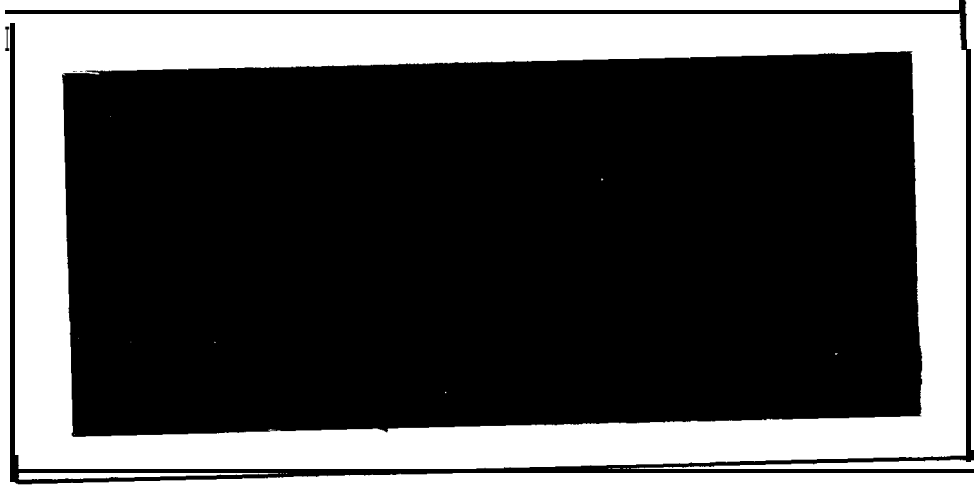


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SCIENCE Applications, INC.

SOUTHERN CALIFORNIA BASELINE STUDY
BENTHIC, YEAR TWO
VOLUME II, REPORT 19.0
VARIATION IN COMMUNITY STRUCTURE OF SHELF,
SLOPE AND BASIN MACROFAUNAL COMMUNITIES OF
THE SOUTHERN CALIFORNIA BIGHT

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VOLUME II, REPORT 19.0

VARIATION IN COMMUNITY STRUCTURE OF SHELF,
SLOPE AND BASIN MACROFAUNAL COMMUNITIES OF
THE SOUTHERN CALIFORNIA BIGHT

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ABSTRACT

The benchmark study was designed to determine the structure of benthic macrofaunal associations and natural variations within these associations, over time, in selected study sites. Five study sites were chosen: off San Pedro, on the slope of San Pedro Basin; off Coal Oil Point and on the slope of Santa Barbara Basin; on the shelf south of San Miguel Island; on the northern portion of the Santa Rosa-Cortes Ridge south of Santa Rosa Island, the slope of Santa Cruz Basin and within the Basin; and on the southern portion of the Santa Rosa-Cortes Ridge, including Tanner Bank, the slope of San Nicolas Basin and the Basin itself. Replicate box core sampling was conducted twice during the year, once in winter and once in summer, at each station in these five areas. Eight replicate samples were collected at each station during each leg of the benthic cruise. Samples underwent preliminary analysis, analysis by the Rapid Identification Procedure (RIP), and detailed, or complete, analysis involving identification of specimens to the lowest practicable taxon (usually the specific level). Population density, species richness and standing crop were determined. Animals were assigned to feeding and mobility types and life stages were determined for species representing a phylogenetic and ecologic spectrum of benthic invertebrates. Data analysis also included computerized classification and recurrent group techniques, calculation of dispersion chi-square values (Jumars, 1975), and determination of values for concordance, diversity, evenness, and dominance. Direct data inspection was applied to each of the five study sites. Multiple discriminant analysis was used to compare biotic and environmental data.

Results of analysis indicated that the mainland shelf sites could be characterized by large, homogeneous assemblages in which the fauna were randomly dispersed. Deposit feeders, especially surface deposit feeders, were dominant, and there were indications of seasonal recruitment from winter to summer in some species. Slope sites could be separated into upper and lower zones. The fauna was randomly dispersed and subsurface deposit feeders predominated. There was no clear evidence of seasonality. The fauna of the ridge and banks exhibited a very patchy distribution forming a mosaic of four assemblages. Diversity was high and there were some indications of seasonality. The basins were each characterized by a distinct faunal assemblage. The fauna was randomly dispersed, surface deposit feeders predominated, and there was no clear evidence of seasonality. It must be borne in mind, however, that these patterns were based on only two data points, one winter and one summer, and must therefore be considered preliminary attempts to delineate community structure and variation within the southern California macrobenthos.

ACKNOWLEDGEMENTS

A project of this magnitude necessarily requires the dedicated work of many individuals. Deep appreciation is extended to the crew of the R/V THOMAS G. THOMPSON who assisted in the collection of samples, to the staff of taxonomists and assistants who painstakingly sorted and identified thousands of specimens, and to the staffs at GEOSSECS and Science Applications, Inc. who assisted with data processing and other matters.

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This work is dedicated with a great deal of affection to our tireless and conscientious staff, and to the memory of Barnaby Jones.

19.0 VARIATION IN COMMUNITY STRUCTURE OF SHELF, SLOPE AND BASIN MACROFAUNAL COMMUNITIES OF THE SOUTHERN CALIFORNIA BIGHT

19.1 INTRODUCTION

19.1.1 Objectives and Rationale

The Southern California Bight is part of a unique geologic area located at the interface between major biogeographic regions. The oceanographic system of the Bight is complex and variable. Similarly, the diversity of its fauna and flora are great, as has been shown in such studies as those of Hartman (1955, 1956, 1963, 1966), Hartman and Barnard (1958, 1960), and Jones (1969).

The lease sale of offshore tracts in the Southern California Bight signaled the imminent development of the energy resources of this region. Environmental studies were thus initiated to describe and quantify the chemical, geological, and biological characteristics of the Bight. These studies were designed to establish a data base documenting the existence and range of naturally occurring variations in the Bight environment and its faunal components. Their intent was to provide the Bureau of Land Management with the information necessary to (1) make sound management decisions in the Southern California Borderland, and (2) assign probable cause in the event of environmental changes associated with resource development in this region.

The baseline study was begun in 1975 with a broad-focus survey of sites in and around areas likely to be affected by the development of offshore oil and gas reserves. In 1977, it was narrowed to the study of carefully selected locations chosen according to the following criteria:

- areas of high oil and gas potential
- areas of high biological resource value
- "control" areas outside possible lease sites
- areas of possible hydrocarbon accumulation
- areas representative of the wide range of physiographic provinces in southern California
- areas representative of the range of current advection and sediment deposition.

¹ Southern California Benthic and Water Column Study, Work Statement of Second Year Baseline Research Effort in FY 1977.

Except in the case of massive impacts, indication of man-caused changes in the marine environment can best be documented by studies of the impact of these changes on sessile or poorly mobile organisms. Organisms in the water masses, like the plankton, are too quickly moved. In contrast, members of most benthic populations move slowly or not at all. Hence, benthic macrofaunal populations are more likely to show the effects of low-level, long-term insults and are the best potential indicators of "the impact of offshore resource development on the biota."

The benthic macrofauna off southern California is often mentioned as being among the best known in the world. In a limited sense this is probably true, as an unusually high proportion of the kinds of animals present has been recognized and described. However, naming animals differs significantly from knowing how their numbers change in space and with time, or how they interact with one another, or what they are doing in and for the ecosystem.

Communities change, both in space and with time. Knowledge of the extent of expected natural variations is a prerequisite to monitoring activities designed to assess the effects of any potential man-caused impacts. Only by knowing how associations of organisms vary naturally can one separate normally occurring changes from man-caused variations. The distinction between natural variation and man-caused changes is basic to determining that an impact has occurred in the marine environment, just as it is fundamental to evaluating the magnitude of the impact and assigning probable causes.

19.1.2 The Southern California Bight

According to Emery (1960, p. 4), "...the sea floor between the mainland shoreline and the continental slope off southern California is much more complex than typical continental shelves of most other areas of the world." He stresses the fact that its features are unique for the sea floor, belonging neither to the continental shelf, to the continental slope nor to the abyssal sea floor. Menard (1964), however, doubts that the area is unique. Unique or not, the sea floor off southern California and northern Baja California (Mexico) is sufficiently different and complex to have been designated by a special term, "the continental borderland" (Shepard and Emery, 1941; Uchupi and Finery, 1963).

The part of the borderland that forms the Southern California Bight includes islands, banks, ridges, basins and troughs. Here, the sea floor consists of basins and ridges with an east-west (in the north) to a northwest-southeast (in the south) orientation. Topographic highs form deeply submerged sills, shallow flat-topped banks, or islands projecting above the sea surface. Thirteen basins and several open troughs are enclosed by these high areas. Numerous

submarine canyons transect the mainland and island shelves and most of these descend into basins. The narrow strip of ocean bottom immediately adjacent to the continent is designated the mainland shelf (Emery, 1960).

Imposed upon this structural variety is a highly diverse substrate pattern that ranges from basement rock through exceedingly fine terrigenous sediments with increasing admixtures of planktonic sediments from inshore to offshore basins. Water depths range from sublittoral to bathyal. Consequently, the sea floor of the Bight consists of a complex set of benthic habitats that is proportionately large, considering the relatively small size of the region.

The diversity of the macrobenthic fauna reflects the complex habitat pattern of the Bight. Indeed, Hartman (1955, 1956) was impressed by the patchy distribution of the biota; "patchiness" became an integral part of her interpretation, and she concluded that, with one exception, "large-scale communities of organisms cannot be identified" (Hartman, 1966, p. 190). Such associations have been recognized, at least on the mainland shelf (Jones, 1969), but their definition is problematic.

The geographic location of the Bight is another reason the benthic fauna is unusually diverse as compared with continental shelf associations in other parts of North America. The Bight is situated in the northern half of the Californian biogeographic region, a transition zone between two much larger biogeographic regions--the Oregonian (its southern boundary is Point Conception) and the Panamic (its northern boundary is Magdalena Bay, Baja California). In addition to a large number of endemic forms, species characteristic of both of these large biogeographic regions are present in the California region.

The complexity of the southern California water masses approaches that of the ocean floor beneath it. The dominant hydrographic feature here, as elsewhere along the California coast, is the California Current. It controls the general water character and circulation of the region. As a result of the indentation of the southern California coast, the Current flows past the borderland at its seaward edge, about 300 km offshore. Over the borderland, east of the Current, eddies predominate. Below 200 m, a deep counter-current, flowing northward along the coast from Baja, California, brings warmer and more saline water to higher latitudes. Localized phenomena, such as "upwelling", further complicate the picture (Emery, 1960; Schwartzlose, 1963; Jones, 1971). The great temporal variability of the current pattern of the Bight may well be another important influence contributing to diversity of benthic associations through the mechanism of larval transport.

19. 1.3 Background

Scientists of the Allan Hancock Foundation of the University of Southern California have carried out research on the benthos of the Southern California Bight for 25 years. The first quantitative sampling of the benthos began in 1952. Hartman (1955, 1966) recorded the organisms from samples collected at 267 locations forming a regular grid between San Pedro, California and Santa Catalina Island. She extended her analysis of the southern California benthos with a study of the fauna of Santa Monica Bay (Hartman, 1956). In the same year, the sampling program of the Allan Hancock Foundation was extended to all of the mainland shelf of southern California. This comprehensive survey was supported by the California State Water Pollution Control Board and was completed in 1961 (AHF:USC, 1959, 1965). During this period, Hartman and Barnard began a study of the benthos of the deep 'basins of the borderland (Hartman and Barnard, 1959, 1960) and Hartman, collaborating with Emery, studied the benthos of the submarine canyons (Hartman, 1963). After the conclusion of the "State Project," Jones began a three-year study of the meiofauna of the mainland shelf (Given and Jones, 1962; Jones, 1964). Jones continued the analysis of the samples and data from the "State Project" (Jones, 1963, 1965, 1967; Jones and Barnard, 1963) and completed a major analysis of the data base in 1967 (Jones, 1969).

Working with a group of Allan Hancock Foundation scientists, Fauchald (1971) studied the impact of the Santa Barbara oil spill on the biota of the Santa Barbara Channel. Fauchald designed and organized the study of the benthic macrofauna. He supervised the sample processing and ensured correct identification of the fauna by helping with difficult systematic problems, and he analyzed the data and prepared the final report.

Together with a post-doctoral fellow (Peter A. Jumars), Fauchald also participated in a research study of a bathyal community in the San Diego Trough. Sampling was conducted with the RUM (Remote Underwater Manipulator) vehicle. They are presently studying the microdistribution and the functional morphology of the organisms of this community.²

¹Developed under the sponsorship of the Office of Naval Research at the Marine Physical Laboratory.

²The extensive research of D. J. Reish, D. F. Soule and others on the harbors and other embayments of southern California is not summarized in this brief review.

19.1.4 The Baseline Study, 1975-1976

The baseline study of the benthic macrofauna performed during 1975-1976 was one of the largest ever undertaken in the Southern California Bight ; only the "State Project" was comparable in size. The benthic macrofaunal survey was part of a coordinated, comprehensive investigation of the sea floor of the Bight that involved--in addition to benthic ecology --micropaleontology, sedimentology, trace metal and hydrocarbon geochemistry. Geochemical measurements were correlated with similar measurements in the water column and with trace metal and hydrocarbon levels in epibenthic invertebrates. The scope of the work done and the diversity of the scientific and technical disciplines involved made the project unique in comparison to previous studies. The project was funded by the Bureau of Land Management (Department of Interior) and was managed by scientists at Science Applications, Incorporated (La Jolla, California). It involved scientists from a number of prestigious California institutions, including the California Institute of Technology, California State University at Northridge, Moss Landing Marine Laboratories, Scripps Institution of Oceanography, the University of California at Santa Cruz and the University of Southern California. Industrial participants were Analytical Research Laboratories, Inc. (Monrovia, California) and Esca-Tech Corp. (Long Beach, California).

Benthic sampling was concentrated in 11 High Density Sampling Areas (HDSA's), most of which were associated with the lease tracts nominated by the Bureau for offshore resource development. Four of these HDSA's were adjacent to the mainland shelf; the others were adjacent to the offshore islands and astride the outer banks. The 372 square nautical mile area of the 11 HDSA's was sampled at 546 stations arranged in regular grids of one nautical mile; 321 other stations were located outside the HDSA's.

This study was the most extensive ever made of the benthos of the Southern California Bight from the standpoint of investigating the widest array of biotopes. It investigated the biota of every major habitat of the Bight: areas of the mainland shelf and its slopes, the nearshore basins, the island shelves, the intermediate basins and their slopes, the outer banks and the deep outer basins and their slopes. Almost the entire range of substrates known to exist in the Bight was studied. Sampling locations varied from shallow shelf depths (minimum, 7.0 m) to deep basin depths (maximum, 1886.0 m).

The two most important aspects of the baseline study of the benthic macrofauna are that the slope fauna--for the most part poorly sampled in all previous surveys--was intensively studied, and that the fauna of the outer island shelves, the banks and ridges--almost unknown to science--was extensively investigated for the first time. Numerous new taxa were discovered; new faunistic assemblages were documented.

The overall objective of the baseline study of the benthic macro fauna was to document the abundance, composition and diversity of the benthic macrofauna of the study area. The program was designed to complement existing data bases in order to maximize information about conditions in the Bight.

19.1.5 The Benchmark Study, 1977-1978

One of the major problems 'in predictive marine benthic ecology has been a lack of understanding of variation in the composition and distribution of the benthos. This problem was evident after the Santa Barbara oil spill (1969), when it was not possible to assign even very drastic changes in benthic standing crop and species composition to any given cause, natural or man-made (Fauchald, 1971). This problem has been known of for a long time and has been commented upon regularly (Petersen, 1913; Thorson, 1957; Holme and McIntyre, 1971). It formed the background for the detailed studies of micro-distributional properties of the benthos initiated by Hessler (Jumars, 1975a, b). These studies were concentrated initially in the deep benthos to avoid some of the obvious complexities of working in shallow water (such as random fluctuations in the depositional environment) or at least to allow such fluctuations to be lessened by distance from the source of variability.

The present study was designed to delimit the extent of the natural variations with time in the benthic faunal associations defined at the selected study sites. The study was to serve both as the foundation for, and the plan of, a monitoring program, but it was not a monitoring program in itself, since this term implies knowledge of what variation might be expected. The intent was to provide the Bureau of Land Management with a means of evaluating changes in the biota in a limited number of selected areas.

The majority of the sampling was conducted in lease areas, offshore regions likely to be affected by oil and gas development, and areas of special biological interest. Where possible, the sampling plan took advantage of other oceanographic programs by coordinating with and complementing these efforts.

Replicate box core¹ sampling was conducted in five areas (benchmark study sites): off Coal Oil Point and the slope of Santa Barbara Basin; off San Pedro, on the slope of San Pedro Basin and within the Basin; south of San Miguel Island; on the northern portion of the Santa Rosa-Cortes Ridge south of Santa Rosa Island, the slope of

¹Modified 1/16 m² USNEL (United States Naval Electronics Laboratory) spade (or box) corer (see Hessler and Jumars, 1974).

Santa Cruz Basin and within the Basin; and on the southern portion of the Santa Rosa-Cortes Ridge, including Tanner Bank, the slope of San Nicolas Basin and the Basin itself. Sampling was done twice during the year, once in the period of low water temperature (late winter to early spring) and once in the period of high water temperature (late summer to early fall)'.

Temporal variation was studied in the replicate samples taken at the benchmark stations. Human and computerized data analysis techniques were used in conjunction in the attempt to evaluate changes in benthic macrofaunal composition and abundance levels occurring during the time encompassed by the study. It should be borne in mind, however, that the biological benchmark objectives were not intended to be satisfied in a single year's effort. Indeed, a minimum of three years (six sampling periods) would be required to document temporal variation in the benthic macrofaunal associations at the benchmark sampling locations in the Bight. For this reason, the results reported in this paper must not be considered conclusive and must be viewed as a preliminary attempt to delineate ranges of natural variation in the southern California macrobenthos.

19.2 LITERATURE REVIEW

Marine benthic communities can vary spatially according to their depth below the ocean surface, penetration into and height above the substrate, and their horizontal distribution on the sea floor. They can also change over time. The spatial or temporal variation to be found in a given marine community depends largely on its depth.

The broad trends of spatial variation are due to the depth, the type and relief of the bottom, the distance from land, and the productivity of the adjacent euphotic zones. Rocky bottoms, escarpments, or coarse, shifting sands will be suitable to motile animals and suspension feeders (Dell, 1954). soft, gently sloping accumulative bottoms will be inhabited by deposit feeders and animals of limited mobility. Greater numbers and biomass of animals usually will be found near land, where food from terrestrial sources, neritic production, and also primary production in the oceanic waters is available. In deep areas or in oligotrophic zones, the need for a larger foraging radius in order to acquire enough food limits the number of animals and their feeding types (Fournier, 1971-72; Sokolova, 1972; Jumars and Fauchald, 1977).

¹In most temporal studies, when sampling cannot be conducted more frequently, a quarterly sampling program is timed to coincide with "the seasons." Four seasons do not occur in the southern California marine environment; there are only two, the period of warm water (May to November), with the warmest water in July, August and September, and the period of cold water (November to May), with the coldest water in January, February, and March (Jones, 1967; SCCWRP, 1973).

The activities of animals on soft bottoms can affect the number and kinds of species to be found there. Deposit feeders, such as the polychaetes Pectinaria spp. and the sea cucumbers Molpadia spp., act as living conveyor belts, selecting fine sediments beneath the surface of the substrate and excreting them at the surface after extraction of food. The fine sediments may be resuspended in the water and clog the filtering mechanisms of suspension feeders. Such activities result in assemblages of deposit feeders and a few small suspension feeders that can live in the cones or mounds produced by the deposit feeders (Gordon, 1966; Rhoads, 1974; Woodin, 1976).

Tube-building animals or animals that form fecal pellets often prevent the establishment of deposit feeders in an area. Masses of tubes bind the sediment so that large burrowers cannot find suitable habitat. Fecal pellets bind sediment into larger particles which will not be suspended in the water as easily as the wastes from deposit feeders. This inhibition of organisms of one feeding type by those of another, termed "trophic amensalism" by Rhoads (1974), can delineate one assemblage from another quite sharply (Mills, 1969; Woodin, 1974, 1976).

The chance settlement of swarms of larvae can produce dense patches of a single species. Planktonic larvae often are released by the adults in swarms. If currents happen to bring a large number of larvae ready to settle into a suitable area, an enormous local increase in the population may result. Rare, fast-moving currents on occasion can carry larvae for thousands of miles and result in isolated patches of expatriate species (Thorson, 1961; Strathmann, 1974).

In shallow water, disturbances by the activities of predators, siltation, or storms are fairly frequent. A "washout" or burial by fine sediment can change an area dominated by tube-builders into an open area in a few weeks (Fager, 1964; Mills, 1969). Similarly, a sudden abundance of food can attract wide-ranging scavengers within hours to a small area (Schulenberg and Hessler, 1974).

In the deep sea, temperatures, oxygen and salinity tend to be constant. High species diversity is usual. Localized increases in biomass and numbers of animals may be due to the quantity and nutritional quality of production in the nearest euphotic zone or to the transport of food through submarine canyons. Seismic activity that causes rapid sedimentation can result in localized depauperate areas (Sanders, 1968; Sanders and Hessler, 1969; Rowe, et al., 1975; Rex, 1976; Jumars and Hessler, 1976).

High species diversity in the deep sea is related to biological accommodation--adaptations that allow the animals to avoid competition (Sanders, 1968). Under the stable conditions prevailing in the deep sea, interactions between individuals become important in

determining the scale of distribution of the animals. Species in which the scale of these interactions (the "ambit" of Jumars, 1975a) is small tend to have higher diversity than those species with more interactions. In deep-sea polychaetes, such interactions may lead to microhabitat specialization noticeable only over areas of 0.10 m or less (Jumars, 1975a, b).

Off southern California, the metazoan fauna is sparse below the sills in the nearshore basins. The sills, located below the level of the oxygen minimum, cut off circulation to deeper waters. Below the sills, nutrient levels are high but the oxygen concentration is severely limited. Bacterial decomposition of organic matter that settles into the basins further depletes the oxygen below the level at which metazoans can survive. During occasional periods of mixing by standing waves or turbidity currents, however, metazoans can survive on the bottoms of the basins until stagnant conditions return (Emery and Hulsemann, 1962; Sholkovitz and Soutar, 1975).

Communities vary over time as well as space. The continental borderlands of southern California date from the early and middle Miocene time (Moore, 1976). However, animals such as monoplacophorans, related to the deep-sea fauna that arose in the Paleozoic and early Mesozoic, still remain in some areas. The fossil record suggests changes from warm to cold water faunas and back, particularly during Pleistocene times. Changes in the composition of the fauna of the inshore area as a whole have been occurring in the Foraminifera over the past few hundred years (Douglas, Walch, and Blake, pers. comm.). The mixture of newer immigrants into shallow waters, immigrants into deeper areas of the borderlands, and older relics has created a diverse fauna in the offshore waters of California (Parker, 1961).

The shallow waters of the continental shelf are close to the euphotic zone, in which blooms of phytoplankton take place. Reproduction and biomass of the benthic fauna often are related to these blooms. In seasonal environments, the production of planktotrophic larvae parallels this seasonality in many invertebrates (Underwood, 1974). When a good supply of food is available from seasonal productivity, crustaceans may attain reproductive maturity more rapidly and reach larger sizes than when food is scarce (Wenner, et al., 1974). Polychaetes often show changes in biomass from a low just before the settlement of the year's class of larvae to a high in late fall (Buchanan and Warwick, 1974; Nichols, 1975). Mass mortalities may take place after the completion of spawning (Mills, 1969). The year-class phenomenon, in which all the individuals of a species are of roughly the same age, is common in some communities (Sanders, 1968). The seasonal patterns of different species, even in areas close to one another, may be out of phase (Frankenberg and Leiper, 1977).

Frequent changes in the shallow/water environment allow for three strategies of reproduction among the invertebrates. Opportunists ("volatile species" of Buchanan, et al., 1974) are the first colonists in an open area. They are fast growing, often produce many small eggs and abundant larvae, have a short life and high mortality rate, and usually do not grow to a large size. Equilibrium species ("conservative species" of Buchanan, et al., 1974) rarely become as abundant as the opportunists, but live longer, grow larger, usually develop slowly, and have lower rates of mortality and recruitment. These species tend to occur in low but constant numbers from year to year. Many polychaetes are opportunists, while echinoderms often are equilibrium species (Grassle and Grassle, 1974; Buchanan et al., 1974; McCall, 1977).

Due to frequent changes in the nearshore environment, communities of the continental shelf can undergo relatively rapid succession. The failure of the larvae of one year class to settle in ample numbers can enable a different species to occupy the vacant territory after mortality of adults (Buchanan et al., 1974). The activities of the amphipod Ampelisca abdita and other pellet-forming species can alter the substrate so that their own larvae cannot settle among the adults. This lack of recruitment causes the community to change as the adults die (Mills, 1969). Depending on the environmental conditions and the settlement of larvae, the community may stabilize into one dominated by one or more equilibrium species or may fluctuate among several stable points (Gray, 1977).

Succession due to competition has been found among shallow/water deposit feeders. This competition may be due to interference (disturbance of burrows, reduction of feeding radius, or local destabilization of sediments) or differences in exploitation (efficiency of use of a given resource, such as the organic content of a sediment). Such interactions between species can result in the eventual extinction of a species in an area or a narrowing of the niche of a species over time (Levinton, 1977).

Off the Pales Verdes Peninsula in Los Angeles County, the fauna recently has been changing from one dominated by the polychaete Capitella capitata and other pollution-tolerant species to one containing the echiuroid Listriolobus pelodes. Restrictions on the sewage outfalls have reduced the areas of anoxic sediments and lessened the percentage of clay-sized sediment. As the disturbed area has declined in size, species characteristic of clean bottoms have settled in the vicinity of the outfalls (SCCWRP, 1976).

Most deep-sea species are long-lived, produce few larvae, and have low rates of recruitment and mortality (Grassle and Sanders, 1973). Usually, the ophiuroids, isopods, and amphipods breed year round, but only a small proportion of the population will be reproductively active at any given time (Rokop, 1974, 1977). Seasonal reproduction

occurs in some ophiuroids, brachiopods, and scaphopods which have extensive vertical ranges from the deep sea to the continental shelf (Schoener, 1968, 1972; Rokop, 1974). Due to the low mortality and recruitment, populations consist mostly of adults (Grassle and Grassle, 1974).

19.3 SAMPLING DESIGN

19.3.1 Benchmark Study Sites

The broad geographic area examined extended from latitude 32°35'N to latitude 34°35'N and longitude 117°00'W to 121° 00'W. The majority of the sampling was conducted within these boundaries, with emphasis on areas of possible leasing, offshore regions likely to be affected by oil and gas development, and areas of special biological interest. Where possible, the sampling plan was designed to coordinate with and complement the efforts of other oceanographic programs. Consideration was given to locations sampled during the baseline study for FY 1975-1976, as well as to such factors as depth ranges, sediment types, and geologic characteristics of the sampling locations, i.e., the stations were arranged where possible along environmental gradients so as to yield the most meaningful scientific results.

The benchmark study sites chosen for sampling and analysis are shown in Figure 11-19.0-1. In all, twenty-one (21) stations were sampled at the following locations:

- San Pedro study site
- Coal Oil Point study site
- Santa Rosa Ridge study site
- Tanner Bank Basin study site

19.3.2 Navigation

Sampling was performed aboard the R/V THOMAS G. THOMPSON of the University of Washington (Seattle, Washington). A navigational system was used that could guarantee an accuracy of + 30.5 m. This system was also used in the baseline study for FY 1975-1976.

As replicate samples were collected at all of the benchmark study sites, a cluster of samples was obtained at each station location. Such clustering was desirable because "... clustering minimizes the probability of crossing large-scale gradients and intercommunity boundaries of no direct interest in the question of within community habitat portioning" (Jumars, 1975a, p. 246).

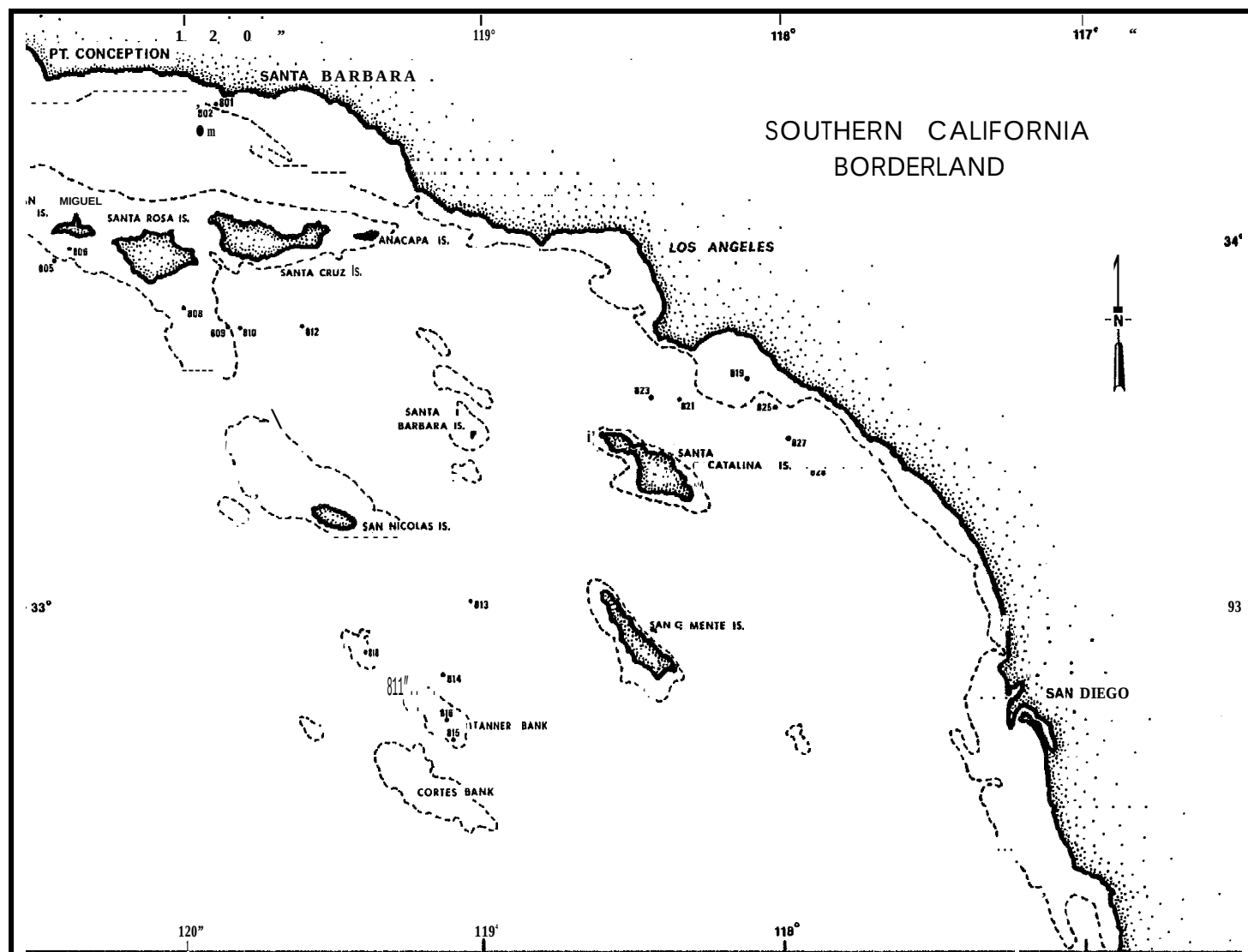


Figure 11-19.0-1. Map of the Southern California Borderland showing the locations of the benchmark study sites.

19.3.3 Periodic Sampling

Each station was sampled twice during the term of the study. The first group of samples was collected during the winter period of low water temperature (late winter to early spring) . The second group of samples was collected during the summer period of high water temperature (late summer to early fall).

It should be emphasized ~~that~~ this "year's effort was not intended to satisfy the biological benchmark objectives of this program. The findings of a single winter- sampling and a single summer sampling must necessarily be inconclusive. Although they might indicate trends in temporal variation, a minimum of three years (six sampling periods) ~~would~~ be required to document changes that occur naturally over time in the benthic ~~macrofaunal~~ associations of the Bight.

19.3.4 Replication

For both the winter and summer sample-sets, eight (8) replicates were collected at each of the twenty-one (21) benchmark sampling locations¹ to ensure adequate representation of the fauna at each study site. In all, three hundred and eighteen (318) biological box cores were collected at the ~~benchmark~~ stations.

19.4 SAMPLING METHODS

19.4.1 Box Coring

The biological box core samples were collected with a 1/16 m² USNEL spade (or box) corer (20 x 30 cm aerial coverage) equipped with stainless steel boxes. An underwater shutter bottom camera was bolted to the box corer frame; this camera unit was designed to photograph the area sampled by the box corer prior to penetration. Photographs of the bottom were to be used to assess the benthic epifauna and to ~~document~~ the general nature of the habitat at each sampling location.

- Upon recovery, the stainless steel box containing the sample was removed from the sampler and placed in a large, fibreglassed wooden biology deck box. The core was measured and described, the description including both sedimentary and biological characteristics. Next, the supernatant water was siphoned into the deck box.

- When siphoning had been completed, a square micropaleontological subsampler (10 x 10 x 1 cm) was pressed into the top of the core and the upper 1 cm of sediment was collected from within the subsampler.

- ¹Hard substrates prevented collection of 18 box core samples during the winter sampling period.

The sub samples for micro faunal analysis were fixed with gluteraldehyde, then were stained with rose bengal in a seawater solution and refrigerated. Similar subsamples were collected at 12-14 cm and 21-24 cm if the cores were long enough. These deeper subsamples were fixed in 70% ethanol and were not refrigerated. Except at stations 816 and 818, where the required number of box cores could not be collected during the winter, micro faunal sub samples were taken out of one to four of the replicates at each sampling location.

With the exception of stations 808 and 816 (winter leg) , a uniform slab of sediment was removed from a single replicate at each station during each of the two legs of the benthic cruise. A side of the core was trimmed and a 30 x 18 x 2 cm plastic tray was used to remove the slab, which was then trimmed, smoothed, radiographed and retained for sedimentary analysis. After subsampling, the subsamplers and the utensils used by the geologists were washed into the biology deck box containing the core and the core trimmings.

The macro faunal invertebrates were separated from the substrate by screening through 1.0 and 0.5 mm mesh screens according to the "over flow-barrel" technique. This sample washing technique minimizes damage to delicate organisms. The macro faunal invertebrates were narcotized for one-half hour in 6% magnesium chloride in seawater, and these animals were then killed and preserved in 10% buffered formalin. After 36 hours, the organisms were transferred to 70% ethanol for preservation. The jars were carefully labeled, both inside and on the lid , with the R/V THOMAS G. THOMPSON cast number.

19.5 METHODS OF SAMPLE ANALYSIS

19.5.1 Sample "Tracking"

On completion of each leg of the benthic cruise, all macro faunal samples and exposed film were received by the principal investigators (or their representative, usually the laboratory supervisor) from the SAI member of the scientific crew at the Benthic Sorting Laboratory (Wilmington, CA). Samples were temporarily archived at this facility. The preliminary analysis of all preserved samples was conducted at the Benthic Sorting Laboratory.

Samples were cataloged and shelved, in order, by the R/V THOMAS G. THOMPSON station and cast number. The assistant marine scientists ("sorters") were required to "sign-out" on appropriate forms as samples were removed from the shelves for processing. Detailed records of the treatment accorded each sample were kept. These indicated the laboratory personnel involved in the work, the length of time required to complete the work, and the results of the analysis .

A record was made of each sample-set transferred to the University for detailed analysis. At the University, the associate marine scientists ("identifiers") kept records of the samples being analyzed or archived in their individual laboratories.

19.5.2 Preliminary Analysis

Depending on the sediment type in the sample, different processing techniques, sieving and/or flotation, were used to reduce the volumes of the sample prior to sorting. Regardless of the method used, however, care was taken to keep the sample in water during "pre-sorting" processing to avoid damage to delicate specimens.

Fine sands, silts and clays that easily passed through a screen with 1.0 mm mesh or less could quickly be reduced to a minimum volume. Samples with large amounts of coarser sediments (medium to coarse sands, pebbles, or rocks) were divided into several size fractions by sieving, and each size fraction was treated separately.

A small portion of animal-containing sediment was placed in water in a plastic pan, and with a gentle "gold-panning" motion the animals were extracted from the sediment and decanted onto a 1.0 mm mesh screen. Each portion was thus treated several times until no more animals were removed. The remaining sediment was examined carefully with a large illuminated lens to ensure maximum retrieval of organisms. The processing of large samples by this method sometimes required several hours of effort, but sorting time was substantially reduced.

Coarse sorting was accomplished with a specially designed sorting tray viewed under a Wild M-3 stereoscopic microscope. The trays were made of black plastic and had two circular depressions connected by a narrow trough, the whole forming a "dog bone" or "dumb-bell" shape. A small portion of reduced substrate containing animals was placed in one of the circular depressions and passed beneath the microscope, through the trough, to the other depression. Animals were removed with fine stainless steel forceps and placed in appropriate vials.

The faunal components of each sample were sorted into five major groups: polychaetous annelids, crustaceans, mollusks, echinoderms, and all other taxa ("minor phyla"). The use of the term "minor phyla" in this report is intended to indicate that the taxa within this category do not contribute significantly to the number of species, the number of individuals, or the standing crop in most samples. "Minor" does not in any way refer to the phylogenetic position of these taxa, or to their biological significance.

After each sample was sorted, the quality and accuracy of the work was verified by the laboratory supervisor. The number of animals in each major group was determined, and the alcohol wet weight standing crop of each major group was measured with a Sartorius 2250 electronic pan-loading balance.

19.5.3 Rapid Identification Procedure (RIP)

The rapid identification procedure (RIP) was initiated and used during the baseline study for FY 1975-1976 and was described in the final report for that study (Fauchald and Jones, 1976). The objective of the RIP is to provide the best possible identifications and enumerations of the taxa in a given sample within a restricted period of time (about 10 minutes) and using limited techniques. When a sample is examined during the RIP, the taxonomist identifies the animals to the lowest practicable taxon and either counts or estimates the numbers of each taxon present.

In the baseline study, the RIP was conducted on consecutive days within a single short time period (about 10 work-days). With the introduction of periodic sampling in the benchmark program, the RIP was modified in that it was conducted first for the sample-set from the winter leg of the benthic cruise and later for the sample-set from the summer leg of the benthic cruise. Further division of the RIP analyses into several sample-subsets (four/season) was necessary to provide an adequate sample flow for analysis during the six-month interval between sampling cruises.

One of the shortcomings of the RIP method lies in the fact that it is not possible to equalize the results of analysis between and among the five major taxonomic groups, either in terms of time or levels of identification. For example, several taxonomists working on a single major group, such as polychaetes, would collectively spend more time analyzing one sample than a single taxonomist working alone on some other group, such as mollusks.

19.5.4 Detailed Analysis

The third level of analysis, the detailed, or complete analysis, was carried out in the taxonomic laboratories of the Allan Hancock Foundation, University of Southern California. Detailed analysis involved identification to the lowest taxon practicable, usually the specific level, and the precise determination of population density. No time limitations are placed on this method of analysis.

Taxonomic analysis is the most difficult and time-consuming aspect of any benthic study; a "team" of highly qualified taxonomic specialists is required. For most phylogenetic groups, these people must be capable of identifying all of the frequently recurring species, relying only occasionally on consultants for assistance with the more difficult forms.

In the benchmark program, as in the baseline study, the efficiency and accuracy of the efforts of the identification team were enhanced by the fact that each person specialized in a particular phylogenetic

group or groups. The repetitive nature of the sampling program also helped ensure a high level of success in naming organisms, as the specialists encountered fewer new forms as their analysis of replicate samples progressed.

19.5.5 Epibenthic Photograph Description

The epibenthic photographs were described by the "identifiers." The descriptions included appearance of the substrate, estimation of bioturbation and identification and enumeration of macrofaunal invertebrates pictured in the photographs.

The prevalent epifaunal taxa visible in the benthic photographs included the pennatulaceans (sea pens), holothuroids, echinoids, asteroids, large ophiuroids, decapods and some species of mollusks. Of these taxa, the echinoderms always accounted for the largest number of animals pictured in the photographs.

19.5.6 Life Stage Techniques

A variety of techniques, some simple and some complex, were used to determine the life stages of collected specimens. Animals were categorized as juveniles, adult males, adult females, adult colonies, reproductive males, reproductive females, or reproductive colonies wherever possible. Species selected for life/stage determinations were those which represented a phylogenetic and ecologic (feeding and mobility types) spectrum of the benthic invertebrate fauna. Samples were then quantitatively analyzed in terms of the life stages listed above.

Essentially, all invertebrates that are not obviously mature (filled with eggs, carrying eggs, etc.) require sectioning and staining for accurate sex identification. Size alone is usually insufficient for determining sex or age, since upper size limits are extremely variable among most species of invertebrates. Furthermore, in southern California, the presence of ripe gonads or the absence of mature females is not necessarily indicative of reproductive seasonality. Emerson (1975) demonstrated that certain polychaetes are mature, i.e., contain mature eggs, throughout the year but that spawning is concentrated in the first half of the year with a peak in June. Thus, without large numbers of individuals for statistical analysis, it would not be possible to determine the breeding season for invertebrates which are not well represented at all times of the year. It is known that most invertebrates in southern California waters breed during the first half of the year or at least tend to concentrate spawning within this period. However, as indicated above, it is perfectly normal to find both mature and completely empty individuals in any given population, even in this period. Any program in which less than several hundred individuals were collected from a single population would thus provide, at best, indeterminate results.

19.6 METHODS OF DATA ANALYSIS AND SYNTHESIS

Faunal analysis by direct data inspection was performed. Recurrent group analysis and classification (normal analysis) were used to identify benthic macrofaunal communities (= faunal associations). Multiple discriminant analysis was used to study the relationship between predetermined groups of entities (= sampling site groups and environmental variables) . Between-community comparisons were made. Temporal variation in community structure was investigated.

19.6.1 Direct Data Inspection

The direct data inspection (DDI) was initiated and used in the baseline study of FY 1975-1976 and described in the report of that study (Fauchald and Jones, 1976). The method was modified for this year's study. Last year, the data were arranged in a "scale model" of the sampling grid of each HDSA before any area was analyzed; obviously, this was not necessary with each study site consisting of from two to six sampling locations instead of the much larger number of sampling locations (26 to 119) of each HDSA (Fauchald and Jones, 1976). Consequently, each "identifier" or "identifier group" could work more independently on the DDI for the benchmark program.

The detailed analysis data base for both the 1.0 and 0.5 mm fractions and the descriptions of epibenthic photographs formed the basis for definition of faunal assemblages by direct data inspection. The benchmark stations were grouped by study site as follows:

- San Pedro study site
- Coal Oil Point study site
- Santa Rosa Ridge study site
- Tanner Bank study site

For each study site, a direct inspection data form package was assembled which included:

1. Study site summary form--one per site for each "identifier" or "identifier group"
2. Benchmark station form--two per station, one winter and one summer, for each "identifier" or "identifier group"
3. Block maps--two per station, one winter and one summer, for each "identifier" or "identifier group"

On the study site summary form, each "identifier" or "identifier group" gave general comments on the most important species occurring

in the sample-set. Spatial variation was also noted, as was temporal variation both in terms of changes in abundance and notable differences in life stages of identified taxa.

The benchmark station form was used to list important taxa by frequency and by abundance (1.0 and 0.5 mm fractions shown separately) and for general comments on the animals selected. The "identifiers" were requested to keep the following items in mind when selecting the important taxa at each-station:

1. Frequency (including large seasonal changes in frequency)
2. Biomass (few, but large animals)
3. Community or association "indicators"
4. Taxa typical of a bathymetric zone or substrate type
5. Bioturbation
6. Feeding/mobility types
7. Trophic position (if known)
8. Influence on other fauna (harboring commensals, constructing extensive tubes affecting mobility of other fauna, etc.)
9. Limited distribution (unique to a station or study site)

The "block maps" for each station showed the location and spatial relationships of the replicates for each season; the depth of collection and the field description of the sediment type were given for each replicate sample.

During direct data inspection, each "identifier" or "identifier group" consulted the computer printout of the detailed analysis data base. This printout listed the data for each station by replicate, by major taxonomic group, and by identified taxa within each group. Analysis of the distribution and abundance of echinoderms was based in part upon the epibenthic photographs.

Each "identifier" or "identifier group" worked independently on direct data inspection. When analysis was complete, the data packages were submitted to one of the principal investigators (Jones), who then defined faunal assemblages for each study site on the basis of these "work sheets" and the original data.

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19.6.2 Data Bases and Data Base Editing

The data of this study resulted from six methods of sample analysis:

1. preliminary analysis of the 318 box core samples;
2. application of the Rapid Identification Procedure (RIP) to the 1.0 mm fractions of these samples;
3. detailed (or complete) analysis of 161 of the 1.0 mm fractions and 81 of the 0.5 mm fractions of these samples;
4. description of the epibenthic photographs;
5. determination of life stages for selected taxa; and
6. definition of feeding/mobility types for selected taxa.

The results of the first three methods of sample analysis (preliminary analysis, RIP, and detailed analysis) were key-punched and stored for computer analysis. They formed three interrelated, computerized data bases. The results of the last three methods of sample analysis (description of photographs, determination of life stages, and definition of feeding/mobility types) were not processed for computer analysis. These data bases were reserved for use in integrative analyses not requiring electronic data processing, such as direct data inspection. The samples analyzed in this study are listed in the Appendix Tables by cast number. The tables indicate the methods of analysis (preliminary analysis, RIP, detailed analysis at the 1.0 mm level, detailed analysis at the 0.5 mm level) applied to these samples.

The taxonomic results of sample analysis, both the RIP and the detailed analysis, were edited to eliminate all names (taxa) that might represent more than a "single species population."¹ With a few exceptions (some mollusks, for example) this editing procedure eliminated taxa identified to the generic level or above. Edited data bases were used for most computerized statistical analyses.

