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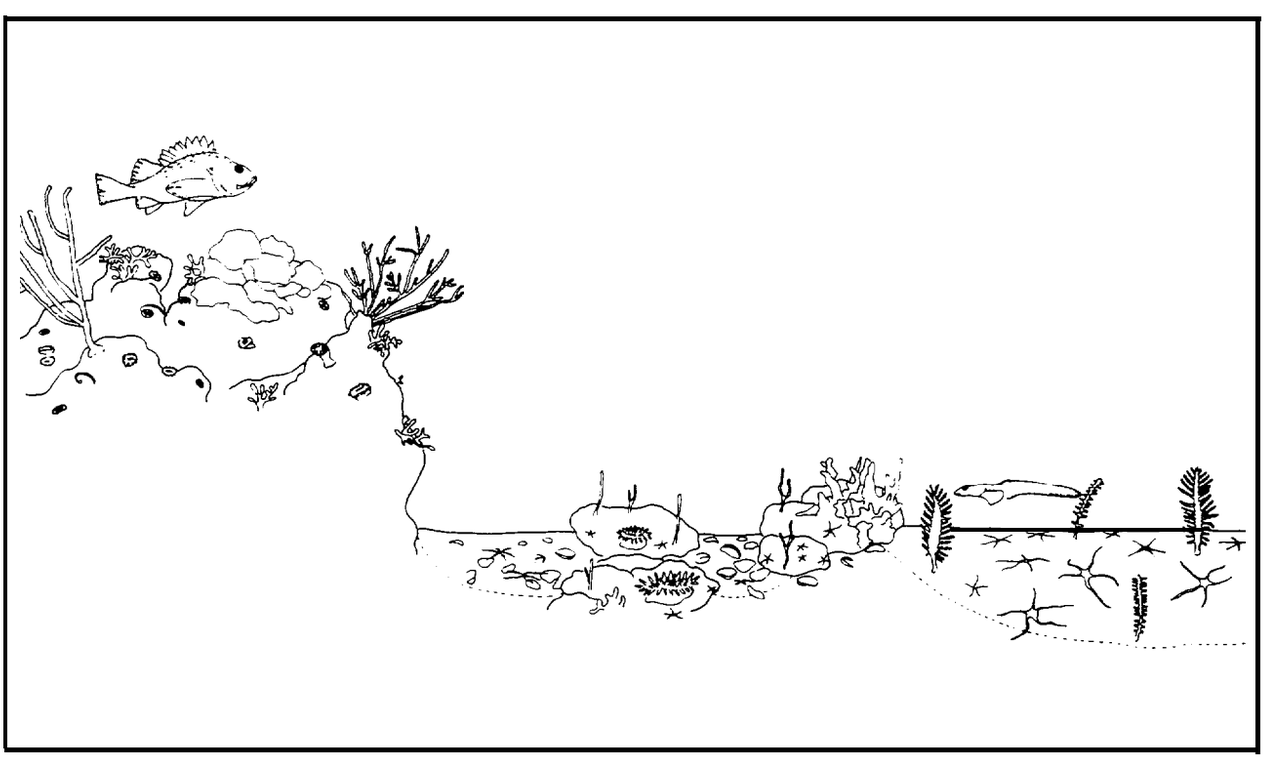
OCS Study
MMS 89-0039

BENTHIC RECONNAISSANCE OF CENTRAL AND NORTHERN CALIFORNIA OCS AREAS

FINAL REPORT 1989
Volume I



U.S. Department of the Interior
Minerals Management Service
Pacific OCS Region

OCS STUDY
MMS 89-0039

BENTHIC RECONNAISSANCE OF CENTRAL AND NORTHERN CALIFORNIA OCS AREAS

FINAL REPORT

VOLUME I: TECHNICAL REPORT

July 1989

Edited by

Andrew Lissner
Science Applications International Corporation

Submitted by

Science Applications International Corporation
4224 Campus Point Court
San Diego, California 92121

and

MEC Analytical Systems, Inc.
2433 Impala Drive
Carlsbad, California 92009

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Minerals Management Service
U.S. Department of the Interior
Pacific OCS Region
1340 West Sixth Street
Los Angeles, California 92121

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PROJECT ORGANIZATION

PROGRAM MANAGER

Dr. Andrew Lissner
Science Applications International Corporation
4224 Campus Point Court
San Diego, California 92121

CONTRACTING OFFICER'S TECHNICAL REPRESENTATIVE

Dr. Gary Brewer
U.S. Department of Interior
Minerals Management Service
Pacific OCS Region
1340 West Sixth Street
Los Angeles, California 90017

PRINCIPAL AUTHORS

Dr. Andrew Lissner-Science Applications International Corporation
Dr. Arthur Barnett-MEC Analytical Systems, Inc.
Dr. Thomas Johnson-MEC Analytical Systems, Inc.
Dr. Robert Kanter-MEC Analytical Systems, Inc.
Dr. Robert Smith-EcoAnalysis, Inc.

CONTRIBUTING AUTHORS

Dr. Douglas Diener-MEC Analytical Systems, Inc.
Mr. John Ljubenkov-MEC Analytical Systems, Inc.
Mr. William Watson-MEC Analytical Systems, Inc.
Mr. Charles Phillips-Science Applications International Corporation
Mr. Dale Roberts-Science Applications International Corporation
Ms. Suzanne Benech-Benech Biological and Associates

QUALITY REVIEW BOARD MEMBERS

Dr. Donald Boesch-Louisiana Universities Marine Consortium
Dr. Paul Dayton-Scripps Institute of Oceanography
Dr. Gilbert Jones-University of Southern California

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Technical Review

Dr. Robert Kelly - SAIC
Mr. Richard Wright - SAIC
Ms. Karen Green - Independent Consultant
Dr. Craig Smith - University of Hawaii
Dr. Gary Taghon

Sample Collection

Dr. Andrew Lissner - SAIC
Mr. Gary Paquette - SAIC
Mr. Richard Wright - SAIC
Mr. Kelvin Barwick - MEC
Mr. Douglas Beanan - MEC
Ms. Cheryl Brown - MEC
Mr. Troy Delle - MEC
Dr. Douglas R. Diener - MEC
Mr. Michael Gunnels - MEC
Mr. John Ljubenkov - MEC
Ms. Suzanne Benech - Benech Biological and Associates

Laboratory Analyses

Dr. Douglas R. Diener - MEC - Crustacea and Echinodermata
Ms. Susan Garner - MEC - Crustacea
Ms. Karen Green - Consultant - Polychaeta and Porifera
Mr. John Ljubenkov - MEC - Mollusca, Cnidaria, and minor phyla
Mr. Larry Lovell - MEC - Polychaeta
Mr. Scott Snover - MEC - Sediment Analyses

Taxonomic QA/QC

Dr. Mary Bergen - SLC - Holothuroids
Dr. Rick Brusca - SDMNH - Isopoda
Mr. Don Cadien - LACSD - Gastropoda
Ms. Karen Green - Independent Consultant - Porifera
Ms. Leslie Harris - AHF - Polychaetes
Dr. Gretchen Lambert - CSUF - Tunicates
Mr. Tony Phillips - Hyperion Biology Laboratory - Crustacea
Mr. Paul Scott - SBMNH - Pelecypoda
Dr. Pete Slattery - Moss Landing Marine Laboratory - Crustacea
Dr. Bruce Thompson - SCCWRP - Sipuncula
Dr. George Wilson - S10 - Crustacea

Production/Graphics

Ms. Joan Solinsky - SAIC - Editor
Mr. James Stone - SAIC - Word Processing
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Ms. Julie Ann Schneider - Independent Consultant - Cover Artwork
Mr. Joe Zorskie - GeoAnalysis - Graphics

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1.0 PROGRAM OVERVIEW

This section presents the background (Section 1.1) and objectives (Section 1.2) of the Minerals Management Service Program to conduct a "Benthic Reconnaissance of Central and Northern California OCS Areas." A summary of findings and recommendations from the study are presented in Sections 1.3 and 1.4, respectively.

The overall report is organized into two volumes. Volume I comprises four major sections and one Appendix: Program Overview (Section 1); Materials and Methods (Section 2); Results and Discussion (Section 3); References (Section 4); and Data Analysis Methods (Appendix A). Volume II contains the technical appendices, including a synopsis of the planned survey locations, actual survey coordinates, and taxonomic lists of hard substrate and soft substrate organisms. A Photographic Documentation Report, including 70-mm and 35-mm photographic slides of the benthic communities and color video tapes of the hard substrate transects, was submitted separately to MMS. A Data Report listing all data collected and analyzed for the study was submitted to MMS in November 1988.

1.1 BACKGROUND

The Minerals Management Service (MMS) program to conduct a "Benthic Reconnaissance of Central and Northern California OCS Areas" was intended to increase the knowledge of marine benthic habitats within the Central and Northern California OCS (Outer Continental Shelf) Planning Areas (Figure l-l). The initial program design also included study sites in the Southern California OCS Planning Area; however, these sites were not surveyed due to weather and schedule constraints. The general program consisted of a field survey conducted in November/December 1987 of selected hard substrate and soft substrate habitats from approximately 50-m to 600-m depth (165 ft to 1850 ft), laboratory and data analyses, and report preparation to characterize the biological communities, particularly as related to differences in geographic range (e.g., latitude), bottom depth, and substrate type. The study area was located in possible oil and gas lease sites from the Central and Northern

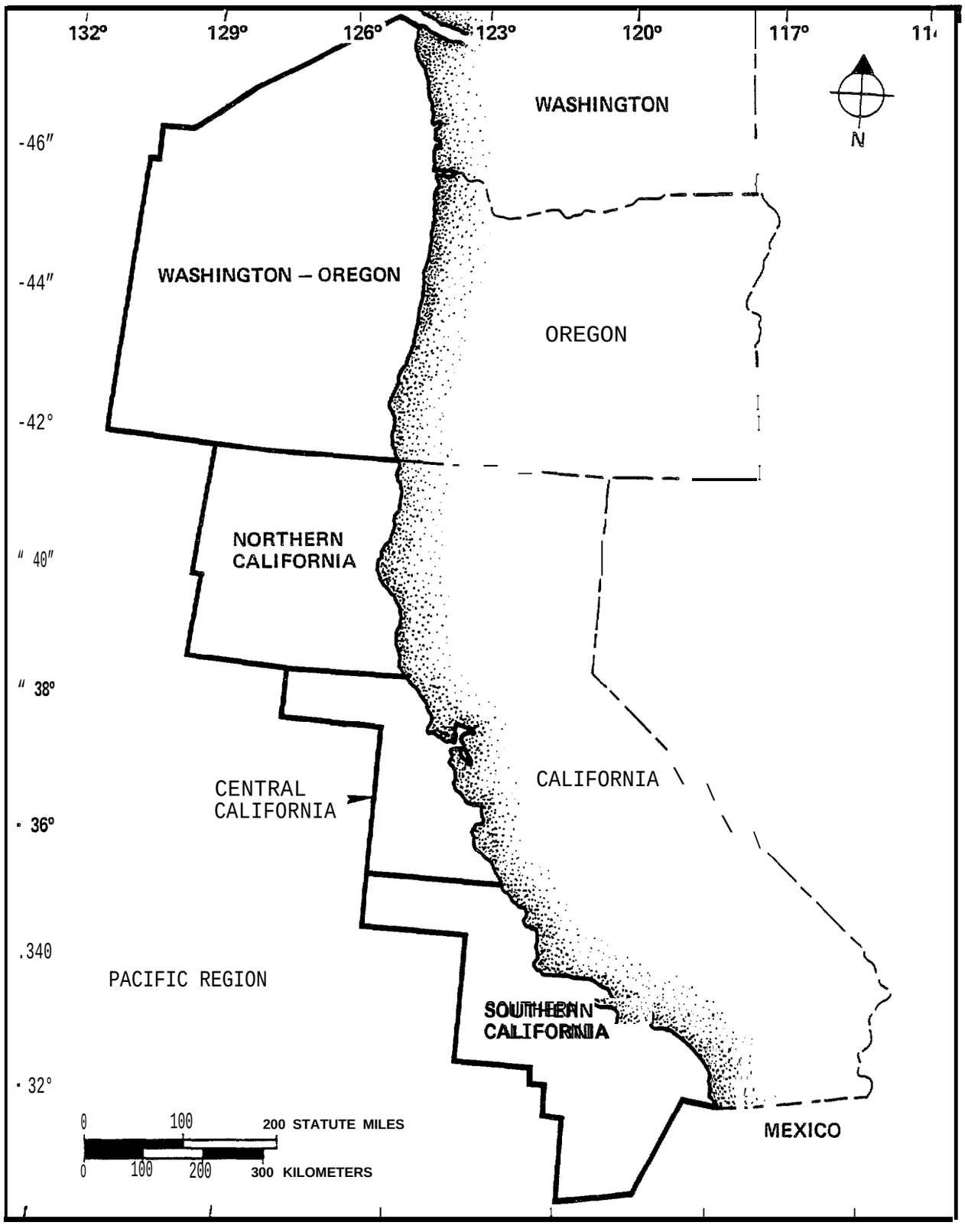


FIGURE 1-1. MMS NORTHERN, CENTRAL, AND SOUTHERN CALIFORNIA PLANNING AREAS

California OCS Planning Areas for which there was little or no information on the benthic communities.

Several historical studies including the BLM Southern California Bight Baseline Program (e.g., Fauchald and Jones, 1977, 1978a,b); the MMS Phase I reconnaissance survey of the Santa Maria Basin and western Santa Barbara Channel (SAIC, 1986); the MMS Phase II monitoring program (Battelle, 1988); and industry-sponsored studies, including Chambers Consultants (1982), Dames and Moore (1983, 1984), Engineering Science (1984), and McClelland Engineers (1985), provide a basis for comparison with the results from the present study. However, most of the historical data were collected south of the present study sites and therefore are most useful for comparing community differences between geographic areas.

1.2 OBJECTIVES

General objectives of the study included:

(1) Survey benthic communities at selected sites within the three California OCS Planning Areas to obtain quantitative data on species distributions and abundances, community structure, and selected environmental variables that may affect the communities; and

(2) Analyze statistically the community structure and variability within and among the sampling sites, and integrate information from previous studies to provide area-wide mapping, comparisons, and interpretations.

The study was designed to provide a broad-scale reconnaissance of the benthic communities of the Planning Areas; however, as noted in Section 1.1, actual survey operations were conducted only in the Central and Northern California OCS Areas. The survey design emphasized collections of single samples at soft substrate sites and surveys of single transects at hard substrate sites in order to provide coverage within the available sampling effort over a range of bottom depths and geographic locations. Replication was performed in some areas to assess within-site variability.

The overall program was conducted by a team of scientists and engineers from Science Applications International Corporation (San Diego, CA and Newport, RI offices), MEC Analytical Systems, Inc. (Carlsbad, CA), EcoAnalysis, Inc. (Ojai, CA), Benech Biological and Associates (Ventura, CA), Remote Ocean Systems (San Diego, CA), and advisors and independent consultants from Scripps Institute of Oceanography, University of Southern California, Louisiana Universities Marine Consortium, Oregon State University, and University of Hawaii.

Different field-sampling methods were used for the hard substrate and soft substrate surveys to meet objective (1) above, The hard substrate survey was conducted using a remotely operated vehicle (ROV). The ROV was equipped with systems to: (1) record continuous color video and observer commentary of the benthic communities; (2) collect 70-mm color photographs for quantitative macrofauna analyses; (3) collect 35-mm macrophotographs for taxonomic verifications; and (4) collect rock samples with attached biota for analysis of smaller fauna and as an aid to taxonomic identifications. The soft substrate survey included collections of infauna/epifauna, sediment TOC, and grain-size samples using a 0.1-m^2 box corer. In addition, 35-mm photographs of the ocean bottom at the point of coring were obtained. Water temperature and dissolved oxygen concentrations were recorded at both the hard substrate and soft substrate sampling sites. Measurements of near-bottom water conductivity and currents, although not specified in the work plan, also were attempted at the hard substrate sites, and incidental observations were made of seabirds, marine mammals, and fishing activity in the survey areas.

The general approach for achieving objective (2) included summary statistics of biological, physical, and chemical parameters; multivariate and univariate data analyses and graphical presentations of community distribution patterns, habitats, species abundances, and environmental parameters; and illustrations and general descriptions of new taxa. The relationships between species/ communities distribution patterns and environmental parameters also were examined using multivariate techniques. Environmental parameters included sediment grain size, TOC, substrate type (e.g., boulders or cobble), and substrate relief; near-bottom water variables such as temperature, salinity,

dissolved oxygen, and currents; bottom depth; and geographic location (e.g., basin).

Another element of the overall program, a "Review of Recovery and Recolonization of Hard Substrate Communities of the Outer Continental Shelf," was submitted to the MMS in June 1988. This report, along with the results from the reconnaissance study of hard substrate and soft substrate communities, will aid the MMS in making environmental analyses and management decisions concerned with potential oil and gas activities within the California OCS Planning Areas.

1.3 SUMMARY OF FINDINGS

This section presents a summary of the major findings from the study, including hard substrate and soft substrate results (Sections 1.3.1 and 1.3.2, respectively) and the observations of seabirds, marine mammals, and fisheries activities (Section 1.3.3).

1.3.1 Hard Substrate

1. Eight of 14 transects estimated to be located in hard substrate areas, based on side-scan sonar records, were characterized entirely or predominantly by soft substrate. These soft substrate areas were presumed to represent hard substrate overlain by sediment veneer. Indirect evidence suggesting this conclusion, in addition to the side-scan records, included hard substrate visible at the bottom of 0.3-1 m holes in some sediment veneer areas and hard substrate epifauna (e.g., basket stars) that were "stranded" in other soft substrate areas, presumably due to sediment encroachment on hard substrate. Only three transects were characterized by extensive (> 75%) hard substrate; one other transect was characterized by approximately 30% hard substrate and four by approximately 3-15%. One deep (224-285 m) transect in the Eel River Basin was unique in having extensive areas of wood

debris which provided (presumably) ephemeral hard substrate habitat.

2. Hard substrate relief greater than 3 m only was observed along one transect each in the Point Arena and Santa Cruz Basins; these transects also corresponded to the shallowest survey depths (61-85 m). The remaining hard substrate areas generally were low relief (< 15 cm).

3. Transect areas characterized primarily by sediment veneer typically had flat muddy bottoms with a range of small- and large-scale disturbances including burrows (indicating biological activity), furrows suggesting trawl tracks, and ripples indicating current patterns. Higher frequencies of burrows observed in the Eel River Basin probably are related to increased infaunal abundances, as noted from the soft substrate core samples (Section 3.2). Ripple patterns observed over a range of bottom depths from 61-192 m probably are the result of significant near bottom currents. These observations and the relatively high (e.g., > 25 cm/see) near-bottom currents recorded at depths greater than 200 m during the survey (including one observation of 50 cm/sec at 246 m depth) suggest a significant potential for sediment resuspension and movement in these deep benthic environments.

4. Near-bottom water temperature data indicated a general decrease with increased bottom depth, ranging from highs of 11.5-12.0 degrees C at 60-66 m depth to lows of 5.1-5.7 degrees C at 235-316 m depth. Dissolved oxygen data also indicated a trend of decreased levels with increased depth, ranging from highs of 9.2-9.3 ml/1 at 60-66 m depth to a low of 2.4 ml/1 at 278 m depth. The temperature and dissolved oxygen data were both within the range of expected values. The salinity data generally showed an expected increase with increased depth, although values < 33 ppt recorded from some shallow transects may represent an equipment

malfunction; other values were within the expected range of approximately 33-35 ppt.

5. Multivariate analyses of the video data delineated five station groups and associated taxa primarily distinguished on the basis of substrate type (hard versus sediment veneer) or substrate-related features (e.g., relief). Of these groups, two represented the majority of the sediment veneer habitats along most of the transects, one represented areas which appeared to be marginal hard substrate habitat (very low relief and heavily "silted"), and the remaining two represented exposed hard substrate areas along the relatively few transects where this habitat was observed.

6. Common taxa were highly representative of the major differences in substrate type (hard versus sediment veneer) observed along the transects. Common taxa on hard substrate included anemones (e.g., Metridium senile), feather stars (Florometra serratissima), cup corals (e.g., Paracyathus stearnsii, Balanophyllia elegans, and Caryophyllia spp.), several sponge taxa (morphs), and rockfish (Sebastes spp.), and in low relief areas brachiopods (Laqueus californianus) and ophiuroids. In contrast, sediment veneer areas generally were characterized by sea pens, Octopus rubescens, sea stars (Luidia foliolata), various flatfish, pacific hake, and poachers. It is notable that some sea pen species (e.g., Stylatula elongata) which typically retract into the bottom generally were absent from the deeper (e.g., > 200 m) sediment veneer transect areas, potentially indicating shallow sediment depths that may limit their retraction or, alternately, to limitations in the depth distribution of this species.

7. The total number of taxa observed from video, photoquadrat, and rock samples data is 134, 139, and 195, respectively. Principal differences between the video/photographic and rock samples taxa (excluding fish, rays, and sharks) are the predominance of coelenterates, echinoderms, sponges, and bryozoans from the

video/photographic data as compared to polychaetes and crustaceans from the rocks. These differences primarily are related to the different viewing scales and level of taxonomic identifications which are possible using these methods.

8. Additional multivariate analyses focusing separately on the hard substrate and sediment veneer data from the transects comprised the primary assessments of community differences and related environmental variables. The hard substrate analyses delineated five main station groups, based on the video data. Of these groups, two represented a broad range of survey depths (101-285 m) from the Eel River Basin and were characterized by sparsely occurring hard substrate species (e.g. , the anemone Metridium senile and low growing sponges) in low relief outcrop areas and some typical soft substrate taxa (e.g., sea pens and Octopus rubescens); two groups represented scattered low relief (< 1 m) "middle depth" (113-161 m) transect areas in the Point Arena and Bodega Basins and were characterized by brachiopods (Laqueus californianus) , ophiuroids, tan zoanthids, feather stars, anemones, basket stars, sparsely occurring cup corals and gorgonians, white foliose sponges, a variety of encrusting sponges, and numerous fish (particularly rockfish) and ray species; and one group which represented the transect areas of highest relief (l-3 m +) and shallowest survey depths (61-85 m) and was characterized by several taxa in common with the middle depth group including feather stars, basket stars, white foliose sponges, gorgonians, and rockfish, but which also had numerous distinguishing taxa including cup corals, the bryozoan Diaperoecia spp., jewel anemones (Corynactis californica), and the rockfish Sebastes mystinus.

9. Multivariate analyses of the photoquadrat data, based on two transects from the Point Arena Basin, delineated two main groups which primarily appeared to be distinguished based on substrate relief and depth. These groups corresponded closely to the middle

depth and shallow depth communities described in Item 8 above, although fewer large taxa (e.g. , feather stars) but more small taxa (e.g., colonial protozoans, Komokoiacea) were observed from the photoquadrats, primarily due to differences in the scale of observation as described in Item 7 above.

10. Rock samples could only be collected from the northern survey area and primarily represented serendipitous collections using box corers. Most of the taxa collected from this survey also were found on rocks from the MMS Phase I program; only six previously described taxa (one species of sponge, one nemertean, one brachiopod, and three crustaceans) were found exclusively from the present survey. Seven new taxa (one species of sponge, one anemone, one kinorhynch, one flatworm, two nemerteans, and one crustacean) were identified from this study as compared to 156 new taxa from the Phase I program; this relatively low number of taxa from the present study probably is associated with the apparently low diversity habitats (sediment and gravel) from which the rocks were collected using the box corers.

11. Multivariate analyses of the video data from the sediment veneer transect areas delineated five station groups. Of these groups, one represented the shallowest transect depths (85-128 m) and was characterized by several hard substrate taxa such as brachiopods, which apparently were attached to a hard surface through a sediment veneer, and some common soft substrate organisms such as octopus, sea pens, ophiuroids, and seastars. Two groups, ranging in depth from 101-192 m, appeared to represent typical sediment veneer habitats with the same taxa as the first group but additionally were characterized by more frequent occurrences of the sea pen S. elongata (potentially indicating deeper sediments) and by the mollusc Pleurobranchaea californica and several fish species. Two groups represented the deepest transects surveyed (246-338 m) and were characterized by most of the sediment veneer taxa noted for the other groups, but notably by the absence of

large retractable sea pens such as S. elongata. The absence of this species may reflect shallow sediment depths or some other habitat restriction or species preference related to bottom depth.

12. Separate ordination and multiple regression analyses of the hard substrate and sediment veneer data indicate changes in the biological communities with changes in depth, some depth-related factors such as temperature, and substrate parameters (such as relief for the hard substrate data). Additional ordination analyses and Mantel tests of these data suggested some separation of the biological communities based on basin differences. However, within the survey area there is an obvious increase in the occurrence of exposed hard substrate and substrate relief at shallower depths and a scarcity of hard substrate data from any depth within some basins (e.g., Eel River). This pattern is associated with a corresponding, predictable change in the biological communities. Consequently, it is likely that the correlations with depth represent artifacts of the limited overall occurrence of hard substrate in the survey area. The primary factors which appear to be influencing the biological communities in the survey area are substrate type, including hard versus sediment veneer, sediment depth (veneer) over hard substrate, and substrate relief. Surveys of exposed hard substrate features, if they occur at approximately the same series of depths within each basin, would be necessary to verify whether the community differences are related additionally to geographic location (basin) or depth.

13. Qualitative comparisons of the results from the present study with those from the MMS Phase I and Phase II programs and several industry-sponsored studies indicate that many of the taxa and communities are similar, apparently representing species which are distributed over broad geographic ranges, but which exhibit some correlations with depth and/or substrate relief. Some of these species include feather stars Florometra serratissima, the

anemone Metridium senile, cup corals (Paracyathus stearnsii, Balanophyllia elegans, and Caryophyllia spp.), and the brachiopod Laqueus californianus. Dominant invertebrate phyla from these studies included coelenterates and echinoderms in most areas, although high densities of brachiopods and sponges were observed in some localized low relief and high relief areas, respectively. With the exception of some predictable differences among the surveys related to study design, the taxa and communities were very similar, at the level of taxonomic resolution and enumeration possible using photographic and video techniques, from at least the Point Conception area to near the California-Oregon border.

1.3.2 Soft Substrate

1. Two major patterns characterized the sediment regime in the study area. The Eel River Basin was characterized by finer-grained sediments than the two other basins. Most sediment phi values were greater than 5.0 in the Eel River Basin and less than 5.0 in the two other basins. On most transects in all three basins, the sediment grain size increased in the offshore direction, rather than decreasing, as observed from most other studies. A cluster analysis of the sediment data identified five sediment types at the soft substrate stations. These types formed a gradient from medium-fine sand (Type A) to silt and clay (Type E). Type A occurred largely at the offshore stations (400-m and 600-m) in the Point Arena and Bodega basins, while Type E occurred largely at the nearshore (100-m) stations in the Eel River Basin.

2. The mean near-bottom water temperature and dissolved oxygen concentrations in the Eel River Basin (8.7°C and 3.5 ml/1) were significantly higher than in the Point Arena Basin (8.2°C and 2.8 ml/1), but only oxygen was significantly higher than in the Bodega

Basin. Temperature and dissolved oxygen values decreased significantly with depth in all three basins, from an average of 11.0°C and 4-6 ml/1 at 100-m to 5.8°C and approximately 1 ml/1 at 600-m.

3. The major pattern in the summary measures of the benthic community was related to depth; sediment-size characteristics were a secondary influence on the benthic community, and other interbasin differences appeared to have only a minor influence. Total abundance, number of species per core, dominance, diversity, and evenness were all significantly higher at 100-m depth, and in some cases at 200-m, than at 400-m and 600-m. The only other consistent finding was that all but two of the summary measures differed significantly among the sediment types. Total abundance was significantly higher in fine-grained (Type E) sediments than in the coarsest sediments (Type A). Only total abundance differed significantly between basins, ranging from 708 organisms per core in the Eel River Basin to 517 per core in the Bodega Basin.

4. Multivariate analyses of the biological data revealed several major patterns. Nine station groups were defined based on the patterns of occurrence and abundance of organisms. Some station groups characterized by similar communities included stations from several of the basins, indicating that basin geography did not strongly influence community composition. Some station groups from narrow depth ranges supported similar biological communities, indicating that depth (and/or depth-related factors such as temperature and oxygen) was an important factor in the organization of the benthos. There were also station groups from similar depths that supported different communities, indicating that factors other than depth (e.g., sediment characteristics) influenced those communities. One group of taxa was common to all depths and basins, suggesting that they tolerated a wide range of environmental conditions.

5. The major difference in the soft substrate communities revealed by the multivariate analysis was between the shallow (100-m and 200-m) and the deep (400-m and 600-m) stations. The analysis showed a much greater degree of similarity among stations from the same depth, regardless of basin, than among stations from the same basin but different depths. The cluster analysis revealed no obvious along-coast geographic patterns.

6. Multiple regression confirmed that depth was most strongly correlated with the ordination axis accounting for the greatest amount of variability in the biological data. The axis expressing the second-greatest amount of variability was strongly correlated with sediment grain-size characteristics.

7. Multivariate hypothesis tests using ordination scores indicated that the Eel River Basin communities were significantly different from those in the ocher two basins. This difference may reflect the significant difference in sediment types between the Eel River Basin and the other two basins; tests also showed that at three of the four depths, the biological communities associated with the two finer-grained sediment types were significantly different from those in the coarser-grained sediment types.

8. Univariate hypothesis testing of selected species showed that species whose patterns of abundance were related to ordination scores on Axis 1 varied significantly in abundance with depth, confirming that Axis 1 expressed community variability associated with depth. Many of the species related to Axis 2 varied significantly with sediment type. There were no apparent relationships between the patterns of abundance of species comprising various feeding-type groups and depth, basin, or sediment type; nor did the most abundant species in each basin show any consistent relationship with environmental variables. Parametric multiple regressions of species abundance against

measures of the environment also did not reveal any clear relationships.

9. Cluster analysis of the combined data from the CARP, BLM, and MMS Phase I studies showed that the soft substrate benthos differed primarily with depth and secondarily with geographic location. The major cluster groups were shelf and upper-slope stations (less than 200 m deep); mid-slope stations (200-450 m); and deep-slope and basin stations (greater than 500 m). Secondary patterns depicted these three major station groups as separated on the basis of geography or small-scale depth differences. The CARP stations formed separate groups from the BLM and Phase I stations, indicating a geographic difference in the nature of the benthic fauna. The geographic coverage represented by the three studies was not sufficiently continuous or synoptic to allow a detailed examination of possible biogeographic provinces.

10. A total of 65 new species were described from the CARP soft substrate samples. Half of those species were crustaceans and none were polychaetes. Analysis of the CARP fauna in conjunction with the fauna sampled by earlier reconnaissance programs in the Southern California Planning Area did not allow a detailed examination of distinct biogeographic provinces along the coast of California. However, a high proportion of the abundant taxa were common in all areas sampled, implying a basic similarity of the soft substrate fauna of the outer shelf and slope regions of the California coast.

11. Three separate approaches to assessing the value of replication in a reconnaissance-type study all concluded that obtaining additional samples at a station would provide less information about the benthic fauna than would collecting more samples over a broader area. The ordination pattern resulting from analysis of either set of replicates closely resembled the pattern resulting from analysis of the mean of the replicates. Values from an analysis

of the mean distances in ordination space between replicates were always less than those between stations, transects, and depths, meaning that the replicates more closely resembled each other than they resembled samples from other stations. An analysis-of-variance approach designed to determine the optimum allocation of sampling resources concluded that given the variability within and among stations, one sample per station represented the optimum allocation of effort.

1.3.3 Seabirds, Marine Mammals, and Fisheries Acclivities

1. Nineteen bird species representing four orders were identified from the surveys. Gulls (*Larus* spp.) were observed most frequently, although black-footed albatross, red phalaropes, common murre, and Cassin's auklets also were common.

2. Nine species of marine mammals representing six families were identified from the surveys. All but one of the mammal sightings were cetaceans; the exception was one California sea lion. The most abundant species was the Pacific whiteside dolphin; occasional species included the northern rightwhale dolphin and Dan's porpoise. Less frequent or unusual sightings included a small pod of common dolphins, one gray whale, two killer whales, two Risso's dolphins, and a pod of approximately seven blue whales.

3. Only nine fishing vessels were observed in the survey area, probably due to the significant sea and wind conditions encountered during much of the survey. Vessel types included crab boats, trollers, and trawlers; of these, crab boats were the most frequently observed (5 of 9).

1.4 . RECOMMENDATIONS

This section presents recommendations from the program related to survey methods (Section 1.4. 1), analytical methods (Section 1.4. 2), and notable habitats and species (Section 1.4.3). Each of these sections is divided into separate subsections for hard substrate and soft substrate. Overall, we believe that the general study design and methods are very appropriate for use on subsequent studies of this type; our recommendations primarily concern minor improvements in methods of data collection and analysis.

1.4.1 Survey Methods

Hard Substrate

1. To improve the predictive capability for identifying exposed hard substrate features, data from side-scan sonar, precision bathymetry, and shallow seismic or subbottom profile systems ideally should be available for use in site selection.

2, A remotely operated vehicle as used for this program can be outfitted to provide high-quality, quantitative data on the benthic communities, and it is much safer (particularly related to personnel exposures) than all or most manned systems under the significant wind and sea conditions characteristic of the survey area. We recommend the continued use of ROVS on subsequent studies of this type.

3. The continued collection of both color video and photoquadrat data in hard substrate areas is highly recommended to characterize the larger epifauna and smaller epifauna, respectively. The different scales of observation represented by the two methods are complimentary and necessary to provide adequate documentation of these taxa. In contrast, although the rock sample analyses provided a few taxonomic confirmations of organisms observed in the video and photoquadrat records, the majority of the information could not be

related to any community patterns. This probably is due to the relatively small size (e.g. , 20 cm long) of the rocks that can be collected practically and their apparent poor or incomplete representation of the communities associated with more characteristic larger rocks and outcrop features. Consequently, due to the relatively minor utility of the rock sample data, as compared to the large effort in obtaining and analyzing the samples, we recommend that these collections be discontinued or at least sharply reduced on future studies until practical methods to collect significantly larger rocks (e.g., $\geq$ 0.5 m long) can be developed.

4. Based on the analysis of within-transect variance (Section 3.1.3) it was determined that one approximately 900-m long video transect (subdivided into 30 band quadrats from which the first 30 seconds of data were analyzed per band quadrat) was sufficient to characterize the biological communities. Additional 900-m transect segments would not add appreciably to the community analyses and therefore may not be necessary for reconnaissance studies of this type.

Soft Substrate

1. The Gray-O'Hare box corer used for this program is highly recommended for use on other reconnaissance programs because it facilitates the collection of high-quality bottom samples and because it is dependable, versatile, and safe to operate under most field conditions. In contrast, we recommend that the use of the Hessler-Sandia box corer be considered carefully before use on other projects because it is too large to operate safely in adverse wind and wave conditions.

2. The bottom photographs collected prior to box core penetration were of limited utility with regard to species identification or

as an interpretive aid to data analysis. Since considerable effort was involved in obtaining and evaluating those photographs, we recommend that they be considered optional for future programs.

3. Redundant, concurrent measurements of temperature and oxygen parameters are recommended as backups for equipment failures and for quality assurance. However, excessive emphasis should not be placed on these measurements in a reconnaissance program because they are only "snapshots" in time, and thus may not represent long-term or even daily variations.

4. Sample replication in reconnaissance programs of this type are not recommended. Single 0.1-m^2 box cores distributed over a study area is the most cost-effective and technically sound approach to characterizing a large geographic area. For example, we were able to define clearly the soft substrate community distribution patterns from the single samples at stations distributed over the study area.

5. Additional sampling of the soft substrate benthos in the Santa Cruz Basin should be conducted to fill in geographic gaps where weather conditions prevented sampling (e.g., Transects 14 and 15; see Appendices A and E, Volume II).

1.4.2 Analytical Methods

Hard Substrate

1. The primary method of analysis for the photoquadrat data consisted of point-contact evaluations. This method samples, by design, only a subset (50 points for this study) of a photoquadrat and yields frequency data for a subset of the total taxa. In contrast, methods providing total enumeration of a photoquadrat yield abundance data (density or percent cover depending on the

species) for all the taxa. A statistical comparison of these two methods (see Section 3.1.5) indicated that a method of total enumeration provides more complete characterization of the biological community than does the point-contact method. The laboratory effort involved in performing total enumeration was essentially the same as for the point-contact method. Therefore, we recommend that a method of total enumeration be used instead of a point-contact method for future studies of this type.

3. Multivariate methods of statistical analysis including cluster, ordination, and multiple regression were very effective in determining patterns in the benthic communities and correlations with environmental parameters; these methods are highly recommended for use by future studies of this type.

soft Substrate

1. Separate processing of the 0.5- and 1.0-mm screen fractions is recommended for ease of laboratory handling only; for data analysis and interpretation for reconnaissance programs we recommend combining the data from the two fractions.

2. Separate vialing of biological specimens (i.e., putting all unique species into separate vials, then combining all vials of these species from different samples into a second container) following the guidelines of the National Museum of Natural History was very labor intensive. It also limited the accessibility of the collections by other archival institutions, since access to specimens from a particular geographic location was difficult, if not extremely impractical. We recommend a clear definition of recipient institutions when the program is initiated and the use of the National Museum format only when that institution is the sole recipient.

3. For future reconnaissance programs, we recommend the continued use of multivariate techniques, including ordination, classification, and multiple regression methods, to describe community distribution patterns and relationships with environmental variables. However, we recommend that multivariate hypothesis testing be applied with caution because the methods are still largely in developmental stages.

4. Univariate hypothesis testing in this reconnaissance program was of limited value. The objective was to provide statistical support for multivariate analytical findings, but the various analyses were often inconclusive and occasionally conflicting. We recommend that only limited univariate hypothesis testing be conducted in the future. Such analyses should be limited to testing a few selected species (that are representative of groups from the multivariate analyses) against correlated environmental variables. Those tests would provide statistical (i.e., with probabilities) verification of the patterns revealed by the multivariate analyses. We recommend against the "exhaustive list" approach of including numerous species, abiotic variables, and community summary variables with the expectation that some analyses will reveal meaningful patterns.

1.4.3 Notable Habitats and Species

Hard Substrate

1. No unique habitats were noted from the surveys; the habitats and associated communities were very similar to those noted from other studies at similar depths offshore California. However, the apparent scarcity of exposed hard substrate in most of the study area, particularly at depths greater than 100 m, may indicate that this type of habitat is significant in general due to its limited occurrence.

2. The hydrocoral Allopora californica probably represents the most significant benthic species noted from this study (Section 3.1), in view of the MMS's historical interest in identifying and potentially avoiding areas where this species occurs. Allopora californica was observed in two transect areas: HB6 near Tolo Bank in the Pt. Arena Basin and HB16 near Half Moon Bay in the Santa Cruz Basin. However, abundances at both locations were low, and the colonies appeared to be less than approximately 10-15 cm in height. Another notable observation was a pod of blue whales observed near Transect HB6 (Section 3.3); however, although this occurrence was unusual the whales appeared to be traveling through the area and therefore were not associated specifically with the site.

Soft Substrate

No unique habitats or species, other than some new taxa that would be expected from any survey of a new geographic area, were observed from the soft substrate program. The soft substrate communities we observed were similar to those recorded during the BLM Southern California Bight Baseline and the MMS Phase I studies.

2.0 MATERIALS AND METHODS

This section describes survey site selection criteria, survey locations, and an overview of the field survey (Section 2.1); navigation methods (Section 2.2); hard substrate survey and laboratory procedures (Section 2.3); soft substrate survey and laboratory procedures (Section 2.4); seabird, marine mammal, and fishing observations (Section 2.5); and data analysis (Section 2.6).

2.1 OVERVIEW OF SURVEY AREA AND ACTIVITIES

2.1.1 Site Selection Criteria

A preliminary review of data on general bottom types from NOAA navigational charts and from U.S. Geological Survey (USGS) records indicated that soft substrate predominated in the Planning Areas (Figure 1-1, Volume I), although several potential and some confirmed hard substrate areas were also present. Criteria used to select survey sites were (1) emphasize regions that had the greatest potential for oil and gas development within the Planning Areas; (2) emphasize areas for which data on benthic communities were lacking; and (3) locate study sites over a range of geographic locations and bottom depths to facilitate assessments of potential community responses and distributional patterns associated with location and depth.

Review of the MMS 5-year outer continental shelf oil and gas leasing program as of 1987 (MMS, 1987) indicated that the greatest potential for gas development was in the Northern Planning Area and for oil in the Southern Planning Area. However, since the Southern Area reserves were not in close proximity to hard substrate features, the initial survey plan included a greater number of sites in the Northern than in the Central and Southern Areas. Known or potential seep areas associated with hard substrate features were identified from USGS open-file and unpublished data reports. Where feasible, based on ROV depth constraints ($\leq$ approximately 400 m) and location in OCS areas, sites were selected that had seeps reported in the vicinity. A summary of planned survey locations and notation of the general occurrence of oil and gas seeps near hard substrate features is presented in Volume II, Appendix A.

Few data were available to describe the benthic communities in the Northern and Central Planning Areas. Consequently, survey sites were selected to maximize large-scale geographic coverage within these Planning Areas. Benthic assemblages within previously studied California areas have been shown to vary significantly with depth (SAIC, 1986; Thompson and Jones, 1986). Studies of the Santa Maria and Santa Barbara Basins (e.g., SAIC, 1986) defined several faunal assemblages that were distinguished on the basis of depth. Groupings of soft substrate communities included a shelf assemblage (approximately 120 m depth), an upper mid-slope assemblage (200-300 m), a mid-slope assemblage (400 m), and a basin-slope assemblage (600 m). Accordingly, soft substrate survey locations for the present study were planned for 100-, 200-, 400-, and 600-m depths over a range of latitudes and geographic basins throughout the Northern and Central Planning Areas. The choice of hard substrate transect locations was limited by the relative scarcity of hard substrate features throughout the Planning Areas; however, the transects were located, as feasible, over a broad range of depths, latitudes, and geographic basins within these areas.

The local or regional extent of hard substrate areas can be estimated partly from indirect methods, such as side-scan sonar and precision bathymetric surveys, which provide a conservative estimate of the amount of hard substrate areas. However, results from numerous reconnaissance surveys (e.g., SAIC, 1986 and the present November/December 1987 survey) of suspected hard substrate features have shown that many of the low-relief features are partly or completely covered by sediments, which in many instances are deep enough (e.g., > 1 m) to support well-developed soft substrate communities. Thus, the actual extent of hard substrate communities is significantly less in some areas than the use of indirect methods alone would suggest, which emphasizes the importance of ground-truth surveys (e.g., using ROVs, manned submersibles, or camera drops).

The MMS currently is evaluating data from several indirect methods to increase the predictive capability for identifying exposed hard substrate features. Data from side-scan sonar and fathometer (bathymetric) methods are most useful because they provide complimentary horizontal and vertical-looking views, respectively, for locating high-relief areas; subbottom profiles and shallow

seismic data can provide an indication of the areal extent of hard substrate but do not by themselves allow assessment of whether these features are buried by a shallow veneer (M. Silverman, MMS, pers. comm.).

The initial survey design included a series of transects located in estimated hard substrate and soft substrate habitats within each of four geologic basins (Eel River, Point Arena, Bodega, and Santa Cruz) located in the Central and Northern California planning areas; uplifted basement ridges generally form the seaward margins of basins (Curray, 1966). Each soft substrate transect was oriented roughly perpendicular to shore with one sampling station at each of the four planned depths. The predominance of soft substrate in the Planning Areas facilitated this type of uniform station placement within these habitats. In contrast, the choice of hard substrate locations was very limited, resulting in a less uniform study design (depths and locations within the Planning Areas) than for the soft substrate survey. The hard substrate transects were planned for estimated outcrops that were one-half of a nautical mile or more in length and at least one-quarter of a nautical mile wide.

Sample replication in the soft substrate habitats was not emphasized because a primary purpose of this reconnaissance program was to characterize the benthic communities in relatively poorly studied OCS Planning Areas. However, some measure of within-site variability was important as a reference for future monitoring program design. Accordingly, duplicate samples were planned within each basin at all stations along selected soft substrate transects (i.e. , T3 in the Eel River Basin, T7 in the Point Arena Basin, T13 in the Bodega Basin, and T15 in the Santa Cruz Basin). The data from the duplicated stations were analyzed as part of the community pattern analysis, but also were subjected to separate univariate analyses and power analyses to characterize within-site variability (Section 2.6.2). The separate photoquadrat and video band quadrat data analyzed from each hard substrate transect provided replicates for use in assessing within-transect variability for the hard substrate program (Section 2.6.1).

2.1.2 Survey Locations

The survey plan included proposed surveys at 20 hard substrate sites within the Northern, Central, and Southern California Planning Areas and at 60 soft substrate stations within the Northern and Central California Planning Areas. A synopsis of these planned locations, presented in Volume II (Appendix A), includes navigational coordinates and bottom depths of the target hard substrate and soft substrate sites.

During the survey operations, some proposed locations were modified so that collections from targeted depths and substrates could be accomplished. For example, the anticipated bottom depths at some NOAA chart coordinates were incorrect for several soft substrate stations, so the stations had to be relocated during the survey to sample the targeted depths. Additionally, adverse wind and sea conditions prevented survey operations at several hard substrate and soft substrate locations and caused delays which resulted in elimination from the survey schedule of the four hard substrate sites proposed in the Southern and one soft substrate transect (T14) from the Central California OCS Planning Areas (Volume II, Appendix A). Further, only one soft substrate station (SB57) in the Santa Cruz Basin could be sampled, so that the results from these analyses reflect three rather than the four basins originally planned.

Field survey operations were conducted at 14 hard substrate transects and 51 soft substrate stations (Figures 2-1 and 2-2 and Figures 2-3 and 2-4, respectively) . Transect and station depths and navigational coordinates are presented in Tables 2-1 and 2-2. Additional, detailed plots of hard substrate navigational coordinates and transect locations are included in Volume II, Appendices C and D, respectively. LORAN-C coordinates for the soft substrate stations are presented in Volume II, Appendix E.

The projected soft substrate sites were almost all confirmed (through sample collections) to be soft substrate. However, the projected hard substrate sites were, with few exceptions, determined to be soft substrate as well. Those sites presumably were hard substrate overlain with a sediment veneer, since

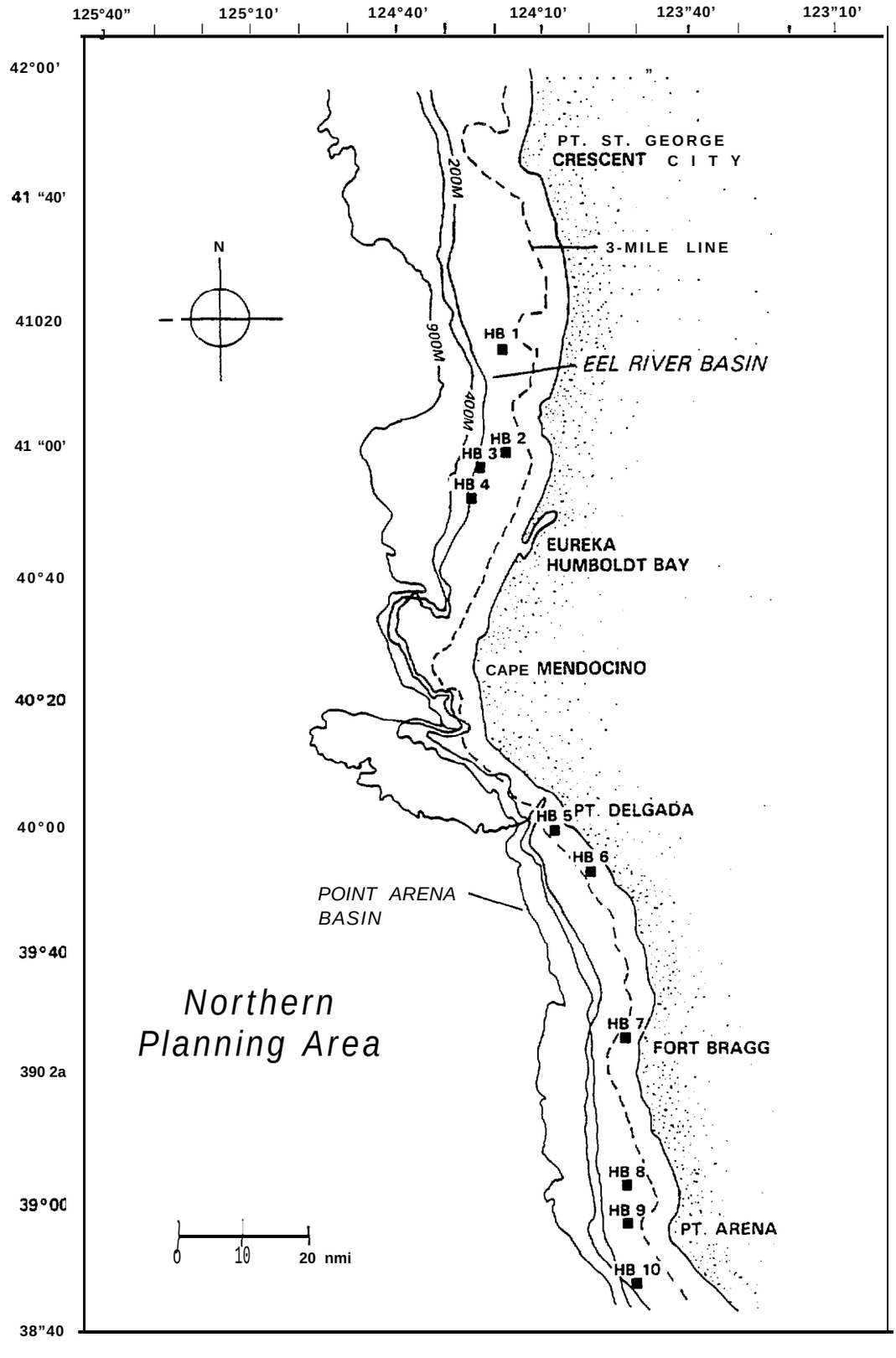


FIGURE 2-1. HARD SUBSTRATE TRANSECT LOCATIONS IN THE NORTHERN CALIFORNIA PLANNING AREA. MMS CARP Survey November/December 1987.

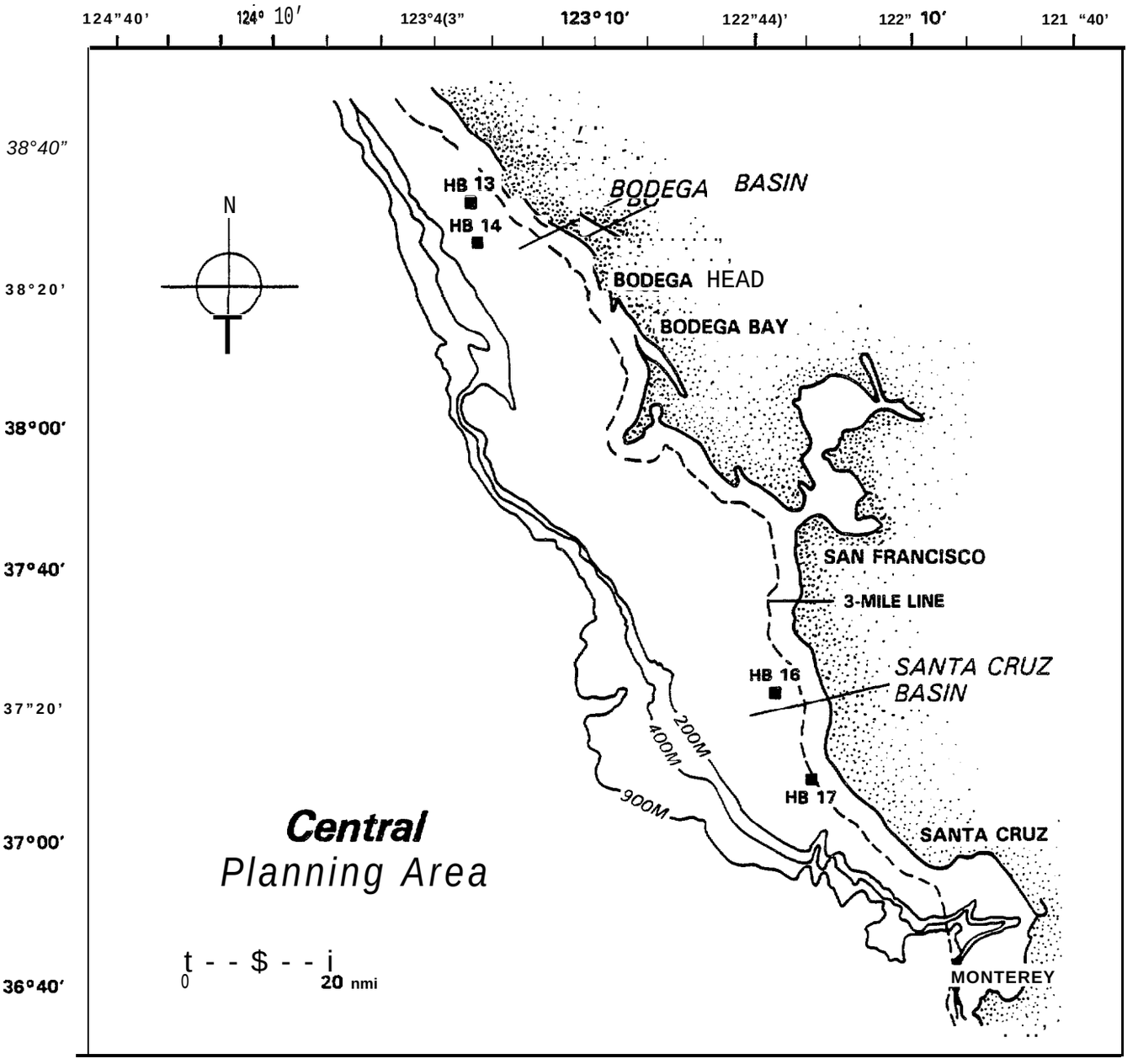


FIGURE 2-2. HARD SUBSTRATE TRANSECT LOCATIONS IN THE CENTRAL CALIFORNIA PLANNING AREA. MMS CARP Survey November/December 1987.

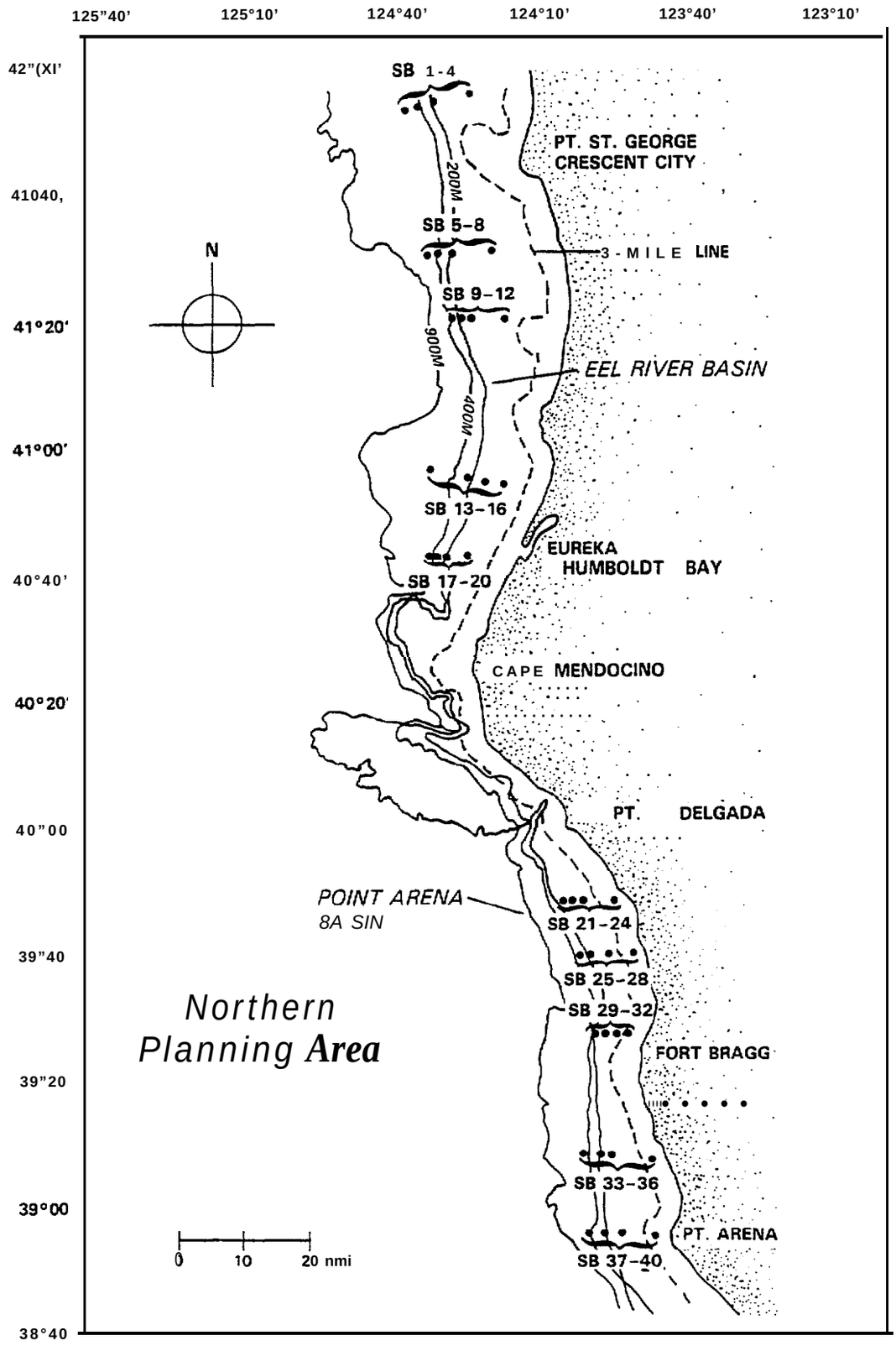


FIGURE 2-3. SOFT SUBSTRATE STATION LOCATIONS IN THE NORTHERN CALIFORNIA PLANNING AREA. MMS CARP Survey November/December 1987.

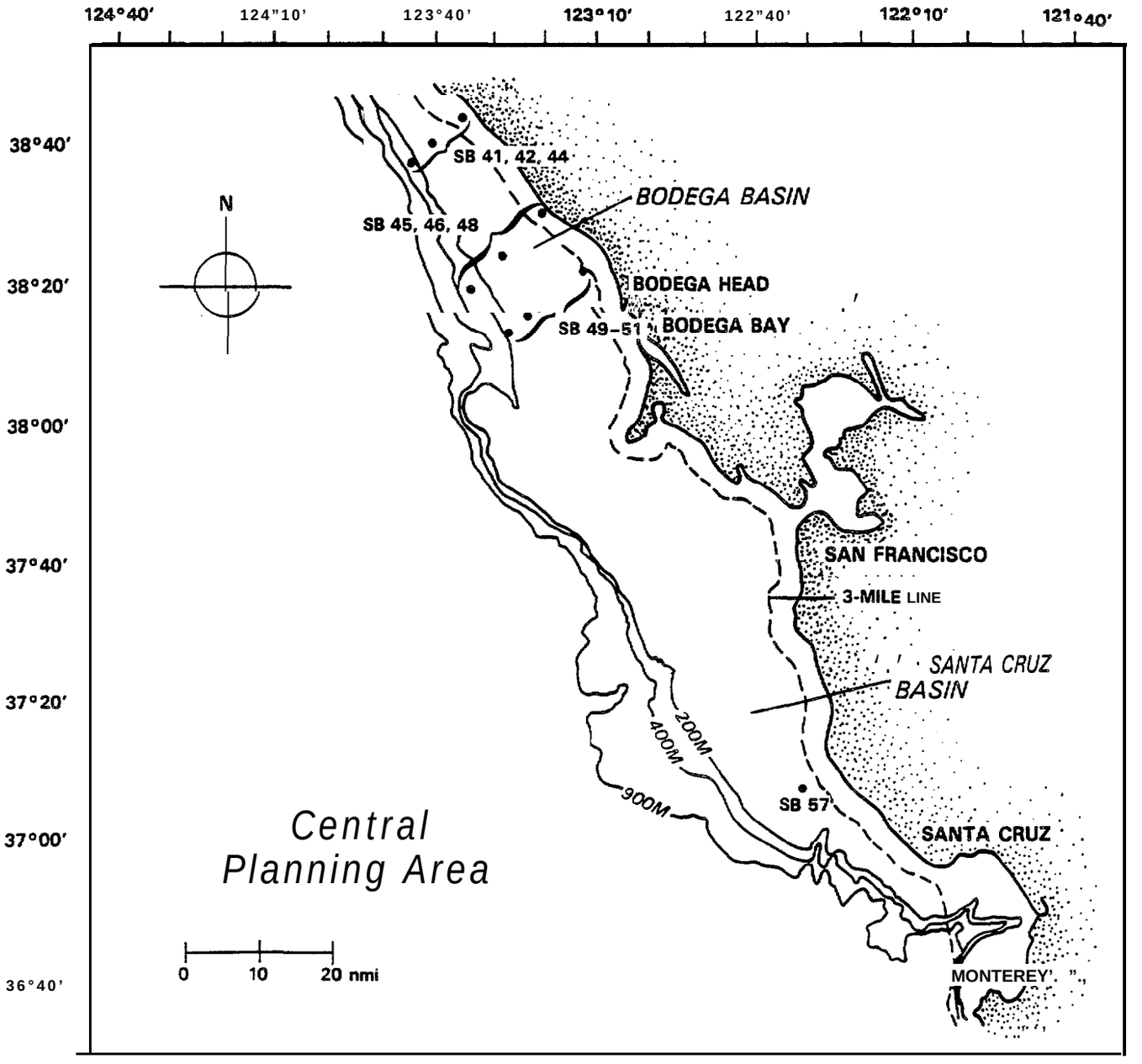


FIGURE 2-4. SOFT SUBSTRATE STATION LOCATIONS IN THE CENTRAL CALIFORNIA PLANNING AREA. MMS CARP Survey November/December 1987.

TABLE 2-1. HARD SUBSTRATE ACTUAL TRANSECT LOCATIONS.
MMS CARP Survey (November/December 1987).

HARD SUBSTRATE TRANSECTS				
Transect	Latitude (N)	Longitude (W)	Depth Range (m)	Basin
HB1				
Start	41° 14.065′	124″ 19.950′	125-127	Eel River
End	41° 14.691′	124° 20.079′		
HB2				
Start	40″ 58.600′	124° 18.844′	101-103	Eel River
End	40″ 59.511′	124″ 18.572′		
HB3				
Start	40° 55.739′	124° 24.887′	225-280	Eel River
End	40° 55.738′	124° 25.818′		
HB4				
Start	40° 51.949′	124° 25.382′	224-285	Eel River
End	40° 52.391′	124″ 26.287′		
HB5				
Start	39° 58.559′	124″ 10.027′	131-141	Pt. Arena
End	39″ 58″.464′	124° 09.320′		
HB6				
Start	39° 52.422′	124° 02.196′	70-85	Pt. Arena
End	39″ 52.861′	124° 02.752′		
HB7				
Start	39° 25.580′	123* 52.890′	104-106	Pt. Arena
End	39° 25.055′	123″ 53.251′		
HB8				
Start	39° 02.352′	123° 53.929′	113-120	Pt. Arena
End	39° 02.516′	123° 52.755′		
HB9				
Start	38° 56.638′	123° 53.213′	124-128	Pt. Arena
End	38° 57.053′	123° 52.918′		
HB10				
Start	38° 47.480′	123° 51.041′	246-338	Pt. Arena
End	38° 46.869′	123″ 51.030′		

TABLE 2-1. (Continued)

HARD SUBSTRATE TRANSECTS

Transect	Latitude (N)	Longitude (W)	Depth Range (m)	Basin
HB13				
Start	38″ 31.517′	123° 34.563′	154-161	Bodega
End	38″ 30,885′	123″ 33.798′		
HB14				
Start	38° 26.922′	123° 32.237′	176-192	Bodega
End	38″ 26.364′	123″ 33.434′		
HB16				
Start	37° 21.627′	122° 35.139′	61-68	Santa Cruz
End	37° 21.266′	122° 35.832′		
HB17				
Start	37° 07.595′	122° 29.963′	85-93	Santa Cruz
End	37° 08.115′	122″ 29.924′		

TABLE 2-2. SOFT SUBSTRATE ACTUAL STATION LOCATIONS.
MMS CARP Survey (November/December 1987).

Station	Rep	Latitude (N)	Longitude (W)	Depth (m)
Transect T1				
SB1	A	41° 56.608′	124° 26.941′	94
SB2	A	41″ 56.520′	124° 33.492′	185
SB3	A	41° 56.418′	124° 35.468′	389
SB4	A	41° 56.346′	124° 37.986′	552
Transect T2				
SB5	A	41° 30.850′	124° 21.634′	95
SB6	A	41″ 30.579′	124° 29.285′	197
SB7	A	41″ 30.462′	124° 31.059′	329
SB8	A	41° 30.519′	124° 32.631′	484
Transect T3				
SB9	A	41° 20.764′	124° 18.256′	93
SB9	B	41° 20.826′	124° 18.260′	91
SB10	A	41° 20.812′	124° 26.497′	182
SB10	B	41° 20.783′	124″ 26.522′	181
SB11	A	41° 20.891′	124° 28.159′	358
SB11	B	41° 20.935′	124° 28.195′	372
SB12	A	41° 20.845′	124″ 29.507′	524
SB12	B	41° 20.985′	124° 29.508′	549
Transect T4				
SB13	A	40° 56.753′	124° 18.452′	93
SB14	A	40° 56.992′	124° 23.448′	188
SB15	A	40° 57.015′	124° 26.972′	366
SB16	A	40° 57.284′	124° 33.197′	555
Transect T5				
SB17	A	40″ 43.063′	124° 27.486′	91
SB18	A	40° 43.072′	124° 30.374′	207
SB19	A	40° 43.029′	124° 31.653′	411
SB20	A	40″ 42.940′	124° 33.330′	560

TABLE 2-2. (Continued)

Station	Rep	Latitude (N)	Longitude (W)	Depth (m)
Transect T6				
SB21	A	39° 48.007′	123° 54.541′	93
SB22	A	39° 48.023′	124″ 03.509′	200
SB23	A	39° 47.998′	124″ 05.530′	403
SB24	A	39° 47.947′	124″ 06.282′	607
Transect T7				
SB25	A	39″ 40.062′	123° 51.127′	92
SB25	B	39° 39.994′	123° 51.156′	93
SB26	A	39° 40.037′	123° 58.232′	185
SB26	B	39° 40.000′	123° 58.257′	186
SB27	A	39° 40,024′	124° 01.360′	402
SB27	B	39° 40,010′	124″ 01.196′	399
SB28	A	39° 39.957′	124° 03.111′	549
SB28	B	39° 39.940′	124° 03.115′	564
Transect T8				
SB29	A	39° 27.130′	123° 53.153′	109
SB30	A	39° 27.661′	123° 57.867′	195
SB31	A	39° 27.789′	123″ 59.219′	396
SB32	A	39° 28.132′	124° 01.206′	529
Transect T9				
SB33	A	39° 07.032′	123° 48.030′	95
SB34	A	39° 07.742′	123° 57.003′	192
SB35	A	39° 07.814′	123° 58.969′	377
SB36	A	39° 08,168′	124° 02.199′	549
Transect TIO				
SB37	A	38° 56.215′	123° 48.333′	102
SB38	A	38″ 56.301′	123° 55.825′	177
SB39	A	38° 56.123′	123° 58.921′	369
SB40	A	38° 56-242′	194° 01.481′	534

TABLE 2-2. (Continued)

Station	Rep	Latitude (N)	Longitude (W)	Depth (m)
Transect T11				
SB41	A	38* 45.143′	123° 38.020′	97
SB42	A	38″ 40.753′	123″ 43.697′	181
SB44	A	38° 38.456′	123° 46.790′	554
Transect T12				
SB45	A	38° 31.602′	123° 22.769′	96
SB46	A	38° 24.906′	123° 30.661′	180
SB48	A	38° 19.766′	123° 36.617′	578
Transect T13				
SB49	A	38° 22.829′	123° 14.481′	96
SB49	B	38″ 22.809′	123″ 14.495′	93
SB50	A	38° 16.240′	123″ 24.314′	184
SB50	B	38° 16.428′	123° 24.358′	183
SB51	A	38° 14.360′	123° 26.986′	410
SB51	B	38° 14.460′	123° 26.941′	390
SB52	A	-38° 14.00′	-123″ 28.00′	468
Transect T14				
No samples collected				
Transect T15				
SB57	A	37° 05.479′	122″ 27.196′	95
SB57	B	37° 05.449′	122° 27.193′	95

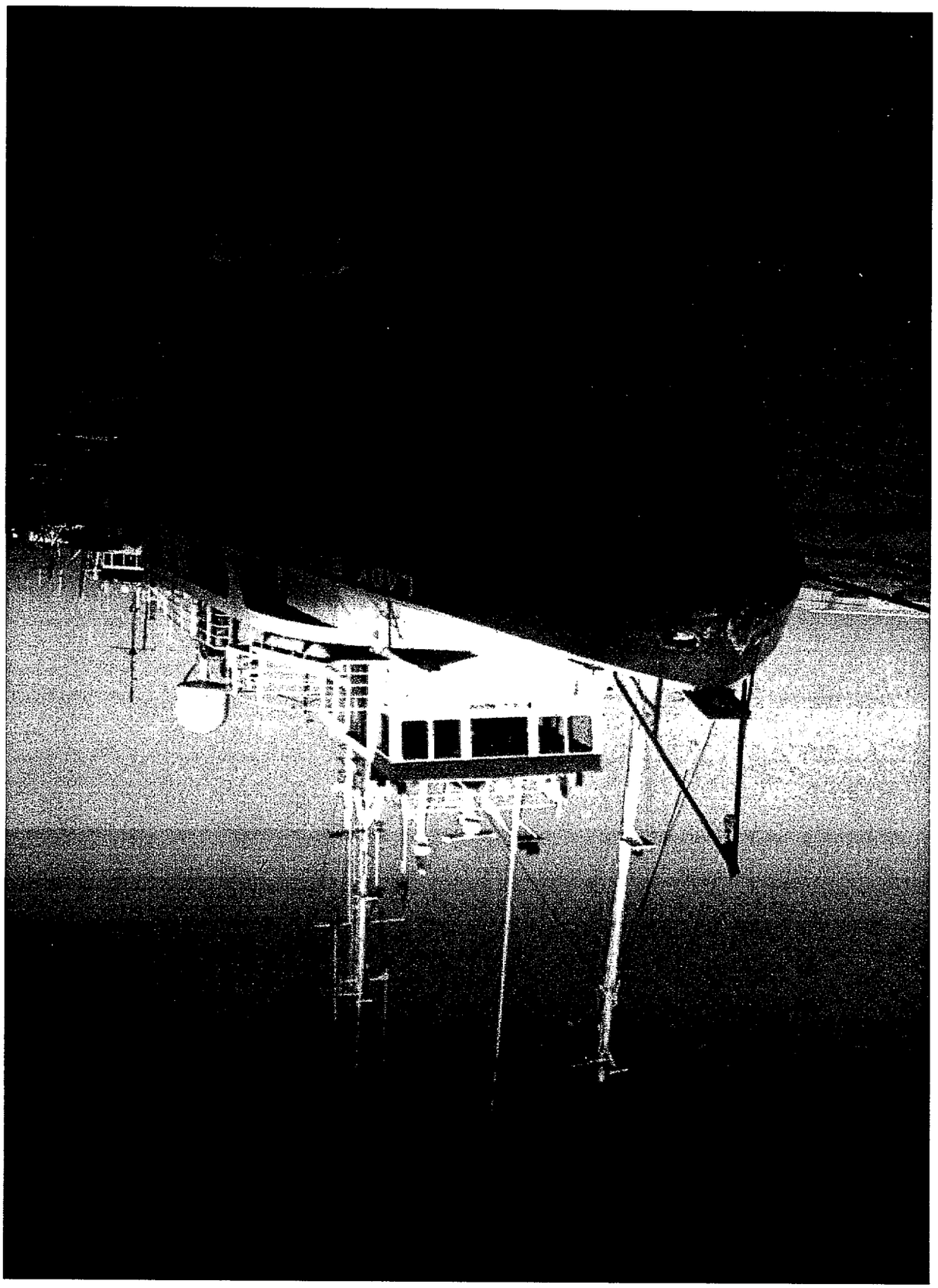
they typically represented very large (i.e. , several miles long) side-scan sonar and/or bathymetric targets. In this report, the soft substrate areas noted along many target hard substrate sites are referred to as "sediment veneer" habitats because of the likelihood that these areas represent a veneer but also to distinguish them from the soft substrate stations characterized on the basis of sediment cores. Because of the scarcity of hard substrate sites, there also was a corresponding limitation in the amount of hard substrate data that could be collected for broad-scale comparisons (e.g., between basins) of the overall study area. We have, however, attempted to maximize the use of the data, particularly the video data which were collected at all the hard substrate sites, in order that information on communities, ranging from those on exposed rock to those in areas that have rocks overlain with a thin or thick sediment veneer, can be evaluated. In this sense, the hard substrate and soft substrate communities correspond to opposite ends of a continuum that characterizes the benthic environment of this OCS region.

2.1.3 Survey Overview

Field survey operations were conducted from November 15 through December 7, 1987, on board the M/V LADY BRIGID, a 48-m (158 ft) converted geophysical survey vessel with a beam of 12-m (38 ft) and a 3-m (10 ft) draft (Figure 2-5). Minor modifications made to the vessel for the survey included reconfiguring the sampler-handling system on the rear deck for box-coring operations and installing navigation, ROV, and sample-processing equipment.

Mobilization and demobilization for the survey were conducted in Eureka, CA and Point Hueneme, CA, respectively. Survey operations were conducted on a 24-hour basis. Alternating survey teams on 12-hour watches generally performed the hard substrate operations during daylight hours and soft substrate operations at night. Survey direction was provided by Dr. A. Lissner of SAIC and Dr. D. Diener of MEG. SAIC had overall responsibility for the survey including the hard substrate operations and all navigation; MEC was responsible for the soft substrate operations.

FIGURE 2-5. SURVEY VESSEL M/V LADY BRIGID.



Hard substrate survey operations were conducted using the ROV TELESUB outfitted with a color sonar system, 70-MM and 35-mm still camera systems, color video systems, a sample collection scoop, and sensors for recording temperature, conductivity, dissolved oxygen, and current speed (Figure 2-6). Soft substrate operations were conducted using a Gray-O'Hare (0.1-m^2) box corer as the primary sampling device (Figure 2-7), although some of the samples were collected using a 0.25-m^2 Hessler-Sandia box corer, The soft substrate samplers were outfitted with a 35-mm camera system and in situ probes for recording temperature and dissolved oxygen. Detailed descriptions of the hard substrate and soft substrate survey equipment and methods are presented in Sections 2.3 and 2.4, respectively.

2.2 NAVIGATION

This section describes the navigation systems and methods utilized to provide positioning of the survey vessel and the ROV during the hard substrate and soft substrate survey operations. Overall navigation control of the survey vessel was provided by the SAIC Integrated Navigation System (INDAS). This system consists of a Hewlett Packard Series 300, Model 310 microcomputer, which for this study was interfaced with a Del Norte Model 542 Trisponder and a Trackpoint II system for the ROV survey. SAIC provided the hardware, software, the navigators, and navigation shore support for the survey. The backup positioning system used for the study was a Northstar 6000 LORAN-C receiver. The accuracy of the LORAN signal in the operations area ranged from $\pm$ 50 m in the Northern Planning Area (Eel River Basin) to $\pm$ 75 m in the Central Planning Area (Santa Cruz Basin).

The Del Norte system included a master transponder and up to four remote transponders located at shore stations. The entire trisponder system was calibrated over a 10-km over-water range 10 days prior to deployment. Range resolution of this system is 0.1 m, and the overall accuracy of the system was rated at $\pm$ 1 m over the ranges encountered during the survey. A total of 20 different shore station locations, extending from Chetco Point in Oregon to Pigeon Point in California, were utilized during this study (Volume II, Appendix B). Wherever possible, stations were set up in Coast Guard

FIGURE 2-6. REMOTELY OPERATED VEHICLE (ROV) TELESUB.

