6.0 BIOLOGICAL FIELD SURVEYS

6.1 BACKGROUND

Two biological field surveys were conducted to collect data in and around the five sand resource areas. The primary objective of the field surveys was to obtain descriptive data on benthic biological conditions (i.e., infauna, epifauna, demersal ichthyofauna, and sediment grain size) and water column characteristics (i.e., temperature, salinity, dissolved oxygen, and depth) in the five proposed sand resource areas. A secondary objective was to obtain descriptive data on the infauna and sediment grain size adjacent to the five proposed sand resource areas.

The locations and dimensions of the five sand resource areas were based on reports by Parker et al. (1993, 1997) and Hummell and Smith (1995, 1996). Although the sand resource areas as described by these authors overlap state/federal boundaries, only the portion of each sand resource area in federal waters was considered for the biological program.

Sample types and numbers for the May 1997 Survey 1 and December 1997 Survey 2 are summarized in Table 6-1. Sampling locations are illustrated in Figures 6-1 through 6-6 and tabulated in Appendix D1.

6.2 METHODS

6.2.1 Survey Design

A total of 20 grab samples for infauna and sediment grain size were collected inside and outside (adjacent to) each sand resource area (16 samples inside and 4 samples outside). The goal in the placement of these sampling stations was to provide uniform coverage within a sand resource area and, at the same time, ensure that the samples would be independent of one another to satisfy statistical assumptions. This systematic sampling with an unaligned grid approach provides more uniform coverage of the target populations that, in many cases, yields more accurate estimates of the mean than simple random sampling (Gilbert, 1987). To achieve uniform sampling coverage, 4 x 4 grids (=16 cells) were placed over figures of each sand resource area. For Sand Resource Areas 1, 2, 3, and 5, the 16-cell grid was placed over a map of the entire sand source area in federal waters. Because the sand resource site within Area 4 was very localized based on surficial sediment samples and subsurface core data of Parker et al. (1993, 1997) and Hummell and Smith (1995, 1996), the 16-cell grid was placed over this specific target site within Area 4. To achieve independence, one sampling station then was randomly placed within each grid cell of each sand resource area. Randomizing within grid cells eliminated biases that could be introduced by unknown spatial periodicities in the sampling area. All station locations then were pre-plotted on geodetically corrected maps from Parker et al. (1993, 1997) and Hummell and Smith (1996).

To sample epifauna and demersal ichthyofauna, two trawl transects were located within each of the sand resource areas. One east-west transect was placed near the northern boundary and one east-west transect was placed near the southern boundary of each sand resource area. This approach allowed characterization of the existing assemblages with respect to water depth. Water column measurements were made near the beginning point of each trawl transect prior to actual trawling.

To satisfy the secondary objective, four stations were placed outside Areas 1, 2, 3, and 5. Four stations were placed outside the specific target site within Area 4. The location of these stations was based upon sedimentary information in Parker et al. (1993, 1997) and Hummell and Smith (1995, 1996).

Table 6-1. Sample types and numbers for the May 1997 Survey 1 and December 1997 Survey 2 of the five sand resource areas offshore Alabama. Gravity coring was conducted only in Area 4 Station 14.

Sand Resource Area	Number of Stations							
	Smith-McIntyre Grab				Epifaunal and Demersal Ichthofaunal Trawls		Water Column	
	Grain Size		Infauna					
	Survey 1	Survey 2	Survey 1	Survey 2	Survey 1	Survey 2	Survey 1	Survey 2
1	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)
2	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)
3	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)
4	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)
5	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	20 (16 inside; 4 outside)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)	2 (1 north; 1 south)
TOTAL	100	100	100	100	10	10	10	10

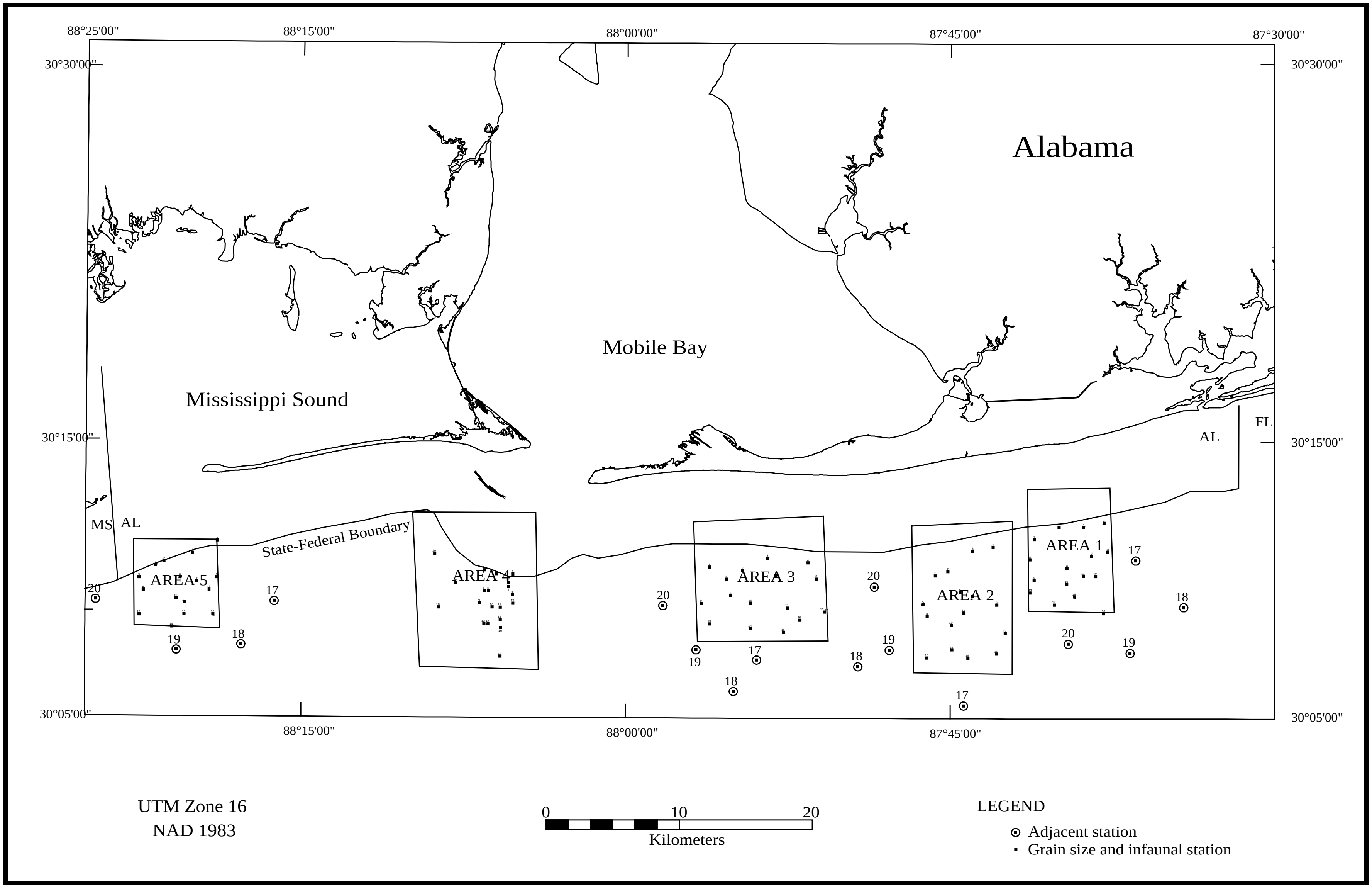

Figure 6-1. Sampling locations for grain size and infauna relative to the five sand resource areas and the Alabama coast (adapted from Parker et al.,1997).

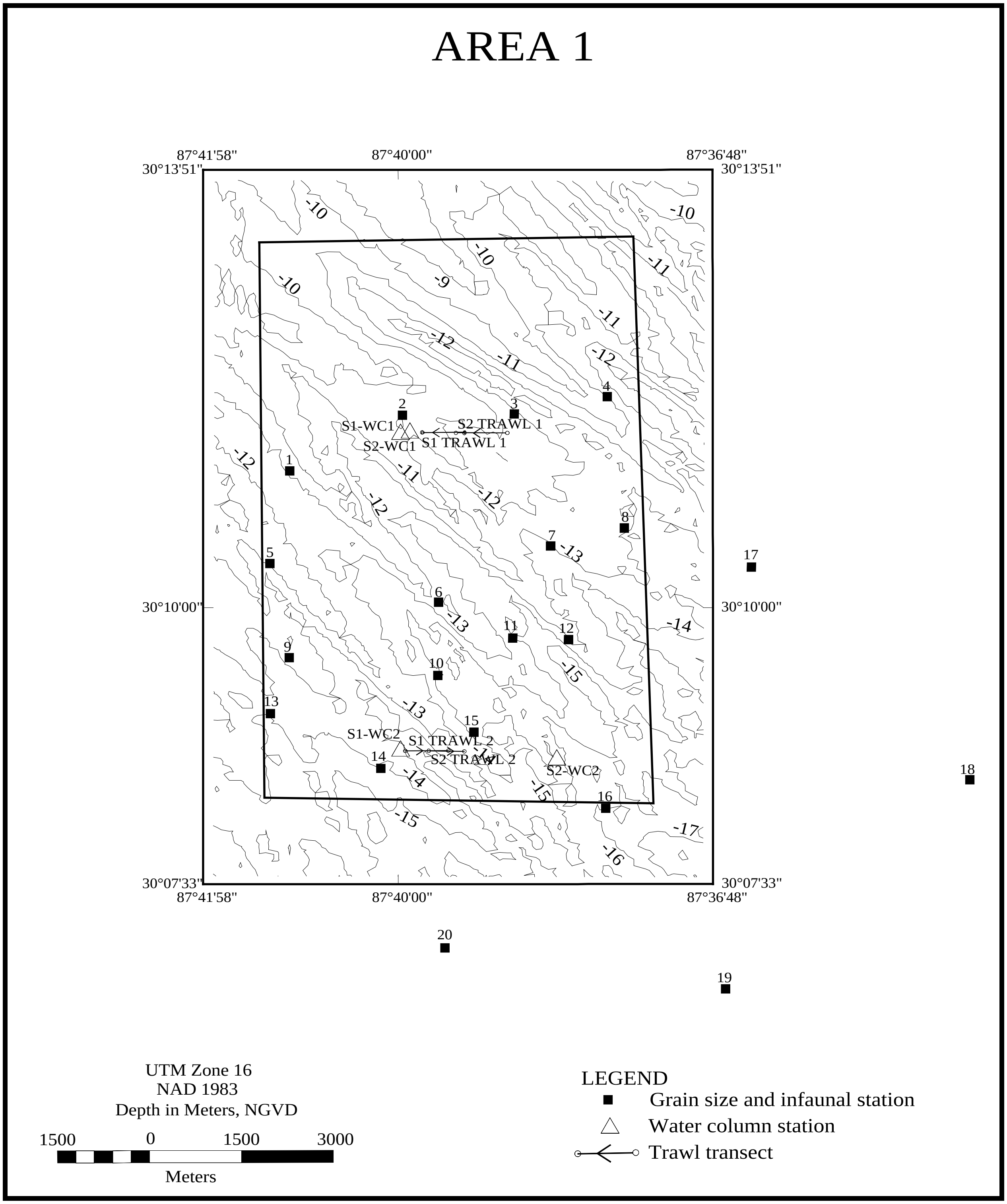

Figure 6-2. Sampling locations for Alabama Sand Resource Area 1. Inner box represents the limits of Area 1. Outer box provides reference coordinates.

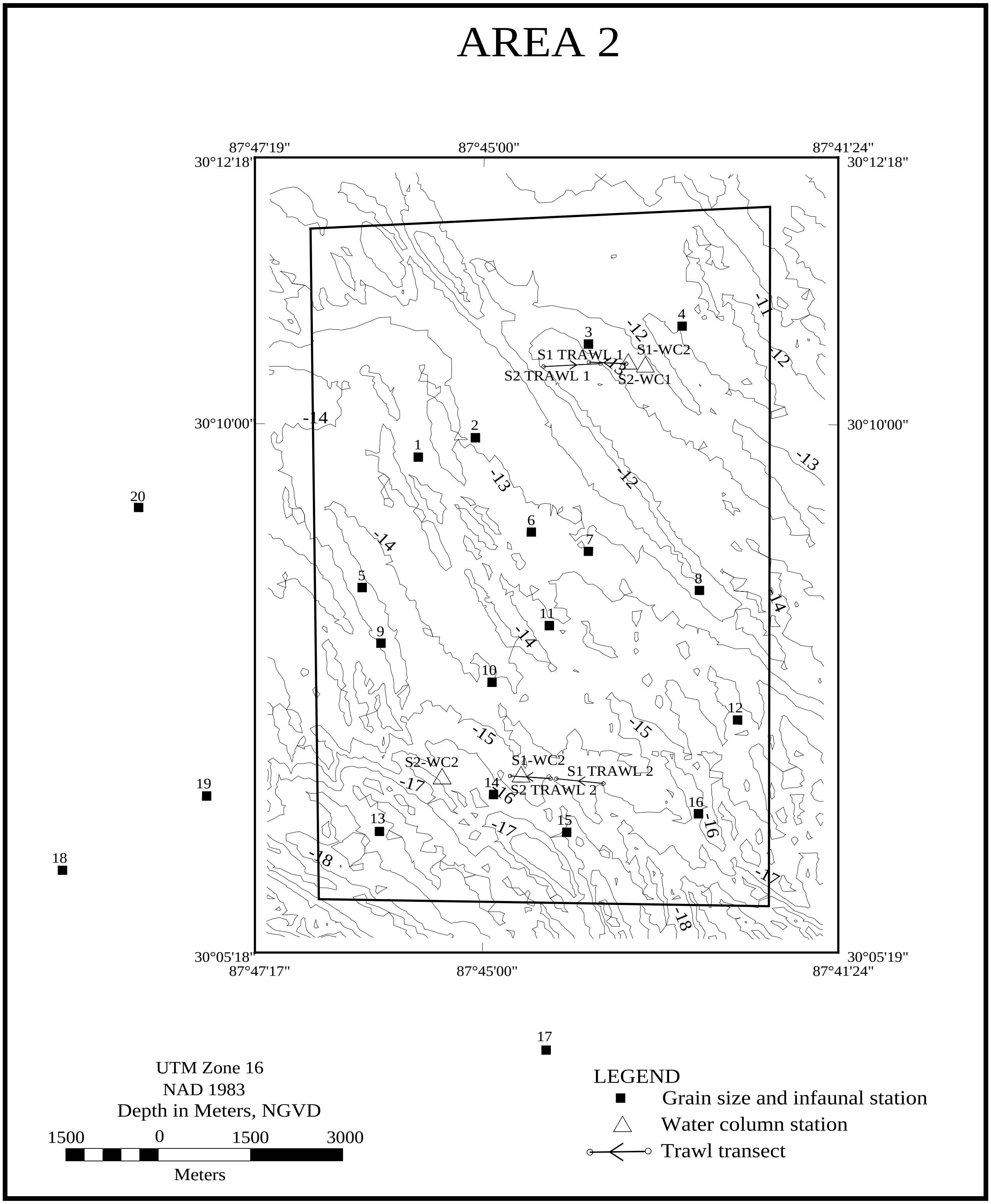

Figure 6-3. Sampling locations for Alabama Sand Resource Area 2. Inner box represents the limits of Area 2. Outer box provides reference coordinates.

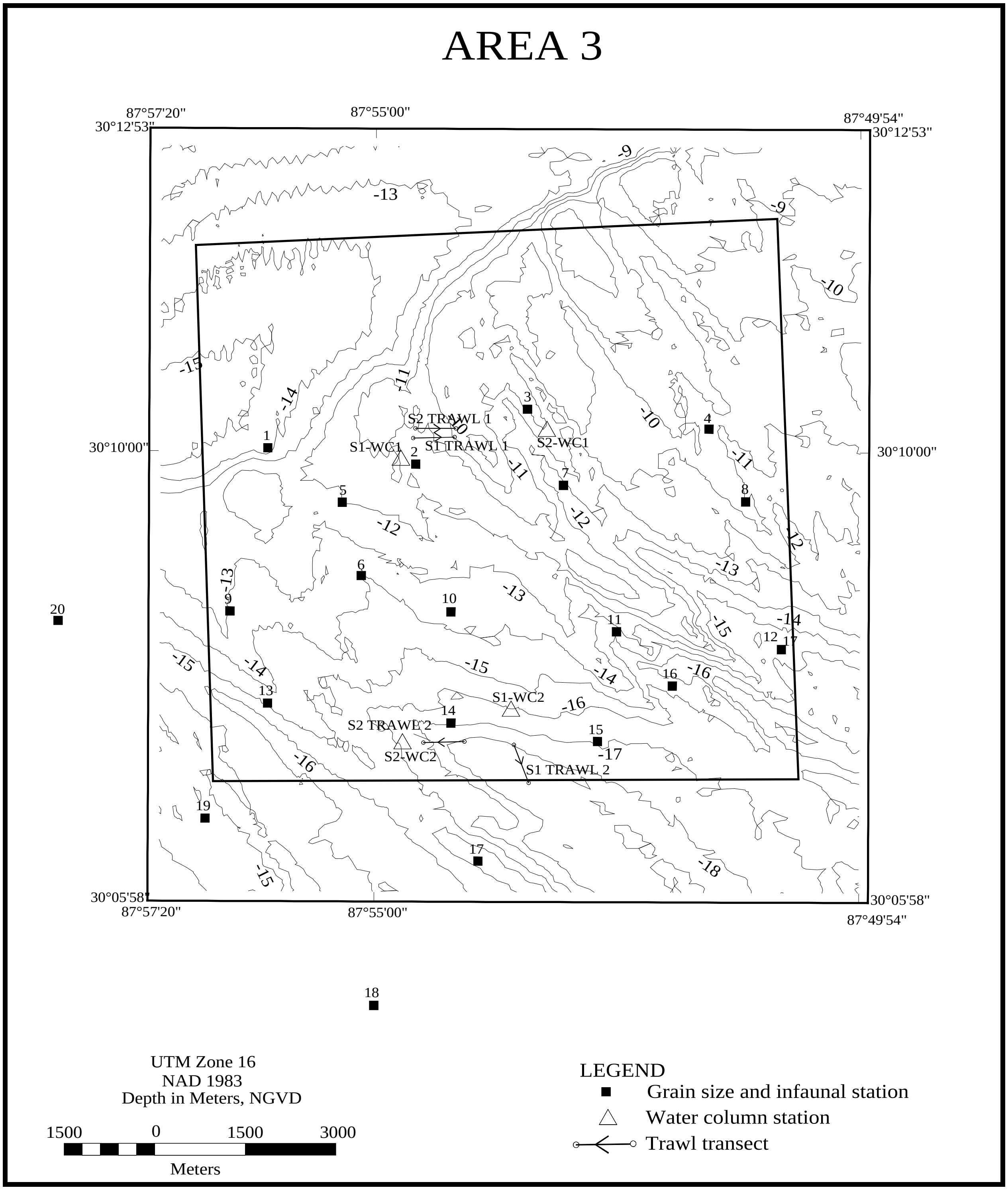

Figure 6-4. Sampling locations for Alabama Sand Resource Area 3. Inner box represents the limits of Area 3. Outer box provides reference coordinates.

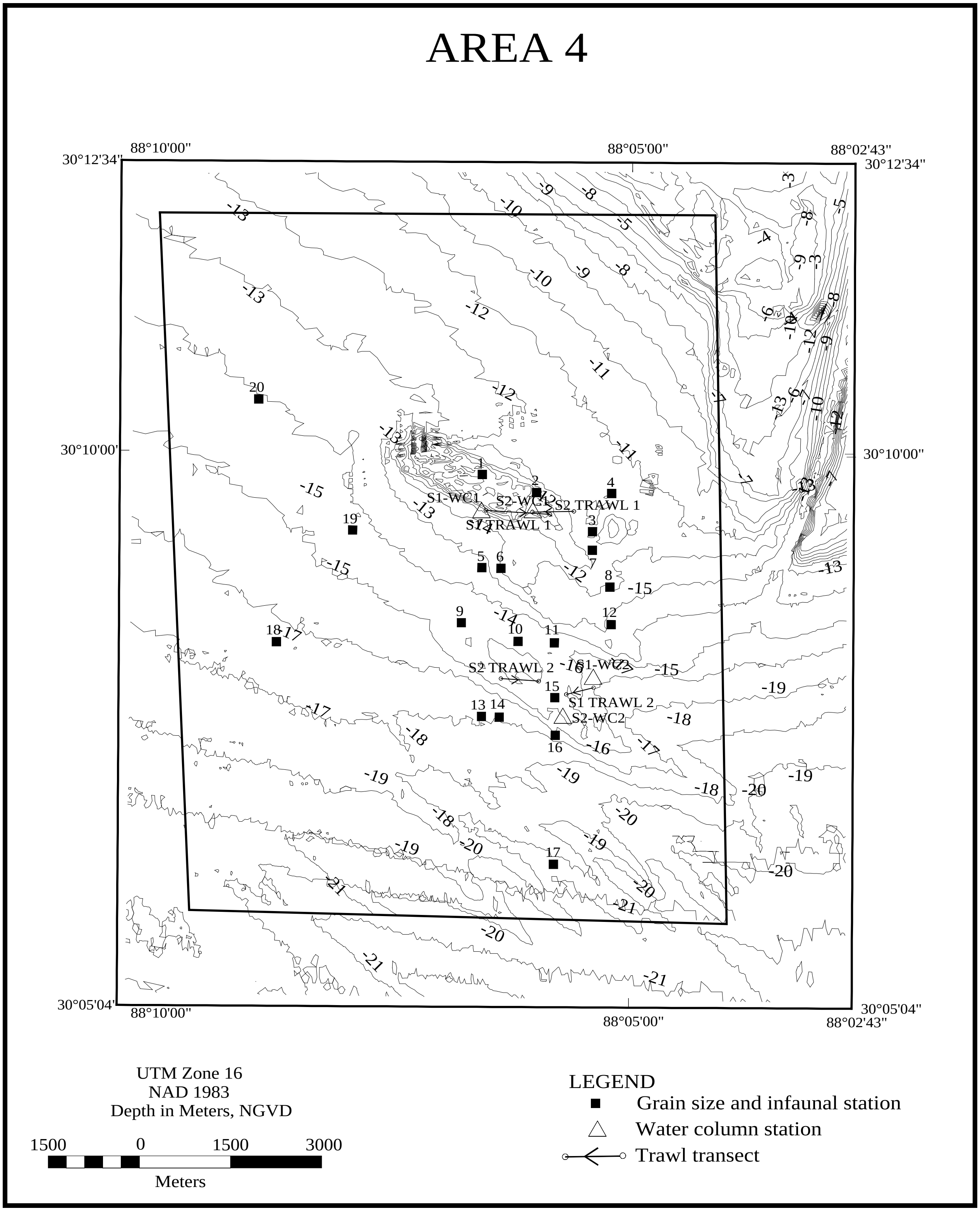

Figure 6-5. Sampling locations for Alabama Sand Resource Area 4. Inner box represents the limits of Area 4. Outer box provides reference coordinates.

