6.0 BIOLOGICAL FIELD SURVEYS

6.1 BACKGROUND

Field surveys for biological characterization provided environmental data in and near the nine sand resource areas offshore central east Florida. Data were collected concerning water column and sediment parameters, infauna, soft bottom epifauna and demersal fishes, and hard bottom epibiota and demersal fishes. The following sections provide the methods, results, and discussion for the biological field surveys.

6.2 METHODS

6.2.1 Survey Design

The objective of the biological field surveys was to characterize benthic ecological conditions in and near the nine sand resource areas (Figure 6-1). Benthic characterization focused on soft bottom (i.e., sediment, infauna, epifauna and demersal fishes) and hard bottom (i.e., epibiota and demersal fishes) parameters. Supporting data collected in the soft bottom areas consisted of water column profiles.

Total numbers of samples by type originally proposed for the biological field surveys were as follows:

SAMPLE TYPE	SURVEY 1	SURVEY 2
Soft Bottom		
Water Column		
Sea-Bird CTD	18 Stations	18 Stations
Sediment and Infauna		
Shipek Grab	62 Stations (1 grab/station)	62 Stations (1 grab/station)
Sediment Only		
Shipek Grab	48 Stations (1 grab/station)	48 Stations (1 grab/station)
Epifauna/Demersal Fishes		
Mongoose Trawl	18 Transects	18 Transects
Hard Bottom		
Epibiota/Demersal Fishes		
Video Camera	9 Line Miles	9 Line Miles
Still Camera	180 Photographs	180 Photographs

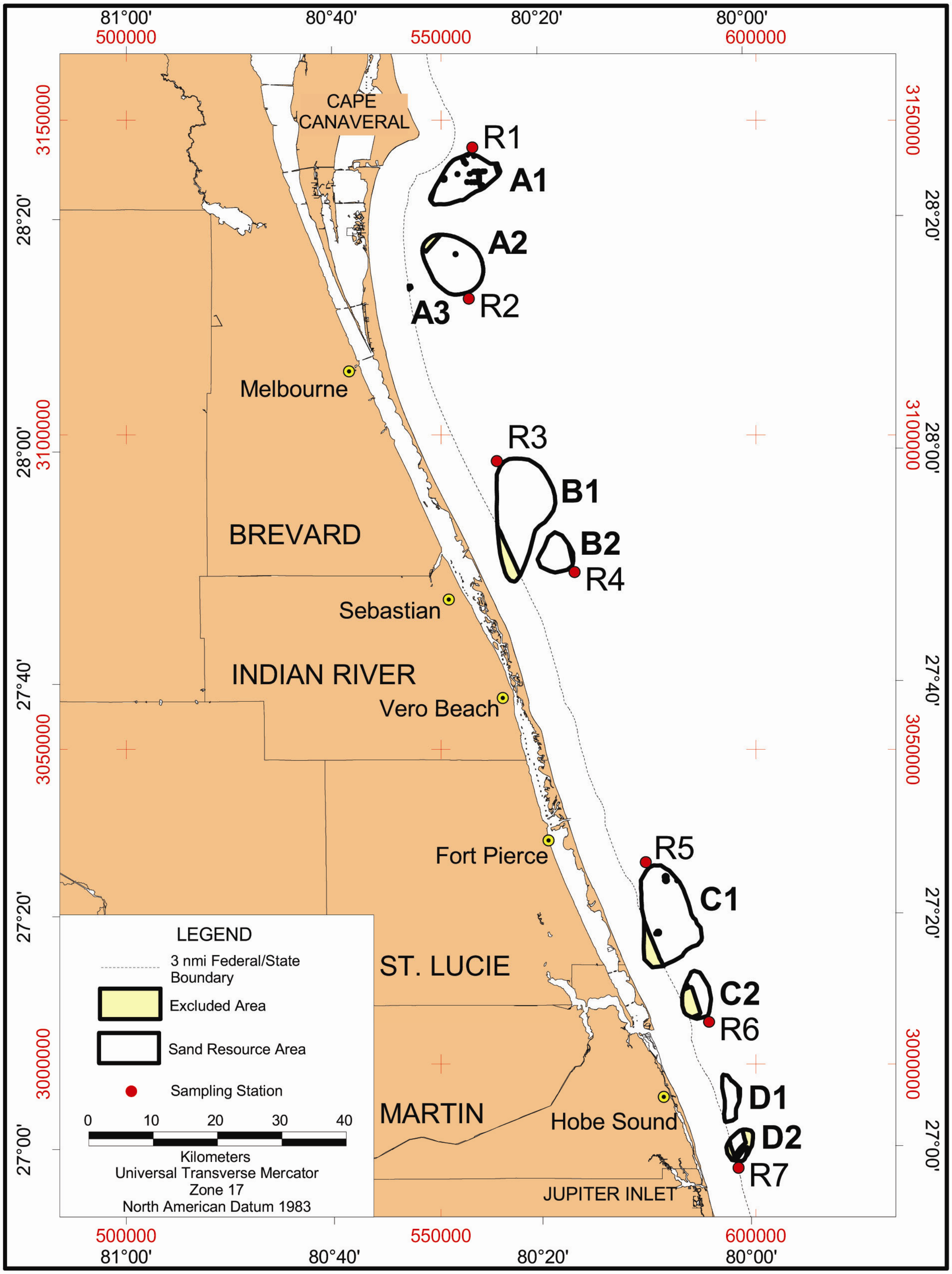

Figure 6-1. Nine sand resource areas (A1, A2, A3, B1, B2, C1, C2, D1, and D2) and seven adjacent stations (R1 through R7) relative to the central east Florida coast.

Actual sampling for the biological surveys is described in subsequent subsections. Two soft bottom and two hard bottom surveys were conducted on dates described in Section 6.2.2.1. Table 6-1 summarizes the actual soft bottom sampling and lists the sand resource areas and adjacent stations along with corresponding water depths, sample types, and number of stations. Actual hard bottom sampling is described in Section 6.2.1.5.

Table 6-1. Actual soft bottom sampling during the central east Florida biological field surveys.

Sand Resource Area (A1, B1, C1, D1, etc.) and Adjacent Station (R1, R2, etc.)	Water Depth (m)	Soft Bottom Sample Type							
		Water Column Profiles		Shipek Grab				Trawl Transects for Epifauna and Fishes	
				Sediment-Only Samples		Sediment/ Infaunal Samples			
		Survey 1	Survey 2	Survey 1	Survey 2	Survey 1	Survey 2	Survey 1	Survey 2
A1	14-18	2	2	6	6	7	7	2	2
A2	15-18	2	2	8	8	7	7	2	2
A3	13-15	2	2	0	0	3	3	2	2
B1	12-20	2	2	14	14-1	13+1	13+1	2	2
B2	10-15	2	2	3	3	4	4	2	2
C1	8-21	2	2	12	12	12	12	2	2
C2	14-21	2	2	2	2	3	3	2	2
D1	19-33	2	2	2	2	3	3	2	2
D2	15-50	2	2	1	1	3	3	2	2
R1	15					1	1		
R2	19					1	1		
R3	17					1	1		
R4	13					1	1		
R5	14					1	1		
R6	20					1	1		
R7	23					1	1		
Total Number of Stations		18	18	48	47	56 + 7 = 63	56 + 7 = 63	18	18

6.2.1.1 Spatial Data Files and Exclusionary Mapping

Spatial data files of environmental features (e.g., sand resource areas, hard bottom areas, shipwrecks, submarine cables, etc.) and exclusionary mapping were used to design the field surveys as discussed in detail in Appendix E. The purpose of exclusionary mapping was to ensure that sampling would include areas in Federal waters shallower than 30 m and exclude areas that were unlikely to be dredged due to the presence of environmental features.

6.2.1.2 Water Column

Eighteen water column profiles were made during each of two soft bottom surveys at locations illustrated in Figures 6-2 through 6-6 and listed in Appendix F1. Parameters measured were conductivity, temperature, and depth. A water column profile was made at the beginning point of each trawl transect prior to actual trawling (see Section 6.2.1.4 for the rationale used for selecting trawl locations).

6.2.1.3 Sediment and Infauna

For each of two soft bottom surveys, 62 stations originally were proposed for samples that would be analyzed for both sediment and infauna, and 48 additional stations originally were proposed for sediment analysis only. The following rationale was used to determine the number of samples that would be collected in the sand resource areas and at adjacent stations. The results of applying this rationale are illustrated in Figures 6-1 through 6-6. The locations also are listed in Appendix F1.

Of the original 62 stations, 7 stations were assigned to adjacent stations near the sand resource areas, leaving 55 stations to be taken within the nine sand resource areas. The 7 adjacent stations were located so that samples would be collected approximately 1,000 m north or south of the nine sand resource areas at median water depths, as illustrated in Figure 6-1.

To determine the number of samples to collect in each sand resource area for sediment and infaunal analyses during each survey, the surface area and percent of the total surface area for each of the sand resource areas were calculated before and after exclusionary mapping was completed (Table 6-2). The percent of the total surface area remaining after exclusionary mapping for each of the sand resource areas then was multiplied by 44 stations, leaving 11 stations for discretionary placement within the sand resource areas. Multiplication by 44 stations indicated that some sand resource areas had none or too few samples due to very small surface areas relative to the total surface area (i.e., Sand Resource Area A3 had 0 samples, C2 had 2 samples, D1 had 2 samples, and D2 had 1 sample; see Table 6-2). Therefore, 7 of the 11 discretionary samples were added to the sample numbers for Sand Resource Areas A3, C2, D1, and D2 such that there would be 3 stations in each of these sand resource areas. This brought the total number of samples to be analyzed for both sediment and infauna to 51. Four of the 11 discretionary samples remained for later location.

Whereas 62 stations were proposed for samples that would be analyzed for both sediment and infauna, 48 additional stations were proposed for sediment analysis only for each survey. The purpose of collecting these additional 48 sediment samples was to extend the interpretation of the infaunal data. To determine the number of samples to collect during each survey in each sand resource area for sediment analysis only, the percent of the total surface area remaining after exclusionary mapping for each of the sand resource areas was multiplied by 48 stations (Table 6-2).

Attention then was directed to selecting locations for the 51 samples that would be analyzed for both sediment and infauna and the 48 samples that would be analyzed for sediment only. The goal in placement of the stations was to provide broad spatial and depth coverage within the sand resource areas and, at the same time, ensure that the samples

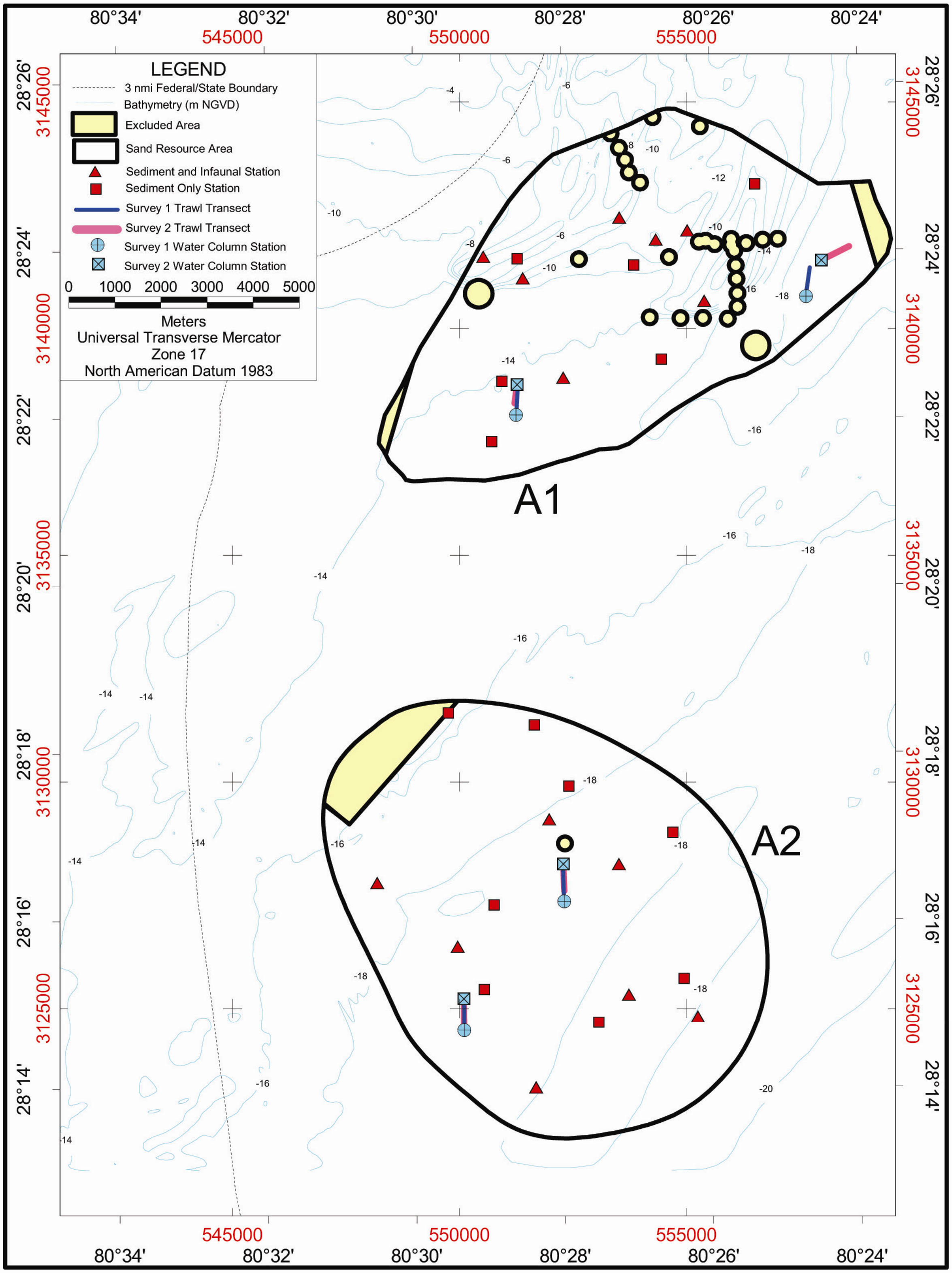

Figure 6-2. Sampling locations for Sand Resource Areas A1 and A2.

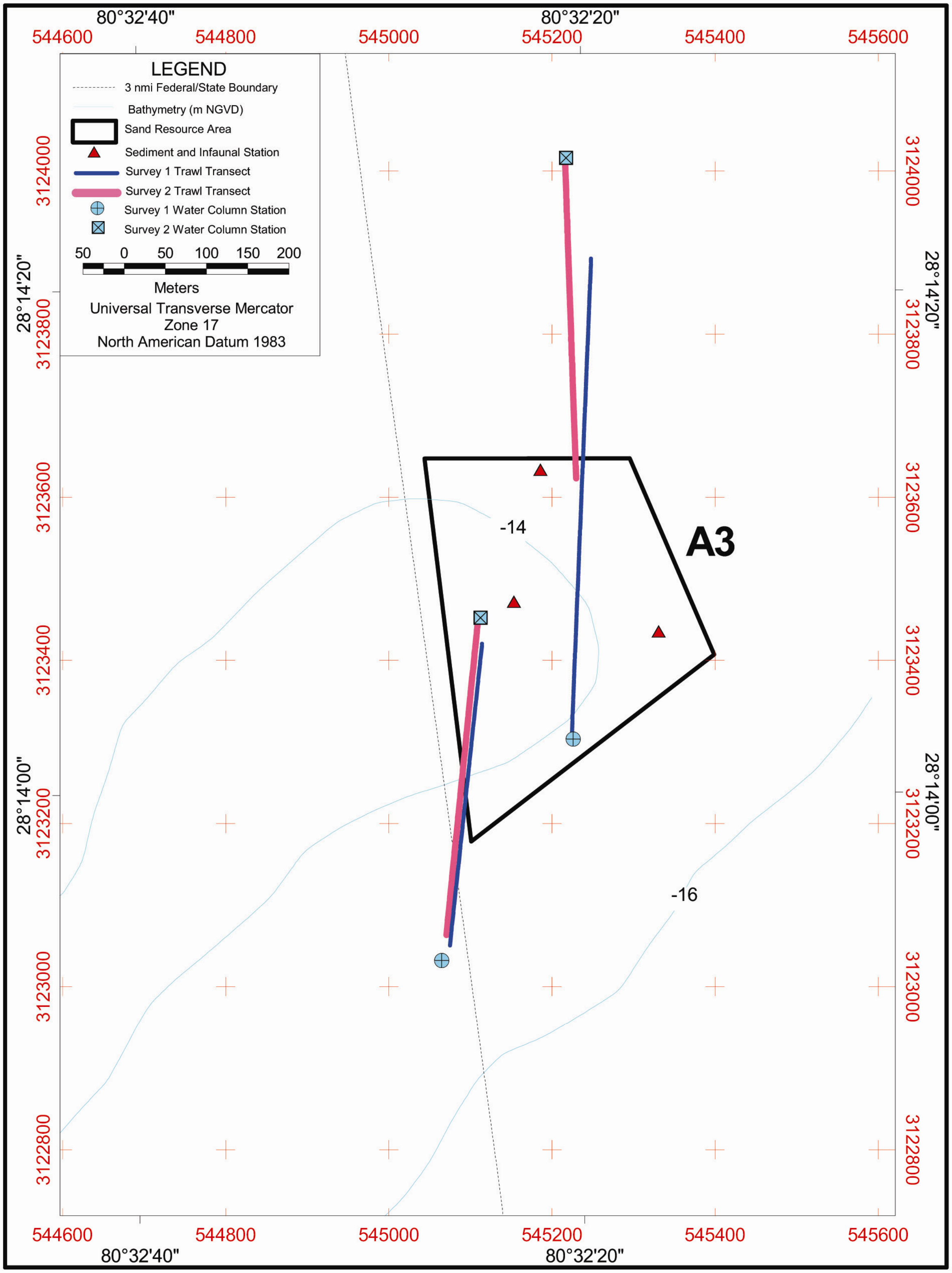

Figure 6-3. Sampling locations for Sand Resource Area A3.

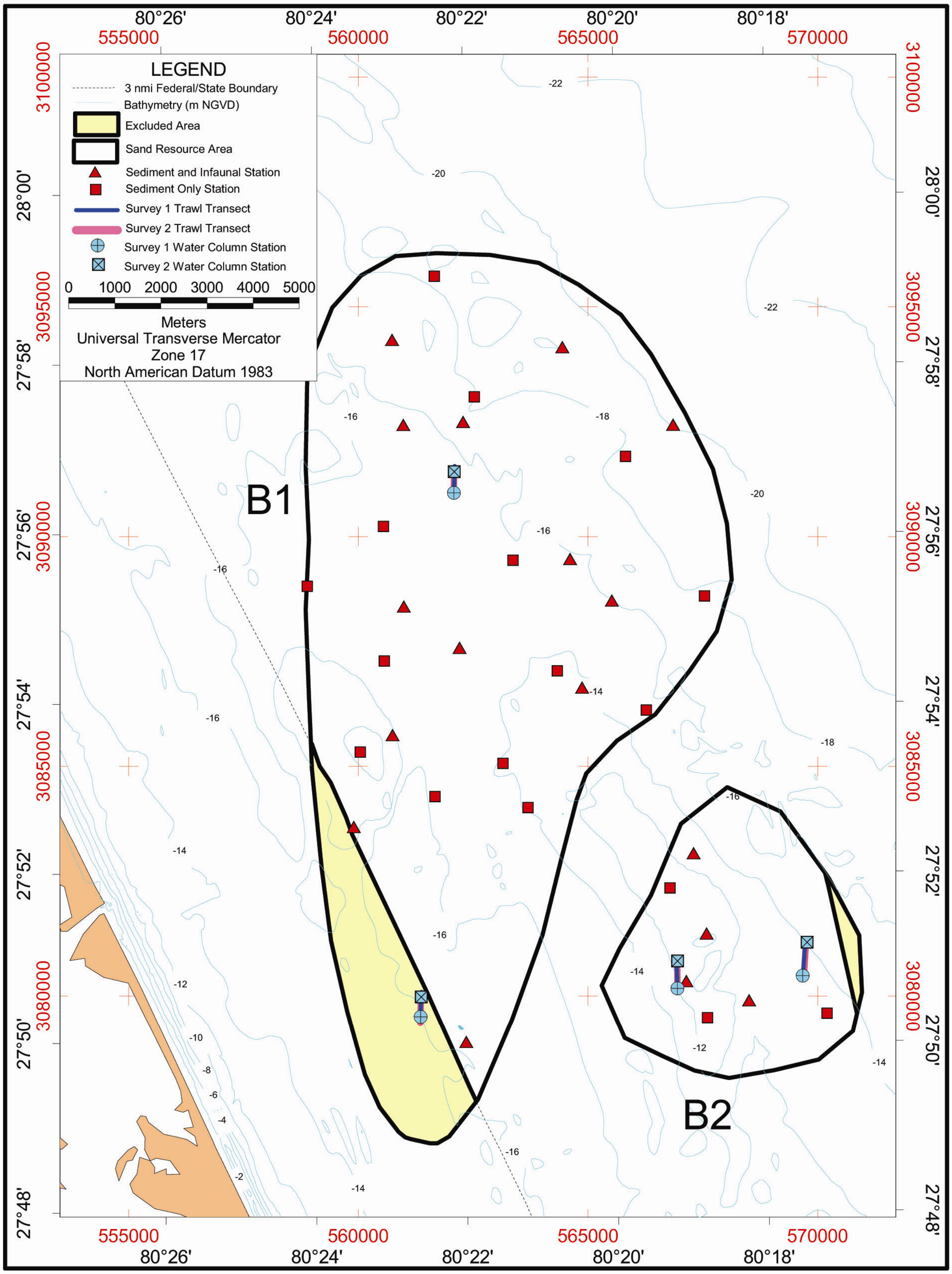

Figure 6-4. Sampling locations for Sand Resource Areas B1 and B2.

