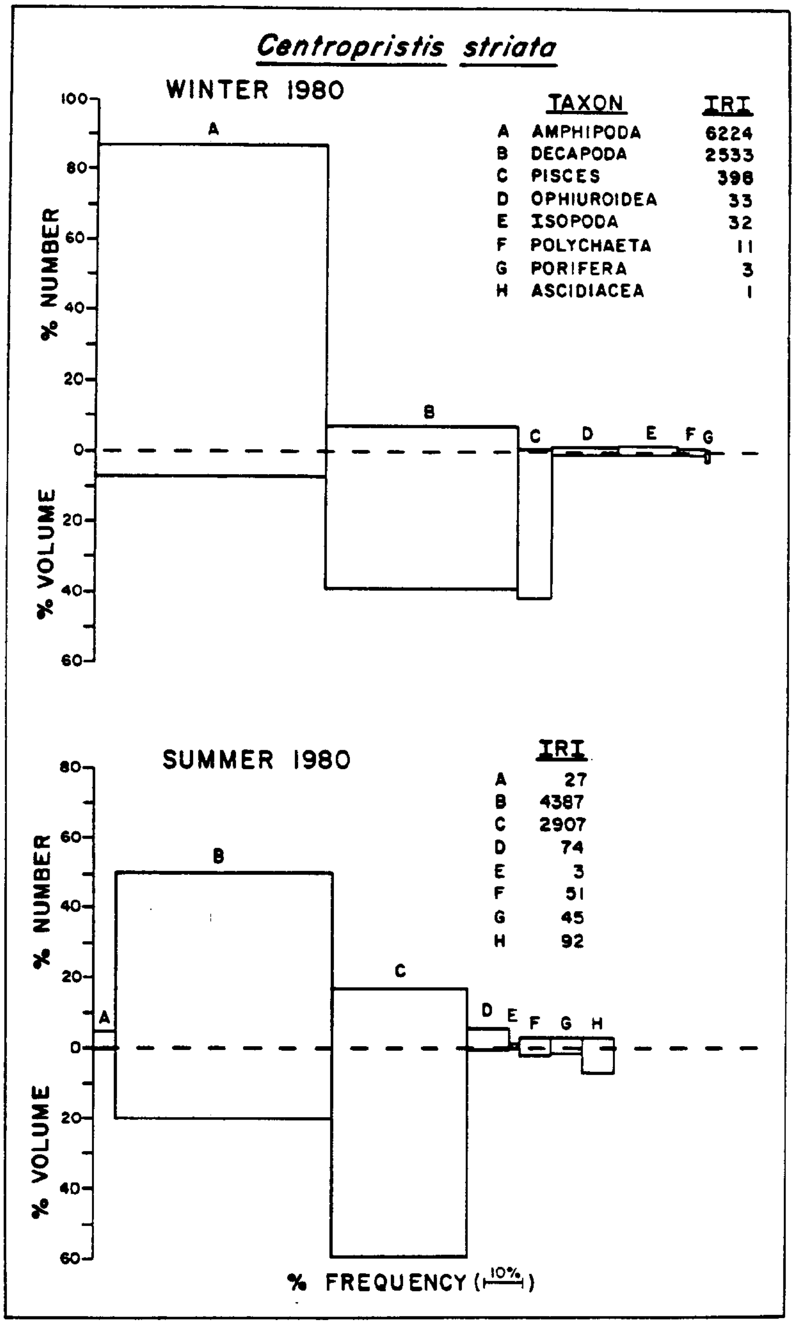


Figure 7.1. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Centropristis striata.

Table 7.1. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in Centropristis striata stomachs for both sampling periods. tr = trace volume.

Taxon Food Item	Winter 1980 F	Winter 1980 N	Winter 1980 V	Winter 1980 IRI	Summer 1980 F	Summer 1980 N	Summer 1980 V	Summer 1980 IRI
Foraminifera								
Unidentified Foraminifera	1.16	0.09	.01	<1				
Porifera								
Unidentified Porifera	1.16	0.04	2.78	3	9.09	3.33	1.61	45
Cnidaria								
Hydrozoa								
Aglaophenia trifida	4.65	0.17	0.05	1				
Campanulariidae	1.16	0.04	0.01	<1				
Unidentified Hydrozoa					1.51	0.56	0.01	1
Total Hydrozoa	5.81	0.22	0.06	2	1.52	0.56	0.01	1
Anthozoa								
Octocorallia	1.16	0.04	0.01	<1				
Telesto fruticulosa	1.16	0.04	0.01	<1				
Telesto sp.					1.51	0.56	0.07	1
Total Anthozoa	2.33	0.09	0.02	<1	1.52	0.56	0.07	1
Annelida								
Polychaeta								
Ampharete americana	1.16	0.04	0.02	<1				
Aphrodita hastata					1.51	0.56	0.07	1
Aphroditidae ?					1.51	0.56	0.29	1
Notopygos crinita					1.51	0.56	0.07	1
Phyllodoce groenlandica					1.51	0.56	0.05	1
P. longipes	1.16	0.04	0.02	<1				
Polynoidae	1.16	0.04	0.19	<1				
Unidentified Polychaeta	4.65	0.17	0.87	5	3.03	1.11	1.79	9
Total Polychaeta	8.14	0.30	1.09	11	9.09	3.33	2.28	51
Mollusca								
Gastropoda								
Calliostoma sp.	1.16	0.04	0.01	<1				
Marginella hartleyanum					1.51	0.56	tr.	1
Mitrella lunata	1.16	0.04	0.01	<1				
Natica pusilla					1.51	2.22	tr.	3
Olividae	1.16	0.04	0.01	<1				
Total Gastropoda	3.49	0.13	0.03	1	3.03	2.78	0.01	8
Pelecypoda								
Laevicardium pictum					1.51	0.56	0.10	1
Musculus lateralis	1.16	0.04	0.03	<1				
Pteria colymbus	3.49	0.22	0.03	1				
Semele purpurascens					3.03	2.22	0.32	8
Total Pelecypoda	4.65	0.26	0.06	1	4.55	2.78	0.42	15
Cephalopoda								
Loliginidae	1.16	0.04	0.14	<1	3.03	1.11	6.97	24
Crustacea								
Copepoda								
Labidocera aestiva	1.16	0.61	0.03	1				
Cirripedia								
Balanus trigonus	2.33	0.09	0.30	1				
Cumacea								
Cyclaspis varians					1.51	0.56	tr.	1
Oxyurostylis smithi	2.33	0.17	0.02	<1				
Total Cumacea	2.33	0.17	0.02	<1	1.52	0.56	tr.	1
Isopoda								
Carpias bermudensis	4.65	0.61	0.03	3				
Cirolana polita	2.33	0.35	0.10	1				

Table 7.1 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Paracerceis caudata	10.46	0.39	0.32	7	3.03	1.11	0.01	3
Unidentified Isopoda	1.16	0.04	tr.	<1				
Total Isopoda	17.44	1.39	0.45	32	3.03	1.11	0.01	3
Amphipoda								
Gammaridea								
Ampelisca sp.	1.16	0.09	0.01	<1				
A. agassizi	1.16	0.09	0.01	<1				
A. vadorum	3.49	0.17	0.03	1				
A. verrilli					1.51	1.11	tr.	2
Ceradocus sp.					1.51	0.56	tr.	1
Cerapus tubularis	4.65	0.48	0.04	2				
Elasmopus sp. A	1.16	0.04	0.02	<1				
Erichthonius brasiliensis	40.70	41.51	1.69	1758				
Leucothoe spinicarpa	2.33	0.09	0.02	<1	1.51	0.56	tr.	1
Listriella clymenellae	1.16	0.04	0.01	<1				
Lysianassa sp.					1.51	0.56	0.01	1
Lysianassidae	1.16	0.04	0.02	<1				
Lysianopsis alba	2.33	0.09	0.02	<1	1.51	0.56	tr.	1
Melita appendiculata	9.30	0.52	0.16	6				
Microdeutopus sp.	1.16	0.04	0.01	<1				
Microjassa sp.	2.33	0.09	0.01	<1				
Photis sp.	1.16	0.04	tr.	<1				
P. pugnator	15.12	2.31	0.17	37				
Podoceridae	1.16	0.04	0.01	<1				
Podocerus sp.	5.81	0.35	0.05	2				
Polycheria sp.	1.16	0.04	0.01	<1				
Stenothoe sp. A	1.16	0.04	0.01	<1				
S. georgiana	15.12	1.00	0.10	17				
Trichophoxus floridanus	1.16	0.04	0.01	<1				
Unidentified Gammaridea	9.30	1.00	0.08	10	1.51	1.11	tr.	2
Caprellidea								
Caprella penantis	2.33	0.26	0.03	1				
Caprellidae	12.79	15.55	1.30	215				
Caprella equilibra	31.39	21.82	2.84	774				
Luconacia incerta	12.79	1.22	0.19	18				
Phtisica marina	1.16	0.04	0.01	<1				
Total Amphipoda	66.28	87.06	6.84	6224	6.06	4.44	0.02	27
Mysidicea								
Bowmaniella portoricensis					1.51	0.56	tr.	1
Unidentified Mysidicea	1.16	0.52	0.04	1				
Total Mysidacea	1.16	0.52	0.04	1	1.52	0.56	tr.	1
Decapoda								
Natantia								
Hippolytidae	1.16	0.04	0.02	<1				
Leptochela sp.	2.33	0.09	0.10	<1				
L. papulata	2.33	0.09	0.15	1				
Lucifer faxoni					9.09	11.67	0.03	106
Neopontonides beaufortensis	4.65	0.35	0.12	2				
Periclimenes sp.	1.16	0.04	0.05	<1				
P. longicaudatus	3.49	0.26	0.10	1	3.03	1.67	0.06	5
Processa bermudensis					3.03	1.11	0.01	3
Sicyonia brevirostris					4.54	1.67	5.60	33
S. typica					3.03	1.11	0.82	6
Synalpheus longicarpus					3.03	1.11	0.25	4
Synalpheus townsendi	3.49	0.22	0.20	1	1.51	0.56	0.00	1
Thor sp.	2.33	0.61	0.11	2	1.51	0.56	tr.	1
T. floridanus	2.33	0.13	0.04	<1				
T. manningi	1.16	0.09	0.03	<1				
Unidentified Natantia	11.63	1.05	0.42	17	7.57	2.78	0.05	21
Reptantia								
Macrura								
Scyllarus chacei					1.51	0.56	1.45	3

Table 7.1 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Anomura								
Albunea paretti	1.16	0.04	3.15	4				
Dardanus fusosus	1.16	0.04	3.98	5				
Galathea rostrata					1.51	1.11	0.05	2
Paguridae	3.49	0.13	0.06	1	1.51	0.56	tr.	1
Pagurus sp.	2.33	0.09	0.08	<1	9.09	4.44	0.12	41
P. carolinensis	3.49	0.13	0.11	1	6.06	2.22	0.03	14
P. hendersoni					3.03	1.11	0.03	3
Brachyura								
Calappa angusta					3.03	1.11	2.57	11
Dromedia antillensis	1.16	0.04	0.28	<1				
Hexapanopeus sp.					1.51	0.56	0.19	1
H. angustifrons					3.03	1.11	0.46	5
Macrocoeloma camptocerum	1.16	0.04	0.37	<1	1.51	0.56	0.03	1
Majidae	1.16	0.04	0.01	<1				
Micropanope sp.	1.16	0.04	0.02	<1				
Mithrax sp.					3.03	1.11	0.24	4
M. hispidus	1.16	0.04	0.19	<1				
M. pleuracanthus	3.49	0.13	4.15	15				
Ovalipes sp.	1.16	0.04	0.01	<1				
O. stephensoni	1.16	0.04	2.32	3				
O. stephensoni?	1.16	0.09	1.09	1				
Pelia mutica	3.49	0.17	0.33	2				
Pilumnus sp.					4.54	1.67	0.25	9
P. floridanus					1.51	0.56	0.44	2
P. sayi	4.65	0.43	12.18	59	21.21	7.78	6.49	303
Pinnotheres maculatus zoea	1.16	1.26	0.04	2				
Pitho lherminieri	1.16	0.04	0.20	<1	3.03	1.11	0.41	5
Podochela gracilipes					1.51	0.56	0.03	1
P. riisei	6.98	0.30	1.77	14	1.51	0.56	0.14	1
Stenorhynchus seticornis	1.16	0.04	0.93	1	1.51	1.11	0.23	2
Xanthidae	2.33	0.09	0.13	<1	1.51	0.56	0.07	1
Brachyuran megalopae	1.16	0.04	0.01	<1				
Unidentified Brachyura	15.12	0.65	6.31	105				
Decapoda larvae	1.16	0.09	0.01	<1				
Unidentified Decapoda	2.33	0.09	0.16	1				
Total Decapoda	54.65	7.14	39.21	2533	62.12	50.56	20.07	4387
Sipunculida								
Sipunculus nudus	1.16	0.04	0.60	1				
Ectoprocta								
Diaperoecia floridana	1.16	0.04	0.01	<1	1.51	0.56	tr.	1
Discoporella umbellata	1.16	0.04	0.02	<1				
Unidentified Ectoprocta					1.51	0.56	0.05	1
Total Ectoprocta	2.33	0.09	0.03	<1	3.03	1.11	0.05	4
Echinodermata								
Ophiuroidea								
Unidentified Ophiuroidea	18.60	1.00	0.77	33	12.12	5.55	0.52	74
Holothuroidea								
Unidentified Holothuroidea	2.33	0.09	4.81	11	3.03	1.11	1.70	8
Chordata								
Ascidiacea								
Ascidiacea?	1.16	0.04	0.18	<1				
Diplosoma macdonaldi?					3.03	1.11	4.12	16
Styela plicata					1.51	0.56	1.70	3
Unidentified Ascidiacea	1.16	0.04	0.23	<1	4.54	1.67	0.92	12
Total Ascidiacea	2.33	0.09	0.41	1	9.09	3.33	6.73	92
Cephalochordata								
Branchiostoma caribaeum	1.16	0.04	0.05	<1				

Table 7.1 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Pisces								
Carangidae					1.51	0.56	0.73	2
Decapterus punctatus					3.03	1.67	6.35	24
Haemulon aurolineatum					4.54	3.33	4.75	37
Labridae	1.16	0.04	1.67	2				
Porichthys plectrodon					3.03	1.11	14.05	46
Rhomboplites aurorubens					1.51	0.56	27.61	43
Sardinella aurita	1.16	0.09	3.33	4	1.51	0.56	0.07	1
Synodontidae					3.03	1.11	1.96	9
Urophycis regia	1.16	0.13	0.69	1				
Unidentified Teleostei	5.81	0.22	36.58	214	22.73	8.33	4.01	281
Total Pisces	9.30	0.48	42.17	398	37.88	17.22	59.52	2907
Number of stomachs examined		142				98		
Examined stomachs with food		86				66		

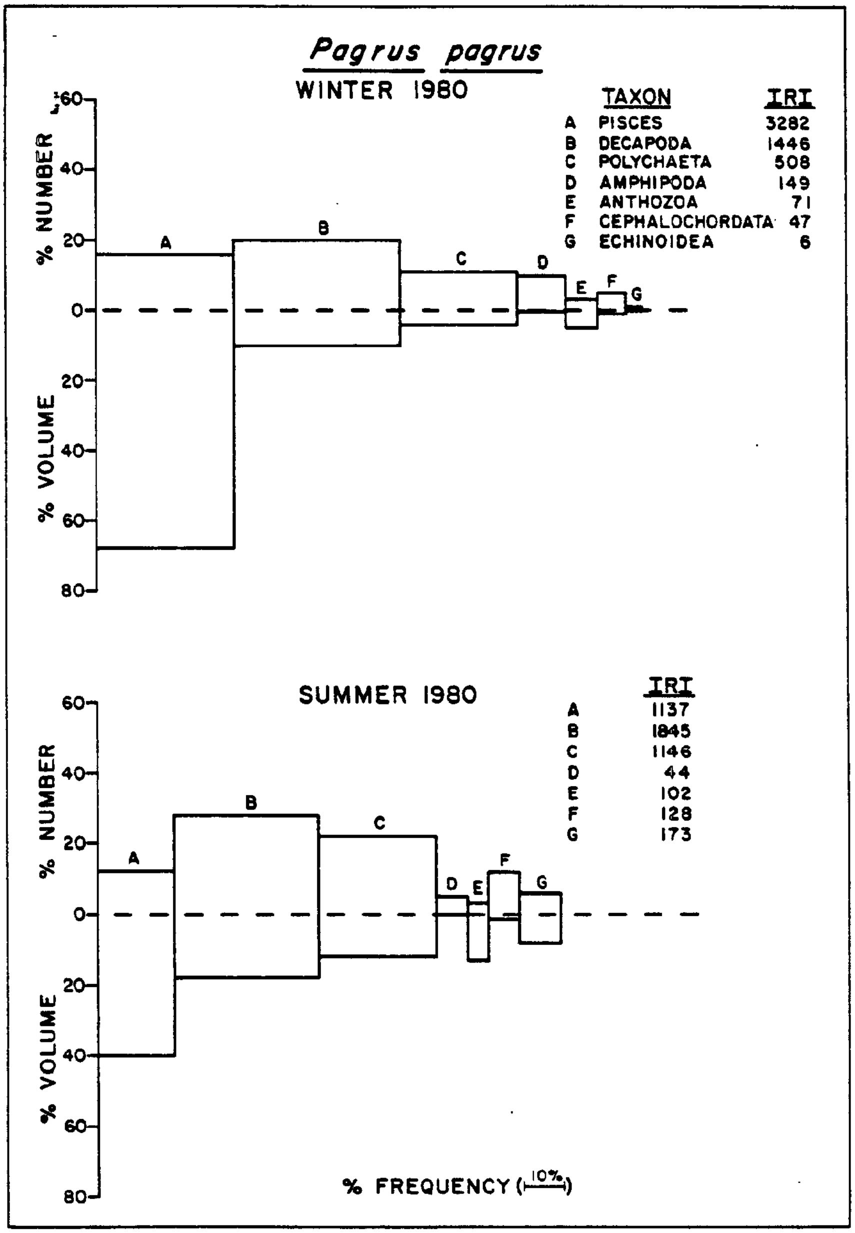


Figure 7.2. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Pagrus pagrus.

Table 7.2. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in *Pagrus pagrus* stomachs for both sampling periods. tr = trace volume.