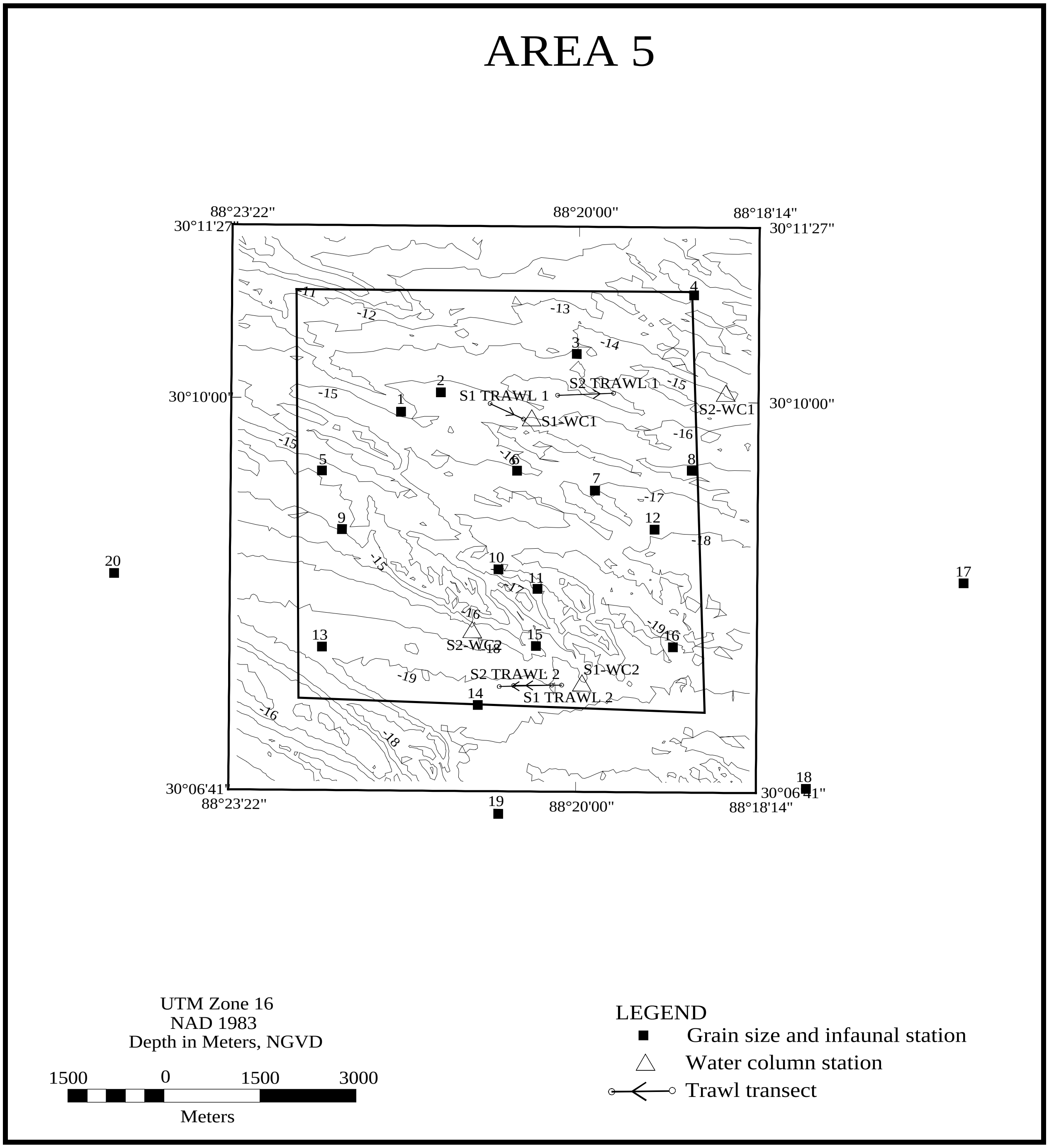

Figure 6-6. Sampling locations for Alabama Sand Resource Area 5. Inner box represents the limits of Area 5. Outer box provides reference coordinates.

Visual observations and laboratory analyses of some Survey 1 grab samples indicated that the surficial sediment in Sand Resource Area 4 contained more silt and clay than expected, rather than sand as identified in the reports by Hummell and Smith (1995, 1996). A small-scale data collection effort was proposed for Survey 2 to further investigate the discrepancy. In a limited reconnaissance effort gravity coring was used to investigate whether there was sand below the mud layer in Area 4.

6.2.2 Field Methods

6.2.2.1 Vessel

The two field surveys were conducted from different vessels. The May survey was completed aboard the M/V CAPTAIN JOHN based at Dauphin Island, Alabama. This cruise took place from 18 May to 24 May 1997 (field sampling occurred from 19 to 23 May). For the December survey, the R/V BEACON based in Bayou La Batre, Alabama was used. This cruise was conducted from 10 December to 16 December 1997 (field samples were collected from 11 to 15 December).

6.2.2.2 Navigation

A differential global positioning system (DGPS) was used to navigate the survey vessels to all sampling stations. The DGPS was connected to an on-board computer equipped with Hypack Navigation Software Version 6.4 (Coastal Oceanographics, 1996). With this system, the ship's position was displayed in real-time on a monitor affixed to a counter top in the wheel house. All sampling stations were pre-plotted and stored in the Hypack program. While in the field, actual positions of all samples collected were recorded and stored by the program.

6.2.2.3 Water Column

Temperature, conductivity, dissolved oxygen, and depth were measured with a portable Hydrolab unit. The Hydrolab was calibrated as needed each working day. Hydrolab measurements of temperature (°C), conductivity (mS), and dissolved oxygen (mg/L) were taken at three depths: surface, middle, and near-bottom. The Hydrolab was fastened to a weighted line, then lowered to depth by hand. All measurements were recorded on standard data sheets. Two water column profiles from each sand resource area produced 10 profiles for each survey.

6.2.2.4 Sediment Grain Size

One grab sample was taken with a Smith-McIntyre grab at each pre-plotted sediment sampling station. Once a sample was deemed acceptable (i.e., adequate penetration and undisturbed surface layer), a subsample of sediment (about 250 g) was removed with a 5-cm diameter acrylic core tube and placed in a labeled plastic bag for grain size analyses. This sample was stored on ice. A total of 20 grain size samples was taken from each sand resource area during each field survey for a total of 100 grain size samples per survey.

As part of the limited reconnaissance coring effort, 12 attempts to collect gravity cores were made at Station 14 in Area 4 using a 1.2-m core tube. Although penetration occurred, the gravity core tube did not hold sediment very well upon retrieval due to a combination of factors, including consistency of the sediment, the shallow water depth for the gravity core drop, vessel movement from strong water currents and high wind conditions, and depth of penetration relative to the core tube length. Eight additional attempts were made using a shorter 0.6-m core tube at Station 14, and a core was retrieved. A Van Veen sampler also was used at Station 14 in Area 4, resulting in only 15 to 18 cm of penetration.

6.2.2.5 Infauna

One grab sample was taken with a Smith-McIntyre grab at each pre-plotted sediment sampling station. Once a sample was deemed acceptable (i.e., adequate penetration and undisturbed surface layer), a subsample of sediment was removed for grain size analysis, and the remainder of the grab sample was sieved through a 0.5-mm sieve for infaunal analyses. The infaunal sample was placed in a container and preserved in 10% formalin with rose bengal stain. At each sand resource area, 20 grab samples were taken, which produced a total of 100 infaunal samples per field survey.

6.2.2.6 Epifauna and Demersal Ichthyofauna

A 25-ft mongoose trawl was towed for 10 min (bottom time) along the pre-plotted transects. The tow path of each trawl tow was logged into the Hypack navigation system. Once the trawl was on deck, the contents of the catch bag were identified, then sorted to the lowest practical taxon. Organisms that could be identified in the field were counted and returned to the sea. Any specimens not identified were saved and preserved with 10% formalin. All specimens identified and counted in the field were recorded on standard trawl data sheets. Each sand resource area yielded two trawl samples for a total of 10 samples per survey.

6.2.3 Laboratory Methods

6.2.3.1 Sediment Grain Size

Sediment grain size analyses were conducted using combined sieve and hydrometer analyses according to recommended American Society for Testing Materials (ASTM) procedures. Grain size samples were washed in demineralized water, dried, and weighed. Coarse and fine fractions (sand/silt) were separated by sieving through a U.S. Standard Sieve Mesh No. 230 (62.5 µm). Sediment texture of the coarse fraction was determined at half-phi intervals by passing the sediment through nested sieves. The weight of the materials collected in each particle size class was recorded. Boyocouse hydrometer analyses were used to analyze the fine fraction (<62.5 µm).

6.2.3.2 Infauna

Formalin-preserved infaunal samples were rinsed on a U.S. Standard No. 30 (0.59 mm) sieve and transferred to 70% isopropanol. Before sorting, samples were passed through a series of sieves (0.3, 0.5, 0.6, 1, and 2 mm) to separate the organisms into size classes. Samples were sorted by hand under dissecting microscopes. All sediment in each sample was examined by a technician who removed all infauna observed. Organisms were identified to lowest practical taxon and counted. A minimum of 10% of all samples were resorted by different technicians as a quality control measure. Voucher specimens of each taxon were archived at the Barry A. Vittor & Associates, Inc. laboratory.

6.2.3.3 Epifauna and Demersal Ichthyofauna

Most fishes and invertebrates were identified, sorted, and counted on board the survey vessels. Specimens returned to the laboratory were rinsed in fresh water then transferred to 70% isopropanol. Specimens were sorted and counted then placed in 70% isopropanol for storage. All fish specimens were deposited in the Florida Museum of Natural History ichthyological collection.

6.2.4 Data Analysis

6.2.4.1 Water Column

Temperature, conductivity, dissolved oxygen, and depth values were entered into an electronic spreadsheet and tabulated. Salinity was calculated from conductivity and temperature using standard formulae.

6.2.4.2 Sediment Grain Size

A computer algorithm was used to determine size distribution and provide interpolated size information for the fine fraction at 0.25-phi intervals. Median grain size, percentages of gravel, sand, silt, clay, and Folk descriptions were provided for each sample (see Appendix D3).

6.2.4.3 Infauna

Summary statistics including number of taxa, number of individuals, density, diversity (*H'*), evenness (*J'*), and species richness (*D*) were calculated for each sampling station. Diversity (*H'*), also known as Shannon's Index (Pielou, 1966), was calculated as follows:

$$H' = -\sum_{s}^{i=1} p_i \ln(p_i)$$

where S is the number of taxa in the sample, i is the ith taxa in the sample, and p_I is the number of individuals of the ith taxa divided by (N) the total number of individuals in the sample.

Evenness (*J'*) was calculated using Pielou's (1966) index of evenness:

$$J' = \frac{H'}{\ln(S)}$$

where *H'* is Shannon's index as calculated above and S is the total number of taxa in a sample.

Species richness (*D*) was calculated by using Margalef's index:

$$D = \frac{(S-1)}{\ln(N)}$$

where S is the total number of taxa in the sample, and N is the number of individuals in the sample.

Spatial and temporal patterns in the infaunal assemblage as a whole were examined by cluster analysis of the entire data set. Additional cluster analyses also were performed on data from each sand resource area. Cluster analyses were performed on similarity matrices constructed from raw data matrices consisting of taxa and samples (station-survey). Species included in the cluster analysis for each of the individual sand resource areas comprised at least 0.4% of total infaunal abundance within the sand resource area being analyzed. Raw counts of each individual infaunal taxon in a sample (n) were transformed to logarithms [$\log_{10}$(n+1)] prior to similarity analysis. Both normal (stations) and inverse (taxa) similarity matrices were generated using the Bray-Curtis index which was calculated using the following formula:

$$B_{jk} = \frac{2\sum_{i} \min(x_{ij}, x_{ik})}{\sum_{i} (x_{ij} + x_{ik})}$$

where B_{jk} (for normal analysis) is the similarity between samples j and k; x_{ij} and x_{ik} are the abundances of species i in samples j and k. B ranges from 0.0 when two samples have no species in common to 1.0 when the distribution of individuals among species is identical between samples. For inverse analysis, the B_{jk} is the similarity between species j and k; x_{ij} and x_{ik} are the abundances of species j and k in sample i.

Normal similarity matrices were clustered using the group averaging method of clustering, and inverse similarity matrices were clustered using the flexible sorting method of clustering (Boesch, 1973). Flexible sorting was performed with $\beta = -0.25$, a widely accepted value for this analysis (Boesch, 1973). For the additional cluster analyses of individual sand resource areas, normal and inverse similarity matrices were clustered by the group averaging method.

The extent to which sample groups formed by normal cluster analysis of the entire data set could be explained by environmental variables was examined by canonical discriminant analysis (SAS Institute Inc., 1989). Environmental variables used were survey (categorical), water depth, percent gravel, percent sand, and percent fines (percent silt + percent clay). Canonical discriminant analysis identifies the degree of separation among pre-defined groups of variables in multivariate space. This analysis examined the relationships among the environmental variables and the station groups as indicated by the normal cluster analysis.

6.2.4.4 Epifauna and Demersal Ichthyofauna

Trawl data were summarized by numbers of taxa and number of individuals per tow in each sand resource area. Normal and inverse cluster analyses as described above (Section 6.2.4.3) were used to examine patterns in the epifaunal/demersal ichthyofaunal data set. Both normal and inverse clustering were performed with the group averaging algorithm.

6.3 RESULTS

6.3.1 Water Column

Temperature, salinity, and dissolved oxygen recorded in surface, middle, and bottom waters of the sand resource areas differed among surveys and sample locations (Appendix D2, Table D2-1). Bottom values for temperature, salinity, and dissolved oxygen for the May and December surveys are shown in Figure 6-7. During the May survey, values for all three parameters indicated some stratification with depth in all sand resource areas. Surface temperatures averaged 25.7°C and ranged from 26.9°C in Area 3 to 24.4°C in Area 1. Middle depth temperatures averaged 22.8°C and ranged from 21.4°C in Area 3 to 23.8°C in Area 5. Bottom temperatures averaged 21.5°C and ranged from 21.2°C in Area 4 to 21.8°C in Area 1. Surface salinities averaged 20.6 ppt and ranged from 17.2 ppt in Area 3 to 27.2 ppt in Area 1. Middle depth salinities averaged 28.9 ppt and ranged from 26.2 ppt in Area 2 to 31.9 ppt in Area 4. Bottom salinities averaged 31.1 ppt and ranged from 28.2 ppt in Area 3 to 33.9 ppt in Area 4. Surface values of dissolved oxygen averaged 5.14 mg/L and ranged from 4.37 mg/L in Area 5 to 7.49 mg/L in Area 1. In middle depths, the values averaged 4.19 mg/L and ranged from 2.07 mg/L in Area 3 to 7.21 mg/L in Area 1. In bottom waters, dissolved oxygen averaged 3.16 mg/L and ranged from 1.22 mg/L in Area 4 to 6.19 mg/L in Area 1.

During the December survey, values for temperature, salinity, and dissolved oxygen revealed much less stratification with depth than was observed during May (Appendix D2, Table D2-2). Surface temperatures averaged 15.6°C and ranged from 14.2°C in Area 5 to 16.9°C in Area 3. Middle depth temperatures averaged 16.1°C and ranged from 14.9°C in Area 2 to 18.1°C in Area 4. Bottom temperatures averaged 16.9°C and ranged from 14.9°C in Area 2 to 18.5°C in Area 4. Salinities in surface waters averaged 30.9 ppt and ranged from 29.2 ppt in Area 5 to 31.7 ppt in Area 3. In middle depths, salinities averaged 31.3 ppt and ranged from 30.2 ppt in Area 5 to 32.0 ppt in Area 4. Bottom salinities averaged 31.7 ppt and ranged from 31.2 in Area 2 to 32.1 ppt in Areas 2 and 5. Surface dissolved oxygen values averaged 7.08 mg/L and ranged from 6.43 mg/L in Area 2 to 7.79 mg/L in Area 1. Middle depth values averaged 6.86 mg/L and ranged from 6.39 mg/L in Area 4 to 7.60 mg/L in Area 1. Bottom values averaged 6.78 mg/L and ranged from 6.37 mg/L in Area 4 to 7.65 mg/L in Area 1.

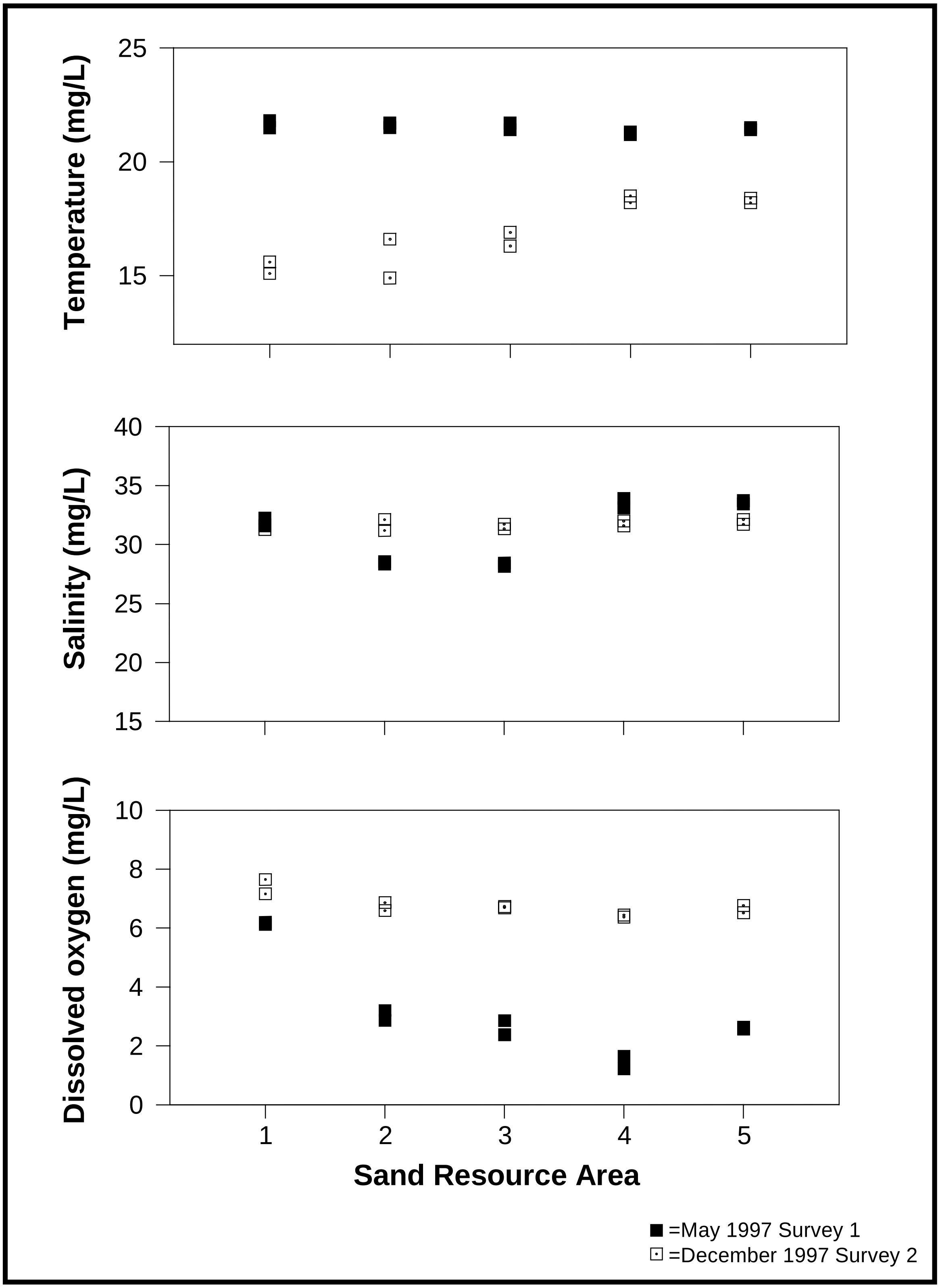

Figure 6-7. Temperature (°C), salinity (ppt), and dissolved oxygen (mg/l) measured near-bottom by Hydrolab during May and December 1997 at the five sand resource areas offshore Alabama. Two sets of measurements were made in each sand resource area.

6.3.2 Sediment Grain Size

Sediment grain size from the grab samples ranged from sand to mud during Survey 1 (Appendix D3, Table D3-1) and Survey 2 (Appendix D3, Table D3-2). Sand Resource Areas 1, 2, and 3 were primarily sand. In Area 1, all samples contained >95% sand with lesser amounts of gravel and no mud. All but two samples from Area 2 and two samples from Area 3 contained >96% sand with some gravel.

