Long-Term Changes in Beach Fauna at Duck, North Carolina

by

R. J. Diaz and J. T. DeAlteris

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Long-term changes in the beach fauna at Duck, North Carolina, were investigated. Twenty-one stations located on three transects on the oceanside and twenty-four stations located on three transects on the sound side were sampled seasonally from November 1980 to July 1981. The data collected in this study were compared to a previous study conducted in 1976 (Matta, 1977) to investigate the potential effects of the construction of the CERC Field Research Facility pier on the adjacent beaches. No effects on the benthic

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*) fauna were found. Changes observed in the benthic macrofauna on the ocean beaches were well within the range attributable to the natural variation of an open coast system. The ocean beach macrofauna was observed to form a single community migrating on and off the beach with the seasons. On the sound beaches, changes were detected in the benthic macrofauna; however, these were attributed to a salinity increase during the 1981 sampling year.

PREFACE

This report was published to provide coastal engineers the results of an investigation of the long-term changes in the beach fauna adjacent to the Coastal Engineering Research Center's (CERC) Field Research Facility pier at Duck, North Carolina. The work was carried out under CERC's Effects of Construction and Operations of Field Research Facility - Duck, North Carolina, work unit, Environmental Impact Research Program, Environmental Quality Area of Civil Works Research and Development.

The report was prepared by R.J. Diaz and J.T. DeAlteris of DeAlteris Associates, Mathews, Virginia, under CERC Contract No. DACW72-81-C-0002.

A.K. Hurme, Ecologist, Coastal Ecology Branch was the CERC contract monitor for the study, under the general supervision of E.J. Pullen, Chief, Coastal Ecology Branch, and R.P. Savage, Chief, Research Division.

Technical Director of CERC was Dr. Robert W. Whalin, P.E., upon publication of the report.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

LONG-TERM CHANGES IN BEACH FAUNA AT DUCK, NORTH CAROLINA

by
R.J. Diaz and J.T. DeAlteris

I. INTRODUCTION

This report provides additional data on the fauna communities inhabiting coastal beaches, and assesses changes, if any, in beach fauna communities caused by coastal engineering projects. The study area was Duck, North Carolina (Fig. 1), which is the site of a research pier constructed and operated since 1976 by the Coastal Engineering Research Center (CERC). A preconstruction study of the fauna of this area was undertaken by CERC, and the results of this study are reported by Matta (1977).

The study area consisted of both the ocean beach, adjacent to the pier facility, and the sound beach, opposite the pier facility. The ocean beach is a high salinity, high energy environment, and in the preconstruction study, was characterized by three faunistic communities. An *Emerita* community was confined to the swash zone and the inner edge of the surf zone, a *Scolelepis* community ranged from the margin of the surf zone to 50 meters offshore, and a *Parahaustorius* community extended from 50 meters offshore to an undetermined point farther offshore. The sound beach is a low energy, low salinity environment, and in the preconstruction study was also characterized by three distinct faunistic communities. The *Scolecolepides* community extended from about 100 to 300 meters offshore, a *Lepidactylus* community extended from the beach margin to about 100 meters offshore, and a small developing marsh community was also found.

This postconstruction study duplicated the techniques used in the field and laboratory during the preconstruction study. The resulting data set is compared with the results of the preconstruction study to evaluate possible significant changes in the beach fauna adjacent to the CERC Field Research Facility (FRF).

II. METHODS AND MATERIALS

The methods and materials used in the final sampling plan of the 1975-76 study (Matta, 1977) were also followed in this study.

1. Transect Locations.

Three transects were established on both the ocean and sound beaches (Fig. 2). On the ocean beach, transect II was located due east of bench mark 16 and 47 meters north of the pier on the FRF site. Transect I was located 258 meters north of transect II. Transect III was located 305 meters south of transect II.

On the sound beach, transect IV was located 118 meters south of bench mark 64; this site included a small marsh. Transect V was located 34 meters north of bench mark 64 and 152 meters north of transect IV; this site

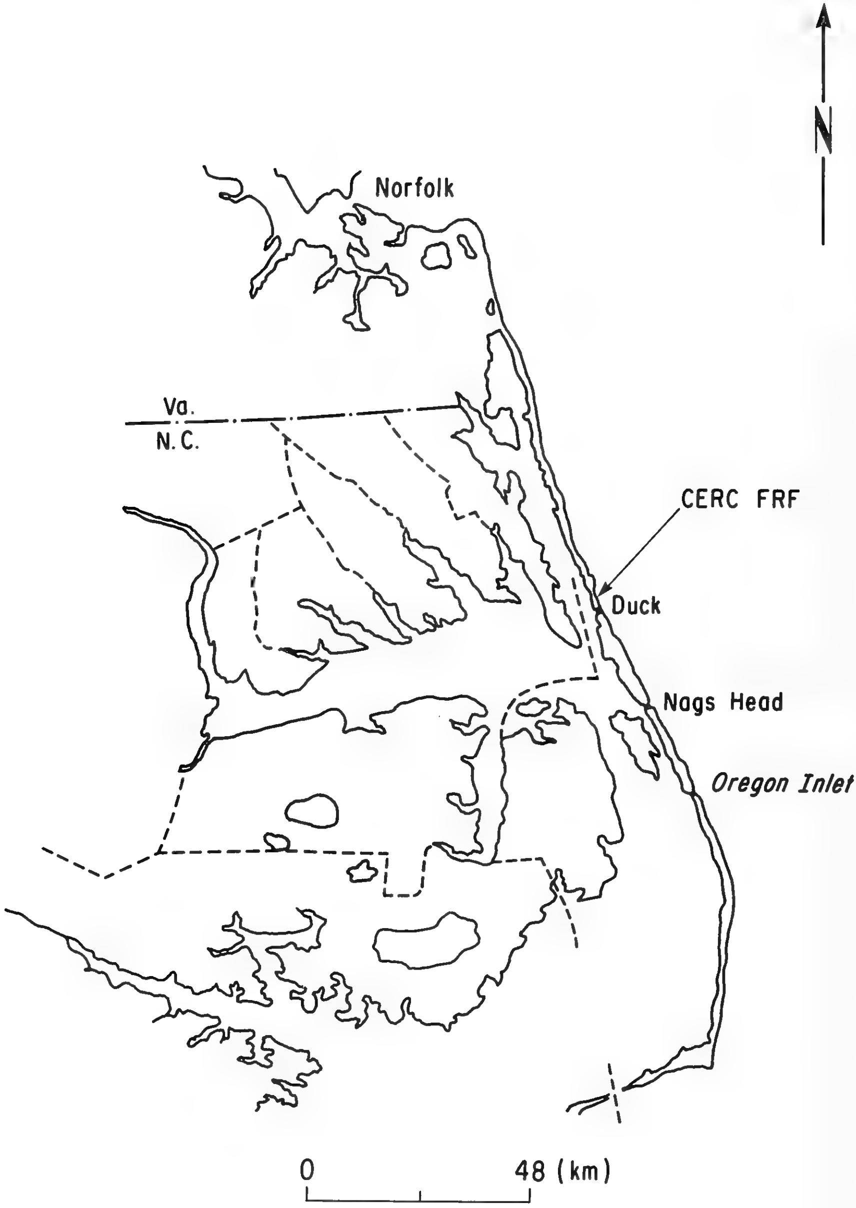

Figure 1. Location of the CERC Field Research Facility.

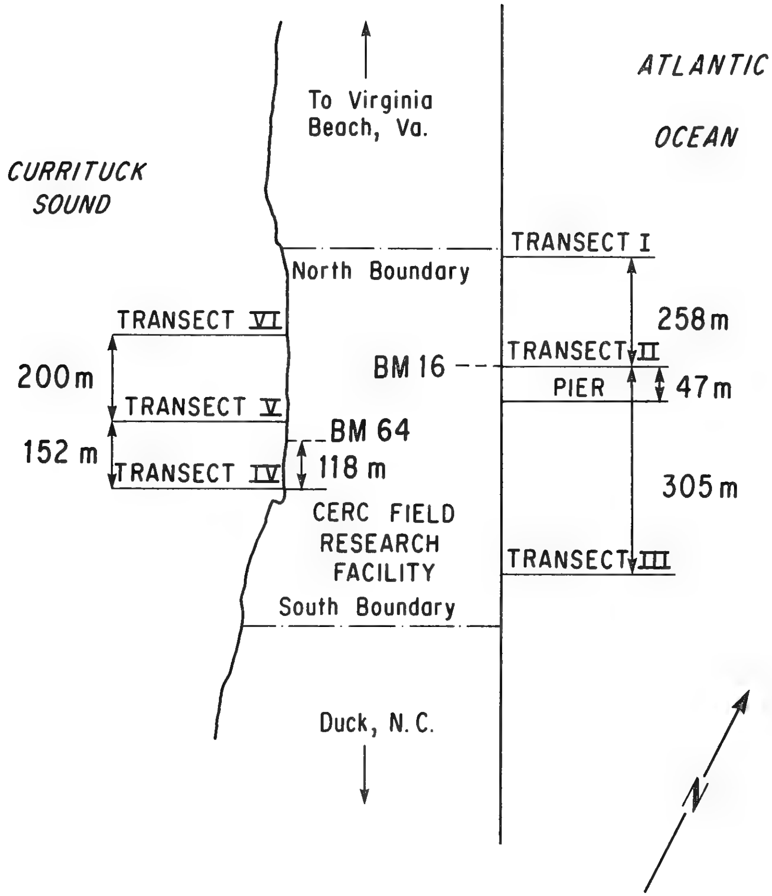

Figure 2. Location of transects on the study site.

contained a shallow east-west depression causing the transect to be in deeper water than the surrounding area. Transect VI was located 200 meters north of transect V in a barren sand area with little slope, which is typical of the sound beach.

2. Sample Locations.

On the ocean beach, the zero point on each transect was the landward margin of the swash zone. Thus, the sites were in the same relative position with reference to the wave activity, but changed position between the sampling series with reference to a fixed point onshore. Sampling sites were located at 3.3, 7.6, 10.6, 15.2, 30.4, 45.6, and 60.8 meters (horizontal distance) from the swash zone. When possible, samples were collected during low tide so the sites were relatively the same distance from mean sea level (MSL) over the sampling series. However, the main criterion in determining the sampling times was the sea conditions.

On the sound beach transects, the zero point was the sound margin (approximately +1.0 foot MSL, 1929 datum). Sampling sites 1 to 8, respectively, were placed 15.2, 38.0, 51.8, 61.0, 68.6, 76.2, 152.4, and 304.8 meters westward of the zero point.

3. Sampling Times.

The sampling of all sites was made during each of the four seasonal sampling periods: November, January, April, and July. These periods were chosen to coincide as closely as possible with Matta's (1977) study and with the period of statistically determined low significant wave heights. The ocean beach was not sampled during unfavorable sea conditions. During the fall, winter, and spring seasons, the northwest winds following the passage of low-pressure centers provided excellent periods for collecting samples in the surf zone.