Taxon / Food Item	Winter 1980 F	N	V	IRI	Summer 1980 F	N	V	IRI
Foraminifera								
Unidentified Foraminifera	3.13	1.11	0.03	4				
Porifera								
Unidentified Porifera	4.69	1.11	2.48	17				
Cnidaria								
Hydrozoa								
Salacia desmoides	1.56	0.37	0.01	1				
Anthozoa								
Actiniaria	7.81	2.20	4.66	54	6.25	3.08	13.23	102
Unidentified Anthozoa	1.56	0.37	0.28	1				
Total Anthozoa	9.38	2.58	4.95	71	6.25	3.08	13.23	102
Annelida								
Polychaeta								
Aphrodita hastata					3.13	1.54	10.05	36
Chaetopteridae					3.13	1.54	0.02	5
Eunice sp.	1.56	0.37	0.28	1	3.13	1.54	0.14	5
E. antennata	1.56	0.37	0.04	1				
E. websteri					3.13	3.08	0.46	11
Glycera americana	1.56	0.37	0.04	1				
Lumbrineridae					3.13	1.54	0.07	5
Lumbrineris sp.					3.13	1.54	0.23	6
Nereidae	1.56	0.37	0.01	1				
Notopygos crinita	3.13	1.10	0.32	4	3.13	1.54	0.07	5
Onuphidae	1.56	0.37	0.07	1				
Onuphis eremita	1.56	0.37	0.14	1				
O. nebulosa	9.38	2.20	0.69	27	3.13	1.54	0.34	6
Owenia fusiformis	1.56	0.37	0.14	1				
Sabellidae	3.13	0.73	0.28	3				
Serpulidae	1.56	0.73	0.14	1	3.13	1.54	tr.	5
Sigalionidae	3.13	0.73	0.70	4				
Syllidae	1.56	0.37	0.14	1				
Syllis regulata carolinae	1.56	0.37	0.01	1				
Terebellidae					3.13	1.54	0.07	5
Unidentified Polychaeta	9.38	2.20	0.69	27	9.38	4.61	0.37	47
Total Polychaeta	34.38	11.07	3.72	508	34.38	21.54	11.81	1146
Mollusca								
Gastropoda								
Naticidae	3.13	0.73	0.15	3				
Unidentified Gastropoda	3.13	0.73	0.11	3				
Total Gastropoda	6.25	1.48	0.27	11				
Scaphopoda								
Dentaliidae	1.56	0.37	0.01	1				
Cephalopoda								
Loligo plei					3.13	1.54	7.99	30
Crustacea								
Ostracoda								
Ostracoda A	1.56	1.11	0.01	2				
Copepoda								
Unidentified Copepoda	1.56	0.37	0.01	1	3.13	1.54	tr.	5
Cirripedia								
Balanus sp.	1.56	1.84	0.03	3				
B. trigonus	3.13	16.54	1.99	58	3.13	1.54	0.02	5
Total Cirripedia	3.13	18.45	2.01	64	3.13	1.54	0.02	5

Table 7.2 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Amphipoda								
Gammaridea								
Ampelisca verrilli					3.13	1.54	0.02	5
Erichthonius brasiliensis	3.13	0.73	0.03	2				
Liljeborgia sp.	1.56	0.37	0.01	1				
Melita appendiculata	1.56	0.37	0.01	1				
Unciola sp.	1.56	0.37	0.01	1				
Unidentified Gammaridea	3.13	0.73	0.03	2	3.13	1.54	tr.	5
Caprellidea								
Phtisica marina	9.38	7.72	0.18	74	3.13	1.54	0.02	5
Total Amphipoda	14.06	10.33	0.28	149	9.38	4.62	0.05	44
Mysidacea								
Bowmaniella portoricensis	10.94	2.95	0.20	34				
Decapoda								
Natantia								
Alpheidae	1.56	0.73	0.01	1				
Alpheus normanni					3.13	1.54	0.11	5
Leptochela sp.	1.56	0.37	0.01	1				
L. papulata	10.94	3.68	0.46	45	9.38	4.61	0.64	49
Periclimenaeus ? sp.					3.13	3.08	0.05	10
Processa bermudensis	1.56	0.37	0.04	1				
Synalpheus townsendi	3.13	0.73	0.10	3	6.25	3.08	0.27	21
Thor sp.	3.13	0.73	0.03	2				
Unidentified Natantia	12.50	4.04	0.76	60	6.25	3.08	0.98	25
Reptantia								
Anomura								
Albunea gibbesii					3.13	1.54	10.96	39
Paguridae	1.56	0.37	0.03	1				
Pagurus sp.					3.13	1.54	0.11	5
P. carolinensis	3.13	0.73	0.06	2				
Brachyura								
Calappa sp.	1.56	0.37	0.82	2				
Macrocoeloma camptocerum	1.56	0.37	0.56	1				
Majidae	4.69	1.47	2.41	18				
Metoporhaphis calcarata	1.56	0.37	0.92	2				
Mithrax pleuracanthus					3.13	1.54	2.72	13
Osachila sp.	1.56	0.37	0.28	1				
Parapinnixa bouvieri	3.13	0.73	0.28	3				
Parthenope sp.	1.56	0.37	0.28	1				
P. fraterculus	1.56	0.37	0.01	1				
Portunus sp.					3.13	1.54	0.05	5
P. anceps	1.56	0.37	0.80	2				
Ranilia muricata	1.56	0.37	0.14	1	3.13	3.08	1.37	14
Unidentified Brachyura	12.50	3.31	1.65	62	3.13	1.54	0.46	6
Decapoda zoea					3.13	1.54	tr.	5
Total Decapoda	48.44	20.22	9.65	1446	40.63	27.69	17.73	1845
Unidentified Crustacea					3.13	1.54	0.02	5
Ectoprocta								
Diaperoecia floridana	7.81	1.84	0.10	15	3.13	1.54	tr.	5
Discoporella umbellata	1.56	0.37	0.01	1				
Parasmittina trispinosa	1.56	0.37	0.01	1				
Total Ectoprocta	9.38	2.58	0.13	25	3.13	1.54	tr.	5
Echinodermata								
Ophiuroidea								
Unidentified Ophiuroidea	10.94	2.58	0.51	34	9.38	4.62	0.48	48
Echinoidea								
Arbacia punctulata					3.13	1.54	1.90	11
Encope sp.					3.13	1.54	5.30	21
Eucidaris tribuloides					3.13	1.54	0.23	6
Lytechinus variegatus	1.56	0.37	0.01	1				
Stylocidaris affinis					3.13	1.54	0.27	6
Unidentified Echinoidea	3.13	0.73	0.13	3				
Total Echinoidea	4.69	1.11	0.14	6	12.50	6.15	7.70	173

Table 7.2 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Holothuroidea								
Unidentified Holthuroidea	1.56	0.37	1.69	3				
Chordata								
Ascidiacea								
Unidentified Ascidiacea	3.13	0.74	4.83	17				
Cephalochordata								
Branchiostoma caribaeum	7.81	4.78	1.25	47	9.38	12.31	1.32	128
Pisces								
Bothidae	1.56	1.10	0.85	3				
Clupeidae	4.69	1.10	29.23	142				
Decapterus punctatus					3.13	1.54	2.74	13
Etrumeus teres	1.56	2.20	0.28	4				
Hippocampus sp.	6.25	5.15	6.83	75				
Ogcocephalidae	1.56	0.37	0.30	1				
Ophidiidae	1.56	0.37	0.25	1				
Rhomboplites aurorubens					3.13	1.54	9.14	33
Rhomboplites aurorubens?					3.13	1.54	14.82	51
Stenotomus sp.	1.56	0.37	10.14	16				
Synodus poeyi					3.13	3.08	11.42	45
Fish scales	1.56	0.37	0.01	1				
Unidentified Teleostei	20.31	5.15	19.89	509	9.38	4.61	1.53	58
Total Pisces	39.06	16.24	67.79	3282	21.88	12.31	39.65	1137
Total number of stomachs examined		119				64		
Examined stomachs with food		64				32		

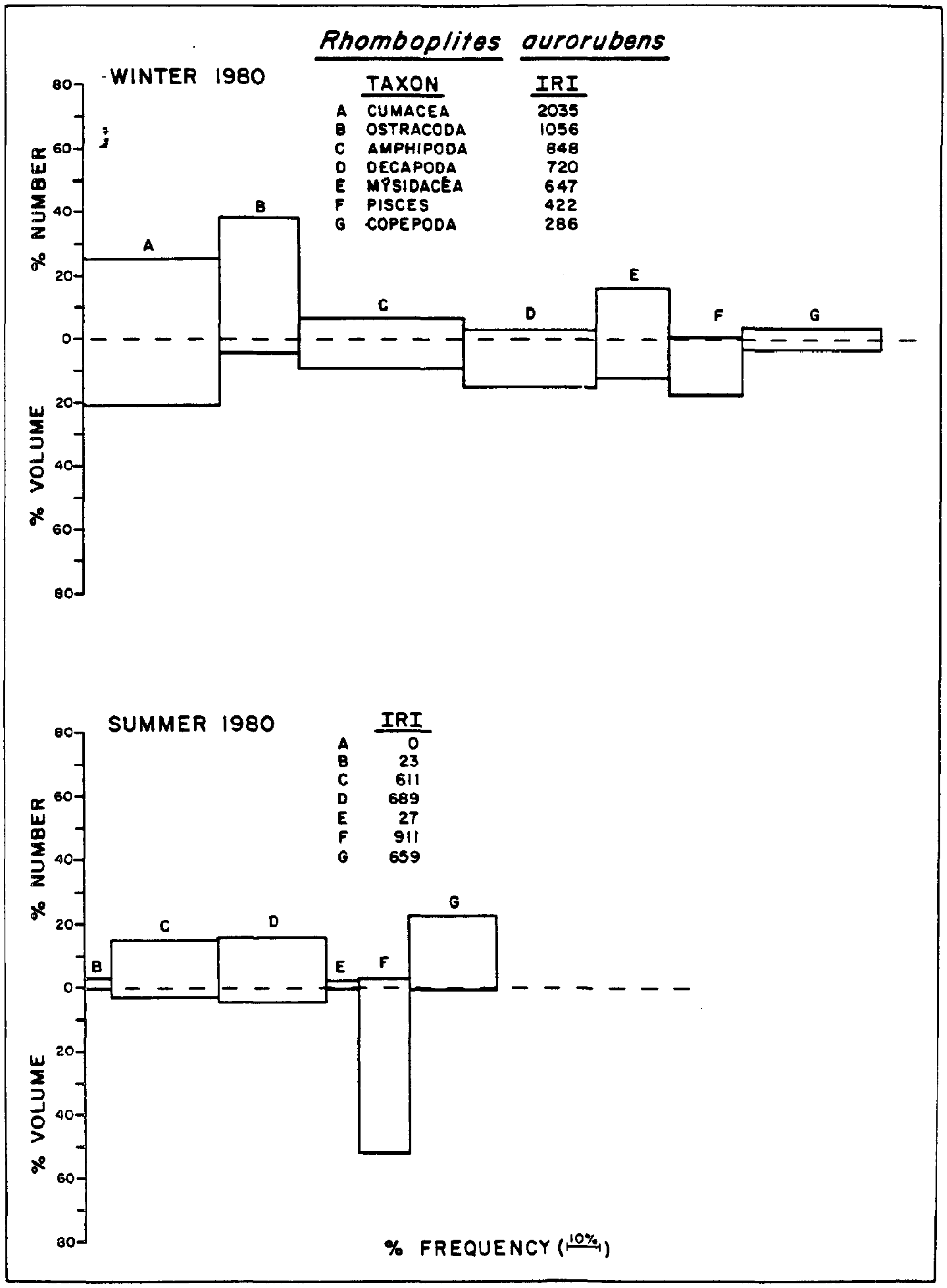


Figure 7.3. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Rhomboplites aurorubens.

Table 7.3. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in Rhomboplites aurorubens stomachs for both sampling periods. tr = trace volume.

Taxon / Food Item	Winter 1980 F	Winter 1980 N	Winter 1980 V	Winter 1980 IRI	Summer 1980 F	Summer 1980 N	Summer 1980 V	Summer 1980 IRI
Annelida								
Polychaeta								
Eunicidae	2.27	0.21	7.71	18				
Phyllodoce longipes	18.18	1.59	6.32	144				
Unidentified Polychaeta					3.28	0.68	0.63	4
Total Polychaeta	20.45	1.80	14.03	324	3.28	0.68	0.63	4
Mollusca								
Gastropoda								
Natica pusilla					6.56	5.82	0.80	43
Naticidae	2.27	0.11	0.20	1				
Naticidae A	2.27	0.21	0.99	3				
Thecosomata					1.64	0.34	0.17	1
Unidentified Gastropoda					1.64	0.68	0.11	1
Total Gastropoda	4.55	0.32	1.19	7	8.20	6.85	1.08	65
Pelecypoda								
Ervilia concentrica					4.92	4.45	0.17	23
Cephalopoda								
Loliginidae					1.64	0.34	22.17	37
Crustacea								
Ostracoda								
Ostracoda A	25.00	38.10	4.15	1056	4.92	2.05	0.06	11
Unidentified Ostracoda					3.28	0.68	tr.	2
Total Ostracoda	25.00	38.10	4.15	1056	8.20	2.74	0.06	23
Copepoda								
Candacia curta	6.82	1.06	0.59	11	1.64	0.34	tr.	1
Corycaeus sp.	2.27	0.21	0.20	1				
Labidocera aestiva	9.09	0.74	0.79	14				
Nannocalanus minor	2.27	0.11	tr.	<1				
Temora stylifera	6.82	0.32	0.20	4				
T. turbinata	13.64	1.59	0.79	32	22.95	19.52	0.28	454
Undinula vulgaris					1.64	0.34	tr.	1
Calanoida	6.82	0.42	0.40	6	4.92	3.08	0.06	15
Total Copepoda	38.64	4.45	2.96	286	27.87	23.29	0.34	659
Stomatopoda								
Stomatopoda larvae					1.64	0.34	0.06	1
Unidentified Stomatopoda					1.64	0.34	0.57	1
Total Stomatopoda					3.28	0.68	0.63	4
Cumacea								
Cyclaspis varians	15.91	1.80	1.98	60				
Oxyurostylis smithi	38.64	21.90	16.80	1495				
Unidentified Cumacea	27.27	1.90	2.77	127				
Total Cumacea	43.18	25.60	21.55	2035				
Amphipoda								
Gammaridea								
Ampelisca agassizi	2.27	0.11	0.20	1				
A. vadorum	2.27	0.11	0.20	1				
Bathyporeia parkeri	2.27	0.11	0.20	1				
Corophiidae					1.64	0.68	0.06	1
Lysianopsis alba	2.27	0.11	0.40	1	1.64	0.34	tr.	1
Microdeutopus sp.	2.27	0.11	0.20	1				
Photis sp.	4.54	0.21	0.40	3				
Protomedia sp.	2.27	0.21	0.20	1				
Synchelidium americanum	6.82	0.32	0.59	6				
Tiron tropakis	4.54	0.21	0.40	3	1.64	0.34	tr.	1
Unidentified Gammaridea	9.09	0.42	1.38	16	3.28	1.03	0.06	4

Table 7.3 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Caprellidea								
Caprellidae	2.27	0.11	0.20	1				
Luconacia incerta	2.27	0.11	0.20	1				
Phtisica marina	27.27	4.34	3.95	226	3.28	1.37	0.06	5
Hyperiidea								
Hyperiidae	9.09	0.63	0.59	11	4.92	1.03	0.28	6
Lestrigonus bengalensis					9.84	7.53	0.40	78
Lycaea sp.					3.28	0.68	0.06	2
Phronima sp.					4.92	1.03	1.71	13
Simorhynchotus sp.					1.64	0.34	0.06	1
Unidentified Hyperiidea					3.28	0.68	tr.	2
Total Amphipoda	52.27	7.11	9.11	848	34.43	15.07	2.67	611
Mysidacea								
Bowmaniella portoricensis	11.36	1.06	1.98	34	8.20	2.05	0.34	20
Mysidopsis bigelowi	6.82	0.32	0.79	8				
M. furca	2.27	0.11	0.20	1				
Promysis atlantica	11.36	14.29	8.50	259				
Unidentified Mysidacea	6.82	0.42	0.79	8	1.64	0.34	0.06	1
Total Mysidacea	22.73	16.20	12.25	647	9.84	2.40	0.40	27
Decapoda								
Natantia								
Alpheidae zoea	4.54	0.21	tr.	1				
Leptochela sp.					1.64	0.34	0.23	1
L. papulata	2.27	0.11	0.20	1	9.84	3.08	2.27	53
Lucifer faxoni					14.75	5.48	0.45	88
Ogyrides sp.	2.27	0.11	0.20	1				
Sicyonia typica					1.64	0.34	0.06	1
Synalpheus townsendi	2.27	0.11	0.59	2				
Natantia larvae	2.27	0.11	0.20	1				
Unidentified Natantia	15.91	1.16	9.88	176	6.56	1.71	0.23	13
Reptantia								
Macrura								
Panulirus sp. larvae					1.64	0.34	0.06	1
Anomura								
Paguridae zoea					1.64	0.68	tr.	1
Porcellanidae zoea	2.27	0.11	0.20	1				
Anomura zoea	2.27	0.11	0.20	1				
Brachyura								
Calappidae megalopae					1.64	0.34	0.11	1
Dromidia antillensis	2.27	0.11	0.20	1				
Hypoconcha sp.					1.64	0.34	0.11	1
Portunus sp.					1.64	0.34	0.28	1
Xanthidae megalopae					1.64	0.34	tr.	1
Xanthidae zoea	2.27	0.21	0.20	1				
Brachyura zoea	4.54	0.32	0.40	3	1.64	0.68	tr.	1
Unidentified Brachyura	2.27	0.11	2.57	6	1.64	0.68	0.45	2
Decapoda zoea					4.92	1.03	tr.	5
Total Decapoda	40.91	2.78	14.82	720	34.43	15.75	4.26	689
Unidentified Crustacea					18.03	19.52	14.27	609
Chaetognatha								
Unidentified Chaetognatha	13.64	1.37	1.98	46	13.11	4.45	0.63	67
Chordata								
Cephalochordata								
Branchiostoma caribaeum	6.82	1.16	0.59	12	1.64	0.34	0.57	1
Pisces								
Fish scales	9.09	0.42	0.59	9	3.28	0.68	tr.	2
Unidentified Teleostei	13.64	0.74	16.80	239	13.11	2.74	52.13	720
Total Pisces	22.73	1.16	17.39	422	16.39	3.42	52.13	911
Number of stomachs examined		59				83		
Examined stomachs with food		44				61		

The diet of vermilion snapper was quite different during summer, but again included many planktonic forms. Cumaceans and ostracods were of lesser importance in summer. Amphipods were nearly as important as in winter, but consisted mainly of planktonic hyperiids. Most decapods were also planktonic (e.g., Lucifer faxoni). Fishes were most important in the diet in summer and consisted mainly of small postlarval forms which could not be identified.

Calamus leucosteus:

Several higher taxa were frequently found in the 93 whitebone porgy stomachs examined (Figure 7.4). In winter, decapods, polychaetes, and gastropods were the most important prey taxa. Brachyurans and pagurids were the important decapods, and several different polychaete species were consumed in approximately equal numbers (Table 7.4). Identifiable gastropods were mostly naticids, which are usually found on sand bottom.

In summer, decapods, polychaetes, and gastropods were again the most important prey, but gastropods were more important than polychaetes. Pagurids and brachyurans were again the most important decapods. Asteroids and pelecypods, which were not consumed in winter, were occasionally eaten in summer.

Stenotomus aculeatus:

Contents of the 96 southern porgy stomachs examined varied seasonally. In winter, amphipods and polychaetes were the most important prey items (Figure 7.5). Live bottom species (Erichthonius brasiliensis, caprellids) were the most important amphipods, and the infaunal cephalochordate, Branchiostoma caribaeum, was also important in the diet (Table 7.5). Several polychaete species were of nearly equal importance, and Oxyurostylis smithi was the most important cumacean. Chaetognaths were relatively important in the winter diet and numerous other taxa were also consumed.

In summer, pelecypods (primarily recently set Ervilia concentrica) replaced amphipods as the most important prey. Polychaetes were not as important as in winter, and fewer cumaceans were consumed. Copepods and ophiuroids remained relatively unimportant in the diet but were more frequently consumed in the summer. Sipunculids were also more frequently consumed in summer.