Grain size was much more variable in Area 4, with many stations containing more silt and clay than expected. Ten of the 16 samples within Area 4 during the May survey had sand percentages <90%. Seven of the 16 samples within Area 4 during the December survey had sand percentages <90%. Sediment grain size for Stations 1, 2, and 7, which are located within the primary sand resource site of Area 4, was <90% sand in the May survey, but >90% in the December survey. This may be because the December samples were not taken in exactly the same spot as the May samples, small-scale grain size variability may exist, or physical processes occurred causing winnowing of fine-grained sediment from surface samples. However, grain size at Area 4 Stations 10, 11, 13, and 14 remained <90% sand.

Grain size also was variable in Area 5. Ten of the 16 samples from the May survey in Area 5 had <90% sand. Eight of the 16 samples from the December survey in Area 5 had <90% sand.

Visual observations indicated that the gravity core from Area 4 Station 14 was mud from top to bottom. The same was true for sediment retrieved from Area 4 Station 14 using a Van Veen sampler. Laboratory analyses indicated that all of the Survey 2 grain size samples from Area 4 Station 14 were <60% sand.

6.3.3 Infauna

The phylogenetic list of infauna collected in bottom grabs during Surveys 1 (May) and 2 (December) is presented in Appendix D4, Table D4-1, and complete data summaries are provided in Appendix D4, Tables D4-2 through D4-7. For both surveys combined, 91,964 individuals were collected, representing 834 taxa in 13 separate phyla. Infauna were more abundant during the May survey, when 64,613 individuals (70% of the project total) were collected. Three hundred ninety-four taxa (47% of the project total) were common to both surveys. Of those taxa found in just one of the two surveys, 70% (308 taxa) were sampled during the May cruise. Numerical dominants were the gastropods *Caecum pulchellum* and *C. cooperi*, which represented 24% and 9%, respectively, of all infauna censused over both surveys.

Numerically dominant taxa sampled during the May survey (Table 6-2) were *C. pulchellum* (25% of all individuals collected during the May survey), *C. cooperi* (10%), unidentified bivalve mollusks (5%), and the spionid polychaetes *Paraprionospio pinnata* (4.5%) and *Spiophanes bombyx* (4%). Most *C. pulchellum* and *C. cooperi* occurred in the easternmost areas during the May survey, with 99.6% of these individuals sampled from Areas 1, 2, and 3. Densities of these two species were particularly high in Areas 1 and 2. Areas 4 and 5 were numerically dominated by *P. pinnata* (28% and 11% of collected individuals, respectively) and the capitellid polychaete *Mediomastus* (lowest practical identification level [LPIL]) (12% and 4%, respectively) during the May survey.

Numerically dominant taxa collected during the December survey (Table 6-2) were *C. pulchellum* (21% of all individuals collected during the December survey), the archiannelid *Polygordius* (LPIL) (8%), *C. cooperi* (7%), the polychaete *Scoletoma verrilli* (3%), and the amphipod *Eudevenopus hondurans* (3%). As was the case during the May survey, *C. pulchellum* and *C. cooperi* were obtained nearly exclusively from the easternmost areas, with 99.8% of these individuals sampled from Areas 1, 2, and 3, and again were particularly abundant in Areas 1 and 2. Area 4 was numerically dominated by the lancelet *Branchiostoma* (9% of collected individuals) and the polychaetes *Armandia maculata* (7%), *Mediomastus* (LPIL) (7%), and *Nereis micromma*

Table 6-2. Five most abundant infaunal taxa from samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in the five sand resource areas offshore Alabama.

May 1997			December 1997		
Area	Taxonomic Name	Count	Area	Taxonomic Name	Count
1	*Caecum pulchellum*	5,866	1	*Caecum pulchellum*	3,835
	Caecum cooperi	2,296		*Caecum cooperi*	1,019
	Bivalvia (LPIL)	781		*Polygordius* (LPIL)	1,001
	Spiophanes bombyx	600		*Eudevenopus honduranus*	503
	Tellina (LPIL)	379		*Scoletoma verrilli*	268
2	*Caecum pulchellum*	9,183	2	*Caecum pulchellum*	1,737
	Caecum cooperi	3,059		*Caecum cooperi*	623
	Bivalvia (LPIL)	1,440		*Polygordius* (LPIL)	615
	Spiophanes bombyx	766		*Scoletoma verrilli*	357
	Tellina (LPIL)	557		*Eudevenopus honduranus*	190
3	*Caecum pulchellum*	960	3	*Polygordius* (LPIL)	321
	Caecum cooperi	851		*Caecum pulchellum*	278
	Spiophanes bombyx	772		*Caecum cooperi*	244
	Bivalvia (LPIL)	717		*Oligochaeta* (LPIL)	165
	Mediomastus (LPIL)	574		*Mediomastus* (LPIL)	132
4	*Paraprionospio pinnata*	1,680	4	*Branchiostoma* (LPIL)	250
	Mediomastus (LPIL)	729		*Armandia maculata*	209
	Spiophanes bombyx	243		N*ereis micromma*	201
	Apoprionospio pygmaea	202		*Mediomastus* (LPIL)	199
	Magelona sp.H	198		*Magelona sp.H*	172
5	*Paraprionospio pinnata*	561	5	*Nereis micromma*	341
	Bivalvia (LPIL*)*	225		*Mediomastus* (LPIL)	211
	Mediomastus (LPIL)	192		*Armandia maculata*	205
	Aricidea taylori	189		*Phascolion strombi*	103
	Polygordius (LPIL)	149		*Aricidea taylori*	75
May Total	*Caecum pulchellum*	16,042	December Total	*Caecum pulchellum*	5,855
	Caecum cooperi	6,254		*Polygordius* (LPIL)	2,065
	Bivalvia (LPIL*)*	3,238		*Caecum cooperi*	1,899
	Paraprionospio pinnata	2,901		*Scoletoma verrilli*	894
	Spiophanes bombyx	2,487		*Eudevenopus honduranus*	835

LPIL = Lowest practical identification level.

(7%). Area 5 was numerically dominated by *N. micromma* (14%), *Mediomastus* sp. (9%), and *A. maculata* (8%).

Table 6-3 summarizes the number of taxa, number of individuals, density, species diversity, evenness, and richness for each sand resource area during the May and December surveys. During the May survey, the mean number of taxa per station was highest in Area 3 (99 taxa), while Area 1 stations averaged the highest number of taxa (67) in the December survey. The highest number of infaunal taxa collected from a single station was collected at Station 20 in Area 2 (126) during the May survey and at Station 19 in Area 1 (116) in the December survey. During both the May and December surveys, the mean number of taxa per station was lowest in Area 4, with values

Table 6-3. Summary of infaunal statistics by survey and sand resource area offshore Alabama.

May 1997 (Survey 1)

Area	No. of Taxa		No. of Individuals		Density (individuals/m^2)		H' Diversity		J' Evenness		D Richness	
	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation
1	84	18	838	503	8,384	5,031	2.96	0.61	0.67	0.14	12.69	2.14
2	95	15	1,182	527	11,823	5,274	2.78	0.61	0.61	0.13	13.54	2.05
3	99	21	643	286	6,433	2,858	3.66	0.41	0.80	0.07	15.21	2.75
4	49	13	305	146	3,046	1,464	2.82	0.74	0.72	0.15	8.52	2.35
5	62	20	262	158	2,622	1,582	3.32	0.55	0.81	0.08	11.01	3.02

December 1997 (Survey 2)

Area	No. of Taxa		No. of Individuals		Density (individuals/m^2)		H' Diversity		J' Evenness		D Richness	
	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation	Mean Per Station	Standard Deviation
1	67	20	571	389	5,714	3,891	2.97	0.59	0.71	0.13	10.63	2.97
2	57	18	345	187	3,447	1,867	2.93	0.36	0.73	0.08	9.69	2.40
3	47	11	184	83	1,839	831	3.20	0.25	0.84	0.06	8.99	1.53
4	35	12	145	73	1,449	725	2.83	0.41	0.81	0.09	6.85	1.90
5	36	15	123	60	1,229	603	2.85	0.59	0.81	0.12	7.27	2.51

of 49 and 35 taxa, respectively. The lowest number of infaunal taxa collected from a single station was collected in Area 5 during both the May (17) and December (15) cruises at Stations 13 and 3, respectively.

During the May survey, highest infaunal abundances were sampled from Area 2 (station average = 1,182 individuals), while Area 1 yielded the greatest abundances in the December survey (571). The highest number of individuals collected from a single station was sampled from Station 16 in Area 1 in both the May and December surveys, with 2,050 and 1,954 individuals collected, respectively. Areas 4 and 5 yielded the lowest mean abundances in both the May survey (305 and 262, respectively) and December survey (145 and 123, respectively). The fewest number of individuals sampled from a single station during the May survey (117) came from Station 13 in Area 5, while the December survey yielded its lowest count (35) from Station 2 in Area 5.

Mean values of species diversity (H′) were similar in all five sand resource areas and between surveys (Table 6-3). Per station averages of species evenness (J′) also were similar in the five areas and between surveys. Mean values of species richness (D) were significantly higher during the May survey than during the December survey.

During the May survey, mean station values of species diversity and richness were highest in Area 3 (3.66 and 15.21, respectively), while the highest measure of mean species evenness was from Area 5 (0.81) (Table 6-3). Lowest mean values of species diversity and evenness during the May survey were in Area 2 (2.78 and 0.61, respectively). During the December survey, the highest mean values of species diversity and evenness were in Area 3 (3.20 and 0.84, respectively), while the highest measure of mean species richness was from Area 1 (10.63). During the December survey, the lowest mean values of species diversity and evenness were from Area 4 (2.83) and Area 1 (0.71), respectively. Lowest mean values of species richness were from Area 4 in both the May (8.52) and December (6.85) surveys.

Cluster Analysis

Patterns of infaunal similarity among stations were examined with cluster analysis. When examined over both surveys, normal cluster analysis produced six groups (Groups A through F) of stations that were similar with respect to species composition and relative abundance (Appendix D4, Table D4-8). Cluster analysis revealed a strong seasonal effect. With the exception of station Group E, which consisted of stations sampled during both surveys, station groups were comprised of samples collected exclusively during one of the two surveys (Figure 6-8). Three of the six station groups were each represented by few stations, primarily in Areas 4 and 5, and were characterized by low abundance during the May (Group A) and December (D and F) cruises. Station Groups B and C represent the *Caecum*-associated assemblages sampled from Areas 1, 2, and 3 during the May and December surveys, respectively. Group E stations were represented in Areas 4 and 5 during both surveys, and were dominated with respect to the number of taxa and abundance by polychaetous annelids, especially *Mediomastus* and *P. pinnata*. Sediment grain size characteristics for all infaunal sampling stations indicate that, except for Station Group E, sedimentary regime is homogeneous within station groupings (Figure 6-9).

Inverse cluster analysis resulted in 13 groups of taxa (Groups 1 through 13) that reflected their co-occurrence in station samples (Table 6-4). Many of these species groups were dominated either by molluscan or crustacean taxa, or by a combination of both of these taxa. Species Groups 3, 5, 6, 8, and 12 were made up primarily or exclusively of molluscan taxa, while amphipod and ostracod crustaceans dominated Group 2. Species Groups 1, 10, 11, and 13 were comprised of a mixture of crustaceans, molluscans, and polychaetes, while Groups 4, 7, and 9 were dominated by polychaete taxa. These latter species groups generally were associated with the western areas (Station Group E), while the remainder of the species groups were found primarily in the eastern half of the study area (Station Groups B and C).

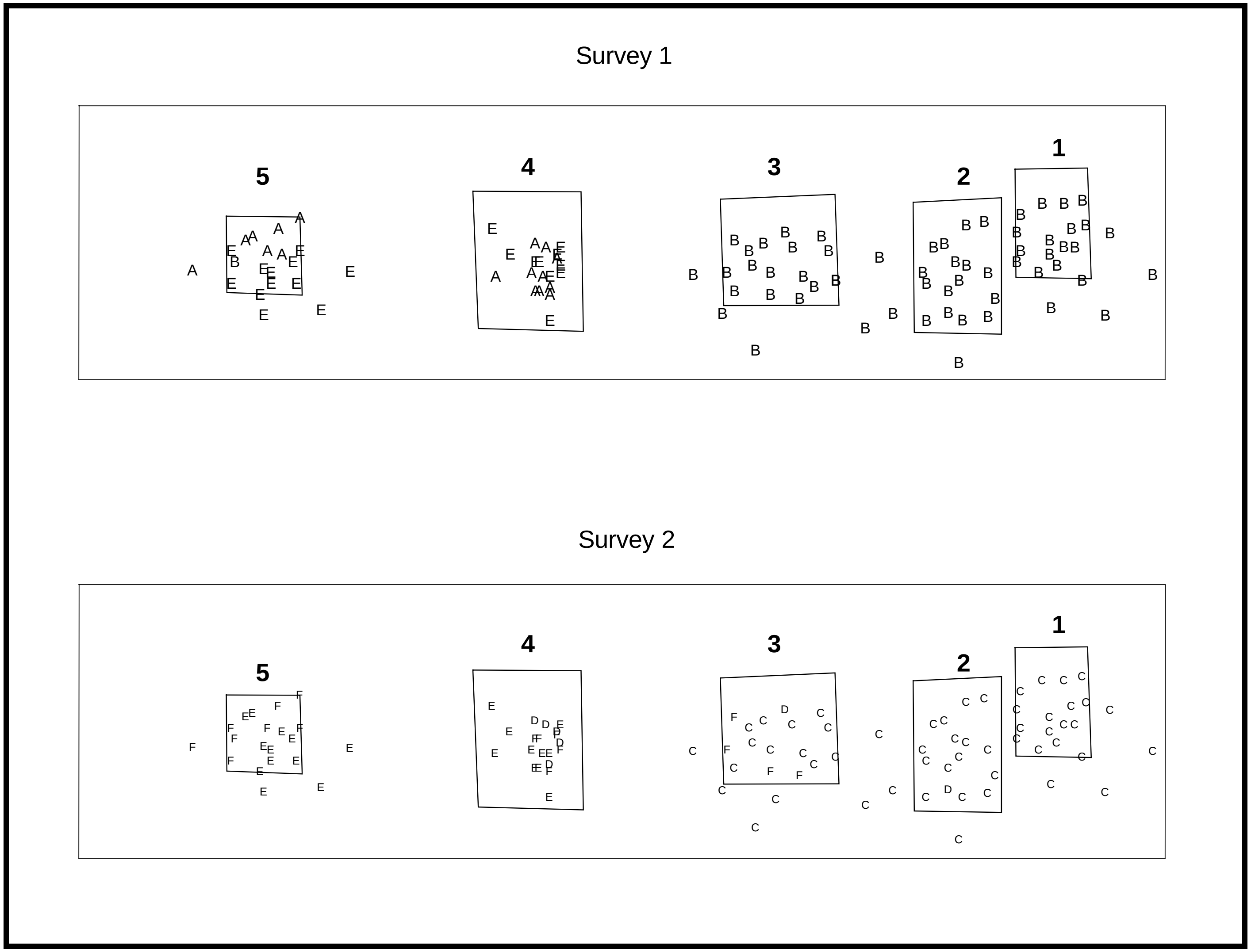

Figure 6-8. Station groupings (A to F) based on normal cluster analysis of infaunal samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in the five sand resources areas (1 to 5) offshore Alabama.

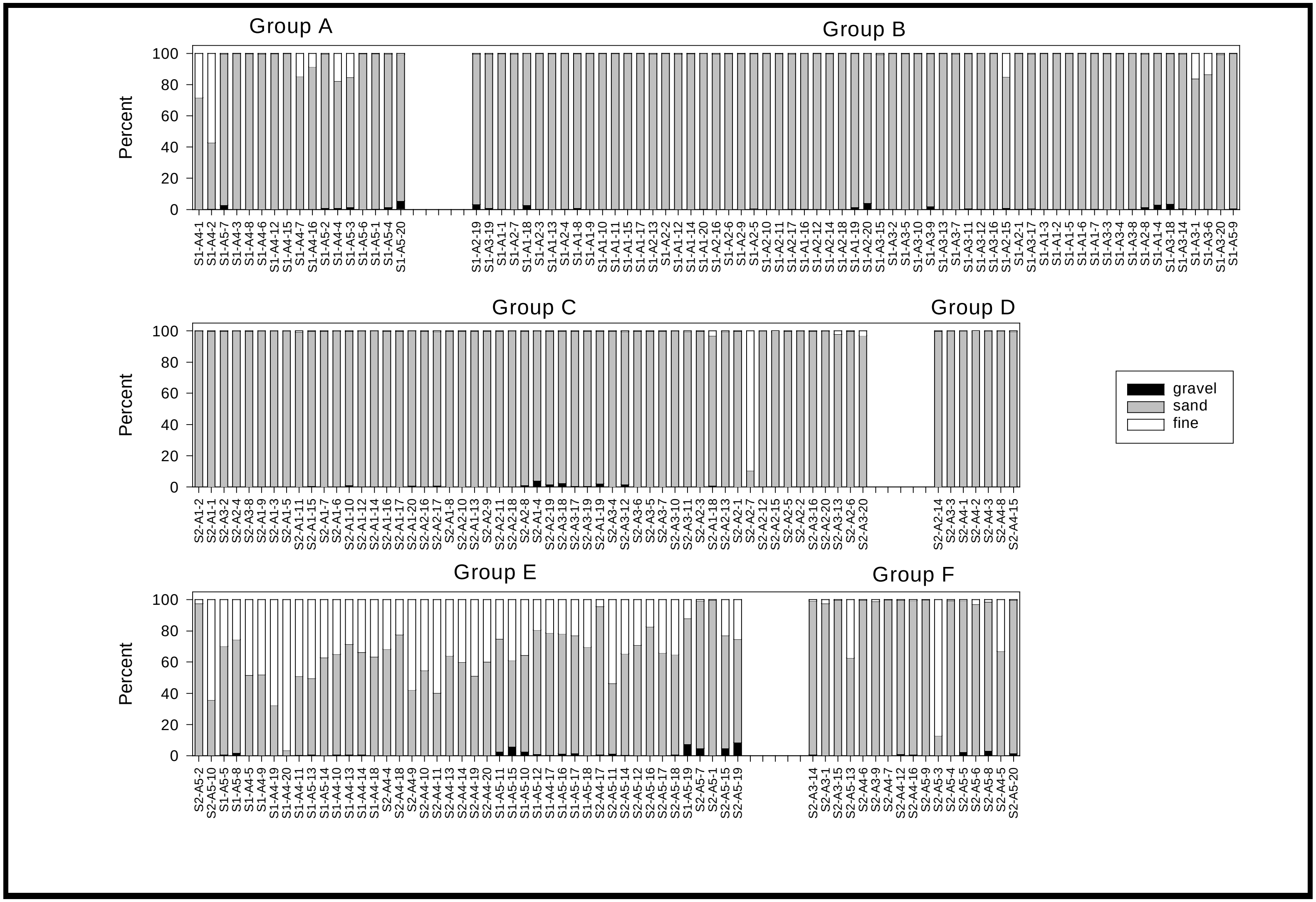

Figure 6-9. Grain size composition of infaunal samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in the five sand resource areas offshore Alabama. Sample order and Groups A-F are based on normal cluster analysis.

Table 6-4. Infaunal species groups resolved from inverse cluster analysis of all samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in the five sand resource areas offshore Alabama.

GROUP 1
Caecum pulchellum
Caecum cooperi
Armanda maculata
Eudevenopus honduranus
Metharpinia floridana
Spiophanes bombyx
Prionospio cristata
Nephtys picta
Tectonatica pusilla
Apoprionospio pygmaea
Ervilia concentrica
Acteocina candei

GROUP 2
Aricidea wassi
Monticellina dorsobranchialis
Acanthohaustorius uncinus
Eusarsiella childi
Asteropterygion oculitristis
Haplocytheridea setipunctata
Ampelisca agassizi
Listriella barnardi
Olivella dealbata

GROUP 3
Pythinella cuneata
Golfingia sp. V
Nuculana acuta
Nassarius albus
Anachis obesa
Argissa hamatipes

GROUP 4
Nereis micromma
Magelona sp. H
Phascolion strombi
Paraprionospio pinnata
Scoletoma verrilli
Aspidosiphon albus
Ampelisca sp. A
Glycinde solitaria
Aricidea taylori
Cossura soyeri
Diopatra cuprea
Scoletoma ernesti

GROUP 5
Chione latilirata

GROUP 6
Lucina multilineata
Photis pugnator
Melinna maculata
Lucina nassula
Strombiformis bilineatus
Anadara transversa
Vitrinella floridana
Haminocea succinea
Abra aequalis
Sthenelais sp. A

GROUP 7
Lumbrineris latreilli
Scoloplos rubra
Tellina versicolor
Spio pettiboneae
Cyclaspis pustulata
Ampharete sp. A
Sigambra tentaculata
Aglaophamus verrilli
Spiophanes cf. *Missionensis*
Eusarsiella texana
Goniada littorea
Paramphinome sp. B
Glycera americana

GROUP 8
Anomia simplex
Varicorbula operculata
Lyonsia hyalina floridana
Amphictene sp. A
Crassinella martinicensis
Strombiformis hemphilli
Phyllodoce arenae
Rictaxis punctostriatus
Galathowenia oculata
Oxyurostylis smithi
Ampelisca sp. C
Ampelisca bicarinata
Volvulella persimilis
Acteocina bidentata
Spiochaetopterus oculatus
Travisia hobsonae
Crenella divaricata
Philine sagra
Chione grus
Pitar fulminatus
Diplodonta punctata
Verticordia ornata

GROUP 9
Polycirrus sp. G
Cirrophorus branchiatus
Glycera sp. A
Pandora trilineata
Levinsenia sp. E
Nereis succinea
Aspidosiphon muelleri
Glycera sp. I
Brania wellfleetensis
Bhawania heteroseta
Goniadides carolinae

GROUP 10
Armandia agilis
Onuphis eremita oculata
Magelona pettiboneae
Linga amiantus
Albunea paretii
Diplodonta semiaspera
Harbansus paucichelatus
Aricidea philbinae
Antalis eboreum
Lumbrineris sp. D
Ceratocephale oculata
Edotia triloba

GROUP 11
Boguea enigmatica
Aonides paucibranchiata
Protohaustorius sp. C
Tellina alternata
Chione intapurpurea
Ophelia denticulata
Crassinella lunulata
Cyclaspis sp. N
Strigilla mirabilis

GROUP 12
Caecum imbricatum
Caecum bipartitum
Natica pusilla

GROUP 13
Magelona sp. B
Owenia fusiformis
Protohaustorius bousfieldi
Americhelidium americanum
Cyclaspis varians
Semele nuculoides
Cumingia tellinoides
Caecum johnsoni
Synelmis ewingi
Acanthohaustorius intermedius
Glycera sp. D
Caecum nitidium
Cyclaspis sp. O
Pectinaria gouldii

Canonical Discriminant Analysis

Data collected during the two surveys were analyzed using canonical discriminant analysis to determine which environmental factors most affected the distribution of the infaunal assemblages. The first two canonical discriminant variates were used to analyze variability among those station groups identified by normal cluster analysis as being similar with respect to species composition and relative abundance. The first canonical variate strongly correlated with survey (0.9867). Within surveys, the second canonical variate correlated well with percent sand (0.9024), percent fine sediments (-0.8857), and to a lesser degree with station depth (0.6118).