4. Measurement of Physical Parameters.

Sites were located to the nearest foot by stretching a precalibrated nylon line, which was anchored to the shore, over the transect. The vertical distance to the nearest foot from MSL was determined by correcting measured site water depth at the time of sampling with tide gage data provided by the CERC FRF. The temperature to the nearest 0.5° Celsius was measured near the bottom of each site using a field thermometer. A bottom water sample was also taken for laboratory analysis to the nearest part per thousand of salinity.

5. Sampling Device.

The sampling device (Fig. 3) was a corer constructed of a 6-millimeter (1/4 inch) circular steelplate with a 1-centimeter hole in the center welded to a 15-centimeter section of 8.55-centimeter-diameter (3-3/8 inch) steel electrical conduit. A 2.54-centimeter (1 inch) pipe coupling was welded to the plate over the hole, and a 2.54-centimeter steel pipe was tightly screwed into the coupling. The leading edge of the steel conduit was sharpened to aid penetration. A long handle (about 100 centimeters) was used in the shallow areas, and a short handle (about 15 centimeters) was used in the deep areas that required diving.

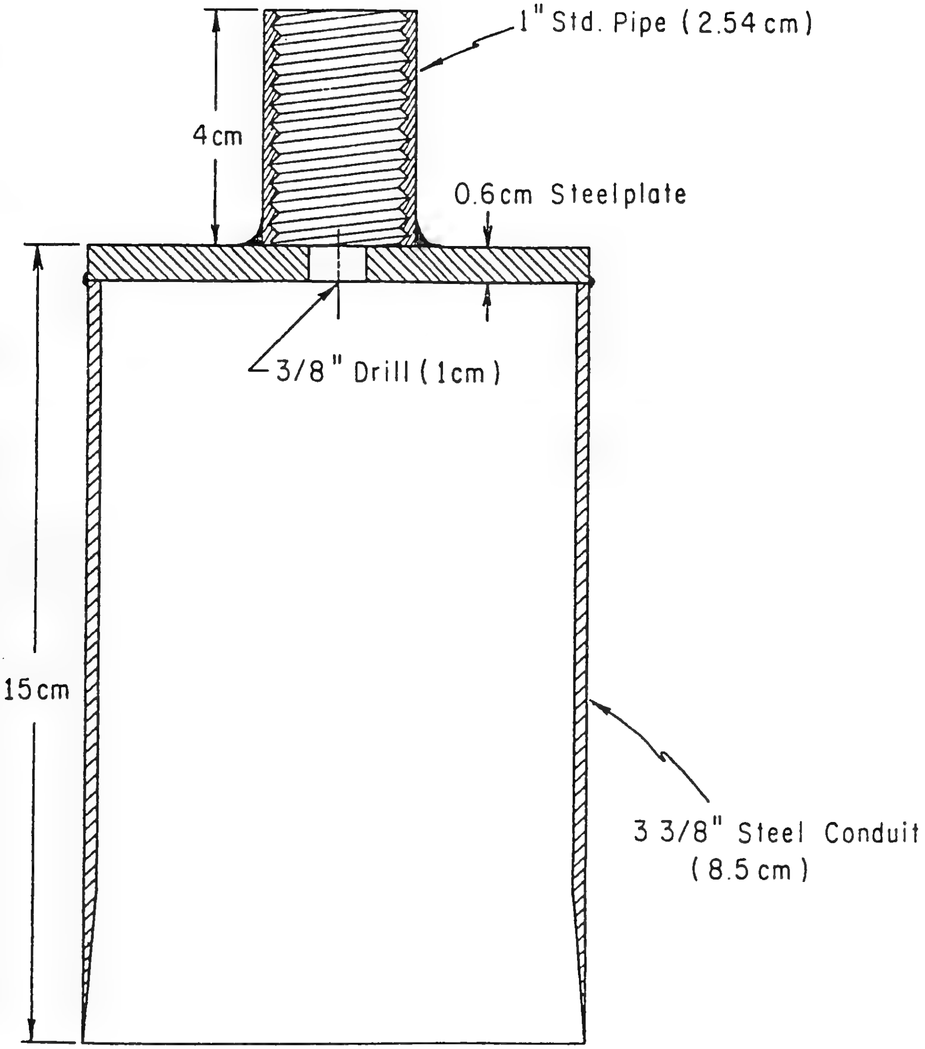

Figure 3. Cross section of the corer used as a sampling device.

The corer was pushed into the substrate, then extracted with the hole at the top of the handle covered. The core sample usually remained in the corer until the sample was placed in a bag, but at the deep sites the open end was covered to prevent the sample from washing out.

Four biological samples, each sample consisting of two combined cores, were taken at each site. Samples were placed in prelabeled plastic bags, stored at 1° to 4° Celsius, and returned to the laboratory for processing. An additional core sample was taken at each site for grain-size and chemical analyses.

6. Biological Sample Processing and Analysis.

A magnesium chloride ($MgCl_2$) and seawater rinsing technique was used to extract the organisms from the ocean core samples (Cox, 1976); rose bengal was added to a 4 percent formalin solution to aid in the sorting. All organisms, 0.5 millimeter and larger, were separated and species identified and counted. The coring and extraction techniques used for the sound samples were identical to the methods used on the ocean samples, but tapwater was substituted for the $MgCl_2$ seawater solution. The resulting data were analyzed for community structure statistics according to methods described previously in detail by Diaz (1977) and Boesch (1972). Cluster analysis was performed on the data according to methods detailed by Boesch (1977).

Animals in all samples were identified to the lowest possible taxonomic level.

7. Sediment Sample Processing and Analysis.

Sand particle diameter and size distribution were determined by the use of U.S. standard sieves. Taylor series sieves (phi interval) and ROTAP[R] shaker were used for grain-size analysis. About 50 ± 2 grams of material was sieved on the ROTAP[R] shaker for 10 minutes. Material retained on each sieve was weighed and the mean, sorting, skewness, and kurtosis statistics were calculated according to Folk (1968).

The total organic content of each sediment sample was determined by the incineration method and the total carbonate content of each sediment sample was determined by the hydrochloric acid (HCl) method (Carver, 1971).

III. RESULTS

1. Ocean Beach.

a. Physical Environment. For a given collection period, the temperature was fairly consistent between transects. There was also no variation in the temperature with depth, except in July, when deeper sites on the transects had slightly lower temperatures (Table 1).

The salinity was also consistent within a collection period, except in November when a range of about 1 part per thousand was observed. There seemed to be no pattern to the salinity variations during any one season. For the entire study the total range of salinity was only 31.8 to 33.7 parts per thousand (Table 2).

Table 1. Water temperature (°Celsius) recorded at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	I	II	III	I	II	III	I	II	III	I	II	III
1	16.0	15.0	16.0	5.0	5.0	5.0	9.0	9.0	9.0	---	---	---
2	16.0	15.0	16.0	5.0	5.0	5.0	9.0	9.0	9.0	20.0	---	---
3	16.0	15.0	16.0	5.0	5.0	5.0	9.0	9.0	9.0	20.0	---	---
4	16.0	15.0	16.0	5.0	5.0	5.0	9.0	9.0	9.0	20.0	20.0	19.5
5	16.0	15.0	16.0	5.0	5.0	5.0	10.0	10.0	9.0	18.9	20.0	18.9
6	16.0	15.0	16.0	5.0	5.0	5.0	10.0	10.0	9.0	18.9	18.9	18.9
7	16.0	15.0	16.0	5.0	5.0	5.0	10.0	10.0	9.0	18.9	18.9	19.5

Table 2. Salinity (parts per thousand) recorded at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	I	II	III	I	II	III	I	II	III	I	II	III
1	31.9	31.9	31.9	32.3	32.3	32.2	33.4	33.6	33.6	---	---	---
2	31.8	32.0	32.1	32.2	32.8	32.0	33.3	33.2	33.7	32.3	---	---
3	32.5	32.1	32.4	32.0	32.1	32.3	33.7	33.6	33.6	33.1	---	32.8
4	32.2	31.9	32.1	32.0	32.2	32.2	33.7	33.5	33.7	33.0	33.2	33.0
5	32.0	31.9	32.2	32.1	32.5	32.1	33.5	33.5	33.6	33.0	32.8	32.8
6	31.9	31.8	32.8	32.0	32.1	32.1	33.6	33.6	33.7	32.9	32.8	32.9
7	32.1	32.3	32.2	32.5	32.2	32.3	33.6	33.3	33.6	32.9	33.0	33.0

The depth range over each transect did change from collection to collection. This reflects the dynamic and unstable nature of the beach and nearshore. The depth relationship between the three transects did not remain the same. In November transect I was deepest, in January it was transect II, in April transect III, and in July transect II (Table 3).

The total carbonate content of the sediment (Table 4) showed no pattern through time with large variation at a given site. However, there were differences along the transects (arc sine transformation, analysis of variance, ANOV, $\alpha = 0.004$) with collecting sites nearest the swash zone having the highest carbonates (3.3 to 30.4 meters), except transect I, where the site at 3.3 meters had consistently low carbonate. There were no differences between transects ($\alpha = 0.11$).

The total organic content of the sediment was uniformly low at all sites through time (Table 5). The range of total organics for the entire study was only 0.05 to 1.29 percent. This range is small and close to the analytical precision of the incineration method.

Mean grain size, sorting skewness, and kurtosis statistics indicate that the granulometry of the sediments was variable through time for any given site and transect (Tables 6 to 9). In general, there was a tendency for the sites 30.4 meters from the swash zone and farther to have finer sediments, poorer sorting, less skewness, and higher kurtosis.

b. Macrobenthos. A total of 22 taxa were identified from all ocean samples (Table 10). One of which was a small meiofaunal nemerteanlike worm that was excluded from any analysis because of its size and overwhelming dominance. The 0.5-millimeter sieve, used in this study, did not adequately quantify this worm's presence.

The haustorid amphipods presented an analysis problem. Matta (1977) identified *Parahaustorius longimerus* as the common haustorid. In the present study, there are three morphologically very similar haustorids common in the collections. They are *P. longimerus*, *Haustorius canadensis*, and *Haustorius* sp. (long rostrate form); therefore, to avoid inconsistencies between Matta (1977) and the present study, all *Parahaustorius* and *Haustorius* are grouped in the category of haustorids. Other haustorid species (*Amphiporeia virginiana* and *Bathyporeia quoddyensis*) will be maintained individually, since it is unlikely that they could be confused with other species.

In November a total of 16 species occurred, while in January there were 8, 9 in April, and 13 in July. Many of these species had single site occurrences for a season. If they were eliminated, the number of species occurring would be reduced to 10, 5, 8, and 10, respectively. Crustaceans were the dominant taxa, followed by polychaetes, and mollusks (Table 10). The distribution of the six dominant taxa is summarized in Table 11.