Further reduction of the data bases was necessary for some procedures. Taxa that occurred infrequently (in only one of eight replicates) were eliminated, unless their population density in that

¹For purposes of this report, the term "single species population" is used to indicate all monospecific taxa, as well as animals that were identified as members of unique and distinct populations, whether or not these populations could be characterized accurately at the specific level.

single replicate was 10 ($=160 / m^2$) or more. Additional reduction was required in some statistical programs to reduce the number of taxa to a set maximum number, for example, 255 taxa in classification by the inverse method; in such cases, the appropriate number of the most frequently occurring taxa in the entire sample-set--for example, 161 samples for the detailed analysis at the 1.0 mm level--were used.

In a few instances, the effects of editing reduced the number of taxa in a particular replicate to the point that the replicate was nearly eliminated from the data base (80204, 82301, and 82303 were reduced to a single species).

19.6.3 RIP/Detailed Analysis Comparison

As discussed previously (Section 19.5.3, Rapid Identification Procedure), the RIP method of sample analysis was subject to a number of inherent shortcomings. Among these were the limitations on identification time and specialized laboratory techniques imposed upon the systematists. These restrictions necessarily limited the taxonomists' abilities to identify specimens to the specific level. A further difficulty in standardizing the results of RIP analysis was presented by the fact that certain major phylogenetic groups, such as polychaetous annelids, were identified by groups of systematists, whereas other groups, such as mollusks, could be identified by a single individual. Because of this, even though each systematist was limited to approximately 10 minutes identification time per sample, the amount of time accorded to each of the major groups could vary considerably.

The introduction of seasonal sampling into the benchmark program also introduced a problem in standardizing the results of RIP analysis in that each benchmark sampling location was sampled twice, with an interval of approximately six months between sampling cruises. In order to avoid major delays which would severely impact completion of sample and data analysis requirements, the RIP method had to be applied in separate stages--first to the samples collected in the winter and later to the samples collected in the summer. The systematists thus worked on the samples in the following manner: RIP winter samples; detailed analysis, winter samples; RIP summer samples; detailed analysis, summer samples. Given the fact that the RIP could not be conducted within a single intensive session, the taxonomists unavoidably gained in familiarity with the specimens collected from the benchmark sampling locations.

Because of the factors outlined above, a comparison was made of the results of RIP and detailed analysis. As shown in Table 11-19.0-1, there was a considerable increase in accuracy of identification to species between the winter and summer RIP analyses. For example, in the winter 46% of the polychaetes were identified to species during the RIP, whereas in the summer 64% could be identified to this level. The overall gain in accuracy for all groups was 11% (55% to 66%) identified to species.

Table 11-19.0-1. Comparison of results from RIP and Detailed Analysis.

	RIP								DETAILED ANALYSIS							
	To Species		To Genus		To Family or above		Totals		To Species		To Genus		To Family or above		Totals	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
WINTER:																
POLYCHAETES	1267	46	747	27	732	27	2746	100	2343	82	380	13	146	5	2869	100
MOLLUSKS	583	72	208	26	15	2	806	100	787	91	67	8	8	1	862	100
ARTHROPODS	873	76	199	17	80	7	1152	100	1114	92	80	6	20	2	1214	100
ECHINODERMS	412	49	154	18	276	33	842	100	509	51	246	24	250	25	1005	100
MINOR PHYLA	184	40	70	15	211	45	465	100	243	58	72	17	107	25	422	100
TOTAL OF ALL GROUPS	3319	55	1378	23	1314	22	6011	100	4996	78	845	13	531	8	6372	99
SUMMER :																
POLYCHAETES	3080	64	922	19	825	17	4827	100	4044	84	409	9	353	7	4806	100
MOLLUSKS	861	85	154	15	2	0	1017	100	961	92	80	8	1	0	1042	100
ARTHROPODS	1513	79	297	16	106	5	1916	100	1628	86	219	12	37	2	1884	100
ECHINODERMS	612	48	259	20	401	32	1272	100	593	46	278	22	403	32	1274	100
MINOR PHYLA	276	49	85	15	201	36	562	100	322	65	50	10	127	25	499	100
TOTAL OF ALL GROUPS	6342	66	1717	18	1535	16	9594	100	7548	79	1036	11	921	10	9505	100

11-19.0-22

In contrast, 78% of all animals were identified to species "during detailed analysis of winter samples, whereas 79% were identified to species during detailed analysis of the summer samples. Comparison of RIP and detailed analysis results indicated a difference of 23% between the two methods in identification to species during the winter and a difference of 13% between the two methods for the same level of identification in the summer.

Comparison was also made of the results of statistical analysis using the data bases resulting from each of the two methods. As illustrated in the sample Figure 11-19.0-2, showing diversity values for RIP and detailed analysis at the San Pedro study site, values were consistently higher when the results of the detailed analysis were used.

In contrast to the results of the baseline study, in which a proportion of the total number of samples were analyzed in detail, four replicates per season per station were subjected to detailed analysis during the benchmark program. Because the resulting data base was large and accurate enough (in terms of avoiding "no data" sites), it was decided that for most purposes of statistical and classification analysis the detailed analysis data base, edited to eliminate all but monospecific taxa and single species populations, would provide the most suitable data. A list of the classification analyses conducted, showing data base used and edit criteria has been presented in Table 11-19.0-2.

It must be emphasized that the RIP analysis is applicable primarily to large-scale investigations. Finer ecological studies require the greater systematic accuracy afforded by detailed sample analysis.

19.6.4 Species Ranking

One of the simplest and most direct statistical methods of faunal analysis is ranking of the species collected in a sample-set. For this study ranking was based upon three criteria: abundance or population density, frequency of occurrence, and the number of affinities with other species. The third basis for species ranking is derived from the recurrent group analysis (Fager, 1957; Fager and McGowan, 1963); species are ranked on the basis of the number of affinities they have with other species.

Species are considered to show affinity which have an index of affinity equal to or greater than 0.50. An index of affinity is calculated for each pair of species in a sample-set. The index of affinity is defined as follows:

"...the geometric mean of the proportion of joint occurrences, corrected for sample size:

11-19.0-24

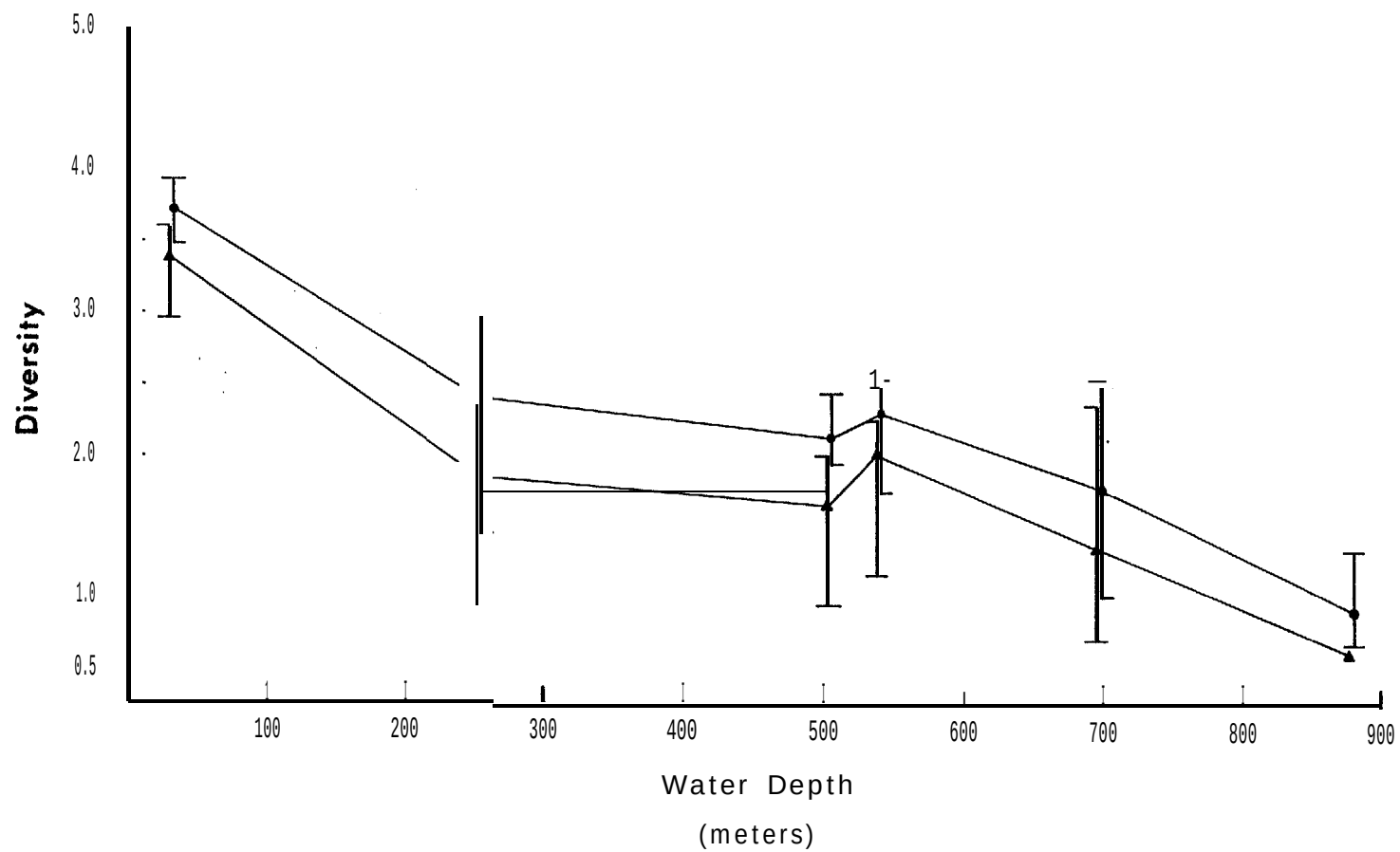


Figure 11-19.0-2. San Pedro Study Site - Comparison of RIP (A) and Detailed (●) Analyses Diversity Values by Station. Bars represent maximum and minimum values.

Table 11-19.0-2. Classification Analyses Conducted Indicating
Data Base and Edit Criterion.

Data Base	Edit Criterion	
	. #occurrences	% Total #
1. Detailed Analysis; all replicates each station	>15	60.4
2. Detailed Analysis; all replicates each station	>10	69.2
3. Detailed Analysis; all replicates each station	>6	81.0
4. Detailed Analysis; all replicates each station	>4	90.0
5. Detailed Analysis; all replicates each station	>1	96.2
6. Detailed Analysis; all replicates each station - species averaged	>1	96.2
7. Detailed Analysis; winter-all replicates	>1	
Detailed Analysis; summer-all replicates	>1	
Detailed Analysis; winter-all replicates	>15	
Detailed Analysis; summer-all replicates	>15	
8. Detailed Analysis; individual study sites	>1	(varies w/area)
Detailed Analysis; individual study sites	>5 except Tanner->4	
9. RIP, all replicates @ each station	>1	98.17
RIP; winter-all replicates	>4	88.01
RIP; summer-all replicates	>4	92.41
RIP; individual study sites	>3 except COP->2	(varies w/area)

$$(J/(N_A N_B)^{1/2}) - 1/2(N_B)^{1/2}$$

where J is the number of joint occurrences; N_A is the total number of occurrences of species A; N_B is the total number of occurrences of species B; and species are assigned to the letters so that $N_A \leq N_B$. Pairs of species for which this expression was equal to or greater than 0.50 were considered to show affinity; those for which the values were lower were considered not to show affinity." (Fager and Mc Go wan, 1963, p. 454)

Identified taxa of the unedited RIP data base and the edited detailed analysis ("fine-sort") data base were ranked by abundance (= density; total number of individuals). Data from each replicate at each station were ranked separately. Abundances were expressed also as percents of the total number of individuals in the sample; dominant taxa, based on an occurrence of 5% or more of the total number of individuals in the sample, were indicated.

To define the relative importance of the faunal components at each sampling location, species were ranked by mean abundance, frequency, and the number of affinities in the replicate sample-set (winter + summer) with use of the detailed analysis data base.

19.6.5 Concordance

In order to assess the degree of association among the members of each sample-set, the agreement between species rankings was tested by Kendall's Coefficient W (Siegel, 1956).¹ This statistic tests the relationship among several rankings of n items. The coefficient of concordance, W, is a measure of the divergence of the actual agreement shown in the data from the maximum possible or perfect agreement. The possible values of W range from 0 to +1. The significance of W for large samples, N larger than 7, is approximately distributed as chi square; if the value of X^2 , computed by the formula

$$X^2 = K(N-1)W$$

(Siegel, 1956, p. 236)

where k is the number of rankings and N the number of items, is equal to or exceeds the 0.01 level of significance for the particular value of degrees of freedom (df) = N-1, then the null hypothesis that the k rankings are unrelated may be rejected.

¹Each of the three types of species rankings--by frequency, by abundance, and by affinity--served separately as the basis for a test of the degree of association between the members of each sample-set.

Concordance served as one method to measure the degree of faunal homogeneity/heterogeneity in each replicate sample-set or each group of sample-sets collected from the same benthic macrofaunal community.

The rankings by abundance for the edited detailed analysis data base were used in calculating concordance values. Each benchmark station was considered independently, and concordance was determined for the winter and summer sample-sets both separately and combined as a unit.

19.6.6 Diversity, Evenness (= Equitability) and Dominance

In certain situations, species diversity may serve as a "single number index" of man-caused change in the composition and structure of benthic associations. Species diversity changes may be of particular value in assessing changes with time.

One measure of the community's diversity is simply the number of species it contains. However, this is an unweighed measure that fails to take into account the relative quantities of each species. To arrive at a weighted measure, the relative importance of each species must be considered (Pielou, 1975).

The number of species in a community and their relative importance are combined in the concept of "species diversity." Species diversity increases both with increasing number of species and with increasing quality of importance among the species of a community. Diversity is high when it is difficult to predict to species a randomly selected specimen, and low when it is not (Pianka, 1974).

The index of Shannon and Weaver (1949) is one of the methods most widely used by ecologists to estimate community diversity. The Shannon-Weaver index is:

$$\bar{H} = - \sum (N_i/N) \log_n (N_i/N)$$

where: N_i = importance value for each species; in the case of these data, the importance value is the number of individuals of each species; and N = total of importance values; in the case of these data, the sum of the importance values represents the total number of individuals.

¹Relative importance has variously been based upon relative abundance, biomass or energy flow. In our case, the first item can be assessed; the determination of species biomass measurements must be based on ash-free dry weights; and energy flow is not available except in experimental studies.

Diversity was calculated for the completely analyzed samples (1.0 mm fraction) with use of an edited version of the detailed analysis data base.

Diversity depends not only on the number of species but is also influenced by the evenness with which the total number of individuals is distributed among the species. It is possible for a sample with only a few evenly represented species to have a diversity index equal to, or very similar to, that of a sample with many unevenly represented species. Therefore, calculated diversity indices and evenness must be considered together in interpretations of diversity. In calculating evenness, the value is usually expressed as the ratio of the observed Shannon-Weaver diversity to the maximum Shannon-Weaver diversity when all species are equally represented.¹ Through a series of derivations, the working formula becomes:

$$e = \bar{H} / \log_n s$$

Where: $\bar{H}$ = Shannon-Weaver index; and S = number of species. The value for evenness will lie in the range $0 < e < 1$. In most cases, as the calculated Shannon-Weaver index increases, evenness will also increase. The data base for calculation of evenness was the same as that for calculation of diversity indices: the edited version of the detailed analysis data base.

The degree to which species in a community are "common" or dominant is measured by Simpson's index of dominance (1949). This value was also calculated for the detailed analysis samples, with the same data base as that used for the diversity and evenness calculations. The index of dominance is given by the formula:

$$c = \sum (N_i/N)^2$$

where: N_i = importance value for each species; in the case of these data, the importance value is the number of individuals in each species; and N = total of importance values; in the case of these data, the sum of the importance values represents the total number of individuals. The index of dominance represents the probability that any two individuals picked independently and at random from a community will belong to the same species. It thus measures a

¹Equitability, which takes as the standard of evenness the so-called "broken stick" distribution (MacArthur, 1957), provides another valid measure of evenness in an observed community. However, evenness was calculated in the method described above in order to maintain consistency in statistical analysis between the first and second year efforts of the study program.

property that is the complement of diversity. If the probability of picking two members of the same species is high, it would be expected that there might not be too many different species in the community and that, therefore, diversity is low. Although this is not necessarily true, in most cases, calculated dominance and diversity values will vary inversely. If only one species is present, it is easy to see that the dominance value would be 1. Values for this index of dominance are in the range of $0 < C \leq 1$.

19.6.7 Dispersion Chi-Square

Jumars' index of dispersion, or dispersion chi-square (1975), was used to evaluate species distributions at each of the benchmark study sites. This analysis was performed by using the formula:

$$s^2(n-1) = \sum_{i=1}^S \left[\frac{s_i^2}{\bar{X}_i} - (n-1) \right]$$

where: s = number of species; and n = number of samples. The term in brackets is Fisher's (1970) index of dispersion.

This method calculates the index of dispersion for each species (X_i). The index of dispersion tests the assumption that each species is randomly dispersed and there is no significant difference ($P < 0.05$) from a Poisson distribution (where $s_i^2 = \bar{X}_i$) with a corresponding mean. If s_i^2 is significantly larger than its degrees of freedom (d.f.), the population is considered to be aggregated. If s_i^2 is significantly smaller than its d. f., the population is uniformly distributed.

Jumars extended this procedure to allow estimation of the overall dispersion of the entire assemblage of populations at a sampling site. The individual species indices of dispersion are summed; this total value approximates chi-square with corresponding d.f. In this method, the species are considered as replicates and summing their indices accumulates small departures from randomness that otherwise may not be detected.

Total chi-square, the sum of each species index of dispersion, gives a chi-square value for the site. It is compared to the total for deviation from a Poisson distribution. The total chi-square is partitioned into two components, pooled chi-square and heterogeneity chi-square.

Pooled chi-square is the index of dispersion for the sums of the total number of species in each replicate, i.e., it indicates how much variation there is in the abundances from each replicate. This

value accounts for the variation in the total **chi-square** caused by differing abundances in each replicate. If it is significantly different ($P < 0.05$) from its degrees of freedom, then the total number of individuals of all species are considered to be either aggregated or uniform among the replicates, depending on the direction of the difference.

Heterogeneity **chi-square** accounts for the portion of variability that results from discordance in species abundance. Since it is obtained by **total chi-square** minus pooled **chi-square**, it accounts for the differences in total abundance between the replicates. If this value is significantly different from the d.f., it indicates that each species contributes variably to the community, and **Jumars** believes this may be interpreted as habitat partitioning.

It must be noted that all of the total **chi-square** may be contained in the pooled **chi-square** if there is considerable variability between the replicates. Conversely, all of the total may be contained in the heterogeneity **chi-square** if each species contributes variably to the total **chi-square**.

The data base used in calculation of dispersion of **chi-square** was the edited detailed analysis data base. Separate analyses were conducted for the winter and summer replicate sample sets for each study site.

19.6.8 Analysis of Feeding/Mobility Types

Analysis of feeding/mobility types was performed. with the edited detailed analysis data base (only monospecific taxa or those representing a single species population). The top 90% (310 species) of these taxa, ranked by abundance, was used. This included all animals that occurred four or more times within the entire study area.

Both feeding and mobility types were assigned by the systematists working on each of the major phylogenetic groups. Decisions were based on literature reports and morphological adaptations, and in some instances estimates were required for species that feed in several modes or feed variably at different life stages. For purposes of this analysis, the primary adult feeding mode was used.

Feeding categories included: filter/suspension feeders, carnivores, surface detritus feeders, subsurface detritus feeders, herbivores, parasites, and unknowns. Mobility categories were limited to motile, sessile and unknown.

For each benchmark station present, the percent of animals (based on abundances) in each feeding category, and in each feeding/mobility category was calculated. Additionally, in an attempt to delineate the primary trophic function of the assemblages at each site, i.e., suspension- or deposit-feeding, a simple index was calculated based on the ratio of suspension-feeding animals to deposit-feeding animals:

$$\frac{1}{\frac{S}{D} + 1}$$

where: S = total number of suspension feeders; and D = total number of deposit feeders (both surface and subsurface forms). This ratio was scaled between 0 (totally suspension-feeding) and 1.0 (totally deposit feeding). The index was based on the following rationale.

In marine benthic communities the ultimate source of food energy is the influx of organic material from the overlying water. It is generally agreed that a major function of the benthos is the conversion of this organic material into nutrients (primarily nitrates) which may be then returned to the surface waters.

The method of trapping organic material, while variable, can be divided into two major categories: 1) Suspension feeders, organisms that remove particulate material from the water directly above the sediment; and 2) Deposit feeders, those organisms that remove organic material from the sediment.

Animal communities that inhabit areas characterized by a good supply of particulate organic material in the water that is kept circulating by current or wave action should be expected to be primarily suspension-feeding forms. Conversely, communities that inhabit areas characterized by low sedimentation rates and rather stable, quiet hydrography should support deposit-feeding forms.

Deposit feeders may be supported by bacterial growth on sediment particles and are thus more independent of particulate organic matter. Finer sediments with a greater surface/volume ratio provide more attachment area for bacteria, and thus deposit feeders should be more common in fine sediments, whereas, suspension-feeding forms usually require an attachment site and would be expected to occupy coarser sediments or rocky areas.

19.6.9 Species Recurrence and Recurrent Groups

Before the structure of a community can be studied, it is first necessary to identify the community. When numerous small samples of the same size are taken, membership in a faunal association (or community) can be postulated on the basis of the frequency of joint occurrence of species (Fager, 1957). Application of this method is predicated on the rationale that species which are frequently part of one another's environment, e.g., 50% of the time, constitute appropriate ecological units. This method has been used to identify zooplankton species groups in the North Pacific Ocean (Fager and McGowan, 1963) and benthic species groups on the southern California mainland shelf (Jones, 1967, 1969). Recurrent group analysis (Fager, 1957; Fager and McGowan, 1963) is one method that has been used to identify and document faunal groups.

A recurrent group is defined by Fager (1957, p. 589) as a group of species satisfying the following requirements:

- "(1) The evidence for affinity is significant at the .05 level for all pairs of species within the group.
- (2) The group includes the greatest possible number of species.
- (3) If several groups with the same number of members are possible, those are selected which will give the greatest number of groups without members in common.
- (4) If two or more groups with the same number of species and with members in common are possible, the one which occurs as a unit in the greatest number of samples is chosen."

Fager (1957) further explains that the requirements are taken in order. The group or groups fulfilling the first and second are determined. If there are several possible combinations, a selection is made on the basis of the third requirement. The fourth requirement is employed if necessary.

In recurrent group analysis, a program determines the largest group that can be formed and tests to see if all the species have affinity with each other; if they do, the group is printed out. If they do not, it tests the next smaller group, and so on. When several groups of the same size can be formed, the group whose component species have the largest total number of occurrences is selected. After the selection of a group, any species which have affinities only with this group, or with this group and preceding groups, are listed. The process continues until all species with at least one affinity have been grouped or listed as species affiliated with a particular group.

The usefulness of recurrent group analysis is limited (Jones, 1969). Other techniques, principally classification, have replaced this method. Recurrent group analysis is employed sparingly in this report and then only for comparative purposes. Analyses are based upon the edited detailed analysis data base.

19.6.10 Faunal Analysis by Classification

Classification analysis by the methods of Smith (1976) was used as the principal means of defining faunal associations. The edited detailed analysis data base was employed for these analyses. As an ecological tool, classification has the advantages of (1) objectivity and (2) the ability to handle very large amounts of data, both of which are lacking in direct inspection analyses. The actual computerized process comprises several distinct steps.

Step 1. Data reduction and transformations. Usually, rare species are eliminated from the analysis in order to save computer time and money. It has been shown (Day et al., 1971) that moderate data reduction does not adversely affect the analysis. In this study, monospecific taxa only were used.

Most distance indices are sensitive to the magnitude of the data values involved. For example, a species with relatively high abundance values could disproportionately dominate the analysis and, as a result, potentially valuable information contributed by other species might be lost. To lessen this type of dominance, i.e., to reduce the relative magnitude of the larger values, data are usually transformed before analysis. In this study, the values of the larger numbers were reduced (to a greater extent than the smaller numbers) by a square-root transformation of each data value. This data transformation was monotonic with the raw data values; this means, simply, that the rank order was maintained.

After the data were transformed, a data standardization was applied to improve the distance measures; in other words, a scale adjustment was made to compensate for non-monotonic curves in the final input data. Basically, a non-monotonic curve can have more than one point with identical species counts. A test of various species standardization methods, using simulated data, has shown the species mean to be the most sensitive to the criteria of an optimal species standardization. Calculation of the species mean standardization is as follows:

$$\frac{X_{ij}}{\sum_{k=1}^M X_{ik}/T}$$

where: X_{ij} is the count of species i in site j and represents the number being standardized; M is the number of sites; X_{ik} is the count of species i in site k ; and T is the number of sites with species i .

The distance measure also suffers from uneven habitat sampling. To compensate for this, a weighting factor was calculated and applied to the data. This factor gave the more "unique" sites, i.e., sites separated by more ecological distance, greater weight in the calculations of the species means.

Finally, this transformed, standardized, and weighted data were used in the classification analysis to calculate ecological distance and generate dendrograms, two-way tables, etc. For a more exhaustive treatment of this subject, see Smith (1976).

Step 2. Generation of similarity matrices. For "normal" classification, in which stations are grouped, it is first necessary to measure the similarity of each pair of stations. A number of such

indices are available, all of which are based on the abundance and occurrence of species in the two samples being considered. The Bray-Curtis Measure (Bray and Curtis, 1957) was selected for the present work. This index is calculated by:

$$D_{ij} = \frac{\sum_{k=1}^n |X_{ki} - X_{kj}|}{\sum_{k=1}^n (X_{ki} + X_{kj})}$$

where: D_{ij} is the distance between entities i and j respectively; and n is the number of attributes. This index is calculated for each pair of stations or species to be analyzed and is usually stored in matrix form.

For "inverse" classification, in which species are grouped according to their distribution among the stations, the same measure was applied.

Step 3. Sorting strategy. Clustering, or sorting, is the process by which the most similar stations (or species) are grouped together, while dissimilar entities are separated. Several techniques are available; "flexible" sorting strategy was used in this case.

Step 4. **Dendrogram.** The dendrogram is a graphic representation of the results of clustering. It shows both the order in which the entities fuse and the level at which they do so. It should be noted that the level at which the dendrogram is broken to delimit groups is arbitrary. Ideally, groups will fuse at a high level of similarity and these separate groups will fuse to one another at a high level of dissimilarity.

Step 5. Two-way tables. In the original raw data matrix, species and stations are usually arranged in random fashion, in taxonomic order or by station number. As such, the species counts/station counts form no pattern. However, when stations and species are arranged along their respective axes in the same order in which they were placed by classification, patterns do emerge. Lines drawn manually between adjacent species and station groups (as established from the dendrograms) then form "cells" which serve to associate particular station groups and species groups. Such two-way tables were generated for all analyses and were used in naming species which, by their frequency or abundance, characterized each station group.

19.6.11 Discriminant Analysis

In order to study the distribution of species with respect to environmental variables, weighted discriminant analysis using the methods of Smith (1978) was applied to the edited detailed analysis

data base (monospecific taxa only). The environmental parameters used were: 1) water depth, 2) percent total organic carbon in sediments, 3) percent calcium carbonate, 4) percent sand, 5) percent silt, 6) percent clay, 7) mean phi, 8) sorting coefficient, and 9) skewness.

Weighted discriminant analysis uses selected physical parameters to form discriminant axes for an ordination plot of species data from each site. A number of axes can be selected, the first including those physical parameters that mathematically contribute the most to variation between the sites, the second, third and so on showing the second-most, third-most, etc. until all variation between the sites has been accounted for. As input, either species groups resulting from classification analysis or sites can be used. For this analysis, each site was chosen to represent a "group" and the winter and summer replicate sample-sets were averaged and treated separately.

Discriminant analysis has been described by Smith (1978) as follows:

- *'1) A hypothetical, multidimensional "space" is set up. The dimensions of this space represent the measured environmental variables. The position of a site (sample, observation, etc.) will depend on the level of each variable measured at the site.
- '2) A new variable, the discriminant score, which best separates the groups, is defined. This variable is represented in the space by a line called a discriminant axis. .the value of this new variable at a site is the perpendicular projection of the site point onto the discriminant axis.
- 3) The position of the discriminant axis in this space will depend on which combination of variables best separates the groups. The discriminant axis will not extend far into dimensions which represent variables showing little relationship to group separation...The discriminant axis will be situated mostly in dimensions representing variables which are related to group separation.
- 4) When more than two groups have been defined, more than one discriminant axis may be required to separate the groups. . . To avoid redundancy of information on the different axes, the site scores on the different axes are made to be uncorrelated. The axes are not necessarily at right angles to each other. . . .The axes are usually ordered according to the amount of group separation accounted for, i.e., the first axis will show the most group separation, the second axis, the second most, and so on.

To determine which of the physical variables used are related to each axis coefficients of separate determination are calculated. Each axis has a separate set of coefficients, with one coefficient for each original variable. The magnitude of the absolute value of a coefficient is **proportional** to the importance of the corresponding variable on the axis in question. The coefficients are adjusted to account for differing scales of the physical parameters during calculation."

Weighted **discriminant** analysis was performed in order to emphasize the species most representative of their groups. Weighting was applied by using the sums of squares and **crossproduct** matrices. The result of these calculations "...allows the observations more representative of the group in question to receive greater weight in the calculations for the group. This is done in two ways. 1) since a weighted mean is used, the observations with higher weight (i.e., more representative of the group) will have more influence on the mean value, and 2) the cross product itself is weighted, thus the observations more representative of the group will add more to the sum of the cross products for the group." (Smith, 1978).

19.7 COMMUNITY STRUCTURE AND CHARACTERIZATION

19.7.1 San Pedro Study Site

The six sampling stations of the San Pedro study site were arranged in two three-station transects: one extending westerly from the shelf to the **basin**, the other trending southeasterly down the slope (Figure II-1 9.0-3). Eight replicate box core samples were collected at each of the locations during each of the two sampling periods.

Because all six locations were part of the same shelf-slope-basin system, they have been treated as though they were all a part of the same transect or depth gradient. Station 819 was on the shelf (mean depth of replicates: 33 m; range: 31-34 m); station 825 was on the upper slope (mean: 256 m; range: 250-270 m); stations 827 and 828 were on the slope (mean: 504 m, range: 501-508 m and mean: 541 m; range: 536-556 m, respectively); station 821 was on the lower slope (mean: 698 m; range: 687-710 m); and station 823 was in San Pedro Basin (mean: 880 m; range: 875-881 m). The depth of collection, field sediment description, core length, sub-sampling and type of analysis (RIP only or both" RIP and detailed analysis [DA]) for each replicate in each sample-set are presented in Table 11-19.0-1.

Environmental data for this study site have been summarized in Table 11-19.0-3. Sediments became finer, less well sorted and richer in organic carbon and carbonates with increasing depth. At each of the sampling locations, sediments were somewhat finer (higher mean phi values) in the summer than in the winter. As expected, bottom water oxygen content decreased with increasing depth; values at the lower slope station (821) and in the basin (823) were quite low (0.32 to 0.15 ml/l).

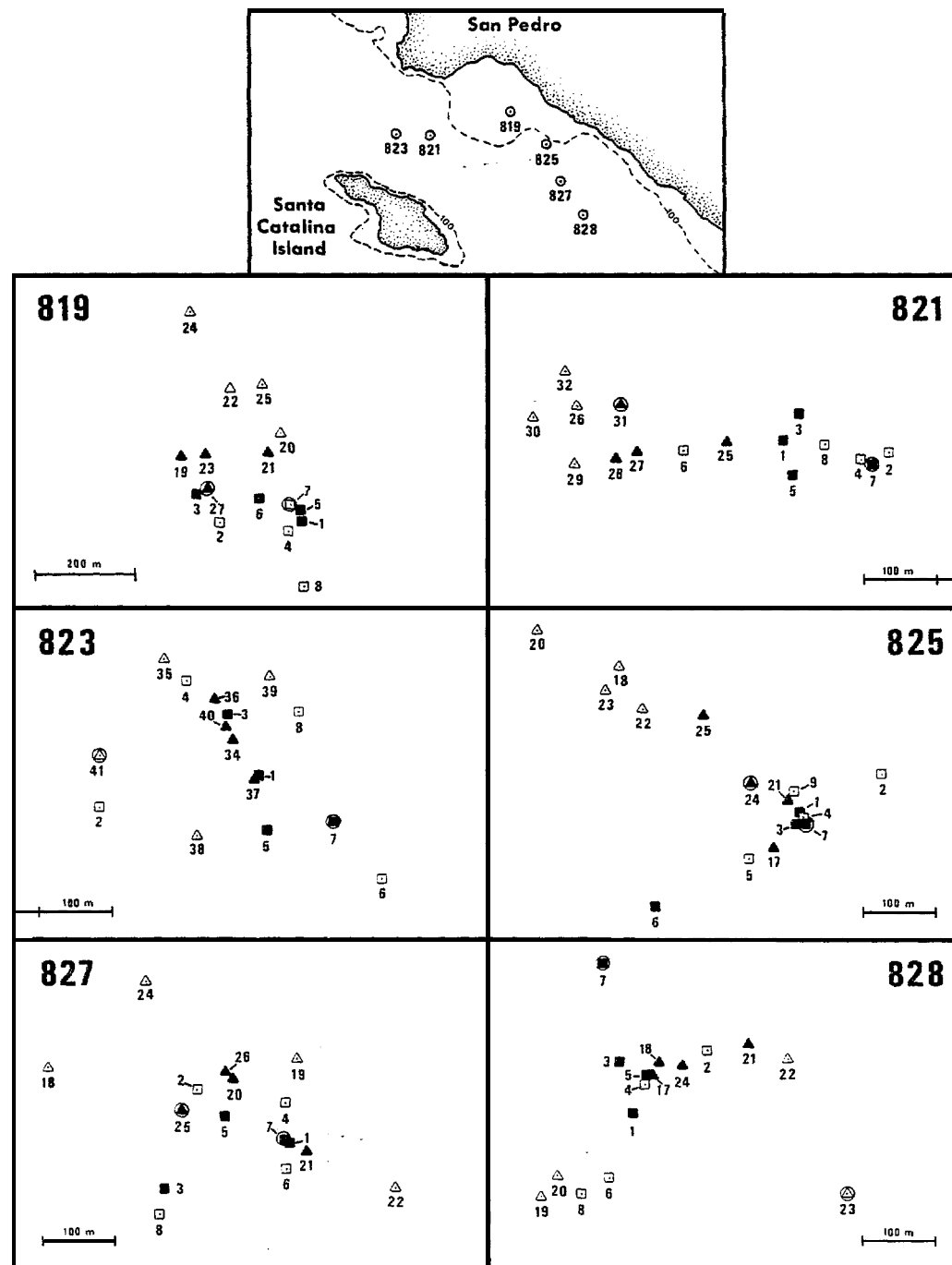


Figure 11-19.0-3. Map of the San Pedro Study Site - Symbol Explanation:
 A-Summer Stations, Cl-Winter Stations, - RIP Analysis only, and Detailed Analyses, Δ , $\square$ - RIP Analysis only, $\blacksquare$ - RIP
 0-geology slab removed from core.

Table 11-19.0-3. San Pedro Study Site - Environmental Data.

Caat Number	Depth (meters)	Bottom °C	Bottom O ₂ (ml/l)	% Sand	% silt	% Clay	Mean Grain Size (phi)	Sorting Coeff.	% TOC	% CaCO ₃
81907	33	---	---	86.6	9.5	3.9	3.97	0.81	0.54	1.0
81927	32	---	---	70.3	24.8	4.9	4.41	0.95	0.55	0.1
819	20	15.77	5.70	---	---	---	---	---	---	---
819	31	12.73	5.40	---	---	---	---	---	---	---
82507	257	---	---	33.3	50.8	15.9	5.86	1.64	1.39	3.0
82524	259	---	---	14.4	63.3	22.3	6.65	1.77	1.53	4.2
825	2 3 7	9.20	2.13	---	---	---	---	---	---	---
825	244	9.11	2.16	---	---	---	---	---	---	---
82707	504	---	---	5.0	69.9	25.1	7.00	1.82	2.40	7.2
82725	504	---	---	2.5	55.8	41.7	8.03	1.69	2.48	6.4
827	482	6.50	0.40	---	---	---	---	---	---	---
827	491	6.90	0.57	---	---	---	---	---	---	---
82807	536	---	---	22.8	42.5	34.6	7.11	1.76	2.17	7.6
82823	552	---	---	13.0	34.5	52.5	8.46	1.88	2.35	8.3
828	539	6.19	0.34	---	---	---	---	---	---	---
828	533	6.49	0.51	---	---	---	---	---	---	---
82107	689	---	---	8.3	60.3	31.4	7.23	1.84	2.91	6.2
82131	704	---	---	5.8	57.7	41.5	7.95	1.68	3.19	7.9
821	707	5.26	0.24	---	---	---	---	---	---	---
821	694	5.27	0.32	---	---	---	---	---	---	---
82307	881	---	---	1.9	50.4	47.7	8.26	1.94	3.98	9.2
82341	879	---	---	2.3	36.6	61.1	8.81	3.24	4.14	17.2
823	875	5.07	0.16	---	---	---	---	---	---	---
823	872	5.03	0.15	---	---	---	---	---	---	---

19.7. 1.1 Epibenthic Photographs

None of the epibenthic photographs taken during the winter benthic cruise were utilized in the preparation of this report. None of these photographs could be positively identified and correlated with the biological box core cast with which they were taken.

No usable photographs were taken of the sea floor at station 819 (on the shelf). Bioturbation was evident in the photographs taken at all slope locations, but was lacking in the basin. At station 825, which was on the upper slope (seven photographs, poor to moderate quality), bioturbation was slight and consisted of only a few small holes and some urchin tracks. Epifaunal invertebrates were limited to the urchins Allocentrotus fragilis (approximately two per photograph) and Brissopsis pacifica. A flatfish was shown in one photograph.

Photographs from the mid-slope stations (827 and 828; 16 photographs, poor to good quality) were similar. Bioturbation was moderate at both sites; photographs revealed numerous small holes, holes of medium size, a few large holes, urchin tracks and a few unidentified worm tubes. The most prominent epifaunal animal at these two locations was the asteroid Myxoderma platyacantha (approximately three per photograph). Other echinoderms seen in these photographs included the urchins Brissopsis pacifica and Brisaster latifrons, unidentified heart urchins buried beneath the sediment surface, a large unidentified holothuroid and a few unidentified ophiuroids. Additional epifaunal invertebrates pictured at these stations included sea pens (Pennatula phosphorea, ? Virgularia sp., Umbellaria sp. A) and burrowing anemones (possibly cerianthids). Several fish, scorpaenids, a cottid, and a skate were also photographed.

Bioturbation at the lower slope sampling location, station 821 (eight photographs, good to excellent quality), was considerable. There were many depressions in the soft sediments, small holes were numerous and there were a few medium and large holes. Tracks were nearly lacking, and there were no urchin tracks. There were a few unidentified worm tubes pictured in the photographs, and in one photograph there was a large worm tube mass.

The prominent epifaunal invertebrates at this station were the ophiuroids Ophioscolex corynetes (approximately nine per photograph), and Asteronyx longifissus (approximately seven per photograph). Other echinoderms pictured in these photographs included the asteroid Myxoderma platyacantha, an unidentified asteroid, an unidentified holothuroid and, in one photograph, literally dozens of small, unidentified ophiuroids on a large sponge. Sea pens, burrowing anemones, a galatheid crab and the gastropod Mitrella permodesta were also shown in the pictures. A flatfish was shown in one photograph.

In the basin, at station 823 (eight photographs, moderate to good quality), there was very little evidence of any bioturbation. A few small worm tubes may have been present. Only one epifaunal invertebrate, the gastropod Mitrella permodesta, was prominent at this station; it was very abundant, averaging more than 40 specimens per photograph. The only other invertebrates evident in the photographs from this sampling location were a sponge and a galatheid crab.

19.7.1.2 Concordance

In order to assess the degree of association among the members of each sample-set, the agreement between species rankings by abundance (edited detailed analysis data base) was tested by Kendall's Coefficient of Concordance (W) (Siegel, 1956). The winter and summer sample-sets were combined for this test.

The results of this analysis have been presented in Table 11-19.0-4. Concordance was demonstrated at the 0.01 level of significance for all sample-sets except stations 827 and 823. Spacing of the replicates at both of these locations was reasonably close, and it is unlikely that any large-scale gradients were crossed at either site. Each of these replicate sample-sets was probably collected from within a single benthic association at each of these sites. If this was true, the lack of concordance between members of each of these sample-sets may be considered one indication of considerable intra-community heterogeneity at both of these locations.

19.7.1.3 Density, Species Richness and Standing Crop

Density and species richness¹ values were highest on the shelf, declined with increasing depth and were lowest in the basin (Figure 11-19.0-4 a and b).₂ The mean density on the shelf (station 819) was 4,310 specimens/m² (range: 2,960-5,472). Mean values at the stations on the slope varied from 756 specimens/m² (station 825) to 362 specimens/m² (station 828). The mean value for the replicate samples collected in the San Pedro Basin was 92 specimens/m² (range: 16-224). The mean species richness for the replicate samples collected on the shelf was 82 species/sample (range: 65-94); the mean values for the stations on the slope varied from 23 species/sample (station 825) to 14 species/sample (station 827); the mean value for replicates from the basin was 3 species/sample (range: 1-7).

¹Density and species richness were calculated for all study sites. Values were based on the results of detailed analysis, winter and summer replicates combined.

Table 11-19.0-4. San Pedro Study Site - Kendallts Coefficient of Concordance. K = number of rankings, N = number of items, and W = coefficient of concordance.

Station (Method of Analysis)	K	N	W	Chi-squared	Significance Level
819					
Detailed Analysis	8	88	0.334	232.293	< 0.01
RIP	16	87	0.293	403.761	< 0.01
825					
Detailed Analysis	8	17	0.293	37.461	< 0.01
RIP	16	20	0.347	105.461	< 0.01
827					
Detailed Analysis	8	11	0.160	12.833	> 0.05
RIP	16	15	0.114	25.590	< 0.05
828					
Detailed Analysis	8	11	0.306	24.447	< 0.01
RIP	16	14	0.140	29.099	< 0.01
821					
Detailed Analysis	8	11	0.384	30.684	< 0.01
RIP	16	8	0.472	52.812	< 0.01
823					
Detailed Analysis	7	7	0.139	5.841	> 0.05
RIP	14	3	0.196	5.500	>0.05

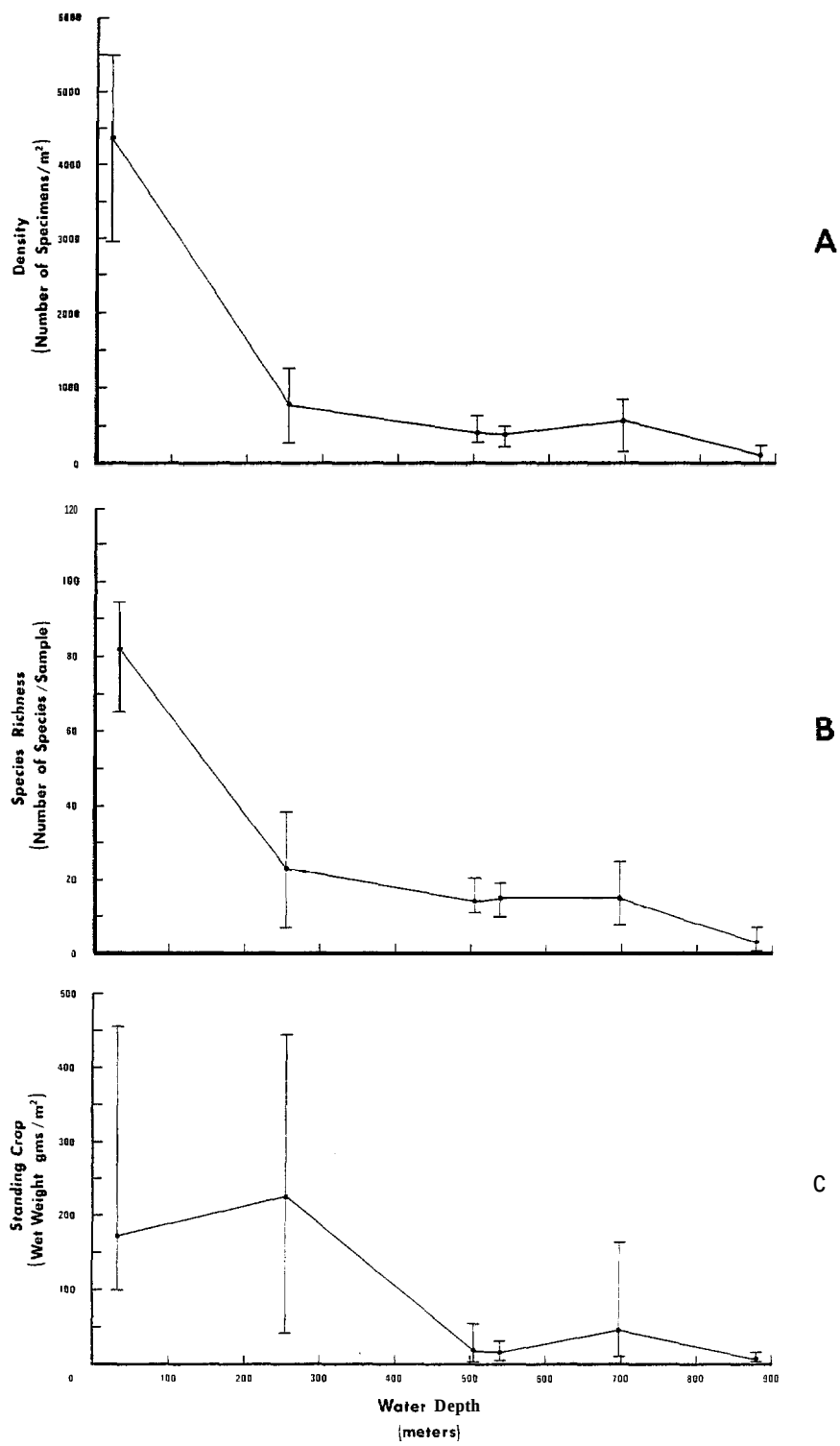


Figure II-19.0-4. San Pedro Study Site - A) Density, B) Species Richness, and C) Standing Crop Values by Station. Bars represent maximum and minimum values.