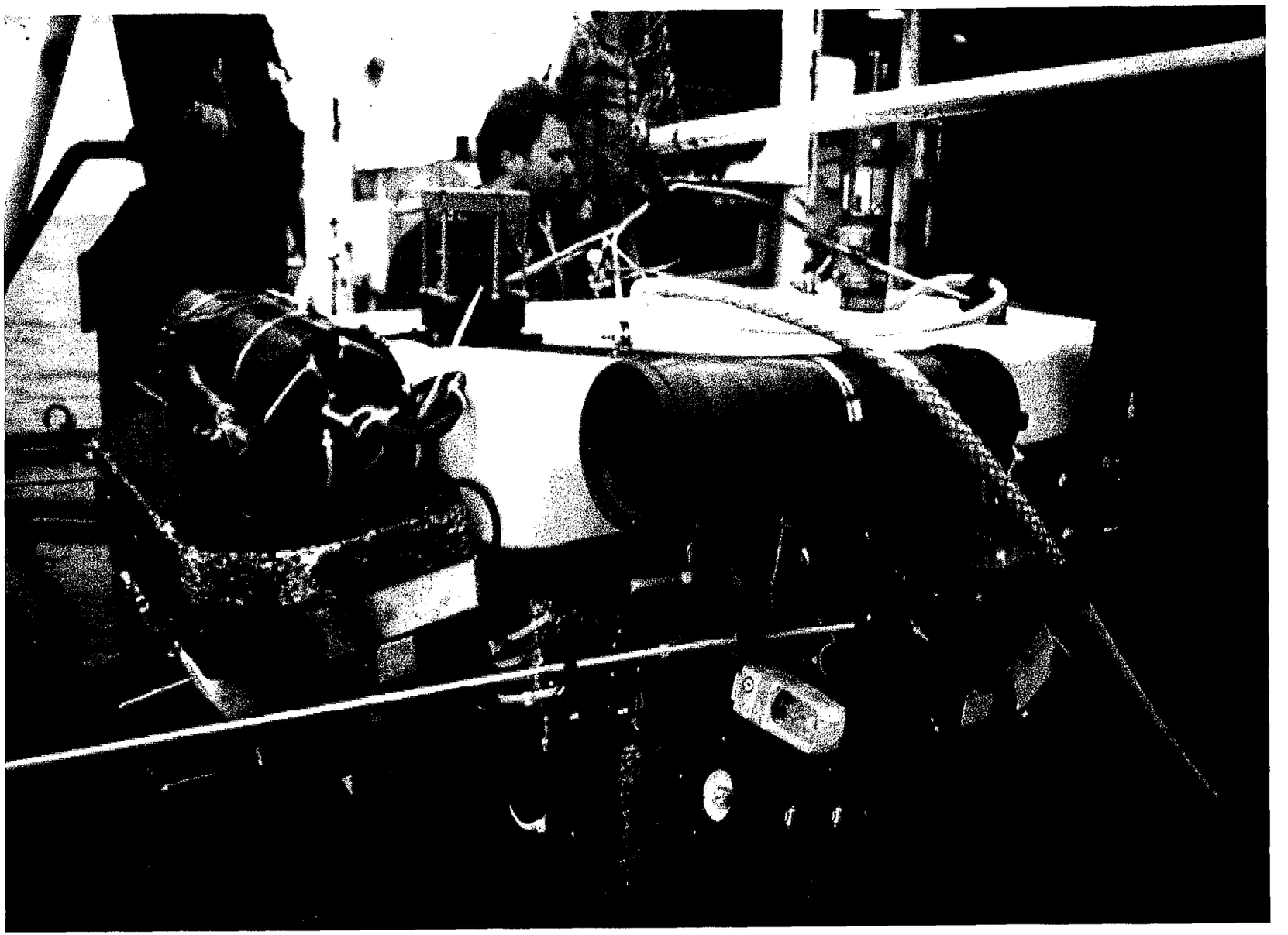
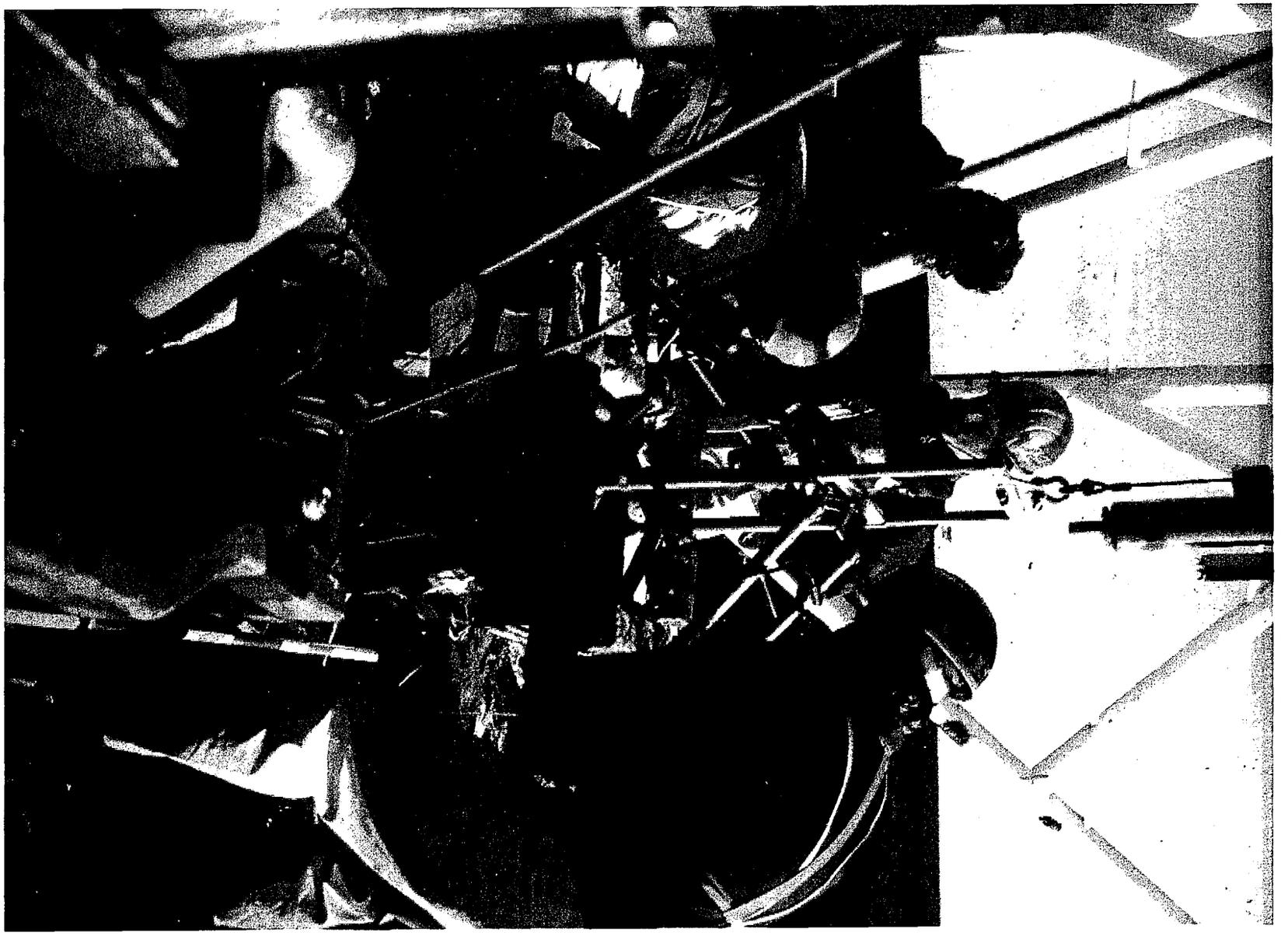


FIGURE 2-7. GRAY-O'HARE BOX CORER.



lighthouses whose positions are known to at least third-order accuracy. When additional trisponder stations were required, they were set up near horizontal control benchmarks established by the U.S. Coast and Geodetic Survey. At locations where physical conditions such as obstructions made it impossible to set up the trisponder directly over the benchmarks, measurements were made to determine the offset from the benchmark, and eccentric positions for the trisponders were calculated.

Tracking of the ROV along hard substrate transects was accomplished using the INDAS navigation system interfaced to a Model 441OB Trackpoint II system. The Trackpoint II presents the user with a video display of the underwater position of the ROV relative to a reference point on the surface vessel. In addition to the graphic display of target position, the instrument provides an RS-232 interface to the navigation computer.

During survey operations for which high navigational accuracy was required, such as during box core sampling and ROV tracking, the trisponder system provided positional accuracies on the order of $\pm$ 3 m. While in transit, LORAN-C was used to navigate the survey vessel and provide information such as distance to the next survey location and estimated arrival time. During box-coring operations, the INDAS was configured so that it gathered LORAN-C data passively; this provided LORAN-C coordinates (in addition to the trisponder data) for each box core sample location, thereby enabling future investigators to return to the same locations, even if a precision navigation system is not available (Volume II, Appendix E).

Navigational positions and the time that each position was determined were recorded every 10 seconds on magnetic tape and printed every 30 seconds along hard substrate transects and at the time of bottom contact at the soft substrate stations. This high recording frequency of navigational positions and the time of each position were important in determining the locations from which photographic and video data were collected along the hard substrate transects. The times at which the photographic and video data were obtained were recorded during the survey; these times were cross-referenced with the

times of navigational positions to allow the locations of these data-collection points to be determined (see Section 2.3).

2.3 HARD SUBSTRATE FIELD AND LABORATORY METHODS

This section presents a description of the hard substrate survey and laboratory methods. Section 2.3.1 describes the survey equipment. Sections 2.3.2 and 2.3.3 describe the field and laboratory methods, respectively.

2.3.1 Survey Equipment

Survey equipment for the hard substrate operations included the remotely operated vehicle (ROV) TELESUB 2000; Photosea 70-mm and 35-mm macro still cameras and strobe systems: a MESOTECH color sonar system; Osprey 1335 and Photosea TV 2000 color video cameras; sample-collection scoop; and in situ physical probe (temperature, dissolved oxygen, and conductivity) and current meter systems. The ROV TELESUB is designed and operated by Remote Ocean Systems (ROS; San Diego, CA). The ROV has a 400-m operational depth range and was specifically modified to integrate all photographic, video, sample-collection, and physical-measurement systems utilized for the survey. Detailed descriptions of these systems are presented below.

Photographic Systems

A Photosea 70-mm color still camera obtained high-resolution photographs of the sea bottom and benthic communities along the transects. The camera and strobe system were attached to a single-axis rotation unit on the ROV. This configuration allowed photographs to be taken in either a vertical or horizontal plane, depending on substrate orientation (horizontal or vertical, respectively). Quantitative photoquadrats were taken randomly at timed intervals (see Section 2.3.2) by using a distance probe (80 cm long) to standardize the camera's distance from the subject, thereby standardizing the surface area of the photoquadrats to 0.3 m^2 (56 x 56 cm). This distance represented an average offset that allowed excellent photographic resolution and achieved a relatively large surface area, while still allowing photographs

to be taken during most conditions of turbidity encountered during the survey. The camera has an internal data chamber which was keyed to the time and transect number to allow cross-referencing with the navigational data (time at which the ROV was at a specific navigational position). This time record also allowed cross-referencing with the video record, which also had a time overprint.

A Photosea 35-mm macro (close-up) color still camera was utilized to collect voucher photographs to aid in the identification of organisms that were too small (e.g., < 1 cm) to identify using the larger format (70 mm) camera system. The camera has two fixed-distance probes which allowed the ROV operator to maneuver towards and photograph a selected subject by touching the probes on the target surface and triggering the camera simultaneously.

Video Systems

An Osprey 1335 color video system was utilized to provide continuous, high-resolution video records and observer commentary along the transects. A Photosea TV 2000 color video system also was utilized to aid in orienting the still cameras and as an additional reference camera and back-up system to the Osprey camera. Recording equipment onboard the survey vessel consisted of a Panasonic Model AG6200 recorder using a 1/2 inch VHS format. The Osprey camera and Panasonic recording system provided a minimum of 350 lines of resolution; the video signal was adjusted to the length of the ROV cable by using a longline compensation amplifier to enhance resolution. The focal distance of the Osprey is from 5 cm to infinity. The video recording system included an alphanumeric display near the bottom of the image screen, which contained information on the time, date, transect number, and depth of the ROV. The time codes were necessary for cross-referencing with the times of ROV navigational positions so that precise locations of the video transect data could be determined.

Color Sonar

The MESOTECH color sonar system was utilized in a search-and-documentation mode during the hard substrate surveys. The system displays a sonar image of the sea bottom on a monitor aboard the survey vessel. Hard reflecting surfaces such as rock outcrops typically are indicated as white or magenta-colored images; softer reflecting features such as soft substrate and sediment veneer are indicated as yellowish colored images. Depressions including some anchor scars, trawl tracks, or furrows on soft substrate are indicated as black to blue-black. The range of the sonar system is approximately a 100-m radius; this allowed the shipboard observers to identify and locate significant hard substrate features within this radius of the transect. The ability to search a relatively broad survey area was particularly important during the present survey because of the scarcity of exposed hard substrate along most of the transects.

Sample Collection Scoop

A collection scoop, custom-designed by Remote Ocean Systems, was planned for use in obtaining rock samples and associated specimens along the hard substrate transects. However, during the survey, the scoop was only successful along one transect due to severe sea and wind conditions and the scarcity of rocks for collection in most areas. However, several serendipitous and intentional collections of rock samples were made using a Smith-MacIntyre grab and the Gray-O'Hare box corer; rocks collected in this manner were either lodged in the jaws or enclosed within the scoop or box.

Physical Measurements System

The physical measurements system used for the hard substrate survey consisted of temperature (Texmate 150X temperature meter), dissolved oxygen (Cole-Parmer J5948-50), and conductivity (Cole-Parmer 1481-60) sensors, and a current meter (Hydro-Products Savonius rotor). These components were custom-packaged by Remote Ocean Systems for in situ use with TELESUB. During the survey, digital readouts of the data from these sensors were scanned by the color video camera

and displayed on the video monitor (for recording by the observers) and on the videotape record.

2.3.2 Field Survey Methods

Hard substrate data were collected using the ROV systems described in Section 2.3.1. Field survey operations to collect photographic and video data along the hard substrate transects included presurvey, survey, and postsurvey testing and data-collection activities.

Prior to each launch of the ROV, the photographic still cameras were test-fired, a video color/image check was performed, a Winkler titration was performed to calibrate the dissolved oxygen probe, the temperature probe was calibrated against a high-resolution thermometer, and the conductivity probe was calibrated against a standard seawater solution. Postsurvey calibrations of the physical measurements probes were performed in the same manner and test strips of the 70-mm and 35-mm photographic film also were developed periodically to ensure that the light exposure and camera focus were correct.

After the presurvey tests had been completed, the ROV was launched from the survey vessel and maneuvered to the sea bottom. Once the ROV was on the bottom, the color video recording and observer commentary was initiated; the navigational position of the ROV relative to the planned start of a transect was determined; and a color imaging sonar scan was conducted to evaluate the presence of hard substrate features. 'l'he biological observers (A. Lissner, S. Benech, and J. Ljubenkov) during the surveys recorded photographic information (e.g. , the time at which a photograph was taken and any collection problems which might affect data quality) and summaries of the species, habitats, and notable events (e.g. , unusual organisms or substrate features) on log sheets. If a hard substrate feature was present or visible in the color sonar image, the ROV was maneuvered to investigate the feature and begin data collection. If no significant hard substrate features were detected, the ROV was directed along the planned transect.

Photographic Data

Photoquadrats using the 70-mm camera system were conducted randomly at a minimum of three-minute intervals along the transect path in hard substrate areas and along selected sediment veneer areas that contained commercially important species such as the shrimp Pandalus jordani. In low-relief ($\leq$ 1 m) areas, consecutive photoquadrats were obtained every one to three minutes, depending on the diversity of the community and the survey conditions, or photoquadrats were taken of the next hard substrate feature encountered after one to three minutes, if the outcrops were scattered. Photoquadrats were collected every one to two minutes, if the community appeared to require additional characterization and/or if the survey time was limited due to significant sea and wind conditions; however, a consistent time interval was attempted along individual transects.

To collect photoquadrat information, the ROV pilot oriented the camera system, including the distance probe, vertically or horizontally (i.e. , perpendicular to horizontal or vertical relief features, respectively) when hard substrate first was encountered and then settled "blindly" (i.e., randomly) towards the feature. A photoquadrat was obtained by utilizing the video camera to determine exactly when the distance probe touched the feature; a topside observer then triggered the camera system and verified that a photograph had been taken by seeing the camera strobe flash. If high vertical relief (defined as > 1 m) was encountered, attempts were made to conduct photoquadrats at the base of the feature and at l-m, 2-m, 5-m, and 10-m, etc., intervals, as conditions warranted. Photoquadrats (looking downward) on the top of the feature also were attempted before maneuvering down the other side and attempting photoquadrats at the same intervals on the way down. This process was intended to characterize high-relief features thoroughly when they were encountered.

During the survey, additional 70-mm photographs (vouchers) and 35-mm macro photographs (close-up) also were taken to document general community and habitat conditions and to aid in subsequent taxonomic identifications, respectively. In particular, nonphotoquadrat 70-mm photographs were collected

to document many of the transect areas that were characterized by sediment veneer.

Video Data

The color video camera was oriented at approximately a 45° angle downward during most of the transect surveys to document the general habitat and biological community in each area. These data were used for recording presence/absence information on large benthic organisms and associated physical parameters such as substrate type, relief, and sediment cover. Other survey documentation, including close-up video recording of features and organisms of interest, was performed by selective panning and refocusing of the video camera by topside observers.

Physical/Chemical Measurements

Physical/chemical measurements of near-bottom conditions were attempted at the beginning and end of a transect and, occasionally, at various points along the transect, as time and conditions permitted. Data were recorded by first allowing the sensors to equilibrate for at least one minute with the ROV maintained in a stationary position on the bottom. A microvideo camera was focused on the digital readouts for dissolved oxygen, temperature, conductive ty, and current speed; and these data were recorded on a log sheet by topside observers and on the videotape record.

Rock Collections

Rock collections using the ROV's biological scoop were planned for each of the hard substrate transects. Operationally, a photographic/video ROV dive was conducted first along a transect to identify potential areas for rock collections; a rock-collection dive then was planned in selected transect areas. However, due to significant wind and sea conditions encountered during much of the survey period and the scarcity of exposed hard substrate (particularly individual rocks of a reasonable size for collection), only one rock was collected using the scoop. Several rock samples were collected,

however, using a Smith-MacIntyre grab and a Gray-O'Hare box corer at some locations identified from the ROV survey. The use of these samplers did not allow the same type of visual assessment of the rock samples prior to collection as is possible using the ROV; however, the samplers did permit remote sample collections, which otherwise would not have been possible due to wind and sea constraints. Rock samples were placed in labeled buckets and preserved in 100% formalin until delivery to the laboratory for processing and analysis.

2.3.3 Hard Substrate Laboratory Methods

This section presents the laboratory methods used to analyze the photographic records, the video records, and the rock samples collected during the hard substrate survey. Signed log forms listing the photographic film rolls, videotapes, and rock samples served as chain-of-custody forms during transport of these data from the field and through laboratory processing and analysis.

Photographic Records

Photographic slides were collected along 14 transects in the Northern and Central California Planning Areas. The types of slides included (1) voucher photos (70 mm) taken at various ranges and angles from the bottom to document species, community types, and habitats; (2) photoquadrats (70 mm) of the benthic communities taken at standardized distances and orientations for quantitative analysis; and (3) 35-mm close-up (macro) photographs to facilitate identification of smaller (e.g., < 1 cm diameter) organisms.

A preliminary species list for standardizing taxonomic identifications was generated by first examining the 35-mm slides and the 70-mm nonphotoquadrat slides. Descriptive names (e.g., "purple sponge") were utilized when a more precise species name could not be determined. Each taxon was labeled with an identification number that referred to at least one representative photograph in which the organism was found. Following preparation of the preliminary species list, the 70-mm photoquadrats were examined and additional taxa were added to the list as they were identified.

The criteria for selection of acceptable photoquadrats (i.e., those photographs suitable for analysis) included:

(1) The camera was at a standardized distance of 80 cm (as determined using a distance probe attached to the ROV) and at an angle normal to the bottom or vertical face, depending on the relief;

(2) There were no obvious suspended sediments or excessive (> 20%) shadow; and

(3) There was spatial separation between photographs (i.e., nonoverlapping photographs).

Laboratory analysis of the photoquadrats taken on hard substrate was performed using a random-point contact method; however, selected photographs also were analyzed by enumerating all visible organisms and substrate. For the point-contact analysis, each slide was projected at actual size on a white background containing 50 randomly placed dots. Twelve different random-dot patterns were generated, and one pattern was selected randomly for use in the analysis of each photoquadrat. The feature (organisms, substrate, or photographic artifacts such as shadows) that occurred directly beneath each dot was recorded on a coding sheet. In addition, total quadrat counts were made of nonencrusting macrobenthos (e.g., corals, anemones, brittle stars, and fish) and a list of all species noted incidentally in the quadrat also was recorded. Finally, for transects which did not contain hard substrate, counts of commercially important, soft-substrate species, such as fish and shrimp, within acceptable photoquadrats also were recorded.

Photoquadrat Methods Evaluations

In order to assess the variability inherent using the point-contact method, two statistical comparisons were made: (1) selected photoquadrats were analyzed two additional times (resulting in triplicate analyses) using the same dot pattern, and (2) all taxa were recorded in selected photoquadrats, and these results compared with the point contact data. These data were converted to presence/absence to allow direct comparisons of the two methods. For the first comparison, a selected slide/dot pattern pair initially was analyzed using the point-contact method and then removed (from the slide projector and white

background, respectively); replicate analyses were performed by repositioning the same slide and dot pattern as accurately as possible and then performing a reanalysis. Assuming there is no variation in the observers (the same two scientists analyzed all slides), this method provides an assessment of the variability of the method since even slight movements (e.g. , 1 mm) in slide or dot pattern orientation may result in a different feature being contacted by individual dots. In relatively homogeneous environments, slight differences in dot orientations would be predicted to have a negligible effect on slide characterization (i.e., taxa and frequency of occurrence). The second comparison tested whether there was a significant difference in selected slides as determined using the point-contact method compared to analysis of all taxa in the same slides.

Video Data

The original purpose of the videotape recordings was to provide a continuous record of the habitat and community types along each transect; quantitative data primarily were to be obtained using standardized 70-mm photoquadrats. However, due to the scarcity of exposed hard substrate along the majority of the transects (see Table 3-1) photoquadrat data were limited and greater use was made of the video data for making statistical comparisons between transects and basins. Analysis of the photographic data served to familiarize the observers with species morphology, distribution, and habitats prior to analyzing the video tape records. To provide continuity with the photographic data, organisms identified during the video analysis were assigned to the lowest practical taxon, or given descriptive names based on the photographic species list.

Presence/absence data were recorded from standardized segments of 17 videotapes , representing 14 transect locations. Presence/absence, rather than numerical data, were utilized because somewhat variable movement in the speed and height of a ROV over the bottom made it difficult to standardize the area covered by video recordings, thus precluding the calculation of strictly quantitative data.

For the video analyses, 1:2000 scale navigational post plots of each transect were divided into a continuous series of "band quadrats." Each band quadrat represented a 30-m length of ROV video coverage which fulfilled two primary criteria:

(1) The ROV was within clear view of the bottom.

(2) The ROV did not overlap or circle the same area.

Video segments which did not fulfill these criteria were not included in the analyses. The start time of each 30-m band quadrat was identified by a time code. For example, along transect HB6 band quadrat 1 began at 11:36:00 and band quadrat 2 began at 11:37:24.

Once the band quadrats were identified along each transect, the number of acceptable band quadrats occurring within the shortest distance transect was used as a standard sample size for each of the remaining sites. The shortest transect distance was 900 m (30-30-m segments) at transect HB9. When the length of a transect permitted (i.e., a longer transect), the transect was divided into two subsets, each containing 30-band quadrats. Maintaining equal sample sizes in this manner between transects enhanced the power of the statistical analyses and the ease of biological interpretation (see Section 2.6.1, Data Analysis).

The video record for each band quadrat was reviewed until a 30-second segment of acceptable video record was accumulated. The video data were reviewed by two observers using a professional editing recorder and a high-resolution monitor. The recorder featured variable play and search speeds from single frame through normal and up to 10 times frame speed. The primary recorder set-up that was used was the automatically stabilized, single-frame capability, which allowed for detailed viewing/reviewing. This feature allowed the observers to stop, reverse, or review in slow motion each video segment, as needed, without picture distortion; and it greatly facilitated taxonomic identifications. Presence/absence data on physical features (e.g., substrate type, substrate relief, and other notable features such as wood debris) and all taxa observed were recorded for each band quadrat.

Video Methods Evaluation

In order to identify any significant variability associated with the technique, a selected number of band quadrats (10 on hard substrate and 20 on sediment veneer) were reanalyzed using, when possible, the second 30-second segment along each band quadrat. If only 30 seconds of acceptable coverage were available in a quadrat, then the same 30 seconds were reviewed again. This served to assess the variability of band quadrats within and among transects.

Rock Sample Laboratory Processing

In the laboratory, each rock sample was transferred from formalin, soaked in freshwater for 2-4 hours, and then transferred into 70% ethanol. Animals that had fallen off the rocks in the original preservation buckets were rinsed through a 0.5-mm screen and placed in labeled jars filled with 70% ethanol.

Technicians experienced in working on rock samples of this type sorted the motile and nonencrusting organisms and debris. The organisms were sorted into the nine major taxonomic groups: Annelida, Mollusca, Arthropods, Echinodermata, Porifera, Ectoprocta, Hydroida, Nematoda, and other phyla. Each rock was examined and picked using instruments such as forceps to ensure that all nonencrusting material was removed; rocks containing encrusting material were maintained separately.

After sorting, the animals in each taxonomic group were distributed to taxonomic experts. Entire rock specimens that contained encrusting forms were provided to appropriate taxonomic experts (i.e., those specializing in sponges, bryozoans, etc.) for identification. The taxonomists identified the animals to the lowest practical taxonomic level. A representative voucher collection was prepared as a reference for future monitoring studies and for distribution to the "Smithsonian National Museum. Undescribed species were given a provisional species designation using NODC code formats. This entailed coding the taxa as appropriate using the NODC hierarchical coding base (e.g. , phylum, class, order, family, genus), then assigning an MEC provisional suffix to the NODC

base. In addition, a brief description was prepared using the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) format.

2.4 SOFT SUBSTRATE FIELD AND LABORATORY METHODS

This section presents a description of the soft substrate survey and laboratory methods. Section 2.4.1 describes the field-sampling gear and techniques and the procedures for processing samples in the field. Laboratory procedures for sediment and infaunal analyses are described in Section 2.4.2. Quality assurance procedures associated with the various analyses are described in the corresponding text.

2.4.1 Field Survey Methods

All soft substrate sampling activities were conducted from the survey vessel M/V LADY BRIGID (Section 2.1.3). Bottom samples were collected using either a 0.1-m^2 Gray-O'Hare box corer or a 0.25-m^2 Hessler-Sandia box corer. When the 0.25-m^2 corer was used, a 0.1-m^2 stainless-steel insert was installed; a 0.1-m^2 sample was obtained by removing the material isolated by this insert. At each station, the sampler was lowered from the survey vessel by controlled descent to within approximately 10 m of the bottom. At that point, the speed of descent was increased to maximize sediment penetration and sample volume. The volume of sediment retrieved varied somewhat between stations, depending on the sediment type and surface weather conditions.

Upon recovery of the corer, the sample was inspected and the core quality was graded by assessing the amount of disturbance to the sediment surface. A rating of "Excellent" indicated that there was no apparent surface disturbance, no vertical disturbance, and that activity of infauna at the surface may have been apparent. A "Good" sample had slight surface disturbance, but no unnatural depressions or bulges on the surface. An "Acceptable" sample showed slight-to-moderate surface disturbance and slight vertical perturbation; siphoned water might have been turbid. A "Poor" sample showed obvious signs of surface disturbance, including vertical perturbation. Samples rated as "Poor"

were discarded, and the station was sampled again. Observations of the biotic and abiotic features of each sample were recorded on field log sheets.

Core Subsampling of Abiotic Parameters

For samples that were retained, the surface water was siphoned off and the sediment color, composition, odor, volume, and the presence of debris, including shell hash or tar balls, were recorded. Sediment subsamples for grain size and organic carbon analysis also were collected at this time. To accomplish this, a small coring device, 5 cm in diameter and 10 cm long, was inserted into the top of the core approximately 5 cm from any side of the corer. The subsample was removed from the main portion of the core, extruded, and split longitudinally with a stainless steel spatula. Each half was placed into a labeled plastic bag and frozen at -10"C until subsequent grain-size and organic carbon analyses were conducted on the respective halves. Laboratory processing of the sediments for grain size and organic carbon is described in Section 2.4.2.

Sieving of Biological Samples

After the collection of abiotic samples, the top 10 cm of each box core sample was scooped from the remainder of the core sample (i.e. , that portion > 10 cm deep) . The two sections (i.e., upper 10 cm and the remainder) were placed into separate large plastic trays and carried to the shipboard washing and sieving area. The upper 10-cm portion of the sample was placed in a specially constructed washing apparatus composed of stacked sieves with I.O-mm, 0.5-mm, and 0.3-mm screen sizes. The sediments then were washed gently with seawater. Sediments below the 10-cm level were sieved only through the I.O-mm screen. Animals, sediment, and debris retained by each screen size were placed in labeled jars. The organisms were handled gently to avoid breakage, and those organisms adhering to the screens were carefully removed with forceps. The sample labels included station, date, sampler, core-portion designation, screen size, and container information (e.g. , jar 1 of 2).

Preservation

Following the screening of the biological samples, a solution of 7% magnesium chloride ($MgCl_2$), an anesthetic, was added to each of the jars. The jar was filled to approximately 90% capacity and allowed to stand for at least 20 minutes. This procedure minimized fragmentation during fixation and subsequent handling, and it aided taxonomic identification because relaxed organisms tend to remain uncontracted. After the sample had been anesthetized for 20 minutes, 100% formalin was added to achieve a fixative concentration of approximately 10%. After approximately 72 hours, the sample was rinsed free of formalin and transferred into 70% ethanol for preservation. At the completion of the field effort, the samples were sent to the laboratory for further processing (Section 2.4.3).

Collection of Physical Measurements Data

Additional data on the soft substrate habitat were collected by means of various collection and measurement gear attached to the box corers. A custom external frame was fitted to the Gray-O'Hare corer to hold the supplementary instrumentation. The gear consisted of:

- Photosea 35-mm camera and strobe with a bottom-contact trigger adjusted to photograph a 1-m^2 area of the bottom prior to corer penetration.
- Water bottle sampler with reversing thermometers attached to the deployment cable and rigged to sample when the corer made bottom contact.
- Seabird CTD fitted with sensors to record dissolved oxygen, temperature, and depth at the point of collection.

Upon retrieval of the corer, data from each piece of supplementary instrumentation were recorded on a form. The beginning and ending photographic frames were noted, temperature was recorded from both the reversing thermometers and the Seabird CTD, and dissolved oxygen and depth were recorded from the Seabird CTD. Temperature also was recorded from the water bottle sample, and the dissolved oxygen concentration was determined using both a YSI

Model 51B DO meter and Hach Winkler Titration DO Kit. The redundant abiotic measurements were made to ensure that some data were obtained even if one system failed.

2.4.2 Laboratory Processing of Soft Substrate Samples

Sample Tracking Procedure

Chain-of-custody forms accompanied all samples. Sample-tracking sheets maintained by the laboratory manager ensured that samples were tracked from their origin in the field through laboratory processing to archiving and completion of data sheets for computer input.

Infauna Sample Sorting

Samples were sorted using stereoscopic dissection microscopes into five major taxonomic groups: Mollusca, Echinodermata, Polychaeta, Crustacea, and other invertebrate phyla. Every sample was assessed for sorting efficiency by using a statistically based sorting QA/QC procedure. The QA/QC procedure was based upon the results of resorting successive 10% subsamples of the original sample, up to a maximum of 30%. A statistical program provided the QA/QC analysts with a table showing, for a given total number of animals initially removed, the number of animals that could be found in resorted successive 10% subsamples and still meet the criterion of 95% initial sorting efficiency. If the resort showed that the sample passed (i.e., if the QA/QC analyst found no more than the number indicated in the table for the first 10% subsample), then no further resorting was necessary. If the number of animals found in the resort exceeded the number allowed for 10% but was no more than the number indicated for 30% of the sample, then another 10% subsample was resorted, and a third after that if the 20% number was exceeded but the 30% number was not, If at any point the total number of animals found in the resorted sample exceeded the number allowed for the 30% of the sample, the sample failed and the remaining fraction was resorted. By utilizing this stepped QA/QC procedure, a minimum of 95% sorting efficiency was attained for every sample.

Infauna Taxonomic Analysis

Specimens sorted from the samples were distributed to expert taxonomists who counted and identified animals to the lowest practical taxonomic level. Animals were identified using Wild M-5 stereoscopic dissection microscopes and, when appropriate, compound microscopes. The animals belonging to each taxon from each sample were placed in separate vials. A representative voucher collection was prepared as a reference for future monitoring studies and for distribution to the Smithsonian National Museum. Reference voucher collections from previous MMS- and BLM-sponsored programs, including the BLM Southern California Bight Baseline program and the MMS Phase I and II benthic programs, were reviewed to ensure taxonomic consistency. Undescribed species were given a provisional species designation by coding the taxa using the National Oceanographic Data Center (NODC) hierarchical coding base (e.g. phylum, class, order, family, genus), and then assigning an MEC provisional suffix to the NODC base. In addition, a brief description of each new species was prepared in the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) format.

Statistical comparisons with MMS Phase I (SAIC, 1986) and BLM studies (Fauchald and Jones, 1979a) were conducted for this study (Sections 2.6.2 and 3.2). Historical data were restricted to those for which taxonomic standardization was accomplished during the Phase I program by reexamination and reidentification of BLM samples. Additional standardization was accomplished through review of the reference collections from the Phase I and II studies and by using many of the same taxonomists who worked on these earlier studies. Prior to the analyses, the sample characteristics including areal coverage of the corer and the screen size also were standardized. The data from all three studies were standardized to 0.1 m^2, and only 1.0 mm screened samples were included since 0.5-mm data were not available from the BLM samples.

Biomass

The wet-weight biomass of each of the five major taxonomic groups was measured before taxonomic analysis. All of the animals from each group were blotted on

paper towels for 30 seconds to remove excess alcohol. The animals then were placed in weighing boats and weighed to the nearest 0.01 g on a Sartorius Model 1212 digital electronic balance.

Sediment Grain Size

The grain-size analytical procedure followed the protocol of Plumb (1981). For the analysis, a 38- to 40-g (wet weight) subsample was transferred to a 240-ml bottle, mixed with 150 ml of deflocculent (sodium hexametaphosphate), and allowed to stand overnight. The deflocculated sediment sample was sieved through a 63-pm sieve (U.S.A. Standard Testing Sieve No. 230) to separate the sand fraction from the silt-clay fraction. The sand fraction was thoroughly dried and then shaken for 10 minutes through a series of 11 U.S.A. Standard Testing Sieves, which ranged in 0.5-phi intervals from -1.0 to +4.0 phi (2 mm to 0.062 mm). The fraction of the sample retained on each sieve was weighed on a Sartorius model 1212 digital electronic balance. The silt-clay fraction (+4.0 to +10.0 phi; 0.062 mm to 0.001 mm) was measured in whole phi intervals by standard pipette timed-withdrawal methods, and weights for each phi interval were calculated. These two methods provided the fractional weights, for each interval. A computer program, GRAINY, was used to analyze the grain-size distribution and calculate values for mean and median phi size, dispersion, skewness, kurtosis, and percentages of sand, silt, and clay.

Quality control consisted of visual inspection of all screens and equipment prior to and following analysis, as well as strict adherence to the grain-size protocols. Duplicate analyses were conducted on a random 10% of the samples.

Sediment Organic Carbon

Sediment samples were analyzed for total organic carbon (TOC) using an Oceanography International Corporation (OIC) Model 524-B carbon analyzer fitted with a Horiba Model PIR 2000 infrared gas analyzer and ampule sealing unit. The method used was that recommended by the manufacturer with the modifications of OIC (1977).

A 10- to 15-gram (wet weight) subsample of sediment was dried at 60"c and ground to a uniform powder. A weighed 20- to 50-mg subsample of the dried powder was placed in a precombusted, sterile ampule. To remove the inorganic $CaCO_3$, 1.0 ml of 10% phosphoric acid was added and allowed to react for 30 minutes. The ampule was purged with oxygen for 8 minutes to drive off residual CO_2, sealed, and placed in an autoclave at 130°C for 4 hours to convert the remaining organic carbon to CO_2. After the sample cooled, the concentration of CO_2 was measured with an infrared CO_2 detector, and the concentration (in moles) was recorded. Standards and blanks were analyzed with each set of samples. Duplicate analyses were conducted on 10% of the samples for quality assurance.

2.5 SEABIRD, MARINE MAMMAL, AND FISHERIES OBSERVATIONS

Standardized seabird and marine mammal observations were conducted daily throughout the survey to record the occurrence of those animals within the general survey areas. Fishing activities observed within the study area also were recorded.

For the seabird and marine mammal surveys, continuous, fifteen-minute observations using standard 7x50 field binoculars were conducted in each hard substrate survey area (i.e., during the daylight survey periods). Incidental sightings of birds and mammals during other survey periods also were recorded. The observations included identifications to the lowest possible taxonomic level, estimated numbers of each taxon, and general activities (e.g., feeding, rafting, etc.). Incidental observations of fishing activity, including the general class of vessel (e.g., crab boats, trollers, and trawlers) and its activity, also were noted.

2.6 DATA ANALYSIS METHODS

The statistical methods presented in this section provide an overview of the various analytical techniques applied to hard and soft substrate biotic and environmental data. Appendix A, Volume I, provides a more detailed description of the methods including experimental design, multivariate community pattern

analysis, multivariate and univariate hypothesis testing, evaluation of environmental relationships to biological data, and replication analysis.

2.6.1 Multivariate Analyses

Ordination and cluster analyses were used to identify and display spatial patterns in both the hard and soft substrate benthic community data (Clifford and Stephenson, 1975; Gauch, 1982; Pielou, 1984). Fjor these methods multiple variates (e.g., species) are utilized simultaneously to yield an output that summarizes the relationships of the observations (e.g., stations or transects).

Ordination displays the observations (e.g., stations) in a multidimensional space. The dimensions of the space are called axes, and the projections of the points onto the axes are called scores. The axes are ordered according to the amount of variation in their scores; the first axis has the greatest variation, and the last axis has the least. Major environmental gradients, which are associated with biological changes, will tend to correlate with the axes characterized by larger proportions of the variability. The axes are positioned so that the scores on the different axes are uncorrelated to minimize redundancy. Further discussions on ordination techniques are found in Gauch (1982) and Pielou (1984).

The ordination method used here, called nonmetric multidimensional scaling (Kruskal, 1964; Kruskal and Wish, 1978; Sibson, 1972; Prentice, 1977), requires the input of an intersample dissimilarity matrix and an initial ordination configuration. The Bray-Curtis dissimilarity index was used (Bray and Curtis, 1957; Clifford and Stephenson, 1975); large dissimilarities were re-estimated from the smaller dissimilarities using the step-across procedure (Williamson, 1978; Smith, 1984; Bradfield and Kenkel, 1987). Detrended correspondence analysis scores (Hill and Gauch, 1980; Gauch et al., 1981; Gauch, 1982) were used as the initial ordination configuration. This methodology results in an ordination space relatively free of distortion and one in which the biological relationships among the stations or transects are accurately represented. The approach is discussed in more detail in Smith et al. (1987).

Cluster analysis involves delimiting groups of observations which are biologically similar (Clifford and Stephenson, 1975; Pielou, 1984). Cluster analysis is also used to identify groups of species which occur in similar habitats. The specific clustering method used is an agglomerative, hierarchical clustering method (Clifford and Stephenson, 1975) called flexible sorting. The sorting coefficient Beta was set at the standard value of -.25 (e.g., Tetra Tech, 1985). Agglomerative clustering consists of successive fusion of the most similar entities (or groups of entities) to form larger and larger groups. The dissimilarity measures used in the clustering are computed from the ordination space. The relationships between the entities being clustered (samples or species) are displayed with a two-dimensional hierarchical structure called a dendrogram.

The results of the cluster analyses of the samples (stations or transects) and species are used to generate a two-way coincidence table that optimally displays the patterns of species-importance values over the observations (Kikkawa, 1968; Clifford and Stephenson, 1975). The two-way table makes it easier to see the patterns of species abundance and composition because similar samples and species are contiguous in the table, as they are on the respective dendrograms.

Prior to the analyses, rare species were eliminated because they normally have little effect on the results (e.g., Day et al., 1971; Smith, 1976). Raw biological data were transformed using a square-root transformation to remove potential overdominance of species with highly skewed abundance distributions. The transformed data were then standardized by the species mean (of values >0). The standardization somewhat equalizes the contributions of the various species and gives more weight to species that are more variable across the different habitats (Smith, 1976).

Once the benthic community patterns were defined, correlational analyses were applied to develop hypotheses concerning the environmental causes of these

patterns. Separate community patterns were defined in terms of scores on the different ordination axes and/or station or transects groupings from the cluster analyses. The relationships between the community patterns and the environment were investigated with multiple regression analysis.

The first few ordination axes quantify the major patterns of community change in the biological data. Therefore, these axes will correlate with the environmental measurements that quantify the environmental gradient(s) causing the community changes. However, high correlations between the ordination scores and some of the measured environmental parameters do not prove a cause-and-effect relationship. Accordingly, the observed correlations are used only to generate hypotheses of cause and effect.

To simplify the regression analysis, a variable selection technique which considers all possible combinations of the measured environmental variables was used (SAS, 1985; R-SQUARE procedure). The model chosen was that containing the number of variables at which the R-SQUARE values began to level off. Diagnostic aids were utilized in the interpretation of the multiple regression results (SAS, 1985; REG procedure). Statistical tests were performed to determine the probability that the regression results were due to chance. All results presented here were significant at the $\alpha = 0.05$ type-1 error level. Note, however, that statistical significance does not guarantee an ecologically meaningful result.

The spatial patterns of the ordination scores and selected environmental variables were plotted on maps of the area, which included the positions of the sampling sites and other pertinent geographic features. Isopleths were drawn to emphasize the patterns.

Since the relative positions of the observations in an ordination space correspond to the communities associated with the observations, the ordination scores, or the distances between observations in the ordination space, were used to test hypotheses concerning community differences between spatial areas or sediment types. The distances between observations in an ordination space were also used to describe quantitatively the amounts of community change

associated with different amounts of spatial change or with methodological differences. Finally, the ordination results from different levels of soft substrate station replication were compared in an evaluation of the need for station replication in large-scale studies.

A cluster analysis based on measurements of sediment size also was performed to define groups of stations having similar sediment types.

A more detailed discussion of these methods is presented in Appendix A, Volume I. Appendices A-1 and A-2 contain methodological details which are specifically relevant to the hard substrate and soft substrate analyses, respectively.

2.6.2 Univariate Analyses

The univariate analyses involved the use of single variates in the evaluation of patterns and differences among the observations in the soft substrate survey data. Variates considered in these analyses were abundances of individual species, community summary parameters, and environmental measurements.

The species selected for analyses were the more abundant species in each basin and those representative of known feeding types. Community summary variables included total abundance, number of species, diversity, dominance, biomass, and abundance by major taxonomic category.

Hypotheses concerning differences in these variates among basins, depths, and sediment types were tested with analysis of variance (ANOVA). analysis of covariance (ANCOVA), and multiple comparisons (Tukey-Kramer range tests). The within-station and between-station variabilities of selected variates were computed and compared. The results of these analyses should assist the design of future sampling programs in the survey area. Finally, the correlations between the individual species and the environmental measurements were examined with multiple regression. Additional details of the univariate methods are presented in Appendix A, Volume I.

3.0 RESULTS AND DISCUSSION

This section presents the results and discussion from the hard substrate and soft substrate studies (Sections 3.1 and 3.2, respectively) and the incidental observations of seabirds, marine mammals, and fisheries activities (Section 3.3). The hard substrate section addresses both the exposed hard substrate and soft substrate (presumably sediment veneer covering hard substrate) habitats and communities observed during the ROV transect surveys. The soft substrate section addresses the habitat and community data collected from the box-core samples. The raw data from the survey are tabularized in the Data Report submitted to the MMS in hard copy and on computer diskettes in November 1988.

3.1 HARD SUBSTRATE

This section presents the results and discussion of the data from the hard substrate program. An overview of the study area and the types and numbers of samples collected is presented first, followed by sections on the physical environment, particularly the relative occurrence of hard substrate and soft substrate habitat (Section 3.1.1); an overview of characteristic taxa and biological communities (Section 3.1.2); community patterns, new taxa, and environmental correlations (Section 3.1.3); large-scale spatial patterns, including comparisons between basins in the survey area and comparisons with historical data (Section 3.1.4); and video and photoquadrat methods evaluations (Section 3.1.5).

Overview of Survey Area and Data Collected

Hard substrate survey operations were conducted along 14 transects (numbered HB1 through HB10, HB13, HB14, HB16, and a transect renumbered as HB17) within four geographic basins located in the MMS Northern and Central California Planning Areas (Figures 1-1, 2-1, and 2-2 of Volume I). In the Northern Planning Area, four transects were surveyed in the Eel River Basin, and six were surveyed in the Point Arena Basin. In the Central Planning Area, two transects each were surveyed in the Bodega and Santa Cruz Basins. A summary of navigational start-and-end coordinates and a detailed listing of the

navigational coordinates at 30-second intervals along each transect are presented in Table 2-1, Volume I and in Appendix C, Volume II, respectively. Navigational plots of each transect at a scale of 1:2,000 along with a summary of the biological communities are presented in Appendix D, Volume II. Charts of the transects at a scale of 1:96,000 were submitted to MMS as a separate deliverable. Originally planned transects HB11, HB12, HB15, and HB17 (original) through HB20 (see Volume II, Appendix A) were not surveyed due to weather/schedule constraints.

Data collected during the survey consisted of: (1) 235-70 mm photoquadrats, of which 81 (which fulfilled the acceptance criteria for photographs listed in Section 2.3) were analyzed from two transects (HB6 and HB8) using the point-contact method; (2) 947-70 mm voucher specimen/habitat characterization photographs; (3) 56-35 mm macro (close-up) voucher specimen photographs; (4) approximately 31 hours of color videotape records from which presence/absence data were analyzed from all 14 transects; (5) nine rock samples collected from two hard substrate transects (HB8 and HB9) and three soft substrate stations (SB39, SB43, and SB52; station locations shown in Figures 2-3 and 2-4, Volume I); and (6) measurements of temperature, dissolved oxygen, salinity (converted from conductivity), and current speed from each transect, with the exception of DO and current speed at one transect and salinity at four transects. General characteristics based on observer survey logs of the 14 transects including basin, depth range, approximate percentage of hard predominant substrate, common species, and notable features are presented in Table 3-1 and summarized below.

Overview of Data Analyses

The survey and analytical design for the study is significantly influenced by the overall scarcity of exposed hard substrate in the survey area (summarized in Table 3-l), but also by the lack of this substrate at the same series of depths (e.g., 50, 100, 200, 300 m) within each basin, thereby preventing a strictly balanced design to assess within- and between-basin differences. There are, however, many valid comparisons which can be made.

IABLE 3-1. SUMMARY FROM OBSERVER SURVEY LOGS OF GENERAL CHARACTERISTICS OF HARD SUBSTRATE TRANSECTS. ffMS CARP SURVEY (November/December 1987).

Transect	Basin	Depth (m)	Approx. % Hard Substrate	Common Taxa	Notable Features
HB1	Eel River	125-127	0	Footnote 1 species + panda lid shrimp	High shrimp densities; part of commercial shrimp grounds
HB2	Eel River	101-103	3	Footnote 1 species + other sea pens	Probable trawl tracks; schools of Pacific hake
HB3	Eel River	225-280	0	Luidia, Octopus	No retractable sea pens (suggesting <1 m sediment veneer); mysid swarms; some wood debris
HB4	Eel River	22.4-285	5	Luidia, Octopus; galatheid crabs and seastars (Rathbunaster) on wood debris	Extensive wood debris; rocks sparse; no retractable sea Pens (suggesting < 1 m sediment veneer); mysid swarms
HB5	Pt. Arena	131-141	15	Footnote 1 species + dense brittle stars	Rocks sparse; single salmon at - 140 m-depth
HB6	Pt. Arena	70-05	100	Anemones (incl. Metridium), feather stars (Florometra), basket stars (Gorgonocephalus), rockfish (Sebastes spp.), CUP corals	Allopora present; extensive fractured reef and boulder complex
HB7	Pt. Arena	104-106	0	Footnote 1 species	None
HB8	Pt. Arena	113-120	75	Brachiopods (Lagueus) dense, feather stars, calcareous sponges, rock fish, gorgonians, ophiuroids	Low-relief (0-1 m) outcrops and boulders; sediment veneer
HB9	Pt. Arena	124-128	30	Similar to HB8 but more sparse	Sparse, low relief (0-0.3 m); sediment veneer; isolated areas Of high seastar (Stylasterias and Mediaster) densities
HB10	Pt. Arena	246-338	0	Rathbunaster, sea urchins (Allocentrotus), Octopus, Luidia, sea cucumbers (Parastichopus)	No retractable sea pens (suggesting . 1 m sediment veneer)
HB13	Bodega	154-161	10	Footnote 1 species + seastars (Mediaster)	Sparse outcrops w/Metridium and Lagueus; single salmon at 160-m depth

TABLE 3-1. (cent inued)

Transect	Basin	Depth (m)	Approx. % Hard Substrate	Common Taxa	Notable Features
HB14	Bodega	176-192	0	Parastichopus, Octopus, Luidia # --Media aster, Sebastes Spp ., Allocentrotus	Only rocks were at bottom of 0.3-1 m deep "holes" in sediment; Gorgonocephalus "stranded" on soft substrate; schools of pacific hake
HB16	Santa Cruz	61-68	75	Metridium, gorgonians, vase sponges, cup corals	Boulders from O-2 m high; Allopora
HB17	Santa Cruz	85-93	5	Footnote 1 species + other sea pens	None

1 Common species include: sea pens (Stylatula elongata), Octopus rubescens, seastars (Luidia foliolata), and miscellaneous demersal fish (e-g. , flatfish and poachers).

Due to the large number of transects characterized by sediment veneer, the data analyses were structured to address questions which first evaluated obvious differences between transects or transect areas characterized by hard substrate versus sediment veneer. These analyses were based on the video presence/absence data, since the 70-mm photoquadrat data were limited to hard substrate areas, and broadly served to separate the biological communities based on their association with different substrate regimes. A subset of the video database was used to address separately the differences among transects and basins for hard substrate and sediment veneer data; these analyses, which included cluster, ordination, and multiple-regression techniques, considered biological and environmental variables.

The two different types of habitats are referred to in this section as (1) hard substrate, pertaining to transect areas with predominantly exposed hard substrate, usually with some relief, or (2) sediment veneer, pertaining to transect areas with predominantly soft substrate and no relief. The sediment veneer areas apparently represent regions of sediment cover of varying depths over hard substrate, as judged from the side-scan sonar records reviewed for this study (Section 2.1); it is not known if these underlaying hard substrate areas are intermittently exposed or buried depending on scouring or deposition of bottom sediments, although some indirect evidence that this occurs is summarized in Table 3-1 and discussed in this section. The data base from the 70-mm photoquadrats represented only two hard substrate transects (HB6 and HB8) both located in the Point Arena Basin; therefore, these analyses were restricted to evaluating between transect differences. Discussion of the results from the separate analyses of the hard substrate and soft substrate video data and the hard substrate photoquadrat data is presented in Sections 3.1.3 and 3.1.4.

Overview of Transect Characteristics

The bottom depths over the 14 transects ranged from 61 m to 338 m. Eight of these transects were located at depths between 100 m to 200 m and of the remaining six, three were located at depths less than 100 m and three at depths greater than 200 m (Table 3-l). The broadest depth range of the transects

within a basin was 70 m to 338 m in the Point Arena Basin, followed by 101 m to 285 m in the Eel River Basin. In contrast, transect depth ranges within the Bodega and Santa Cruz Basins were much more restricted (154 m to 192 m and 61 m to 93 m, respectively).

The most notable substrate features observed from the survey were that 8 of the 14 transects were characterized entirely or predominantly by sediment veneer, with only three transects (HB6, HB8, and HB16) representing extensive (> 75%) hard substrate features (Table 3-l). Transect HB9 was characterized by approximately 30% hard substrate. These transects also represented most of the shallowest survey areas, ranging from 61-128 m depth. A discussion of the significance of these extensive sediment veneer areas to the formulation and testing of hypotheses on the benthic environment is presented in Section 3.1.1.

Common taxa were strongly representative of the major differences in substrate type (hard versus sediment veneer) observed along the transects. Sediment veneer areas generally were characterized by sea pens, octopus (O. rubescens), sea stars (Luidia foliolata), various flatfish, Pacific hake, and poachers. These taxa are very similar to those noted in "soft substrate" areas from the MMS Phase I and Phase II surveys (SAIC, 1986 and Battelle, 1988, respectively). Notable exceptions to this trend for the present survey were the occurrence along one transect (HB14) of basket stars (Gorgonocephalus eucnemis), which normally are found only on hard substrate, but which appear to have been "stranded" on soft substrate, presumably by sediment encroachment into a rocky habitat; this suggests shallow sediment cover over hard substrate. Further, sea pen species such as Acathoptilum gracile, which do not retract into sediment, were found along Transects HB3, HB4, and HB10, while retractile species such as Stylatula elongata were absent; this may represent further evidence of shallow sediment depths, although limitations in the depth distribution of S. elongata also may be a factor (see Section 3.1.1). Common taxa on hard substrate included anemones (e.g., Metridium senile), feather stars (Florometra serratissima), cup corals, sponges, and rockfish (Sebastes spp.), and along one low-relief transect in particular (HB8) brachiopods (Laqueus californianus) and ophiuroids. The taxa observed in the hard

substrate areas also are very similar to those documented from other studies at similar depths (e.g., SAIC, 1986 and Battelle, 1988).

3.1.1 Characteristics of the Physical Environment

The transect locations summarized in Table 3-1 correspond to large (e.g., at least one quarter of a square nautical mile) side-scan and/or bathymetric targets which suggest the occurrence of hard substrate (see Section 2.1). However, based on the survey results indicating that 8 of the 14 transects were characterized entirely or predominantly by soft substrate, we hypothesized that these soft substrate areas actually represent hard substrate features overlain by a sediment veneer. Supportive evidence for this hypothesis included visible rocks at the bottom of approximately 0.3-1 m deep holes and apparently "stranded" hard substrate epifauna (e.g., the basket star, Gorgonocephalus eucnemis) along Transect HB14, and the lack of large, retractable sea pens along three transects, as noted above. These examples suggest a relatively thin (e.g., $\leq$ 1 m) sediment veneer along these transects; it is likely that some of the hard substrate features overlain by the veneer are intermittently exposed as a result of sediment movement from near-bottom currents as discussed later in this section. In contrast, the epifaunal communities observed along the other transects characterized by sediment veneer were more typical of well-developed soft substrate communities noted from other studies (e.g., SAIC, 1986); no evidence other than the side-scan records is available to support the occurrence of hard substrate at these sites. Sea pens in particular may be useful indicators of minimum substrate depths since some species such as Stylatula elongata, which were common along many of the transect areas, retract completely into the sediment and can be up to one meter in length (J. Ljubenkov, pers. ohs.); therefore, the sediments in these areas probably are at least one meter deep. However, even though S. elongata has been observed commonly at depths up to 260 m (SAIC, 1986), the three transects (HB3, HB4, and HB10) from which this species was absent were located at the deepest survey depths (224-338 m) from the present study; thus, their distribution may be influenced by a limited species depth range, as opposed or in addition to the possibility of substrate depth limitations (see Section 3.1.3).

General physical characteristics for each transect based on the video data are summarized in Table 3-2. Data are presented separately for the two replicate halves (designated "A" or "B") of a transect, as appropriate, and also provide an initial indication of high within-transect similarities. A detailed discussion of within-transect variability is presented in Section 3.1.3. Each transect replicate represents data from 30 band quadrats (see Section 2.3). The band quadrats each were evaluated for all the physical attributes listed in Table 3-2; therefore, more than one type (e.g., 1-3 m relief and > 3 m relief) may be represented in the same quadrat.

Hard substrate primarily was observed along three transects (HB6, HB8, and HB16) located in the Point Arena and Santa Cruz Basins, ranging from approximately 100% to 75% cover. Transect HB9, also located in the Point Arena Basin, was very similar (depth range and common taxa) to HB8 but was characterized by a lower frequency of hard substrate (30%). Four other transects (HB2, HB5, HB13, and HB17) had low percentages of hard substrate, ranging from approximately 3-15%; however, even these occurrences represent very limited, low-relief features.

Transect. HB4 in the Eel River Basin was unique in having extensive wood debris which served as a habitat for some species (e.g., galatheid crabs) usually characteristic of hard substrate. Transect HB3 in the Eel River Basin also had some wood debris, as noted from the shipboard observer logs; however, these occurrences were not recorded from the video band quadrats analyzed in the laboratory. Substrate relief greater than 3 m was observed only along Transects HB6 (60%) and HB16 (10%); the remaining hard substrate areas generally were low relief (< 15 cm) with Transect HB8 representing the only other area of significant relief between 15 cm and 1 m.

Inspection of the 70-mm slides from the transects indicated several features about the geology of the hard substrate features:

TABLE 3-2. PERCENT OF BANDQUADRATSWITH PRESENCE OF SELECTED PHYSICAL ATTRIBUTES ALONG HARO SUBSTRATE TRAMSECTS. Data are summarized from color video, presence/absence information derived from 30, 30-m observational band quadrats. "Rep" (replicate) refers to the fir St ("A") or second (*'B") 30, 30-m band quadrats along a transect, as appropriate.

Transect	Rep	Basin	Burrows	Furrows	Hummocks	Ripples	Boulders	Cobbles	Pebbles	Sheil Hash	Sediment Veneer	Turf	Wood Debris	Flat	0-15 cm Relief	15 cm-l m Relief	1-3 m Relief	>3 m Relief
HB1	A	Eel River	57	47	0	0	0	0	0	0	100	0	0	100	0	0	0	0
HB2	A	Eel River	100	27	100	3	0	0	0	0	100	0	0	97	3	0	0	0
HB2	B	Eel River	100	20	100	0	0	0	0	0	100	0	0	100	0	0	0	0
HB3	A	Eel River	53	13	0	0	0	7	0	0	100	0	0	100	0	0	0	0
HB4	A	Eel River	17	17	0	0	0	7	0	73	100	13	63	87	13	0	0	0
HB4	B	Eel River	0	0	0	0	0	0	0	0	100	0	100	100	0	0	0	0
HB5	A	Pt. Arena	20	23	0	0	10	?	0	0	100	10	0	87	7	10	0	0
HB6	A	Pt. Arena	0	0	0	10	40	20	0	37	37	100	0	3	10	13	70	60
HB7	A	Pt. Arena	10	3	3	100	0	0	0	0	100	0	0	100	0	0	0	0
HB8	A	Pt. Arena	0	17	0	27	57	50	3	70	93	77	0	23	73	63	0	0
HB8	B	Pt. Arena	0	0	0	0	67	83	7	3	90	90	0	10	90	63	0	0
HB9	A	Pt. Arena	27	3	0	0	13	10	0	0	97	37	0	67	30	3	0	0
HB10	A	Pt. Arena	3	20	0	0	0	3	0	0	100	0	0	100	0	0	0	0
HB10	B	Pt. Arena	7	0	0	0	0	0	0	0	100	0	0	100	0	0	0	0
HB13	A	Bodega	67	40	3	3	0	3	0	0	100	3	0	97	3	0	0	0
HB13	B	Bodega	53	37	3	0	0	a	0	0	100	7	0	90	10	0	0	0
HB14	A	Bodega	23	7	0	23	0	o	0	0	100	0	0	100	0	0	0	0
HB14	B	Bodega	63	0	0	30	0	0	0	0	100	3	0	100	0	0	0	0
HB16	A	Santa Cruz	0	0	0	7	87	0	0	10	7	100	0	0	3	3	100	10
HB17	A	Santa Cruz	40	0	0	97	0	3	0	0	100	3	0	97	3	0	0	0

- o Transect HB4 (Eel River Basin; 224-285 m depth) has some areas of rounded cobbles which suggest bedrock of sedimentary origin; that is, a conglomerate from which the cobbles were eroded, since it appears unlikely that these cobbles could be transported this distance offshore.

- o Transect HB6 (Point Arena Basin; 70-85 m depth) is characterized by extensive rocky reefs and fractured boulder fields, possibly of basaltic origin.

- o Transect HB8 (Point Arena Basin; 113-120 m depth) has some areas which appear to be massive basalt features (possibly pillow lavas); some photographs were obtained of unweathered basalt.

Ten transects were characterized primarily by sediment veneer (Table 3-l); they typically had flat, muddy bottoms with a range of small- and large-scale disturbances including burrows (indicating biological activity), furrows (possibly of biological origin but in some areas of the Eel River Basin suggesting trawl tracks), and ripples (probably indicating current patterns) . In general, the frequency of burrows was highest for Eel River Basin Transects HB1-HB3 and the Bodega Basin transects (HB13 and HB14), generally ranging from > 50% to 100%; these higher levels in the Eel River Basin probably are related to the increased infaunal abundances in this basin relative to the other basins (see discussion in Section 3.2). Furrows showed a similar pattern as noted for the burrows but because of the larger scale of these disturbances it is unlikely that they are related to bioturbation; a combination of fishing activity and/or current induced patterns may be the cause, as distinguished by the shape of the feature. Trawl-produced features were evident as angular-edged furrows often associated with accumulations of subsurface sediments such as clay, while presumed current-produced features were more rounded. Bottom ripples, probably indicating current patterns, were noted primarily from three transects in the Eel River Basin, one in the Bodega Basin, and two in the Santa Cruz Basin; however, the relatively small viewing scale of the photographic and video records may underestimate these occurrences. It is noteworthy that ripple patterns were observed over a range of bottom depths from 61-192 m, as would be predicted in offshore areas which are commonly exposed to significant near-bottom currents and wind and sea conditions. Current data from the survey are discussed below.

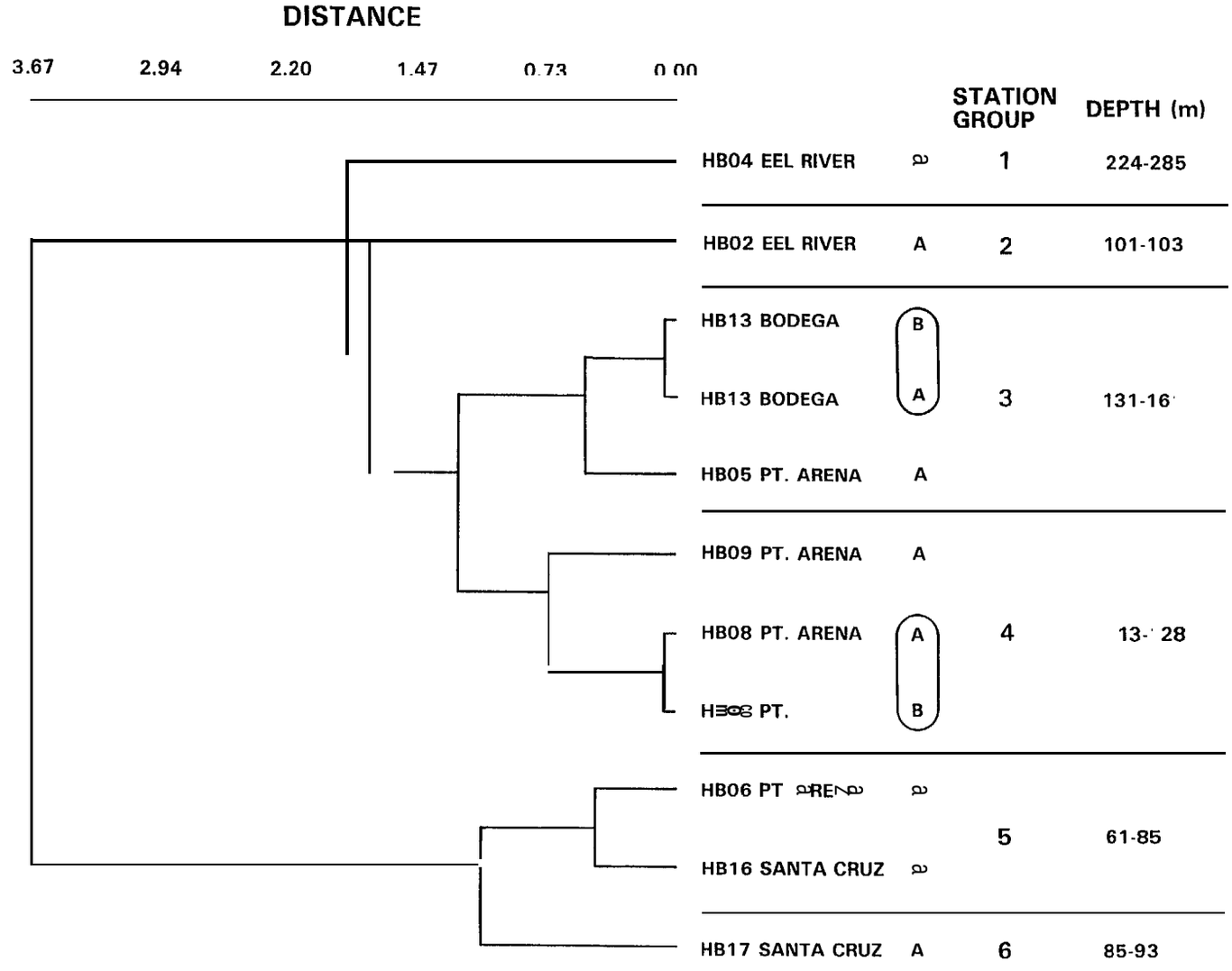


FIGURE 3-7. CLUSTER ANALYSIS OF EXPOSED HARD SUBSTRATE VIDEO PRESENCE/ABSENCE DATA TO ASSESS THE VARIABILITY AMONG TRANSECT REPLICATES. Station groups (1-6) and their depth ranges are shown. Replicates (A and B) from the same transect are circled.

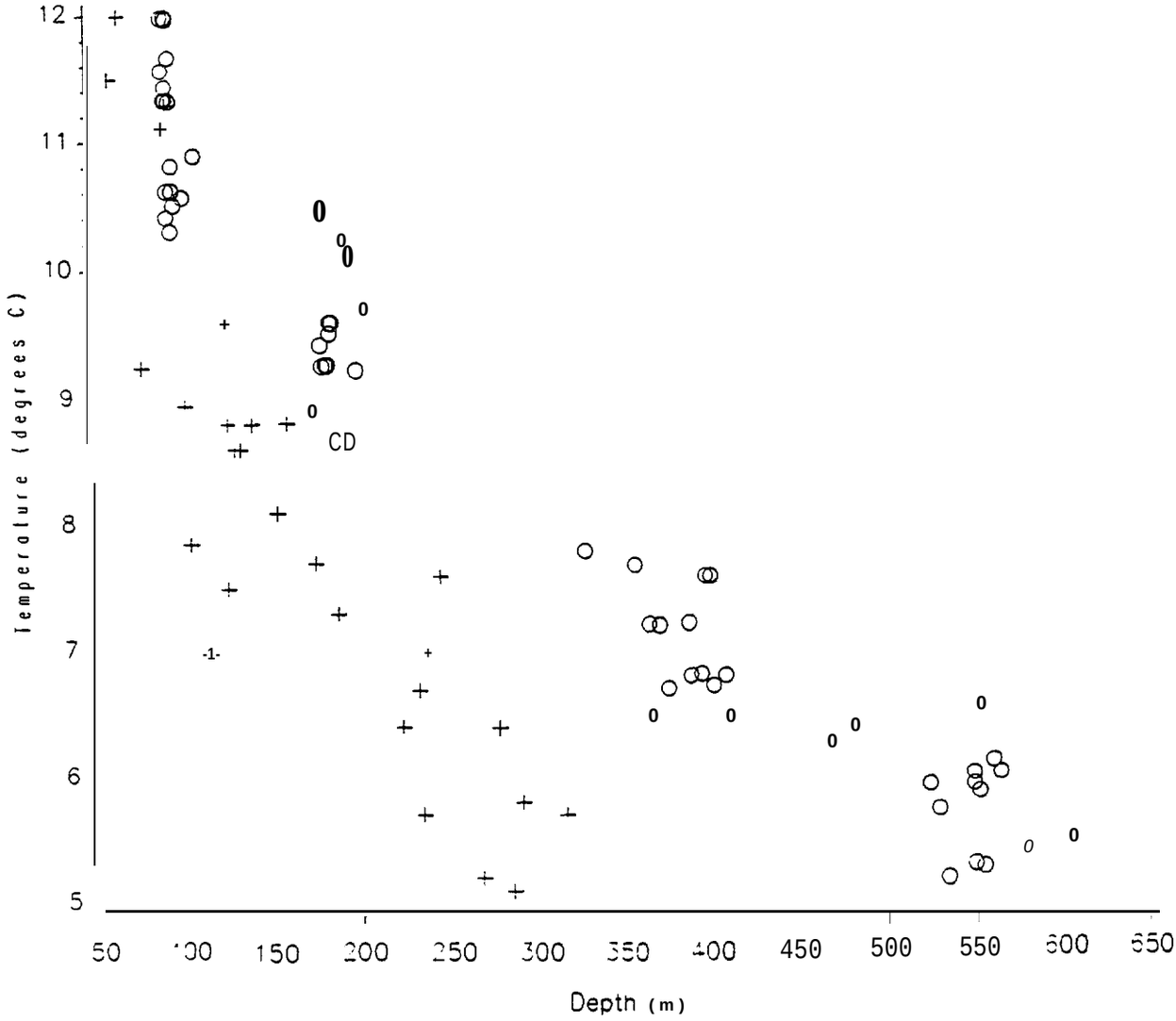


FIGURE 3-1. NEAR-BOTTOM WATER TEMPERATURE (DEGREES C) VERSUS DEPTH (M) PLOTS FROM THE HARD AND SOFT SUBSTRATE SURVEYS. Hard substrate data are indicated by a "+"; soft substrate data are indicated by a "o". MMS CARP Program (November/December 1987).

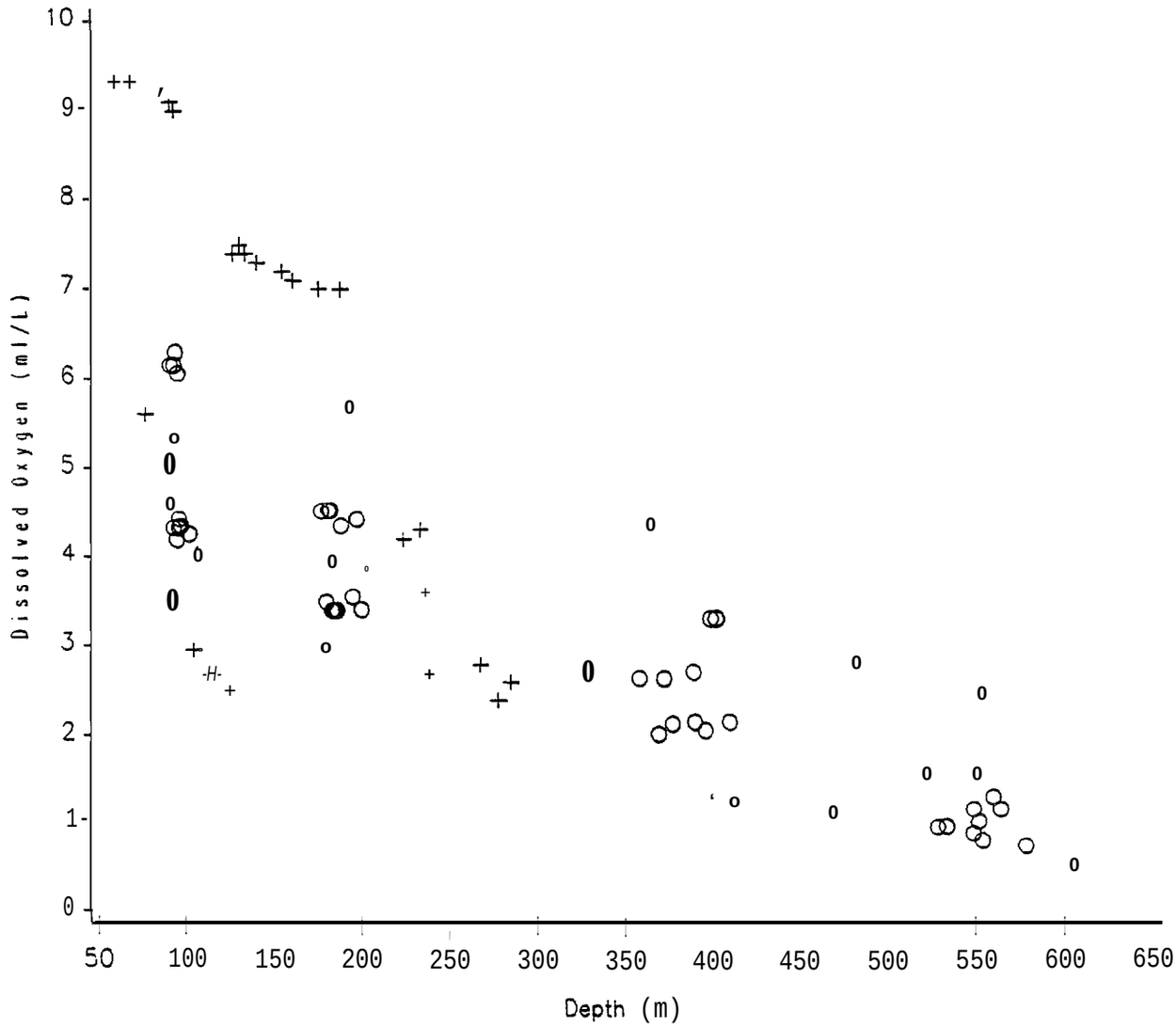


FIGURE 3-2. NEAR-BOTTOM WATER DISSOLVED OXYGEN (ML/L) VERSUS DEPTH (M) PLOTS FROM THE HARD AND SOFT SUBSTRATE SURVEYS. Hard substrate data are indicated by a "+"; soft substrate data are indicated by a "o". MMS CARP Program (November/December 1987).

California offshore waters (Sholkovitz and Gieskes, 1971; Lynn and Simpson, 1987) .

The salinity data showed a general trend of increased levels with increased depth (Table 3-3), ranging from 31.8 ppt at 76 m depth (Transect HB6 in the Point Arena Basin) to 34.8 ppt at 278 m depth (Transect HB3 in the Eel River Basin) . These values are consistent with near-bottom salinity measured during CODE (Huyer and Kosro, 1987). A value of 31.3 ppt recorded from 246 m depth (Transect HB10) is believed to reflect a temporary malfunction of the conductivity probe since the other data from similar depths along this transect were approximately 2 ppt higher. Salinity values less than approximately 33 ppt are low relative to results from other studies of California offshore waters (e.g. , summarized in BLM, 1978) and also may indicate equipment malfunctions. The remaining data are within expected levels of approximately 33 to 35 ppt over the range of survey depths.

The near-bottom current data generally reflect low-to-moderate speeds which did not have a strong relationship with depth (Table 3-3). Current speeds ranged from 5-50 cm/sec (50 cm/sec is approximately equal to 1 nautical mile/hour) with this highest speed recorded from 246 m depth along Transect HB3 in the Eel River Basin. This range of data is very comparable to results from other studies of California offshore regions (e.g., SAIC, 1986). Similarly, Cacchione et al. (1987) measured near-bottom current speeds up to 30 cm/sec along the northern California shelf during passage of a moderate storm. The relatively high current speeds (e.g., > 25 cm/see) at depths greater than 200 m, and combinations of current speeds and large wave stress in shallower depths, are a strong indication of the potential for sediment resuspension and movement in these benthic environments. These currents may influence exposure or burial of some hard substrate features in the survey area.

The relationship of the environmental data (physical/chemical and substrate variables) to the distribution and abundance of the benthic communities is discussed in Section 3.1.3.

3.1.2 Characteristic Taxa and Biological Communities

This section provides an overview of the common taxa and communities observed along the hard substrate transects, including areas of exposed hard substrate and the extensive areas of sediment veneer which predominated along most of the transects. Summaries are presented on the number of taxa (total taxa and total taxa by major phyla), total occurrences, and the major species groups (defined based on their association with specific station groups) within the survey area. The discussion of species groups incorporates the results from multivariate analyses of the video presence/absence data. This video record includes biological and environmental data from each of the 14 transects and therefore allows a broad-scale assessment of species and station groups over the entire survey area. The multivariate analyses serve to separate the groups initially between those taxa occurring on hard substrate and those occurring on sediment veneer; subsequent analyses (see Section 3.1.3) treated the hard substrate and sediment veneer data separately to focus better on differences within each type of habitat.

Dominant Taxonomic Groups

The total number of taxa observed from the video, photoquadrat, and rock samples data is 134, 139, and 195, respectively (Appendix F, Volume II). However, if fish, rays, and sharks are excluded, the video and photoquadrat lists are reduced to 91 and 132 taxa, respectively. Principal differences between the video/photographic and the rock samples taxa (excluding fish, rays, and sharks) are the predominance of coelenterates, echinoderms, and sponges from the video/photographs as compared to polychaetes and crustaceans from the rocks. These differences primarily are related to the different viewing scales and level of taxonomic identifications which are possible using these methods; video provides identification of larger (e.g., > 1 cm) organisms over scales of a few meters; photoquadrats provide identification of smaller organisms at a scale of 0.3 m^2, and the rock samples provide identification of all taxa on the rocks, limited to rock sizes generally < 20 cm. The group designated "minor phyla" includes by convention several phyla which, when added together, may artificially increase the apparent importance of this group. However, sponges

in particular were well represented in the photoquadrat data (23 taxa; taxa generally = morphs for the sponges) constituting the majority of the taxa in the minor phyla group. Also of importance in this group were bryozoa (18 taxa) from the rock samples.