Community structure statistics of occurrence and diversity (Table 12) indicate a strong seasonal influence. The lowest values were in winter (January 1981) with many sites sampled that did not have any fauna. The highest abundance and diversity, overall, occurred in the fall (November 1980) followed by summer (July 1981). Sites 30.4 meters and farther from the beach (sites 5, 6, and 7) had the highest statistics throughout the study.

Table 3. Vertical distance (in meters) from MSL for each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	I	II	III	I	II	III	I	II	III	I	II	III
1	-0.27	-0.42	-0.30	0.15	0.57	0.00	0.06	0.48	0.36	0.70	0.97	0.82
2	-0.57	-0.57	-0.60	-0.09	0.18	-0.18	-0.09	0.33	0.21	0.39	1.03	0.82
3	-0.88	-0.85	-1.21	-0.24	0.03	-0.33	-0.15	0.27	0.15	0.24	1.12	0.36
4	-1.64	-1.15	-1.67	-0.79	-0.27	-0.94	-0.24	0.00	0.00	0.09	0.51	0.21
5	-1.52	-1.21	-1.67	-1.43	-1.79	-1.21	-1.37	-1.00	-1.70	-1.40	0.21	-0.70
6	-1.70	-1.28	-1.61	-1.73	-2.25	-1.58	-1.67	-1.31	-2.01	-1.55	-1.15	-1.31
7	-1.73	-0.76	-1.49	-2.07	-2.68	-1.76	-1.98	-1.61	-2.31	-1.70	-1.61	-1.31

Table 4. Carbonate concentration (in grams per 100 grams) on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	I	II	III	I	II	III	I	II	III	I	II	III
1	2.15	1.14	3.93	2.91	11.02	1.96	1.59	4.60	3.34	1.08	4.14	4.57
2	3.54	6.00	9.77	3.76	4.42	3.88	2.37	3.38	3.27	3.94	2.75	2.53
3	3.94	5.83	10.48	4.68	2.65	4.19	5.01	7.88	5.18	0.91	3.78	0.06
4	10.47	3.91	2.50	3.82	14.97	11.86	5.55	4.63	14.31	4.56	4.05	5.07
5	1.98	15.65	11.87	0.07	3.21	0.03	1.88	2.20	6.37	4.41	5.69	2.13
6	2.99	1.96	1.16	1.50	3.76	0.10	0.35	1.49	2.39	1.46	1.89	1.03
7	1.74	2.97	2.37	2.91	2.40	0.37	1.01	0.56	2.29	0.32	3.00	3.94

Table 5. Organic content of sediments (in grams per 100 grams) on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	I	II	III	I	II	III	I	II	III	I	II	III
1	0.41	0.51	0.33	0.05	0.08	0.11	0.29	0.52	0.72	0.68	0.58	0.42
2	0.13	0.56	0.93	0.98	0.06	0.30	0.43	0.98	0.32	0.85	1.56	0.16
3	1.04	0.46	0.73	0.33	0.57	0.79	0.09	2.19	0.99	0.97	0.38	0.58
4	0.34	0.27	0.89	0.17	0.47	0.08	0.36	0.62	0.68	0.81	0.16	0.55
5	0.39	0.09	0.70	0.14	0.59	0.05	0.09	0.16	1.29	0.55	0.32	0.22
6	0.31	0.33	0.38	0.08	0.23	0.10	0.29	0.52	0.85	0.84	0.32	0.16
7	0.90	0.91	0.57	0.05	0.26	0.06	0.96	0.45	0.65	1.04	0.48	0.45

Table 6. Mean grain size (in phi) of sediments at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	I	II	III	I	II	III	I	II	III	I	II	III
1	0.25	0.53	0.74	1.23	-0.30	1.11	1.77	0.90	0.80	1.73	0.89	0.98
2	-0.11	-0.38	-1.02	0.88	0.59	0.28	1.36	0.23	0.86	1.03	1.05	1.19
3	-0.98	0.42	1.17	-0.38	-0.39	-1.24	1.13	-0.98	-0.87	2.12	0.84	1.00
4	-1.24	0.53	1.68	0.58	-2.78	-1.35	0.31	-0.24	-2.50	-0.30	0.74	0.32
5	2.05	1.12	2.14	2.23	0.69	2.27	1.77	1.90	-3.26	1.14	-1.14	1.09
6	2.09	1.94	2.05	0.35	0.42	3.62	2.41	1.92	2.23	2.07	1.66	2.05
7	1.85	1.93	1.77	0.68	1.25	2.15	2.22	1.92	2.35	2.45	1.35	1.07

Table 7. Sorting of sediments at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	I	II	III	I	II	III	I	II	III	I	II	III
1	1.10	1.26	1.04	1.04	1.35	1.05	0.55	1.26	1.34	0.50	4.66	1.25
2	1.13	0.95	0.66	1.23	0.88	1.63	0.96	1.41	1.39	0.95	0.78	1.15
3	1.10	1.55	0.70	0.97	1.55	0.75	0.89	2.35	2.50	0.38	0.95	1.10
4	2.65	1.50	0.91	1.44	1.72	1.70	1.25	2.11	2.10	2.40	1.10	2.07
5	0.50	1.20	0.50	0.49	1.85	0.37	0.61	0.65	1.60	2.76	1.07	1.28
6	0.48	0.57	0.40	2.06	1.73	0.29	0.38	0.65	0.50	0.69	0.75	0.45
7	0.56	0.76	0.70	2.24	1.67	0.26	0.49	0.54	0.35	0.35	0.98	0.72

Table 8. Skewness of sediments at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	I	II	III	I	II	III	I	II	III	I	II	III
1	0.17	0.05	0.05	-0.26	0.05	-0.16	-0.13	-0.16	0.05	-0.10	-0.27	0.20
2	0.00	-0.14	-0.10	-0.31	0.00	0.26	-0.33	0.14	0.25	-0.22	-0.19	-0.16
3	0.13	0.03	0.00	0.06	-0.51	0.01	0.10	0.04	0.02	-0.29	-0.32	-0.27
4	-0.03	-0.07	-0.62	-0.01	0.00	0.10	0.08	0.06	0.00	-0.04	-0.11	0.13
5	-0.23	-0.34	-0.22	-0.18	-0.42	-0.05	0.24	-0.35	0.64	-0.60	0.05	-0.37
6	-0.37	-0.28	-0.30	-0.13	-0.06	-0.05	0.00	-0.38	-0.24	-0.34	-0.46	-0.32
7	-0.43	-0.68	-0.37	-0.62	-0.71	-0.19	-0.15	-0.28	0.06	0.00	-0.37	-0.17

Table 9. Kurtosis of sediments at each site on the ocean beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	I	II	III	I	II	III	I	II	III	I	II	III
1	0.86	0.84	0.94	1.00	0.85	0.74	1.05	0.79	0.78	0.94	0.73	0.59
2	1.13	0.98	1.16	0.79	1.13	0.72	0.93	0.77	0.79	0.97	0.94	1.10
3	1.20	0.80	1.03	1.08	0.98	0.99	0.99	1.09	0.80	1.53	0.79	0.85
4	0.91	0.80	1.75	0.81	0.82	1.08	0.87	1.19	1.06	0.61	0.74	0.60
5	1.08	1.00	1.28	1.44	0.76	1.20	0.90	1.79	1.00	0.68	1.16	0.71
6	1.18	1.25	1.23	0.75	0.74	1.40	1.35	1.62	1.11	3.07	1.24	2.07
7	1.05	2.47	1.36	0.84	0.91	0.82	1.34	1.16	2.27	1.29	1.40	1.07

Table 10. Taxonomic list of macrofauna collected from November 1980 to July 1981 from the ocean beach.

Taxon	Occurrences[1]			
	Nov.	Jan.	Apr.	July
Polychaeta				
Scolelepis squamata	14	5	4	9
Nephtys bucera	1	0	0	2
Magelona rosea	1	0	0	0
Sigambra sp.	2	0	0	0
Glycera dibranchiata	1	0	0	0
Hesionid	1	0	0	0
Phyllodocid	0	0	0	1
Mollusca				
Donax spp.	10	1	0	3
Acteon sp.	0	1	0	0
Epitonium sp.	1	0	0	0
Amphipoda				
Parahaustorius longimerus[2]	13[3]	2	4	8
Haustorius canadensis[2]	13[3]	1	2	6
Haustorius sp.[2]	13[3]	4	5	7
Amphiporeia virginiana	11	0	4	6
Bathyporeia quoddyensis	3	5	0	3
Corophiid	0	0	1	0
Decapoda				
Emerita talpoida	8	5	15	13
Ovalipes ocellatus	1	0	2	1
Isopoda				
Edotea sp.	0	0	3	2
Cumacea	0	0	0	1
Mysidacea	3	0	0	0

[1]Site occurrences out of a possible total of 21 for each collection date.

[2]Combined for analyses as haustorids.

[3]Total haustorid occurrences for November not speciated.

Table 11. Distribution of dominant taxa from ocean transects. Values represent the sum of four replicates for a total area of 0.023 square meter. For densities per square meter multiply by 43.1.

Scolelepis squamata

Transect Site	November 1980 I	II	III	January 1981 I	II	III	April 1981 I	II	III	July 1981 I	II	III
1	3	1	0	0	0	0	0	0	0	2	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0
3	0	3	2	0	0	0	0	0	0	0	0	0
4	0	5	3	0	0	0	0	0	0	0	0	0
5	3	4	4	2	2	0	0	0	0	158	0	11
6	1	2	3	0	5	0	6	0	1	77	81	69
7	1	1	0	0	3	0	23	1	0	528	30	180

Donax spp.