Standing crop¹ values likewise generally declined with increasing depth, but the mean value was somewhat higher for the replicates collected on the upper slope than for the shelf sampling station (Figure 11-19.0-4 c). The mean value for station 819 on the shelf was 173 g/m² (range: 99-454); on the upper slope at station 825, the mean was 223 g/m² (range: 42-445); at the mid- and lower slope sampling locations the mean values varied from 45 g/m² (station 821) to 16 g/m² (station 828). In the basin, the mean standing crop was 6 g/m² (range: 2-14).

Regardless of the magnitude of population density and species richness, polychaetes were numerically the most prominent group at this study site (Figure 11-19.0-5 a and b). Only at station 828, where mollusks were slightly more numerous, and in the basin, where other groups--mollusks, echinoderms and minor phyla--were somewhat more prominent, did polychaetes fail to dominate numerically.

The standing crop pattern differed (Figure 11-19.0-5 c). Echinoderms comprised the largest percent of the total standing crop at the sampling location on the shelf; their importance decreased with increasing depth. Polychaetes were the most important group on the upper slope, with the minor phyla and echinoderms secondary in importance. Mollusks predominated at one mid-slope station, 827, and polychaetes and the minor phyla were secondary in importance at this location. With increasing depth, the minor phyla assumed an increasingly larger proportion of the standing crop and were the most prominent group on the lower slope and in the basin.

19.7.1.4 Diversity, Evenness and Dominance

Diversity values at this study site decreased with increasing depth (Figure 11-19.0-6 a). The average diversity on the shelf (station 819) was 3.723 (range: 3.480-3.913); on the slope the mean diversity values varied from 2.378 (station 825) to 1.787 (station 821); the mean diversity for the replicate samples collected from the basin was 0.917 (range: 0.693-1.332). Diversity values calculated for the combined 1.0 mm and 0.5 mm fractions were generally higher than those calculated for the 1.0 mm fraction only; these are shown as "open circles" in Figure 11-19.0-6 a.

Evenness values were relatively high (0.825) except at station 821 (mean: 0.740; range: 0.535-0.926) (Figure 11-19.0-6 b). Values calculated for the combined 1.0 mm and 0.5 mm fractions were generally lower than those based on the 1.0 mm fraction alone.

¹ Standing crop, like density and species richness, was calculated for each station at each study site. This value, however, was based on all 16 replicates, winter and summer combined.

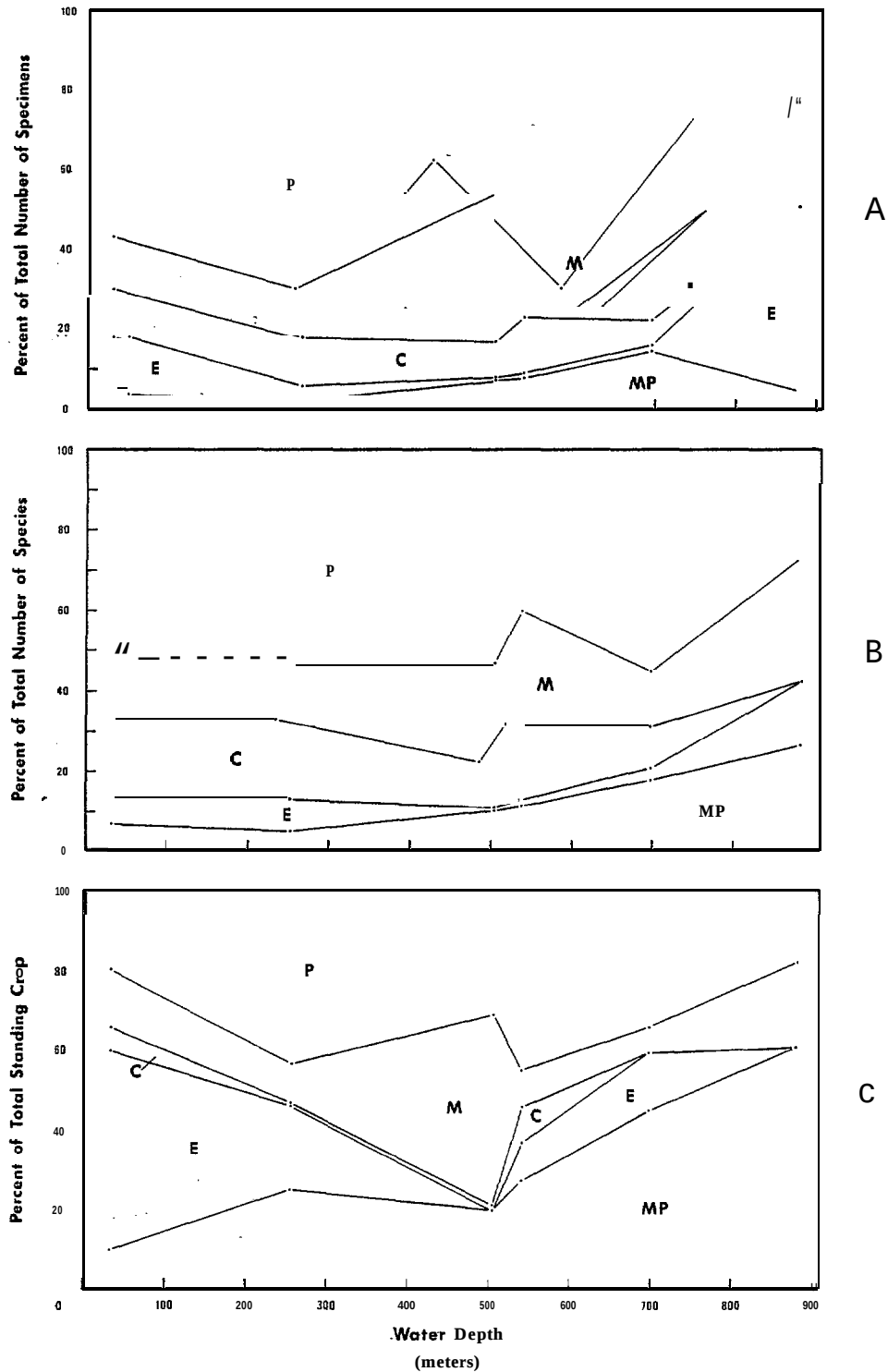


Figure 11-19.0-5. San Pedro Study Site - A) Percent of Total Number of Specimens, B) Percent of Total Number of Species, and C) Percent of Total Standing Crop for the five major systematic groups by station: P=Polychaetes, M=Mollusks, C=Crustaceans, E=Echinoderms, and MP=Minor Phyla.

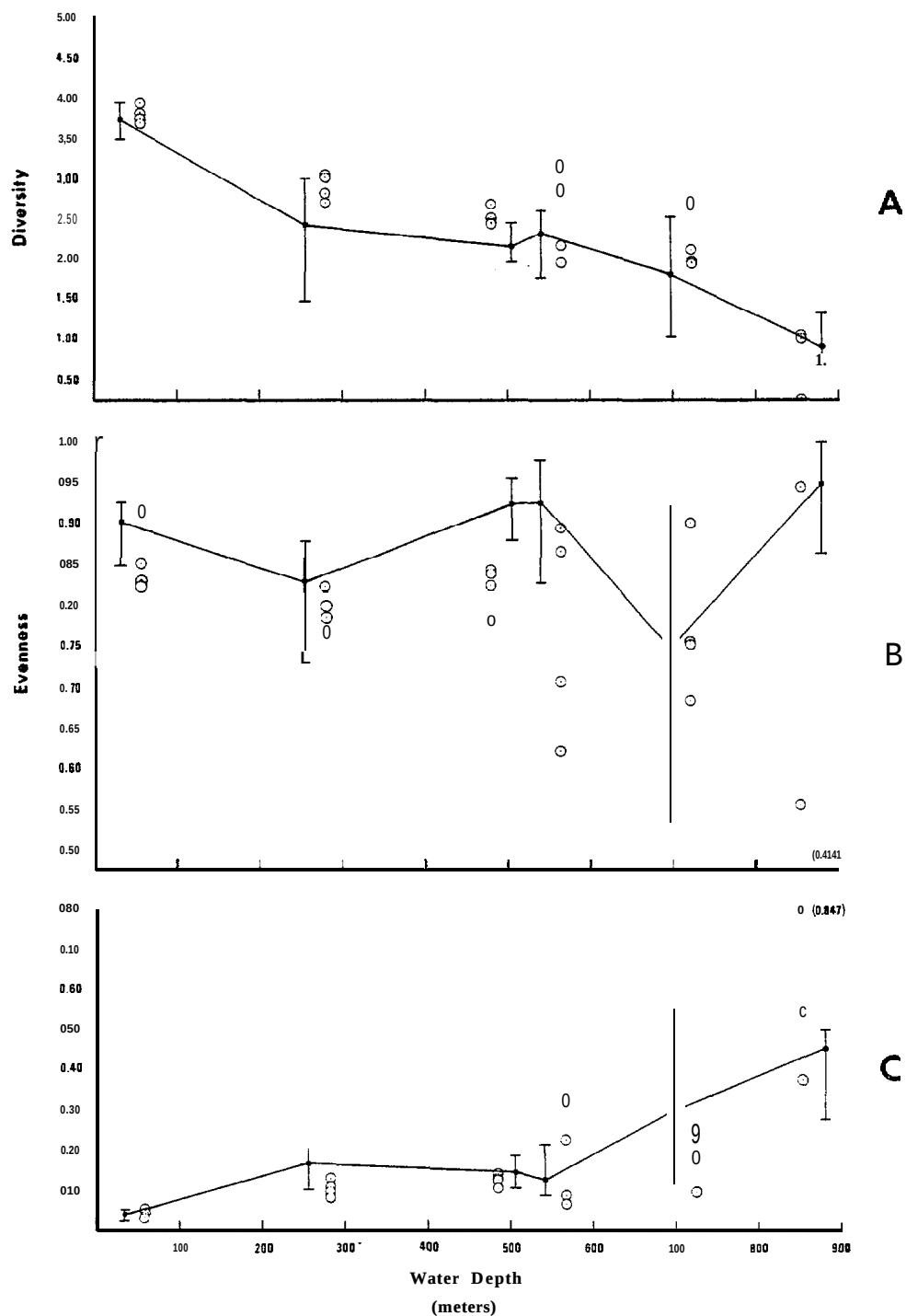


Figure 11-19.0-6. San Pedro Study Site - A) Diversity, B) Evenness, and C) Dominance Values by station: ● -1.0 mm fraction and ○ -1.0 mm fraction plus 0.5 mm fraction. Bars represent maximum and minimum values.

The relationship of dominance values to depth was the inverse of that for diversity (Figure 11-19.0-6 c). Dominance values for the 1.0 mm and 0.5 mm fractions combined were generally slightly lower than those based upon the 1.0 mm fraction alone; exceptions to this generalization were stations 828 and 823. -

19.7. 1.5 Faunal Composition

The species that numerically dominated each sampling location of the San Pedro study site (ranking by abundance) have been listed in Table 11-19.0-5. Their distribution with depth has been illustrated. A considerable number of the taxa were faunal elements at more than one station; this was particularly true for species that were prominent faunal elements at sampling stations on the slope.

The ophiuroid Amphiodia (Amphisphaera) urtica and the polychaetes Spiophanes missionensis and Mediomastus californiensis were the dominant faunal elements at station 819 on the shelf. On the upper slope, at station 825, the polychaete Maldane sarsi outranked all other species in importance.

The dominant faunal elements of the mid-slope, stations 827 and 828, were more variable. Prominent species included the pelecypods Tindaria californica and Axinopsida serricata, the mollusks Chaetoderma sp. B and Limifossor fratula, and the polychaetes Nephtys cornuta franciscana and Allis monicae. A single species, the polychaete Eclysippe trilobatus, overwhelmingly dominated the lower slope station, 821. Somewhat surprisingly, the sparsely populated basin site, station 823, was dominated by a relatively large epifaunal gastropod, Mitrella permodesta. The polychaete Phyllochaetopterus limicolus was also an important species at this location.

19.7.1.6 Spatial Variation

Dispersion chi-square statistics (method of Jumars, 1975a, b) were used to analyze the spatial variation of the benthic macrofauna at each sampling location of the San Pedro study site.² In this

¹A minimum of 10 of the most abundant species at each location were included in the table. The percent that each comprised of the total number of specimens collected in the replicate sample-set was given; the "dominant species," species that made up 5% or more of the total number of specimens were indicated; the frequency that each of the species had in the sample-set and the number of affinities that each had with other species in the sample-set were also recorded.

²The same analysis was also performed for the other study sites of the benchmark program.

Table 1-19.0-5. San Pedro Study Site - Abundance, % of Total, Frequency, and Affinity Values for the ten most abundant species at each station. Bold letters and underlining indicate the dominant species based on 5% or more of the total number.

analysis , an index of dispersion was calculated for each species collected in the replicate sample-set from each station. This index indicated whether a species was regularly distributed, randomly distributed or contiguously distributed ("clumped" or '*aggregated') within the replicates. A single value, the heterogeneity chi-square, accumulated the contribution made by each species to the overall spatial variability and thus served as a measure of the spatial character of the benthic association at the sampling location.

The analyses presented in this report were based upon the samples collected in the summer'. The winter samples generally had fewer taxa and were not used for this reason. When the winter and summer sample-sets "were combined, any temporal variation between the seasonal sample sets at a location was "interpreted" by the method as increased spatial variability. (For example, the ice cream cone worm Pectinaria californiensis was absent in the winter samples collected at station 819. It was present in all of the summer replicates from this location, index of dispersion 6.00. When the winter and summer sample-sets were combined, the index of dispersion for this species increased to 76.19).

The benthic association on the shelf, station 819, displayed a marked degree of aggregation; on the upper slope, station 825, and at station 827, mid-slope, aggregation was less pronounced. At the other mid-slope sampling location, station 828, on the lower slope, station 821, and in the basin, randomness characterized the spatial distribution of the benthic fauna (Table 11-19.0-6). The number of species having significantly aggregated distributions decreased with increasing depth at the sampling locations of this study site.

19.7.1.7 Feeding/Mobility Types

The assignment of taxa to generalized feeding and mobility types, however tentative, permitted the comparison of the faunal associations on the basis of trophic structure. The relative importance of each of the feeding/mobility types at the sampling locations of the San Pedro study site has been illustrated in Figure 11-19.0-7.

Motile carnivores comprised about 10% of the fauna at all locations except in the basin, where their relative abundance was reduced to about 6%. Similarly, filter feeders made up a relatively small fraction of the fauna at most locations. They were slightly more prominent at mid-slope station 828 than elsewhere, and slightly less prevalent in the basin. Motile filter feeders, primarily micro-crustaceans , were mainly confined to the shelf and upper slope. Surface detrital feeders comprised the largest fraction of the fauna on the shelf, lower slope and in the basin. On the shelf, the motile surface detrital feeders predominated: the ophiuroid Amphiodia urtica and the polychaetes Spiophanes missionensis, Prionospio

Table 11-19.0-6. San Pedro Study Site - Spatial Variation.

Station Number	Heterogeneity Chi-Square	Degrees of Freedom	Spatial Character	Probability	Species with Aggregated Distribution	Index of Dispersion	df	p
819	495.37	312	aggregated	<0.0	Mediomastus californiensis	44.73	3	<0.01
					Ampelisca brevisimulata	18.33	3	<0.01
					Kurtziella beta	14.14	3	<0.01
					Paraprionospio pinnata	14.09	3	<0.01
					Axinopsida serricata	12.00	3	<0.01
					Metaphoxus frequens	12.00	3	<0.01
					Silophasma geminata	12.00	3	<0.01
					Ampelisca, near brevisimulata	10.80	3	<0.05
					Tellina carpenter	10.69	3	<0.05
					Streblosoma crassibranchia	10.00	3	<0.05
					Mysella tumida	9.27	3	<0.05
					Ampelisca pugetica	9.00	3	<0.05
					Spirochaetopterus costarum	9.00	3	<0.05
825	134.26	108	aggregated	<0.02	Pectinaria californiensis	25.46	3	<0.01
					Melinna heterodonta	9.00	3	<0.05
					Spiophanes, near berkeleyorum	9.00	3	<0.05
827	131.68	99	aggregated	<0.01	Mysella compressa	21.00	3	<0.01
					Allis monicae	14.56	3	<0.01
					Chaetoderma sp. B	12.00	3	<0.01
828	76.14	72	random	>0.70	Chaetoderma sp. A	9.00	3	<0.05
821	75.92	66	random	>0.20	Hypaniola sp. A	8.60	3	<0.05
823	12.40	12	random	>0.90	No aggregated taxa			

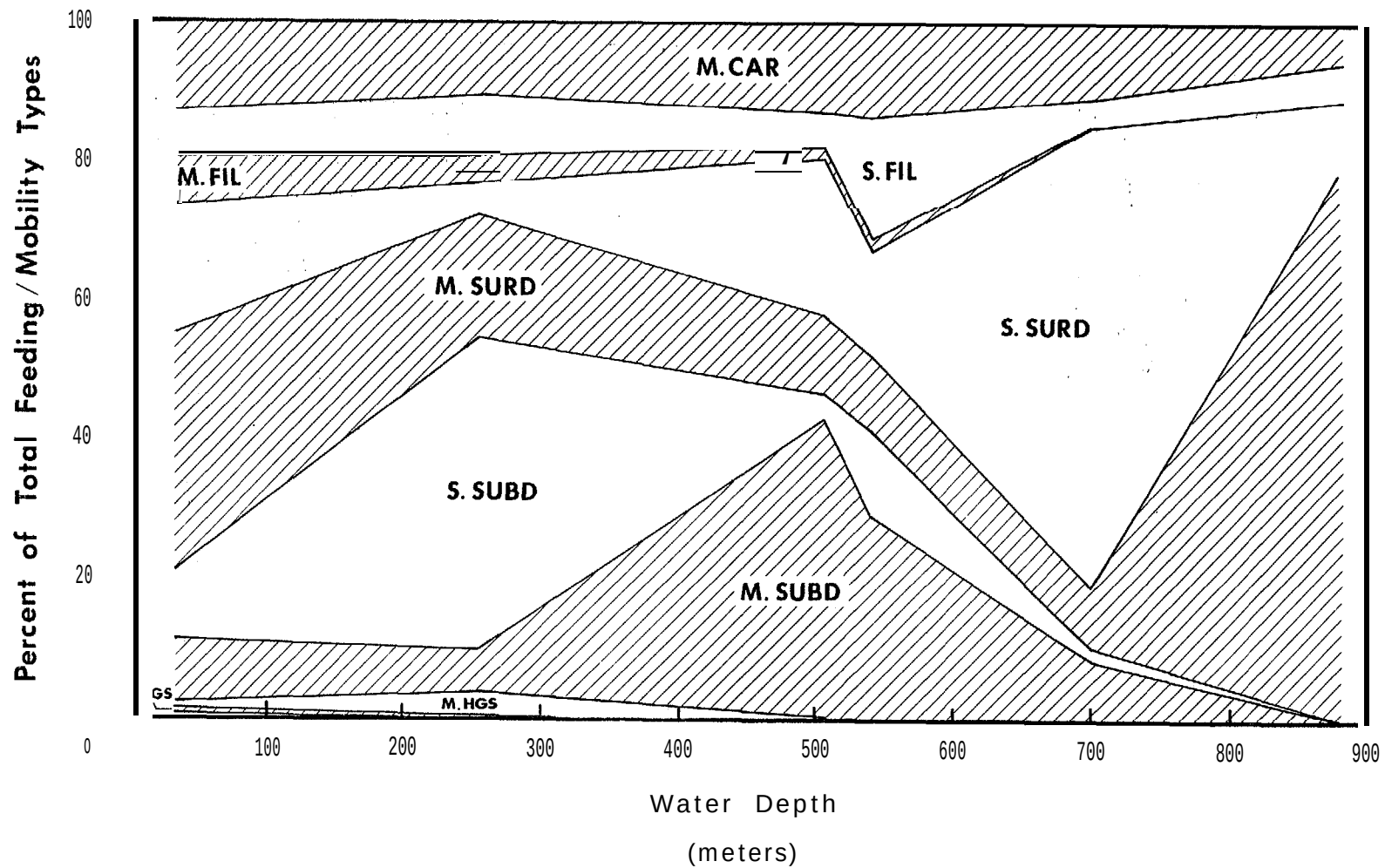


Figure 11-19.0-7. San Pedro Study Site - Percent of Total Feeding/Mobility Types: M=Mobile, S=Sessile, CAR=Carnivores, FIL=Filter Feeder, SURD=Surface Detrital Feeder, SUBD=Subsurface Detrital Feeder, HGS=Herbivore, Grazer, Scavenger.

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steenstrupi and Paraprionospio pinnata. On the lower slope (station 821) a single species, the polychaete Eclysippe trilobatus, dominated overwhelmingly. In the basin the principal surface detrital feeder was a relatively large motile invertebrate, the gastropod Mitrella permodesta.

Subsurface deposit feeders were most common on the upper slope, where sessile species predominated (the polychaetes Maldane sarsi and Myriochele gracilis) and at mid-slope, where motile species (the aplacophorans Chaetoderma sp. B, Prochaetoderma californicum and Limifossor fratula and the polychaete Allis monicae) were the most abundant elements.

Herbivores, grazers and scavengers comprised only a small fraction of the fauna at shallow depths.

19.7.1.8 Classification of Sampling Locations

The technique of classification (Smith, 1976) was used to assess the similarity and dissimilarity of the faunal associations at the sampling stations of this study site. The replicates from each sampling station were grouped on the basis of their faunal composition. The two-dimensional dendrogram resulting from this analysis could easily be divided into five clusters (Figure 11-19.0-8); each cluster identified by a letter. With one exception, cluster C, each cluster was composed of the replicates from a single sampling station (A = 819; B = 825; D = 821; and E = 823). Of the sampling locations comprising this study site, only the two mid-slope sampling stations, 827 and 828 (cluster C), appeared to be located within the same benthic association.

Taxa of the sample-sets collected from the sampling locations of this study site were classified by inverse analysis. The dendrogram resulting from this analysis was very large and hence was not included in this report except as it formed the vertical axis of the two-way table for this study site (Figure 11-19.0-9). The upper half of this dendrogram, and the two-way table, consisted of shelf species; the lower portion included species that predominated at slope locations and in the basin.

The relationship between the normal and the inverse analyses was illustrated in the two-way table (Figure 11-19.0-9); the lines on the table indicate where these two dendrograms were subdivided. The two-way table includes the faunal elements used to segregate the replicate samples in normal analysis.

Recurrent group analysis (Fager, 1957; Fager and McGowan, 1963) was also used to group the taxa of these sampling locations. This analysis resulted in 12 levels of recurrent groups. These results

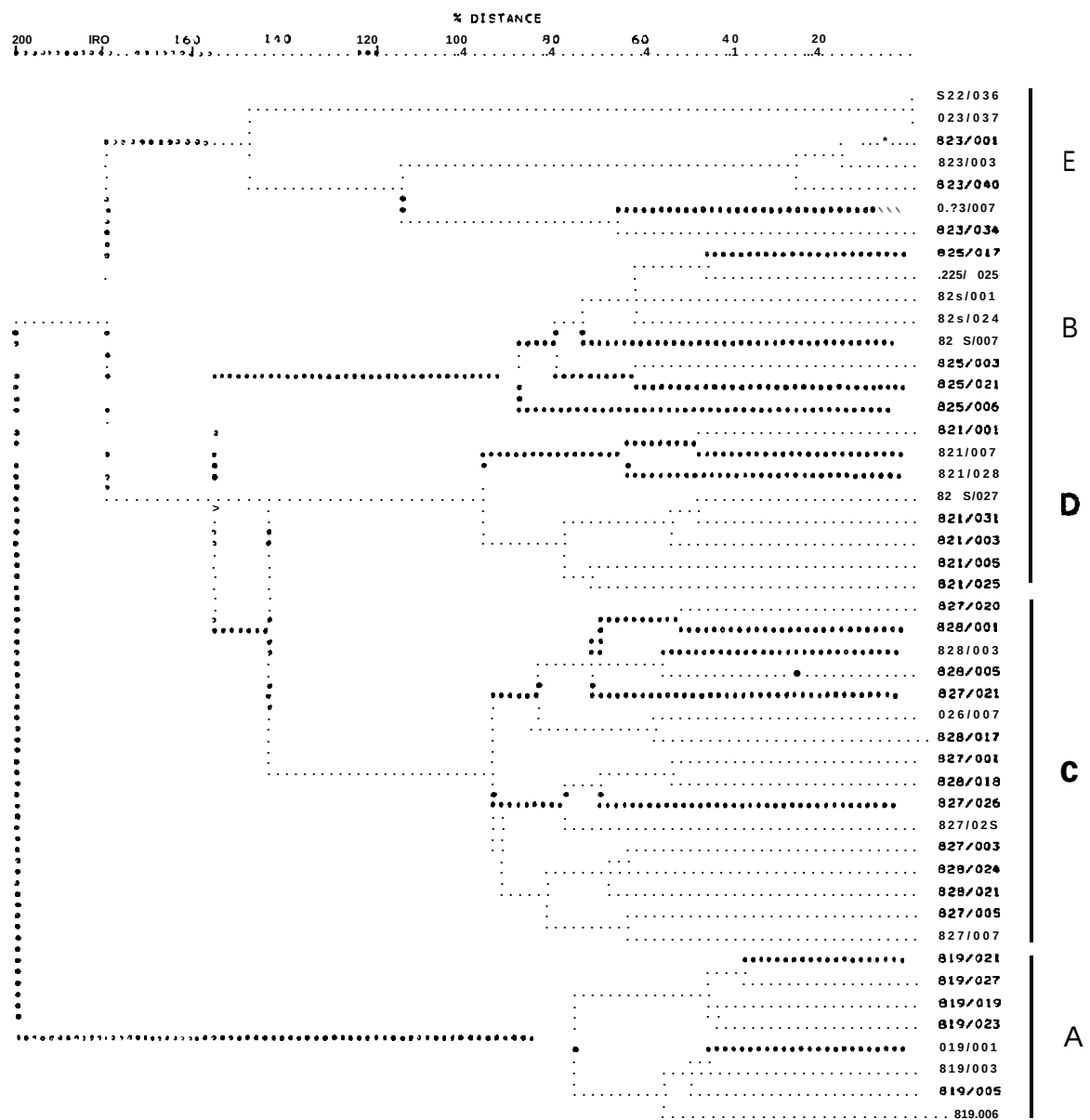


Figure 11-19.0-8. San Pedro Study Site - Dendrogram. Data Base - Edited Detailed Analysis. Editing Criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Letters represent the different clusters referred to in the text.

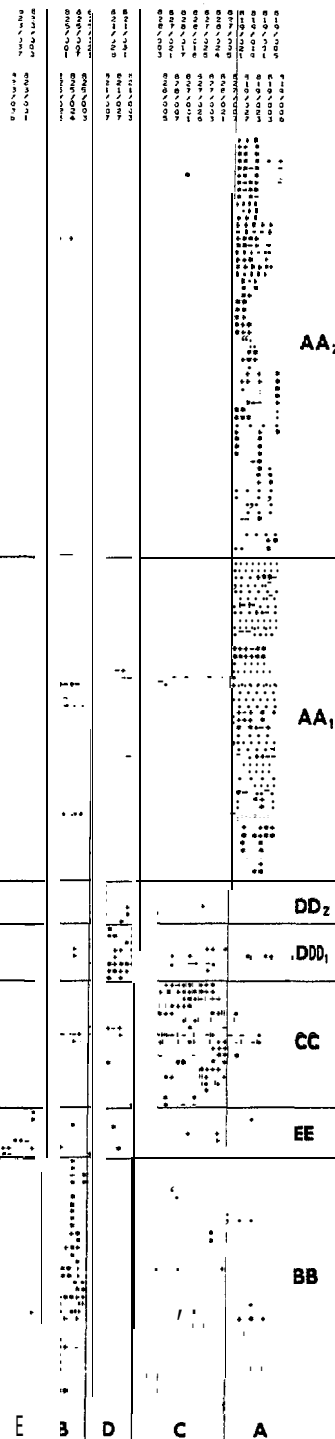


Figure II-19.0-9. San Pedro Study Site - Two Way Table. Data Base - Edited Detailed Analysis. Editing criteria - non-monospecific taxa and frequency of occurrences < 1 omitted. Abundances have been scaled from 0 to 1. The five symbols correspond to the following intervals: blank (≤ 0), $.$ ($> 0 - .25$), $-$ ($> .25 - .5$), $+$ ($> .5 - .75$), and $*$ ($> .75$). Single letters represent the clusters derived from normal analysis, double letters represent the clusters derived from inverse analysis.

were compared to the inverse analysis obtained by inverse classification analysis. All of the recurrent groups were subdivisions of the upper half of the dendrogram, the shelf fauna. Species characteristic of the slope stations and the basin were not included in any recurrent groups. The technique of recurrent group analysis was not a useful method of distinguishing the benthic associations along a gradient, in this case depth, where a substantial decrease in density and species richness occurred. This was not surprising, as the technique is based upon the number of affinities that a species has with other species, and this would obviously be higher at locations with more species.

19.7.2 Coal Oil Point Study Site

The three stations of the Coal Oil Point study site formed a gradient from the shelf to the lower slope of Santa Barbara Basin (Figure II-19.0-10). Eight replicate box core samples were collected at each of the sampling locations during each of the two sampling periods. Station 801 was on the shelf (mean depth of replicates: 68 m; range: 60-71 m); station 802 was on the upper slope (mean: 336 m; range: 323-347 m); and station 803 was on the lower slope of Santa Barbara Basin (mean: 504 m; range: 499-506 m). The depth of collection, field sediment description, core length, subsampling and type of analysis for each replicate in each sample-set have been presented in Table IV-19.0-2.

Environmental data for this study site have been summarized in Table 11-19.0-7. Sediments became finer and richer in organic carbon and carbonates with increasing depth, but sorting was relatively unchanged. There was little difference between the sedimentary variables between winter and summer samples. Bottom water oxygen content was less than 0.40 ml/l (winter, 0.37 ml/l; summer, 0.32 ml/l) at the deepest sampling station of this study site.

19.7.2.1 Epibenthic Photographs

Photographs of the sea floor at station 801 (nine photographs, moderate to good quality) revealed a slight amount of bioturbation consisting of a number of small holes and a few medium-sized and large holes. Epifaunal invertebrates were mainly limited to the urchin Lytechinus anamesus (-approximately 16 per photograph) and the sea pen Virgularia bromleyi (approximately seven per photograph). Another sea pen and two unidentified fish were also seen in these photographs.

Bioturbation at station 802 (six photographs, moderate to good quality) was moderate but quite variable, including small, irregular depressions, small humps, a few small, medium and large holes, and a few tracks. A few worm tubes were also evident. Few epifaunal

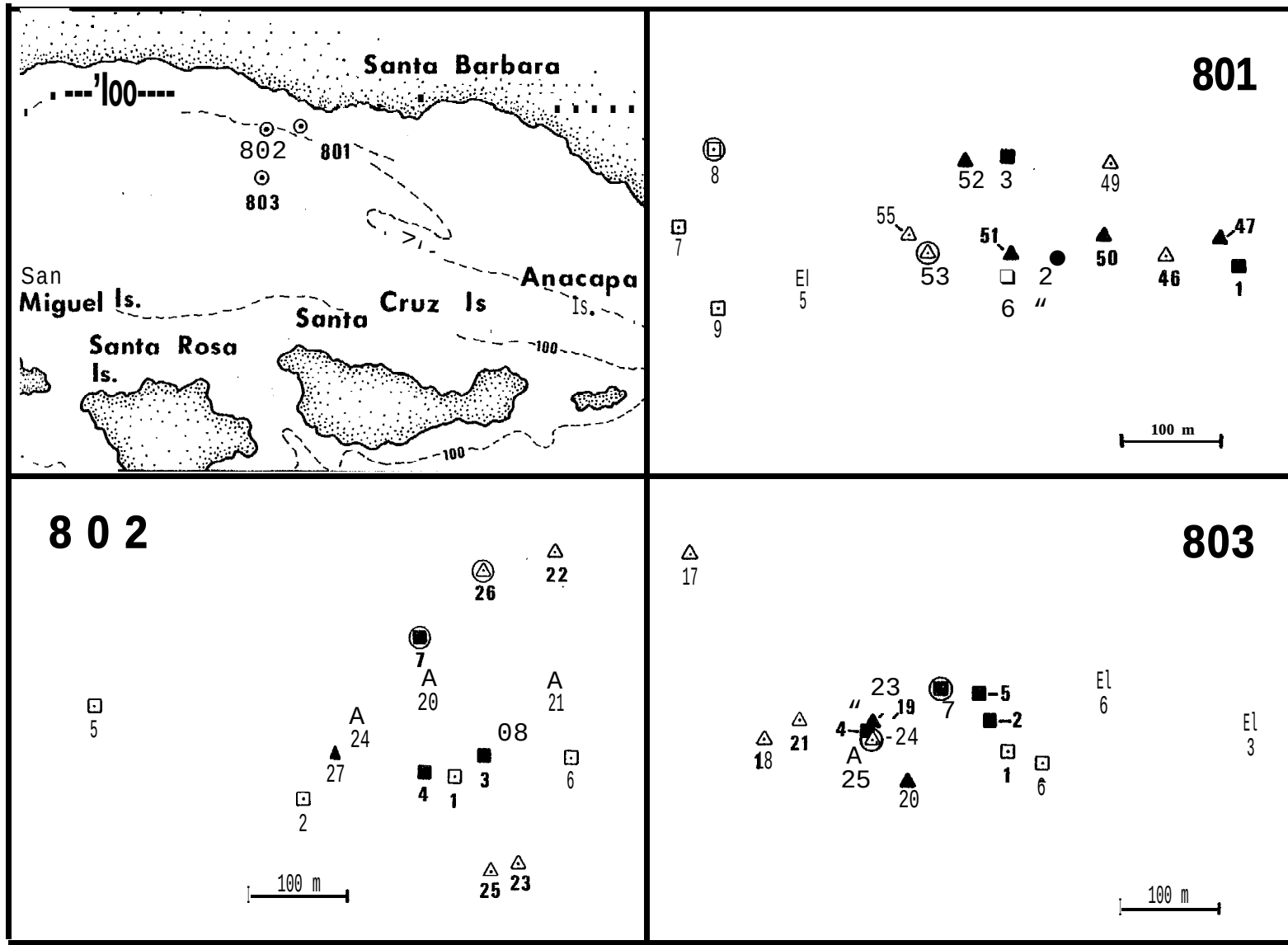


Figure 11-19.0-10. Map of the Coal Oil Point Study Site - Symbol Explanation: Q-Summer Stations, □-Winter Stations, ▲, ■-RIP and Detailed Analyses, △, □-RIP Analysis only, 0-geology slab removed from core.

Cast Number	Depth (meters)	Bottom 'C	Bottom θ_2 (ml/l)	% Sand	% silt	% Clay	Mean Grain Size (phi)	Sorting Coeff.	% TOC	% CaCO_3
80108	66	---	---	74.9	15.3	9.8	4.27	1.87	0.77	1.1
80153	69	---	---	77.4	13.1	9.5	4.33	1.69	0.82	0.7
801	59	13.39	4.91	---	---	---	---	---	---	---
801	67	10.98	4.21	---	---	---	---	---	---	---
80207	329	---	---	2.5	66.8	30.7	7.22	2.03	2.59	4.8
80226	325	---	---	1.6	56.4	42.0	8.04	1.79	2.76	5.3
802	269	8.22	1.07	---	---	---	---	---	---	---
802	336	8.01	1.12	---	---	---	---	---	---	---
80307	504	---	---	0.7	49.1	50.2	8.56	1.92	3.26	7.2
80324	506	---	---	0.9	44.3	54.8	8.95	1.92	3.42	6.8
803	482	6.68	0.37	---	---	---	---	---	---	---
803	497	6.43	0.32	---	---	---	---	---	---	---

Table 11-19.0-7. Coal Oil Point Study Site - Environmental Data.

invertebrates were evident in these photographs; those seen were the urchin Brissopsis pacifica, the asteroid Myxoderma platyacantha, an unidentified asteroid and an unidentified holothuroid.

At the deepest station, 803 (eight photographs, poor to moderate quality), only slight bioturbation (a few medium-sized holes) was evident. Numerous unidentified worm tubes were evident in all photographs. The numerically prominent epifaunal invertebrate seen in these photographs was the gastropod Mitrella permodesta (approximately 50 or more per photograph). Large scaleworms (about five per photograph) were also common.

19.7.2.2 Concordance

The degree of association among the members of the sample-sets collected from each sampling location at this study site was tested by Kendall's Coefficient of Concordance (Table 11-19.0-8). Concordance was demonstrated at the < 0.01 level of significance for the sample-sets of this study site; this indicated that the members of each sample-set were collected from within a single faunal association.

19.7.2.3 Density, Species Richness and Standing Crop

Density values were highest on the shelf (mean: 3,518 specimens/m²; range: 2,752-4,560). Values on the slope were substantially lower than those on the shelf; the mean density was lower on the upper slope (station 802; mean: 474 specimens/m², range: 32-928) than on the lower slope (station 803; mean: 730 specimens/m², range: 576-1,008) (Figure 11-19.0-11 a).

Species richness declined with increasing depth at this study site (Figure 11-19.0-11 b). Shelf replicates averaged 62 species/sample (range: 52-67). On the upper slope the mean value was 16 species/sample (range: 3-30), and on the lower slope the average was 11 species/sample (range: 8-14).

Due to the heavy weights of a few echinoderms, mainly urchins, standing crop was higher on the upper slope (station 802; mean: 254 g/m², range: 10-765) than on the shelf (station 801; mean: 146 g/m², range: 96-250) (Figure 11-19.0-11 c). The mean standing crop was lower (59 g/m²; range: 46-98) at the deepest station (803).

Over 40% of the specimens in the replicate sample-set collected on the shelf (station 801) were polychaetes. Echinoderms, mainly the ophiuroid Amphiodia urtica, were secondary in importance, accounting for over 30% of the total population density (Figure 11-19.0-12 a). On the upper slope (station 802) polychaetes, with 65% of the specimens, were the only prominent group. Mollusks (40%) were slightly more prominent than polychaetes (34%) at station 803 on the lower slope. Arthropods (25%), mainly microcrustaceans, were the only other group of any importance.

Table 19-8. Coal Oil Point Study Site - Kendall's Coefficient of Concordance, K = number of rankings, N = number of items, and W = coefficient of concordance.

Station (Method of Analysis)	K	N	W	Chi-squared	Significance Level
801					
Detailed Analysis	8	42	0.372	122.147	0.01
RIP	16	51	0.344	275.545	0.01
802					
Detailed Analysis	8	11	0.352	28.148	0.01
RIP	15	12	0.244	40,229	0.01
803					
Detailed Analysis	8	15	0.467	52,311	0*01
RIP	16	18	0.386	105.064	0.01

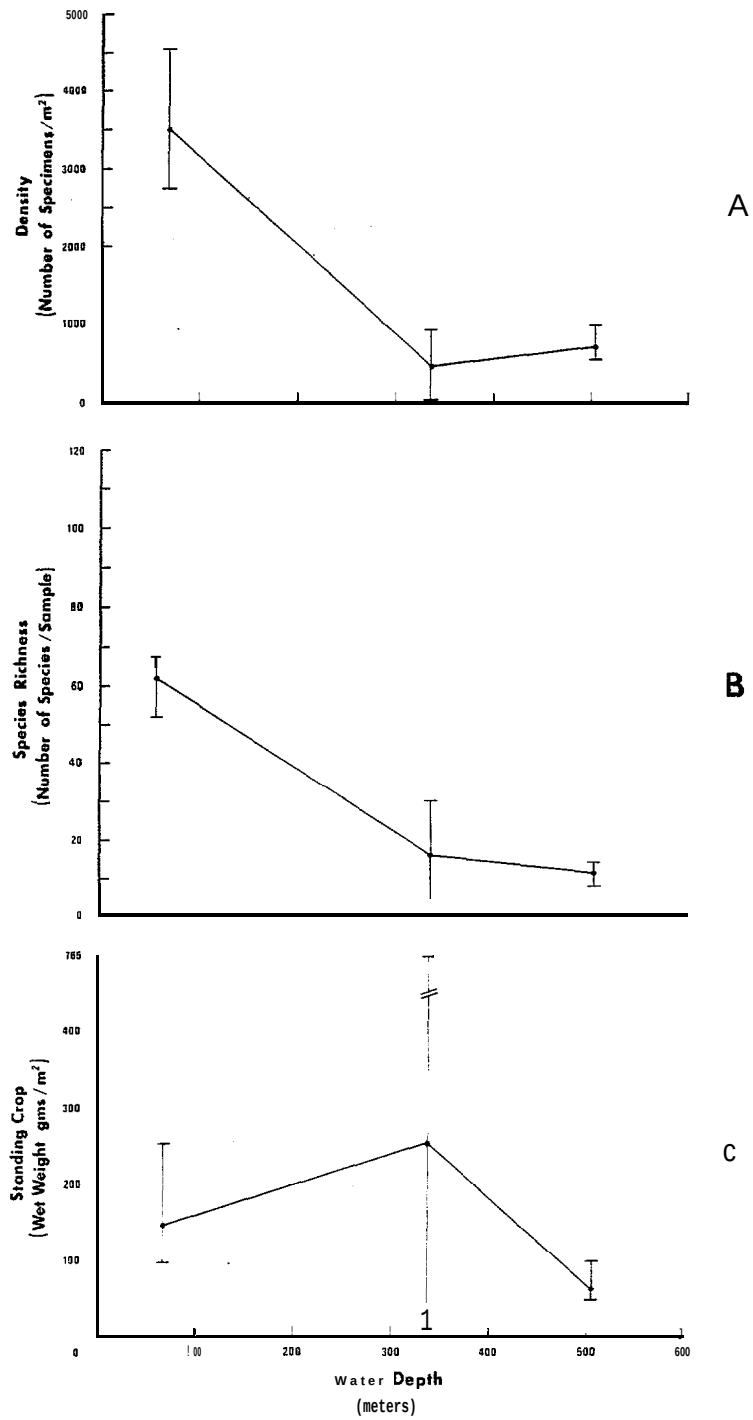


Figure 11-19.0-11. Coal Oil Point Study Site - A) Density, B) Species Richness, and C) Standing Crop Values by Station. Bars represent maximum and minimum values.

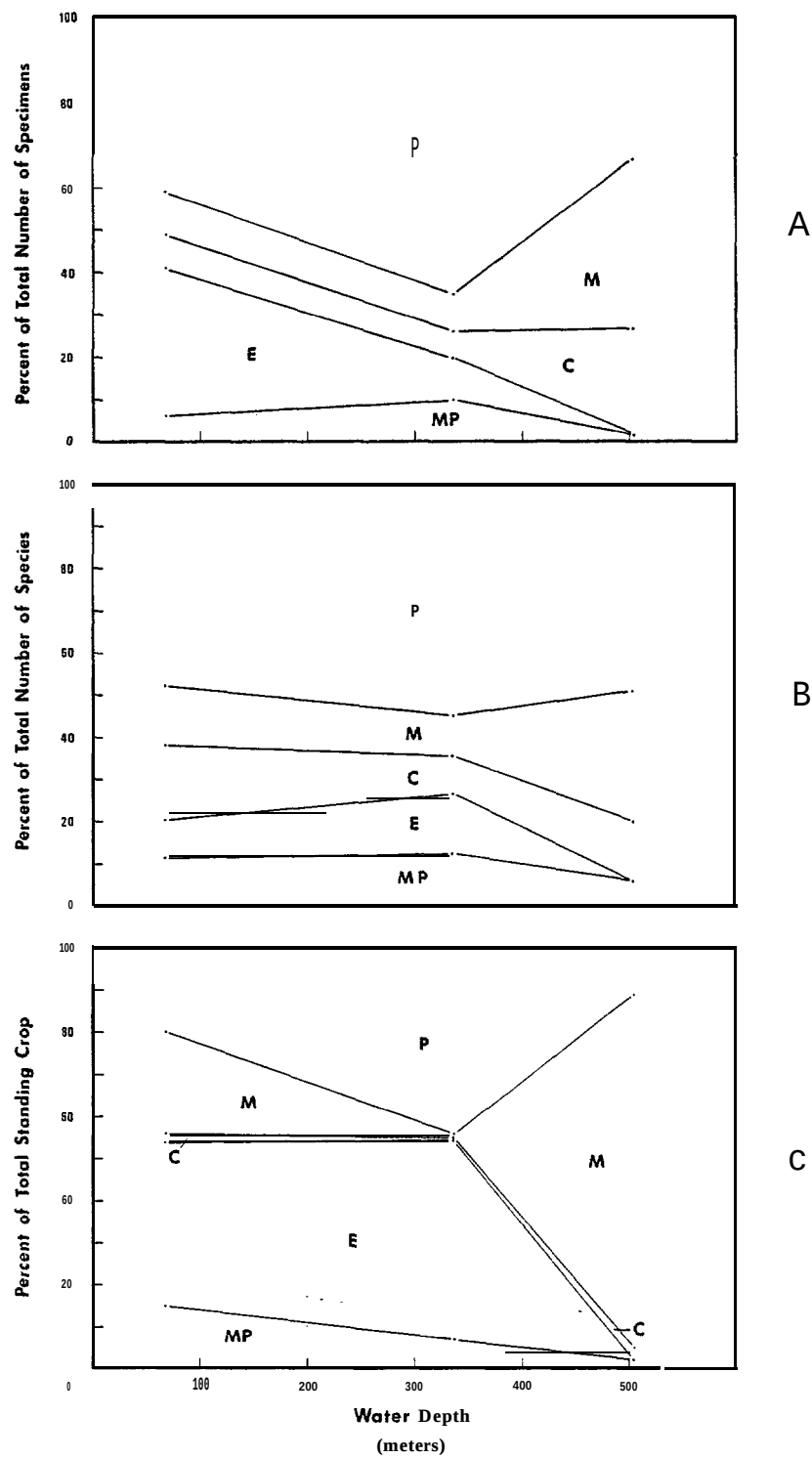


Figure 11-19.0-12. Coal Oil Point Study Site - A) Percent of Total Number of Specimens, B) Percent of Total Number of Species, and C) Percent of Total Standing Crop for the five major systematic groups by station: P=Polychaetes, M=Mollusks, C=Crustaceans, E=Echinoderms, and MP=Minor Phyla.

About half of all of the species at all three Coal Oil Point sampling locations were polychaetes (station 801, 48%; 802, 55%; and 803, 49%) (Figure 11-19.0-12 b). Mollusks were secondary in importance at the deepest sampling location.