The selection of any sand resource area as a sediment source for nourishment projects will be based largely on its environmental characteristics. Patterns of infaunal similarity among stations (normal cluster analysis) and the co-occurrence of taxa within samples (inverse cluster analysis) were therefore examined for each sand resource area. The following describes the results of this area-by-area analysis for each survey, as well as the affinities of the station groups and species groups identified by cluster analyses.

Area 1

Normal cluster analysis resulted in two station groups (Groups A and B) in Area 1 that were separated entirely by survey (Figure 6-10). Group A consisted of all 20 stations sampled during May, while Group B was comprised of all Area 1 stations sampled during December. Differences in assemblage composition between the two station groups were evident both in the relative densities of taxa common to both surveys and also in the presence of particular taxa within either station group. Group A stations yielded relatively high numbers of the bivalves *Chione* (LPIL), *Ervilia concentrica*, and *Tellina* (LPIL) and the spionid polychaetes *Paraprionospio pinnata*, *Prionospio cristata*, and *Spiophanes bombyx*. The amphipod *Protohaustorius bousfieldi* and the bivalves *Anomia simplex* and *Nearomya* (LPIL) were exclusive to Group A stations. Group B stations yielded relatively high numbers of the amphipod *Ampelisca agassizi*, the archiannelid *Polygordius* (LPIL), and the ostracod *Haplocytheridea setipunctata*. Certain polychaetes were relatively more abundant in Group B stations as well, including *Armandia maculata*, *Aricidea wassi*, and *Scoletoma verrilli*. Taxa collected exclusively during the December survey (Group B) included the amphipod *Protohaustorius* sp. C, the bivalve *T. alternata*, the echinoid *Encope* (LPIL), and the polychaete *Aonides paucibranchiata* (Table 6-5).

Inverse cluster analysis produced four groups of taxa (Groups 1 through 4) that reflected their co-occurrence in samples collected in Area 1 (Figure 6-11). Species Groups 1 and 2 were characterized by a single taxon and by a pair of co-occurring taxa, respectively, that were rare in samples. Group 1 was represented by the gastropod *Caecum nitidium*. Group 2 included a pair of the molluscan taxa (*C. imbricatum* and *Nearomya*) that were found predominantly at a single station. Group 3 represented the *Caecum cooperi* and *C. pulchellum*-associated assemblage. Along with those two numerically dominant taxa, Group 3 included the amphipods *A. agassizi*, *Eudevenopus honduranus*, and *Metharpinia floridana*, the lancelet *Branchiostoma*, the polychaetes *A*. *maculata*, *A*. *wassi*, *Nephtys picta*, and *Scoletoma verrilli*, and the archiannelid *Polygordius*. Species Group 4 taxa included the amphipod *Protohaustorius bousfieldi*, the bivalves *A*. *simplex*, *Chione* (LPIL), *E. concentrica*, and *Tellina* (LPIL), the gastropods *Caecum johnsoni* and *Acteocina candei*, and the polychaetes *P. pinnata*, *P. cristata*, *Monticellina dorsobranchialis*, and *S. bombyx* (Table 6-5).

Sediment texture was characterized as slightly gravelly sand at all Area 1 stations during both surveys. The spatial homogeneity of sediment composition was reflected in the broad distribution of the *Caecum*-associated assemblage (Species Group 3) in this area, especially during the December survey (Station Group B). Because area sediment composition was spatially homogeneous, some other environmental factor(s) presumably had a greater influence on those

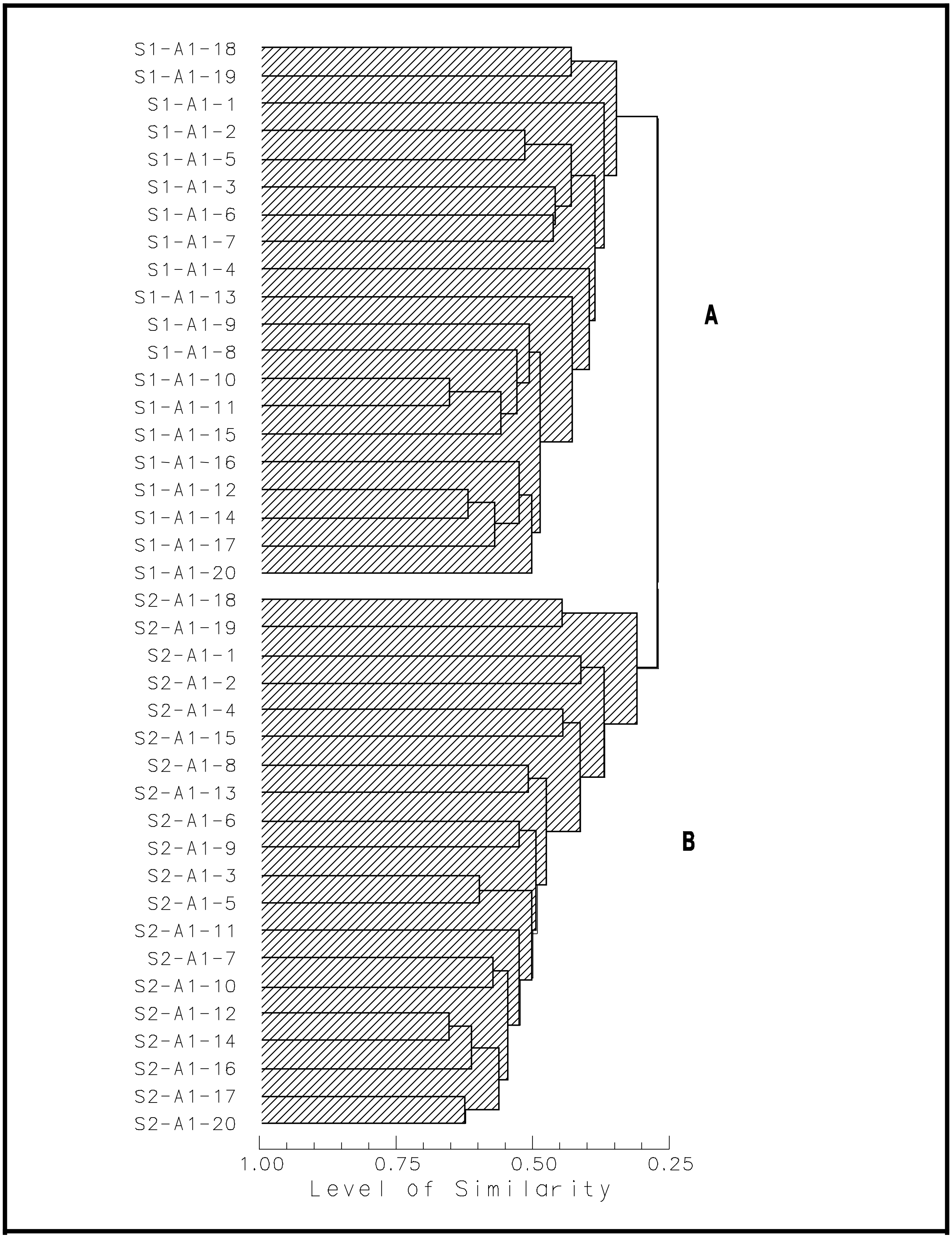

Figure 6-10. Normal cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey (S2) in Sand Resource Area 1 offshore Alabama.

Table 6-5. Two-way matrix from cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 1 offshore Alabama.

STATION GROUPS

TAXA	A																				B																				
	S1-A1-18	S1-A1-19	S1-A1-1	S1-A1-2	S1-A1-5	S1-A1-3	S1-A1-6	S1-A1-7	S1-A1-4	S1-A1-13	S1-A1-9	S1-A1-8	S1-A1-10	S1-A1-11	S1-A1-15	S1-A1-16	S1-A1-12	S1-A1-14	S1-A1-17	S1-A1-20	S2-A1-18	S2-A1-19	S2-A1-1	S2-A1-2	S2-A1-4	S2-A1-15	S2-A1-8	S2-A1-13	S2-A1-6	S2-A1-9	S2-A1-3	S2-A1-5	S2-A1-11	S2-A1-7	S2-A1-10	S2-A1-12	S2-A1-14	S2-A1-16	S2-A1-17	S2-A1-20	
Caecum nitidium							29	75																																	1
Caecum imbricatum						215																							2	33	4	2									2
Nearomya (LPIL)				12		215	8		3																																
Haplocytheridea setipunctata			2									1	2	1		2									1	33	14	4		5	10		15	24		2	1	3			
Caecum pulchellum	5	51	3	15	27	588	12	521	48	22	85	392	554	858	516	1211	83	234	77	564	118	24		3	4	430	173	74	15	30		27	308	266	138	88	216	1394	148	379	
Caecum cooperi	8	47	62	43	49				66	50	97	120	116	182	301	219	178	254	224	280	16	21			8	223	28	16	15		64	22	49	44	95	31	32	180	48	127	
Aricidea wassi		4								7						7	8	13	2	9		1					1	17	7	30	1	5	15	6	3	17	26	20	10	12	
Polygordius (LPIL)	3	8	12												4	12	1	9	15	16	83	6	39	22	4	10	19	88		67	45	47	148	12	77	24	35	111	68	96	
Scoletoma verrilli	8	24	2					4		1		2			1	18		9			31	37	2	3		19	33	6	3	3		1	30	31	21	5	19	6	12	6	
Eudevenopus honduranus	2	1	3	27	8	7	7	9	8	2		15	12	13	11	6	4	9	20	23	1	3	21	22	4	5	54	48	18	25	48	30	17	18	9	43	43	26	31	37	
Metharpinia floridana	4	5		12	4	5	1	2	1	2	6	6		2	13	4	9	6	5	12		9	6	21	16	8	6	3	21	9	24	2	6	10	7	18	43	24	7	8	
Nephtys picta	9	3	9	6	2	7	1	4	3	2	3	4	11	3	19	13	5	6	18	14	3		3	3	1		4	7	4	6	2	4	7	2	4	3	6	7	4	2	
Eusarsiella childi		1	3	5	8	2	2	8	1	2	4	1	7	5	6	1	5	7	8	5			2	4		1	6		8	5	8	4	4	10	7	21	8	10	9	2	3
Armandia maculata	6	3			2	3	1		2		1	2	1	3	1		4	5	2	1	15	17			15	11	1	4	3	2		9	11	13	4	8	23	5	8	7	
Branchiostoma (LPIL)	1		1	3				1			3	4	1	1	9	1	1	2	3	4	2	2	3	6	39	5	2	1	4	3	3	3	9	19	7	8	11	2	3	7	
Mediomastus (LPIL)	5	17				3			6	1		3		6	17			1	14	3	25	9	1		3	3			1	3	1	1	8	1		1		1	6	7	
Boguea enigmatica									7																4	4			11		2	7	23		7	34	8	7	8	24	
Aonides paucibranchiata																						6		3	40			1	9	4	7	7	1		4	5	8	4	9	14	
Protohaustorius sp.C																							8	43		1	5	3	12	8	12	4	5	28	14	28	14	3	14	15	
Tellina alternata																								7	3				8		10	7		13	14	26	13	17		4	
Encope (LPIL)																						1			23	11	12	2	7	14	11	24	5	18	8	12	26	6		2	
Ampelisca agassizi		1		1	3				1								1				1	2			3	8	4	4	5	10		7	3	5	4	8	10	15	2	8	
Chione (LPIL)									28	2	1	6	12	8	17	6	6	50	47						3	4			1				1						1		
Caecum johnsoni					1				53			17	6	5	42				10						23	14			1	9	1		1	2							
Anomia simplex	2	18							14	1			6	2	9	46	3	9	4	24																					
Tellina (LPIL)	9	2	3	13	2	57		9		9	42		74	40	29	12			48	30	7	1		4	13	8	3	2	1	7	4	5	4		1				7		
Spiophanes bombyx	37	19	43	37	24	52	22	16	36	16	20	33	22	32	39	33	23	30	34	32	2	1	6	1	2	1	4	1	3	2	3	3	5	2	2	1	7	1	1	3	
Prionospio cristata	14	23	1	8	4	9	5	12	3	3	21	4	13	2	17	15	21	28	19	10	7		3		1		1			2		2	4				2	4	1	1	4
Paraprionospio pinnata	33	27	7	3	3	4	1	8	1	6	4	11	5	5	6	10	6	4	2	5	9	9										1			2					1	
Acteocina candei			4	1	2	9	3	5	7	1	4	3	15	4	13	18	4	10	46	21					2	1	1				2	2		1		3	1	1			
Protohaustorius bousfieldi	2		5	14	13	11	4	5	2	4	1	10	18	11	23	5	11	10	8	18																					
Ervilia concentrica			1	2	7	4	5	13	15	9	10	2	11	3	7	9	2	9	2	3				4	2		2	5	2										2		
Monticellina dorsobranchialis		4								2	1	1	2	25	2	3	4	22		1	2	2				1	1	2		1			13		3		4	1	1	2	

LPIL = Lowest practical identification level.

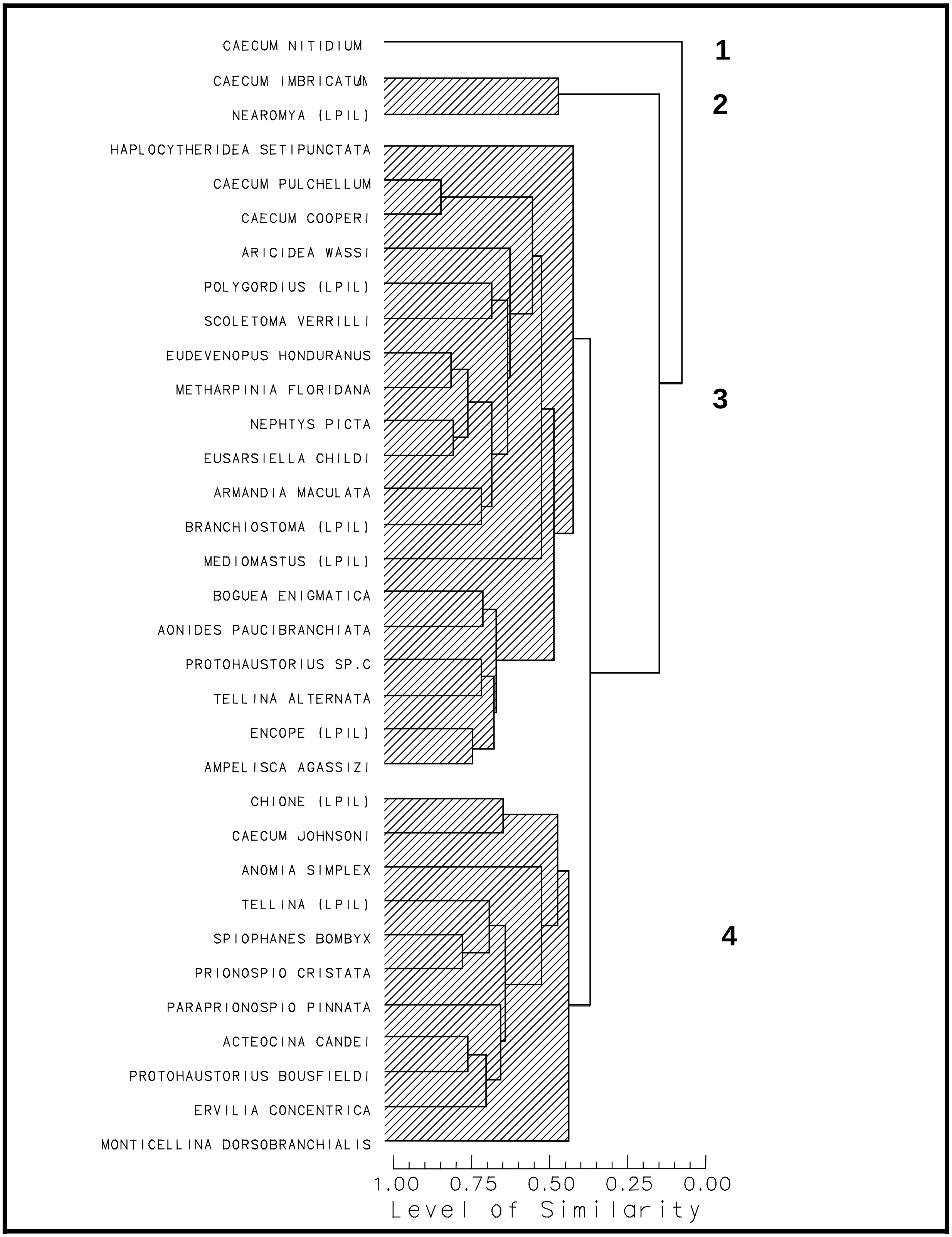

Figure 6-11. Inverse cluster analysis of infaunal taxa from samples collected during the May 1997 Survey 1and December 1997 Survey 2 in Sand Resource Area 1 offshore Alabama.

differences in assemblage distribution and composition that were indicated by station groupings generated from normal analysis. Canonical discriminate analysis indicated that after season and sediment composition, depth was the environmental factor that most affected the distribution of the infaunal assemblages censused during the present study. Some indication of a depth factor was apparent in Area 1, with the two deepest stations [Stations 18 (21 m) and 19 (23 m)] closely associated with one another within station groupings (Table 6-5). These two stations also were the most dissimilar to other stations. The average depth at Area 1 stations was 14 m.

Area 2

Station groupings in Area 2 were defined by survey, and normal cluster analysis resulted in three station groups (Groups A through C) (Figure 6-12). Group A consisted of one station during the September survey that was depauperate both in numbers of taxa and individual abundance. Station Group B was comprised of all Area 2 stations sampled during May. This group was distinguished by relatively high abundances of most of the numerically dominant taxa collected from Area 2. In addition to *C. cooperi* and *C. pulchellum*, the bivalves *Chione*, *E. concentrica*, *Lyonsia hyalina floridana*, and *Tellina*, and the polychaetes *Amphictene* sp. A, *N. picta*, *P. cristata*, *P. pinnata*, and *S. bombyx* were relatively abundant in Station Group B. The bivalves *A. simplex* and *Varicorbula operculata* were exclusive to the May survey (Group B). Station Group C was further distinguished from Group B by yielding relatively high abundances of *Polygordius* and the ostracod *Haplocytheridea setipunctata*.

Inverse cluster analysis produced three species groups (1 through 3) from the surveys of Area 2 (Figure 6-13). Group 1 was comprised of three co-occurring taxa: *Branchiostoma*, *C. johnsoni*, and the sipunculid *Aspidosiphon mulleri*. Group 2 was represented only by *V. operculata*, which did not show any pattern of association with other numerically dominant taxa. Species Group 3 was the *Caecum*-associated assemblage, and included 21 of the 25 numerically dominant taxa collected from Area 2. Taxa included in this group were mostly polychaetes, including *A. pygmaea*, *Amphictene* sp. A, *Aricidea wassi*, *A. maculata*, *M. dorsobranchialis*, *Mediomastus*, *N. picta*, *P. cristata*, *P. pinnata*, *S. bombyx*, and *S. verrilli*. Bivalves were well represented in Group 3, including *A. simplex*, *Chione* (LPIL), *E. concentrica*, *L.h. floridana*, *Tellina*, and *V. operculata*. Other taxa included in Group 3 were *A. candei*, *M. floridana*, and *Polygordius* (Table 6-6).

As in Area 1, Area 2 stations were characterized by slightly gravelly sand. The spatial homogeneity of sediment composition was reflected in the broad distribution of the *Caecum*-associated assemblage (Group 3) during both surveys. Two stations (8 and 19) were closely associated within station groups (surveys) and also were most dissimilar to other stations (Table 6-6). These stations had depths of 12 and 13 m, respectively, compared to a station average of 14 m in Area 2.