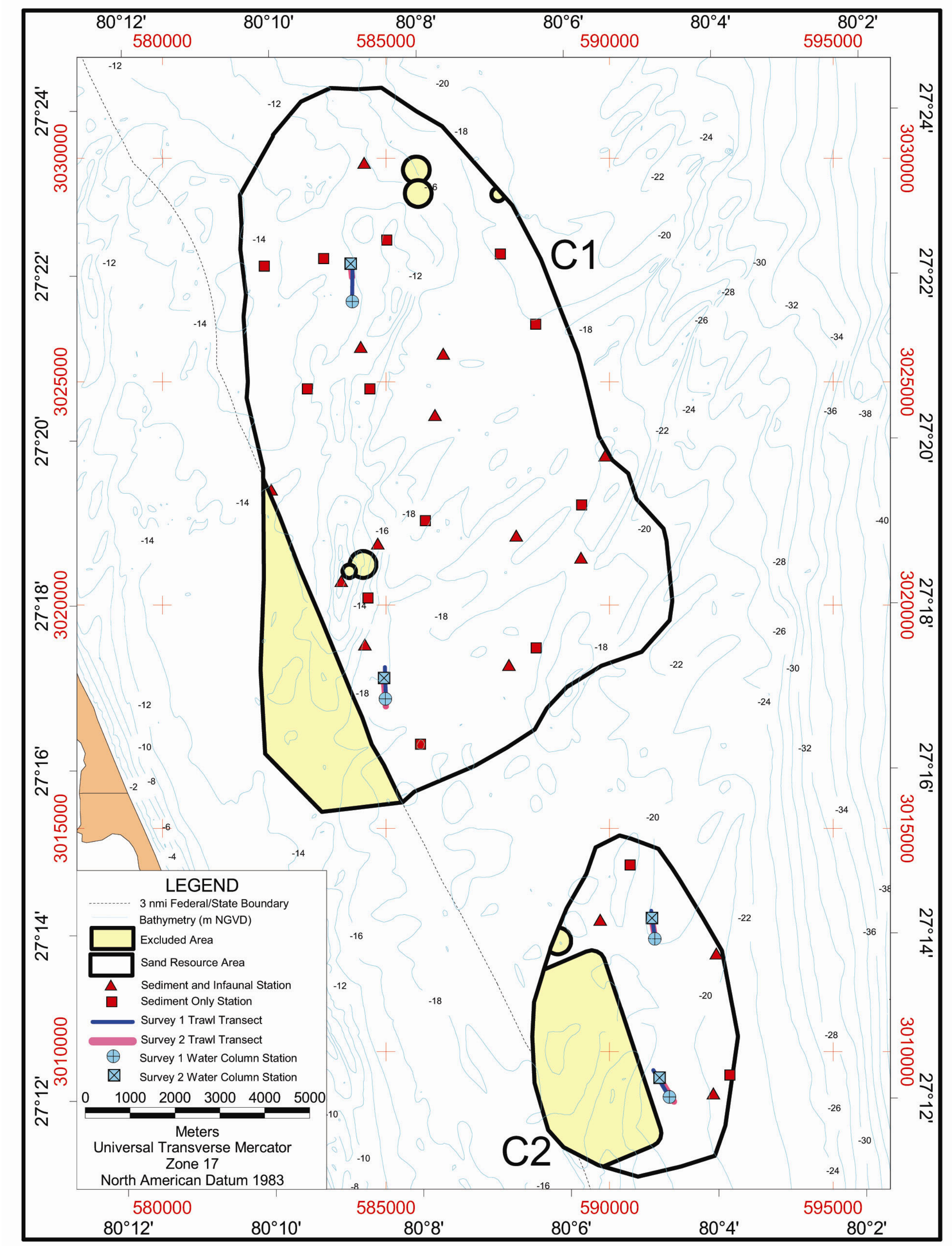

Figure 6-5. Sampling locations for Sand Resource Areas C1amd C2.

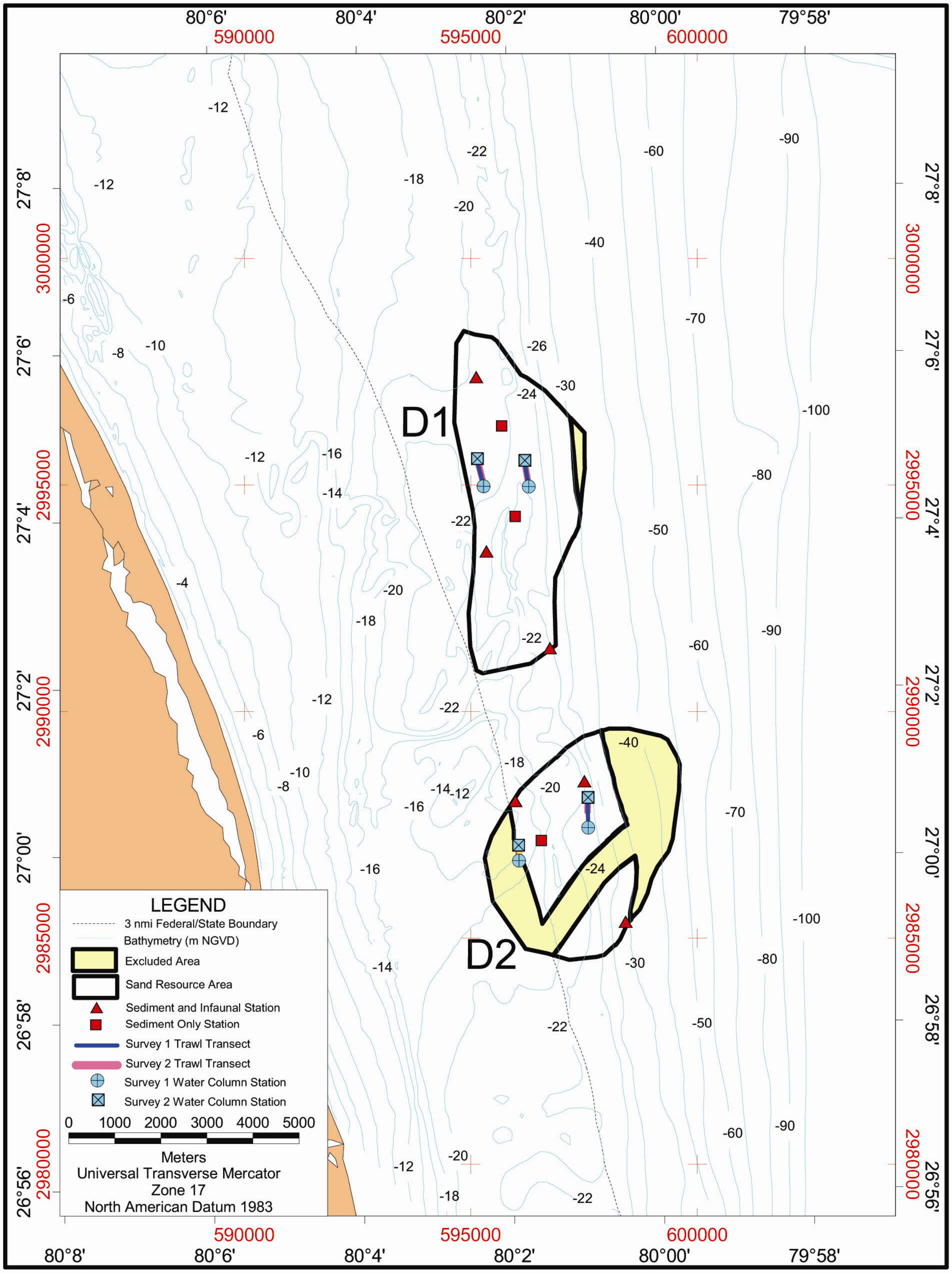

Figure 6-6. Sampling locations for Sand Resource Areas D1 and D2.

Table 6-2. Summary of rationale for allocating sediment/infaunal and sediment-only samples inside the sand resource areas for each survey (seven additional sediment/infaunal samples were allocated to seven adjacent stations [1 sample/adjacent station] outside the sand resource areas for each survey).

Sand Resource Area	Original Area (m^2)	Area Excluded (m^2)	Percent Area Excluded	Remaining Area (m^2)	Percent Area Remaining	Percent of Total Area	Sediment/Infaunal Samples				Sediment-Only Samples Based on 48 Total
							Based on 44 Total Samples	Discretionary Samples: Adjustment for 3 Sample Minimum	Discretionary Samples: Adjustment to Sample Shoals	Based on 55 Total Samples	
A1	53,289,280	2,993,781	6	50,295,498	94	13	6	0	1	7	6
A2	68,279,893	3,081,888	5	65,198,004	95	17	7	0	0	7	8
A3	188,789	0	0	188,789	100	0	0	3	0	3	0
B1	122,397,880	11,708,428	10	110,689,451	90	29	12	0	1	13	14
B2	24,997,834	762,234	3	24,235,600	97	6	3	0	1	4	3
C1	108,776,177	11,517,985	11	97,258,192	89	25	11	0	1	12	12
C2	26,421,335	9,687,302	37	16,734,033	63	4	2	1	0	3	2
D1	14,674,932	331,512	2	14,343,420	98	4	2	1	0	3	2
D2	15,355,029	7,640,912	50	7,714,117	50	2	1	2	0	3	1
	434,381,148	47,724,043	11	386,657,105	89	100	44	7	4	55	48

would be independent of one another to satisfy statistical assumptions. To accomplish this goal, a systematic sampling approach was used to provide broad spatial and depth coverage of the target populations. This approach can, in many cases, yield more accurate estimates of the mean than simple random sampling (Gilbert, 1987). The ArcView extension "Sample" by Quantitative Decision was used to create sampling grids with cell sizes appropriate for the number of samples required for an area. Grids were placed over figures of each sand resource area. One sampling station then was randomly placed within each grid cell of each sand resource area such that sediment and infaunal sample cells alternated with sediment-only sample cells. Randomizing within grid cells eliminates biases that could be introduced by unknown spatial periodicities in a sampling area. This systematic sampling approach resulted in designation of 99 sample locations.

The 51 locations for collecting samples that would be analyzed for both sediment and infauna then were examined to determine where best to place the remaining 4 of the 11 discretionary stations. Because the 51 locations were randomly located, there were cases where isobaths indicated that high points of shoals would not be sampled. Therefore, the remaining four discretionary stations were located on the tops of shoals in Sand Resource Areas A1, B1, B2, and C1.

All sediment and infaunal samples were collected according to the previously described plan except for three samples, two of which were sediment/infaunal samples and one being a sediment-only sample. An extra sediment/infaunal sample was collected in Area B1 during both Surveys 1 and 2. One sediment-only sample was not collected in Area B1 during Survey 2 (Table 6-1).

6.2.1.4 Soft Bottom Epifauna and Demersal Fishes

Eighteen mongoose trawl transects for epifauna and demersal fishes were made during each of two soft bottom surveys at locations illustrated in Figures 6-2 through 6-6 and listed in Appendix F1. One north-south transect was placed near the eastern portion and one north-south transect was placed near the western part of each sand resource area to allow characterization of existing assemblages with respect to water depth.

6.2.1.5 Hard Bottom Epibiota and Demersal Fishes

Nine line miles of video camera data and 180 still photographs were proposed for each hard bottom survey. Totals of 23.5 line miles and 700 still photographs actually were collected during the two hard bottom surveys. One hard bottom survey was near southern Sand Resource Areas C2, D1, and D2 and the other survey was near the more northern Areas B1 and B2. The general locations of these sand resource areas are illustrated in Figure 6-1. Figures showing the specific locations of hard bottom video and still photography transects are provided in Section 6.3.4.

6.2.2 Field Methods

6.2.2.1 Vessel and Survey Dates

Both soft bottom field surveys were conducted aboard the R/V GEOQUEST, which is operated by the Florida Geological Survey. The September 2000 Survey 1 was mobilized on 7 September, conducted from 8 to 14 September, and demobilized on 15 September

2000. The June 2001 Survey 2 was mobilized on 30 May, conducted from 31 May to 4 June, and demobilized on 4 June 2001.

Because water clarity was unsuitable during the September 2000 Survey 1 and video equipment problems prevailed during the June 2001 Survey 2, hard bottom photodocumentation data (i.e., video and still photographs) were collected during two separate field surveys. The first hard bottom survey covering southern Areas C2, D1, and D2 was conducted on 18 April 2002 from the M/V THUNDERFORCE owned by M&S Enterprises, Inc. The second survey covering northern areas in and around Areas B1 and B2 was conducted on 7 October 2002 from a Parker outboard work boat owned by Continental Shelf Associates, Inc. (CSA).

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 wheelhouse. All sampling stations were pre-plotted and stored in the Hypack program. While in the field, the actual positions of all samples collected were recorded and stored by the program.

6.2.2.3 Water Column

Conductivity, temperature, and depth (CTD) were measured with a Sea-Bird electronic CTD unit. Continuous profiles were made from the water surface to the bottom.

6.2.2.4 Sediment and Infauna

Sediment and infaunal samples were taken with a Shipek grab. Once a sample was deemed acceptable (i.e., adequate sample quantity), a subsample of sediment was removed with a 5-cm diameter acrylic core tube and placed in a labeled plastic bag for analyses. This sediment sample was stored at 4^{o}C (i.e., on ice). If infauna were to be analyzed from the sample, then 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.

6.2.2.5 Soft Bottom Epifauna and Demersal Fishes

A 7.6-m mongoose trawl was towed for 10 min (bottom time) along transect lines. 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 sorted and identified to the lowest practical taxon. Any specimens that proved difficult to identify accurately in the field were placed in 10% formalin and transported to the laboratory.

6.2.2.6 Hard Bottom Epibiota and Demersal Fishes

During the April 2002 hard bottom survey of the southern portion of the study area, observations were made and recorded with underwater video and still cameras mounted on a standard tow sled. Video and still cameras were aligned so that both had the same field of view at the time of shutter activation. Both cameras could be aimed at varying degrees below the horizontal using a pan-and-tilt mechanism. Video observations were recorded continuously. Qualitative photographs were taken at the discretion of the on-board biologist. The sled was towed above the bottom at vessel speeds of 1.7 to 3.0 m/s (0.9 to 1.5 kn).

During the October 2002 survey, hard bottom areas were characterized using CSA's mini underwater video/still camera system. This system is equipped with still and video cameras mounted on a fixed frame of an aluminum sled. This sled was either towed slowly or allowed to drift across pre-plotted hard bottom areas in or around the sand resource areas. The path covered by each camera tow was logged into the Hypack navigation system. Video was recorded continuously and still photographs were taken selectively by an on-board biologist.

6.2.3 Laboratory Methods

6.2.3.1 Sediment

Sediment sample analysis consisted of drying a sample and providing a visual description of texture and lithology. Grain size analysis was conducted in accordance with American Society for Testing and Materials (ASTM) Standard D-442. A sediment sample was removed from a collection bag, wet weighed to confirm sufficiency of sample size, and wet sieved through a 62.5-micron screen to separate the clay/silt fraction from sand. The clay/silt fraction was analyzed using standard pipette procedures to determine the size distribution (Folk, 1980).

After wet sieving, the coarse fraction retained on the screen was dried and weighed. The retained fraction was passed through a 2-mm screen to remove gravel sized material (>2 mm in diameter). The weight of the gravel-sized fraction was recorded.

The coarse fraction (the portion left behind after wet sieving and gravel separation) then was weighed, and the gravel and sand fractions were combined. The combined sample was passed through a stack of 0.25-phi screens with openings ranging from -2 to 4 phi. If the -2 phi fraction was greater than 5% of the sample, the material collected on the -2 phi screen was passed through a second stack of sieves, consisting of screens arranged at 0.5-phi intervals ranging from -4 to -2 phi in size. Weight percent collected on each screen was calculated and recorded. Graphical and statistical parameters were determined for each sampling distribution.

Carbonate content was determined for sediment samples from Survey 1. After determining the overall grain size distribution, a sediment sample was recombined then digested in hydrochloric acid. After digestion, the sample was wet sieved through a 63-micron mesh, dried, weighed, and then dry sieved. The fraction remaining on each sieve then was weighed to determine the grain size distribution of the non-carbonate content. The weight percent of the non-carbonate fraction was subtracted from the overall weight percent for each sieve interval to determine the carbonate percent assigned to that interval. Cumulative weight percent for the carbonate fraction then was calculated.

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 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 identification level (LPIL) 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 Soft Bottom Epifauna and Demersal Fishes

Formalin-preserved epifauna and demersal fishes were rinsed in freshwater for 12 hours, then transferred to 70% isopropanol. Specimens were then identified to the lowest practical taxonomic level.

6.2.3.4 Hard Bottom Epibiota and Demersal Fishes

Videotapes collected during the camera sled tows over hard bottom areas were reviewed on a jog shuttle video cassette recorder. The videotapes were replayed using the jog shuttle function, which allowed frame-by-frame viewing when necessary. Qualitative observations of the hard bottom and lists of visually conspicuous epifauna and fishes were generated during these reviews.

6.2.4 Data Analysis

6.2.4.1 Water Column

CTD values were entered into an electronic spreadsheet and tabulated. Depth profiles were plotted for temperature-salinity.

6.2.4.2 Sediment

A computer algorithm was used to determine size distribution and provide summary statistics for each sediment sample using Folk's inclusive graphic measures and Method of Moment calculations. For each sample, grain color, median grain size, and percentages of gravel, sand, silt, and clay were recorded along with a Folk's classification. Percent carbonate was recorded only for Survey 1 samples.

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:

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

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 with 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 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. Differences in *H′*, *J′*, and *D* between surveys were assessed using analysis of

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

variance.

Spatial and temporal patterns in infaunal assemblages were examined with cluster analysis. Cluster analyses were performed on similarity matrices constructed from raw data matrices consisting of taxa and samples (station – survey). Only species-level taxa, with the exception of two species complexes that can be only reliably identified to genus, were included in the analyses. Of these taxa, only those contributing at least 0.1% of the total abundance of species level taxa were included. Raw counts of each individual infaunal taxon in a sample (n) were transformed with the $\log_{10}(n+1)$ transformation prior to similarity analysis. Both normal (stations) and inverse (taxa) similarity matrices were generated using the Bray-Curtis index (Bray and Curtis, 1957), which was calculated using the following formula:

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).

The extent to which sample groups formed by normal cluster analysis of the entire data set could be explained by environmental variables such as sediment parameters was examined by canonical discriminant analysis (SAS Institute Inc., 1989). Canonical discriminant analysis identifies the degree of separation among predefined 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 Soft Bottom Epifauna and Demersal Fishes

Raw counts of individual epifaunal and demersal fish taxa were tabulated by sand resource area for both field surveys. These counts were used to construct a sample by taxa data matrix. From this data matrix, a sample similarity matrix was generated using the Bray-Curtis similarity index. A group average cluster analysis was used to cluster the similarity matrix.

6.2.4.5 Hard Bottom Epibiota and Demersal Fishes

Hard bottom areas observed during the two surveys were described qualitatively. Simple substrate categories encountered along the survey transects were matched with navigation data to generate plots relative to the location of each discrete substrate type. Two basic substrate types, sand and hard bottom, were mapped along the hard bottom transects. Secondarily, epibiotal cover was described based on the most conspicuous organisms present, for examples "algal sponge" or "dense octocorals."

6.3 RESULTS

6.3.1 Water Column

Depth profiles of temperature and salinity for the September 2000 Survey 1 are shown in Figures 6-7 to 6-10. Temperature profiles varied little across all sand resource areas, indicating a well mixed water column. Surface temperatures across stations ranged from 29.7ºC in Area A3 to 27.1ºC in Area C2, whereas bottom temperatures ranged from 28.9ºC in Area A1 to 27.9ºC in Area D2. Bottom salinity was similarly uniform with depth in all areas, averaging about 35.5 parts per thousand (ppt). Surface salinity ranged from 36.9 ppt at Area C1 to 35.3 ppt in Area D1. Bottom values varied little among samples, ranging from 36.2 ppt in Area D2 to 36.7 ppt in Area B1.

Depth profiles of temperature and salinity for the June 2001 Survey 2 are depicted in Figures 6-11 to 6-14. Temperature profiles indicated that bottom waters were generally cooler than surface waters in all sand resource areas. The effect was most pronounced in Areas A, B, and C. Surface temperatures ranged from 27.0ºC in Area B1 to 24.4ºC in Area C1. Bottom temperature values ranged from 26.2ºC in Area D1 to 22.2ºC in Area C2. Salinity did not show the same profile as temperature and maintained a vertical profile in all areas. Surface values ranged from 36.5 ppt in Area A1 to 36.1 ppt in Area D1. Bottom salinities also were very similar among samples and ranged from 36.5 ppt in Area C1 to 36.3 ppt in Areas C2, D1, and D2.

6.3.2 Sediment

Results of the sediment analyses are detailed in Hoenstine et al. (2001a,b). Sediment summary statistics are provided in Appendix F2. Sedimentary characteristics of grab samples taken in the sand resource areas during the surveys consisted of various proportions of gravel, sand, silt, and clay. These proportions were used to determine Folk's classifications for the individual samples that provide a general picture of the type of sediments found in each sand resource area. Table 6-3 indicates that most samples (68 of 221 samples; 31%) were sand, followed by gravelly sand (63; 29%), slightly gravelly sand (32; 14%), sandy gravel (25; 11%), muddy sand (25; 11%), slightly gravelly muddy sand (7; 3%), and gravel (1; <1%). Within sand resource areas, sediments at stations analyzed for infauna were similar to sediments at stations analyzed for grain size only.