Lutjanus campechanus:

Red snapper were infrequently captured during both seasons, and food habits analysis was limited (31 stomachs). Fishes were the most important prey for L. campechanus (Figure 7.6). Few invertebrates were consumed (Table 7.6), and most were consumed by smaller red snapper. The fishes that were consumed were abundant demersal and pelagic species. Lutjanus campechanus is evidently a top carnivore that feeds on fish which are found on, or in the water column above live bottom.

Mycteroperca microlepis:

Gag were very rarely captured by any gear (only 5 stomachs were collected), but are apparently common at middle shelf stations, based on diver observations. Gag, like red snapper, were top predators which fed mainly on fish (Table 7.7). The only identifiable fish remains were Rhomboplites aurorubens, which is a very abundant live bottom species.

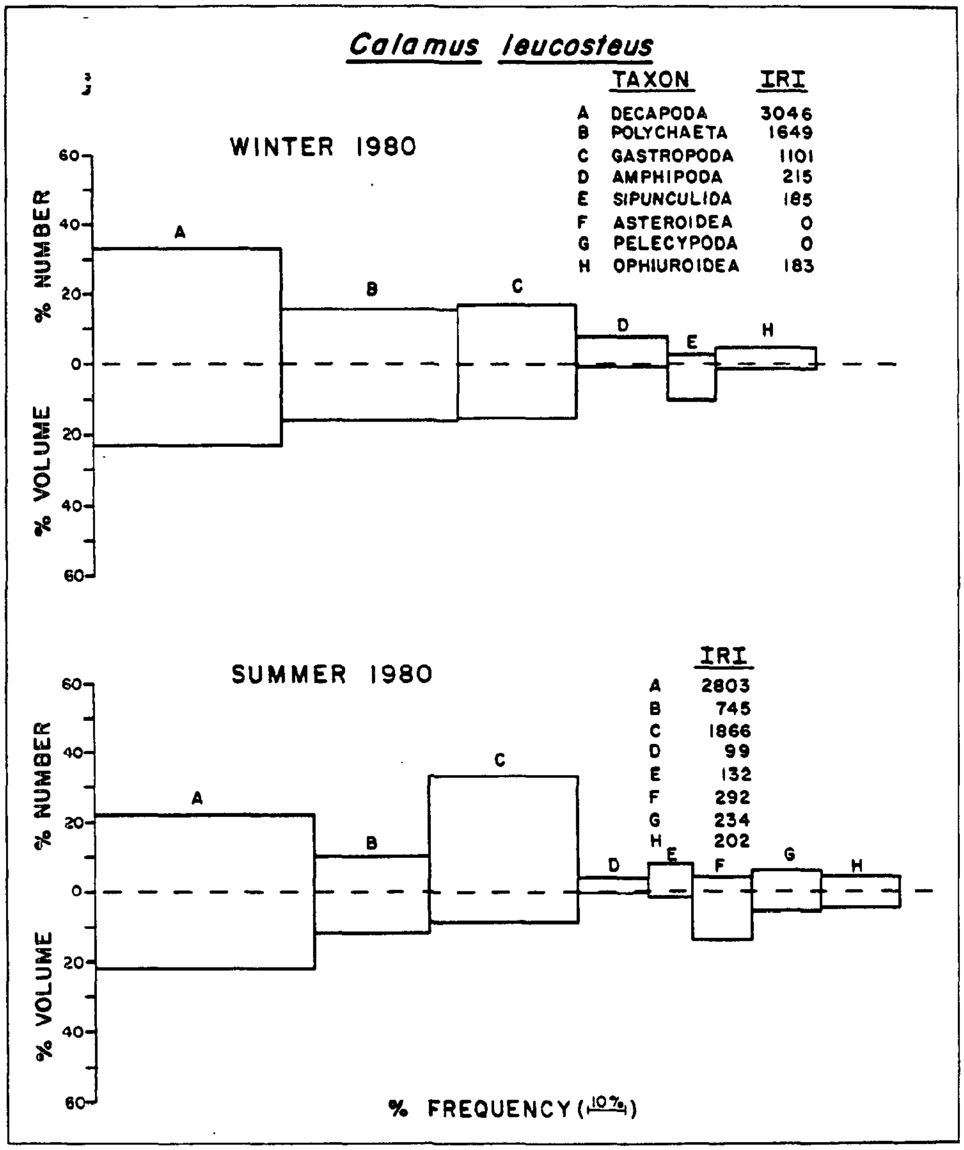


Figure 7.4. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Calamus leucosteus.

Table 7.4. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in *Calamus leucosteus* stomachs for both sampling periods. tr = trace volume.

Taxon	Winter 1980				Summer 1980			
Food Item	F	N	V	IRI	F	N	V	IRI
Algae								
Bacillariophyceae					3.33	0.54	tr.	2
Porifera								
Unidentified Porifera					3.33	0.54	1.09	5
Cnidaria								
Anthozoa								
Actiniaria	11.43	2.10	6.34	96	3.33	0.54	3.26	13
Renilla reniformis	2.86	0.52	0.48	3	3.33	0.54	18.13	62
Total Anthozoa	14.29	2.63	6.81	135	6.67	1.09	21.39	150
Annelida								
Polychaeta								
Arabella iricolor	2.86	0.52	1.29	5				
A. mutans	2.86	0.52	1.70	6	3.33	0.54	4.35	16
Capitellidae	2.86	0.52	0.48	3				
Cirratulidae					6.67	1.09	1.09	14
Diopatra cuprea	2.86	0.52	2.86	10				
Dodecaceria corallii					3.33	0.54	0.07	2
Glycera sp.	2.86	1.05	0.68	5				
Lumbrineris coccinea	2.86	0.52	1.02	4				
Maldanidae	2.86	0.52	0.68	3	3.33	1.09	2.18	11
Nephtyidae					6.67	1.09	0.15	8
Nereidae	2.86	0.52	0.07	2				
Onuphis eremita	2.86	0.52	0.07	2	3.33	1.63	2.83	15
O. nebulosa	2.86	0.52	0.34	2				
O. pallidula	2.86	0.52	0.34	2				
Opheliidae					3.33	0.54	0.07	2
Paranaitis polynoides					3.33	0.54	0.07	2
Petaloproctus socialis	2.86	0.52	0.20	2				
Phyllodocidae	2.86	0.52	0.07	2				
Scalibregmidae?					6.67	1.09	0.44	10
Sigalionidae	2.86	0.52	0.14	2				
Spionidae	2.86	0.52	0.14	2				
Sthenelais sp.	2.86	0.52	0.68	3				
Syllidae	2.86	0.52	0.07	2				
Terebellidae?	2.86	0.52	2.59	9				
Travisia parva	2.86	0.52	0.14	2				
Unidentified Polychaeta	25.71	5.26	2.72	205	10.00	2.17	0.80	30
Total Polychaeta	51.43	15.79	16.28	1649	33.33	10.33	12.04	745
Mollusca								
Gastropoda								
Anachis avara	5.71	2.10	0.34	14				
Epitonium sp.					3.33	10.33	0.36	36
E. multistriatum	2.86	0.52	tr.	2				
Marginella sp.					3.33	0.54	0.44	3
Natica canrena	2.86	0.52	0.07	2	6.67	2.72	1.02	25
Naticidae B	2.86	0.52	0.20	2				
Naticidae					6.67	3.80	0.22	27
Unidentified Gastropoda	28.57	13.16	14.65	794	36.67	16.30	7.32	866
Total Gastropoda	34.29	16.84	15.26	1101	43.33	33.70	9.35	1866
Pelecypoda								
Americardia media					3.33	0.54	0.07	2
Corbula dietziana					3.33	1.63	1.45	10
Tellina sp.					6.67	1.63	0.29	13
Unidentified Pelecypoda					10.00	2.17	3.92	61
Total Pelecypoda					20.00	5.98	5.73	234
Cephalopoda								
Unidentified Cephalopoda	2.86	0.53	0.07	2				

Table 7.4 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Crustacea								
Cirripedia								
Balanus sp.					10.00	1.63	0.22	18
B. trigonus					6.67	1.09	1.02	14
B. venustus					6.67	1.09	0.36	10
Unidentified Cirripedia	2.86	1.58	3.41	14				
Total Cirripedia	2.86	1.58	3.41	14	16.67	3.80	1.60	90
Cumacea								
Cyclaspis varians	2.86	0.52	tr.	2				
Oxyurostylis smithi	17.14	4.21	0.20	76				
Unidentified Cumacea	2.86	0.52	tr.	2				
Total Cumacea	22.86	5.26	0.20	125				
Amphipoda								
Gammaridea								
Ampelisca sp.					6.67	1.09	0.00	7
Ampelisca sp. A					3.33	0.54	0.15	2
A. agassizi	2.86	0.52	0.07	2				
A. vadorum	2.86	0.52	0.07	2				
Erichthonius sp. A	2.86	0.52	tr.	2				
E. brasiliensis	2.86	0.52	tr.	2				
Haustoridae	5.71	1.05	0.07	6				
Lembos unicornis	2.86	0.52	0.07	2				
Tiron tropakis	2.86	0.52	0.07	2				
Trichophoxus floridanus	2.86	0.52	0.07	2	3.33	1.63	0.36	7
Unidentified Gammaridea	5.71	1.58	0.07	9	6.67	1.09	0.07	8
Caprellidea								
Phtisica marina	8.57	1.58	tr.	14				
Total Amphipoda	25.71	7.89	0.48	215	20.00	4.35	0.58	99
Mysidacea								
Bowmaniella portoricensis	2.86	1.05	0.07	3				
Unidentified Mysidacea	2.86	0.52	0.07	2				
Total Mysidacea	5.71	1.58	0.14	10				
Decapoda								
Natantia								
Leptochela papulata	11.43	7.37	2.59	114				
Unidentified Natantia	5.71	1.58	3.54	29	3.33	0.54	tr.	2
Reptantia								
Macrura								
Callianassa atlantica	5.71	1.05	2.72	22				
Panulirus sp. larvae					3.33	0.54	tr.	2
Anomura								
Albunea sp.					6.67	1.09	2.90	27
Euceramus praelongus	2.86	0.52	0.54	3				
Paguridae	8.57	2.10	0.41	22	10.00	2.17	0.58	28
Pagurus sp.	20.00	8.42	1.91	207	20.00	8.15	2.03	204
P. carolinensis	14.21	3.16	1.50	67	23.33	3.80	1.23	118
P. hendersoni	2.86	0.52	tr.	2	3.33	0.54	0.07	2
P. longicarpus	2.86	0.52	0.07	2				
P. piercei					3.33	0.54	0.51	4
P. piercei?	2.86	0.52	0.48	3				
Pylopagurus discoidalis	2.86	0.52	0.07	2				
Brachyura								
Hepatus epheliticus					6.67	1.09	5.37	43
Hypoconcha arcuata	5.71	1.05	0.14	7	3.33	0.54	1.09	5
Mithrax pleuracanthus					3.33	0.54	4.71	18
Parthenope sp.					3.33	0.54	2.18	9
Pinnixa sp.	2.86	0.52	0.07	2				
Xanthidae	5.71	1.05	0.14	7				
Unidentified Brachyura	22.86	4.21	8.79	297	13.33	2.17	1.31	46
Total Decapoda	54.29	33.16	22.96	3046	63.33	22.28	21.97	2803
Unidentified Crustacea	2.86	0.52	0.07	2				
Sipunculida								
Aspidosiphon spinalis	11.43	2.63	0.27	33	13.33	8.15	1.74	132

Table 7.4 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Unidentified Sipunculida	2.86	0.52	9.54	29				
Total Sipunculida	14.29	3.16	9.81	185	13.33	8.15	1.74	132
Ectoprocta								
Diaperoecia floridana	2.86	0.53	0.07	2				
Echinodermata								
Asteroidea								
Astropecten sp.					3.33	0.54	2.18	9
A. articulatus					10.00	1.63	10.01	116
A. duplicatus					3.33	1.63	1.52	11
Total Asteroidea					16.67	3.80	13.71	292
Ophiuroidea								
Unidentified Ophiuroidea	28.57	5.26	1.16	183	23.33	3.80	4.86	202
Echinoidea								
Clypeasteroida					3.33	0.54	0.22	3
Holothuroidea								
Unidentified Holothuroidea	5.71	1.05	6.13	41				
Chordata								
Ascidiacea								
Unidentified Ascidiacea	2.86	0.53	11.92	36				
Pisces								
Decapterus punctatus					3.33	0.54	4.42	17
Unidentified fish scales	2.86	0.52	0.07	2				
Unidentified Teleostei	17.14	3.16	5.18	143	3.33	0.54	1.31	6
Total Pisces	20.00	3.68	5.25	179	6.67	1.09	5.73	45
Number of stomachs examined		50				43		
Examined stomachs with food		35				30		

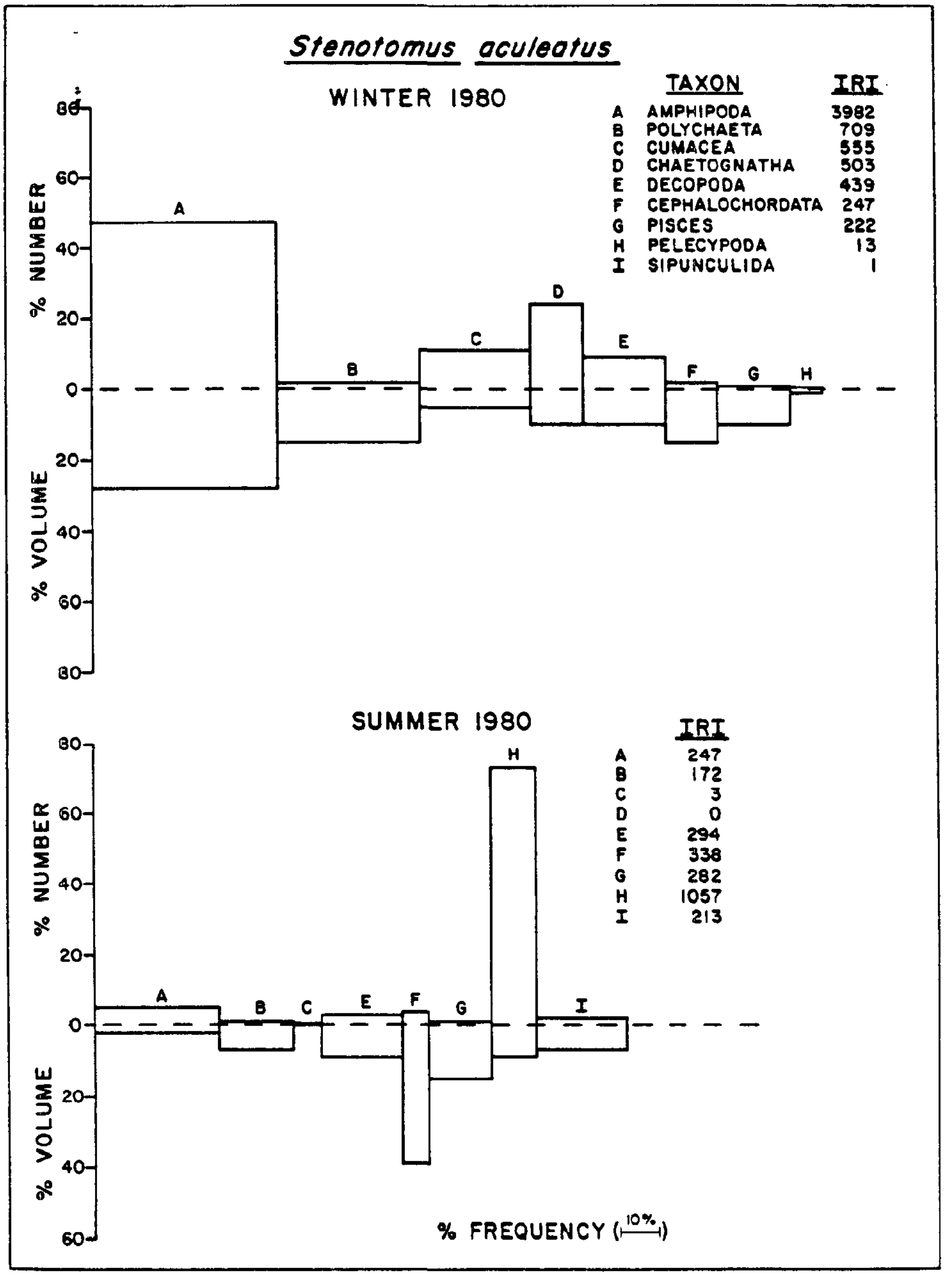


Figure 7.5. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Stenotomus aculeatus.

Table 7.5. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in *Stenotomus aculeatus* stomachs for both sampling periods. tr = trace volume.