The total taxa, total occurrences, and numerically dominant taxa by transect and replicate are summarized in Tables 3-4 and 3-5 for the video and photoquadrat data, respectively. Total occurrences for the video data is defined as the sum of all taxa present along each of the 30-band quadrats per replicate (A or B); the maximum possible occurrences per transect is the number taxa times 30. Total occurrences for the photoquadrat data refers to the sum of all taxa present within the photoquadrats per transect. Total occurrences provides a measure of how frequently the taxa occur along a transect since neither the video presence/absence or point contact methods result in numerical abundance data.

For the video data, the total taxa ranged from 11 at Transect HB3(A) to 41 at Transect HB8(A). It is notable that the greatest number of taxa occurred at the predominantly (100% and 75%) hard substrate transects (HB6 and HB8), ranging from 36-41 taxa; intermediate numbers of taxa (23-30) generally occurred along transects characterized by at least 10% hard substrate; and the fewest number of taxa (e.g., 11-14) generally occurred along transects with less than 5-10% hard substrate (Table 3-l). This pattern likely is related to the greater habitat diversity (relief and crevices) represented by the hard substrate areas as well as the increased diversity produced by the occurrence of both hard and sediment veneer habitats (and associated organisms) along most of the transects. However, the abundance of soft substrate taxa, particularly most infauna, clearly is underestimated by the video and photographic methods utilized.

There was no obvious pattern for the dominant taxonomic groups associated with the different transects and habitats; coelenterates, fish, and echinoderms, predominated along most transects (Table 3-4), although the species composition within the groups was very different between the sediment veneer and hard substrate habitats (Table 3-1 and Section 3.1.3). The data on total

TABLE 3-4. SUMMARY OF TOTAL TAXA AND TOTAL OCCURRENCES BY TRANSECT AND BASIN FROM ANALYSIS OF VIDEO DATA. The first and second numerically dominant taxonomic groups are listed as Dominant 1 (Taxon)/Dominant 2 (Taxon); C = Coelenterata, Cr = Crustacea, E = Echinodermata, M = Mollusca, P = Polychaeta, Mist = Miscellaneous Minor Phyla, F = Fish.

Transect	Rep	Basin	Total Taxa	Dominant Taxa	Total Occurrences	Dominant Taxa
HB1	A	Eel River	18	7(C)/4(F)	108	42(C)/30(Cr)
HB2	A	Eel River	17	6(C)/6(F)	91	42(C)/15(M)
HB2	B	Eel River	14	5(F)/4(C)	94	53(C)/19(M)
HB3	A	Eel River	11	3(E,F,M)	38	15(M)/9(E)
HB4	A	Eel River	19	5(E,F)	74	28(M)/13(E)
HB4	B	Eel River	14	4(Cr,E)	32	13(C)/12(Cr)
HB5	A	Pt. Arena	30	8(C,F)	120	34(C)/32(E)
HB6	A	Pt. Arena	38	10(Misc)/9(C)	256	90(C)/68(Misc)
HB7	A	Pt. Arena	15	5(C)/3(E)	108	42(C)/38(E)
HB8	A	Pt. Arena	41	14(F/10(E)	201	58(Misc)/48(C)
HB8	B	Pt. Arena	36	13(F)/10(E)	202	57(Misc)/49(E)
HB9	A	Pt. Arena	25	7(C,E)	93	30(E)/23(Misc)
HB10	A	Pt. Arena	23	10(F)/6(E)	82	37(E)/27(F)
HB10	B	Pt. Arena	15	9(F)/4(E)	94	62(E)/28(F)
HB13	A	Bodega	23	8(E)/5(C,F)	86	36(C)/22(E)
HB13	B	Bodega	23	7(F)/5(C)	82	42(C)/16(E)
HB14	A	Bodega	21	7(F)/5(E,M)	133	40(F)/27(E)
HB14	B	Bodega	19	7(E)/5(F)	84	29(F)/24(C)
HB16	A	Santa Cruz	21	7(C)/6(Misc)	207	110(C)/45(Misc)
HB17	A	Santa Cruz	18	7(C)/5(E)	138	90(C)/29(E)

TABLE 3-5. SUMMARY OF TOTAL TAXA AND TOTAL OCCURRENCES BY TAXONOMIC GROUP FROM ANALYSIS OF PHOTOQUADRAT DATA. Point Contact (PC) data and photoquadrat total enumeration of Whole Photoquadrat (WP) data. Data are from hard substrate Transects HB6 and HB8, Pt. Arena Basin.

Taxonomic Group	TOTAL TAXA				TOTAL OCCURRENCES			
	HB6(PC)	HB6(WP)	HB8(PC)	HB8(WP)	HB6(PC)	HB6(WP)	HB8(PC)	HB8(WP)
Coelenterata	15	18	7	17	71	147	15	73
Crustacea	1	7	1	4	1	8	1	10
Echinodermata	6	10	7	10	32	68	42	77
Mollusca	1	7	0	3	1	8	0	4
Polychaeta	2	5	0	2	3	15	0	2
Miscellaneous (Porifera, Bryozoa, other phyla)	35	51	12	25	115	219	47	169
Fish	1	3	1	4	1	4	1	5
Total	61	101	28	65	224	469	106	340

occurrences (Table 3-4) indicated a similar trend as total taxa; total occurrences were highest along the predominately hard substrate transects, generally decreasing by transect with decreasing percentages of hard substrate. The dominant taxa, in terms of occurrences, also were similar to the trends for total taxa; coelenterates and echinoderms predominated along most transects. However, in contrast to the total taxa, fish were less dominant and molluscs were more dominant along two transects (HB3-A and HB4-A).

The data on total taxa and total occurrences from the photoquadrat data are somewhat similar to the video data in the predominance of coelenterates and echinoderms; however, a notable difference is the overall predominance of minor phyla (including sponges and bryozoans). Another significant difference is the much greater number of total taxa and total occurrences observed from the photoquadrat data; the differences ranged from approximately 1.5 to over 2 times higher for total taxa and total occurrences, respectively. These differences primarily reflect expected differences in the methods of observation. The video data provide excellent documentation of larger epifaunal organisms, but generally allow limited identification of smaller (e.g., $\leq$ 1 cm long) taxa; in contrast, the photoquadrat data typically document smaller organisms, which often are very diverse on relatively small scales.

A notable difference in the results obtained from two methods of photoquadrat analysis (point contact versus total enumeration) is evident from inspection of the data in Table 3-5. The total taxa identified are from approximately 1.5 to over 2 times higher using the total enumeration (WP) method and the total occurrences are from approximately 2 to 3 times higher, with both increases related primarily to the number of taxa representing minor phyla and secondarily to coelenterates and echinoderms. These results are predictable since the point-contact method is by definition sampling only a portion (50 dots) of each photoquadrat; the broader significance of these results to sampling design is discussed in Section 3.1.5 and Section 1.4 (Recommendations).

Community Patterns

Multivariate analysis of the video data was performed to delineate spatial patterns of the biological communities and correlations of these patterns with the environmental data. The analyses discussed in this section assessed community differences among the transects based initially on the data from all of the band quadrats (i.e. , the complete video database). Preliminary cluster analyses reduced this data matrix using averaging techniques, thereby creating a smaller and computationally simpler matrix (Section 2.6). This reduced matrix then was used to ordinate and cluster the biological data to define community patterns based on station groups.

Results from the cluster analyses and ordination delineated five station groups (Figure 3-3) which largely were distinguished on the basis of substrate type (hard substrate versus sediment veneer) or substrate related features (e.g., relief or "turf"; turf is defined as a mixed epifaunal mat on hard substrate), as indicated in Figure 3-4. General differences among the five station groups include (1) Groups 1 and 2, representing the majority of the sediment veneer habitat and associated taxa along most of the transects; (2) Group 3, representing transect areas which appear to be marginal hard substrate habitat (very low relief and heavily "silted"); and (3) Groups 4 and 5, representing hard substrate habitat and associated taxa along the relatively few transects where exposed hard substrate was observed.

Sediment veneer Groups 1 and 2 appeared to be distinguished from each other on the basis of substrate depth (i.e. , the depth of sediment cover over presumed hard substrate; see Section 3.1.1). Group 2 is the largest of the five groups and is characterized by a variety of sea pens (e.g. , Acanthoptilum gracile, pennatulid sea pen #10, and Stylatula elongata), the seastar Luidia foliolata, Octopus rubescens, the ophiuroid Ophiura lutkeni, and a variety of fish taxa including Pleuronectidae and Pacific hake (Merluccius products). The occurrence of S. elongata along the Group 2 transects may indicate sediment depths of a least one meter, corresponding to retraction depths of one-meter long individuals, as discussed in Section 3.1.1. It is notable that S. elongata is not represented in the Group 1 data; this observation coupled with

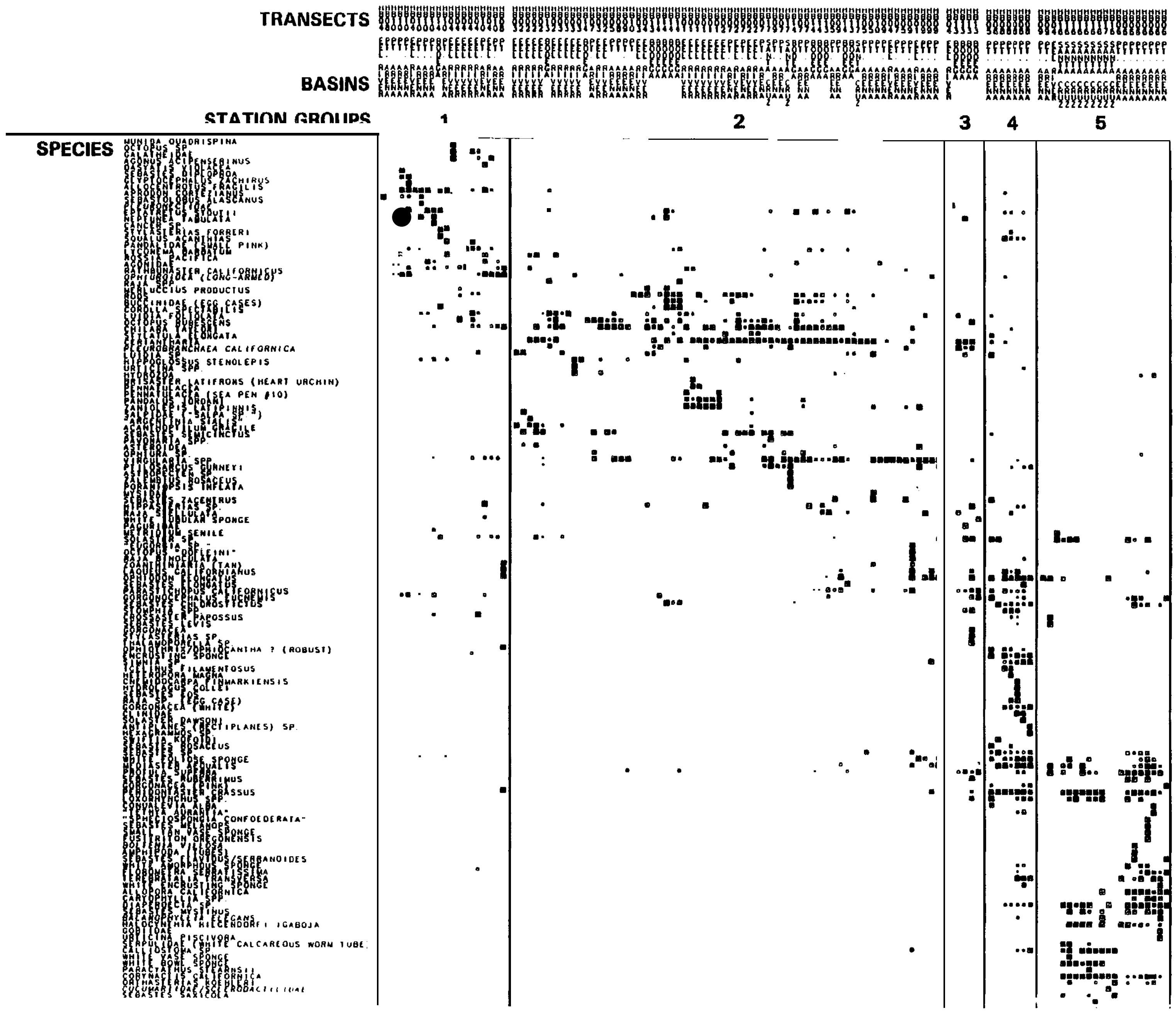


FIGURE 3-3. TWO-WAY COINCIDENCE TABLE BASED ON MULTIVARIATE ANALYSIS OF THE HARD TRATE AN M VENEER VIDEO PRESENCE/ABSENCE DATA. Both exposed hard substrate and sediment veneer data are included. Station Groups (1-5) and associated taxa are listed.

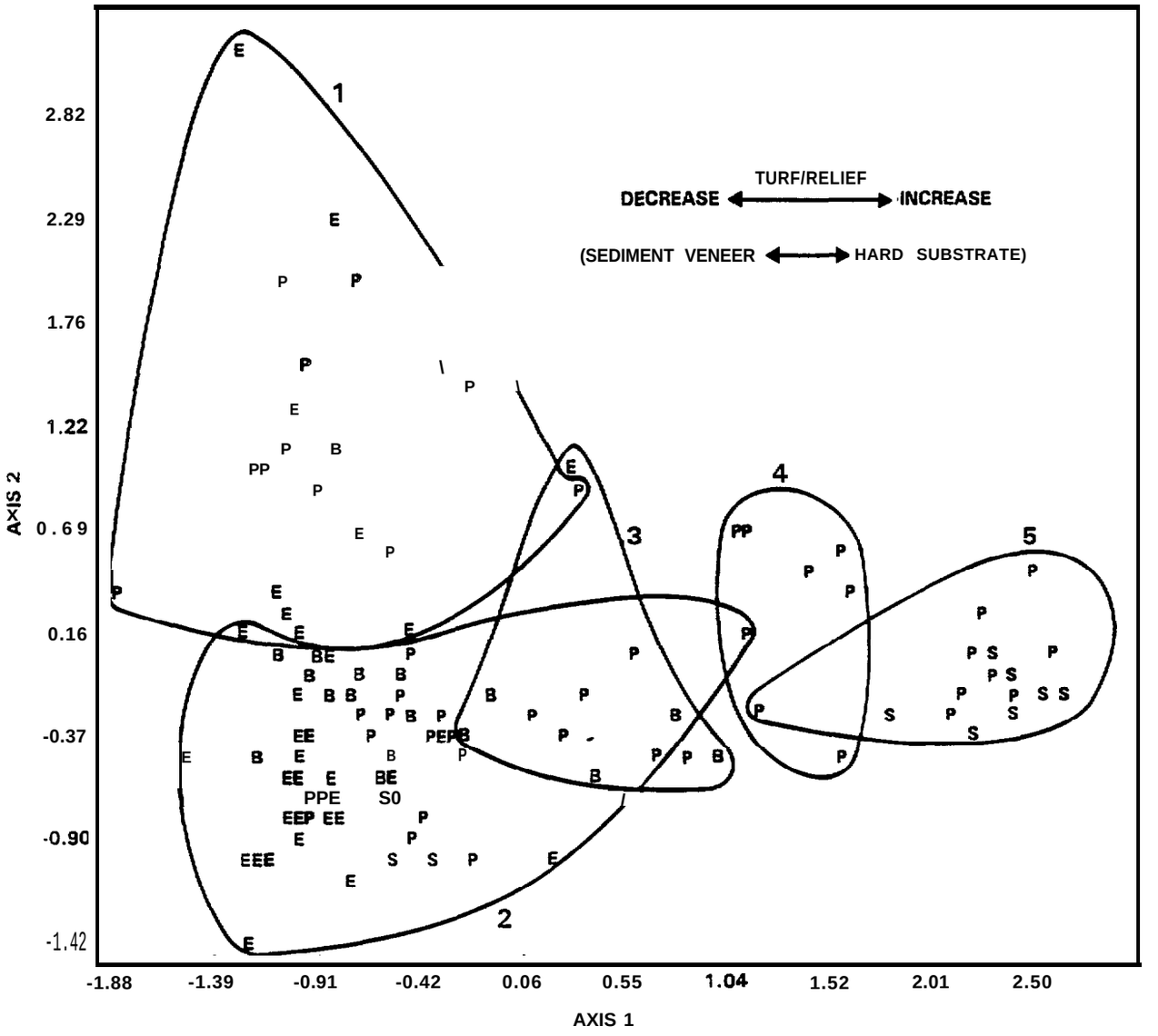


FIGURE 3-4. ORDINATION PLOT (AXIS 1 AND AXIS 2) WITH THE FIVE STATION GROUPS DELIMITED IN FIGURE 3-3 AND THE BASINS WITH WHICH THEY ARE ASSOCIATED. Video presence/absence data were utilized. Letters indicate basins: E = Eel River, P = Pt. Arena, B = Bodega, and S = Santa Cruz.

the occurrence of isolated 0. 3-1 m holes with rocks visible at the bottom and "stranded" epifauna along at least one the Group 1 transect (HB14) (see Section 3.1.1 and Table 3-1) may indicate relatively shallow sediment cover over hard substrate.

However, the Group 1 transects also represent the deepest survey areas, and even though sea pens such as S. elongata were commonly reported up to 260 m depth (SAIC, 1986), there may be a depth effect (e.g., preference for shallower depths) which is affecting the distribution pattern for this species. Similarly, "polar emergence", or the tendency for some species to occur at shallower depths (potentially temperature related) with increased latitude, may influence some of these patterns (Ernst and Morin, 1982; Austin, 1985). We hypothesized that areas of shallow sediment depth may represent more ephemeral soft substrate habitats, with corresponding differences in the biological communities. The most common taxa along the Group 1 transects were the sea urchin Allocentrotus fragilis and pleuronectid fish over sediment veneer and the seastar Rathbunaster californicus and pandalid shrimp and galatheid crabs associated with extensive areas of wood debris along Transect HB4. These taxa are relatively motile and, therefore, would be more effective than larval dispersers as early (adult) colonizers of presumably ephemeral habitat such as wood debris. The general lack of most sessile taxa, such as sponges, on the wood debris probably is related to substrate unsuitability and instability and to the relatively short time that the debris is present (before decomposing) for colonization through larval recruitment (e.g., SAIC, 1988). Infauna data from soft substrate survey stations near Group 1 Transects HB4 and HB10 (see Section 3.2) were evaluated to determine if there were any notable differences in these samples as compared to other areas. This evaluation indicated that the soft substrate stations (SB15 and SB19) closest to Transect HB4 were relatively more depauperate (20-40 fewer taxa) than other stations in the basin. In contrast, Station sB38 (closest to Transect HB10) was not notably different from other stations at similar depths, although this station was located several kilometers away from the transect and therefore may not provide an accurate basis for comparison.

Group 3 was characterized by relatively few taxa which included some sediment veneer taxa such as the sea pen S. elongata and cerianthid anemones and some hard substrate species such as the anemone Metridium senile and the brachipod Laqueus californianus. The primary transect in this group was HB13 located in the Bodega Basin. This transect was characterized mostly by sediment veneer (90%) with very sparse rock outcrops, and it appeared to be roughly intermediate (habitat and taxa) between the predominantly sediment veneer and hard substrate groups.

The predominantly hard substrate Groups 4 and 5 were distinguished from each other primarily by differences in substrate relief, although depth may have been a secondary factor. Group 4 was characterized almost entirely by low-relief (< 1 m) areas of Transect HB8 with minor representation by some low-relief areas of Transects HB6 and HB9. In contrast, Group 5 was characterized almost entirely by high-relief (e.g., > 1-3 m) areas of Transects HB6 and HB16. These differences in relief also appeared to be associated with relatively sharp differences in the taxa associated with each group. Group 4 was characterized by relatively high abundances of the brachiopod Laqueus californianus. ophiuroids such as Ophiothrix/Ophiocantha, and skate (Raja sp.) egg cases in addition to several species such as basket stars (Gorgonocephalus eucnemis), feather stars (Florometra serratissima) encrusting sponges, white foliose sponges, rockfish (Sebastes spp.), pink gorgonians (Lophogorgia ?), and cup corals (Caryophyllia spp.), which also were common in Group 5 (Figure 3-5). Taxa which distinguished Group 5 were the seastar Mediaster aequalis. white amorphous and white encrusting sponges, the bryozoan Diaperoecia sp. , serpulid worms, cup corals (Paracyathus stearnsii and Balanophyllia elegans), jewel anemones (Corynactis californica), and in isolated patches, the hydrocoral Allopora californica (Figure 3-6). Species such as P. stearnsii and C. californica are characteristic of relatively shallow depths such as those (61-85 m) along the Group 5 transects.

The taxa associated with these five station groups are very similar to the species reported from other studies of the California outer continental shelf (e.g., SAIC, 1986 and Battelle, 1988). A discussion of the large-scale

FIGURE 3-5. EXAMPLE OF LOW RELIEF HARD SUBSTRATE COMMUNITY SHOWING BRACHIOPODS (*Laqueus californianus*), *Lophogorgia*-LIKE GORGONIANS, OPHIUROIDS, AND SPONGES. The photograph is from Transect I-1138 at 127 m depth.

FIGURE 3-6. EXAMPLE OF HIGH RELIEF HARD SUBSTRATE COMMUNITY SHOWING JEWEL ANEMONES (*Corynactis californica*), *Loph0gorgia*-LIKE GORGONIANS, BRYOZOANS, SPONGES, THE ANEMONE (CONTRACTED) *Metridium senile,* AND CUP CORALS (*Paracyathus stearnsii*).

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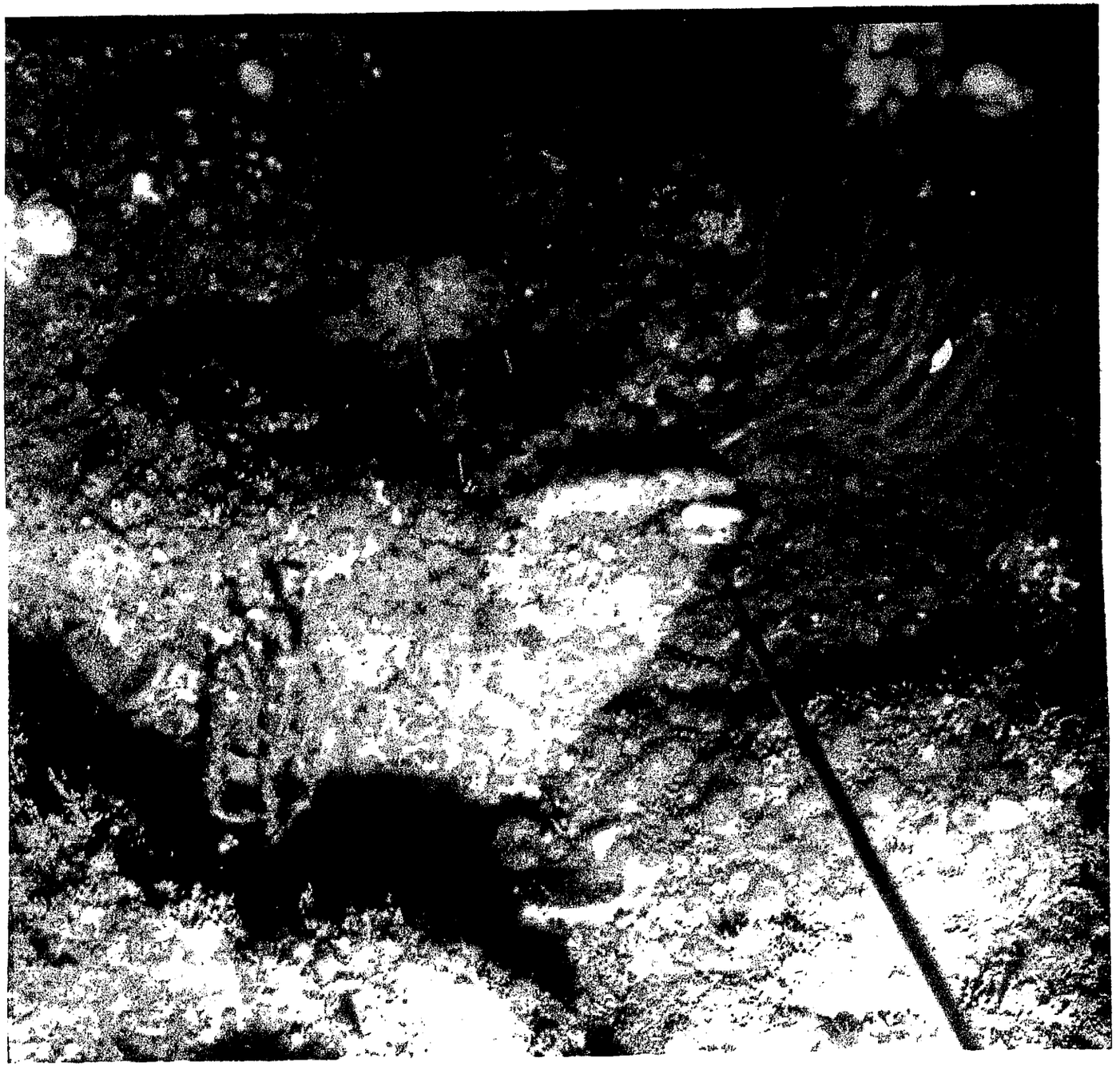


geographic patterns represented by the present data and other studies along the California coast is presented in Section 3.1.4.

3.1.3 Community Patterns and Environmental Relationships

The broad-scale differences between the biological communities occurring in sediment veneer versus exposed hard substrate areas of the transects were discussed in Section 3.1.2. This section focuses on these two data sets separately to emphasize differences related to environmental and biological factors independent of the primary substrate differences. Results from analyses of within transect variability are presented first, followed by separate sections on hard substrate habitat, including video, photoquadrat, and rock sample data; sediment veneer habitat; and environmental relationships, emphasizing transect differences. Basin differences are discussed in Section 3.1.4 (Large-Scale Spatial Patterns).

Within-Transect Variability

Separate analyses of the hard substrate and sediment veneer video data were conducted using cluster, ordination, and multiple-regression techniques (Section 2.6.1) to define community differences among the transect replicates and relate these to environmental parameters. All transect replicates (A and B, as appropriate, with each replicate representing 30 video-band quadrats; see Sections 2.3 and 2.6) of each substrate type (hard or sediment veneer) were analyzed. The hard substrate data set was represented by 9 of 14 transects of which only two were replicated. The sediment veneer data set was represented by 12 of 14 transects of which 6 were replicated.

The results from the analysis of the hard substrate data indicated that the A and B replicates were very similar for each of the two replicated transects (HB8 and HB13), as shown by the cluster diagram and the ordination plot presented in Figures 3-7 and 3-8, respectively. Similar results were indicated by the cluster and ordination analyses of the sediment veneer data (Figures 3-9 and 3-10, respectively) with the exception of Transect HB8 which had very dissimilar replicates. Transect HB8 replicate B was extremely depauperate

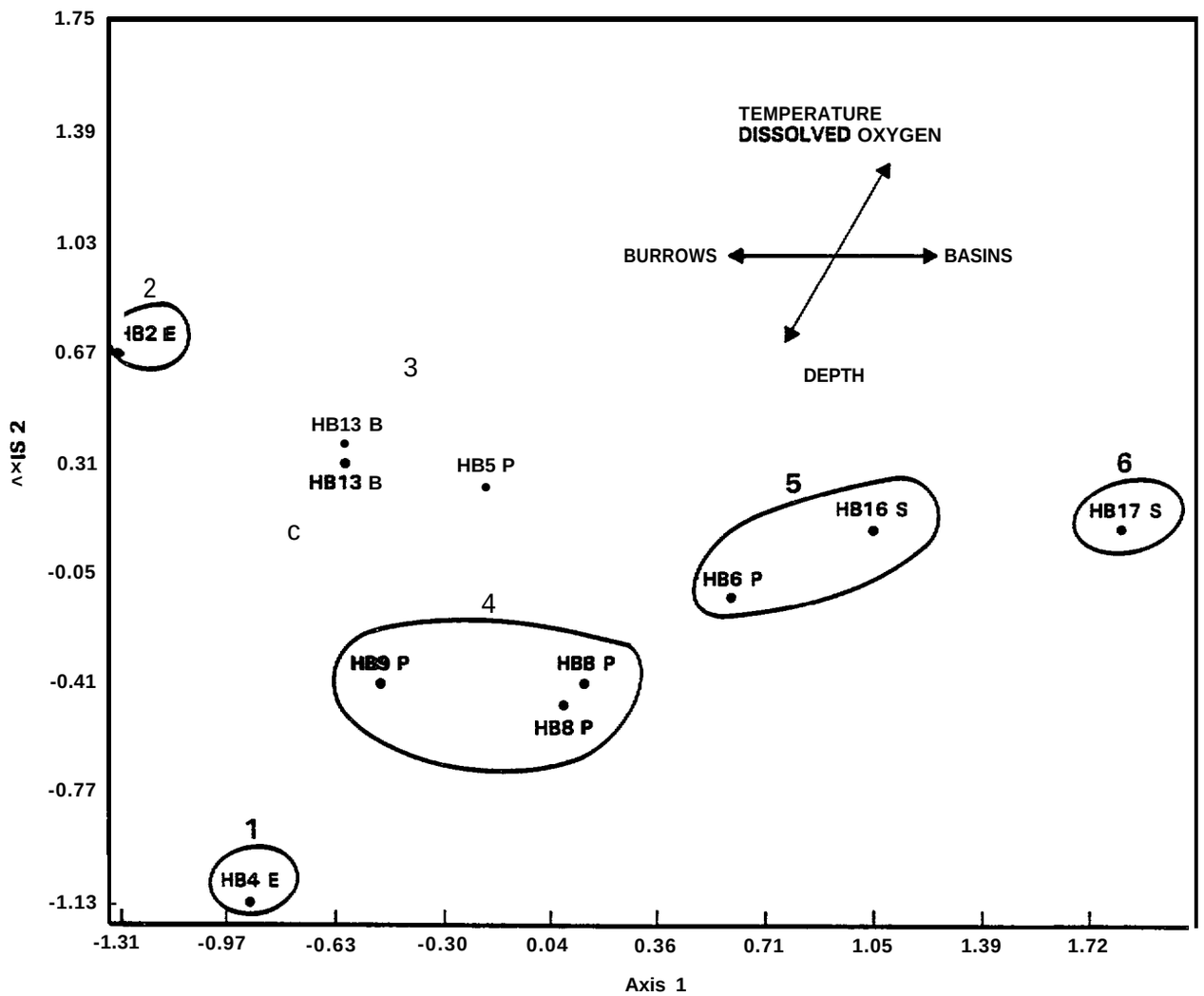


FIGURE *3-8.* ORDINATION PLOT (AXIS 1 AND AXIS 2) WITH THE SIX STATION GROUPS AND THEIR ASSOCIATED TRANSECTS, DELIMITED IN FIGURE 3-7, AND TRENDS OF ENVIRON MENTAL CORRELATES FROM THE MULTIPLE-REGRESSION ANALYSIS. Data are based on exposed hard substrate video presence/absence data. Letters associated with transect codes indicate basins: E = Eel River, P = Pt. Arena, B = Bodega, and S = Santa Cruz.

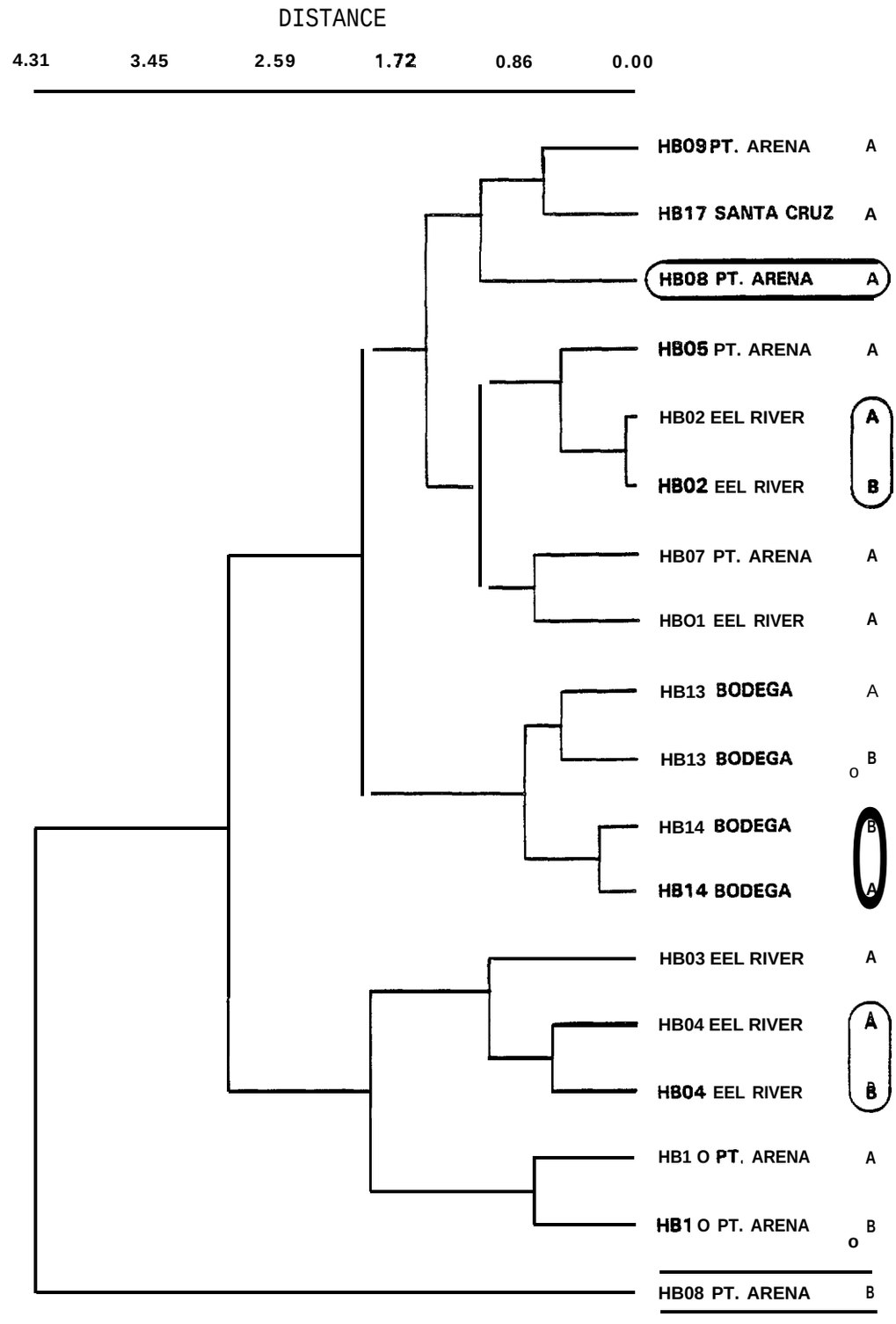


FIGURE 3-9. CLUSTER ANALYSIS OF SEDIMENT VENEER VIDEO PRESENCE/ABSENCE DATA TO ASSESS THE VARIABILITY AMONG TRANSECT REPLICATES. Replicates (A and B) from the same transect are circled.

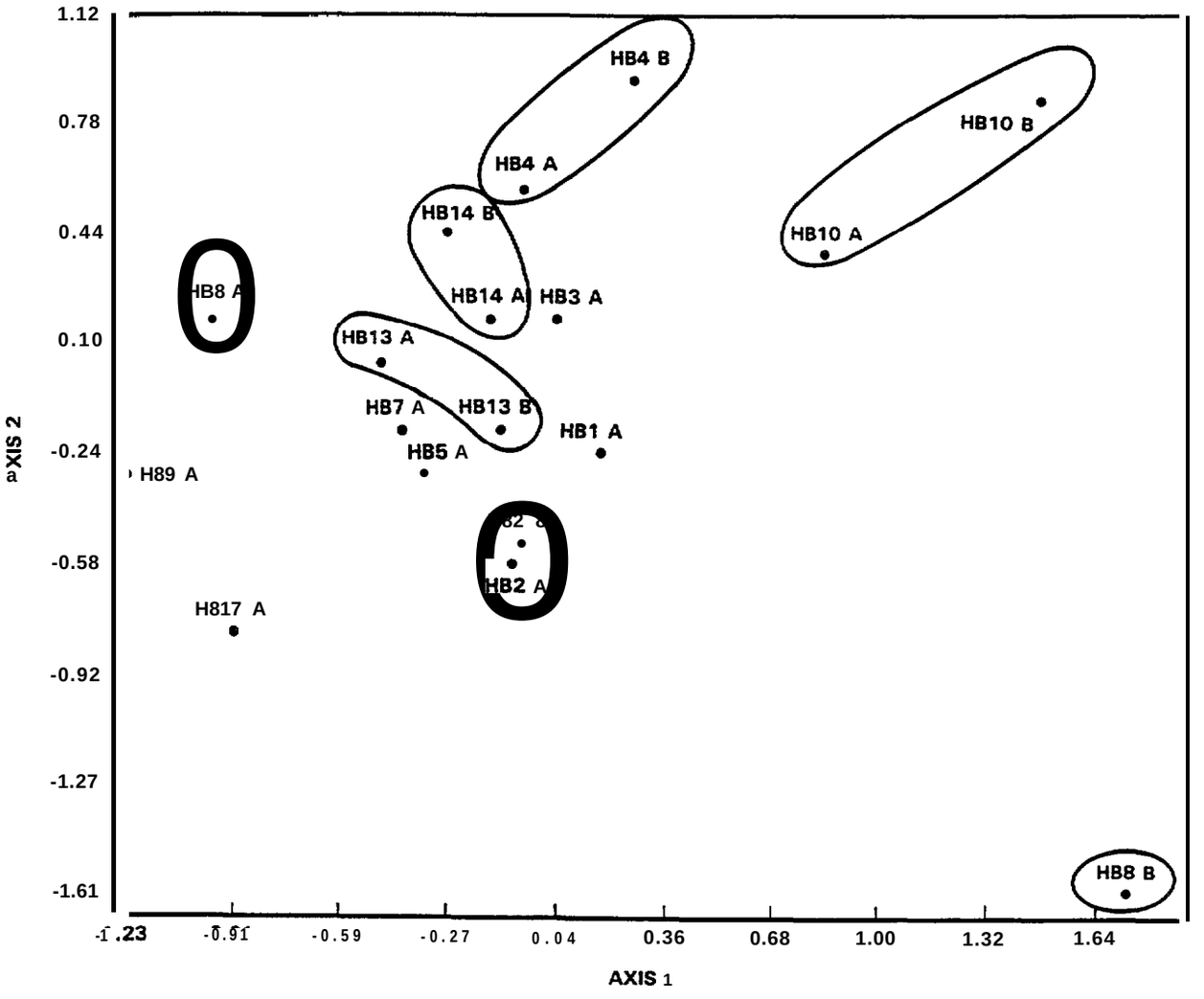


FIGURE 3-10. ORDINATION PLOT (AXIS 1 AND AXIS 2) SHOWING THE POSITIONS OF TRANSECT REPLICATES (A AND B), Data are based on sediment veneer video presence/absence data.

(only one species) as compared to all other transect replicates; this difference strongly influenced the ordination analysis, and consequently these data were eliminated for subsequent analyses of transect differences. With the exception of this one replicate, the results indicate that, in most cases, one replicate (A or B) was sufficient to document the patterns of community change among the transects. Additional comparisons which also suggest high within-transect similarity for the video data are discussed in Section 3.1.5 (Methods Evaluations).

The separate analyses of the hard substrate and sediment veneer data (minus the sediment veneer data from Transect HB8, replicate B) provide the primary basis for interpretation of the biological communities and associated environmental parameters from these distinct habitats. The results and discussion of the hard substrate data, including the video, photoquadrat, and rock sample data, are presented first, followed by the sediment veneer results and discussion.

Hard Substrate Habitat

Video Data: Six station groups, as delimited in the hard substrate cluster diagram (Figure 3-8), and associated taxa are depicted in a two-way coincidence table (Figure 3-11). This two-way table reflects the primary community differences among the hard substrate transects, based on the video data.

Groups 1 and 2 represent one transect each (HB4 and HB2, respectively) from the Eel River Basin. The transects reflect very different depth ranges (HB2 ranged from 101-103 m and HB4 ranged from 224-285 m); however, the associated taxa apparently occur over a broad enough depth range that this difference is not significant. The transects generally were characterized by soft substrate species such as Octopus rubescens and sea pens, which occurred along occasional sediment veneer areas of predominantly hard substrate band quadrats, and sparsely occurring hard substrate species including Metridium senile and white amorphous sponges. These and the other hard substrate species associated with Groups 1 and 2 often are observed in isolated, low-relief outcrop areas as noted during the present study and by SAIC (1986). The sediment veneer species in these groups are very characteristic of the taxa observed in the

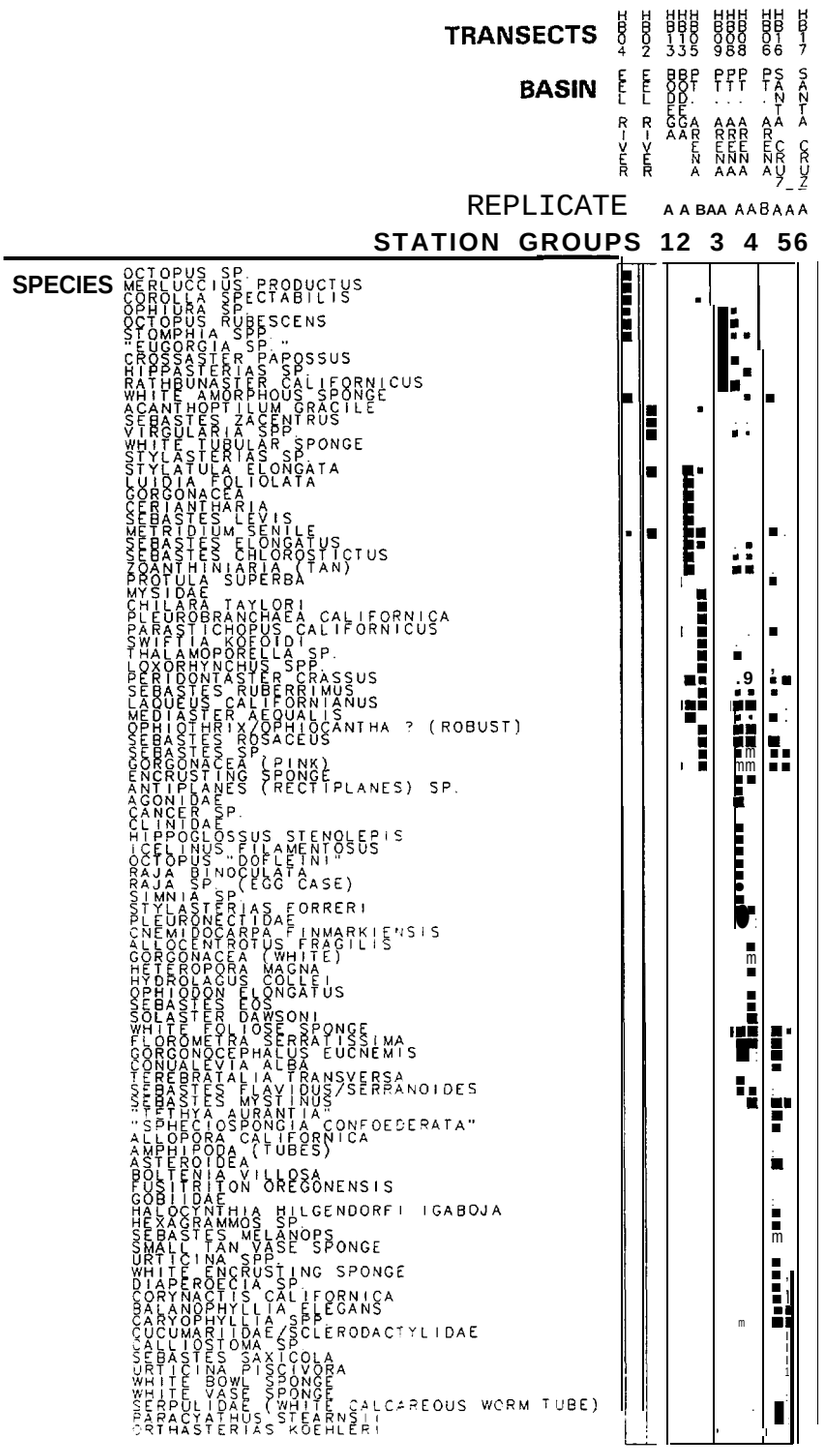


FIGURE 3-11. TWO-WAYCOINCIDENCE TABLEBASEDON MULTIVARIATE ANALYS IS OF EXPOSED HARD SUBSTRATE VIDEO PRESENCE/ABSENCE DATA. Station groups (1-6) and associated taxa are listed.

predominantly sediment veneer areas of the transects from this study and by SAIC (1986) and Battelle (1988).

Groups 3 and 4 primarily represent scattered low-relief (< 1 m), "middle depth" (113-161 m) transect areas and associated taxa in the Point Arena and Bodega Basins. Group 3 represents slightly deeper depths than Group 4 (131-161 m versus 113-128 m, respectively) although this difference would not be expected to produce a significant change in the communities. Numerous taxa in common between the groups include the brachiopod Laqueus californianus, rockfish (Sebastes elongatus, S. chlorostictus, and S. rosaceus), ophiuroids (Ophiothrix/Ophiocantha), pink gorgonians (Lophogorgia ?), and tan zoanthids (e.g., Figure 3-5). A primary difference between the groups probably was related to the much sparser occurrence of rock outcrops along the Group 3 transects (Table 3-1), The primary taxa which characterized Group 3 were species such as the anemone Metridium senile and the sea cucumber Parastichopus californicus, which are common in many ecotone areas such as those occurring along these transects. In contrast, the Group 4 transects represented more continuous hard substrate areas with a corresponding increase in the diversity of taxa. Taxa which distinguished Group 4 were feather stars Florometra serratissima, basket stars Gorgonocephalus eucnemis, white foliose sponges, and a variety of encrusting sponges, in addition to numerous fish and ray species (Raja binoculata, Icelinus filamentosus, and clinids), somewhat sparse occurrences of gorgonians and cup corals, and those taxa listed above for both groups.

Group 5 represented the areas of highest relief (e.g., 1-3 m +) from the survey but also corresponded to the shallowest survey depths (61-85 m). Group 5 had several taxa in common with Group 4 including feather stars, basket stars, white foliose sponges, pink gorgonians, and various rockfish species. However, Group 5 also had numerous distinguishing taxa including cup corals (Paracyathus stearnsii, Balanophyllia elegans, and Caryophyllia spp.), the bryozoan Diaperoecia spp., jewel anemones Corynactis californica, and the rockfish Sebastes mystinus (e.g., Figure 3-6). Some of these species, particularly C. californica and S. mystinus, are characteristic of these shallow depths (e.g., SAIC, 1986 and Miller and Lea, 1972) and make it difficult to distinguish the

importance of depth versus substrate type and relief in structuring these communities.

Group 6 corresponds to a single transect (HB17 in the Santa Cruz Basin) which had an extremely limited, apparently scoured, hard substrate area and was represented by very few taxa. Because of the limited data set, this group does not add any significant information to the interpretation of the survey data and is not discussed further.

Photoquadrata Data: The analysis of the photoquadrat data, based on Transects HB6 and HB8 within the Point Arena Basin, indicated a strong distinction in the communities between these transects, based on substrate relief and depth (Figures 3-12 and 3-13). Three station groups were distinguished: Group 1 was represented entirely by Transect HB8; Group 2 primarily by Transect HB6; and Group 3, representing the largest group, also primarily by Transect HB6 (Figure 3-12).

Photoquadrat Group 1 corresponded closely to Group 4 described above from the video data. Both these groups were characterized by the brachiopod Laqueus californianus, ophiuroids (Ophiura and Amphipholis), pink gorgonians (Lophogorgia ?), zoanthids, and bryozoans (e.g., Figure 3-5). An important difference between these groups is the broader representation in the video data (Group 4) of larger taxa such as feather stars, basket stars, sponges, and fish, primarily due to the larger field of view as compared to the photo-quadrats. The lower densities of many larger taxa in the study area make field methods with large viewing formats (e.g., video) more appropriate for documenting these species, while methods such as 70-mm photoquadrats provide better resolution for taxonomic identification and enumeration of smaller species (e.g., Komokoiacea observed in many of the photoquadrats). Komokoiacea is a protozoan Order, many taxa of which form branching colonies.

Photoquadrat Group 2 corresponded primarily to a relatively limited pinnacle area of up to approximately 20-30 m relief along Transect HB6. The taxa which characterized the group were the cup coral Caryophyllia spp. , bryozoans, Komokoiacea, and various sponges (sepia encrusting and white encrusting). This

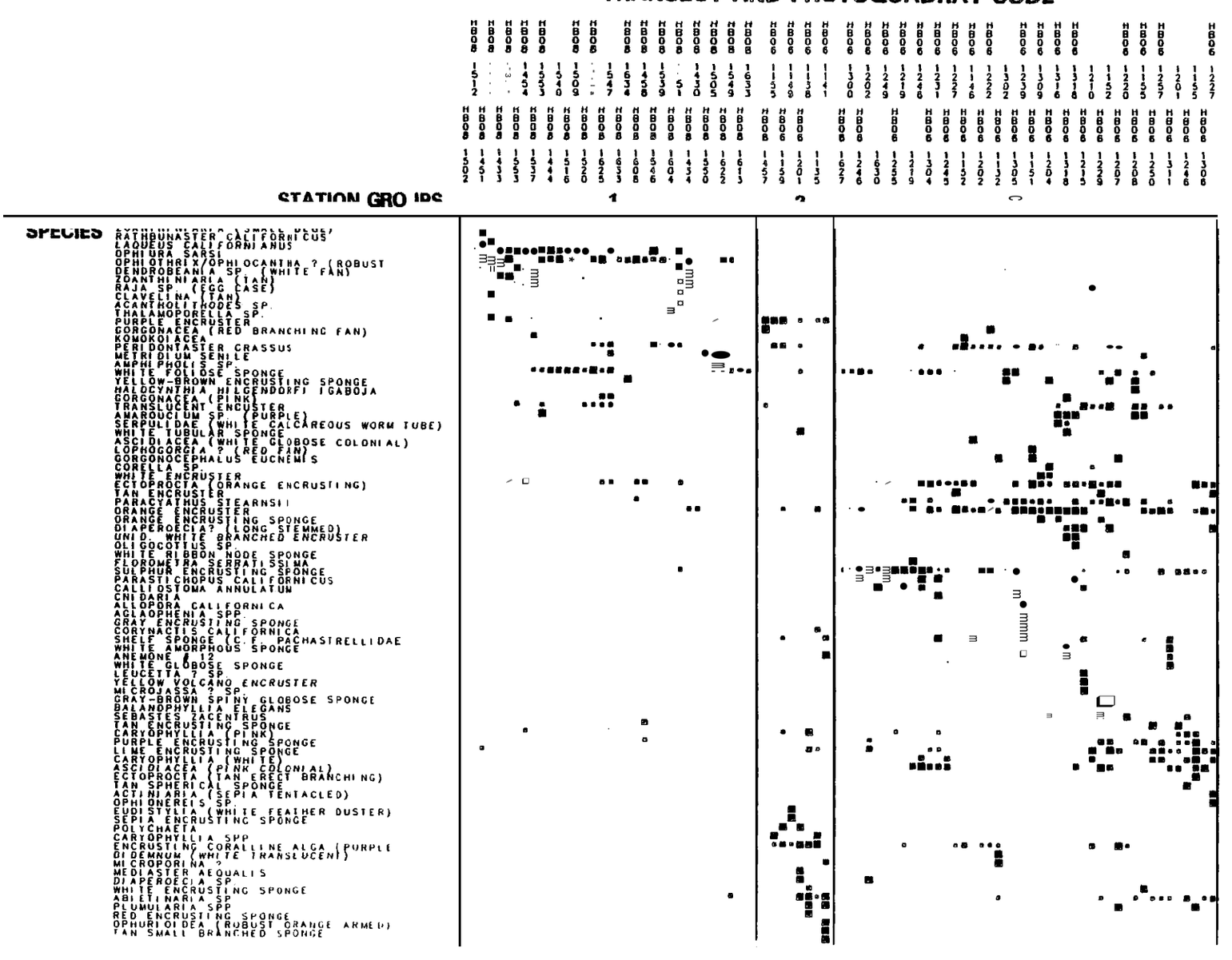


FIGURE 3-12. TWO-WAY COINCIDENCE TABLE BASED ON MULTIVARIATE ANALYSIS OF PHOTOQUADRAT DATA. Station groups (1-3) and associated taxa are listed.

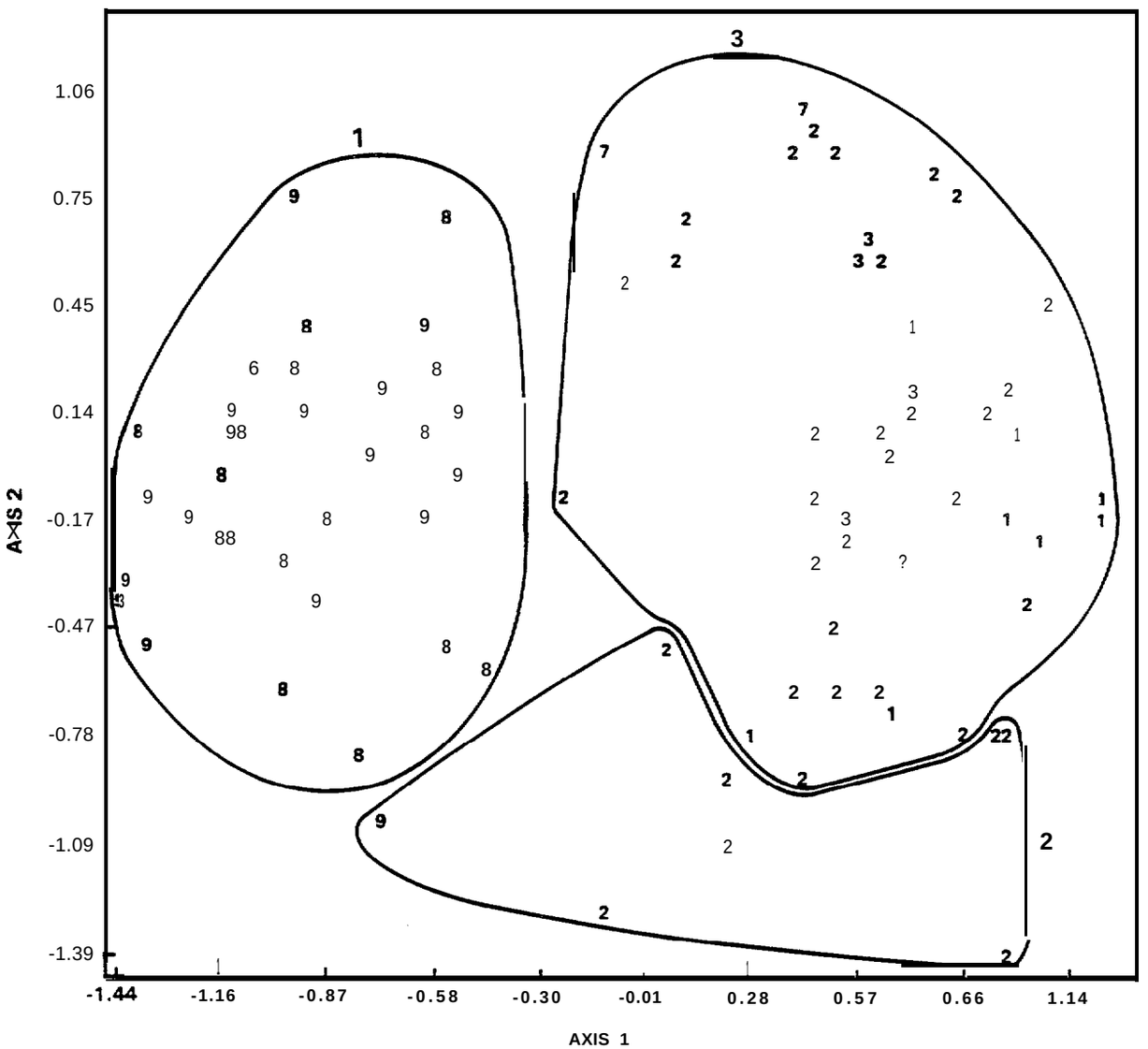


FIGURE 3-13. ORDINATION PLOT (AXIS 1 AND AXIS Z) WITH THE THREE STATION GROUPS (LARGE NUMBERS 1,2, 3) DELIMITED IN FIGURE 3-12. All symbols> 3 are Transect HB8; All symbols <4 are Transect HB6. Data are from photoquadrat analysis.

group has many species in common with photoquadrat Group 3, representing the majority of Transect HB6. The differences between the groups probably are influenced by differences in the camera orientation between the transect areas; for Group 2, the photoquadrats were predominantly downward-looking to document the communities of the pinnacle field, while the Group 3 photoquadrats were more sideways-looking. Thus, these differences may be related more to methodological rather than biological differences.

Photoquadrat Group 3 corresponded closely to video Group 5 noted above, representing transect areas of high relief (e.g., 1-3 m +) and characterized by a diverse epifaunal community. Common taxa included cup corals (Paracyathus stearnsii, Balanophyllia elegans, and Caryophyllia sp.), the jewel anemone Corynactis californica, numerous sponge taxa (white encrusting, purple encrusting, lime encrusting, sulphur encrusting) , Komokoiacea, gorgonians (pink and red; Lophogorgia ?) , numerous unidentified but distinct encrusting organisms (e.g., white encruster and tan encruster) , and localized high abundances of the feather star Florometra serratissima (e.g., Figure 3-6).

Rock Sample Data: In addition to the video and photquadrat data, nine rock samples were collected and analyzed. Only one of these samples (from Transect HB9, Sample A) was collected using the ROV sample collection scoop because of the scarcity of rock samples along most transects coupled with operational constraints due to severe wind and sea conditions. The remaining eight rock samples were collected intentionally or serendipitously using the box corers. During the MMS Phase I survey (SAIC, 1986), rocks were collected using a manned submersible with a manipulator arm. That procedure collected many more usable rock samples than could be collected during the current program. As a consequence, substantially more species were collected during the Phase I program, and they were more representative of the rock fauna of the total Phase I study area (Santa Maria Basin and western Santa Barbara Channel). The rocks collected during the current program were from the northern survey area only.

Most of the taxa collected on rocks during this survey also were found on rocks collected during the Phase I program (Table 3-6). A complete list of taxa identified from the rock samples is presented in Appendix F (Table F-3) ,

TABLE 3-6. SIMILAR SPECIES OR CLOSELY RELATED GENERA AND SPECIES COLLECTED ON ROCK SAMPLES DURING THE MMS CARP AND PHASE I SURVEYS.

Phase I	CARP
PORIFERA	
Clathrina coriacea	Clathrina blanca
Hymedesmia sp. A, B, D	Hymedesmia sp.
Infatella sp. (Coelosphaeridae)	Coelosphaera sp. A
Microciona sp. A	Microciona sp.
Poecilosclerida sp. A	Poecilosclida sp. A
COELENTERATA	
Acryptolaria pulchella	Lafoea fruticosa, L. dumosa
Abietinaria traski, A. amphora	Abietinaria pacifica
Anemone #49 (brown tent anemone)	Anemone ##49
NEMERTEA	
Cerebratulus sp.	Cerebratulus sp.
Paranemertes spp.	Paranemertes spp.
Amphiporus formidabilis	Amphiporidae, A. cruentatus
MOLLUSCA	
Puncturella cucullata	not collected, but visible in 70-mm photos
Lepidozona sp.	Ledpidozona sp.
Odostomia spp.	Odostomia spp.
Leptochiton rugatus	Leptochiton rugatus
Aldisa sanguinea	Aldisa sp. (A. sanguinea)
Megacrenella columbiana	Megacrenella columbiana
POLYCHAETA	
Spiophanes berkleyorum	Spiophanes berkleyorum
Polydora spp.	Polydora spp.
Sabellaria cementarum	Sabellaria cementarum
ECHINODERMATA	
Ophiopholis bakeri	Ophiopholis bakeri
Ophiura lutkeni	Ophiura lutkeni
Amphipholis squamata	Amphipholis squamata
Psolus Sp.	Psolidae
BRACHIOPODA	
Terebratulina unguicola	Terebratulina unguicola

TABLE 3-6. (Continued)

Phase I	CARP
CRUSTACEA	
Photis bifurcata, P. macrotica	Photis bifurcata, P. macrotica
Caprella spp.	Caprella spp.
Stenothoidae	Stenothoe spp.
Perotripus brevis	Perotripus brevis
Leptognathia sp.	Leptognathia sp. G, sp. E
Munna sp., Munna sp. A	Munna sp.
Byblis veleronis	Byblis veleronis, B. bathyalis
Arcoscalpellum californicum	Arcoscalpellum californicum
Microjassa litotes	Microjassa litotes
Ampelisca lobata	Ampelisca lobata
Munnogonum tillerae	Munnogonum tillerae
Metopa dawsoni	Metopa dawsoni
ECTOPROCTA (Bryozoa)	
Clavopora occidentals	Clavopora occidentals
Lichenopora sp.	Lichenopora sp.
Cellaris diffusa	Cellaris diffusa
Stephanosella vitrea	Stephanosella biaperta, S. bolini
Smittina landborovi, S. spathulifera	Smittina landborovi, S. spathulifera
Lagenipora punctulata	Lagenipora punctulata
Costazia robertsoniae, C. costazi	Costazia cf. procombens
Reginella furcata	Reginella furcata
Emballotheca obscura	Emballotheca obscura
Hippomonavella longirostrata	Hippomonavella longirostrata
Fenestrulina malusi	Fenestrulina malusi
Caulorhamphus brunnea	Caulorhamphus echinus

Volume II. Only a few species were found exclusively in the current survey samples. These included the sponge Tetilla arb, the nemertean Carinoma mutabilis, the brachiopod Laqueus californianus, and the crustaceans Leptochelia sp. A, Typhlotanais sp. A, and Loxorhynchus crispatus. No corals or gorgonians were collected on rocks from the current program, although the photographic and video records showed these groups, particularly the genera Paracyathus, Balanophyllia, Caryophyllia, and Lophogorgia ? to be quite common along some transects (e.g. , HB6). Only the brachiopod L. californianus and the ophiuroids Amphipholis, Ophiopholis, and Ophiura were represented in both the rock samples and the video/photographic data.

Taxonomic groups with highly motile species, such as Polychaeta and Nemertea, have representatives which occur both in mud and on rock; some examples from this study are Nephtys cornuta franciscana, Levinsenia gracilis, Cerebratulus sp. , and Paranemertes spp. In general, for the present program the rock samples were indistinguishable from the soft substrate samples in their polychaete and nemertean fauna except for the presence of a few species that occur exclusively on hard substrates (e.g., Sabellarium cementarum).

Only seven new taxa representing six groups were identified from the rock samples: Coelosphaera sp. A (Porifera), Anemone sp. 118 (Coelenterata), Pycnophyes sp. A (Kinorhyncha), Eurylepta sp. A (Platyhelminthes), Tetrastemma Sp . A and Amphiporus sp. (Nermetea), and cf. Pachychelium sp. A (Crustacean). This low number of taxa probably is related to the somewhat random nature (principally using box corers) with which the rocks were collected and the predominantly sediment and gravel bottom types in the collection areas; these types of habitats typically have low cover and diversity of epifaunal organisms. In comparison, 156 new taxa were identified from the Phase I study (SAIC, 1986).

Environmental Factors: The general factors which appear to distinguish the video and photoquadrat groups are differences in the substrate type and relief: video Groups 1 and 2 represent very limited, apparently marginal hard substrate habitat; video Groups 3 and 4 and photoquadrat Group 1 represent more continuous but still low-relief habitat; and video Group 5 and photoquadrat

Groups 2 and 3 represent continuous, relatively high-relief habitat. These patterns are consistent with other studies offshore California (e.g., SAIC, 1986 and Battelle, 1988); however, the differences in depth among the present groups somewhat confuses this interpretation.

The results from the ordination and multiple-regression analyses provide additional information on general environmental factors which may be influencing these communities. Evaluation of the ordination plot for the video hard substrate data (Figure 3-8) provides an indication of the environmental factors which are correlated with differences among the transects. Ordination Axis 1 accounts for the majority (75%) of the variance in the data set; the regression analysis indicated that the factors which correlated most strongly (R^2 = .83) with Axis 1 were temperature and burrows (burrows indicating biological activity in sediment veneer areas which were part of a predominantly hard substrate band quadrat). Basins also were separated on Axis 1 as discussed in Section 3.1.4. The factors which correlated most strongly (R^2 = .84) with ordination Axis 2 were depth, dissolved oxygen, and temperature. As noted in Section 3.1.1, dissolved oxygen and temperature exhibited a curvilinear decrease with increased depth in the survey area. It is predictable, therefore, that the station group data, which appear to indicate a difference in the biological communities based on depth, would be correlated with depth-related parameters. Similarly, the factor which appeared to correlate most strongly with Axis 1 of the ordination analysis for the photoquadrat data was depth (Figure 3-13). Nonetheless, the primary factors that appear to be influencing the species composition of these communities are substrate-related or, more specifically, the occurrence in the survey areas of very limited exposed hard substrate along the deeper transects, grading to much higher relief and more continuous hard substrate along the shallower transects. Thus, the correlations with depth and depth-related factors may simply be artifacts of habitat-related differences. Data from the same type(s) of hard substrate habitat over a range of depths would be required to evaluate fully the relationships of these biological and environmental parameters.

In contrast to depth-related factors, the correlation of Axis 1 from the video data with burrows may represent a more direct indication of environmentally related differences among the transects. The transects with the highest occurrence of burrows were associated with the deepest station groups (Groups 1 and 2) followed by decreasing occurrences for the middle-depth groups (Groups 3 and 4) and the shallowest group (Group 5), respectively. If it is assumed that a higher occurrence of burrows is representative of higher biological activity, then this also may indicate that these areas are more stable soft substrate (sediment veneer) habitats with well-developed communities. We suggest that the higher incidence of apparently stable sediment veneer at the deeper depths (and the corresponding increase of hard substrate at shallower depths) is reflective of deeper sediment cover of hard substrate at the deeper depths.

Sediment Veneer Habitat

The analysis of the sediment veneer video data also focused on community differences among the transects and relationships to environmental factors. The results of the cluster analysis of these data indicated five station groups as summarized in Figures 3-14 and 3-15. The predominant trend represented by these groups appeared to depth-related as summarized in Figure 3-14. Similarly, the parameter that was most strongly correlated (R^2 =.73) with Axis 1, which accounted for 50% of the variability in the data, was depth. However, as noted above for the hard substrate analyses, the primary factors influencing the soft substrate communities appear to be substrate-related, including the depth of sediment veneer over hard substrate, rather than depth. This hypothesis is discussed below as related to the five station groups.

Group 1 represents the shallowest transect depths (85-128 m) and is characterized by several hard substrate taxa, such as brachiopods and zoanthids (which presumably were attached through a shallow sediment veneer to a hard surface) , and common soft substrate (sediment veneer) organisms such as Octopus rubescens, ophiuroids (Ophiura sp.), sea pens (Acanthoptilum gracile, Virgularia spp., and Stylatula elongata) , and the seastar Luidia foliolata; these taxa occurred in most of the station groups. The transects (HB8, HB9, and HB17) included in Group 1 also are represented in the hard substrate data

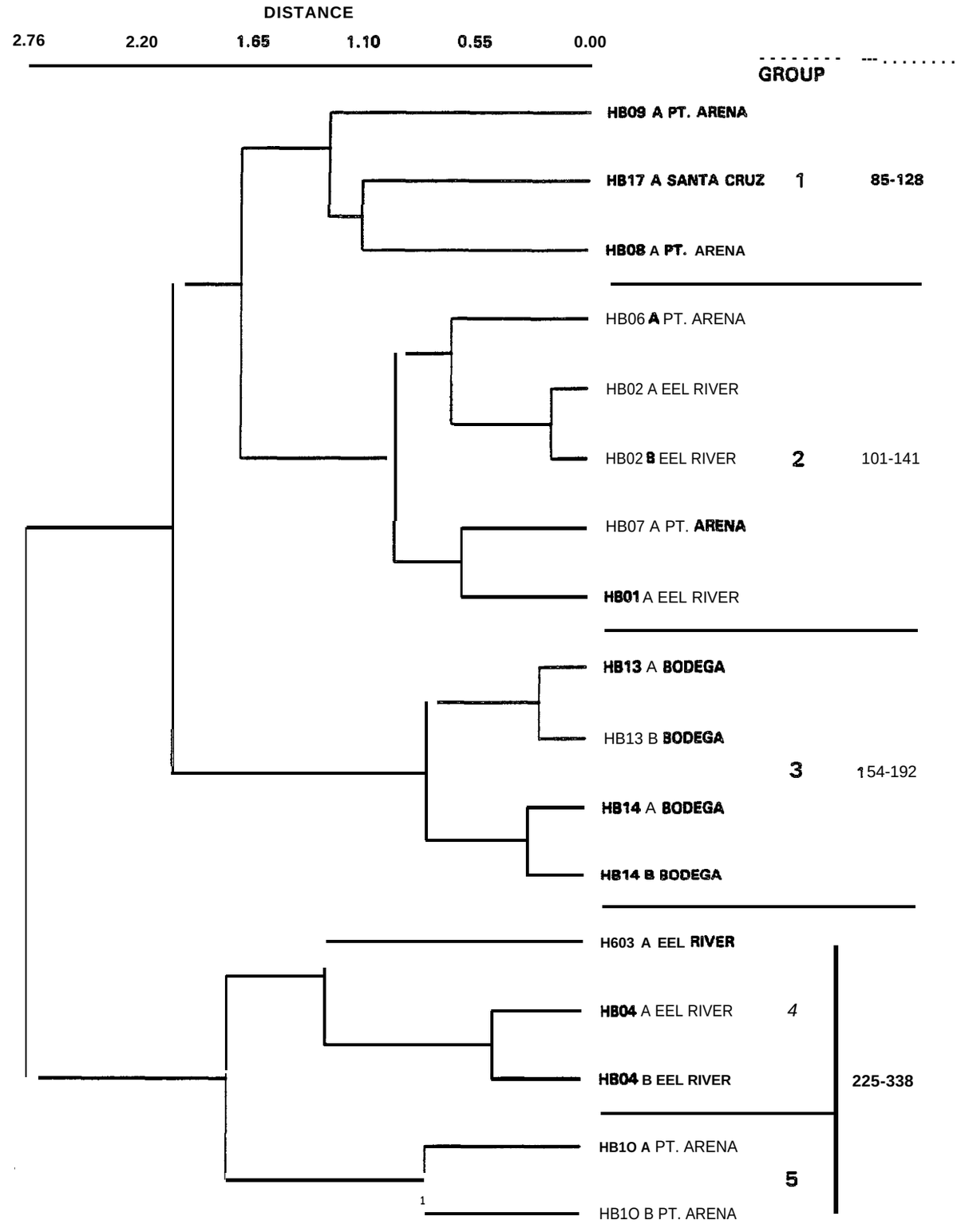


FIGURE 3-14. CLUSTER ANALYSIS OF SEDIMENT VENEER VIDEO PRESENCE/ABSENCE DATA (TRANSECT HB8, REPLICATE B NOT INCLUDED) SHOWING STATION GROUPS (1-5) AND THEIR DEPTH RANGES.

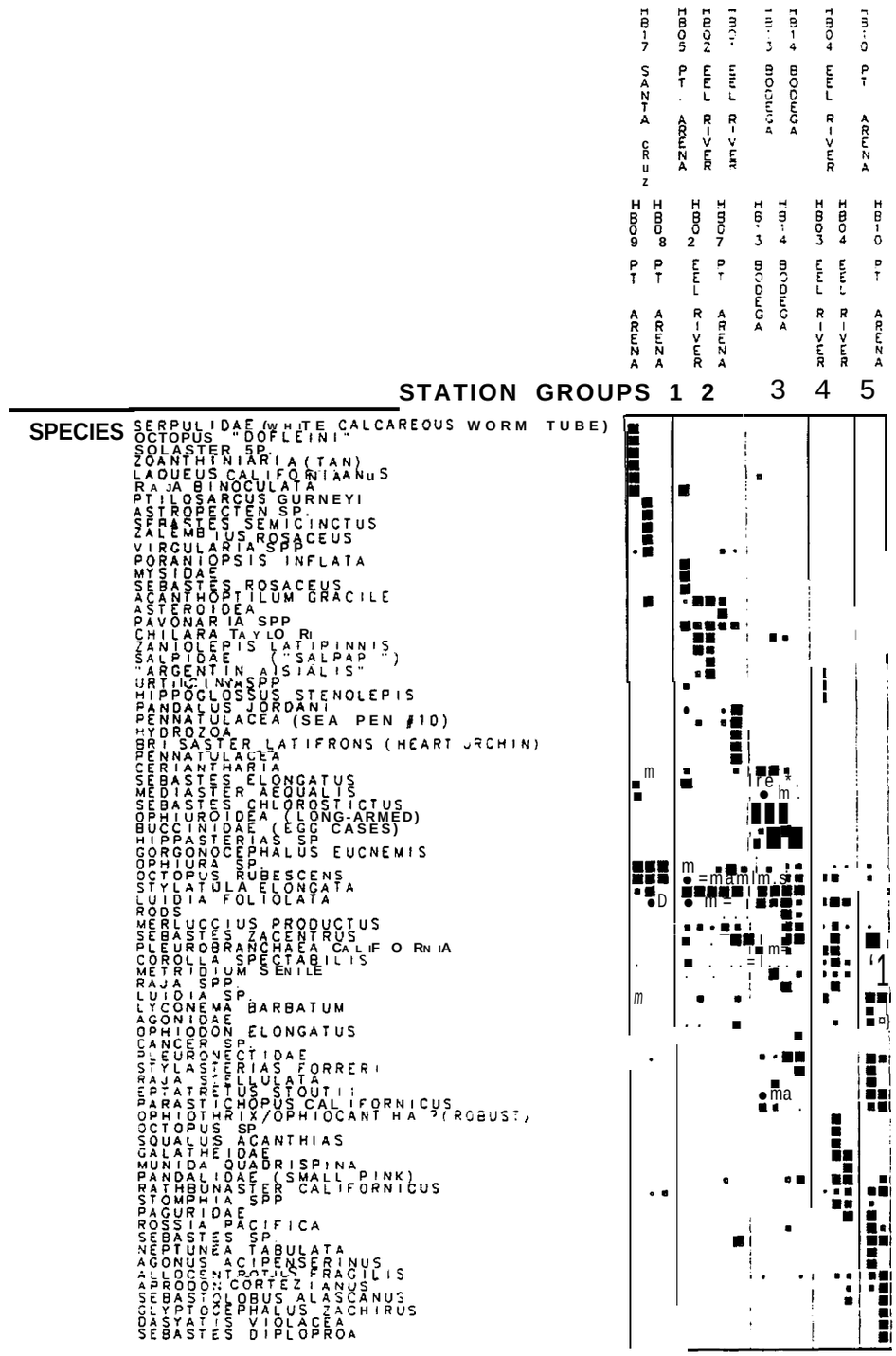


FIGURE 3-15. TWO-WAY COINCIDENCETABLE BASED ON MULTIVARIATE ANALYSIS OF SEDIMENT VENEERVIDEOPRESENCE/ABSENCE DATA. Station groups (1-5) and associated taxa are listed.

set but those segments are characterized by scattered low relief. Thus, the proximity of exposed hard substrate along many of the transect segments, coupled with the original side-scan sonar data indicating the occurrence of hard substrate, may suggest that some of the sediment veneer areas of the Group 1 transects have relatively shallow sediment cover. Other areas, however, appear to have deeper sediment cover (e.g. , $\geq$ 1 m), as judged by the occurrence of retractable sea pens such as Stylatula elongata in some of the areas (see discussion in Section 3.1.1).

The transects in Groups 2 and 3 ranged from 101-141 m and 154-192 m, respectively, and were characterized by many of the same sediment veneer taxa observed in Group 1. These taxa include sea pens such as S. elongata, which, however, were more common than in Group 1, and Pavonaria spp. (Group 2 *only),* octopus rubescens, the seastar L. foliolata, the ophiuroid Ophiura sp. , the mollusc Pleurobranchaea californica, and several fish species (e.g., Chilara taylori, Merluccius productus, and Sebastes zacentrus) . A Group 2 fish species which may be associated with the shallower depths of these transects is Zaniolepis latipinnis (SAIC, 1986; and Miller and Lea, 1972). Groups 2 and 3 appear to represent typical sediment veneer communities such as those characterized by SAIC (1986) from similar depths. The common occurrence of S. elongata also may indicate relatively deep sediment depths over much of these transect areas.

Groups 4 and 5 represent the deepest transects surveyed, ranging from 225-285 m and 246-338 m depth, respectively. These groups were characterized by many of the same relatively motile taxa such as octopus, seastars, ophiuroids, and fish species (Merluccius productus and Sebastes zacentrus) as noted for Groups 2 and 3. However, there was a notable absence in Groups 4 and 5 of many sea pen taxa, particularly S. elongata. As noted above in the hard substrate section, it is unclear whether the absence of some sea pen species is attributable to shallow sediment depths, thereby limiting retraction of these organisms into the substrate, or some other habitat restriction or species preference (e.g. , polar emergence, as discussed in Section 3.1.2) related to bottom depth. The occurrence in Group 4 of several taxa, such as galatheid crabs and the ophiuroid Ophiothrix/Ophiocantha that typically are associated with hard

substrate, is related to extensive areas of wood debris (which served as a presumably temporary habitat) along Transect HB4 in the Eel River Basin.