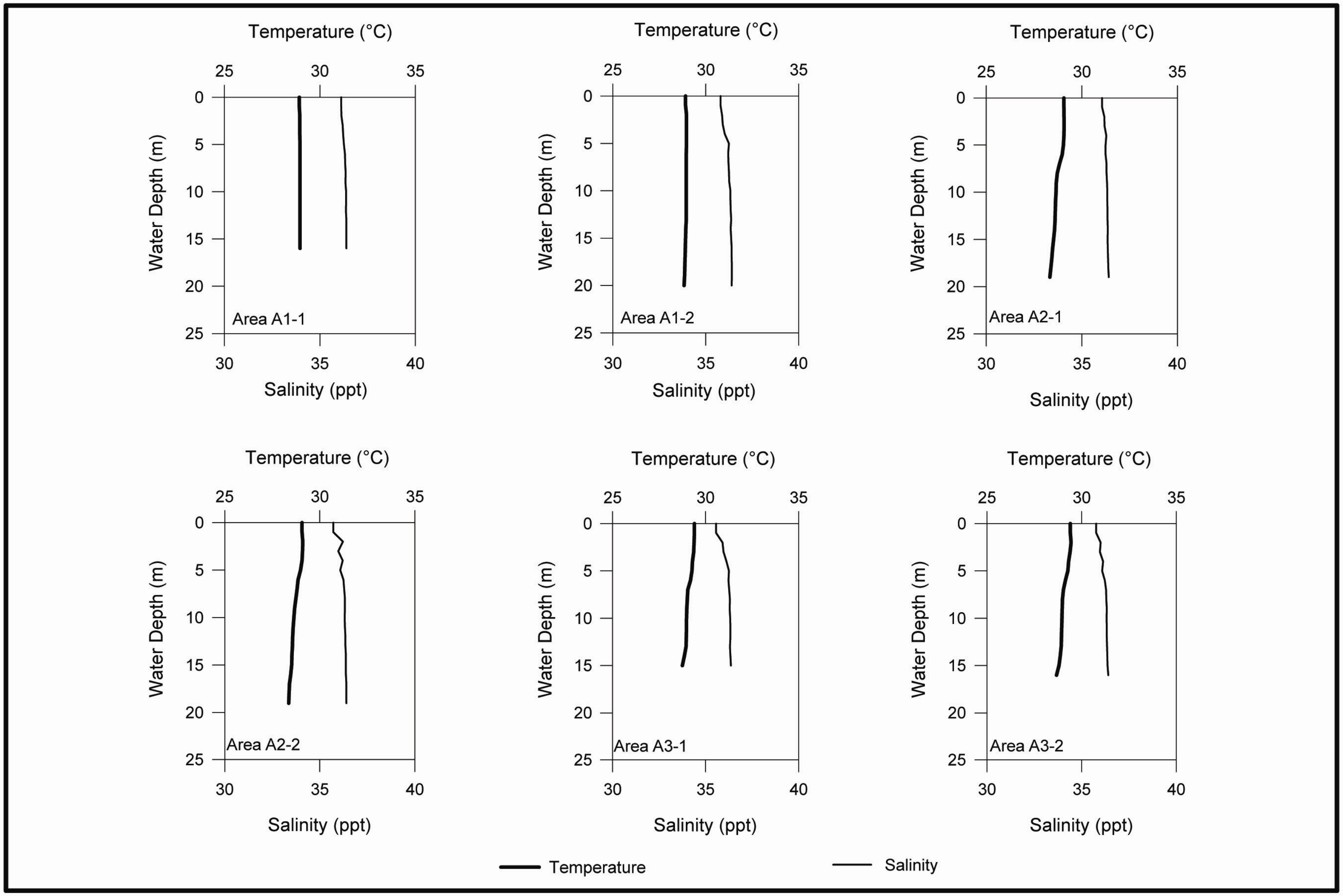

Figure 6-7. Temperature and salinity profiles recorded during September 2000 in Sand Resource Arease A1, A2, and A3.

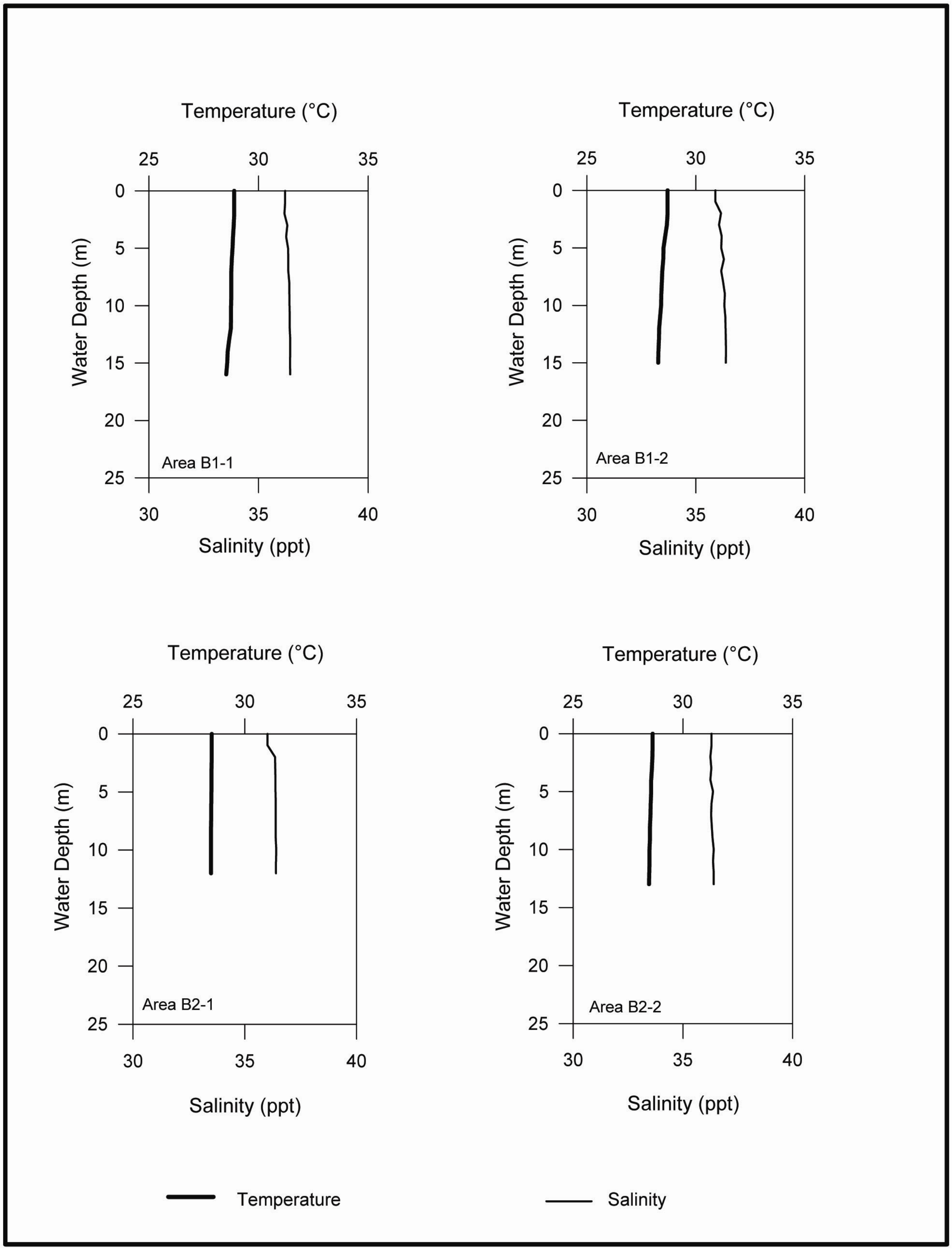

Figure 6-8. Temperature and salinity profiles recorded during September 2000 in Sand Resource Areas B1 and B2.

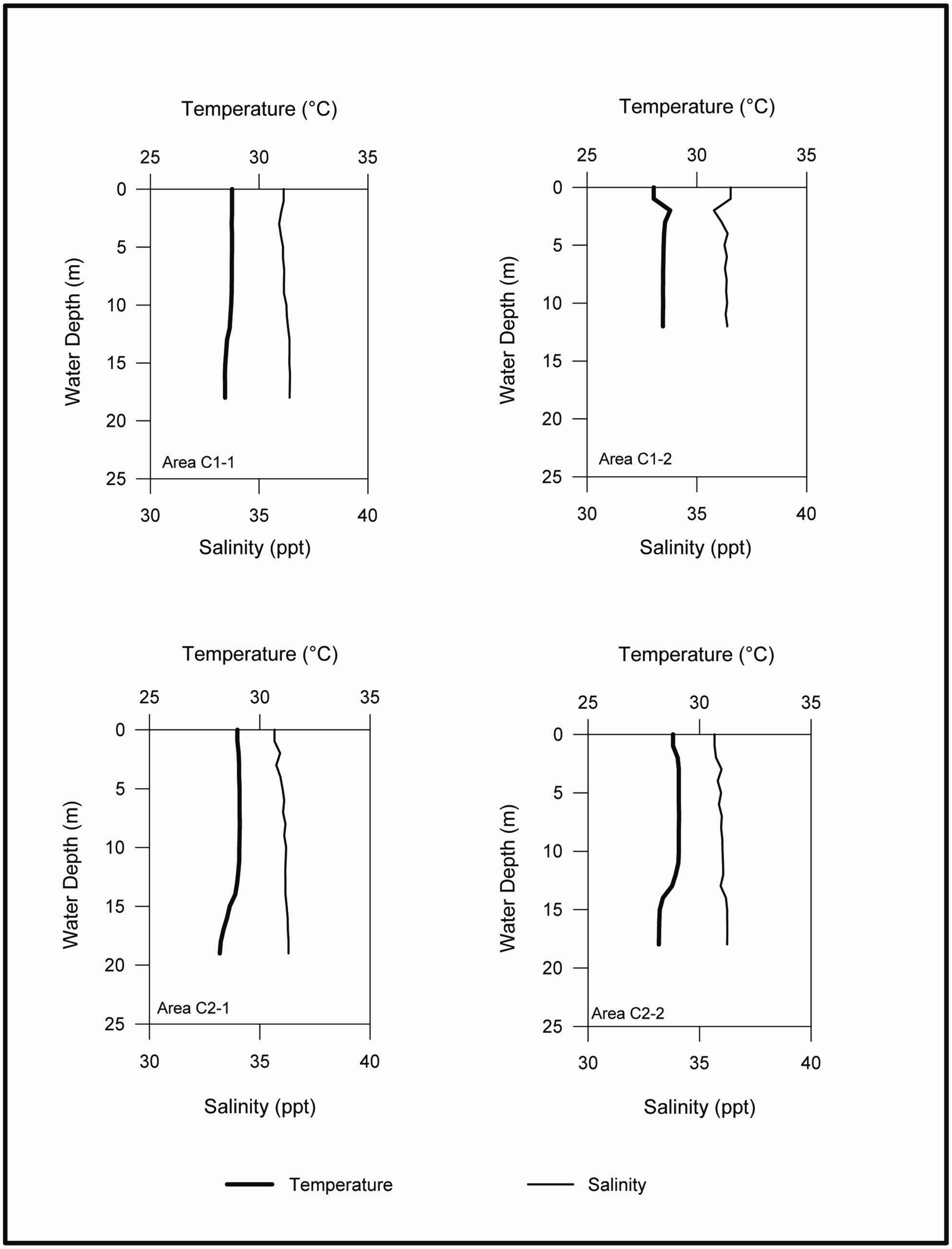

Figure 6-9. Temperature and salinity profiles recorded during September 2000 in Sand Resource Areas C1 and C2.

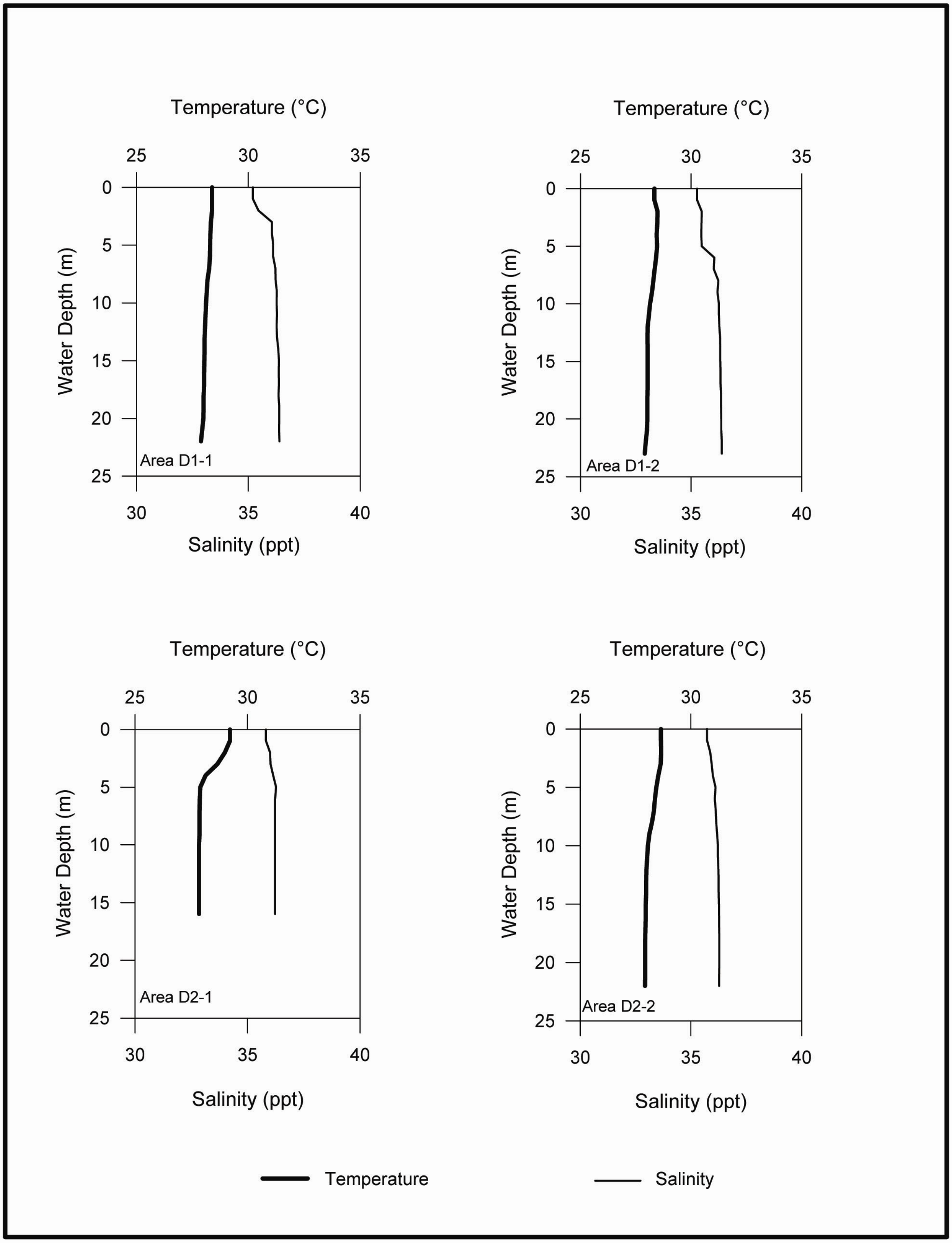

Figure 6-10. Temperature and salinity profiles recorded during September 2000 in Sand Resource Areas D1 and D2.

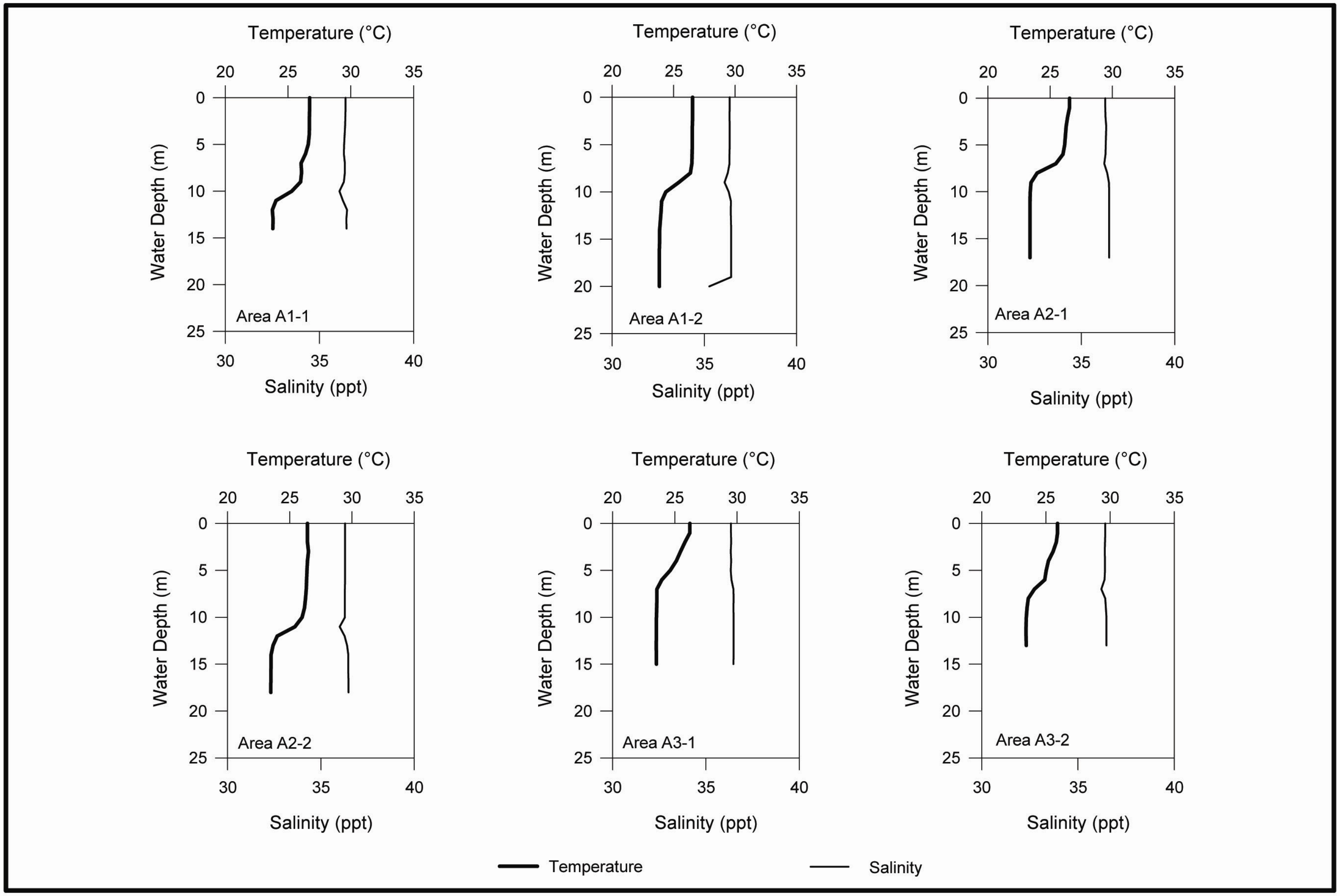

Figure 6-11. Temperature and salinity profiles recorded during June 2001 in Sand Resource Areas A1, A2, and A3.

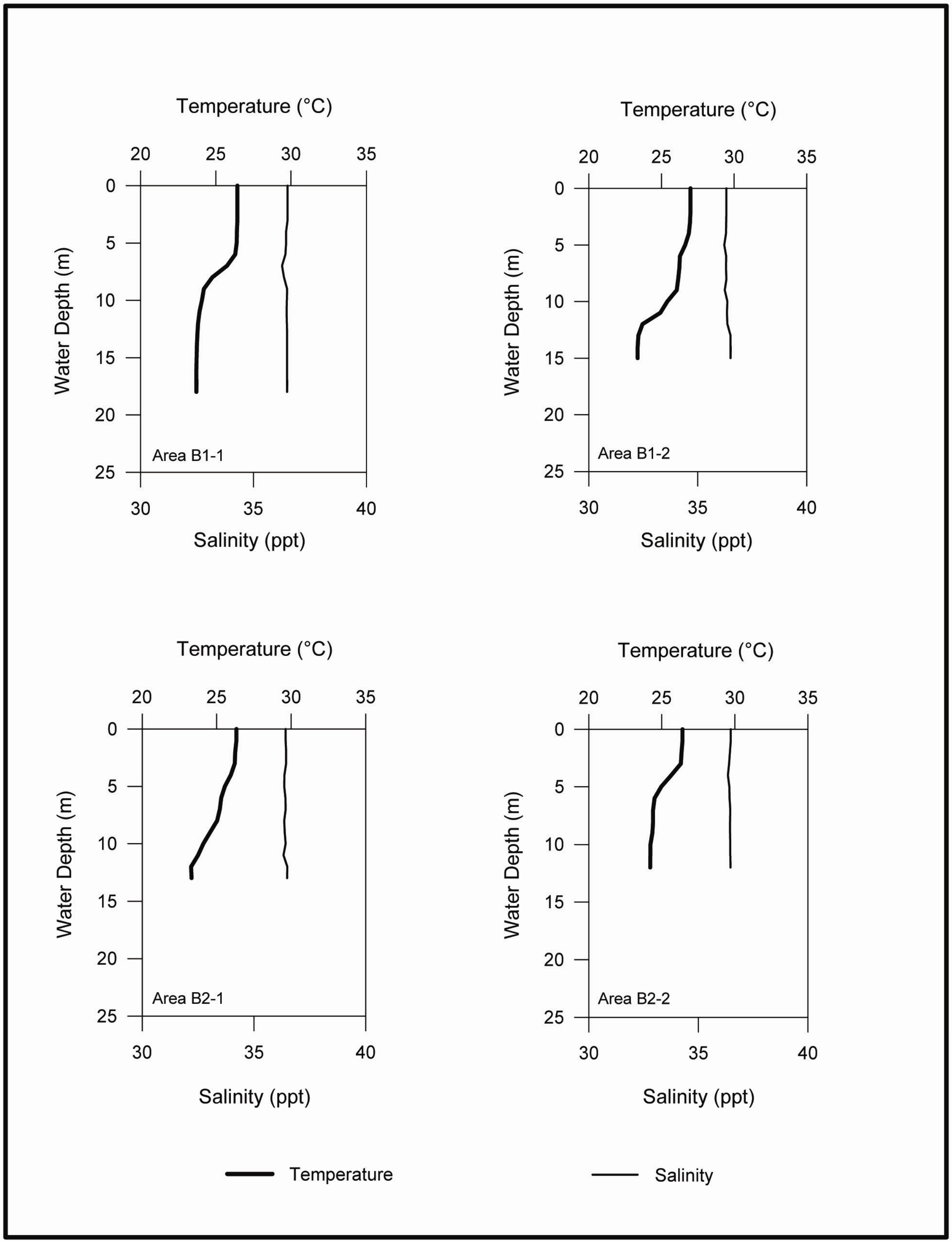

Figure 6-12. Temperature and salinity profiles recorded during June 2001 in Sand Resource Areas B1 and B2.