Area 3

As in Areas 1 and 2, station groupings in Area 3 were separated by survey (Figure 6-14). Normal cluster analysis resulted in two station groups (Groups A and B). Group A was comprised of 19 of the 20 Area 1 stations sampled during May and yielded generally higher abundances than did stations in Group B. Taxa found at higher densities in Group A relative to Group B included the molluscans *C. johnsoni*, *Pythinella cuneata*, and *Semele nuculoides*, the polychaetes *N. picta*, *P. cristata*, *P. pinnata*, and *S. bombyx*, and the sipunculid *Golfingia* sp. V. Several taxa were found nearly exclusively at Group A stations, including the molluscans *Chione*, *L. h. floridana*, and *V. persimilis* and the polychaetes *Ampharete* sp. A and *Phyllodoce arenae* (Table 6-7). The polychaete *Nereis micromma* was collected almost exclusively in Group B stations. The echinoid *Encope* (LPIL) was collected only from Group B stations (December survey).

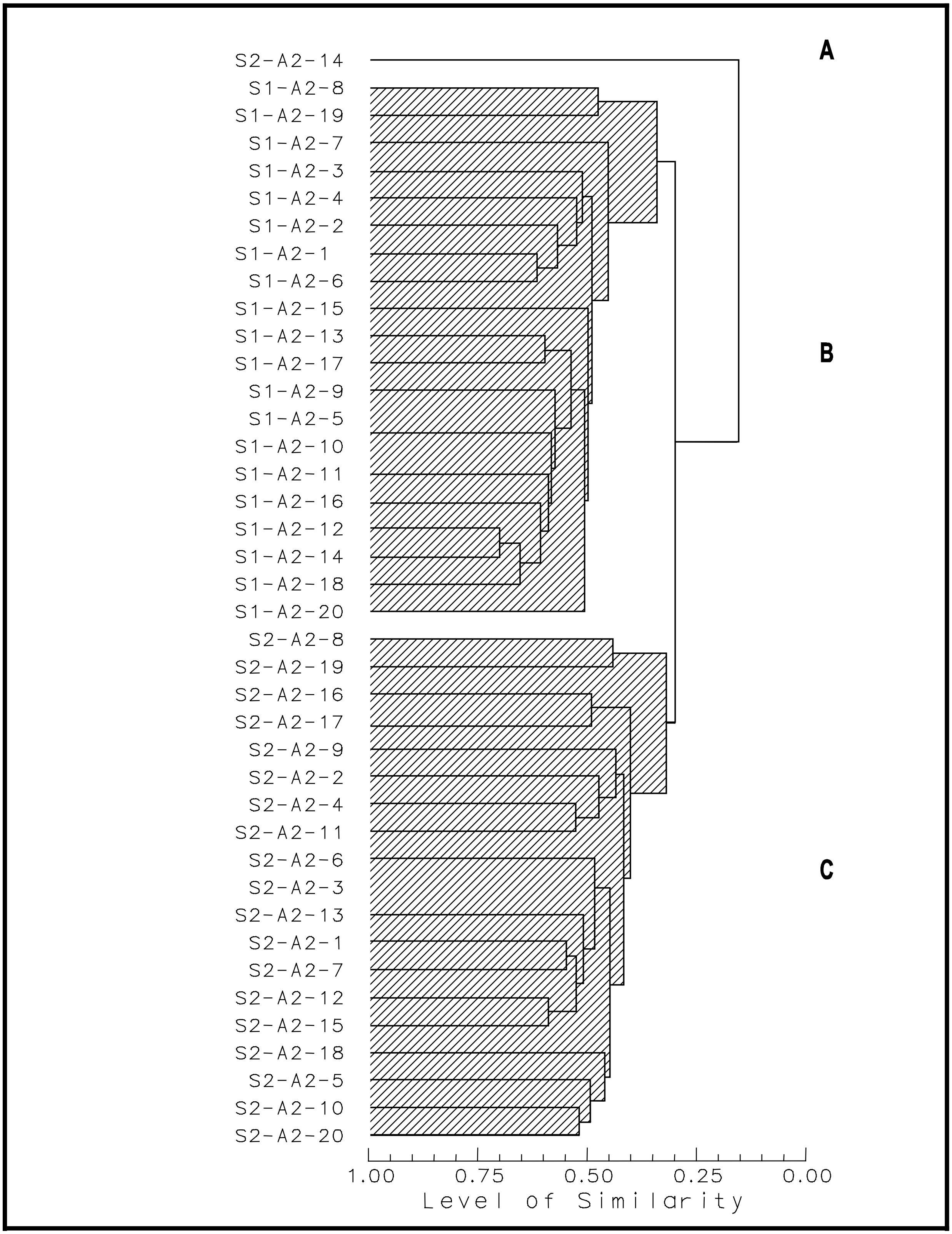

Figure 6-12. Normal cluster analysis of infaunal samples collected during the May 1997 Survey 1(S1) and December 1997 Survey 2 (S2) in Sand Resource Area 2 offshore Alabama.

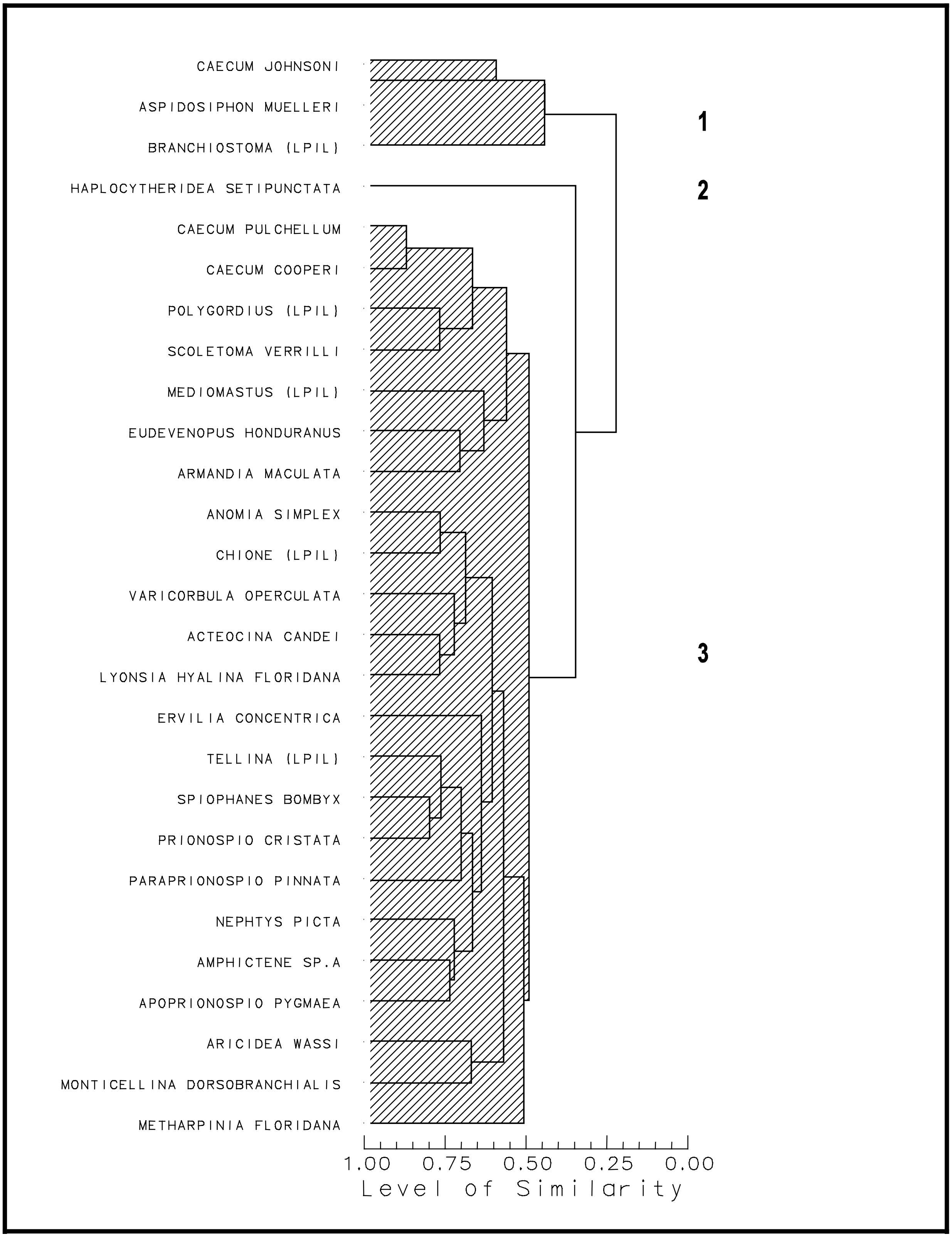

Figure 6-13. Inverse cluster analysis of infaunal taxa from samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in Sand Resource Area 2 offshore Alabama.

Table 6-6. Two-way matrix from cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 2 offshore Alabama.

	STATION GROUPS																																								
	A	B																				C																			
TAXA	S2-A2-14	S1-A2-8	S1-A2-19	S1-A2-7	S1-A2-3	S1-A2-4	S1-A2-2	S1-A2-1	S1-A2-6	S1-A2-15	S1-A2-13	S1-A2-17	S1-A2-9	S1-A2-5	S1-A2-10	S1-A2-11	S1-A2-16	S1-A2-12	S1-A2-14	S1-A2-18	S1-A2-20	S2-A2-8	S2-A2-19	S2-A2-16	S2-A2-17	S2-A2-9	S2-A2-2	S2-A2-4	S2-A2-11	S2-A2-6	S2-A2-3	S2-A2-13	S2-A2-1	S2-A2-7	S2-A2-12	S2-A2-15	S2-A2-18	S2-A2-5	S2-A2-10	S2-A2-20	
Caecum johnsoni		273	126	3	1									4	2						2	20	12																		
Aspidosiphon muelleri		27	108															1				1	2										1								**1**
Branchiostoma (LPIL)	33	6	32		1	1	3		1	1			1						1		3	7	13	4	2	1			1				2	3					1		
Haplocytheridea setipunctata		1			2			7	2					1						1	3	1	1		3	1	2		3	4	2	11	38	23	53	3		1	4	4	**2**
Caecum pulchellum		48	11	141	26	27	156	76	575	82	829	740	304	1176	1053	838	1021	791	709	557	23	15	4	99	333	123	23	3	24	33	10	70	33	308	190	115	81	101	120	52	
Caecum cooperi		36	11	25	44	71	140	56	237	34	1	534	346	252	322	244	113	197	96	258	42	10	9	26	84	12	14	4	37	18	18	11	148	40	29	35	18	32	42	36	
Polygordius (LPIL)		5	3		3	5		13	6				19	4		22	21	42	19	18		5	7	112	79	57	3	28	39	12	35	47	27	4	15	5	36	24	48	32	
Scoletoma verrilli			1	5	9		1	6	3	2	21	19	3	5	2	14	4	46	41	23		3		26	29	11	11	8	23	12	4	21	5	26	44	41	20	18	30	25	
Mediomastus (LPIL)		4	9	15			3	2		5	1	1	3	1	1	3	7	1	1	1	3	3	5	8		1			1	39	15	7	9	59	11		1		3	4	
Eudevenopus honduranus	25	20		2	3	7	5	2	8	7	16	2		12	12	11	13	12	2	4	7	20	5	9	32	6	2	21	9	4	2	2	6	5	10	5	8	2	16	1	
Armandia maculata	1	4	15		3	1		1	1	2	3	5	3	2	8	2	5	2	3	1	3	7	6	10	9	2	2	2	2	1	12	7	4	3	3	6	2	3	6	4	
Anomia simplex		9	161		2	1	1			20	23	18	13	22	9	19	24	3	12	2	14																				
Chione (LPIL)		13	6		1					5	17	20	24	64	53		31	3	10	42	35					1						2									
Varicorbula operculata			2	5			2	1	9	16	143	33	9	11	25	27	23	11	46	9	9																				
Acteocina candei		2		1	7	3	4	10	12	6	28	15	20	18	11	9	9	25	16	9	36	1	4		4							1	2						1	1	
Lyonsia hyalina floridana					3	1	3	4	4	9	23	22	3	17	6	4	2	3	12	4	7				1							1	1			1					**3**
Ervilia concentrica	10	54	38	4		14	14	7	39	4	48	10	12	19	12	29	3	11	36	28			32	1	7					3		2				1	9				
Tellina (LPIL)	1			41	10	9	23	69	20	5	35	27	118		24	38	16	18	31	38	35			3	8	1	1	2	2	1		9	5	5	3	2	4				
Spiophanes bombyx	1	33	29	10	51	5	60	44	35	23	21	31	39	26	27	66	12	55	42	38	119			2	1	3	3	5		2	9	6	3	1	6	6	1	1	5	3	
Prionospio cristata	1	10	33	2	15	12	2	23	9	8	15	28	22	15	17	10	5	23	6	25	28			16		4	1	1	1	2	10	18	12	1	4		2				
Paraprionospio pinnata				50	14		14	21	8	22	10	13	1	4	4	4	2	23	15	3	18		1	1	5			1	1	1	6	3	5	5	7	7	1			8	
Nephtys picta		2	1	5	18	21	9	19	19	10	2	3	18	14	7	17	3	9	11	9	6	1	1	2		2	2	5		1		3	2	2	1	1		3	2	3	
Amphictene sp.A				2	9	8	11	3	8	4	15	2	6	3	3	10	2	8	11	6	15			5	1					1	2	1			1	1	1	1			
Apoprionospio pygmaea		1	2		1	3	5	2	6	10		1	7	7	2	17	1	9	7	9	5			1			2			2	2	2	3	2	2	1	1				
Aricidea wassi			1	16		10	12	1	4		6	10	20	6	11	10	3	6	5	18	2		1	23	11	17	2	2	9			6	2			2	1	1	2		
Monticellina dorsobranchialis				4			6	1	1	1	1	5	37	4	4	3	1	4	5	4	1			2	5	11				1		1	1					5			
Metharpinia floridana	1	6			2	2	1			2	1	5		2	3	1	7	12	10	4	5		8	11	16				1				1		5	2					

LPIL = Lowest practical identification level

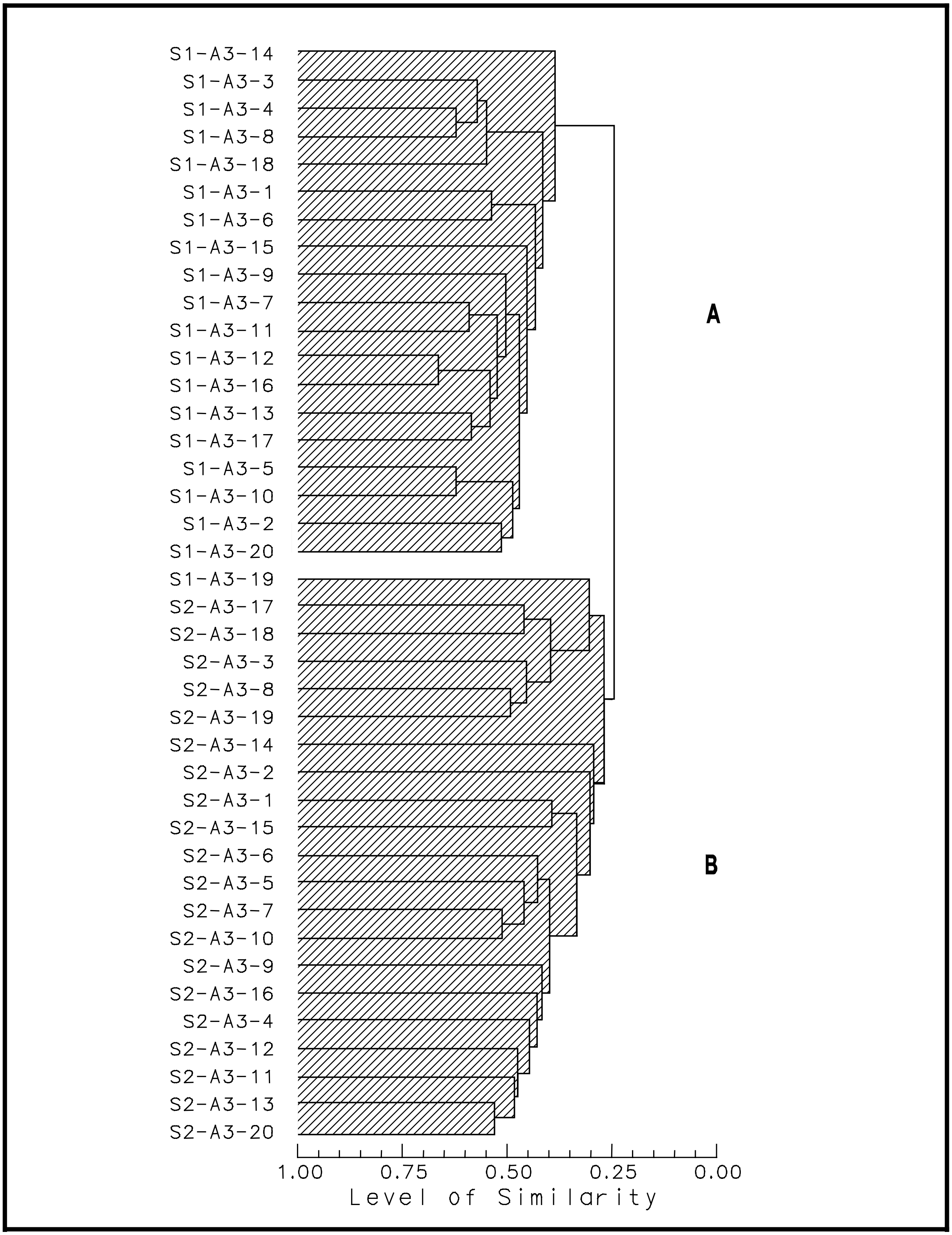

Figure 6-14. Normal cluster analysis of infaunal samples collected during the May 1997 Survey (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 3 offshore Alabama.

Table 6-7. Two-way matrix from cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 3 offshore Alabama.

STATION GROUPS

	A																			B																					
TAXA	S1-A3-14	S1-A3-3	S1-A3-4	S1-A3-8	S1-A3-18	S1-A3-1	S1-A3-6	S1-A3-15	S1-A3-9	S1-A3-7	S1-A3-11	S1-A3-12	S1-A3-16	S1-A3-13	S1-A3-17	S1-A3-5	S1-A3-10	S1-A3-2	S1-A3-20	S1-A3-19	S2-A3-17	S2-A3-18	S2-A3-3	S2-A3-8	S2-A3-19	S2-A3-14	S2-A3-2	S2-A3-1	S2-A3-15	S2-A3-6	S2-A3-5	S2-A3-7	S2-A3-10	S2-A3-9	S2-A3-16	S2-A3-4	S2-A3-12	S2-A3-11	S2-A3-13	S2-A3-20	
Encope (LPIL)																					25	2	9	28	14							2				39					**1**
Nereis micromma								1														2			1			1	2	4	4	1	1	8	3	5	8	12	25	21	**2**
Semele nuculoides	3	127		100	27				1			1		1	1					1	1	7	12																		**3**
Caecum johnsoni		84	17	19	28	2				3						1		1				19		7																	
Haplocytheridea setipunctata						20	6		1	4	8				3	13	20	4	1			2								4	20	4	34					3	1	2	
Sigambra tentaculata	1					50	12	3		1	2	1			2			1								2		7	3					2	2	2	3	3	9	3	
Phascolion strombi	3					22	17	5		6		3	1		1	1		1	7							1	2	1	2	1	3	2		1			4		1	3	
Chione (LPIL)		3	8	20	63		9		30	2	1	5	44		4			13	3	4														2							
Scoletoma verrilli						4		7	3	9	8	3	5	20	7	3	2				2			2	1		2			4	4	7	14	5	1	2	1	7	22	20	
Mediomastus (LPIL)	10	4	5	8	13	398	73	8	10	4		6	6	3	3	2	6	11	4		7	1	17	2	1	2		6	6	1	1		1	13	3	19	11	14	14	13	
Tellina (LPIL)	23	3	41	16	7	110	24		8	4	1	10	15	5	7			1			6	1	3		8	20			10	3	3			1				2		1	
Caecum pulchellum		8	11	75	325	2	12	5	43	10	20	56	73	48	50	29	19	76	11	87	104	22		3	2	1			1	6	3	2	5		20	9	7	22	25	46	
Caecum cooperi		20	10	37	217	5	11	15		13	30	74	105	111	32	47	25		39	60	54	20	2	9	26		1	4	2	8	2	1	10		19	10	7	28	28	13	
Polygordius (LPIL)		18	64	17			1	8	25	10	12	9	14	37	5	27	9	4	12	1	12	6	28	44	59	1	4	2	4	9	2	6	4	6	3	45	27	4	49	6	
Eudevenopus honduranus		41	10	35	17	2	4		10	12	5	4	4	11	8	16	12	26	2	10	5	8	15	27	17		2		2		1	5	1	1	2	15	2		3	3	
Spiophanes bombyx	27	55	80	52	18	32	32	43	46	71	62	47	54	29	24	26	32	22	19	1	1	2	3	2	1		6			5	7	7	2		6	5	1	6	2	1	
Paraprionospio pinnata	19	2	4	3	3	44	21	25	3	12	23	44	22	7	19	12	11	3	6							8		1	2	5	1	2	4	1	1	2		6	2	1	
Tectonatica pusilla	3	1	6	7	5	7	2	3	98	6	7	4	8	10	2		8	8	5	2	4	1	1	2	2	1	1	1	3	1	3	5	5	3	1	1	2	4		5	**4**
Nephtys picta	3		2	2			1	12	10	28	21	3	7	13	14	3	10	7	4	2	1	1	2	1	1		1		4		2	1	4		4	1	1	2		1	
Prionospio cristata	4	10	20	15	9	3	3	21	15	5	14	14	14	11	3	18	13	13	2				9	1	6	2	4				7	1	6	2			3	6	1		
Apoprionospio pygmaea	4	2	7	9		9		10	3	10	8	8	4	8	6	4	10	5	5				1			1	3			2	2	1	1	3	2		5				
Branchiostoma (LPIL)		31	8	9	5		1		5	6	5	1	1	1	1		1			5	9	10	10	9	10		1	1	2	1	2	3			1	10		4	2		
Metharpinia floridana		11	16	3	6		2		19	5	2		1	1			1	1		2	13	10	11	19	10						1	3				9			1	1	
Ervilia concentrica		18	8	4	14				14			2	4	7	2		28	2		3		1	1		3			2	1		1	1		5		4				2	
Armandia maculata	3	3	4	1	2	2	1	1	2	2	1			5	4		4	1	1		1	6	1	5	7	1				2		5	1	8	5	1		3	3	4	
Amphictene sp.A	10			11				2	10	9	7		18	5	9		7																					1			
Golfingia sp.V	19		1			63	1	52	7	8	7	13	23	11	6	1	1	7	8							1	3		3								2				
Pythinella cuneata	3	3				1	3	4		66	5	17	14	10			1	1	3								18		4		1	2						8			
Ampharete sp.A	2	5	10	1		3	5	8		9	2	14	2	2	2	15	2	7	1			1		2	1	2	2				3	1								2	
Lyonsia hyalina floridana			2	3	1	2	7	25	8		11	9	30	7	4	11	14	3											1											1	
Volvulella persimilis	1			1		1	3	13		2	10	25	18	1	10	6	6		1									1			2										
Acteocina candei		1	1	4	6	3	4		4	1	5	4	6	5	3	4	3	1	5	1		3	5	2							1				2			7		1	
Phyllodoce arenae	3	9	9		5	14	1	5	5	1	2	6		4	2		2	1	2	1					2												1				

LPIL = Lowest practical identification level.