Analyses of the hard substrate and sediment veneer transect data indicate that distinct changes in the biological communities occur with changes in depth, depth-related factors such as temperature, and substrate parameters. Within the survey area, there is an obvious increase in the occurrence of exposed hard substrate and substrate relief at shallower depths; this pattern is associated with a corresponding, predictable change in the biological communities. Two potential factors are suggested to explain these observations:

(1) Sediment depths (veneer) over hard substrate and/or burial rates of hard substrate are higher at deeper depths, resulting in less exposed hard substrate at deeper depths and the associated community changes.

(2) The greater occurrence of exposed hard substrate along the shallower transects actually represents an artifact of the limited overall occurrence of hard substrate within the survey areas.

It is not possible based on the present data to select a single factor as the primary determinant of these trends. However, we believe that factor 2 is more likely to be accurate given the range of geographic basins in which the different substrate types and relief were observed and the likelihood that some areas of exposed hard substrate also are present at deeper depths than recorded from this survey (although perhaps not extensively within the MMS areas of interest) . Notable features associated with individual transects were very likely related to shallow sediment cover or sediment encroachment on hard substrate; for example, "stranded" hard substrate organisms (basket stars) were observed in an extensive sediment veneer area along Transect HB14, and hard substrate was noted at the bottom of shallow holes along the same transect (Table 3-l). The potential trend of decreased occurrences of sea pens at deeper depths may be related to shallow sediment cover along some of the deeper transects; however, the possibility of depth-range limitations for individual species also cannot be excluded as a mechanism influencing this pattern.

Sediment transport patterns, including the incidence of intermittent exposure or burial or hard substrate by scouring and deposition of sediments, and their effects on habitats and communities within the basins are expected to be significant given the relatively high near-bottom currents measured, the high wave and sea conditions characteristic of the region, and the presence of numerous river discharges. At present, much of this information is qualitative so that the magnitude and seasonality of these potential effects within the survey area are unknown. However, similar mechanisms have been hypothesized to influence hard substrate communities observed from other California offshore regions (e.g., SAIC, 1986 and 1988). Comparisons of broad-scale spatial patterns between the present study and historical studies of other California sites is presented in Section 3.1.4.

3.1.4 Large-Scale Spatial Patterns

This section describes the results from analysis of between-basin differences from the present Study, and compares the communities and associated environmental factors with selected historical studies of the California outer continental shelf. The between-basin comparisons for the present study were based on the video transect data since photoquadrat information only was available for two transects (HB6 and HB8) in the same basin (Point Arena). Results presented in Section 3.1.3 from the analysis of video transect data indicated that depth was strongly correlated with community differences among the transects, but also suggested some separation, particularly for the exposed hard substrate data, based on basin differences (Figures 3-8 and 3-14).

The ordination analysis of the exposed hard substrate video data indicated a clear separation of the basins along Axis 1 (Figure 3-16), This trend was tested further using a Mantel test which compared the basin communities based on distances between the transects in the ordination space. These results indicate that the basin communities differ statistically from each other (Table 3-7), although as discussed in Section 3.1.3, these differences are influenced strongly by large differences among the transects in depth and the occurrence of exposed hard substrate and high relief. Areas with the highest occurrence of exposed hard substrate and substrate relief were along the shallowest

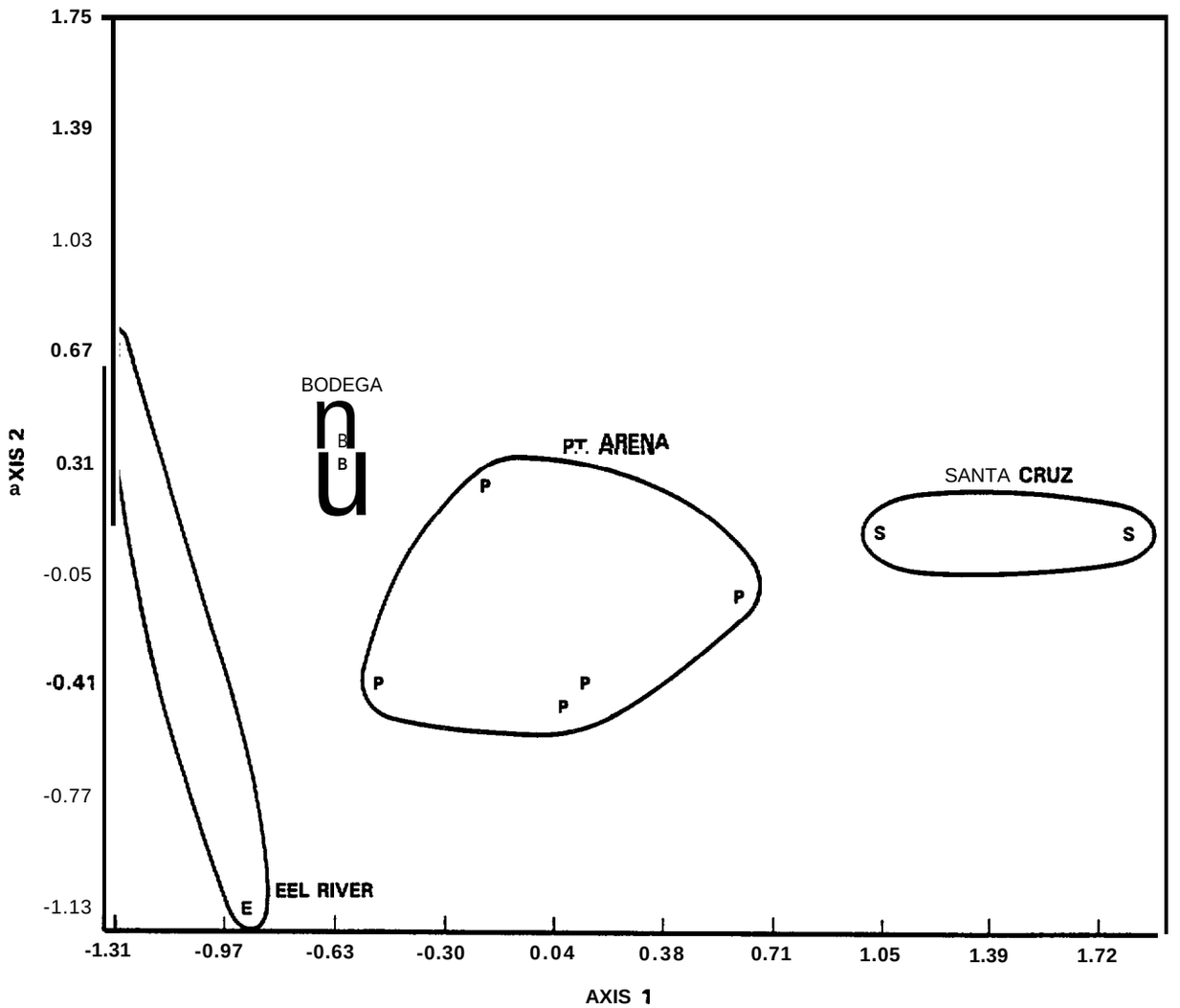


FIGURE 3-16. ORDINATION PLOT (AXIS 1 AND 2) OF THE EXPOSED HARD SUBSTRATE BASIN GROUPS. Data are from video presence/absence analyses.

transects (e.g., HB6 in the Point Arena Basin) grading to extremely scarce, low-relief areas along the deeper transects (e.g., HB4 in the Eel River Basin).

TABLE 3-7. RESULTS OF A WTEL TEST ASSESSING THE PROBABILITIES THAT COMMUNITY DIFFERENCES AMONG BASIN PAIRS ARE SIGNIFICANT. Data are based on exposed hard substrate video presence/absence data.

Basin	BASIN			
	Eel River	Pt. Arena	Bodega	Santa Cruz
Eel River	--			
Pt. Arena	.006*	--		
Bodega	.093	.011*	--	
Santa Cruz	.079	.016*	.079	--
No. Transects	2	5	2	2

*Indicates a significant difference ($p < 0.5$).

The initial analyses of the sediment veneer video data suggested some separation of the basins (Figure 3-14). However, a strong depth effect was apparent, particularly due to the deepest transects (HB3 and HB4 in the Eel River Basin and HB10 in the Point Arena Basin). To focus on basin rather than depth differences, the data from these deeper transects were removed and the remaining data reanalyzed using ordination and multiple regression. The ordination results indicated a separation of the basins along Axis 1 (Figure 3-17). Axis 1 accounted for 40% of the variability in the data; however, depth still was the strongest environmental correlate ($R^2 = .52$) along this axis. A final statistical comparison of the basin communities was performed using a Mantel test to further evaluate basin differences. These results indicate that the Bodega Basin is significantly different ($p < .05$) from all other basins and that the Eel River and Santa Cruz Basins also are significantly different from each other (Table 3-8). Thus, there are significant statistical differences between most of the basins; however, this distinction still appears to be related primarily to depth differences; thus, the basin differences probably are statistical artifacts of this strong depth effect. These conclusions,

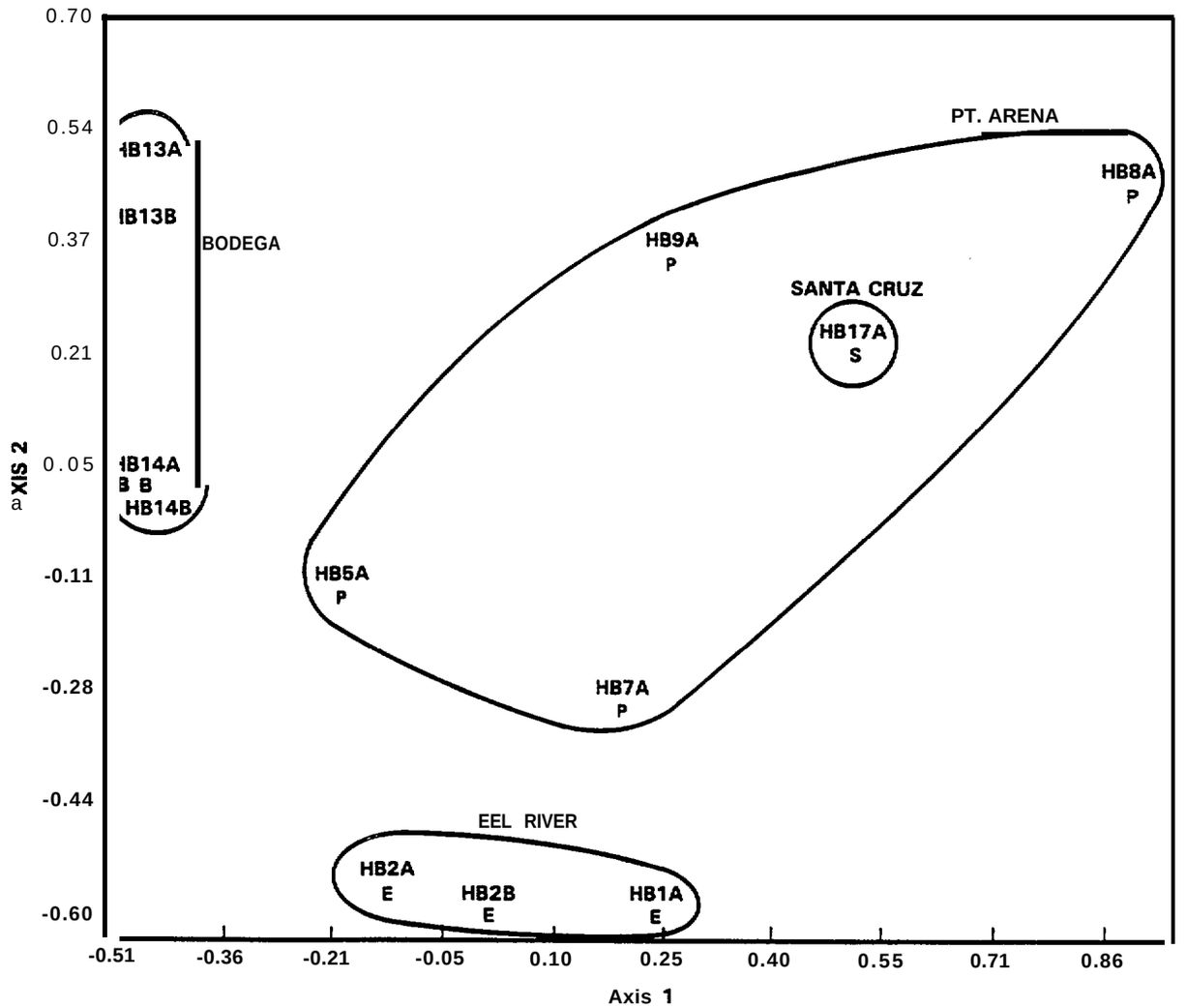


FIGURE 3-17. ORDINATION PLOT (AXIS 1 AND 2) OF THE SEDIMENT VENEER BASIN GROUPS. Data are from video presence/absence analyses.

primarily representing sediment veneer epifaunal communities, are similar to the results (i.e., no significant basin differences) observed for the soft substrate infaunal communities (Section 3.2). Surveys conducted at approximately the same depth series within each basin would be necessary to verify whether the community differences are related more strongly to geographic location (basin) or depth.

TABLE 3-8. RESULTS OF A MANTEL TEST ASSESSING THE PROBABILITIES THAT COMMUNITY DIFFERENCES AMONG BASIN PAIRS ARE SIGNIFICANT. Data are based on sediment veneer video presence/absence data; data from Transects HB3, HB4, and HB10 are not included.

Basin	BASIN Eel River	Pt. Arena	Bodega	Santa Cruz
Eel River	--			
Pt. Arena	.242	--		
Bodega	< .001*	< .001*	--	
Santa Cruz	. 044*	1.000	. 027*	--
No. Transects	3	4	4	1

*Indicates a significant difference ($p < 0.5$).

The assessment of large-scale patterns of the hard substrate communities focused on qualitative comparisons of the results from the present reconnaissance study off northern and central California with results from (1) the MMS Phase I reconnaissance survey of the Santa Maria Basin and western Santa Barbara Channel (SAIC, 1986), (2) the MMS Phase 11 monitoring survey program (CAMP) conducted at selected sites in the Point Arguello region (Battelle, 1988), and (3) selected industry-sponsored studies (Dames and Moore, 1982 and 1983; Nekton, 1983 and 1984) focusing on selected features which, when combined, represent the area from Pt. Conception to Purisima Pt. Survey depths from the present study ranged from 61-338 m; the Phase I program ranged from 54-237 m, with the majority of the data collected from 100-120 m; the CAMP Program ranged from 105-215 m; and the industry studies from approximately

100-300 m. There is sufficient overlap in these survey depths to allow some broad-scale comparisons to be made; however, differences in study objectives (reconnaissance versus monitoring) and in the collection and analysis techniques generally restrict quantitative comparisons between the studies.

The present study and the Phase I study were reconnaissance programs extending over large geographic areas. They provided information on a broad range of habitats from sediment veneer to high-relief hard substrate and included many areas of very marginal or ecotone-type habitats. The results from both studies indicated that the vast majority of the targeted hard substrate features, as identified from side-scan sonar records, were covered by sediment veneer that appeared to vary in thickness from a centimeter or less to at least a meter or more. In contrast, the CAMP and the combined industry studies focused on known high-relief and low-relief features associated primarily with oil and gas platforms or proposed platform sites, with relatively minor representation of sediment veneer and ecotone habitats. Other differences are that the Phase I results were based on photoquadrat and video data collected using a manned submersible and analyzed using total enumeration of the photoquadrat data, while the present Study and the CAMP program utilized a ROV to collect photoquadrat and video data and analyzed the photoquadrat data using a point-contact method. The industry studies used a variety of ROV and submersible methods but generally provided only semiquantitative data. These differences between the studies require that any comparisons be done carefully, particularly between different depths and substrate types.

Overall conclusions from the Phase I and the CAMP studies reflect somewhat different interpretations of the factors influencing trends in the distribution of various taxa. Specifically, the Phase I results suggested that the primary distinctions among the communities were based on substrate relief (low versus high relief), with a depth gradient observed for some species (SAIC, 1986). In contrast, the CAMP results (Battelle, 1988) suggested a primary distinction based on depth, with substrate relief producing a secondary effect (e.g., enhanced abundances in high-relief areas of those taxa which exhibited increased abundances with increased depth). Both studies recognize depth and substrate relief as key factors influencing the hard substrate communities; the

distinction of which factor is primary or secondary probably changes with differences in the scale (range of depths, substrate types, and geographic location) of a particular study. The different purposes (reconnaissance versus monitoring) of these studies result in very different study designs with differing abilities to detect community trends and their association with environmental factors. For example, the primary hard substrate data from the Phase I study were collected from a relatively narrow depth range (100-120 m) but over a broad range of substrate types, substrate relief, and location. Depth effects would not be expected to be a significant factor in these analyses; however, any substrate effects would be much easier to detect from the analyses. In contrast, the CAMP study represented a broader depth range (105-215 m) such that any trends related to depth may be more prominent in the analyses; additional analysis of these data would be valuable to examine independently the effect of substrate relief on the data.

The results from the analysis of video data from the present study indicated a strong depth effect on the hard substrate communities, similar to the CAMP conclusions. However, further evaluation of these data suggested that the trend primarily was influenced by the much greater occurrence of hard substrate and higher relief at shallower depths within the survey area. The overall scarcity of exposed hard substrate within the survey area limits the usefulness of these data to distinguish between broad-scale effects of depth and substrate type and relief. However, on a smaller (within basin) scale, analysis of photoquadrat data indicated a strong community difference between the two transects (HB6 and HB8) analyzed; these differences were concluded to be influenced primarily by substrate effects since the depth ranges of these transects were similar (70-85 m and 113-120 m, respectively), but there was a pronounced difference in the height and extent of substrate relief.

Results from the Phase I study (SAIC, 1986) suggested that sediment veneer, and presumably sediment transport, are major factors influencing the shallow (to approximately 200 m) hard substrate assemblages in that survey region. Types of effects may include fouling of filter feeding structures, burial, and decreased area for larval settlement or attachment. These sediment loads should have the greatest potential effect in low-relief areas, and potentially

on most horizontal surfaces including ridge tops, and should be moderated in higher-relief areas, particularly vertical walls where sedimentation levels are reduced. This relationship also was concluded to be a primary factor influencing the assemblages observed during the industry-sponsored studies of the region (Dames and Moore, 1983 and 1983; Nekton, 1983 and 1984). Nekton (1983) noted an apparent "band" of increased diversity, beginning approximately 2 m up from the base and extending to the top of high-relief features, that probably was related to sedimentation effects. Similar bands were not observed during the present or Phase I surveys although local differences in current structure and sediment transport are likely to occur. Dames and Moore (1983) noted that hard substrate communities occurring deeper than approximately 150 m appeared to be characterized by greater diversity, perhaps as related to a lower suspended sediment load at these and greater depths. Few data on bottom currents and sediment transport in the survey areas are available; additional data are needed to assess adequately the relationship between these variables and the long-term stability and diversity of these benthic communities.

In general, the taxa and communities observed by the studies are very similar, apparently representing species which are distributed over broad geographic ranges, but which exhibit some correlations with depth and/or substrate relief. Some of these species include feather stars Florometra serratissima, the anemone Metridium senile, cup corals (Paracyathus stearnsii, Balonophyllia elegans, and Caryophyllia spp.), and the brachiopod Laqueus californianus. Several sponge taxa (e.g., "white foliose sponge") also appear to be common in all study areas; however, limited taxonomic knowledge of this group make most comparisons problematic.

Dames and Moore (1983) noted that crinoids (Florometa serratissima) and basket stars (Gorgonocephalus eucnemis) occurred most commonly at depths greater than approximately 100 m; Dames and Moore (1982) noted that G. eucnemis was more common below 150 m. Similar trends were observed from the Phase I survey; F. serratissima occurred most frequently and abundantly below approximately 100 m depth and G. eucnemis was present from at least 90 m with increased abundance beginning at 140 m. Trends in common between the present survey, the Phase I survey, and Dames and Moore (1982 and 1983) included (1) increased frequency

and abundance of the cup corals Paracyathus stearnsii and Corynactis californica at depths shallower than 140 m and 100 m, respectively, and (2) increased abundance of caryophilliid cup corals at deeper depths (approximately greater than 100 m). Similar broad patterns of species zonation with depth were defined by Lissner and Dorsey (1986) for Tanner and Cortes Banks offshore of southern California.

Dominant invertebrate phyla from the studies included coelenterates and echinoderms in most areas, although high densities of brachiopods and sponges were observed in some localized low-relief and high-relief areas, respectively. The majority of the representative taxa in these phyla and other characteristic groups (bryozoans, tunicates, and polychaetes) are suspension feeders. Battelle (1988) noted that there was an increase in the abundance of suspension feeders with increased depth; all the studies noted an increase with increased substrate relief. The potential sensitivity of these organisms, particularly sessile taxa such as cup corals and sponges, to increased suspended sediment loads from either natural or man-induced effects makes these organisms particularly important to document as indicators of environmental stability and change (SAIC, 1988; Battelle, 1988).

The primary differences between the studies in the types of taxa appeared to be related to differences in the survey depths and the extent and height of hard substrate relief. Battelle (1988), SAIC (1986), and Nekton (1983 and 1984) observed diverse deeper water (e.g. , > 200-m depth) communities which included numerous sponge taxa, and notably the cup coral Desmophyllum crista-galli and the colonial coral Lophelia californica which were not observed at all from the present study, probably due to the relatively shallow water depths at which significant hard substrate areas occurred. Additionally, the abundances of these and other suspension-feeding taxa exhibited a notable increase in higher-relief areas, as discussed above. In contrast, the hydrocoral Allopora californica was noted in limited abundances along some shallow water (e.g. , < 80-m depth) transects from the present study and SAIC (1986) but was evidently outside of the deeper depths surveyed by Battelle (1988). With the exceptions of these broad differences which appeared to be associated with differences in study design and habitat occurrence the taxa and communities were very similar

among the studies. Thus, at the level of taxonomic resolution and enumeration which is possible using photographic and video techniques, the hard substrate communities of the outer continental shelf region from at least the Point Conception area to near the California-Oregon border appear to be very consistent in the associated taxa for the depth ranges surveyed. The main source of variability among the studies appeared to be associated with depth (or depth-related factors) and habitat availability rather than geographic location. Other differences that are related to geographic location will likely be observed as further refinements in the taxonomy of deeper-water organisms and in survey and analysis methods are possible in the future.

3.1.5 Video and Photoquadrat Methods Evaluation

This section presents the results from methods evaluation analyses that were conducted as part of the laboratory analysis of videotape and 70-MM photo-quadrat data from the transect surveys. Discussions of these results, including implications for sampling design, are presented separately for the two analyses.

Video Methods Study

Community differences within the video band quadrats were compared to those among different band quadrats to assess the scale of community changes along the transects, provide an assessment of the variability in applying the laboratory analysis method (detailed in Section 2.3), and aid in the design of future sampling programs. For this study, data were recorded from an additional 30 seconds of videotape from some of the band quadrats for two transects: (1) 20-band quadrats from Transect HB2, which consisted almost entirely of sediment veneer and (2) 10-band quadrats from Transect HB6, which consisted almost entirely of high-relief hard substrate. The additional 30 seconds in each band quadrat was considered a separate entity in the analysis and was identified by the band-quadrat number and replicate, which was always "Q." The first 30 seconds of each band quadrat was always called replicate "A." An ordination and cluster analysis was performed on the data from each transect separately.

The cluster analysis was used to evaluate the relationships between the replicates in the same band quadrat in relation to the overall community patterns. The ordination analysis was used to examine the relationship between spatial distance and community differences. First, the distances between the band-quadrat replicates in the ordination space were used to test whether the community differences within a band quadrat (differences between replicates A and Q) were smaller than community differences among band quadrats. A Mantel test was used to test the null hypothesis that the within-band quadrat distances were the same as the between-band quadrat distances. Finally, the distances in the ordination space were plotted against the differences in the band-quadrat numbers (representing increasingly greater separation between band quadrats) to assess the relationship between spatial distance and community differences.

Sediment Veneer - Transect HB2

The dendrogram from the cluster analysis indicates that the Q and A replicates within a band quadrat usually are clustered into very different groups (Figure 3-18). The two-way coincidence table (Figure 3-19) shows the faunal differences associated with the various potential groups and indicates that there is no gradient of community change with distance along the transect (i.e., one community appears to be represented by Transect HB2). Table 3-9 compares the within- and between-band quadrat community differences using the results from the Mantel test.

TABLE 3-9. WITHIN- AND BETWEEN-BAND QUADRAT DISTANCES IN THE ORDINATION SPACE. A Mantel test was used to compare these sets of differences.

Within-Band Quadrat Distance (W)	Between-Band Quadrat Distance (B)
.979	.928

Mantel Test for Equality of W and B
p = .53
Accept Null Hypothesis

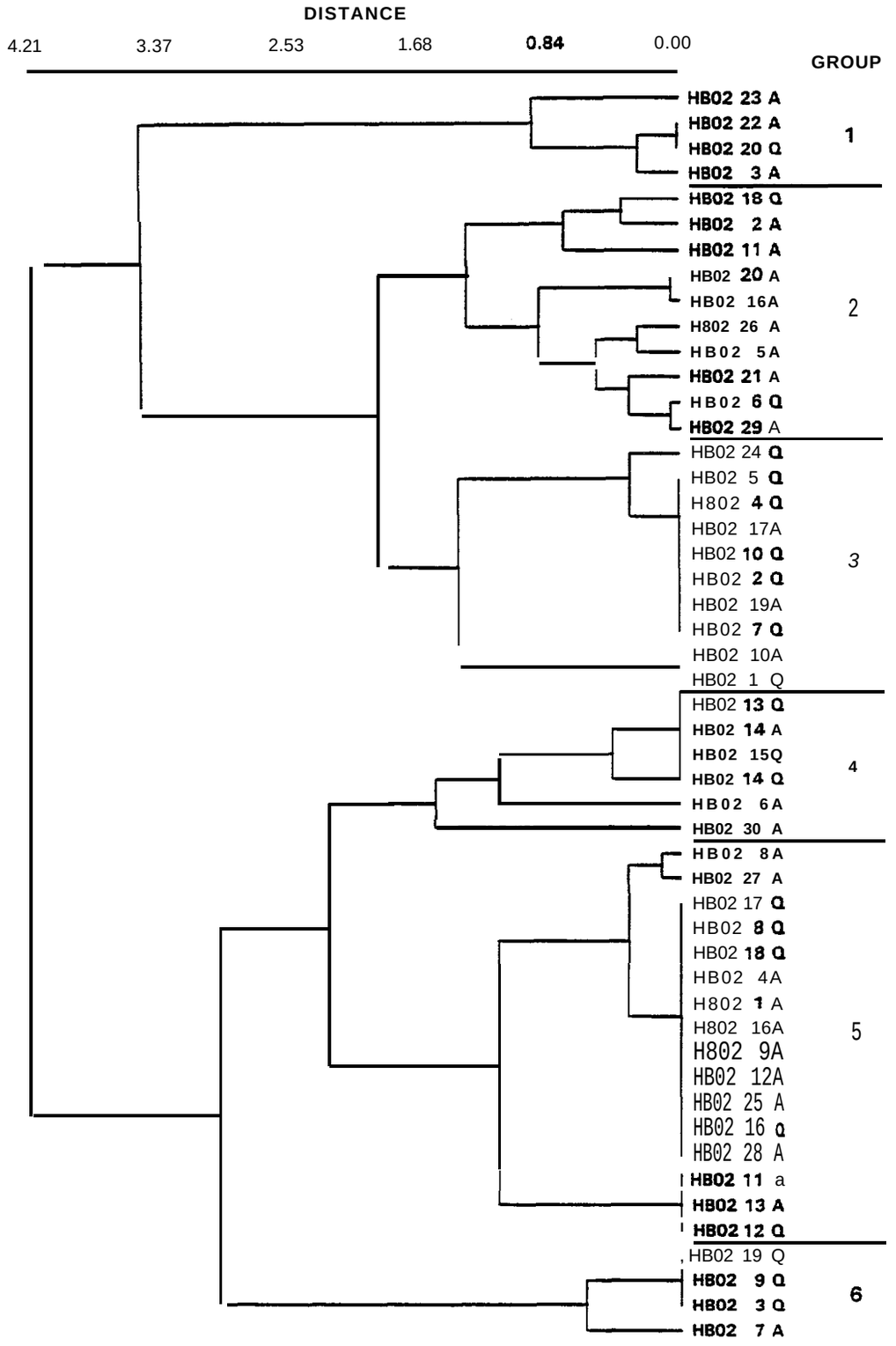


FIGURE 3-18. CLUSTER ANALYSIS OF REPLICATE DATA FROM TRANSECT HB2 VIDEO PRESENCE/ABSENCE DATA. "A" refers to the first 30 seconds of analysis for a 30 m band quadrat and "Q refers to the second 30 seconds of analysis.

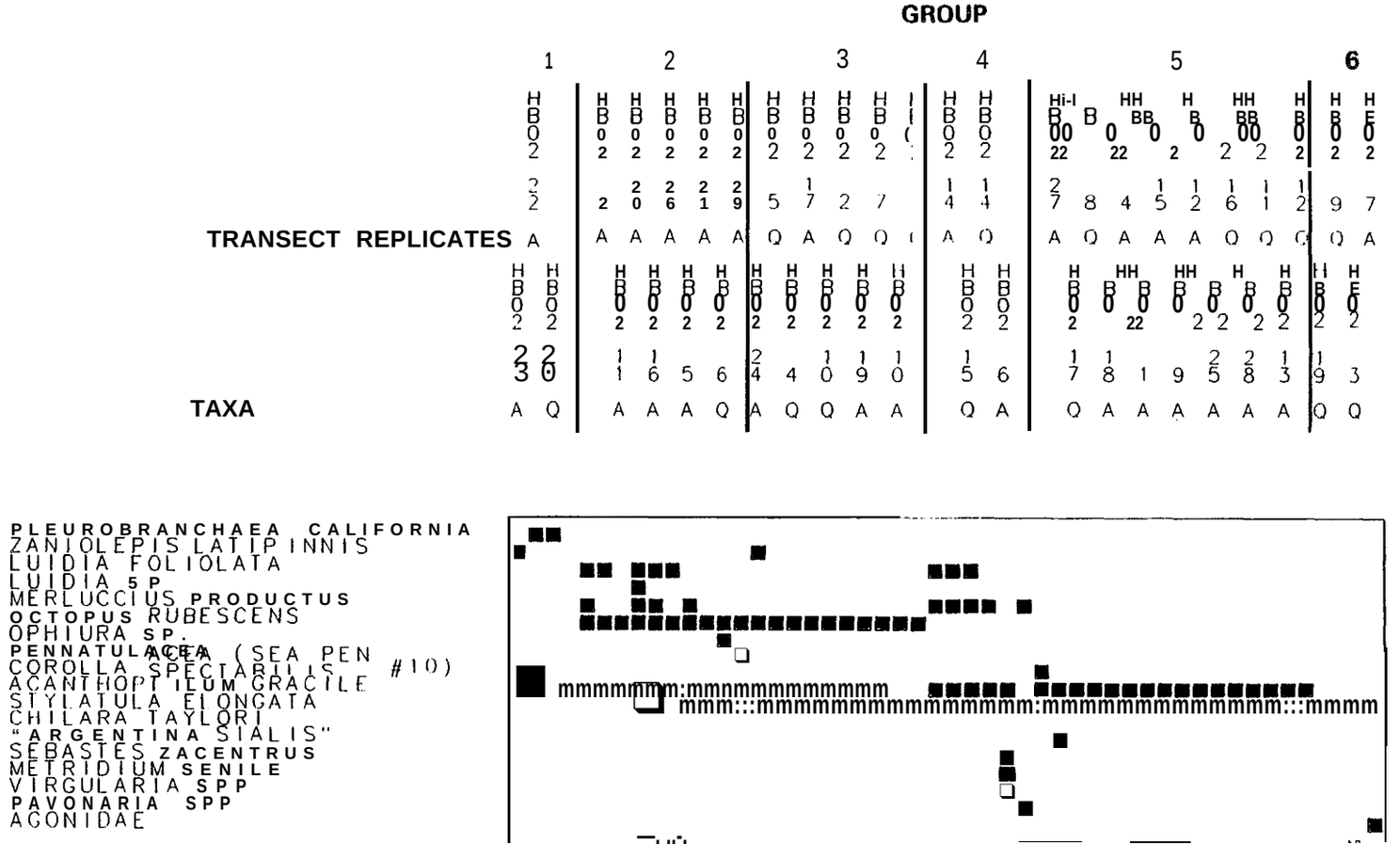


FIGURE 3-19. TWO-WAY COINCIDENCE TABLE BASED ON MULTIVARIATE ANALYSIS OF TRANSECT HB2 VIDEO PRESENCE/ ABSENCEDATA. "A" refers to the first 30 seconds of analysis for a 30 m band quadrat and "Q" refers to the second 30 seconds of analysis.

The Mantel test indicates that the communities within band quadrats are no more similar than communities in different band quadrats. In fact, these results suggest that there is no relationship at all between spatial distances and community differences. This is consistent with the random-like ordering of replicates within a single-band quadrat with different groups on the dendrogram (Figure 3-18). The two-way coincidence table shows that the community differences are based on a small number of species and that most of the species are somewhat dispersed along the transect. This can lead to apparently large faunal differences within short distances along the bottom. However, inspection of Figure 3-19 indicates that the primary taxa which contribute to broad-scale differences between cluster Groups 1, 2, and 3 and Groups 4, 5, and 6 are relatively motile organisms (Octopus rubescens, the seastar Luidia, and the mollusc Pleurobranchaea californica). Thus, the statistical differences between replicates probably reflect a somewhat random distribution of these motile taxa. In contrast, sessile taxa such as the sea pens Acanthoptilum gracile and Stylatula elongata are very evenly distributed over the cluster groups (Figure 3-19). Analyses based on sessile taxa alone would minimize differences between replicates and may be more appropriate to characterize long-term changes in these benthic communities.

To sample the community in this area adequately, either a single long-band quadrat or several shorter-band quadrats (as was done in the present study) could be analyzed. Which of these two strategies are used should not matter, since there is no gradient of community change with physical distance. It is important that the coverage be somewhat similar to the present study (e.g., a 900-m long transect), however, because several motile species are present and they are somewhat dispersed and occur in low densities. More transect replicates separated by different physical distances would need to be sampled in order to determine how far apart the replicates should be to obtain independent samples.

Hard Substrate - Transect HB6

The dendrogram from the cluster analysis indicates that the Q and A replicates within a band quadrat usually are clustered into similar groups (Figure 3-20).

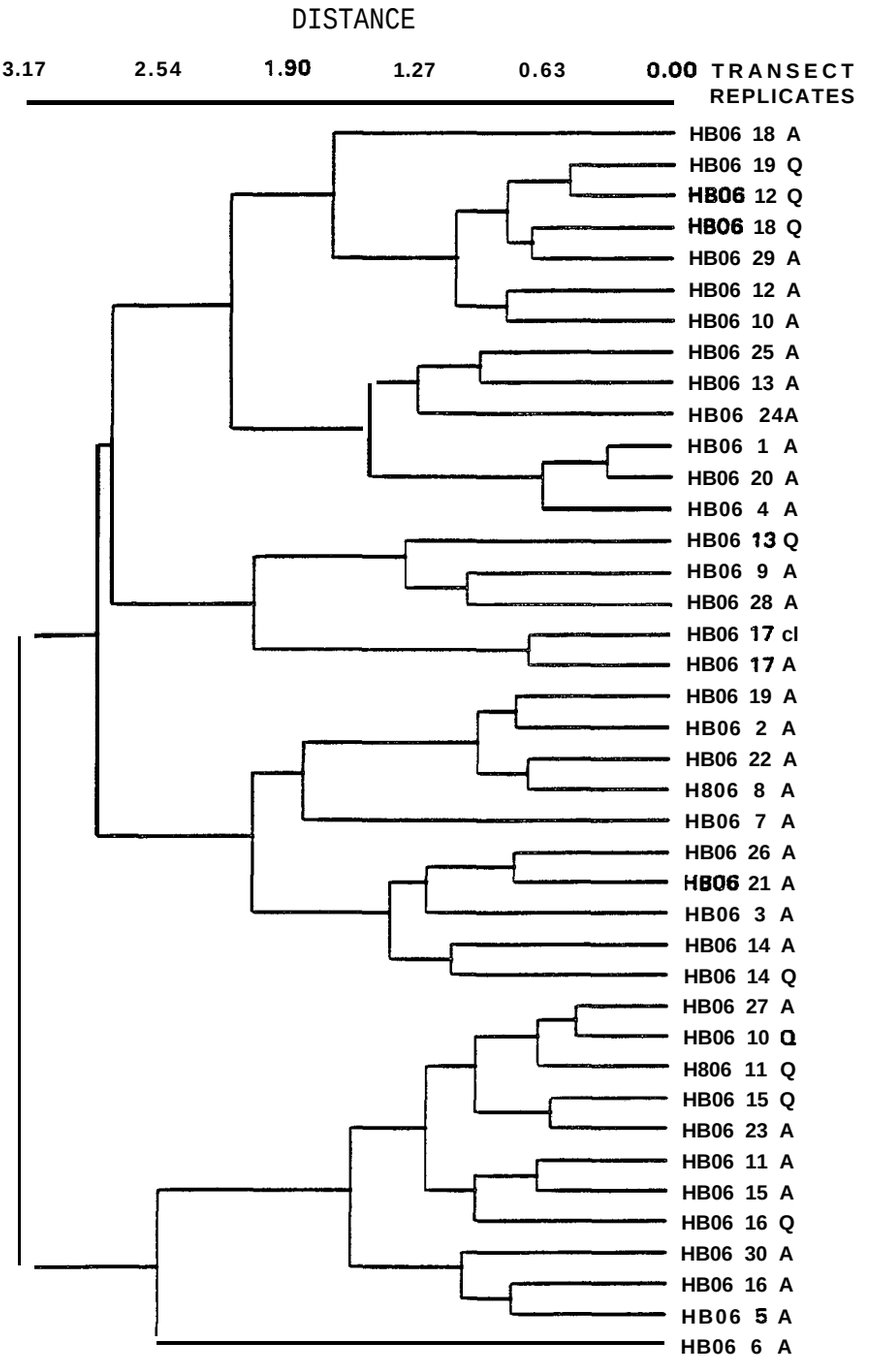


FIGURE. 3-20. CLUSTER ANALYSIS OF REPLICATE DATA FROM TRANSECT HB6 VIDEO PRESENCE/ ABSENCE DATA. "A" refers to the first 30 seconds of analysis for a 30 m band quadrat and "Q" refers to the second 30 seconds of analysis,

Only two out of the ten band quadrat pairs (HB6-10 and HB6-19) cluster in very different groups. The two-way coincidence table (Figure 3-21) shows the faunal differences associated with the various groups. Table 3-10 compares the within- and between-band quadrat community differences using the results from a Mantel test.

TABLE 3-10. WITHIN- AND BETWEEN-BAND QUADRAT DISTANCES IN THE ORDINATION SPACE. A Mantel test was used to compare these sees of differences.

Within-Band Quadrat Distance (W)	Between-Band Quadrat Distance (B)
.997	1.451

Mantel Test for Equality of W and B
p = .0001
Reject Null Hypothesis

The Mantel test indicates that the communities within band quadrats are more similar than communities in different band quadrats. The within-band quadrat community differences are on the average smaller than the between-band quadrat differences, but community differences do not continue to increase with physical distances up to and beyond a distance of one band quadrat.

The two-way coincidence shows that, compared to the results from sediment veneer Transect HB2, the hard substrate community at Transect HB6 contains more species which generally occur in more of the band quadrats along the transect. The community evidently does not usually change rapidly within the first 60 seconds of a band quadrat. This probably reflects the scale of habitat heterogeneity.

The distribution (e.g., random, even, or clumped) of individual taxa is determined by a variety of biotic and abiotic factors including competition and larval substrate preference (e.g., reviewed in SAIC, 1988). These patterns

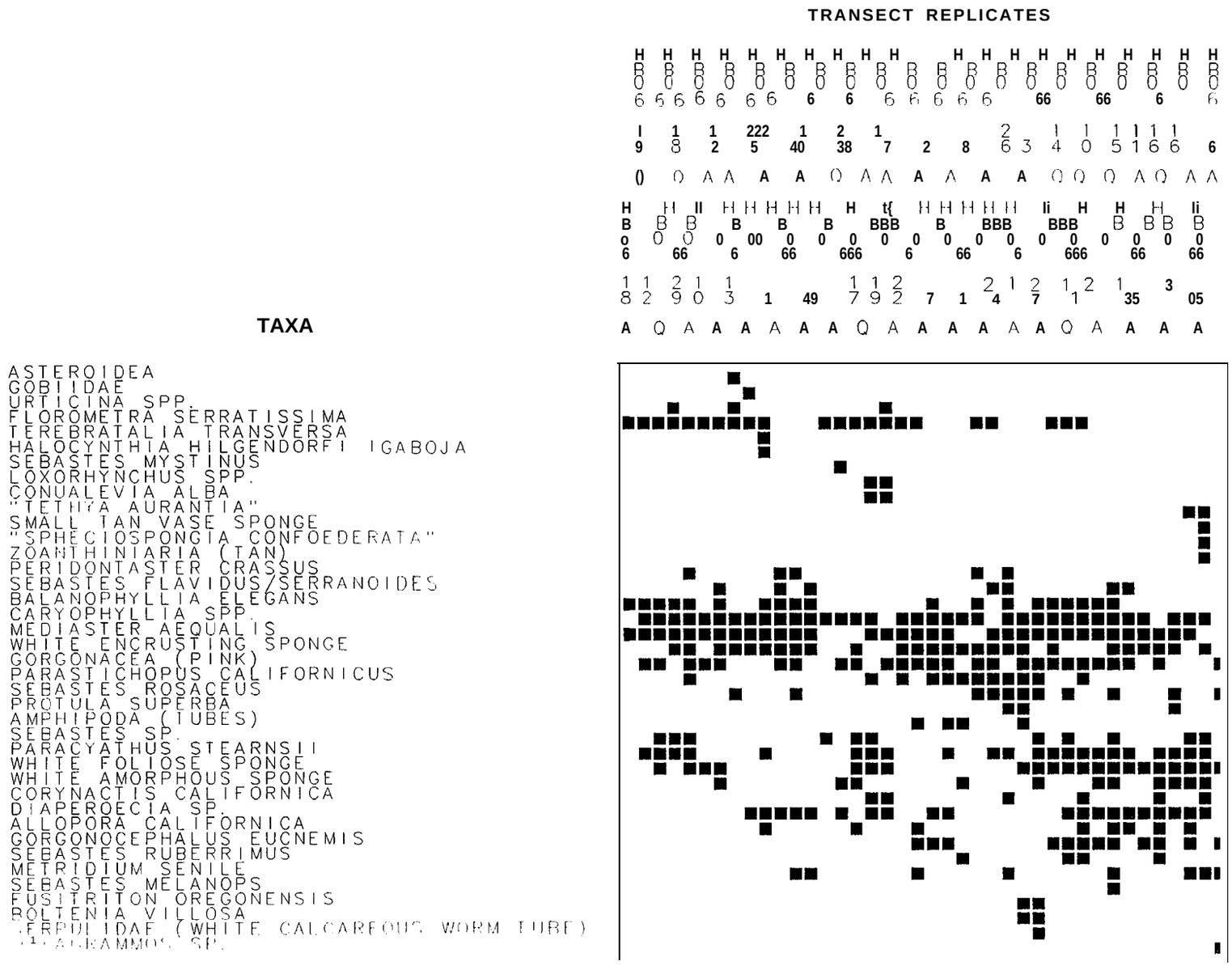


FIGURE 3-21. TWO-WAY COINCIDENCE TABLE BASED ON MULTIVARIATE ANALYSIS 0FTRANSECTHB6VIDEOPRESENCE/ ABSENCE DATA. "A" refers to the first 30 seconds of analysis fora30m bandquadratand ''Q''refers to the second 30 seconds of analysis.

also are influenced significantly by substrate availability (e.g., the occurrence of exposed hard substrate or the depth of sediment veneer). Both of the substrate types (hard or sediment veneer along Transects HB6 and HB2, respectively) for this comparison appeared to be relatively homogeneous. Differences in the types of organisms comprising the associated communities were evaluated to further assess the differences in variability between the hard substrate and sediment veneer replicates. One important factor appears to be the occurrence of sessile versus motile organisms; the majority of the hard substrate taxa are sessile organisms (e.g., cup corals, sponges, and anemones), while many of the taxa along the sediment veneer transect are relatively motile. Sessile organisms along both types of transects appear to be somewhat evenly distributed, and they appear to have a significant effect on the similarity of band quadrats, while motile taxa occurring along the sediment veneer transect seem to be more randomly distributed and significantly increase the within-band quadrat variability. The much higher diversity of sessile taxa appears to dominate the results for hard substrate Transect HB6; the relatively few motile taxa in this community do not significantly increase the variability between-band quadrat replicates.

Photoquadrat Method Study

Community differences were evaluated based on two different photoquadrat analysis methods: point-contact versus a total-enumeration method of all taxa in a photoquadrat (see Methods Section 2.3). This comparison provides an assessment of the variability in applying these methods and serves as an aid in the design of future sampling programs.

Two separate analyses were performed on the photoquadrat data from Transects HB6 and HB8. The first analysis utilized point-contact data converted to percent cover (the number of point contacts per taxon was divided by 50, the maximum number of possible contacts/photoquadrat) and compared community differences between laboratory QC replicates, field replicates along the same transect, and transects. The second analysis utilized point-contact and total-enumeration data converted to presence/absence data. The presence/absence analysis evaluated several data types:

- Point Contact (PC) = taxa noted as present from the standard 50 point-contact method of analysis,
- Point Contact plus (PC+) = point-contact data plus those taxa noted incidentally as present during the point contact analysis.
- Whole Photoquadrat (WP) = taxa noted as present from a separate (nonpoint-contact) analysis focusing on all taxa present in a photoquadrat (= total enumeration). These analyses were performed on a random subset of the photoquadrats.
- Quality Control (QC) replicates = three separate analyses of the same photoquadrat performed at different times.
- Field replicates = separate photoquadrats along the same transect analyzed using the point-contact method.
- Transects = all photoquadrats along the same transect (either HB6 or HB8).

The PC+ data minus the WP data provides an indication of method (including observer) variability, since the distance should be near zero for analyses of the same photoquadrat, but methods represent a slightly different focus (see definitions above). The QC replicates also should be near zero since this comparison represents the same method of analysis performed at different times by the same observers.

The PC data minus the PC+ data provides a measure of the additional taxa which are added to the community by analysis of the entire photoquadrat (i.e., how many community elements are missed by using the point-contact method alone) . Finally, the PC data minus the WP data provides a similar comparison as PC minus PC+; however, the WP evaluation is more focused and, therefore, is a better indicator of the community elements missed by using the point-contact method.

For both analyses, the data were used to compute an ordination space, and the distances between the samples (photoquadrat analyzed using a particular methodology) in the ordination space were used to compute the average distances (average community differences) between different categories of spatial scale and method. Table 3-11 shows the average distances (average community differences) between the QC replicates, and between the photoquadrat data on

various spatial scales for the point-contact data. Table 3-12 shows the results for the presence/absence data.

TABLE 3-11. MEAN DISTANCES BETWEEN THE VARIOUS SPATIAL SCALES, AND BETWEEN QC REPLICATES FOR POINT-CONTACT DATA. Distances are distances between samples in the ordination space. See text for definitions.

Type	Average Distance	Range
QC Replicates	0.69	1.02 - 1.19
Field Replicates	1.66	0.01 - 3.90
Transects	2.20	0.48 - 4.04

TABLE 3-12. MEAN DISTANCES BETWEEN THE VARIOUS SPATIAL SCALES, AND BETWEEN METHODOLOGIES FOR PRESENCE/ABSENCE DATA. Distances are distances between samples in an ordination space. See text for definitions.

Type	Average Distance	Range
PC+ - WP	**0.68**	**0.25 - 1.13**
QC Replicates	0.76	0.02 - 1.37
Pc - PC+	1.01	0.26 - 2.05
Pc - WP	1.40	0.89 - 1.99
Field Replicates	1.60	0.89 - 2.56
Transects	2.16	0.47 - 3.79

As indicated in Tables 3-11 and 3-12, the rank order of the spatial variability is *lowest* for "replicate" (PC+ - WP and QC replicates) analyses of the same photoquadrat, with increasing variability related to differences between methods (PC - PC+ and PC - WP), essentially comparing point contact with incidental and focused counts of additional taxa, followed by field replicates along the same -transect, and finally differences between transects. The distances for the PC+ - WP and the QC replicate data are similar, but both are clearly greater than zero (Tables 3-11 and 3-12), indicating that some variability exists in applying the methods. This variability is somewhat inherent to the analysis of photoquadrats from relatively complex communities, since even the slightest movement in aligning a photographic slide with a point-contact pattern or of the visual reference points of an observer during a WP analysis can produce different results (see Section 2.3). Some improvements in applying these methods are possible such as increasing the number of point-contact dots above 50 (thereby providing increased "sampling" of the photoquadrat so that more community elements are represented) and through the use of computer-scanning techniques for WP analyses, thus providing closely defined subsets of the photoquadrat area for reference and enumeration.

In contrast to the PC+ - WP and QC replicate data, the methods comparison analyses (PC - PC+ and PC - WP) both indicate that the point-contact method undersamples the photoquadrats relative to the taxa noted incidental to point-contact results (PC+) and the focused enumeration of all taxa (WP). These differences are not surprising since, by design, the point-contact method only samples a subset of the photoquadrat (in this case 50 dots); analysis of the entire photoquadrat or greater numbers of dots for point-contact methods would obviously sample more of the environment. The effort involved in performing total enumerations of the photoquadrats was not substantially different than performing the point-contact method; since the total enumeration approach provides more complete sampling of a photoquadrat, we recommend that this method be used instead of point contact for analysis of communities exhibiting similar or lower complexity than those observed by the present study.

The greater distances observed between the transect as compared to those within transects (Tables 3-11 and 3-12) are consistent with the multivariate analysis

of the photoquadrat data (Section 3.1.4) . These combined results indicate a significant difference in the biological communities associated with Transect HB6 as compared to HB8.

3.2 SOFT SUBSTRATE COMMUNITIES

The objectives of the soft substrate study were to characterize the benthic communities of the Central and Northern California Planning Areas; describe spatial patterns in the composition, abundance, and distribution of the infauna; describe, to the extent possible, relationships between those patterns and the physical environment; and examine large-scale spatial patterns of the benthic communities in the Central, Northern, and Southern California OCS Planning Areas. Given those objectives, the analytical program was designed to answer the following questions:

1. What are the patterns in the distributions of the soft substrate communities and environmental variables within the central and northern planning areas?
2. Are there any differences in soft substrate communities or environmental variables among the three basins that were sampled?
3. Are there differences in soft substrate communities or environmental variables among depths?
4. Are there differences in soft substrate communities among sediment types at the same depth?
5. Are differences in community summary measures correlated with environmental features?
6. What are the distributional patterns in soft substrate communities along the California coast when data from the northern, central, and southern California OCS regions are combined?
7. How variable are repeated measures of the soft substrate community at a station?

To address these questions, a total of 51 stations on 14 transects in four basins were sampled for infauna, sediment characteristics, and selected near-bottom water chemistry. The data from the only station sampled in the Santa Cruz Basin (Station 57) were not included in subsequent analyses (except in the

case of some multivariate analyses) because a single station could not be assumed to represent the basin as a whole. The actual data analyzed, therefore, represented 50 stations on 13 transects in three basins. The data were analyzed using a variety of techniques. Environmental variables (sediment and near-bottom water characteristics) were mapped. Groups of stations with similar sediment types were defined with cluster analysis of the sediment-size data, and spatial patterns in the biological data were summarized with ordination and cluster analyses. Contours of ordination scores were mapped to display geographic patterns. Relationships between the biological and environmental patterns were assessed using regression, and hypotheses concerning biological or environmental differences with different basins or sediment types were tested using parametric and multivariate statistics.

The results of the analyses of the environmental data are presented in Section 3.2.1. The overall summary characteristics of the soft substrate community (number of species, number of individuals, diversity, biomass) at individual stations, at the various depths, and in each basin are presented in Section 3,2.2. Descriptions, based on the multivariate analyses, of community patterns in the basins sampled and their relationships to the environmental variables are presented in Section 3.2.3. Statistical support provided by multivariate and univariate hypothesis testing for the patterns of individual species of interest also is presented in Section 3.2.3. Section 3.2.4 describes the results from pattern analyses that combined data from earlier BLM and MMS soft substrate programs in the Santa Maria Basin and Southern California Bight with the data from the present study. Section 3.2.5 presents a discussion of the new species described by this study and examines zoogeographic ranges for selected species encountered on OCS programs. The utility of sample replication in a reconnaissance program is discussed in Section 3.2.6. Finally, an overview of quality assurance results is presented in Section 3.2.7.

3.2.1 Soft Substrate Physical Environment

The physical environment of the soft substrate was described in terms of the nature of the sediment and the near-bottom water to which the benthic fauna

would be exposed. Results of the data analyses indicated two major environmental patterns. First, the environment of the Eel River Basin differed from that of the other basins. Near-bottom water temperatures and dissolved oxygen concentrations were higher in the Eel River Basin than elsewhere in the survey area. The mean grain size of sediments in the Eel River Basin was smaller than in the other two basins. The second major pattern concerned a change in sediment character related in part to depth. Fine sediments tended to occur shoreward of the coarser sediments, rather than farther offshore.

Sediment Character

The analyses of the sediment data allowed the first three questions listed in the introduction to this section to be addressed. The nature of the sediments varied considerably between basins and depths. The map of mean phi size (Figure 3-22) suggests two major patterns:

(1) Mean phi was much higher (i.e., the sediment was finer) in the Eel River Basin than elsewhere: most values in the Eel River Basin exceeded a phi size of 5.0 (medium silt); four values were greater than 7.0 (very fine silt); and none was less than 4.0 (coarse silt); whereas, in the other two basins only one-third of the values exceeded 5.0, only one exceeded 6.0, and some were less than 3.0 (fine sand).

(2) Mean phi generally was higher nearshore (at the 100-m stations) than farther offshore (at the 200-m and some 400-m stations) on most transects. This pattern is contrary as to the typical trend of increasing values of phi with increasing distance offshore noted in most studies (e.g., SAIC, 1986).

The maps of percent sand and percent silt/clay (Figures 3-23 and 3-24) are consistent with the pattern of phi size: percent silt/clay was highest, and percent sand lowest, in the Eel River Basin and at most of the inshore stations.

The cluster analysis based on the sediment size and distribution measures defined five major groups of stations. The sediment regimes which characterized the stations in each group were designated by the letters A-E. The definition of each type was as follows: A = medium-fine sand; B = very

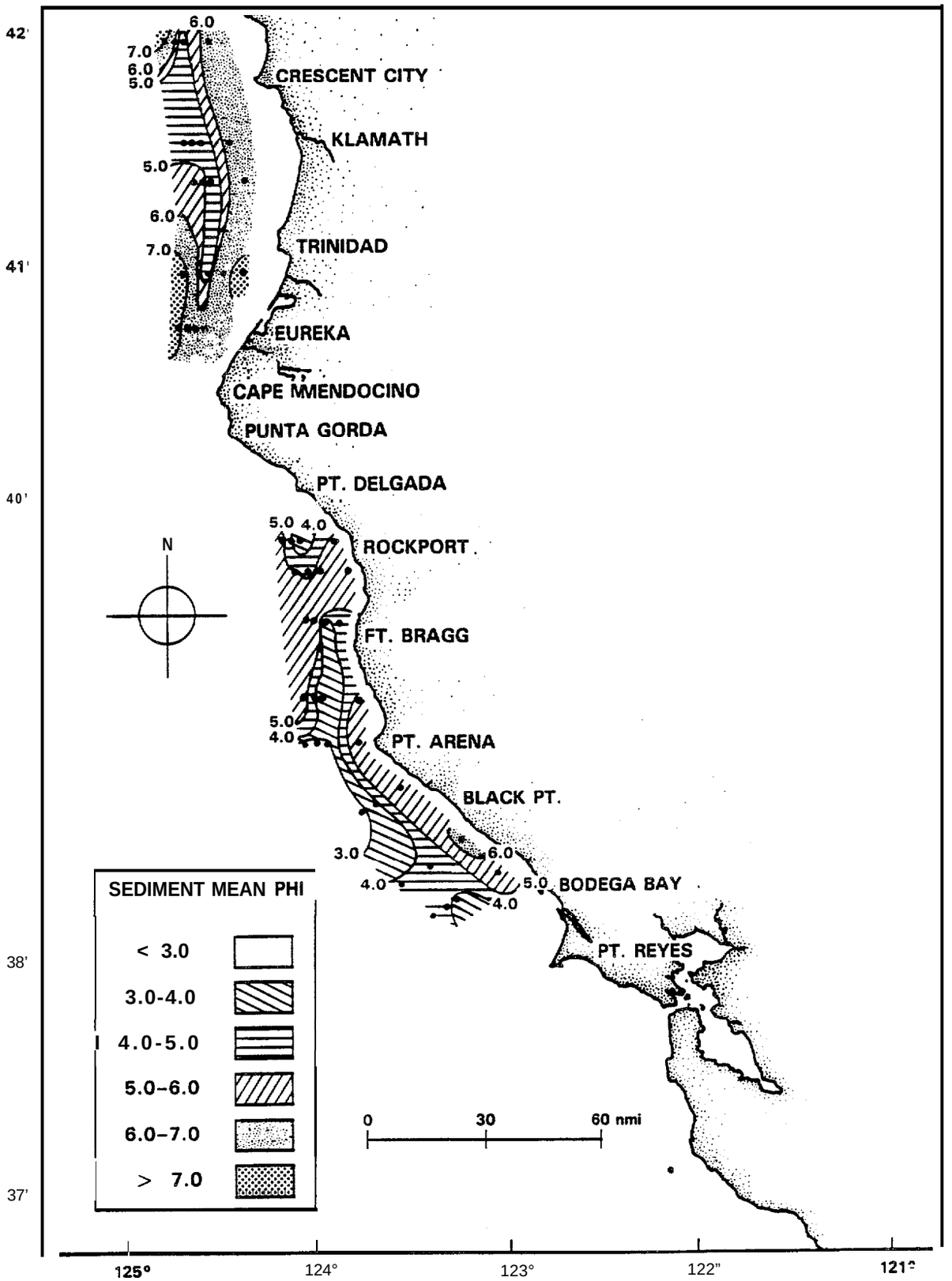


FIGURE 3-22. MAP OF VALUES OF MEAN PHI SIZES IN SEDIMENT SAMPLES COLLECTED IN THE CENTRAL AND NORTHERN PLANNING AREAS. Values are phi.

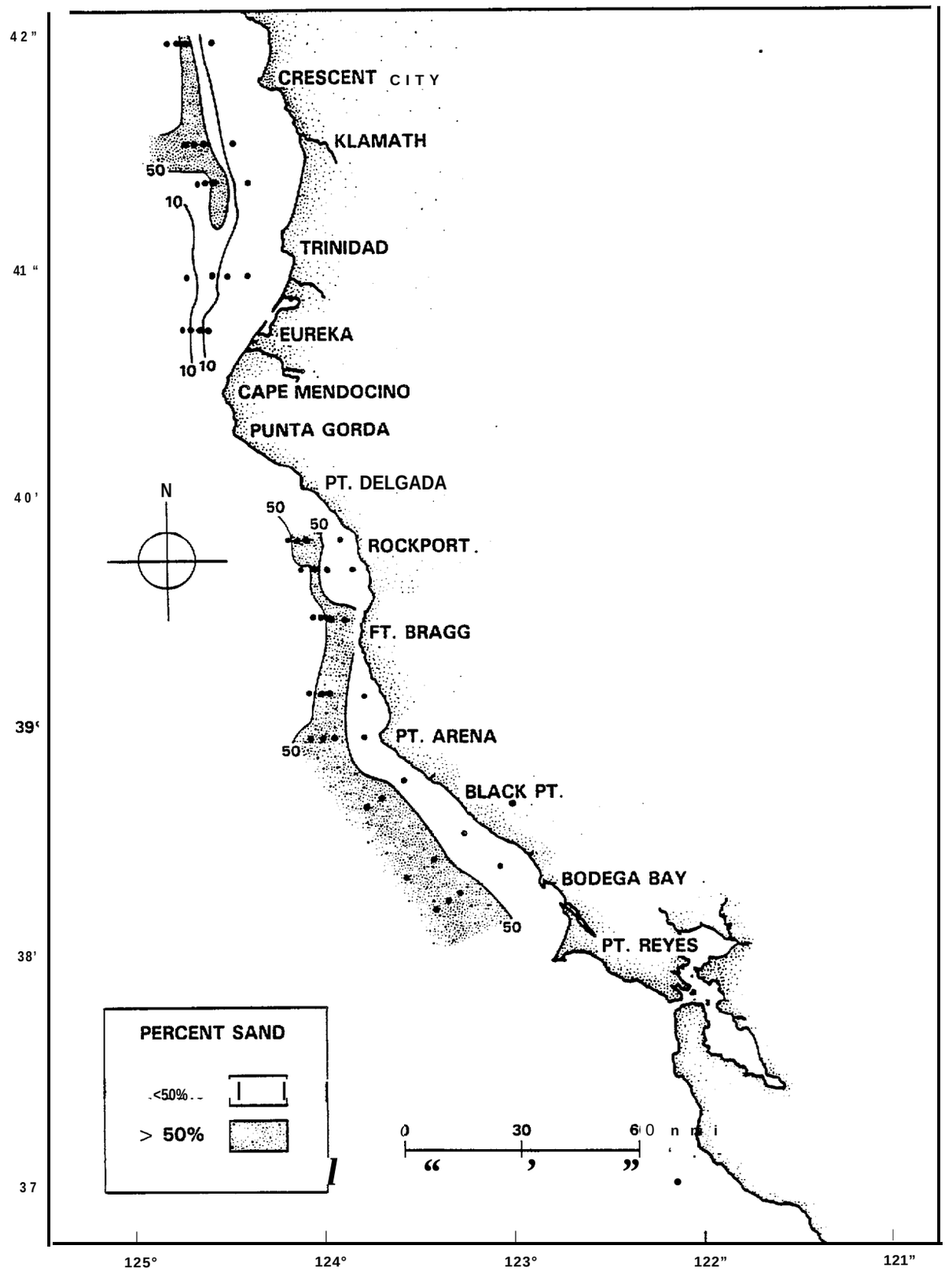


FIGURE 3-23. MAP OF VALUES OF PERCENT SAND IN SEDIMENT SAMPLES COLLECTED IN THE CENTRAL AND NORTHERN PLANNING AREAS.

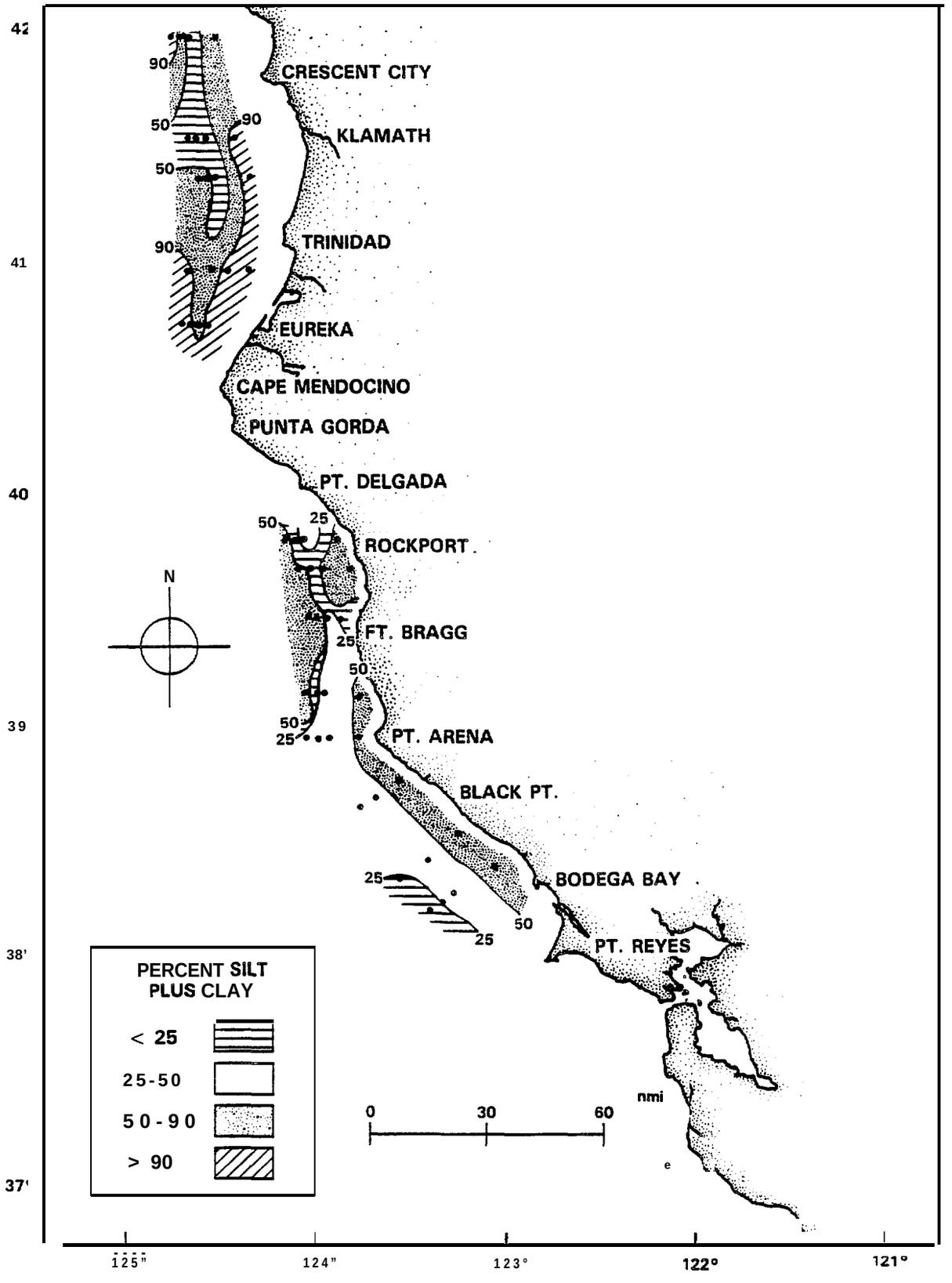


FIGURE 3-24. MAP OF VALUES OF PERCENT SILT PLUS CLAY IN SEDIMENT SAMPLES COLLECTED IN THE CENTRAL AND NORTHERN PLANNING AREAS.

fine sand with silt; C = silt and very fine sand; D = silt with very fine sand and clay; E = silt and clay only. Grain-size distribution plots for stations representing each of the sediment types are displayed in Figure 3-25. The geographic distribution of the types is shown in Figure 3-26. Sediment Type A consisted of coarser sediments (coarse-to-fine sand, phi = O to 3) ; a small admixture of silts gave these sediment distributions very high positive values of skewness. Sediment Type A occurred at the deep stations in the southern part of the Point Arena Basin. Sediment Type B was characterized by fine sand (phi = 3) with an admixture of a broad range of silt sizes and clay, so that the grain-size distribution showed high positive values of skewness. These sediments occurred only at 200-m stations. Sediment Type C was characterized by high percentages of silt and some fine sand, which resulted in a grain-size distribution with high positive values of skewness, Type C sediments occurred at nearshore stations in the Point Arena Basin and at most of the Bodega Basin stations. Sediment Type D seemed to be characterized by a broad range of grain sizes in the silt/clay range. These sediments occurred in a band that included many of the offshore stations in the Eel River Basin and northern Point Arena Basin. Sediment Type E was composed of silts and clay (phi = 6-10) and represented the finest-grained sediments encountered. Sediment Type E occurred only in the Eel River Basin, primarily at the shallowest (100 m) and deepest (600 m) stations.

Figure 3-22 displays one aspect of the sediment regime, mean phi, throughout the sampling area, and shows the two major patterns of mean grain size. Those patterns are not, however, as apparent in Figure 3-26 because the cluster groups incorporated and were heavily influenced by several measures of grain size and grain-size distribution, including skewness, sorting, kurtosis, and mean phi. This was particularly true in the two southern basins. In the Eel River Basin, however, the cluster analysis supported the interpretation based solely on mean phi (Figure 3-22): Sediment Type E occurred only in the northern basin, and it occurred shoreward (as well as seaward) of the coarser sediments of Sediment Types B and D. These major sediment patterns are important in the consideration of biological patterns (Section 3.2.4) because of the strong correlation between the two types of patterns.

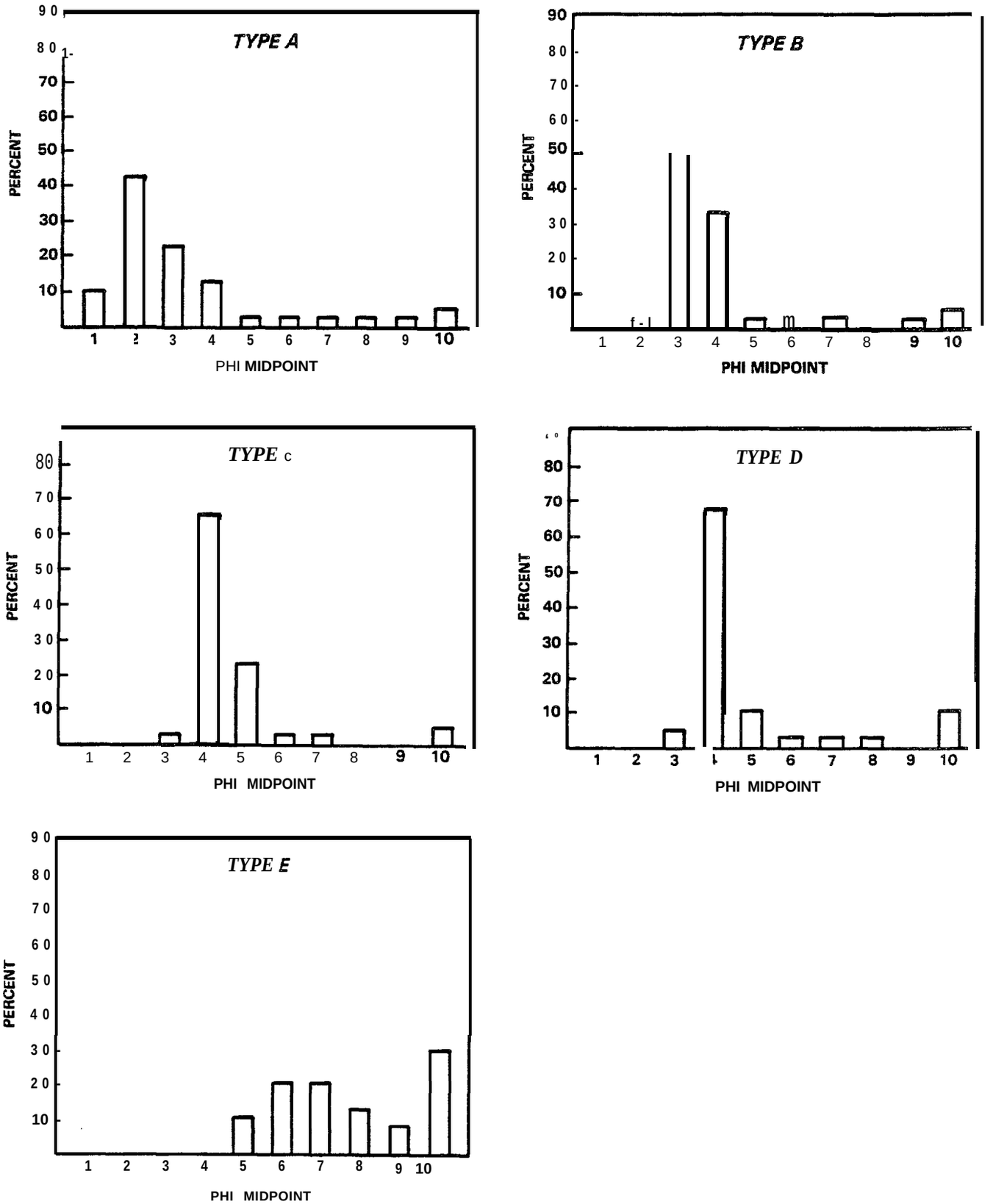


FIGURE 3-25. REPRESENTATIVE HISTOGRAMS OF GRAIN-SIZE DISTRIBUTIONS OF THE FIVE SEDIMENT TYPES IDENTIFIED BY CLUSTER ANALYSIS OF SEDIMENT DATA.

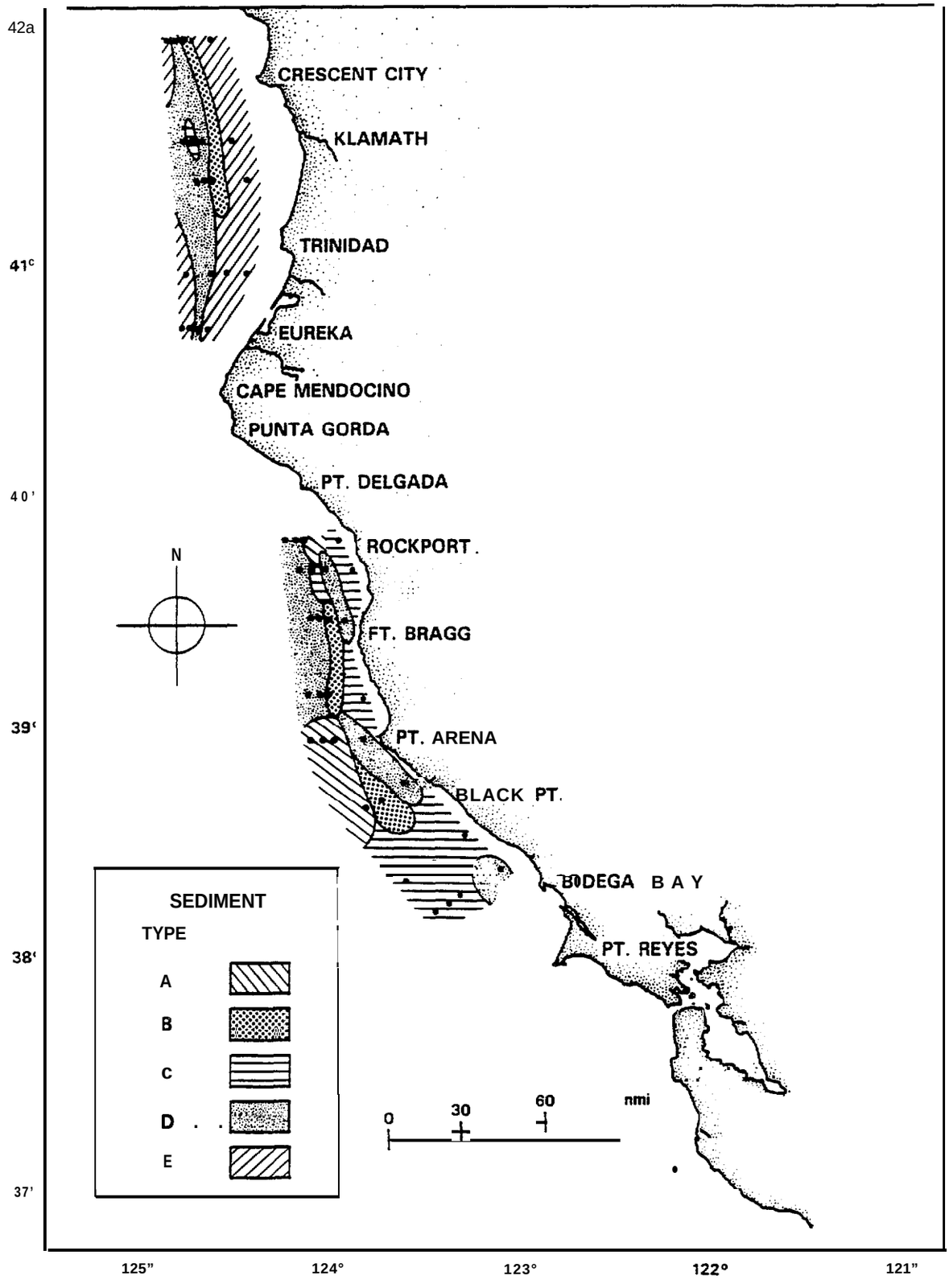


FIGURE 3-26. GEOGRAPHICAL DISTRIBUTION OF THE FIVE SEDIMENTTYPES IN THE CENTRAL AND NORTHERN PLANNING AREAS.

Sediment Organic Carbon

Concentrations of total organic carbon (TOC) in the sediments ranged from nondetectable to approximately 2% dry weight, with most values between 0.4 and 1.2%. The ANOVA did not reveal any significant differences between basins, but did show that there were consistent differences with depth. The highest concentrations occurred in the finer sediments at the 100-m and 600-m stations, and the lowest occurred in the coarser sediments at the 200-m stations and, in the southern part of the study area, at the 400-m and 600-m stations. The patten of TOC in the sediments closely paralleled that of mean phi (Figure 3-22) .