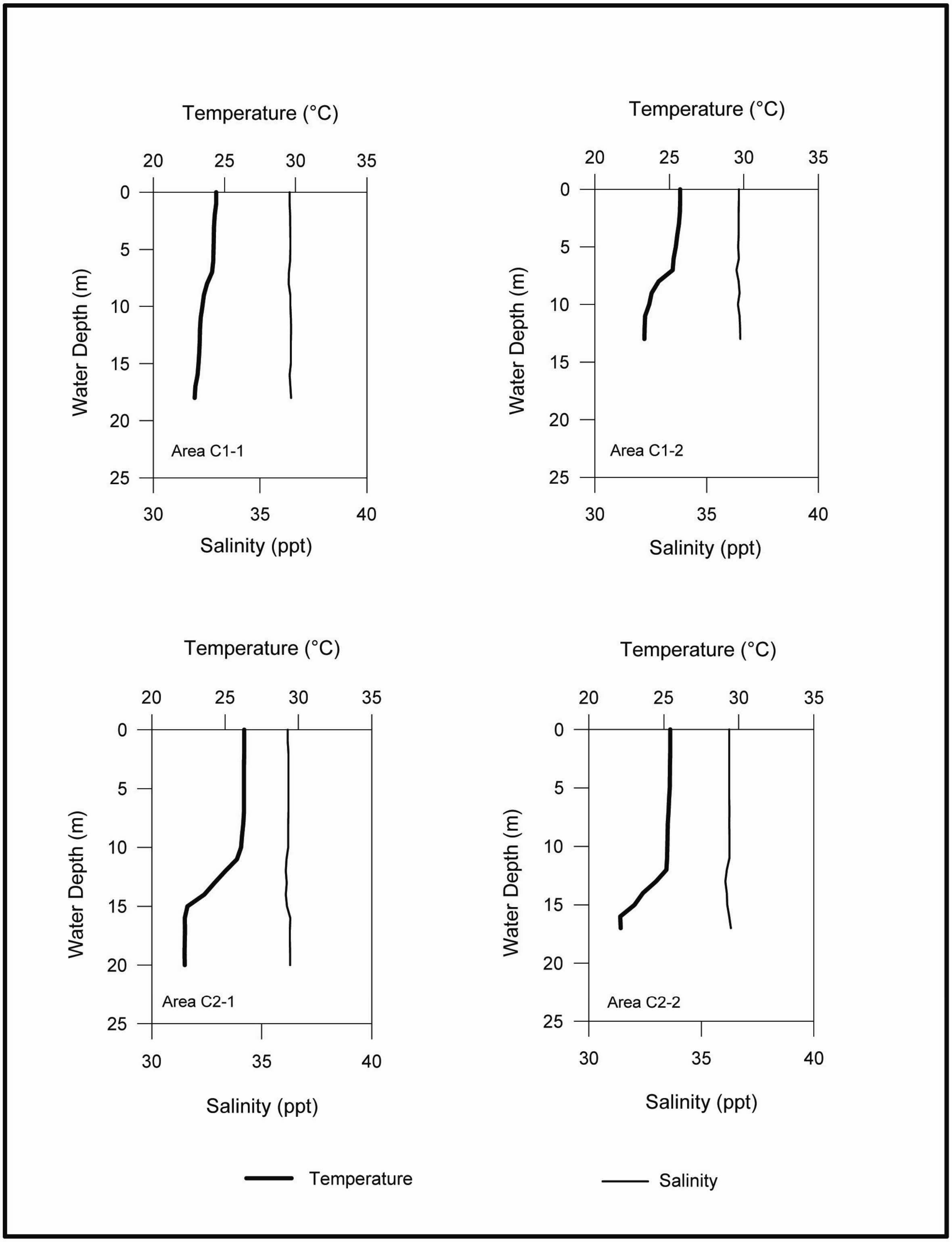

Figure 6-13. Temperature and salinity profiles recorded during June 2001 in Sand Resource Areas C1 and C2.

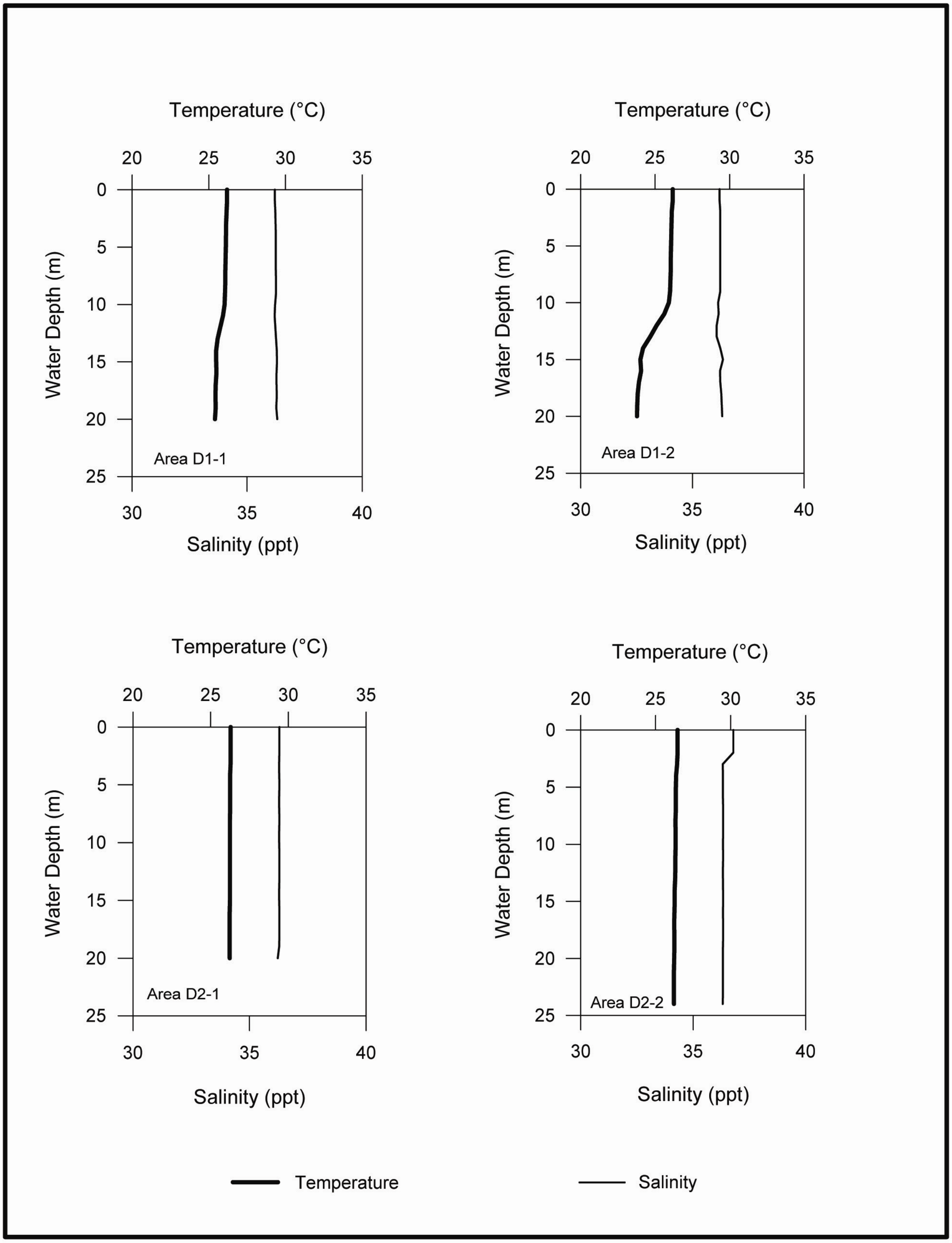

Figure 6-14. Temperature and salinity profiles recorded during June 2001 in Sand Resource Areas D1 and D2.

Table 6-3. Sediment type summary for September 2000 Survey 1 and June 2001 Survey 2 in the nine sand resource areas and seven adjacent stations offshore central east Florida.

Sand Resource Area (A1, B1, C1, D1, etc.) and Adjacent Station (R1, R2, etc.)	Survey	Total No. of Samples Collected	No. of Samples with Particular Sediment Types Based on Folk's Classifications						
			Gravel	Sandy Gravel	Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Muddy Sand	Sand	Muddy Sand
A1	1	13						9	4
	2	13				5	1	4	3
A2	1	15						6	9
	2	15					5	6	4
A3	1	3			1			2	
	2	3			1	1		1	
B1	1	28		11	12	3		2	
	2	27	1	12	10	3		1	
B2	1	7			5			2	
	2	7			5	2			
C1	1	24			9	3		11	1
	2	24			10	10	1	3	
C2	1	5			1	1		3	
	2	5			1	2		2	
D1	1	5						4	1
	2	5						4	1
D2	1	4				1		3	
	2	4				1		3	
R1	1	1			1				
	2	1			1				
R2	1	1							1
	2	1							1
R3	1	1		1					
	2	1		1					
R4	1	1			1				
	2	1			1				
R5	1	1			1				
	2	1			1				
R6	1	1						1	
	2	1						1	
R7	1	1			1				
	2	1			1				
Total No. of Samples		221	1	25	63	32	7	68	25

During September, samples from the northernmost areas (A1, A2, and A3) were predominantly sand or muddy sand following Folk's classification. In Area A1, most (9 of 13) samples were classified as sand with the remainder classified as muddy sand. Samples from Area A2 were either muddy sand (9 of 15) or sand (6), and samples from Area A3 yielded 2 described as sand and 1 described as gravelly sand. In Area B1, most samples were either gravelly sand (12 of 28) or sandy gravel (11). Only 2 samples from this area were classified as sand, and the remaining 3 samples were slightly gravelly sand. Most (5 of 7) Area B2 samples were classified as gravelly sand, while the remaining 2 were sand. In Area C1, 11 of 24 samples were sand, 9 were gravelly sand, 3 were slightly gravelly sand, and 1 was muddy sand. In Area C2, 3 of 5 samples were sand, whereas the remaining 2 samples were gravelly sand and slightly gravelly sand. Four of 5 samples from Area D1 were sand and the fifth sample was muddy sand. In Area D2, 3 of 4 samples were sand and the remaining sample was slightly gravelly sand.

Grab samples from the June survey were more variable with respect to Folk's classification than samples from the September survey. Sediment types from June that did not occur during September were gravel (1 sample) and slightly gravelly muddy sand (7 samples). Of 13 samples collected in Area A1, 5 were classified as slightly gravelly sand, 4 as sand, 3 as muddy sand, and 1 as slightly gravelly muddy sand. In Area A2, of 15 samples collected, 6 were sand, 5 were slightly gravelly muddy sand, and 4 were muddy sand. Area A3 had 3 samples, including 1 classified as sand, 1 as gravelly sand, and 1 as slightly gravelly sand. Area B1 yielded 12 of 27 samples classified as sandy gravel and 10 classified as gravelly sand. Remaining samples from Area B1 were slightly gravelly sand (3 samples), gravel (1 sample), and sand (1 sample). In Area B2, samples were either gravelly sand (5 of 7) or slightly gravelly sand (2). Area C1 samples were classified mostly as gravelly sand (10 of 24) or slightly gravelly sand (10). The other 4 samples from Area C1 were classified as sand (3 samples) or slightly gravelly muddy sand (1 sample). The 5 samples collected in Area C2 were sand (2 samples), slightly gravelly sand (2 samples), and gravelly sand (1 sample). In Area D1, 4 of 5 samples were sand, and the remaining sample was muddy sand. In Area D2, 3 of 4 samples were sand, with the fourth sample designated slightly gravelly sand.

Unlike sand resource area stations, all samples taken from a particular adjacent station had the same sediment type during both surveys. Sediment type from adjacent stations only occasionally reflected the major sediment type from the nearest sand resource area.

6.3.3 Soft Bottom

6.3.3.1 Infauna

A phylogenetic list of infauna collected in bottom grabs during the September 2000 and June 2001 surveys is presented in Appendix Table F3-1. A total of 11,757 individuals was collected during the surveys, representing 420 taxa in 13 separate phyla. Infauna were more abundant during September, when grabs yielded an average of 117 individuals, whereas 69 individuals were collected per grab during June. One hundred and eighty-nine taxa (45% of total) were common to both surveys. Of those taxa found in just one of the two surveys, 66% (152 taxa) were sampled during September.

The polychaete *Goniadides carolinae* was numerically dominant, particularly during September, and represented 6.2% of all infauna censused during both surveys.

Other than *G. carolinae*, taxa among the top 10 numerical dominants during both the September and June surveys were the bivalve *Crassinella lunulata*, unidentified rhynchocoels, and the polychaete *Exogone lourei*. Polychaetes and bivalves contributed most to overall abundance, although amphipods were a conspicuous infaunal component at sand bottom stations.

Table 6-4 lists numerically dominant infaunal taxa sampled from each sand resource area during September. Overall, numerically dominant taxa included the polychaete *Mediomastus* (4.57% of all collected individuals), bivalve *Crassinella lunulata* (3.9%), polychaete *G. carolinae* (3.7%), and unidentified ophiuroids (2.9%). The 10 most abundant taxa comprised 27.5% of all infaunal individuals during September. Numerically dominant taxa collected during June are listed in Table 6-5 and included *G. carolinae* (10.4% of all individuals collected), *C. lunulata* (7.0%), and unidentified tubificid oligochaetes (4.7%). The 10 most abundant taxa comprised 37.5% of all infaunal individuals during June.

Table 6-6 presents summary statistics for each sand resource area and combined adjacent stations for the September and June surveys. Values are provided for number of taxa, number of individuals, density, species diversity, evenness, and richness.

The highest mean number of infaunal taxa per station occurred in Area B1 (50 taxa) during September and in Areas B1 (33), C2 (32), and C1 (31) in June. Areas A1 and D1 yielded the lowest mean number of taxa per station during both September (19 and 21, respectively) and June (13 and 14, respectively). Mean number of taxa for combined adjacent stations during September was greater than mean values in the sand resource areas, except for Area B1. Mean number of taxa for combined adjacent stations during June was comparable to the sand resource areas.

Highest infaunal densities (individuals/m^2) were from Area B1 (station average = 4,875) in September and Areas B1 (2,443) and C1 (2,294) during June. Lowest mean densities were from Area D1 (1,083) in September and Area D2 (767) during June. Mean infaunal density for the combined adjacent stations (3,543) in September was greater than densities in the sand resource areas, except for Area B1. Mean infaunal density for combined adjacent stations (1,793) during June was comparable to average densities in the sand resource areas.

Mean values of species diversity (H') and evenness (J') were similar for September and June. Mean values of species richness (D) were greater in September as compared to June ($F = 4.24$, $p<0.05$).

During September, highest mean values of species diversity and richness were found at Area B1 stations (3.26 and 9.31, respectively), and highest mean evenness was found in Areas A3 and C2 (0.92). Area A1 had the lowest mean values of species diversity, evenness, and richness during September (2.34, 0.82, and 4.47, respectively). Stations in Areas C2 and B1 yielded the highest mean values of species diversity (2.99 and 2.98, respectively) during June. Area A2 had the highest mean value of evenness (0.92) and Area C2 had the highest mean richness (7.16) during June. Areas D1 and A1 yielded the lowest mean values of species diversity (2.15 and 2.16, respectively) and richness (3.50 and 3.56, respectively) during June, and lowest mean evenness was in Areas A3 and D1 (0.82).

Table 6-4. Ten most abundant taxa by individual sand resource area and combined adjacent stations (R) for September 2000 Survey 1 offshore central east Florida.

Area	Taxonomic Name	Count	Area	Taxonomic Name	Count
A1	*Crassinella lunulata*	48	C1	*Caecum cooperi*	134
	Bivalvia (LPIL)	44		*Crassinella lunulata*	113
	Metharpinia floridana	39		*Crassinella martinicensis*	86
	Tanaissus psammophilus	26		*Protodorvillea kefersteini*	81
	Echinoidea (LPIL)	24		*Tellina* (LPIL)	74
	Magelona sp. H	20		*Goniadides carolinae*	73
	Goneplacidae (LPIL)	16		*Chione cancellata*	62
	Semelidae (LPIL)	13		*Mediomastus* (LPIL)	60
	Protohaustorius sp. B	10		Arcidae (LPIL)	49
	Acanthohaustorius pansus	9		*Ceratonereis mirabilis*	24
A2	*Lucina radians*	116	C2	*Ceratonereis mirabilis*	23
	Tellinidae (LPIL)	80		*Mediomastus* (LPIL)	17
	Scoletoma verrilli	63		*Armandia maculata*	16
	Magelona sp. H	32		*Protodorvillea kefersteini*	15
	Tellina (LPIL)	24		Glyceridae (LPIL)	10
	Sipuncula (LPIL)	22		*Nephtys simoni*	10
	Goniada littorea	20		Nereididae (LPIL)	8
	Sabellaria vulgaris	18		*Aspidosiphon* (LPIL)	7
	Cerithiidae (LPIL)	16		*Caecum cooperi*	7
	Dentalium texasianum	16		*Goniadides carolinae*	7
A3	Glyceridae (LPIL)	22	D1	*Nereis succinea*	14
	Aspidosiphon albus	15		*Goniada littorea*	10
	Goniadides carolinae	10		*Atys sandersoni*	9
	Caecum johnsoni	7		Tubificidae (LPIL)	9
	Acanthohaustorius intermedius	6		*Mediomastus* (LPIL)	8
	Mediomastus (LPIL)	6		*Prionospio cirrifera*	7
	Metharpinia floridana	5		*Eudevenopus honduranus*	4
	Notomastus americanus	4		*Lucina multilineata*	4
	Owenia fusiformis	4		*Xenanthura brevitelson*	4
	Paraprionospio pinnata	4		*Armandia agilis*	3
B1	*Mediomastus* (LPIL)	170	D2	*Ceratonereis mirabilis*	16
	Ophiuroidea (LPIL)	121		*Atys sandersoni*	14
	Exogone lourei	111		*Armandia maculata*	10
	Goniadides carolinae	104		*Tellina* (LPIL)	10
	Sphaerosyllis piriferopsis	102		*Caulleriella* (LPIL)	9
	Crassinella lunulata	101		*Crassinella lunulata*	8
	Eunice unifrons	96		*Lembos setosus*	7
	Parapionosyllis longicirrata	82		*Aspidosiphon* (LPIL)	6
	Rhynchocoela (LPIL)	80		*Lucina radians*	6
	Pitar fulminatus	78		Arcidae (LPIL)	5
B2	Ophiuroidea (LPIL)	52	R	*Mediomastus* (LPIL)	62
	Goniadides carolinae	25		*Goniadides carolinae*	52
	Sipuncula (LPIL)	24		*Tellina versicolor*	49
	Dentatisyllis carolinae	23		*Anadara transversa*	45
	Anadara ovalis	16		*Caecum johnsoni*	39
	Branchiostoma (LPIL)	14		Rhynchocoela (LPIL)	29
	Rhynchocoela (LPIL)	13		*Lucina radians*	27
	Crassinella martinicensis	11		*Armandia maculata*	22
	Tubificidae (LPIL)	10		*Opisthodonta* sp. B	21
	Filogranula sp. A	9		*Maera caroliniana*	20

LPIL = Lowest practical identification level.

Table 6-5. Ten most abundant taxa by individual sand resource area and combined adjacent stations (R) for June 2001 Survey 2 offshore central east Florida.

Area	Taxonomic Name	Count	Area	Taxonomic Name	Count
A1	*Crassinella lunulata*	49	B2	*Goniadides carolinae*	60
	Metharpinia floridana	19		Tubificidae (LPIL)	49
	Bathyporeia parkeri	16		*Syllis ortizi*	16
	Rhynchocoela (LPIL)	11		*Glycera* (LPIL)	14
	Acanthohaustorius millsi	7		Sipuncula (LPIL)	12
	Bivalvia (LPIL)	6		Oligochaeta (LPIL)	11
	Protohaustorius wigleyi	6		*Crassinella lunulata*	10
	Tubificidae (LPIL)	6		*Aspidosiphon* (LPIL)	8
	Acanthohaustorius shoemakeri	5		*Limopsis cristata*	8
	Echinoidea (LPIL)	5		*Tanaissus psammophilus*	7
	Lucina multilineata	17		*Crassinella lunulata*	153
A2	*Ervilia concentrica*	13	C1	*Goniadides carolinae*	74
	Acanthohaustorius intermedius	11		Tubificidae (LPIL)	59
	Bivalvia (LPIL)	9		Sipuncula (LPIL)	50
	Tellina (LPIL)	9		Maldanidae (LPIL)	42
	Echinoidea (LPIL)	8		*Protodorvillea kefersteini*	42
	Magelona sp. H	8		*Syllis ortizi*	42
	Metharpinia floridana	6		*Metharpinia floridana*	39
	Mitrella lunata	6		*Armandia maculata*	33
	Rhynchocoela (LPIL)	6		*Caecum imbricatum*	30
	Goniadides carolinae	40		*Goniadides carolinae*	18
A3	*Prionospio cristata*	26	C2	Tubificidae (LPIL)	13
	Acanthohaustorius intermedius	21		Terebellidae (LPIL)	11
	Aspidosiphon (LPIL)	14		*Syllis ortizi*	10
	Crassinella lunulata	11		*Dissodactylus* (LPIL)	7
	Metharpinia floridana	9		*Odontosyllis enopla*	7
	Rhynchocoela (LPIL)	8		Ophiuroidea (LPIL)	7
	Acteocina candei	5		*Crassinella lunulata*	6
	Balanoglossus (LPIL)	5		*Glycera* (LPIL)	6
	Caecum johnsoni	5		*Tellina* (LPIL)	6
	Goniadides carolinae	206		*Eudevenopus honduranus*	19
B1	*Exogone lourei*	65	D1	Tellinidae (LPIL)	16
	Crassinella lunulata	58		*Ophelina acuminata*	14
	Tubificidae (LPIL)	54		*Goniada littorea*	11
	Caecum johnsoni	47		*Armandia maculata*	9
	Glycera (LPIL)	44		*Cyclaspis varians*	7
	Maera caroliniana	43		*Lucina multilineata*	5
	Bhawania heteroseta	38		Rhynchocoela (LPIL)	5
	Syllis ortizi	34		*Bathyporeia parkeri*	4
	Mediomastus (LPIL)	33		*Armandia agilis*	3
	Tellinidae (LPIL)	10		*Goniadides carolinae*	50
D2	*Goniada littorea*	8	R	*Atrina seminuda*	44
	Goniadides carolinae	7		*Mediomastus* (LPIL)	19
	Synelmis ewingi	6		Cirratulidae (LPIL)	18
	Aspidosiphon muelleri	4		Tubificidae (LPIL)	18
	Caecum imbricatum	4		*Crassinella lunulata*	16
	Metharpinia floridana	4		Sipuncula (LPIL)	14
	Aspidosiphon (LPIL)	3		Maldanidae (LPIL)	13
	Bathyporeia parkeri	3		*Glycera* (LPIL)	12
	Branchiostoma (LPIL)	3		*Maera caroliniana*	11

LPIL = Lowest practical identification level.

Table 6-6. Summary of infaunal statistics for September 2000 Survey 1 and June 2001 Survey 2 in each sand resource area and combined adjacent stations (R) offshore central east Florida.