The standing crop pattern was quite variable (Figure 11-19.0-12 c). Echinoderms, polychaetes and mollusks formed prominent components of the shelf standing crop; echinoderms and polychaetes comprised nearly all of the standing crop on the upper slope; on the lower slope, mollusks (84%) were overwhelmingly important.

19.7.2.4 Diversity, Evenness and Dominance

Diversity values at this study site decreased with increasing depth (Figure 11-19.0-13 a). The average diversity on the shelf (station 801) was 2.765 (range: 2.328-3.141). On the upper slope (station 802), the mean diversity was 2.294 (range: 1.762-2.757), and at the lower slope sampling location (station 803), diversity values averaged 1.960 (range: 1.749-2.108). Diversity values for the shelf replicates, when calculated for the combined 1.0 mm and 0.5 mm fractions, were higher than those calculated for the 1.0 mm fractions alone. For replicates from the upper slope, the values based on the combined fractions were within and well below the range for the 1.0 mm fraction. There was little difference between the diversity values for the combined fractions and the 1.0 mm fraction for the lower slope replicates.

Evenness values were lowest on the shelf (mean: 0.722, range: 0.655-0.799), and highest at the upper slope sampling location (mean: 0.878; range: 0.765-0.948). At the deepest sampling station, the mean evenness, 0.840 (range: 0.758-0.897), was only slightly lower than that for the upper slope (Figure 11-19.0-13 b). Evenness values based on the combined 1.0 and 0.5 mm fractions were above the average of the 1.0 mm fractions on the shelf, were well below the average on the upper slope, and were near or slightly above the average on the lower slope.

Dominance values changed little with depth (Figure 11-19.0-13 c): station 801, mean: 0.166 (range: 0.117-0.271); station 802, mean: 0.140 (range: 0.099-0.245); and station 803, mean: 0.186 (range: 0.146-0.224). Values for the combined fractions were lower than the average on the shelf, above the average on the upper slope, and near the average on the lower slope.

19.7.2.5 Faunal Composition

The numerically dominant species of each sampling location of the Coal Oil Point study site (ranking by abundance) have been listed in Table 11-19.0-9, and their distribution with depth has been illustrated. Few taxa were prominent faunal elements at more than one station.

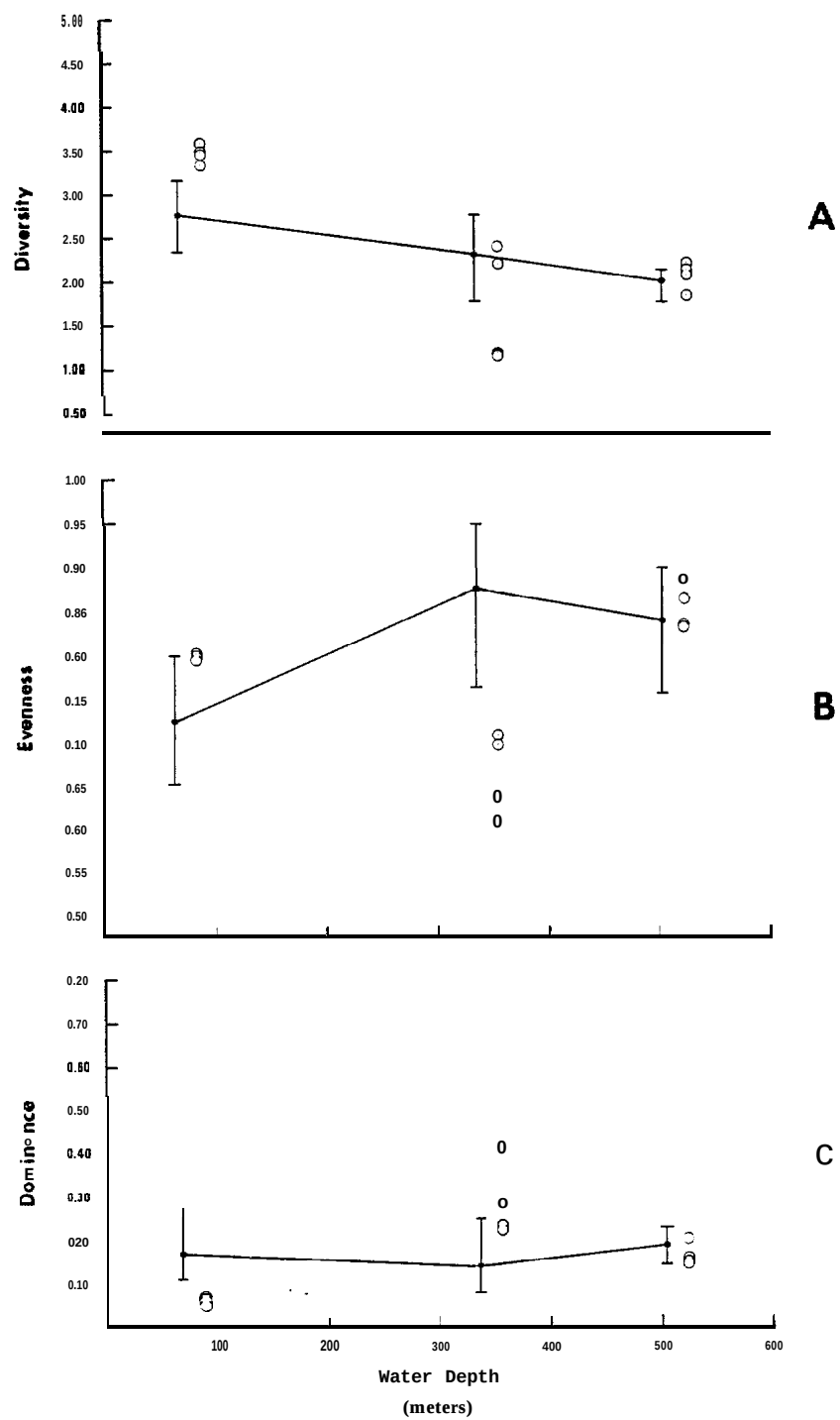


Figure 11-19.0-13. Coal Oil Point Study Site - A) Diversity, B) Evenness, and C) Dominance Values by Station:
 ● -1.0 mm fraction and ○ -1.0 mm fraction plus 0.5 mm fraction. Bars represent maximum and minimum values.

Table 11-19.0-9. Coal Oil Point Study Site - Abundance, % of Total, Frequency, and Affinity Values for the ten most abundant species at each station. Bold letters and underlining indicate the dominant species based on 5% or more of the total number

	Station 801 (68 m)				Station 802 (336 m)				Station 803 (504 m)			
"	Abund.	% of Total	Freq.	Affin.	Abund.	% of Total	Freq.	Affin.	Abund.	% of Total	Freq.	Affin.
Laxon												
AMPHIODIA (AMPHISPINA) URTICA	<u>480</u>	<u>34.48</u>	<u>1.00</u>	<u>38</u>	1	0.48	0.13	1				
SPIOPHANES MISS IONENSIS	<u>187</u>	<u>13.43</u>	<u>0.88</u>	<u>31</u>								
Mysella tumida	49	3.52	1.00	38								
Prionospio steenstrupi	40	2.87	0.75	28								
Axiopsida serricata	26	1.87	0.88	31								
Fauberia gracilis	25	1.80	0.88	25								
Cyclocardia ventricosa	22	1.58	0.75	26					4	2.51	0.25	1
Glycera capitata	21	1.51	0.88	31	2	0.95	0.25	0				
Levinseniella stroemii	21	1.51	0.88	31								
Nedionaspis calliforniensis	21	1.51	0.88	30								
Cossura candida	21	1.51	0.75	28								
HETEROMASTUS SP.					48	22.86	0.88	6				
PRIONOSPIO LOBULATA					25	11.90	0.75	7	21	5.85	0.63	5
NEPHYTIS CORNUTA FRANCISCANA					24	11.43	0.75	7	22	6.13	0.88	6
Chilocardia pinnata	2	0.14	0.25	2	8	3.81	0.38	3				
Saxicavella pacifica					8	3.81	0.25	1				
Brisaster latifrons					8	3.81	0.63	3				
Nothria iridescent					7	3.33	0.63	5				
Eunice americana					7	3.33	0.63	5				
Paraprionospio pinnata	14	1.01	0.88	31	7	3.33	0.63	3				
Janirallata occidentals					6	2.86	0.13	9				
NITRELLA PERMODESTA									87	24.23	1.00	10
BYBLIS BARBARENSIS									69	19.22	0.75	6
FAUBERIA MULTIBRANCHIATA									36	10.03	1.00	10
CYCLOCARDIA BARBARENSIS									30	8.36	0.75	8
SPIOPHANES KROEYERI									19	5.29	0.75	5
VALLETHIOPSIS SP. /SPP									18	5.01	0.13	0
Valledonpumilus									9	2.51	0.50	5

The ophiuroid Amphiodia urtica and the polychaete Spiophanes missionensis were the dominant faunal elements at station 801 on the shelf. On the upper slope, station 802, three polychaetes, Heteromastus sp., Prionospio lobulata and Nephtys cornuta franciscana, predominated. The numerically dominant species at the lower slope sampling locations included the gastropod Mitrella permodesta, the amphipod Byblis barbarensis, the polychaete Tauberia multibranchiata and the pelecypod Cyclocardia barbarensis.

19.7.2.6 Spatial Variation

The benthic association on the shelf displayed a marked degree of randomness (Table 11-19.0-10). Only three species had significantly aggregated distributions, and only one of these was significant beyond the 95% probability level. Randomness also characterized the spatial organization of the upper slope association. The fauna of the lower slope sampling location was very slightly aggregated. Only a single species, the polychaete Prionospio lobulata, demonstrated an aggregated distribution. The winter sample-set from this location was more highly aggregated. A single species, the amphipod Byblis barbarensis (index of dispersion: 49.16), accounted for nearly half of the heterogeneity in this sample-set. When the winter and summer sample-sets were combined, the heterogeneity was reduced only slightly. Four species, Byblis barbarensis, the pelecypods Cyclocardia ventricosa and C. barbarensis, and Prionospio lobulata, accounted for much of the spatial variation.

19.7.2.7 Feeding/Mobility Types

Motile forms dominated all of the sampling locations of the Coal Oil Point study site (station 801, 89%; 802, 94%; and 803, 85%) (Figure 11-19.0-14). Motile carnivores comprised a relatively small proportion of the fauna at all three locations (8% on the shelf; 18% on the upper slope, and 5% on the lower slope). Filter feeders made up a somewhat larger fraction of the fauna on the shelf (13%; sessile forms, 12%), and on the lower slope (32%; motile forms, 21%).

Motile surface deposit feeders dominated the shelf (62%). On the upper slope, they comprised 40% of the fauna, while another 30% was composed of motile subsurface detrital feeders. Motile surface deposit feeders again predominated on the lower slope, where they made up 48% of the fauna.

19.7.2.8 Classification of Sampling Locations

The replicates from each sampling station were grouped on the basis of their faunal composition (normal analysis). The two-dimensional dendrogram resulting from this analysis consisted of three clusters; each cluster included the replicates from one of the stations of this study site (F = 801; G = 802; H = 803) (Figure 11-19.0-15).

Table 11-19.0-10. Coal Oil Point Study Site - Spatial Variation.

Station Number	Heterogeneity Chi-Square	Degrees of Freedom	Spatial Character	Probability	Species with Aggregated Distribution	Index of Dispersion	df	p
801	187.48	180	random	>0.50	<i>Spiophanea missionensis</i>	15.64	3	<0.01
					<i>Ampelisca brevisimulata</i>	9.0	3	<0.05
					<i>Axinopsida serricata</i>	8.52	3	<0.05
802	88.75	75	random	>0.10	<i>Nephtys cornuta franciscana</i>	8.29	3	<0.05
803	52.08	39	aggregated	<0.05	<i>Prionospio lobulata</i>	12.64	3	<0.01

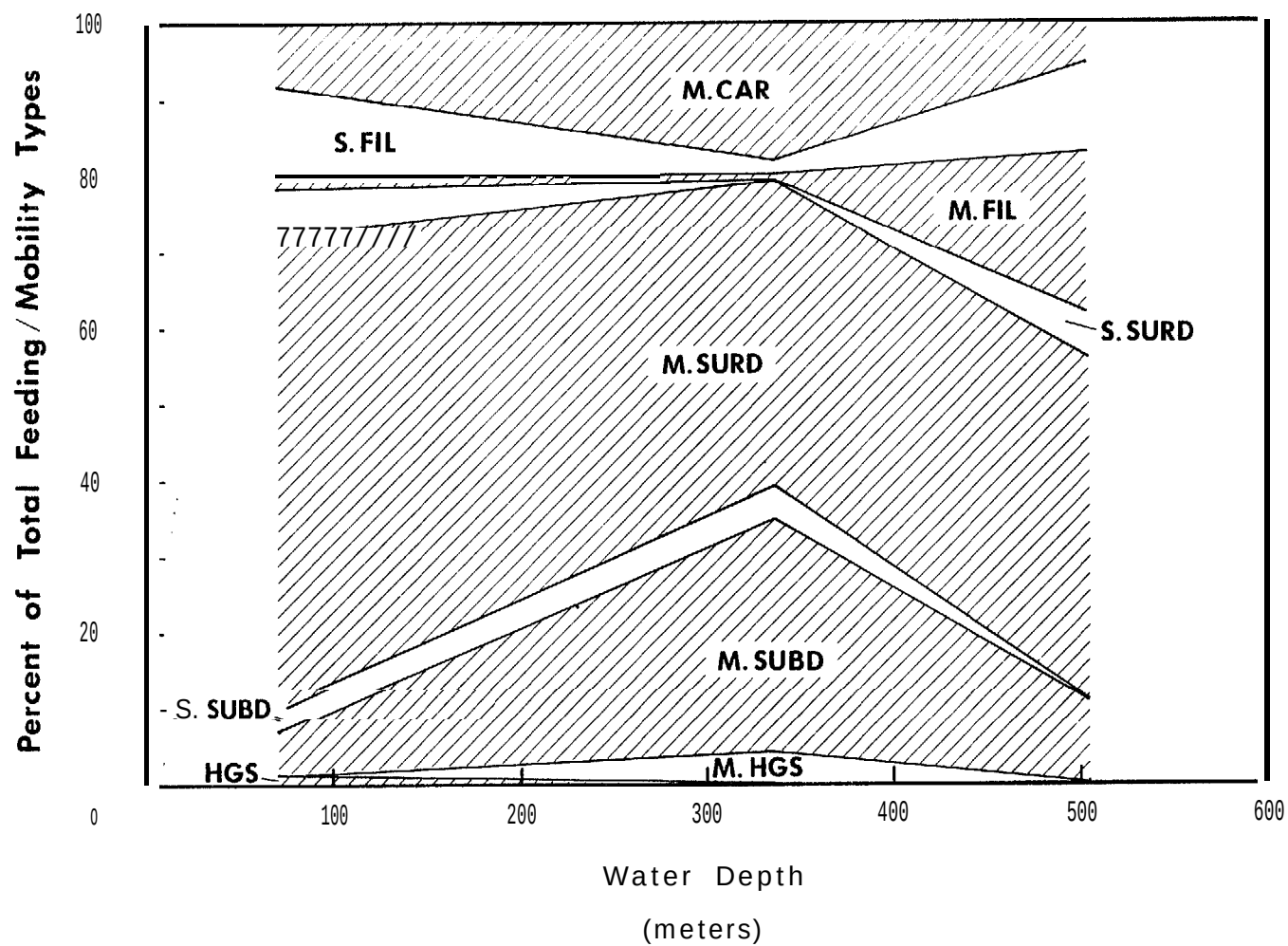


Figure 11-19.0-14. Coal Oil Point Study Site - Percent of Total Feeding/Mobility Types: M=Motile, S=Sessile, CAR=Carnivores, FIL=Filter Feeder, SURD=Surface Detrital Feeder, SUBD=Subsurface Detrital Feeder, HGS=Herbivore, Grazer, Scavenger.

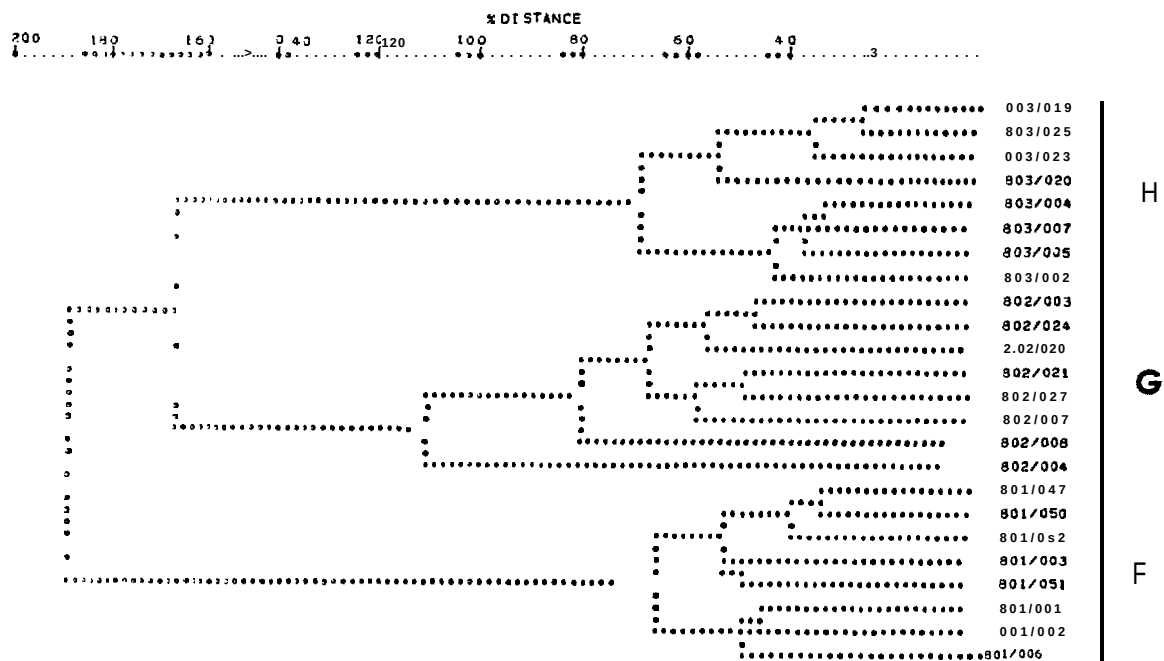


Figure 11-19.0-15. Coal Oil Point Study Site - Dendrogram. Data Base - Edited Detailed Analysis. Editing Criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Letters represent the different clusters referred to in the text.

The taxa of the sample-sets collected from the sampling locations of this study site were classified by inverse analysis. The relationship between the normal and the inverse analysis has been shown in the two-way table (Figure 11-19.0-16); the lines on the table indicate where these two dendrograms were subdivided. The two-way table indicates the faunal elements used to segregate the replicate samples in normal analysis.

19.7.3 Santa Rosa Ridge Study Site

The six stations on the insular shelf, the ridge, the ridge slope and in the Santa Cruz Basin formed a single study site (Figure II-19.0-17). For the purposes of this report, they have been treated as though they were part of the same transect or depth gradient. Eight replicate box core samples were collected at each location during each of the two sampling seasons, except at station 808, where only five samples were collected during the winter season. Station 806 was on the San Miguel Island shelf (mean depth of replicates: 99 m; range: 96-101 m); station 808 was on the ridge (mean: 105 m; range: 103-108 m); station 805 was on the San Miguel Island shelf (mean: 239 m; range: 214-251 m); station 809 was on the ridge (mean: 254 m; range: 222-271 m); station 810 was on the ridge slope (mean: 468 m; range: 444-500 m); and station 812 was in the basin (mean: 1,864 m; range: 1,862-1,871 m). The depth of collection, field description, core length, subsampling and type of analysis for each replicate in each sample-set have been presented in Table IV-19.0-3.

Environmental data for this study site have been summarized in Table 11-19.0-11. Except in the basin, sediments consisted of sands, sand mixed with silt, and at several locations, admixtures of coarse material of elastic and organic origin. These sediments were generally high in carbonates (12-72%) and low in organic material (2%). The organic content of the basin sediment was higher (5%), and the carbonate content was relatively high (8-12%) at the basin sampling location. Bottom water oxygen content, as expected, decreased with increasing depth. Values in the basin (station 812) ranged from 0.24 ml/l (winter) to 0.35 ml/l (summer).

19.7.3.1 Epibenthic Photographs

The ocean bottom at stations 805 (10 photographs, poor to moderate quality) and 806 (nine photographs, poor to moderate quality) was monotonous. Bioturbation was slight, consisting of only some small and medium-sized holes." At station 806, there were a few worm tubes and macroalgal fragments. The epifauna at both of these locations was limited in the photographs. The gastropod Nassarius ? insculptus (four per photograph) and the urchin Allocentrotus fragilis (two per photograph) were the only species consistently pictured at station 805. At station 806, only an occasional sea pen or urchin (Lytechinus anamesus) was photographed. The foraminiferan Astrorhiza sp. populated the bottom at this site.

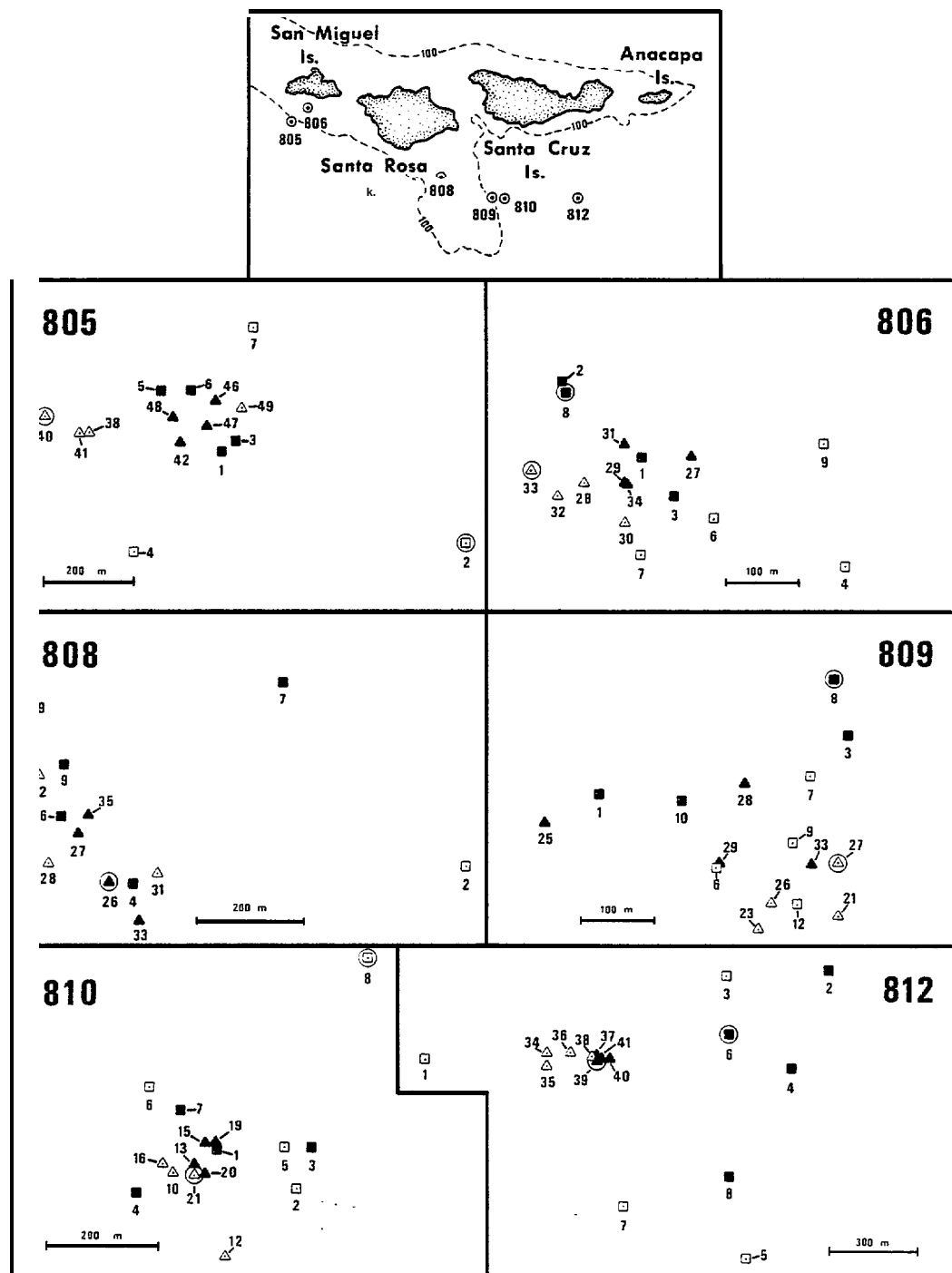


Figure 11-19.0-17. Map of the Santa Rosa Ridge Study Site - Symbol Explanation: A -Summer Stations, 0-Winter Stations, A, ■ -RIP and Detailed Analyses, △, n-RIP Analysis only, ○-geology slab removed from core.

Table 11-19.0-11. Santa Rosa Ridge Study Site - Environmental Data.

Cast Number	Depth (meters)	Bottom °C	Bottom O ₂ (ml/l)	% Sand	% silt	% Clay	Mean Grain Size (phi)	Sorting Coeff.	% TOC	% CaCO ₃
80607	96	---	---	69.2	23.6	7.2	4.35	1.66	0.98	19.2
80633	9 9	---	---	63.6	24.4	12.0	4.80	1.78	0.83	18.4
806	92	11.75	4.28	---	---	---	---	---	---	---
806	105	10.00	3.55	---	---	---	---	---	---	---
808	---	---	---	---	---	---	---	---	---	---
80826	106	---	---	87.9	4.7	7.4	3.61	2.19	0.54	11.8
808	1 0 3	10.60	3.52	---	---	---	---	---	---	---
808	104	9.46	3.04	---	---	---	---	---	---	---
80502	244	---	---	89.1	6.6	4.3	3.58	1.65	0.80	35.5
80540	247	---	---	69.1	18.7	12.2	4.56	2.04	0.84	32.3
805	259	8.02	1.56	---	---	---	---	---	---	---
805	246	8.73	1.95	---	---	---	---	---	---	---
80908	271	---	---	86.6	6.8	6.6	3.38	2.49	0.76	61.3
80927	249	---	---	84.7	7.8	7.5	3.40	2.62	0.55	72.0
809	237	8.53	1.73	---	---	---	---	---	---	---
809	236	8.57	1.54	---	---	---	---	---	---	---
81008	500	---	---	77.9	13.8	8.3	4.17	1.80	1.61	19.1
81021	454	---	---	69.8	15.7	14.5	4.74	1.90	1.62	27.0
810	340	7.65	0.88	---	---	---	---	---	---	---
810	422	7.39	0.86	---	---	---	---	---	---	---
81206	1864	---	---	2.3	48.7	49.0	8.35	2.05	4.66	7.7
81239	1862	---	---	1.1	40.7	58.2	8.99	2.45	5.31	12.1
812	1866	4.19	0.24	---	---	---	---	---	---	---
812	1861	4.19	0.35	---	---	---	---	---	---	---

11-19.0-70

The sea floor at station 808 (nine photographs, moderate quality) was highly variable, consisting of unconsolidated sediments (two photographs), unconsolidated sediments with shell debris (one photograph), and unconsolidated sediments plus rocks and shell debris (six photographs). There was little evidence of bioturbation in any of the photographs. Epifaunal invertebrates were lacking or limited to a few scaleworms where rocks were absent. The crinoid Florometra serratissima predominated in areas where rocks occurred; other taxa seen in these photographs included gastropod (Nassarius ? insculptus, Epitonium sp., an unidentified trochid and other unidentified forms), sea pens, burrowing anemones and sponges.

Similarly, the photographs taken at station 809, (12 photographs, moderate to good quality); revealed the variable nature of the bottom, ranging from monotonous areas of unconsolidated sediments to areas mixed with rocks and cobbles; shell debris was evident in almost every photograph. Very slight evidence of bioturbation, a few small holes, was seen in the photographs lacking rocks. The only epifaunal invertebrates seen in the photographs of unconsolidated sediments were a single specimen of the urchin Allocentrotus fragilis and two individuals of the gastropod genus Nassarius. Where rocks were present, more taxa were seen; included were sponges, sea pens, tube-building polychaetes (? Spirorbidae), the gastropods Nassarius ? insculptus and Fusinus sp., the urchins Lytechinus anamesus and numbers of unidentified ophiuroids under the rocks. Two unidentified fish were also seen in these photographs.

The character of the ocean floor was also quite variable at the sampling location on the ridge slope (station 810; 11 photographs, moderate quality); rocks were evident in five of the photographs. Bioturbation was negligible in all of the pictures taken at this station. Where rocks were absent, the epifauna consisted of sea pens, an unidentified holothuroid and gastro-pods (Scissurella sp. and an unidentified turrid). Where rocks were present, the epifauna included sea pens, sponges, the gastropod Scissurella sp., the urchins Lytechinus anamesus (four per photograph) and Allocentrotus fragilis, and an unidentified holothuroid.

In the basin, station 812 (eight photographs, moderate to good quality), bioturbation was again minimal, consisting of only a few small holes and some depressions. The epifauna was abundant. The large ophiuroid Ophiura leptoctenia dominated, approaching a density of nearly 100 per photograph. Other forms included the pelecypod Delectopecten sp. (two per photograph), an anemone (possibly Actinauge, near verrilli, one or two per photograph), sea pens and a large unidentified asteroid.

19. 7.3.2 Concordance

Kendall's Coefficient of Concordance (Table 11-19.0-12) was used to test the degree of association among the members of the sample-sets collected from each sampling location of this study site. Concordance was demonstrated at the 0.01 level of significance for the sample-sets of this study had indicated that the members of each sample-set were collected from within a single faunal association.

19.7.3.3 Density, Species Richness and Standing Crop

Generally, density and species richness declined with increasing depth (Figure 11-19.0-18 a and b). Density values were lower at station 806 (San Miguel Island shelf: 99 m; mean: 3,248 specimens/m²) than at station 808 (Santa Rosa Ridge: 105 m; mean: 4,290 specimens/m²). Mean values declined to 2,756 specimens/m² (station 805), San Miguel Island shelf) and 2,012 specimens/m² (station 809, Santa Rosa Ridge) between 200 and 300 m. On the ridge slope, station 810, the mean density was 1,048 specimens/m². In the basin the density averaged 454 specimens/m²; this value was based on box core samples only and did not include the large forms seen in epibenthic photographs taken at this sampling location. If these forms were included the number of individuals would probably average about 500/m².

Species richness was highest at the shallow stations on the insular shelf (station 806; mean: 83 species/sample) and ridge (station 808; mean: 80 species/sample), declined to 49 species/sample on the insular shelf (station 805) and 55 species/sample on the ridge (station 809), decreased to 32 species/sample on the ridge slope (station 810), and averaged 16 species/sample in the basin.

Standing crop values were highest at station 809 (mean: 194 g/m²), were intermediate at the other shelf, ridge and slope stations (73-82 g/m²) and were lowest in the basin (24 g/m²). (Figure 11-19.0-18 c).

The importance of polychaetes at all sampling locations, regardless of the magnitude of the population density and species richness has been clearly illustrated in Figure 11-19.0-19 a and b. Echinoderms, crustaceans and mollusks all were of secondary importance. The minor phyla were relatively unimportant. Echinoderms formed the predominant component of the standing crop at all locations except in the basin, where polychaetes were the major group (Figure 11-19.0-19 c).

19.7.3.4 Diversity, Evenness and Dominance

Diversity values were somewhat higher on the insular shelf and ridge (station 806, mean: 3.768; station 809, mean: 3.117); station 808, mean: 3.006; and station 805, mean: 2.769). They declined somewhat on the ridge slope (station 810, mean: 2.755) and were lowest in the

Table 11-19.0-12. Santa Rosa Ridge Study Site - Kendall's Coefficient of Concordance. K = number of rankings, N = number of items, and W = coefficient of concordance.

Station (Method of Analysis)	K	N	W	Chi-squared	Significance Level
806					
Detailed Analysis	8	82	0.383	248.466	< 0.01
RIP	16	88	0.412	573.623	< 0.01
808					
Detailed Analysis	8	62	0.252	123.108	< 0.01
RIP	13	68	0.299	260.176	< 0.01
805					
Detailed Analysis	8	39	0.533	161.933	< 0.01
RIP	16	46	0.319	229.648	< 0.01
809					
Detailed Analysis	8	44	0.201	69.302	< 0.01
RIP	16	58	0.150	136.933	< 0.01
810					
Detailed Analysis	8	19	0.282	40.649	< 0.01
RIP	16	26	0.186	74.224	< 0.01
812					
Detailed Analysis	8	14	0.220	22.849	< 0.05
RIP	16	11	0.331	53.019	< 0.01

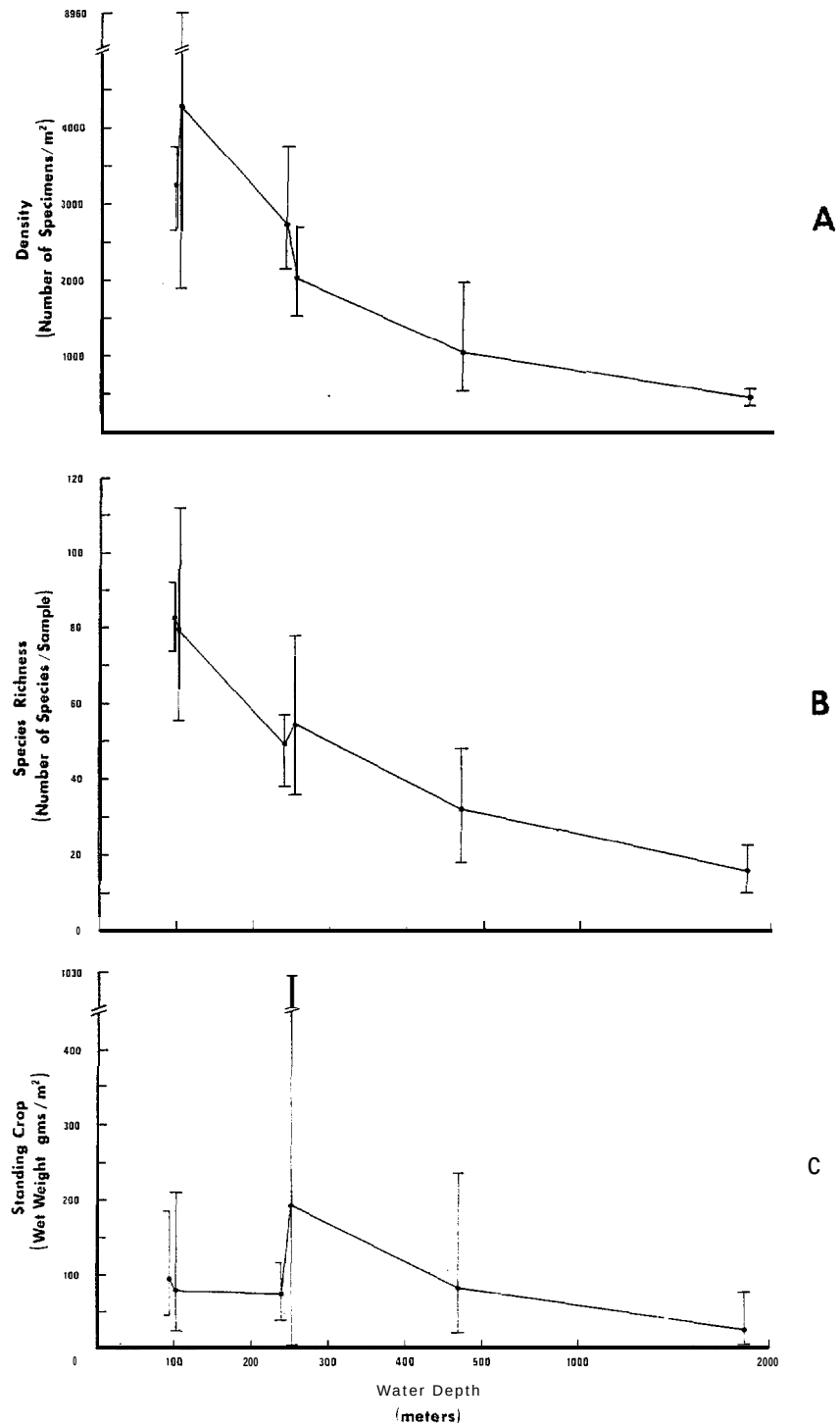


Figure 11-19.0-18. Santa Rosa Ridge Study Site - A) Density, B) Species Richness, and C) Standing Crop Values by Station. Bars represent maximum and minimum values.

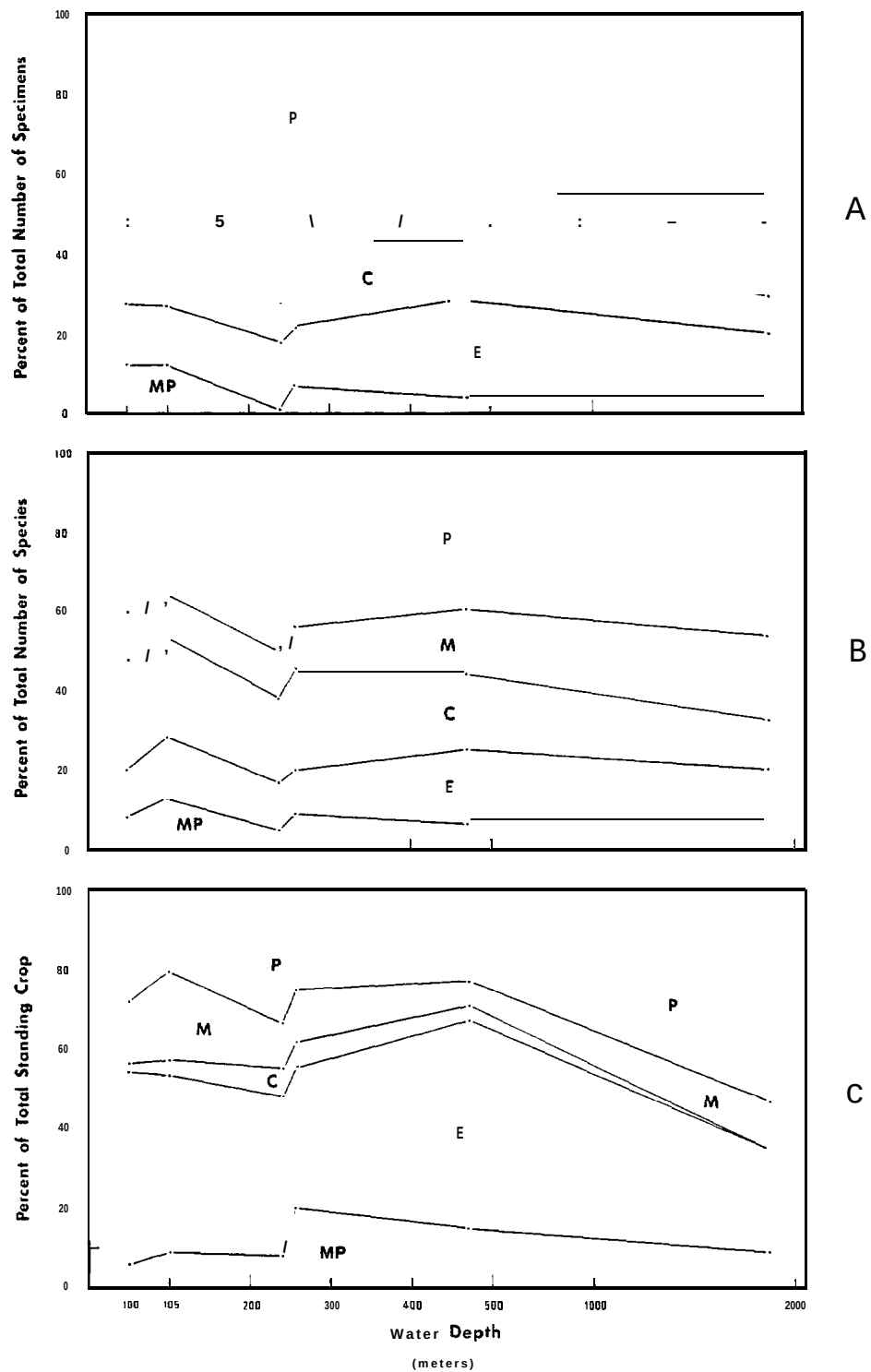


Figure 11-19.0-19. Santa Rosa Ridge Study Site - A) Percent of Total Number of Specimens, B) Percent of Total Number of Species, and C) Percent of Total Standing Crop for the five major systematic groups by station: P=Polychaetes, M=Mollusks, C=Crustaceans, E=Echinoderms, and MP=Minor Phyla.

basin (station 812, mean: 2.177) (Figure II-1 9.0-20 a). For the most part, the diversity values for the combined 1.0 mm and 0.5 mm fractions were at or above the means at all locations.

The pattern of evenness values on the insular shelf and ridge was similar to that of the diversity values, but instead of decreasing with increasing depth, evenness values were slightly higher on the ridge slope and in the basin (Figure 11-19.0-20 b). Most of the values for the combined fractions exceeded the means for the values calculated on the 1.0 mm fractions alone.

Dominance values varied little with depth (Figure 11-19.0-20 c). The lowest mean value was at station 806 (0.038). The highest was at station 808 (0.54). At the other stations on the insular shelf and ridge, and on the ridge slope, values were intermediate (0.083-0.137). The mean dominance of the replicates collected in the basin was 0.144. Most of the values calculated for the combined fractions were below the means determined for the 1.0 mm fractions alone.

19.7.3.5 Faunal Composition

The species that numerically dominated each sampling location of the Santa Rosa Ridge study site (ranking by abundance) have been listed in Table 11-19.0-13. Their distribution with depth has also been illustrated. Most of the taxa included in this table were faunal elements at more than one station. Indeed, a number were important at more than one location. Only the fauna of the basin was reasonably distinct.

The sipunculid Golfingia (Phascoloides) minuta, the ophiuroid Amphiodia (Amphisphaera) urtica and the pelecypod Parvilucina tenuisculpta were the numerically dominant forms at station 806 (99 m; San Miguel Island shelf). Although all three of these taxa also occurred at station 808 (105 m) on the Santa Rosa Ridge, the latter sampling location was overwhelmingly dominated by the polychaete Chloeia pinnata and the ostracod Euphilomedes carcharodonta.

At station 805 (239 m; San Miguel Island shelf) the polychaete Onuphis, near nebulosa dominated. This same species, along with another polychaete, Magelona, near cornuta, also dominated the fauna of station 809 (255 m; Santa Rosa Ridge).

On the ridge slope, the polychaetes Lumbrineris cruzensis and Onuphis, near nebulosa, the ophiuroid Amphipholis squamata and the caprellid amphipod Mayerella banksia were the numerically dominant faunal elements.

In the basin, the major faunal components were the pelecypod Tindaria kennerlyi, the ophiuroids Ophiura leptoctenia and Ophiophthalmus normani and the scaphopod Dentalium, near rectius.

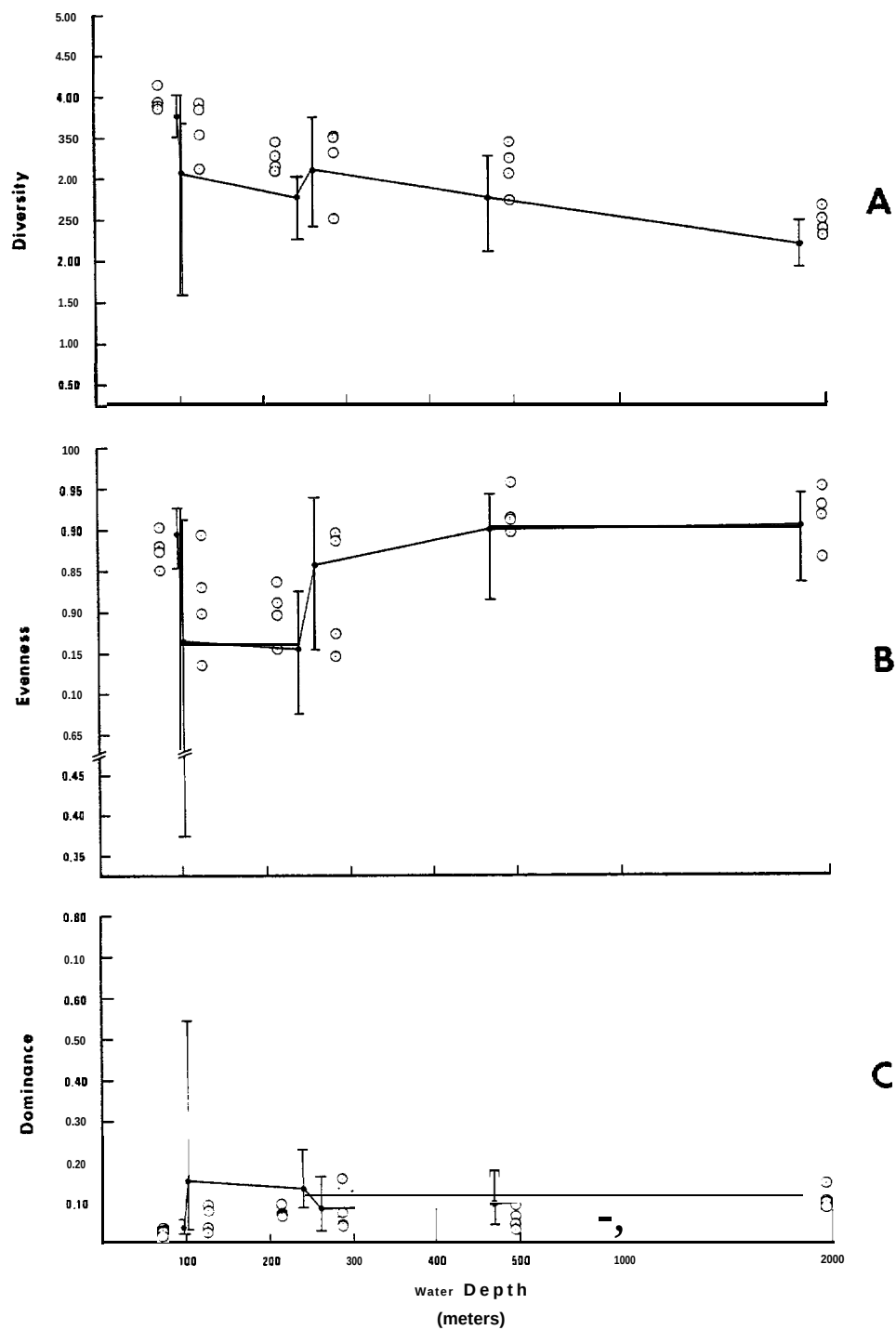


Figure 11-19.0-20. Santa Rosa Ridge Study Site - A) Diversity, B) Evenness, and C) Dominance Values by Station: ● -1.0 mm fraction and ○ -1.0 mm fraction plus 0.5 mm fraction. Bars represent maximum and minimum values.