Transect Site	November 1980 I	II	III	January 1981 I	II	III	April 1981 I	II	III	July 1981 I	II	III
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	10	0	0	0	0	0	0	0	0	0
5	9	1	24	0	0	0	0	0	0	0	0	0
6	11	42	78	0	0	0	0	0	0	0	0	1
7	34	50	36	0	3	0	0	0	0	1	0	0

Haustorids

Transect Site	November 1980 I	II	III	January 1981 I	II	III	April 1981 I	II	III	July 1981 I	II	III
1	1	0	0	0	0	0	2	0	0	0	0	0
2	0	0	0	1	0	0	0	0	0	2	0	2
3	0	1	0	0	0	0	0	0	0	2	0	1
4	0	1	3	1	0	0	0	0	0	1	0	0
5	12	7	7	0	0	1	0	13	0	19	0	12
6	7	21	34	5	0	9	6	8	1	6	1	11
7	21	12	25	0	0	2	10	0	0	16	23	1

Table 11. Distribution of dominant taxa from ocean transects. Values represent the sum of four replicates for a total area of 0.023 square meter. For densities per square meter multiply by 43.1.--Continued

Amphiporeia virginiana

	November 1980			January 1981			April 1981			July 1981		
Transect	I	II	III	I	II	III	I	II	III	I	II	III
Site												
1	0	1	3	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	11	0	0	0	0	0	0	0	0	0	0
4	7	7	1	0	0	0	0	0	0	1	0	0
5	0	1	0	0	0	0	0	0	0	0	3	0
6	1	1	0	0	0	0	0	0	0	0	0	7
7	2	1	0	0	0	0	0	0	0	0	0	11

Bathyporeia quoddyensis

	November 1980			January 1981			April 1981			July 1981		
Transect	I	II	III	I	II	III	I	II	III	I	II	III
Site												
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0	0
4	0	1	0	1	0	0	0	0	0	0	0	0
5	0	0	0	3	0	9	0	0	0	1	0	0
6	0	0	2	1	0	2	0	0	0	0	0	8
7	0	0	0	0	0	0	0	0	0	0	2	0

Emerita talpoida

	November 1980			January 1981			April 1981			July 1981		
Transect	I	II	III	I	II	III	I	II	III	I	II	III
Site												
1	44	112	47	0	0	0	0	1	9	0	0	1
2	23	225	10	0	0	0	0	4	25	54	4	12
3	12	18	0	0	0	1	7	8	7	23	2	7
4	0	0	0	0	0	0	31	3	2	9	17	5
5	0	0	0	0	0	2	0	16	0	0	52	1
6	0	0	0	1	0	2	0	2	3	0	0	0
7	0	0	0	0	0	1	0	2	4	36	0	0

Table 12. Community structure statistics from ocean transects.

Site	Statistical[1]	November 1980			January 1981			April 1981			July 1981		
		I	II	III	I	II	III	I	II	III	I	II	III
1	Ind	48	114	50	0	0	0	3	1	9	2	0	1
	Spp	3	3	2	0	0	0	2	1	1	1	0	1
	H'	0.48	0.14	0.33	0.0	0.0	0.0	0.92	0.0	0.0	0.0	0.0	0.0
	J'	0.25	0.09	0.33	0.0	0.0	0.0	0.92	0.0	0.0	0.0	0.0	0.0
	R	0.52	0.42	0.26	0.0	0.0	0.0	0.91	0.0	0.0	0.0	0.0	0.0
2	Ind	24	225	10	1	0	1	0	4	25	114	6	26
	Spp	2	1	1	1	0	1	0	1	1	4	3	3
	H'	0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.48	1.25	1.31
	J'	0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.74	0.79	0.83
	R	0.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.63	1.12	0.61
3	Ind	13	34	8	0	0	1	7	8	7	30	2	8
	Spp	2	5	2	0	0	1	1	1	1	5	1	2
	H'	0.39	1.62	0.81	0.0	0.0	0.0	0.0	0.0	0.0	1.21	0.0	0.54
	J'	0.39	0.70	0.81	0.0	0.0	0.0	0.0	0.0	0.0	0.52	0.0	0.54
	R	0.39	1.13	0.48	0.0	0.0	0.0	0.0	0.0	0.0	1.18	0.0	0.48
4	Ind	10	14	7	2	0	0	32	3	2	10	17	5
	Spp	2	4	4	2	0	0	2	1	1	2	1	1
	H'	0.88	1.57	1.57	1.0	0.0	0.0	0.20	0.0	0.0	0.47	0.0	0.0
	J'	0.88	0.79	0.79	1.0	0.0	0.0	0.20	0.0	0.0	0.47	0.0	0.0
	R	0.43	1.14	1.06	1.44	0.0	0.0	0.29	0.0	0.0	0.43	0.0	0.0
5	Ind	24	13	35	5	2	12	0	32	1	178	52	26
	Spp	3	4	3	2	1	3	0	3	1	3	1	4
	H'	1.41	1.57	1.20	0.97	0.0	1.04	0.0	1.35	0.0	0.54	0.0	1.50
	J'	0.89	0.79	0.75	0.97	0.0	0.66	0.0	0.85	0.0	0.34	0.0	0.75
	R	0.63	1.17	0.56	0.62	0.0	0.80	0.0	0.58	0.0	0.39	0.0	0.92
6	Ind	20	71	118	7	5	13	14	10	12	84	90	89
	Spp	4	6	5	3	1	3	4	2	4	3	3	4
	H'	1.44	1.52	1.20	1.15	0.0	1.20	1.59	0.72	1.55	0.46	0.52	1.04
	J'	0.72	0.59	0.68	0.72	0.0	0.76	0.80	0.72	0.78	0.29	0.33	0.52
	R	1.00	1.17	0.84	1.03	0.0	0.78	1.14	0.43	1.21	0.45	0.45	0.67
7	Ind	60	65	62	0	8	3	44	3	15	581	64	182
	Spp	6	5	3	0	3	2	4	2	2	4	5	3
	H'	1.45	1.02	1.08	0.0	1.56	0.92	1.58	0.92	0.84	0.53	1.67	0.10
	J'	0.56	0.44	0.68	0.0	0.99	0.92	0.79	0.92	0.84	0.27	0.72	0.06
	R	1.22	0.96	0.48	0.0	0.96	0.91	0.79	0.91	0.37	0.47	0.96	0.38

[1]Ind - Number of individuals in all four replicates
Spp - Number of species in all four replicates
H' - Diversity (Shannon-Weaver formula)
J' - Evenness (Shannon-Weaver formula)
R - Richness (spp - 1/ln IND)

The cluster analysis delineated five major station groups from all the data (sites, transects, and seasons). Station group 1 was composed of mostly near-beach sites in November and April, and middepth sites in July (Table 13). *Emerita talpoida* was the dominant species at these sites (Table 11). Station group 2 was the deeper of the sites in November and July. Only one site in January and two in April were included in group 2. The dominant species at this station group were *Scolelepis squamata* (particularly in July), *Donax* spp., and the haustorids. Group 3 appeared to be transitional between groups 1 and 2. In November group 3 was in between groups 1 and 2. In January and April group 2 was the deeper of the sites, indicating the absence or low abundance of many dominant species. In July group 2 was close to the beach (Table 13). Group 4 represented the depauperate stations with only a few occurrences of any species. This group occurred mainly in January with one site in November and one site in July being included. Station group 5 was all the sites that had no fauna, which occurred mainly in January, with two occurrences in April and one in July (Table 13).

Since there were only seven species that occurred at more than four of the collecting sites, the species cluster was not very informative. *Emerita talpoida* was in a group by itself and was the only species characteristic of the shallow nearshore sites. *Edotea* spp. was also in a group by itself because of its rareness; it occurred only five times during the study. The other five species, *Scolelepis squamata*, *Donax* spp., haustorids, *Amphiporeia virginiana*, and *Bathyporeia quoddyensis*, were all placed together as a single species group.

2. Sound Beach.

a. Physical Environment. The temperature was constant at all the collecting sites in both January and July. In November there was a slight gradient, with deeper sites on all transects having lower temperatures. In April the temperature increased from transects 4 to 5 to 6, indicating diel warming of the water as samples were collected. Collecting started early in the morning at transect 4 and ended in the afternoon at transect 6 (Table 14). The range of temperature for the study was 0.0° to 23.8° Celsius.

Salinity throughout the course of the study increased from about 3 parts per thousand to a little less than 8 parts per thousand. The increase in salinity is related to the general drought conditions that existed in the Currituck Sound drainage basin during the study period. There was a slight drop in salinity in the winter (January) with the average being 2.3 parts per thousand (Table 15).

The depth from MSL on any transect was never greater than 1.09 meters (Table 16). The bottom on all transects sloped gradually out to a 304.8-meter distance. From collection to collection there was a maximum 0.5-meter difference in depth at any one site along a transect, with most differences being less than 0.2 meter.

The total carbonate content of the sediments was very low, except at three sites where the fragments of *Rangia cuneata* shells were found (Table 17). No patterns in the carbonate content could be discerned. If the three high values are eliminated, the total range for all transects and seasons is only 0.00 to 0.83 percent.

Table 13. Station groups from cluster analysis of all ocean beach data. See text for explanation.

	November 1980			January 1981			April 1981			July 1981		
Transect	I	II	III	I	II	III	I	II	III	I	II	III
Site												
1	1	1	1	5	5	5	3	1	1	4	5	1
2	1	1	1	3	5	4	5	1	1	3	3	3
3	1	3	4	5	5	1	1	1	1	3	1	1
4	3	2	2	3	5	5	1	1	1	1	1	1
5	2	2	2	4	4	3	5	3	3	2	1	2
6	2	2	2	3	4	3	2	3	3	2	2	2
7	2	2	2	5	2	3	2	1	3	2	2	2

Table 14. Water temperature (° Celsius) recorded at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	17.0	16.0	21.0	0.0	0.0	0.0	10.0	---	---	23.8	23.8	23.8
2	17.0	17.5	19.0	0.0	0.0	0.0	10.0	---	17.0	23.8	23.8	23.8
3	16.0	17.0	18.0	0.0	0.0	0.0	10.0	14.0	17.0	23.8	23.8	23.8
4	16.0	18.0	18.0	0.0	0.0	0.0	10.0	14.0	15.0	23.8	23.8	23.8
5	16.0	18.0	17.0	0.0	0.0	0.0	10.0	14.0	15.0	23.8	23.8	23.8
6	16.0	17.0	16.0	0.0	0.0	0.0	10.0	14.0	15.0	23.8	23.8	23.8
7	16.0	15.0	16.0	0.0	0.0	0.0	11.0	14.0	15.0	23.8	23.8	23.8
8	16.0	14.0	15.0	0.0	0.0	0.0	11.0	12.0	15.0	23.8	23.8	23.8

Table 15. Salinity (parts per thousand) recorded at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	3.5	3.2	3.0	---	---	---	6.7	---	4.8	7.4	7.4	7.6
2	3.2	3.4	3.4	---	---	---	4.9	---	4.8	7.4	7.9	7.3
3	3.2	3.9	3.3	---	---	1.8	5.7	5.5	5.8	7.6	7.9	7.7
4	3.1	3.8	3.4	3.0	4.1	---	6.5	4.9	5.9	7.8	7.9	7.8
5	3.7	3.1	3.2	---	---	1.9	6.5	6.8	6.5	7.5	7.6	7.3
6	3.3	3.3	3.8	2.3	---	1.3	6.5	6.8	6.0	7.3	7.9	7.8
7	3.2	3.2	3.4	2.2	1.8	2.2	5.2	6.4	5.7	7.8	7.3	7.6
8	3.2	3.9	3.4	2.5	2.3	2.4	6.7	5.0	4.9	7.4	7.4	7.3