Area	No. of Stations (n)	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
September 2000													
A1	7	19	8.25	57	40	1,421	1,009	2.34	0.35	0.82	0.07	4.47	1.42
A2	7	31	9.52	107	21	2,679	513	2.84	0.47	0.83	0.07	6.46	1.82
A3	3	24	5.13	54	38	1,342	941	2.92	0.09	0.92	0.08	6.06	0.37
B1	14	50	19.19	195	119	4,875	2,964	3.26	0.38	0.85	0.07	9.31	2.62
B2	4	29	7.87	84	38	2,088	941	2.86	0.22	0.85	0.01	6.39	1.25
C1	12	36	9.39	120	72	2,998	1,797	2.96	0.28	0.84	0.06	7.37	1.41
C2	3	33	18.58	89	66	2,233	1,650	3.06	0.55	0.92	0.06	7.32	2.78
D1	3	21	10.15	43	28	1,083	711	2.63	0.52	0.88	0.07	5.30	1.85
D2	3	28	9.64	63	43	1,575	1,064	3.00	0.24	0.91	0.05	6.62	1.36
R	7	43	20.39	142	94	3,543	2,351	3.12	0.58	0.85	0.09	8.54	3.08
June 2001													
A1	7	13	4.68	32	13	800	327	2.16	0.50	0.85	0.11	3.56	1.12
A2	7	21	1.86	34	8	861	195	2.84	0.18	0.94	0.04	5.67	0.63
A3	3	18	1.15	66	47	1,642	1,176	2.38	0.19	0.82	0.08	4.37	0.53
B1	1	33	9.42	98	59	2,443	1,474	2.98	0.28	0.87	0.05	7.07	1.37
B2	4	28	8.04	78	36	1,938	905	2.81	0.30	0.85	0.04	6.25	1.35
C1	12	31	9.27	92	42	2,294	1,048	2.88	0.37	0.86	0.06	6.60	1.61
C2	3	32	17.90	71	53	1,775	1,331	2.99	0.66	0.90	0.00	7.16	3.13
D1	3	14	2.52	39	11	983	277	2.15	0.43	0.82	0.11	3.50	0.87
D2	3	16	3.46	31	10	767	260	2.51	0.13	0.91	0.05	4.40	0.58
R	7	27	13.90	72	62	1,793	1,557	2.83	0.42	0.91	0.06	6.20	2.03

Cluster Analysis

Patterns of infaunal similarity among stations were examined with cluster analysis. Cluster analysis excluded those taxa that were rare in samples or that were redundant (i.e., had an LPIL designation except for *Mediomastis* [LPIL] and *Tellina* [LPIL]). Most taxa included in the cluster analysis were polychaetes (42 taxa), followed by bivalves (17), various crustaceans (8), and gastropods (7).

When examined over both surveys, normal cluster analysis produced five groups (Groups A through E) of stations (samples) that were similar with respect to species composition and relative abundance. Station Groups B and C mostly included the same stations; Station Group C (33 stations) was composed exclusively of September samples, and Group B (39 stations) had mostly June samples. Groups A (23 stations), E (27 stations), and D (4 stations) included samples from both September and June.

Group A stations yielded high numbers of certain taxa that were relatively rare at other stations, including the burrowing amphipods *Acanthohaustorius intermedius*, *Bathyporeia parkeri*, and *Metharpinia floridana*. Overall, Group A stations were relatively depauperate. Sediments were sand at 75% of Group A stations, with remaining stations containing slightly gravelly sand. Station Groups B and C included stations with measurable gravel and yielded the greatest numbers of overall numerical dominants, particularly the bivalves *Chione cancellata*, *Crassinella lunulata*, *Crassinella martinicensis*, and *Tellina* (LPIL), gastropod *Caecum cooperi*, and polychaetes *Goniadides carolinae*, *Mediomastus* (LPIL), *Protodorvillea kefersteini*, and *Sphaerosyllis piriferopsis*. Certain Group C (September) stations yielded several taxa that were rare or absent in other station groups, including the bivalves *Anomia simplex* and *Pitar fulminatus*, gastropod *Calyptraea centralis*, and polychaetes *Dentatisyllis carolinae*, *Eunice unifrons, Exogone dispar, Mediomastus californiensis*, *Parapionosyllis longicirrata*, and *Sabellaria vulgaris*. Group D included four stations with variable sediments that were relatively depauperate, but did contain relatively high numbers of taxa that were otherwise rare in samples, including the bivalve *Atrina seminuda,* gastropod *Atys sandersoni*, and polychaete *Nereis succinea*. Group E included muddy sand and pure sand stations that yielded taxa that were rare or absent at other stations, especially at stations with measurable gravel. Taxa collected primarily from muddy sand Group E stations included the bivalve *Lucina radians* and polychaetes *Magelona* sp. H, *Paraprionospio pinnata*, and *Scoletoma verrilli*. Group E stations with pure sand were relatively depauperate but did yield sand taxa such as the amphipod *Eudevenopus honduranus* and polychaete *Armandia agilis*.

Figure 6-15 shows the spatial distribution of stations grouped by normal analysis of infaunal data. Station Group A mostly included stations in Areas A1, A2, and A3 and also included a few stations from the southern portion of the study area. Station Groups B and C mostly included stations in the central part of the study area, primarily Areas B1, B2, C1, and C2. Group D stations were located at the southernmost portion of the study area (Areas D1, D2, and Adjacent Station 7). Group E stations were scattered throughout the study area, but were most concentrated in Area A2.

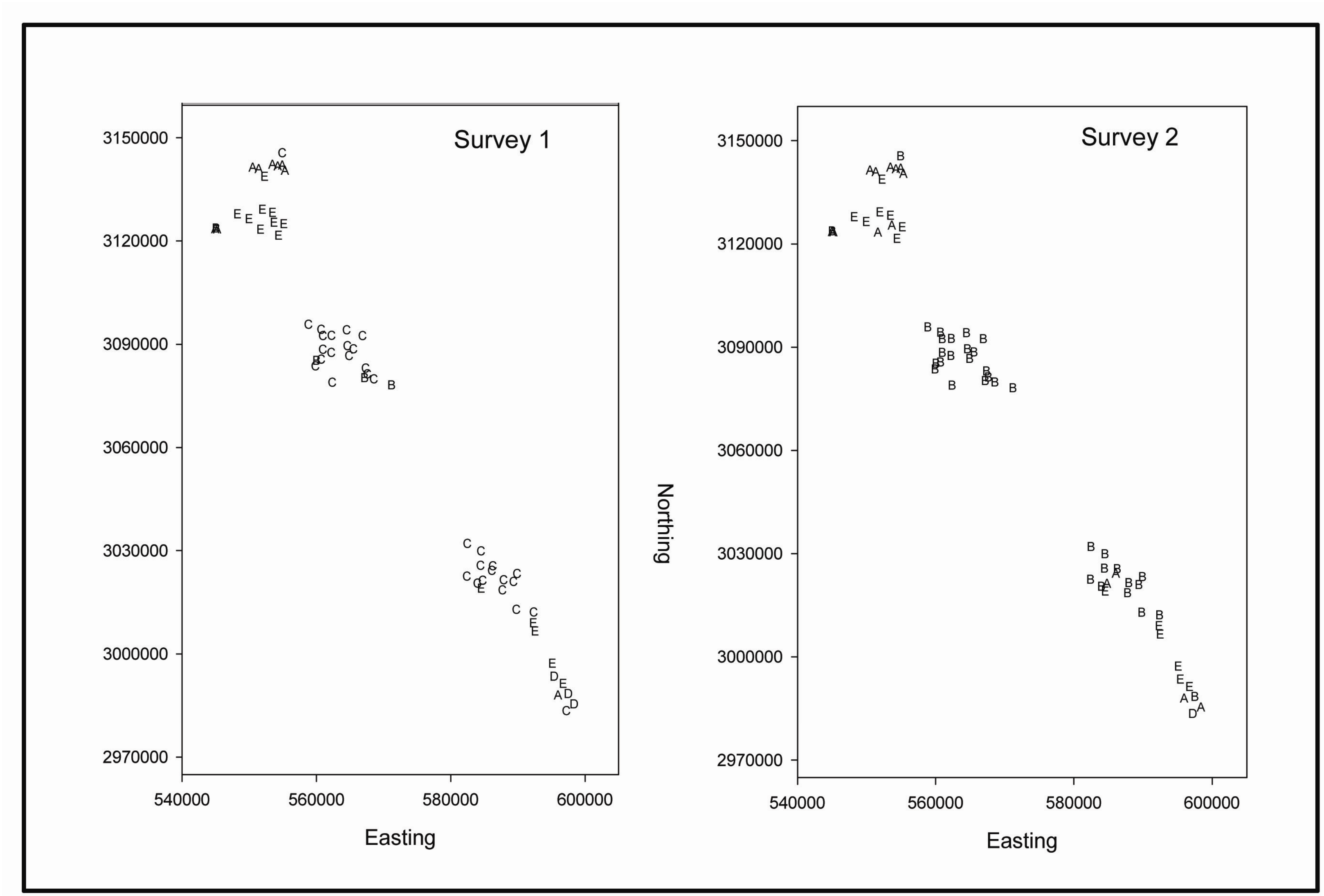

Figure 6-15. Station groups (A to E) based on normal cluster analysis of infaunal samples collected during September 2000 Survey 1 and June 2001 Survey 2 in the nine sand resource areas and adjacent stations offshore central east Florida.

Inverse cluster analysis examining both the September and June surveys resulted in four groups of taxa (Groups 1 through 4) that reflected their co-occurrence in sand resource area samples (Table 6-7). Many infauna included in the overall cluster analysis were relatively rare and heterogeneously distributed across sand resource area stations, and these taxa were not included in the four species groups clearly defined by the inverse analysis.

Table 6-7. Infaunal species groups resolved from inverse cluster analysis of all samples collected during the September 2000 Survey 1 and June 2001 Survey 2 in the nine sand resource areas and adjacent stations offshore central east Florida.

GROUP 1	GROUP 3
Goniadides carolinae	*Lucina radians*
Crassinella lunulata	*Scoletoma verrilli*
Protodorvillea kefersteini	*Magelona* sp. H
Caecum cooperi	*Dentalium texasianum*
Chione cancellata	*Paraprionospio pinnata*
Crassinella martinicensis	*Semele proficua*
Anadara ovalis	
Ervilia concentrica	
Hemipodus roseus	GROUP 4
Owenia fusiformis	*Exogone lourei*
Podarke obscura	*Caecum johnsoni*
Axiothella sp. A	*Sphaerosyllis piriferopsis*
Ceratonereis mirabilis	*Dentatisyllis carolinae*
Magelona pettiboneae	*Maera caroliniana*
Heteropodarke formalis	*Bhawania goodei*
Arene tricarinata	*Bhawania heteroseta*
Aonides mayaguezensis	*Mediomastus californiensis*
Isolda pulchella	*Sabellaria vulgaris*
	Eunice unifrons
	Pitar fulminatus
GROUP 2	*Parapionosyllis longicirrata*
Metharpinia floridana	*Exogone dispar*
Acanthohaustorius intermedius	*Anomia simplex*
Acteocina candei	*Calyptraea centralis*
Goniada littorea	*Nereis riisei*
Eudevenopus honduranus	*Anadara transversa*
Armandia agilis	*Chione grus*
Lucina multilineata	*Kupellonura* sp. A
Bathyporeia parkeri	*Opisthodonta* sp. B
	Eumida sanguinea

Species Group 1 included taxa collected from stations with measurable gravel, located primarily in Areas B1, B2, and C1. The most abundant taxa in Group 1 included the bivalves *Chione cancellata*, *Crassinella lunulata*, and *Crassinella martinicensis*, gastropod *Caecum cooperi*, and polychaetes *Goniadides carolinae* and *Protodorvillea kefersteini*. Group 2 taxa were most abundant at sand stations and at a few stations with measurable mud, particularly in Areas A1 and A2, and included the amphipods *Acanthohaustorius* *intermedius*, *Bathyporeia parkeri*, *Eudevenopus honduranus*, and *Metharpinia floridana* and polychaetes *Armandia agilis* and *Goniada littorea*. Species Group 3 included taxa predominantly from muddy sand stations, and included the bivalves *Lucina radians* and *Semele proficua*, polychaetes *Magelona* sp. H, *Paraprionospio pinnata*, and *Scoletoma verrilli*, and scaphopod *Dentalium texasianum*. Species Group 4 included taxa abundant at stations with gravel bottoms, particularly in Area B1 during September, and included the amphipod *Maera caroliniana*, bivalves *Anomia simplex* and *Pitar fulminatus*, gastropods *Caecum johnsoni* and *Calyptraea centralis*, and polychaetes *Dentatisyllis carolinae*, *Eunice unifrons*, *Exogone lourei*, *Parapionosyllis longicirrata*, and *Sphaerosyllis piriferopsis*.

Adjacent stations in the central portion of the study area (R2, R3, R4, and R5) had sediments and infauna similar to stations in their adjacent sand resource areas. Normal analysis therefore grouped these adjacent stations with stations in their adjacent areas. Those adjacent stations with sediment different from most stations in their respective adjacent areas (R1, R6, and R7) yielded different infaunal assemblages, placing these stations in different groups from those in their adjacent sand resource areas.

Canonical Discriminant Analysis

Data collected during the two surveys were analyzed using canonical discriminant analysis to determine which environmental parameters most affected the abundance and distribution of infaunal populations. The first two canonical discriminant axes 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 (CAN1) correlated best with the amount of silt in the benthic grabs (-0.8040) and to a lesser degree with the amount of clay (-0.6479) and station depth (-0.6460). The second canonical variate (CAN2) best correlated with survey/month (0.7803).

6.3.3.2 Soft Bottom Epifauna

Trawl samples yielded a total of 32 taxa and 510 individuals of epifauna. September trawls yielded 329 epifaunal individuals in 25 taxa (Table 6-8), and 90% of these individuals were collected from Areas A1, A2, and A3. The most numerous species collected during September were the mantis shrimp (*Squilla empusa*), swimming crabs *Portunus gibbesii* and *P. spinimanus*, unidentified squids, white shrimp (*Litopenaeus setiferus*), longnose spider crab (*Libinia dubia*), blue crab (*Callinectes sapidus*), and calico box crab (*Hepatus epheliticus*). These eight taxa collectively accounted for 89% of the total epifaunal catch during September.

June trawls yielded 181 epifaunal individuals in 16 taxa (Table 6-9). The most abundant taxa collected during this survey were the sand dollars *Encope michelini* and *Mellita isometra*, longnose spider crab (*Libinia dubia*), and calico scallop (*Argopecten gibbus*). These four taxa collectively accounted for 86%, with the sand dollars from Area B2 contributing 60%, of the total epifaunal catch during June. Except for *E*. *michelini* and longnose spider crab, which were collected from multiple stations, epifaunal taxa were heterogeneously distributed during June.

Table 6-8. Epifauna and demersal fishes collected by mongoose trawl during the September 2000 Survey 1 of the nine sand resource areas offshore central east Florida.

Taxa	A1		A2		A3		B1		B2		C1		C2		D1		D2		Total
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Invertebrates																			
Squilla empusa	32	17	35	18	9	1		1											113
Portunus gibbesii		9	5	5	7	3	1				2				1	1			34
Squid		13		13	2	6													34
Litopenaeus setiferus	11	15	3					4											33
Libinia dubia	16	1	4	1		1													23
Portunus spinimanus		10	3		6	1	1	1	1										23
Callinectes sapidus	8	8	1	1															18
Hepatus epheliticus	12		3			1													16
Argopecten gibbus					1	1		4											6
Renilla sp.	3	1		1		1													6
Mellita isometra												3							3
Podochela sp.																		3	3
Alpheidae			2																2
Cronius ruber								1								1			2
Iliacantha sp.	2																		2
Sicyonia sp.			1			1													2
Aplysia sp.																		1	1
Bryozoa		1																	1
Calappa flammea								1											1
Calappa gallus																1			1
Encope michelini																	1		1
Hypselodoris webbi																	1		1
Luidia senegalensis						1													1
Lytechinus variegatus																1			1
Majidae																	1		1
Fishes																			
Anchoa lyolepis	1			10	60	50	50	500	50		58	2			39	52			872
Cynoscion nothus	125	38	15	16	7	5													206
Centropristis philadelphica	8	24	7	2	12	7		1											61
Stellifer lanceolatus	16	12	5	3	1	5													42
Micropogonias undulatus		16			4	3		3						10		1			37
Selene setipinnis	19	6		1	2	2		3							1				34
Trichiurus lepturus				1				2					21	5		1			30
Prionotus scitulus	1			1	18	5		2											27
Prionotus rubio	11	3	4	1	1														20
Eucinostomus gula					6	9		1											16
Menticirrhus americanus	6	2	5	1				1											15
Etropus crossotus	7	1	3	1			1												13
Sphyraena borealis		1	1	3	1	1	1						4						12
Selene vomer		7							1										8
Harengula clupeola	2		1	2					1										6
Monacanthus hispidus	1				1			1	1								1	1	6
Sardinella aurita											6								6
Anchoa hepsetus	2		3																5
Bothus robinsi															4		1		5
Citharichthys sp.															5				5
Citharichthys spilopterus	1	3			1														5
Larimus fasciatus	3	1			1														5
Opisthonema oglinum	1			2		1							1						5
Arius felis	1	2														1			4
Citharichthys macrops		3			1														4
Narcine brasiliensis	1	2						1											4
Scorpaena		3	1																4
Sphyrna tiburo								4											4
Acanthostracion quadricornis																3			3
Eucinostomus argenteus							2									1			3
Chloroscombrus chrysurus			1	1															2
Cryptotomus roseus																1	1		2
Diplectrum bivittatum					2														2
Diplectrum formosum		1					1												2
Ogcocephalus radiatus		1														1			2
Scomberomorus cavalla				1							1								2
Aluterus monoceros																	1		1
Bairdiella chrysoura																1			1
Chaetodipterus faber							1												1
Chilomycterus schoepfi																1			1
Cynoscion regalis																1			1
Echeneis naucrates																1			1
Gymnura mircrura		1																	1
Haemulon aurolineatum																1			1
Harengula jaguana															1				1
Hippocampus erectus						1													1
Lutjanus synagris						1													1
Ophidion sp.								1											1
Orthopristis chrysoptera								1											1
Rachycentron canadum																1			1
Symphurus diomedianus								1											1
Syngnathus louisianae							1												1
Synodus foetens						1													1
Invertebrate Totals																			
Total Individuals	84	75	57	39	25	17	2	12	1	0	2	3	0	0	1	4	3	4	329
Total Taxa	7	9	9	6	5	10	2	6	1	0	1	1	0	0	1	4	3	2	25
Fish Totals																			
Total Individuals	206	127	46	46	118	91	57	522	53	0	65	2	26	15	50	67	4	1	1,496
Total Taxa	17	19	11	15	15	13	7	14	4	0	3	1	3	2	5	14	4	1	53
Fish and Invertebrate Totals																			
Grand Total Individuals	290	202	103	85	143	108	59	534	54	0	67	5	26	15	51	71	7	5	1,825
Grand Total Taxa	24	28	20	21	20	23	9	20	5	0	4	2	3	2	6	18	7	3	78

Table 6-9. Epifauna and demersal fishes collected by mongoose trawl during the June 2001 Survey 2 of the nine sand resource areas offshore central east Florida.

Species	A1		A2		A3		B1		B2		C1		C2		D1		D2		Total
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
Invertebrates																			
Encope michelini									35	31			2		2			4	74
Mellita isometra									18	25									43
Libinia dubia	5		3	7		6		1											22
Argopecten gibbus		2					15												17
Podochela sp.								1	1	5									7
Arca zebra						3				1									4
Luidia senegalensis	3																		3
Portunus gibbesii																		2	2
Portunus sp.	1														1				2
Holothuria sp.														1					1
Luidia clathrata								1											1
Lytechinus variegatus								1											1
Octopus sp.													1						1
Ophioderma sp.								1											1
Squilla empusa			1																1
Sicyonia sp.	1																		1
Fishes																			
Synodus foetens	2		9	1	4	3													19
Bothus ocellatus																	5		5
Bothus robinsi							1			1							1	2	5
Trachinocephalus myops																		5	5
Sphoeroides spengleri																4			4
Cryptotomus roseus																3			3
Etropus crossotus					1	2													3
Prionotus scitulus							1	2											3
Canthigaster rostrata																2			2
Citharichthys spilopterus																	1	1	2
Diplectrum formosum							1	1											2
Monacanthus hispidus																2			2
Acanthostracion quadricornis																1			1
Aluterus scriptus						1													1
Centropristis philadelphica		1																	1
Chaetodon sedentarius																1			1
Citharichthys macrops	1																		1
Hemipteronotus novacula									1										1
Prionotus sp.	1																		1
Sparisoma sp.																1			1
Synodus sp.															1				1
Invertebrate Totals																			
Total Individuals	11	4	5	9	1	11	16	7	55	64	1	2	4	3	4	2	1	8	181
Total Taxa	5	2	3	2	1	3	2	6	4	5	1	1	3	2	3	1	1	3	16
Fish Totals																			
Total Individuals	4	1	9	1	5	6	3	3	1	1	0	0	0	0	1	14	7	8	64
Total Taxa	3	1	1	1	2	3	3	2	1	1	0	0	0	0	1	7	3	3	21
Fish and Invertebrate Totals																			
Grand Total Individuals	14	3	13	8	5	15	18	8	55	63	0	0	3	1	4	14	7	14	245
Grand Total Taxa	7	2	3	2	2	5	4	7	4	5	0	0	2	1	3	7	3	5	37

6.3.3.3 Soft Bottom Demersal Fishes

Trawl samples yielded a total of 63 taxa and 1,560 individuals of demersal fishes. September trawls yielded 1,496 fishes in 53 taxa (Table 6-8). The most numerous species were dusky anchovy (*Anchoa lyolepis*), silver seatrout (*Cynoscion nothus*), rock sea bass (*Centropristis philadelphica*), star drum (*Stellifer lanceolatus*), and Atlantic croaker (*Micropogonias undulatus*). These five species collectively accounted for 81% of the total fish catch during September. The largest catches were made in Areas B1, A1, and A3. Trawl catches averaged 83.1 fishes per haul and ranged from 522 individuals in Trawl 2 from Area B1 to 0 individuals in Trawl 2 from Area B2. The total number of fish taxa per trawl ranged from 19 in Trawl 2 from Area A1 to 0 in Trawl 2 from Area B2. The average number of fish taxa per trawl was 2.9. Areas A1 and B1 yielded the highest total numbers of fish taxa during September.

June trawls yielded 64 fishes in 21 taxa (Table 6-9). The most abundant taxa were inshore lizardfish *Synodus foetens*, eyed flounder *Bothus ocellatus*, spottail flounder *Bothus robinsi*, and snakefish *Trachinocephalus myops*. These four species collectively accounted for 53% of the total fish catch during June. Trawl catches averaged 3.6 fishes per haul and ranged from 0 individuals per haul at Areas C1 and C2 to 14 individuals in Trawl 2 from Area D1. The number of taxa per area ranged from 0 in Areas C1 and C2 to 7 in Trawl 2 from Area D1 during June.