Table II-19.0-13. Santa Rosa Ridge Study Site - Abundance, % of Total, Frequency, and Affinity Values for the ten most abundant species at each station. Bold letters and underlining indicate the dominant species based on 5% or more of the total number.

Species	Abund.	% of Total	Freq.	Affin.	Abund.	% of Total	Freq.	Affin.	Abund.	% of Total	Freq.	Affin.	Abund.	% of Total	Freq.	Affin.
CORYNE (PACHYMERIS) NERTA	11	10.21	1.00	28	37	3.26	1.00	37	16	1.31	0.75	10	26	5.51	0.75	10
ANTHUS (ANTHUS) DITTA	10	7.82	1.00	26	37	3.13	1.00	37	16	1.31	0.75	10	13	1.76	0.75	8
PACHYMERIS TENNISULATA	72	5.25	1.00	28	6	0.36	0.75	2	2	0.22	1.00	26	18	2.43	0.63	9
Alvinia cornea	56	4.03	0.88	63	2	0.11	0.75	0	2	0.11	0.75	0	1	0.14	0.13	15
Amphioxus undata	54	3.88	1.00	58												
Cylocardia ventricosa	34	2.44	1.00	58	2	0.11	0.13	16	2	0.17	0.13	9	4	0.54	0.38	3
Siphonura masoniana	38	2.77	0.88	40	9	0.51	0.38	16								
Terebellidae atrovall	27	1.96	1.00	58	7	0.40	0.50	15	2	0.17	0.25	2				
Doppelopsis alaphacata	25	1.80	0.88	41					13	1.10	0.75	29				
Tubaria gracilis	23	1.65	1.00	58	2	0.11	0.25	0	4	0.36	0.38	3				
Pectinaria californiensis	23	1.65	0.88	42					7	0.59	0.63	14	5	0.68	0.38	8
CORBULA SPINATA	18	0.72	0.63	29	10	0.48	0.50	21	1	0.14	0.13	21	1	0.14	0.13	21
SPHILLUMS CORDILLOMONTA	1	0.07	0.13	13	10	0.48	0.50	21	2	0.27	0.25	4	27	3.65	0.75	21
Arctidea columbica	6	0.29	0.25	4	67	3.81	0.75	24								
ANTHUS (ANTHUS) SPINATA	21	1.51	0.88	43	55	3.13	1.00	37	31	1.46	0.50	21	2	0.27	0.25	4
Ummatopsis actina					31	1.46	0.50	21	28	1.59	0.63	11				
Pharia californica	1	0.07	0.13	13	25	1.42	0.50	16	76	1.17	0.63	10	1	0.14	0.13	2
ELMANTIS GRACILIS	5	0.36	0.38	15												
Medusa vesi	10	0.72	0.63	29	4	0.23	0.38	12	26	2.37	0.75	29	1	0.14	0.13	21
Aurelia, urea, anastella	4	0.29	0.50	26	8	0.46	0.63	16	25	2.12	0.75	19	9	1.22	0.50	6
Pada sp. B	17	1.22	1.00	58	2	0.11	0.13	8	26	2.03	1.00	26	1	0.14	0.13	4
Parapionia bicapitata									26	2.03	1.00	26				
Apollonia microcephala									26	2.03	0.88	23				
Phyllonura densata																
Ulyca tenuis					2	0.11	0.25	5								
Longum boreal					3	0.17	0.38	10								
Meris stalle					7	0.40	0.25	5	1	0.08	0.13	13	16	2.16	0.63	12
MYDIA BANDA	3	0.22	0.38	14	1	0.06	0.13	17	13	1.76	0.63	12	13	1.76	0.63	12
LODIAHUS CHERESIS	22	1.58	0.68	40	2	0.11	0.25	4	16	1.35	0.88	20	2	0.27	0.25	3
Apollonia pugione					1	0.06	0.13	17					7	0.95	0.13	17
Cremella olivacea																
Stelliolemina					7	0.40	0.63	19	16	1.52	0.75	27	8	1.08	0.50	7
Strimopsis parvita	2	0.14	0.25	4	2	0.11	0.13	16	3	0.25	0.25	0	5	0.68	0.25	2
Amphioxus medialis	2	0.14	0.13	5												
S. lamella cripata									1	0.14	0.13	15				
CORYNE, LEPTOCORYNE																
OPHIOTRACHUS FURCATUS																
OSTIALIN, REAR RECTUS																
SPHILLUMS SPINATA																
Siphonura kroyeri																
Neapollonia fulgens																
Neapollonia sp. A																
Neapollonia dentifera																
Isopodopsis pacificum																
Fraxillaria allende petrice																
Abudefdufa yella																

19.7.3.6 Spatial Variation

Aggregated distributional patterns characterized the benthic associations of the insular shelf and ridge (Table 11-19.0-14). At one location on the ridge, station 808, the fauna was highly aggregated. A single species, the polychaete Chloeia pinnata, with an index of dispersion of 471.62, accounted for over half of the heterogeneity at this location. The fauna of the ridge slope was randomly distributed; only two of the 41 species collected in the sample-set at this location had aggregated distributions. The basin fauna was aggregated.

19.7.3.7 Feeding/Mobility Types

Carnivores constituted a considerable fraction of the benthic fauna except at station 806, the shallowest location on the insular shelf and ridge, and in the basin. In fact, at three stations (805, 806 and 810), they dominated numerically. Filter feeders comprised a small but fairly consistent proportion of the fauna (6-20%) at all locations; they were least abundant in the basin (Figure 11-19.0-21).

Surface detrital feeders numerically dominated or were of secondary importance at all of the stations of this study site. They overwhelmingly dominated the basin fauna (85% abundance). Subsurface detrital feeders constituted a relatively small fraction of the fauna at all locations; the highest values for this feeding type were on the San Miguel Island shelf (station 806, 10%; station 805, 19%).

Motile forms dominated all sampling locations. Sessile forms were important only in the basin.

19.7.3.8 Classification of Sampling Locations

As with the other study sites, faunal composition formed the basis for grouping the replicates from each sampling location in the Santa Rosa Ridge study site. The two-dimensional dendrogram resulting from this analysis consisted of a large central cluster and two smaller clusters (Figure 11-19.0-22). One of the smaller clusters (M) included all of the replicates from the basin (station 812); the other (L) - was composed of all of the replicates from the ridge slope (station 810). The large central cluster (I, J and K) included all of the sampling locations on the insular shelf and the ridge. Only the replicates of station 806 were isolated in a sub-branch (1) of this major cluster. There was some intermixing of the replicates of the other stations (805, 808 and 809), but this was minimal.

The taxa of the sample sets collected at the sampling locations in this study site were classified by inverse analysis. The two-way table (Figure 11-19.0-23) shows the relationship between the normal

Table 11-19.0-14. Santa Rosa Ridge Study Site - Spatial Variation.

Station Number	Heterogeneity Chi-Square	Degrees of Freedom	Spatial Character	Probability	Species with Aggregated Distribution	Index of Dispersion	df	p
806	432.29	321	aggregated	<0.01	Allis nolani Alvinia rosana Golfingia (P.) minuta Lumbrineris cruzensis Minuspio cirrifera and eight additional species	15.00 13.62 12.76 12.29 12.00 <11.341	3 3 3 3 3 3	<0.01 <0.01 <0.01 <0.01 <0.01 <0.05
808	882.56	336	aggregated	<0.01	Chloeia pinnata Amphipholis squamata Palythoa SP. A Euphilomedes carcharodonta Ampelisca pugetica Maera simile Aoroides columbiae Photis lacia Lepidozona mertensii Prionospio steenstrupi Caprella mendax	471.62 57.39 34.00 27.84 21.00 18.00 16.88 16.52 15.00 13.10 12.00	3 3 3 3 3 3 3 3 3 3 3	<0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01 <0.01
805	262.01	213	aggregated	<0.01	Onuphis, near nebulosa and three additional species	14.85 <11.341	3 3	<0.01 <0.05
809	413.99	246	aggregated	<0.01	Golfingia (P.) minuta Prionospio steenstrupi Magelona, near cornuta Philomedes dentata Tellina carpenter and three additional species	24.85 18.00 16.24 14.56 12.00 <11.341	3 3 3 3 3 3	<0.01 <0.01 <0.01 <0.01 <0.01 <0.05
810	133.47	120	random	>0.20	two species	<11.341	3	<0.05
812	68.29	48	aggregated	<0.01	Melinnampharete gracilis and one additional species	15.00 <11.341	3 3	<0.01 <0.05

11-19.0-21

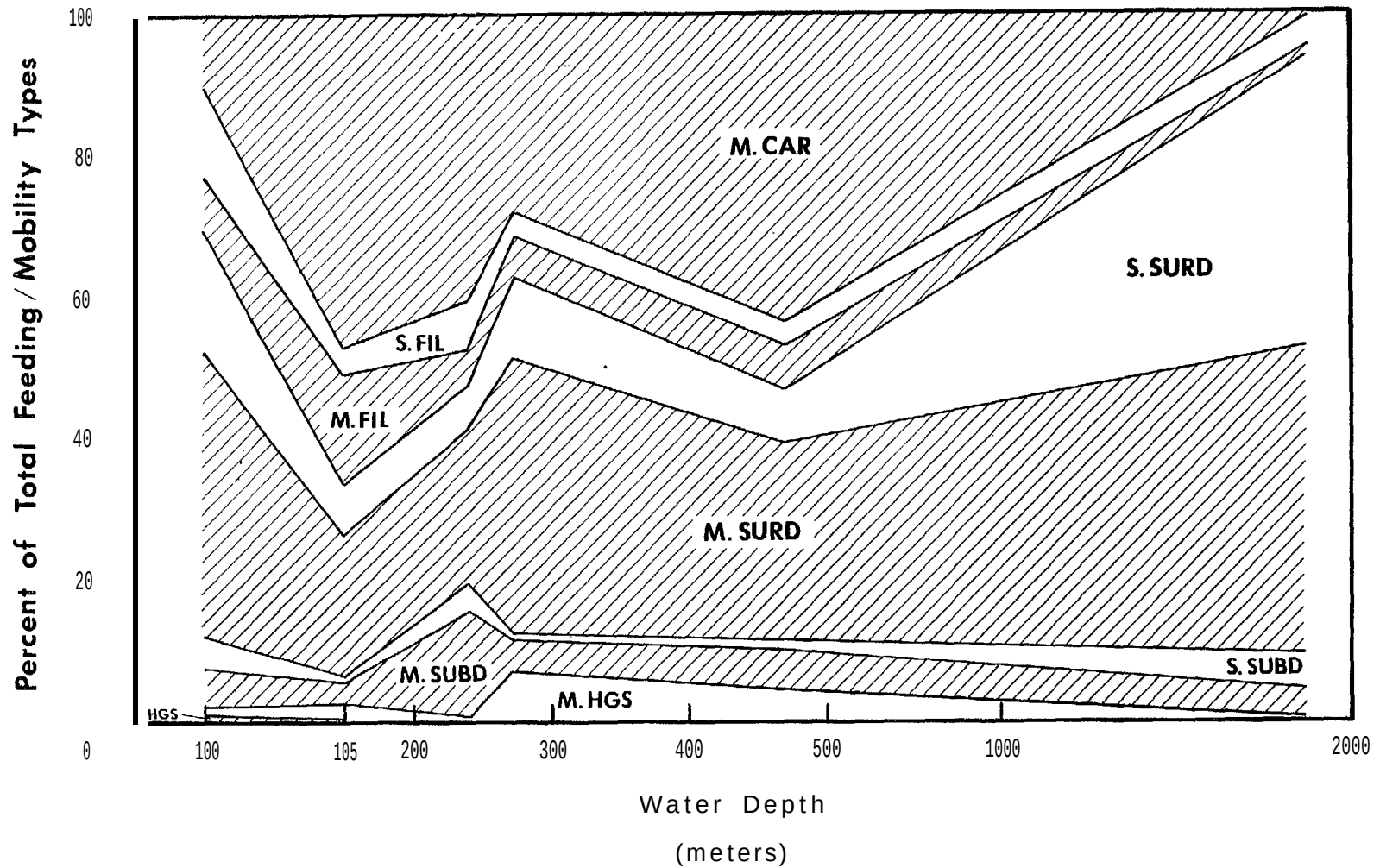


Figure 11-19.0-21. Santa Rosa Ridge Study Site - Percent of Total Feeding/Mobility Types: M=Motile, S=Sessile, CAR=Carnivores, FIL=Filter Feeder, SURD= Surface Detrital Feeder, SUBD= Subsurface Detrital Feeder, HGS=Herbivore, Grazer, Scavenger.

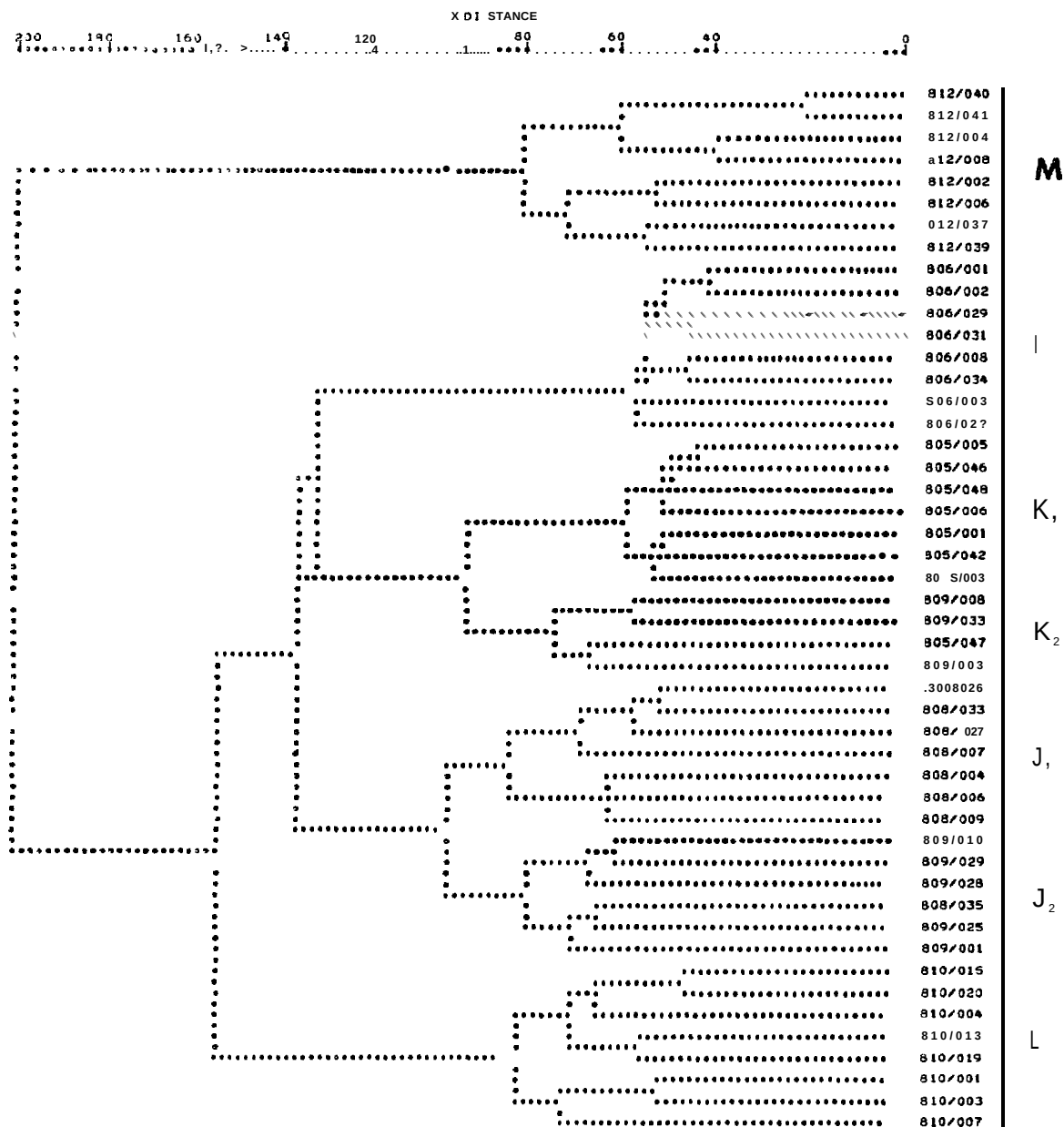


Figure 11-19.0-22. Santa Rosa Ridge Study Site - Dendrogram. Data Base - Edited Detailed Analysis. Editing Criteria - non-mono-specific taxa and frequency of occurrences ≤ 1 omitted. Letters represent the different clusters referred to in the text.

Figure 11-19.0-23. Santa Rosa Ridge Study Site - Two Way Table. Data base - edited Detailed Analysis. Editing criteria - ~~non-mono-~~specific taxa and frequency of occurrences ≤ 1 omitted. Abundances have been scaled from 0 to 1. The five symbols correspond to the following intervals: blank (<0), . ($>0-.25$), - ($>.25-.5$), + ($>.5-.75$), and * ($>.75$). Single letters represent the clusters derived from normal analysis, double letters represent the clusters derived from inverse analysis.

and inverse analysis . Subdivisions of the dendrograms have been indicated by lines on the table. The two-way table indicates the faunal elements used to segregate the samples in normal analysis.

19.7.4 Tanner Bank Study Site

Four of the six sampling locations of the Tanner Bank study site were on the bank and the ridge north of it; one station was on the basin slope and one was in the San Nicolas Basin (Figure 11-19.0-24). Eight replicate box core samples were collected at each of these locations during each of the two sampling periods, except at stations 816 and 818. Consolidated sediments prevented collection of samples at station 816 in the winter; the station was relocated for the summer cruise. Similarly, only a single core was collected at station 818 in the winter and the sampling location was moved for the summer cruise.

Because all six locations were part of the same ridge-slop-basin system, they have been treated as though they were all a part of the same transect or depth gradient. Station 816 was on the bank (mean depth of replicates: 75 m; range: 73-77 m); station 815 was at the south end of the bank (mean: 100 m; range: 96-103 m); station 818 was north of Tanner Bank on a small, unnamed anticlinal structure (mean: 188 m; range: 173-203 m); station 817 was at the northern "edge" of Tanner Bank (mean: 519 m; range: 511-530 m); station 814 was on the basin slope (mean: 935 m; range: 922-953 m); and station 813 was in the San Nicolas Basin (mean: 1,754 m; range: 1,751-1,758 m). The depth of collection, field sediment description, core length, subsampling and type of analysis for each replicate in each sample set have been presented in Table IV-19.0-4.

Environmental data for this study site have been summarized in Table 11-19.0-15. Sediments became finer and richer in organic carbon with increasing depth. Calcium carbonate content at several locations (station 816, > 80%; and 818, 57-79%) was very high; at the other locations, including the basin, values exceeded 19%. At each of the sampling locations (except 816), sediments were somewhat finer (higher-mean phi values) in the summer than in the winter. As expected, bottom water oxygen content decreased with increasing depth.

19.7.4.1 Epibenthic Photographs

All efforts to take photographs at the sampling locations of the Tanner Bank study site during the summer cruise failed due to a malfunction of the camera system.

19.7.4.2 Concordance

The degree of association among the members of the sample sets collected from each sampling location of this study site was tested by Kendall's Coefficient of Concordance (Table 11-19.0-16). Con-

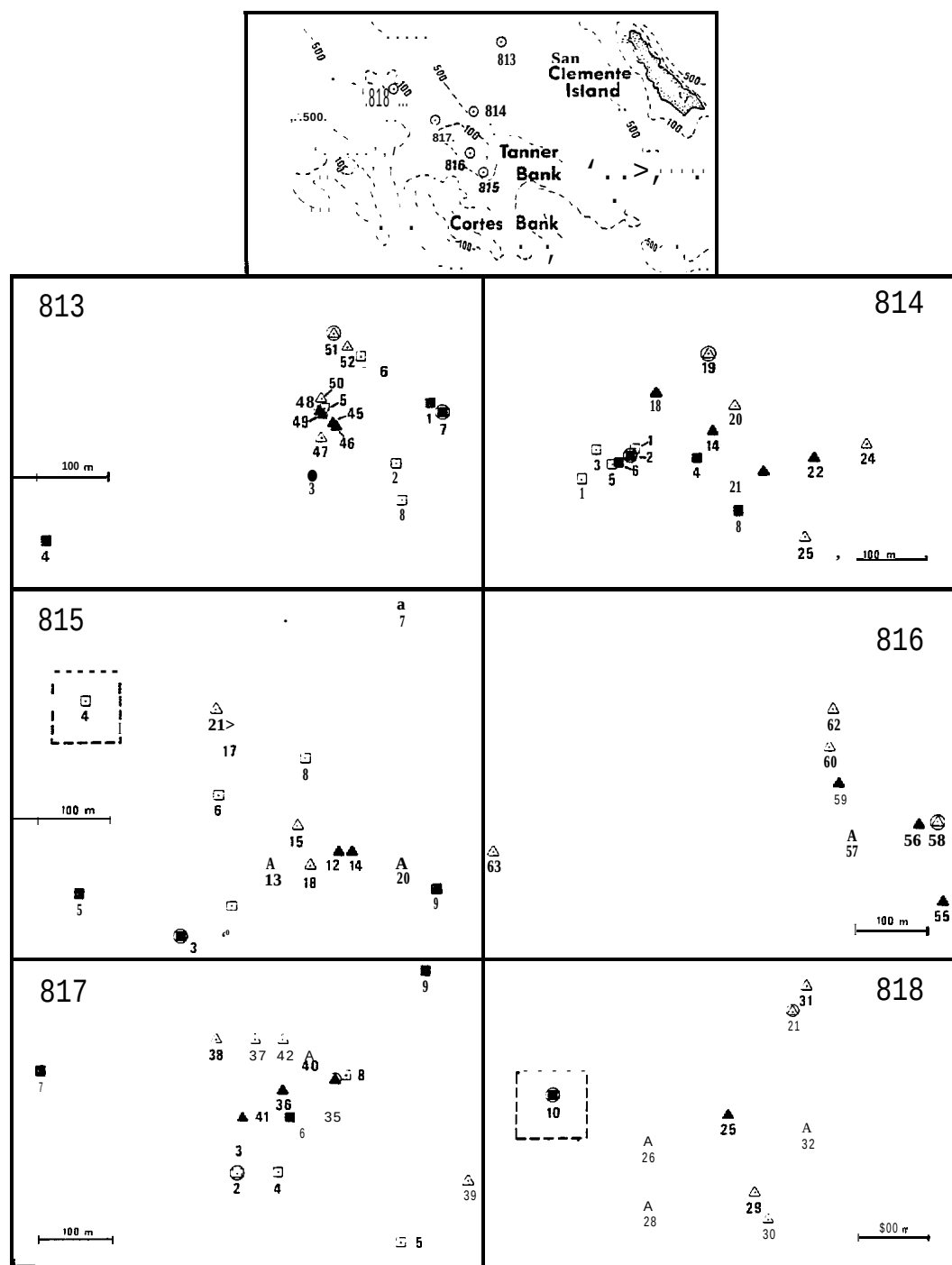


Figure 11-19.0-24. Map of the Tanner Bank Study Site - Symbol Explanation:
 △-Summer Stations, □-Winter Stations, ▲, □-RIP
 and Detailed Analyses, △, □-RIP Analysis only,
 ○-geology slab removed from core, □-station 81504
 is 3,790 m NNW of 81506 and station 81810 is 3,482 m
 SW of 81825.

Table 11-19.0-15. Tanner Bank Study Site - Environmental Data.

Cast Number	Depth (meters)	Bottom 'c	Bottom θ_2 (till/l)	% Sand	% silt	% Clay	Mean Grain Size (phi)	Sorting Coeff.	% TOC	% CaCO_3
81658	7 3	---	---	98.3	1.3	0.4	2.40	2.40	0.35	81.6
816	52	14.43	6.12	---	---	---	---	---	---	---
816	72	10.83	4.46	---	---	---	---	---	---	---
81503	100	---	---	95.1	2.6	2.3	3.10	1.77	0.29	26.6
81512	102	---	---	91.8	4.4	3.8	3.30	1.77	0.35	26.6
815	93 ,	12.14	5.22	---	---	---	---	---	---	---
815	95	10.02	4.03	---	---	---	---	---	---	---
81810	113	---	---	99.7	0.2	0.1	2,23	2.73	0.23	57.3
81827	203	---	---	80.0	5.5	14.5	4.04	2.72	0.75	79.1
818	105	10.50	4.96	---	---	---	---	---	---	---
818	198	8.84	2.69	---	---	---	---	---	---	---
81702	512	---	---	88.5	5.2	6.3	3.71	1.82	1.31	39.0
81735	519	---	---	73.0	17.8	9.2	4,23	2.02	1.56	22.4
817	528	5.73	0.31	---	---	---	---	---	---	---
817	510	6.25	0.48	---	---	---	---	---	---	---
81402	931	---	---	5.1	49.5	45.5	8.17	1.77	4.80	25.8
81419	944	---	---	5.6	38.6	55.8	8.83	2.10	5.30	27.0
814	913	4.29	0.31	---	---	---	---	---	---	---
81307	1754	---	---	7.9	52.3	39.8	7,70	1.88	4.79	19.1
81351	1751	---	---	6.6	34.4	59.0	9.20	2.34	4.48	20.6
813	1762	3.71	0.42	---	---	---	---	---	---	---

Table 11-19.0-16. Tanner Bank Study Site - Kendall's Coefficient of Concordance. K = number of rankings, N = number of items, and W = coefficient of concordance.

Station (Method of Analysis)	K	N	W	Chi-squared	Significance Level
816					
Detailed Analysis	4	34	0.226	29.845	> 0.05
RIP	8	34	0.304	80.169	< 0.01
815					
Detailed Analysis	8	33	0.284	72.653	< 0.01
RIP	16	24	0.264	97.117	< 0.01
818					
Detailed Analysis	5	21	0.229	22.946	> 0.05
RIP	9	22	0.343	64.781	< 0.01
817					
Detailed Analysis	8	29	0.310	69.506	< 0.01
RIP	16	31	0.353	169.219	< 0.01
814					
Detailed Analysis	8	15	0.125	14.037	> 0.05
RIP	16	14	0.123	25.600	< 0.05
813					
Detailed Analysis	8	6	0.087	3.466	< 0.05
RIP	14	3	0.141	3.935	< 0.05

cordance was demonstrated at the 0.01 level of significance for all of the sample-sets of this study site except for the detailed analysis of sampling locations 814, 816 and 818. This indication of variability between the replicates at these sampling sites appears to have been more a function of the natural heterogeneity of the benthic associations at these sites than of the sample spacing (see Table II-19.0-18; section on Spatial Variation).

19.7.4.3 Density, Species Richness and Standing Crop

Density was highest (mean: 3,480 specimens/m²; range: 2,176-5,200) at the shallowest location on the bank (Figure 11-19.0-25 a). Values were substantially lower at the other station on the bank, station 815 (mean: 1,150 specimens/m²; range: 592-1,648) and on the rise north of Tanner Bank (1,484 specimens/m²; range: 592-2,448). On the slope of the bank, station 817, density was surprisingly high (mean: 2,184 specimens/m²; range: 1,520-2,992). The lower values on the basin slope (mean: 528 specimens/m²; range: 352-656) and in the basin (mean: 214 specimens/m²; range: 96-368) were characteristic.

Species richness declined with increasing depth (Figure II-19.0-25 b). On the bank (stations 816 and 815) and on the ridge (station 818), the mean values varied from 35 to 49 species/sample. At station 817, on the bank slope, replicate samples averaged 30 species/sample. The mean number of species/sample declined to 22 on the basin slope and 8 in the basin.

Standing crop values were low at most of the sampling locations of this study site (Figure 11-19.0-25 c). On the bank, the means were 36 g/m² (range: 30-43) and 66 g/m² (range: 30-121). Values were highest on the rise north of Tanner Bank (mean: 93 g/m²; range: 19-340). At station 817, on the bank slope, standing crop decreased to an average of 22 g/m² (range: 14-35). The replicate collected on the basin slope had the lowest average value, 7 g/m² (range: 5-8). The standing crop in the basin was slightly more than twice as high as that of the slope (mean: 15 g/m²; range: 20-40).

The relative importance of the major faunal groups at the sampling locations of this study site was 'quite variable'. Polychaetes were the most abundant group at the shallow locations, the bank on the rise north of the bank, and at the deepest locations, the basin slope and in the basin (Figure 11-19.0-26 a); crustaceans predominated in between. Similarly, polychaetes and crustaceans comprised the majority of the species at each of the sampling locations (Figure II-19.0-26 b); again, polychaetes were most important at the shallower and the deeper locations and crustaceans were more prominent at intermediate depths.

The standing crop pattern was complex (Figure 11-19.0-26 C). Polychaetes were predominant at the shallowest location on the bank. Echinoderms dominated the other location on the bank and the station

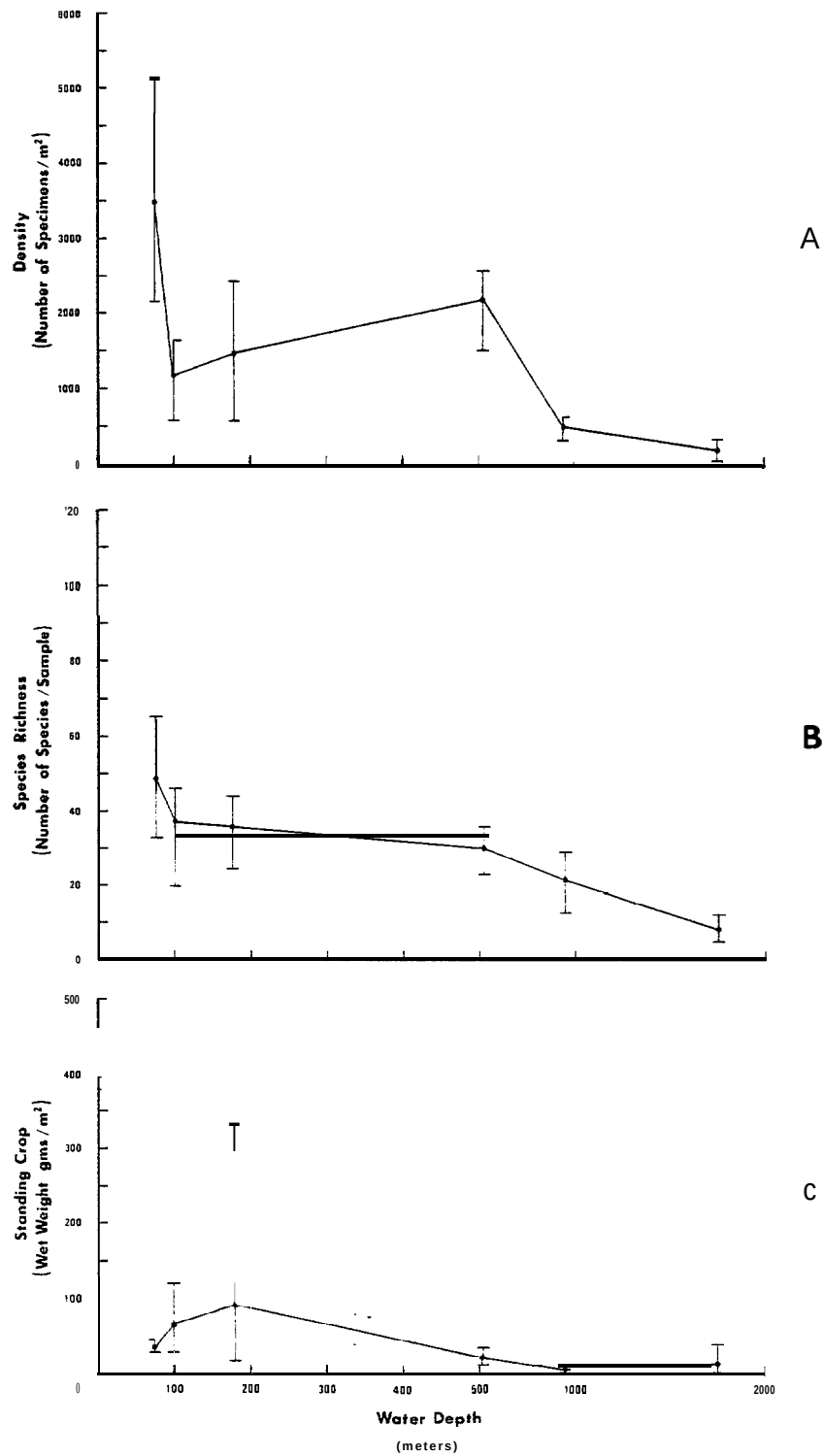


Figure 11-19.0-25. Tanner Bank Study Site - A) Density, B) Species Richness, and C) Standing Crop values by Station. Bars represent maximum and minimum values.

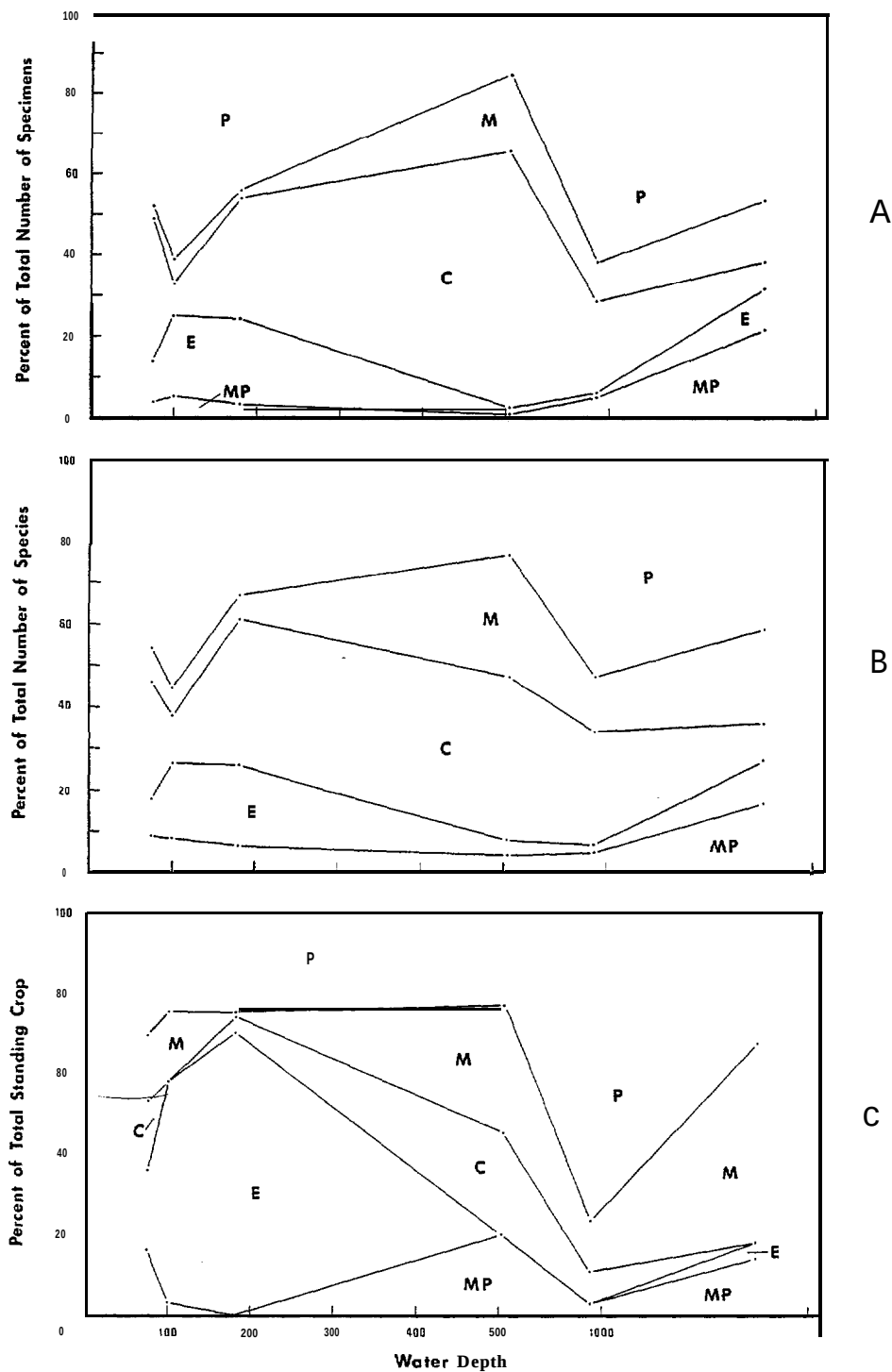


Figure 11-19.0-26. Tanner Bank Study Site - A) Percent of Total Number of Specimens, B) Percent of Total Number of Species, and C) Percent of Total Standing Crop for the five major systematic groups by station: P= Polychaetes, M=Mollusks, C= Crustaceans, E= Echinoderms, and MP= Minor Phyla.

on the rise north of the bank; polychaetes were of secondary importance at these two stations. Each of the five groups formed a significant proportion of the standing crop on the bank slope. Polychaetes dominated the basin slope location. In the basin, mollusks were the predominant group, while polychaetes were secondary in importance.

19.7.4.4 Diversity, Evenness and Dominance

The relationship between diversity, evenness and dominance and depth for the Tanner Bank study site has been illustrated in Figure 11-19.0-27 a, b and c. Except in the basin, where they were lowest, diversity values varied relatively little with depth (Figure 11-19.0-27 a). Evenness values were extremely variable, but showed no particular relationship to depth, except that the values were highest on the basin slope and in the basin. The diversity values calculated for the combined 1.0 mm and 0.5 mm fractions were, for the most part, at or above the means at all locations.

Evenness values were extremely variable but showed no particular relationship to depth aside from being highest on the basin slope and in the basin (Figure 11-19.0-27 b). Most of the values for the combined fractions were within the range of the variation for the 1.0 mm fractions.

The pattern of the dominance values was the inverse of the pattern of the diversity values, and most of the values for the combined fractions were within or below the range of the values for the 1.0 mm fractions (Figure 11-19.0-27 c).

19.7.4.5 Faunal Composition

The numerically dominant species of the sampling locations within the Tanner Bank study site (ranking by abundance) have been listed in Table 11-19.0-17. Their distribution with depth has been illustrated. Most of the taxa at the three shallowest stations, on the bank and the rise north of the bank, occurred at more than one of the three locations. Few of the taxa of the deeper stations, the bank slope, the basin slope and the basin, were prominent faunal elements at more than one station.

The polychaete Chloeia pinnata overwhelmingly dominated at stations 816 and 818. An amphipod, Ampelisca cristata, and the ophiuroid Amphiodia (Amphispina) urtica were also prominent taxa at station 818. Two polychaetes, Nothria iridescent and Pista sp. B, and two echinoderms, Amphiodia (Amphispina) urtica and Amphiura acrystata, dominated at station 815.

Amphipods (Byblis, near bathyalis, B. bathyalis, Ampelisca macrocephala, and A. pacifica) and pelecypods (Adontorhina cyclia and Tomburchus redo-ndoensis) were the numerically dominant taxa at station 817.

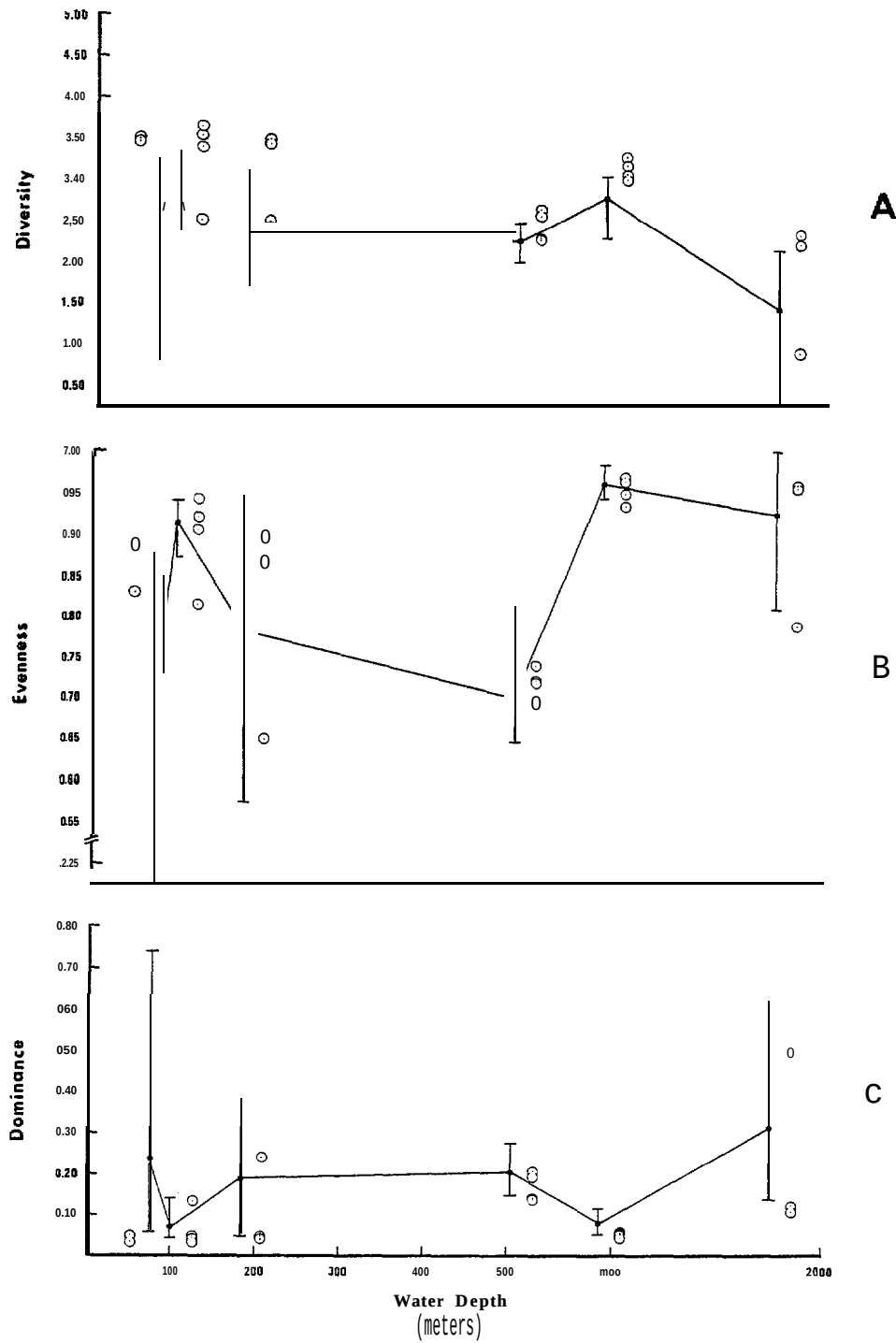


Figure 11-19.0-27. Tanner Bank Study Site - A) Diversity, B) Evenness, and C) Dominance Values by Station: ○ -1.0 mm fraction and ⊙ -1.0 mm fraction plus 0.5 mm fraction. Bars represent maximum and minimum values.

Table II-19.0-17. Tanner Bank Study Site - Abundance, % of Total, Frequency, and Affinity
 Values for the ten most abundant species at each station. Bold letters
 and underlining indicate the dominant species based on 5% or more of the
 total number.

Station	Station 05 (100 m)			Station 06 (100 m)			Station 07 (100 m)			Station 08 (100 m)			Station 09 (100 m)			Station 10 (100 m)			Station 11 (100 m)			Station 12 (100 m)			Station 13 (100 m)			Station 14 (100 m)			Station 15 (100 m)			Station 16 (100 m)			Station 17 (100 m)			Station 18 (100 m)			Station 19 (100 m)			Station 20 (100 m)			Station 21 (100 m)			Station 22 (100 m)			Station 23 (100 m)			Station 24 (100 m)			Station 25 (100 m)			Station 26 (100 m)			Station 27 (100 m)			Station 28 (100 m)			Station 29 (100 m)			Station 30 (100 m)			Station 31 (100 m)			Station 32 (100 m)			Station 33 (100 m)			Station 34 (100 m)			Station 35 (100 m)			Station 36 (100 m)			Station 37 (100 m)			Station 38 (100 m)			Station 39 (100 m)			Station 40 (100 m)			Station 41 (100 m)			Station 42 (100 m)			Station 43 (100 m)			Station 44 (100 m)			Station 45 (100 m)			Station 46 (100 m)			Station 47 (100 m)			Station 48 (100 m)			Station 49 (100 m)			Station 50 (100 m)			Station 51 (100 m)			Station 52 (100 m)			Station 53 (100 m)			Station 54 (100 m)			Station 55 (100 m)			Station 56 (100 m)			Station 57 (100 m)			Station 58 (100 m)			Station 59 (100 m)			Station 60 (100 m)			Station 61 (100 m)			Station 62 (100 m)			Station 63 (100 m)			Station 64 (100 m)			Station 65 (100 m)			Station 66 (100 m)			Station 67 (100 m)			Station 68 (100 m)			Station 69 (100 m)			Station 70 (100 m)			Station 71 (100 m)			Station 72 (100 m)			Station 73 (100 m)			Station 74 (100 m)			Station 75 (100 m)			Station 76 (100 m)			Station 77 (100 m)			Station 78 (100 m)			Station 79 (100 m)			Station 80 (100 m)			Station 81 (100 m)			Station 82 (100 m)			Station 83 (100 m)			Station 84 (100 m)			Station 85 (100 m)			Station 86 (100 m)			Station 87 (100 m)			Station 88 (100 m)			Station 89 (100 m)			Station 90 (100 m)			Station 91 (100 m)			Station 92 (100 m)			Station 93 (100 m)			Station 94 (100 m)			Station 95 (100 m)			Station 96 (100 m)			Station 97 (100 m)			Station 98 (100 m)			Station 99 (100 m)			Station 100 (100 m)			Station 101 (100 m)			Station 102 (100 m)			Station 103 (100 m)			Station 104 (100 m)			Station 105 (100 m)			Station 106 (100 m)			Station 107 (100 m)			Station 108 (100 m)			Station 109 (100 m)			Station 110 (100 m)			Station 111 (100 m)			Station 112 (100 m)			Station 113 (100 m)			Station 114 (100 m)			Station 115 (100 m)			Station 116 (100 m)			Station 117 (100 m)			Station 118 (100 m)			Station 119 (100 m)			Station 120 (100 m)			Station 121 (100 m)			Station 122 (100 m)			Station 123 (100 m)			Station 124 (100 m)			Station 125 (100 m)			Station 126 (100 m)			Station 127 (100 m)			Station 128 (100 m)			Station 129 (100 m)			Station 130 (100 m)			Station 131 (100 m)			Station 132 (100 m)			Station 133 (100 m)			Station 134 (100 m)			Station 135 (100 m)			Station 136 (100 m)			Station 137 (100 m)			Station 138 (100 m)			Station 139 (100 m)			Station 140 (100 m)			Station 141 (100 m)			Station 142 (100 m)			Station 143 (100 m)			Station 144 (100 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The dominant species on the basin slope were the polychaetes Tauberia oculata and Phyllochaetopterus limicolus and the microcrustacean Leucon magnadeutata. In the basin, the polychaete Prionospio lobulata, a sipunculid, Golfingia (Phascoloides) sp. C, the hydrozoan Sertularia desmoides and the pelecypod Thyasira excavata were the numerically dominant taxa.