Taxon / Food Item	Winter 1980 F	Winter 1980 N	Winter 1980 V	Winter 1980 IRI	Summer 1980 F	Summer 1980 N	Summer 1980 V	Summer 1980 IRI
Cnidaria								
Hydrozoa								
Unidentified Hydrozoa	2.94	0.11	0.21	1	2.56	0.12	0.27	1
Annelida								
Polychaeta								
Arabella iricolor	2.94	0.11	3.20	10				
Armandia maculata	8.82	0.55	0.64	11				
Cirratulidae					2.56	0.12	0.27	1
Eunicidae					2.56	0.12	2.66	7
Exogone sp.					2.56	0.12	0.27	1
Glycera sp. A	2.94	0.11	2.35	7				
Lumbrineris sp.					2.56	0.12	0.27	1
Maldanidae	2.94	0.11	1.49	5				
Nereidae					2.56	0.12	0.27	1
Opheliidae					2.56	0.12	1.86	5
Phyllodocidae	2.94	0.11	0.43	2				
Sabellaria vulgaris	2.94	0.11	0.21	1				
Sthenelais boa					2.56	0.12	1.06	3
Unidentified Polychaeta	20.59	0.77	7.04	161	5.13	0.36	0.53	5
Total Polychaeta	41.18	1.88	15.35	709	20.51	1.19	7.18	172
Mollusca								
Gastropoda								
Natica pusilla					5.13	0.24	0.27	3
Philine sagra					2.56	0.12	0.27	1
Unidentified Gastropoda					2.56	0.12	2.13	6
Total Gastropoda					7.69	0.48	2.66	24
Pelecypoda								
Ervilia concentrica					12.82	73.36	9.04	1056
Pteria colymbus	2.94	0.11	0.21	1				
Unidentified Pelecypoda	5.88	0.33	0.85	7				
Total Pelecypoda	8.82	0.44	1.06	13	12.82	73.36	9.04	1057
Crustacea								
Ostracoda								
Ostracoda B	2.94	0.11	tr.	<1				
Ostracoda C	2.94	0.11	tr.	<1				
Total Ostracoda	5.88	0.22	tr.	1				
Copepoda								
Alteutha sp.	2.94	0.11	tr.	<1				
Bradya sp.					2.56	0.12	tr.	<1
Calanoida	8.82	0.55	tr.	5	7.69	0.83	0.27	8
Harpacticoida					2.56	0.36	tr.	1
Labidocera aestiva	2.94	0.11	tr.	<1				
Longipedia helgolandica					2.56	0.12	tr.	<1
Temora turbinata					10.26	6.06	0.53	68
Total Copepoda	14.71	0.77	tr.	11	20.51	7.49	0.80	170
Branchiura								
Argulus sp.					2.56	0.12	tr.	<1
Cumacea								
Cyclaspis varians	14.70	0.77	0.64	21				
Oxyurostylis smithi	20.59	10.28	4.05	295				
Unidentified Cumacea	8.82	0.77	0.64	12	7.69	0.36	tr.	3
Total Cumacea	32.35	11.82	5.33	555	7.69	0.36	tr.	3
Isopoda								
Erichsonella filiformis	2.94	0.11	0.64	2				
Paracerceis caudata	2.94	0.11	0.43	2				
Total Isopoda	2.94	0.22	1.07	4				

Table 7.5 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Amphipoda								
Gammaridea								
Ampelisca sp.					2.56	0.12	0.27	1
A. agassizi	2.94	0.11	tr.	<1				
Amphipoda E	2.94	0.66	0.21	3	7.69	0.83	0.27	8
Amphithoidae	2.94	0.11	0.21	1				
Corophiidae					5.13	0.47	0.27	4
Erichthonius brasiliensis	17.65	19.56	9.81	518				
Gitanopsis sp.	5.88	0.44	0.21	4	2.56	0.12	tr.	<1
Maera sp.	2.94	0.11	0.21	1				
Microdeutopus myersi	2.94	0.22	tr.	1	2.56	0.12	0.27	1
Photis sp.	5.88	0.22	0.21	3	5.13	0.47	0.27	4
P. pugnator	8.82	0.88	0.43	12				
Podoceridae	2.94	0.33	0.21	2				
Podocerus sp.	14.70	5.64	2.56	120				
Rudilemboides naglei					2.56	0.12	tr.	<1
Stenothoe georgiana	20.59	2.43	0.64	63				
Synchelidium americanum					2.56	0.12	tr.	<1
Unidentified Gammaridea	14.70	2.10	0.85	43	12.82	1.07	0.00	14
Caprellidea								
Caprella sp.	2.94	0.11	0.21	1				
C. penantis	5.88	0.22	0.43	4	2.56	0.71	0.27	3
Luconacia incerta	14.70	6.74	4.48	165	2.56	0.12	0.27	1
Phtisica marina	17.65	3.42	2.99	113	5.13	0.36	0.27	3
Caprellidae A	17.65	1.77	2.99	84				
Unidentified Caprellidea	17.65	1.77	1.71	61				
Hyperiidea								
Lestrigonus sp.					2.56	0.12	tr.	<1
Total Amphipoda	52.94	46.85	28.36	3982	35.90	4.76	2.13	247
Mysidacea								
Bowmaniella portoricensis	14.70	0.88	1.49	35	12.82	0.95	2.93	50
Promysis atlantica	5.88	0.44	0.64	6				
Total Mysidacea	20.59	1.33	2.13	71	12.82	0.95	2.93	50
Decapoda								
Natantia								
Alpheidae					2.56	0.12	0.27	1
Hippolytidae	2.94	0.11	0.21	1				
Latreutes parvulus	8.82	8.18	7.68	140				
Lucifer faxoni					7.69	2.14	2.93	39
Palaemonidae	2.94	0.11	0.21	1				
Processa sp.					2.56	0.12	tr.	<1
Sicyonia typica					5.13	0.24	2.39	13
Synalpheus longicarpus					2.56	0.12	2.39	6
Unidentified Natantia	11.76	0.44	1.71	25				
Reptantia								
Anomura								
Pagurus sp.					2.56	0.12	0.27	1
P. carolinensis					2.56	0.12	0.27	1
Brachyura								
Brachyura megalopae					2.56	0.24	0.27	1
Unidentified Brachyura					5.13	0.24	0.53	4
Total Decapoda	23.53	8.84	9.81	439	23.08	3.45	9.31	294
Sipunculida								
Aspidosiphon misakiensis					2.56	0.12	0.27	1
A. spinalis	2.94	0.11	0.21	1	12.82	0.71	3.72	57
Unidentified Sipunculida	2.94	0.11	tr.	<1	15.38	0.83	2.66	54
Total Sipunculida	2.94	0.22	0.21	1	25.64	1.66	6.65	213
Ectoprocta								
Diaperoecia floridana	2.94	0.22	0.21	1	2.56	0.12	tr.	<1
Echinodermata								
Ophiuroidea	11.76	0.44	1.07	18	17.95	0.83	4.52	96
Chaetognatha								
Unidentified Chaetognatha	14.71	24.20	10.02	503				

Table 7.5 (Continued)

	Winter 1980				Summer 1980			
	F	N	V	IRI	F	N	V	IRI
Chordata								
Cephalochordata								
Branchiostoma caribaeum	14.70	1.66	15.14	247	7.69	4.28	39.63	338
Pisces								
Unidentified Teleostei	20.59	0.77	10.02	222	17.95	0.83	14.89	282
Number of stomachs examined		49				47		
Examined stomachs with food		34				39		

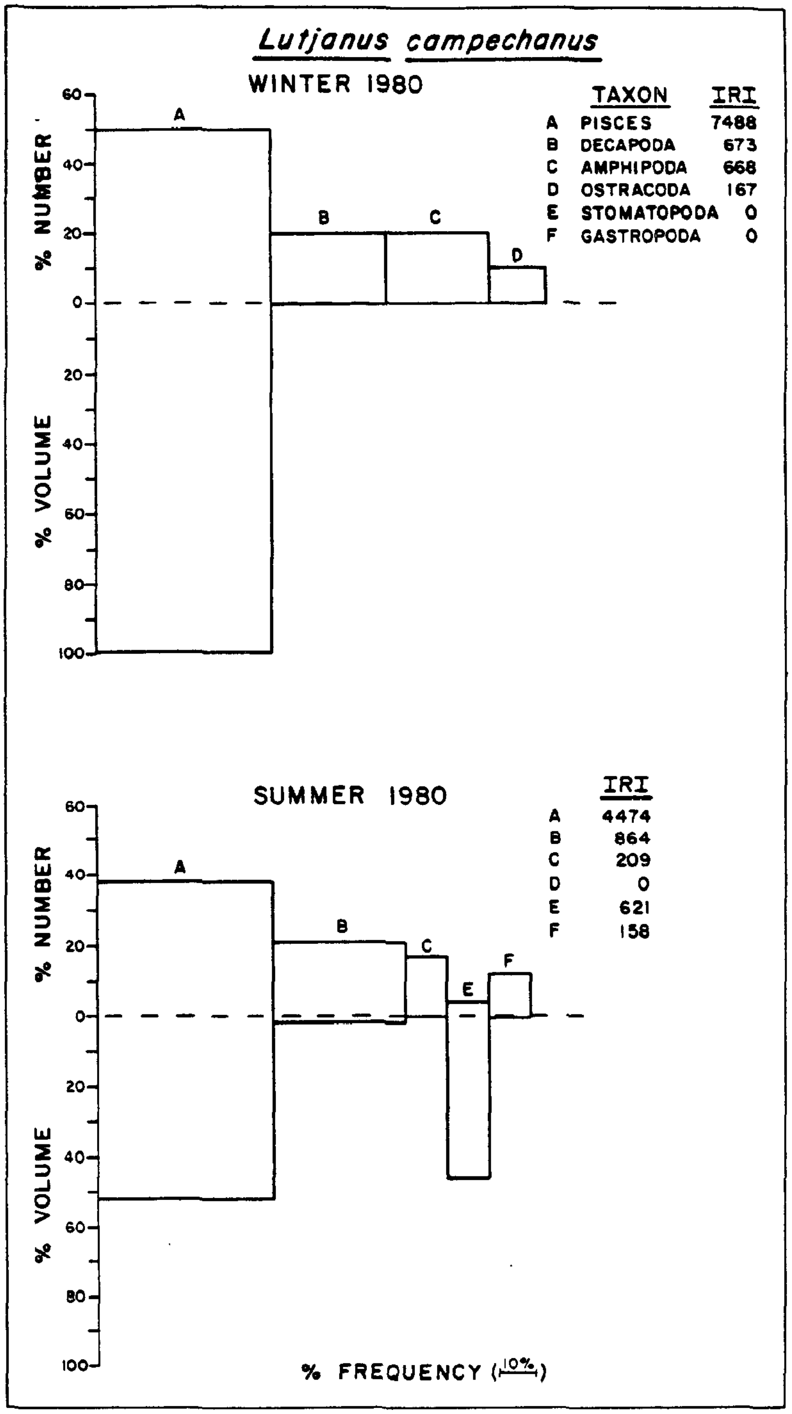


Figure 7.6. Frequency, number, volume (percents) and index of relative importance (IRI) of higher taxonomic groups of food in the diet of Lutjanus campechanus.

Table 7.6. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in *Lutjanus campechanus* stomachs for both sampling periods. tr = trace volume.

Taxon / Food Item	Winter 1980 F	Winter 1980 N	Winter 1980 V	Winter 1980 IRI	Summer 1980 F	Summer 1980 N	Summer 1980 V	Summer 1980 IRI
Mollusca								
Gastropoda								
Cavolinia longirostris					12.50	12.50	0.21	159
Crustacea								
Ostracoda								
Ostracoda A	16.67	10.00	0.01	167				
Stomatopoda								
Squilla sp.					12.50	4.17	45.53	621
Cumacea								
Cyclaspis varians					12.50	4.17	0.04	53
Isopoda								
Serolis mgrayi					12.50	4.17	tr.	52
Amphipoda								
Erichthonius brasiliensis	16.67	10.00	0.01	167	12.50	16.67	0.04	209
Hippomedon sp.	16.67	10.00	0.01	167				
Total Amphipoda	33.33	20.00	0.02	668	12.50	16.67	0.04	209
Decapoda								
Natantia								
Leptochela sp.	16.67	10.00	0.01	167				
Thor sp.					12.50	4.17	0.79	62
Unidentified Natantia					12.50	4.17	0.25	55
Reptantia								
Macrura								
Scyllarus chacei					12.50	4.17	0.62	60
Brachyura								
Ovalipes stephensoni	16.67	10.00	0.18	170				
Portunus anceps					12.50	4.17	0.46	58
Unidentified Brachyura					12.50	4.17	0.08	53
Total Decapoda	33.33	20.00	0.19	673	37.50	20.83	2.20	264
Chordata								
Pisces								
Decapterus punctatus					12.50	20.83	37.28	726
Haemulon aurolineatum					12.50	4.17	5.39	119
Rhomboplites aurorubens					12.50	4.17	4.56	109
Stenotomus sp.	16.67	10.00	71.21	1353				
Unidentified Teleostei	50.00	40.00	28.56	1952	25.00	8.33	4.76	327
Total Pisces	50.00	50.00	99.77	7488	50.00	37.50	51.99	4474
Total stomachs examined		20				11		
Examined stomachs with food		6				8		

Table 7.7. Percent frequency occurrence (F), percent number (N), percent volume (V), and index of relative importance (IRI) of food items in Mycteroperca microlepis stomachs for both sampling periods.

Taxon Food Item	Winter 1980 F	N	V	IRI	Summer 1980 F	N	V	IRI
Mollusca								
Gastropoda								
Natica canrena					50.00	16.67	3.15	991
Crustacea								
Decapoda								
Ranilia muricata					50.00	33.33	13.01	2317
Chordata								
Pisces								
Rhomboplites aurorubens	50.00	50.00	99.82	7491				
Unidentified Teleostei	50.00	50.00	0.18	2509	100.00	50.00	83.84	13384
Total Pisces	100.00	100.00	100.00	20000	100.00	50.00	83.84	13384
Total number of stomachs examined		2				3		
Examined stomachs with food		2				2		

Overlap in Diet:

Results of cluster analysis (Figure 7.7) indicated very low similarity in diet among predator species examined in both winter and summer. Individual similarity comparisons between species (Figure 7.8) were also low. In winter, P. pagrus and C. leucosteus were most similar in diet. Although the most abundant prey species for these two predators differed, they shared many of their less abundant prey species. Rhomboplites aurorubens and S. aculeatus both had Oxyurostylis smithi as an abundant prey species and were more similar in diet to each other than to any other predator group. Centropristis striata was joined to these two predators because it primarily consumed Erichthonius brasiliensis, the second most abundant prey species in the diet of S. aculeatus. Mycteroperca microlepis and L. campechanus both consumed fish and were joined together at a low similarity value.

In summer, S. aculeatus and R. aurorubens were the two species most similar in diet, although similarity values were again quite low. Pelecypods (Ervilia concentrica), copepods (Temora turbinata), and pelagic decapods (Lucifer faxoni) were common in the diet of both species. Centropristis striata and Calamus leucosteus overlapped in diet slightly. Although the most abundant prey consumed by these two species differed, they had some prey in common which were not consumed as much by other species (e.g. pagurids, ophiuroids). In summer, L. campechanus consumed many more invertebrates (Table 7.6) and was more similar in diet to P. pagrus, which also included more fish as well as invertebrates in its diet. Mycteroperca microlepis remained primarily piscivorous and was grouped with these two species.

Habitat of Prey Items:

All predators examined fed on live bottom organisms to some extent, and some species appeared to be highly dependent on live bottom prey (Figure 7.9). Centropristis striata and P. pagrus, in particular, consumed a large volume of live bottom species. Stenotomus aculeatus had a diet dominated by live bottom species in winter, but in summer this species consumed predominantly sand bottom fauna. Rhomboplites aurorubens fed mainly in the water column. The large predators, M. microlepis and L. campechanus, consumed mainly fish from several habitats.

DISCUSSION

Randall (1967), in an extensive study of the food habits of 212 species of West Indies fishes, classified reef fishes into seven feeding types: (1) plant and detritus feeders, (2) zooplankton feeders, (3)sessile animal feeders, (4) "shelled" - invertebrate feeders, (5) generalized carnivores on a variety of mobile benthic animals, (6) ectoparasite feeders, and (7) fish feeders. Although most tropical reef fishes fit into more than one category and may even change from one type to another with age, Randall grouped his 212 species into one of these categories based on the volume of major prey taxa.

Most fishes examined in the present study were generalized carnivores on a variety of mobile benthic invertebrates and fish. This category included

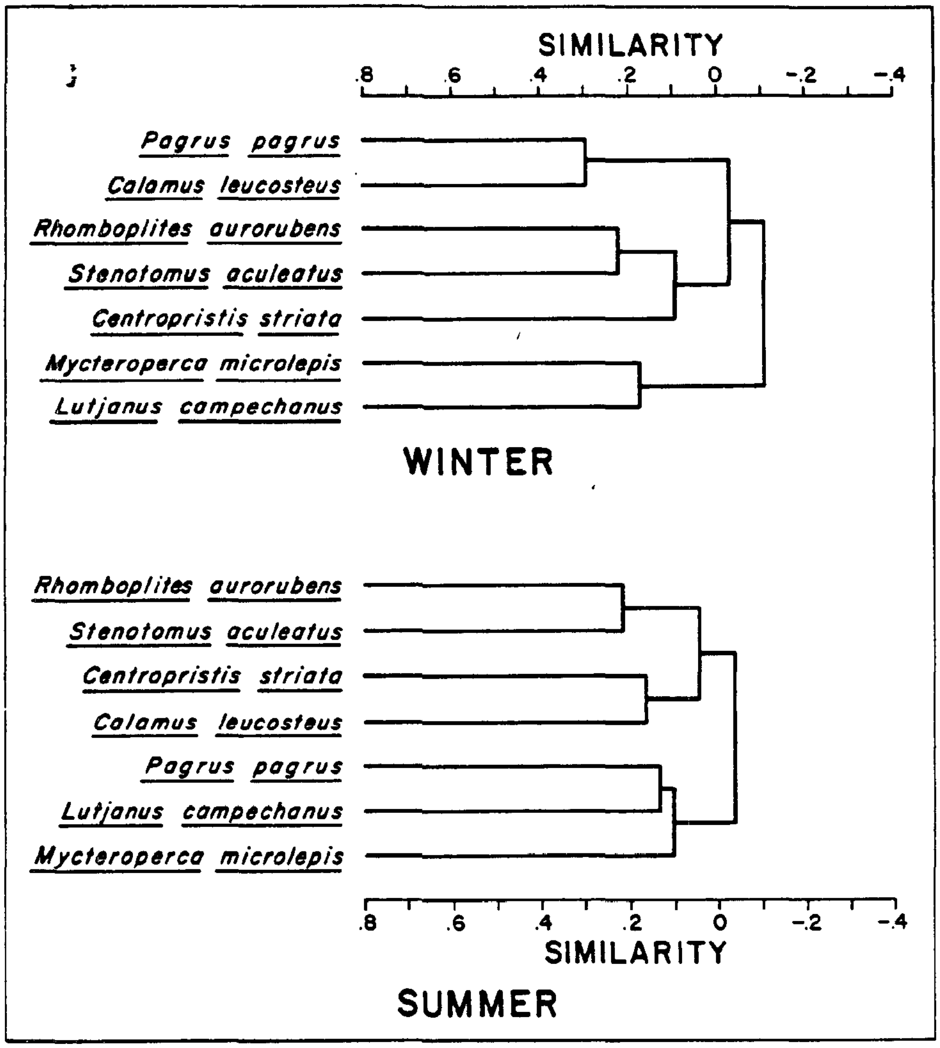


Figure 7.7. Dendrograms depicting overlap in diet among predators.

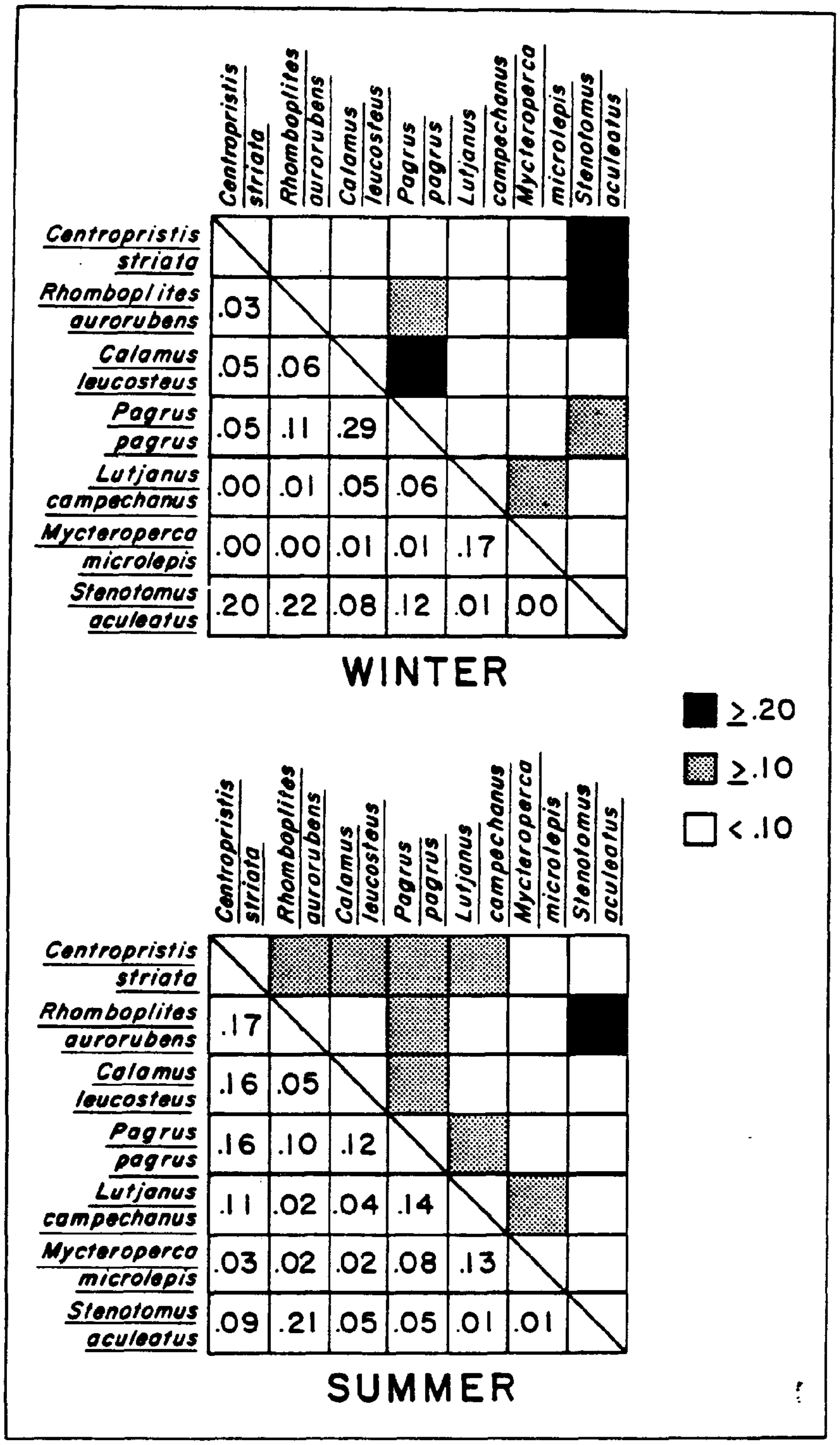


Figure 7.8. Diet overlap between predators as measured by the Bray-Curtis similarity measure.