Near-Bottom Water

The plot of isotherms throughout the study area shows that bottom-water temperatures in the Eel River Basin were generally higher than those in the other basins (Figure 3-27). Eel River Basin temperatures averaged 8.65°C, Point Arena Basin temperatures averaged 8.16°C; and temperatures in Bodega Basin averaged 8.59°C. The ANOVA showed that the mean temperature in the Eel River Basin was significantly different ($p < 0.05$) from the mean temperature in the Point Arena Basin. Temperatures decreased markedly with depth in all three basins, averaging 11.0°C at the 100-m stations and 5.8°C at the 600-m stations. The ANOVA showed that those differences were also significant. Since those measurements reflect only one point in time, however, the emphasis of the interpretation should be on the patterns rather than on the actual differences in temperature. These temperature patterns are consistent with those reported by other studies of the shelf area of northern California and southern Oregon (e.g., Huyer, 1977).

Dissolved oxygen concentrations near the bottom (Figure 3-28) ranged from 4 to 6 ml/1 at the 100-m stations to less than 1 ml/1 at many of the 600-m stations. The ANOVA showed that concentrations in the Eel River Basin, which averaged 3.5 ml/1, were significantly higher ($p < 0.05$) than those in the other two basins, where concentrations averaged 2.8 ml/1. These concentrations are typical of

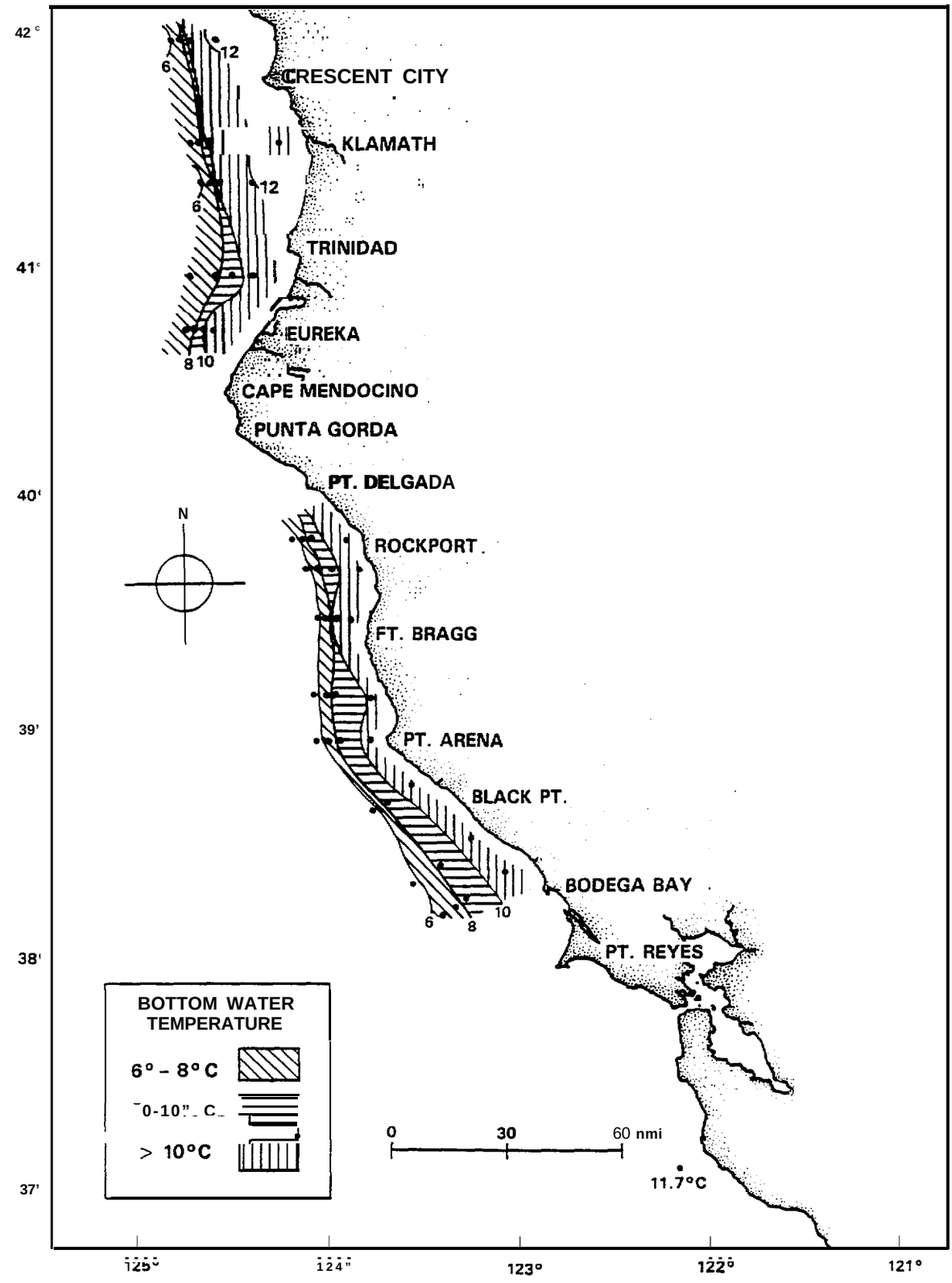


FIGURE 3-27. MAP OF ISOTHERMS OF BOTTOM-WATER TEMPERATURE IN THE CENTRAL AND NORTHERN PLANNING AREAS.

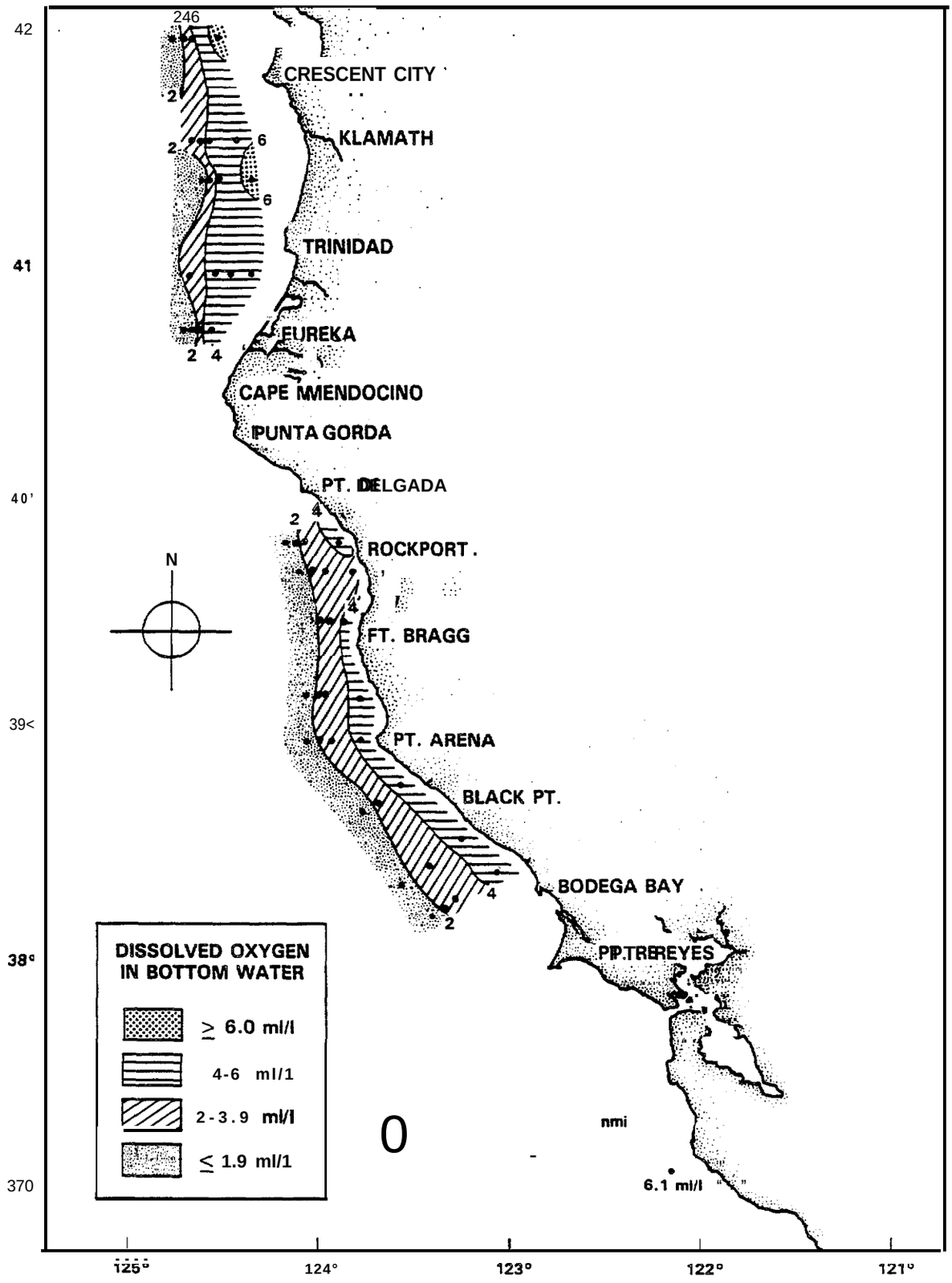


FIGURE 3-28. MAP OF DISSOLVED OXYGEN CONCENTRATION IN BOTTOM WATER IN THE CENTRAL AND NORTHERN PLANNING AREAS. Value for Station 57 (not shown) is 6.1 ml/l.

those reported from the waters off the California coast (e.g., Lynn and Simpson, 1987).

3.2.2 Soft Substrate Community Summary Variables

Several summary measures commonly are used to provide an overview of the abundance, structure, and composition of benthic soft substrate communities. These measures include total abundance; total biomass; community structure measures such as diversity, dominance, and evenness; and abundances by major taxonomic groups within the community as a whole. To allow comparison with other benthic studies, these summary measures were calculated for the present program.

In this study, the patterns of the summary measures by depth, basin, and sediment type were investigated using analysis of variance (ANOVA) and analysis of covariance (ANCOVA). The primary test for each measure was ANOVA of untransformed data to detect the presence of statistically significant (alpha = 0.05) differences by basin and depth. Significant differences were identified by the use of the Tukey-Kramer range test. Finally, all of the summary measures were tested against the environmental variables by multiple regression to determine which variable or combination of variables was most strongly correlated with each summary measure.

Mean total abundance was significantly different among the three basins and among the four depths. Mean abundance ranged from 708 animals per core (0.1 m^2) in the Eel River Basin to 517 per core in the Bodega Basin, and from 1135 animals per core at 100 m to 293 per core at 600 m (Table 3-13). The statistical tests (Table 3-14) showed that abundance was significantly higher in the Eel River Basin than in the Bodega Basin, suggesting that abundance was higher in the northern than in the southern part of the study area. Abundance was significantly higher at 100 m than at the other depths, and it decreased with depth. Abundance was significantly higher in sediment type E (the finest sediments) than in sediment type A (the coarsest; see Section 3.2.1 for discussion of sediment types), but there were no other statistically significant differences in abundance among the sediment types. The multiple

TABLE 3-13. MEAN VALUES OF SUMMARY MEASURES OF THE SOFT SUBSTRATE INFAUNA COMMUNITY.

	BASIN			DEPTH (m)				SEDIMENT TYPE				
Measure	Eel River	Point Arena	Bodega	100	200	400	600	A medium sand	B fine sand	C fine sand/silt	D fine sand/clay	E silt/ clay
Total Abundance[1]	708.0	606.0	517.0	1135.0	599.0	464.0	293.0	404.0	555.0	613.0	584.0	837.0
Biomass[2]	17.11	18.21	18.34	29.89	11.70	13.20	15.70	12.64	11.33	27.19	16.70	17.02
Number of species[1]	69.2	73.1	71.3	97,2	85.5	56.0	43.7	67.2	82.6	72.4	64.7	73.1
Diversity[3]	1.35	1.46	1.47	1.58	1.60	1.26	1.21	1.47	1.56	1.47	1.3	1.41
Dominance[3]	1.05	1.19	1.22	1.31	1.35	0.98	0.92	1.21	1.26	1.21	1.05	1.12
Evenness[3]	0.74	0.79	0.80	0.80	0.83	0.72	0.74	0.81	0.82	0.81	0.74	0.77
Crustacea[1]	104.2	82.3	81.9	116.1	104.1	107.0	39.3	104.0	82.6	80.5	84.9	106.7
Polychaetes[1]	472.0	362.0	249.0	7.8	363.0	231.0	198.0	190.8	364.6	337.7	343.3	586.0
Molluscs[1]	81.6	87.0	96.8	145.6	73.7	90.3	38.2	53.6	58.6	109.9	89.6	82.4
Echinoderms	11.7	39.4	58.9	79.3	26.3	13.3	7.2	27.4	25.8	54.3	37.4	9.9
Miscellaneous	39.7	35.2	30.7	76.0	32.1	24.1	10.3	28.2	23.8	35.6	30.8	52.4

[1] Number per core (0.1 m^2)
[2] g wet weight per core
[3] Value of measure (dimensionless)

TABLE 3-14. RESULTS OF THE ANALYSIS OF VARIANCE (ANOVA), ANALYSIS OF COVARIANCE(ANCOVA), AND TUKEY-KRAMER RANGE TESTS OF SUMMARY MEASURES OF THE SOFT SUBSTRATE INFAUNA COMMUNITY.

Group	Transformation	ANOVA RESULTS Basins	Depth	Interaction	ANCOVA RESULTS Sediment	
Crustacea[1]	log (x+1)	NS	100 400 200 600	NS	E A C B D	p < .01
Echinoderms[1]	UNTR			SIG (BB100 > PA100 > Rest)	C D A B E	p > .10 < .01
Miscellaneous[1]	Rank			SIG (63 groups - large overlap)		NS
Molluscs[1]	log (x+1)			SIG (2 groups with wide overlaps)	C D E B A	< .01
Polychaetes[1]	UNTR			SIG (more abund. at 100-200 m) ER100 PA100 ER200 BB100	E B D C A	< .01
Biomass[2]	Rank			SIG (one group)		NS
Diversity[3]	UNTR	NS	200 100 400 600	NS	B A C E D	< .01
Dominance[3]	UNTR	NS	200 100 400 600	NS	B C A E D	< .01
Evenness[3]	UNTR	NS	200 100 400 600	NS	B A C E D	.03
Total Abundance[1]	UNTR	ER PA PB	100 200 400 600	NS	E C D B A	< .01
Number of Species[1]	UNTR	NS	100 200 400 600	NS	B E C A D	< .01

[1] number per core (0.1 m²)
[2] g wet weight per core
[3] value of measure (dimensionless)

regression indicated a strong correlation (R^2 = 0.685) with depth and the percent of fine (silt) sediments (Table 3-15).

Mean biomass ranged from 18.34 g per core in the Bodega Basin to 17.11 g per core in the Eel River Basin, and from 29.89 g per core at 100 m to 11.70 g per core at the 200-m stations (Table 3-13). High variability in the data obscured trends: the ANOVA of the biomass data (Table 3-14) suggested that there was a significant difference between stations (a significant basin-by-depth interaction prevented separate analyses of basin and depth effects), but the Tukey-Kramer test was unable to identify the difference. There were no statistically significant differences in biomass between sediment types. None of the environmental variables were strongly correlated with biomass (Table 3-15).

The mean number of species per core varied significantly among depths but not among basins. The average number of species per core ranged from 73.1 in the Point Arena Basin samples to 69.2 in the Eel River Basin samples, and from 97.2 at 100 m to 43.7 at 600 m (Table 3-13). The ANOVA showed that the numbers of species along the two shallower isobaths were significantly higher than the numbers along the two deeper isobaths (Table 3-14), a pattern that paralleled the pattern of total abundance. The ANCOVA suggested that there was a significant difference between sediment types, but the Tukey-Kramer test was unable to detect that difference. As in the case of total abundance, the multiple regression showed a strong correlation with depth and the percentage of silt (Table 3-15).

The patterns of dominance, evenness, and diversity (Table 3-13) were very similar to one another and to that of the number of species. Differences between basins were not statistically significant in any case (Table 3-14). All three measures were highest at the 100-m and 200-m stations and lowest at the 400-m and 600-m stations (Table 3-13), a pattern that the ANOVA showed to be significant (Table 3-14). As with the number of species, the ANCOVA suggested a significant difference between sediment types, but the range tests were unable to identify that difference. None of the measures were strongly correlated with the environmental variables (Table 3-15).

TABLE 3-15. RESULTS OF MULTIPLE REGRESS1ON ANALYSES OF SUMMARY MEASURES OF THE SOFT SUBSTRATE INFAUNA COMMUNITY AGAINST ENVIRONMENTAL VARIABLES.

GROUP	MULTIPLE REGRESSION RESULTS R^2(Untransformed Oata)	Variables in Regression	R^2(log(x+1)-Transformed Data)
Crustacea[1]	.396	clay depth mean phi sand silt	.382 depth skew
Echinoderms	.455	depth disp mean phi silt do	
Miscellaneous[1]	.561	temp carbon depth mean phi silt	
Molluscs[1]	.306	depth sand silt	.411 depth sand silt
Polychaetes[1]	.658	temp silt	
Biomass[2]	.171	temp disp skew do	
Diversity[3]	.554	depth disp	
Dominance[3]	.460	depth disp	
Evenness[3]	.272	temp disp	
Total Abundance[1]	.685	depth silt	
Number of Species[1]	.742	clay depth	

[1] number per core (0.1 m^2)
[2] g wet weight per core
[3] value of measure (dimensionless)

Abundances of four of the five major taxonomic groups showed significance depth-by-basin interactions that prevented those factors from being examined independently. The exception was Crustacea, which were nearly three times as abundant at the 100-m, 200-m, and 400-m stations (104 to 116 animals per core; Table 3-13) as at 600-m stations (39 animals per core). The difference between the 600-m stations and the other stations was statistically significant, but the differences between basins were not (Table 3-14). The ANCOVA indicated that there was a significant difference in abundance among sediment types, but the Tukey-Kramer test was unable to identify that difference.

The patterns of abundance of polychaetes (Table 3-13) indicate that they were most abundant at shallow stations and in the two northern basins and were least abundant at deep stations and in the southern basin: they were significantly more abundant at the 100-m stations in the Eel River and Point Arena Basins than at any other station except the Eel River Basin 200-m stations (Table 3-14). Polychaetes were significantly more abundant in fine sediments (e.g., Type E) than in coarse sediments (Type A), but there were no other significant differences among sediment types. The multiple regression confirmed the relationship between polychaete abundance and the proportion of fine-grained sediments (Table 3-15).

Molluscs showed trends of higher abundance in the Bodega Basin and at the 100-m stations (Table 3-13), but the ANOVA failed to identify any significant differences in the patterns of abundance (Table 3-14). Similarly, although abundances appeared to be lower in the coarser sediments (Types A and B; Table 3-13), the Tukey-Kramer test with the ANCOVA failed to identify a difference.

Echinoderms were 10 times as abundant in the 100-m samples as in the 600-m samples, and 5 times as abundant in the Bodega Basin as in the Eel River Basin (Table 3-13). These trends emerged in the ANOVA as significantly higher abundances at the 100-m stations in the Bodega and Point Arena Basins (Table 3-14). There was no obvious trend in abundance with sediment type, although the ANCOVA indicated a significant difference.

The Miscellaneous Taxa, which include a number of minor phyla such as Cnidaria, Echiura, and Bryozoa, were more abundant at the 100-m stations than at deeper ones, and in the finer sediments than in the coarser ones (Table 3-13). The ANOVA identified abundances at the 100-m stations in the Point Arena and Eel River Basins as significantly higher than those at the 400-m and 600-m 130dega Basin stations and the 600-m Point Arena Basin stations, but the ANCOVA did not identify significant differences between sediment types (Table 3-14).

In summary, we detected a consistent pattern of higher abundance at the 100-m and 200-m stations than at the deeper stations, and in the case of total abundance that pattern was statistically significant. The significant basin-by-depth interaction in the other tests of abundance prevented detection of statistically significant differences with depth alone, but the strong, consistent trend in the patterns of abundance indicates that depth had a strong influence on the soft substrate infauna. For all but two of the measures (total biomass and the abundance of Miscellaneous Taxa), the ANCOVA detected significant differences in abundance between sediment types, indicating that the nature of the sediment, as would be expected, influenced the soft substrate communities. The fact that the Tukey-Kramer test rarely located a difference among the sediment types suggests that the influence of sediment type was not strong enough to produce differences as great as those caused by depth. Differences between basins were not detected for any of the measures except total abundance, which suggests that interbasin differences in the variables measured were of secondary importance in the organization of the soft substrate communities in the study area.

3.2.3 Patterns in Soft Substrate Communities, Relationships to Environmental Variables, and Tests of Hypotheses

One of the primary objectives of the CARP program was to describe the patterns of occurrence of soft substrate infauna in areas of the outer continental shelf that have not been extensively studied. The study area includes a wide variety of benthic habitats and environmental factors that affect infaunal composition and abundance. The large geographic area and sampling regime yielded an extensive data base of both biological and environmental variables.

Multivariate analytical techniques allowed quantitative descriptions to be made of the biotic patterns and the relationship of those patterns to environmental variables. In this section, the results of the multivariate pattern analyses of the communities and correlations with environmental variables are discussed first. Next, tests of hypotheses are discussed concerning patterns of infaunal distribution, individual patterns of species abundance, and their relationships to environmental variables (basins, depth, sediment type, and bottom-water variables). Finally, a brief discussion is presented of the photographic records of the soft substrate epifauna collected simultaneously with the infaunal samples.

Community Patterns and Correlations With Environmental Variables

The soft substrate infauna was described on the basis of samples from 51 individual stations distributed among four basins (Eel River, Point Arena, and Bodega, and Santa Cruz). Single samples were collected at 39 of those stations and replicate (two) samples were collected at 12 stations, yielding a total of 63 discrete samples (see also Section 2.4).

Multivariate analyses were conducted on the data to examine infaunal distribution patterns and their relationships to measures of the physical environment. The biological data set consisted of 241 of the 615 taxa identified from the combined I.O-mm and 0.5-mm fractions (see Section 2.4.1), selected on the basis of abundance and frequency of occurrence (see Appendix A, Volume I).

The analytical approach and results are summarized below; a more detailed presentation and discussion of results follows:

- Multivariate ordination analyses were used to describe patterns of community change.
- Clustering techniques were used to delimit groups of biologically similar samples (i.e., stations from the various geographic areas) and groups of species that had similar distribution patterns among the stations.

- o The clustering produced station and species dendrograms that were used to produce a two-way table summarizing patterns of species distributions throughout the study area (see also Appendix A, Volume I).

Cluster Analysis. Results of the pattern analysis (Figures 3-29 and 3-30) showed several distinct features of the distribution of the soft substrate benthic communities:

(1) Groups of stations from different geographic areas supported similar communities; these similarities transcended the boundaries of the basins.

(2) Groups of stations from similar depths supported similar benthic communities. Groups of stations from similar depths also contained different benthic communities, thus reflecting the influence of several environmental factors on the biota.

(3) Groups of species with patterns of abundance characterized specific geographic areas and depths along the central and northern California coast.

(4) One group of taxa was common to all depths and geographic areas sampled. We infer that these organisms tolerate a broad range of environmental conditions based on the variety of habitats in which they were found. Conversely, some groups of taxa were found in very few areas and within a limited range of environmental variables and thus appear to have rather narrow habitat requirements.

(5) Depth appeared to be the primary environmental factor controlling the general biological patterns described above, but other environmental factors, including sediment grain size, were correlated with secondary and more subtle patterns in the data.

The classification analysis of stations produced nine major cluster groups of stations (labeled 1 through 9 on Figure 3-29). The ten most abundant species characteristic of each station group, as well as mean values of various summary measures and measures of the environment, are presented in Table 3-16. Note that these nine station groups, which were defined on the basis of their species composition, were not the same as the five defined in Section 3.2.1.1 on the basis of sediment variables. The primary separation on the dendrogram was depth related, and it separated the shallower stations (shelf, 100 m and upper slope, 200 m; Station Groups 1 through 4 on Figure 3-29) from all deeper

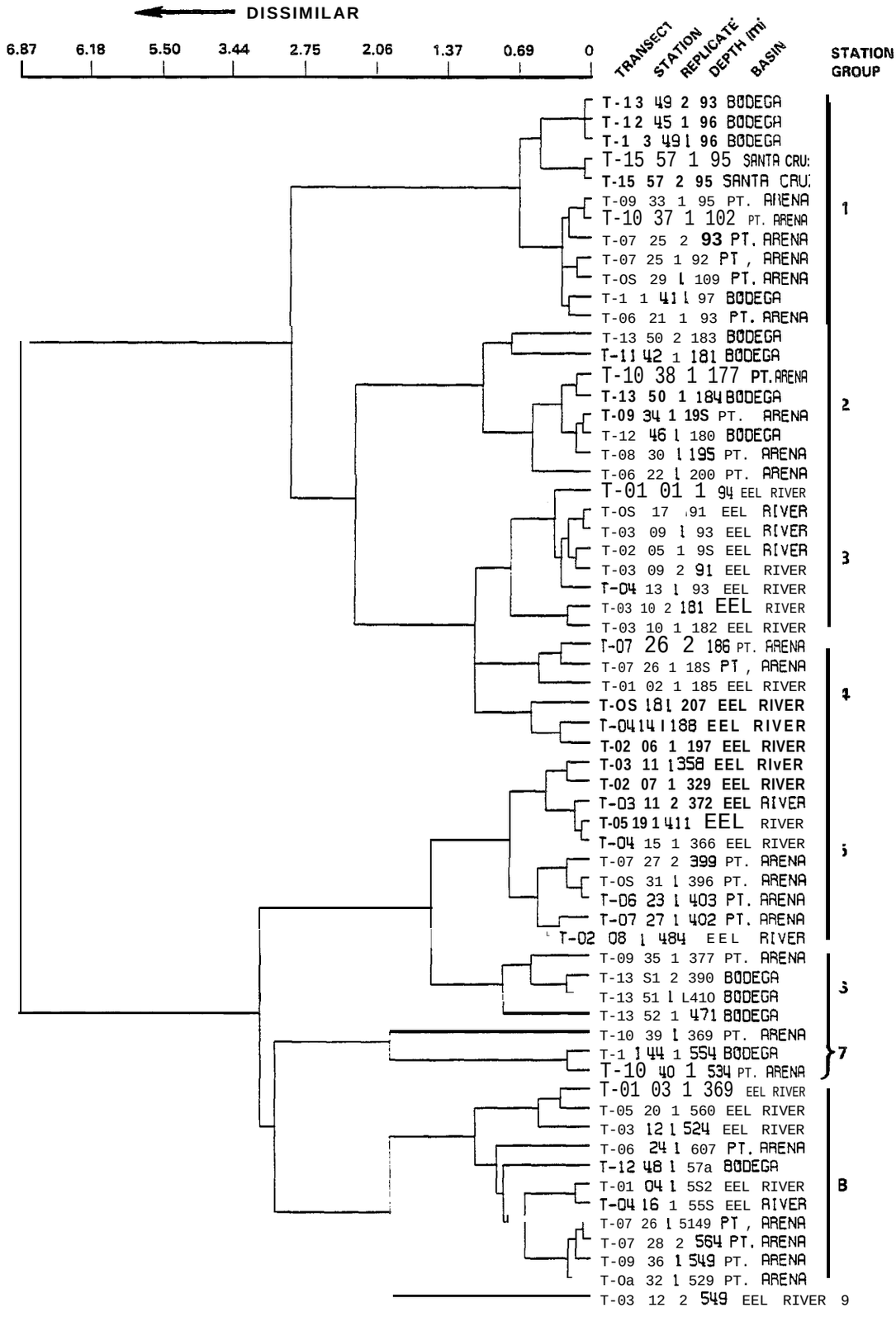


FIGURE 3-29. STATION DENDROGRAM FROM THE CLUSTER ANALYSIS OF CARP SOFT SUBSTRATE SAMPLES. Arabic numerals (1-9) down the right side indicate station groups. Sample label data indicate (from left to right) transect number, station number, replicate number, depth (m), and basin location, respectively. For example, sample T-13 49293 Bodega was collected on T~.wet 13, at Station 49, Replicate 2, 93 m, in the Bodega Basin.

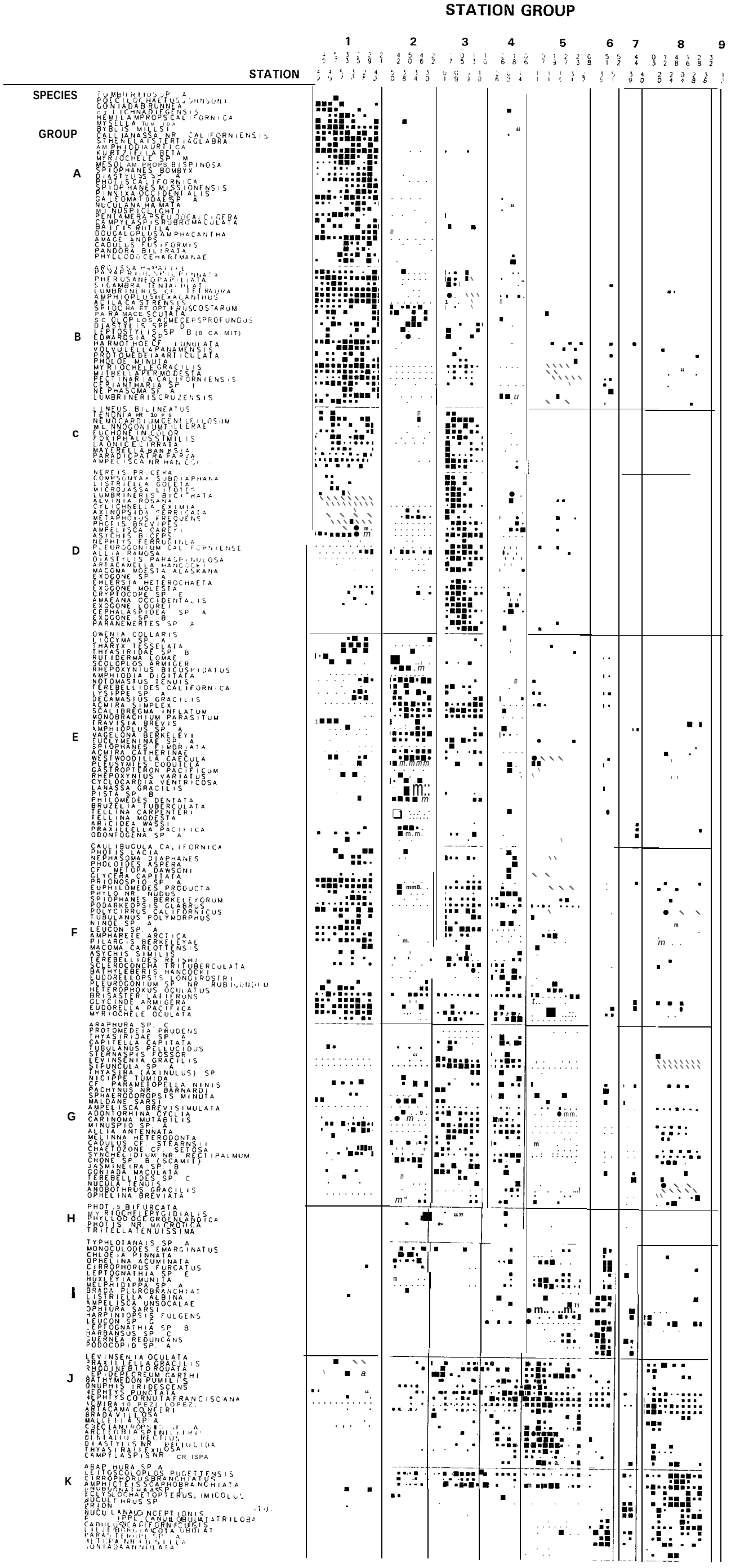


FIGURE 3-30. TWO-WAY COINCIDENCE TABLE FROM THE CLUSTER ANALYSIS OF CARP SOFT SUBSTRATE SAMPLES. Stations are listed across the top of the table; the order from left to right corresponds to the order from top to bottom on the station dendrogram, Figure 3-29. Taxa are listed down the left side of the table. Station groups are identified by numerals at the bottom (these correspond to Station Groups 1-9 shown in Figure 3-29; taxon groups are identified by letters down the left side of the table. Higher levels of relative abundance are denoted by larger square symbols.

TABLE 3-16. COMMUNITY SUMMARY VARIABLES, PHYSICAL AND CHEMICAL VARIABLES, AND TEN MOST ABUNDANT INFAUNA SPECIES IN EACH CLUSTER GROUP.

Abundances (i parentheses) is expressed as number per core (O. 1 m^2).

SUMMARY VARIABLES	CLUSTER GROUPS								
	Group I	Gmop 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Biomass	36.85	17.13	14.11	7.30	18.03	12.55	12.10	15.49	0.67
Diversity (H')	1.60	1.65	1.54	1.51	1.35	1.12	1.35	1.16	0.98
Dominance (D)	1.34	1.42	1.25	1.24	1.11	0.17	1.04	0.87	0.82
Evenness (J')	0.80	0.86	0.79	0.81	0.78	0.66	0.78	0.72	0.81
Total Abundance	1114.92	509.75	1065.38	601.83	452.20	383.25	326.(XI	308.91	96.00
Depth (m)	96.33	186.88	115.00	191.33	392.00	412.00	485.67	541.45	549.00
Dissolved Oxygen	4.47	3.81	5.33	3.90	2.67	1.91	1.28	1.34	1.60
Mean Sediment Phi Sire	5.17	3.47	6.09	5.71	5.15	4.16	2.81	5.95	5.16
Temperature	10.98	9.28	11.27	9.54	7.15	6.64	5.65	5.%	5.92
'40. Species	99.33	84.25	90.00	76.50	55.70	49.25	54.33	41.73	16.00
	Amphiodia urtica (589)	Decamastus gracilis (223)	Levinsenia gracilis (700)	Spiophanes berkeleyorum (212)	Nephtys comma franciscana (615)	Huxleyia munita (291)	Anobothrus sp. A (115)	Nephtys comuta franciscana (589)	Levinsenia gracilis (17)
	Levinsenia gracilis (576)	Mitrella permodesta (109)	Spiophanes berkeleyorum (507)	Nephtys comuta franciscana (183)	Huxleyia munita (597)	Chloeia pinnata (161)	Harbansus sp. C (28)	Levinsenia gracilis (297)	Capitella capitata (13)
	Pholoe minuta (481)	Myriochele gracilis (102)	Ehlersia heterochaeta (292)	Levinsenia graciliis (130)	Levinsenia gracilis (280)	Nephtys comuta franciscana (130)	Eclysippe (anobothrus) trilobatus (14)	Cirophorus branchiatus (86)	Nephtys comma franciscana (10)
	Spiophanes berkeleyorum (407)	Spiophanes fimbriata (86)	AUia ramosa (246)	Chaetozone cf. setosa (92)	Chaetozone Cf. setosa (219)	Guernea reduncans (49)	Chaetozone cf. setosa (12)	Araphura sp. A (82)	Ampharete arctica (3)
	Myriochele gracilis (392)	Alvinia msana (82)	Exogone lourei (246)	Spiophanes fimbriata (67)	Heterophoxus oculatus (49)	Harbansus sp. C (44)	Araphura 'p. A (8)	Stemaspis fossor (71)	Onuphis iridescens (3)
	Lumbrineris cf. tetraura (266)	Amphioplus (64) 'p" ^	Decamastus gracilis (179)	Stemaspis fossor (46)	Onuphis iridescens (46)	Chaetozone cf. setosa (27)	Cadulus cf. steamsii (8)	Acmirapezi lopezi(3B)	Axinulus sp. A (2)
	Pinnixa occidentalis (170)	Huxleyia munita (46)	Paradopatra parva (143)	Decamastus gracilis (44)	Harpinopsis fulgens (42)	Heterophoxus oculatus (25)	Chloeia pinnata (7)	Axinulus sp. A (55)	Chaetozone cf. setosa (2)
	Mysella tumida (166)	Pholoe minuta (58)	Pholoe minuta (89)	Heterophoxus oculatus (22)	Rhodine bitorquata (40)	Typhlotanais sp. A (15)	Ehlersia heterochaeta (6)	Chaetozone cf. setosa (55)	Glycinde armigera (2)
	Sigambra tentaculata (150)	Amphiodia digitata(45)	Acmira simplex (86)	Ampelisca careyi (20)	Carinoma mutabilis (31)	Onuphis iridescens (11)	Phyllochaet opterus limicolus (6)	Prionospio cf. lobulata (39)	Huxleyia munita (2)
	Nephtys comuta franciscana (129)	Levinsenia gracilis (28)	Scalibregma inflatum (83)	Eudorella pacifica (17)	Ampelisca unsocalae (28)	Carinoma mutabilis (7)	Maldane sarsi (5)	Onuphis iridescens (32)	Metopa nr. pusilla (2)

stations (mid-slope, 400 m and deep slope, 600 m; Station Groups 5-9 on Figure 3-29). Note that all depths discussed in this section are nominal depths (e.g., -100 m). The secondary separations that defined the individual groups (e.g., Station Groups 1 through 4) did not correspond strictly to station depth. For instance, Station Group 3 included stations from both 100 m and 200 m. Since these station groups reflect community similarities, the biota probably were responding to similar environmental factors in addition to depth. These observations indicate that depth and, to a lesser extent, other environmental factors influenced the community composition in similar ways in all basins.

There was some indication that communities differed between basins; for example, all of Station Group 3 and most of Station Group 4 consisted of Eel River Basin stations. However, most of the other station groups contained stations from more than one basin. This indicates, first, that the shallow to mid-slope communities of the Eel River Basin were comparatively distinct, whereas the deeper-slope community shared similarities with those in other basins (Station Group 8); and second, that communities were similar among other basins.

The cluster analysis of stations did not suggest any consistent north-to-south pattern in the communities. This was particularly true among the deeper station groups (5 through 9), each of which contained stations from more than one basin. However, there was some indication of a north-to-south pattern in the communities at the shallower depths (Station Groups 1 through 4). For example, Station Groups 1 and 2 included stations from the more southerly areas (Bodega and Santa Cruz Basins), whereas Station Groups 3 and 4 contained only stations from the more northerly areas (Point Arena and Eel River Basins).

Station Group 9 was composed of one sample from Station 12 (depth 549 m; replicate 2) in the Eel River Basin. This somewhat anomalous sample was separated from the other replicate at this station as well as from all other stations. Examination of photographs and cruise records indicated nothing unusual about the sample collection or handling. However, the data showed this station to be particularly depauperate in species and individuals.

The station dendrogram clearly showed the greater degree of similarity among stations from the same depth, regardless of basin, than among stations from different depths in the same basin, and also suggested that other environmental variables besides depth influenced the community, although to a lesser degree. The relationships between the communities at each station, the community patterns, and environmental variables were examined in greater detail through ordination analyses and multiple regression, as discussed in the following sections.

Note that the differences among stations discussed above reflect differences in the species composition of the communities and in patterns of abundance. The species dendrogram provided the basis for describing the differences among stations, since the presence (or absence) of particular species, as well as their relative abundances, constitute the biological definition of a station. The cluster analysis of species resulted in 11 species groups, labeled A through K on Figure 3-30. Each species group contained many taxa, which are discussed as a group. A few of the taxa from each group are cited as examples to illustrate the group characteristics. Many of the taxa cited individually were also selected for ANOVA hypothesis testing. The results of the hypothesis testing provided further support (i.e., through probability levels) for the patterns described by the station and species groups.

Species Group A was found almost exclusively at the shelf-depth (100 m) stations. These taxa were particularly characteristic of Station Group 1, which included shallow-water stations from the Santa Cruz, Bodega, and Point Arena Basins. Representative species from this group included the echinoderms Dougaloplus amphacantha and Amphiodia urtica; the crustaceans Callianassa nr. californiensis, Pinnixa occidentals, and Campylaspis rubromaculata; and the polychaetes Poecilochaetus johnsoni and Goniada brunnea.

Group B taxa showed a similar pattern of high abundance at the shelf-depth stations of Station Group 1, but most were also abundant at stations in Station Groups 2 and 3, representing the upper-slope depths (200 m). In addition, some of the species were found in low abundances at 400-m and 600-m stations. Species from this group occurred at stations from all basins. Polychaetes

accounted for over 50% of the taxa in this group, and included Paraprionospio pinnata, Lumbrineris cf. tetraura, Pholoe minuta, and Pectinaria californiensis.

Species Group C also characterized Station Groups 1, 2, and 3, Taxa from this group primarily were confined to the shelf and upper-slope depths (100 and 200 m). They were consistently very abundant at stations from the Eel River Basin. Species typical of this group included the polychaetes Tenonia priops, Paradiopatra parva, and Nephtys ferruginea; the crustacea Ampelisca careyi, Pleurogonium californiense, and Metaphoxus frequens; and the molluscs Nemocardium centifilosum and Alvinia rosana.

Species Group D was somewhat unique among the species groups because it was characteristic of both a specific depth range and a geographic location. These taxa were very abundant at the Eel River Basin stations from the shelf and upper-slope depths (100 and 200 m), and some occurred in relatively low abundance at similar depths in other basins. The taxa in this group were primarily polychaetes, including Exogone molests, E. lourei, and two new species of Exogone. In addition, the molluscs Macoma moesta alaskana and Cryptocope sp. E were also represented in this group.

Representatives of Species Group E occurred in all station groups except Station Group 9, but were particularly characteristic of Station Group 2, where they were present in high and very high relative abundances. Station Group 2 was composed primarily of upper-slope stations (200 m) from the Point Arena and Bodega basins. Group E taxa occurred only sporadically and usually at low abundances at other stations and depths. Species that illustrate the pattern of occurrence of Species Group E include the polychaetes Terebellides californica, Decamastus gracilis, Acmira simplex, and A. catherinae; the echinoderms Amphiodia digitata and Amphioplus sp. A; and the molluscs Tellina carpenter and I. modesta.

Representatives of Species Group F ranged throughout the entire study area, but were rarely found at the deep (600 m) stations. These taxa tended to be somewhat more abundant at stations from Station Group 1, but there were no

other well-defined patterns. Among the species from this group were the polychaetes Glycera capitata, Prionospio sp. A, Glycinde armigera, and Ampharete arctica; the crustaceans Heterophoxus oculatus, Eudorella pacifica, and Eudorellopsis longirostris; and the echinoderm Brisaster latifrons.

Taxa forming Species Group G were ubiquitous, with representatives at all depths and in all basins. The abundances of these taxa varied considerably from station to station. Generally, fewer of the taxa from Species Group G occurred at the mid-slope and deep-slope (400 and 600 m) stations than elsewhere, and those that did tended to be relatively less abundant there than elsewhere. The widespread distribution of these taxa suggests that they are more tolerant of the range of environmental conditions encountered in the study area than are most species in the other groups. Group G included the polychaetes Chaetozone cf. setosa, Sternaspis fossor, Levinsenia gracilis, and Maldane sarsi; the crustaceans Nicippe tumida and Ampelisca brevisimulata; the molluscs Nucula tenuis and Adontorhina sp. A; and the nemertean Carinoma mutabilis.

Species Group H represented a distinct assemblage of five species that occurred almost exclusively at Station 39, where they were very abundant, from the mid-slope area of the Point Arena Basin (369 m depth). Two of the species were polychaetes (Myriochele pygidialis and Phyllodoce groenlandica), and the other three were crustaceans (Photis bifurcata, Photis nr. macrotica, and Tritella tenuissima).

Species Group I primarily characterized the mid-slope (400 m) stations from Station Groups 5 and 6, although they also occurred infrequently and at moderate abundances at other stations, Crustaceans, including Monoculodes emarginatus, Leptognathia sp. E, Harpiniopsis fulgens, and Harbansus sp. C, accounted for 67% of the species in this group. Characteristic polychaetes included Chloeia pinnata and Brada pluribranchiata.

Although some representatives of Species Group J were found in low abundances throughout the study area, taxa from this group were more characteristic of the upper-slope (200 m) stations of Station Group 4. It is noteworthy that taxa

from Species Group J were absent or rare at other stations at the same depth (e. g., Station Group 2), which suggests that environmental features found at 200 m in the Eel River Basin provided a favorable habit for these species. This possibility is examined in greater detail in the ordination and multiple regression sections presented below. Representative taxa of Species Group J included the polychaetes Onuphis iridescent, Nephtys punctata, and Nephtys cornuta franciscana; the crustaceans Caecianiropsis sp. A and Bathymedon pumilis; and the molluscs Dentalium rectius and Malletia sp. A.

Finally, Species Group K characterized the deep-slope stations (600 m) of Station Group 8. Deep stations from all basins were represented in Station Group 8, so that the taxa in Species Group K did not appear to reflect any interbasin differences. Taxa representative of this group included the polychaetes Cirrophorus branchiatus and Phyllochaetopterus limicolus; the molluscs Axinulus sp. A and Nuculana conceptions; and the crustaceans Leptognathia sp. C and Liljeborgia sp. A.

The overall findings suggested that a closer examination of the secondary biological patterns was necessary in order to address the relationships between those patterns and measured environmental variables. To accomplish this, ordination techniques were used to examine the patterns in the biological and environmental data. Multiple regression techniques were applied to provide correlations between the biological patterns and the environmental variables.

Ordination Analyses. This section emphasizes the results of the sample ordination. Species whose patterns of abundance follow the gradients described by the ordination axes are presented in the later discussion of Species Associated with Ordination Axes.

In this discussion, the term "station," rather than "sample," is used since the samples collected for this program represent distinct geographic areas, and the focus of the study is on spatial patterns. It is important to note, however, that the ordination analyses define station dissimilarity on the basis of the taxonomic composition and abundance of animals in samples collected from those stations.

The station ordination analyses defined four axes (designated 1 through 4) which accounted for 62%, 17%, 14%, and 7%, respectively, of the variance in the biological data. Station scores were plotted in the ordination space defined by Axes 1 and 2. Ordination plots for Axes 3 and 4 were not considered because almost all of the biological information of interest was contained in Axes 1 and 2 and because Axes 3 and 4 showed little correlation with measured environmental variables or geographic location.

The introduction to Section 3.2 outlined the original objectives for this project. One question related to basin differences can be rephrased as: Do the ordination results separate stations by basin? The ordination results displayed in Figure 3-31 did not clearly separate all stations by basin, as indicated by the considerable overlap of station groups when lines were drawn around the sample plots from a particular basin. However, some separation of basins along Axis 2 was suggested by the Eel River Basin stations, particularly those at depths greater than 100 m. This point is addressed further by the ANOVA of selected species.

Figure 3-32 presents the same ordination plot, but with the station groups defined by the cluster analysis delineated. This presentation shows that the station groups were well separated along Axis 1 and were not as well separated along Axis 2. Given that the ordination axes reflect biological dissimilarity, the closer the station groups are in the ordination space, the more biologically similar they are. Conversely, station groups separated by greater distances along an axis are biologically more dissimilar. From this, it is apparent that the nine station groups can be distinguished from one another based on species composition and abundance. Further, Station Group 1 and Station Groups 8 and 9 appear to represent the extremes of station differences along Axis 1, and reflect different soft substrate biological communities.

Multiple Regression Analysis

In nature, community patterns often reflect underlying environmental gradients (Smith et al., 1988). Accordingly, the patterns described above may reflect environmental factors responsible for the observed community differences.

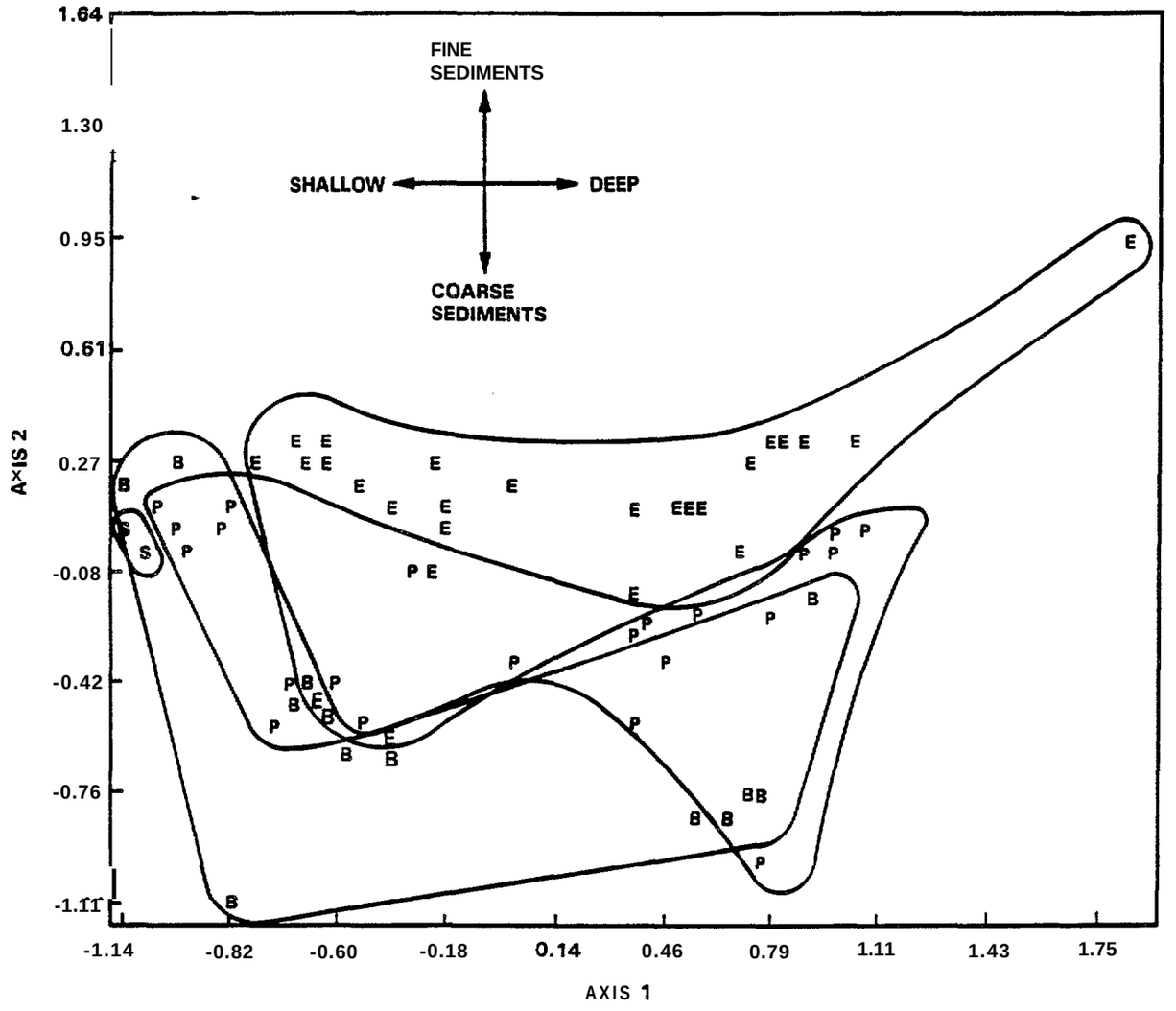


FIGURE 3-31. PLOT OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2. Lines enclose the stations in each of the four basins: E = Eel River; P = Pt. Arena; B = Bodega; and S = Santa Cruz.

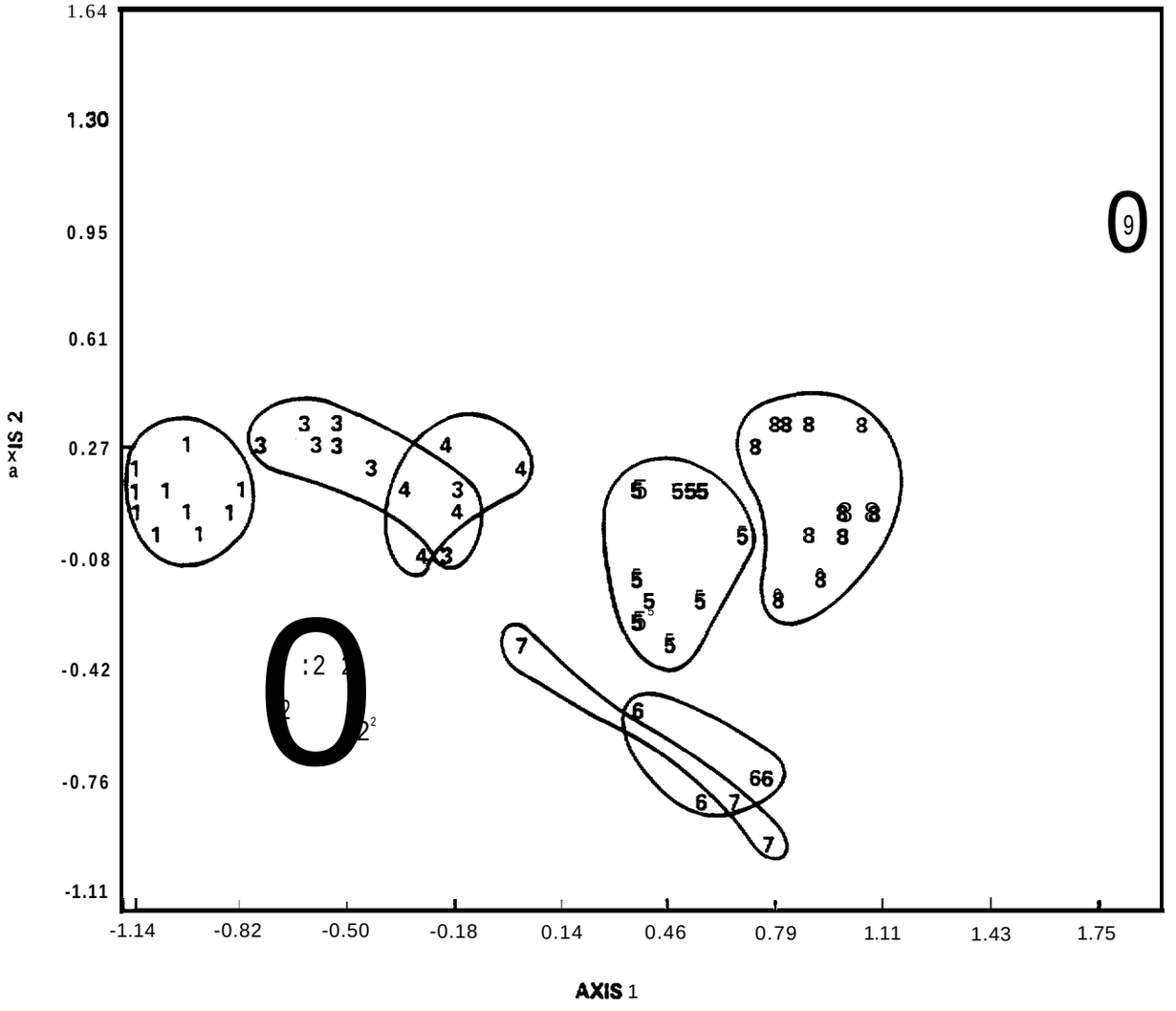


FIGURE 3-32. PLOT OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2. Station groups defined by the cluster analysis are enclosed by lines and identified by numerals (these correspond to Station Groups 1-9 shown in Figure 3-29).

Multiple regression was used to examine which, if any, of the measured environmental variables were correlated with the observed community patterns. These analyses considered the ordination axis scores as the dependent variable and the various environmental features as the independent variables(s) in the regression analyses. Analyses considered each ordination axis separately and identified the abiotic variables most highly correlated with that axis.

A single-factor multiple regression of Axis 1 on the independent environmental variables (Table 3-17) revealed that depth was most highly correlated with Axis 1 scores, (R^2 = 0.89). Multiple regression models that included 2, 3, 4, 5, and 6 variables did not appreciably increase the correlation of environmental variables with Axis 1 scores. The depth pattern along Axis 1 was clearly illustrated by substituting scaled depth values of each station for the station designations on the ordination plots (Figure 3-33). Thus, scaled values of 1 correspond approximately to the 100-m stations, and values of 8 and 9 correspond approximately to 600-m stations. Note that the shallowest (100 m) stations comprising Station Group 1 lie at one extreme of Axis 1 while the deepest stations (600 m) comprising Station Groups 8 and 9 lie at the other extreme. Dissolved oxygen and bottom-water temperature also were highly correlated with depth, and therefore with Axis 1 scores (R^2 = 0.63 and 0.81, respectively), suggesting that the influence of those factors also is expressed on Axis 1.

The data from the MMS Phase I reconnaissance study of the Santa Maria Basin suggested that low concentrations of dissolved oxygen in deeper water may be an important determinant of the structure of the benthic infaunal slope communities (e.g., Smith et al., 1988). The major community gradient, as expressed by the first ordination axis, appeared to be correlated more closely with (somewhat incomplete) oxygen data than with depth. In the present study, the trends of dissolved oxygen and depth coincided so that it was not possible to distinguish between the effects of depth and oxygen on the benthic communities. Nevertheless, the trend of fewer species at greater depths in both studies suggest that oxygen may be an important factor, since other studies (e.g., discussed in Sanders, 1968) have suggested that the number of species would actually increase with depth.

TABLE 3-17. MULTIPLE REGRESSION RESULTS FOR AXIS 1 USING THE SINGLE-VARIABLE MODEL .

Variable	R- Square
Kurtosis	***0.01078837***
Silt	0.01093035
Sorting	***0.01713112***
Clay	***0.02352443***
Dissolved Oxygen	***0.63050274***
Temperature	***0.81466192***
Depth	0.89300284

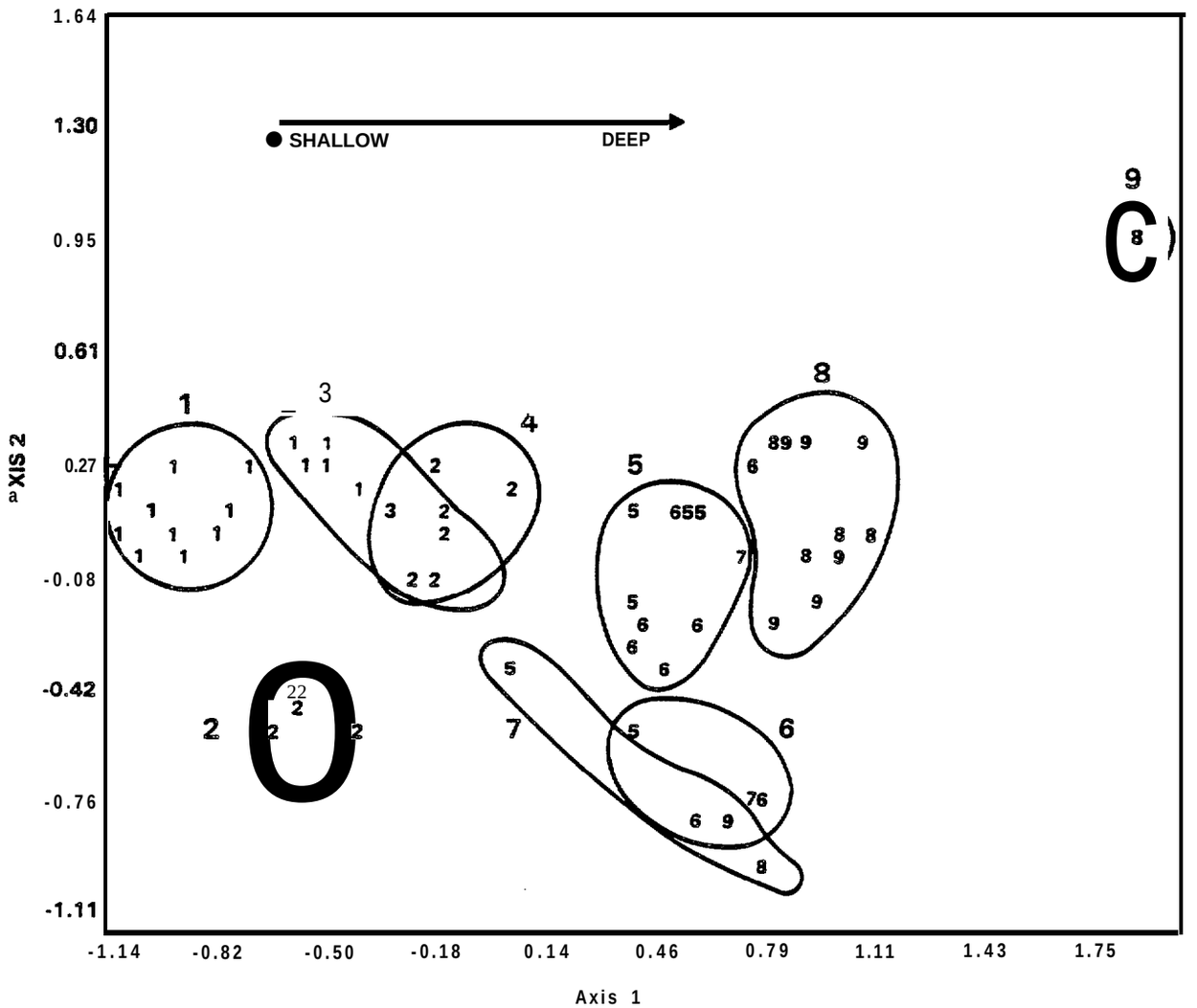


FIGURE 3-33. PLOT OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2, WITH RELATIVE DEPTH SUBSTITUTED FOR THE STATION DESIGNATIONS. Relative depth of stations enclosed by solid lines: 1 = shallower, 9 = deeper. The station groups defined by the cluster analysis are enclosed by lines and identified by numerals (these correspond to Groups 1-9 shown in Figure 3-29).

A three-variable multiple regression model that included sediment mean phi, skewness, and percent clay provided the best correlations with Axis 2 scores (Table 3-18); other multiple-variable models provided little improvement in the correlation and thus limited additional insight into the factors correlated with Axis 2. The pattern of sediment type along Axis 2 was illustrated by substituting scaled values of variables representing mean phi for the station designation on the ordination plot (Figure 3-34). The plot showed that stations with positive ordination scores on Axis 2 (e.g. , Station Groups 1 and 3) had sediment distributions characterized by finer sediments with high percentages of silt and clay, Stations with negative scores (e.g., Station Groups 2 and 6) supported coarser sediments (e.g., fine sands).

To put the biological patterns defined by multivariate analysis into a geographical perspective, the axis scores for each station were plotted onto maps of the central and northern California coastline. Isopleths of scores were then constructed on the figures. This technique provided a less abstract portrayal than the plots in ordination space presented earlier (Figures 3-31 through 3-34).

The plot of Axis 1 scores (Figure 3-35) showed that the isopleths paralleled the coast, corresponding, as expected, to the depth contours. This representation confirmed that depth was the primary environmental factor associated with station (i.e. , community) differences along Axis 1. A similar plot (Figure 3-36) of station scores on Axis 2, with the areas between the isopleths shaded to highlight the patterns of stations with similar scores, attempts to elucidate the environmental features responsible for the secondary biological patterns after the influence of depth has been accounted for. The multiple-regression analyses showed that mean-phi size, percent clay, and skewness variables were highly correlated with Axis 2. The pattern of sediment mean-phi isopleths (Figure 3-22) was very similar to that of the Axis 2 ordination scores (Figure 3-36). Plots of the percent clay and skewness variables also displayed almost identical patterns. The close agreement of the soft substrate community distribution patterns with the patterns of the sediment strongly suggests that many of the infaunal species were responding in

TABLE 3-18. MULTIPLE REGRESSION RESULTS FOR AXIS 2 USING THE THREE -VARIABLE MODEL .

Variables	R-Square
Skewness Clay Silt	0.69709535
Skewness Clay Kurtosis	0.69748620
Skewness Silt Sand	0.69848922
Skewness Clay Temperature	0.70301389
Skewness Clay Dissolved Oxygen	0.70661785
Skewness Clay Sorting	0.71269510
Skewness Clay Mean Phi	0.72397700

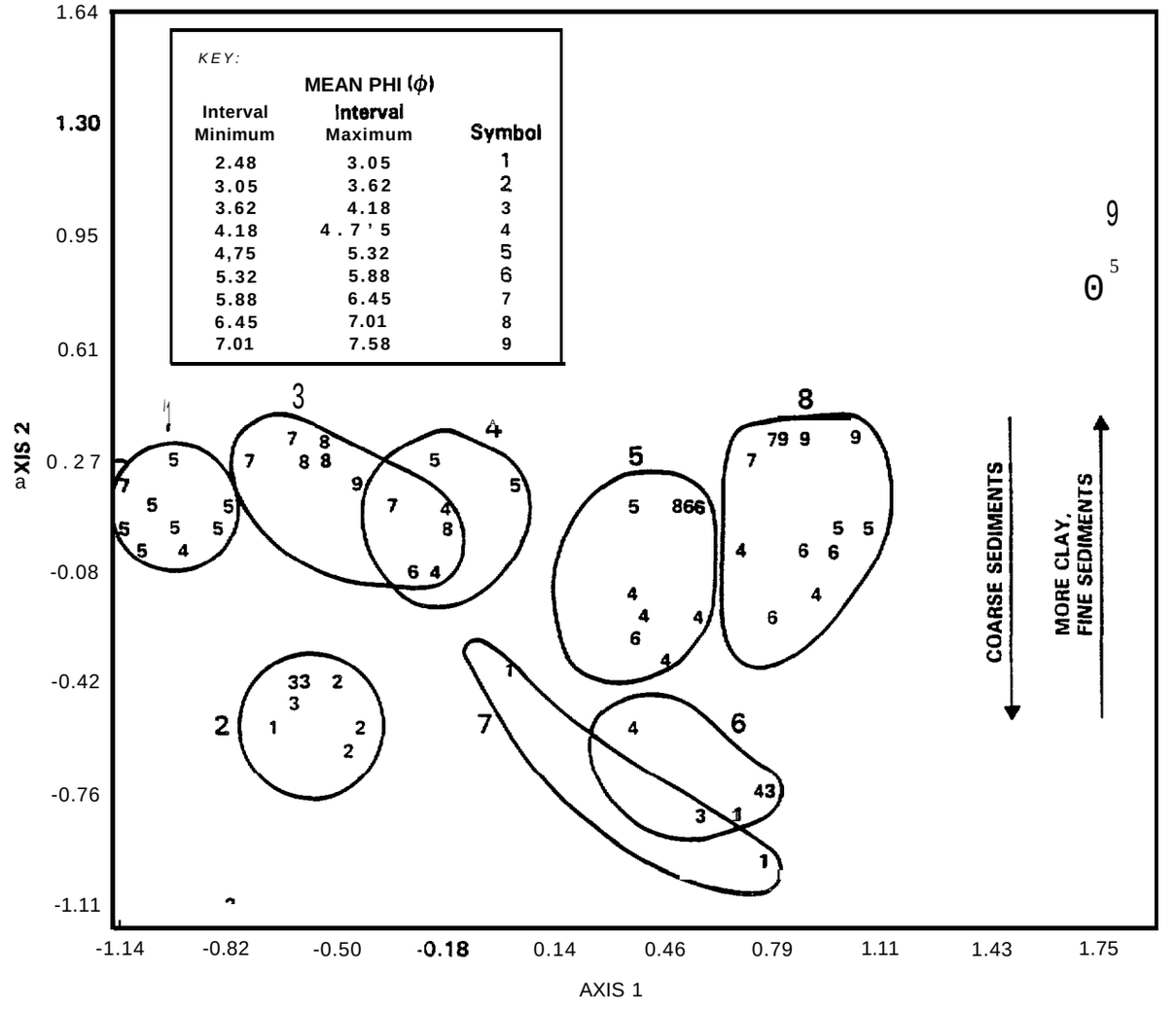


FIGURE 3-34. PLOT OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2, WITH RELATIVE DIRECTIONS OF INCREASE IN MEAN GRAIN SIZE AND QUANTITY OF CLAY. The station groups defined by the cluster analysis are enclosed by lines and identified by numerals (these correspond to Groups 1-9 shown in Figure 3-29).

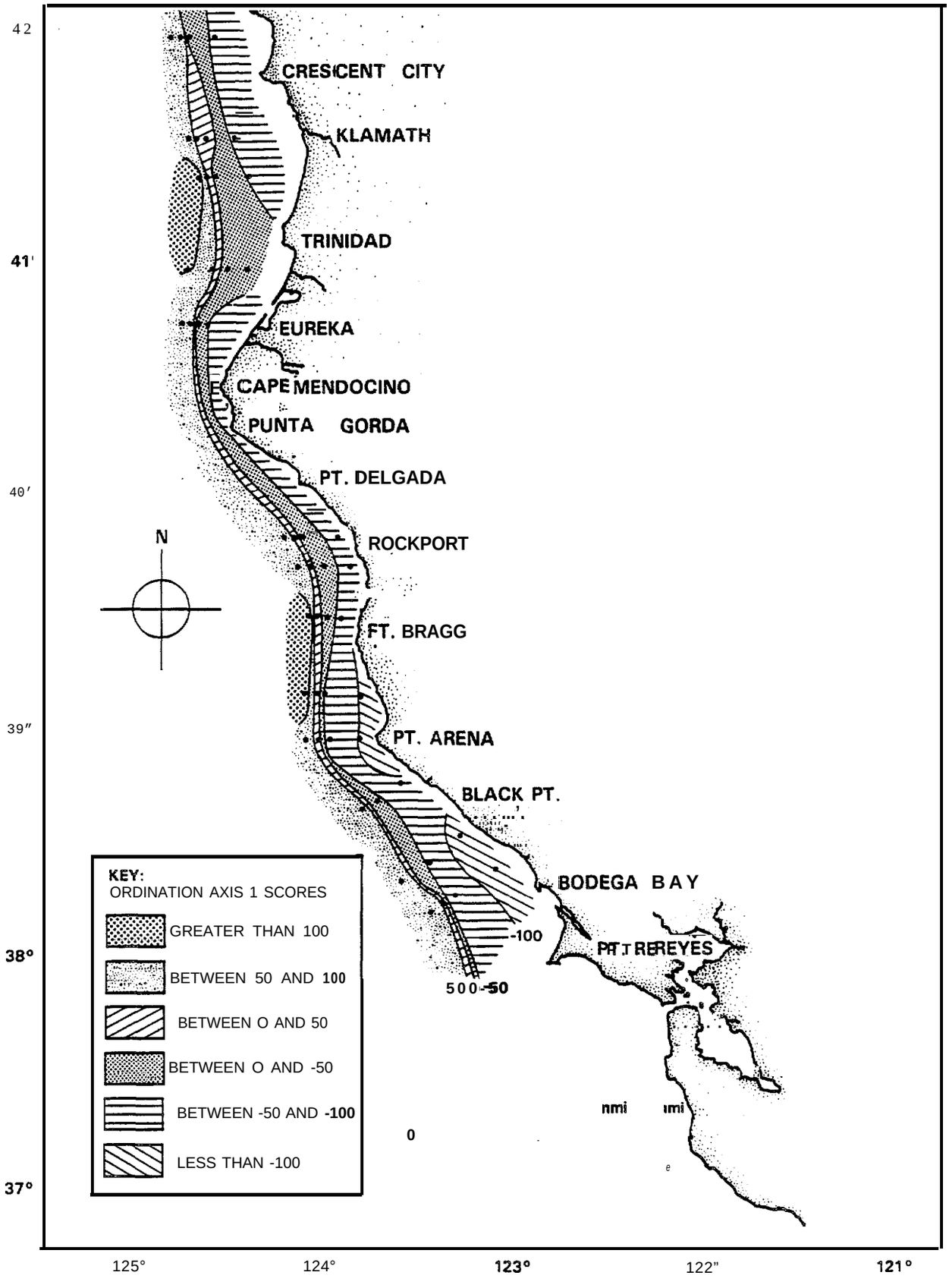


FIGURE 3-35. MAP OF CARP ORDINATION AXIS 1 SCORES (X 100). Ordination score isopleths correspond to isobaths of 100,200,400, and 600 m.

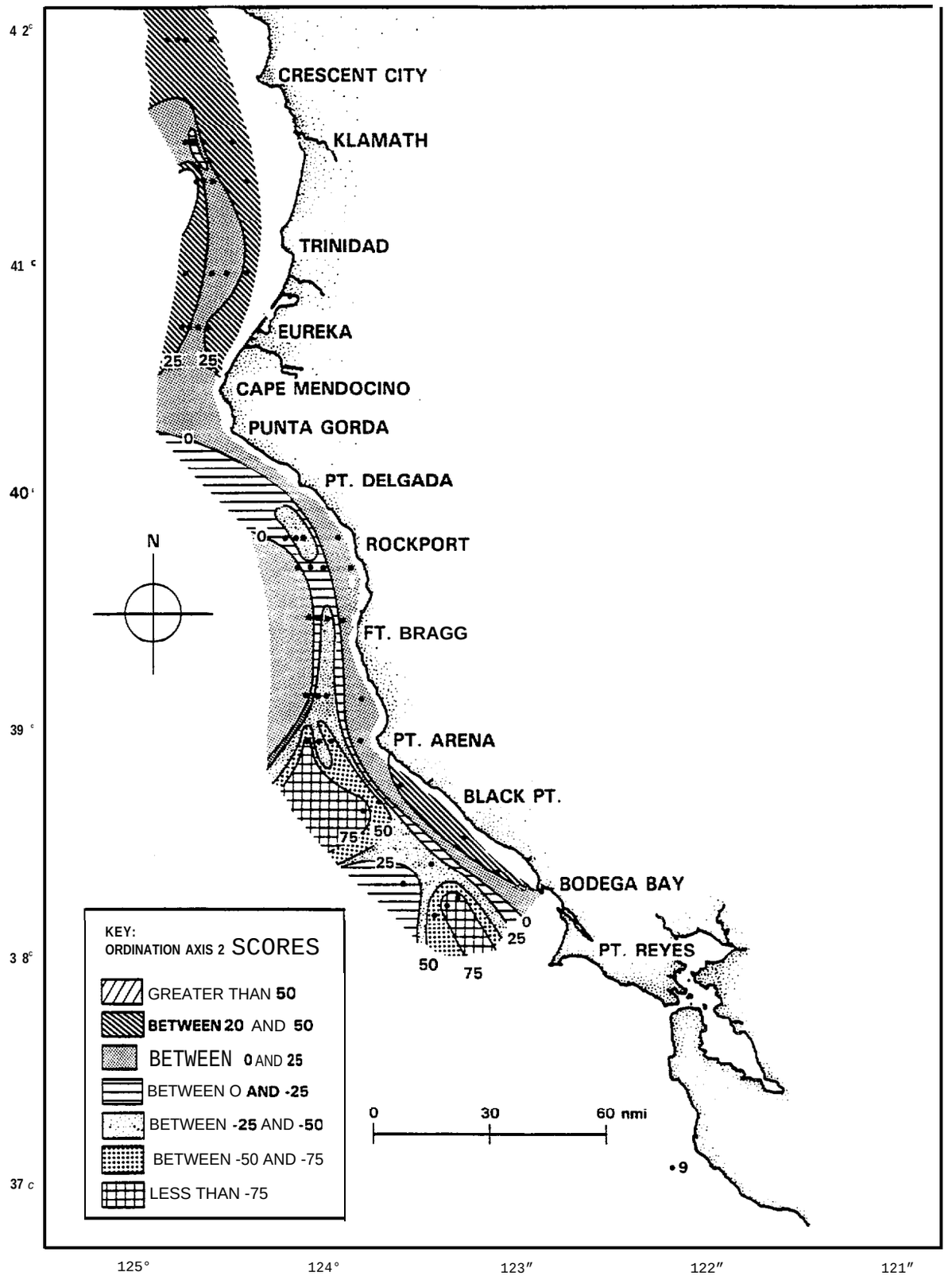


FIGURE 3-36. MAP OF CARP ORDINATION AXIS 2 SCORES (X 100). The soil substrate communities are similar within shaded areas enclosed by isopleths of ordination axis scores.

part to these environmental variables. This response may reflect food and/or habitat requirements provided by the substrate.

Species Associated with Ordination Axes

The first two axes of the multivariate ordination of the soft substrate infauna data expressed 79% of the variability in the data. Tests relating environmental variables to the axes indicated that Axis 1 was strongly associated with depth (Section 3.2.1), the negative scores representing shallow-water stations and the positive scores representing deeper-water stations. Axis 2 appeared to be related primarily to a gradient of sediment size.

The patterns of occurrence of many of the soft substrate species closely followed the gradients defined by the ordination scores. Species gradient tables for Axes 1 and 2 are presented in Figures 3-37 and 3-38, respectively. The index code on the figures is a measure of the correspondence of a given species to the community and environmental gradients defined by the ordination axis, with a value of 100 signifying the closest correspondence. Successive, evenly-spaced positions along the ordination axis are represented by the columns of the table, and the rows represent the species, which are ordered according to the average positions along the ordination axis. The symbols in the table indicate the estimated relative abundances of the species at the respective positions along the axis. The information in these tables shows where the species tend to occur along the defined gradients. For example, the mollusc Cylichna diegensis was found only at the negative end of Axis 1. Since this axis was positively correlated with depth, this species tended to be confined to shallower depths. On the other extreme, the polychaete Prionospio cf. lobulata was found only at the positive end of Axis 1 representing deeper depths .