19.7.4.6 Spatial Variation

Aggregated distributional patterns characterized the benthic associations of the bank, the rise north of the bank and the bank slope (Table 11-19.0-18). At one location on the bank, station 816, the heterogeneity chi-square was very high, 1,124.88, indicating a highly aggregated fauna. A single species, the polychaete Chloeia pinnata, with an index of dispersion of 783.00, accounted for over half of the heterogeneity at this location. Chloeia pinnata also contributed substantially to the heterogeneity at station 818.

The benthic fauna of the basin slope and the basin was randomly distributed.

19.7.4.7 Feeding/Mobility Types

The composition of feeding and mobility types was highly variable at the sampling locations of this study site (Figure 11-19.0-28). Motile forms dominated all sampling locations; sessile forms were important only in the basin. Carnivores were predominant at station 816 and station 818. At station 815, the other shallow sampling location, surface detrital feeders were the dominant feeding type. Motile filter feeders, particularly amphipods, overwhelmingly dominated station 817 on the bank slope. Subsurface detrital feeders were the most abundant feeding type on the basin slope. Surface detrital feeders were of secondary importance at this station. Surface detrital feeders dominated the basin fauna.

19.7.4.8 Classification of Sampling Locations

The replicates from each sampling station were grouped on the basis of their faunal composition. The two-dimensional dendrogram resulting from this analysis could be divided into six clusters (Figure 11-19.0-29); each cluster was identified by a letter. With one exception, cluster N, each cluster was composed of the replicates from a single sampling station (O = 7 replicates from 815; P = 817; Q = 814; and R = 813). Clusters N₁ and N₂ included replicates from stations 816 and 818 and a single replicate² from station 815.

Taxa of the sample sets collected from the sampling locations of this study site were classified by inverse analysis.

Table 11-19.0-18. Tanner Bank Study Site - Spatial Variation.

Station Number	Heterogeneity Chi-Square	Degrees of Freedom	Spatial Character	Probability	Species with Aggregated Distribution	Index of Dispersion	df	p
816	1124.88	171	aggregated	<0.01	Chloeia pinnata	783.00	3	<0.01
					Spiophanes missionensis	84.00	3	<0.01
					Photis californica	50.22	3	<0.01
					Hippomedon denticulatus	45.00	3	<0.01
					Synchelidium sp. A	24.00	3	<0.01
					Lysippe labiata	21.00	3	<0.01
					Lanice conchilega	19.89	3	<0.01
					Tiron tropakis	18.00	3	<0.01
					Chone ecaudata	17.00	3	<0.01
					Lytechinus, near anamesus	15.48	3	<0.01
					Pagurus setosus	14.38	3	<0.01
					Ampelisca cristata	13.77	3	<0.01
					Amphiura acrystata	12.00	3	<0.01
					Pionosyllis uraga	12.00	3	<0.01
					and three additional species	<11.341	3	<0.05
815	208.03	159	aggregated	<0.01	Heathia porosa	15.00	3	<0.01
					and three additional species	<11.341	3	<0.05
818	213.18	144	aggregated	<0.01	Chloeia pinnata	121.56	3	<0.01
					and two additional species	<11.341	3	<0.05
817	179.80	108	aggregated	<0.01	Ampelisca pacifica	26.00	3	<0.01
					Ampelisca macrocephala	14.88	3	<0.01
					Melphidippa, near amorita	11.47	3	<0.01
					and two additional species	<11.341	3	<0.05
814	91.02	82	random	>0.30	Allis ramosa	9.00	3	<0.05
813	20.00	15	random	>0.10	Prionospio lobulata	9.00	3	<0.05

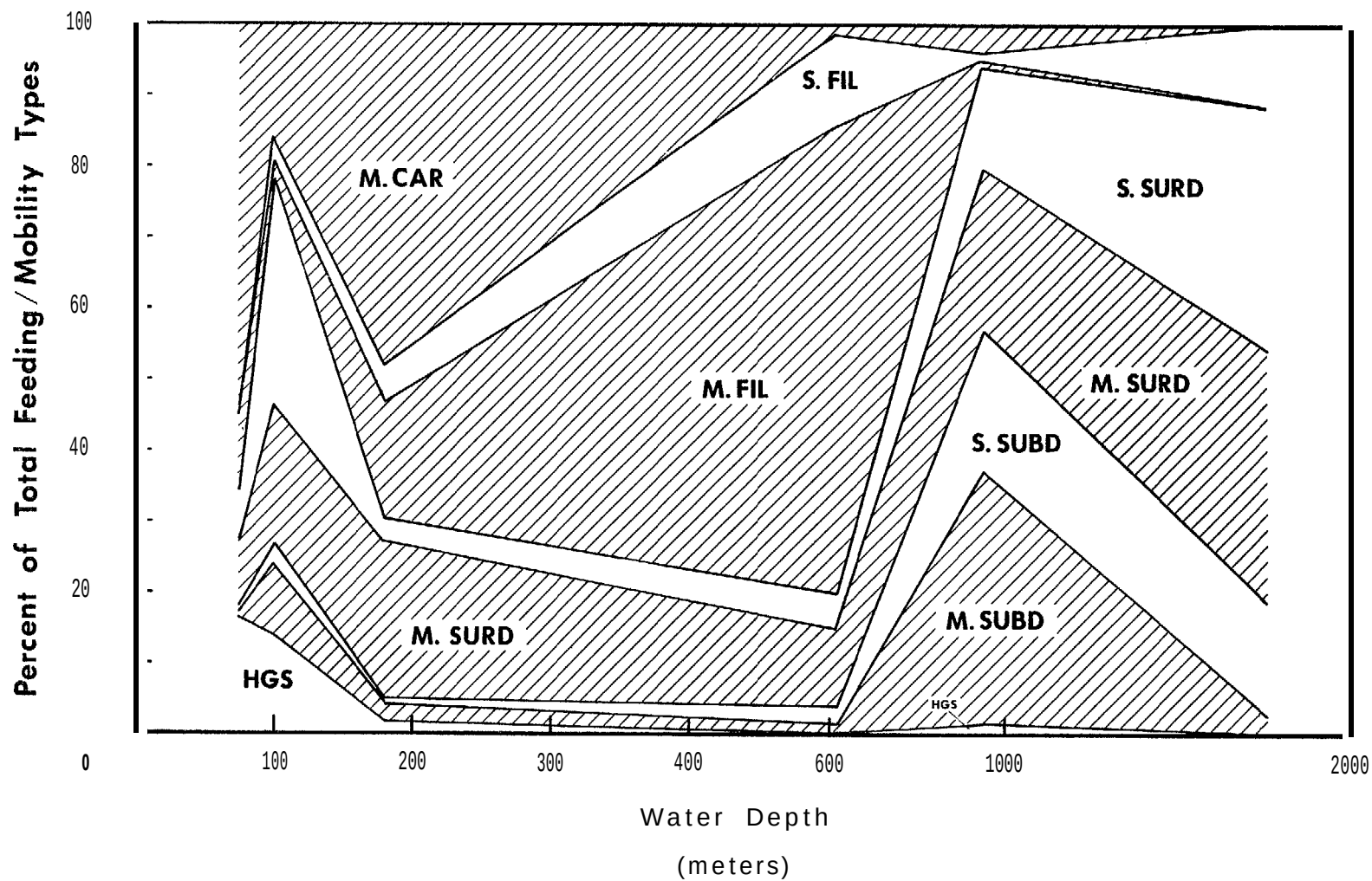


Figure 11-19.0-28. Tanner Bank Study Site - Percent of Total Feeding/Mobility Types: M=Motile, S=Sessile, CAR=Carnivores, FIL=Filter Feeder, SURD=Surface Detrital Feeder, SUBD=Subsurface Detrital Feeder, HGS=Herbivore, Grazer, Scavenger.

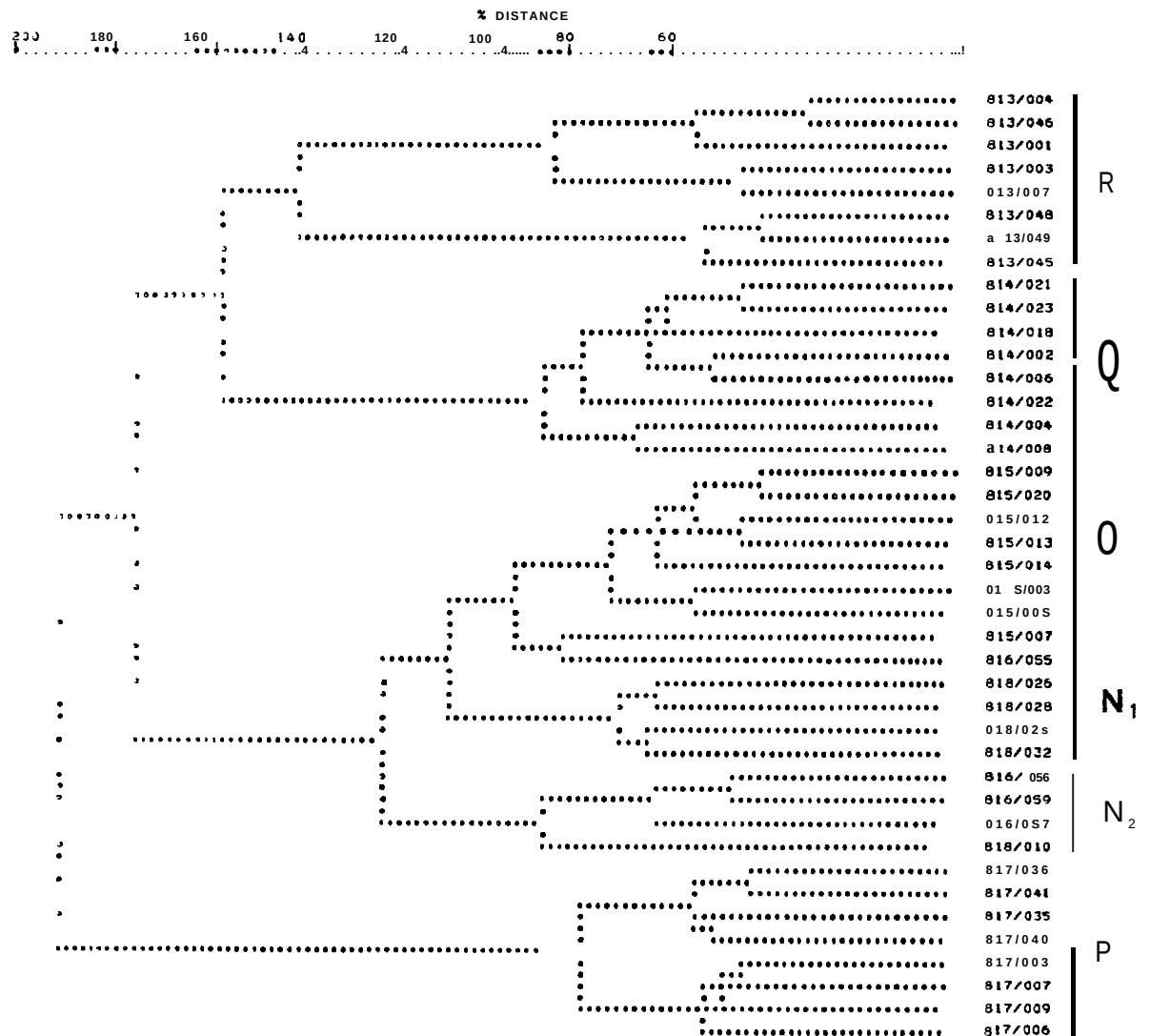


Figure 11-19.0-29. Tanner Bank Study Site - Dendrogram. Data Base - Edited Detailed Analysis. Editing Criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Letters represent the different clusters referred to in the text.

The relationship between normal and inverse analysis has been illustrated in the two-way table (Figure 11-19.0-30); the lines on the table indicate where the two dendrograms were subdivided. The two-way table includes the faunal elements used to segregate the replicate samples in normal analysis.

19.8 BETWEEN-AREA COMPARISONS

Each sampling location was considered as an entity and all sampling locations were pooled for an overall analysis of the study sites. The study sites described in Section 19.7 were not used per se, but because they did represent discrete geographic and hydrographic regions supporting characteristic faunal associations, comparisons and contrasts were made between and among the four study sites.

19.8.1 Classification Analysis

For this analysis, the edited detailed data base (monospecific taxa only) was used. In an attempt to optimize the information necessary to classify the sites, various percentages of the total species counts were used. The "best" site groups were obtained when the most information (most species) was used. For the following two analyses, only single occurrences were eliminated; the resulting data base included 96.2% of all taxa identified to species level.

19.8.1.1 All Replicates

Each of the winter and summer replicates (eight per site) was considered as an entity. This was done to determine whether the replicates would be classified together, indicating within-habitat sampling, or with replicates from other sites, indicating that major habitat gradients had been crossed. The normal dendrogram (site groups) has been presented in Figure 11-19.0-31. In this analysis the 160 replicates formed 13 site groups. Of these, only four groups contained more than one site (composed of the eight replicates). Generally, the site groups corresponded to specific geographic and bathymetric features of the Borderland (Figure 11-19.0-1).

The species groups formed by inverse classification analysis, which corresponded to each site group, have been shown in the two-way table (Figure 11-19.0-32). Because of limitations in the computer analysis, only the top-ranked 255 species could be included in this analysis, although the site groups were based on all but single occurrences, as noted above.

Mainland groups. The mainland shelf group was divided into two components, one comprised of station 819, the other including stations 801 and 806. The most widely dispersed faunal association in the Southern California Borderland, the Amphiodia urtica assemblage, was present at all three of these stations. Station 819,

Figure 11-19.0-30. Tanner Bank Study Site - Two Way Table. Data Base - Detailed Analysis. Editing criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Abundances have been scaled from 0 to 1. The five symbols correspond to the following intervals: blank (<0), $\cdot$ ($>0-.25$), $-$ ($>.25-.5$), $+$ ($>.5-.75$), and $*$ ($>.75$). Single letters represent the clusters derived from normal analysis, double letters represent the clusters derived from inverse analysis.

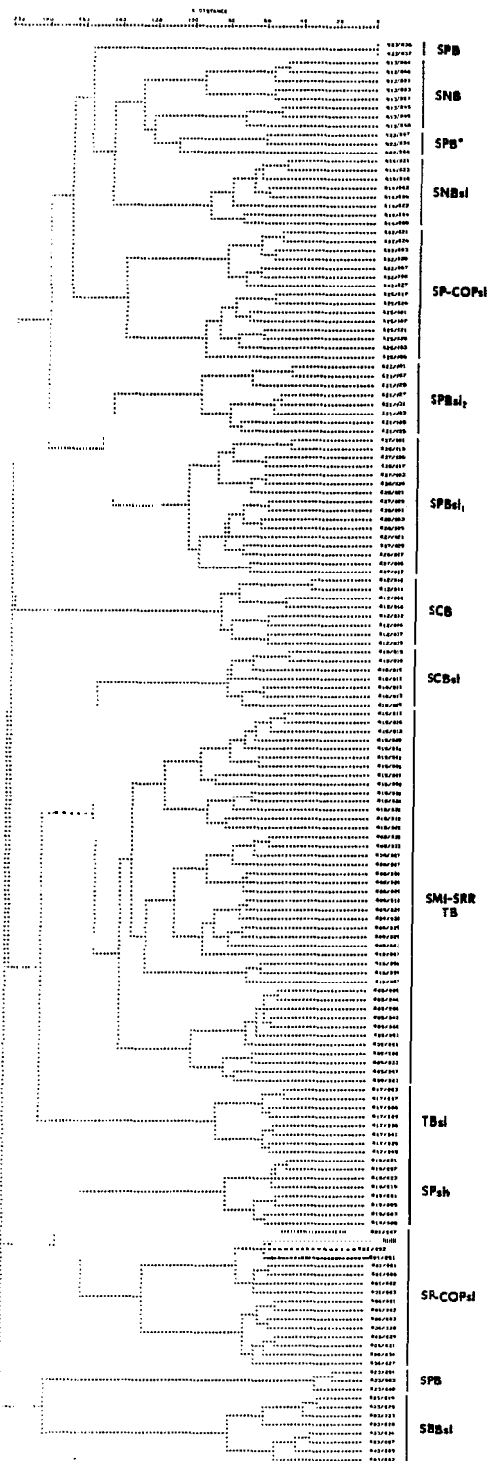


Figure 11-19.0-31. All Sites Dendrogram. Data Base - Edited Detailed Analysis. Editing criteria - non-monospecific taxa and frequency of occurrences < 1 omitted. SPB=San Pedro Basin, SNB=San Nicolas B-asin, SNB sl=San Nicolas Basin Slope, SP-COP sl=San Pedro-Coal Oil Point slope, SPB sl₁, and SPB sl₂=San Pedro Basin slope, SCB=Santa Cruz Basin, SCB sl=Santa Cruz Basin slope, SMI-SRR-TB=San Miguel Island-Santa Rosa Ridge-Tanner Bank, TB sl=Tanner Bank slope, SP sh=San Pedro shelf, SBB sl=Santa Barbara Basin slope.

Figure 11-19.0-32. All Sites Two Way Table. Data base - Edited Detailed Analysis. Editing criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Abundances have been scaled from 0 to 1. The five symbols correspond to the following intervals: blank (≤ 0), " ($>0-.25$), - ($>.25-.5$), + ($>.5-.75$), and * ($>.75$). Spsh=San Pedro Shelf, SP/COPsh=San Pedro/Coal Oil Point shelf, SP/COPs1=San Pedro/Coal Oil Point slope, SBBs1=Santa Barbara Basin slope, SCB=Santa Cruz Basin, SCBs1=Santa Cruz Basin slope, SNBs1=San Nicolas Basin slope, SPBs1₁ and SPBs1₂=San Pedro Basin slope, TBs1=Tanner Bank slope, SMI/SRR/TB=San Miguel Island/Santa Rosa Ridge/Tanner Bank, SNB=San Nicolas Basin, SPB=San Pedro Basin.

however, although it shared numerous species with the other stations in the mainland shelf site group, was in quite shallow water (33 m) and showed a diverse fauna containing animals usually not found in deeper water. These species were largely part of the shallow-water Onuphis nebulosa assemblage.

The mainland shelf site group as a whole showed the rather unexpected grouping of a mainland shelf sampling location (819) with an insular shelf sampling location (806). The latter station did, however, have a distinct ridge fauna in addition to the mainland shelf fauna. The converse was also found, in that there was a distinct mainland shelf assemblage at station 801 that was not present at station 806. Station 806 was the most diverse sampling location encountered.

It must be noted that all replicates from each sampling location were grouped separately, even though the three stations shared faunal components characteristic of mainland shelf assemblages.

The upper mainland slope stations, 802 and 825, were grouped together with the exception of a single winter replicate from station 802 that grouped with two replicates from station 823, in the San Pedro Basin. This grouping occurred because only three organisms were collected in the replicate from station 802 and the animals were eliminated by editing. In consequence, this replicate became a null site and grouped most closely with those of the basin station.

Each of the upper mainland slope stations had a distinct faunal association, but they did share several other faunal components. These sampling locations could be characterized by the polychaetes Paraprionospio pinnata, Nephtys cornuta franciscana, Prionospio lobulata, Hesperonoe laevis, Maldane sarsi and the echinuran Arhynchite californicus.

Station 803 (500 m) on the Santa Barbara Basin slope was directly downslope from station 802, and as such these two stations shared some of the same species. However, station 803 was such a faunistically unique site that all of the replicates grouped together and were distinctly different from those of all other stations. None of the species that formed the discrete assemblage found at this station were found at station 802, and only a few were found incidentally at other sampling locations at similar depths. The uniqueness of "this station" was difficult to explain, but was most likely due to the very low (0.21 ml/l) dissolved oxygen values measured at this station. Species characteristic of this station were Mitrella permodesta, Byblis barbarensis, Tauberia multibranchiata, and Cyclocardia barbarensis.

The three sampling locations (stations 821, 827 and 828) from the lower slope of the San Pedro Basin formed a fairly distinct site group. Stations 827 and 828 were indistinguishable, all replicates

being grouped together. The replicates from station 821 were also grouped together and formed a subgroup of this lower slope assemblage. Station 821, nearly 200 m deeper than stations 827 and 828, shared most of its fauna with those shallower sites. Stations 827 and 828, however, had a faunal group that was not found at station 821. Species common to this lower slope zone were the polychaetes Eclysippe trilobatus and Acesta lopezi rubra, the echiuran Listriolobus hexamyotus, and the predatory nemertean Cerebratulus californiensis.

Ridges and Banks. The sampling locations from the shallow Santa Rosa Ridge and Tanner Bank were grouped into one large site group (stations 805, 808, 809, 815, 816 and 818) that reflected the large-scale homogeneity of the ridge and banks. The replicates from each station (with the exception of station 815) were not grouped as separate entities but were shown to be variously related to one another. The fauna of the shallow ridge and banks was diverse and widely dispersed. Many of the species were also found at the shallow mainland shelf stations and the insular shelf station, 806. The characteristic species group consisted of the ophiuroid Amphipholis squamta, the amphipod Urothoe varvarini and the sipunculan Golfingia minuta. As previously stated, the Amphiodia urtica assemblage was also found on the shallow ridge.

The two sites on the ridge slopes, stations 810 and 817, are here discussed together but were not shown to be similar in the analysis. Both sites were deep enough to have lost association with much of the shallow shelf fauna, and each contained a rather distinct assemblage. Station 180 shared a small group of species with station 817. The latter, however, also possessed a faunal component that was the most unique on the entire ridge, though the reasons for this were not clear.

Station 814, at the base of the San Nicolas Basin slope, was another unique sampling location. It was 400 m downslope from station 817, and the fauna was entirely different. This most likely resulted from a change in sediment and depth to conditions more closely resembling those of basin stations. This station shared several species with stations in the outer basins, e.g., the polychaetes Phyllochaetopterus limicolus and Sternaspis sp. A.

Basins. Single stations in the' San Pedro, Santa Cruz and San Nicolas Basins were sampled. Classification analysis showed that the fauna of each of these basins was fairly distinct. The San Pedro Basin station (823) was very poorly defined in this classification analysis. This station was characterized by low numbers of poorly known organisms that occurred only at this location. Editing of the data prior to analysis removed most of these organisms, leaving essentially a null site whose replicates were grouped erratically.

The replicates from each of the outer basins were grouped separately, but did show a small degree of association; the faunal group that was strongly represented at station 812 was also, though weakly, present at station 813. Notably, the undescribed polychaete Sternaspis sp. A was found in both basins, as well as at station 814, and the endemic ophiuroid Ophiophthalmus normani was also shared. The mollusk Tindaria kennerlyi was found only in the Santa Cruz Basin, whereas the undescribed sipunculan Golfingia (Phascoloides) sp. C was endemic to the San Nicolas Basin.

19.8.1.2 Winter and Summer Replicates Averaged

Since most of the replicates from a common site were grouped together in the previous analysis, and since it was of interest to define "characteristic species" groups, a second classification analysis was performed. In this analysis, all four replicates from each season were averaged. For the normal analysis (site groups), only single species occurrences were eliminated, as on the previous run; for the inverse analysis, only species with 10 or more occurrences were used. With this data base, species groups containing infrequently occurring organisms were eliminated from the two-way table. Since the winter and summer replicates were kept separate, the seasonal information at each sampling location was maintained while the number of entities that were sorted and classified was reduced.

The resulting dendrogram (Figure 11-19.0-33) showed nearly the same site groups as the previous analysis but defined more clearly the relationships between those sites that were erratically grouped in the first analysis.

The winter replicates were always grouped with the summer replicates, thus indicating seasonal continuity to the site groups. The dendrogram was particularly interesting because, again, the groups were arranged by geographic and bathymetric similarities, though much more consistently than before. The two largest clusters represented shallow and deep stations, and these main clusters could be broken into site groups which also reflected major depositional environments.

The two-way table showing species groups that reflected average abundances of the "most common" species has been presented in Figure 11-19.0-34.

Group 1A was very large and widely distributed. This was the Amphiodia urtica assemblage that was previously known only from the mainland shelf and was described by Barnard and Ziesenhenné (1961) and Jones (1969) as the dominant assemblage on the southern California mainland shelf. The results of the present study indicated that the distribution of this large community may extend from the mainland shelf to the insular shelf, ridge, and offshore banks. Each of these geographic regions, however, also had characteristic species groups.

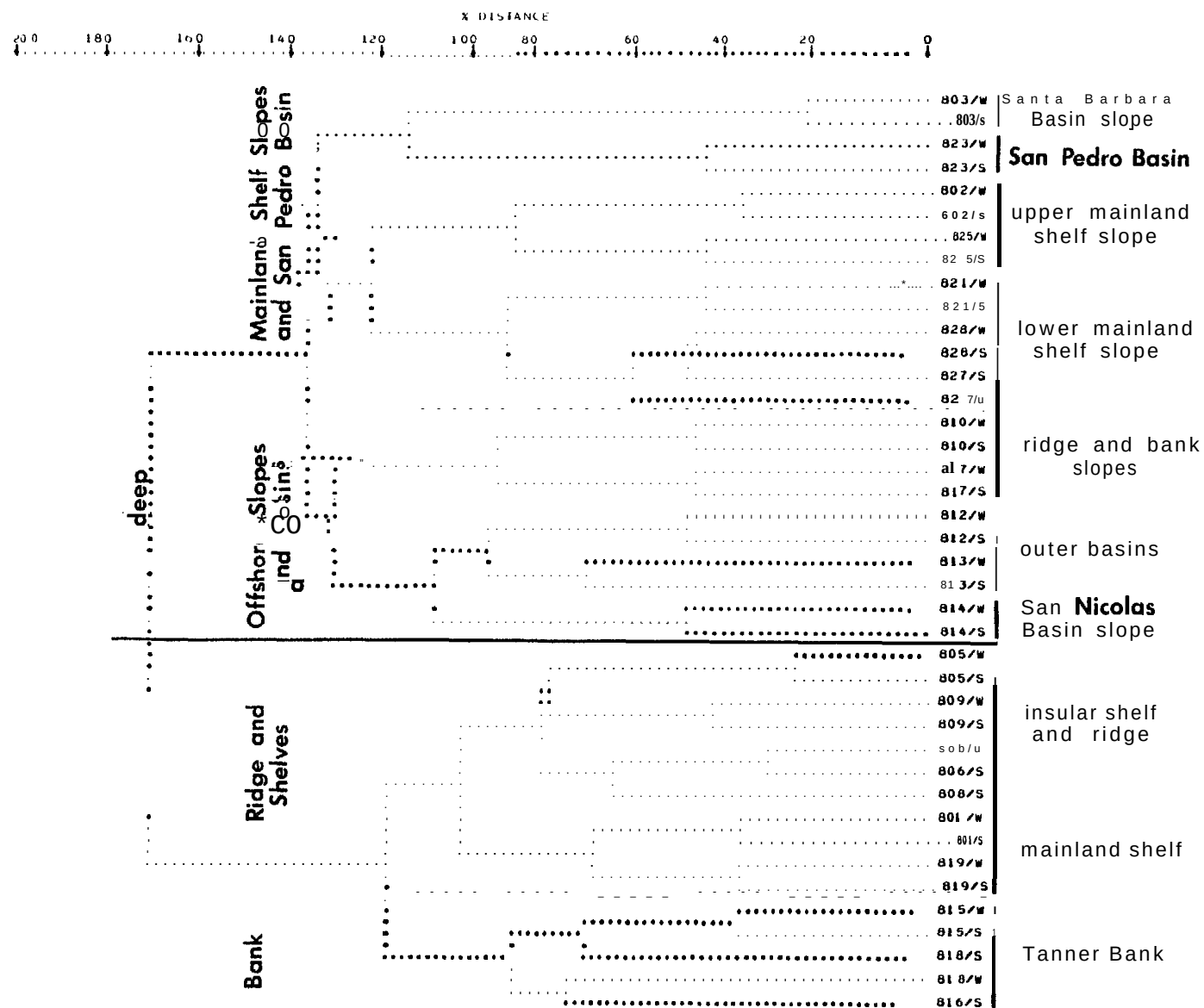


Figure 11-19.0-33. Winter/Summer Replicates Averaged Dendrogram. Data base - Edited Detailed Analysis. Editing Criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted.

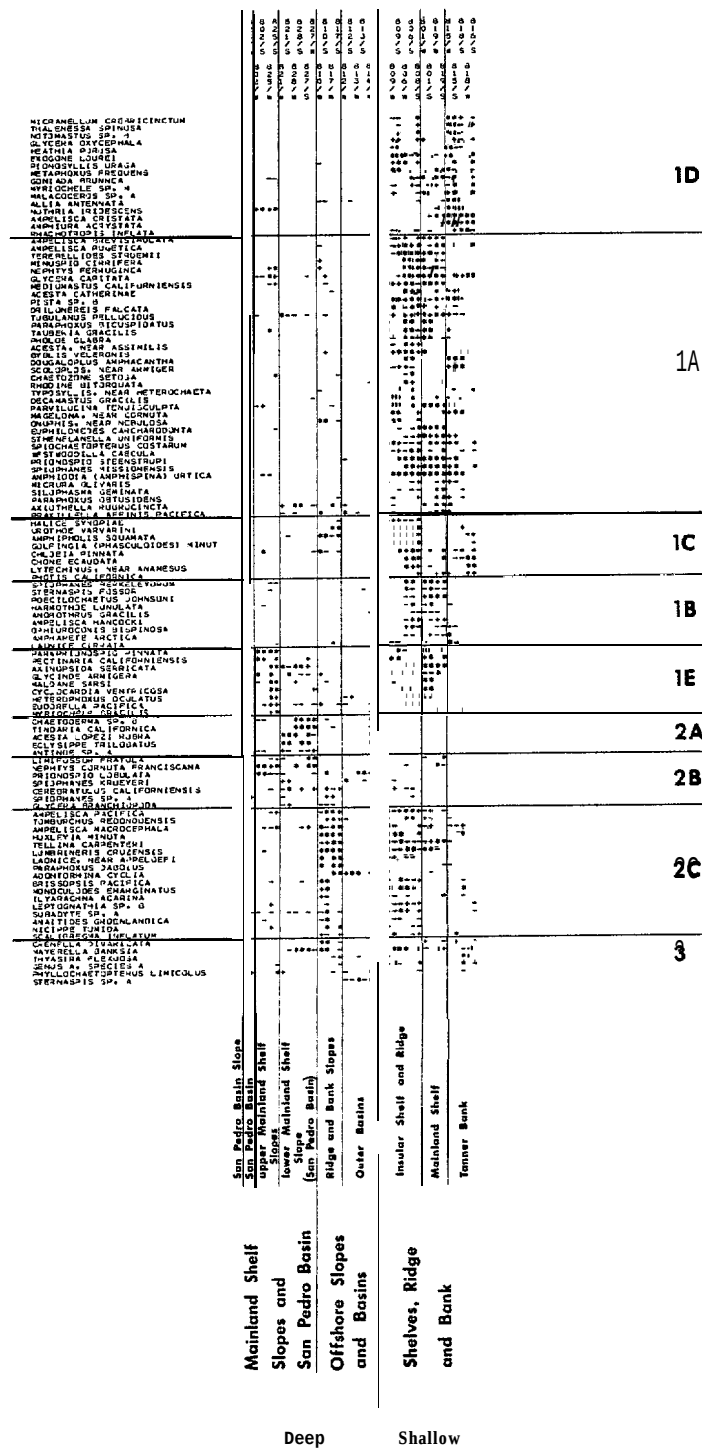


Figure 11-19.0-34. Winter/Summer Replicates Averaged Two-Way Table. Data Base - Edited Detailed Analysis. Editing criteria - non-monospecific taxa and frequency of occurrences ≤ 1 omitted. Abundances have been scaled from 0 to 1. The five symbols correspond to the following intervals: blank (≤ 0), . ($> 0-.25$), - ($> .25-.5$), + ($> .5-.75$), and * ($> .75$). Single numbers and letters represent the clusters derived from inverse analysis. Area descriptors represent the clusters derived from normal analysis.

The mainland shelf stations (801 and 819) were nearly indistinguishable in this analysis. Group 1B was primarily associated with these stations but these species also occurred on the shallow insular shelf.

The Tanner Bank stations were separated from the Santa Rosa Ridge stations in this analysis. Although both areas shared numerous faunistic components, there were discrete assemblages characteristic of each area. Group 1C was the Amphipholis squamata-Golfingia minuta-Urothoe varvarini subgroup characteristic of the Santa Rosa Ridge. The Tanner Bank assemblage (1D) was characterized by another ophiuroid group, the Amphiura acrystata-Ampelisca cristata-Lumbrineris acutiformis assemblage.

Group 1E occurred at the upper mainland slope stations (802 and 825). They were apparently grouped with the other shallow sampling locations because of the large degree of overlap in their fauna. In fact, all of the common species found at these stations were found at other shelf or ridge locations, and some of these species extended down the slopes to the lower slope group. The upper slope thus appeared to represent a transitional zone, even though it did support several characteristic species.

The lower mainland slope stations (821, 827 and 828) showed a rather distinct species group (2A) characterized by the same species described in the first analysis. These species were also found at station 814, on the lower ridge slope, but almost none were found at station 803, on the lower Santa Barbara Basin slope. The fauna most strongly represented at station 803 (group 2B) was also shared with many other deep stations. It was a poorly defined species group.

Group 2C was the lower ridge slope group. The two stations, 810 and 817, were grouped separately in the first classification analysis but here were not easily distinguished. Almost all of the species found at these sampling locations were also common on the shallow ridge, although some species were characteristic of these two stations in particular. This area probably represented a transition zone.

Group 3 was a miscellaneous group that probably would represent the basins if the species with lower occurrences had not been eliminated from the two-way table. In normal analysis, however, the outer basin stations (812 and 813) grouped together and did, as was discussed above, share same species.

Both this and the all-replicates classification analyses showed that species groups could be assigned loosely to major geographic and bathymetric regions. Most of the species groups were shown to overlap with adjacent sites or with site groups found in similar depositional environments. Sites on basin (upper and mid-) slopes might generally be considered transitional between the more stable shelf or ridge tops and the basins.

19.8.2 Recurrent Groups Analysis

Recurrent groups analysis (Fager, 1957; Fager and McGowan, 1963) was conducted with the edited detailed analysis data base (monospecific taxa only) to determine which species were found associated at the 0.05 and 0.65 significance levels. This method of analysis gives essentially the same information as classification analysis, but is limited by the sizes of groups that may be found, especially when a very large species list is involved. The method appears to work best when used in a homogeneous area where species numbers are constant. With the data from this study, the shallower sites were characterized by large numbers of co-occurring species which always showed the highest number of affinities.

The results of recurrent groups analysis (Table 11-19.0-19) show the recurrent groups at the 0.05 significance level. Twenty-six recurrent groups were found at this level, but only the first six contained four or more species. Fifteen of these groups had only two species.

The first and largest group was composed of eight species, all members of the very large Amphiodia urtica assemblage.

The second level (group) was also part of this assemblage. These recurrent groups were all grouped in the same manner by the classification analyses, thus confirming these associations.

The third group was composed of five species characteristic of station 803 on the Santa Barbara Basin slope. These species were unique to this station and, considering the low oxygen levels at this sampling location, these forms were most likely organisms particularly well adapted to low oxygen tensions. The mollusk Mitrella permodesta, found in this group, was also collected at station 823 in the San Pedro Basin, another low oxygen location.

The fourth and sixth groups were composed of species that occurred at station 819 on the San Pedro shelf. Group 4 contained the polychaete Onuphis nebulosa, characterized by Jones (1969) as a shallow-water co-dominant with Amphiodia urtica.

Group 5 was an "outer basin association composed of species found only at those stations (812 and 813). The remaining species groups were small and characteristic of the areas shown in Table 11-19.0-19.

When recurrent groups analysis was conducted at the 0.65 significance level (fewer combinations to be considered), the analysis produced no information that was considered useful.

Table 11-19.0-19. Recurrent Groups Analyses - 26 groups found at the 0.05 significance level.

Level	Species
MAINLAND SHELF, SANTA ROSA RIDGE, TANNER BANK	
1	<i>Amphiodia urtica</i> <i>Myrella tumida</i> <i>Spiophanes missionensis</i> <i>Prionospio steenstrupi</i> <i>Sthenelanelia uniformis</i> <i>Euphilomedes carcharodonta</i> <i>Scoloplos nr. armiger</i> <i>Dougaloplus amphacantha</i> <i>Tauberia gracilis</i> <i>Terebellides stroemii</i> <i>Euphilomedes products</i> <i>Pholoe glabra</i> <i>Nemocardium centifilosum</i>
SLOPE OF SANTA BARBARA BASIN	
3	<i>Tauberia multibranchiata</i> <i>Lagisca lamellifera</i> <i>Cyclocardia barbarensis</i> <i>Mitrella permodesta</i> <i>Byblis barbarensis</i>
SHALLOW MAINLAND SHELF	
4	<i>Streblosoma crassibranchia</i> <i>Apoprionospio pygmaea</i> <i>Cylichna attonsa</i> <i>Onuphis nebulosa</i> <i>Asychis disparidentata</i>
SANTA CRUZ BASIN	
5	<i>Ophiura leptoctenia</i> <i>Tindaria kennerlyi</i> <i>Ophiophthalmus normani</i> <i>Adontorhina cyclica</i>
SHALLOW MAINLAND SHELF	
6	<i>Melinna oculata</i> <i>Spiophanes bombyx</i> <i>Volvulella panamica</i> <i>Pinnixa schmitti</i>
SANTA ROSA RIDGE	
7	<i>Amphissa undata</i> <i>Travisia brevis</i> <i>Diastylis sp. A</i>
8	<i>Mediomastus californiensis</i> <i>Glycera capitata</i> <i>Paraprionospio pinnata</i> <i>Minuspilio cirrifera</i> <i>Ampelisca brevisimulata</i> <i>Drilonereis falcata</i>
9	<i>Cossura candida</i> <i>Poecilochaetus johnsoni</i> <i>Podarkeopsis glabra</i>

Table 11-19.0-19. Recurrent Groups Analyses - 26 groups found at the 0.05 significance level (continued).

Level	Species
SANTA ROSA RIDGE (Continued)	
10	Euchone hancocki Photis lacia
11	Maera simile Glycera tessellata Lepidozона mertens ii
12	Lumbrineris acutiformis Amphiura acrystata
13	Golf ingia (P.) minuta Urothoe varvarini Pionosyllis uraga
14	Paraphoxus ep is tomus Harmothoe priopa Amphicteis scaphobranchiata Chone veleronis
15	Cyclocardia ventricosa Heterophoxus oculatus
16	Onuphis nr. nebulosa Huxleyia minuta
SANTA ROSA RIDGE, TANNER BANK	
17	Acesta catherinae Acesta nr. ass imilis Byb lis veleronis
18	Parvilucina tenuisculpta Paraphoxus bicuspidatus Decamastus gracilis
19	Asabellides lineata Lanice conchilega
20	Pista sp. B Magelona nr. cornuta
21	Subadyte sp. A Amphipholis squamata
22	Lumbrineris cruzensis Tomburchus redondoensis
23	Artacamella hancocki Alvinia rosana
24	Chaetoderma sp. B Tindaria californica
25	Axinopsida serricata Listriolobus pelodes
26	Pectinaria californiensis Spiophanes berkeleyorum

19.8.3 Weighted Discriminant Analysis

The classification analyses indicated that geographically and bathymetrically similar sites tended to group together. To investigate further the influence of environmental variables upon site groups and to verify the similarity of such variables within each site group, weighted discriminant analysis was performed. In this analysis, selected physical parameters are used to form discriminant axes for an ordination plot of species data from each site. The first axis includes those physical parameters that mathematically contribute the most to variation between the sites. The second and succeeding axes are selected in the same manner until all variation between sites has been accounted for.

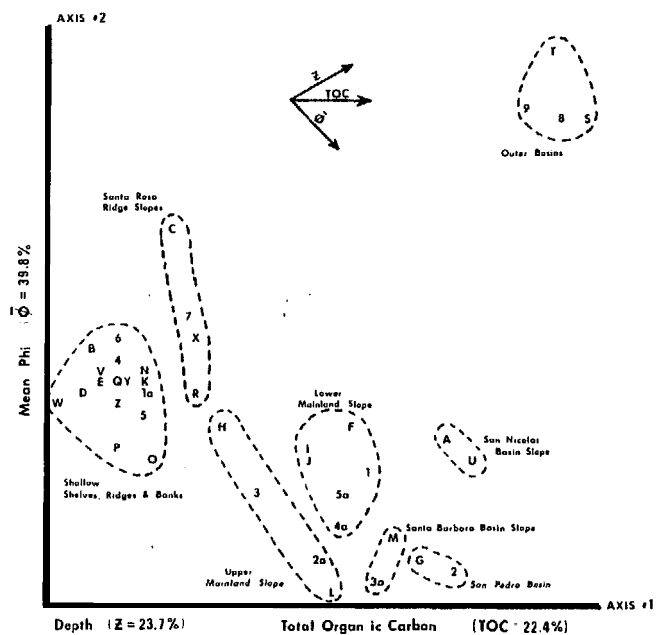
To provide another check on the groups defined by classification analysis, each station was used as a "group" in this analysis. The edited detailed analysis data base was used and, to allow the seasonal information to be expressed, the winter and summer replicates from each station were averaged and analyzed separately. No data for the winter was available for stations 808 and 816.

On the first run of this analysis, nine parameters were included. It was found that the sediment parameters (percent sand, silt and clay) dominated strongly on all axes. As such, none of the other potentially important variables could be expressed. For this reason, and since percent sand and percent clay provided the highest and lowest sediment values, the percent silt variable was eliminated. Mean phi was also somewhat redundant, but it was a better measure of average sediment condition and was retained. The results of analysis, incorporating these changes, have been presented in Table 11-19.0-20. The coefficients of separate determination showed that on the first axis (which accounted for 54% of the variation between the sites) depth and total organic carbon in the sediments were the most important variables in determining that axis. Depth and organic carbon are highly correlated variables (0.89), however, and it is probable that depth alone was the most important factor separating these sites. The second axis was determined by mean phi; the third axis was also determined most strongly by mean phi but was also influenced by the sorting coefficient and skewness, both sediment parameters.

The discriminant scores for each site were plotted on these axes (Figure 11-19.0-35). Each plot showed only two axes at a time. These plots showed each location (summer and winter replicates separately) in relation to the physical factors at that site. Ten site groups were identifiable, and these groups corresponded well to the major depositional environments sampled. In Figure 11-19.0-35 a, stations 803 and 823 were shown to group closely with the lower mainland slope stations, but considering their proximity and the similarities of environments, this could be expected. However, when

Table 19-20. Weighted Discriminant Analysis - Coefficients of Separate Determination. Values under the axes numbers indicate the cumulative percentage of variation accounted for by each axis.

Physical Variables	AXES		
	1 54.0%	2 74.9%	3 85.0%
Total Organic Carbon	22.4	0.0	3.2
% CaCO ₃	2.5	1.8	6.5
% Sand	16.7	17.3	6.1
% Clay	15.9	10.3	0.6
Mean Phi	6.8	39.8	35.8
Sorting Coefficient	0.8	1.5	25.4
Skewness	11.2	16.3	20.9
Depth	23.7	13.1	1.5



Symbol	Station / Season	Symbol	Station / Season
A	814W	U	814S
B	815W	V	815S
C	817W	W	818S
D	818W	X	817S
E	819W	Y	818S
F	821W	Z	619S
G	823W	1	821S
H	825W	1a	801W
I	821W	2	823S
J	828W	2a	802W
K	801S	3	802S
L	002S	3a	803W
M	803S	4	805W
N	805S	4a	821S
O	806S	5	806W
P	806S	5a	828S
Q	809S	6	809W
R	010S	6	810W
S	812S	6	812W
T	813S	9	813W

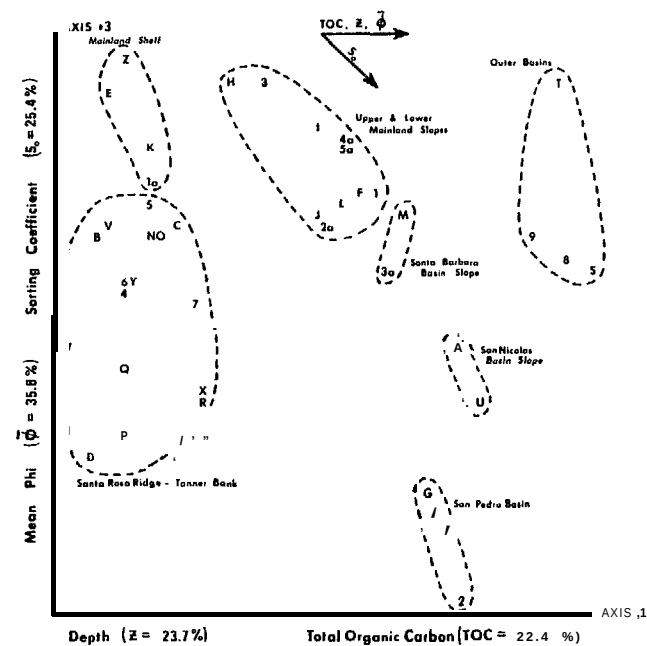


Figure 11-19.0-35. Plot of Weighted Discriminant Scores - A) Axes = Depth, Total Organic Carbon, and Mean Phi and B) Axes = Depth, Total Organic Carbon, Mean Phi and Sorting Coefficient.

another axis (Figure 11-19.0-35 b) was shown, these sites became more distinct. Interestingly, these plots revealed site groups almost identical to those produced by the classification analyses. It is important to emphasize that for this analysis no predetermined site groups were used. Each sampling location was used as an entity and the analysis produced results similar to those of the classification analysis, although these results were produced by species relationships with the physical parameters whereas classification used ecological distance based on species abundances alone. It was thus clear that the species groups found by classification analysis were the result of the organisms' responses primarily to depth and the sediment characteristics of their environment.