Four groups of taxa (Groups 1 through 4) were observed in Area 3 (Figure 6-15). Species Groups 1 and 2 each were characterized by a single taxon that showed no pattern of association with other taxa: *Encope* (Group 1) and *N. micromma* (Group 2). These two groups were collected mostly during the December survey. A co-occurring pair of molluscan taxa (*C. johnsoni* and *S. nuculoides*) collected primarily during the May survey represented Species Group 3. Twenty-nine of the 33 numerically dominant taxa collected from Area 3 were included in Group 4. In addition to the gastropods *C. cooperi* and *C. pulchellum*, this group consisted of annelids (12 taxa), bivalves (5), other gastropods (3), crustaceans (3), *Polygordius,* and miscellaneous taxa, including *Branchiostoma* and the sipunculids *Phascolion strombi* and *Golfingia* sp. V (Table 6-7).

Area 3 stations were fairly consistent with respect to sediment texture. There was some variability in sediment composition in Area 3 during the May survey (Station Group A), with two stations (1 and 6) characterized by slightly gravelly muddy sand, compared to slightly gravelly sand at all other stations. Those two stations yielded relatively high numbers of *Mediomastus* (LPIL), *P. strombi*, and the polychaete *Sigambra tentaculata* relative to other Area 3 stations. Station water depth also may have influenced assemblage composition in Area 3. May survey Stations 3, 4, 8, and 18 were closely associated within Station Group A and had depths averaging 11.5 m. These stations yielded high densities of *C. johnsoni* and *S. nuculoides* (Species Group 3). The remaining Group A stations had an average depth of 14.2 m.

Area 4

Three station groups (Groups A through C) were identified by normal cluster analysis (Figure 6-16). Groups A and B were comprised of the same stations sampled during the May and December surveys, respectively. Group C included stations from both surveys. Station Group A (nine stations) was distinguished from other groups by yielding relatively high numbers of the polychaetes *A. pygmaea, Magelona* sp. B, and *S. bombyx*. Group B yielded relatively high numbers of *A. maculata* and *Branchiostoma*. Groups A and B both yielded low numbers of several of the numerically dominant taxa found at Group C stations (Table 6-8). Group C taxa were mostly polychaetes, including *Aricidea taylori*, *Cossura soyeri*, *Diopatra cuprea*, *Glycinde solitaria*, *Magelona* sp. H, *Mediomastus*, *N. micromma*, *P. pinnata*, *S. tentaculata*, and *Scoletoma verrilli*. Other Group C taxa included *Ampelisca* sp. A and the rhynchocoel *Tubulanus*.

Inverse cluster analysis delineated three groups of co-occurring taxa (Groups 1 through 3) in Area 4 (Figure 6-17). Group 1 was represented by the acorn worm *Balanoglossus* (LPIL) and showed no pattern of association with other taxa. Species Group 2 included the amphipods *E. honduranus* and *Protohaustorius bousfieldi*, the bivalves *Chione* and *E. concentrica*, *Branchiostoma*, the decapod *Pagurus* (LPIL), the gastropod *Nassarius albus*, the polychaetes *A. pygmaea*, *Magelona* sp. B, and *S. bombyx*, and *Polygordius*. Species Group 3 was comprised predominantly of polychaetes, including *Magelona* sp. H, *Mediomastus* (LPIL), *N. micromma*, *P. pinnata*, *S. tentaculata*, and *S. verrilli* (Table 6-8).

Sediment composition in Area 4 stations was variable during both surveys. Species groups were clearly associated with particular station groupings. Those Area 4 stations with slightly gravelly sand (Station Groups A and B) supported amphipods, lancelet, pagurid decapods, polychaetes such *A. pygmaea*, *Magelona* sp. B, and *S. bombyx*, and *Polygordius* (Species Group 2). Those stations with slightly gravelly muddy sand, muddy sand, slightly gravelly sandy mud, or clayey sand (Station Group C) yielded a preponderance of polychaetes, including *Magelona* sp. H, *Mediomastus*, and *P. pinnata* (Species Group 3) (Table 6-8). No relationship between the composition of infaunal assemblages and station depth was apparent in Area 4.

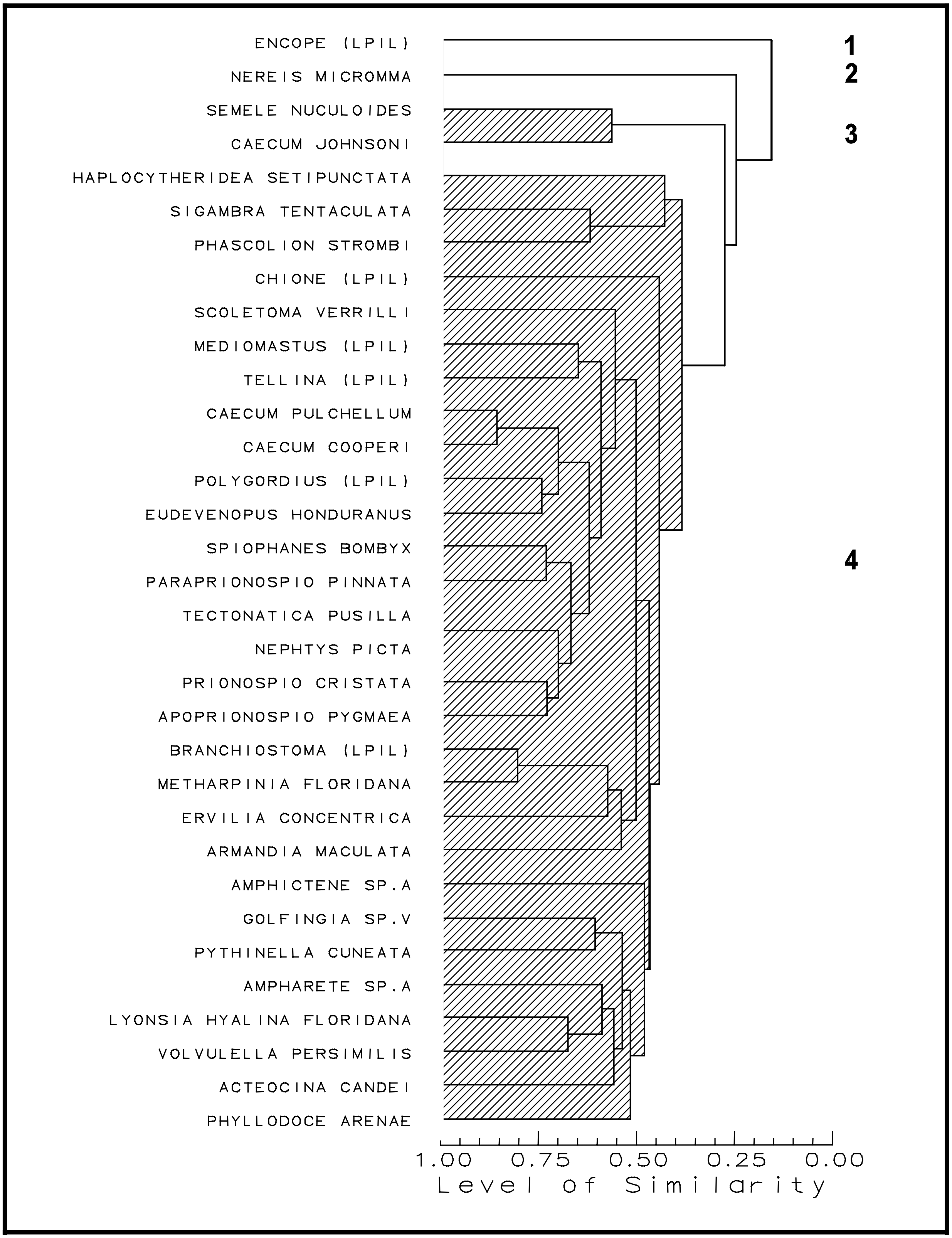

Figure 6-15. Inverse cluster analysis of infaunal taxa from samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in Sand Resource Area 3 offshore Alabama.

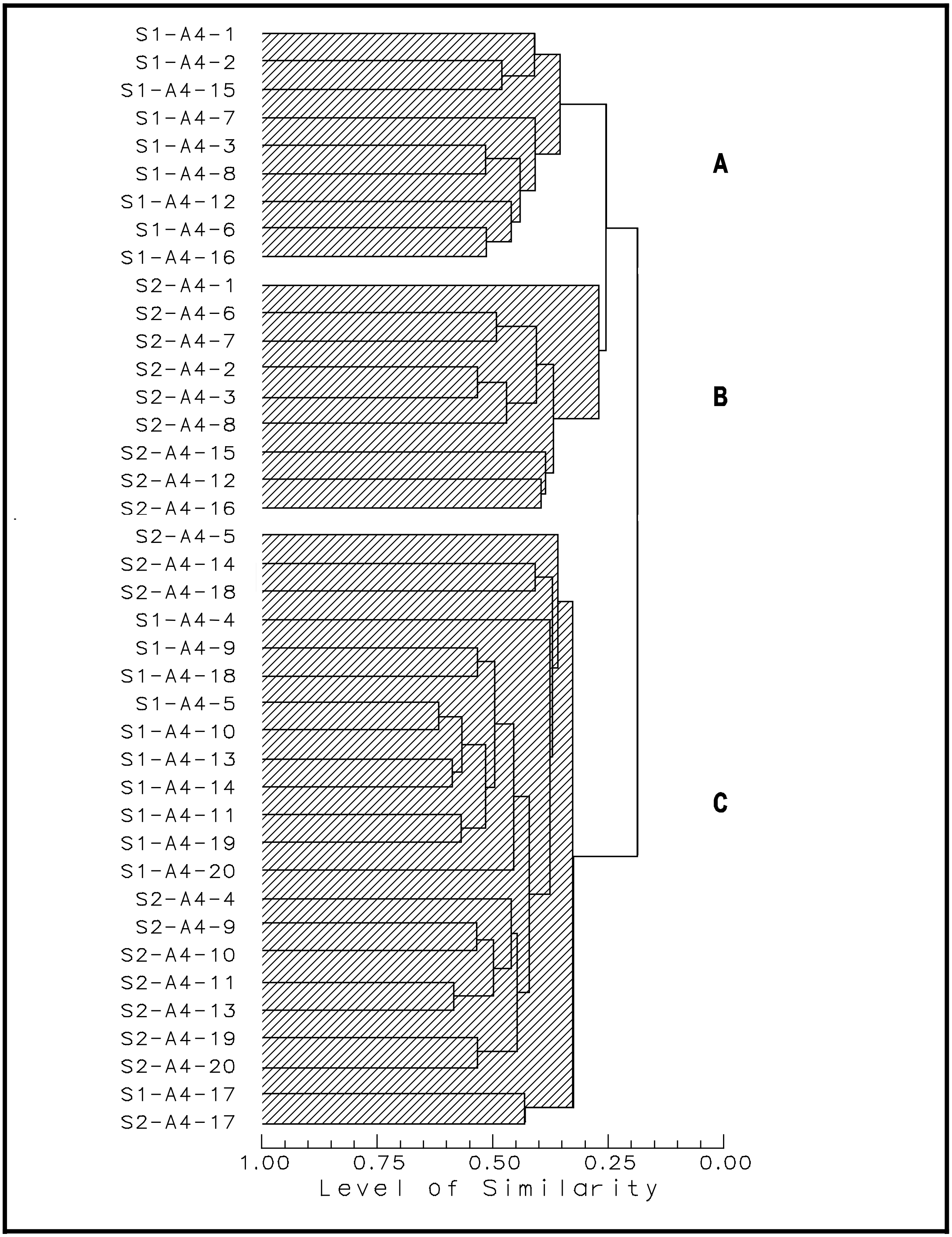

Figure 6-16. Normal cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 4 offshore Alabama.

Table 6-8. Two-way matrix from cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 4 offshore Alabama.

	STATION GROUPS																																								
	A									B									C																						
TAXA	S1-A4-1	S1-A4-2	S1-A4-15	S1-A4-7	S1-A4-3	S1-A4-8	S1-A4-12	S1-A4-6	S1-A4-16	S2-A4-1	S2-A4-6	S2-A4-7	S2-A4-2	S2-A4-3	S2-A4-8	S2-A4-15	S2-A4-12	S2-A4-16	S2-A4-5	S2-A4-14	S2-A4-18	S1-A4-4	S1-A4-9	S1-A4-18	S1-A4-5	S1-A4-10	S1-A4-13	S1-A4-14	S1-A4-11	S1-A4-19	S1-A4-20	S2-A4-4	S2-A4-9	S2-A4-10	S2-A4-11	S2-A4-13	S2-A4-19	S2-A4-20	S1-A4-17	S2-A4-17	
Balanoglossus (LPIL)																						1									100										**1**
Armandia maculata					1	1		3	1	1	3	10	2	31	4	7	137	10		1	1										2			1			1				
Branchiostoma (LPIL)	11	5	15	2	27	5	1	2	1	27	5	14	24	80	19	66	6	4	3	1		1			1			2						1							
Polygordius (LPIL)		4	17	1	3	9	10	3	1	1	4	7	20	8	24	17	6	19					1									2	2		2						
Eudevenopus honduranus	10	1		3	1	1		1		9		1	6	5	1	5	1	1	4			1			1																
Spiophanes bombyx	5	9	7	100	6	18	35	25	20			8	2	3	4		3					7	2	2		1				1									5		
Apoprionospio pygmaea	7	3	4	78	7	11	25	25	21		1						1	1				20				1														1	
Nassarius albus	2	2		2	10	8	6	1	3													23				2					1										**2**
Pagurus (LPIL)	5	4	2	1		14	10															4			3																
Nephtys picta			4	1	2	3	8	9	3	2			1	1	2				1																				3		
Ervilia concentrica	9	6	3			4				17				3		1																	1							1	
Magelona sp.B	5		13		14	20	2	6					5	2	1	5	7																								
Chione (LPIL)	5		12			20		1			1			1																											
Protohaustorius bousfieldi	20				7	9																			2																
Prionospio cristata				8	1		1	3	5		1	3			1		5						4		1	2	2	1									7		2		
Tellina (LPIL)	1			16		2		2	2					1		2						7				1	1					3		8	1	1	2		43	12	
Pinnixa (LPIL)	1	1	5		3	2					2		1	1		3		1			3	4		3			1		1	2				3	1		1			1	
Ampharete sp.A		1	1	1	1							2			2	1	1	1	2			7	1	1		1	1			2			1	1				1	2	7	
Phascolion strombi			3		16	8	7	10	4		6	17	1	3	2	1	7	4	20	1	2	3	4	4	20	9	5	2	6			19	3	6	4	3		2			
Tectonatica pusilla	4	3	5		7	7	6	2	2	2	7	7	5	4								10	2	2	4	6	5		1	1	1	1	1	4					6		
Paraprionospio pinnata				4	3	3	13	9	24		1	1					1	2	1	4	10	172	243	42	255	98	152	98	162	94	294	49	9	1	5	5	4	5	14	13	
Mediomastus (LPIL)	1	4	6	25	4	2	18	8	17		5	3		2	1	3	1	6	8			154	75	5	129	82	42	20	19	61	51	82	15	19	11	14	13	6	6	10	
Magelona sp.H									1				1			1		2	9	10	8	42	29	14	18	16	18	13	12	16	14	22	10	18	21	18	36	5	5	11	
Nereis micromma	2			2	1			1	9						1	2	4	1	9	12	4	9	2	6	1	18	19	19	5		1	18	21	36	5	29	11	7	3	41	**3**
Scoletoma verrilli				1					4			1							3	3	8		5	7	3	6	9	3	1	5	1	10	16	6	8	11	13	1	12	23	
Tubulanus (LPIL)	1		1	1		1	3	2				1							2		11	14			12	2		2		2		10	8	8	9	7	4	6	3	5	
Ampelisca sp.A					2			2											3		9	9	26		10	2	1	1		4	4	12			1		1	2	4		
Sigambra tentaculata		2		1				1			1											4	14	1	3	5	4		2	1	8	9	3	1	4	3	1	1	2	1	
Glycinde solitaria			1													1			2	4	1	5		1	2		1	1	4	1	1	4	3	2	3	1	7	1			
Cossura soyeri																1							1	3	5	1			4	7	49		1				30	14	5	7	
Aricidea taylori									2									1		3	5		2	8	5	3	1	2	1				2	2		10	2		11	12	
Aglaophamus verrilli												1						3	2	3	6			2									3	5	2				1	9	
Diopatra cuprea	3																			4	1			2	1	2	3		3	4	3			2	3	2	4	5	9	3	
Scoletoma ernesti	2	2		9																2				2	1	1	2	1							2	1			7	3	

LPIL= Lowest practical identification levels.

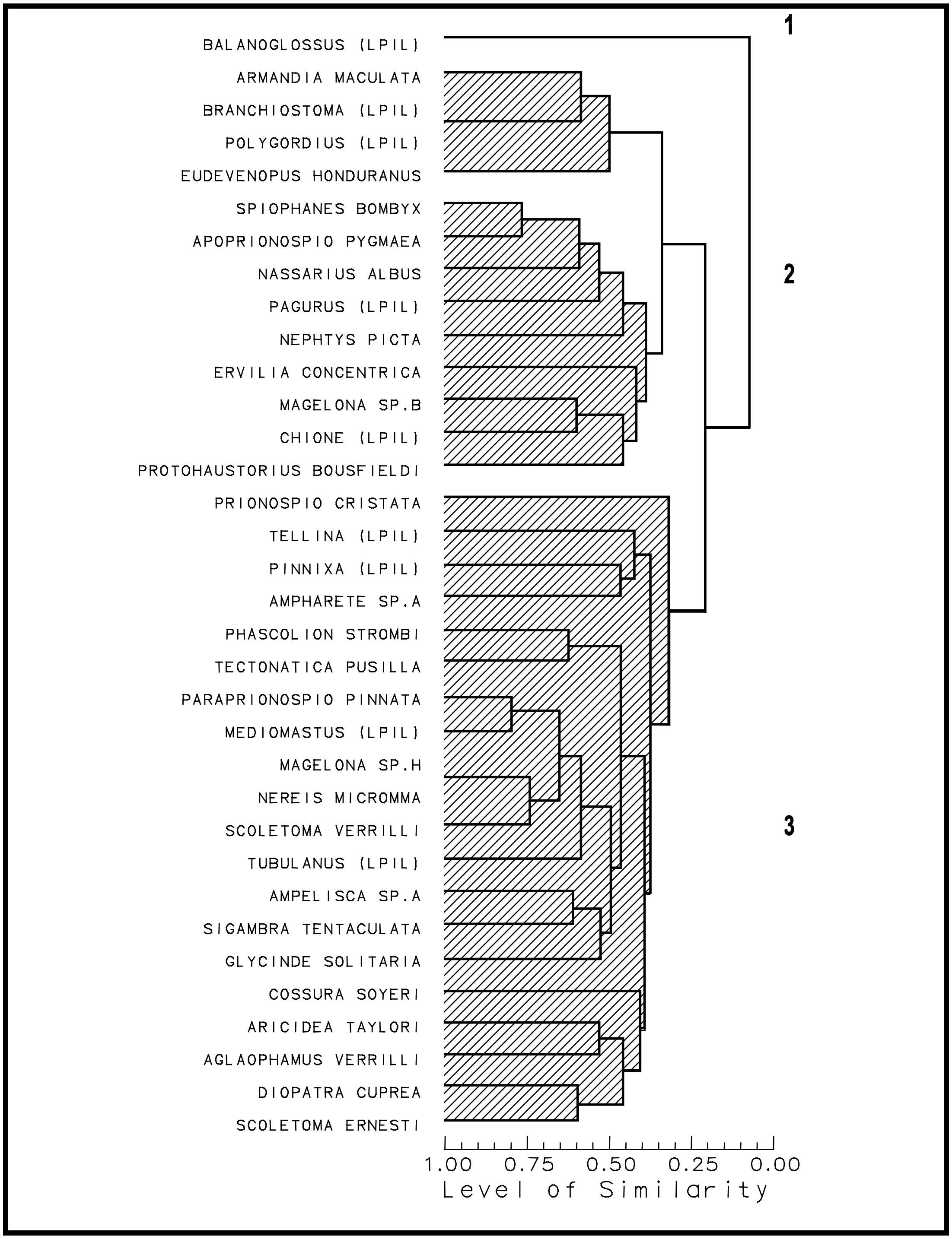

Figure 6-17. Inverse cluster analysis of infaunal taxa from samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in Sand Resource Area 4 offshore Alabama.