Cluster analysis of the sample similarity matrix indicated a clear difference in the species composition between Surveys 1 and 2 (Figure 6-16). Species composition varied from the southernmost areas (D1 and D2) to the northernmost areas (A1, A2, and A3). Species composition and abundance of fishes collected in Areas A and B were fundamentally different than the species composition found in Areas C and D. Species such as silver seatrout *Cynoscion nothus*, Atlantic croaker *Micropogonias undulatus*, banded drum *Larimus fasciatus*, and star drum *Stellifer lanceolatus* were most common in September catches made in Areas A and B. In contrast, southern Areas C and D supported a mixture of species including demersal forms such as lizardfishes, flatfishes, and searobins. In Area D, hard bottom associated fishes, including reef butterflyfish *Chaetodon sedentarius*, bluelip parrotfish *Cryptotomus roseus*, and sharpnose puffer *Canthigaster rostrata*, were among the species caught.

6.3.4 Hard Bottom

Appendix E provides information and figures concerning hard bottom in the sand resource sites and throughout the study area based on existing information. The following two subsections concerning hard bottom epibiota and demersal fishes discuss results and provide figures based on the biological field surveys for this study.

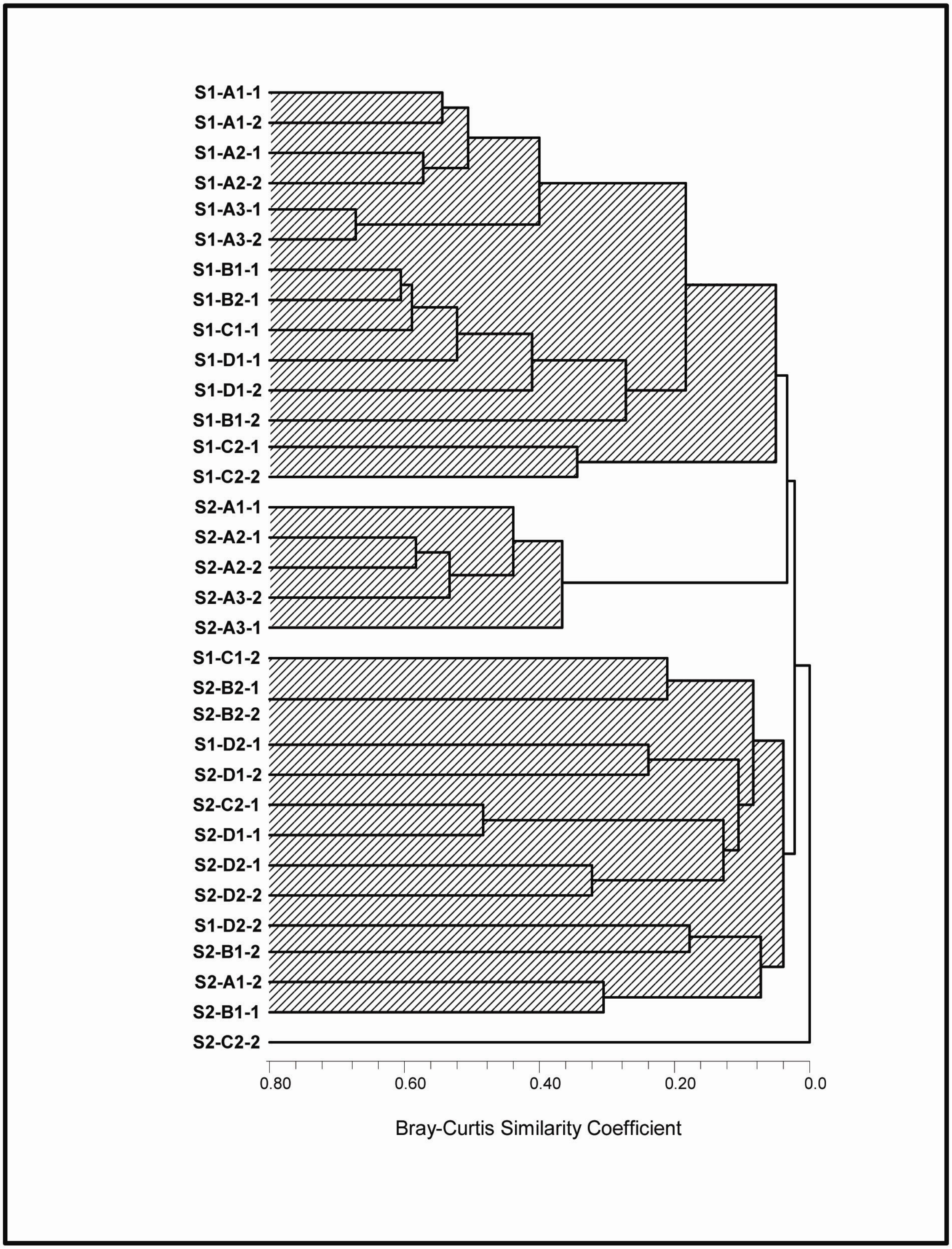

Figure 6-16. Dendrogram of all trawl samples collected for epifauna and demersal fishes during the September 2000 Survey 1 and June 2001 Survey 2 of the nine sand resource areas offshore central east Florida.

6.3.4.1 Hard Bottom Epibiota

The southern hard bottom transect extended from slightly south of Area D2 to slightly east of Area C2 within a depth stratum that averaged 24 m (Figures 6-17 through 6-19). Hard bottom was present discontinuously along much of the transect. Outcrops of varying relief were observed in and around Areas D1 and D2, between Areas D1 and C2, and east of Area C2. Along the transect, 38% was identified as hard bottom and 62% as sand. Although hard bottom profiles ranged from high to low relief along the entire transect, epibiota, particularly octocorals, exhibited a marked south to north trend in density and species composition. Numbers of octocoral taxa and their observed densities decreased with increasing latitude. Table 6-10 lists epibiota observed along the entire transect. Appendix F4 (Photos 1 to 44) provides still images taken along the transect.

Conspicuous epibiota observed along the transect consisted of algae, sponges, octocorals, stony corals, mollusks, and ascideans. In the southern portion of the transect, octocorals (*Iciligorgia schrammi*, *Muricea* spp., *Pseudopterogorgia* spp., and *Swiftia exserta*) were observed on most exposed hard bottom (Appendix F4, Photos 2 to 4). Large sponges including *Ircinia* sp. and *Spheciospongia* sp. also occurred in this area along with calcareous algae (*Halimeda* spp.), hydrozoans, and ascideans (*Eudistoma* sp.). Some stony corals were present but colonies were too small to discern in video and most still photographs (see Appendix F4, Photo 5). Higher relief (1.5 to 2 m) features supported the highest observed densities of octocorals (see Appendix F4, Photos 6 to 10). On the high relief feature south of Area D2, octocorals were large and very dense. Octocoral density and species richness declined in Area D1. In the center of Area D2 (Figure 6-17) there was a transect segment where medium to low relief hard bottom was covered by dense stands of *Sargassum* algae (Appendix F4, Photos 15 and 16). Hard bottom north of Area D1 and in Area D2 was covered with algae, sponges, hydrozoans, ascideans, and sparse octocorals (Appendix F4, Photos 19 to 25). Eventually an algal-sponge assemblage predominated on outcrops, regardless of relief. Near the end of the transect, to the east of Area C2 (Figure 6-19), hard bottom was frequently covered by a layer of sediment (Appendix F4, Photos 35 and 36) and epibiota consisted primarily of algae such as *Dictyota* spp. (Appendix F4, Photo 37). The octocoral *Lophogorgia* sp. was the only conspicuous octocoral observed north of Area D2 (Appendix F4, Photos 39 and 40). Large sponges were occasionally observed along this segment of the transect (Appendix F4, Photo 43).

To characterize hard bottom habitats in the northern study area, eight target sites were chosen in the vicinity of Areas B1 and B2 to perform drift transects with the camera sled (Figure 6-20). Target sites were selected using information obtained from local fishers, researchers (F. Vose, 2002, pers. comm., FMRI), and charts. Hard bottom surveyed along these northern transects ranged from low relief areas totally or partially covered by sediment to medium relief undercut ledges supporting dense epibiotal assemblages. Epibiota observed was composed of species similar to those observed near Area C2 on the southern transect. Algae, sponges, hydrozoans, the octocoral *Lophogorgia* sp., and stony corals were most frequently observed.

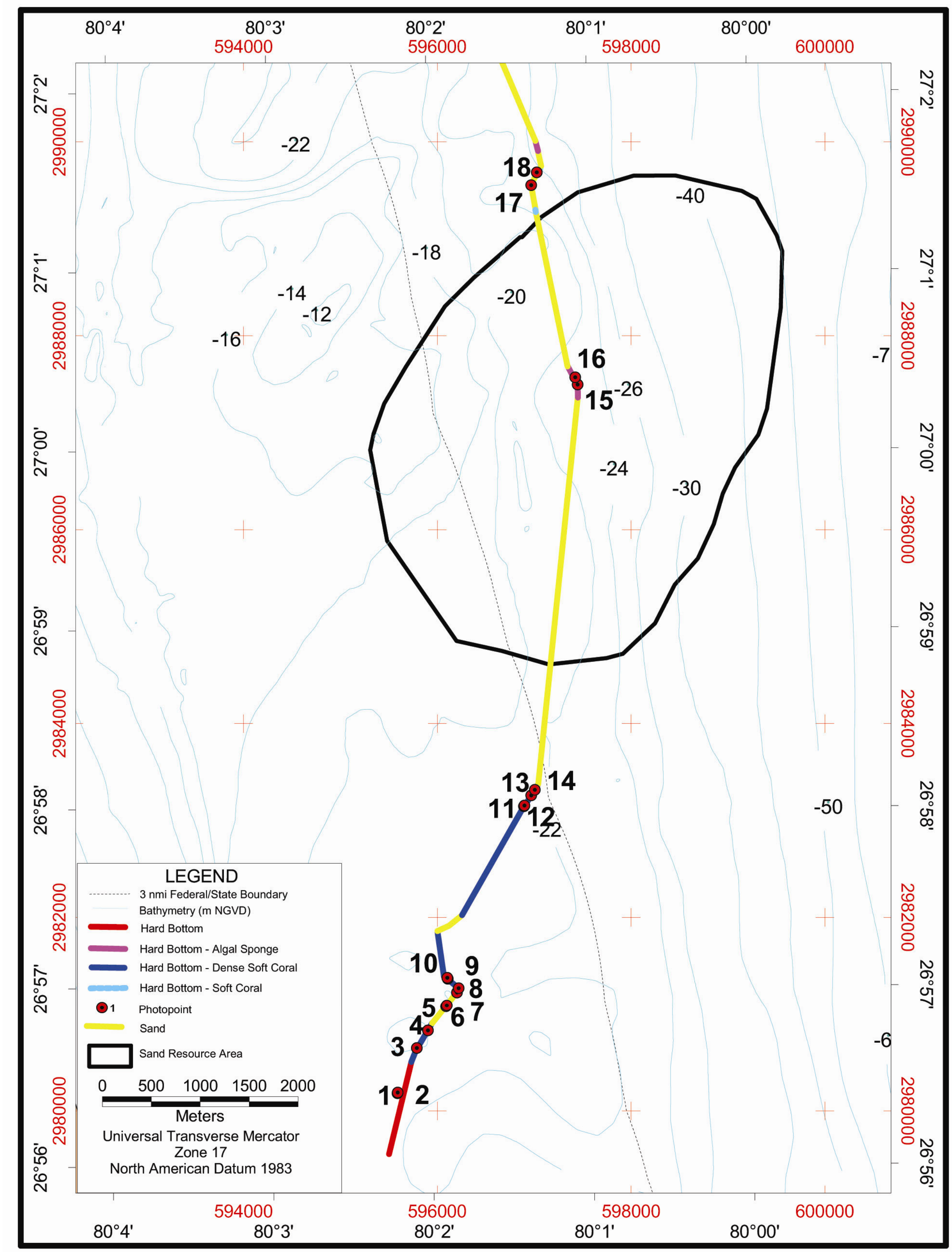

Figure 6-17. Hard bottom video and still photographic transect relative to Sand Resource Area D2.

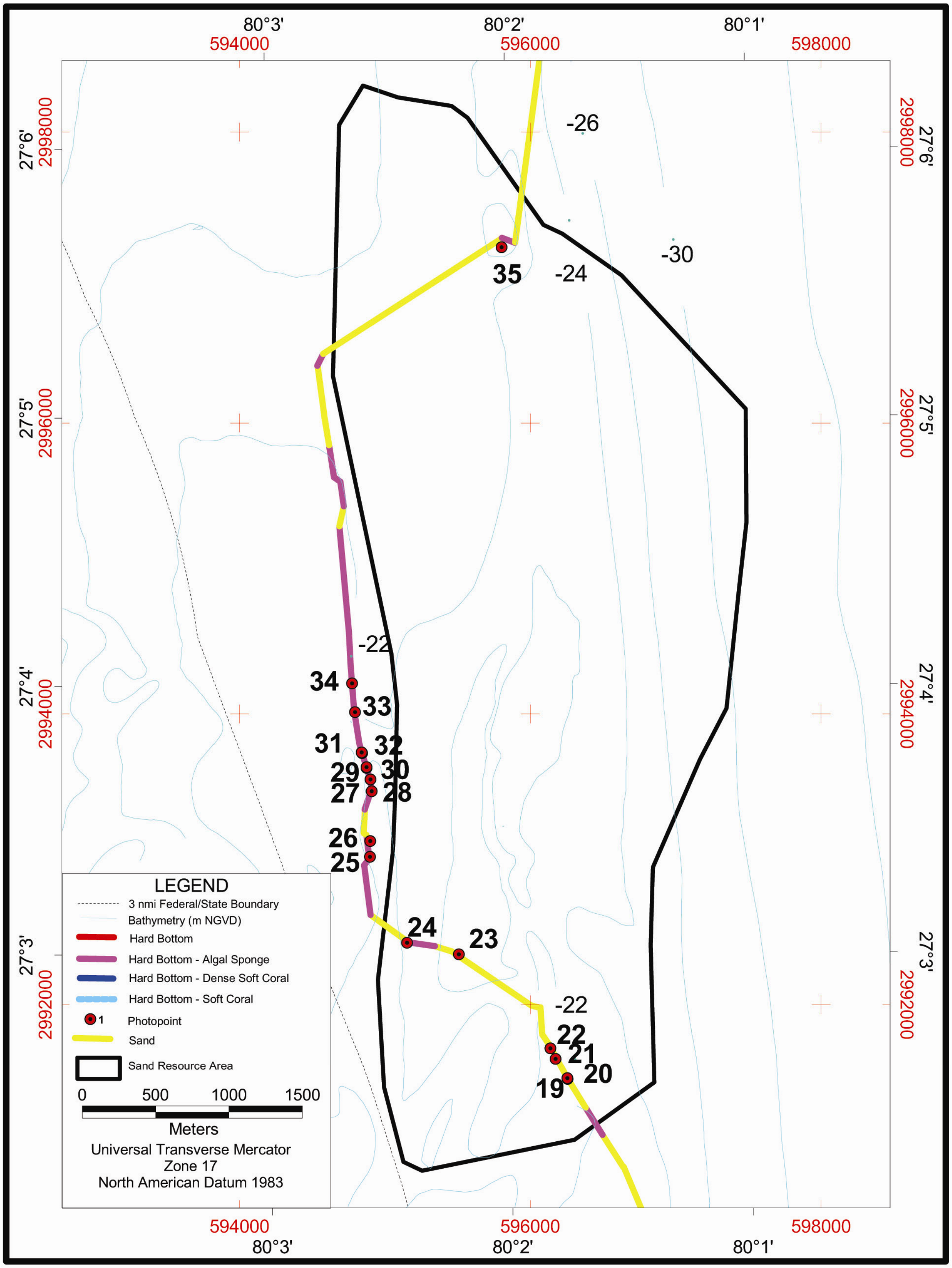

Figure 6-18. Hard bottom video and still photographic transect relative to Sand Resource Area D1.

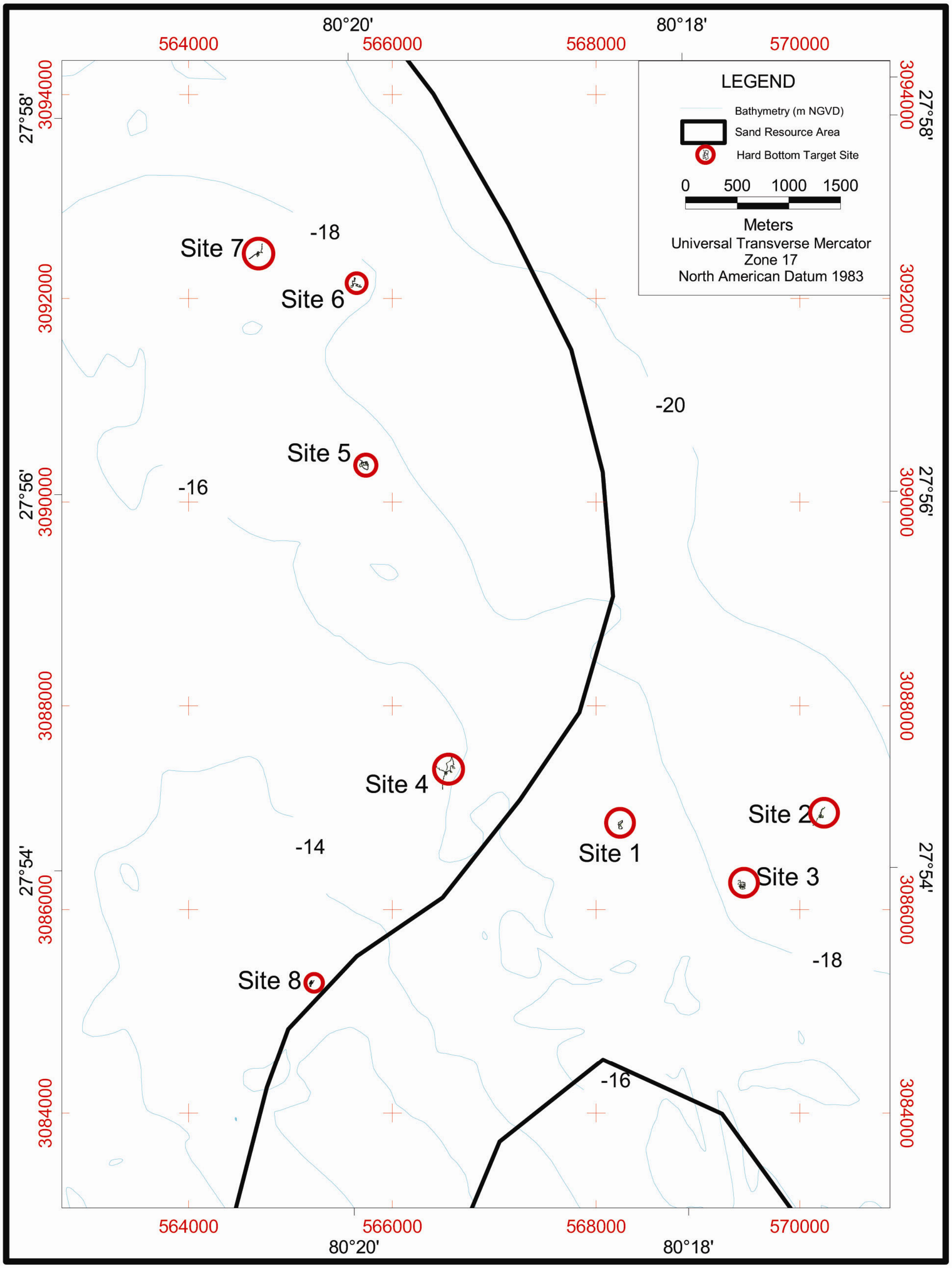

Figure 6-19. Hard bottom video and still photographic transect relative to Sand Resource Area C2.

Table 6-10. Conspicuous epibiota observed in video and still images collected during southern (April 2002) and northern (October 2002) hard bottom surveys.

Group and Taxa	Southern Area	Northern Area
Algae		
Avrainvillea sp.	X	
Caulerpa spp.	X	
Dictyota spp.	X	
Gracilaria spp.	X	X
Halimeda spp.	X	X
Padina sp.		X
Sargassum spp.	X	X
Udotea spp.	X	
Sponges		
Agelas spp.	X	
Cinachyra sp.	X	
Cliona sp.	X	X
Iotrochota birotulata	X	
Ircinia sp.	X	
Niphates sp.	X	
Spheciospongia sp.	X	
Octocorals		
Ellisella sp.	X	
Erythropodium caribaeorum	X	
Eunicea spp.	X	
Iciligorgia schrammi	X	
Lophogorgia sp.	X	X
Muricea spp.	X	
Plexaurella spp.	X	
Pseudoplexaura sp.	X	
Pseudopterogorgia spp.	X	
Pterogorgia citrina	X	
Swiftia exserta	X	
Stony (Scleractinian) Corals		
Eusmilia fastigiata	X	
Oculina varicosa		X
Stephanocoenia intersepts	X	
Hydrozoans		
Dentitheca dentritica	X	
Mollusks		
Cassius madagascarensis	X	
Pinna sp.	X	
Echinoderms	X	
Isostichopus sp.	X	
Ascidians		
Didemnidae	X	X
Eudistoma sp.	X	X

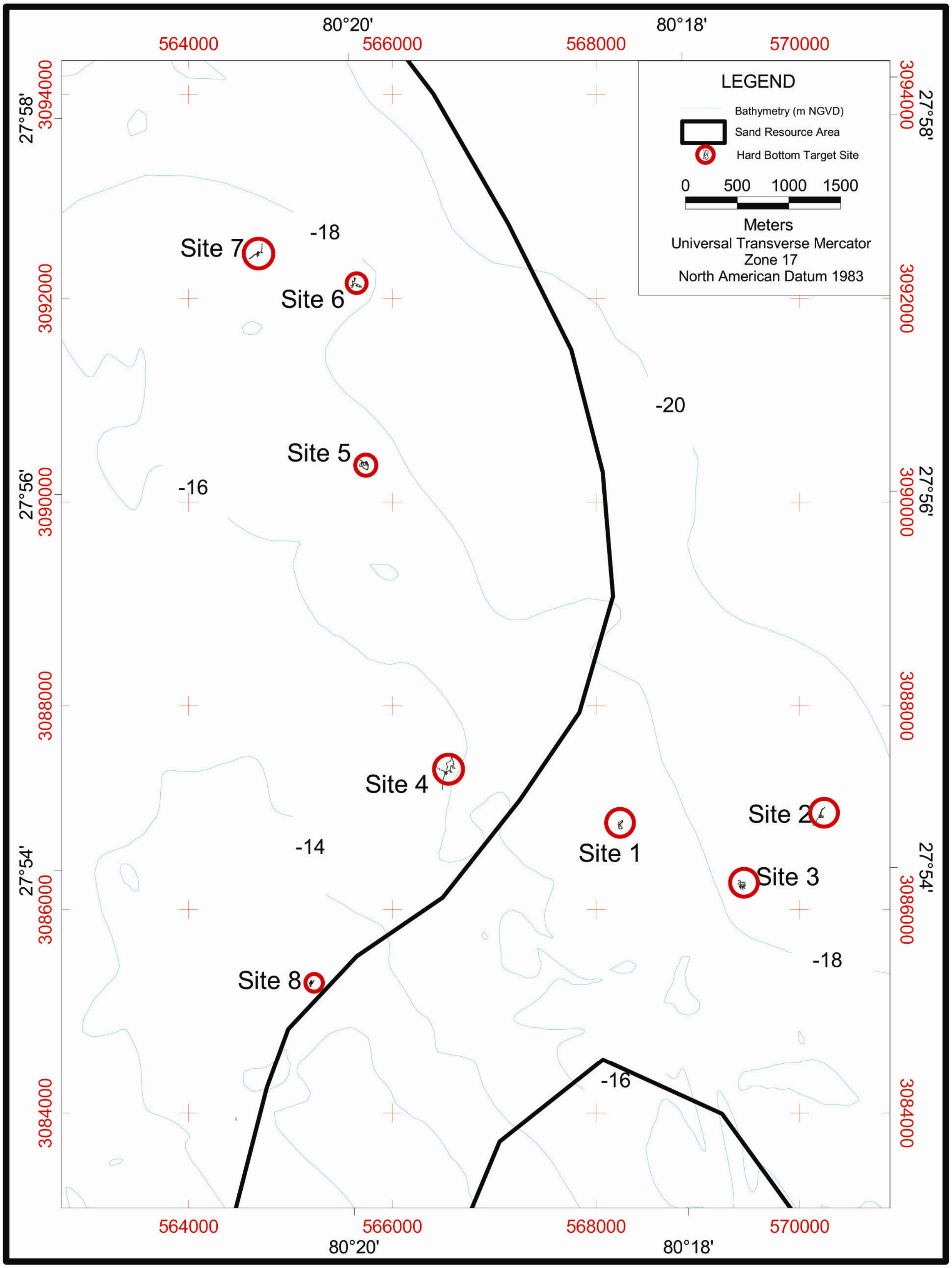

Figure 6-20. Eight hard bottom sites surveyed by video and still cameras relative to Sand Resource Areas B1 and B2.