19.8.4 Summary of Results

The results of the three analyses produced only slightly different site and species groups, and each method showed the data from a slightly different aspect. The all-replicate classification analysis showed the variation among the replicates and used the maximum number of species in the inverse analysis to produce large, generally conspicuous species groups.

The second classification analysis was based on average abundances and used the most common species to produce species groups. However, the most common species were not always those which were characteristic of a particular area. Most often, they were the most widely dispersed species, which were not characteristic of any particular site group. On the basis of the analyses and species rankings performed in this study, it was found that most associated species that were characteristic of an area occurred in lower numbers than were represented in the second classification run.

The weighted discriminant analysis produced site groupings based on similarities in physical factors. Not surprisingly, depth and sediment characteristics were found to be the most influential physical parameters.

Rather than choose any one analysis as producing the "best" results, the best aspects of each method were combined to derive site groups and species groups consistent with good ecological theory and current knowledge of the biology of benthic organisms.

Ten site groups were selected. These were based, as in all of the analyses, on major depositional environments:

1. Mainland shelf (stations 801 and 819)
2. Upper mainland slope (stations 802 and 825)
3. Lower mainland slope (stations 821, 827 and 828)

4. Santa Barbara Basin slope (station 803)
5. Santa Rosa Ridge-Tanner Bank (stations 805, 806, 808, 809, 815, 816, and 818)
6. Santa Rosa Ridge slope (stations 810 and 817)
7. Lower Santa Rosa Ridge slope (station 814)
8. San Pedro Basin (station 823)
9. Santa Cruz Basin (station 812)
10. San Nicolas Basin (station 813)

These groups were identical to those produced by the weighted discriminant analysis and by the second classification analysis, except that on the latter the Santa Rosa Ridge and Tanner Bank sites were grouped separately (Table 11-19.0-21). These sites have been considered as a group here because of their similar depositional environments, indicated by relatively shallow depths, coarse sediments, low organic material in the sediments and current and tidal instability. Such physical factors could be expected to produce habitat heterogeneity. This phenomenon was best reflected in the diversity and species richness (Figure 11-19.0-36) and in the large number of associated species found at these sites.

19.8.4.1 Species Groups

Thirteen species groups were identified (Table 11-19.0-22). Each species group corresponded to one or more site groups. The component species of each group were selected on the basis of the classification analyses and recurrent groups analysis, and because their distributions indicated that they were the most "characteristic" of the area to which they were assigned. It is important to note that almost all species also occurred incidentally at adjacent areas. These species groups should in no way imply that biological interactions among the species are known. These groups may have existed in response to environmental and/or biological limitations.

Station 819 on the mainland shelf could be characterized as a shallow-water subcommunity of the large Amphiodia urtica community. The presence of species associated with the polychaete Onuphis nebulosa were indicative of this and corresponded well with the data of Jones (1969) for this shallow-water facies.

The Amphiodia urtica association was found at sites on the mainland shelf, upper slope, Santa Rosa Ridge and Tanner Bank. This association might be considered the dominant species group in the

Table 19-21. Site Groups Derived from Classification versus Weighted Discriminant Analysis.

Site Groups		
Classification Analysis All Replicates		Weighted Discriminant Analysis
819	819	819
801	801	801
806		
	802	802
802	825	825
825		
	821	821
821	827	827
827	828	828
828		
	803	803
803		
	805	805
805	806	806
808	808	808
809	809	809
815		815
816	815	816
818	816	818
	818	
810		
	810	810
817	817	817
814	814	814
823	823	823
812	812	812
813	813	813

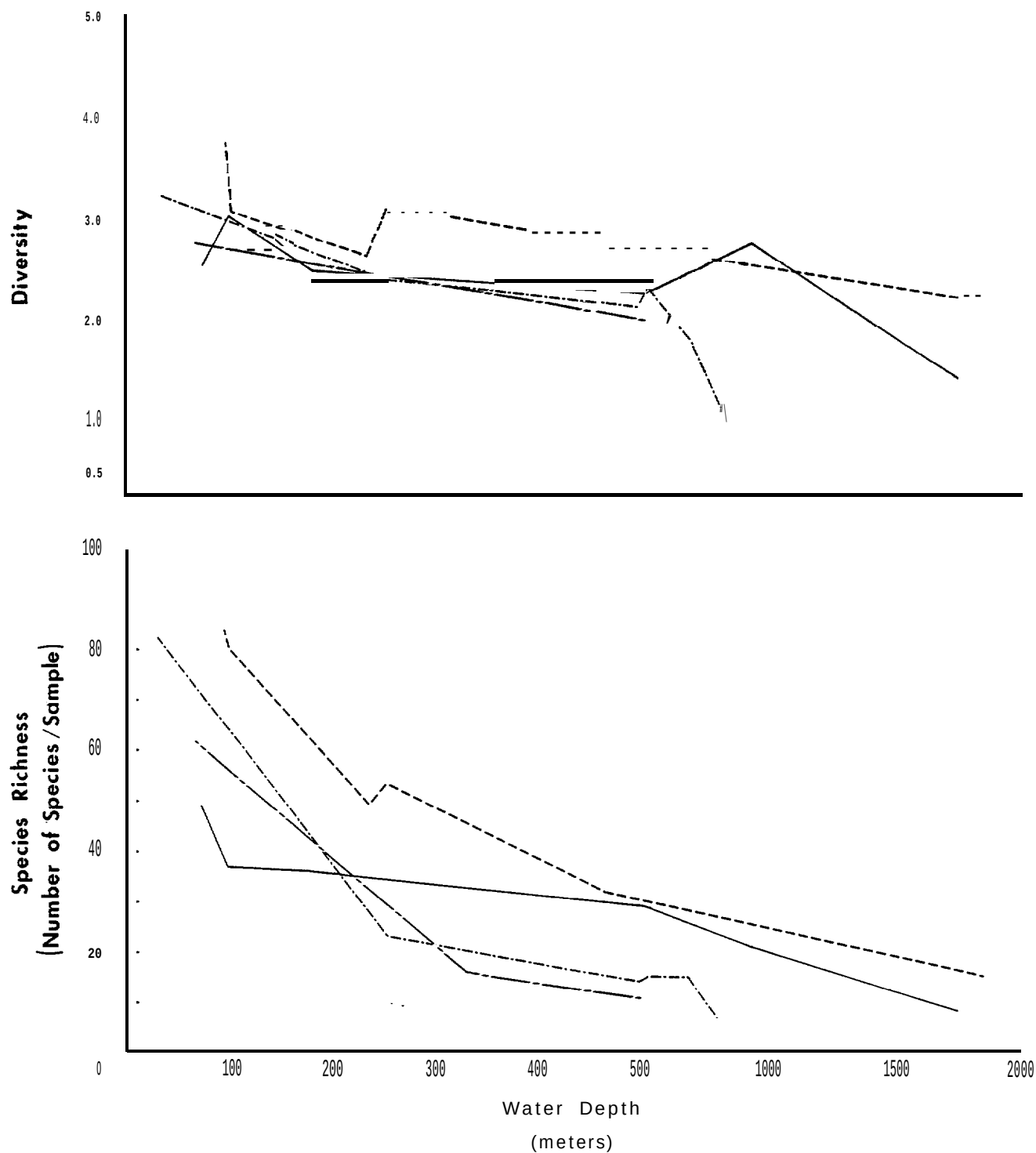


Figure 11-19.0-36. Between Area Comparison - Diversity and Species Richness Values for all sites: San Pedro (---·---·), Coal Oil Point (---·---·), Santa Rosa Ridge (----), and Tanner Bank (—) .

Table 19-22. Species Groups Derived from Classification and Recurrent Group Analysis.

	Species Name	Recurrent Group Level
Mainland Shelf; Santa Rosa Ridge-Tanner Bank; <u>Amphiodia urtica</u> assemblage	<i>Amphiodia urtica</i>	1
	<i>Glycera capitata</i>	8
	<i>Mediomastus californiensis</i>	8
	<i>Paraprionospio pinnata</i>	8
	<i>Spiophanes missionensis</i>	1
	<i>Prionospio steenstrupi</i>	1
	<i>Sthenelanelia uniformis</i>	1
	<i>Euphilomedes carcharodonta</i>	1
	<i>Mysella tumida</i>	1
	<i>Listriolobus pelodes</i>	25
Shallow Mainland Shelf; <u>Onuphis nebulosa</u> assemblage; 819	<i>Onuphis nebulosa</i>	6
	<i>Melinna oculata</i>	6
	<i>Pinnixa schmitti</i>	6
	<i>Streblosoma crassibranchia</i>	4
	<i>Apoprionospio pygmaea</i>	4
	<i>Cylichna attonsa</i>	4
	<i>Asychis disparidentata</i>	4
	<i>Spiophanes bombyx</i>	6
	<i>Volvulella panamica</i>	6
Upper Mainland Slope; 802-825	<i>Nephtys cornuta franciscana</i>	0
	<i>Maldane sarsi</i>	0
	<i>Brisaster latifrons</i>	0
	<i>Heteromastus</i> sp.	0
	<i>Hesperonoe laevis</i>	0
	<i>Arhynchite californicus</i>	0
Lower Mainland Slope; 821-827-828	<i>Chaetoderma</i> sp. B	24
	<i>Acesta lopezi rubra</i>	0
	<i>Eclysippe trilobatus</i>	0
	<i>Cerebratulus californiensis</i>	0
	<i>Tindaria californica</i>	24
	<i>Listriolobus hexamyotus</i>	0
Santa Barbara Basin Slope; 803	<i>Mitrella permodesta</i>	3
	<i>Tauberia multibranchiata</i>	3
	<i>Byblis barbarensis</i>	3
	<i>Cyclocardia barbarensis</i>	3
	<i>Lagisca lamellifera</i>	3

Table 19-22. (Continued)

	Species Name	Recurrent Group Level
Santa Rosa Ridge-Tanner Bank; 805, 806, 808, 809, 815, 816, 818 <u>Lumbrineris cruzensis-</u> <u>Parvilucina tenui-</u> <u>sculpta</u> assemblage	<u>Lumbrineris cruzensis</u>	22
	<u>Parvilucina tenuisculpta</u>	18
	<u>Chloeia pinnata</u>	0
	<u>Byblis veleronis</u>	17
	<u>Decamastus gracilis</u>	18
	<u>Acesta catherinae</u>	17
	<u>Acesta nr. assimilis</u>	17
	<u>Ampelisca pugetica</u>	0
	<u>Tomburchus redondoensis</u>	22
	<u>Glycera tessellata</u>	11
	<u>Amphissa undata</u>	7
	<u>Travisia brevis</u>	7
	<u>Diastylis sp. A</u>	7
	<u>Maera simile</u>	11
	<u>Allocentrotus fragilis</u>	0
	<u>Euchone hancocki</u>	10
	<u>Photis lacia</u>	10
	<u>Amphipholis squamata-</u>	21
	<u>Golfingia minuta</u> assem-	13
	<u>blage</u>	13
<u>Ampelisca cristata-</u> <u>Amphiura acrystata</u> assemblage	<u>Urothoe varvarini</u>	13
	<u>Subadyte sp. A</u>	21
	<u>Pionosyllis uraga</u>	13
	<u>Ampelisca cristata</u>	0
Santa Rosa Ridge Slope; 810-817	<u>Amphiura acrystata</u>	12
	<u>Lumbrineris acutiformis</u>	12
	<u>Lumbrineris cruzensis</u>	0
	<u>Huxleyia minuta</u>	0
	<u>Ampelisca pacifica</u>	0
Lower Santa Rosa Ridge; 814	<u>Paraphoxus daboius</u>	0
	<u>Adontorhina cyclia</u>	0
	<u>Phyllochaetopterus limicolus</u>	0
	<u>Tauberia oculata</u>	0
	<u>Asychis Sp. C</u>	0
	<u>Leucon magnadeutata</u>	0
	<u>Harpiniopsis epistomatus</u>	0
	<u>Rhodine bitorquata</u>	0

Table 19-22. (Continued)

	Species Name	Recurrent Group Level
San Pedro Basin; 823	Phyllochaetopterus limicolus	0
	Mitrella permodesta	0
	Entoprocta	0
Santa Cruz Basin; 812	Ophiophthalmus normani	5
	Tindaria kennerlyi	5
	Adontorhina cyclia	5
	Ophiura leptoctenia	5
	Harpiniopsis fulgens	0
	Neoamphitrite sp. A	0
San Nicolas Basin; 813	Sternaspis sp. A	0
	Golfingia (Phascoloides) sp. C	0
	Dynamena desmoides	0

Southern California Borderland. Amphiodia urtica was the most abundant and widespread organism found throughout the samples collected. Within this range it occurred at an average abundance of 265/m². The Amphiodia urtica assemblage was the most prevalent on the mainland shelf (stations 801 and 819) but also formed a major part of the fauna on the Santa Rosa Ridge and Tanner Bank, where the distribution of this assemblage apparently became much less homogeneous.

The upper mainland slope sites (stations 802 and 825) could be characterized as more of a transitional zone than as sites with discrete species groups. There were, however, a small number of species that appeared to be characteristic of this zone. None, however, were shown to be associated by recurrent groups analysis and most were also found both deeper and shallower on the slopes.

The deep mainland slope sites (stations 821, 827 and 828) formed a more definable association. Two of the species were shown to be associated by the recurrent groups analysis and all of these species were more or less restricted to these sites. Some overlap could be seen with other lower slope sites (stations 814 and 803). Station 803 at 500 m was located slightly below the sill depth (475 m; Hartman and Barnard, 1960) of Santa Barbara Basin. The dissolved oxygen levels at that location were very low (0.21 ml/l) and the species correspondingly represented organisms adapted to such an environment. Some, however, were shared with other slope sites.

Four species groups could be identified from the Santa Rosa Ridge-Tanner Bank site group (stations 805, 806, 808, 809, 815, 816 and 818). In addition to the Amphiodia urtica assemblage, two other ophiuroid assemblages were found at these locations: the Amphipholis squamata-Golfingia minuta assemblage and the Amphiura acrystata-Ampelisca cristata assemblage.

The fourth association was the Lumbrineris cruzensis-Parvilucina tenuisculpta assemblage. This was a loosely aggregated species group found at almost all stations in this site group. Many species were shown to be associated by the recurrent groups analysis, but those results did not indicate a large association as shown here. These species were all loosely grouped in the classification analyses.

The two stations (810 and 817) on the slopes of the outer basins appeared to represent slope transition areas. Although these sites produced more or less distinct species groups in the classification analyses, most of the species also occurred on the shallower ridge and banks and a few were also found in deeper water. The species group represented in Table 11-19.0-22 should not be interpreted as a strong species association but rather as a loose aggregation of common species which co-occurred at these sites.

The station at the bottom of the Tanner Bank slope, 814, was an interesting one. Its faunal composition was very different from that of the shallower ridge stations because of the environmental factors which became similar to those in the outer basins. The organic carbon content in the sediment at this station was the highest found anywhere in the areas sampled. This finding attested to the high productivity of the ridge system. Most of the produced matter is eventually deposited at the base of the slopes. The fauna here was different from that at any other sampling location, although some species were sporadically found at other similar sites. None of these species were shown to be associated by the recurrent groups analysis, but two species, Asychis sp. C and Leucon magnadeutata, were found nowhere else.

Each of the basin stations (823, 813 and 812) generally contained a different faunal associations, but the polychaete Phyllochaetopterus limicolus and the cnidarian Dynamena desmoides occurred at all three sites and the polychaete Sternaspis sp. A occurred at both outer basin sites (812 and 813). Santa Cruz Basin supported the most closely associated species group. This group was associated at level 5 of the recurrent groups analysis. These species were similarly described by Hartman and Barnard (1960). None of the other basins were shown to have such distinct species groups, although an undescribed sipunculan, Golfingia (Phascoloides) sp. C was found only in San Nicolas Basin. Hartman and Barnard (1960) also described this basin as being a "sipunculid" facies of a more widespread basin community, the Aricidea uschakovi-Tharyx tessellata community. No species were collected from station 823 that were not found at other sites.

19.8.5 Aspects of the Structure and Function at the Site Groups

In addition to delineating the faunal composition and physical similarities of the site groups, community spatial structure and trophic function were characterized. For these analyses, the 10 site groups previously identified and their corresponding species groups were each considered.

19.8.5.1 Spatial Analysis

Spatial structure based on dispersion chi-square statistics showed individual species dispersion patterns as well as an index of community dispersion. Additionally, when adjacent sites were compared it provided an indication of the scale of this spatial structure. This analysis was made with the edited detailed analysis data base.

Mainland Shelf (Stations 819 and 801). Station 819 has been identified as a shallower subgroup of the Amphiodia urtica assemblage characterized by the presence of the polychaete Onuphis nebulosa. It

was also a very diverse station with a large number of organisms (see Figure 11-19.0-36). Physical instability, due to wave action, and high diversity apparently produced the patchy community shown by the dispersion chi-square for both the winter and the summer replicate sample-sets (Table II-1 9.0-23). Neither Amphiodia urtica nor Onuphis nebulosa showed aggregation in the winter samples, but Amphiodia urtica became clumped in the summer samples, possibly indicating recruitment in this species.

Station 801 was characterized by a typical mainland shelf Amphiodia urtica assemblage. It showed no departure from the random distribution characteristic of this large assemblage.

Upper Mainland Slopes (Stations 802 and 825). Station 825 deviated slightly from randomness, and this was due entirely to the occurrence of apparent patches of the polychaete Pectinaria californiensis in the summer replicates. This species was not shown to deviate from randomness in the winter replicates. Except for this deviation, the organisms at these stations appeared to be randomly dispersed. Generally, few species showed any deviation from randomness, and at station 825 (winter) and station 802 (summer), none of the species deviated significantly from random.

Lower Mainland Slope (Stations 821, 827 and 828). Generally, at these stations the trend appeared to be toward randomness. Although station 827 was shown to be aggregated, the individual species indices of dispersion in the winter replicates showed no species that deviated significantly ($p < .05$) from randomness. It was, rather, the accumulation of small deviations from perfect randomness ($s^2=x$) by each species that apparently caused this total deviation. Station 828 (winter replicates only) showed one species, the mollusk Tindaria californica, that was aggregated, and it was this species that caused the site to deviate from randomness. The only truly aggregated samples were those collected at station 827 in the summer. The others could all be interpreted as being generally randomly dispersed.

Station 803 was also a lower slope site and, as was shown in the discriminant analysis, was very similar to the other lower slope sites. It is considered here for comparison of its spatial dispersion pattern with those of similar sites.

In the winter at station 803, two of the species found only at this location (the amphipod Byblis barbarensis and the mollusk Cyclocardia barbarensis) were shown to be significantly aggregated. In the summer replicates, these species did not deviate from randomness. Again, as at the other slower slope sites, the trend was toward randomness but appeared aggregated because of probable recruitment of a few species. The mainland slopes thus all appeared to support randomly dispersed communities except for apparent patches of newly settled organisms.

Table 19-23. Dispersion Chi-Square for the Winter/Summer Replicates.
c = Clumped and R = Random.

SITE	WINTER			SUMMER		
	Index of Dispersion	Degrees of Freedom	C/R	Index of Dispersion	Degrees of Freedom	C/R
801	204.89	180	R	187.48	180	R
819	404.60	270	c	495.37	312	c
802	69.64	60	R	88.75	75	R
825	114.78	114	R	134.26	108	c
821	79.18	72	R	75.92	66	R
827	91.11	69	c	131.68	69	c
828	91.57	66	c	76.14	72	R
803	111.14	45	c	52.08	39	R
805	247.83	201	c	262.01	213	c
806	368.24	309	c	432.29	321	c
808	484.02	291	c	882.56	336	c
809	465.96	231	c	413.99	246	c
815	210.81	141	c	208.30	159	c
816	--	--		1124.48	171	c
818	--	--		213.18	144	c
810	204.55	117	c	133.47	120	R
817	178.26	102	c	179.80	108	c
814	90.05	93	R	91.02	81	R
823	12.73	8	R	12.40	12	R
813	29.28	30	R	20.00	15	R
812	101.06	72	C	68.29	48	C

Santa Rosa Ridge-Tanner Bank (stations 805, 806, 808, 809, 815, 816 and 818). All of the sites differed significantly from random dispersion. These findings were, at first glance, precisely the opposite of those found in classification analysis in which most of these sampling locations were shown not to be clearly sorted on the basis of their faunal composition. The difference was explainable when scale was considered. On a large scale, the Santa Rosa Ridge sampling locations and the Tanner Bank sampling locations appeared to be homogeneous. But when spatial dispersion information between the replicates was obtained the organisms appeared to be clumped at that scale (theoretically, 1000 m from a central point).

From the classification analysis and the recurrent groups analysis, four fairly discrete species groupings were identified from these locations. The Amphiodia urtica group, most abundant on the mainland shelf, extended with decreasing abundance along the Santa Rosa Ridge to Tanner Bank.

The Amphipholis squamata assemblage was most abundant on the Santa Rosa Ridge but also extended onto Tanner Bank. Amphiura acrystata was found only on Tanner Bank (except for a single specimen collected at Station 819 (Table 11-19.0-24). Additionally, there was the large and diverse Lumbrineris cruzensis-Parvilucina tenuisculpta assemblage found both on the Santa Rosa Ridge and at Tanner Bank. At many stations, two or three of these assemblages could be found together. There was also evidence that these different species groups were temporally separated. For example, at station 809 (summer replicates), Amphipholis squamata and a closely related species, A. pugetana, showed aggregation. Amphiodia urtica was present but was not highly aggregated. In the winter replicates, Amphipholis squamata was randomly dispersed, A. pugetana was not present, and Amphiodia urtica was shown to be more aggregated. Additionally, species such as the polychaete Chloeia pinnata showed extremely large deviations from randomness. This species sometimes occurred in these areas in amazingly high numbers, as high as 5,984/m². These large patches apparently were made up of newly recruited organisms. Large patches of a single species will cause the dispersion chi-square value for the site to reflect this aggregation.

The resulting picture that emerged was one of a spatial and temporal mosaic of several associated species groups that resulted in an overall elevation of diversity at these stations (see Figure II-19.0-36). A community so structured should be expected to show strongly aggregated spatial orientation.

Santa Rosa Ridge-Tanner Bank Slopes (Stations 810 and 817). These stations have been characterized as being part of a rather transitional zone. Many members of the ridge and banks fauna were still found at these locations and had their characteristic spatial

Table 19-24. Characteristic Ophiuroid Assemblages of the Southern California Borderland.

	Number of Occurrences	Total Number
MAINLAND SHELF (819,801)		
Amphiodia urtica	18	603
Amphipholis squamata	0	0
Amphiura acrystata	1	1
SANTA ROSA RIDGE (805, 806, 808, 809, 810)		
Amphiodia urtica	28	300
Amphipholis squamata	26	138
Amphiura acrystata	0	0
TANNER BANK (815, 816, 818)		
Amphiodia urtica	12	59
Amphipholis squamata	6	12
Amphiura acrystata	10	36

structure. In the station 810 summer replicates, no species had indices of dispersion significantly different from random. This station was aggregated in the winter mainly as a result of aggregations of Amphipholis squamata, Amphipholis pugetana and Chloeia pinnata. All of these species were randomly dispersed in the summer. Much of the apparent aggregation at station 817 was due to the presence of patches of the amphipods Ampelisca macrocephala, A. pacifica and Byblis bathyalis.

Lower San Nicolas Basin Slope (Station 814). This site was described above (Section 19.8.4.1, Species Groups). The high organic carbon level in the sediment, the fine grain size and the depth of this station provided a relatively stable habitat. This site was characterized as having a randomly dispersed fauna; no species dispersion was significantly different from random. The site was similar in structure to that of the lower slope stations on the mainland shelf.

Basins (Stations 823, 812 and 813). The San Pedro Basin station (823) and the San Nicolas Basin station (813) were both characterized as being randomly dispersed. The Santa Cruz Basin location (station 812), however, was shown to have aggregated species. The reasons for this disparity between apparently similar habitats was not clear. None of the characteristic species of the Santa Cruz Basin site showed significant departures from randomness. The apparent aggregation may have been the result of transient species aggregation. In the winter, only two species were shown to deviate from randomness. However, neither of these species was present at this station in the summer and a single other species was responsible for a very slightly significant deviation from randomness at that time. The observed aggregation at this site may not have represented the general conditions that are known to be typical of the other deep basins: randomly dispersed communities with low species diversity.

19.8.5.2 Analysis of Primary Feeding Structure

The benthos depends ultimately upon food deposited from the overlying water. Almost all benthic organisms that rely primarily on this influx are either suspension-feeding forms that actively pass the bottom water through a filter or other catch device or passively trap food carried past them by the current, or they are deposit feeders that eat particulate organic material trapped in the sediments or clean microbes from the sediment grains. The proportions of animals in these two primary trophic roles should provide information on the relative availability of their food sources and on the depositional environments in which they live.

A simple scaled ratio, the primary feeding index, of the abundances of suspension-feeding forms to deposit-feeding forms (including surface and subsurface deposit feeders) was calculated for each

station. Additionally a summary of the feeding and motility analysis at each site was prepared. The edited detailed analysis data base was used and the top-ranked (by abundance) 90% of the organisms were considered.

The results of this analysis have been plotted in Figure 11-19.0-37 and included in Table 11-19.0-25. The three curves represented the mainland shelf and slope sites, the Santa Rosa Ridge-Tanner Bank sites, and the basin sites.

The mainland sites were generally strongly dominated by deposit feeding organisms, and there was little variation in the proportions of suspension feeders to deposit feeders at any of the sites. All sites were dominated by deposit-feeding forms, but interestingly, only at the slope sites were subsurface deposit feeders found to be dominant. At station 803, the primary feeding index was the lowest of all those for the mainland sites. Just why this site should have supported fewer deposit feeders was not clear. The sediment was composed of the finest grain sizes sampled and should have been expected to contain high organic carbon values. It may have been another consequence of low oxygen at this site, although station 823 was also a low oxygen station and did not show a similar trend. Two of the species found only at station 803, the amphipod Byblis barbarensis and the mollusk Cyclocardia barbarensis, are suspension feeders. At station 828, subsurface deposit feeders predominated, but large numbers of the filter-feeding pelecypod Axinopsida serricata produced a lower index value than was seen for adjacent sites. Overall, the fine sediments and homogeneous communities of the mainland shelf and slopes supported deposit-feeding organisms.

The Santa Rosa Ridge and Tanner Bank sites had lower and more variable primary feeding indices. These sites were heterogeneous both physically and biotically, and these results were not surprising. Additionally; ample food for higher trophic levels appeared to have been supplied by the high diversity and species richness found at these sites. Carnivores were the dominant feeding type at four of the seven sites. Two species of polychaetes, Chloeia pinnata and Onuphis, near nebulosa were the animals responsible for these high values. These species, especially Chloeia, appeared in large patches and may have contributed to the maintenance of the high diversity in this area. These species did co-occur, but when the abundance of one species was high, that of the other was low.

The primary feeding index at station 815 was much higher than at any other ridge or bank site. This finding was difficult to explain. A review of the species list showed no single species that dominated strongly, and the sediments were very sandy with a low percentage of organic carbon.

11-19.0-123

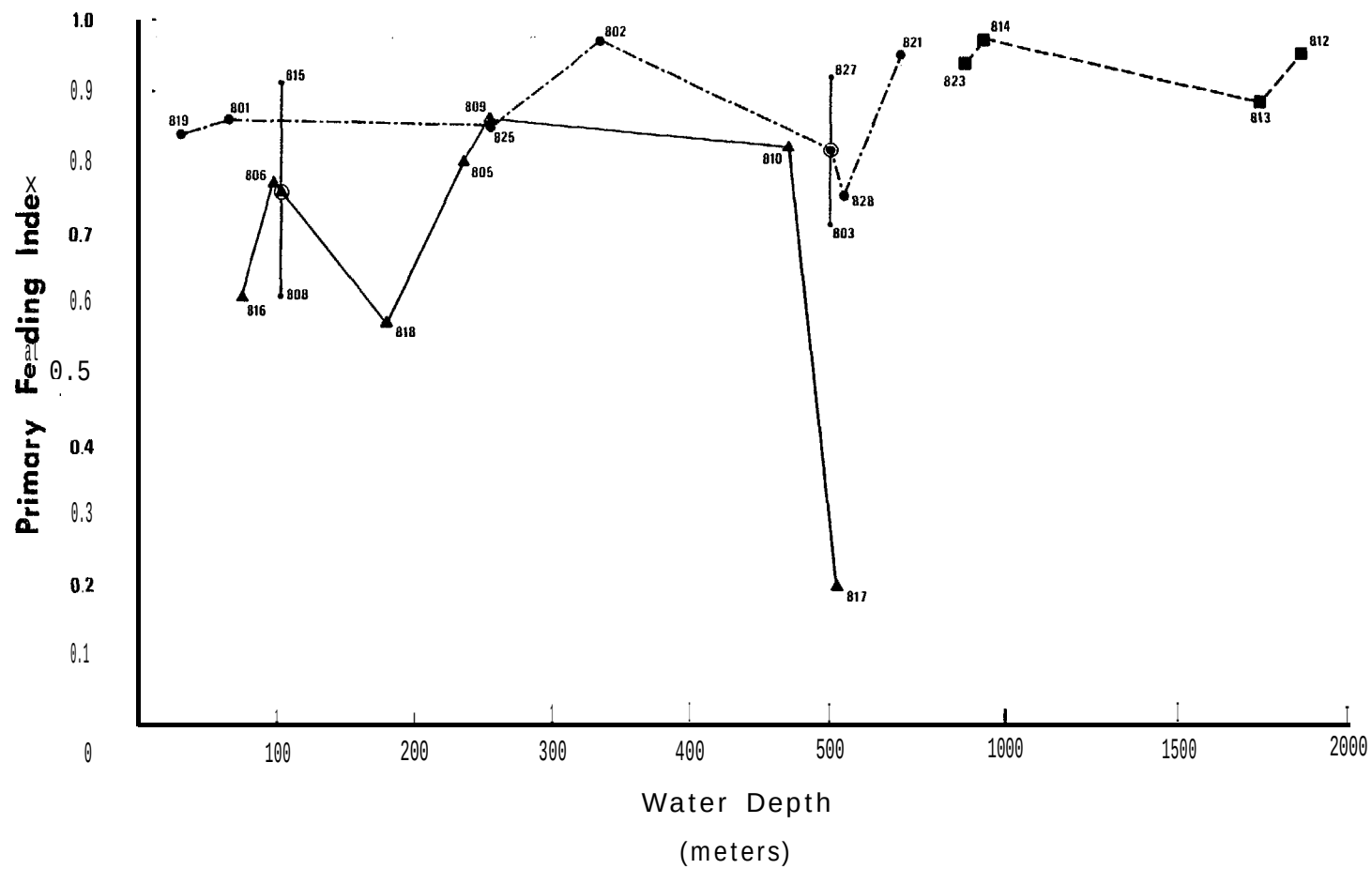


Figure 11-19.0-37. Primary Feeding Index for the mainland shelf and slopes (●- - - - ●), the Santa Rosa Ridge and Tanner Bank (A ——— A), and the basins (■ - - - - ■).

Table 19-25. Primary Feeding Index. MOT=Motile, SES=Sessile, SURF=Surface, SUB=Subsurface, D=Detrital Feeder, CARN=Carnivore, FIL=Filter Feeder.

Site	Primary Feeding Index	Dominant Feeding/Motility Type	Motility	
			% Motile	% Sessile
801	.86	Mot, Surf D (62.2%)	79.2	20.8
819	.84	Mot, Surf D (36.3%)	67.4	32.6
802	.97	Mot, Surf D (40.4%)	94.2	5.8
825	.85	Ses, Sub D (45.2%)	40.4	59.6
821	.95	Ses, Surf D (66.2%)	28.3	71.7
827	.92	Mot, Sub D (40.9%)	68.2	31.8
828	.75	Mot, Sub D (29.5)	49.2	50.8
803	.66	Mot, Surf D (48.3%)	85.2	14.8
805	.80	Mot, Cam (40.5%)	82.6	17.3
806	.77	Mot, Surf D (39.8%)	65.4	34.6
808	.61	Mot, Cam (47.1%)	88.7	11.3
809	.86	Mot, Surf D (38.8%)	84.6	15.3
815	.91	Mot, Surf D (38.5%)	83.0	17.0
816	.61	Mot, Cam (54.1%)	91.1	8.9
818	.57	Mot, Cam (47.9%)	92.3	7.7
810	.82	Mot, Cam (43.6%)	89.1	10.9
817	.20	Mot, Fil (65.0%)	80.0	19.2
814	.98	Mot, Sub D (36.0%)	64.0	36.0
823	.94	Mot, Surf D (70.6%)	76.5	23.5
813	.88	Ses, Surf D (34.9%)	37.2	62.8
812	.95	Mot, Surf D (43.8%)	48.9	51.1

Generally, the results strengthened the idea of faunal heterogeneity at these sites and showed that the Santa Rosa Ridge system supported a highly variable trophic structure not found on the mainland shelf or slopes.

The sites on the Santa Rosa Ridge slope showed much the same trend. Station 817 was strongly dominated by suspension-feeding organisms, primarily because of the presence of large numbers of the amphipod Byblis bathyalis. Carnivores were again the dominant feeding group at station 810, but here the abundances of Chloeia and Onuphis were nearly equal. Station 814 has been shown in Figure 11-19.0-37 along with the basin sites, since their depositional environments were probably very similar. Most of the organic material produced on the banks and ridge is deposited at the base of the slope or in the basins. At station 814, the subsurface forms were the most abundant and reflected this heavy deposition.

Deposit feeders always dominated in the basin sites. The basins act as food traps and these results were expected. Station 813 in the San Nicolas Basin showed a slight decrease in the primary feeding index, due mainly to the presence of the hydroid Dynemena desmoides.

The sites in areas characterized by fine sediments with high percentages of organic carbon and more stable hydrographic conditions supported mostly deposit-feeding fauna. In contrast, the Santa Rosa Ridge system, a high-production, coarse-grained, hydrographically dynamic area, supported a much more complex trophic structure. It could be characterized by a greater number of suspension-feeding forms and higher trophic level carnivorous and predatory organisms.

19.9 TEMPORAL VARIATION

19.9.1 Background

Variation in the benthos over time has not been well investigated, and little background information is available on this topic. A major reason for this has been the expense of repeated sampling in the same environment. What little is known about variation with time in the soft benthos is limited to studies of the intertidal (e.g., Woodin, 1974).

In subtidal areas, temporal studies are compounded by a sampling problem. The patch size characteristic of any benthic environment varies a great deal; patchiness can be exhibited at any level from areas as small as a dime- (Eckman, in preparation) to areas as large as about half a mile in diameter (Jumars, in press). Since temporal analysis consists of a close comparison of sample content with time, any patchiness exhibited at the level of the sample size could easily create so much random "noise" that evidence of any temporal variations would be obliterated.

Jumars (1975) and Thistle (1978) have both demonstrated that in the San Diego Trough patch sizes of the appropriate size are present. Caution was thus needed in interpreting the results of the current study, especially as it concerned the basin samples. Further precautions were required by the fact that only two data points (one set of winter samples and one set of summer samples) were available for comparison, and any trends noted in the samples could easily have been caused by random effects rather than by what might be called normal sequences in the benthos.

Investigators studying reproductive periods of marine invertebrates in southern California waters have remarked on the length and poor focus of the reproductive period in the shelf depths and also in deep water (Emerson, 1975; Pilger, 1977; Rokop, 1974). These results imply that, at least for the species investigated, recruitment can take place at almost any time of the year. Since most species appear to be sexually mature in the first half of the year, however, the most recruitment would be expected in the same half of the year. This long period of recruitment would create another source of confusion in any analysis of temporal variation and would make any comments based on a limited amount of material very tentative in nature. For these reasons, it must be repeated that the variations noted in the following comments could have been interpreted as spatial, rather than temporal variation, and that the conclusions must be considered suggestive, rather than firm at this point.

19.9.2 San Pedro Study Site

Station 819 (32-34 m) exhibited an increase in both species richness and population density from winter to summer. The overall change in faunal composition, i.e., the percent of species showing meaningful changes in population density, was 16% in the 1.0 mm fraction and 25% in the 0.5 mm fraction. The latter change was attributable to the presence of small polychaetes in the summer samples. Numerical and life stage data indicated a spat-fall between winter and summer in the polychaete Pectinaria californiensis. Another polychaete, the spionid Prionospio steenstrupi, was sexually mature in winter and apparently underwent a spawning period in spring. Specimens of the mollusk Mysella tumida were all juveniles in the winter, while 28% of those collected in summer were either mature or reproductively active.

Station 825 (250-270 m) showed an overall change in faunal composition of approximately 7% for both the 1.0 and 0.5 mm fractions. There was recruitment of the polychaete Pectinaria californiensis which, since most of the animals were adult, may have represented an influx into the area. Recruitment was also noted for the mollusk Macoma sp. In contrast, there was a loss in the lumbrinerid polychaete Lumbrineris, near crassidentata from winter to summer, with average densities falling from 56/m² to 0.

Station 827 (504-507 m) showed only minor changes from winter to summer. The overall change in faunal composition was about 5%. Unidentifiable mysids (crustaceans), were lacking in winter and present at an average density of 432/m² in summer. These animals are highly motile, however, and their occurrence was not considered meaningful evidence of seasonality. No other species exhibited seasonal tendencies.

Station 828 (536-543 m) showed no change in density and species richness. The overall change in faunal composition was relatively minor--3% in the 1.0 mm fraction and 7% in the 0.5 mm fraction. There was recruitment in the polychaete family Cirratulidae between winter and summer. In the mollusk, Prochaetoderma californiensis, population densities dropped from 728/m² in winter to 152/m² in summer. The cause of this change, however, could not be ascertained.

Station 821 (689-706 m) also showed no change in density and species richness. Evidence of seasonal change was very weak, with an overall change in faunal composition of 5% in the 1.0 mm fraction and 3% in the 0.5 mm fraction. Aside from a possible recruitment in the capitellid polychaete Leiochrides hemipodus, no other meaningful seasonal tendencies were noted in individual species.

Station 823 (875-881 m) exhibited a substantial increase in density (48/m² in winter, 136/m² in summer). There was no overall change in faunal composition in the 1.0 mm fraction and a change of 11% in the 0.5 mm fraction. Small ophiuroids were lacking in winter, while an average of 84 juveniles per square meter were collected in summer. This apparent recruitment may have been due either to a spat-fall or to vertical transport.

19.9.2.1 Review Comments for the San Pedro Study Site

Recruitment appeared to have taken place among the polychaetes in shallow water. At slope depths, there was an increase in the numbers of a single species of polychaete, Pectinaria californiensis, but most of the specimens were adult. The same species was among those recruiting in shallow water, but in very small specimens. This pattern could indicate that the apparent increase at slope depths might be due to patchiness in the environment, or, possibly, to a local influx of specimens from shallow water. At slope depths, there was a large influx of mysids that may have represented recruitment; also, change in the numbers of mollusks in this region indicated considerable activity, either in the form of transport or recruitment. In the basin samples, a sudden influx of very small ophiuroids may have represented a spat-fall, but again, this may have taken place in shallower water, since transport in to the San Pedro Basin is very active. Changes in density, species richness,

diversity, evenness, and dominance are presented in Table II-19.0-26. Numbers of meaningful changes, by major taxonomic group, are presented in Table II-19.0-27.

19.9.3 Coal Oil Point Study Site

Station 801 (66-71 m) showed an overall change in faunal composition of 5% in the 1.0 mm fraction and 10% in the 0.5 mm fraction. Overall density and species richness were both higher in winter than in summer. Recruitment was noted from winter to summer in the polychaetes Pectinaria californiensis, Spiochaetopterus costarum, and Maldanidae, unidentified. Another polychaete, Pholoe glabra, appeared to be reproductively active in winter and spring, with a recruitment of juveniles in summer. In the mollusk Paramya sp. A, many of the animals collected in winter were juveniles, while 40% of those collected in summer were adults.

Overall changes in faunal composition at station 802 (329-340 m) were negligible in the 1.0 mm fraction and 17% in the 0.5 mm fraction. There was no increase in density and species richness from winter to summer. There was recruitment of juveniles in the amphinomid polychaete Chloeia pinnata and possible recruitment of the pectinariid polychaete Pectinaria californiensis, but numbers of specimens were too small in the latter for certain determination. Other changes among individual species were minor.

Station 803 (502-506 m) showed little change in overall density and species richness between winter and summer. The overall change in faunal composition was 10 to 12% in the 1.0 and 0.5 mm fractions, respectively. The only noticeable change in individual species was the amphipod Bathymedon pumilus, which was present at relatively high densities in winter but absent in summer.

19.9.3.1 Review Comments for the Coal Oil Point Study Site

In shallow water, recruitment took place among the polychaetes between winter and summer. At slope depths a very striking increase in the numbers of Chloeia pinnata indicated a veritable spat-fall of this species. This apparent spat-fall was of interest because Chloeia pinnata is carnivorous and has been implied in feeding on foraminiferans. Such a recruitment pattern could then easily lead to distinct patchiness in the foraminiferans over the next year or so. There was little change in populations with time at greater depths off Coal Oil Point. Changes in density, species richness, diversity, evenness, and dominance are presented in Table II-19.0-28. Numbers of meaningful changes, by major taxonomic group, are presented in Table II-19.0-29.

Table 11-19.0-26. San Pedro Study Site - Temporal Variation.

Taxonomic Group	Density (#/m ²)		Species Richness/Sample		Diversity		Evenness		Dominance	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Station 819 (depth 32-34 m)										
Polychaetes	~~2280~~	2684	38	41						
Mollusks	472	~~620~~	12	16						
Arthropods	420	668	13	21						
Echinoderms	588	~~588~~	6	6						
Minor Phyla	128	172	5	5						
Summary	~~3888~~	4732	74	90	3.572	3.873	.885	.895	.046	.032
Station 825 (depth 250-270 m)										
Polychaetes	460	588	11	15						
Mollusks	60	152	2	5						
Arthropods	100	84	5	5						
Echinoderms	28	12	2	1						
Minor Phyla	12	16	1	1						
Summary	660	852	20	26	2.179	2.576	.803	.870	.218	.115
Station 827 (depth 504-507 m)										
Polychaetes	124	248	7	9						
Mollusks	120	152	4	3						
Arthropods	28	36	2	2						
Echinoderms	4	0	0	0						
Minor Phyla	36	16	2	1						
Summary	312	452	14	15	2.170	2.115	.937	.910	.137	.148
Station 828 (depth 530-543 m)										
Polychaetes	144	116	6	6						
Mollusks	164	132	4	4						
Arthropods	68	36	4	2						
Echinoderms	4	4	0	0						
Minor Phyla	28	28	2	2						
Summary	408	316	16	14	2.161	2.394	.913	.961	.152	.102
Station 821 (depth 689-706 m)										
Polychaetes	400	392	8	8						
Mollusks	68	24	3	2						
Arthropods	20	36	1	2						
Echinoderms	8	4	1	1						
Minor Phyla		76	3	2						
Summary	576 ⁸⁰	532	16	14	1.807	1.767	.729	.751	.317	.277
Station 823 (depth 873-881 m)										
Polychaetes	8	32	1	2						
Mollusks	36	16	1	1						
Arthropods	0	0	0	0						
Echinoderms	0	84	0	1						
Minor Phyla			1	1						
Summary	44	136	3	4	.444	.584	.320	.716	.76	.61

Table 11-19.0-27. San Pedro Study Site - Number Notable Changes/Number Taxa. Determined as increase in abundance occurring (1) at three or more replicates and/or (2) in numbers greater than 25 individuals per season.

Taxonomic Group	Station 819 (depth 32-34 m)		Station 825 (depth 250-270 m)		Station 827 (depth 504-507 m)		Station 828 (depth 536-543 m)		Station 821 (depth 689-706 m)		Station 823 (depth 875-881 m)	
	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm
Polychaetes	24/103	23/77	6/54	4/47	0	2/26	2/27	2/29	1/35	0/20	0/6	1/6
Mollusks	4/50	6/28	2/18	0/5	0	1/13	0/17	2/10	3/13	1/5	0/3	0/1
Arthropods	6/61	12/49	0/36	3/41	0	0/8	0/18	0/13	0/6	0/10	0/0	0/1
Echinoderms	4/14	0/4	0/0	0/3	0	0/0	0/2	0/2	0/5	0/1	0/1	0/1
Minor Phyla	3/19	2/14	0/8	0/5	0	0/8	0/12	0/4	0/14	0/3	0/4	0/0
Summary Values	41/247	43/172	8/116	7/101	0	3/55	2176	4/58	4/73	1/39	0/14	1/9

Table 11-19.0-28. Coal Oil Point Study Site - Temporal Variation.

Taxonomic Group	Density (#/m ²)		Species Richness /Sample		Diversity		Evenness		Dominance	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Station 801 (depth 66-71 m)										
Polychaetes	1112	1824	27	33						
Mollusks	240	504	9	9						
Arthropods	264	260	11	10						
Echinoderms	1056	1340	5	6						
Minor Phyla	184	252	6	8						
Summary	4180	5480	58	66	2.717	2.814	.726	.719	.190	.141
Station 802 (depth 329-340 m)										
Polychaetes	292	384	9	10						
Mollusks	60	40	2	2						
Arthropods	40	40	1	2						
Echinoderms	20	28	1	2						
Minor Phyla	32	12	2	1						
Summary	444	504	15	17	1.761	2.253	.672	.664	.345	.150
Station 803 (depth 502-506 m)										
Polychaetes	256	220	6	5						
Mollusks	312	260	4	3						
Arthropods	192	200	2	1						
Echinoderms	0	0	0	0						
Minor Phyla	12	8	1	1						
Summary	772	688	13	10	2.001	1.920	.824	.856	.190	.182

Table 11-19.0-29. Coal Oil Point Study Site - Number Notable Changes/Number Taxa. Determined as increase in abundance occurring (1) at three or more replicates and/or (2) in numbers greater than 25 individuals per season.