Table 16. Vertical distance (in meters) from MSL for each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	-0.09	-0.12	-0.09	-0.30	-0.45	-0.30	-0.15	0.15	0.00	0.09	0.21	-0.06
2	-0.24	0.03	-0.52	-0.45	-0.45	-0.45	-0.24	0.00	-0.09	0.03	0.15	-0.12
3	-0.24	0.06	-0.09	-0.45	-0.54	-0.54	-0.15	-0.09	0.00	-0.06	0.00	-0.12
4	-0.39	0.00	-0.15	-0.54	-0.54	-0.45	-0.24	-0.09	-0.09	-0.06	0.00	-0.12
5	-0.30	-0.27	-0.18	-0.45	-0.36	-0.54	-0.24	-0.09	0.00	-0.06	0.00	-0.12
6	-0.39	-0.24	-0.27	-0.54	-0.36	-0.54	-0.24	-0.15	-0.12	-0.06	-0.09	-0.06
7	-0.67	-0.33	-0.79	-0.60	-0.60	-0.76	-0.39	-0.39	-0.30	-0.27	-0.30	-0.42
8	-1.00	-0.73	-1.09	-0.76	-1.06	-1.06	-0.60	-0.76	-0.60	-0.42	-0.39	-0.57

Table 17. Carbonate concentration (in grams per 100 grams) on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Site \ Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	0.17	0.16	0.15	3.56	0.34	0.07	0.23	0.78	0.26	0.42	0.00	0.76
2	0.04	0.11	0.26	0.68	0.18	0.31	0.26	0.33	0.29	0.00	0.00	0.00
3	0.00	0.28	0.49	0.32	0.44	0.06	0.23	1.38	0.13	0.00	0.00	0.09
4	0.00	0.24	0.11	0.10	0.31	0.03	0.26	0.83	0.20	0.90	0.68	0.00
5	0.05	0.35	0.11	0.06	0.30	0.07	0.56	0.46	0.23	0.00	0.00	0.06
6	0.57	0.21	0.15	0.10	0.55	0.35	0.82	0.09	0.13	0.00	0.00	0.00
7	0.20	0.00	0.32	0.13	0.55	0.03	0.19	1.67	0.39	0.22	0.13	0.13
8	0.43	0.11	0.12	0.13	0.27	0.40	0.69	0.46	0.36	1.23	0.00	0.00

Total organic content of the sediments was very low at all sites for all collections (Table 18). Total organic content ranged from 0.00 to 1.03 percent during the study. This range, analogous to the ocean beach organic content data, is likely within the analytical precision of the loss on the incineration method used. There were no discernible patterns of organic content within or between transects by the collection date, or between collection dates (ANOV, arc sine transformation, $\alpha>0.14$).

The mean grain size, sorting, skewness, and kurtosis statistics indicated that the granulometry of the sound sediments was very consistent along the transects and through time (Tables 19 to 22). The total range for the mean grain size was 1.46 to 2.76 phi. Variation in the mean grain size was greatest between transects and time at the sites nearest the shore (sites 1 and 2), but this was still not much variation. Sorting was low, ranging from 0.34 to 1.26 for the study, with a weak tendency for sorting to increase nearer the shoreline. No trends were discernible in the skewness and kurtosis statistics.

b. Macrobenthos. A total of 19 taxa were identified from all sound samples (Table 23). The chironomids presented the only analysis problem. Matta (1977) grouped all species as immature chironomids. In this study it was found that there were two genera *Polypedilum* and *Cryptochironomus* present. For comparability all the chironomid species were grouped for all analyses.

The dominant taxa were polychaetes, oligochaetes, amphipods, and chironomids. Within each major taxonomic group one species numerically dominated. *Limnodrilus* spp. was the dominant oligochaete and overall dominant in the sound samples. They were followed by *Lepidactylus dysticus*, an amphipod, and *Laeonereis culveri*, a polychaete. *Polypedilum* was the dominant chironomid but it did not occur in large numbers. Another abundant species was *Scolecolepides viridis*. Several species were common but never were abundant. They were *Rangia cuneata*, *Gammarus* sp., *Monoculodes* sp., *Cyathura polita*, and *Cryptochironomus* sp. The polychaete *Streblospio benedicti* was common only in July 1981, not having occurred during the other three seasons. Its appearance in July was undoubtedly due to the increasing salinity in the study area. The distribution and abundance of the more important taxa are presented in Table 24. There were only three species with only one or two occurrences.

The community structure statistics of occurrence and diversity (Table 25) indicated two general trends. The first is related to time, as the study progressed community structure statistics all gradually increased, except for the number of individuals. This trend in general was not seasonal but a response to the increasing salinity. The changes in the number of individuals seemed to be neither seasonal nor salinity related. The second trend, which held for all community structure statistics, was that sample sites farther from the shore (sites 5 to 8) had higher statistics. The difference between the nearshore and the offshore sites was most pronounced in January 1981 where there were more than twice as many individuals as the offshore sites (Table 25). The sites farther from shore were deeper and better buffered from temperature extremes and ice. Community structure statistics did not show much seasonality over the course of the study.

Table 18. Organic content of sediments (in grams per 100 grams) on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	0.00	0.44	0.33	0.05	0.48	0.02	0.29	0.19	0.13	0.00	0.29	0.06
2	0.02	0.13	0.29	0.02	0.02	0.75	0.69	0.06	0.19	0.58	0.42	0.06
3	0.38	0.00	0.50	0.26	0.14	0.00	0.39	0.23	0.06	0.55	0.22	0.22
4	0.27	0.46	0.38	0.23	0.00	0.40	0.36	0.19	0.46	0.42	0.45	0.42
5	0.63	0.42	0.45	0.08	0.76	0.00	0.23	0.33	0.23	0.52	0.29	0.09
6	0.58	0.18	0.00	0.14	0.29	0.20	0.62	0.19	0.09	0.00	0.19	0.09
7	0.56	0.40	0.75	0.20	0.67	0.00	0.59	0.26	0.52	0.29	0.16	0.06
8	0.00	0.34	0.00	0.27	0.52	1.03	0.13	0.43	0.65	0.22	0.65	0.42

Table 19. Mean grain size (in phi) of sediment at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	2.36	2.49	2.36	2.41	2.46	2.38	1.69	2.42	2.29	2.31	2.40	2.31
2	2.20	2.52	2.28	2.46	2.54	1.46	2.49	2.50	2.76	2.03	2.36	2.41
3	2.49	2.45	2.36	2.49	2.43	2.48	2.40	2.50	2.40	2.36	2.36	2.38
4	2.31	2.41	2.43	2.44	2.49	2.46	2.27	2.45	2.47	2.46	2.38	2.35
5	2.46	2.37	2.44	2.45	2.46	2.48	2.38	2.43	2.41	2.36	2.35	2.32
6	2.42	2.55	2.44	2.44	2.43	2.41	2.36	2.51	2.48	2.44	2.26	2.37
7	2.45	2.49	2.38	2.47	2.47	2.37	2.41	2.40	2.31	2.28	2.35	2.34
8	2.37	2.43	2.32	2.47	2.49	2.50	2.44	2.47	2.35	2.41	2.29	2.29

Table 20. Sorting of sediments at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	0.55	0.42	0.53	0.41	0.42	0.54	1.26	0.45	0.52	0.52	0.45	0.40
2	0.64	0.48	0.63	0.44	0.43	0.44	0.39	0.46	0.53	0.63	0.45	0.41
3	0.40	0.41	0.46	0.40	0.50	0.42	0.38	0.41	0.50	0.55	0.48	0.43
4	0.50	0.48	0.45	0.38	0.40	0.46	0.52	0.39	0.45	0.42	0.46	0.46
5	0.37	0.54	0.45	0.44	0.45	0.39	0.46	0.48	0.43	0.99	0.45	0.63
6	0.45	0.39	0.49	0.45	0.42	0.47	0.45	0.40	0.42	0.39	0.56	0.45
7	0.45	0.40	0.51	0.44	0.41	0.46	0.43	0.51	0.51	0.34	0.43	0.47
8	0.35	0.40	0.40	0.36	0.40	0.37	0.38	0.37	0.37	0.37	0.50	0.43

Table 21. Skewness of sediments at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	-0.13	0.02	-0.75	0.01	0.01	-0.11	-0.58	0.13	-0.09	-0.23	-0.04	-0.12
2	-0.21	-0.01	-0.17	-0.04	-0.02	0.88	0.00	0.01	-0.12	0.08	-0.06	0.00
3	0.00	0.00	0.06	0.00	-0.06	-0.06	-0.01	0.00	-0.06	-0.09	-0.12	-0.04
4	-0.11	0.00	0.02	-0.02	-0.01	-0.04	-0.20	0.06	-0.02	0.05	-0.09	-0.07
5	-0.01	-0.14	0.00	0.00	-0.08	-0.25	-0.09	-0.05	0.00	-0.11	0.00	-0.19
6	-0.29	0.01	-0.09	0.04	-0.09	0.00	-0.77	0.00	-0.03	-0.02	-0.12	-0.07
7	-0.02	-0.03	-0.07	-0.06	-0.01	-0.08	0.00	-0.07	-0.04	-0.08	0.00	-0.11
8	-0.14	0.03	-0.10	-0.05	0.00	-0.04	-0.03	-0.07	0.00	0.06	-0.07	-0.03

Table 22. Kurtosis of sediments at each site on the sound beach.

Season	November 1980			January 1981			April 1981			July 1981		
Transect / Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	1.45	1.14	1.21	1.12	1.23	1.24	1.96	1.24	1.22	1.47	1.05	1.39
2	1.48	1.34	1.61	1.54	1.99	1.30	1.63	1.28	1.45	1.00	1.36	1.23
3	1.34	1.26	1.12	1.24	1.44	1.18	1.18	1.16	1.31	1.40	2.98	1.33
4	1.28	1.37	1.23	1.21	1.22	1.25	1.63	1.48	1.11	1.40	1.63	1.13
5	1.21	2.02	1.21	1.15	1.27	1.22	1.46	1.73	1.12	1.34	1.29	2.60
6	1.27	1.23	1.21	1.17	1.13	1.20	1.33	1.11	1.22	1.27	1.70	1.14
7	1.00	1.15	1.31	1.27	1.58	1.52	1.28	1.25	1.17	1.47	1.25	1.23
8	1.22	1.25	1.67	1.17	1.13	1.13	1.19	1.25	1.06	1.30	1.19	1.21

Table 23. Taxonomic list of macrofauna collected from November 1980 to July 1981 from the sound beach.

Taxon	Occurrences[1] Nov.	Jan.	Apr.	July
Nemertea				
Unidentified sp.	0	0	0	1
Polychaeta				
Scolecolepides viridis	0	0	0	17
Laeonereis culveri	24	23	15	23
Lysippides grayi	3	0	0	0
Polydora ligni	1	0	0	1
Oligochaeta				
Limnodrilus spp.	24	23	21	23
Hirudinea				
Glossiphonid	1	1	0	0
Mollusca				
Rangia cuneata	8	12	4	8
Macoma sp.	0	0	0	6
Amphipoda				
Lepidactylus dysticus	23	23	23	24
Gammarus sp.	5	4	9	4
Leptocheirus plumulosus	0	0	9	3
Monoculodes sp.	5	1	13	2
Corophium sp.	0	0	2	2
Isopoda				
Cyathura polita	6	3	6	5
Edotea triloba	1	0	0	0
Chironomidae[2]				
Polypedilum spp.	8	21	15	16
Cryptochironomus sp.	0	7	9	4

[1]Site occurrences out of a possible total of 24 for each collection date.