Tests of Hypotheses Related to Community Differences

Comparisons of Basins and Depth. The ordination analysis revealed differences between communities found at various depths, and suggested that there were some differences among the basins. Four hypotheses related to patterns in the study

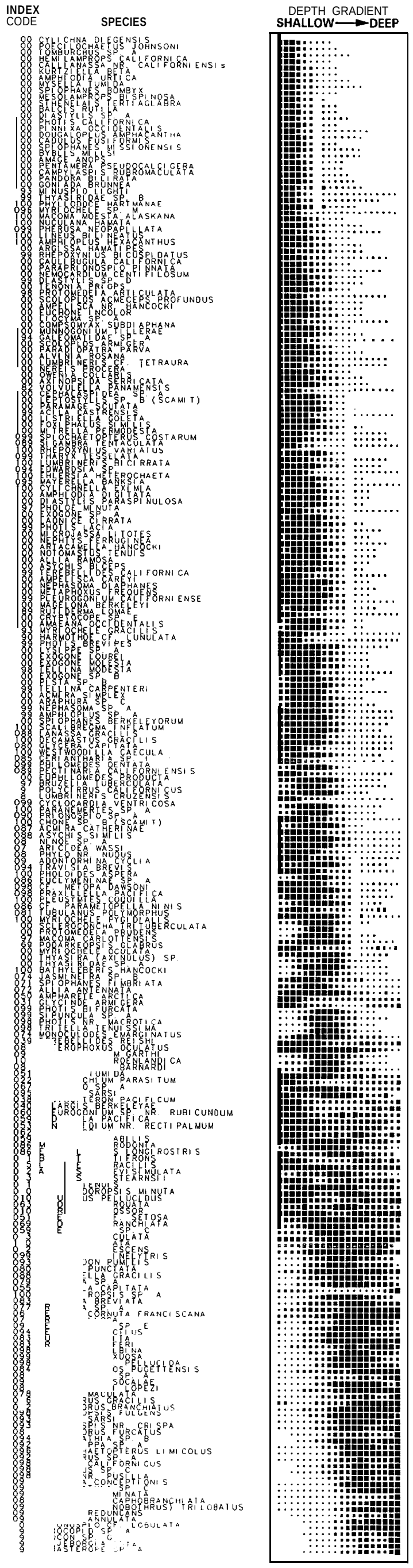


FIGURE 3-37. SPECIES GRADIENT PLOT, SHOWING THE TAXAASSOCIATED WITH ORDINATION AXIS 1. The index code to the left of each species' name indicates goodness of fit of the species' relative abundances to the gradient defined by Axis 1. The gradient is shown across the top, divided into 20 equal parts. Higher levels of relative abundance are denoted by larger square symbols.

[redacted] - - - - -

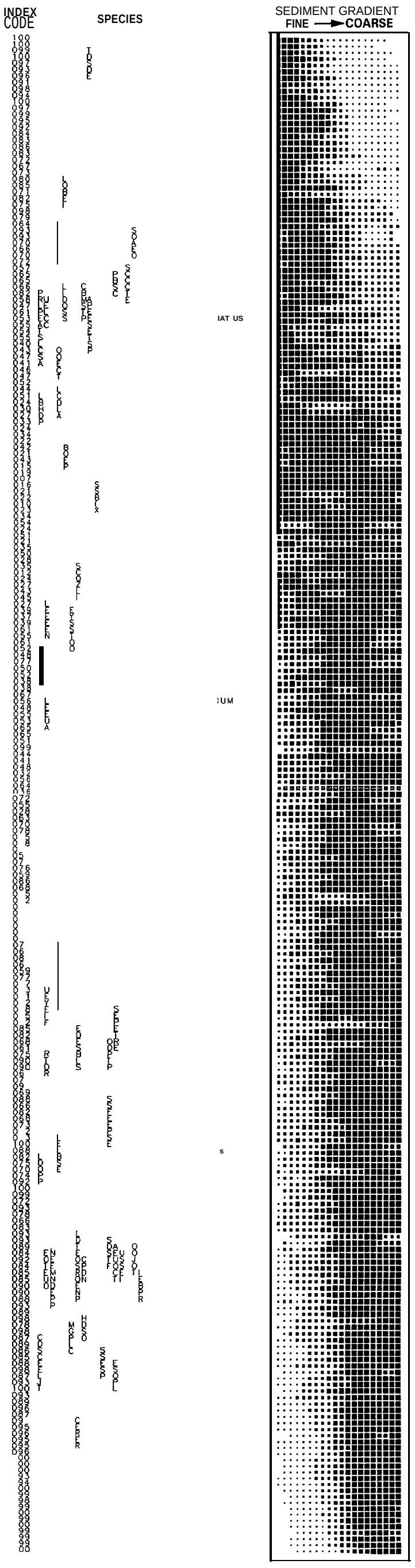


FIGURE 3-38. SPECIES GRADIENT PLOT, SHOWING THE TAXAASSOCIATED WITH ORDINATION AXIS 2. The index code to the left of each species' name indicates goodness of fit of the species' relative abundances to the gradient defined by Axis 2. The gradient is shown across the top, divided into 20 equal parts. Higher levels of relative abundance are denoted by larger square symbols.

area were tested to allow quantitative assessments (i.e. , the assignment of probabilities) to be made about those differences.

(1) Ho: There are no differences in benthic communities or species abundance between depths.

(2) Ho: There are no differences in benthic communities or species abundance between basins.

(3) Ho: There are no differences in benthic communities or species abundance between sediment types (depth and basin controlled for) .

(4) Ho: There are no correlations between differences in the benthic communities or species abundance and the measured environmental variables.

Multivariate methods tested for community differences among depths, basins, and sediment types. Univariate tests used the patterns of abundance of individual species to address the first three hypotheses. Analysis of variance (ANOVA) examined depth and basin differences, and analysis of covariance (ANCOVA) was used to examine differences among sediment types.

The MANOVA using both basin and depth as the main effects showed that the communities differed both with basin and with depth ($p < 0.0001$). The MANOVA also showed that there was a significant interaction between basin and depth ($p < 0.0001$).

Since benthic communities are expected to change with depth, it is more informative to examine interbasin differences at each of the four different depths sampled than to examine differences with depth. The interbasin differences were examined by means of seven different multivariate tests (see Section 2.6 and Appendix A, Volume I). Table 3-19 and Figure 3-39 show the results of the hypothesis tests comparing the basin communities. At all depths , the Eel River Basin community was significantly different from the communities within other basins. The Point Arena and Bodega basins differed significantly from one another only at the 100-m depth. This result is consistent with the pattern analyses, which showed that the pattern of sediments in the Eel River Basin was quite different from that of the other

TABLE 3-19. RESULTS OF MULTI VARIATE HYPOTHESIS TESTS FOR BETWEEN-BASIN COMPARISONS OF SOFT SUBSTRATE COMMUNITIES. The mean distances in ordination spaceand the probabilities associated with tests of the null hypothesis that there were no differences between basins are shown. A dash (-) indicates too few samples.

	DISTANCE		PROBABILITIES						
	Between	Within	Mantel	z	KC	MRPP	Dyer	MANOVA	No. Stations
DEPTH 1 (91-109 m)									
All Basins	.581	.253	< .001	.003	.003		< .001	< .001	
BASIN COMPARISONS:									
Pt. Arena									
Eel River	.657	.256	< .001	.008	.008	.002	< .001	< .001	
Pt. Arena									
Bodega									
Santa Cruz									
Bodega									
Eel River	.759	.263	< .001	.015	.015	.006	< .001	.019	
Pt. Arena	.355	.237	.002	.028	.065	.013	< .001	.028	
Bodega									
Santa Cruz									
Santa Cruz									
Eel River	.711	.273	.015	.190	.190		< .001	.076	5
Pt. Arena	.367	.239	.031	.173	.173		.005	.308	5
Bodega	.318	.231	.106	.250	.250		.120		3
Santa Cruz									1
DEPTH 2 (177-207 m)									
All Basins	.768	.553	< .001	.018	.008	.002	< .001	< .006	
BASIN COMPARISONS :									
Pt. Arena									
Eel River	.854	.579	< .001	.018	.018	.007	< .001	< .001	
Pt. Arena									
Bodega									
Bodega									
Eel River	.930	.534	< .001	.020	.020	.004	< .001	.017	5
Pt Arena	.462	.532	.880	.753	.690	.585	.768	.202	5
Bodega									3

Table 3-19. (Continued)

	DISTANCE		PROBABILITIES						
	Between	Within	Mantel	z	KC	MRPP	Dyer	MANOVA	no. Stations
DEPTH 3 (329-411 m)									
All Basins	.891	.720	< .102				< .003	< .001	
BASIN COMPARISONS:									
Pt. Arena									
Eel River	.875	.720	.001			.009	< .001	.004	
Pt. Arena									
Bodega									
Bodega									
Eel River	.978	.643	.040				.013	.123	5
Pt. Arena	.884	.998	.429				.562	.180	5
Bodega									3
DEPTH 4 (471-607 M)									
All Basins	.924	.648	< .001	.003	.003	.013	< .001	.032	
BASIN COMPARISONS:									
Pt. Arena									
Eel River	.847	.585	< .001	.013	.013	.002	< .001	.063	
Pt. Arena									
Bodega									
Bodega									
Eel River	1.078	.674	< .001	.018	.040	.015	< .001	.064	5
Pt. Arena	.899	.722	.072	.113	.203	.264	.074	.230	5
									3

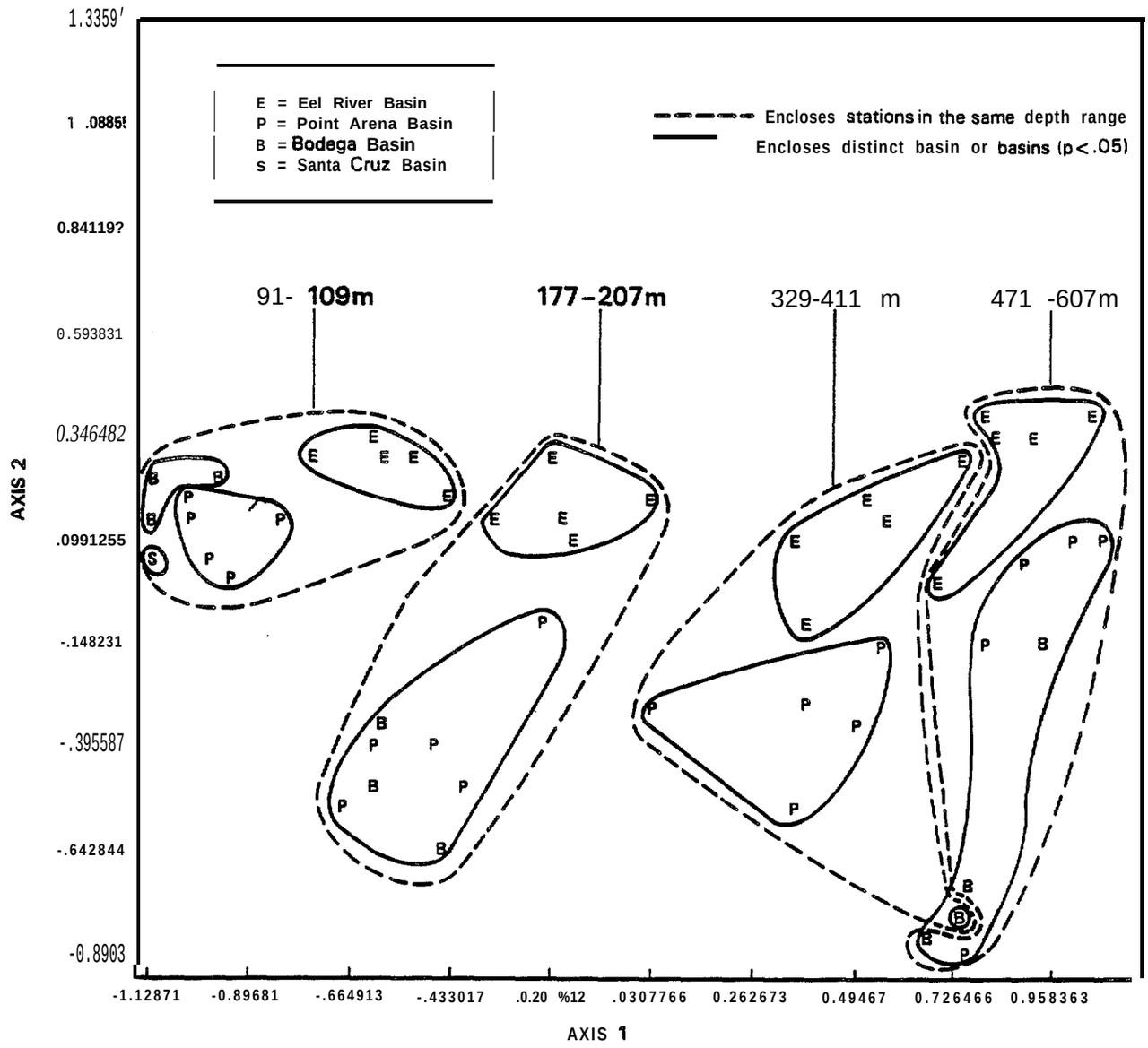


FIGURE 3-39. POSITIONS OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2. Basins are designated by letters E= Eel River; P = Pt. Arena; B = Bodega; S = Santa Cruz. Dashed lines enclose stations in the same depth range; solid lines enclosed basin(s) groupings that differ significantly ($p \leq 0.05$ by some tests).

basins and that those differences were most strongly correlated with the community variation along ordination Axis 2, the sediment size axis (Figures 3-31 and 3-34). In addition, the community at 100-m depth in the Eel River Basin appeared to be more similar to the 200-m community from that basin than to the 100-m communities from other basins. This is evident from the relatively higher position of the Eel River Basin stations along Axis 1 (Figure 3-39), which is highly correlated with depth, and in the station dendrogram (Figure 3-29). This pattern is partly responsible for the depth-by-basin interaction detected in the interaction tests (see below).

Although the probabilities associated with the various hypothesis testing methods varied somewhat, the results of those methods did not, in general, lead to different conclusions at a Type-1 error level of p = 0.05. The exceptions included comparisons with the Santa Cruz Basin at the 100-m depth and comparisons with Bodega Basin at the 300-m depth. In both cases, the Mantel and Dyer tests showed probabilities less than 0.05 for one or two comparisons (Table 3-19), whereas the other tests did not; the discrepancy occurred because in both cases one of the basins (Santa Cruz) being compared contained only a single sample, which reduced the sensitivity of some of the methods (Appendix A, Volume I).

Mean distance in ordination space between depths in the different basins was tested to examine the interactions between depth and basin. The results (Table 3-20) showed that in all but one case the changes in community with comparable changes in depth were smaller in the Eel River Basin than in the other basins. In six out of nine cases, the associated probability was less than 0.05.

Comparison of Sediment Types. Previous MMS studies (e.g., SAIC, 1986) found that both sediment type and depth affect the infaunal community. In the present study, the communities associated with the five different sediment types (A-E) (Section 3.2.1) were compared separately for the four depths sampled. The sediment types of the various groups were A = medium-fine sand, B = fine sand with silt, C = silt and fine sand, D = silt with some clay, E = silt and clay. Figure 3-40 shows the positions of the stations in the first two dimensions of the ordination space. The stations were designated by the

TABLE *3-20.* RESULTS OF TESTS OF INTERACTIONS BETWEEN DEPTH AND BASINS. T-tests, with probabilities determined by randomization, are used to compare the mean distances in ordination space between depths in the different basins. Depth 1 = 100 m, 2 = 200 m, 3 = 400 m, 4 = 600 m. Mean distances follow the equals signs, probabilities are in parentheses, and dashes indicate no test because only one sample was available in one of the basins.

		BASIN	
		Eel River	Pt. Arena
Depth Comparison	Basin		
	Pt. Arena		
1-2		E = .63 (.044) P = .85	
1-3		E = 1.40 (.126) P = 1.63	
1-4		E = 1.55 (.002) P = 2.06	
2-3		E = .95 (.144) P = 1.16	
2-4		E - 1.20 (.022) P = 1.59	
3-4		E = .74 (.024) P = 1.26	
	Bodega		
1-2		E = .63 (.016) B = 1.01	P = .85 (.140) B = 1.01
1-3		E = 1.40 (-) B = 2.17	P = 1.63 (-) B = 2.17
1-4		E = 1.55 (0.18) B = 2.14	P = 2.06 (.570) B = 2.14
2-3		E = .95 (-) B = 1.58	P = 1.16 (-) B = 1.58
2-4		E - 1.20 (.148) B = 1.50	P = 1.59 (.424) B = 1.50
3-4		E = .74 (-) B = .57	P= 1.26 (-) B= .57

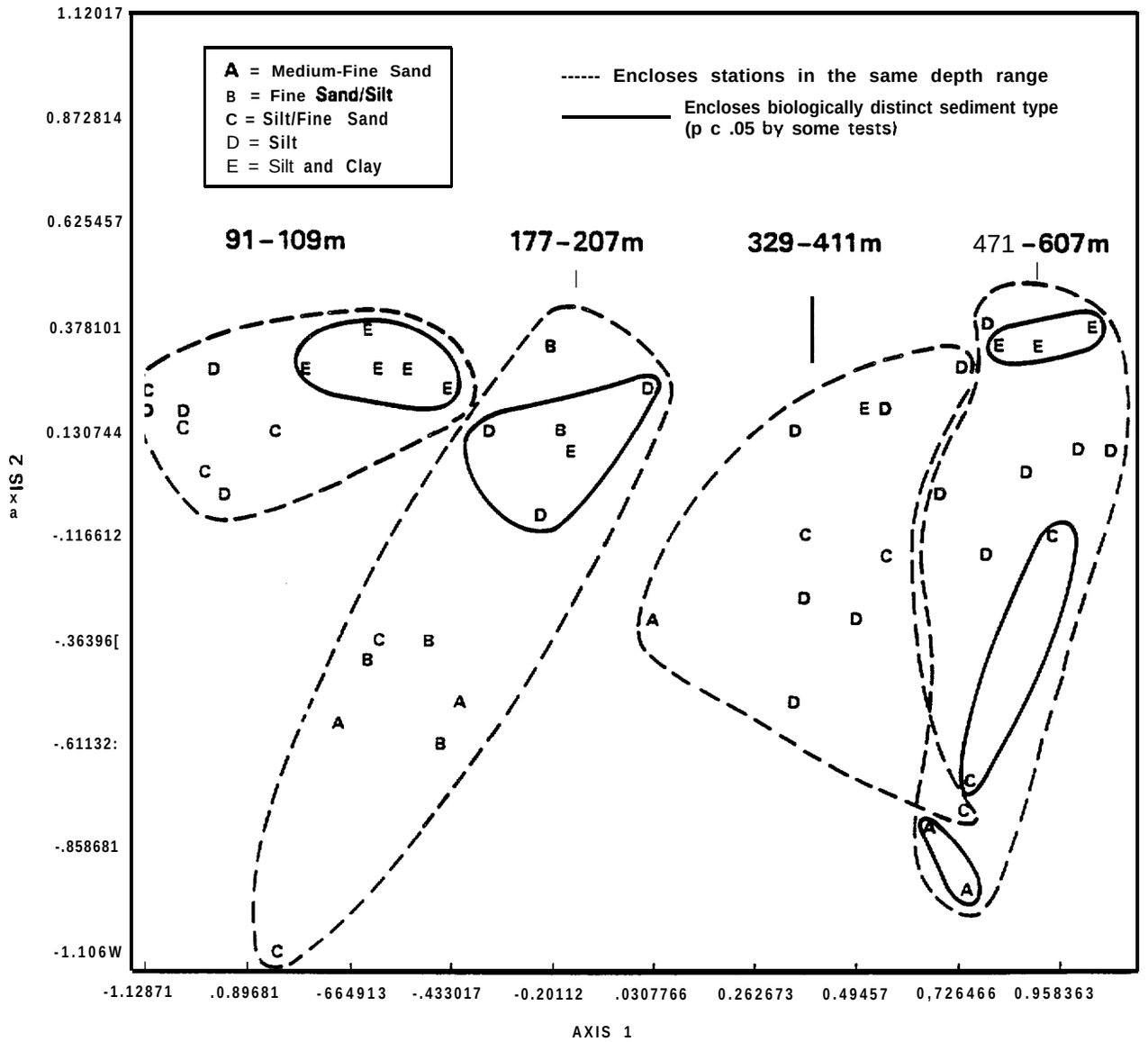


FIGURE 3-40. POSITIONS OF THE CARP STATIONS IN THE ORDINATION SPACE OF AXES 1 AND 2. Symbols indicate sediment type (A-E) at each of the CARP stations. Sediment Type A is the coarsest and Type E is the finest. Dashed lines enclose stations in the sample depth range; solid lines enclose biologically distinct ($p \leq 0.05$ by some tests) sediment types within each depth range.

letters A through E representing the sediment regimes characteristic of the respective stations. The communities associated with the sediment types were compared by the same multivariate approach used to test hypotheses related to community differences with depth and by basin. The results of the hypothesis testing are presented in Table 3-21.

At the 100-m stations, the community associated with sediment type E was significantly different from the communities associated with the other two sediment types at that depth. At the 200-m stations, a few of the tests showed significant ($p < 0.05$) differences between communities in sediment type D and the other three types present at that depth. At the 400-m stations, the communities in the two sediment types present were not distinguishable. At the 600-m stations, the communities in all sediment types except D and E were significantly different according to at least one of the tests. At three of the four depths, the communities in the finest sediments (D or E) were different from those in most or all of the coarser sediments.

As with the hypothesis tests comparing differences between basins, the various tests sometimes supported different conclusions; this was largely due to the small number of stations in some of the sediment groups, which permitted only limited numbers of different permutations for the Z and KC methods (see Appendix A). Methods such as Mantel, Dyer, and WOVA can be more sensitive in such situations, as long as the risk in making the additional assumptions associated with those methods is acceptable.

The results of the hypothesis testing are consistent with and support the pattern analyses, which showed the community changes along ordination Axis 2 to be correlated with sediment differences. This pattern is most evident at 600 m, where the average position of the four sediment types followed a gradient of sediment size along Axis 2 (Figures 3-39 and 3-40), but the pattern is also discernible at the other depths.

Comparison of Species. Since community patterns are the sum of the patterns exhibited by the individual species comprising the community, the relationships were examined between the community patterns expressed by the ordination

TABLE 3-21. RESULTS OF MULTI VARIATE HYPOTHESIS TESTS FOR BETWEEN-SEDIMENT TYPE COMPARISONS OF SOFT SUBSTRATE COMMUNITIES. The mean distances sediment types are shown. A dash (-) indicates too fewsamples.

	DISTANCE		PROBABILITIES						
	Between	Within	Mantel	z	KC	MRPP	Dyer	MANOVA	No. Stations
DEPTH 1 (91-109 m)									
All Sediment Types	.576	.304	< .001	.005	.005	.001	< .001	.002	
SEDIMENT TYPE COMPARISONS:									
Sediment O									
Sediment C	.278	.330	.920	1.000	1.000	1.000	.910	.993	
Sediment O									
Sediment E									
Sediment E									
Sediment C	.684	.287	< .001	.010	.010	.003.	< .001	.003	4
Sediment D	.707	.301	< .001	.003	.003	.003	< .001	.005	4
Sediment E									5
DEPTH 2 (177-207 m)									
All Sediment Types	.832	.683	.065	.075	.080	.069	.065	.048	
SEDIMENT TYPE COMPARISONS:									
Sediment B									
Sediment A	.701	.637	.32.4	.283	.158	.330	???	.065	
Sediment B									
Sediment C									
Sediment D									
Sediment C									
Sediment A	.612	.649	.92C	1.000	1.000		1.000		
Sediment B	.798	.680	.277	.37B	.470		.284	.740	
Sediment C									
Sediment O									
Sediment O									
Sediment A	.972	.693	.052	.100	.200		.030		2
Sediment B	.807	.689	.087	.125	.190	.177	.090	.022	5
Sediment C	1.174	.812	.031	.100	.200		.020		2
Sediment O									3

Table 3-21. (Cent inued)

	DISTANCE		PROBABILITIES						
	Between	Within	Mantel	z	KC	MRPP	Dyer	MANOVA	No. Stations
DEPTH 3 (329-411 m)									
All Sediment Typea	.595	.622	.726	.613	.723	.812	.621	.725	
SEDIMENT TYPE COMPARISONS:									
Sediment O									
Sediment C	.595	.622	.724	.613	???	.812	.621	.725	3
Sediment D									6
DEPTH 4 (471-607 m)									
All Sediment Types	.923	.607	.001	.005	.058	.005	< .001	.002	
SEDIMENT TYPE COMPARISONS:									
Sediment C									
Sediment A	1.057	.644	.083	.333	.333		.004	???	
Sediment O									
Sediment A	1.126	.599	< .001	.053	.053	.011	< .001	.017	
Sediment C	.896	.658	.036	.113	.180	.353	.032	.061	
Sediment E									
Sediment A	1.397	.428	.008	.100	.100		< .001		2
Sediment C	.983	.642	.060	.200	.200		.030		2
Sediment O	.599	.603	.523	.403	.478	.267	.523	.442	6
Sediment E									3

analysis, the patterns expressed by individual species, and the environmental variables. Examining all of the species used in the multivariate analyses was not feasible. Accordingly, three sets of species that represented the community as a whole or that were major contributors to the biological patterns within the community were selected for analysis. The three sets were species whose patterns of occurrence and abundance appeared to correspond with biological ordination axes defined by the multivariate analyses, species representative of various feeding-motility types ("trophic-motility groups"), and the most abundant species not considered in the other two groups. Although the analysis on the first set of species is similar to presorting the data, which would be expected to yield a greater number of significant tests, we used the approach to explore patterns already revealed, rather than to discover them.

The analyses used univariate techniques to test the first three hypotheses. Analysis of variance (ANOVA) tested the hypotheses concerning differences by basin and by depth, and analysis of covariance (ANCOVA) tested the hypothesis concerning differences by sediment type. Parametric multiple-regression analysis was used to test the fourth hypothesis, which concerned relationships between organisms and the environmental variables.

Feeding Groups

Several studies have demonstrated that the interpretation of responses of benthic species to gradients or changes in their environment may be facilitated by grouping ecologically similar taxa for analysis (e.g., Rhodes, 1974; Dorsey et al., 1983). If the groupings reflect functional attributes, information concerning the functional aspects of the community can be gained from these analyses (Woodin, 1976; Van Blaricom, 1978; Biernbaum, 1979). Accordingly, six sets of species were considered that represented the major feeding-type groups of the soft substrate benthic habitat according to Pearson and Rosenberg (1978) (Table 3-22). The species were assigned to feeding groups based on literature reports of their ecology and mode of feeding. Species belonging to the same genus were assumed to possess similar functional characteristics unless otherwise specified in the literature. The feeding types are necessarily

TABLE 3-22. SPECIES REPRESENTATIVE OF INFAUNAL FEEDING TYPES. The symbols indicate patterns of abundance based on untransformed data; **: abundances ≥ 0.5 of the maximum mean abundance; --: abundance 0.1-0.5 of the mean maximum; ..: abundance < 0.1 of mean maximum, but > 0; blank: not present. Results of ANOVA/ANCOVA tests of abundance indicated by ns, 1, or 2 (see legend). Results evaluated using the appropriate data transformation (Section 2.6.2).

Group	DEPTH (M) 100	200	400	600		BASIN Bodega	Point Arena	Eel River		SEDIMENT TYPE+ E	D	C	B	A	
SUSPENSION FEEDER															
Ampelisca careyi	**	-	-	-		1	**	•-	**	ns	**	-	-	-	**	--	1
Spiophanes berkeleyorum	**	•	*	--	..	1	--	--	**	ns	**	--	--	**	--	1
Paraprionospio pinnata	**	..			..	1	**	--	..	1	**	**	**	--	..	ns
Huxleyia munita		..		**	. .	2	•-	▲▲	**	2	..	**	**	-	- - -	ns
Monoculodes emarginatus		**		• *	..	1	**	▲▲	..	1	- - - -		**	--	--	ns
SUBSURFACE DEPOSIT															
Levinsenia gracilis	**	-	-	- -	- -	1	..	--	**	1	**	-	-	--	--	..	1
Myriochele gracilis	**	--		..	..	1	**	**	..	1	--	**	**	**	**	ns
Myriochele sp. M	•*			. .	. .	2	--	•-	..	2	..	**	**			ns
Nucula tenuis	**	**	•	*	--	ns	--	--	**	ns	**	.	.	.	.	--	ns
Acmira lopezilopezi	--	--		•*	**	ns	--	▲▲	•*	1	**	**	.	.	. . .	ns
Typhlotanais sp. A	..	**		**	..	1	•*	\\	--	1	•	*	--	**	**	ns
SURFACE DETRITUS - DEPOSIT															
Anobothrus gracilis	..	.	.	. .	**	2	..	**	..	2	..	**	.	.	..	- -	ns
Chaetozone cf. setosa	**	**		**	--	ns	--	**	**	ns	**	**	**	**	--	ns
Eudorella pacifica	**	..		**	--	ns	**	**	**	ns	**	•*	**	--		ns
Terebellides reishi	**	•*		**	..	ns	--	--	**	ns	**	.	.	--	. .	..	ns
Westwoodilla caecula	--	**		--	..	1	**	**	**	ns	- - -	-	**	**	**	ns
Argissa hamatipes	**	..				1	**	--	..	1	**	**	**	..	--	ns
Artacamella hancocki	**	-	-	. .		1	--	--	**	ns	**	..	--	--		ns

TABLE 3-22. (Continued)

Group	DEPTH (M) 100	200	400	600		BASIN Bodega	Point Arena	Eel River		SEDIMENT TYPE+ E	D	c	B	A	
MULTIFEEDING															
Amphiodia urtica	**	..				**	**	..	1	..	**	**			1
Amphiodia digitata	--	**	-	-		--	**	..	1	.	.	.	--	**	**	1
CARNIVORE - OMNIVORE															
Chloeia pinnata	--	**	--		1	**	**	**	ns	--	**	**	**	**	ns
Pholoe minuta	**	.	.	.	..	1	•*	**	--	ns	--	--	**	.	.	1
Carinoma mutabilis	**	•	*	.	.	ns	--	**	**	ns	**	.	.	•	*	**	--	ns
Munnogonium tillerae	**	..				1	**	--	•*	ns	**	.	.	.	.	..	ns
Sigambra tentaculata	**	.	.	.	.	.	.	1	**	**	..	1	--	**	**	.	.	ns
Alvinia rosana	**	--	..			1	**	•*	**	ns	**	.	.	..	**	.	.	ns
CARNIVORE/OMNIVORE DETRITUS FEEDER															
Nephtys cornuta franciscana	--	--	**	•	*	1	..		**	1	•*	•	*	--	..	.	.	1
Metaphoxus frequens	**	**	..			1	--	".	**	ns	**	.	.	--	**		--	1
Lumbrineris cf. tetraura	**	.	.	.	.	1	**	•*	--	ns	..	•	*	**	--			ns
Synchelidium nr. rectipalmum		**	.	.	--	1	**	**	**	ns	-	-	-	-	..	**	..	ns
Nephtys punctata	..	**	**		--	ns	..	--	**	ns	..	**		--	--			1

Legend

+ A = medium sand
B = fine sand
C = fine sand/silt
D = fine sand/clay
E = silt clay
ns = nonsignificant ($p > 0.05$) ANOVA/ANCOVA
1 = ANOVA or ANCOVA significant ($p < 0.05$)
2 = data tested as ranks by one-way ANOVA, no test of basins and depths separately

general because some species have been reported to use more than one feeding mode and because the feeding modes of many species are poorly known. For each feeding-type group, the abundances of several of the most widespread species were analyzed by ANOVA for basin and depth patterns, by ANCOVA for sediment-type differences, and by parametric multiple-regression analysis for correlation with environmental variables.

The results (Table 3-22) showed that few of the patterns were similar among the species within a feeding-type group. Most species were found in all three basins. Within each group, there was no consistent pattern with depth except that carnivore-omnivores tended to be more abundant at the 100-m stations. Few significant relationships were noted with respect to sediment type. Those that were significant suggested a pattern of lower abundance in the coarser sediments (Type A) .

A notable and statistically significant pattern was found in the multifeeding group (Table 3-22). The congeners Amphiodia urtica and A. digitata (which comprised the entire group) occurred in the same basins, but the former was found in highest abundances at the 100-m stations in finer sediments, whereas the latter was most abundant at the 200-m stations in coarser sediments. The status of these two species of Amphiodia currently is being evaluated by the Southern California Association of Marine Invertebrate Taxonomists. The "species" may represent subspecies or a polymorphic single species, but because they are morphologically distinct and have different patterns of occurrence, we suggest that regarding them as separate species maximizes the amount of information to be gained from them. In contrast, the congeners Nephtys cornuta franciscana and N. punctata, both carnivore-detritus feeders, did not show clear, nonoverlapping distributions.

The parametric multiple regressions showed that the suspension detrital/deposit feeders exhibited the strongest relationships to the individual environmental variables (Table 3-23). All of these species were strongly correlated with temperature. This reflects the fact that each species had high abundances inshore, high-to-moderate abundances at 200 m, and low abundances or was absent at 400 and 600 m in all basins. This strong gradient of decreasing abundance

TABLE 3-23. RESULTS OF STATISTICALLY SIGNIFICANT ($P < 0.01$) MULTIPLE REGRESSIONS FOR SPECIES REPRESENTATIVE OF VARIOUS FEEDING GROUPS. See Table 3-22 for a complete list of the species tested. Only regression with R^2 values greater than 0.50 are shown.

Group	R^2	Environmental Variables									
SUSPENSION FEEDER											
Spiophanes berkeleyorum	0.77	depth	temp	DO	TOC	mean phi	disp	skew	sand	-silt	clay
Paradiopatra parva	0.75	depth	temp	DO	TOC	-mean phi	disp	skew	sand	silt	clay
Paraprionospio pinnata	0.60	depth	temp	-DO	Toc	mean phi	disp	skew	sand	silt	clay
Ampelisca careyi	0.57	depth	temp	00	TOC	mean phi	diap	skew	sand	silt	clay
Ampelisca nr. hancocki	0.51	depth	temp	Do	TOC	-mean phi	disp	skew	sand	silt	clay
SUBSURFACE DEPOSIT FEEOER											
Levinsenia gracilis	0.61	depth	temp	DO	-Toe	mean phi	disp	skew	sand	silt	-clay
Amaeana occidentals	0.56	depth	temp	DO	TOc	mean phi	-disp	skew	-sand	-silt	-clay
Aricidea wassi	0.55	-depth	temp	00	10C	mean phi	disp	-skew	sand	-silt	-clay
SURFACE DETRITUS-DEPOSIT FEEDER											
Pista sp. B	0.60	depth	temp	DO	TOC	-mean phi	disp	skew	sand	silt	clay
Crypt ocope sp. E	0.57	depth	- temp	DO	-TOC	mean phi	-disp	skew	- sand	silt	clay
Harpiniopsis fulgens	0.51	-depth	-temp	DO	TOC	mean phi	-disp	skew	sand	silt	-clay
Metaphoxus frequens	0.51	depth	temp	DO	TOC	-mean phi	-disp	skew	sand	silt	+clay
CARNIVORE/OMNIVORE											
Pholoe minuta	0.77	-depth	temp	-Do	TOC	mean phi	disp	skew	sand	silt	clay
Exogone lourei	0.53	depth	temp	+DO	TOC	mean phi	-disp	skew	- sand	-silt	-clay
Sigambra tentaculata	0.50	depth	temp	-00	TOC	mean phi	disp	-skew	sand	silt	clay
CARNIVORE/OMNIVORE DETRITUS FEEDER											
Ninoe sp. A	0.59	-depth	temp	00	-Toe	mean phi	disp	skew	sand	silt	clay
Lumbrineris cf. tetraura	0.58	-depth	temp	-DO	TOC	mean phi	disp	skew	sand	silt	clay
Nephtys cornuta franciscana	0.53	-depth	- temp	DO	TOC	mean phi	disp	skew	sand	silt	clay

from 200 to 400 m is similar to the percent change in temperature observed over these same depths. For example, 40% of the decrease in abundance occurred from 200 to 400 m and 40% from 400-600 m, while 53% of the total temperature gradient occurred from 200-400 m and 23% from 400-600 m. Thus, the greatest decrease in abundance closely paralleled the greatest temperature drop.

Additional variables entered into the regressions improved the regression relationships for all but one species. For most species, however, the improvement was not great. The sediment variables tended to account for no more than 10% of the variability.

For the subsurface deposit feeders, sediment measures were more closely related to abundances than for suspension detrital/deposit feeders. Mean phi accounted for 23% of the variability in the abundance of Levinsenia gracilis, and silt and clay accounted for 31% of the variability in the abundance of Aricidea wassi. Dissolved oxygen was also an important factor in some regressions, and for Amaeana occidentals oxygen accounted for 48 of the 56% of the total variability in abundance accounted for by all variables.

Among the carnivores, Exogone lourei exhibited the highest abundances inshore in the Eel River Basin, but decreased sharply in abundance in the central and southern basins. Dissolved oxygen and silt constituted 40 of the 51% of total variability in abundance accounted for by all variables.

None of the other multiple regressions revealed consistent relationships between species of a trophic group or among all groups. Although some of the other regressions were moderately strong, they were not significant enough, nor did they follow a sufficiently clear pattern to provide conclusive evidence of cause-and-effect relationships, given the large spatial and environmental gradients involved in this study.

Most Abundant Species

Data on the five most abundant species in each basin (a total of 11 species because of overlaps between basins; Table 3-24) were analyzed by ANOVA to

TABLE 3-24. ELEVEN SPECIES COMPRISING THE FIVE MOST ABUNDANT SPECIES IN EACH BASIN. The symbols indicate patterns of abundance based on untransformed data; **: abundances ≥ 0.5 of the maximum mean abundance; --: abundance 0.1-0.5 of the mean maximum; ..: abundance <0.1 of mean maximum, but > 0; blank: not present. Results of ANOVA/ANCOVA tests of abundance indicated by ns, 1, or 2 (see legend). Results evaluated using the appropriate data transformation (Section 2.6.2).

	DEPTH (M)				BASIN				SEDIMENT TYPE+					
	100	200	400	600		Bodega	Point Arena	Eel River		E	D	C	B	A	
Amphiodia urtica	**	..			1	•*	**	**	1	..	**	**			1
Chloeia pinnata		..	**	..	1	**	•*	**	ns	--	**	**	**	**	ns
Huxleyia munita		..	•*	--	2	•*	--	•*	2	..	•*	**	..	--	ns
Levinsenia gracilis	**	..	--	--	1	..	--	•*	1	•*	--	..	--	..	1
Metopa nr. pusi lla			**	..	ns			•*	ns	--	**				ns
Mitrella permodesta	**	..	..	..	1	..	•*	..	1	..	--	**	**	--	ns
Myriochele gracilis	•*	..	..	..	1	**	**	--	1	..	**	•*	**	**	ns
Myriochele sp. M	•*		..	..	2	..	•*	..	2	..	**	**			ns
Nephtys ferruginea	..	..	**	**	1	..	..	**	1	**	**	--	..	..	1
Pholoe minuta	•*	--	..	..	1	**	**	--	ns	--	--	**	--	..	1
Spiophanes berkeleyorum	**	**	.-	..	1	..	**	**	ns	**	--	--	**	..	1

Legends

+ A = medium sand
B = fine aand
C = fine sand/silt
D = fine sand/clay
E = silt clay
ns = nonsignificant (p>0.05) ANOVA/ANCOVA
1 = ANOVA or ANCOVA significant (p < 0.05)
2 = data tested as ranks by one-way ANOVA, no teat of basins and depths separately

detect differences in distribution among basins and depths and by ANCOVA to detect differences in distribution among sediment types. This analysis was conducted to yield insights into factors controlling the community that might be obscured by the presence of many less abundant species. Huxleyia munita, Levinsenia gracilis, Nephtys cornuta franciscana, and Spiophanes berkeleyorum were among the five most abundant species in two basins. Huxleyia munita and N. cornuta franciscana were the most abundant in the most northern and southern basins but not in the Point Arena Basin. Amphiodia urtica, Pholoe minuta, Chloeia pinnata, Metopa nr. pusilla, Mitrella permodesta, Myriochele sp. M, and Myriochele gracilis were among the five most abundant species in one of the basins.

Overall, the patterns of abundance of these species (Table 3-24) provided some support to the patterns revealed by the multivariate analysis. Most of the species were more abundant at shallow stations, which corresponds to the relationship of Axis 1 with depth in the multivariate analysis, and most of the species were less abundant in the coarser sediments, which corresponds to the relationship of Axis 2 with sediment type. However, the correspondences with the multivariate analyses were not strong, probably because most of the species were widespread. With the exception of the brittle star, Amphiodia urtica, and the amphipod, Metopa nr. pusilla, all of the species were either ubiquitous in terms of basin, depth, and sediment type, or they tended to be more abundant in deeper waters of the Eel River Basin and shallower waters of the other basins. In addition, these species tended to be less abundant in coarser sediments. Amphiodia urtica occurred at the shallow stations of the southern basins, whereas M. nr. pusilla was found inconsistently but in extremely high abundances at a few deep-water stations with fine sediments (Types D and E) in the northern (Eel River) basin. All species except the polychaete Spiophanes berkeleyorum either exhibited no trends with sediment type or tended to occur in finer sediments. Spiophanes berkeleyorum occurred primarily at shallower stations with fine sand (Type B).

Only three (Levinsenia gracilis, Pholoe minuta, and Spiophanes berkeleyorum) of the eleven species yielded significant multiple regressions with environmental variables . The abundance of L. gracilis showed a strong relationship with mean

phi and dissolved oxygen; the abundance of P. minuta showed a strong relationship with depth; and the abundance of S. berkeleyorum showed a strong relationship with temperature. Thus, the distributions of the most abundant species could not be clearly related to any of the environmental variables measured in this study.

Analysis of Power of the ANOVA Test

The univariate statistical tests failed to identify significant differences in a number of cases. The actual ability of the tests to identify differences, given the nature of the data, is of interest as a guide to the interpretation of the test results. That ability was assessed by an analysis of power. The power of the test is that the probability of rejecting a false null hypothesis (i.e., detecting a real difference; 1 minus the power is the Type II error) and the uncertainty associated with that test is the probability of rejecting a true null hypothesis (i.e., detecting a difference that does not exist, which is a Type I error). The objective of this power analysis was to determine how large differences needed to be for the statistical tests to detect them at given levels of power and uncertainty, and then to compare those calculated differences to the actual observed differences to determine whether the ANOVA tests could have defined them as statistically significant.

For this analysis, the minimum power was set at 0.80 (80% chance detecting a real difference) and the uncertainty was set at 0.05 (5% chance of defining a difference when in fact there was not one). These values were used following the method of Cohen (1977) to calculate the minimum differences that could be detected by this sampling plan (Table 3-25). The same underlying error term (i.e., the average of the variance of stations within a basin at each depth) used in the two-way ANOVA was used to analyze basin and depth differences in the denominator of the F-test for significance.

The comparisons of the actual differences in community summary variables and environmental measures by basin and depth with the calculated detectable differences agreed in all cases with the results of the ANOVA comparisons of

TABLE 3-25. ACTUAL AND CALCULATED DETECTABLE MAXIMUM DIFFERENCES FOR COMMUNITY MEASURES ANO ENVIRONMENTAL MEASURES BETWEEN BASINS, DEPTHS, AND STATIONS. Detectable differences are based on power analyses.

Measure	Trans-formation	Mean Value	BASIN DIFFERENCES Max. Actual	BASIN DIFFERENCES Calc. Detectable	DEPTH DIFFERENCES Max. Actual	DEPTH DIFFERENCES Calc. Detectable	STATION DIFFERENCES Max. Actual	STATION DIFFERENCES Calc. Detectable
Species (no./core)	Untr	71.2	3.9	13.3	55.5	14.7	65.0	16.0
Individuals (no./core)	Untr	629.1	191.2	168.7	841?8	185.6	979.7	202.5
Diversity (H')	Untr	1.4	0.1	0.2	0.4	0.2	0.6	0.2
Dominance (D)	Unt r	1.1	0.2	0.2	0.4	0.3	0.7	0.3
Evenness (J')	Untr	0.8	0.1	0.1	0.1	0.1	0.2	0.1
Biomass (g/core)	Rank power analysis not appropriate							
Crustacea Individuals (no./core)	Log10	1.9	0.1	0.2	0.5	0.3	0.7	0.3
Echinodermata Individuals (no./core)	Untr	33.0	47.2	15.4	72.2	16.9	161.3	18.4
Mollusca Individuals (no./core)	Log10	1.8	0.1	0.3	0.6	0.3	0.9	0.3
Polychaeta Individuals (no./core)	Untr	383.5	223.4	106.9	519.9	117.5	749.0	128.2
Miscellaneous Individuals (no. /core)	Rank power analysis not appropriate							
Temperature (°C)	Untr	8.4	0.5	0.5	5.3	0.5	6.1	0.6
Total Organic Carbon (%)	Untr	0.8	0.2	0.3	0.3	0.3	0.6	0.3
Dissolved Oxygen (ml/liter)	Untr	3.1	0.7	0.7	3.4	0.7	4.8	0.8
Mean phi size	Untr	5.4	2.1	1.2	1.6	1.3	3.6	1.4
Median phi size	Untr	4.5	1.8	1.0	1.4	1.2	3.1	1.3
Skewness	Untr	0.4	0.1	0.2	0.1	0.2	0.3	0.2
Dispersion	Rank power analysis not appropriate							
% Sand	Untr	45.7	39.3	21.4	38.4	23.5	80.6	25.7
% Silt	Untr	37.2	25.1	14.9	31.3	16.4	59.3	17.9
Z Clay	Rank power analysis not appropriate							

basin and depth. When the calculated detectable differences were less than the largest maximum actual differences, the ANOVA showed significant results.

Table 3-25 shows that between-basin differences were too small to be recognized as significant for many of the community and environmental measures. However, all but one of the actual maximum between-depth differences were larger than the minimum necessary for detection. As an example, the number of species would have needed to differ by 13.3 between basins to give a statistically significant ANOVA result; whereas, the actual maximum observed difference was only 3.9 (Table 3-25). However, in the between-depth comparisons the actual maximum between-depth difference of 55.5 was far greater than the calculated detectable difference of 14.7.

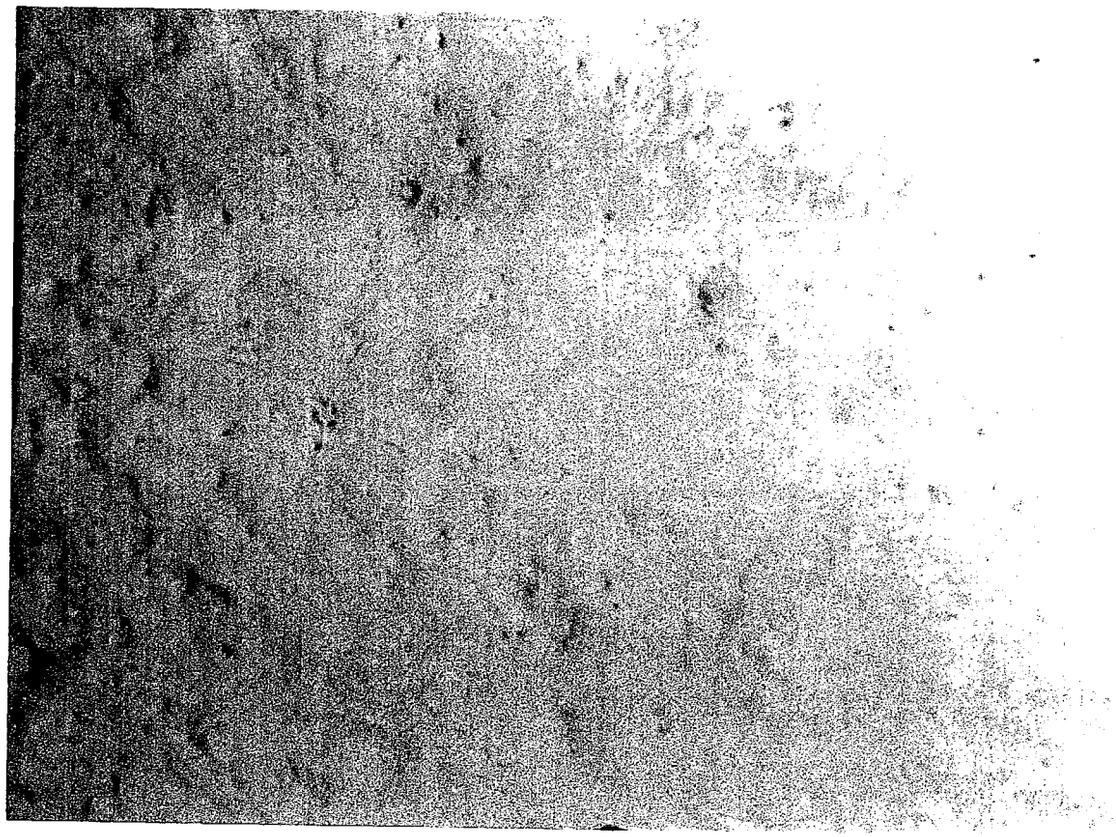
In summary, it appears that the analytical program was strong enough to detect important biological differences. The validity of this conclusion is illustrated by the results of the between-basin analyses (Table 3-25). In cases in which differences were not detected, the actual maximum differences were almost always less than 10% of the mean. Few biological or water quality programs expect to be able to detect differences of less than 10% of the mean.

Soft Substrate Photographs

Before each box-core sample of the soft substrate was collected, the sample site was photographed by a 35-mm Benthos camera attached to the coring device. The apparatus had a remote trigger set to fire at 1.5 m above the bottom; at that height, the field photographed was 1 m^2. However, as a result of bottom topography and variations in wire angle, the actual height likely deviated from the nominal 1.5 m, and in those cases, the area photographed was different (potentially somewhat larger or smaller) than 1 m^2.

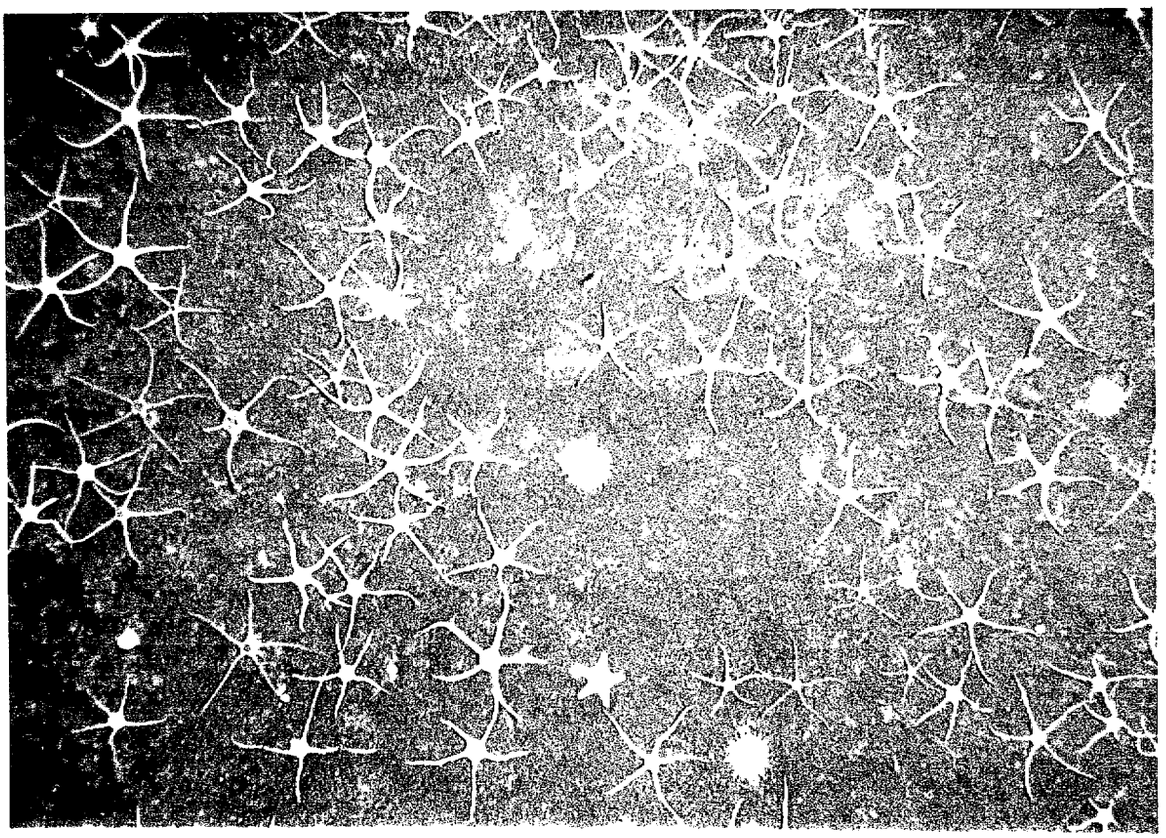
In total, 113 35-mm photographs were collected at 55 of the 56 stations where soft substrate sampling was attempted. At a few stations, particularly those in the Santa Cruz Basin, infaunal sampling was unsuccessful but photographs of the bottom were obtained. Organisms were visible in 60 photographs from 34 stations. Fifty of those photographs (examples are presented in Figure 3-41)

FIGURE 3-41. PHOTOGRAPHS OF THE SOFT SUBSTRATE. A) Station SB26, 185 m, in the Pt. Arena Basin, showing extensive bioturbation; the brittlestar is *Ophiura sarsi*. B) Station SB32, 529 m, in the Pt. Arena Basin, showing a California scorpionfish (*Scorpaena guttata*), *Ophiura sarsi*, and various burrows. C) Station SB40, 534 m, in the Pt. Arena Basin, showing a high density of *Ophiura sarsi*, together with specimens of the sea urchin *Allocentrotus fragilis* and an unidentified starfish. D) Station SB50, 184 m, in Bodega Basin, showing unidentified sea pens and a slender sole (*Lyopsetta exilis*).

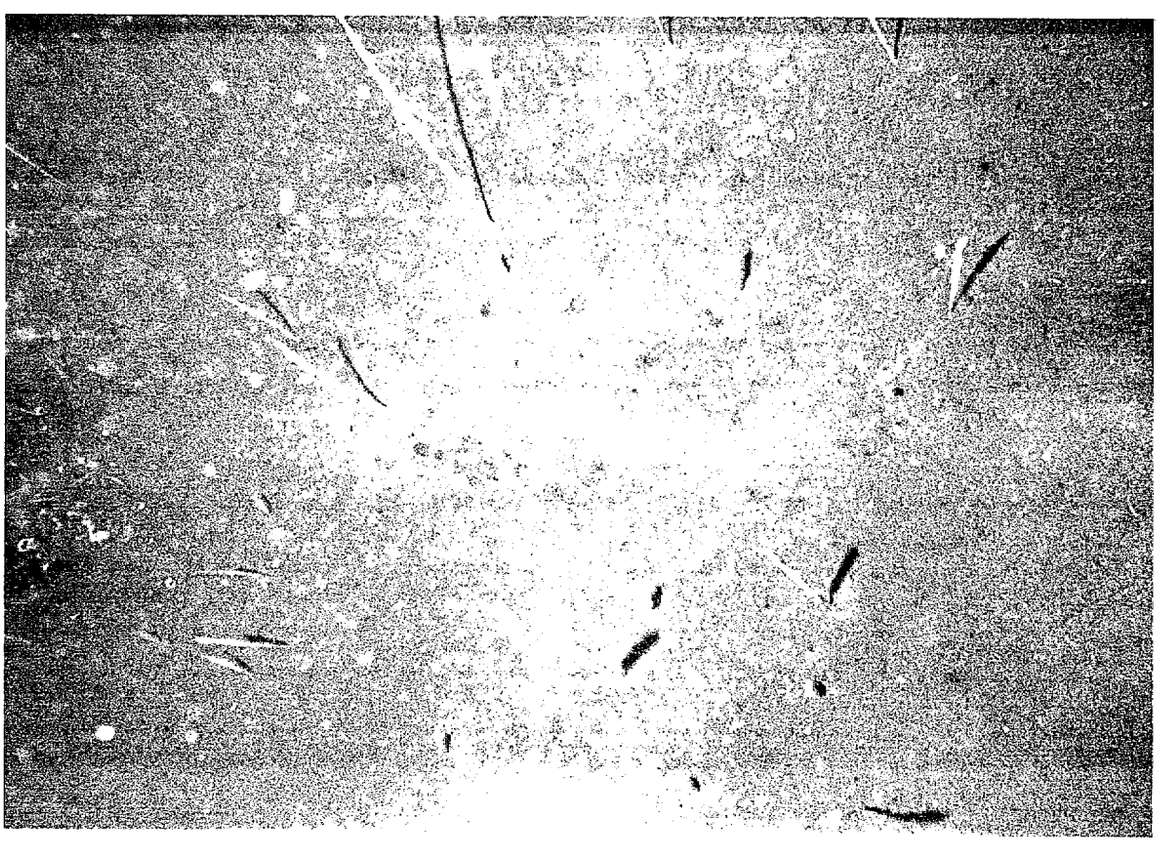


A

B



C



D

were sufficiently clear to allow at least tentative identification to the level of genus or species of some (or all) of the organisms in the field of view (Table 3-26). Bioturbation was clearly evident in most photographs, but ripple marks, indicative of currents, typically were not apparent. Intensive bioturbation of the surface sediments was apparent at some stations (e.g., SB12, SB26). The low occurrence of ripple marks is in contrast to the hard substrate survey video observations which indicated ripple marks, particularly at depths < 200 m (Section 3.1); these differences probably are due to the relatively larger viewing area afforded by the video camera.

Thirteen of the photographs (22% of those showing evidence of organisms) showed fish; a single fish was visible in 12 photographs, while two fish were shown in one photograph. The apparently low density ($\leq$ 1 per frame, corresponding roughly to $\leq 1/m^2$) of fish in the photographic record probably is due in part to the fish detecting and moving away from the descending sampler before the camera was triggered.

At least seven and possibly as many as 10 fish taxa were present. Half (seven) of the specimens were pleuronectid flatfish, mainly Dover sole (Microstomus pacificus, three fish) and slender sole (Lyopsetta exilis, three fish). Scorpaenidae was the second most common family (three fish); one or two were scorpionfish Scorpaena guttata and the other(s) one was a rockfish Sebastes sp. A single example each of skate (Raja sp.), sablefish (Anoplopoma fimbria), bigfin eelpout (Aprodon cortezianus), the remaining pleuronectid flatfish (either M. pacificus or Glyptocephalus zachirus), and an unidentified fish were recorded. These species are consistent with those observed from the hard substrate survey, which included many extensive soft substrate areas (sediment veneer) (Section 3.1 and the species list presented in Appendix F, Volume II).

Fifty-nine of the photographs (98% of those showing evidence of organisms) showed epibenthic invertebrates and/or evidence of infauna (e.g., various burrows or heart urchin holes). The majority of those photographs showed more than five individual macroinvertebrates; at some stations more than 50 individuals were recorded (e.g. , Station SB40, 534 m, in the Point Arena Basin). Most of the epibenthic macroinvertebrates photographed were echinoderms and

TABLE 3-26. OCCURRENCES OF TAXA IN THE SOFT SUBSTRATE PHOTOGRAPHS. Only the 34 stations at which photographs were of sufficient quality to allow identification of organisms are included on this table.

	EEL RIVER BASIN										POINT ARENA BASIN												BODEGA BASIN									SANTA CRUZ BASIN	
Taxon	02	03	04	07	08	10	11	12	18	20	22	23	24	26	27	28	29	31	32	34	35	36	39	40	42	44	46	47	48	50	51	52	58	59
ANTHOZOA																																		
Stylatula sp.					X																			X								X	
Virgularia sp.			X																						X				X				
Sea Pen, unidentified																													x					
Anemone Type A							X																					X						
Anemone "Pink"																																		
Anemone, unidentified																											X			X				
Ceriantharia **Purple Tentacles"												x			X													X					
Ceriantharia (sp. nov. ?)							X																											
Ceriantharia, unidentified															x																			
ECHINODERMATA																																		
Florometra serratissima																									x									
Holothuroidea, Elasipoda															X						x													
Holothuroidea, Psolid																						X												
Allocentrotus fragilis		X									X		X	X									X		x					X			X	
Brisaster latifrons	X												X																					
Cross aster papposus								X														X			x									
Luidia (?) sp.							X																											
Zoroaster sp.																						X												
Starfish, unidentified							X									x							X						X		X		
Ophiomusium jolliensis														X			X																	
Ophioscolex corynetes																													X					
Ophiura sarsi		X		X		X		x	x		X	X	X	X			X	x	X	X	X		X						X					
MOLLUSCA																																		
Mitrella ap.				X											X																			
Snail, Fusinid or Muricid																																		X
Whelk, Buccinid				X																														
Nudibranchiata, Aeolid (sp. nov.?)																																		
Nudibranchiata, unidentified																																		

TABLE 3-26. (Cent inued)

Taxon	EEL RIVER BASIN									POINT ARENA BASIN													BODEGA BASIN							SANTA CRUZ BASIN	
	02	03	04	07	08	10	11	12	18	20	22	23	24	26	2?	28	29	31	32	34	35	36	39	40	42	44	46	47	48	50	51	52	58	59
CRUSTACEA																																		
Hermit Crab, unidentified			x																										X		x		
Shrimp, unidentified																													x		X		
UNIDENTIFIED INVERTEBRATA																																		
Zooplankton, Gelatinous																														X				
FISH																																		
Raja sp.																				X														
Anoplopomaf imbr i a										e																				X			
Scorpaena guttata																		x																
Scorpaenidae, unidenti f ied						X																											X	
Aprodon cortezianus							X																											
Lyopsetta exilis																														X	X			
Micros tomuspacificus																																X		
Pleuronectidae (Glyptocephalus or Microstomus																														X				
Unidentified																				X														

anthozoans; molluscs and crustaceans were relatively uncommon. These results also are consistent with observations from the hard substrate survey which included many soft substrate areas (Section 3.1). About 25 macroinvertebrate taxa were recorded, including an apparently new (i.e., undescribed) cerianthid anemone (Station SB12, 524 m, in the Eel River Basin) and an apparently new aeolid nudibranch (Station SB36, 549 m, in the Point Arena basin). Overall, the dominant epibenthic taxon was the brittlestar, Ophiura sarsi. This species occurred principally in the Eel River and Point Arena Basins, where it typically was most abundant 'at the deeper (≥ 389 m) stations (> 35 per photograph, corresponding roughly to densities > 35/m^2). Few sarsi were apparent in the Bodega Basin photographs (fewer than 10 per frame; usually none), and none were seen at the four stations photographed in the Santa Cruz Basin. Similarly, in the box core samples, O. sarsi occurred principally at the Eel River and Point Arena Basin stations, mainly between 300 m and 500 m deep. Other echinoderms were less common. Most displayed no clear distributional patterns; the exception was the sea urchin Allocentrotus fragilis, which occurred almost exclusively in the 329-554 m depth range in all four basins.

Overall, the subdominant taxonomic group was the sea pens, including the genera Stylatula and Virgularia (unidentified species). Sea pens occurred at stations in all basins except Point Arena Basin, but they appeared to be most common in Bodega and Santa Cruz Basins. Interestingly, sea pens were only found at the upper-slope stations between 174 m and 184 m deep. The lack of these sea pens at depths deeper than 184 m is generally consistent with observations from the hard substrate survey conducted partly in soft substrate areas, although in those areas, S. elongata was observed over a much broader depth range (e.g., 60-200 m) and has been reported to at least 260 m depth (SAIC, 1986). The differences between the hard substrate and soft substrate observations likely are related to the much larger viewing scale (30-60, 30-m long band quadrats per transect) afforded by the video camera used for the hard substrate survey; larger taxa such as sea pens typically are not surveyed well (abundances are underestimated) using camera systems with relatively small viewing areas. Approximate densities of sea pens were less than 5/m^2, except at Station SB50 in Bodega Basin (18/m^2), and Station SB58 in Santa Cruz Basin (9/m^2). Other

anthozoans occurred in all four basins, but they were relatively uncommon and displayed no clear distributional patterns.

Molluscs (nudibranchs and gastropod) were photographed at only six stations. They occurred in low numbers (usually $\leq$ 2 per photograph) at various depths in all four basins. Crustaceans (hermit crabs and small unidentified shrimp) likewise were relatively rare. They were photographed at only four of the deeper stations in the Eel River (one station), Point Arena (one station), and Bodega (two stations) basins. Notable differences between these results and the hard substrate survey observations are the relatively high densities (e.g., $25/0.3m^2$) noted for the shrimp Pandalus borealis/jordani along some of the Eel River Basin transects (see hard substrate Section 3.1 and Appendix D, Volume II).

3.2.4 Large-Scale Spatial Patterns

The Department of the Interior, through the Bureau of Land Management (BLM) and the Minerals Management Service (MMS), sponsored a series of studies of the benthic environment off the California coast during the years 1975-1988. Data from three of those studies were compared for this study:

1. The Bureau of Land Management's Outer Continental Shelf Survey (BLM-OCS) (e.g., Fauchald and Jones, 1976, 1977);
2. The Phase I reconnaissance of the Santa Maria Basin and western Santa Barbara Channel (SAIC, 1986); and
3. The present Central and Northern California Reconnaissance Program (CARP).

One of the goals of the data analysis was to put the present study into the context of a larger geographical region. To achieve this goal, an analysis of large-scale spatial patterns in the soft substrate benthos along the California coastline was conducted by combining data from the present study with data from those previous studies.

The analysis used the same multivariate techniques used in the analysis of community patterns in the CARP data alone (see Section 3.2.3): ordination and clustering to reveal patterns in the biological data, and multiple regressions to examine relationships between the biological patterns and environmental variables.

Overview

The multivariate analyses of the combined data demonstrated that the benthic communities off the coast of California are organized primarily according to depth and secondarily according to geographical location (i.e., latitude).

Three sets of station groups were separated in the cluster analysis at the highest levels of dissimilarity:

- Shelf and upper-slope stations, typically shallower than about 200 m (Davis, 1972; Menard, 1964);
- Mid-slope stations, typically within about the 200-450 m range; and
- Deep-slope and basin stations, typically deeper than about 500 m.

Stations corresponding to those three depth ranges separated along ordination Axis 1, which accounted for the largest amount (25.7%) of the variability in the biological data. Multiple regression analysis indicated that depth was strongly correlated with Axis 1 scores ($\hat{R}^2 = 0.74$); additional environmental variables provided little improvement in the correlation.

Within the three larger groupings of stations by depth, eight station groups, reflecting geographic and smaller-scale depth separations, were distinguished at lower levels of dissimilarity in the cluster analysis (Figure 3-42). These groups were:

- Shelf and upper-slope groups corresponding to BLM (Station Groups 1 and 2) and Phase I (Station Group 3) shelf stations, shallower than about 100 m, and CARP shelf and upper-slope stations (Station Group 4), shallower than about 200 m;

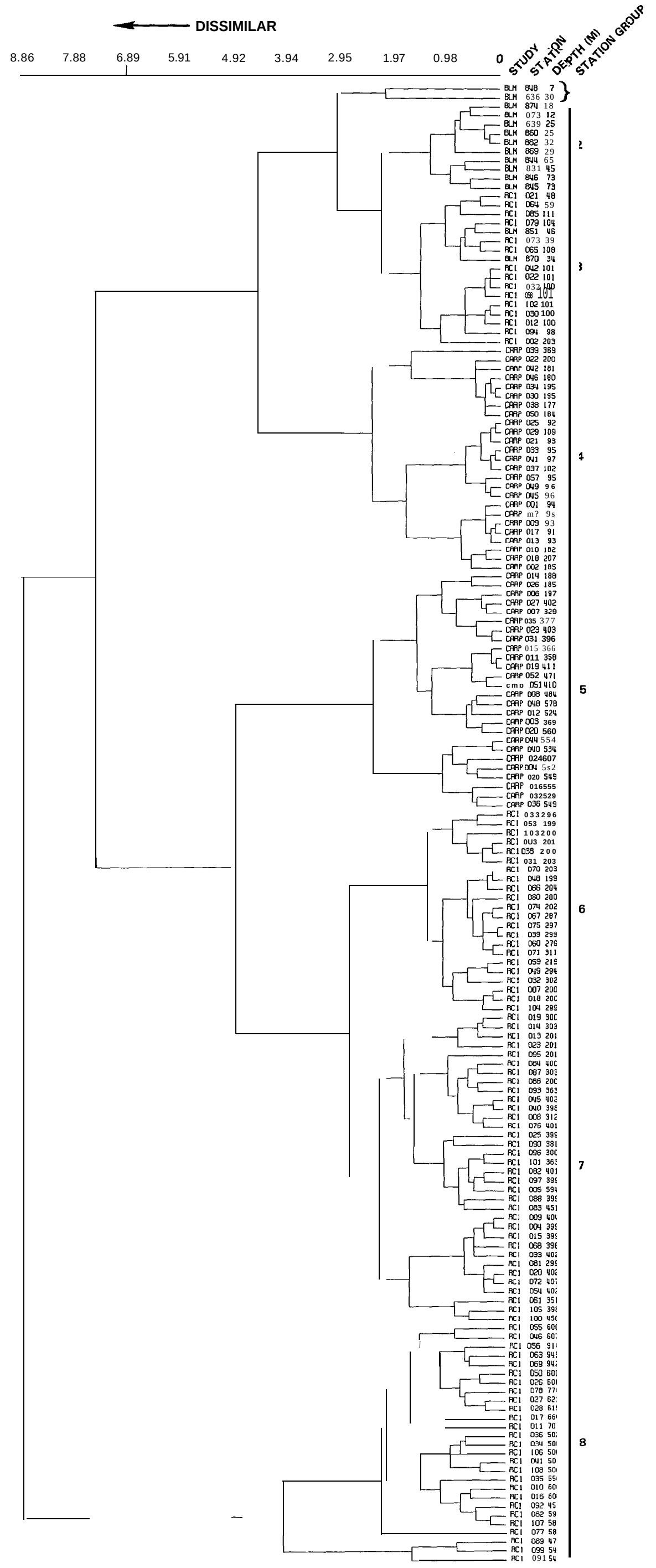


FIGURE 3-42. STATION DENDROGRAM FROM THE CLUSTER ANALYSIS OF CARP, BLM, AND PHASE I STATIONS. The eight major cluster groups are identified by numerals (1-8) to the right of the dendrogram. Stations are identified by survey, station number, and depth (m); for example, BLM 8487 refers to BLM Station 848,7 m depth.

- o Mid-slope (200-450 m) stations corresponding to a set of deeper CARP slope stations (Station Group 5), Phase I slope samples in the approximately 200-300 m depth range (Group 6), and Phase I slope samples in the approximately 300-450 m depth range (Station Group 7); and

- o The deepest Phase I slope and basin stations (Station Group 8).

Although these groups largely reflected depth, the separation of all CARP stations from all BLM and Phase I stations also clearly reflected a north-south difference in infaunal community structure. Ordination showed that the CARP stations to the north were separated from the BLM and most Phase I stations to the south along ordination Axis 2. This axis, which accounted for 18.6% of the variability in the biological data, thus reflected the major alongshore trend in the infaunal assemblage patterns (see also Section 3,2.5). Multiple regression analyses indicated only weak correlations of sediment characteristics and station depth with Axis 2 scores.

The presence of minor subgroups within the station group of shallow CARP stations (Station Group 4) suggested that Cape Mendocino may represent a zoogeographic boundary, the infaunal assemblages inhabiting the shelf and upper slope in the north being somewhat different from those in the south. A similar boundary condition at Point Conception was not particularly apparent, but that may reflect the limited geographic coverage of the area to the south of Point Conception afforded by the data incorporated in this study.

The cluster analysis of infaunal taxa identified 15 principal taxonomic groupings that reflected depth, geography, and combinations of both. About half (8) of the taxonomic groups primarily reflected station depth within one of the two major geographic areas studies (CARP versus BLM + Phase I) ; five groups were composed of taxa that tended to occur within fixed depth ranges in all study areas; one group contained taxa that tended to occur everywhere; and one 'group of three taxa rarely occurred, except at a single Phase I deep-slope station. Taxa characteristic of the deeper continental slope tended to be rather widespread around Point Conception and/or along the northern California slope.

Detailed Results

Eight principal station groups were delineated by the cluster analysis of samples (Figure 3-42). At the highest level of dissimilarity, a group (Station Group 8) composed of the deepest Phase I stations (depth range 451-945 m; 85% of them deeper than 500 m) was separated from all other sites. That pattern indicated that the infaunal assemblages at the Phase I deep slope and basin stations had less in common with those at the other sites than the assemblages at any of the other 'stations had with each other. This relatively large difference was reflected in the separation at a high level of dissimilarity of taxonomic Group O (Figure 3-43), the characteristic deep-slope and basin taxa, from all other groups in the cluster analysis of taxa.

Four groups of shelf and upper-slope stations (Station Groups 1 through 4; depth range 7-369 m, 93% of them shallower than 200 m) were separated from three groups of mid-slope stations (Station Groups 5 through 7; depth range 185-607 m, 79% of them between 200 and 450 m) at the second highest level of dissimilarity. Ordination (Figure 3-44) showed a separation of these three major depth groupings along ordination Axis 1, with shallower stations to the left, deeper stations to the right, and only a few minor overlaps, principally between the lower mid-slope (Station Group 7) and deep-slope and basin (Station Group 8) station groups. Axis 1 accounted for almost 26% of the variability in the biological data. Multiple regressions of station depth and sediment variables on Axis 1 scores indicated that depth was strongly correlated with the axis scores ($R^2 = 0.74$), and that inclusion of sediment variables yielded little improvement in the correlation. This result and the reasonably clear separation of the major depth groupings along Axis 1 suggest that station depth is an important factor in the major community patterns.

Continental Shelf and Upper Slope Assemblage

Among the four continental shelf and upper-slope station groups (Station Groups 1 through 4), the CARP deep-shelf and upper-slope samples (Station Group 4) were distinct from all others (Figure 3-44). The CARP station group was clearly separated from the other shallow-station groups along ordination Axis 2

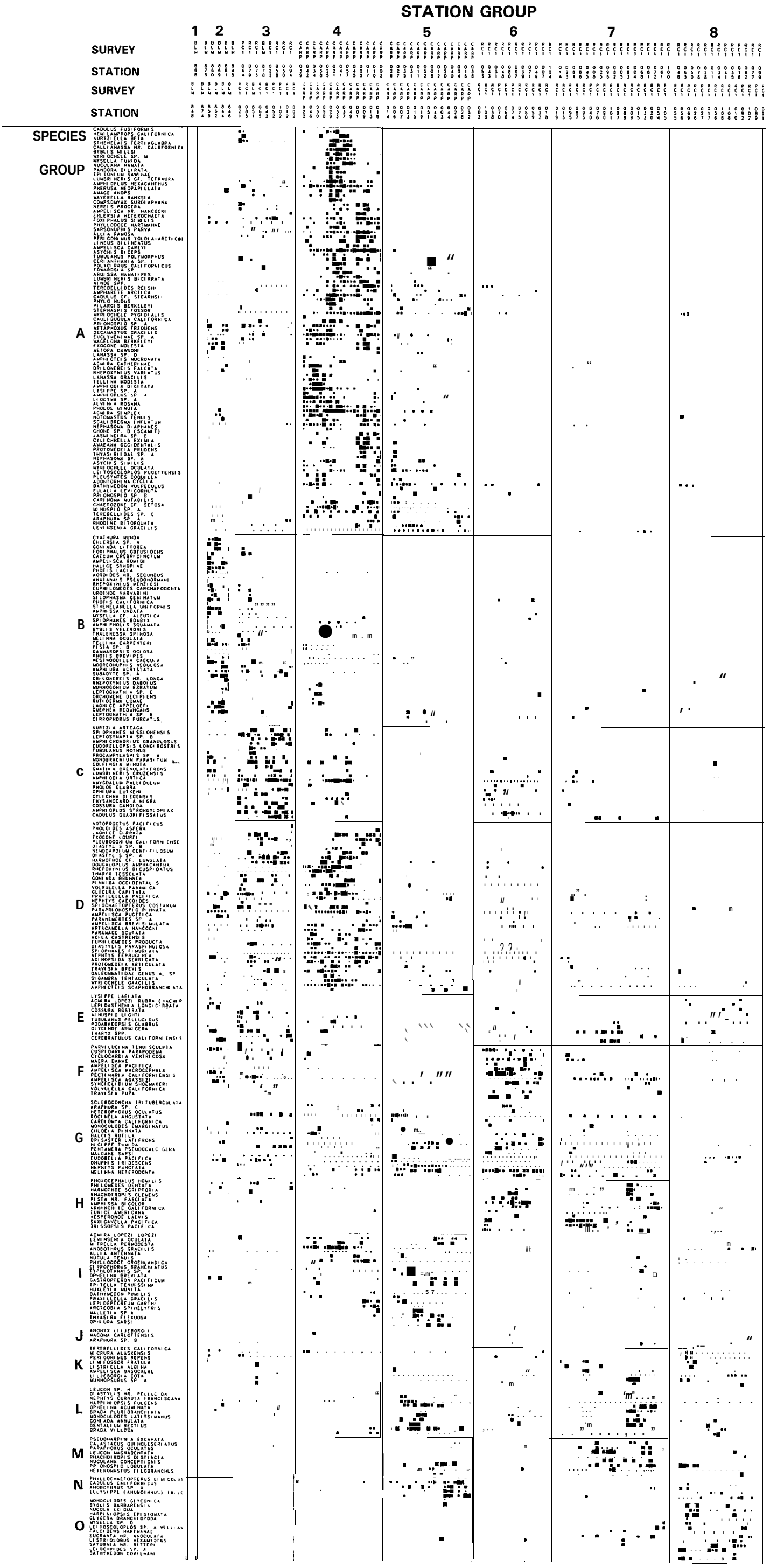


FIGURE 3-43. TWO-WAY COINCIDENCE TABLE FROM THE CLUSTER ANALYSIS OF CARP, BLM, AND PHASE I SAMPLES. Stations are listed across the top of the table; taxa are listed down the left side. Station groups are identified by numerals at the bottom (these correspond to the station groups shown in Figure 3-42); taxon groups are identified by letters down the right side of the table. Higher levels of relative abundance are denoted by larger square symbols.