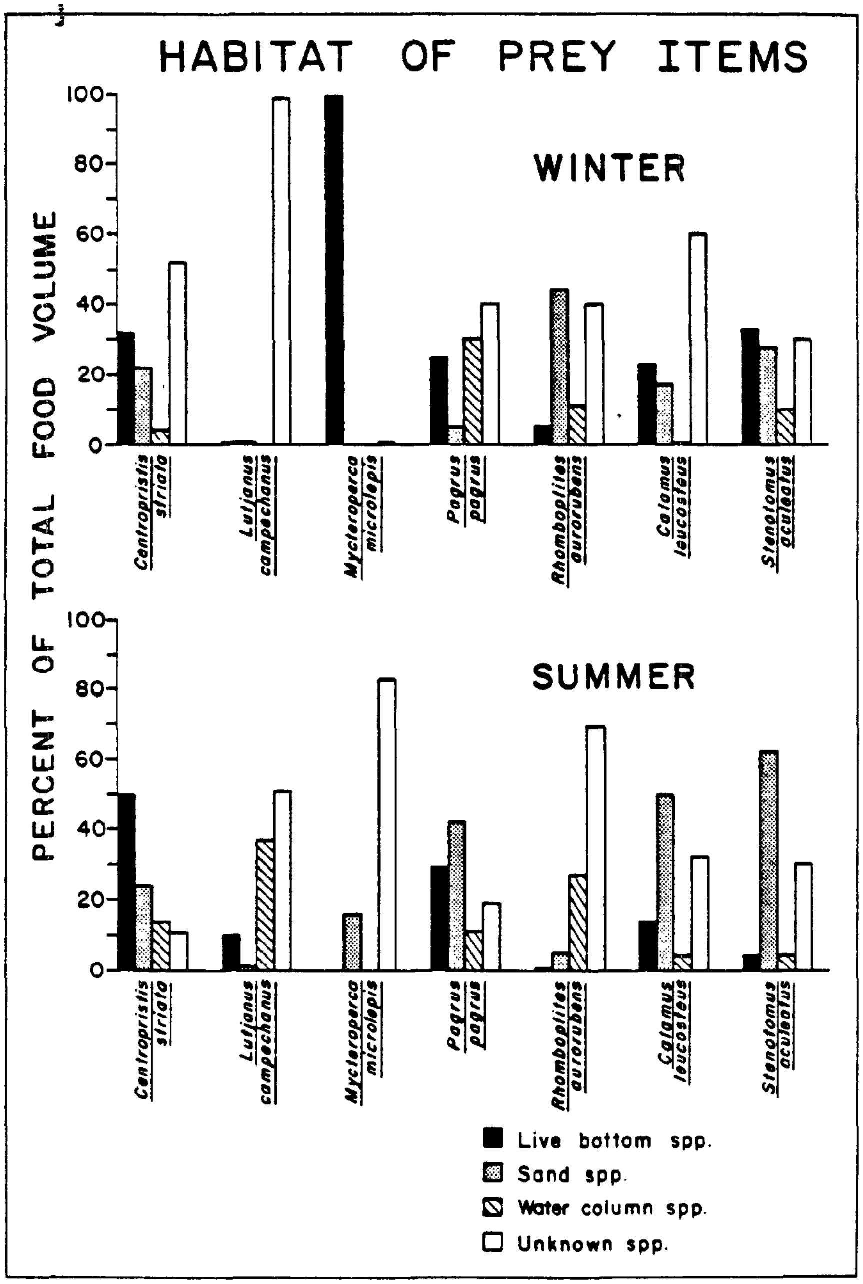


Figure 7.9. Percent of total volume of food consisting of live bottom organisms, sand bottom organisms, water column organisms or prey for which habitat is unknown.

the black sea bass, C. striata. Link (1980) studied the food habits of C. striata and also noted a generalized diet. Many of the prey (decapods, fishes) that were frequently consumed were also frequent in the present study. The most noteworthy differences were the relatively high frequency of gastropods and the infrequency of amphipods in stomachs which he examined. The most noteworthy seasonal difference in the food habits of black sea bass in the present study was the relative abundance of amphipods in the diet in winter and their scarcity in the diet in summer. Decapods were the most abundant prey taxon in summer and this was also found to be true for black sea bass collected off North Carolina (Volume II).

Red porgy, P. pagrus, was also a generalized predator on mobile benthic species. Manooch (1977) noted a very diverse diet in this species and found decapods and fish were frequent food items, a finding duplicated by the present study. Manooch (1977) also noted a high frequency of mollusks in winter (24.0%) and summer (30.9%). Mollusks were very infrequent in the diet of red porgy in the present study; polychaetes and amphipods, which Manooch found to be rare, were frequently consumed. Because Manooch (1977) included intestine contents in his analysis, shelled mollusks, which are slowly digested and may be retained in the intestine, would appear to be more frequent than more rapidly digested polychaetes and small crustaceans.

Southern porgy, S. aculeatus, was also a generalized benthic carnivore, and is apparently a very opportunistic predator as evidenced by the large seasonal differences in diet (Figure 7.5). Southern porgy switched from a diet dominated by amphipods in winter to a diet dominated by bivalves, which were abundant following recent settlement from the plankton, in summer. Southern porgy collected off North Carolina had a diet dominated volumetrically by algae, reflecting the increased availability of algae for food in North Carolina waters (Volume II). Southern porgy apparently change their diet depending on prey availability, and opportunistically feed on whatever prey is abundant.

These generalized carnivores, such as black sea bass, red porgy, and southern porgy, include the greatest number of species of any feeding type on tropical reefs (Randall 1967, Parrish and Zimmerman 1977) and are also represented by many species on live bottom reefs in the South Atlantic Bight. Other dominant species which are included in this feeding type are Haemulon aurolineatum, Equetus lanceolatus, Bothus ocellatus, Scorpaena spp., and Dactylopterus volitans (Randall 1967). Some of the most abundant live bottom species (S. aculeatus and H. aurolineatum) are included in this group. These species fed heavily on organisms from sand bottom areas of the shelf. Haemulon aurolineatum is known to move off the reef to feed over sand bottom at night, returning to the reef during the day (Parrish and Zimmerman 1977). This feeding behavior may also occur in other species which fed heavily on sand bottom organisms (e.g., C. leucosteus, S. aculeatus) and could function in transferring energy from sand bottom areas to adjacent live bottom.

Two species analyzed in the present study were fish feeders: Mycteroperca microlepis and Lutjanus campechanus. Both species fed on other live bottom or schooling pelagic fishes. Lutjanus campechanus also frequently consumed invertebrates, as noted by Bradley and Bryan (1975). Other species collected in the present study and categorized as piscivores (Randall 1967) were Ginglymostoma cirratum, Rhizoprionodon terraenovae, Synodus spp., Rachycentron canadum, Caranx spp., and Seriola dumerili. Most of these species were present but uncommon at our study sites.

Rhomboplites aurorubens examined in the present study was a zooplankton feeder which also fed heavily on benthic invertebrates. Grimes (1979) examined the food habits and morphology of this species and also concluded that this species was a water column forager.

Grimes (1979) examined stomachs of R. aurorubens caught off the Carolinas and, although he examined few stomachs from winter (N = 2), his summer results (N = 46) were quite different than those presented here. Cephalopods, pelagic gastropods, colonial tunicates, and hyperiid amphipods dominated volumetrically whereas fish, a dominant item in the present study, constituted a small volume of the diet. The different results between these two studies and the seasonal variation found within both studies is not surprising in light of the planktonic diet of this species and the marked seasonal fluctuations in species composition of plankton communities in the South Atlantic Bight (Bowman 1971). Other abundant live bottom species caught in the present study and which feed in the water column include Decapterus punctatus and Apogon pseudomaculatus (Randall 1967).

Calamus leucosteus, which was very generalized in its food habits and could be included in several feeding categories, also fed heavily on shelled invertebrates (mollusks, barnacles, hermit crabs). Randall included several related species of Calamus in this feeding type. Other species found on live bottom in the present study and which Randall included in this group were Haemulon plumieri and Sphoeroides spengleri.

Although attached sessile forms (anthozoans, hydroids, bryozoans, ascidians, sponges, etc.) were included in the diet of most predators, no predator specialized on these animals. This is not surprising since these organisms often possess chemical or mechanical defenses which deter many predators (Randall 1967, Stoecker 1980). Many of the mobile benthic invertebrates that were important as prey are associated with sessile forms (e.g., alpheid shrimps, caprellids), and these sessile forms may have been accidentally ingested by fish preying on mobile species. Of the 11 fish species noted by Randall as sessile animal feeders, only Acanthostracion quadricornis commonly occurs in the South Atlantic Bight and was caught at all inner and middle shelf stations.

No ectoparasite feeders were found among the species examined. Grimes (1979) noted a high incidence of fish scales in Rhomboplites aurorubens stomachs and attributed this to scale eating or parasite picking. However, Randall (1967) noted fish scales in the stomachs of several species and concluded that they were probably eaten after they were detached from schooling pelagic fishes as a result of the activity of other predators. Rhomboplites aurorubens is primarily a plankton feeder and could ingest scales in this manner. No ectoparasites were found in stomachs by Grimes (1979) or in the present study. The only known ectoparasite feeder (Randall 1967, Cressy and Lachner 1970) captured in the present study was Echeneis naucrates.

None of the species included in the present analysis were plant and detritus feeders; however, Aluterus schoepfi, a common shelf and live bottom species which was captured in this study, feeds on plant material (Randall 1967).

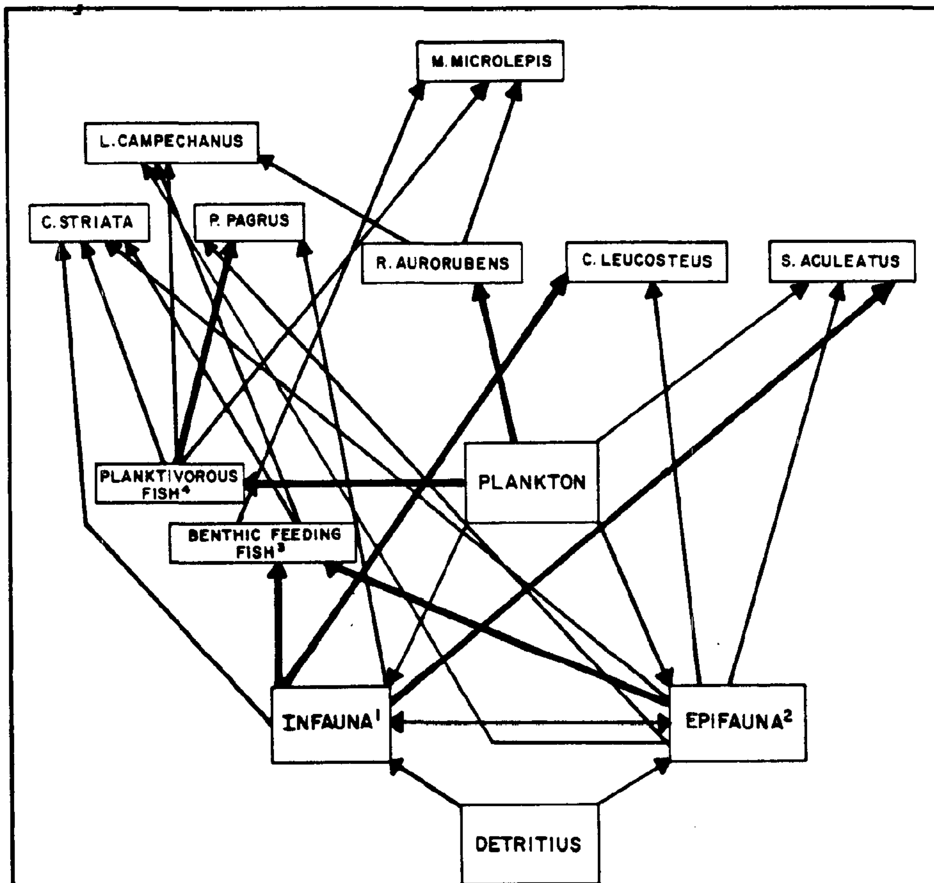
Overlap in diet among the fishes examined was low compared to similarity values found in other studies (McEachran et al. 1976, Ross 1977, Sedberry 1980). Most comparisons between species in this study resulted in values less than 0.20, and groups of predators were joined together at even lower similarity levels, usually less than zero. Sedberry (1980), using the same clustering algorithm on dominant shelf fishes in the Middle Atlantic Bight, found interspecific comparisons as high as 0.68, with most predator groups formed at levels higher than 0.20. Whereas, Sedberry (1980) found most benthic feeding fish shared abundant prey species (mainly two epifaunal amphipod species), the present study indicates that the live bottom fish community is supported by a variety of organisms, with no species that were important to several predators. The higher diversity of fishes on live bottom in the South Atlantic Bight (see Chapter 6 for further discussion) should result in finer resource partitioning (Huston 1979), and thus result in lower food overlap. The complex habitat structure of live bottoms provides abundant epifaunal, infaunal, and water column food resources. Adjacent sand bottom areas protected from erosion by surrounding rock and the sand layer often noted on rock surfaces (Chapter 3) provides feeding ground for infaunal feeders. The variety of food resources allows more specialization among predators and less overlap in diet. These alternative food sources for the live bottom fishes examined in this study and their relative importance are depicted in Figure 7.10, which illustrates the basic trophic structure observed at our live bottom study areas.

Predation can be an important factor in controlling community structure of infaunal (Virnstein 1977, 1979) and epifaunal (Paine 1974, Peterson 1979) communities, and grazing by herbivores influences community structure in algal communities (Lubchenco 1978). Predation and grazing by fishes may influence the structure of live bottom communities; however, investigation of these effects was beyond the scope of this study. Because natural phenomena such as predation may affect live bottom community structure as much as petroleum development could, the importance of predation as a factor in community structure should be investigated in future studies. Such studies should include predator removal, exclosure, and enclosure experiments.

IMPACT/ENHANCEMENT

The potential impact of oil and gas development on live bottom fishes may be directly related to their food habits and the trophic structure of live bottom areas. Drilling itself would destroy potential prey habitat. Overboard discharge of drill cuttings and drilling muds may cause smothering of benthic organisms resulting in reduced prey abundance. Introduction of toxic concentrations of trace metals and hydrocarbons could also reduce prey abundance in localized areas which would, in turn, result in localized reduction of predator abundance. Fishes are highly mobile and may be able to avoid areas disturbed by oil development. However, many reef fishes, including the priority species *L. campechanus* and *R. aurorubens* (Fable 1980) may move very little from a "home" reef. In addition, many species feed heavily on live bottom organisms. Destruction of a live bottom habitat would adversely affect those species that could not utilize infaunal sand bottom prey or could not be accommodated on an adjacent reef because of space limitations thought, by some, to control reef fish population size (Smith and Tyler 1972, Luckhurst and Luckhurst 1978).

Besides eliminating food resources, oil development has other potential effects on the feeding of fishes. A major effect of petroleum on marine



[1]Mainly sand bottom species
[2]Mainly mobile forms associated with attached fauna
[3]Other abundant demersal species (H. aurolineatum, E. lanceolatus)
[4]Schooling pelagic species (D. punctatus, clupeids, anchovies)

Figure 7.10. Schematic food web depicting alternate food sources for live bottom fishes. Wider lines indicate major food sources; narrower lines indicate less important food sources.

organisms is a reduction in chemosensory ability (Kittredge 1974). Feeding in fishes is often initiated through chemoreception (Kleerekoper 1969, Hara 1971), and chemosensory cues have been shown to be important in the feeding behavior of several fishes (Bardach and Case 1965, de Groot 1969). Oil spills could negatively affect these species. Reduced visibility caused by drilling could also decrease fishes' ability to locate prey visually.

On the other hand, drilling and production structures offer a potential for enhancement of food resources. These platforms would provide additional substrate for the growth and production of sessile invertebrates and associated mobile species which are important prey for many fishes. Drilling and production structures would also attract schooling pelagic species (Klima and Wickham 1971) which are important prey for top carnivores, including priority species of commercial and recreational importance.

CONCLUSIONS

- Seven fish species were proposed as priority species for food habits analysis: *Centropristis striata*, *Epinephelus niveatus*, *Lutjanus campechanus*, *Mycteroperca microlepis*, *M. phenax*, *Pagrus pagrus*, and *Rhomboplites aurorubens*. *Epinephelus niveatus* and *M. phenax* were not collected, and two dominant non-priority species were substituted: *Stenotomus aculeatus* and *Calamus leucosteus*.

- Black sea bass, *Centropristis striata*, and red porgy, *Pagrus pagrus*, were generalized carnivores which fed mainly on live bottom taxa. Both of these species fed heavily on decapods and fishes; however, black sea bass also consumed many amphipods, whereas red porgy fed heavily on polychaetes.

- Vermilion snapper, *Rhomboplites aurorubens*, is a zooplankton feeder which fed primarily in the water column. Food habits of vermilion snapper varied greatly with season; cumaceans, ostracods, and amphipods were the most important prey in winter, whereas fish, decapods, and copepods were most important in summer.

- Whitebone porgy, *Calamus leucosteus*, fed primarily on sand bottom taxa, but many live bottom taxa were also consumed. Decapods, polychaetes, and gastropods were the most important prey during both seasons.

- Southern porgy, *Stenotomus aculeatus*, is a generalized carnivore which consumed many live and sand bottom species. Amphipods, fishes, and polychaetes were the most important prey in winter, whereas fishes, pelecypods, and amphipods were the most important prey in summer.

- Red snapper, *Lutjanus campechanus* and gag, *Mycteroperca microlepis*, both fed heavily on fishes. Red snapper also consumed several invertebrates from sand and live bottom habitats.