Area 5

Normal cluster analysis resulted in three station groups (Groups A through C) in Area 5 (Figure 6-18). As was the case in Area 4, Groups A and B were restricted by survey, with Group A (six stations) comprised of December samples and Group B (nine stations) comprised of May samples. Four of the six Group A stations also were included in Group B. Group C included stations from both surveys, although May survey stations were closely associated within the grouping. Group A was distinguished from other station groups by yielding relatively low numbers of infauna, and by lacking many of the numerically dominant taxa found at other stations in Area 5. Group B stations contained high numbers of the molluscans *Chione*, *N. albus*, and *Tellina*, *Pagurus*, the polychaetes *A. pygmaea*, *P. cristata*, and *S. bombyx*, and *Polygordius*. Group C stations were distinguished from Group B by relatively high densities of *C. soyeri*, *D. cuprea*, and *S. verrilli*, and low numbers of, or lacking altogether, many of the taxa found at Group B stations (Table 6-9).

Four groups of co-occurring taxa (Groups 1 through 4) were observed in Area 5 (Figure 6-19). Group 1 consisted of a single gastropod species (*C. cooperi*) that showed no pattern of association with other Area 5 taxa. Group 2 included two co-occurring taxa that were distributed across all station groups: *A. maculata* and *Branchiostoma*. Group 3 was comprised mostly of polychaetes, including *A. taylori*, *A. verrilli*, *C. soyeri*, *D. cuprea*, *Magelona* sp. H, *Mediomastus*, *M. dorsobranchialis*, *N. micromma*, *N. picta*, *P. pinnata*, *Sabaco americanus*, and *S. verrilli*. Group 3 also included *Ampelisca* sp. A, the sipunculids *Aspidosiphon albus* and *P. strombi*, and *Tubulanus*. Most taxa in Species Group 3 were distributed across all station groups. Species Group 4 included *A. pygmaea*, *Chione*, *Golfingia* sp. V, *N. albus*, *P. cristata*, *P. cuneata*, *Pagurus*, *Polygordius*, *S. bombyx*, and *Tellina* (Table 6-9).

Sediment composition across Area 5 stations was variable during both surveys. Area 5 stations were characterized by the presence of slightly gravelly sand or gravelly sand (Station Group B) and supported the molluscans *Chione* and *N. albus*, polychaetes such as *P. cristata* and *S. bombyx*, *Polygordius*, and *Pagurus* (Species Group 4). Stations with slightly gravelly sand or sand (Station Groups A and B) supported fewer polychaete taxa, and exhibited lower abundances generally and higher numbers of *P. cuneata* and *P. strombi*. Stations with slightly gravelly muddy sand and muddy sand (Station Group C) tended to yield more polychaetes, including *C. soyeri*, *Magelona* sp. H, *N. micromma*, *Scoletoma ernesti*, and *S. verrilli* (Species Group 3). *Mediomastus* and *P. pinnata* were evenly distributed across station groups. No relationship between the composition of infaunal assemblages and depth was apparent in Area 5.

6.3.4 Epifauna and Demersal Ichthyofauna

Fishes and invertebrates collected in trawls during Surveys 1 and 2 are listed in Tables 6-10 and 6-11, respectively. Twenty trawl hauls made over two field surveys produced 3,619 specimens (1,628 fishes and 1,991 invertebrates) in 70 taxa (44 fishes and 26 invertebrates). The numerically dominant fish taxa in the hauls included longspine porgy (*Stenotomus caprinus*), spot (*Leiostomus xanthurus*), silver seatrout (*Cynoscion nothus*), Atlantic croaker (*Micropogonias undulatus*), and rock seabass (*Centropristis philadelphica*). The most abundant invertebrates collected were roughneck shrimp (*Trachypenaeus constrictus*), squid (*Loligo* sp.), striped sea star (*Luidia clathrata*), and rock shrimps (*Sicyonia* spp.). These taxa collectively accounted for 80% of all specimens collected.

Taxonomic composition, abundance, and richness in trawl hauls differed somewhat between surveys. The May survey trawls yielded 2,068 individuals (1,140 fishes and 928 invertebrates) and 47 taxa (27 fishes and 20 invertebrates) from all five sand resource areas. Most abundant were longspine porgy, rock seabass, lizardfish (*Saurida brasiliensis*), striped sea star, squid, and roughneck shrimp. The total number of individuals (fishes and invertebrates combined) per trawl in the May survey ranged from 42 to 433 and averaged 207 individuals. Fishes averaged 114 individuals and invertebrates averaged 93 individuals per haul. The number of taxa (fishes and

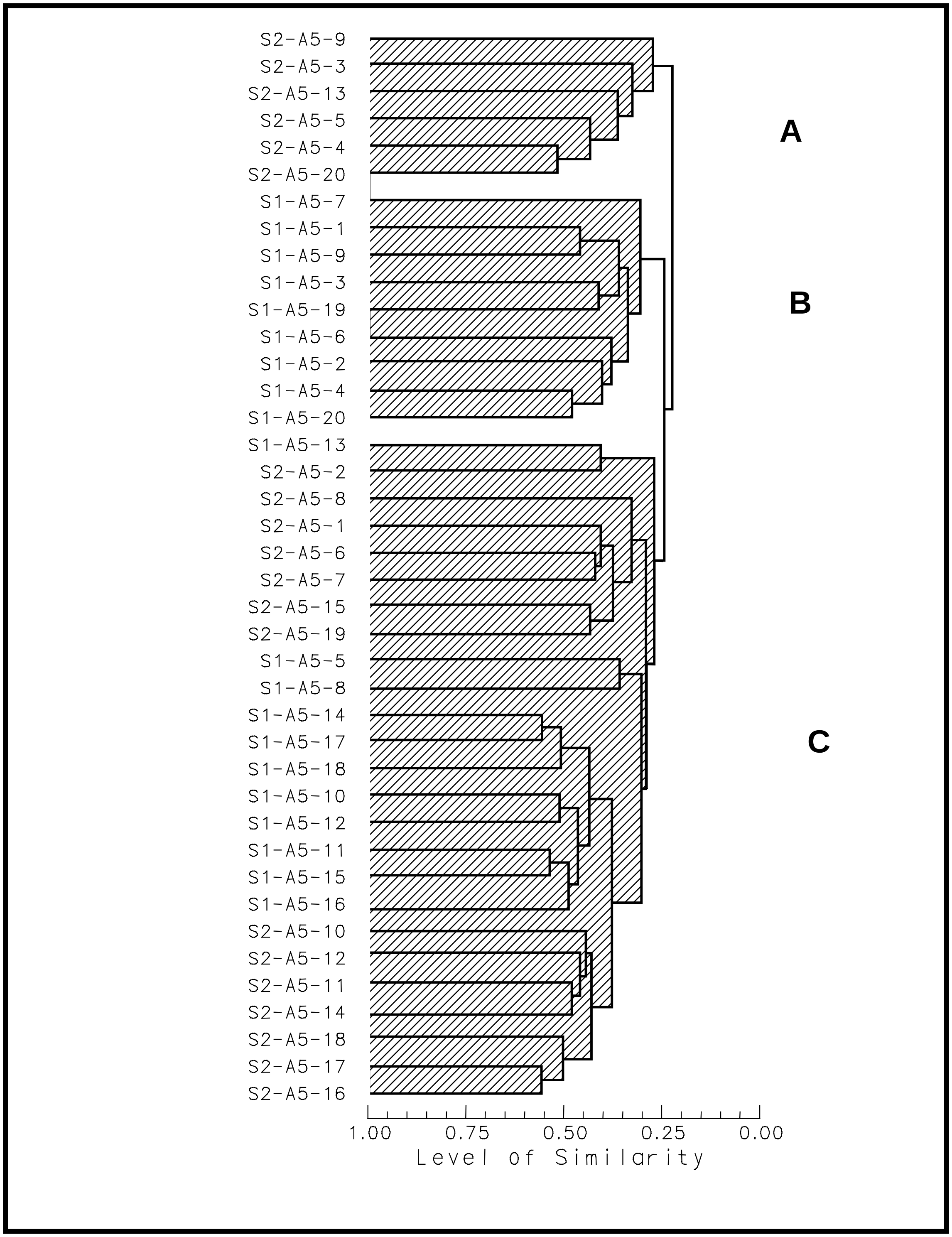

Figure 6-18. Normal cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 5 offshore Alabama.

Table 6-9. Two-way matrix from cluster analysis of infaunal samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in Sand Resource Area 5 offshore Alabama.

STATION GROUPS

TAXA	A						B									C																									
	S2-A5-9	S2-A5-3	S2-A5-13	S2-A5-5	S2-A5-4	S2-A5-20	S1-A5-7	S1-A5-1	S1-A5-9	S1-A5-3	S1-A5-19	S1-A5-6	S1-A5-2	S1-A5-4	S1-A5-20	S1-A5-13	S2-A5-2	S2-A5-8	S2-A5-1	S2-A5-6	S2-A5-7	S2-A5-15	S2-A5-19	S1-A5-5	S1-A5-8	S1-A5-14	S1-A5-17	S1-A5-18	S1-A5-10	S1-A5-12	S1-A5-11	S1-A5-15	S1-A5-16	S2-A5-10	S2-A5-12	S2-A5-11	S2-A5-14	S2-A5-18	S2-A5-17	S2-A5-16	
Caecum cooperi	11								37					1						1																					**1**
Armandia maculata	5		2		1	4	2	1	2		8						1	7	50	21	21	40	31									1		1		1		4	12	4	**2**
Branchiostoma (LPIL)			2	2	2	2	2	2			2	2	1	2	2		2		4	3	2	7	3		1																
Strombiformis hemphilli								2	3															1			7		11	9	4	1									
Ampelisca sp.A					3	1		1		5			2					3				1		3	1				3		4	8	3				1	2			
Nephtys picta			1				5		1		5	4	12		5			1		1	2			3					5	3	1		8					1		1	
Tectonatica pusilla	1	1	6	3		1		4	3	3		4		1	2			1		1			1		1	1	2	4	3	2	1		3			2		2		3	
Nuculana acuta						1		3	2	1		6	2	3	3			1			1		3	5	1			2		5	2		1	2	1			3		2	
Aglaophamus verrilli				3	2	2							4		1				1		1	3	5						1	6			6	1	2	2	1	1	3	5	
Paraprionospio pinnata		2				1	2	15	6	89	47	4	15	12	9	63		5	5	2		1	6	19	14	66	61	17	49	13	16	19	25	2	9	3	2		3	5	
Nereis micromma	2	3	3	9	32	9		1	1	7	6		2	1	1	8	2	67	15	39	23	27	15	5	10	5	11	19	9	5	3	1	3	2	13	3	4	20	38	15	
Mediomastus (LPIL)	1	84	1	1	5	5	9	1	1	45	24	2	4	4	2		1		4	29	14	14	7	3	14	3	5	4	19	3	8	35	6	2	5	8		5	4	21	
Phascolion strombi	9	12	1	10	38	12	8	3	5	24		2	8	30	6	1		2	3	5		1		4	4	1			3	6	2	1				3	1	2		4	**3**
Tubulanus (LPIL)		1					2		3	11	12	1						1		3			1	2		2	1	1	6	1	2	13	3	5	5	3	1	4	3	1	
Aricidea taylori									1		90		2			1					1	4	7		3	5	19	2	7	6		1	52		14	6	3	4	13	23	
Scoletoma verrilli	1										7					1		1		2		1	7			5	16	19	10	3	3	5	12		6	4	2	30	13	5	
Aspidosiphon albus				1				2			10	3			9			1	2			1	14				12	11	3	17	17	5	9	3	2	2	6	3	8	5	
Magelona sp.H		2		1		8	2					1	4	1		18	12			1				1	5	8	7	8	8	6	4	1	9	3	6	1	9	1	12	9	
Cossura soyeri																	3									5	4	3		2	3	3	4	4		14	6	8	12	10	
Lucina nassula										1	1		2	1		1										4	6	2	2	4	1	4	5							7	
Diopatra cuprea											1					2	2	1				3	2	3	6		1	8	2	5	1	2	1	1				2	1	3	
Scoletoma ernesti		1		1							5											1		1	4		1	2	5	2	1	1	4		1		2		1	2	
Anadara transversa								24			19				1									76	25			2	1												
Pythinella cuneata		2	17	4	13			5	7			2	1	2	4																										
Nassarius albus								4	1	7		3		58										3																	
Golfingia sp.V							1	6		2		5		10	13									2				1	1	8											
Tellina (LPIL)	1			3				4	5	30			2															1					2					2		1	
Pagurus (LPIL)	1							2	1	31																															**4**
Chione (LPIL)							1	14	29	3					2									1														1			
Polygordius (LPIL)							18	22	16	12	72	2	2		1	2		3	3	7		2							1	1						1					
Prionospio cristata								4	8	14	37	2	5	2	1															1	1	2	1		7					1	
Apoprionospio pygmaea							1	1	4	13	3		21	4	3																1	1	1						1		
Spiophanes bombyx							4	1	29	18	9		23	1	13									1						4			3								

LPIL=Lowest practical identification levels

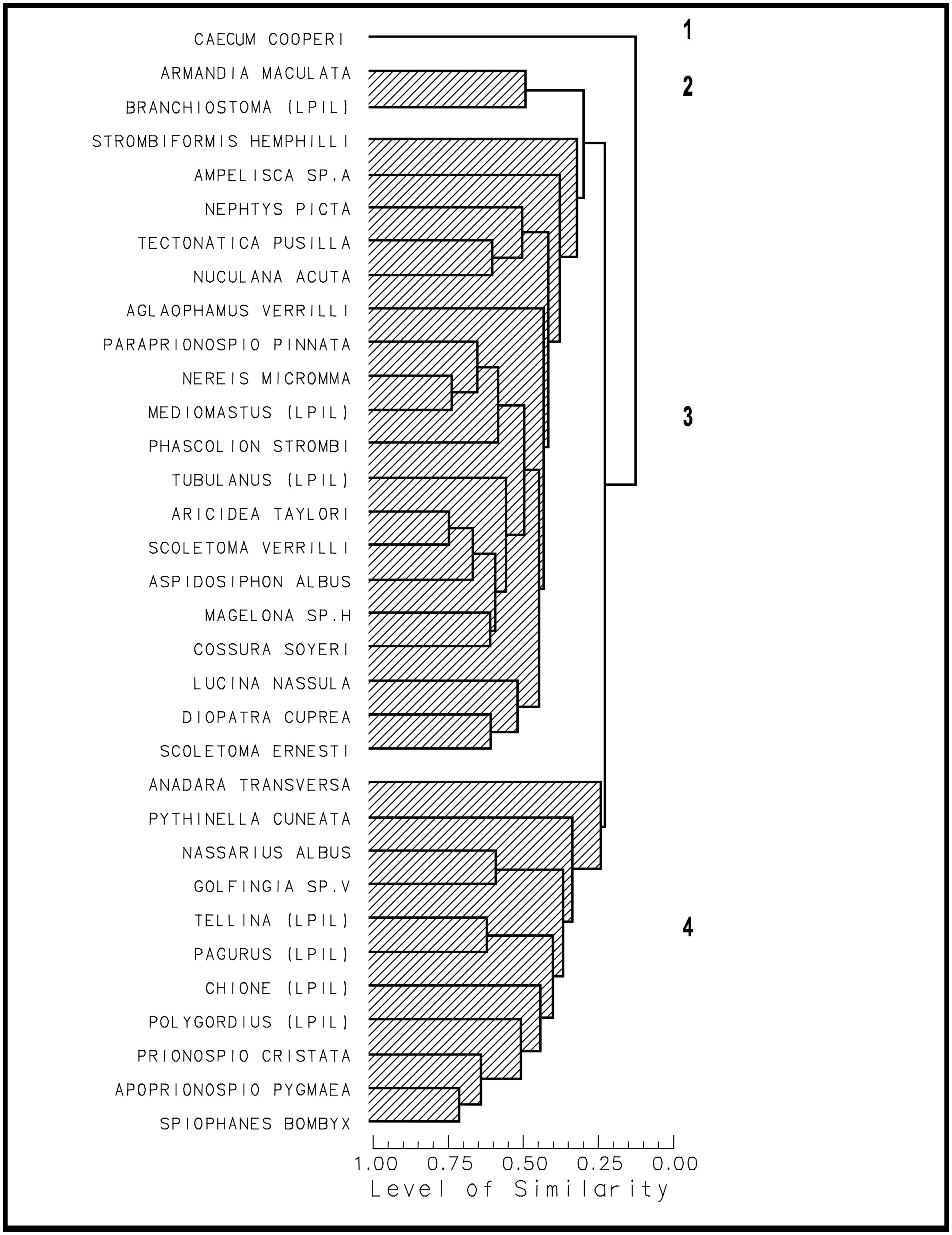

Figure 6-19. Inverse cluster analysis of infaunal samples collected during the May 1997 Survey 1 and December 1997 Survey 2 in Sand Resource Area 5 offshore Alabama.

Table 6-10. Epifauna collected by mongoose trawl and ranked by numerical abundance from the May 1997 Survey (S1) in the five potential sand resource areas (A1 to A5) along north (1) and south (2) transects offshore Alabama.											
Species	S1-A1-1	S1-A1-2	S1-A2-1	S1-A2-2	S1-A3-1	S1-A3-2	S1-A4-1	S1-A4-2	S1-A5-1	S1-A5-2	Total
FISHES											
Stenotomus caprinus	32	68	52	7	133	116		47	120	184	759
Centropristis philadelphica					8	2	1	42	4		57
Saurida brasiliensis								14	20	17	51
Bothids juv.								43			43
Anchoa hepsetus									39		39
Diplectrum bivittatum				1		1		15	5	9	31
Peprilus burti		2			4				5	18	29
Prionotus scitulus	2	1	4		4		1	9			21
Ophidion marginatum			2		1	16				1	20
Syacium sp.			12	2		3					17
Prionotus rubio			1		2	7					10
Syacium papillosum	1	1			8						10
Trachurus lathami										8	8
Prionotus sp.									6		6
Sphoeroides nephelus			2		1	1				2	6
Symphurus plagiusa						2		2		2	6
Upeneus parvus	1	4									5
Etropus crossotus			1					2	1		4
Synodus foetens	2						1		1		4
Ophidion sp.					3						3
Antennarius radiosus			1							1	2
Gobionellus hastatus								2			2
Lutjanus campechanus					1				1		2
Urophycis floridana						1				1	2
Citharichthys spilopterus							1				1
Prionotus tribulus					1						1
Sphoeroides parvus									1		1
INVERTEBRATES											
Luidia clathrata		4	1	42		237					284
Loligo sp.		5	1				53		100	76	235
Trachypenaeus constrictus					71	14		48	1	29	163
Sicyonia burkenroadi								101			101
Sicyonia sp.			2		5	18			7	11	43
Portunus spinimanus								23	1	1	25
Squilla empusa								8		5	13
Portunus gibbesii									11		11
Squilla sp.						11					11
Astropecten	1	6				1					8
Pagurus pollicaris								6			6
Encope michelini	3		2								5
Stenorhynchus seticornis				1		2		1	1		5
Penaeus sp.			3	1							4
Pleurobranchea hedgpethi					4						4
Callinectes sapidus								3			3
Hepatus epheliticus						1				1	2
Nudibranch			1				1				2
Porcellana sayana								1	1		2
Penaeus setiferus								1			1
FISH TOTALS											
Total Individuals	38	76	75	10	166	149	4	176	203	243	1,140
Total taxa	5	5	8	3	11	9	4	9	11	10	27
INVERTEBRATE TOTALS											
Total Individuals	4	15	10	44	80	284	54	192	122	123	928
Total taxa	2	3	6	3	3	7	2	9	7	6	20
FISH AND INVERTEBRATE TOTALS COMBINED											
Total Individuals	42	91	85	54	246	433	58	368	325	366	2,068
Total taxa	7	8	14	6	14	16	6	18	18	16	47

Table 6-11. Epifauna collected by mongoose trawl and ranked by numerical abundance from the December 1997 Survey (S2) in the five potential sand resource areas (A1 to A5) along north (1) and south (2) transects offshore Alabama.

Species	S2-A1-1	S2-A1-2	S2-A2-1	S2-A2-2	S2-A3-1	S2-A3-2	S2-A4-1	S2-A4-2	S2-A5-1	S2-A5-2	Total
FISHES											
Leiostomus xanthurus					10		2	3	4	79	98
Cynoscion nothus							28	3	48	2	81
Micropogonias undulatus					11		2	5	9	53	80
Lagodon rhomboides					6	15	1	2	6	1	31
Prionotus rubio					1	3		2	11	3	20
Larimus fasciatus					4		14	1			19
Ophidion grayi					1		1	12	2		16
Cynoscion arenarius								1	3	10	14
Peprilus burti				4	2				7		13
Engraulis eurystole					2	8					10
Lepophidium brevibarbe									7	3	10
Sphoeroides parvus			1					5	4		10
Symphurus diomedianus						1			4	5	10
Anchoa lyolepis					1	8					9
Etropus crossotus			1				1	2	4	1	9
Diplectrum bivittatum									1	7	8
Lutjanus campechanus							7	1			8
Ophidion selenops								7	1		8
Prionotus martis				5	1						6
Saurida brasiliensis				4							4
Centropristis philadelphica							1		2		3
Ophidion sp.								3			3
Ophidion welshi						1			1	1	3
Citharichthys sp.								2			2
Menticirrhus littoralis					2						2
Syacium papillosum		1						1			2
Symphurus plagiusa								1		1	2
Symphurus sp.							1		1		2
Synodus foetens		1		1							2
Anchoa hepsetus								1			1
Citharichthys spilopterus				1							1
Prionotus tribulus							1				1
INVERTEBRATES											
Trachypenaeus constrictus						126	89	100	84	69	468
Loligo sp.						113	27	31	54	15	240
Penaeidae						26	64	83	33	6	212
Sicyonia dorsalis						50	19	1	18	6	94
Luidia clathrata							5	1	1	2	9
Penaeus aztecus							3	1	1	2	7
Calliactus tricolor									4	2	6
Penaeus setiferus							4		2		6
Sicyonia sp.						2	3				5
Pagurus pollicaris									3	1	4
Squilla neglecta							2		1	1	4
Sicyonia brevirostris						1			1	1	3
Pleurobranchea hedgpethi								2			2
Portunus gibbesii						1	1				2
Portunus spinimanus						1					1
FISH TOTALS											
Total Individuals		2	2	15	41	36	59	52	115	166	488
Total Taxa		2	2	5	11	6	11	17	17	12	33
INVERTEBRATE TOTALS											
Total Individuals						320	217	219	202	105	1,063
Total Taxa						8	10	7	11	10	15
FISH AND INVERTEBRATE TOTALS COMBINED											
Grand Total Individuals		2	2	15	41	356	276	271	317	271	1,551
Grand Total Taxa		2	2	5	11	14	21	24	28	22	47

invertebrates combined) per trawl in the May survey averaged 12. The average number of fish taxa per haul was 8 and the average number of invertebrate taxa per haul was 5.