[2]Combined for analyses as chironomids.

Table 24. Distribution of dominant taxa from sound transects. Values represent sum of four replicates for a total area of 0.023 square meter. For densities per square meter multiply by 43.1.

Scolecolepides viridis

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	1	0	0	1	0	0	22	2	0	2	0	1
2	9	0	0	1	0	0	22	2	22	12	11	23
3	6	0	2	1	0	1	43	6	5	26	3	36
4	11	0	0	2	0	1	25	6	13	11	7	35
5	3	4	1	15	0	0	29	4	8	22	3	5
6	7	0	8	1	0	1	22	8	22	17	7	27
7	7	8	7	3	0	2	28	3	40	13	0	14
8	8	5	9	9	6	2	23	9	57	23	36	21

Streblospio benedicti

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	2	0	4
3	0	0	0	0	0	0	0	0	0	3	2	4
4	0	0	0	0	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0	0	3	3	2
6	0	0	0	0	0	0	0	0	0	0	1	1
7	0	0	0	0	0	0	0	0	0	4	4	0
8	0	0	0	0	0	0	0	0	0	3	6	4

Laeonereis culveri

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	30	1	13	22	4	2	0	0	1	39	290	44
2	21	45	9	11	30	12	0	3	18	22	30	30
3	39	10	12	8	4	30	1	2	0	0	31	24
4	31	11	28	3	3	10	4	0	3	41	58	35
5	31	32	35	0	15	27	3	2	0	27	46	30
6	19	28	20	7	7	19	0	0	5	20	61	21
7	36	8	25	26	17	29	15	0	14	18	28	23
8	40	22	13	11	16	21	1	21	3	28	34	39

Limnodrilus spp.

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	220	3	3	19	1	1	263	0	22	4	7	0
2	577	26	1	29	3	1	42	3	1	9	6	16
3	120	2	4	11	1	0	40	0	3	115	3	8
4	172	18	9	14	10	1	26	2	5	6	13	5
5	169	30	22	111	24	26	14	5	1	11	3	9
6	350	20	9	16	2	29	5	29	2	18	12	9
7	108	42	59	291	61	118	62	0	27	113	39	54
8	52	8	40	221	32	74	45	46	42	230	195	98

Table 24. Distribution of dominant taxa from sound transects. Values represent sum of four replicates for a total area of 0.023 square meter. For densities per square meter multiply by 43.1.--Continued

Rangia cuneata

Transect	November 1980			January 1981			April 1981			July 1981		
Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	1	0	0	0	0	0	0	0	0	5	0	0
2	1	1	0	0	2	0	0	0	0	3	0	0
3	0	0	0	1	0	0	0	0	0	0	1	0
4	0	0	0	2	0	0	0	0	0	0	0	0
5	2	0	0	4	0	0	0	0	0	0	0	0
6	2	0	0	1	0	1	0	0	0	2	0	0
7	0	0	1	6	3	4	2	0	1	2	0	3
8	0	0	1	4	1	4	10	2	0	6	7	0

Lepidactylus dysticus

Transect	November 1980			January 1981			April 1981			July 1981		
Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	1	34	0	0	8	4	3	3	10	14	52	31
2	17	45	90	8	18	78	4	43	24	43	45	70
3	2	83	71	10	7	75	13	12	8	33	59	39
4	6	47	121	3	34	66	5	19	18	26	53	92
5	4	32	51	14	69	56	6	15	16	19	15	18
6	5	45	29	17	14	23	4	8	18	57	67	13
7	2	9	6	12	9	6	5	3	3	3	18	18
8	2	1	3	3	4	4	1	1	0	10	9	11

Gammarus sp.

Transect	November 1980			January 1981			April 1981			July 1981		
Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	3	8	0	1	0	0	34	3	0	0	0	0
2	0	1	0	1	0	0	0	0	5	0	0	0
3	1	0	0	0	0	0	2	4	2	0	0	1
4	0	0	0	0	0	1	0	4	10	0	0	1
5	0	1	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	1	0	1	0	0	0	1

Monoculodes sp.

Transect	November 1980			January 1981			April 1981			July 1981		
Site	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	0	0	0	0	0	0	2	0	1	0	0	0
2	0	0	0	1	0	0	2	0	0	1	0	0
3	0	0	0	0	0	0	2	0	3	1	0	0
4	0	0	0	0	0	0	0	0	2	0	0	0
5	0	2	1	0	0	0	1	0	1	0	0	0
6	1	1	1	0	0	0	0	1	2	0	0	0
7	0	0	0	0	0	0	0	3	0	0	0	0
8	0	0	0	0	0	0	0	4	1	0	0	0

Table 24. Distribution of dominant taxa from sound transects. Values represent sum of four replicates for a total area of 0.023 square meter. For densities per square meter multiply by 43.1.--Continued

Cyathura polita

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	4	3	0	7	0	0	2	0	0	4	0	0
2	0	2	0	0	1	0	0	0	1	0	1	0
3	0	1	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	1	1	0	0
5	0	1	1	1	0	0	0	1	0	0	1	0
6	0	0	0	0	0	0	2	0	0	0	0	0
7	0	0	0	0	0	0	0	3	0	0	0	2
8	0	0	0	0	0	0	0	0	0	0	0	0

Chironomids

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	1	0	0	2	1	1	0	127	33	1	2	1
2	0	2	0	1	3	2	1	1	0	1	1	3
3	0	0	0	6	0	1	3	0	4	1	0	0
4	0	7	0	5	0	4	0	2	2	1	1	0
5	0	4	0	0	3	7	4	0	0	4	0	2
6	0	4	0	5	3	10	2	4	0	1	4	0
7	0	2	0	27	8	14	5	0	3	6	1	0
8	0	5	1	14	12	19	32	14	13	3	2	4

Table 25. Community structure statistics from sound transects.

Site	Statistical[1]	November 1980			January 1981			April 1981			July 1981		
		IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
1	Ind	273	51	16	52	14	8	327	135	67	69	357	77
	Spp	9	7	2	6	4	4	7	4	5	7	4	4
	H'	1.08	1.62	0.70	1.84	1.52	1.75	1.03	0.42	1.62	1.92	0.72	1.15
	J'	0.34	0.58	0.70	0.71	0.76	0.88	0.37	0.21	0.70	0.68	0.39	0.58
	R	1.43	1.53	0.36	1.26	1.14	1.44	1.03	0.61	0.95	1.42	0.51	0.69
2	Ind	626	122	100	52	57	93	72	53	75	93	94	146
	Spp	6	7	3	7	6	4	6	6	7	8	6	6
	H'	0.53	1.84	0.52	1.80	1.73	0.78	1.52	1.11	2.19	2.13	1.79	2.00
	J'	0.21	0.66	0.32	0.64	0.67	0.39	0.59	0.43	0.78	0.71	0.69	0.78
	R	0.78	1.25	0.43	1.52	1.24	0.66	1.17	1.26	1.39	1.54	1.10	1.00
3	Ind	169	96	89	37	12	108	139	22	27	179	99	112
	Spp	6	4	4	6	3	5	7	3	7	6	6	6
	H'	1.17	0.71	0.97	2.21	1.28	1.07	1.88	1.43	2.63	1.45	1.46	2.04
	J'	0.45	0.35	0.49	0.86	0.81	0.46	0.63	0.91	0.94	0.56	0.56	0.79
	R	0.97	0.66	0.67	1.38	0.80	0.85	1.22	0.65	1.82	0.96	1.09	1.06
4	Ind	221	77	158	89	47	83	25	35	56	86	134	169
	Spp	5	4	3	6	3	6	1	7	9	6	7	6
	H'	1.07	1.41	0.97	1.03	1.07	1.07	0.0	2.04	2.62	1.83	1.76	1.66
	J'	0.46	0.70	0.61	0.40	0.67	0.41	0.0	0.73	0.82	0.71	0.63	0.64
	R	0.74	0.69	0.40	1.11	0.52	1.13	0.0	1.69	1.99	1.12	1.22	0.97
5	Ind	209	109	113	166	111	116	57	25	26	86	72	66
	Spp	5	8	8	5	4	4	6	4	4	6	7	6
	H'	0.92	2.21	1.80	1.37	1.43	1.72	1.49	1.52	1.32	2.31	1.63	2.01
	J'	0.40	0.74	0.60	0.59	0.72	0.86	0.71	0.76	0.66	0.82	0.58	0.78
	R	0.75	1.49	1.48	0.78	0.64	0.63	1.48	0.93	0.92	1.35	1.40	1.19
6	Ind	384	98	67	43	26	83	35	54	49	115	152	71
	Spp	6	5	5	6	4	6	5	7	5	6	6	5
	H'	0.58	1.76	1.89	2.16	1.63	2.05	1.71	2.05	1.76	1.93	1.73	1.96
	J'	0.23	0.76	0.81	0.84	0.82	0.79	0.66	0.70	0.76	0.75	0.67	0.84
	R	0.84	0.87	0.95	1.33	0.92	1.13	1.41	1.75	1.03	1.05	1.00	0.94
7	Ind	153	69	98	353	98	173	119	10	88	168	118	117
	Spp	4	5	5	5	5	6	7	4	6	9	9	8
	H'	1.13	1.69	1.53	0.95	1.63	1.47	1.94	1.90	1.90	1.79	2.52	2.15
	J'	0.57	0.73	0.63	0.40	0.70	0.57	0.69	0.95	0.68	0.54	0.80	0.72
	R	0.60	0.94	0.87	0.68	0.87	0.97	1.26	1.30	1.34	1.76	1.68	1.47
8	Ind	102	41	67	262	71	125	165	108	116	313	306	188
	Spp	4	5	6	6	6	7	7	9	5	9	9	8
	H'	1.42	1.81	1.67	0.96	2.06	1.76	2.12	2.34	1.63	1.50	1.81	2.06
	J'	0.71	0.78	0.65	0.37	0.80	0.63	0.71	0.71	0.63	0.47	0.57	0.68
	R	0.65	1.08	1.19	0.90	1.17	1.24	1.37	1.92	1.05	1.39	1.40	1.34

[1]Ind - Number of individuals in all four replicates
Spp - Number of species in all four replicates
H' - Diversity (Shannon-Weaver formula)
J' - Evenness (Shannon-Weaver formula)
R - Richness (spp. - 1/ln Ind)

The cluster analysis did not produce a concise grouping of stations with data trends that could be attributed to season, depth, or sediment statistics. At the group 6 level there was a mixing of stations from different seasons and locations along the transects (Table 26). Group 1, mainly transect IV in November, and the deepest stations (sites 7 and 8) from all transects in July, had the highest densities of the dominant species and also tended to have low evenness. Group 2, mainly transect IV in January and April, and the deeper sites from November, January, and April on all transects, had lower densities of dominant species and occurrences of *Rangia cuneata* and chironomids. Group 3 was the only station group to be entirely made up of one collection period, April, and represents stations of low community structure statistics. Group 3 was primarily transects V and VI. Group 4 also represented stations with low community structure statistics, but mainly in January, for transect V. Group 5 was mainly stations (sites 2 to 5) on transects V and VI in November and transect VI in January. Group 5 appears to be transitional between groups 3 and 4 in its character, having low densities of some dominants, but not others (Table 24). Group 6 is mainly stations (sites 1, 2, 4, 5, and 6) from July and represents more the increased salinity through time than the seasonality. The abundance of freshwater forms (*Gammarus* sp. and chironomids) decline while estuarine forms increase (*Lepidactylus dystics*, *Rangia cuneata* and *Laeonereis culveri*). In July there was also the appearance of additional estuarine forms that did not occur previously (*Streblospio benedicti* and *Macoma* sp.).