- Overlap in diet among predators was low. This is probably due to the high diversity of predator and prey communities, and to the various alternative food sources (infauna, epifauna, zooplankton) found in live bottom areas.

- The impact of oil development on live bottom fishes may be directly related to their food habits and feeding behavior. Drilling itself and mud disposal could cause destruction of prey habitat or smothering of prey organisms. Petroleum from oil spills may reduce prey abundance or interfere with prey detection and feeding behavior in fishes.

- Drilling and production platforms may enhance fish productivity by providing additional substrate for epifaunal invertebrates, which are an important food source for some priority species. Attraction of schooling pelagic fishes to production structures could provide additional food for top carnivores (snappers and groupers).

CHAPTER 8

METHODOLOGY EVALUATION AND RECOMMENDATIONS FOR FUTURE STUDIES

METHODOLOGY EVALUATION

Overall, the wide variety of sampling gears utilized in this study provided a good characterization of the diverse fauna present at the study sites. Due to constraints in funding and the amount of time available to analyze samples, the number of replicate collections obtained using each gear was limited. Thus, many species were probably missed, especially cryptic forms common under ledges and in crevices. Additionally, estimates of the relative abundance and frequency of occurrence of species collected were crude due to high variability among replicates (as noted below). Even so, this study provides a far more comprehensive data base on live bottom biota than any previous studies in the South Atlantic Bight. Evaluations of each gear are provided below.

Remote Censusing Gears:

Television Transects - Reconnaissance transects performed using the underwater television system were extremely useful in defining the extent of live bottom, even when this type of bottom was not detected on the fathometer. The camera was also very useful in assessing: (1) the percentages of various bottom types within the study area; and (2) the presence and relative frequency of megafauna and large fish which were often not captured in removal sampling gears. A limitation of this gear is the relatively narrow field of view, but our technique of analyzing the tapes does provide an estimate for the surrounding area. Better quantitative estimates of selected invertebrates could have been obtained if the camera had been mounted on a sled and towed in transects across the study areas so that the sled was in continuous contact with the bottom. This would eliminate variability in the width of the sled paths analyzed and permit accurate counts instead of presence/absence frequency estimates. However, using a sled at many of the sites might have resulted in camera damage or loss from rock relief. Color video would have greatly improved our ability to identify organisms, although these cameras are substantially more expensive.

Still Camera Transects - Remote still photographic transects conducted 3 m above bottom helped to confirm television observations and provided a more quantitative means of establishing densities of selected fauna. Unfortunately, poor water clarity and the limited number of live bottom photographs analyzed decreased the effectiveness of this technique. When water clarity permits a good view of the bottom from this height, this technique should prove quite effective, provided that a large number of quadrats are assessed. The photographs taken 1 m above bottom were not as useful as we originally thought they would be, and we do not recommend this effort in future studies. From 1 m above bottom, the size of the quadrat analyzed is small ($0.5\ m^2$), and recognizable fauna is not well represented due to patchy distribution patterns.

Removal Sampling Gears:

Trawl - The trawl used in our study was the most effective gear for sampling a high diversity of demersal fishes. Because the distance towed was known, we were able to obtain standardized (by area) estimates of fish abundance and biomass. The trawl was less effective at capturing large, highly mobile species, and probably missed many small cryptic forms as well. Because of diel changes in the fish fauna, replicated tows are necessary for both day and night. Although it is not a quantitative sampler for invertebrates, the trawl did catch large sessile species (sponges, octocorals) and several mobile decapod crustaceans that were missed with other gears.

Baited Fishing Gears - Although the baited gears were not as effective at capturing fishes present at our study areas, these gears were the only way to catch fish at untrawlable sites. Vertical longlines were the least effective gear and should not be deployed in future studies. Hook and line collections were useful, but more time should be spent on this effort. Electric reels and fishing rods are easier to deploy than manual snapper reels and should be substituted in hook and line collections. Traps were effective in catching some fish species at stations which could not be trawled. They were particularly useful at outer shelf stations where water depth and high drift speed made hook and line fishing difficult.

Fish Sled - As stated in the original proposal, a question of significance to this study concerns the importance of live bottom areas as nursery habitats for larval and juvenile fishes. Conventionally, larval fishes are collected with plankton nets that sample at the surface or throughout the entire water column. As a result, larvae associated with the bottom are not frequently sampled. Most juvenile fishes (particularly young-of-the-year) are probably also undersampled because of their ability to avoid sampling gears designed to capture larvae and adults, and because most conventional surveys do not employ gear specifically designed to catch small fishes (20 - 100 mm).

The epibenthic sled used in this study provided a means of quantitatively sampling larval fishes that occur within 1 m of the bottom. The opening and closing mechanism, when properly functioning, insures that the net is collecting only when the gear is in contact with the bottom, thus preventing contamination of the sample by non-resident water column plankton. Mouth opening, mesh size and towing speed are adequate for sampling fish larvae; however, this gear is apparently not an efficient sampler of juvenile fishes. Although specimens ranged in size from 2 to 78 mm SL, mean minimum and maximum lengths were 9.1 mm and 11.1 mm, respectively. Full fin ray complements are frequently present in larvae at sizes of 9 - 11 mm, but pigmentary and behavioral changes associated with transition to the juvenile stage generally occur at larger sizes (15 - 20 mm or larger). Well over 90% of the specimens collected with the epibenthic sled were clearly larval or postlarval in form and pigmentation. Of the juveniles collected, the majority represented groups that are characteristically sedentary or slow moving such as ophichthid eels, ophidiids, triglids, carapids, gobiids, blenniids, batrachoidids, and dactyloscopids. Although juveniles of some active swimming groups (e.g. two apogonids and one pomacentrid) were taken, they were, for the most part, notably absent from the samples, apparently due to their ability to avoid the small, relatively slow moving, fine mesh net.

Juveniles of the seven priority species are not sedentary and, thus, not likely to be taken in the epibenthic sled. The importance of live bottom areas as nursery grounds for these species and many others cannot be determined using gear that samples primarily larval and postlarval stages. Although some larvae may become associated with the bottom at small sizes, well before juvenile transition, other (e.g. groupers) remain planktonic to sizes of 15 mm or more, at which time they settle and undergo morphological and behavioral changes related to juvenile transition. In these late settling species, bottom residence commences at sizes that are already beyond the typical sampling capability of the sled.

Additional methodological problems associated with the sled involved gear malfunction and sampling design. During the winter cruise, the opening and closing device was not functioning properly, and the net was at least occasionally open through the water column during setting and retrieval. Unfortunately, there is no way to determine how often and in which collections this occurred. The uncertainty of the opening and closing operation was alleviated during the summer cruise by locking the net open. Thus, a portion of each sample consists of specimens collected in the water column. If several tows had been made in a simple oblique pattern (without allowing the net to fish at the bottom), some rough indication of the magnitude and composition of a water column sample would be available. Without these "controls", we can only assume that each sample represents primarily bottom associated specimens.

Finally, with the present sampling design it is difficult to draw sound conclusions concerning the preferential association of the species collected in relation to live bottom habitat. Plankton nets are rarely towed on the bottom in larval fish surveys, and consequently, we know very little about the distribution and habits of epibenthic fish larvae. Some species may well be restricted to live bottom while others may be randomly distributed over the bottom. The marked influence of Gulf Stream intrusion on diversity at OS02 illustrates the overriding importance of currents and water masses to larval fish distribution. Recognition of true resident species can only be achieved if additional comparative tows are made on sand bottom areas. This was not, however, included in the scope of this study.

Dredges - Both the rock dredge and the Cerame-Vivas dredge were quite effective in collecting sessile and encrusting macrofauna including cnidarians, ascidians, bryozoans, small sponges, and octocorals. Since the gears were equipped with large mesh bags, smaller motile faunal components (such as amphipods and polychaetes) were not effectively sampled, because most were undoubtedly washed out of the bags. As noted previously, only two replicate tows were made at all study areas. A greater number of tows could not have been analyzed in the time allotted in the contract without sacrificing sample workup from other gears. Due to the high variability noted in replicated dredge catches, more tows at every station would have provided a better assessment of community structure.

Suction Sampler and Smith-McIntyre Grab - Sampling small invertebrates with the suction sampler proved to be a very simple, yet effective, technique. Samples were quantitative because suctioning was confined to the surface area within the walled box placed on the substratum. The Smith-McIntyre grab, which was substituted for the suction sampler at deeper stations, was less reliably quantitative because the volume of sediment sampled was not consistent for all collections, especially when the grab hit hard bottom without a sand veneer. However, we know of no other remote quantitative sampler which would have been more effective on hard surfaces. An additional problem with grab sampling is that our assessment of the exact bottom type sampled is necessarily conjectural and based solely on the contents of the grab. This problem could be rectified by deploying a still camera with the grab as done by Boesch et al.

(1977), but the cost would be substantially increased.

With respect to quantitative population estimates, we found suction and grab catches to be highly variable between replicates. We attribute this variability primarily to natural dispersion of the organisms and bottom substratum variability. Differences in sampling efficiency may also have been a factor. An examination of distributional patterns for the ten dominant species revealed that most were highly contagious. Information on the effective level of replication needed to detect significant changes in population density of these species was calculated by the expression:

$$n = \frac{s^2}{D^2\bar{x}^2}$$

where s^2 is the variance, $\bar{x}$ is the arithmetic mean and D^2 is expressed as $\frac{1}{\bar{x}} \cdot S_{\bar{x}}$ (or the standard error of the mean) (Elliott 1977). As shown in Table 8.1, the level of replication necessary to detect (with 95% confidence) an estimate of the population mean, within $\pm$ 40% of the true value, varied greatly among species. In most instances, the necessary number of replicates was much greater than five. Species accumulation curves (Figure 8.1) further point out the inadequacy of five replicates in censusing populations of patchily distributed organisms. Considering the large number of replicates needed to accurately assess the abundance of highly contagious organisms, we feel that our current efforts must suffice to keep survey costs minimal. In any case, suction and grab samplers at least provide crude abundance estimates of the smaller fauna not represented in trawl and dredge collections.

Diver Assessments and Swimming Transects - Diver assessment allowed direct measurements of relief at inner and middle shelf study sites, but rock samples were difficult to obtain. Ledge faces and evident outcrops were typically sampled by divers, and most rock collections gathered by this method were somewhat eroded and biologically excavated by marine borers.

Swimming transects aimed at delineating ichthyological assemblages were somewhat adversely affected by poor water clarity and other factors (i.e., species attraction, avoidance), but generally appeared to provide meaningful estimates. Stone et al. (1979) demonstrated that such diver transect counts can adequately approximate reef fish abundances, as well as determine the presence of cryptic fish species. Additionally, divers were able to detect the presence of certain large species not captured by trawl.

RECOMMENDATIONS FOR FUTURE RESEARCH

The scope of the first year study effort provided only limited information on seasonal changes in community structure. Furthermore, no study areas were located between Charleston, S. C. and Cape Fear, N. C. Our recommendations to sample live bottom areas during all four seasons and to relocate some stations to areas off South Carolina have already been incorporated into a second year study effort. These modifications should greatly assist in providing predictive information on live bottom community composition and structure in the South Atlantic Bight.

Other recommended research, which would be especially valuable with respect to impact assessment, includes recolonization and growth rate studies on live bottom fauna. If these areas are adversely affected, there is no existing data base on which to predict expected recovery rates, particularly for the large invertebrate fauna. Additional information is also needed on

Table 8.1. *Index of dispersion* (I, Elliott 1977) *and estimated number of samples* (n) *needed to obtain an estimate of the population mean within* ± 40% of the true value for the ten numerically dominant invertebrate species in suction and grab samples. Asterisk (*) indicates significant deviation of I from Poisson distribution. Additional information on each species is provided in Chapter 5.

	ISO1		ISO2		ISO3		MSO1		MSO2		MSO3		OSO1		OSO2		OSO3	
	I	n	I	n	I	n	I	n	I	n	I	n	I	n	I	n	I	n
WINTER																		
Filograna implexa	-	-	24.0*	125	1.0	125	4707.1*	98	-	-	4.0*	125	-	-	-	-	-	-
Phyllochaetopterus socialis	26.8*	93	1.0	125	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiophanes bombyx	4.9*	14	2.1	66	0.5	21	1.8	38	4.0*	13	2.4	27	11.5*	36	3.9*	82	2.8*	16
Exogone dispar	9.1*	23	10.4*	6	7.2*	3	5.2*	20	2.9*	14	2.0	125	-	-	-	-	-	-
Photis sp.	3.0*	6	13.0*	10	5.0*	8	2.4	7	12.0*	8	13.7*	41	1.5	47	1.0	125	0.8	47
Podocerus sp.	14.9*	6	46.9*	68	4.0*	8	3.9*	10	3.8*	63	0.9	23	1.4	30	3.0*	125	3.0*	125
Luconacia incerta	26.9*	30	9.9*	12	1.2	5	11.9*	10	19.3*	30	1.4	30	1.3	56	2.0	125	2.0	36
Syllis spongicola	0.7	47	9.9*	52	2.4	12	11.7*	32	-	-	27.0*	99	1.0	125	-	-	2.0	50
Erichthonius sp. A	-	-	-	-	-	-	-	-	-	-	-	-	6.6*	41	-	-	5.8*	91
Ophiothrix angulata	1.0	21	9.1*	13	13.2*	8	9.5*	33	2.0	100	2.2	28	-	-	-	-	1.0	125
SUMMER																		
Filograna implexa	5.0*	125	3938.0*	125	41.0*	125	1973.9*	116	-	-	75.7*	29	-	-	-	-	3317.5*	113
Phyllochaetopterus socialis	-	-	-	-	1.0	125	4.0*	56	1.0	125	1.0	125	2.0	36	-	-	2208.0*	125
Spiophanes bombyx	0.7	47	1.0	125	0.9	27	0.5	21	-	-	1.0	125	57.8*	18	12.1*	9	4.8*	67
Exogone dispar	-	-	-	-	10.1*	25	0.9	27	1.0	125	-	-	-	-	-	-	-	-
Photis sp.	-	-	-	-	13.8*	47	-	-	-	-	-	-	6.3*	22	9.9*	62	1.3	56
Podocerus sp.	-	-	-	-	2.0	125	0.7	47	6.0*	125	1.0	125	-	-	1.0	125	5.1*	58
Luconacia incerta	-	-	-	-	11.6*	42	0.9	27	1.3	56	1.3	56	-	-	-	-	7.7*	64
Syllis spongicola	12.0*	125	3.0*	75	2.7	42	41.1*	25	9.0*	125	9.3*	20	-	-	60.0*	125	2.2	47
Erichthonius sp. A	-	-	-	-	-	-	-	-	-	-	-	-	4.2*	31	2.0	36	315.5*	90
Ophiothrix angulata	-	-	2.4	27	21.8*	42	5.0*	125	-	-	4.4*	17	1.0	125	-	-	1.0	125

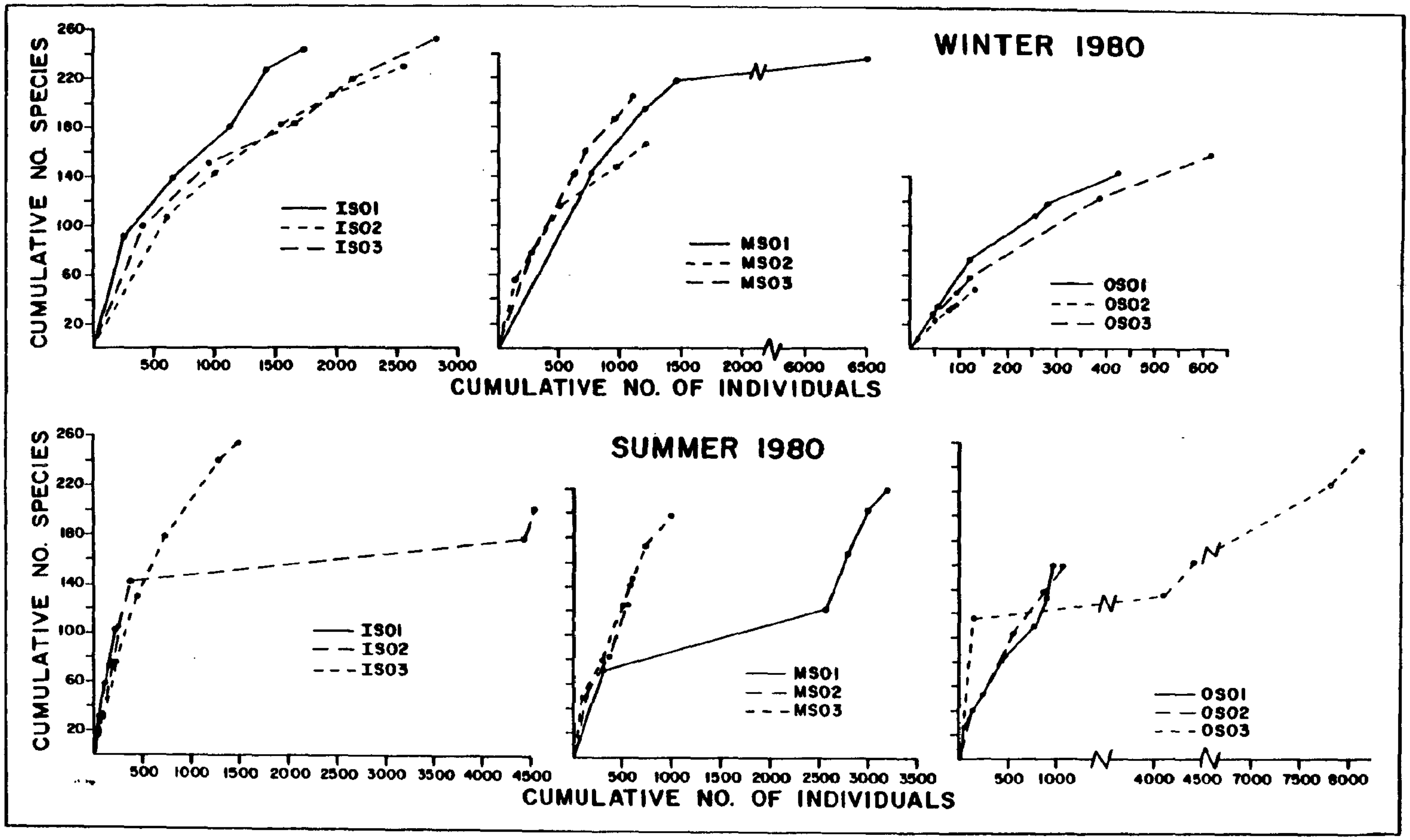


Figure 8.1. Species accumulation curves for invertebrates at stations sampled by suction and grab during winter and summer, 1980.

the diets of several of the dominant priority and non-priority fishes. While the current study is examining the diets of some species, constraints on the time allotted for laboratory analysis limited the number of stomachs which could be examined. Thus, food habits for different size (age) fish could not be considered, and more stomachs need to be examined for each species in general. This effort would not necessarily require further sampling since we are currently collecting more fish stomachs than we are able to analyze. Finally, if drilling or production platforms are placed in the South Atlantic Bight near live bottom areas, we strongly recommend monitoring studies to assess whether effects from these rigs are negative, positive, or non-existent.