At Site 1, low and medium relief hard bottom was present (Appendix F4, Photos 45 and 46). Figure 6-21 shows the drift path of the transect, which was mostly hard bottom. Much of the area classified as low relief hard bottom was covered with sand. Hard bottom presence was confirmed by algae, hydrozoans, and octocorals protruding through the sediment veneer along much of this transect. At Site 2 much of the soft bottom between rocky outcrops consisted of very coarse sand and shell hash (Appendix F4, Photo 47). Only a short segment of this transect was classified as hard bottom, and that was partially covered with sand (Figure 6-22; Appendix F4, Photo 48). The camera drift made over Site 3 revealed no hard bottom, only coarse sediment and shell fragments, thus this transect was not shown. Video images from Site 4 revealed hard bottom along much of the transect (Figure 6-23). Hard bottom observed along this transect included medium (Appendix F4, Photo 49) and low relief (Appendix F4, Photos 50, 51, and 52) features. Algae, hydrozoans, octocorals, and sponges were present on the hard bottom. Red and brown algae contributed most to the observed epibiotal cover along this transect.

At Site 5 (Figure 6-24), medium relief hard bottom with an undercut ledge along a portion of its length was present (Appendix F4, Photos 53 and 54). To the north of Site 5, Site 6 (Figure 6-25) also revealed medium relief areas with undercut ledges (Appendix F4, Photo 55). Epibiotal assemblages on hard bottom along this transect ranged from dense stands of algae, hydrozoans, sponges, and stony corals (Appendix F4, Photo 56) to sparse rock (Appendix F4, Photo 57). Site 7 (Figure 6-26) showed medium relief hard bottom ledges and low relief hard bottom on top of the ledges. Algae, sponges, and octocorals also were present at Site 7. The survey of Site 8 did not reveal any hard bottom, only coarse to medium sand with mixed shell fragments. Because there was no hard bottom encountered, the transect from Site 8 was not shown.

6.3.4.2 Hard Bottom Demersal Fishes

Fishes observed during the April 2002 hard bottom survey of the southern area are listed in Table 6-11. Forty-three taxa from 21 families were observed in video or still images along the entire transect. Most fishes recorded were reef-associated forms, with grunts (Haemulidae), seabasses (Serranidae), and wrasses (Labridae) having the highest numbers of species.

Video and still photos from the northern area transects completed during October 2002 yielded 24 fish taxa from 17 families. Most of these taxa also were observed along the southern transect. Some species including sand perch *Diplectrum formosum*, belted sandfish *Serranus subligarius*, twospot cardinalfish *Apogon pseudomaculatus*, and round scad *Decapterus punctatus* were only observed in northern transects.

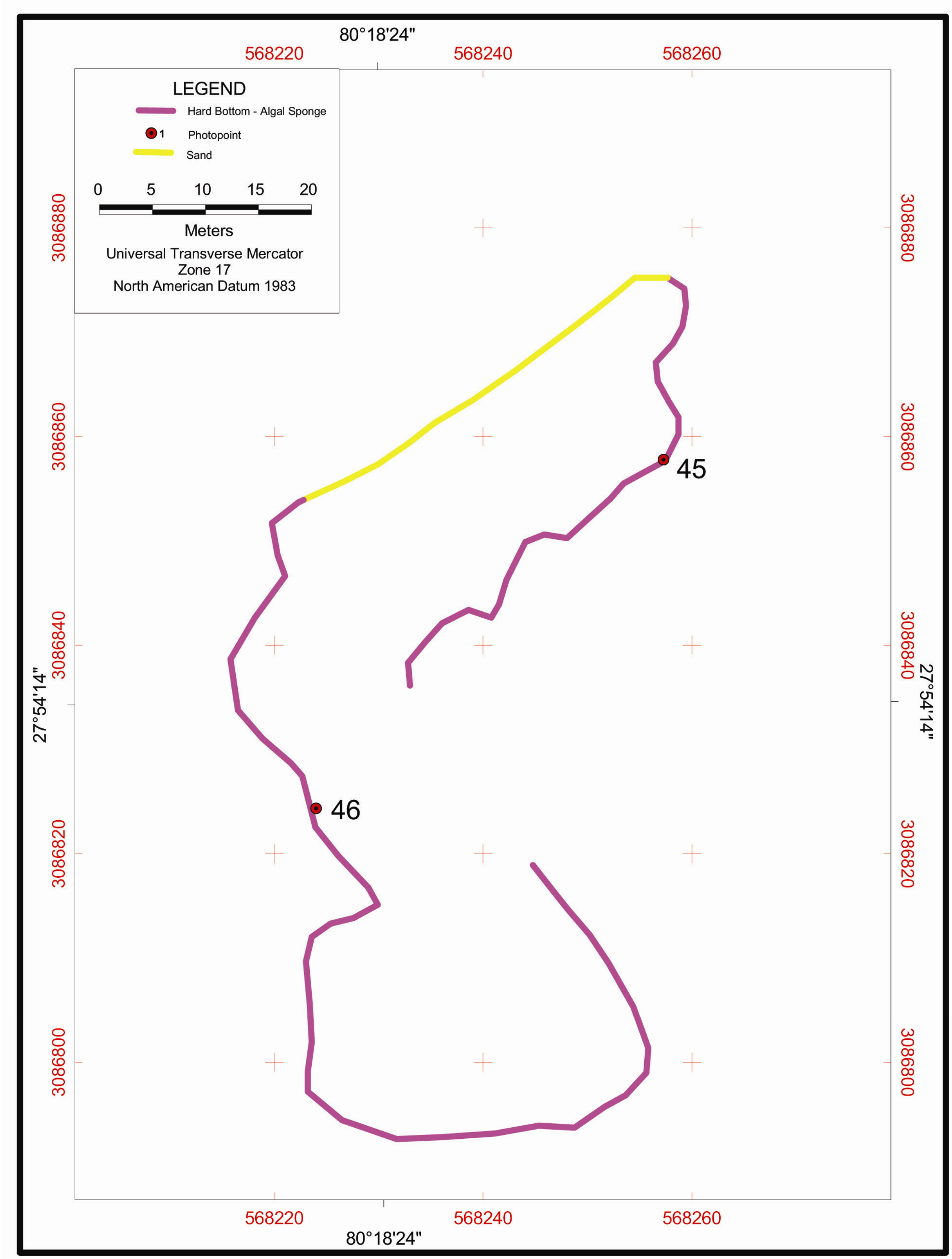

Figure 6-21. Video and still photographic transect surveyed at hard bottom Site 1 during October 2002.

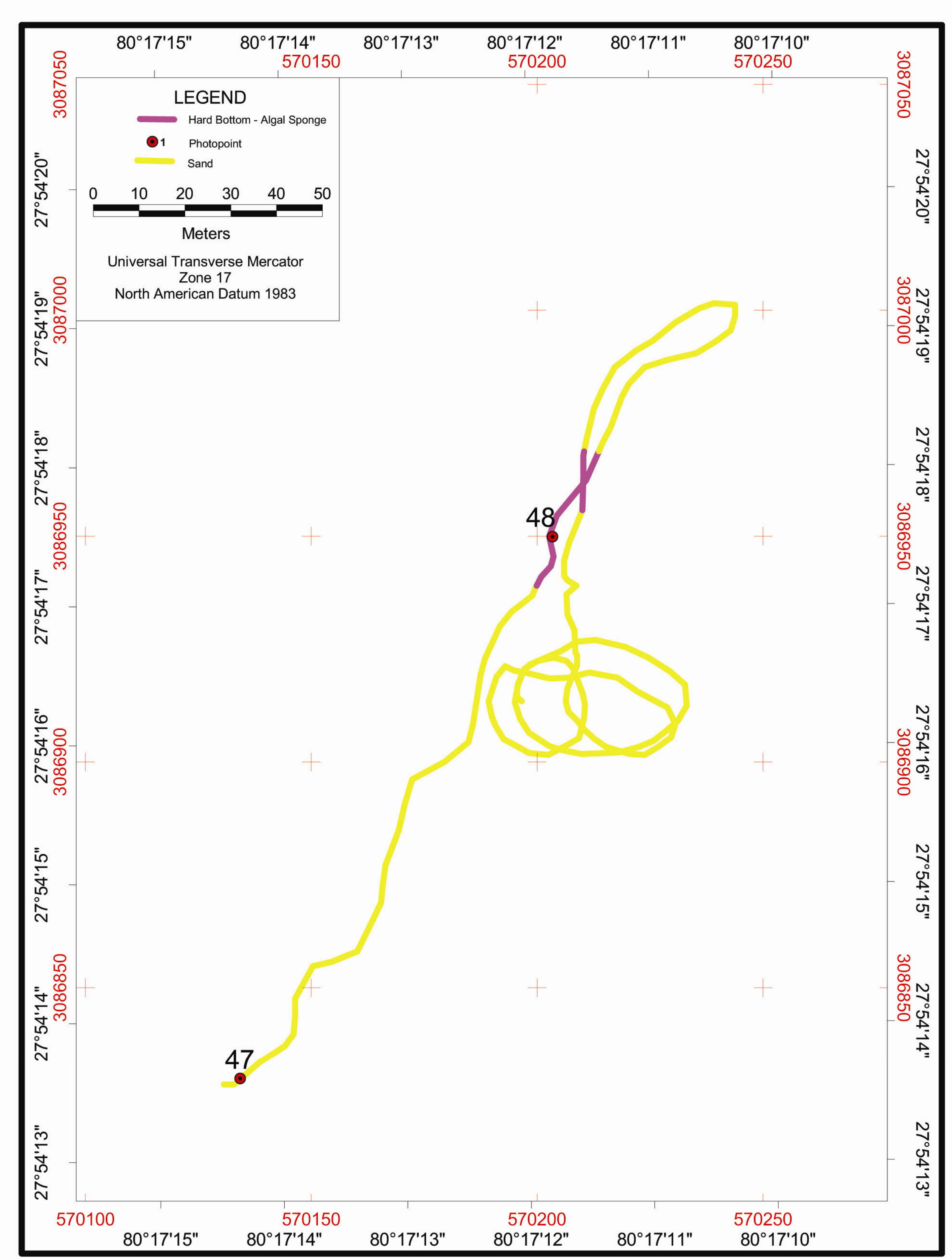

Figure 6-22. Video and still photographic transect surveyed at hard bottom Site 2 during October 2002.

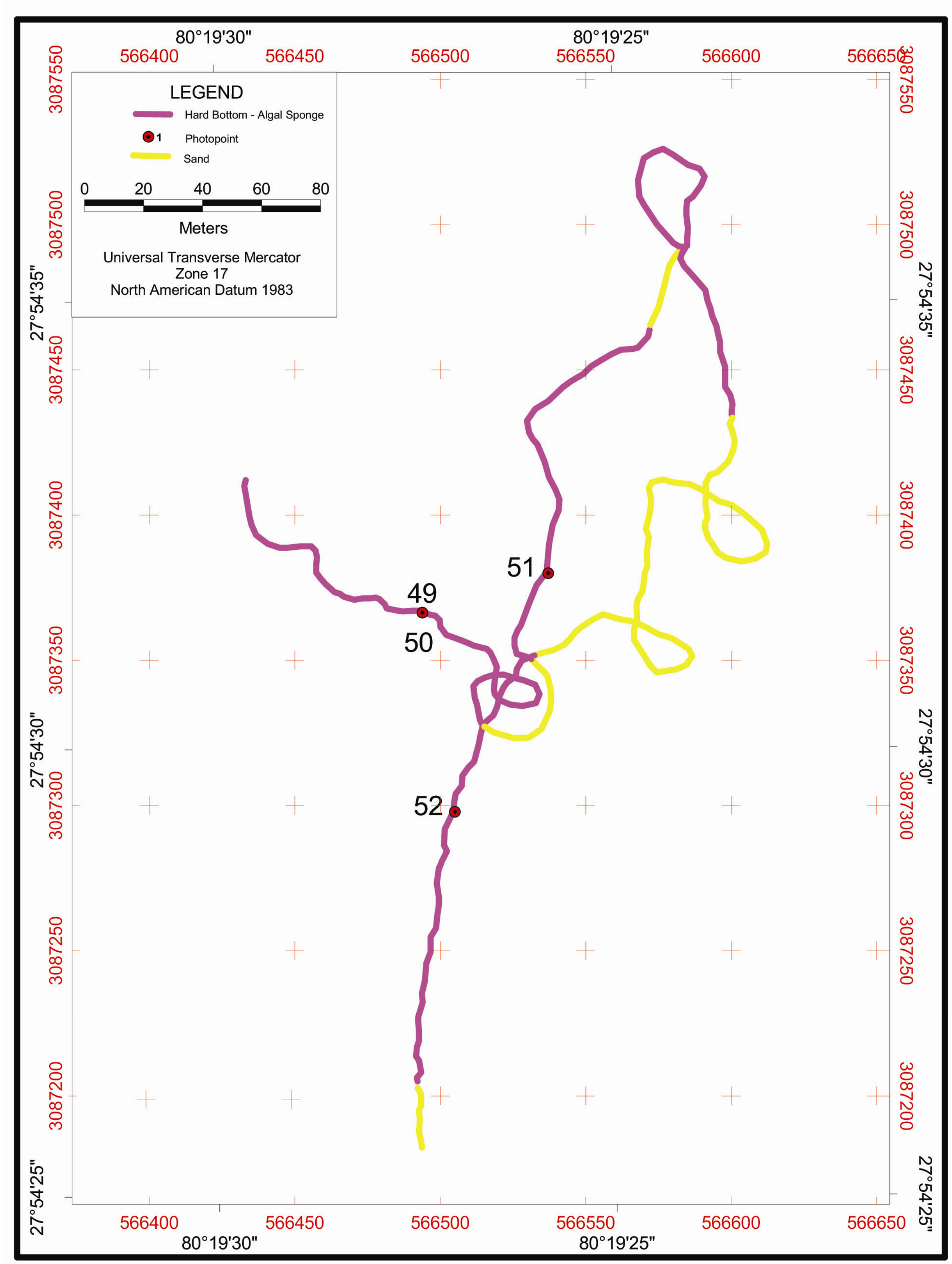

Figure 6-23. Video and still photographic transect surveyed at hard bottom Site 4 during October 2002.

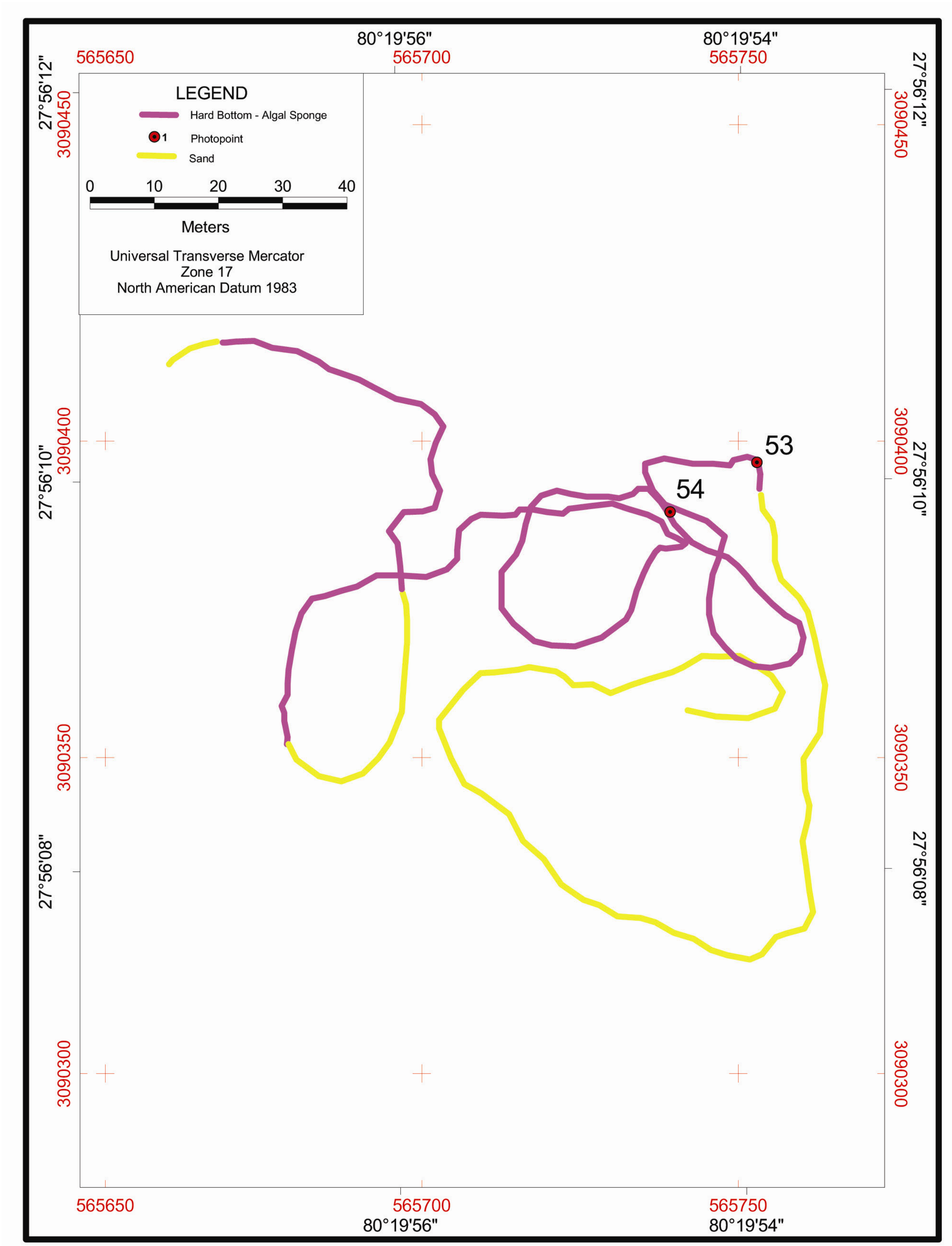

Figure 6-24. Video and still photographic transect surveyed at hard bottom Site 5 during October 2002.

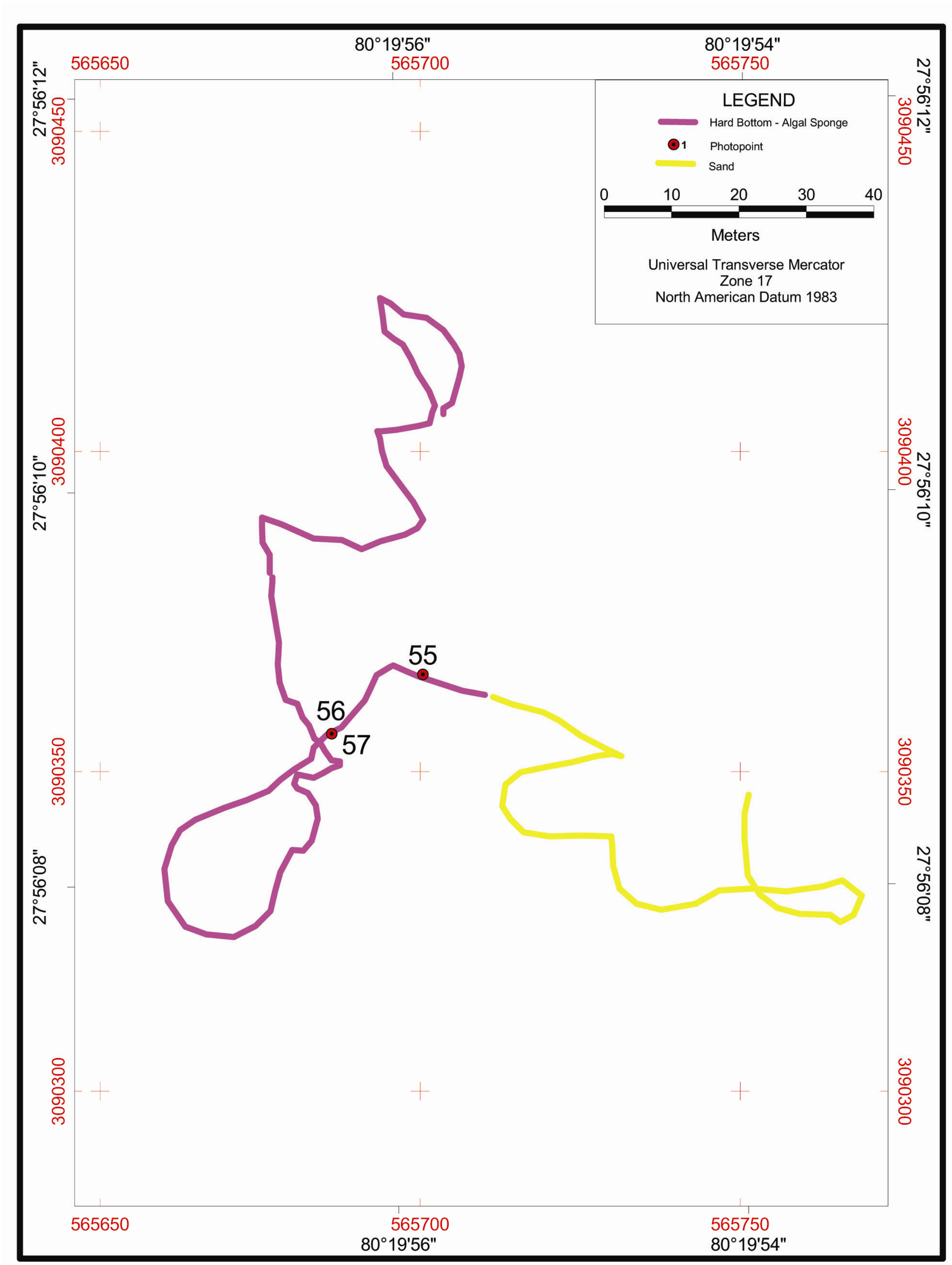

Figure 6-25. Video and still photographic transect surveyed at hard bottom Site 6 during October 2002.