Table 26. Station groups from cluster analysis of all sound data. See text for explanation.

	November 1980			January 1981			April 1981			July 1981		
Transect	IV	V	VI	IV	V	VI	IV	V	VI	IV	V	VI
Site												
1	1	4	4	4	4	4	1	3	2	6	6	6
2	1	5	5	2	6	5	2	4	3	6	6	6
3	1	5	5	2	4	5	2	3	3	1	5	6
4	1	5	5	2	4	5	3	3	3	6	6	6
5	1	5	5	1	5	5	2	3	3	6	6	6
6	1	5	6	2	4	2	3	2	3	6	6	6
7	1	2	2	1	2	2	2	3	2	1	1	2
8	2	4	2	1	2	2	2	2	2	1	1	1

From the species cluster analysis, four species groups were identified that related to dominance and the increasing salinity. Species group 1 was composed of *Limnodrilus* spp., *Scolecolepides viridis*, *Laeonereis culveri*, and *Lepidactylus dysticus*. These species were the major dominants that occurred at most stations for all collections. They were the most characteristic of station groups 1 and 2. Species group 2 was *Cyathura polita*, *Gammarus* sp., *Monoculodes* sp., and *Leptocheirus plumulosus*. Group 2 did not seem to be characteristic at any station group, but is diffusely represented in all station groups. Species group 3 was *Rangia cuneata* and chironomids, which were characteristic of the deeper stations in station groups 1 and 2. Species group 4 was *Streblospio benedicti* and *Macoma* sp., which were the most characteristic of station group 6 for July.

The cluster analyses indicate a complex pattern of change through time. There was a shifting of the community structure that was in part due to the seasonality and increasing salinity. Station groups 1 and 2 represent the dominant fauna throughout the seasons. They are also the stations where species patterns did not seem to vary. If these two station groups are then considered constants, there is a progression of the other four station groups through time. Station group 5 was most typical of November, group 4 was typical of January, group 5 was typical of April, and group 6 was typical of July (Table 26). The faunal changes that occurred at these four station groups coincide best with the salinity. However, station group 4 does seem to reflect the severe water conditions of low abundance and species diversity.

IV. DISCUSSION

1. Ocean Beach.

a. Present conditions. The physical environment at the Duck ocean beach is typical of the high energy, sand beaches found along exposed ocean coasts. The sediment is graded from coarse sand in the swash zone to finer sand 30 to 60 meters from shore. The bottom is very unstable, creating a physically dominated environment. The fauna inhabiting these high energy beaches, which are very extensive environments along the Atlantic and Gulf of Mexico coasts, while not diverse, has been remarkably successful in coping with unstable substrate caused by high kinetic wave energy (Croker, 1967; Dexter, 1976; Holland and Dean, 1977; Shelton and Robertson, 1981). *Emerita* spp., *Donax* spp., and haustorid amphipods are three dominant groups of species that inhabit ocean beaches all around the world (Pearse, Humm, and Warton, 1942; Dahl, 1952; Dexter, 1972, 1974, 1976; Diaz, 1980). These three taxa were also dominant at Duck, accounting for 33 percent of all taxa and 71 percent of all occurrences (Table 10).

Emerita talpoida was the only species at Duck, North Carolina, to be common in the swash zone. It also exhibited a seasonal migration off the beach to deeper water in the winter and back to the beach in spring and summer. While the *Emerita talpoida* was not separated by sex, its pattern of recruitment seemed to follow the sequence as described by Diaz (1980) and Bowman (1982) for the Duck, North Carolina, beach and for Bogue Banks, North Carolina, populations. At Duck, North Carolina, the highest numbers of immature individuals, summer of 1980 recruits, occurred in November 1980. In January 1981 they were not present in the sampling area probably having moved farther offshore than the transects. This offshore migration was documented by Bowman (1982). By April they were moving back to the beach and increasing in size. In July there were numbers of large ovigerous females.

The *Donax* spp., which may reach densities as high as 60,000 per square meter (for comparison 1,392 in 0.023 per square meter)(Mikkelsen, 1981) on other beaches, was not consistently dominant at Duck. This species only occurred in any great number in November 1980 and then only subtidally and not intertidally as most other *Donax* spp. populations (Pearse, Humm, and Warton, 1942). The subtidal occurrence of *Donax* spp. at Duck may be related to the coarse grain size and the steep slope of the beach (Edgren, 1959).

The haustorid amphipods were the most diverse taxonomic group to occur on the Duck, North Carolina beach. Five species occurred with varying regularity. The genera *Haustorius* and *Parahaustorius* were the most common. *Haustorius* spp. occurred high in the swash zone to subtidal, while *Parahaustorius longimerus* was mainly subtidal. The other haustorids were mainly subtidal (Table 10).

Scolelepis squamata, a spionid polychaete, which is common in high energy, sandy areas (Shelton and Robertson, 1981) was only common in July 1981. This may have been the result of a late spring or early summer recruitment, since most of the individuals were very small. No other species occurred at Duck that were other than incidental (five or fewer occurrences out of a possible 84, Table 10). This low number of species, while typical of the ocean beach, is a bit lower than was reported for other beaches (Pearse, Humm, and Warton, 1942; Dahl, 1952; Shelton and Robertson, 1981). The maximum species diversity (H') seasonally for the Duck beach--1.62 in November, 1.56 in January, 1.59 in April, and 1.67 in July--was lower than the average diversity reported by Shelton and Robertson (1981) for the surf exposed Texas beaches. Even if the Duck haustorids were considered separately, maximum diversity would not reach the average diversities reported by Shelton and Robertson.

The Duck ocean fauna formed a single community unit. While *Emerita talpoida* was the only important species in the swash zone, it also occurred subtidally. This agrees with other beach studies that indicate a single community inhabits the high energy ocean beach environment (Pearse, Humm, and Warton, 1942; Dahl, 1952; Shelton and Robertson, 1981). The Duck beach fauna then was typical of other beaches in this respect. While Knott, Calder, and Van Dolah (1982) found distinct communities in the intertidal and subtidal habitats at beaches around Murrells Inlet, South Carolina, their transects were about 1 kilometer long. Where Knott, Calder, and Van Dolah's stations were similar to the current study in distance from shore, their data also indicated a single community.

b. Comparison between 1975-76 and 1980-81. Matta (1977) surveyed the Duck beach in 1975-76. The present study occupied the same transects and stations as Matta and also employed the same methodologies. It is therefore possible to compare the two studies and establish what changes have occurred in 5 years. Matta's (1977) data are continually referred to as the early study or the 1976 conditions.

On the average, temperature and salinity were higher in 1976. The depth was variable for both studies, but stations at the offshore end of the transects were deeper in 1976. The carbonate and organic content of sediments were similar between 1976 and 1981. While sediments appeared to be coarser in the beginning of the 1976 study, there is no overall difference in the grain size between 1976 and 1981. Sorting, skewness, and kurtosis are also similar between studies. It appears that the physical sedimentary environment at the sites sampled has not changed from 1976 to 1981. While the temperature and salinity are different, they are well within the range of the natural variation that open coast systems experience.

In comparing the fauna (only polychaetes, mollusks, and crustaceans) the qualitative similarity (Jaccard's coefficient) is 0.67, which is a moderate similarity for the overall fauna. If the comparison is made by a major taxonomic group, then the similarity between studies is 0.88 for polychaetes, 0.33 for mollusks, and 0.64 for crustaceans. The polychaetes are very similar between studies with two taxa occurring in 1976 that did not occur in 1981, and one taxon in 1981 that was not found in 1976. The only mollusk in common was *Donax* spp., with two other species occurring in 1976 that did not occur in 1981, and vice versa. The crustacean fauna had seven species in common and four that occurred in one study, but not the other. The overall number of species was 22 for 1976 and 21 for 1981. If only the four top dominant taxa are compared, they are identical between studies (*Emerita talpoida*, *Donax* spp., *Scolelepis squamata*, and haustorids). Species differences between the studies occur only in the uncommon species (Table 27).

In 1976, the *Emerita talpoida* remained in the swash zone throughout the study because the temperatures on all four collection dates were always above 10° Celsius. In 1981 the temperature in January was low, 5° Celsius, and the *Emerita talpoida* left the swash zone. Densities of this decapod were lower in November 1975 than in 1980, but well within the range described by Diaz (1980) and Bowman (1982) for yearly variation. In the other comparable collections (April to July) densities were surprisingly similar between 1976 and 1981.

In 1976, the *Scolelepis squamata* was more common, occurring at more than 70 percent of all collecting sites. In 1981 it occurred at 62 percent of the sites. Densities in 1976 were comparable to those in 1981, being slightly higher overall from April to July 1976. The November collections were similar, averaging 86 worms per square meter in 1976 and 74 worms per square meter in 1981. *Scolelepis squamata* occurred in and near the swash zone commonly in June to July 1976. In July 1981, when it was most abundant, it had one occurrence in the swash zone.

In 1976, *Donax* spp. was widely distributed in June and July with occurrences in and near the swash zone. In July 1981, *Donax* spp. was virtually absent. In November 1975, there were few occurrences of *Donax* spp., all being found farther offshore. In November 1980 it was common, but only offshore. From the dynamic nature of this species populations (Mikkelsen, 1981) the differences between 1976 and 1981 are not outside the range of variation usually found in beach populations.

The haustorid amphipods (*Parahaustorius longimerus* in Matta, 1977) were distributed similarly in 1976 and 1981, with there being slightly higher densities in 1976. After comparing the four dominant species, it seems that the basic species distributions and abundances are similar or within the ranges of variation reported in the literature.