During the December survey, trawls produced 1,551 individuals (488 fishes and 1,063 invertebrates) in 48 taxa (33 fishes and 15 invertebrates) with roughneck shrimp, squid, penaeid shrimps, rock shrimps, spot, silver seatrout, and Atlantic croaker numerically dominating the catches. Catches during the December survey ranged from 0 to 356 individuals and averaged 155 individuals per haul. Fish catch averaged 49 individuals per tow and ranged from 0 to 166 individuals per tow. Invertebrates were more numerous, averaging 106 individuals per tow and ranging from 0 to 320 individuals. In December, the number of taxa ranged from 0 to 28 and averaged 13 per haul. Fishes averaged 8 taxa and invertebrates averaged 5 taxa per haul, respectively.

During both surveys, trawl catches from Areas 3, 4, and 5 yielded the most individuals and taxa. The highest number of individuals (433) in a single haul was recorded in Area 3 during the May cruise. During the December survey, the highest number of individuals (356) was collected in Area 3. The fewest number of individuals (0) in a single haul came from Area 1 during the December cruise. The highest number of taxa (18) collected during the May survey was from Areas 4 and 5. The highest number of taxa (28) collected during the December survey was from Area 5. Areas 2 and 4 yielded the fewest trawl-caught taxa (6) during the May survey.

Patterns of similarity among trawl samples were examined with cluster analysis. Normal cluster analysis produced four groups of samples that were similar with respect to species composition and relative abundance (Figure 6-20) The first major separation evident in the normal analysis was that, with the exception of Groups 1 and 4, samples from the two surveys formed distinctive groups. Group 1 was comprised of three samples with sparse numbers of taxa and individuals. Group 2 consisted of six samples collected exclusively during the December survey. These samples were characterized by high numbers of roughneck shrimp, squid, penaeid shrimps, silver seatrout, spot, and Atlantic croaker. Samples from Areas 1 to 5 collected exclusively during the May survey formed Group 3. Longspine porgy, striped sea star, and rock shrimp were abundant in these samples.

Inverse cluster analysis generated six groups (A to F) of taxa that reflected the co-occurrence of taxa in the samples (Figure 6-21). Group A consisted of taxa that were commonly collected during the May survey, including longspine porgy, striped sea star, and rock shrimp. Group B was composed of sparsely distributed taxa such as juvenile flounder (*Syacium* sp.) and shrimp (*Penaeus* sp.) collected primarily in Area 2 during the May survey. Group C was a large group of 16 taxa distributed sparsely in samples from both surveys and all sand resource areas. Group D included six taxa that occurred in low numbers at stations from both field surveys. Group E included taxa collected primarily during the December cruise. The most abundant of these were roughneck shrimp, squid, rock shrimp, silver seatrout, spot, and Atlantic croaker. Group F consisted of four infrequently occurring taxa with no particular distribution pattern within the samples.

6.4 DISCUSSION

Benthic assemblages surveyed in the five sand resource areas offshore Alabama consisted of members of the major invertebrate and vertebrate groups that are commonly found in the study region. Numerically dominant infaunal groups included numerous crustaceans, echinoderms, molluscans, and polychaetous annelids, while epifaunal invertebrate taxa consisted primarily of sea stars, squid, and various shrimps. These infaunal and epifaunal groups typically dominate abundance in the study area. Similarly, the numerically dominant demersal ichthyofauna collected in trawls within the sand resource areas revealed a consistency with previous surveys. Fishes such as Atlantic croaker (*Micropogonius undulatus*), longspine porgy (*Stenotomus caprinus*), silver seatrout (*Cynoscion nothus*), and spot (*Leiostomus xanthurus*) were numerical dominant during the

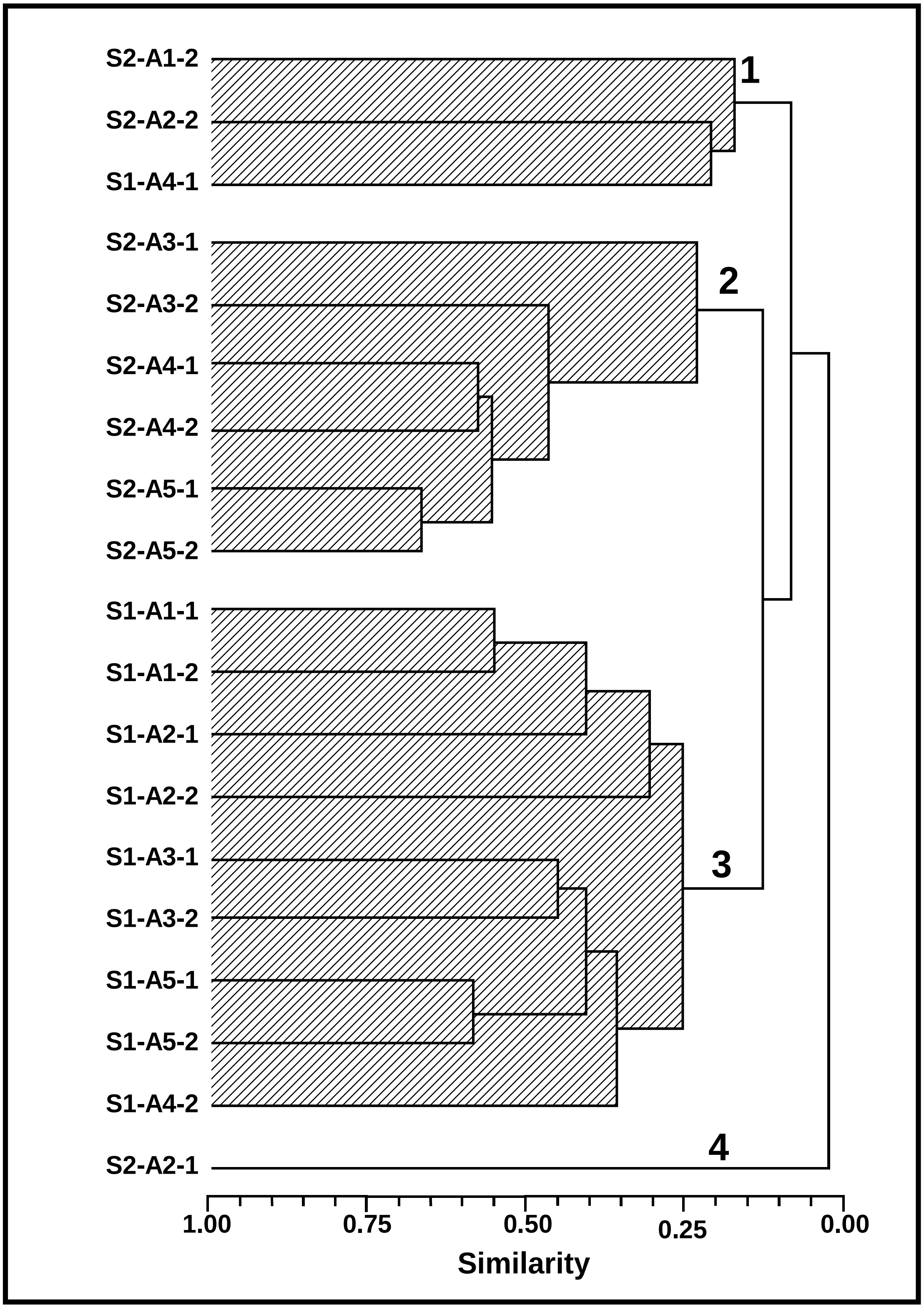

Figure 6-20. Normal cluster analysis of epifaunal trawl samples collected during the May 1997 Survey 1 (S1) and December 1997 Survey 2 (S2) in the five sand resource areas (A1 to A5) along the north (1) and south (2) transects offshore Alabama.

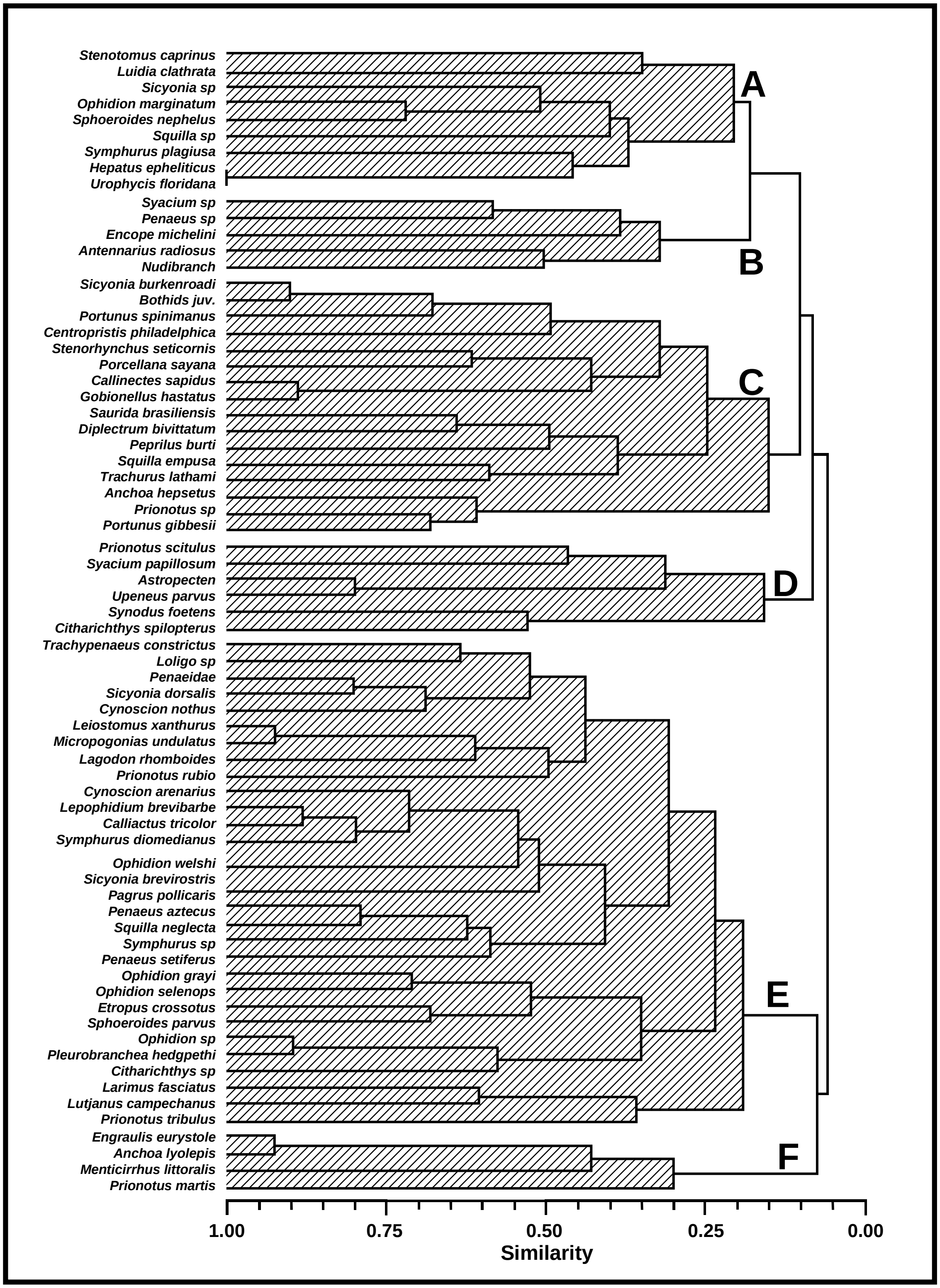

Figure 6-21. Inverse cluster analysis of epifaunal taxa from trawl samples collected during the May 1997 Survey 1 and the December 1997 Survey 2 in the five sand resource areas along north and south transects offshore Alabama.

1997 sand resource area surveys, and these species consistently are among the most ubiquitous and abundant demersal taxa in the region (Chittenden and McEachran, 1976; Barry A. Vittor & Associates, Inc., 1985; Darnell and Kleypas, 1987).

Seasonal variability in the composition of benthic assemblages was apparent in the sand resource area surveys, as the grouping of stations based on similar infaunal composition and abundance was correlated primarily with survey (Figure 6-8). Infaunal abundance was substantially higher during the May survey than was observed in December. This seasonal difference reaffirms the findings of previous area surveys which found substantial temporal variation in the composition of infaunal assemblages, with generally lower densities occurring in winter relative to summer months (Shaw et al., 1982; Continental Shelf Associates, Inc. and Barry A. Vittor & Associates, Inc., 1989; Harper, 1991). Infaunal species richness varied between surveys as well. Nearly half of the infaunal taxa sampled over the entire project were found in both the May and December surveys; however, most (70%) of the remainder of censused taxa were collected only during the May cruise, resulting in higher mean values of species richness compared to the December survey.

Epifaunal and demersal ichthyofaunal taxa collected in trawls differed between surveys as well. Two of the four groups of trawl samples produced by normal cluster analysis were separated by survey. The May survey was characterized by an abundance of longspine porgy, rock shrimps (*Sicyonia* spp.), and striped sea star (*Luidia clathrata*), while December trawls were characterized by high numbers of spot, silver seatrout, croaker, and roughneck shrimp (*Trachypenaeus constrictus*). Although seasonal trends cannot be reliably discerned from relatively limited sampling, the temporal variability in the composition of sand resource area demersal assemblages does agree with previous local sampling efforts that indicated a community of spatially widespread taxa that migrate inshore seasonally (Comiskey et al., 1985).

In addition to seasonal trends, spatial variability was evident in the 1997 sand resource surveys. Infaunal abundance generally increased from west to east in both the May and December surveys (Table 6-3). This result was primarily due to high numbers of the gastropod *Caecum* spp., which accounted for 33% of all infaunal individuals censused over the entire project. *Caecum* (mostly *C. pulchellum*) was found nearly exclusively in Areas 1, 2, and 3 during both surveys. High numbers of *Caecum* collected during the sand resource area surveys resulted in higher infaunal abundance than was found during previous area studies (Barry A. Vittor & Associates, Inc., 1985; Harper, 1991). It may be concluded that a major recruitment episode occurred at some time prior to the 1997 surveys of the sand resource areas. It is unknown whether high *Caecum* densities were indicative of typical benthic assemblages in the area, or whether members of the genus form an opportunistic group of taxa that can occur in offshore sandy areas on an intermittent basis, exploiting available habitat when suitable conditions exist. Previous benthic surveys of the area did not find *Caecum* in such high numbers. *Caecum* does include several epibenthic species that generally inhabit areas of sandy substrata, especially seagrass beds and beach drift (Andrews, 1971).

As with previous surveys, infaunal assemblage type was closely tied to sediment grain size. Overall, canonical discriminant analysis indicated that season was the most important factor that affected the composition and distribution of infaunal assemblages offshore Alabama. Within season, discriminant analysis indicated that sedimentary regime most affected infaunal assemblages. Surface sediment included a mixture of sand and mud at most stations in the western sand resource areas (Areas 4 and 5), as compared to the easternmost areas (Areas 1, 2, and 3) which were predominantly sand (Figure 6-9). Infaunal assemblage types reflected sediment type distributions; station groupings based on cluster analysis of infaunal samples from the May and December surveys indicated spatial homogeneity of assemblage distributions in the eastern sand resource areas and heterogeneity of assemblage distributions in Areas 4 and 5, regardless of season (Figure 6-8). Of the six station groups identified through cluster analysis, Group E was comprised of stations in Areas 4 and 5 common to both the May and December surveys. Apparently, infaunal assemblages in the western sand resource areas are affected as much by sedimentary regime as by seasonal effects. This contrasts with Areas 1, 2, and 3 where assemblages differed between seasons. The results of the sand resource area surveys therefore reflect a sediment-related longitudinal arrangement of infaunal assemblages.

The eastern areas tended to support assemblages numerically dominated by the gastropod *Caecum* spp. and included many arthropods, bivalves, and gastropods, while the western areas supported assemblages that tended to be dominated by polychaetes in terms of abundance and species richness. Stations in Areas 4 and 5 that had sandier sediments supported taxa commonly associated with Areas 1, 2, and 3, including the archiannelid *Polygordius*, lancelet *Branchiostoma*, and polychaete *Spiophanes bombyx*. Furthermore, stations characterized by sandy substrate in Areas 4 and 5 exhibited different infaunal assemblages between seasons, as did the entirety of the eastern sand resource areas (Figure 6-8). The numerically dominant taxa in Areas 4 and 5, especially the polychaetes *Mediomastus* and *Paraprionospio pinnata*, are more ubiquitous species that typically inhabit areas characterized by fine sediment. These ubiquitous taxa are less abundant in the eastern areas, which provide less suitable habitat due to relatively coarser sediments and higher salinities.

The density of infaunal taxa was high during both field surveys when compared with historical surveys. Other surveys have recorded values of species richness comparable to the present study (Shaw et al., 1982; Continental Shelf Associates, Inc. and Barry A. Vittor & Associates, Inc., 1989); however, those earlier estimates were calculated for stations where multiple samples were taken, thus increasing the potential of sampling more taxa. Stations sampled during the present surveys were censused with just a single bottom grab and, therefore, high values of species richness were generated from relatively limited areas. It may be that a period of higher than usual recruitment levels preceded the surveys of the candidate borrow areas.

Variability between sand resource areas also was evident in the composition of trawl samples. Trawl catches from Areas 3, 4, and 5 yielded the most individuals and taxa during both the May and December surveys, while Areas 1 and 2 yielded the fewest trawl-caught taxa and individuals. A similar geographic trend was identified by pattern analyses performed by Comiskey et al. (1985) on various data sets from previous trawl surveys in the region. Their analyses indicated that the nearshore environment off Alabama was characterized by low numbers of taxa and individuals relative to areas nearer the Mississippi Delta, where the environment is under the influence of considerable riverine discharge. The influence of Mobile Bay outflow on the western sand resource areas relative to the eastern sand resource areas apparently affects demersal assemblages in much the same way, albeit on a smaller scale.

Temperature, salinity, and dissolved oxygen measurements were taken in each of the sand resource areas during the field surveys (Figure 6-7) and compared to the community parameters in Table 6-3 to assess any apparent hydrographic influences upon infauna. Temperatures were lower during the December survey than the May survey. During the December survey, Areas 4 and 5 showed higher bottom water temperatures than Areas 1, 2, and 3. Possible effects of relatively higher temperatures in Areas 4 and 5 during the second survey were not discernable in the infaunal data when comparing surveys or areas. Salinity was similar among sand resource areas during both surveys. Dissolved oxygen values measured during the May survey were low in Areas 2, 3, 4, and 5, and were very low in Area 4, where bottom values were measured as low as 1.22 mg/L. The mean number of infaunal taxa collected per station was substantially lower in Area 4 than in other areas during the May survey (Table 6-3), although it is ultimately unknown whether this was a result of hypoxic conditions. A negative relationship between hypoxia and infaunal density can only be inferred from the data; however, a significant negative effect does occur for many benthic invertebrates at concentrations of 2.0 mg/L or lower (Diaz and Rosenberg, 1995). Trawl catches in Area 4 also may have been influenced by hypoxic conditions during the May survey.

Hummell and Smith (1995, 1996) indicate that the surficial sediment texture of the primary sand source in Area 4 should be sand. However, results from the biological field surveys indicate that grain size in Area 4 is actually quite variable, with more silt and clay than expected. This may have been due to the fact that much of the primary sand source within Area 4 also is within the limits of a dredge disposal area (see Figure 33 in Hummell and Smith, 1995). Approximately 13 MCM of sediment were placed offshore as the Mobile Outer Mound (Hands, 1994). Storm-induced resuspension of sediments on this site may result in transport to parts of Area 4, resulting in a layer of fine-grained material at the sediment surface. Changes in Area 4 surficial sediments also could be attributed to annual disposal of maintenance dredging material from the Mobile Ship Channel and Bar Channel.

In summary, the results of the sand resource area surveys agree well with previous descriptions of benthic assemblages residing in shallow waters off the Alabama coast. Seasonality had the greatest effect on community composition; normal cluster analysis revealed that most groups of biologically similar stations were separated according to survey. Spatial differences in community composition also were obvious, with western areas supporting assemblages dominated by those taxa capable of exploiting the fluctuating, riverine-influenced habitats nearer Mobile Bay. Certain euryhaline opportunists, including infauna such as *Mediomastus* and *P. pinnata*, are widespread over all surveyed areas, while the *Caecum*-associated assemblages of the eastern areas apparently are restricted to the more stable environmental characteristics of those sand sediment areas. The composition of demersal assemblages across the Alabama sand resource areas is influenced by fluctuating hydrographic parameters in the western areas relative to the more stable eastern areas.