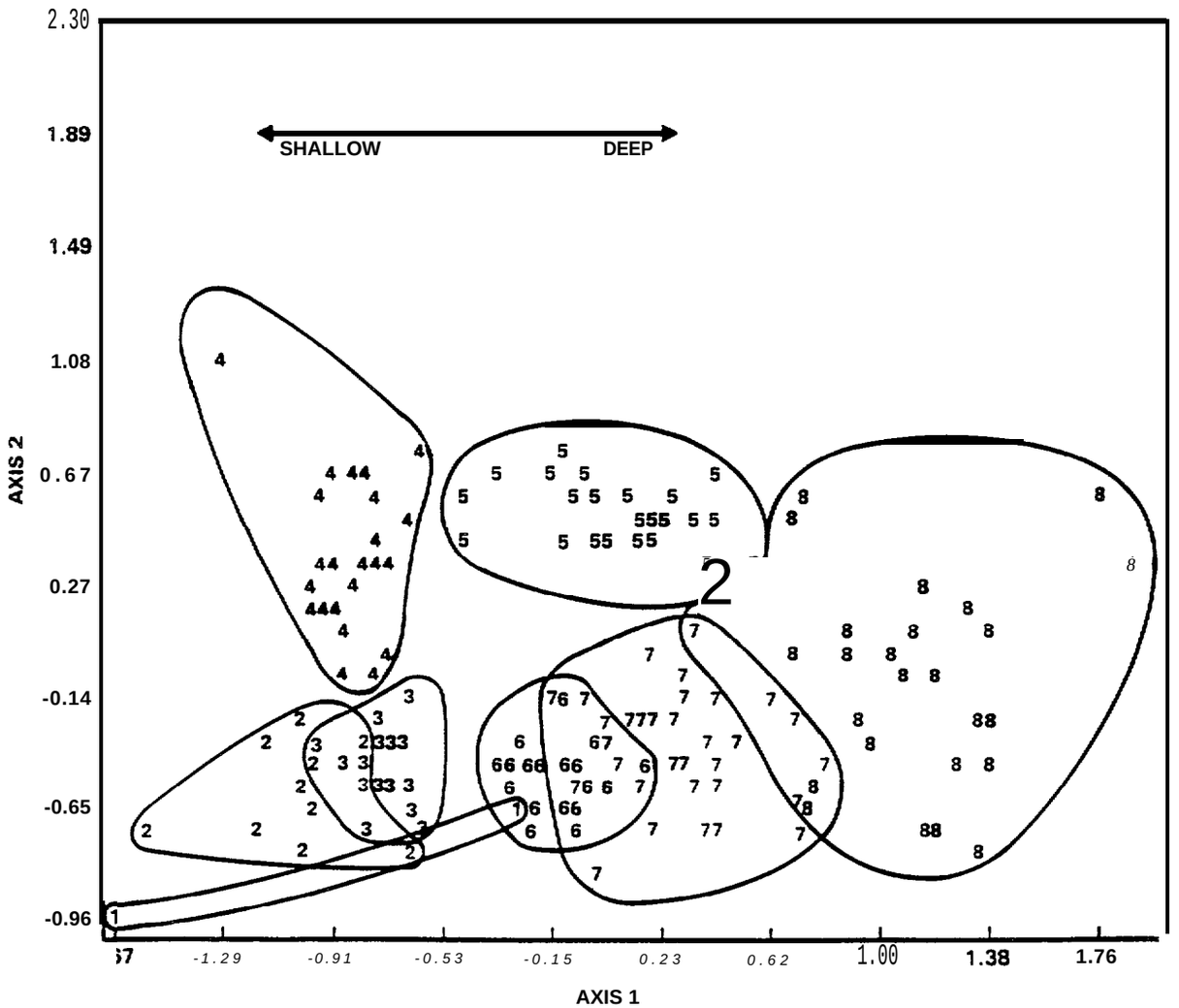


FIGURE 3-44. PLOT OF THE CARP, BLM, AND PHASE I STATIONS IN THE SPACE DEFINED BY ORDINATION AXES 1 AND 2. The envelopes enclose the stations included in each of the eight major station groups identified in the cluster analysis.

(Figure 3-44), reflecting the major alongshore pattern in the biological data the separation of the shallow northern Californian assemblages from those i the general vicinity of Point Conception. The species in the cluster analysi distinguished a large group of taxa (Taxonomic Group A) that were mos characteristic of the CARP shelf and upper-slope stations (Figure 3-43).

Among the groups of shallow stations in the Point Conception vicinity, a pai of BLM stations was separated as Station Group 1 from all others on the basi of the depauperate faunas at those two stations; the remaining stations wer separated into a set of 10 BLM stations (Station Group 2) along the continents shelf near Santa Cruz and Anacapa Islands (Figure 3-45) and a set of 17 Phase and BLM stations (Station Group 3), most of them located on the shelf regio between Point Estero and Santa Barbara.

The two stations in Station Group 1 appeared to have little in common apar from depauperate faunas. Only four species, all bivalves, includin Parvilucina tenuisculpta, Tellina carpenter, Macoma carlottensis, an Nemocardium centifilosum were at Station 868, off the northern shore of Sant Cruz Island, and only 14 species occurred at Station 848, near Port Hueneme.

In Station Group 2, subsets of shallower (12-32 m) and deeper (45-73 m) shel stations were distinguished. These subgroups tended to separate alon ordination Axis 1, suggesting a minor depth-related biological pattern although inspection of the cluster analysis two-way coincidence table (Figur 3-43) suggested that the subgroups differed little in their taxonomi composition. Station Group 2 as a whole was characterized by taxa belonging t taxonomic Cluster Group B. Crustaceans, especially amphipods, dominated th group (56% of the taxa), and polychaetes were subdominant (29% of the taxa) These taxa (e.g., the amphipod Urothoe varvarini and the polychaete Goniad littorea) were, with some exceptions, more abundant at the BLM shelf statior than elsewhere.

Station Group 3, composed of mid-shelf to deep-shelf stations (mostly 34 111 m), contained two minor subgroups that could be discerned on the static dendrogram but which did not separate on any of the ordination axes examine

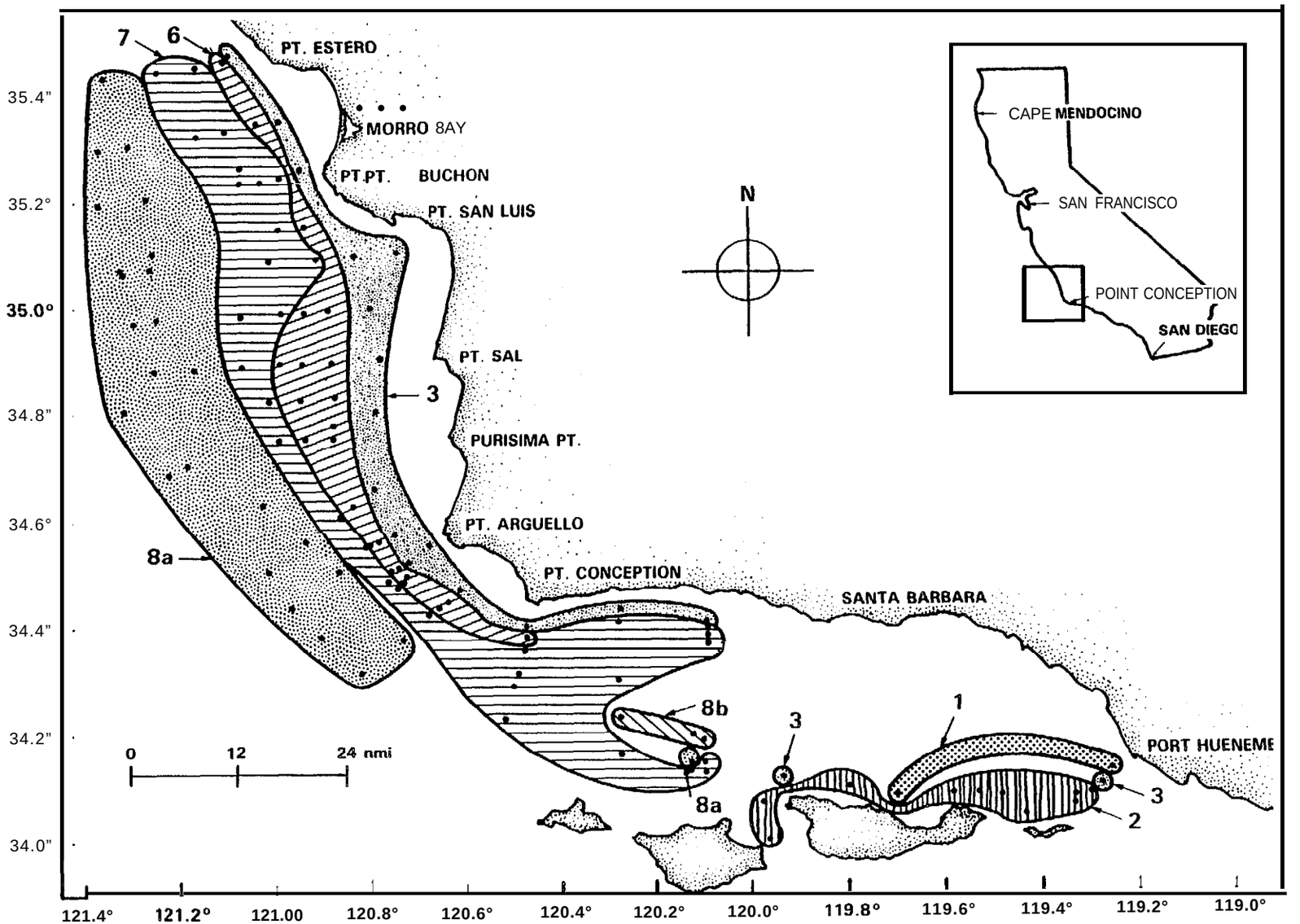


FIGURE 3-45. MAP OF THE SIX MAJOR STATION CLUSTER GROUPS OF BLM AND PHASE] STATIONS. Two subgroups (8a and 8b) of the deep Phase I station group are shown.

and did not appear to represent biologically meaningful entities. Statio Group 3 as a whole was characterized by a diverse soft substrate fauna including representatives from all but one of the 15 taxonomic cluster group, (Figure 3-43). Taxonomic Group C, in particular, and to a somewhat lesse extent Taxonomic Groups D, E, and F, characterized this station group. Th species in Taxonomic Group C were well distributed over seven major taxonomi categories: 25% of the taxa were echinoderms, 20% molluscs, 20% polychaetes 15% crustaceans, 10% sipunculids, and 5% each of hydroids and nemerteans Taxonomic Groups D and E were strongly dominated by polychaetes (54% and 73% o the taxa, respectively); crustaceans were subdominant in Taxonomic Group (27% of the taxa), while nemerteans were subdominant in Taxonomic Group E (18 of the taxa). Echinoderms and molluscs were not particularly well represent in either group. Taxonomic Group F was dominated by crustaceans (45% of th taxa) and molluscs (36% of the taxa). Many of the taxa in Taxonomic Groups and D, including the brittlestar Amphiodia urtica and the cumacean Diastyli sp. A, were common at the CARP shelf and upper-slope stations as well as at th Phase I shelf stations. The appearance of these taxa in all of the BLM/MM programs indicated that they have broad geographic ranges.

The separation of the Phase I shelf stations (Station Group 3) from the Phase upper-slope stations (Station Group 6) is analogous to the depth separation shown for the more intensively sampled CAMP (Phase II) stations (Battelle *1988)*. Cluster analyses on the Phase II infaunal data, which were obtaine with different sample processing methods that resulted in retention of muc smaller organisms (in addition to the larger organisms utilized in the presen study), separated stations along the 90-m isobath from those in about th 150-160-m depth range. Likewise, Phase I samples from depths that most closel approximated the Phase 11 depth were separated in the present analysis int shallower (Group 3, mostly 34-111 m) and deeper (Group 6, mostly 199-299 m station groups. Thus, the major spatial pattern appears to be largel independent of sampling methodology and is instead a real biological gradient.

Station Group 4 contained three subgroups of stations from the CARP progra (Figure 3-46). South of Cape Mendocino, the subgroups reflected dept separations, but north of the Cape they did not. The subgroups consisted c

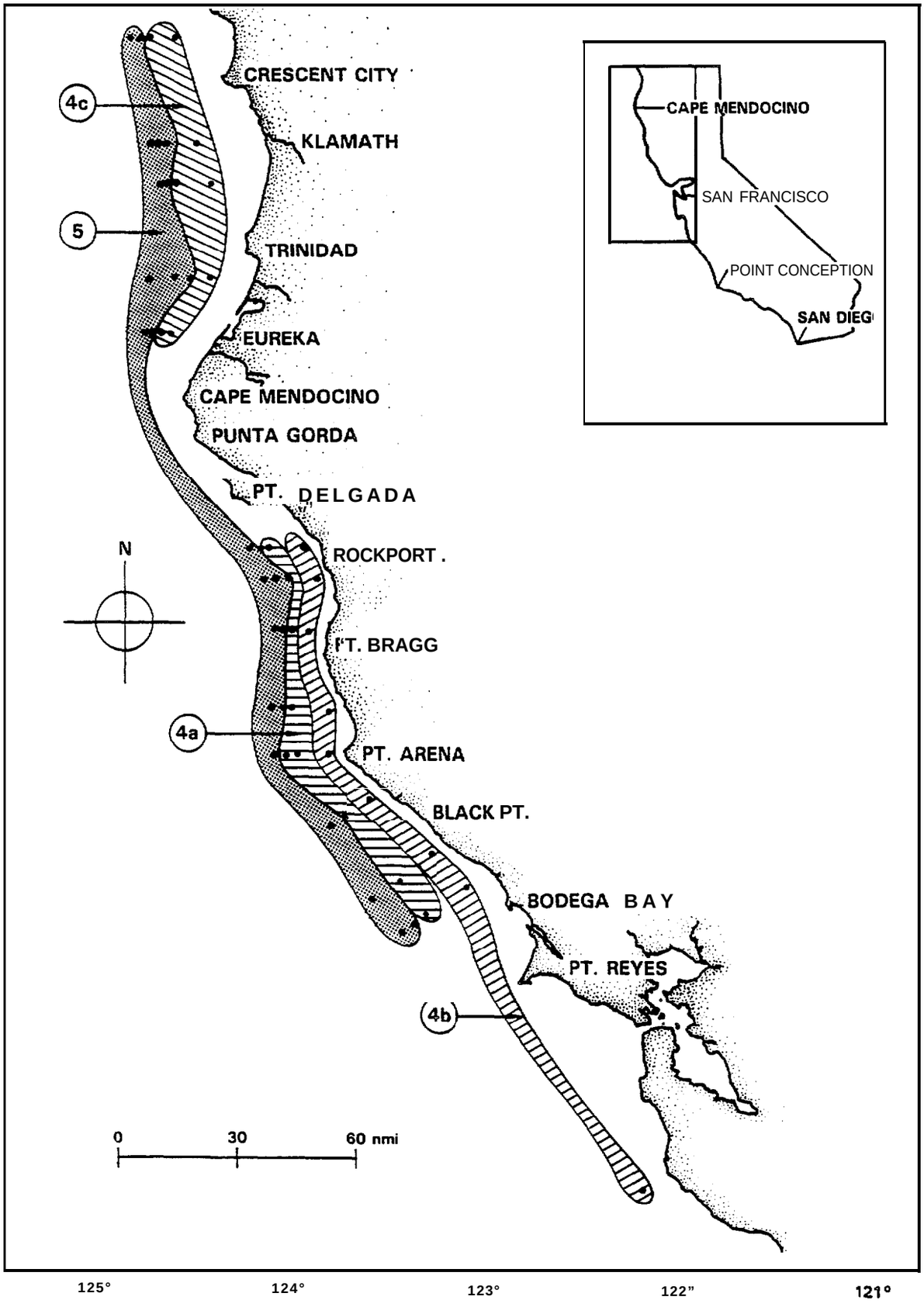


FIGURE *3-46.* MAP OF THE CLUSTER GROUPS OF CARP STATIONS, SHOWING THE THREE SUBGROUPS (4A, 4B, 4C) OF THE CONTINENTAL SHELF AND UPPER SLOPE STATION GROUP 4.

the upper-slope stations south of Cape Mendocino (subgroup 4a), the deep-shel stations south of Cape Mendocino (subgroup 4b), and the deep-shelf an upper-slope stations to the north of Cape Mendocino (subgroup 4c). Th stations north and south of Cape Mendocino were separable along both ordination axes. In addition, the separation between the shallower and deeper station. south of Cape Mendocino was along Axis 2, thought to reflect primarily th north-south pattern in the biological data, rather then along Axis 1, the dept gradient. The separation between the two subgroups south of Cape Mendocino an the subgroup north of the cape may refelct the differences associated wit sediment character noted in Section 3.2.3. A single mid-slope station (Statio 39, from 369 m) clustered with the shelf and upper-slope stations in Statio Group 4. This station was well separated in ordination space from th remainder of Station Group 4 and from mid-slope CARP stations in Station Grou 5, suggesting only weak affinities with either group. Station 39 resemble mid-slope CARP stations having relatively few infaunal taxa, but the taxa tha did occur tended to be more characteristic of the shallower Station Group stations (e.g., the bryozoan Caulibugula californica and the polychaete Amphicteis mucronata and Laonice appeloefi) .

Station Group 4 as a whole was characterized by a diverse fauna that include taxa from all but one of the 15 cluster groups of taxa (Figure 3-43) Taxonomic Group A, in particular, characterized Station Group 4; Taxonomi Groups D and G were also well represented in this station group. Taxonomi Group A was dominated by polychaetes (53% of the taxa); crustaceans an molluscs were the subdominant taxonomic categories (17% and 16% of the taxa respectively) . Taxa in Taxonomic Group A occurred almost entirely on th continental shelf and upper slope, mainly in the CARP area. (Many of thes Group A taxa are common off southern California as well; however, no station in southern California south of Santa Cruz Island were included in thi analysis) . Taxa in Taxonomic Groups D and G were more cosmopolitan, wit representatives occurring at all depths above about 450 m and throughout bot the CARP and the BLM plus Phase I areas. Members of Taxonomic Group D predominantly polychaetes (e.g., Laonice cirrata) and crustaceans (e.g. Pinnixa occidentals) typically were most abundant on the shelf and upper slop in both major study areas; whereas, the taxa of Taxonomic Group G (44

crustaceans, 31% polychaetes, and 13% each of molluscs and echinoderms) tended to be more common at the upper- and mid-slope stations in both areas.

Inspection of the cluster analysis two-way table (Figure 3-43) suggested that the north-south differences among the subgroups in Station Group 4 were attributable mainly to patterns of occurrence of some of the taxa within Taxonomic Groups B, C, and G that were more characteristic of the Point Conception vicinity than of the CARP area. Those essentially southern species, for example, the hydroid Monobrachium parasitum and the heart urchin Brisaster latifrons, were relatively common in stations south of Cape Mendocino, but absent from stations to the north. The shallower (shelf) vs. deeper (upper-slope) distinction between stations south of Cape Mendocino was largely attributable to patterns of occurrence of species within Taxonomic Group A. For example, the snail Kurtziella beta and the ghost shrimp Callianassa nr. californiensis were absent from the slope but common on the shelf, whereas the polychaete Acmira catherinae and the brittlestar Amphiodia digitata were common on the upper slope, but relatively rare on the shelf. Amphiodia urtica (Taxonomic Group C) was abundant on the shelf and rare on the slope, in contrast to A. digitata's pattern (note, however, that these may not be distinct species, as discussed in Section 3.2.3).

Mid-Slope Assemblages. Within the set of three mid-slope (200 to 600 m) station groups, the CARP stations (Station Group 5) were separated from two sets of Phase I stations (Station Groups 6 and 7; Figure 3-42). Furthermore, the mid-slope CARP station group was more clearly separated from the mid-slope Phase I station groups along ordination Axis 2 than was the case with the shallower station groups (Figure 3-44), suggesting that the distinctions between the mid-slope infaunal assemblages of northern California and the Point Conception vicinity were stronger at mid-slope depths than at shelf and upper-slope depths. Inspection of the cluster analysis two-way table indicated that this distinction among mid-slope assemblages was based primarily on taxa belonging to Taxonomic Groups A, I, and N, which were relatively common at the CARP stations but rare in the Phase I station groups, and taxa from Taxonomic Groups F and H, which were relatively common in Phase I station groups but rare in the CARP station group.

Station Group 5, composed of mid-slope CARP stations (185 to 607 m, 88% deeper than 200 m), contained subgroups of stations mostly shallower than 500 m (83%) and deeper than 500 m. In addition to these minor depth groupings, stations north of Cape Mendocino tended to have slightly higher ordination Axis 2 scores than those south of Cape Mendocino, suggesting a subtle geographic distinction. Station Group 5 as a whole was characterized by a moderately diverse fauna, including representatives from all but one of the 15 taxonomic cluster groups. The fauna was not, however, nearly as diverse as that characterizing the CARI shelf and upper-slope stations (Station Group 4). Only Taxonomic Groups G, I, L, and N were well represented in Station Group 5 as a whole (Figure 3-43). Members of Taxonomic Groups G and L (50% polychaetes, 40% crustaceans, 10% molluscs) were relatively abundant at Phase I stations (Station Group 6) as well at the CARP stations of Station Group 5. Taxonomic Group I (43% polychaetes, 33% molluscs, 19% crustaceans, 5% echinoderms) was largely restricted to the CARP stations, but was relatively prominent on the upper slope (e.g., station Group 4) as well as at deeper stations of Station Group 5. Only the six taxa of Taxonomic Group N (50% polychaetes, 33% molluscs, 17% crustaceans) occurred predominantly at the CARP Station Group 5 stations rather than elsewhere.

The two mid-slope (200-600 m) Phase I station groups (6 and 7) were only partially separated from one another along the depth gradient represented by ordination Axis 1 (Figure 3-44). This reflects the overlapping depth ranges of the two groups: Station Group 6 stations ranged between 199 and 311 meters and Station Group 7 stations was between 200 and 594 m (79% between 300 and 450 m). Distinctions between the two station groups were based primarily on taxa belonging to Taxonomic Groups C and F that were relatively common in Station Group 6 but rare in Station Group 7, and Taxonomic Groups L and M that were common in Station Group 7 but rare in Station Group 6.

Station Group 6, consisting of 22 Phase I stations between Point Estero and Point Conception (Figure 3-45), contained two minor subgroups of stations north of Point Arguello, and another consisting predominantly (80%) of stations between Point Arguello and Point Conception (Figure 3-45). Inspection of the cluster analysis two-way table (Figure 3-43) indicated that the differences in

faunal assemblages between the subgroups consisted of only minor variations in relative abundances of a few taxa, principally in Taxonomic Groups C, F, and H.

Station Group 6 as a whole contained some taxa from all 15 taxonomic cluster groups; most of these groups, however, were poorly represented (Figure 3-43). Taxonomic Groups F and G, and to a lesser extent, Taxonomic Groups C and H, characterized Station Group 6. Taxonomic Group F taxa (predominantly crustaceans and molluscs) typically were most abundant in Station Group 6, although they tended to be relatively abundant at shallower depths as well. These taxa included the amphipods Ampelisca macrocephala and A. agassizi, and the mollusc Parvilucina tenuisculpta. Taxonomic Group G taxa were also well represented in Station Group 6, but they tended to be common over a broad depth range in both the northern and central California study areas as well. Only about half of the taxa in Taxonomic Group C were abundant in Station Group 6, and all of those were more characteristic of the shelf and upper slope than of the mid-slope region (e.g., the brittlestar Amphioplus strongyloplax). Only Taxonomic Group H (primarily polychaetes and crustaceans, for example the polychaete Hesperonoe laevis and the crustacean Phoxocephalus homilis) was largely restricted to the mid-slope Phase I stations. These species were equally characteristic of both the shallower mid-slope stations in Station Group 6 and the deeper mid-slope stations in Station Group 7 (Figure 3-43).

Station Group 7 contained 34 Phase I stations along the continental slope from Point Estero to Santa Barbara (Figure 3-45). Although two minor subgroups were discernible on the station dendrogram (Figure 3-42), they reflected neither depth nor geographic patterns within Station Group 7, and showed little evidence of separation along any of the ordination axes examined.

Station Group 7 as a whole contained taxa from all 15 taxonomic cluster groups, but only taxa belonging to the small Taxonomic Groups G, H, L, and M were relatively abundant. Among these four Taxonomic groups, only Taxonomic Group M (5 crustaceans, 2 polychaetes, 1 mollusc) was more characteristic of Station Group 7 than of any other station group. Examples of these taxa are the mud shrimp Calastacus quinqueseriatus and the amphipod Paraphoxus oculatus. Taxonomic Group G was well represented in all of the continental slope station

groups; whereas, Taxonomic Group H was characteristic only of the two Phase mid-slope station groups.

Deep-Slope and Basin Assemblages. The cluster analysis of stations distinguished a single major group (Station Group 8) of deep (> 450 m) Phase stations north of Point Conception and within and adjacent to the Santa Barbar Basin (Figure 3-42). Within this group, three stations in and near the Sant Barbara Basin formed a minor subgroup (8b) that differed somewhat from th remaining stations (Figure 3-45). Ordination clearly showed that the tw stations within the Santa Barbara Basin were separated from the remainder o Station Group 8 along ordination Axis 1, but the station adjacent to the basi (Phase I Station 89) was not separated along either of the ordination axe examined. These stations were faunistically depauperate. The nearly abioti status of the two stations in the basin is reflected in their clear separatio from the remainder of Station Group 8 in the ordination. Smith et al. (1988 speculated that the depauperate nature of the Santa Barbara Basin infauna ma be due to low dissolved oxygen concentrations.

Although Station Group 8 as a whole contained taxa from all 15 taxonomi cluster groups, only Taxonomic Groups K and O were well represented. Taxonomi Group K was strongly dominated by crustaceans (63% of the taxa); polychaetes nemerteans, and hydroids each contributed 13% of the taxa. Species i Taxonomic Group O, however, were distributed more equally (polychaetes, 38% crustaceans, 31%; molluscs, 23%; echiuroids, 8%). Taxonomic Group K tended t occur at shallower depths as well as at the deep Phase I stations, in som cases extending onto the continental shelf (e.g., the polychaete Terebellide californica and the nemertean Micrura alaskensis).

In contrast, the 13 taxa forming Taxonomic Group O were largely restricted i the deep-slope Phase I stations, and thus characterize the station group Examples of these taxa are the amphipod Bathymedon covilhani and the clam Saturnia nr. ritteri and Nucula exigua.

3.2.5 New Taxa and the Zoogeography of Selected Infauna

This section considers new taxa and the zoogeographic distribution of selected species from the BLM-OCS, Phase I, and CARP studies.

New Taxa

Many new invertebrate taxa were collected during these three studies. New species collected during the BLM-OCS study were simply listed as undescribed taxa in Fauchald and Jones (1977). New species collected from the Phase I survey have been cataloged utilizing the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) format. All new species from the CARP survey are listed in Table 3-27. Undescribed taxa are designated by a letter name (e.g., Euphysa sp. A) or a number (e.g., Enteropneusta sp. 1). Those species listed in Table 3-27 as new from the CARP survey have not been recorded from other surveys in California. Other undescribed species collected during the CARP survey, but not included in Table 3-27, were either collected during the BLM-OCS and/or Phase I surveys or are recognized by SCAMIT.

No new polychaete or echinoderm taxa were recorded from the CARP survey. Polychaeta is the most species-rich group of benthic infaunal organisms, and it is interesting that no new species were collected. This may be attributed to the fact that the polychaete fauna has been described extensively. The echinoderms contain fewer species than most groups, therefore, it is less surprising that no new species from this group were found.

A group which has fewer new species than expected was the anemones. Only five new infaunal anemone species were found in the CARP samples, as compared with nine new species from Phase I and many more from the BLM-OCS survey. Infaunal anemones usually have localized distributions, and many more new species were expected from the poorly-known CARP area. The reasons for this paucity of new species are unknown.

Crustacea contributed the most new species, primarily because the level of taxonomic work for this group is not as complete as that for other large

TABLE 3-27. NEW SOFT SUBSTRATE TAXA COLLECTED DURING CARP.

CNIDARIA (8 species)
- Edwardsia sp.
- Ceriantharia sp. S
- Anemone sp. 114
- Anemone sp. 116
- Anemone sp. 117
- Anemone sp. 120
- Hydroid Family A, Genus A, species A
- Stylactis sp. A

HEMICHORDATA (3 species)
- Enteropneusta sp. 1
- Enteropneusta sp. 2
- Saccoglossus sp. A

MOLLUSCA (15 species)
- Mya sp. A
- Yoldia sp. A
- ?Axinulus sp. A
- ?Tomburchus sp. A
- Malletia sp. A
- ?Montacutidae sp. A
- Neomeniomorpha sp. B
- Cuspidaria sp. A
- Cuspidaria sp. B
- ?Odontogena sp. A
- Adontorhina sp. A
- Psephidia sp. A
- Margaritas sp. A
- Trophon sp. A
- Buccinum sp. A

PLATYHELMINTHES (6 species)
- Stylochidae sp. A
- Stylochidae sp, B
- Stylochidae sp. C
- Stylochus Sp.
- Pseudoceros sp. A
- Spinicirrus sp. A

NEMERTEA (1 species)
- Drepanophorus sp. A

CRUSTACEA (32 species)
- Tanaidacea sp, C
- Cryptocope sp. C
- Cryptocope sp. E
- Cryptocope sp. F
- Leptognathia sp. G
- Harbansus sp. C
- cf. Baeonectes sp. A
- cf. Belonectes sp. A
- Caecianiropsis sp. A
- Gnathia sp. A
- Gnathia sp. B
- Gnathia sp. C
- Prochelator sp. A
- Dyopedos sp. A
- Liljeborgia sp. A
- Mysidella sp. A
- Melphidippa sp. A
- Bathymedon sp. A
- Phippsiella sp. A
- Campylaspis sp. D
- Munneurycope sp. A
- Cumella sp. C
- Diastylis sp. D
- Eudorella sp. B
- Leucon sp. N
- Leucon sp. Q
- Metopa sp. A
- Monoculodes sp. A
- Pachynus nr. barnardi
- Monoculodes nr. packardi
- Parasterope sp. A
- Vaunthompsonia sp. C

groups, and the fact that new areas and depths were sampled. Little-known groups such as cumaceans and tanaids contributed heavily to the total numbers of new species. Several new species of Mollusca also were found, primarily small clams belonging to poorly known families such as the Thyasiridae. Additionally, several new flatworm (Platyhelminthes) taxa were discovered, primarily because the level of taxonomic analysis of the group for this survey was more extensive than analyses performed during previous studies.

Zoogeography

The CARP survey studied the northern and central California OCS areas, including the Eel River Basin, the Point Arena Basin, Bodega Basin, and Santa Cruz Basin. The central California area, from Point Estero to the western Santa Barbara Channel, also was sampled during the Phase I survey. For the purposes of this study, the southern California area was represented only by stations in the eastern Santa Barbara Channel sampled during the BLM-OCS study. Zoogeography of the soft substrate shell and slope infauna of California was examined by analyzing patterns of distribution of selected species across all three data sets. The species lists from the three surveys were merged (see Section 2,6.2) into a single list of 1,095 species names that represented current SCAMIT nomenclature. The relative abundances of those species were listed on a table that gave the stations, arranged in order from south to north, as column headings, and the species names as rows. Relative abundances of the species were represented symbolically below each geographic region (see 2.6.2); the zoogeographic patterns were suggested by the patterns of the symbols .

The data considered here provide only a partial view of distributions of many of the species when compared to their published ranges. Other caveats are:

1. Not all station data, especially those from the ELM survey, were included primarily because of incomplete identifications and methodological differences;

2. Different levels of taxonomic resolution were achieved on the three surveys (e.g. , flatworms were not identified beyond phylum in the first two surveys);

3. Some species appeared in one data set but not in another becaus of changes in habitat with latitude. For example, the anemon Pentactinia californica occurs only intertidally along th central California coast and subtidally in southern California because its distribution follows isotherms.

The species distribution data do not suggest clearly defined faunal province along the California coastline. Approximately 15% of the 1095 specie considered in this analysis were common to the CARP, Phase I, and BLM-OC survey areas (Table 3-28); this subset includes, with few exceptions, the mos abundant species. In comparison, species from the MMS studies that occurre along the entire coast (Table 3-29) also have been found in shallower wate from the County Sanitation Districts of Orange County 301(h) study (Tabl 3-30). Although the most abundant taxa typically are widespread along th California coast, there is some evidence of zoogeographic separation betwee the CARP and the two more southerly study areas. In each of the three basin north of San Francisco, several species apparently reach their southernmost limits, at least in the depth range under consideration (see Table 3-31) Species typical of this pattern include Axinulus sp. A and Malletia sp. A i the northern Bodega Basin, Mitrella casciana and Monoculodes nr. packardi i the Point Arena Basin, and several polychaetes in the Eel River Basin.

The most common northern bivalve species was the taxodont clam Huxleyia munita which ranked among the ten most abundant species in two of the three basin (Table 3-32). The ophiuroid Amphioplus sp. A, which was common in all thre northern basins, was the only echinoderm that seemed to have a primaril northern distribution. The ostracod Euphilomedes carcharodonta and the bivalv Parvilucina tenuisculpta, on the other hand, have ranges primarily in souther and central California (Table 3-33).

Lists of the number of species unique to each of the surveys (Table 3-28) suggest a degree of endemism in each area. In fact, however, the majority o those taxa are either new species or very rare species whose single occurrence are not strong indications of endemism.

TABLE 3-28. NUMBER OF SPECIES UNIQUE TO EACH OF THE THREE SURVEY AREAS (CARP, PHASE I, BLM-OCS), AND THE NUMBER COMMON TO ALL THREE AREAS.

BLM-OCS	116	10.5%	(14 stations)
PHASE I	285	26%	(98 stations)
CARP	265	24%	(51 stations)
Total species in common	161	15%	
Total species considered	1095		

TABLE 3-29. SPECIES THAT OCCURRED ALONG THE ENTIRE CALIFORNIA COASTLINE.

MOLLUSCA
- Balcis rutila
- Mitrella permodesta
- Dentalium rectius
- Cyclocardia ventricosa
- Acila castrensis
- Nucula tenuis
- Galeomatidae Genus A sp. A
- Tellina carpenter
- Tellina modesta

POLYCHAETES
- Terebellides reishi
- Cirrophorus branchiatus
- Ehlersia heterochaeta
- Allis ramosa
- Ampharete arctica
- Chaetozone cf. setosa
- Levinsenia gracilis
- Myriochele gracilis
- Chloeia pinnata
- Nephtys cornuta franciscana
- Pectinaria californiensis
- Glycera capitata
- Minuspio lighti
- Paraprionospio pinnata
- Spiophanes missionensis
- Spiophanes fimbriata
- Prionospio sp. A
- Exogone sp. B

CRUSTACEA
- Araphura sp. A
- Eudorella pacifica
- Diastylis nr. pellucida
- Ampelisca brevisimulata
- Procampylaspis sp. A
- Araphura sp. B
- Photis lacia
- Leptophoxus falcatus icelus
- Leptognathia sp. B
- Rutiderma lomae

ECHINODERMS
- Amphiodia urtica
- Amphipholis squamata
- Amphiura acrystata
- Brissaster latifrons
- Pentamera populifera
- Pentamera pseudocalcigera

OTHERS
- Euphysa sp. A
- Monobrachium parasitum
- Nephasoma diaphanes (Golfingia minuta)
- Micrura alaskensis
- Tubulanus polymorphous

TABLE 3-30. TEN MOST ABUNDANT TAXA OFF ORANGE COUNTY.

1. **Spiophanes** missionensis
2. **Euphilomedes carcharodonta**
3. **Parvilucina tenuisculpta**
4. **Prionospio sp.** A
5. **Pectinaria californiensis**
6. **Phoronida**
7. **Tellina** carpenter
8. **Chloeia** pinnata
9. Exogone sp. B
10. **Maldanidae**

TABLE 3-31. SPECIES THAT OCCURRED PRIMARILY IN THE NORTHERN AND CENTRA PLANNING AREAS.

MOLLUSCA
- **Axinulus** sp. A
- **Malletia** sp. A
- Adontorhina sp. A
- **Liocyma sp.** A
- **Cuspidaria glacialis**
- **Mitrella** casciana
- **Huxleyia munita** (primarily northern)

POLYCHAETES
- Perinereis **nr. monterea**
- **Lumbrineris longensis**
- **Ampharete acutifrons**
- **Megalomma** splendida

CRUSTACEA
- **Cryptocope** sp. F
- **Monoculodes** nr. packardi
- **Monoculodes** sp. A
- **Leucon** sp. N
- **Leucon** sp. Q
- Protomedeia prudens

ECHINODERMS
- **Amphioplus sp.** A

TABLE 3-32. TEN MOST ABUNDANT SPECIES IN THE EEL RIVER, POINT ARENA, AND BODEGA BASINS RANKED IN ORDER OF ABUNDANCE.

EEL RIVER BASIN
Nephtys cornuta franciscana
Levinsenia gracilis
Spiophanes berkeleyorum
Huxleyia munita
Metopa nr. pusilla[2]
Chaetozone cf. setosa
Ehlersia heterochaeta
Exogone lourei
Allis ramosa
Amaeana occidentals

Point Arena Basin
Levinsenia gracilis
Mitrella permodesta
Myriochele sp. M
Spiophanes berkeleyorum
Myriochele gracilis
Decamastus gracilis
Nephtys cornuta franciscana
Pholoe minuta
Maldane sarsi
Anobothrus gracilis

Bodega Basin
Amphiodia urtica
Huxleyia munita[1]
Nephtys cornuta franciscana
Pholoe minuta
Chloeia pinnata
Spiophanes berkeleyorum
Anobothrus sp. A
Myriochele gracilis
Adontorhina sp. A[3]
Levinsenia gracilis

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[1] ranges to southern California but largest populations are in the north
[2] only occurs in this basin
[3] only in northern basins

TABLE 3-33. SPECIES THAT OCCURRED PRIMARILY IN SOUTHERN PLANNING AREAS.

MOLLUSCA
- Polinices pallidus
- Nassarius insculptus*
- Caecum crebricinctum*
- Solemya reidi
- Cadulus quadrifissatus*
- Parvilucina tenuisculpta*
- Calliostoma supragranosum
- Calliostoma turbinum*
- Nuculana taphria*

POLYCHAETA
- Glycera sp. B
- Glycera rouxi
- Praxillura maculata
- Aglaophamus sp. A
- Thelepus hamatus
- Amphicteis glabra
- Mooreonuphis sp. C
- Mooreonuphis sp. D
- Subadyte sp. A*

CRUSTACEA
- Tiron tropakis
- Lembos audbettius
- Urothoe varvarini*
- Cyathura munda
- Ampelisca macrocephala*
- Euphilomedes carcharodonta*
- Foxiphalus golfensis*
- Lepidepecreum gurjanovae*

ECHINODERMS
- Amphiodia psara
- Amphioplus strongyloplax*
- Astropecten verrilli*
- Brissopsis pacifica*
- Lytechinus pictus*
- Ophiothrix spiculata
- Ophiura lutkeni*

OTHERS
- Abietinaria variabilis

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*also Occurred north of Point Conception but the majority of collections w
in Southern California

In summary, the data support Schenk and Keen's (1936) view of a single Californian biogeographic province. While rates of endemism in each of the survey areas may seem high (10-26%; Table 3-28), the fact that the most abundant organisms occurred in all three study areas suggests a basic unity of the fauna. The rates of apparent endemism might reflect the fact that the offshore areas of the coast are characterized by a series of basins, an arrangement that tends to promote the development of short-range endemics as observed in the vicinity of Point Conception (Newman, 1979).

3.2.6 Analysis of Sample Replication

Multivariate Approach

One of the objectives of the analytical program was to determine whether collecting and analyzing replicate samples would have yielded additional useful information beyond that provided by single samples. The converse is the determination of whether useful information was lost by not replicating at every station.

This question was addressed by an analysis which only included species data from stations with replicate samples. Ordination and Procrustes analyses were used to compare the community patterns resulting from analyses with and without replication. The community patterns are expressed as patterns of samples in an ordination space.

Three separate ordination analyses were performed: an analysis with replicate 1 data only; an analysis with replicate 2 data only; and an analysis with the mean of the data in replicates 1 and 2. The results of these three analyses are displayed in a common ordination space with the use of Procrustes analysis. When the sampling entities are displayed in a single space in this manner, it is easy to compare results directly from the three ordinations (Figure 3-47).

The results were examined to determine whether the infaunal community pattern described by either set of single replicates was markedly different from the pattern described by the set of means. At most of the stations, the replicates

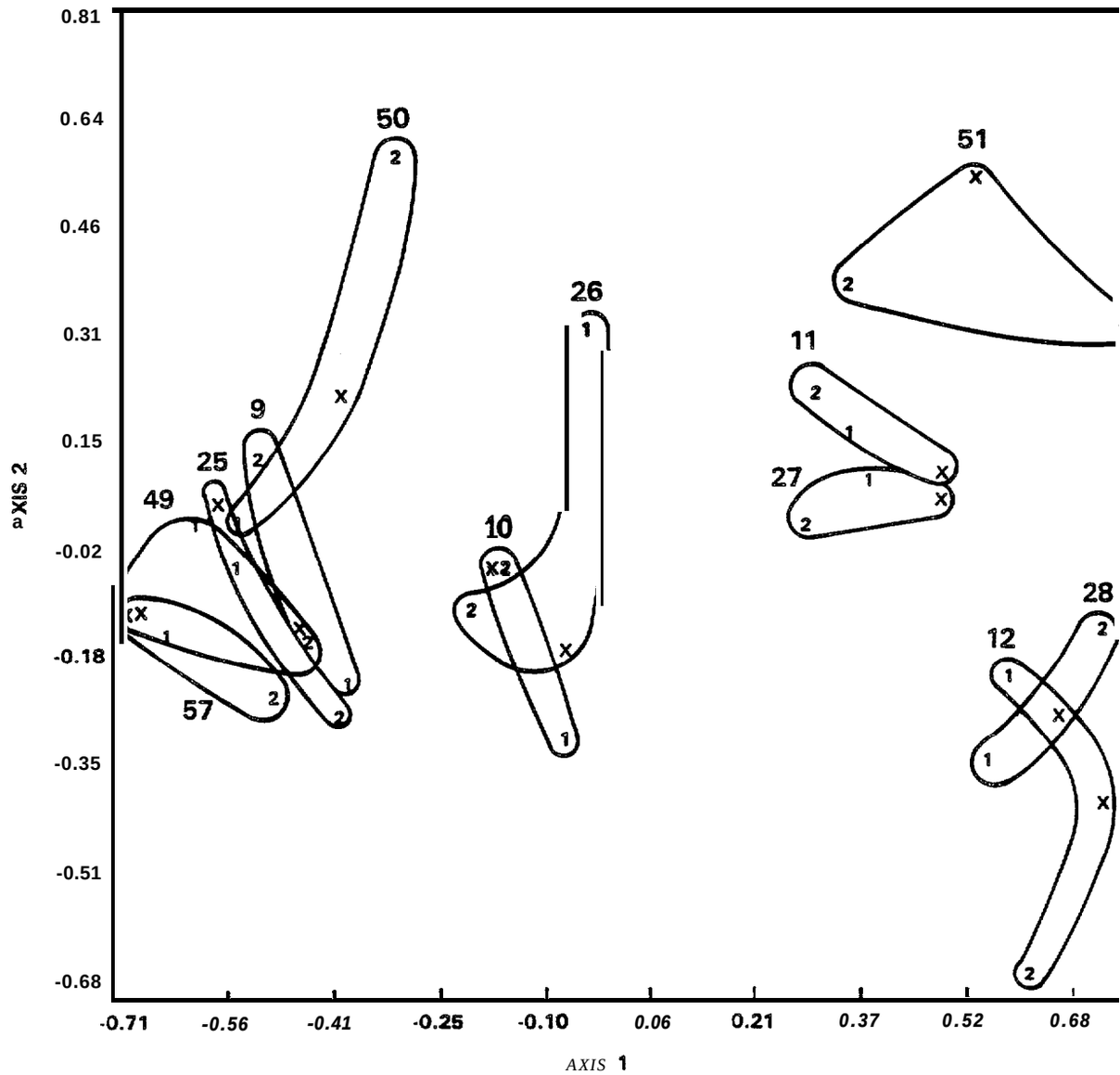

FIGURE 3-47. ROTATED SCORES FROM ORDINATIONS OF REPLICATE 1 (ARABIC NUMERAL 1) AND REPLICATE 2 (ARABIC NUMERAL 2), PLOTTED WITH THE ORDINATION SCORES OF THE MEANS (X) OF THE TWO REPLICATES AT EACH STATION. The two replicates and the mean at each station are enclosed by lines; the station number is given for each station.

were close to one another in ordination space. Only at four stations (Station 12, 26, 50, and 51) were there marked differences between the replicates.

This similarity of the overall pattern suggests that similar conclusions would be drawn concerning distribution patterns of the soft substrate community whether one or the other of the replicates or the mean of two replicates was used. In all three ordinations, the samples form a similar arrangement along Axis 1, with the shallowest (100 m) samples (Stations 9, 25, 49, and 57) on the left, deeper (200 m) samples (Stations 10 and 26) nearer the center, and the deepest (400 and 600 m) samples (Stations 11, 12, 27, 28, and 51) on the right. The exception to this pattern is Station 50, which, although at a similar depth to Stations 10 and 26, does not occur near them in the ordination space. This exception represents a real, consistent difference in the biological community at that station compared with other stations at the same depth. One replicate at three of the stations (50, 26, and 12) varied somewhat from the mean of the replicates along Axis 2, but the overall pattern along this axis would probably not change enough to result in different conclusions if only a single replicate were used. Because the information contained in the replicates is essentially the same as the information in the mean of two replicates, it is clear that collecting more replicates would not yield significantly more information concerning large-scale community patterns in the soft substrate benthos.

A second approach was used to examine the relative amount of information contained in the replicates. It was assumed that if the distance in ordination space between replicates was, on average, appreciably less than that between samples from different locations, then either replicate (or their mean) would have provided the same large-scale community pattern as did single samples. Three sets of comparisons were performed:

- Ordination scores were compared of stations within a basin and transect that were separated by differing amounts of depth; for example, stations such as 1 (100 m) and 2 (200 m) that were separated by one depth, stations two depths away from one another, such as 1 (100 m) and 3 (400 m), and stations three depths away from one another, such as 1 (100 m) and 4 (600 m).

- o Stations were compared that were at the same depth but in differen basins; for example, Stations 1 and 24, both at 100 m but one i the Eel River Basin and one in the Point Arena Basin.

- o Stations were compared on different transects but at the same depth and in the same basin; for example, Station 1, at 100 m on Transec 1, and Station 9, at 100 m on Transect 3, both within the Eel Rive Basin.

- o Finally, the available replicates were compared; for example replicate 1 at Station 9 with replicate 2 at Station 9.

The results indicate that the distance in ordination space between th replicates at a station was, on average, less than for any other set o comparisons, including the comparisons between stations at the same dept within the same basin (Table 3-34). The greatest differences were associate with depth, suggested by the results of the univariate and multivariat community analyses. These results suggest that there was, in fact, mor information on large-scale community patterns to be gained by increasin geographic coverage through more samples than by increasing the degree o replication at a station.

Variance Approach

The level of effort necessary for future reconnaissance-type programs wa estimated from the within-station variability. The variance at each station a which replicates were collected was estimated using the Mean Square Error fro separate one-way ANOVAs for each depth contour. The ratios of the averag within-station variances to the between-station (within basin and isobath variances were computed (Table 3-35) and compared by means of an F-test on th ratio (Zar, 1974) to determine the optimum allocation of resources (Snedeco and Cochran, 1967).

No consistent pattern was apparent in the F-test on within-station variance For example, the variances of number of species and number of individuals wer highest at the 200-m isobath, while the variances of grain-size variables wer highest at the 600-m isobath.

TABLE *3-34.* MEAN DISTANCES IN ORDINATION SPACE BETWEEN SAMPLES FROM THE CARP SAMPLING PROGRAM. "Depth l," "Depth 2," and "Depth 3" refer to samples from stations on the same transect separated by one, two, and three depths, respectively. "Basin" refers to samples at the same depth but on transects in different basins. "Transect" refers to stations in the same basin and at the same depth, but on different transects. "Replicates" refers to the twelve pairs of replicates.

Test	Mean Distance	Std Dev
Replicates	0.355	0.335
Transects	0.550	0.417
Basin	0.785	0.378
Depth 1	0.996	0.350
Depth 2	1.555	0.332
Depth 3	1.947	0.332

TABLE 3-35. BETWEEN-STATION AND WITHIN-STATION VARIANCES FOR COMMUNITY AND ENVIRONMENTAL MEASURES. F-Ratios among isobaths are also shown. The critical value of $F_{(5.5)}$ is 5.05.

Measure	BETWEEN STATION (Within Basin and Within Isobath)	WITHIN STATION Mean	By Depth	Isobath	F-RATIO FOR DIFFERENT DEPTHS 100 m	200 m	400 m	600 m
Species (no. /core)	177.52	218.48	62.67	100	1.00	8.53	14.46	4.34
			534.67	200		1.00	123.38	1.96
			4.33	400			1.00	62.83
			272.25	600				1.00
Individuals (no. /core)	2847.4	22388	21972	100	1.00	1.57	5.92	1.34
			34520	200		1.00	9.30	1.18
			3711	400			1.00	7.91
			29351	600				1.00
Diversity (H')	0.030	0.006	0.001	100	1.00	15.79	7.37	4.38
			0.016	200		1.00	2.14	69. 14
			0.008	400			1.00	32.28
			0.000	600				1.00
Dominance (D)	0.052	0.019	0.001	100	1.00	27.82	41.79	41.77
			0.019	200		1.00	1.50	1.50
			0.028	400			1.00	1.00
			0.028	600				1.00
Evenness (J')	0.007	0.005	0.000	100	1.00	13.90	85.00	.495 .45
			0.000	200		1.00	6.11	35.64
			0.003	400			1.00	5.83
			0.015	600				1.00
Crustacea Individuals Log (no. /core + 1)	0.053	0.047	0.005	100	1.00	3.82	5.07	24.19
			0.021	200		1.00	1.33	6.33
			0.02$	400			1.00	4.78
			0.133	600				1.00
Echinodermata Individuals (no. /core)	235.70	134.71	451.50	100	1.00	112.87	5.73	100.33
			4.00	200		1.00	19.71	1.12

TABLE 3-35. (Continued)

Measure	BETWEEN STATION (Within Basin and Within Isobath)	WITHIN STATION Mean	By Depth	Isobath	F-RATIO FOR DIFFERENT DEPTHS 100 m	200 m	400 m	600 m
Mollusca Individuals	0.081	0.038	0.011	100	1.00	3.13	1.04	*8.63*
Log (no./core + 1)			0.035	200		1.00	3.26	*2.76*
			0.011	400			1.00	9.00
			0.096	600				1.00
Polychaeta Individuals	11417	1697	132444	100	1.00	2.00	19.85	1.84
(no./core)			16214	200		1.00	9.92	1.09
			1634	400			1.00	10.76
			17592	600				1.00
Total Organic Carbon (%)	0.076	0.104	0.003	100	1.00	117.10	1.10	1.89
			0.408	200		1.00	106.31	220.93
			0.004	400			1.00	2.08
			0.002	600				1.00
Mean Phi Size	*1.368*	0.087	0.110	100	1.00	*4.46*	11.34	1.83
			0.025	200		1.00	2.54	8.14
			0.010	400			1.00	20.72
			0.202	600				1.00
Median Phi Size	1.088	0.307	0.103	100	1.00	11.73	2.77	10.48
			0.009	200		1.00	4.23	122.91
			0.037	400			1.00	29.04
			1.079	600				1.00
Skewness	0.034	0.020	0.008	100	1.00	28.38	1.58	8.28
			0.000	200		1.00	17.99	234.90
			0.005	400			1.00	13.06
			0.066	600				1.00
% Sand	457.01	53.96	21.13	100	1.00	2.91	1.98	0.37
			7.27	200		1.00	1.47	24.32
			10.67	400			1.00	16.58
			176.78	600				1.00

TABLE 3-35. (Continued)

Measure	BETWEEN STATION (Within Basin and Within Isobath)	WITHIN STATION Mean	By Depth	Isobath	F-RATIO FOR DIFFERENT DEPTHS 100 m	200 m	400 m	600 m
% Silt	223.33	23.99	11.76	100"	1.00	38.73	1.72	6.55
			0.30	200		1.00	22.54	*253.74*
			6.84	400			1.00	11.26
			77.04	600				1.00

Comparison of between-station variances to the average of the within-station variances shows that the between-station variances were equivalent or slightly larger (i.e., ratio $\geq$ 1) in most cases. The variances of the number of species and number of individuals were applied in the allocation of resources method (Snedecor and Cochran, 1967) using the assumption that moving to another station would cost 50% more than remaining on station and collecting another replicate. The results showed that one replicate per station was the optimum allocation of effort.

3.2.7 Quality Assurance

Soft substrate infaunal sample processing included a sorting QA/QC procedure that ensured 95% sorting efficiency. The taxonomic quality assurance procedure for both hard and soft substrate taxa consisted of sending out 10% of the vouchered species to appropriate taxonomic specialists for verification of identifications. The identifications were, with a few minor exceptions, confirmed by those experts. The few changes that were made were incorporated into the data base.

The sediment grain-size quality assurance program included careful visual scrutiny of all equipment before and after each analysis, strict adherence to EPA protocols (EPA, 1987), and duplicate analyses (results in Table 3-36) on seven randomly selected samples (10% of the total). The results indicate that decreasing grain size lead to somewhat decreased precision in the estimate of the percent of the sediment in each grain size category (e.g. , sand, silt, clay) . The difference between the duplicate sample values (expressed as a percentage of the smaller value) , ranged from 1-81% for percent sand (the majority 5% or less), between 1 and 33% for percent silt (most values between 6 and 11%), and between 12 and 148% for percent clay (most values between 12 and 32%) . Values of the summary measure, median phi size, generally differed by about 5% or less between duplicates, except at a single station (SB12: 13%). Duplicate measures of skewness were less precise, differing by about 3 to 40%, with most differences between 22 and 28% of the smaller value.

TABLE 3-36. GRAIN SIZE DUPLICATE (QA/QC) ANALYSES FROM SEVEN RANDOMLY SELECTE SAMPLES COLLECTED FOR THE MMS CARP PROGRAM (November/Decembe 1987).

	Duplicate (1 and 2) Analyses					
Transect/SCation/Rep	T-2/SB7/A		T-3/SB12/B		T-4/SB13/A	
Sample Split	1	2	1	2	1	2
Median phi size	3.53	3.46	*3.98*	*4.57*	*6.94*	*6.5*
Skewness	0.57	0.71	*0.68*	*0.53*	*0.33*	0.3
Kurtosis	.	.	.	.	.	
% Sand	72.31	75.84	50.44	44.79	0.84	1.5
% Silt	18.82	14.19	32.60	34.46	*63.73*	*70.4*
% Clay	8.87	9.91	16.92	20.75	*35.43*	*28.0*
Transect/Station/Rep	T-2/SB18/A		T-3/SB23/B		T-4/SB29/A	
Sample Split	1	2	1	2	1	2
Median phi size	5.85	5.87	*3.80*	*3.77*	3.69	3.5
Skewness	0.37	0.30	*0.65*	*0.59*	0.56	0.4
Kurtosis	.	.	.	.	.	1.4
% Sand	11.30	11.87	61.37	62.79	63.39	68.3
% Silt	62.60	67.20	*26.22*	*26.54*	24.26	26.6
% Clay	25.38	22.49	12.42	10.67	12.35	4.9
Transect/Station/Rep	T-2/SB7/A					
Sample Split	1	2				
Median phi size	3.46	3.47				
Skewness	0.50	0.41				
Kurtosis	.	3.80				
% Sand	80.29	80.91				
% silt	11.60	12.39				
% Clay	8.11	6.16				

Total organic carbon quality assurance consisted of analysis of standards and blanks with each sample set, and duplicate analyses of six randomly-selected samples (10% of the total). Results of the analyses are presented in Table 3-37. Percent recoveries for the standards averaged 96.4% (range 94.8-99.7%, standard deviation 1.8%). Differences between the duplicate analysis values ranged from 0 to 8.9%, averaging 5%.

3.3 SEABIRDS, MARINE MAMMALS, AND FISHING OBSERVATIONS

Results and discussion of survey observations of seabirds, marine mammals, and fishing activities are presented in Sections 3.3.1 through 3.3.3, respectively.

3.3.1 Seabirds

Nineteen bird species were recorded during the field survey operations (Tables 3-38 and 3-39). Seabirds were represented by four orders, comprising ten species of Charariiformes, (a diverse order including gulls, shorebirds, and auks), five species of Procellariiformes or tube noses (albatrosses, shearwaters), two species of Pelecaniformes (pelicans and cormorants), and one species of Ciconiiformes (wading birds).

The seabirds observed during the survey can be separated by habitat preference into either open-ocean or shore birds. Open-ocean birds are those that occur primarily on the ocean except during breeding season. The nine open-ocean species observed were represented by three species of shearwater, two species of albatross, and one species of fulmar, phalarope, murre, and auklet. The other ten species observed were shorebirds. Shorebirds may feed in open-ocean areas, but generally return to land on a daily basis.

The most commonly observed genus of seabird was Larus, which was represented by seven species of gulls. The most frequently occurring species were the herring gull (L. argentatus), ringbilled gull (L. delawarensis), and Bonaparte's gull (L. Philadelphia). The most unusual observation was the tentative identification of Franklin's gull (L. pipixcan), which normally occurs only as a transient species along the California coast. However, these birds are known

TABLE *3-37.* TOTAL ORGANIC CARBON DUPLICATE (QA/QC) ANALYSES FROM SIX RANDOMLY SELECTED SAMPLES COLLECTED FROM THE MMS CARP PROGRAM (NOVEMBER - DECEMBER 1987) AND RECOVERIES FROM TRIPLICATE ANALYSES OF STANDARDS .

	Duplicate 1 and 2 Analyses					
Transect/Station/Rep	T-1/SB2/A		T-2/SB8/A		T-4/SB14/A	
Sample Split	1	2	1	2	1	2
Organic Carbon (%)	0.721	0.694	0.527	0.562	0.924	0.924
Transect/Station/Rep	T-5/SB20/A		T-6/SB22/A		T-7/SB27/B	
Sample Split	1	2	1	2	1	2
Organic carbon (%)	1.116	1.026	0.457	0.427	0.795	0.766

	Organic Carbon Recovery		
40 µg Carbon Standard	1	2	3
Organic carbon (µg C)	38.380	38.116	37.912
90 µg Carbon Standard	1	2	3
Organic carbon (µg C)	89.735	85.785	87.474

TABLE 3-38. SEABIRD AND MARINE MAMMAL OBSERVATION LOG: INCIDENTAL AND SCHEDULED OBSERVATION PERIODS. MMS CARP Survey (November/December 1987).

General LoCat ion*	Date	Time	Species	Est No.	Activity
HB1	11/20/87	1545	Ringbilled Gull	5	rafting and circling ship
			Bonaparte's Gull	5	rafting and circling ship
			Herring Gull	2	
			Blackfooted Albatross	2	circling
HB2	11/17/87	1000	Common Dolphin	7	bowriding
		1524	Herring Gull	20	rafting
			Ringbil led Gull		
HB3	11/19/87	1045	Bonaparte 's Gull		circling ship
			Ringbilled Gull		
			Herring Gull	20	
			Western Gull		
			Black footed Albatross	2	
transit		1500	Pacific Whiteside Dolphin	15	bowriding
(40°55.71; 125°25.82')	11/21/87	1610	Brown Pelican	2	circling ahip
			Black footed Albatross	4	
			Western Gull		
			Herring Gull	20	
			Heermann's Gull		
			Pink footed Shearwater	5	
HB4	11/18/87	1340	Western Gull	5	circling and rafting
			Herring Gull	3	
			Bonaparte's Gull	2	
			Ring billed Gull	3	
			Black footed Albatross	1	
transit between HB4 and HB5	11/23/87	1516	Pacific Whiteside Dolphin	10	bowriding
HB5	11/24/87	0840	Dall's Porpoise	15 to *20*	bowriding
		1133	Cassin's Auklet	15	flying by
			Northern Fulmar	2	circling
		1230	Gray Whale	1	southbound
HB6	11/25/87	*0930*	Blue Whale	7	northbound
		1320	Red Phalarope	> *50*	flying by
			Bullier's Shearwater	5	circling
			Unid. Gulls	5	
			Blackfooted Albatross	2	

TABLE 3-38. (Continued)

General Location*	Date	Time	Species	Est NO.	Activity
HB7	11/26/87	1045	Dall's Porpoise	6	bowriding
			Bonaparte's Gull	5	circling
			New Zealand Shearwater	10	
			Northern Fulmar	*b*	
HB8	11/26/87	1630	Bonaparte's Gull	ID	circling
			Pink footed Shearwater	3	
HB9	11/27/87	1020	Red Phalorope	10	rafting
			Northern Fulmar	5	circling
			Killer Whale	2	northbound
	11/28/87	1400	Pacific Uhiteside Dolphin	1000	S. E. bound
			Northern Right whaleDolphin	3	In pod of P.W.D.circling ship
			Herring Gull		
			Ringbilled Gull		
			Northern Fulmar		
			Franklin's Gull		
			Blackfooted Albatross		
			Laysan Albatross		head pounding
HB10	11/29/87	1100	Northern Fulmar	5	circling
			Herring Gull	5	circling
			Black footed Albatross	1	circling
HB13	11/29/87	1724	Herring Gull	5	circling
			Northern Fulmar	3	
transit to Bodega	12/1/87	*1200*	Blackfooted Albatross ?		
			Pink footed Shearwater		
			Sooty Shearwater		
			Glacuous-Winged Gull		
			Common Egret	3	
			Herring Gull		
			Bonaparte's Gull	>10	
			Western Gull		
			California Sea Lion	1	swimming by
HB14	12/2/87	1130	Laysan Albatross	1	circling
			Black footed Albatross	2	
			Ringbilled Gull		
			Herring Gull		
			Sooty Shearwater ?		

TABLE 3-38. (Continued)

General Location*	Date	Time	Species	Est NO.	Activity
HB15	12/5/87	1626	Brown Pelican	5	
			Unid. Gulls		
transit between HB15 and HB16	12/6/87	1400	Risso's Dolphin	2	northbound
HB16	12/5/87	1108	Brown Pelican	20	following ship
			Brant's Cormorant	5	northbound
			Black footed Albatross	1	
			Ringbilled Gull		
			Heermann's Gull		
			New Zealand Shearwater		
			Common Murre	35	flying towards coast

● see Figures 2-1 and 2-2 for transect locations

TABLE 3-39. SEABIRD SPECIES LIST. MMS CARP Survey (November/December 1987).

Common Name	Scientific Name	Typical Habitat[1]	Number of Sighting Events[2]
Ringbilled Gull	Larus delawarensis	S	8 (C)
Western Gull	Larus occidentals	P	4 (P)
Bonaparte's Gull	Larus Philadelphia	P	6 (P)
Herring Gull	Larus argentatus	C	10 (c)
Heermann's Gull	Larus heermanni	C	2 (R)
Franklin's Gull	Larus pipixcan	R	1 (R)
Glacous-Winged Gull	Larus glaucescens	R	1 (R)
Northern Fulmar	Fulmarus glacialis	P	6 (P)
Pinkfooted Shearwater	Puffinus creatopus	P	3 (P)
Buller's ShearWater	Puffinus bulleri	P	3 (P)
Sooty ShearWater	Puffinus griseus	R	2 (R)
Blackfooted Albatross	Diomedea nigripes	C	10 (C)
Laysan Albatross	Diomedea immutabilis	R	2 (R)
Brown Pelican	Pelecanus occidentals	P	3 (P)
Brandt's Cormorant	Phalacrocorax penicillatus	R	1 (R)
Red Phalarope	Phalaropus fulicaria	R	2 (R)
Common Egret	Casmerodius albus	R	1 (R)
Common Murre	Uria aalge	R	1 (R)
Cassin's Auklet	Ptychoramphus aleuticus	R	1 (R)

[1] S - shore
O = open ocean

[2] Number out of 17 observation periods

R = rare (l-2)
P = present (3-6)
c = common (7-10)

to be somewhat pelagic and have been observed offshore of the California coast on a casual basis during the winter months (Dohl et al., 1978; Peterson, 1961).

Gulls observed during the survey occurred in flocks of mixed species with both juvenile and adult birds. The species of gulls within each group were identified, but the numbers of gulls usually were estimated as a group. Additionally, some of the more commonly observed gulls, such as the western (L. occidentals) , glacous-winged (L. glaucescens), and herring gulls, are known to hybridize occasionally, thus making positive identifications difficult.

The most frequently observed open-ocean bird was the black-footed albatross (Diomedea nigripes). This species did not occur in large flocks, but rather as individuals *or* in pairs. Red phalaropes (Phalaropus fulicaria) formed the largest flocks observed, commonly exceeding 50 individuals. Common murre (Uris aalge) and Cassin's aukletts (Ptychoramphus aleuticus) also formed moderate-sized flocks.

In general, distinct differences in the numbers of species observed among basins were not apparent. However, albatross appeared to be more common in the northern areas; whereas, murres, pelicans, and cormorants were more common in the southern areas. With the exception of the Franklin's gull, which was a transient, all bird species observed either nest or are seasonal residents off the California coast (Farrand, 1983).

The most frequently occurring bird species were those characterized as opportunistic feeders, which are known to follow ships and scavenge refuse. Ten of the 19 species of birds recorded during the survey, including gulls, the black-footed albatross (D. nigripes and D. immutabilis), and the northern fulmar (F. glacialis), regularly follow ships (Harrison, 1983). The tendency for these birds to follow ships, suggests that the relative abundances of these species may be overestimated by the shipboard observation technique used during this survey.

The Laysan albatross is the most abundant albatross in the North Pacific, although it is rarely seen near shore. The black-footed albatross is the only

albatross which occurs regularly along the Pacific Coast of North America (Harrison, 1983). This distribution pattern is consistent with the survey observations .

Cassin's auklets are one of the most common birds which breed on the Farallon Islands (off San Francisco). The auklets which breed on the Farallon Islands return to the islands to roost during the winter months; whereas, normally these highly pelagic birds remain offshore (Harrison, 1983).

Finally, the three vagrant egrets likely were blown off course and took refuge on the ship during a severe storm.

3.3.2 Marine Mammals

Nine species, representing six families of marine mammals, were observed incidental to the field survey operations (Table 3-40). All mammal sightings, with the exception of one pinniped, were cetaceans. The pinniped sighted was California sea lion (an adult female passed close to the ship as it was moving between sites within the Bodega Basin). None of the marine mammal observations occurred during standardized observation periods (see Section 2.5) , but were recorded incidental to daily operations and were more common when the ship was under way.

The most abundant cetacean numbers and species observed throughout the survey were represented by the family Delphinidae. Pacific whiteside dolphins (Lagenorhynchus obliquidens) were the most frequently occurring, as well as the most abundant, marine mammal. In one instance, pod size was estimated at well over 1,000 individuals. The largest pod of Pacific whiteside dolphin, observed offshore of Point Arena, was encircled by a large number of gulls as the pod moved slowly through the survey area. Head slapping, bow-riding, and leaps were observed among pod members. These animals may have been feeding at that time. Mixed within this pod were northern rightwhale dolphins (Lissodelphis borealis). This usually shy species approached the ship but did not bow-ride.

TABLE 3-40. MARINE MAMMAL SPECIES LIST*. MMS CARP Survey (November/December 1987).

Common Name	Scientific Name	Number of Sighting Events	Est. Pod Size
California Sea Lion	Zalophus californianus	1	1
Gray Whale	Eschrichtius robustus	1	1
Blue Whale	Balaenoptera musculus	1	7
Dan's Porpoise	Phocoenoides dalli	2	15 to 20
Killer Whale	Orcinus orca	1	2
Common Dolphin	Delphinus delphis	1	10 to 15
Risso's Dolphin	Grampus griseus	1	2
Pacific Whiteside Dolphin	Lagenorhynchus obliquidens	3	> 1000
Northern Rightwhale Dolphin	Lissodelphis borealis	1	4

*All marine mammal observations were incidental and were not observed during standardized observation periods.

Dan's porpoise (Phocoenoides dalli) were observed occasionally as the ship moved between survey sites. This species occurred in smaller pods of about 1 to 20 individuals and commonly would spend about 30 minutes bow-riding before departing.

On one occasion, a small pod of common dolphin (Delphinus delphis) briefly rod the ship's bow wave. These animals occurred off the Humbolt Bay area.

A single gray whale (Eschrichtius robustus) was observed moving in a southbound direction through the survey area. Two killer whales (Orcinus orca), two Risso's dolphins (Grampus griseus), and a pod of approximately seven blu whales (Balaenoptera musculus) were observed incidently moving in a northbound direction.

The most unexpected sighting was the pod of blue whales. Both blue and gray whales are listed as endangered on the list of Rare and Endangered Species, an although gray whales commonly are observed migrating along the Californi coast, blue whales are rarely observed (Dohl et al., 1978; Watson, 1981).

The most unusual delphinid sighting was the small pod of common dolphins Although this is a cosmopolitan species in temperate and tropical waters, and it has been observed as far north as British Columbia, the species generally i more common in the eastern Pacific in areas south of Monterey Bay (Watson 1981).

3.3.3 Fishing Observations

Fishing vessels were observed at five of the 14 hard substrate transec locations (Table 3-41). These sightings were recorded from three of the fou basins: Eel River, Point Arena, and Bodega. Vessel types included crab boats trollers, and trawlers. The most frequently observed fishing vessel type wa crab boats. With only one exception, the fishing vessels observed wer transiting through, rather than fishing in, the survey areas. Only one trawle was observed during the survey. It was fishing about 13 miles due west o

TABLE 3-41. COMMERCIAL FISHING ACTIVITY OBSERVED DURING THE MMS CARP SURVEY (NOVEMBER/DECEMBER 1987).

Date	Time	General Survey Area	Type	Number	Activity
11/18/87	1340	HB4	Troller	1	Transit North
11/19/87	1040	HB3	Trawler	1	Transit South
11/24/87	1133	HB5	Troller Crab boat	1	Transit
11/27/87	1020	HB9	Crab boats	4	Transit
11/29/87	1410	HB13	Trawler	1	Hauling net and dumping, unwanted species

Northwest Cape in the Bodega Basin. The vessel at the time of the sighting was hauling in its net and discarding unwanted species.

Although the numbers of commercial fishing vessels appeared to be low, this probably was due to the severe wind and sea conditions encountered during the survey. The lack of any vessels observed near the Santa Cruz Basin sites also was probably due to a severe storm encountered in this region.

The siting of two times as many crab boats, as compared to other vessel types, was attributed to the start-up of Dungeness Crab season; the crabbers were setting out traps in preparation for the first day of the season. No buoyed fishing gear was observed at any time in the survey area.

4.0 REFERENCES

Abbot, R.T. and Sandstrom, G.F. 1968. Seashells of North America. New York: Golden Press. 280 pp.

Austin, M.P. 1980. Searching for a model for use in vegetation analysis. Vegetatio 42:11-21.

Austin, M.P. and L. Belbin. 1982. A new approach to the inverse classification problem in floristic analysis. Aust. J. Ecol. 7:75-89.

Austin, W.G. 1985. Annotated Checklist of Marine Invertebrates in the Cold Temperate Northeast Pacific, Vol. I. Khoyatan Marine Laboratory, Cowichan Bay, British Columbia. p. 12.

Battelle. 1988. California OCS Phase II Monitoring Program, Year-One Annual Report, Vols I and II. Report submitted to MMS, Pacific OCS Region under Contract No. 14-12-0001-30262.

Beals, E.W. 1973. Ordination: mathematical elegance and ecological naivete. J. Ecol. 61(1):23-35.

Berry, K.J., P.W. Mielke, and R.K.W. Wong. 1986. Approximate MRPP P-values obtained from four exact moments. Commun. Statist. -Simula. 15(2):581-589.

Biernbaum, C.K, 1979. Influence of sedimentary factors on the distribution of benthic amphipods of Fishers Island Sound, Connecticut. J. Mar. Biol. Ecol. 38:201-223.

BLM . 1978. Description of the Coastal Environment from Point Reyes to Punta Eugenia, Vol I. Bureau of Land Management, Pacific OCS Office, Los Angeles. 525 pp.

Boesch, D.F. 1977. Application of Numerical Classification in Ecological Investigations of Water Pollution. Ecological Research Series EPA-600/-3-77-033. Washington, D.C.: U.S. Environmental Protection Agency. 130 pp.

Bradfield, G.E. and N.C. Kenkel. 1987. Nonlinear ordination using shortest path adjustment of ecological distances. Ecol. 68(3):750-753.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

Cacchione, D.A., W.D. Grant, D.E. Drake, and S.M. Glenn. 1987. Storm-dominated bottom boundary layer dynamics on the northern California continental shelf: Measurements and predictions. J. Geophys. Res. 92:1817-1827.

Carney, R.S. 1987. A review of study designs for the detection of long-term environmental effects of offshore petroleum activities. In: Long-Term Effects of Offshore Oil and Gas Activities, ed. Boesch, D.F. and N.N. Rabalais. Elsevier Applied Science. pp. 651-696.

Cassie, R.M. and A.D. Michael. 1968. Fauna and sediments of an intertidal mudflat: A multivariate analysis. J. Exp. Mar. Biol. Ecol. 2:1-23.

Chambers Consultants. 1982. Supplmentary Data Report of Characterization of the Marine Biota Between Point Arguello and Point Conception. Report submitted to California State Lands Commission.

Chang, D.H.S. and H.G. Gauch, Jr. 1986. Multivariate analysis of plan communities and environmental factors in Ngari, Tibet. Ecol. 67(6) 1568-1575.

Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerics Classification. San Francisco: Academic Press. 229 pp.

Cohen, J. 1977. Statistical Power Analysis for the Behavioral Sciences. Rev ed. New York: Academic Press. 474 pp.

Curray, J.R. 1966. Geologic structure on the continental margin, fro subbottom profiles, northern and central California. Geological Norther California Bulletin. 190:337-342.

Dames and Moore. 1983. Site-Specific Marine Biological Survey, Chevro Platform Hermosa Project, Western Santa Barbara Channel. Report submitte to Chevron U.S.A., Inc.

Dames and Moore. 1984. Site-Specific Marine Biological Survey, Shamroc Project, Central and Southern Santa Maria Basin. Report submitted t Exxon U.S.A.

Davis, R.A. 1972. Principles of Oceanography. Menlo Park, CA Addison-Wesley. 434 pp.

Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The use of numerics methods to determine the distribution of the benthic fauna across th continental shelf of North Carolina. J. Anim. Ecol. 40:93-126.

Dietz, E.J. 1983. Permutation tests for association between two distanc matrices. Syst. Zool. 32(1):21-26.

Digby, P.G.I?. and R.A. Kempton. 1987. Multivariate Analysis of Ecologica Communities. New York: Chapman and Hall. 206 pp.

Dohl, T.P., K. Norris, R.C. Guess, J.D. Bryant, and M.W. Honig. 1978. Summar of Marine Mammal and Seabird Surveys of the Southern California Bigh Area. Vol. 2 and 3.

Dorsey, J.H., K.D. Green, and R.C. Rowe. 1983. Effects of sewage disposal o the polychaetous annelids at San Clemente Island, California. In: Was t Disposal in the Oceans, Minimizing Impact Maximizing Benefit, 209-233, ed Soule, D.F. and D. Walsh. Boulder, CO: Westview Press.

Dyer, D.P. 1978. An analysis of species dissimilarity using multipl environmental variables. Ecol. 59(1):117-125.

Edgington, E.S. 1987. Randomization Tests. 2d ed. New York: Marcel Dekker. 341 pp.

Ekman, S. 1967. Zoogeography of the Sea. London: Sidgwick and Jackson LTD. 417 pp.

Engineering Science. 1984. Marine Biological Survey for Platform Hidalgo Site and Corresponding Pipeline Route. Report Submitted to Chevron U.S.A., Inc.

Ernst, W. and J. Morin (cd.). 1982. The Environment of the Deep Sea, Vol. II. Prentice Hall, Inc., New Jersey. pp. 324-356.

Farrand, J., Jr., ed. 1983. The Audubon Society Master Guide to Birding. Vol. 1 and 2. New York: Alfred Knopf. 845 pp.

Fauchald, K. and G. Jones. 1977. Benthic macrofauna. In: Southern California baseline study final report, Vol. III, Report 2.4. Prepared for the Bureau of Land Management, Washington, D.C. (SAI-76-809-LJ) .

Fauchald, K. and G.F. Jones. 1978a. A survey of the benthic macrofauna at five additional southern California study sites. Year II Benthic Study. Unpublished report for the Bureau of Land Management, Los Angeles, CA.

Fauchald, K. and G.F. Jones. 1978b. Variation in community structure of shelf, slope and basin macrofaunal communities of the Southern California Bight. Chapter 19 In Year II benthic study. Prepared by Science Applications, Inc. for the—Bureau of Land Management, POCS Office, Los Angeles, California (Contract No. AA551-CT6-40).