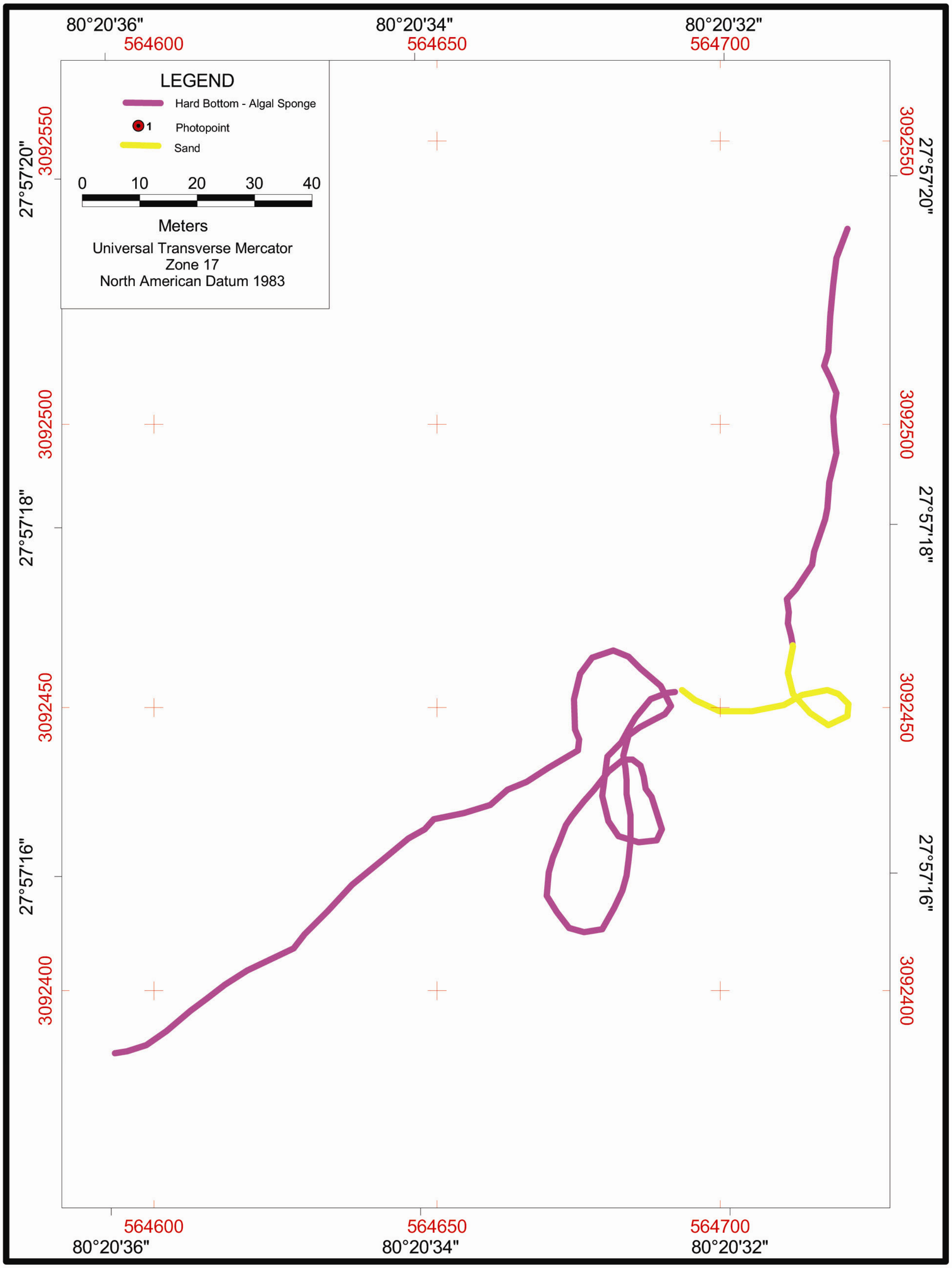

Figure 6-26. Video and still photographic transect surveyed at hard bottom Site 7 during October 2002.

Table 6-11. Fishes observed in video and still images collected during southern (April 2002) and northern (October 2002) hard bottom surveys.

Family	Common Name	Species Name	Southern	Northern
Carcharhinidae	Requeim shark	*Carcharhinus* sp.	x	
Dasyatidae	Southern stingray	*Dasyatis americana*	x	
Serranidae	Black sea bass	*Centropristis striata*	x	x
	Sand perch	*Diplectrum formosum*		x
	Red grouper	*Epinephelus morio*	x	x
	Black grouper	*Mycteroperca bonaci*	x	
	Scamp	*Mycteroperca phenax*	x	
	Whitespotted soapfish	*Rypticus maculatus*	x	
	Belted sandfish	*Serranus subligarius*		x
Priacanthidae	Bigeye	*Priacanthus arenatus*	x	
Apogonidae	Twospot cardinalfish	*Apogon pseudomaculatus*		x
Carangidae	Yellow jack	*Caranx bartholomaei*	x	
	Round scad	*Decapterus punctatus*		x
Lutjanidae	Mutton snapper	*Lutjanus analis*	x	
	Gray snapper	*Lutjanus griseus*	x	x
	Lane snapper	*Lutjanus synagris*	x	
Haemulidae	Black margate	*Anisotremus surinamensis*	x	
	Porkfish	*Anisotremus virginicus*	x	x
	Tomtate	*Haemulon aurolineatum*	x	x
	Cottonwick	*Haemulon melanurum*	x	
	Sailors choice	*Haemulon parra*	x	
	White grunt	*Haemulon plumieri*	x	x
Sparidae	Sheepshead	*Archosargus probatocephalus*	x	x
	Sheepshead porgy	*Calamus penna*	x	
	Porgy	*Calamus* sp.		x
	Silver porgy	*Diplodus argenteus*	x	
Sciaenidae	Cubbyu	*Equetus umbrosus*	x	x
Mullidae	Spotted goatfish	*Pseudupeneus maculatus*	x	x
Chaetodontidae	Spotfin butterflyfish	*Chaetodon ocellatus*	x	x
	Reef butterflyfish	*Chaetodon sedentarius*	x	
Pomacanthidae	Blue angelfish	*Holacanthus bermudensis*	x	x
	Queen angelfish	*Holacanthus ciliaris*	x	
	Gray angelfish	*Pomacanthus arcuatus*	x	x
Pomacentridae	Sunshinefish	*Chromis insolatus*	x	
	Bicolor damselfish	*Stegastes partitus*	x	
	Cocoa damselfish	*Stegastes variabilis*		x
Labridae	Slippery dick	*Halichoeres bivittatus*	x	x
	Yellowhead wrasse	*Halichoeres garnoti*	x	
	Hogfish	*Lachnolaimus maximus*	x	
	Bluehead	*Thalassoma bifasciatum*	x	
Sphyraenidae	Great barracuda	*Sphyraena barracuda*	x	x
Malacanthidae	Sand tilefish	*Malacanthus plumieri*	x	
Gobiidae	Blue goby	*Ptereleotris calliuris*	x	
Acanthuridae	Doctorfish	*Acanthurus chirurgus*	x	x
	Blue tang	*Acanthurus coeruleus*	x	
Scombridae	Mackerels	*Scomberomorus maculatus*		x
Balistidae	Gray triggerfish	*Balistes capriscus*	x	x
Ostraciidae	Scrawled cowfish	*Lactophrys quadricornis*	x	
	Trunkfish	*Lactophrys trigonus*	x	
Diodontidae	Porcupinefish	*Diodon hystrix*	x	
Tetraodontidae	Puffer	*Sphoeroides* sp.		x
Total			43	24

6.4 DISCUSSION

Benthic assemblages surveyed from sand resource areas offshore central east Florida consisted of infauna, soft bottom epifauna and demersal fishes, and hard bottom epibiota and demersal fishes. The assemblages included members of the major invertebrate and vertebrate groups that commonly occur in the study area.

Numerically dominant infauna included numerous polychaetes, mollusks, and crustaceans. Infaunal taxa generally were associated with particular sedimentary habitats. Canonical discriminant analysis of infaunal data indicated that benthic assemblages were affected mostly by the amount of very fine sediments in benthic grabs, primarily silts and to a lesser degree clays. Most animal-sediment associations detected in the data are consistent with observations from other benthic investigations in the western Atlantic (Pearce et al., 1981; Weston, 1988; Barry A. Vittor & Associates, Inc., 1991, 2000; Chang et al., 1992). Infaunal assemblages include taxa that are adapted to particular sedimentary habitats, with foraging effectiveness a key aspect that is closely related to sediment particle size and type (Sanders, 1958; Rhoads, 1974). Very few infaunal taxa in this study were distributed across a broad sedimentary regime. Most taxa were restricted to stations with varied amounts of measurable fines, measurable gravel, or pure sand. Relatively ubiquitous taxa in the sand resource areas during September and June included the bivalve *Crassinella lunulata* and polychaete *Goniadides carolinae*, and these taxa were among the most abundant collected in grab samples.

Stations with surficial sediments containing measurable gravel yielded taxa that were rare at sand and mud stations. Gravel-inhabiting species included the amphipod *Maera caroliniana*, bivalves *Anomia simplex* and *Pitar fulminatus*, gastropods *Calyptraea centralis* and *Caecum johnsoni*, and polychaetes *Dentatisyllis carolinae*, *Eunice unifrons*, *Exogone lourei*, *Parapionosyllis longicirrata*, and *Sphaerosyllis piriferopsis*. Infaunal taxa that were abundant in sand but not in sediments with measurable gravel included the amphipods *Acanthohaustorius intermedius*, *Bathyporeia parkeri*, *Eudevenopus honduranus*, and *Metharpinia floridana*, and polychaetes *Armandia agilis* and *Goniada littorea*. Certain of these sand taxa also were collected from stations with relatively greater silt and clay fractions; however, a distinct mud assemblage was found as well.

The inverse cluster analysis resolved Species Group 3, which included taxa that were found predominantly at muddy sand stations. This group included the bivalves *Lucina radians* and *Semele proficua*, polychaetes *Magelona* sp. H, *Paraprionospio pinnata*, and *Scoletoma verrilli*, and scaphopod mollusk *Dentalium texasianum*. Fine-textured sedimentary habitats generally provide occluded interstitial space and accumulated organic material that limits inhabiting fauna to surface and subsurface deposit-feeding burrowers. Several benthic investigations have found that the amount of very fine sediments (i.e., clay or silt) is a key determinant of infaunal population distributions in soft bottom environments (Sanders, 1958; Nichols, 1970; Flint and Holland, 1980; Weston, 1988). This type of fine sediment assemblage, including many of the same taxa collected in this study, was collected during a previous investigation offshore Cape Canaveral (Barry A. Vittor & Associates, Inc., 1991).

Within sand resource areas, grain size analyses of samples from sediment-only stations were similar to sediments at stations analyzed for both sediments and infauna. Because of high correlation between sediment type and infaunal assemblage composition, it is likely that assemblages within individual sand resource areas are largely homogeneous, particularly Areas A1, A2, A3, B1, B2, C1, and C2, where sediments varied little between stations.

In addition to effects of sediment type on sample composition, cluster analysis of infaunal data detected between-survey differences. Overall mean species richness and individual abundance values were greater in September than in June. These temporal differences are due primarily to life history characteristics of infaunal populations, in which reproduction peaks during warm months and is diminished during cool months (Sastry, 1978).

Normal cluster analysis resulted in Station Groups B (39 stations) and C (33 stations) that were composed of samples collected at gravelly sand stations during September and June, respectively. Between-survey differences at these stations were due primarily to the September presence of species that were largely or completely absent in June samples, such as the polychaetes *Ceratonereis mirabilis*, *Dentatisyllis carolinae*, and *Nereis riisei* and bivalves *Anadara ovalis*, *Anomia simplex*, *Chione cancellata*, *Crassinella martinicensis*, and *Ervilia concentrica*. Unlike stations with measurable gravel, areas of finer sediments were more similar in infaunal composition across surveys. Station Group A (which mostly included sand stations) and Group E (which included sand stations and all stations with measurable mud) included both September and June samples. Sand stations (Group A) yielded burrowing amphipods during both surveys. There were between-survey differences at mud stations, however, mainly because mud-dwelling infauna (Species Group 3) were more abundant in September samples.

In addition to sedimentary habitat and survey month, discriminant analysis indicated that infaunal assemblage differences between stations were correlated somewhat with water depth. Absolute depth is known to affect the composition of benthic assemblages (Day et al., 1971; Flint and Holland, 1980; Tenore, 1985) and is manifest in different infaunal communities at inner-, mid-, and outer-shelf depths at least partly irrespective of sediment type. It is unclear, however, whether infaunal differences were a reflection of station depth or perhaps were due ultimately to sedimentary or hydrologic variation between stations. Except for the northernmost Area A1 (where the shallowest stations were) and southernmost Areas D1 and D2 (where the deepest stations were), station depths were similar throughout most of the study area. Station Group A, composed of stations with similar assemblages, did include the shallowest stations in the study. Group D stations were confined to deeper stations in Areas D1 and D2. The four stations in Group D differed with respect to sediments, including a muddy sand station and a gravelly sand station, suggesting that effects of water depth on assemblages may have been real, and not related primarily to sedimentary habitat. It is possible also that the narrowness of the shelf and proximity of the Gulf Stream to the southern portion of the study area influenced the infaunal community in this area. Near the southern portion of the study area, the inner edge of the Gulf Stream is usually less than 10 km offshore and can influence faunal composition on the inner shelf (Lyons, 1989).

Common epifaunal taxa in the trawls were various decapods, sand dollars, and squids. Individual abundance was dominated by relatively few species during both surveys. The most abundant species collected during September were the mantis shrimp (*Squilla empusa*), iridescent and blotched swimming crabs (*Portunus gibbesii* and *P. spinimanus*, respectively), unidentified squids, white shrimp (*L. setiferus*), longnose spider crab (*Libinia dubia*), blue crab (*Callinectes sapidus*), and calico box crab (*Hepatus epheliticus*). These eight taxa collectively accounted for 89% of the total epifaunal catch during September. The most abundant species collected during June were the sand dollars *Encope michelini* and *Mellita isometra*, spider crab *Libinia dubia*, and calico scallop (*Argopecten gibbus)*. These four taxa collectively accounted for 86% of the total epifaunal catch during June. Most of the common epifaunal taxa collected are widely ranging species that occur in tropical, subtropical, and temperate environments of the western North Atlantic. Many of these common epifaunal invertebrates have been collected previously in the study area, including the calico scallop, calico box crab, swimming crabs, white shrimp, and sand dollar *E. michelini* (Continental Shelf Associates, Inc., 1987).

During September, 90% of all epifaunal individuals were collected from Areas A1, A2, and A3. Epifaunal taxa were heterogeneously distributed during June, except for *E. michelini* and *L. dubia*, which were collected from multiple stations. These between-survey differences in epifaunal distribution may have been due to seasonal changes in water temperature, which is a primary environmental regulator of the distributions of motile epifaunal populations (Cerame-Vivas and Gray, 1966; Wenner and Read, 1982).

Fishes collected by trawling in the nine sand resource areas reflected the transitional regional species pool of central east Florida that includes a complex of tropical, subtropical, and warm temperate taxa (Gilmore, 1995). The fish assemblage found during September in Area A was similar in terms of species composition to that found previously in the Cape Canaveral area (Anderson and Gehringer, 1965; Wenner and Sedberry, 1989). This shelf assemblage is part of the warm temperate/temperate (Carolinean) fauna that generally ranges from Cape Canaveral north to Cape Fear, NC (Wenner and Sedberry, 1989) and is numerically dominated by sciaenids (croakers and drum) and elasmobranchs (sharks and rays). This assemblage gradually changes in a southerly direction from Area A, with warm temperate species dropping out and more subtropical and tropical species occurring towards southern Areas C and D. Species collected in these southern areas were all members of the regional list for the benthic open shelf habitat compiled by Gilmore et al. (1981). Areas C and D yielded fewer individuals and species than the northern sand resource areas, but occurrence of some species suggested the presence of hard bottom. Reef species of tropical origin such as reef butterflyfish (*Chaetodon sedentarius*), tomatate (*Haemulon aurolineatum*), and parrotfishes *Cryptotomus roseus* and *Sparisoma* spp. were collected in Area D2. This indicates that at least some low relief hard bottom was present in the area traversed by the trawl. Had there been high relief features along the tow path, the trawl would have snagged the bottom, and this was not the case.

There were considerable differences between the September and June surveys in the composition, diversity, and numbers of fishes caught by trawling, particularly in the northern areas (Areas A1, A2, A3, and B1). This finding reflects seasonal trends in the occurrence and abundance of fishes in the South Atlantic Bight reported by Wenner and Sedberry (1989). Unfortunately, there are no data available on assemblage structure of demersal fishes in shelf habitats south of Cape Canaveral to compare with data from Areas C and D.

Fish species collected were typical members of the regional ichthyofauna and were common in previous surveys of the study area (Gilmore et al., 1981; Wenner and Sedberry, 1989). A variety of life stages were collected ranging from early juveniles to adults. Most species collected are benthic feeders, relying on epifaunal and infaunal invertebrates as a food source.

Results of the benthic surveys of the sand resource areas agree well with previous descriptions of benthic assemblages residing in shallow shelf waters offshore east Florida. Overall, canonical discriminant analysis indicated that sedimentary habitat most affected the composition of infaunal assemblages. Overall, trawl contents were consistent with historic regional investigations. The 36 trawl samples collected provide a reasonable snapshot of the demersal fish assemblages in and around the sand resource areas.

Video and still photographs were used to characterize hard bottom habitats occurring in water depths similar to those of the sand resource areas. Hard bottom was found in similar water depths of Areas B1, B2, C1, C2, D1, and D2. Regions around Areas A1 and A2 were not surveyed because of persistently poor water clarity. Relief and physiography of the hard bottom features changed with increasing latitude. Higher relief features were observed in the southern survey area than in the northern survey area. A sediment cover over low relief hard bottom was commonly observed along the northern area transects but only occasionally in the southern area.

There has been little documentation of hard bottom and associated epibiota off central east Florida. Moe (1963) described hard bottom areas along the east coast based on interviews with local fishers. Meisburger and Duane (1971) described geological characteristics of portions of the shelf between Jupiter Inlet and Cape Canaveral. The Southeast Area Monitoring and Assessment Program-South Atlantic (2001) mapped all available hard bottom information for the region (also see Appendix E). None of these three studies reported hard bottom in the areas surveyed during this project. Palm Beach County Department of Environmental Resources Management has contracted a detailed shelf-wide survey using laser assisted depth sounding (LADS) (B. Howard, 2003, pers. comm., Palm Beach County Department of Environmental Resources Management). This technology provides high resolution mapping of hard bottom features over large areas, but success of LADS surveys is dependent on consistent water clarity, therefore it is not likely to be viable north of Martin County. Palm Beach County's final maps should encompass the southern portion of the present study area in the vicinity of Areas D1 and D2.

Hard bottom formations surveyed were ledges or outcrops of Anastasia limestone generally arranged in north-south trending outcrops usually forming ledges facing west. All hard bottom supported epibiotal assemblages of varying taxonomic composition. From the qualitative perspective provided by the present hard bottom surveys, species, composition, richness, and cover varied with latitude over the entire study region. Taxonomic richness of conspicuous taxa such as ocotocorals, sponges, and algae was greater in the southern portions of the southern survey transect. Hard bottom outcrops south of Area D2 supported dense accumulations of soft corals of several taxa. These assemblages were similar to those described by Goldberg (1973) for southern Florida and many taxa occur in the Bahamas and Caribbean Sea. Epibiota observed north of Area D1 consisted of low-lying encrusting forms with very few octocoral taxa or individuals present. An epibiotal assemblage of algae, sponges, and hydrozoans was present from this area northward. Algae, particularly red and brown taxa, were most common and represented most of the cover observed north of Area D2.

These findings support the claim that the Jupiter Inlet area represents a northern boundary for many tropical marine species (Briggs, 1974; Jaap, 1984). Other tropical species extend their ranges as far north as North Carolina (Briggs, 1974), but it appears that factors occurring in this area, probably temperature and water clarity associated with the

Gulf Stream and its behavior, influence the ecology and distribution of tropical forms in species-specific fashion.

Because of species richness and composition of octocorals and other sensitive epibiota, the southernmost outcrops are likely to be more susceptible to turbidity, sedimentation, and mechanical damage due to dredging than the assemblages on the northern area hard bottom. Certainly hard bottom assemblages throughout the region are susceptible to these impacts, but the southern areas support species not likely to be well adapted to sedimentation and turbidity. In the northern areas near Areas B1 and B2, there was evidence of regular natural burial of low relief hard bottom in several areas surveyed. There was frequent evidence of partial burial of low relief hard bottom features in the video and still photographs. Algae were among the most common epibiota found in that area, and members of this group are adapted to the dynamic physical situations (Renaud et al., 1997). Similarly, the soft coral *Lophogorgia* sp. was the only commonly observed octocoral north of Area D1. This taxon has been shown to be tolerant of sedimentation in high-energy environments (Gotelli, 1988).

Although the aim of the hard bottom surveys was not to identify and map areas of hard bottom within sand resource areas, hard bottom was discovered inside the boundaries of Areas B1, D1, and D2. This highlights the importance of having site-specific hard bottom surveys conducted prior to any sand mining.