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South Carolina Marine Resources Research Institute and Georgia Coastal Resources Division personnel who contributed to this study as project personnel are listed in Tables 9.1 and 9.2, respectively, along with their areas of responsibility. Other people not designated as project personnel also contributed to the study effort. They include the crews of the R/V Anna, R/V Bagby, and R/V Dolphin to whom we express our gratitude. Special thanks are also expressed to Karen Swanson and Josie Williams for drafting the figures in this volume, to Mary Anne Carson who assisted in typing, and to Priscilla Hinde for her editorial effort.

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H. Porter	University of North Carolina
H. Ruetzler	U. S. National Museum
J. Thomas	Newfound Harbor Marine Institute
V. Zullo	University of North Carolina

Table 9.1. Project personnel from South Carolina Marine Resources Research Institute and their areas of responsibility.

NAME	AREA OF RESPONSIBILITY
Barans, C. A.	Fish community analysis (review)
Burrell, V. G. Jr.	Project Leader, project management
Calder, D. R.	Invertebrate identification
Clise, M. J.	Technical support
Gash, A. G.	Data processing coordination
Hodges, L. H.	Secretarial support
Hodges, W. T., Jr.	Technical support
Johnson, G. D.*	Larval, juvenile fish identification and analysis
Knott, D. M.*	Invertebrate identification, community analysis; physical habitat description
Maclin, M. S.	Technical support
Manzi, J. J.	Algal identification
Mathews, T. D.*	Water chemistry
Miglarese, J. V.*	Project management, invertebrate identification
Nimmich, T. A.	Fish and stomach contents identification; data reduction
O'Rourke, C. B.	Invertebrate identification; data reduction
Roland, E. C.	Invertebrate identification; data reduction
Sedberry, G. R.*	Fish identification; community and food habits analysis
Stapor, F. W.	Physical habitat description
Steele, G. H.	Technical support
Stender, B. W.	Cruise logistics; larval, juvenile fish identification

Table 9.1 (Continued)

Van Dolah, R. F.*	Project Coordinator, project management; community analyses
Wenner, C. A.	Fish community analysis (review)
Wenner, E. L.*	Invertebrate identification and community analysis

Asterisk (*) indicates primary responsibility for data interpretation and written contributions to final report.

Table 9.2. Project personnel from Georgia Coastal Resources Division and their areas of responsibility.

NAME	AREA OF RESPONSIBILITY
Ansley, H. L. H.*	Cruise logistics; diver
Baisden, V. W.	Diver
Blizzard, D.	Invertebrate identification; diver
Boothe, B. B.*	Invertebrate identification; diver
Brigdon, L.	Secretarial support
Cowman, C. F.	Diver
Harris, C. D.	Demersal and pelagic fishes; diver
Hutchinson, J.	Diver
Kinsey, C. L.	Diver
Kroscavage, J. B.	Diver
Lang, G. M.	Diver
Mahood, R. K.*	Project Coordinator; project management; diver
Nicholson, F. L.*	Invertebrate identification, diver
Olsson, S. P.	Diver
Phillips, J.	Project management
Reimold, R. J.	Project Leader, project management
Shipman, S.	Diver
Varnedoe, D.	Diver

Asterisk (*) indicates personnel who contributed to analysis and write-up of final report.

REFERENCES CITED

Anger, K.; Valentin, C. In situ studies on the diurnal activity pattern of Diastylis rathkei (Cumacea, Crustacea) and its importance for the "hyperbenthos". Helgol. Wiss. Meeresunters. 28: 138-144; 1976.

Atkinson, L. P. The results of four oceanographic cruises in the Georgia Bight. Technical Report - Georgia Marine Science Center. 1978; 71 p. Technical Report Series 78-1. Available from: Georgia Marine Science Center, Skidaway Island, GA.

Avent, R. M.; King, M. E.; Gore, R. H. Topographic and faunal studies of shelf-edge prominences off the central eastern Florida Coast. Int. Rev. Gesamten Hydrobiol. 62(2): 185-208; 1977.

Barans, C. A.; Burrell, V. G., Jr. Preliminary findings of trawling on the continental shelf off the southeastern United States during four seasons (1973 - 1975). Technical Report - South Carolina Marine Resources Center. 1976; 16 p. Technical Report No. 13. Available from: S. C. Marine Resources Center, Charleston, SC.

Bardach, J. E. On the movement of certain Bermuda reef fishes. Ecology 39: 139-146; 1958.

Bardach, J. E. The summer standing crop of fish on a shallow Bermuda reef. Limnol. Oceanogr. 4: 77-85; 1959.

Bardach, J. E.; Case, J. Sensory capabilities of the modified fins of squirrel hake (Urophycis chuss) and searobins (Prionotus carolinus and P. evolans). Copeia 1965 (2): 194-206; 1965.

Bearden, C. M.; McKenzie, M. D. An investigation of the offshore demersal fish resources of South Carolina. Technical Report - South Carolina Marine Resources Center. 1971; 19 p. Technical Report No. 2. Available from: S. C. Marine Resources Center, Charleston, SC.

Beaumariage, D. S.; L. H. Bulloch. Biological research on snappers and groupers as related to fishery management requirements. Bullis, H. R., Jr.; Jones, A. C. eds. Proceedings: Colloquium on snapper-grouper fishery resources of the western central Atlantic Ocean; 1975 October 16; Gulf States Marine Fisheries Commission Meeting, Pensacola Beach, FL. Gainesville, FL: Florida Sea Grant Program; report no. 17: 86-94; 1976.

Bender, M. E.; Reish, D. J.; Ward, C. H. Re-examination of the offshore ecology investigation. Ward, C. H.; Bender, M. E.; Reish, D. J. eds. The offshore ecology investigation, effects of oil drilling and production in a coastal environment. Houston, TX: Rice University Studies, Vol. 65 (4 & 5); 1979: 35-118.

Berrill, N. J. Temperature and size in the reorganization of Tubelaria. J. Exp. Zool. 107: 455-464; 1948.

Blanton, J. Exchange of Gulf Stream water with North Carolina shelf water in Onslow Bay during stratified conditions. Deep-Sea Res. 18: 167-178; 1971.

Bliss, C. J. Statistics in biology. Vol. I. New York: McGraw-Hill, Inc.; 1967.

Blumer, M.; Sanders, H. L.; Grassle, J. F.; Hampson, G. R. A small oil spill. Environment 13 (2): 1-12; 1971.

Boesch, D. F. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia. Mar. Biol. 21: 226-244; 1973.

Boesch, D. F. Application of numerical classification in ecological investigations of water pollution. Corvallis, OR: U. S. Environmental Protection Agency, Office of Research and Development; 1977; 114 p. Available from: U. S. Environmental Protection Agency, Office of Research and Development, Corvallis, OR; EPA-600/3-77-033.

Boesch, D. F.; Herschner, C. H. The ecological effects of oil pollution in the marine environment. Boesch, D. F.; Herschner, C. H.; Milgram, J. H. Oil spills and the marine environment. Cambridge, Mass: Ballinger Publ. Co.; 1974: 1-55.

Boesch, D. F.; Kraeuter, J. N.; Serafy, D. K. Distribution and structure of communities of macrobenthos on the outer continental shelf of the middle Atlantic Bight: 1975-1976 investigations. Special Report - Virginia Institute of Marine Science. 1977; 111 p. Special Report Applied Marine Science Ocean Engineering No. 175. Available from: VIMS, Gloucester Point, VA.

Bohnsack, J. A. Photographic quantitative sampling of hard bottom benthic communities. Bull. Mar. Sci. 29: 242-252; 1979.

Bowman, T. E. The distribution of calanoid copepods off the southeastern United States between Cape Hatteras and southern Florida. Smithson. Contrib. Zool. 96; 1971.

Bradley, E.; Bryan, C. E. Life history and fishery of the red snapper (Lutjanus campechanus) in the northwestern Gulf of Mexico: 1970-1974. Proc. Gulf Caribb. Fish. Inst. 27: 77-106; 1975.

Bray, J. R.; Curtis, J. T. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349; 1957.

Bright, T. J. Coral reefs, nepheloid layers, gas seeps and brine flows on hard banks in the northwestern Gulf of Mexico. Taylor, D. L., ed. Proceedings: Third international coral reef symposium; Vol. I; 1976 May; Rosentiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; 1977: 39-46.

Bryan, G. W. Some aspects of heavy metal tolerance in aquatic organisms. Lockwood, A. P. M. ed. Effects of pollutants on aquatic organisms.

Cambridge, England: Cambridge Univ. Press; 1976: 7-34.

Bumpus, D. F. The circulation over the continental shelf south of Cape Hatteras. Trans. Am. Geophys. Union 36 (4): 601-611; 1955.

Cain, T. D. Additional epifauna of a reef off North Carolina. J. Elisha Mitchell Sci. Soc. 88: 79-82; 1972.

Calder, D. R. Seasonal activity-inactivity cycles in some lower Chesapeake Bay hydrozoa. J. Sci. 18: 156; 1967.

Calder, D. R. Hydroids and hydromedusae of southern Chesapeake Bay. Special Paper - Virginia Institute of Marine Science. 1971; 125 p. Special Papers in Marine Science No. 1. Available from: VIMS, Gloucester Point, VA.

Cerame-Vivas, M. J.; Gray, J. E. The distributional pattern of benthic invertebrates of the continental shelf off North Carolina. Ecology 47(2): 260-270; 1966.

Chess, J. R. An airlift sampling device for in situ collecting of biota from rocky substrata. Mar. Technol. Soc. J. 12(3): 20-23; 1979.

Clifford, H. T.; Stephenson, W. An introduction to numerical classification. New York, NY: Academic Press; 1975.

Collette, B. B.; Talbot, F. H. Activity patterns of coral reef fishes with emphasis on nocturnal-diurnal changeover. Bull. Los Angeles Co. Mus. 14: 98-124; 1972.

Collins, L. A.; Finucane, J. H.; Barger, L. E. Description of larval and juvenile red snapper, Lutjanus campechanus. Fish. Bull. 77(4): 965-974; 1980.

Connell, J. H. The influence of interspecific competition and other factors on the distribution of the barnacle, Chthalmalus stellatus. Ecology 42: 710-723; 1961a.

Connell, J. H. Effect of competition, predation by Thais lappillus, and other factors on natural populations of the barnacle, Balanus balanoides. Ecol. Monogr. 31: 61-104; 1961b.

Continental Shelf Associates. South Atlantic hard bottom study. Prepared for Bureau of Land Management; Contract AA551-CT8-25; 1979; 356 p. Available from Bureau of Land Management, Washington, D. C.

Corner, E. D. S.; Harris, R. P.; White, K. J.; Mackie, P. R. Hydrocarbons in marine zooplankton and fish. Lockwood, A. P. M. ed. Effects of pollutants on aquatic organisms. Cambridge, England: Cambridge Univ. Press; 1976: 71-105.

Cressy, R. F.; Lachner, E. A. The parasitic copepod diet and life history of diskfishes (Echeneidae). Copeia 1970(2): 310-318; 1970.

Cummins, R., Jr.; Rivers, J. B.; Struhsaker, P. J. Exploratory fishing off the coast of North Carolina, September 1959 - July 1960. Comm. Fish. Rev. 24: 1-9; 1962.

Cupka, D. M.; Dias, R. K.; Tucker, J. Biology of the black sea bass, Centropristis striata (Pisces: Serranidae), from South Carolina waters. S. C. Marine Resources Center, Charleston, S. C. Unpublished manuscript; 1973.

Davis, P. H.; Spies, R. B. Infaunal benthos of a natural petroleum seep: study of community structure. Mar. Biol. 59: 31-41; 1980.

Day, J. H. A monograph on the polychaeta of southern Africa. Part 2. Sedentaria. London: Trustees of the British Museum (Natural History); 1967.

Day, J. H. New polychaeta from Beaufort, with a key to all species recorded from North Carolina. Technical Report - National Marine Fisheries Service. 1973; 140 p. NOAA Technical Report NMFS Circular-375. Available from: U. S. Government Printing Office, Washington, D. C.

Day, J. H.; Field, J. G.; Montgomery, M. P. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol. 40: 92-125; 1971.

Dayton, P. K. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. Ecol. Monogr. 41: 351-389; 1971.

Dayton, P. K. Experimental evaluation of ecological dominance in a rocky intertidal algal community. Ecol. Monogr. 45: 137-159; 1975.

Ecomar, Inc. Maximum mud discharge study conducted for Offshore Operators Committee, Environmental Subcommittee under direction of Exxon Production Research Company. New Orleans, LA: Offshore Operators Committee; 1980. 114 p.

Eddy, J. E.; Henry, V. J.; Hoyt, J. H.; Bradley, E. Description and use of an underwater television system in the Atlantic continental shelf. U. S. Geol. Surv. Prof. Pap. 575-e: 72-76; 1967.

Edwards, R. L. Fishery resources of the North Atlantic area. Univ. Wash. Publ. Fish. New Ser. 4: 52-61; 1968.

Elliott, J. M. Some methods for the statistical analysis of samples of benthic invertebrates. Freshw. Biol. Assoc. Sci. Publ. No. 25. 160 p. 1977.

Fable, W. A., Jr. Tagging studies of red snapper (Lutjanus campechanus) and vermilion snapper (Rhomboplites aurorubens) off the south Texas coast. Contrib. Mar. Sci. 23: 115-121; 1980.

Fahay, M. P. An annotated list of larval and juvenile fishes captured with surface-towed meter net in the South Atlantic Bight during four R/V Dolphin cruises between May 1967 and February 1968. Technical Report - National Marine Fisheries Service. 1975; 39 p. NOAA Technical Report. NMFS SSRF-685. Available from: U. S. Government Printing Office, Washington, D. C.

Fine, M. L. Sexual dimorphism of the growth rate of the swimbladder of the toadfish Opsanus tau. Copeia 1975: 483-490; 1975.

Foell, E. J.; Musick, J. A. Community structure analysis and food habits of fishes II: community structure analysis of fishes. Special Report - Virginia Institute of Marine Science. 1979: 81-159. Special Report in Applied Marine Science Ocean Engineering No. 197. Available from: VIMS, Gloucester Point, VA.

Folk, R. L. Practical petrographic classification of limestones. Bull. Am. Assoc. Petrol. Geologists 43: 1-38; 1959.

Foster, M.; Neushul, M.; Zingmark, R. The Santa Barbara oil spill: Part 2 - Initial effects on intertidal and kelp bed organisms. Environmental Pollution 2: 115-134; 1971.

Frankenberg, D. The dynamics of benthic communities off Georgia, USA. Thalassia Jugosl. 7(1): 49-55; 1971.

Frankenberg, D.; Leiper, A. S. Seasonal cycles in benthic communities of the Georgia continental shelf. Coull, B. C. ed. Ecology of Marine Benthos. Columbia: Univ. South Carolina Press; 1977: 383-397.

Gardiner, S. L. Errant polychaete annelids from North Carolina. J. Elisha Mitchell Sci. Soc. 91: 77-220; 1975.

Gauch, H. G., Jr. ORDIFLEX: A flexible computer program for four ordination techniques: weighted averages, polar ordination, principal components analysis, and reciprocal averaging. Ithaca, NY: Cornell University Press; 1977.

George, R. V.; Staiger, J. C. Epifauna: benthic invertebrate and demersal fish populations in the Georgia Bight continental shelf environment. Texas Instruments, Inc. South Atlantic benchmark program. Vol. 3. Draft Report; 1978: 211-254. Available from: Bureau of Land Management, Outer Continental Shelf Office, New Orleans, LA.

Gladfelter, W. B.; Gladfelter, E. H. Fish community structure as a function of habitat structure on West Indies patch reefs. Rev. Biol. Trop. 26 (suppl. 1): 65-84; 1978.

Gore, R. H.; Scotto, L. E.; Becker, L. J. Community composition, stability, and trophic partitioning in decapod crustaceans inhabiting some sub-tropical sabellarid worm reefs. Bull. Mar. Sci. 28(2): 221-248; 1978.

Gray, J. E.; Cerame-Vivas, M. J. The circulation of surface waters in Raleigh Bay, North Carolina. Limnol. Oceanogr. 8(3): 330-337; 1963.

Grimes, C. B. Certain aspects of the life history of the vermilion snapper Rhomboplites aurorubens (Cuvier) from North and South Carolina waters. Chapel Hill, NC: Univ. North Carolina; 1976. 240 p. Dissertation.

Grimes, C. B. Diet and feeding ecology of the vermilion snapper, Rhomboplites aurorubens (Cuvier) from North Carolina and South Carolina waters. Bull. Mar. Sci. 29(1): 53-61; 1979.

Grimes, C. B.; Manooch, C. S.; Huntsman, G. R.; Dixon, R. L. Red snappers of the Carolina coast. Mar. Fish. Rev. 39(1): 12-15; 1977.

Groot, S. J. de. Digestive system and sensorial factors in relation to the feeding behavior of flatfishes (Pleuronectiformes). J. Cons. Int. Explor. Mer 32: 385-294; 1969.

Hara, T. J. Chemoreception. Hoar, W. S.; Randall, D. J. eds. Fish Physiology. Vol. V.: Sensory systems and electric organs. New York: Academic Press; 1971; 79-120.

Hargitt, C. W. A contribution to the natural history and development of Pennaria tiarella McCrady. Am. Nat. 34: 387-416; 1900.

Hawkins, A. B. The sensitivity of fish to sounds. Oceanogr. Mar. Biol. Ann. Rev. 11: 291-340; 1973.

Heitz, J. R.; Lewis, L.; Chambers, J; Yarbrough, J. D. The acute effects of empire mix crude oil on enzymes in oysters, shrimp and mullet. Vernberg, F. J.; Vernberg, W. B. eds. Pollution and physiology of marine organisms. New York, NY: Academic Press; 1974: 311-328.

Henry, V. J.; Giles, R. T. Chapter 8; Distribution and occurrence of reefs and hardgrounds in the Georgia Bight. U. S. Geological Survey, Office of Marine Geology. South Atlantic OCS geological studies: Final Report F. Y. 1976. Washington, D. C.: Bureau of Land Management; 1979: 36 p. Available from NTIS, Springfield, VA; PB-300820.

Henry, V. J.; Hoyt, J. H. Quaternary paralic and shelf sediments of Georgia. Southeast. Geol. 9: 195-214; 1968.

Henry, V. J., Jr.; McCreery, C. J.; Foley, F. D.; Kendall, D. R. Ocean bottom survey of the Georgia Bight: Final Report F. Y. 1979. Woods Hole, MA: U. S. Geological Survey, Office of Marine Geology; 1980; 82 p. Available from USGS, Office of Marine Geology; Woods Hole, MA; contract no. 14-08-0001-06266.

Hill, M. D. Reciprocal averaging: an eigenvector method of ordination. J. Ecol. 61: 237-249; 1973.

Hobson, E. S. Diurnal-nocturnal activity of some inshore fishes in the Gulf of California. Copeia 1965(3): 291-302; 1965.

Hughes, G. M. Polluted fish respiratory physiology. Lockwood, A.P.M. ed. Effects of pollutants on aquatic organisms. Cambridge, England: Cambridge Univ. Press; 1976: 163-183.

Hunt, J. L. The geology and origin of Gray's Reef, Georgia continental shelf. Athens, GA: University of Georgia; 1974. Thesis. 1-83.

Huntsman, G. R.; Macintyre, I. G. Tropical coral patches in Onslow Bay. American Naturalist 7(2): 32-34; 1971.

Huston, M. A general hypothesis of species diversity. Am. Nat. 113(1): 81-101; 1979.