Fauchald, K. and G. Jones. 1979a. A survey of five additional southern California study sites. Report 18 in: SAI Southern California Outer Continental Shelf Environmental Baseline Study, 1976/1977 (Second Year) Benthic Program. vol. II Principal Investigators' Reports, Series 2, Reports 18-24, 720 pp.

Frey, H.W. 1971. California's Living Marine Resources and Their Utilization. Sacramento, CA: State of California, the Resource Agency, Dept. of Fish and Game. 148 pp.

Gauch, H.G., et al. 1981. A comparative study of nonmetric ordination. J. Ecol. 69:135-152.

Gauch, H.G., Jr. *1982.* Multivariate Analysis in Community Ecology. Cambridge Studies in Ecology. New York: Cambridge Univ. Press. *298 pp.*

Gittins, R. 1979. Ecological applications of canonical analysis. In: Multivariate Methods in Ecological Work, ed. L. Orloci, C.R. Rae, and W.M. Stiteler, *309-535.* Oxford: Blackwell.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. New York: John Wiley and Sons. 257 pp.

Green, R.H. and G.L. Vascotto. 19780 A method for the analysis o. environmental factors controlling patterns of species composition i aquatic communities. Water Res. 12:583-590.

Haley, D., ed. *1978.* Marine Mammals of Eastern North Pacific and Arcti Waters. Seattle: Pacific Search Press. 256 pp.

Harrison, P. 1983. Seabirds an Identification Guide. Boston: Houghto Mifflin Co. 448 pp.

Helvey, M. and R.W. Smith. 1985. Influence of habitat structure on the fis assemblages associated with two cooling-water intake structures i Southern California. Bull. of Mar. Sci. 37(1):189-199.

Hill, M.O. and H.G. Gauch, Jr. 1980. Detrended correspondence analysis: A improved ordination technique. Vegetatio 42:47-58.

Hubert, L.J. 1978. Generalized proximity function comparisons. Br. J. Math Statist. Psychol. 31:179-192.

Huyer, A. and R.M. Kosro. 1987. Mesoscale surveys over the shelf and slope i the upwelling regions near Point Arena, California. J. Geophys. Res 92:1655-1682.

Keen, A.M. 1971. Sea Shells of Tropical West America, 2d ed. Stanford, CA Stanford University Press. 1064 pp.

Kikkawa J. 19680 Ecological association of bird species and habitats i Eastern Australia: similarity analysis. J. Anim. Ecol. 37:143-165.

King, J.E. 1983. Seals of the World. 2d ed. Ithaca, NY: Comstock Publishin Associates, Cornell University Press. 240 pp.

Kruskal, J.B. 1964. Multidimensional scaling by optimizing goodness of fit t a nonmetric hypothesis. Psychometrika 29:1-27.

Kruskal, J.B. and M. Wish. 1978. Multidimensional Scaling. Sage Universit Papers on Quantitative Applciations in the Social Sciences, Series No 07-011. Beverly Hils and London: Sage Publications. 93 pp.

Lance, G.N., and W.T. Williams. *1967.* A general theory of classificatory sorting strategies. I. Hierarchical systems. Computer J. 9:373-380.

Lentz, S.J. 1987. A description of the 1981 and 1982 spring transitions ove the northern California shelf. J. Geophys. Res. 92:1545-1568.

Lissner, A. and J. Dorsey. 1986. Deep-water biological assemblages of hard-bottom bank-ridge complex of the southern California continents borderland. Bull. Southern California Acad. Sci. 85:87-101.

Lynn, R.J. and J.J. Simpson. 1987. The California current system: Th seasonal variability of its physical characteristics. J. Geophys. Res 92:12,947-12,966.

Mahon, R. , and R.W. Smith. In Press. Comparison of species composition in a bottom trawl calibration experiment. J. Northwest Atlantic Fish. Sci.

Mantel, N. 1967. The detection of disease clustering and a generalized regression approach. Cancer Res. 27:209-220.

McClelland Engineers. 1985. Site-Specific Marine Biological Survey, San Miguel Project, Santa Maria Basin, California. Report submitted to Cities Service Oil and Gas Corporation.

Menard, H.W. 1964. Marine Geology of the Pacific. San Francisco: McGraw Hill. 271 pp.

Mielke, P.W. 1978. Classification and appropriate inferences for Mantel and Valand's nonparametric multivariate analysis technique. Biometrics 34:272-282.

Mielke, P.W. 1984. Meteorological applications of permutation techniques based on distance functions. In: Handbook of Statistics, Vol. 4: Nonparametric Methods, ed. P.R. Krishnaiah and P.K. Sen, 813-830. Amsterdam: North-Holland Publishing.

Miller, D. and R. Lea. 1972. Guide to the coastal marine fishes of California. Fish Bulletin 157:1-249.

MMS. 1987. Proposed 5-year Outer Continental Shelf Oil and Gas Leasing Program: mid-1987 to mid-1992. Final Environmental Impact Statement MMS Document No. 86-0127.

Morrison, D.F. 1967. Multivariate Statistical Methods. San Francisco: McGraw-Hill. 338 pp.

Nekton. 1983. Site-Specific Faunal Characterization Survey for Platform Harvest, OCS Lease P-0315, Point Conception, California. Report submitted to Texaco U.S.A.

Nekton. 1984. Supplemental Survey Program Faunal Characterization Survey for Platform Harvest, OCS Lease P-0315. Report submitted to Texaco U.S.A.

Newman, W.A. 1979. California transition zone: Significance of short range endemics. In: Historical Biogeography: Plate Tectonics and the Changing Environment, 37th Annv. Biol. Colloquium. ed. J. Gray and A. Boucot. Corvallis, OR: Oregon State University Press.

OIC. 1977. Operating Procedures Manual for 0524B Total Carbon System and Direct Injection Module. OIC, College Station, TX. Vols. 1 and 2.

Pearson, T.H. and R. Rosenberg. 1978 . Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceangr. Mar. Biol. Ann. Rev. 16:229-311.

Peterson, R.T. 1961. A Field Guide to Western Birds. 2d ed. Boston: Houghton Mifflin Co. 309 pp.

Pielou, E.C. 1984. The Interpretation of Ecological Data. New York: Joh Wiley and Sons. 263 pp.

Plumb, R.H., Jr. 1981. Procedures for handling and chemical analysis o sediment and water samples. Technical Report EPA/CE-81-1. U.S Environmental Protection Agency/U.S. corps of Engineers Technica Committee on Criteria for Dredged and Fill Materials, U.S. Army Waterway Experiment Station, Vicksburg, MS. 471 pp.

Prentice, I.C. 1977. Nonmetric ordination methods in ecology. J. Ecol. 65:85 94.

Prentice, I.C. 1980. Vegetation analysis and order invariant gradient models Vetetatio 42:27-34.

Rhoads, D.C. *1974.* Organism-sediment relations of the muddy sea floor Oceanogr. Mar. Biol. Ann. Rev. 12:263-300.

SAIC . *1986.* Assessment of long-term changes in biological communities in th Santa Maria Basin and western Santa Barbara Channel - Phase I. Vol. 2 Synthesis of Findings. Prepared for Minerals Management Service, Lo Angeles, CA. MMS Contract No. 14-12-0001-30032.

SAIC . *1988.* Review of Recovery and Recolonization of Hard Substrate Commu nities of the Outer Continental Shelf. Final Report submitted to MMS Pacific OCS Region under Contract No. 14-12-0001-30388.

Sanders, H.L. 1968. Marine Benthic Diversity: A comparative study. Th American Naturalist 102(925):243-282.

SAS . *1985.* SAS User's Guide: Statistics. 1985 Ed. Cary, NC: SAS Institut Inc.

SAS Institute Inc. 1985. SAS Users Guide: Basics, Version 5 Ed. Cary, NC SAS Institute Inc. 1290 pp.

SAS Institute Inc. 1985a. SAS User's Guide: Statistics Version 5 Edition Cary, NC: SAS Institute Inc., 956 pp.

Schenk, H.G. and Keen, M. 1936. Marine Molluscan Provinces of Western Nort America. Proc. Amer. Philosoph. Sot. Vol. 76, No. 6.

Schonemann, P.H. and R.M. Carroll. 1970. Fitting one matrix to another uncle choice of a central dialation and a rigid motion. Psychometric 35(2):245-255.

Sholkovitz, E.R. and J.M. Gieskes. 1971. A physical-chemical study of th flushing of Santa Barbara Basin. Limnol. Oceanogr. 16:479-489.

Sibson, R. *1972.* Order invariant methods for data analysis. J. Royal Stat Sot. B., 34(3):311-349.

Smith, R.W. 1976. Numerical analysis of ecological survey data. Ph.D. Thesis, Univ. of S. Calif., Los Angeles. 401 pp.

Smith, R.W. 1979. Discriminant Analysis. EAP Technical Report No. 1. Ojai, CA: EcoAnalysis Inc.

Smith, R.W. 1982. Analysis of ecological survey data with SAS and EAP. Proc. 7th Annual SAS Users' Group International (SUGI). Cary, NC: SAS Institute Inc. 610-615.

Smith, R.W. 1984. The re-estimation of ecological distance values using the step-across procedure EAP Technical Report-No. 2. Ojai, CA: EcoAnalysis Inc.

Smith, R.W. In prep. Display of species distributions along ecological gradients.

Smith, R.W. and C.S. Greene. 1976. Biological communities near submarine outfall. J. Water Poll. Cont. Fed. 48(8):1894-1912.

Smith, R,W., B.B. Bernstein, and R.L. Cimberg. 1987. Community-environmental relationships in the benthos: Application of multivariate analytical techniques. In: Marine Organisms as Indicators. New York: Springer-Verlag.

Smith, R.W., B.B. Bernstein, and R.L. Cimberg. 1988. Community-environmental relationships in the benthos: Applications of multivariate analytical techniques, Chapter 11. In: Marine Organisms as Indicators, 247-326. New York: Springer-Verlag.

Smouse, P.E., J.C. Long, and R.R. Sokal. 1986. Multiple regression and correlation extensions of the Mantel test of matrix correspondence. Syst. Zool. 35(4):627-632.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical Methods Ames, IA: ed. Iowa State Univ. Press. 507 pp.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. 2d ed. San Francisco: W.H. Freeman and Company. 859 pp.

Spiess, F.N., R. Hessler, G. Wilson, and M. Weydert. 1987. Environmental effects of deep sea dredging. S10 Reference 87-5. La Jolla, CA: Scripps Institution of Oceanography. 86 pp.

Strub, P.T., J.S. Allen, A. Huyer, R.L. Smith, and R.C. Beardsley. 1987. Seasonal cycles of currents, temperatures, winds, and sea level over the Northeast Pacific continental shelf: 35°N to 48°N. J. Geophys. Res. 92:1507-1526.

Swan, J.M.A. 1970. An examination of some ordination problems by use of simulated vegetational data. Ecol. 51:89-102.

Tetra Tech, Inc. 1985. Recommended Biological Indices for 301(h) Monitorin Programs. Final report in preparation for the U.S. Environments Protection Agency. Bellevue, WA. 17 pp.

Thompson, B. and G. Jones. 1986. Benthic macrofaunal assemblages of slop habitats in southern California borderland. Allan Hancock Occ. Paper 7 49 pp.

Thompson, B.E. and G.F. Jones. 1987. Benthic macrofaunal assemblages of slop habitats in the southern California borderland. Allan Hancock Found. Occ Papers, New Series No. 6, 21 pp.

Van Blaricom, G.R. 1978. Disturbance, predation, and resource allocation in high-enery sublittoral sand-bottom ecosystem: Experimental analysis o critical structuring processes 'for the infaunal community. Ph.D Dissertation, Univ. Calif. San Diego, 328 pp.

Watson, L. 1981. Sea Guide to Whales of the World. New York: E.P. Dutton 301 pp.

Williamson, M.H. 1978. The ordination of incidence data. J. Ecol. 66:911 920.

Winant, C.D., R.C. Beardsley, and R.E. Davis. 1987. Moored wind, temperature and current observations made during Coastal Ocean Dynamics Experiments and 2 over the northern California continental shelf and upper slope. J Geophys. Res. 92:1569-1604.

Woodin, S.A. 1976. Adult-1arval interactions in dense infaunal assemblages Patterns of abundance. J. Mar. Res. 34:25-41.

Zar, J.H. 1974. Biostatistical Analysis. Englewood Cliffs, NJ: Prentice Hall, Inc. *620 pp.*

Zimmerman, G.M., H. Goetz, and P.W. Mielke, Jr. 1985. Use of an improve statistical method for group comparisons to study effects of prairie fire Ecol. 66(2):606-611.

APPENDIX A

DATA ANALYSIS METHODS

Appendix A.1 presents detailed rationale and descriptions of the statistical methods applied in this study, including the experimental design, multivariate community pattern analyses, multivariate and univariate hypothesis testing, evaluation of biological and environmental relationships, and replication analyses. Major sections address community pattern analysis (Section A.1.1), correlating community patterns with environmental variables (Section A.1.2), and hypothesis testing for community differences (Section A.1.3). Appendices A.2 and A.3 describe specific analyses, data manipulations, and presentation formats used for the individual hard and soft substrate analyses, respectively.

A.1 RATIONALE AND EXPLANATIONS OF STATISTICAL METHODS

A.1.1 Community Pattern Analysis

The overall approach to the hard and soft substrate analyses for community patterns is summarized in Figure A-1. The biological data first were analyzed separately by multivariate analyses to determine the community patterns. The resulting patterns then were related to the environmental variables with correlational and hypothesis-testing techniques.

Defining Community Patterns

Ordination and cluster analysis (Clifford and Stephenson, 1975; Gauch, 1982; Pielou, 1984) were used to identify and display the spatial patterns in the biological community of the soft substrate habitat. Ordination and clustering are based upon the degree of biological dissimilarity, as expressed by differences in the species composition and patterns of abundance, among a set of samples. Because ordination relies on a direct measure of dissimilarity, the first step in the multivariate analysis is to calculate dissimilarity indices for the set of samples being considered. Once the dissimilarity

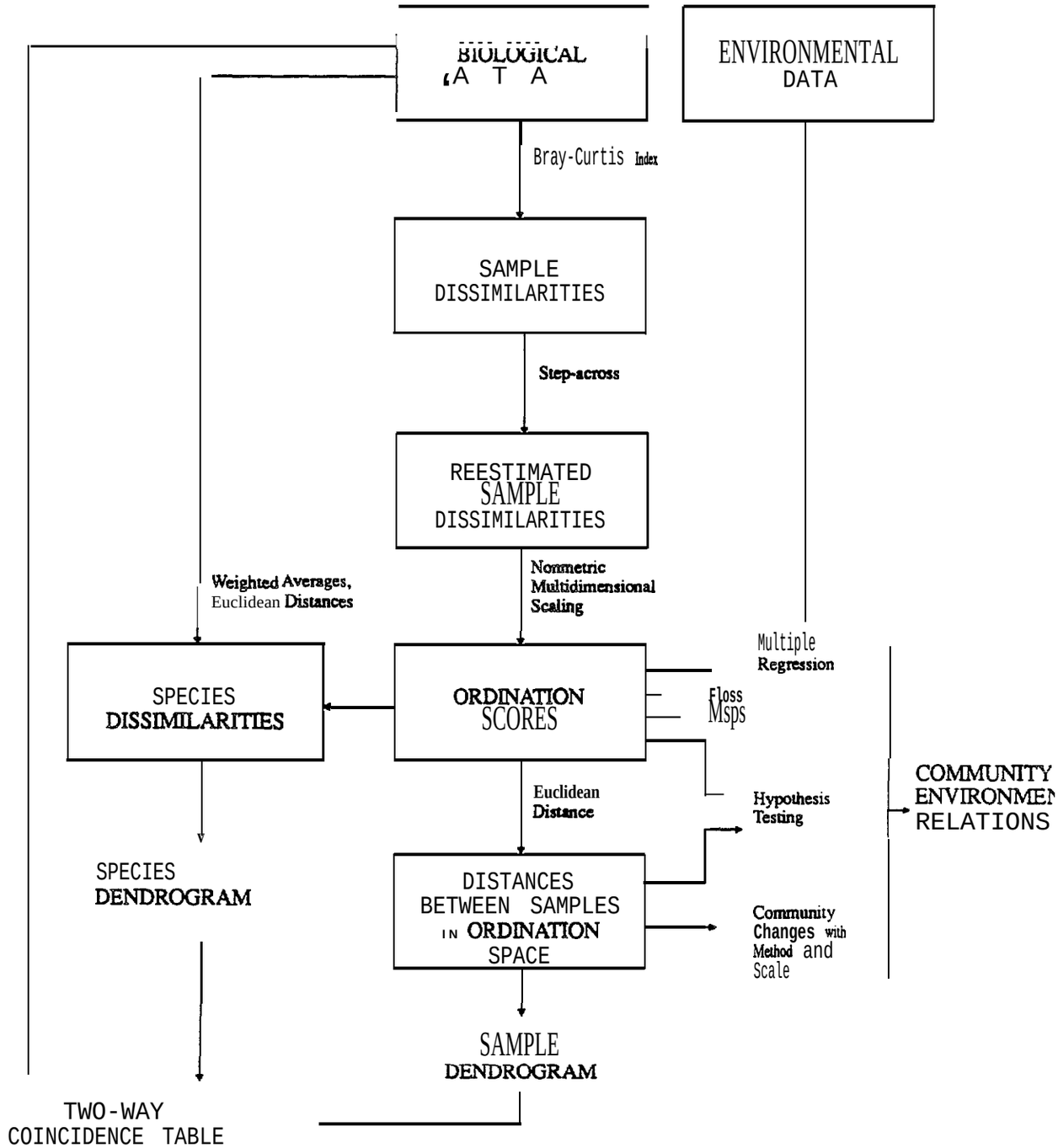

FIGURE A-1. FLOW CHART ILLUSTRATING THE GENERAL ANALYTICAL SCHEME. Data matrices ar enclosed within the rectangles. Outside the rectangles, analysis output descriptions are given i capital letters, and methods in lower case letters. "Sample" refers to sampling entities, which ma vary for different analyses.

indices have been calculated, the ordination analysis can proceed. Cluster analysis uses dissimilarity measures calculated from ordination scores, so that cluster analysis is conducted after the ordination has been accomplished.

Dissimilarity Index

A dissimilarity index quantifies the degree of similarity between a pair of samples or species. A pair of samples containing similar species at similar abundances will have a relatively low dissimilarity value, as will a pair of species that occur in similar patterns in time and space. A dissimilarity matrix is composed of index values for all pairs of observations.

For samples, the dissimilarity index values approach an asymptote as the samples being compared show greater degrees of biological differences (Beals, 1973) and reach a maximum when there are no species in common in the two samples being compared. Differences beyond this point will not be expressed by further increases in the values of the dissimilarity index. This is because the dissimilarity indices are based on faulty assumptions about the distributions of species along gradients of change (Beals, 1973; Austin, 1980; Swan, 1970). This problem is eliminated by the step-across method (Williamson, 1978; Smith, 1984; Bradfield and Kenkel, 1987). In this procedure, the larger dissimilarity values are reestimated from the smaller ones.

The computation of the Bray-Curtis or Czekanowski sample dissimilarity index (Clifford and Stephenson, 1975; Boesch, 1977) requires three steps. First, the data set is consolidated by eliminating very rare species. Then, the remaining species abundances are transformed and standardized to minimize bias caused by skewed distributions and abundances. Finally, the actual dissimilarity index is calculated and then reestimated by the step-across procedure.

Prior to the computation of the dissimilarity values, the rarer species in the data were eliminated. Such species would have little effect on the results (Day et al., 1971; Smith, 1976), and in many cases keeping them in the analyses would greatly increase both the computation time and the difficulty of presenting the results. In the analysis of the central and northern basins for

this study, the 615 species identified in the soft substrate core samples were reduced to 241 by eliminating all species not occurring at least six times or having a total abundance of 20. In the historical analysis, 305 of the 91! species were used; all species not occurring at least 5 times or having a tots abundance of 25 were eliminated. In addition, species occurring only once were eliminated, regardless of their total abundance.

The data for all analyses were transformed by a square root and standardized by the species mean (of values > 0). The transformation reduces sensitivity to skewed species distributions, and the standardization reduces the domination of the species with higher counts in the Bray-Curtis index computations. The effect of several different types of standardization are discussed in Smith (1976).

The Bray-Curtis dissimilarity values were then calculated by the method described by Smith et al. (1987). All dissimilarity values above 0.8 (the point at which Bray-Curtis dissimilarities become less sensitive) were reestimated by the step-across procedure. The dissimilarity values calculated in this step were among samples. Species dissimilarities were calculated in a different manner for use in the cluster analysis as described below.

Ordination Analysis

Ordination techniques display the biological data in a multidimensional space that is defined by the degree of dissimilarity within the set of samples being considered (Gauch, 1982; Pielou, 1984). The distance between any two points (representing two samples) in the space reflects their biological dissimilarity. The dimensions of the space are called axes, and the projections of the points in space onto the axes are called scores.

The objective of ordination analysis is to display a maximum amount of the biological variation in the data in a minimum number of ordination axes. The axes are ordered according to the degree of variability among scores, so that the first axis (Axis 1) has the greatest variation, and the last axis has the least. The greater the amount of variation among the scores (i.e., the greate

the degree of biological differences among the samples), the more the points are spread out along the axes. Major biological patterns will be expressed as a wide range of scores on the axes that account for larger proportions of the variability, and the environmental gradients that are associated with such patterns will be correlated with those same axes.

The ordination axes are positioned so that the scores on the different axes are uncorrelated, thus minimizing the amount of redundant information. The ordination technique used for this study, called local nonmetric multidimensional scaling (Sibson, 1972; Prentice, 1977, 1980), starts with the sample dissimilarity matrix consisting of the Bray-Curtis indices and an initial ordination configuration consisting of detrended correspondence analysis scores (Hill and Gauch, 1980; Gauch et al., 1981; Gauch, 1982). The detrended correspondence analysis (DCA) scores are only used as an initial configuration for the multidimensional scaling computations. Starting with DCA scores decreases computational time (since the starting configuration will be relatively close to the final results), and serves as a standard starting point for all analyses since the details of the final results can be somewhat affected by the starting configuration.

One output of the ordination analyses consists of bivariate plots of the ordination scores. These plots show the patterns of community relationships among sampling entities. The axes of the plot correspond to a pair of ordination axes. These are usually the first two ordination axes, since these axes represent the two strongest biological gradients in the data. The points in the plot represent the individual sampling entities.

Symbols were applied to the sampling entities in the ordination space to convey additional information. For example, symbols were used to indicate different levels of measured environmental variables. The patterns of these symbols in the ordination space demonstrated how well the environmental variables related to the community patterns. In addition, group designations from the cluster analysis, as well as geographic (e.g., basin) designations, were added to the ordination plot figures to enhance the interpretation.

In another approach, scores for each ordination axis of interest were plotte on maps of the sampling area to show the relationships between the communit gradients and the spatial pattern.

Cluster Analysis

Cluster analysis is used to identify groups of biologically similar samples o groups of species that occur in similar spatial and temporal patterns (Cliffor and Stephenson, 1975; Boesch, 1977; Pielou, 1984). A commonly used techniqu in benthic ecological studies is agglomerative hierarchical cluster analysis This method involves successive pairings of the most similar (or leas dissimilar) samples or groups of samples until all samples are in one larg group. The results, which are the similarity relationships among the entitie being clustered, are displayed in a tree-like structure called a dendrogram.

Most agglomerative cluster analysis techniques utilize a dissimilarity matri to determine the most similar samples and groups of samples as the pairin process proceeds. This study used an agglomerative hierarchical clusterir method called flexible clustering (Lance and Williams, 1967; Clifford ar Stephenson, 1975), with the flexible coefficient, Beta, set equal to th customary value of -0.25. The values in the dissimilarity matrix used in th cluster analysis of the samples are the Euclidean distances between the point (samples) in the ordination space. Thus, the sample dissimilarities wer derived directly from the ordination scores.

The cluster analysis computations could begin with either the Bray-Curti dissimilarities or with the distances between samples in the ordination space For this study, the distances between samples in the ordination space were use based on the following rationale:

1. The ordination space is the main focus of the analysis. When th distances from the space are used in the cluster analysis, th ordination space is partitioned into areas which contain sample with similar communities. In conjunction with the two-w. coincidence table, this approach simplifies the visualization o the species patterns throughout the ordination space, and assist in the choice of the number of dimensions of the space to inter pret. From this viewpoint, the cluster analysis is supportive c-

the ordination analysis; it serves this purpose best if it is derived directly from the ordination space.

2. The step-across procedure, which is essential to large-scale surveys of this type, can lead to reestimated Bray-Curtis dissimilarities which may be in a meaningful rank order, but not necessarily with the most meaningful magnitudes (Smith, 1984; Smith et al., 1988). Nonmetric multidimensional scaling is well suited for used with the reestimated distances since it is only sensitive to the rank order of the distances. Most importantly, this means that reestimated Bray-Curtis dissimilarities will reflect the shortcomings of the step-across procedure, but the ordination scores, on which they are based, will not.

3. The distances between samples in the ordination space will be based on the species data in all samples, but each Bray-Curtis dissimilarity will be based only on the species data in two samples being compared. From this viewpoint, the distances in the ordination space are based on much more information. The distances in the ordination space will be "smoothed" versions of the Bray-Curtis dissimilarities, with the random error and inconsistencies in the dissimilarities reduced.

The species were clustered utilizing interspecies dissimilarities (instead of intersample dissimilarities) calculated in a somewhat different way. The approach used to calculate the interspecies dissimilarities assumes that the dissimilarities are proportional to the dissimilarity of the habitats in which different species are found in greatest abundance (Austin and Belbin, 1982). The habitats of the species are the samples in which they are found, so that the dissimilarity of the habitats is defined by the dissimilarity of the samples. In this approach, the dissimilarity index continues to increase as the members of the species pair are found in increasingly dissimilar habitats.

The interspecies dissimilarities were computed from the ordination scores used in the ordination of samples. The weighted mean position of each species in the ordination space was computed, with the weights proportional to the transformed species abundances. The Euclidean distances between the weighted mean positions constituted the dissimilarity measure for the species.

Two-Way Coincidence Tables

A two-way coincidence table represents a biological data matrix with the row, and columns arranged in orders that optimally display the patterns of specie' importance within the samples. The orders of the rows and columns of th two-way table correspond to the orders along respective species and sampl dendrograms produced by the hierarchical cluster analysis (Kikkawa, 1968 Clifford and Stephenson, 1975). The task of choosing groups from a dendrogra is greatly facilitated by studying a two-way coincidence table (Boesch, 1977) Smith (1982) suggested a method of optimizing the orders of the species an samples without changing their group memberships. For compactness and ease o interpretation, the transformed (by square root) data values were standardize, by species maximum and converted to symbols (Smith and Greene, 1976; Helvey an Smith, 1985). When the data are standardized in this manner, they represen relative abundance values: the data values for a species are relative to th (transformed) maximum abundance for that species. A specific standardize, value will correspond to very different absolute abundances for species whit have very different maximum values.

Describing Species Patterns Along Gradients Defined by the Ordination Axes

The ordination axes define gradients of biological (species) change. It i useful to know which species define these gradients as well as the distribu tions of abundance of these species along the gradient. The following metho was used to display this information on ordination axis (Smith, i preparation):

1. For each species, the position of the peak of the abundant distribution in the ordination space was estimated. Data value in the top 20% of the abundance values were used as weights t compute the weighted average scores (position) for the species o each ordination axis.

2. For an ordination axis and a species, the species abundances wer estimated at twenty equally-spaced positions along the ordinatio axis. The positions of these estimates on all other axes bein utilized were held constant at the position of the peak of th abundance distribution for that species. This minimized gaps i the abundance distribution along the axis in question, since th

positions on the other axes were situated near the peak abundances for the species. The abundances were estimated from a weighted average of the abundances of the surrounding data points (samples) in the ordination space. The weights were:

$$\frac{1}{D_{ip}^2},$$

where D_{ip} is the distance between sample i and position p in the ordination space. Position p is the position of the point being estimated. Thus, closer points will receive more weight in the estimate.

3. For each axis, the estimated values for each species were converted to symbols (as with the two-way coincidence tables) and the symbols for the twenty successive positions along the ordination axis were printed out. All species were included, and the species were ordered according to their mean position along the ordination axis.

4. The abundance distributions of species best defining a gradient (ordination axis) tend to be unimodal, and the estimated abundances vary somewhat. When several species are included, it is useful to eliminate from the display species not meeting these criteria. For this study, an index, varying from 0 to 100, was computed for each species. The index value is low when the distribution of estimated values for a species is multimodal with the modes far apart on the gradient and/or when the estimated values vary a relatively small amount along the gradient. High index values occur for unimodal species distributions with larger amounts of variation along the gradient. All species with index values less than some chosen level can be eliminated easily from the display.

Comparison of Ordinations With and Without Replication

Two replicates were taken at each of twelve soft substrate stations. An analysis was performed to assess how much the replication would affect large-scale patterns shown in an ordination analysis of the twelve stations. The analysis consisted of the following steps:

1. The stations were ordinated with data from the first replicate at each station.

2. The stations were ordinated with data from the second replicate at each station.

3. The stations were ordinated using the mean of the two replicate at each station.

4. The ordination results were compared.

To assist in this comparison, Procrustes rotation (Schonemann and Carroll 1970; Digby and Kempton, 1987) was performed on the first two ordinations. Th rotation maximizes the correspondence between the axes of two differen ordinations. In this case, the ordination axes from the first analysis were rotated to correspond maximally to the axes of the third ordination. Th ordination axes from the second analysis were likewise rotated maximally t correspond to the axes of the third ordination. The Procrustes rotation doe not alter the pattern of points in the ordination spaces, but only orients th axes for better direct comparison. To compare the ordinations, the scores fro the three analyses are plotted together in the same space. The three position. for each station are outlined in the plot. This shows the effect of replica tion on the position of each station and whether the pattern of stations in th space changes with replication.

A.1.2 Correlating Community Patterns with Environmental Variables

Environmental Correlations with the Ordination Axes

Since environmental gradients often cause community changes, community pattern! which are expressed by the scores on the first few ordination axes will ofte be correlated with environmental gradients. Once the community patterns were defined by the multivariate analyses, correlational analyses were performed t define possible environmental relationships with those patterns. For the sof substrate box-core data, hypotheses were then developed concerning those relationships, and tested by univariate statistical analysis. Relationship! were examined through the use of multiple regression analysis, canonica. correlation analysis, weighted discriminant analysis, and mapping techniques.

Multiple Regression

The major patterns of change in the biological community are expressed in the first few ordination axes. If these patterns are related to environmental factors, then the scores on these ordination axes will correlate with appropriate environmental variables. As an example, if the major changes in the biological community are caused by increasing depth, then the scores on ordination Axis 1 should be *strongly* correlated with depth. Note that high correlations do not prove cause and effect, and are only used to generate hypotheses of cause and effect. In addition, it often happens that correlations with all environmental variables are low because none of the measured environmental variables were associated with the cause of the observed biological changes.

In the present study, the relationships between the scores on an ordination axis and the environmental variables were examined using multiple regression (Cassie and Michael, 1968; Chang and Gauch, 1986). The ordination scores were the dependent variables, and the environmental variables were the independent variables. A variable-selection technique that considers all possible combinations of the measured environmental variables ("models") was used to simplify the analysis (SAS, 1985; RSQUARE procedure). For each combination of variables , an R-squared value (coefficient of determination) was computed. All of the best-fit regression models were run; the model with the minimum number of variables (i.e. , the one at which increasing the number of variables did not improve the R-square value) was chosen for interpretation. This procedure prevents overdependence on a single regression model.

Statistical tests were used to indicate whether the regression equation or the individual regression slopes were significant (alpha = 0.05, Type-1 error); nonsignificant analyses were not interpreted further. These statistical tests were not emphasized, however, since statistical significance alone does not ensure either ecological relevance or a thorough analysis.

Canonical Correlation Analysis

This technique is similar to the multiple regression analysis, except tha instead of using a single ordination axis as a dependent variable, all th ordination axes are simultaneously used as dependent variables (Gittens, 1979) To avoid problems caused by high intercorrelations of environmental variables the sediment-size data (phi, skewness, kurtosis, and percents in various siz fractions) were transformed to principal component scores, using princip component analysis (PCA), before analysis.

PCA is an ordination technique that creates new composite environments variables from conventional environmental data. The new variables, which ar actually the scores on the various PCA axes, are uncorrelated with one another and they tend to be fewer in number than the original variables. Th correlations between the new variables and the original variables show which o the original variables are the most important components of the new variables The new variables are used instead of the original variables in multipl regression and canonical correlation analyses.

Weighted Discriminant Analysis

Discriminant analysis was used to determine which environmental variable correspond to the groups defined in the cluster analysis (Green and Vascotto 1978). Weighted discriminant analysis utilizes additional within-group an between-group biological information (contained in the ordination space) in th computations (Smith, 1976; 1979). Again, to avoid problems caused by hig intercorrelations of environmental variables, the PCA scores were used a environmental variables for the sediment-size data.

Mapping of Spatial Patterns

The ordination axis scores were placed at the sample locations on a map, an isolines, or lines of equal score value, then were drawn (Smith and Greene 1976; SAIC, 1986). A separate map was prepared for each ordination axis o interest. The results were interpreted by comparing the spatial pattern

formed by the contours of ordination scores with the spatial patterns of pertinent environmental variables.

Final Results Presentation

In the analyses correlating the community patterns and the environmental variables, only the multiple regression results are presented. This analysis is the simplest to display and understand due to the use of the variable-selection procedure, which reduces the number of variables in the regression models considered and allows for the use of original variables rather than the more abstract PCA scores. More importantly, the canonical correlation and weighted discriminant analyses did not provide any additional information or insight that was not already evident in the simpler multiple regression results.

A.1.3 Hypothesis Testing for Community Differences - Soft Substrate Box Core Data

The results of the multiple regression and canonical correlation analyses were used to generate hypotheses concerning possible environmental causes of the observed biological patterns. The methods used to test those hypotheses involved both multivariate and univariate techniques.

The multivariate techniques included multivariate analysis of variance (MANOVA) of the ordination scores and tests of dissimilarity indices (the distances between the samples in the ordination space). Since variation or distances in the ordination space reflected changes in the biological community, the hypotheses tested involved overall community differences. The independent variables tested with these methods were the same as those used with the univariate parameters; thus, the tests examined community differences between basins, depths, and sediment types.

The univariate analyses included analysis of variance (ANOVA) to detect significant differences in community summary measures, the abundances of selected species, and environmental variables between basins, depths, and

sediment types. Pairwise Tukey-Kramer a posterior tests were used to provid more detailed analyses of those differences.

Multivariate Analyses

MANOVA

MANOVA is similar to standard univariate analysis of variance (ANOVA), excep that there are multiple dependent variables with MANOVA (Morrison, 1967). I the present application, the scores for each ordination axis represented th dependent variables. Because the scores on different ordination axes ar uncorrelated, the MANOVA test of the null hypothesis is equivalent to separat univariate analysis of variance tests on each ordination axis, with allowanc made for the multiple tests. If the univariate null hypothesis is disproven o any one axis, the MANOVA null hypothesis is disproven. This method assume that the distribution of samples within a treatment group are multivariat normal, and that the variance-covariance matrix of each treatment group is th same.

Correlation Methods with Dissimilarity or Distance Indices

Assessment of the relationship between the elements in two distance matrice can provide insight into community patterns. Standard t-tests or one-wa ANOVAs normally cannot be used to compare sets of distances because all th distances are not independent observations. This is due to the fact that th same sample can be associated with more than one distance value. Instead correlational analysis must be applied to the two distance matrices. In th tests used in the present study, one of the distance matrices, D, consisted o the distances between samples in the ordination space, and the other distant matrix, M, consisted of 1s and 0s. In each test, Matrix M was establish specifically to test a particular null hypothesis. For example, th communities in two basins were compared by testing whether the between-basi distances in Matrix D tended to be larger than the within-basin distances in D All distances in M that corresponded to between-basin distances were set equa to 1, and those corresponding to within-basin distances were set equal to O

If the between-basin distances in D tended to be larger than the within-basin distances, then matrices D and M were considered to be positively correlated.

Several approaches to correlational analysis of distance matrices are available (e.g., Mantel, 1967; Dietz, 1983). Basically, the correlation between the elements in two symmetric distance matrices, called M and D, is assessed from:

$$Z = \sum_{i=2}^{n} \sum_{j=1}^{i-1} m_{ij} d_{ij},$$

where:

m_{ij} = the element in the ith row and jth column of M
d_{ij} = the element in the ith row and jth column of D.

The number of rows and columns in M and D must be identical. The corresponding elements in M and D will contain values describing the same samples (which are represented by the same rows and columns of M and D).

One of the approaches used in the present study assessed the probability that the computed Z value could be obtained by chance alone. The assessment compared the computed Z value with one generated from a null distribution obtained from random rearrangements of one of the distance matrices. The actual one-tailed probability for positive correlation will be the number of Z values in the null distribution which are greater than or equal to the computed Z value, divided by the number of Z values in the null distribution. The computed Z value is considered as part of the null distribution, so the numerator will always be at least one (1).

The second approach used a different computed parameter, Kc (instead of Z) to assess relationships between M and D (Dietz, 1983). It is computed as:

$$Kc = \sum_{j<k} \text{sign}[(m_{ij} - m_{ik})(d_{ij} - d_{ik})],$$

where:

$i \neq j \neq k$
sign(x) = 0 for x = 0
-1 for x < 0
+1 for x > 0.

Kc is the Kendall tau-correlation statistic which only includes "connected pairs of distances, i.e., pairs of distances with an entity (row or column i, D, M), in common.

Distance correlation methods such as Z and Kc which require actual permutation of the rows and columns of the distance matrix lose sensitivity when there ar a limited number of effectively different permutations of the data. Fo example, in the comparison of the data on the 100-m depth communities from th Point Arena and Santa Cruz Basins, there are 720 possible permutations of th rows and columns of the distance matrix (6!), but 120 of those permutation. (5!) will give the same results as the computed Z or Kc value. With such test, therefore, the smallest probability possible when comparing those basin (or any two treatment groups of 5 and 1 observations) is 120/720, or 0.167.

Multiresponse Permutation Procedure

An approach called multiresponse permutation procedure (MRPP), also can be use to compare the positions of treatment groups in the ordination space (Zimmerma et al., 1985). The null distribution (generated as for the correlation analysis of distances) of the average within-treatment (basin or depth, fo example) group distances is compared with the computed value of this paramete (Mielke, 1984). Instead of permuting the samples to compute the nul distribution, as is done in the correlational analysis, MRPP estimates th probabilities from a continuous probability density function that is based o the computed moments of the distribution (Berry et al., 1986).

Multiple Regression with Dissimilarity or Distance Indices

This method utilizes a multiple regression model with the between-sampl distances in the ordination space as the dependent variable and corresponding

changes in environmental variables as the independent variables. The technique was used when more than one treatment factor was involved in the null hypothesis. For example, when both depth and basin were treatment factors, the following model was used:

$$D_{ij} = b_0 + b_1 B_{ij} + b_2 `ij'$$

where:

D_{ij} = the distance between samples i and j
b_0 = the intercept term
b_1, b_2 = the regression slopes for the corresponding effects
B_{ij} = 0 if both samples i and j are in the same basin
D_{ij} = 0 if both samples i and j are at the same depth.

If the values for B_{ij} or D_{ij} were not set equal to zero, they were set equal to one. The null hypothesis of no difference between basins or depths was evaluated by testing the null hypotheses that the regression slopes are less than or equal to zero. This was a one-tailed test since we were interested in the situation where the distances between the different treatment groups are greater than those within the treatment groups. The significance tests on the slopes were not performed in the same manner as standard least-squares regression since all the distance values are not independent observations.

Two methods of testing the null hypotheses for the slopes were used. The method of Dyer (1978) is based on an estimate of the covariance of the error for distances with an entity in common (called r), which is assumed to be the same throughout the entire distance matrix. Dyer (1978) does not discuss the use of probability tests with his method; we used simulated data to check whether the probabilities from the standard t table with N-p-1 degrees of freedom were a good estimate of the type-1 error level for the slope tests. At least for the simulated data used, the actual type-1 errors from the simulations corresponded fairly well with the t-table values at p = .05. This technique has been applied to ecological data in Spiess et al. (1987), Mahon and Smith (in press), and SAIC (1986).

The method of Smouse et al. (1986) is an extension of the Mantel (1967) correlational test (see above). Here, null distributions of the slopes are

generated from random permutations of the rows and columns of the distant matrix. The positions of the computed slopes in the null distributions are used to estimate the probabilities that these parameters are due to chance alone (represented by the null distribution). Since the probabilities are generated from the data, this method is associated with fewer assumptions than the Dyer (1978) method.

Interaction Between Basin and Depth

The nature of any basin by depth interaction was assessed in detail using multiple tests comparing the between-depth distances on the same transect in the different basins. An interaction between basin and depth would be expected to show up as differences in the between-depth distances on the same transect between basins. This can be illustrated with a simple example (Table A-1). The null hypothesis in the test for interaction between basin and depth is that the mean of distances D12 and D34 is not different from the mean of distances D56 and D78, where, for example, D56 is the distance between stations 5 and 6. A t-test can be used to compare these distances (e.g., between stations because the distances are independent observations. To avoid violation of normality and equal-variance assumptions associated with the standard t-test the probabilities for the t-tests are computed from a randomization procedure (Edgington, 1987). This simply involves generating a null distribution of values from several random assignments (without replacement) of samples to treatment groups. For the present application, 500 randomizations were used to build the null distribution. The actual tests for interaction involved several more individual tests because there were four depths and three basins. Data from the Santa Cruz Basin, which contains only a single station, were not included in these analyses.

The pattern of results from these multiple tests showed the general nature of the interaction. It is theoretically possible to perform an overall test for interaction by including an interaction term in the MANOVA model. However, in this study interaction was not tested with the regression method because in tests with simulated data we have found that this method does not measure th

TABLE A-1. EIGHT STATIONS ON FOUR TRANSECTS IN TWO BASINS, USED TO ILLUSTRATE THE INTERACTION TESTS.

	DEPTH	
	1	2
Basin 1		
Transect A	1	
Transect B	3	
Basin 2		
Transect C	5	6
Transect D	7	8

interaction accurately. Table A-2 describes the codes used in the results to indicate the various methods.

A.2 HARD SUBSTRATE ANALYTICAL METHODS

The initial analysis of community relationships among the transect band quadrats showed that two very different (as far as the fauna were concerned) habitats were represented by the band quadrats. One habitat, referred to as "hard substrate, " consisted of band quadrats with exposed hard substrate (some sediment veneer could also be present). The other habitat, referred to as "sediment veneer, " consisted of segments with no relief but with a (presumed) veneer of soft sediments over hard substrate. These habitats were examined separately in subsequent analyses to avoid obscuring other information of interest by the differences between the two habitats.

The hard substrate data were analyzed by multivariate statistical techniques to examine community patterns and their relationships with environmental variables. These analyses involved computations utilizing all or a large part of the sampled species. Therefore, the results reflected patterns of community change rather than patterns of individual species populations. Univariate

TABLE A-2. SUMMARY OF CODES AND TYPES OF METHODS USED IN THE STATISTICA ANALYSES .

Code	Method
Mantel	Correlational method, Prob(G) from normal distribution
z	Correlational method, Prob(Z) using null distribution fro permutation
KC	Correlational method, Prob(Kc) using null distribution fro permutation
MRPP	Multiresponse permutation procedure (MRPP)
Dyer	Regression with distances, using method of Dyer (1978)
Smouse	Regression with distances, using method of Smouse et al. (1986)
MANOVA	Multivariate analysis of variance (MANOVA)

All the methods for which a null distribution is generated (Z, KC, Smouse) ar based on 400 random permutations of the rows and columns of the distant matrix.

analyses of individual species were not conducted because the data did no provide sufficient power for such analyses.

Successive analyses focused on community patterns among transect band quadrats band quadrat replicates, transect replicates, transects, and basins (Figur A-2) . For each analysis, the sampling entities involved were selected to focu on the particular question of interest. In some cases, the methods used i analysis were dependent on results from the preceding analysis, thu necessitating some review of results as detailed in Section 3.1.

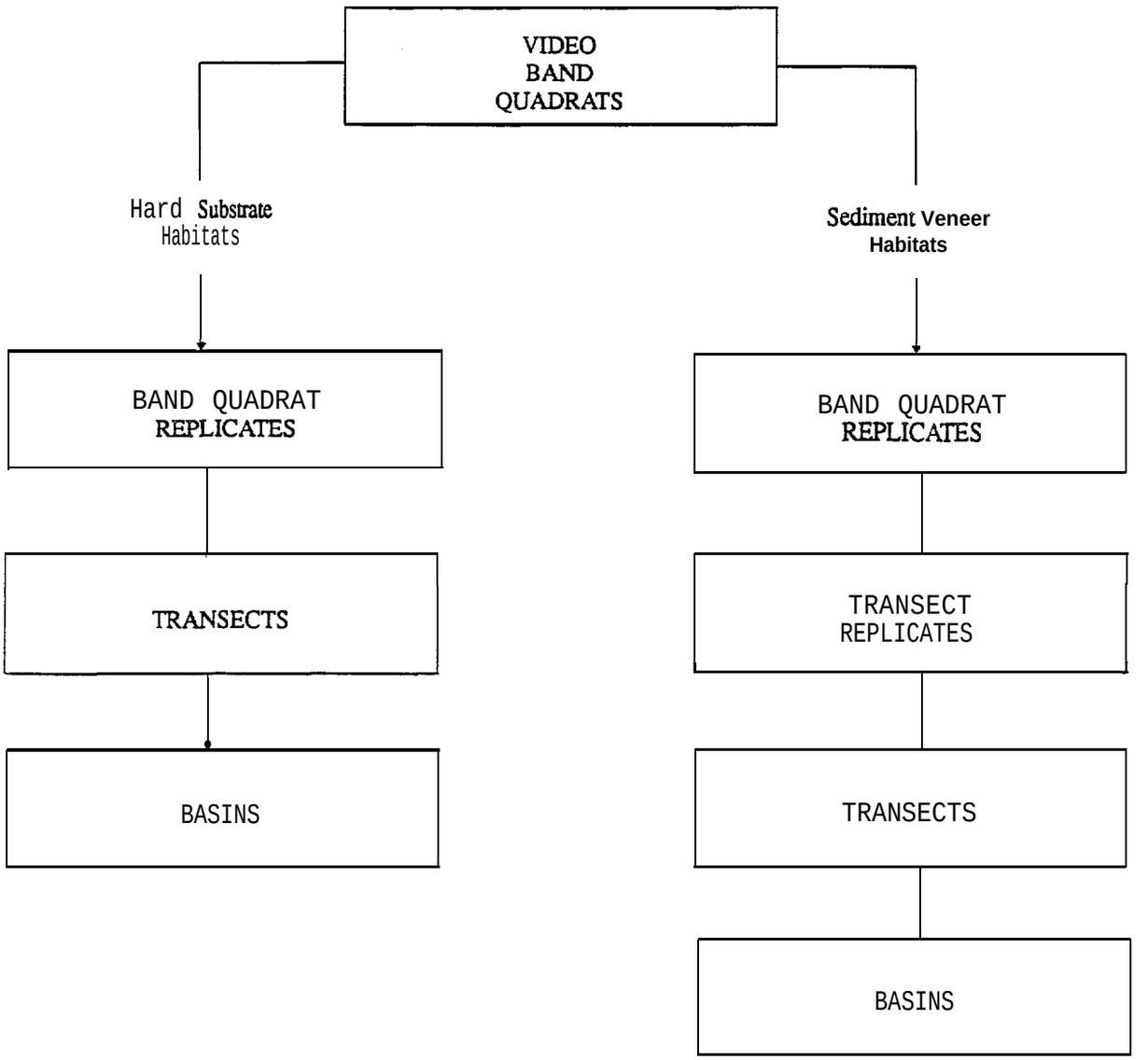

FIGURE A-2. SEQUENCE OF ANALYSES FOR THE HARD SUBSTRATE VIDEO DATA. The community contrasts on which the analyses were focused are given within the rectangles. After the initial analysis, the hard substrate and sediment veneer habitats were analyzed separately.

A.2.1 Video Data

Description of Original Data

The original video data consisted of 14 transect locations. Each transec consisted of one or two series of 30 band quadrats. Each band quadra corresponded to 30 m of coverage by the video camera. For each band quadrat the data recorded in the first 30 seconds of video tape were used in th original data matrix. The bottom distance represented by each 30 seconds i approximately 7 m, assuming an average speed of the ROV of 0.5 kn. Six of th 14 transects were long enough to result in two series (A and B replicates) fo a total of 20 transects (series) of data. The data were recorded as presence absence (1 presence, O absence). There were data for a total of 600 ban quadrats (20 transect series x 30 band quadrats).

An additional set of data was obtained for each of two transects (HB2 and HB6 to examine variability within the 30-m segments. These data were obtained b viewing an additional 30 seconds (immediately following the first 30 seconds of the video tape for 20 segments in HB2 and 10 segments in HB6. The methods o measurement of faunal and environmental data were identical to those used fo the first 30 seconds in each segment. These data, along with data from th first 30 seconds of the same segments, are referred to as band quadra replicates.

The data measurements were made for all recognizable taxa and 15 environments variables. The environmental variables included the presence or absence o boulders, burrows, cobble, furrows, hummocks, pebbles, ripples, shell hash soft substrate, turf, wood debris, l-cm to 15-cm relief, 15-cm to 1-m relief l-m to 3-m relief, and > 3-m relief.

Analysis of Transect Band Quadrats

The purpose of these analyses was to define the patterns of communit differences among the individual transect band quadrats and relate thos

patterns to the patterns of environmental variables. The original data matrices were reduced to a manageable size in the following manner:

1. A separate cluster analysis was performed for each transect, to delimit groups of band quadrats with similar fauna. Band quadrats cluster groups on a transect were chosen using the two-way coincidence table and dendrogram for that transect. Prior to these analyses, 24 band quadrats on seven transects were eliminated because they completely lacked fauna. All taxa in the original data were used in the analyses.

2. A new faunal data matrix was created by averaging the faunal data in each band quadrat cluster group, and a new environmental variables data matrix was created by averaging the environmental data for each band quadrat cluster group. The averaged data from all transects were merged to form two overall data matrices (one for the biological and one for the environmental data). The matrix had 118 observations (118 averaged transect band quadrats), in contrast to the 600 observations in the original matrix (band quadrats). The reduced data matrix provided a manageable and biologically meaningful subset of data. The sampling entities in this analysis were band quadrat groups that contained similar communities. The data values were equivalent to the proportion of band quadrats (in the average transect band quadrat group) which contained the taxon or environmental variable in question.

Ordination, cluster, and multiple regression analyses were performed on the averaged transect band quadrat groups. The ordination output included bivariate plots for the first two ordination axes. The symbols used in the plots included those for the overall cluster analysis groupings, basins, and the environmental variables shown to be correlated with the ordination axes in the multiple regression analyses. A two-way coincidence table was produced to show the distribution of the fauna across the averaged transect band quadrat groups (and the habitats they represent).

Analysis of Band Quadrat Replicates

The purpose of this analysis was to compare community differences within band quadrats to those among different band quadrats on the same transect. This approach allowed an evaluation of the scale of community changes along transects, particularly as related to the design of future sampling programs.

The band quadrats replicates analyzed were from two consecutive 30-secon viewings in 20 of the band quadrats in Transect HB2 and 10 of the band quadrat in Transect HB6. Transect HB2 consisted almost entirely of sediment venee substrate, and Transect HB6 was composed entirely of exposed hard substrate The first 30 seconds of a band quadrat were called replicate A, and the secon 30 seconds in the same band quadrat were called replicate Q. The samplin entities in this analysis were all of the A and Q band quadrat replicates i Transect HB2 and HB6.

Cluster analysis was performed to show the relationships between the replicate in the same band quadrat. A two-way coincidence table was produced to show th pattern of species occurrence among the band quadrat replicates.

Ordination analysis was used to examine the relationships between spatia distance and community differences. The distances between the band quadra replicates in the ordination space were used to test the null hypothesis tha the community differences within a band quadrat (differences between replicate A and Q within a band quadrat) were no smaller than community differences amen band quadrats. This was accomplished with a Mantel test which compared th within-band quadrat distances to the between-band quadrat distances. The nul hypothesis was rejected if the between-band quadrat distances we r significantly ($p \leq 0.05$) larger than the within-band quadrat-segmen distances.

The distances in the ordination space then were plotted against the difference in the band quadrat (or segment) numbers, which were 0 for replicates in th same segment, 1 for adjacent segments, 2 for segments separated by a segment and so forth, up to 29 when comparing the first and last segment.

Analysis of Transect Replicates - Sediment Veneer Habitat

The purpose of this analysis was to define the community differences among th replicates at the same transect locations and to relate those to environments differences. Six sediment veneer transects were sufficiently long ($\geq$ 1800 m to allow two replicate series (A and B replicates of 30, 30-m band quadrat

each) of data to be recorded. All transects except HB6 and HB16 (i. e., 18 of 20 transect series), which lacked sediment veneer, were included. The sampling entities in this analysis were transects (i.e. , quadrats were averaged over transects) . These data values were equivalent to the proportion of band quadrats in the transect which contained the taxon or environmental variable in question.

Cluster and ordination analyses were performed to show the relationships between the replicates at the same transect location. In all but one case (HB8), the communities at the two transect replicates at a specific location were relatively similar. Because the communities in the two replicates at HB8 were dissimilar, the environmental variables for those two replicates were directly compared to generate hypotheses for possible causes of the difference.

Analysis of Transects - Sediment Veneer Habitat

The purpose of this analysis was to define the community differences among the transect locations and to relate those differences to environmental differences. The data used were identical to those used in the analysis of transect replicates, except that the unusual replicate at Transect HB8 was eliminated. This enabled us to emphasize transect differences instead of transect replicate differences.

Ordination, cluster, and multiple regression analyses were performed. The ordination output included bivariate plots for the first two ordination axes. The symbols used in the ordination plots included those for cluster-analysis groupings and for the environmental variables that the multiple regression analyses showed were correlated with the ordination axes. A two-way coincidence table was produced to show the distribution of the fauna across the transects.

Analysis of Basins - Sediment Veneer Habitat

The purpose of this analysis was to define the community differences among the basins and to relate those differences to abiotic factors. In the analysis of

transects, depth was shown to be correlated with community differences amen the transects. To focus the analysis more on basin (rather than depth differences, the three deeper transects (HB3, HB4, and HB10) were eliminate the data were the same as those used in the analysis of transects (see above).

Ordination analysis was performed on the remaining data. The ordination score for the first two axes were plotted and the basins were outlined to indicat the relationships among the communities in the various basins.

The distances between the transects in the ordination space were used in Mantel test to test the null hypothesis that there was no difference among th basin communities. A separate test was performed for each basin pair. Whe the distances (in the ordination space) between the transects (or transec replicates) in different basins were significantly larger than the distant within the basins, then the null hypothesis was rejected for that pair c basins.

Analysis of Transects - Hard Substrate Habitat

The purpose of this analysis was to define the community differences among th transect locations and to relate them to environmental differences. The dat included 11 transects that contained hard substrate habitats. The data wer prepared in the same manner as for the sediment veneer habitat.

Ordination, cluster, and multiple regression analyses were performed. Th ordination output included bivariate plots for the first two ordination axes The symbols used in the plots included those for cluster-analysis groupings an for the environmental variables that the multiple regression analyses showe were correlated with the ordination axes. A two-way coincidence table wa produced to show the distribution of the fauna across the transects.

Analysis of Basins - Hard Substrate Habitat

The purpose of this analysis was to examine community differences among the basins. The same data used in the transect analysis were used in the basin analysis.

The basins segregated well in the ordination space from the analysis of transects; therefore, it was not necessary to conduct separate ordination, cluster, and regression analyses emphasizing the basins. The distances between the transects in the ordination space (for the transect analysis) were used with Mantel tests 1) to test the null hypothesis that the communities in a pair of basins were the same. If the distances (in the ordination space) between the transects (or transect replicates) in different basins were significantly larger than the distances within the basins, then the null hypothesis was rejected for that pair of basins.

A.2.2 Photoquadrat Data

Description of Original Data

Photoquadrat data (see Section 2.3) were collected only from two transects (HB6 and HB8), both in the Point Arena Basin. The limited nature of these data allowed only a very simple pattern analysis comparing the photoquadrats of these transects. Most of the analyses focused on measured community changes associated with various levels of spatial and methodological variation. The levels of spatial variation included variation between replicates (i.e., between randomly collected photoquadrats) in the same general area, different locations (called times, since the location changed with time), and transects. The various methodological variations included standard-point contact readings, replicate-point contact readings of the same photoquadrats and same-point pattern by the same observers (called QC replicates), point-contact readings with indications of the presence of organisms that were not contacted by a point, and percent cover and abundances from examination of the entire photoquadrat (= total enumeration).

Analysis of Photoquadrats - Transects

The purpose of this analysis was to define the community differences among th transect locations and to relate -them to environmental differences. The point contact data were used for this analysis.

Ordination and cluster analysis were performed. The ordination scores for th first two axes were plotted and a two-way coincidence table based on th. cluster analysis results was produced to show the faunal differences betwee the two transects.

Comparisons of Spatial and Methodological Variability

Point Contact Data Only. The purpose of this analysis was to estimate th community variability associated with different spatial scales and to compar those variabilities with the variabilities between QC replicates. All point contact data were used, including the QC replicates, where they were taken The data were used to compute an ordination space, and distances between th sampling entities in the ordination space were used to compute the averag distances between various categories of spatial-scale and analytical methods.

All Data as Presence/Absence. The purpose of this analysis was to estimate th community variability associated with different spatial scales and to compar them with the variabilities between QC replicates and between differen methodologies . All data were converted to presence/absence (1 = present, O absent) . This approach allowed the point-contact data to be combined with th data from the other methodologies. All photoquadrats, with the fauna measure by all methods, were the sampling entities. The data were used to compute a ordination space, and selected distances between the sampling entities in th ordination space were used 'to compute the average distances between variou categories of spatial-scale and analytical methods.

A.3 SOFT SUBSTRATE ANALYTICAL METHODS

Description of Original Data

Fifty-one stations were sampled in four basins of the Central and Northern California Planning Areas (see Section 2.4). At twelve of these stations, a second replicate sample was collected, resulting in a total of 63 samples.

The biological data used in the analyses consisted of the pooled data from the 0.5-mm and 1.0-mm screens (Section 2.4). The species values were abundance counts, except for colonial species, which were quantified as presence/absence. Taxa potentially containing multiple species or containing only juveniles, and those represented by fragments were eliminated, thus resulting in a total of 615 species.

The environmental data included measurements of dissolved oxygen, temperature, water depth, sediment total organic carbon, and proportions of the sediment in 12 grain-size categories (phi units). The percentage of gravel, sand, silt, and clay, the mean and standard deviation, skewness, and kurtosis of the sediment-size distribution were computed. A variable measuring the degree of sorting in the sediment, defined as -1 times the standard deviation of the sediment distribution, also was calculated.

A.3.1 Community and Environmental Patterns and Correlational Analyses

Sediment Types at the Stations

The purpose of this analysis was to identify groups of stations with similar sediment types. The data attributes of the sediments included proportions of sediment in 12 grain-size categories (phi units) and sediment-distribution parameters, including mean phi, sorting, skewness, and kurtosis.

Cluster analysis of the sediment data defined groups of stations characterized by different sediment types. The sediment types with specific qualities were

assigned letters (e.g. , A-E), each with a corresponding descriptive term fo the overall category (e.g., Type A = medium sand).

Prior to the cluster analysis, the sediment-size variables were transformed t principal component (PCA) scores, and the Euclidean distances between th stations in the first four dimensions of the PCA space were utilized in th cluster computations. The elimination of the PCA axes beyond the fourth axi excluded minor patterns of no interest from the analysis.

Soft Substrate Community Analysis

The purpose of this analysis was to determine the patterns of soft substrat community distribution in the survey area and relate those patterns t gradients in the environment. The sampling entities were the individual gra samples, including the replicates. The number of species was reduced from 61 to 241 by retaining only those species that occurred in at least 6 samples o had a total abundance of at least 20.

The soft substrate infauna was described on the basis of samples from 5 individual stations distributed among three basins (Eel River, Point Area, ar Bodega). Single samples were collected at 39 of those stations, and replicate (two) samples were collected at 12 stations, yielding a total of 63 discret samples (also see Section 2.4).

Ordination, cluster, and multiple-regression analyses were performed. Th ordination output included bivariate plots for the first two ordination axes To facilitate interpretation of biological patterns and of relationship between biological patterns and environmental variables, different symbols we used on the bivariate plots. The symbols included those representir cluster-analysis groupings, basins, and the environmental variables shown to l correlated with the ordination axes in the multiple-regression analyses.

The ordination scores for the first two axes were plotted on a map of th entire survey area. At each station location, the score for the station w. indicated, and isopleth contours were drawn to summarize and illustrate th

geographic pattern of the scores. At stations where there were two replicates, an average of the two scores was used.

The species that comprised the community gradients represented by the first two ordination axes were displayed in two tables called a species-gradient plot, which is similar to a two-way coincidence table. However, the columns of the plot represented hypothetical samples (i.e., stations) at equal intervals along the ordination axis. The rows represented the species, with the species order corresponding to the average position of the species along the axis. The data output in this form is referred to as a species-gradient table. The data values in the table are estimated relative abundances which are indicated by symbols . Only the species which appeared to be part of the community gradient represented by the ordination axis were retained in the table.

The cluster analysis output consisted of a dendrogram depicting biological relationships among the stations. A two-way coincidence table was produced to show the distribution patterns of the species among the samples (i.e. , stations and replicates).

To facilitate the interpretation of community-environmental relationships, the values of some of the environmental variables shown by multiple regression analyses to be correlated with the ordination scores were plotted on maps of the area.

Multiple-regression analysis was the primary tool used to examine community-environmental relationships. Dependent variables included the ordination scores for Axis 1 and Axis 2. Independent variables included dissolved oxygen, temperature, depth, total organic carbon, and several measures of sediment character (mean phi, kurtosis, skewness, sorting index, and percentages of gravel, sand, silt, and clay). The multiple-regression technique used is that described for hard substrate communities.

A.3.2 Testing of Hypotheses - Multivariate Approach

Hypotheses (see also Appendix Al) were tested using seven different multi variate techniques which directly or indirectly used ordination scores t compare the community types in basins, depth ranges, and sediment types. Thes seven analytical methods are described in Appendix Al, Volume I, and ar summarized in Table A-2. For each null hypothesis tested, all seven analytica techniques were used.

The multivariate analyses tested the null hypotheses that the communities ar the same between basins, depths, and sediment types. Hypothesis testing fo community differences is a relatively new and undeveloped field, so it wa useful to compare the results of the different methods. The use of multipl tests increased the probability that some comparisons would show significant differences due to chance alone (a Type-1 error). Rather than reducing th Type-1 error significance level (e.g., with the Bonferroni adjustment; Jones *1984)* to control the level of the experimental error, the patterns of result and the relative positions of the various treatment groups in the ordinatio space were used to help interpret the statistical results.

Community Changes with Respect to Basin and Depth

The purpose of these analyses was to test the null hypothesis that th communities in the different basins (or basin pairs) or at different depth were the same. The null hypothesis that there was no interaction between basi and depth also was examined. Data consisted of the ordination results fro analyses with all samples.

The Dyer and Smouse regression methods were used for tests with basin an depth, and MANOVA was used for tests with basin, depth, and interaction betwee basin and depth. All seven analytical methods were applied to test the nul hypothesis for each of the four depths. Separate tests also were run for al possible pairs of basins and for all basins together. The average within-basi and between-basin distances (in the ordination space) also were compared. I there were different communities in the basins being compared, it would 1

expected that the between-basin distances would be significantly larger than the within-basin distances.

Community Changes From the Basin-by-Depth Interaction

In the overall test for interaction (with MANOVA), the null hypothesis was rejected, meaning that there was significant interaction between basin and depth. To help understand the nature of this interaction, the specific null hypothesis was tested that the communities in a pair of basins changed at the same rate with depth. Data consisted of the ordination results from the analysis with all samples.

The null hypothesis was tested by comparing the between-depth ordination distances in one basin with the corresponding between-depth distances in another basin. Only between-depth distances for stations on the same transect were included. The average between-depth distances for the two basins in question were compared using a t-test (with the probabilities estimated by randomization) . Separate analyses were run for each possible pair of depths. The methods in Table A-2 were not used for this analysis because only a limited subset of independent distances were compared.

The average between-depth ordination distances for each basin also were presented. If the communities in the basins being compared changed at the same rate with depth, it would be expected that the between-depth ordination distances would not be significantly different between the two basins.

Community Changes with Sediment Type

The purpose of this analysis was to test the null hypothesis that the communities in areas with different sediment types were the same. The results of the cluster analysis on the sediment-size data defined groups of stations that had similar sediments. Those groups of stations were treated in the tests of the null hypothesis. The ordination results from the analysis with all samples were used as quantitative measures of the community patterns.

All methods in Table A-2 were applied to test the null hypothesis for al sediment types and all possible pairs of sediment types. Separate tests wer run for each of the four depths. The average within- and between-sediment-typ distances (in the ordination space) were presented. If there were differen communities in the sediment types being compared, it would be expected that th between-sediment-type distances would be significantly larger than th within-sediment-type distances.

A.3.3 Northern and Central Basins Plus Historical Data

Description of the Data

The data from the present survey (CARP) and selected data from two other OC programs (BLM Southern California Bight Baseline and MMS Phase I) were poole to examine community spatial patterns from the Eel River Basin to the Ventur Area. Data from the Ventura area and around the northern Channel Islands wer from the BLM studies, and samples to the south of the present study area wer from the Phase I reconnaissance study. All data were from the 1.0-mm screen since the BLM study used only a 1.0-mm screen size.

For stations with replicate samples, only the first replicate was retained Colonial species sampled in the present study were converted to presence absence in the data bases of all of the studies. All other data were specie abundances. The data matrix included 163 samples and 919 species.

It should be emphasized that the samples from the different surveys wer collected at different times, so the community patterns revealed by th analyses reflected both spatial and temporal variability. If the tempera community variability is not too large in relation to the spatial variability the data can be assumed to represent an approximate picture of the large-scal spatial patterns of the community. It was assumed for interpretive purpose that there was very limited temporal variability, although no estimate of tha variability was available.

Community Pattern Analysis

The purpose of this analysis was to examine patterns of community distribution over the area covered by the three OCS surveys. The number of species was reduced from 919 to 305 by retaining only those species which occurred in at least 5 samples or had a total abundance of at least 25. In addition, no species occurring only once, no matter how abundant, were retained.

A cluster analysis of these data was performed. Data products included a map showing the locations of the various cluster groups and a two-way coincidence table to facilitate interpretation of spatial community patterns.

Zoogeography of the Species

The purpose of the analysis was to determine the geographic extent of the species over the three survey areas (CARP, Phase I, and BLM). All distinct, identifiable species in the original data bases were used in the analysis.

Data products included a table similar to a two-way coincidence table. The columns of the table (i.e., stations) were ordered according to the position of the station transect along the California coastline (from south to north). All stations on a transect were ordered from shallow to deep. The BLM stations were not sampled on discrete transects and, therefore, were ordered by station numbers, in ascending order. The rows of the table represented the species ordered according to their weighted-average column number in the table. The weights in the weighted average were the square-root-transformed species abundances. This ordering put the species tending to occur in the southern area toward the top of the table and those tending to occur in the northern areas toward the bottom. As with the two-way coincidence tables, the data values were displayed as symbols indicating relative abundances. From this table, the geographic extent of the various species was apparent.

A.3.4 Analysis of the Value of Sample Replication

The analyses described in this section examined whether an increase i replication during a reconnaissance Study such as this one would produc results that would lead to significantly different conclusions regardin benthic community distribution patterns.

Analysis of Replicate Data

The purpose of this analysis was to study the effects of replication on th results of a community pattern analysis. The data for the 12 stations wit replicate samples were included. The same 241 species utilized in the previou analysis of all samples were included in this analysis (if present). Thre separate ordinations were performed: the first utilized only the firs replicate at each station, the second utilized only the second replicate, an the third used the mean species abundances for the two replicates at eac station. The scores from the three ordinations were displayed in a singl ordination space with the use of Procrustes analysis. This permitted th comparison of results from one and two replicates.

Community Changes at Different Spatial Scales

The purpose of this analysis was to examine the relative amounts of communit change associated with different spatial scales. Community changes wer measured at the spatial scales represented by station replicates, by differen depths on the same transect, by stations within the same basin, and by station in different basins. The ordination results from the analysis in which al samples were used. The average distances between subsets of samples in th ordination space were computed as measures of the degree of community change a the different spatial scales. Specifically, the following were computed:

1. Average ordination distance between replicate samples at station.

2. Average ordination distance between samples on the same transec at different depths. Three subsets of average distances wer computed. The first subset compared adjacent depths, the secor

subset compared depths separated by one depth, and the third subset compared depth separated by two other depths.

3. Average ordination distance between samples in different basins and at approximately the same depth.

A.3.5 Testing of Hypotheses - Univariate Approach

Parametric analysis of variance (ANOVA), analysis of covariance (ANCOVA), and Tukey-Kramer range tests were conducted to support the interpretations of spatial differences and relationships revealed by community pattern analyses and multivariate correlational analyses. These analyses were the formal tests that demonstrated whether observed differences and relationships were statistically valid. The parametric tests addressed one variate at a time (univariate) and were, therefore, applied to more restrictive null hypotheses than were the multivariate tests.

Description of the Data

The parametric analyses addressed a suite of environmental variables and two types of biological variables, community summary variables (Table A-3), and the abundances of selected individual species (Table A-4). The environmental variables were dissolved oxygen, temperature, depth, organic carbon content, and several measures of sediment character (mean phi, kurtosis, skewness, sorting index, and percentages of gravel, sand, silt, and clay). The community summary variables were total abundance, number of species, diversity, dominance, biomass, and abundance by major taxonomic category.

The usefulness of these community summary variables is somewhat questionable (Carney, 1987), but often they are used in other similar studies. They are included here for comparative purposes.

Individual species also were selected. They consisted of the five most abundant in each of the three northern basins and those that represented known feeding types in each of these basins.

TABLE A-3. BIOLOGICAL SUMMARY VARIABLES. Community parameters calculated fo the soft substrate data.

Variable	Definition
Number of Species	The number of unique species in eac sample was calculated.
Individuals	The total number of individual collected, calculated for each majo taxonomic group, and for the tots sample.
Biomass	Biomass by major taxonomic group; tota biomass was calculated for each sampl by summing the weights of taxonomi group representatives.
Shannon-Wiener Diversity (H')	$I\text{-}1' = -\Sigma p_i \times \log_{10}$ where $pi = n_i/n_{total}$
Evenness (J'); Pielou (1975; p.15) .	$J' = H'/\log_{10}$ (number of species)
Dominance (1)); Pielou (1977; p. 311)	$D = -\Sigma \log_{10} pi^2$

TABLE A-4. SPECIES USED IN UNIVARIATE HYPOTHESIS TESTING BY ANOVA AND ANCOVA WITH THE DATA TRANSFORMATIONS NECESSARY FOR THE F-MAX TEST.

Taxon	Transformation
Amira lopezi lopezi	log
Alvinia rosana	log
Ampelisca carey	none
Amphiodia digitata	log
Amphiodia urtica	none
Anobothrus gracilis	rank
Angissa hamatipes	none
Artacamella hancocki	log
Carinoma mutabilis	log
Chaecozone cf. setosa	none
Chloeia pinnata	log
Eudorella pacifica	none
Huxleyia munita	rank
Levinsenia gracilis	log
Lumbrineris cf. tetraura	log
Mecaphoxus frequens	log
Metopa nr. pusilla	log
Mitrella permodesta	log
Monoculodes imarginatus	none
Munnogonium tillerae	log
Myriochele gracilis	log
Myriochele sp. B	rank
Nephtys cornuta franciscana	log
Nephtys ferruginea	none
Nephtys punctata	none
Nucula tenuis	none
Paraprionospio pinnata	log
Pholoe minuta	log
Sigambra tentaculata	log
Spiophanes berkeleyorum	log
Synchelidium rectipalmum	log
Terebellides reishi	log
Typhlotanais sp. A	none
Westwoodilla caecula	none

Testing Basin and Depth Differences

The purpose of the ANOVAS was to test the hypotheses that there were n differences in biological or environmental variables between basins and tha there were no differences in biological or environmental variables betwee depths. Tukey-Kramer multiple pairwise comparisons were used to identif significant differences between sets of basins, depths, and stations.

Sample data for the various biotic and environmental variables from each dept within each basin formed the replicates (e.g., Stations 1, 5, 9, 13, and 1 were replicates for the 100-m depth in the Eel River Basin). For many of th species (and some of the community summary variables), abundances varied widel and variances were not homogeneous. Homogeneous variance is an assumption o the parametric analyses employed here, especially for the unequal sample size we encountered. Therefore, an F-max test (Sokal and Rohlf, 1981) was conducte on the data of each species to determine the transformation necessary. Dat were either untransformed, log(x+l) -transformed, or rank-transformed, dependin on the results of the test.

A two-way ANOVA model with interaction was the basic model used to analyze th data from all transects, depths, and basins (except Santa Cruz) . The tw factors in this ANOVA were basin and depth. The depth factor identifie whether there were significant differences between the mean values of th biological and environmental variables within each depth averaged over al basins. Significant ANOVA tests were followed by a posteriori pairwis Tukey-Kramer tests to identify which differences were significant.

The basin factor measured differences between the mean values within each basi averaged over all depths. Significant results indicated that difference within basins were not as great as differences between basins. Significant ANOVA tests were followed by a posteriori pairwise Tukey-Kramer tests. Th basin term was included in the model mainly to prevent any basin different from being included in, and inflating, the error variance.

The depth-by-basin interaction term contained the information of greatest interest. That term was used to determine whether the extent of differences by depth differed between basins, and vice versa. The ANOVA F-test of the interaction term simultaneously tested whether all the means of each cell (all stations at a given depth in a basin) were equal. If significant, the ANOVA test was followed by an *a posteriori* Tukey-Kramer test (SAS, 1985a). The pairwise test identified, for any variable, which pairs were significantly different.

Testing Sediment Type Differences

The purpose of this analysis was to test the hypothesis that there were no differences in biological variables between sediment types at the same depth. The results of the cluster analysis on the sediment grain-size data identified groups of stations characterized by the same general sediment type. For these analyses, data from each depth (100 m, 200 m, 400 m, and 600 m) were tested separately (all stations at each depth for each sediment type were averaged). This was done to prevent confounding by depth effects.

Differences in biological variables between the sediment types were tested using a one-way ANCOVA. If significant differences were found, the Tukey-Kramer test was used to identify which sediment types were different for each variable. The use of ANOVA to examine differences in the summary measures among sediment types for all stations simultaneously would have been inappropriate because of the pronounced changes with depth that were apparent. On the other hand, conducting a series of four ANOVAs which tested only stations on a single isobath for differences in summary measures among sediment type would raise other problems: specifically, far fewer degrees of freedom, insufficient power, and an unbalanced design due to the distribution of sediment types among stations. Consequently, ANCOVA was used to test differences by sediment type, with depth used as the covariate. This approach allowed stations at all depths to be tested simultaneously for the significance of sediment effects while accounting for (and setting aside) depth effects (the variances in abundances at stations due to depth).

A.3.6 Tests of Correlations Between Species Abundances and Environmental Variables

The purpose of this analysis was to examine how well species abundances wer, correlated with selected environmental variables. The analyses were applied to all species considered in earlier analyses: specifically, the specie: representing the different trophic groups and the most abundant species. Th environmental variables considered were temperature, dissolved oxygen, depth percent sand, percent silt, percent clay, mean grain size, dispersion skewness, and total organic carbon.

Relationships between the environmental variables and univariate biologica. variables were investigated using linear and nonlinear multiple-regression techniques. The primary approach was to use linear techniques; nonlinea techniques were employed only if the relationship between a biological variabl and some environmental factor was shown graphically to be nonlinear o nonmonotonic (e.g., Green, 1979; p. 207).

Sample Variability-Variance Analyses

The purpose of these analyses were to determine the variability among th replicate samples collected at all four depths on one transect in each basi and to estimate, on the basis of the results, the level of replication require for future site-specific studies. Values of the community summary variable: were used in the analyses. The first step in the analysis was to estimate th within-station variances by applying a separate, one-way ANOVA to the data fro each depth. The "treatment" in the model was basins, and the mean square erro (MSE) from the ANOVA was the estimated variance at a station within a dept contour.

The second step was to compare the estimates of variances among depth contour by testing the null hypothesis that there was no differences between variant pairs:

$$F = \frac{s^2_{\text{depth 1}}}{s^2_{\text{depth 2}}}$$

A nonsignificant F-value indicated that the variability at the two depths was similar and, therefore, that similar numbers of samples should be collected at each depth. If, however, the F-value was significant, then the ratio between the variances (i.e., standard deviation) was an approximation of the ratio between the sampling efforts necessary to produce comparable confidence bounds on the means at each depth. In future sampling, the effort placed toward sampling at a station (i.e. , the number of replicates per station) can be weighted to reflect the differences in the within-station variances at the four depths relative to each other and relative to variances among stations. For this approach, it should be noted that the estimated within-station variance at a depth (i.e., the MSE) represents the average variance found at stations from different basins.