Taxonomic Group	Station 801 (depth 66-71 m)		Station 802 (depth 329-340m)		Station 803 (depth 502-506 m)	
	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm
Polychaetes	6/98	7/68	1/38	4/17	1/16	1/9
Mollusks	4/37	2/29	0/10	0/3	2/10	0/3
Arthropods	0/28	7/62	0/15	2/10	1/7	1/4
Echinoderms	0/14	1/7	0/7	0/3	0/0	0/0
Minor Phyla	0/25	0/17	0/10	0/1	0/5	0/0
Summary Values	10/202	17/183	1/80	6/34	4/38	2/16

19.9.4 Santa Rosa Ridge Study Site

Station 806 (96-99 m) exhibited no meaningful change in density, species richness, diversity, evenness or dominance. The overall change in faunal composition was insignificant at the 1.0 mm level and 12% for the 0.5 mm fraction. Among polychaetes and arthropods, from winter to summer, there was a general decrease in the number of individuals in the 0.5 mm fraction (small, immature animals) and a general increase in the number of individuals in the 1.0 mm fraction (larger, adult animals). There were indications of recruitment in the polychaete family Cirratulidae, but no other meaningful changes in individual species.

Station 808 (103-106 m) exhibited between winter and summer a large increase in density (2400/m² to 6100/m²) and in species richness (72 to 89). Diversity was somewhat reduced in summer and dominance increased, probably as a result of recruitment among species. Overall changes in faunal composition were 5% in the 1.0 mm fraction and 12% in the 0.5 mm fraction. In the 1.0 mm fraction, the amphinomid polychaete Chloeia pinnata showed recruitment from winter to summer, with population densities going from 0 in winter to 2500/m² in summer. Recruitment in summer was also evident for the amphipods Photis sp. and Gammaropsis ociosa. Juvenile spatangoids (echinoderms) also appeared in summer. In the 0.5 mm fraction, there was an apparent drop in the numbers of individuals in polychaetes between winter and summer.

Station 805 (231-246 m) showed an increase in density from winter to summer, but little increase in species richness. The overall change in faunal composition was minor--3% in the 1.0 mm fraction and 7% in the 0.5 mm fraction. There was a general increase in the number of large animals (present in the 1.0 mm fraction) from winter to summer, with a corresponding decrease in the number of small animals in the 0.5 mm fraction. No other identifiable changes occurred.

Station 809 (222-271 m) had an overall change in faunal composition of 10% for the 0.5 mm fraction, but less than 3% for the 1.0 mm fraction. There was a modest increase in density and species richness from winter to summer. Most of the increase in density represented the non-polychaete fractions, as there was a drop in the most numerous polychaetes from one sampling period to the next.

Station 810 (444-464 m) showed an overall change in faunal composition which was minor (3-4%) for both the 1.0 and 0.5 mm fractions. There was also very little change in density and species richness from winter to summer. Changes among individual species were minor with the exception of an apparent recruitment in summer, represented by increase in numbers of polychaetes belonging to the family Cirratulidae, the polychaete Cossura sp., the mollusk Dentalium sp., and certain ophiuroids.

Station 812 (1862-1871 m) showed only modest overall changes in faunal composition--2% in the 1.0 mm fraction and 4% in the 0.5 mm fraction. Similarly, there were very minor changes in density and species richness. Among individual species, no meaningful seasonal changes were noted.

19.9.4.1 Review Comments for the Santa Rosa Ridge Study Site

Characteristically, polychaetes and amphipods appeared to have recruited into the area from winter to summer, at least in shallower water. An intermediate (slope) depths there were indications of growth without recruitments in a number of taxa, in that species present in the 0.5 mm fraction during the winter were prominent in the 1.0 mm fraction during the summer. At slope depths there also seemed to have been a recruitment of polychaetes, mollusks and ophiuroids between winter and summer. Little change was noted in the Santa Cruz Basin. Changes in density, species richness, diversity, evenness, and dominance are presented in Table II-19.0-30. Numbers of meaningful changes, by major taxonomic group, are presented in Table 11-19.0-31.

19.9.5 Tanner Bank Study Site

Station 813 (96-103 m) showed an increase in density of 924/m² to 1376/m² and an increase in species richness of 32 to 42 between winter and summer. The overall change in faunal composition was 5% in the 1.0 mm fraction and 14% in the 0.5 mm fraction. Among individual species, there was an influx of the asteroid echinoderm Astropecten sp. between winter and summer and an apparent recruitment of various small polychaetes. The spionid polychaete Prionospio steenstrupi seemed to be reproductively active in winter.

Station 817 (511-530 m) showed an overall change in faunal composition from winter to summer of 9% and 7%, respectively, for the 1.0 and 0.5 mm fractions. Species richness and density appeared to increase from winter to summer. There appeared to be recruitment in winter of spionid polychaetes belonging to the genus Laonice, with small animals occurring in the winter 0.5 mm fraction and larger animals occurring in the summer 1.0 mm fraction. There were also indications of recruitment in the amphipod Ampelisca pacifica at this station.

Station 814 (929-940 m) showed no meaningful change in density and species richness between winter and summer. The overall change in faunal composition was 3% in the 1.0 mm fraction and 7% in the 0.5 mm fraction. There was recruitment of polychaetes belonging to the family Cirratulidae and possible recruitment of the capitellid polychaete, Notomastus precocis, but the situation otherwise remained stable.

Table 11-19.0-30. Santa Rosa Ridge Study Site - Temporal Variation.

Taxonomic Group	Density (#/m ²)		Species Richness/Sample		Diversity		Evenness		Dominance	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Station 806 (depth 96-99 m)										
Polychaetes	1024	1348	33	36						
Mollusks	504	696	9	11						
Arthropods	624	520	24	21						
Echinoderms	504	476	10	10						
Minor Phyla	360	440	7	6						
Summary	3016	3480	82	84	3.806	3.732	.905	.884	.036	.040
Station 808 (depth 103-106 m)										
Polychaetes	644	3476	22	36						
Mollusks	224	172	10	7						
Arthropods	652	1620	18	25						
Echinoderms	548	412	12	11						
Minor Phyla	384	448		11						
Summary	2452	6128	70	89	3.515	2.616	.903	.627	.046	.261
Station 805 (depth 231-246 m)										
Polychaetes	1484	1952	24	25						
Mollusks	268	280	5	7						
Arthropods	260	296	11	11						
Echinoderms	412	476	6	6						
Minor Phyla	52	32	2	3						
Summary	2476	3036	48	51	2.733	2.805	.750	.760	.146	.127
Station 809 (depth 222-271 m)										
Polychaetes	1020	1032	21	27						
Mollusks	120	208	5	6						
Arthropods	304	480	11	17						
Echinoderms	212	388	4	8						
Minor Phyla	116	144	4	6						
Summary	1772	2252	46	63	2.851	3.383	.813	.904	.113	.053
Station 810 (depth 444-464 m)										
Polychaetes	512	372	14	12						
Mollusks	96	132	4	5						
Arthropods	168	180	7	6						
Echinoderms	312	236	5	7						
Minor Phyla	48	40	3	2						
Summary	1136	960	32	32	2.691	2.820	.875	.926	.109	.079
Station 812 (depth 1862-1871 m)										
Polychaetes	224	204	8	7						
Mollusks	96	124	3	3						
Arthropods	40	40	2	2						
Echinoderms	84	52	2	2						
Minor Phyla	32	12	2	1						
Summary	476	432	17	14	2.230	2.124	.902	.905	.140	.149

Table 11-19.0-31. Santa Rosa Ridge Study Site - Number Notable Changes/Number Taxa. Determined as increase in abundance occurring (1) at three or more replicates and/or (2) in numbers greater than 25 individuals per season.

Taxonomic Group	Station 806 (depth 96-99 m)		Station 808 (depth 103-106 m)		Station 805 (depth 231-246 m)		Station 809 (depth 222-271 m)		Station 810 (depth 444-464 m)		Station 812 (depth 1862-1871 m)	
	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm
Polychaetes	5/108	8/63	7/135	4/58	4/73	7/51	2/112	9/62	3/64	1/26	0/30	1/12
Mollusks	2/28	1/14	0/49	1/14	1/24	0/9	1/29	0/7	0/19	1/6	1/14	0/2
Arthropods	1/88	9/65	8/86	12/60	0/48	1/42	2/64	2/34	1/32	0/21	0/8	0/8
Echinoderms	0/22	0/3	2/38	0/7	1/20	0/7	2/27	0/2	2/19	0/4	0/3	0/2
Minor Phyla	1/22	1/15	1/49	0/9	0/17	0/11	0/30	1/13	0/16	0/4	0/9	0/5
Summary Values	9/268	19/160	18/357	17/148	6/182	8/120	7/262	12/118	6/150	2/61	1/64	1/29

Station 813 (1 751-1758 m) showed little change from winter to summer in density, diversity, or species richness. The overall change in faunal composition was 11% in the 1.0 mm fraction and 5% in the 0.5 mm fraction. Numbers of specimens were too low for certain definition, but there were indications of recruitment in certain species, such as polychaetes of the family Cirratulidae, the mollusk Adontorhina cyclia, the amphipod Harpiniopsis sp. B, and juvenile ophiuroids.

19.9.5.1 Review Comments for the Tanner Bank Study Site

This area appeared to be stable from winter to summer in terms of densities and species richness, both in shallow and deep water. Recruitment of polychaetes was identified in both shallow and deep water. Spionids appeared to be recruiting in shallow water and cirratulids in deeper water. The information about sexual maturity did not indicate any major changes from winter to summer. Changes in density, species richness, diversity, evenness, and dominance are presented in Table 11-19.0-32. Numbers of meaningful changes, by major taxonomic group, are presented in Table 11-19.0-33.

19.9.6 Discussion

In inshore water, along the mainland shelf, recruitment of the polychaete Pectinaria californiensis took place in both regions (San Pedro and Coal Oil Point study sites). Since these regions are geographically well separated, this recruitment was considered to indicate a very successful spat-fall for this year for this species. In shallow water there was a general increase in both density and species richness from winter to summer; such a general trend was not present in deeper water.

In the offshore and intermediate areas, the increase in species richness and density appeared to be distinct down to about 500 m, i.e., about twice as far down the slope as in the inshore areas. Again, little change appeared to take place at basin depths. It should be remarked that the two offshore basins are considerably deeper than the corresponding basins in inshore waters. The recruitment of individual species was extremely varied, and no patterns were discernible, except that cirratulid polychaetes (presumably a species of Tharyx) appeared to be recruiting in deeper water in both basins.

In waters shallower than 150 m, there were distinct changes between winter and summer in all regions, especially among the polychaetes. The same species, however, did not seem to be involved in recruitment into all areas, indicating a mosaic pattern of recruitment to the southern California shelf. The polychaete Prionospio steenstrupi was sexually mature during winter both at Tanner Bank and on the mainland shelf off San Pedro, indicating a possibly restricted breeding season.

Table 11-19.0-32. Tanner Bank Study Site - Temporal Variation.

Taxonomic Group	Density (#/m ²)		Species Richness/Sample		Diversity		Evenness		Dominance	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Station 816 (depth 73-77 m)										
Polychaetes	*	1900	•	23						
Mollusks	•	100	*	4						
Arthropods	•	1036	*	14						
Echinoderms	*	332	*	5						
Minor Phyla	•	112	*	5						
Summary	*	3480	•	49	*	2.556	*	.703	*	.237
* no winter samples										
Station 815 (depth 96-103 m)										
Polychaetes	512	904	16	25						
Mollusks	68	56	3	2						
Arthropods	84	88	4	5						
Echinoderms	188	254	6	8						
Minor Phyla	72	44	4	3						
Summary	924	1376	32	42	2.884	3.177	.902	.922	.057	.054
Station 818 (depth 113-203 m)*										
Polychaetes	592	756	21	10						
Mollusks	0	56	0	3						
Arthropods	880	284	19	11						
Echinoderms	80	320	3	8						
Minor Phyla	0	52	1	3						
Summary	1552	1468	44	34	2.903	3.997	.838	.766	.109	.209
• Winter value based on 1 sample only										
Station 817 (depth 511-530 m)										
Polychaetes	312	368	6	8						
Mollusks	440	376	8	9						
Arthropods	1268	1492	10	14						
Echinoderms	16	36	1	2						
Minor Phyla	16	44	1	2						
Summary	2052	2316	26	34	2.246	2.183	.737	.686	.196	.215
Station 814 (depth 929-940 m)										
Polychaetes	376	296	14	10						
Mollusks	40	56	2	3						
Arthropods	96	124	5	6						
Echinoderms	80	80	1	0						
Minor Phyla	48	12	2	1						
Summary	568	488	24	20	2.699	2.635	.964	.962	.076	.383
Station 813 (depth 1751-1758 m)										
Polychaetes	136	76	4	3						
Mollusks	60	12	3	1						
Arthropods	8	16	1	1						
Echinoderms	8	24	1	1						
Minor Phyla	52	36	2	1						
Summary	264	164	10	7	1.662	1.18	.917	.938	.240	.391

Table 11-19.0-33. Tanner Bank Study Site - Number Notable Changes/Number Taxa. Determined as increase in abundance occurring (1) at three-or more replicates and/or (2) in numbers greater than 25 individuals per season.

Taxonomic Group	Station 816 (depth 73-77 m)		Station 815 (depth 96-103 m)		Station 818 (depth 113-203 m)		Station 817 (depth 511-530 m)		Station 814 (depth 929-940 m)		Station 813 (depth 1751-1758 m)	
	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm	1.0 mm	0.5 mm
Polychaetes	None; Summer Sample Only		6/27	7/52	1 Winter Sample Only		4/30	2/14	3144	2/31	2/20	1/8
Mollusks			0/12	1/4			3/29	0/2	0/12	1/6	1/10	0/3
Arthropods			0/26	2/21			4/45	1/25	0/28	0/16	1/4	0/4
Echinoderms			2/17	0/2			0/7	0/1	0/3	0/1	0/4	0/1
Minor Phyla			0/17	1/3			0/6	0/0	0/8	1/3	1/6	0/5
Summary Values			8/149	11/82			11/117	3/42	3395	4/57	5/44	1/21

11-19.0-145

At shallow slope depths (150-250 m) there were no distinct patterns present. At deeper slope depths (down to 1000 m except in the Santa Barbara and San Pedro Basins) identifiable recruitment of cirratulid and capitellid polychaetes appeared to take place in most areas. The large changes in mysids and amphipods in some of the inshore basins were difficult to interpret, but were taken to indicate patchiness and non-temporal variations rather than recruitment and loss in a stable population. At basin depths there appeared to be few general patterns. There were distinct changes in the ophiuroid and amphipod populations as discussed above in the inshore basins. In the Santa Cruz Basin, few changes could be discerned; in the San Nicolas Basin, distinct recruitment took place.

With only two data points, it was extremely difficult to comment on the validity of the patterns identified. At present, it appears best to indicate that seasonal recruitment may take place both in shallow and in deeper water. The identifiable changes appeared most clear-cut in shallow water and at basin depths. The changes in slope depths were less clearly interpretable, and this may indicate the time instability in the slopes, more than a lack of clear-cut recruitment in these areas. It was also certain that for this year, with one exception, no species recruited into the whole Southern California Bight at one time, at least as far as the patterns could be identified. In fact, it would appear that recruitment is a local phenomenon rather than a regional one, but this must, of course, be interpreted extremely carefully, since the apparent lack of recruitment in any one area may have represented patchiness at a scale that could not be discerned in the samples collected.

19.10 SUMMARY AND DISCUSSION

Aside from instances of massive impacts, the best documentation of man-caused changes in the marine environment is provided by studies of the impact of these changes on organisms that move only a little or not at all. Plankton and other organisms in the water masses are too quickly moved, whereas members of most benthic populations are sessile or poorly mobile. Benthic macrofaunal populations are thus more likely to show the effects of low-level, long-term insults, and because of this are the best potential indicators of the impact of offshore resource development on the biota.

Communities exhibit changes in space and also with time. Monitoring activities intended to assess the effects of any potential man-caused impacts must begin with knowledge of the extent of expected natural variations. By knowing how benthic associations vary naturally, one can then separate normal variations from man-caused changes. This distinction is basic to determining whether an impact has occurred, just as it is fundamental to evaluating the magnitude of the impact and assigning probable causes.

The sea floor of the Southern California Bight is much more complex than are typical continental shelves in most other parts of the world; it includes islands, banks, ridges, basin and troughs. A narrow strip of the sea floor, the mainland shelf, lies immediately adjacent to the continent. Both the mainland shelf and the island shelves are transected by numerous submarine canyons, and most of these descend into the basins.

Over this structural variety lies a highly diverse substrate pattern ranging from basement rock through extremely fine terrigenous sediments with increasing admixtures of planktogenic sediments from inshore to offshore basins. Water depths range from sublittoral to bathyal, and as a result the sea floor of the Bight consists of a complex set of benthic habitats that is large in proportion to the relatively small size of the region.

Just as the ocean floor is complex, so are the southern California water masses. The California Current is the dominant hydrographic feature, here as elsewhere along the California coast. This current controls the general water character and circulation of the region, and because of the indentation of the southern California coast, it flows past the Bight at its seaward edge, about 300 km offshore. Eddies predominate within the bight, east of the Current. A deep countercurrent, below 200 meters, flows northward along the coast of Baja California and brings warmer, more saline water to higher latitudes. "Upwelling" and other localized phenomena further complicate the picture. The great temporal variability of the current pattern of the Bight may well be an important influence contributing to the diversity of benthic associations. Certainly, the diversity of the macrobenthic fauna reflects the complex habitat pattern of the Bight.

The geographic location of the bight also contributes to the unusual diversity of the benthic fauna, as compared with other North American continental shelf associations. The Bight is located in the northern half of the Californian biogeographic region, which in itself is a transition zone between the Oregonian and Panamic, two much larger biogeographic regions. In addition to a large number of endemic forms, the Californian region also contains species characteristic of both of these larger biogeographic regions.

The present study was designed to describe the community structure and to delimit the extent of natural variations with time in the benthic macrofaunal associations at selected study sites. The benchmark study sites chosen for sampling and analysis were carefully selected to represent the wide range of benthic habitats in the Bight. Areas of possible leasing, offshore regions likely to be affected by oil and gas development, and areas of special biological interest were also emphasized. Where possible, the sampling plan was designed to coordinate with and complement the efforts of other oceanographic programs.

This study was intended to serve as the foundation for, and the plan of, a monitoring program. It was not a monitoring program in itself, since this term implies knowledge of natural variations that may be expected. The intent of the benchmark study program was to provide the Bureau of Land Management with a means to evaluate changes in the biota in a limited number of selected areas.

Replicate box core sampling was conducted in five areas: off San Pedro, on the slope of San Pedro Basin; off Coal Oil Point and on the slope of Santa Barbara Basin; on the shelf south of San Miguel Island; on the northern portion of the Santa Rosa-Cortes Ridge, including Tanner Bank, the slope of San Nicolas Basin and the Basin itself. Eight replicate samples were collected at each of the sampling locations comprising the five study sites. For analysis, the San Miguel Island shelf samples were combined with those from the Santa Rosa Ridge, its slope, and the Santa Cruz Basin. Replication provides the basis necessary to detail community structure and to determine spatial variability.

Sampling was conducted twice during the year, once in a period of low water temperature (late winter to early spring) and once in the period of high water temperature (late summer to early fall). With two data points alone (one winter and one summer), however, it is impossible to be certain of the validity of observed patterns.

It must be remembered that the biological benchmark objectives were not intended to be satisfied in a single year's effort. At least three years (six sampling periods) would be required to document temporal variation in the benthic macrofaunal associations at the benchmark sampling locations studied. For this reason, the results reported in this paper must be viewed as inconclusive, a preliminary effort to delineate ranges of natural variation in the southern California macrobenthos. Unfortunately, variation over time in the benthos has been little studied and scant background information is available on this topic.

As mentioned above, biological samples were collected with a box corer. The equipment used was a 1/16 m² USNEL spade (or box) corer. Bolted to this was an underwater camera unit designed to photograph the area sampled prior to penetration by the box corer. Photographs of the bottom were used to assess the benthic epifauna and to document the general nature of the habitat at the sampling locations.

On retrieval, the core was measured, described and subsampled and the macrofaunal invertebrates were separated from the substrate by screening through 1.0 mm and 0.5 mm mesh screens, using the "overflow-barrel" technique. The animals were narcotized in 6% magnesium chloride in seawater, killed and fixed in 10% buffered

seawater formal in, and preserved in 70% ethanol. Sample containers were labeled carefully, and detailed logs were kept of all sampling operations.

On completion of each leg of the benthic cruise, preliminary analysis of all preserved samples was conducted at the Benthic Sorting Laboratory. Depending on the sediment type of each sample, different processing techniques were used to reduce the volume of the sample prior to sorting. The faunal components of each sample were sorted into five major groups: polychaetous annelids, mollusks, crustaceans, echinoderms, and all other taxa ("minor phyla"). The number of specimens in each major group and the alcohol wet weight standing crop of each major group were determined after sorting.

Following preliminary analysis, samples were analyzed by the Rapid Identification Procedure (RIP). The objective of this method is to provide the best possible identifications and enumerations of the taxa in a sample within a restricted time period and with use of limited techniques. Samples were temporarily archived at the Benthic Sorting Laboratory.

Detailed analysis (complete analysis) was carried out in the taxonomic laboratories of the Allan Hancock Foundation, University of Southern California. In this phase of sample analysis, every specimen was identified to the lowest practicable taxon (usually the specific level) and the population density of each taxon was determined precisely.

Life stages of specimens were determined by a variety of techniques. Life stage categories used were juvenile, adult male or female, adult colony, reproductive male or female, and reproductive colony. A phylogenetic and ecologic (feeding and mobility types) spectrum of the benthic invertebrates was represented by the species selected for life stage determinations.

Feeding and mobility types were assigned by the systematists working on each of the major phylogenetic groups. Their determinations were based both on information from the literature and on assessments based on morphological considerations. For the purpose of this analysis, the primary adult feeding mode was used. Feeding categories included filter/suspension feeders, carnivores, surface detritus feeders, subsurface detritus feeders, herbivores, parasites, and unknowns. Mobility categories were motile, sessile and unknown.

Samples were characterized by wet weight standing crop per sample for each major group; total wet weight standing crop per sample; number of individuals per sample for each major group; total number of individuals per sample; a list of identified taxa with a count of the number of individuals of each identified taxon; determination of the life stage, feeding mode and mobility mode of each identified taxon

where practicable. Conversion of these data yielded the following variables and measures: percent of the total wet weight standing crop by major phylogenetic group; percent of the total number of individuals by major phylogenetic group; percent distribution of each species in each sample expressed as a percent of the total number of specimens; dominant species based on the occurrence of 5% or more of the total number of specimens in the sample; species richness; species diversity by the index of Shannon and Weaver (1949); evenness based on the Shannon-Weaver index; and dominance using the index of Simpson (1949).

Preliminary faunal analysis was accomplished by direct data inspection, although this method proved to be much less useful than in the baseline study.

Concordance, Kendall's Coefficient W (Siegel, 1956), was used to assess the degree of association among the members of each sample-set. Species were ranked by mean abundance, frequency and the number of affinities in a replicate sample set (winter + summer) in order to define the relative importance of the faunal components at each sampling location. Jumars' index of dispersion, or dispersion chi-square (Jumars, 1975) was used to assess spatial variation at each sampling location. Recurrent group analysis (Fager, 1957; Fager and McGowan, 1963) and classification (Smith, 1976) were used to identify benthic macrofaunal associations. Multiple discriminant analysis (Smith, 1978) was used to study the relationship between the biota and environmental variables. Between-community comparisons were made. Temporal variation in community structure was investigated. The results of the benchmark study provide an intensive analysis of the benthic macrofauna of the study sites.

Two study sites, the San Pedro study site and the Coal Oil Point study site, were on the mainland shelf, its slopes and in the adjacent basins. The sampling stations of the San Pedro study site were arranged in two transects of three stations each. One extended westerly from the shelf to the basin, the other followed a southeasterly trend down the slope. In the Coal Oil Point study site, the three stations formed a gradient from the shelf to the slope of Santa Barbara Basin, with the deepest station in this transect slightly below sill depth.

The faunal groups comprising the predominant feature of the benthic associations of each of these sampling locations were delineated. Criteria applied to the selection of the component species of each group included classification analysis, recurrent group analysis, and distributions which indicated that these species were the most "characteristic" of the areas in which they were identified.

Station 801 (68 m, Coal Oil Point study site) on the mainland shelf was typical of the Amphiodia urtica community. In addition to this dominant ophiuroid, species characteristic of this association

included the polychaetes Glycera capitata, Mediomastus californiensis, Paraprionospio pinnata, Spiophanes missionensis, Prionospio steenstrupi and Sthenelanelia uniformis, the pelecypod Mysella tumida, the ostracod Euphilomedes carcharodonta and the echiuran Listriolobus pelodes.

Station 819 (33 m, San Pedro study site) was the shallowest location on the mainland shelf and could be characterized as a shallow-water subcommunity of the larger Amphiodia urtica community. The presence of species associated with the polychaete Onuphis nebulosa were indicative of this, consistent with Jones, 1969. In addition to the subdominant polychaete Onuphis, species characteristic of this subcommunity included the polychaetes Streblosoma crassibranchia, Apoprionospio pygmaea, Asychis disparidentata, Melinna oculata, and Spiophanes bombyx, the gastropod Cylichna attonsa and Volvulella panamica, and the crustacean Pinnixa schmitti.

The sites on the upper mainland slope (station 825, 256 m, San Pedro study site; station 802, 336 m, Coal Oil Point study site) could be considered a transitional zone rather than sites with discrete species groups. A small number of species, however, appeared to be characteristic of this habitat, although none were "joined" by recurrent group analysis. Species characteristic of this upper slope environment were the polychaetes Nephtys cornuta franciscana, Maldane sarsi, Heteromastus sp., and Hesperonoe laevis, the echinoderm Brisaster latifrons, and the echiuran Arhynchite californicus. Most of these species also occurred at deeper locations on the slope.

The deeper mainland slope sites of the San Pedro study site (station 827, 504 m; 828, 541 m; and 821, 698 m) formed a more definite association. The species characteristic of this assemblage were restricted primarily to these sites. Predominant forms included the polychaetes Eclysippe trilobatus and Acesta lopezi rubra, the aplacophoran mollusk Chaetoderma sp. B and the pelecypod Tindaria californica, the echiuran Listriolobus hexamyotus and the nemertean Cerebratulus californiensis.

Station 803 (Coal Oil Point study site) at 504 m was situated on the slope slightly below the sill depth of Santa Barbara Basin, where the dissolved oxygen levels could be expected to drop to very low values. Species adapted to this situation comprised the benthic association inhabiting this location; some of these species were not encountered elsewhere in this study. The important forms here were the polychaetes Tauberia multibranchiata and Lagisca lamellifera, the gastropod Mitrella permodesta, the pelecypod Cyclocardia barbarensis and the amphipod Byblis barbarensis.

Station 823, in the San Pedro Basin, was very poorly defined by classification analysis. It was characterized by low numbers of poorly known organisms that occurred only at this location, and

editing of the data prior to analysis removed most of these organisms, to leave essentially a null site. Direct inspection of the data from this location revealed the polychaete Phyllochaetopterus limicolus, the gastropod Mitrella permodesta, and an unidentified entoproct to be the most important forms at this location.

At both the San Pedro and Coal Oil Point study sites, density, species richness and diversity values were highest on the mainland shelf. Generally, values declined with increasing depth on the slope. The principal exception was that species richness was nearly twice as great at station 803, just below the basin sill, than at station 802, on the slope above it. Values for these variables were lowest in San Pedro Basin.

Total standing crop values likewise generally declined with increasing depth, although the mean values were somewhat higher for replicates collected on the upper slope (stations 802, Coal Oil Point study site; station 825, San Pedro study site) than for shelf sampling stations. This was due mainly to the heavy weights of a few echinoderms, mainly urchins. Echinoderms, particularly the ophiuroid Amphiodia urtica, comprised the largest fraction of the standing crop at the shelf sampling locations. Polychaetes were second in importance. Polychaetes and echinoderms also made up well over half of the standing crop on the upper slope, with polychaetes somewhat more important at the San Pedro location and echinoderms slightly more important at Coal Oil Point.

Echinoderms decreased markedly with increasing depth, and polychaetes also became less important. On the lower slope of the San Pedro shelf and in the basin, members of the minor phyla became the dominant organisms by weight. At station 803, mollusk weights far exceeded those of all other groups.

At the shallowest location on the mainland shelf (station 819), physical instability, perhaps due to wave action, apparently produced a high-diversity, patchy community structure as shown by dispersion chi-square based on both the winter and the summer replicate sample-sets. Neither dominant of the shallow-water subcommunity of the Amphiodia urtica assemblage--Onuphis nebulosa nor Amphiodia--showed aggregation in the winter samples; Amphiodia was clumped in the summer samples, possibly indicating recruitment of this species. The Amphiodia urtica assemblage at station 801 (Coal Oil Point study site) was typical for the mainland shelf. It showed no departure from the random distribution characteristic of this large faunal unit.

The spatial distribution of the benthic macrofauna of the upper mainland shelf slopes (stations 802 and 825) displayed little deviation from randomness. The only important exception was the

occurrence of apparent patchiness of the polychaete Pectinaria californiensis in the summer replicates collected at station 825, which appeared to be strongly aggregated.

Generally, the fauna at the sampling locations on the lower slope at the San Pedro study site (stations 827, 828 and 821) appeared to be randomly distributed. Station 827 was shown to be aggregated, but the individual species indices of dispersion in the winter replicates showed no species that deviated significantly from randomness. Rather, the accumulation of small deviations from randomness by many species accounted for the total deviation. The summer samples from this station were truly aggregated. A single species, the pelecypod Tindaria californica, was sufficiently aggregated to cause the tinter samples collected at station 828 to deviate from randomness.

In the winter at station 803, also a lower slope site, two of the species found only at this location were shown to be significantly aggregated; these were the amphipod Byblis barbarensis and the pelecypod Cyclocardia barbarensis. These species did not deviate from randomness in the summer replicates. As at the other lower slope sites, there was a trend toward randomness but with the appearance of aggregation because of probable recruitment in a few species.

Randomness characterized the spatial distribution of the benthic macrofauna of the San Pedro Basin in both the winter and the summer.

In the consideration of trophic structure, it must be remembered that the benthos is ultimately dependent upon food deposited from overlying water. Almost all benthic organisms that rely primarily on this influx are either suspension or deposit feeders. The proportion of these animals in these two primary trophic roles provides information on the relative availability of food sources, as well as on the depositional environments in which they live.

The deposit-feeding organisms were generally strongly dominant at the mainland shelf sites, and there was little variation in the proportion of suspension to deposit feeders at any of the sampling locations. All sites were dominated by deposit-feeding forms, but subsurface deposit-feeders were dominant only on the slope. The prevalence of this feeding mode may be a response to sediment instability on the slopes.

The primary feeding index was lower at station 803 than at any other mainland shelf station. Just why this location would have supported fewer deposit feeders than usual was not clear.

Motile surface deposit feeders dominated the benthic fauna of the San Pedro Basin.

Ten percent of the fauna at all of the San Pedro study site sampling locations were motile carnivores, except in the basin, where their relative abundance was approximately 6%. Similarly organisms of this feeding mode comprised a relatively small proportion at two of the three sampling locations at Coal Oil Point (8% on the shelf; 18% on the upper slope; and 5% on the lower slope).

There has been little investigation of variation in the benthos over time, and there is consequently little background information available on this topic. A major reason for this has been the expense of repeated sampling of the same locations. In subtidal areas, temporal studies are subject to a sampling problem. Since temporal analysis consists of a close comparison of sample content with time, any patchiness exhibited at the level of the sample size could easily create enough random "noise" to obscure evidence of any temporal variations. Such patchiness has been exhibited. Further, caution is required in interpreting the results of the current study, as only two data points (one set of winter samples and one set of summer samples) were available for comparison, and any trends noted in the samples could easily have been caused by random effects rather than by normal temporal events in the benthos.

The length and poor focus of the reproductive period of benthic organisms both from shelf depths and deep water have been remarked upon by various investigators studying the reproductive periods of marine invertebrates in southern California (Emerson, 1975; Pilger, 1977; Rokop, 1974). These investigators have implied that, at least for the species investigated, recruitment can occur at almost any time of the year. Most species appear to be sexually mature in the first half of the year, however, and consequently the most recruitment would be expected in this time period. Such a long period of recruitment would create another source of confusion in any analysis of temporal variation. Any comments based on limited information would necessarily be very tentative in nature.

There appeared to have been recruitment among the polychaetes between winter and summer at the sampling locations on the shelf: Pectinaria californiensis, Spiochaetopterus costarum and maldanids at Coal Oil Point (station 801) and Pectinaria californiensis at San Pedro (station 819). On the upper slope, at station 825 in the San Pedro study site, there was an increase in the numbers of Pectinaria californiensis, but most of these specimens were adults. This pattern could indicate that the apparent increase on the slope might be due to environmental patchiness or, possibly, a local influx of specimens from shallow water. At station 802, on the slope at Coal Oil Point, there was recruitment of juveniles of the amphinomid polychaete Chloeia pinnata and possible recruitment of Pectinaria. Temporal variation was less evident at sampling locations on the lower slopes of both study sites.

In San Pedro Basin, density increased substantially from winter to summer at station 823. Many small ophiuroids, lacking in winter, were collected in the summer sample-set. The apparent recruitment in these animals may have been due either to a spat-fall or to vertical transport.

Two study sites, the Santa Rosa Ridge study site and the Tanner Bank study site, were associated with the Santa Rosa-Cortes Ridge and its slopes and the adjacent basins. One of the study sites, the Santa Rosa Ridge study site, also included two sampling locations on the nearby insular shelf. Seven of the stations comprising these two sites were relatively shallow (808 and 809 on the Ridge; 815, 816 and 818 on Tanner Bank and an adjacent topographic high; and 805 and 806 on the San Miguel Island shelf). Two stations, 810 and 817, were on the ridge and bank slopes, respectively. Eight replicate box core samples were collected at each sampling location during each of the two sampling periods with these exceptions: no winter collections were made at station 816; only a single sample was collected at station 818 in the winter; and but five of the eight required winter replicates were collected at station 808.

On the basis of classification and recurrent group analysis, four species groups could be identified from the Santa Rosa Ridge - Tanner Bank sampling location "complex" (stations 805, 806, 808, 809, 815, 816 and 818). In addition to the Amphiodia urtica assemblage which is also characteristic of the mainland shelf, two other ophiroid assemblages were identified at these locations: the Amphipholis squamata-Golfingia minuta (a sipunculid) assemblage and the Amphiura acrystata-Ampelisca cristata (an amphipod) assemblage. The other species associated with Amphipholis and Golfingia included the amphipod Urothoe varvarini and the polychaetes Subadyte sp. A and Pionosyllis uraga. The polychaete Lumbrineris acutiformis was associated with Amphiura and Ampelisca.

The fourth of the associations identified in this "complex" of stations was the Lumbrineris cruzensis (a polychaete)-Parvilucina tenuisculpta (a pelecypod) assemblage. This loosely aggregated species group occurred at almost all of the stations in this grouping. Many of the species were associated by recurrent group analysis, but those results did not include all of the co-occurring members of the assemblage. "All of the species, however, were loosely grouped by classification analysis. Associated species included the polychaetes Chloeia pinnata, Decamastus gracilis, Acesta catherinae, A*, near assimilis, Glycera tessellata, Travisia brevis and Euchone hancocki; the gastropod Amphissa undata and the pelecypod Tomburchus redondoensis; the microcrustaceans Byblis veleronis, Ampelisca pugetica, Diastylis sp. A, Maera simile and Photis lacia; and the urchin Allocentrotus fragilis.

The two stations (810 and 817) on the slopes of the ridge and bank appeared to represent a slope transition area. Although these sites produced a rather distinct species group as a result of classification, most of these species also occurred at the shallower locations on the ridge and bank and a few were also collected in deeper water. This species group--which includes the polychaete Lumbrineris cruzensis, the pelecypods Huxleyia minuta and Adontorhina cyclia, and the amphipods Ampelisca pacifica and Paraphoxus daboius--was not a strongly associated group, but rather a loose aggregation of common species that co-occurred at these two stations.

Generally, the values of the density, species richness and diversity measures were high in shallow-water samples; they did not, however, decrease in a consistent pattern with increasing water depth as seen in the mainland sites. In several instances, they were surprisingly high in relatively deep water (for example, station 809; density, 2,012 specimens/m²; species richness, 55 species/sample; and diversity, 3.117). For the most part, values on the insular shelf and ridge were higher than those on the banks; station 817 on the bank slope was a notable exception, as these values for this location exceeded those at station 810 on the ridge slope.

Below 200 meters, values for these three variables tended to be higher than for locations at corresponding depths on the mainland slope. Like the mainland shelf and its slopes at depths above 500 meters, polychaetes were the numerically most important taxon.

Standing crop values were generally higher at sampling locations on the insular shelf, the ridge and its slope than at locations on the bank and its slope. Standing crop values were highest at station 809 (mean, 194 g/m²) on the ridge. They were nearly as high on the rise north of Tanner Bank, station 818 (mean, 93 g/m²); they were intermediate at the other shelf, ridge and ridge slope stations (73-82 g/m²) and were lowest on the banks (36-66 g/m²) and on the bank slope (station 817, 22 g/m²).

Echinoderms formed the predominant component of the standing crop at all locations except the shallowest on the bank, where polychaetes were dominant. Polychaetes were secondary in importance at all of the other locations except on the bank slope. At station 817, all five major groups contributed nearly equally to the standing crop.

The spatial distribution of the benthic fauna at all of the sites of the Santa Rosa Ridge - Tanner Bank "complex" differed significantly from random dispersion. At first glance, these findings were precisely the opposite of the results of classification analysis, wherein most of these locations were not clearly sorted on the basis of faunal composition. The difference could be explained by considerations of scale. On a large scale, the Santa Rosa Ridge sampling locations seemed to be homogeneous, but when spatial

dispersion information between the replicates was obtained, the organisms appeared to be clumped (scale, theoretically 1000 m from a central point).

Of the four assemblages described previously, the Amphiodia urtica assemblage, most abundant on the mainland shelf, extended with decreasing abundance along the Santa Rosa Ridge to Tanner Bank. The Amphipholis squamata assemblage, best developed on the Santa Rosa Ridge, also extended onto Tanner Bank. Amphiura acrystata was found only on Tanner Bank, with the exception of a single specimen from station 819. The large, diverse Lumbrineris cruzensis-Parvilucina tenuisculpta assemblage was found both on the Santa Rosa Ridge and at Tanner Bank. At many of the stations, two to three of these assemblages were found together. These different species groups also appeared to be separated temporally. For example, in the summer replicates from station 809, Amphipholis squamata and a closely related species, A. pugetana, showed aggregation. Amphiodia urtica was present, but 'not highly aggregated. In the winter replicates, Amphipholis squamata was randomly dispersed, A. pugetana was absent, and Amphiodia urtica was more aggregated. In-addition, species such as the polychaete Chloeia pinnata showed extremely large deviations from randomness. This species was sometimes collected in these areas in very high numbers, up to 5,984/m², and these large patches were apparently made up of newly recruited organisms. This aggregation of large patches of a single species would then be reflected in the dispersion chi-square value for the site.

These several associated species groups contributed to a spatial and temporal mosaic and a resulting overall elevation of diversity at these stations. Such a community should be expected to show strongly aggregated spatial orientation.

The benthic macrofauna on the ridge slope (810) and the bank slope (817) has been characterized as transitional. Many members of the ridge and bank fauna were still present at these depths and thus retained the similar characteristic spatial associations. In the summer replicates from station 810, no species had an index of dispersion significantly different from random. This station was aggregated in winter mainly because of aggregations of Amphipholis squamata, Amphipholis pugentana and Chloeia pinnata. Much of the apparent aggregation at station 817 resulted from patches of the amphipods Ampelisca macrocephala, A. pacifica and Bybilus bathyalis.

The primary feeding indices for the Santa Rosa Ridge and Tanner Bank sites were lower and more-variable than at the mainland sites. Both physically and biotically heterogeneous, these sites had ample food for higher trophic levels apparently stemming from their high diversity and species richness. Carnivores were dominant at four of the seven sites, primarily because of two species of polychaetes, Chloeia pinnata and Onuphis, near nebulosa. Chloeia in particular

appeared in large patches; the two species may have contributed to maintaining the high diversity in this area. Although the two did co-occur, when one was abundant the other was not.

Station 815 had a much higher primary feeding index than any other ridge or bank site. This finding was difficult to explain, as no single species dominated strongly and the sediments were very sandy, with a low percentage of organic carbon.

In general, the results supported the idea of faunal heterogeneity at these sites and showed that the Santa Rosa Ridge system supported an assemblage with a highly variable trophic structure not present on the mainland shelf or slopes.

Much the same trend was shown for the sites on the Santa Rosa Ridge slope. Suspension-feeding organisms strongly dominated at station 817, primarily because of large numbers of the amphipod Byblis bathyalis. At station 810, carnivores were the dominant feeding type, but Chloeia and Onuphis were nearly equally abundant. Station 814, as shown in Figure 19-37, was grouped with the basin sites because their depositional environments were probably very similar. Organic material produced on the banks and ridge is deposited primarily at the base of the slope and in the basins, and this heavy deposition was reflected at station 814 by the predominance of subsurface forms.

Only slight evidence of temporal change was observed at sampling locations on the ridge and the bank. On the insular slope and ridge, polychaetes and amphipods characteristically appeared to be recruited into the area from winter to summer. At intermediate depths there appeared to be growth without recruitment in a number of taxa. At slope depths, there also seemed to have been recruitment of polychaetes, mollusks and ophiuroids between winter and summer. Seasonal information for the shallow-water bank locations was limited, as winter sampling was incomplete at three stations. Generally, both on the bank (815) and its slope (817) densities and species richness were stable from winter to summer. Recruitment of spionids was identified at both of these locations.

Each of the basins sampled in this study, the nearshore San Pedro Basin and the outer Santa Cruz and San Nicolas Basins, supported a different faunal association. However, the polychaete Phyllochaetopterus limicolus occurred at all three sites and another polychaete, Sternaspis sp. A, occurred at both outer basin sites (812 and 813). The Santa Cruz Basin had the most closely associated species group. This assemblage included the ophiuroids Ophiophthalmus normani and Ophiura leptoctenia, the mollusks Tindaria kennerlyi and Adonorhina cyclia, the polychaete Neoamphitrite sp. A, and the microcrustacean Harpiniopsis fulgens.

The faunal association of the San Nicolas Basin sampling location was poorly defined. An undescribed sipunculan, Golfingia (P.) sp. C was collected only in San Nicolas Basin. The other members of this assemblage were the polychaete Sternaspis sp. A and the cnidarian Dynamena desmoides.

Station 814, at the bottom of the Tanner Bank slope, was interesting. Its faunal composition differed markedly from that of the shallower ridge station, apparently in response to the environmental factors which were similar to those of the outer basins. The organic carbon in the sediment at station 814 was higher than at any other area sampled. This finding attested to the high productivity of the ridge system and to the fact that most of the organic material produced on the bank top must eventually be deposited at the base of the slopes. The faunal assemblage at this location included two species not found elsewhere, the polychaete Asychis sp. C and the microcrustacean Leucon magnadeutata. The other species of this assemblage were the polychaetes Phyllochetopterus limicolus, Tauberia oculata and Rhodine bitorquata, and the microcrustacean Harpiniopsis epistomatus.

Density, species richness and diversity values were higher for the samples collected from Santa Cruz Basin than for those from San Nicolas Basin. The values for these variables were much higher for the outer basins than for San Pedro Basin. Polychaetes were the numerically dominant group at both outer basin sampling locations.

The sampling location on the lower slope of San Nicolas Basin had higher density, species richness and diversity values than either outer basin. Polychaetes dominated the fauna at this site also.

Standing crop was highest in Santa Cruz Basin (24 g/m²), intermediate in Santa Cruz Basin (15 g/m²) and lowest in San Pedro Basin (6 g/m²). Standing crop was also quite low (7 g/m²) at station 814, on the lower slope of San Nicolas Basin. Polychaetes were numerically dominant in Santa Cruz Basin, mollusks in San Nicolas Basin "and representatives of the minor phyla in San Pedro Basin. Polychaetes were strongly dominant at station 814.

Random dispersion characterized the spatial distribution of the benthic macrofauna of the San Nicolas Basin sampling location; the fauna at the San Pedro Basin location was similarly distributed. The Santa Cruz Basin location (station 812), however, was shown to have aggregated species, but the reason for this disparity between apparently similar habitats was not clear. The apparent aggregation may have resulted from transient species aggregation. Two species were shown to deviate from randomness in winter; in summer, neither of these species was present at this station and a single other species was responsible for a barely significant deviation from randomness. The observed aggregation at this site may not have represented the general conditions typical of the other deep basins, i.e., random dispersion with low species diversity.

The fauna at station 814 on the lower slope of San Nicolas Basin was randomly distributed.

The basin sites were dominated by deposit feeders. These results were expected, since the basins act as food traps. Station 813 in San Nicolas Basin had a slightly lower primary feeding index than the other stations, due mainly to the presence of the hydroid Dynamena desmoides. As at other slope locations, sub surface deposit feeders were numerically dominant at station 814.

Temporal changes in faunal composition in Santa Cruz basin were only modest. Similarly, there were very minor changes in density and species richness. Among individual species, no meaningful seasonal changes were noted. The fauna of station 813, in San Nicolas Basin changed little from winter to summer in density, species richness and diversity. There were indications of recruitment in certain species, such as cirratulid polychaetes, the pelecypod Adontorhina cyclia, the amphipod Harpiniopsis sp. B, and juvenile ophiuroids.

No meaningful change in density and species richness between winter and summer was detected at station 814. The faunal composition remained stable with the exception of apparent recruitment of cirratulid polychaetes and possible recruitment of the capitellid polychaete Notomastus precocis.

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