Hyman, L. H. The invertebrates. Volume V. Smaller coelomate groups. New York: McGraw Hill; 1959.

Hynes, H. B. N. The food of freshwater sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius), with a review of the methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36-58; 1950.

Jackson, J. B. C. Competition on marine hard substrata: The adaptive significance of solitary and colonial strategies. Am. Nat. 3(980): 743-767; 1977.

Johannes, R. E. Pollution and degradation of coral reef communities. Wood, E. J. F.; Johannes, R. E. eds. Tropical marine pollution. Amsterdam, The Netherlands: Elsevier Sci. Publ. Co.; 1975: 13-51.

Kendall, A. W., Jr. Description of black sea bass, Centropristis striata (Linnaeus), larvae and their occurrences north of Cape Lookout, North Carolina, in 1966. Fish. Bull. 70(4): 1243-1260; 1972.

Kittredge, J. S. Comparative biochemistry: marine biochemistry. Mariscal, R. N. ed. Experimental marine biology. New York: Academic Press; 1974: 226-267.

Kleerekoper, H. Olfaction in fishes. Bloomington, IN: Indiana Univ. Press; 1969.

Klima, E. F. A review of the fishery resources in the western central Atlantic. FAO Western Central Atlantic Fish. Comm. Stud. No. 3; 1976. Available from FAO, Rome.

Klima, E. F.; Wickham, D. A. Attraction of coastal pelagic fishes with artificial structures. Trans. Am. Fish. Soc. 100(1): 86-99; 1971.

Krebs, C. J. Ecology: The experimental analysis of distribution and abundance. New York: Harper and Row; 1972.

Lambert, J. M.; Williams, W. T. Multivariate methods in plant ecology. IV. Nodal analysis. J. Ecol. 50: 775-802; 1962.

Lance, G. N.; Williams, W. T. A general theory of classificatory sorting strategies. I. Hierarchical systems. Comput. J. 9: 373-380; 1967a.

Lance, G. N.; Williams, W. T. Mixed data classificatory programs. I. Agglomerative systems. Aust. Comput. J. 1:15-20; 1967b.

LaRoche, W. A. Description of larval and early juvenile vermilion snapper, Rhomboplites aurorubens. Fish. Bull. 75(3): 547-554; 1977.

Link, W. L., Jr. Age, growth, reproduction, feeding and ecological observations on the three species of Centropristis (Pisces: Serranidae) in North Carolina waters. Chapel Hill, NC: Univ. North Carolina; 1980. 270 p. Dissertation.

Livingston, R. J. Circadian rhythms in the respiration of eight species of cardinal fishes (Pisces: Apogonidae): comparative analysis and adaptive significance. Mar. Biol. 9: 253-266; 1971.

Longley, W. H.; Hildebrand, S. F. Systematic catalogue of the fishes of Tortugas, Florida. Carnegie Inst. Wash. Publ. 535; 1941.

Lubchenco, J. Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. Am. Nat. 112(983): 23-39; 1978.

Luckhurst, B. E.; Luckhurst, K. Diurnal space utilization in coral reef fish communities. Mar. Biol. 49: 325-332; 1978.

Macintyre, I. G. New data on the occurrence of tropical reef corals on the North Carolina continental shelf. J. Elisha Mitchell Sci. Soc. 86(4): 178; 1970.

Macintyre, I. G.; Milliman, J. D. Physiographic features on the outer continental shelf and upper slope, Atlantic continental margin, southeastern United States. Geol. Soc. Am. Bull. 81: 2577-2598; 1970.

Macintyre, I. G.; Pilkey, O. H. Tropical reef corals: tolerance of low temperatures on the North Carolina continental shelf. Science 166: 374-375; 1969.

Manooch, C. S., III. Reproductive cycle, fecundity, and sex ratios of the red porgy, Pagrus pagrus (Pisces: Serranidae) in North Carolina. Fish. Bull. 74(4): 775-781; 1976.

Manooch, C. S., III. Foods of the red porgy, Pagrus pagrus Linnaeus (Pisces: Sparidae), from North Carolina and South Carolina. Bull. Mar. Sci. 27(4): 776-787; 1977.

Manooch, C. S., III; Barans, C. A. Distribution, abundance, and age and growth of tomtate, Haemulon aurolineatum Cuvier, along the southeastern United States. National Marine Fisheries Service, Beaufort, NC. In preparation.

Margalef, D. R. Information theory in ecology. Gen. Syst. 3: 36-71; 1958.

Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department. A study of the ecological effects of rubble weir jetty construction at Murrells Inlet, South Carolina. Rept. to Coastal Engineering Research Center, Dept. of Army, Ft. Belvoir, VA. 1979; 86 p. Available from: S. C. Marine Resources Research Institute, Charleston, SC.

Mathews, T. D.; Pashuk, O. A description of oceanographic conditions off the southeastern United States during 1973. Technical Report - South Carolina Marine Resources Center. 1977; 105 p. Technical Report No. 30. Available from: S. C. Marine Resources Center, Charleston, SC.

McCloskey, L. R. The dynamics of the community associated with a marine scleractinian coral. Int. Revue Ges. Hydrobiol. 55(1): 13-81; 1970.

McEachran, J. D.; Boesch, D. F.; Musick, J. A. Food division within two sympatric species-pairs of skates (Pisces: Rajidae). Mar. Biol. 35: 301-317; 1976.

McErlean, A. J. A study of the age and growth of the gag, Mycteroperca microlepis Goode and Bean (Pisces: Serranidae) on the west coast of Florida. Technical Report - Marine Research Laboratory. 1963; 29 p. Technical Report Series No. 41. Available from: Florida State Board Conservation, Marine Research Laboratory, Gainesville, FL.

McNaughton, S. J. Relationships among functional properties of California grasslands. Nature 216: 168-169; 1967.

Menge, B. A.; Sutherland, J. P. Species diversity gradients: synthesis of the roles of predation, competition, and temporal heterogeneity. Amer. Natur. 110: 351-369; 1976.

Menzies, R. J.; Pilkey, O. H.; Blackwelder, B. W.; Dexter, D.; Huling, P.; McCloskey, L. A submerged reef off North Carolina. Int. Revue Ges. Hydrobiol. 51(3): 393-431; 1966.

Mercer, L. P. The reproductive biology and population dynamics of black sea bass, Centropristis striata. Williamsburg, VA: College of William and Mary; 1978. 196 p. Dissertation.

Miller, G. C.; Richards, W. J. Reef fish habitat, faunal assemblages and factors determining distributions in the South Atlantic Bight. Proc. Gulf Caribb. Fish. Inst. 32: 114-130; 1979.

Moore, S. F.; Dwyer, R. L. Effects of oil on marine organisms: a critical assessment of published data. Water Res. 8: 819-827; 1974.

Morse, M. The autotomy of the hydranth of Tubularia. Biol. Bull. 16: 172-182; 1909.

Musick, J. A.; McEachran, J. D. Autumn and winter occurrences of decapod crustaceans in Chesapeake Bight, USA. Crustaceana 22(2): 190-200; 1972.

Nicholson, N. L.; Climberg, R. L. The Santa Barbara oil spills of 1969: A post-spill survey of the rocky intertidal. Straughan, D. Compiler. Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. 1. Allan Hancock Foundation; Univ. Southern Calif. 1971: 325-399.

Odum, H. T.; Odum, E. P. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecol. Monogr. 25: 291-320; 1955.

Olsen, D. A.; Dammann, A. E; Neal, D. A vertical longline for red snapper fishing. Mar. Fish. Rev. 36(1): 7-9; 1974.

Osman, R. W. The establishment and development of a marine epifaunal community. Ecol. Monogr. 47: 37-63; 1977.

Paine, R. T. Food web complexity and species diversity. Am. Nat. 100: 65-75; 1966.

Paine, R. T. Intertidal community structure: experimental studies on the relationship between a dominant competitor and its principal prey. Oecologia 15: 93-120; 1974.

Parker, R. O., Jr.; Colby, D. R.; Willis, T. D. Estimated amount of reef habitat on U. S. South Atlantic and Gulf of Mexico continental shelf. National Marine Fisheries Service, Beaufort, NC. In preparation.

Parker, R. O., Jr.; Stone, R. B.; Buchanan, C. C. Artificial reefs off Murrells Inlet, South Carolina. Mar. Fish. Rev. 41: 12-23; 1979.

Parrish, J. D.; Zimmerman, R. J. Utilization by fishes of space and food resources on an offshore Puerto Rican coral reef and its surroundings. Taylor, D. L. ed. Volume 1; Biology. Proceedings Third International Coral Reef Symposium; University of Miami, Miami, FL: Rosenstiel School of Marine and Atmospheric Science; 1977: 297-303.

Pearse, A. S.; Williams, L. G. The biota of the reefs off the Carolinas. J. Elisha Mitchell Sci. Soc. 67: 133-161; 1951.

Peterson, C. H. The importance of predation and competition in organizing the intertidal epifaunal communities of Barnegat Inlet, New Jersey. Oecologia 39: 1-24; 1979.

Pielou, E. C. Ecological Diversity. New York: John Wiley & Sons; 1975.

Pinkas, L.; Oliphant, M. S.; Iverson, I. L. K. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Dep. Fish Game Fish Bull. 152: 1-105; 1971.

Porter, J. W. Predation by _Acanthaster_ and its effect on coral species diversity. Am. Nat. 106: 487-492; 1972.

Porter, J. W. Community structure of coral reefs on opposite sides of the Isthmus of Panama. Science 186: 543-545; 1974.

Powles, H. Larval distributions and recruitment hypotheses for snappers and groupers in the South Atlantic Bight. Proc. Annu. Conf. Southeast. Assoc. Fish. Wildl. Agencies 31: 362-371; 1977.

Powles, H.; Barans, C. A. Groundfish monitoring in sponge-coral areas off the southeastern United States. Mar. Fish. Rev. 42(5): 21-35; 1980.

Presley, R. F. Larval snowy grouper, _Epinephelus_ _niveatus_ (Valenciennes, 1828), from the Florida Straits. Leaflet Series - Marine Research Laboratory. 1970; 6 p. Leaflet Series Vol. 4, Part 1, No. 18. Available from: Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL.

Randall, J. E. Tagging reef fishes in the Virgin Islands. Proc. Gulf Caribb. Fish. Inst. 14: 201-240; 1962.

Randall, J. E. An analysis of the fish populations of artificial and natural reefs in the Virgin Islands. Caribb. J. Sci. 3(1): 31-47; 1963.

Randall, J. E. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. (Miami) 5: 665-847; 1967.

Ranzi, S. Sparidae. Lo Bianco, S. ed. Eggs, larvae, and juvenile stages of teleostei. Parts 1 & 2, Fauna and Flora of the Bay of Naples, Monograph No. 38: 330-375. Washington, D. C.: Smithsonian Institution; 1969. Translated from Italian by L. Franchetti.

Rao, P. K.; Strong, A. E.; Koffler, R. Gulf Stream meanders and eddies as seen in satellite infrared imagery. J. Phys. Oceanogr. 1: 237-239; 1971.

Roe, R. B. Distribution of royal-red shrimp, _Hymenopenaeus_ _robustus_, on three potential commercial grounds off the southeastern United States. Fish. Ind. Res. 5(4): 161-174; 1969.

Ross, S. T. Patterns of resource partitioning in searobins (Pisces: Triglidae). Copeia 1977 (3): 561-571; 1977.

Sanders, H. L. Florida oil spill impact on the Buzzards Bay benthic fauna: West Falmouth. J. Fish. Res. Board Can. 35: 717-730; 1978.

Schneider, C. W. Spatial and temporal distributions of benthic marine algae on the continental shelf of the Carolinas. Bull. Mar. Sci. 26(2): 133-151; 1976.

Schumacher, J. D.; Korgen, B. J. A seabed drifter study of near-bottom circulation in North Carolina shelf waters. Estuarine Coastal Mar. Sci. 4: 207-214; 1976.

Science Applications, Inc. South Atlantic OCS physical oceanography, final progress report, Volume II, technical report. Washington, D. C.: Bureau of Land Management; 1981; 354 p. Available from: Bureau of Land Management, Washington, D. C.; contract no. AA551-CT8-52.

Sedberry, G. R. Food habits, prey selectivity, and food resource partitioning of a community of fishes on the outer continental shelf. Williamsburg, VA: College of William and Mary; 1980. 166 p. Dissertation.

Sekavec, G. B.; Huntsman, G. R. Reef fishing on the Carolina Shelf. Proc. Ann. Int. Game Fish Res. Conf. 15: 78-86; 1972.

Sharp, J. R.; Fucik, K. W.; Neff, J. M. Physiological basis of differential sensitivity of fish embryonic stages to oil pollution. Vernberg, W. B.; Calabrese, A.; Thurberg, F. P.; Vernberg, F. J. eds. Marine pollution: functional responses. New York, NY: Academic Press; 1979: 85-108.

Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill; 1956.

Smith, C. L.; Tyler, J. C. Space resource sharing in a coral reef fish community. Bull. Los Angeles Co. Mus. 14: 125-170; 1972.

Smith, C. L.; Tyler, J. C. Population ecology of a Bahamian suprabenthic shore fish assemblage. Am. Mus. Novit. 2528: 1-38; 1973.

Smith, F. E. Spatial heterogeneity, stability and diversity in ecosystems. Deevey, E. S. ed. Growth by intussusception. Ecological essays in honor of Evelyn Hutchinson. Trans. Conn. Acad. Arts and Science 44; 1972.

Sneath, P. H. A.; Sokal, R. R. Numerical taxonomy: the principles and practice of numerical classification. San Francisco, CA: W. H. Freeman Co.; 1973.

Sokal, R. R.; Rohlf, F. J. Biometry. San Francisco, CA: W. H. Freeman Co.; 1969.

Spies, R. B.; Davis, P. H. The infaunal benthos of a natural oil seep in the Santa Barbara Channel. Mar. Biol. 50: 227-237; 1979.

Stefansson, U.; Atkinson, L. P.; Bumpus, D. F. Seasonal studies of hydrographic properties and circulation of the North Carolina shelf and algae waters. Deep-sea Res. 18: 383-420; 1971.

Stoecker, D. Chemical defenses of ascidians against predators. Ecology 61(6): 1327-1334; 1980.

Stone, R. B.; Pratt, H. L.; Parker, R. O., Jr.; Davis, G. E. A comparison of fish populations on an artificial and natural reef in the Florida Keys. Mar. Fish. Rev. 41(9): 1-11; 1979.

Strickland, J. D. H.; Parsons, T. R. A practical handbook of seawater analysis. Ottawa, Canada: Fisheries Research Board of Canada; 1972.

Struhsaker, P. Demersal fish resources: composition, distribution and commercial potential of the continental shelf stocks off the southeastern United States. Fish. Ind. Res. 4(7): 261-300; 1969.

Tardent, P. Regeneration in the hydrozoa. Biol. Rev. 38: 293-333; 1963.

Taylor, C. C. Nature of variability in trawl catches. Fish. Bull. 54: 145-166; 1953.

Tenore, K. R. Macroinfaunal benthos. Texas Instruments, Inc. South Atlantic OCS Benchmark Program, 1977 report. New Orleans, LA: Bureau of Land Management; 1978; Vol. III: 257-288. Available from BLM, New Orleans, LA. Contract no. AA550-CT7-2.

Terry, R. D.; Chilingar, G. V. Summary of "Concerning some additional aids in studying sedimentary formations" by M. S. Shvetsov. J. Sediment. Petrol. 25: 229-234; 1955.

Thomas, M. L. H. Effects of Bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia. J. Fish. Res. Bd. Canada: 30: 83-90; 1973.

Thomas, R. E.; Rice, S. D. The effect of exposure temperatures on oxygen consumption and opercular breathing rates of pink salmon fry exposed to toluene, naphthalene, and water-soluble fractions of Cook Inlet crude oil and No. 2 fuel oil. Vernberg, W. B.; Calabrese, A.; Thurberg, F. P.; Vernberg, F. J. eds. Marine pollution: functional responses. New York, NY: Academic Press; 1979: 39-54.

U. S. Department of Commerce, Office of Coastal Zone Management. Final Environmental impact statement on the proposed Gray's Reef Marine Sanctuary; 1980. Available from U. S. Department of Commerce, NOAA, Office of Coastal Zone Management, 3300 Whitehaven Street, N. W., Washington, D. C.

U. S. Dept. of the Interior, Bureau of Land Management. Final environmental impact statement; OCS Sale 56. Proposed 1981 OCS oil and gas lease sale 56. Washington, D. C.; 1981.

U. S. Geological Survey Office of Marine Geology. Southeast Atlantic OCS geological studies; Final Report F. Y. 1976; Washington, D. C.: Bureau of Land Management; 1979.

Uzmann, J. R.; Cooper, R. A.; Theroux, R. B.; Wigley, R. L. Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: submersible vs. camera sled vs. otter trawl. Mar. Fish. Rev. 39(12): 11-19; 1977.

Van Dolah, R. F.; Calder, D. R.; Knott, D. M.; Maclin, M. S. Effects of dredging and unconfined disposal of dredged material on macrobenthic communities in Sewee Bay, South Carolina. Technical Report - S. C. Marine Resources Center. 1979; 54 p. Technical report no. 39. Available from: S. C. Marine Resources Center, Charleston, SC.

Virnstein, R. W. The importance of predation by crabs and fishes on benthic infauna in Chesapeake Bay. Ecology 58(6): 1199-1217; 1977.

Virnstein, R. W. Predation on estuarine infauna: response patterns of component species. Estuaries 2(2): 69-86; 1979.

Waldichuk, M. Some biological concerns in heavy metals pollution. Vernberg, F. J.; Vernberg, W. B. eds. Pollution and physiology of marine organisms. New York, NY: Academic Press; 1974: 1-57.

Waltz, C. W.; Roumillat, W. A.; Wenner, C. A. Biology of the whitebone porgy Calamus leucosteus in the South Atlantic Bight. S. C. Marine Resources Center, Charleston, SC. In preparation.

Wathne, F. Observations on trawl-door spread and a discussion of influencing factors. Commer. Fish. Rev. 21(10): 7-15; 1959.

Wells, H. W.; Gray, I. E. Summer upwelling of the northeast coast of North Carolina. Limnol. Oceanogr. 5(1): 108-109; 1960.

Wells, H. W.; Wells, M. J.; Gray, I. E. Ecology of sponges in Hatteras Harbor, North Carolina. Ecology 45: 752-767; 1964.

Wenner, C. A.; Barans, C. A.; Stender, B. W.; Berry, F. W. Results of MARMAP otter trawl investigations in the South Atlantic Bight. V; Summer, 1975. Technical Report - S. C. Marine Resources Center. 1980; 57 p. Technical Report No. 45. Available from: S. C. Marine Resources Center, Charleston, SC.

Whittaker, R. H. Dominance and diversity in land plant communities. Science 147: 250-260; 1965.

Whittaker, R. H. Communities and ecosystems. London, England: The Macmillan Company; 1970: 162.

Williams, W. T. Principles of clustering. Annu. Rev. Ecol. Syst. 2: 303-326; 1971.

Williams, W. T.; Lambert, J. M. Multivariate methods in plant ecology. III. Inverse association - analysis. J. Ecol. 49: 717-729; 1961.

Windell, J. T. Food analysis and rate of digestion. Ricker, W. E. ed. IBP Handbook No. 3. Methods for assessment of fish production in fresh waters. London, England: Blackwell Scientific Publications; 1971: 215-226.