The species diversity (H') for both studies was low, with a slightly greater range in 1976 of 0.00 to 1.85. In 1981, the range of diversity was 0.00 to 1.67. One distinct faunal community seemed to be present in both

Table 27. Taxonomic comparison between 1976 (Matta, 1977) and 1981 (present study) macrobenthic species collected from the ocean beach.

Taxon	1976	1981
Polychaeta		
Scolelepis squamata	+	+
Spiophanes bombyx	+	
Nephtys bucera	+	+
Magelona rosea	+	+
Sigambra sp.		+
Microphthalmus sczelkowii	+	
Travisia carnea	+	
Glycera dibranchiata	+	+
Eteone heteropoda	+	
Hesionid		+
Phylodocid		+
Mollusca		
Donax spp.	+	+
Ensis sp.	+	
Anadara ovalis	+	
Acteon sp.		+
Epitonium sp.		+
Amphipoda		
Haustorids	+	+
Amphiporeia virginiana	+	+
Bathyporeia quoddyensis	+	+
Corophidd		+
Jassa falcala	+	
Decapoda		
Emerita talpoida	+	+
Ovalipes ocellatus	+	+
Pagurus longicarpus	+	
Isopoda		
Edotea sp.		+
Cumacea	+	+
Mysidacea	+	+

1976 and 1981. While Matta (1977) felt there were two other communities in the deeper water, analysis of the 1981 data for species patterns showed there was no distinct deeper water community. Considering the great similarity of dominants, it is likely that cluster analysis of the 1976 data would produce the same single community found in 1981.

2. Sound Beach.

a. Present conditions. The physical environment at the Duck sound beach is characteristic of the low energy, low salinity, sandy sounds in the North Carolina area. Sediments are virtually 100 percent sand with low organic and carbonate contents. The grain size of sediments is consistent, being fine sand. The water temperature was influenced by the air temperature. In January the temperature was 0° Celsius with a 5- to 10-centimeter ice cover. Temperatures higher than 24° Celsius do occur in the summer due to the shallowness of the sound system. Matta (1977) recorded 35° Celsius in July 1976. The salinity during the study increased from about 3 to 8 parts per thousand, reflecting the sensitivity of the system to the prevailing drought conditions. The fauna that inhabits these low salinity, shallow-water areas has to be able to cope with temperature extremes encountered during winter and summer. While not diverse, the fauna is generally a mixture of the eury-tolerant freshwater and estuarine species. Shifts in the balance between these forms are determined by what appears only slight shifts in salinity, on the order of 5 parts per thousand (Tenore, 1972; Diaz, 1977; Boesch, 1977).

Oligochaetes, polychaetes, chironomids, and at times amphipods or mollusks are the dominant taxa in the low salinity areas in temperate estuarine systems along the North and South American and the European coasts (Tenore, 1972; Leppakoski, 1975; Diaz, 1977, 1980). Within any one of these major taxonomic groups there are generally only one or two species dominant in any particular area. In the Duck sound the dominants were *Limnodrilus* spp. (very likely all *L. hoffmeisteri* from several mature specimens examined), an oligochaete, *Laeonereis culveri* and *Scolecolepides viridis*, both polychaetes, *Polypedilum* sp., a chironomid, and *Lepidactylus dysticus*, an amphipod. While the clam *Rangia cuneata* is a dominant in the deeper water sampled, it was not a dominant in the shallow water sampled. These four dominants accounted for 21 percent of all taxa and 71 percent of all occurrences (Table 23).

The Genus *Limnodrilus* contains the most widely distributed and eury-tolerant species of oligochaetes known (Brinkhurst and Cook, 1974, Diaz, 1980). At Duck, North Carolina, *Limnodrilus* spp. was the top numerical dominant on every collection date, reaching densities as high as 24,870 per square meter and averaging 2,290 per square meter for the entire study. While many *Limnodrilus* species can be pollution indicators, particular *L. hoffmeisteri*, which is likely the only species at Duck (Brinkhurst and Cook, 1974), their presence at Duck does not indicate a degraded environment. At Duck the *Limnodrilus* spp. is part of a low salinity community in a physically controlled environment. They are well adapted to salinity (Diaz, 1980) and temperature (Kennedy, 1966) stress. Through the course of the study, the size of the *Limnodrilus* spp. was always small with very few mature specimens. This is likely a result of the salinity, which is very close to their maximum reported field tolerance (Diaz, 1980).

The *Laeonereis culveri* is a eury-tolerant nereid polychaete that is common over a wide range of salinity, from 0.5 to at least 18 parts per thousand (Tenore, 1972; Diaz, 1977). It was widely distributed at Duck, being most abundant in July, possibly as a result of the higher salinity. As with *Limnodrilus* spp. most of the *Laeonereis culveri* were juveniles. They were only scattered occurrences of adult individuals from each collection date. *Laeonereis culveri* was always uniformly distributed with depth and between transects. In January it was the only dominant to occur in the same densities at the nearshore stations (sites 1 to 4) and offshore stations (sites 5 to 8). Its lowest densities occurred in April with about twice as many worms occurring at the offshore stations (Table 24).

The *Scolecolepides viridis*, a spionid polychaete, is a eury-tolerant species with a large salinity range from 0.5 to 25 parts per thousand. It seems to do best in the 5 to 10 parts per thousand range. At Duck it commonly occurred in all collections, but was never really dominant until April and July, when salinities were more than 5 parts per thousand (Table 24). Unlike the other annelid dominants when *Scolecolepides viridis* occurred, the individuals tended to be larger.

The chironomid larvae are predominantly freshwater fauna, but there are several Genera, including *Polypedilum* and *Cryptochironomus*, that are eury-tolerant (Roback, 1974). *Polypedilum* sp. was the dominant species at Duck. Chironomids were common but were never abundant. The greatest densities occurred in April and again in January.

The *Lepidactylus dysticus*, a haustorid amphipod, has the lowest salinity tolerance of the haustorids. It ranges from 0.5 to about 15 parts per thousand. It is also a eury-tolerant species that is widely distributed in low salinity zones of estuaries. At Duck, *Lepidactylus dysticus* occurred about as frequently as *Limnodrilus* spp. and was second in numerical dominance, averaging about 1,025 per square meter for the entire study. The greatest densities occurred in July, followed by November. For all collection dates there were more *Lepidactylus dysticus* in the nearshore stations (sites 1 to 4) than the offshore stations (sites 5 to 8), even in January with a 5- to 10-centimeter ice cover (Table 24).

The Duck sound fauna formed a single community unit for any one collection date. There was a gradual changing of the community from November to July. While the dominants were the same throughout the study the less common species changed with three species dropping out after November (*Lysippides grayi*, *Edotea triloba*, leech) and six appearing (*Streblospio benedicti*, nemertean, *Macoma* sp., *Leptocheirus plumulosus*, *Corophium* sp., *Cryptochironomus* sp.). The leech was the only freshwater form to drop out and *Cryptochironomus* sp. was the only freshwater form to be added after November. All other species changes were due to estuarine species. Despite these changes there was still a single community characteristic of the Duck sound in July. The qualitative similarity (Jaccard's coefficient) between November and the other collections was 0.83 in January, 0.72 in April, and 0.69 in July, indicating the gradual shift in the nondominant taxa. Cluster analysis also documented this gradual shift. The fauna assemblage in the sound at Duck is not unique. The same species occur in similar community groups in other estuarine systems (Diaz, 1977).

b. Comparison between 1976 and 1981. Matta (1977) surveyed the Duck sound in 1975-76. The present study occupied the same transects and stations as Matta and also employed the same methodologies. This facilitates the 5-year comparison between the two data sets. Matta's (1977) data will be continually referred to as the early study or the 1976 conditions.

The water temperature appeared higher in 1976, but the only month where samples were collected in 1976 and 1981 was July. In July 1976 the water temperature was 7° Celsius higher than the sampling date for 1981. This is well within the monthly range of temperature that is expected for that period of the year. Salinity was lower in 1976, being about 2 parts per thousand in October 1975 and March 1976, and about 3 parts per thousand in May and July 1976. In 1981 salinity went from about 3 parts per thousand in November 1980 to 8 parts per thousand in July 1981. This is a substantial increase in salinity considering the sensitivity of the low salinity fauna to changes in salinity (Leppakoski, 1975; and Diaz, 1977). The overall depth at the transects increased from 1976 to 1981 by about 0.25 meter at many sites. The sediment organic and carbonate content were slightly lower than in 1976, but since 1981 values were very low, this is probably not an important change to the fauna. The mean grain size was similar between studies, except in May 1976, when there appeared to be exactly a 1-phi decrease in grain size at all sites sampled. By July 1976 the mean grain size had increased from 2.3 to 2.5 phi, the approximate model value for both studies. Sorting was similar, but skewness and kurtosis were greater in 1976. The major change in the physical environment between 1976 and 1981 was the increased salinity. The other changes (depth, skewness, and kurtosis) probably did not have any biological significance.

In comparing the fauna (only annelids, mollusks, crustaceans, and chironomids) the qualitative similarity (Jaccard's coefficient) is 0.73, which is a moderate overall resemblance of the fauna from 1976 to 1981. If the comparison is made on the major taxonomic level, then the similarity between studies is 0.73 for annelids, 0.40 for mollusks, and 0.80 for crustaceans (Table 28). Chironomids cannot be compared since they were not speciated in 1976. All polychaetes from 1976 occurred in 1981, plus two other species (*Polydora ligni* and *Streblospio benedicti*). Among the oligochaetes there seemed to be a complete change in species. Matta (1977) reported finding *Peloscolex* sp. and *Lumbriculus* sp. In the 2 to 3 parts per thousand salinity range, which existed in 1976, the only oligochaetes known to commonly occur are tubificids in the genus *Limnodrilus* and *Tubificodies* (= *Peloscolex*) *heterochaetus* (Diaz, 1980). Most *Lumbriculus* species are robust worms that resemble earthworms and prefer high organic sediments. The samples from the sound are not the correct habitat for *Lumbriculus* sp. Considering the possible differences between the 1976 and 1981 identifications, oligochaetes will be compared only as a higher taxon. The only mollusk in common between 1976 and 1981 was *Rangia cuneata*. Two other freshwater forms (*Physa* sp. and *Ferrissia* sp.) disappeared and *Macoma* sp., an estuarine species

Table 28. Taxonomic comparison between 1976 (Matta, 1977) and 1981 (present study) macrobenthic species collected from the sound beach.

Taxon	1976	1981
Polychaeta		
Scolecolepides viridis	+	+
Laeonereis culveri	+	+
Lysippides grayi	+	+
Polydora ligni		+
Oligochaeta	+	+
Mollusca		
Rangia cuneata	+	+
Macoma sp.		+
Physa sp	+	
Ferrissia sp.	+	
Amphipoda		
Lepidactylus dysticus	+	+
Gammarus sp.	+	+
Leptocheirus plumulosus	+	+
Monoculodes sp.	+	+
Corophium sp.		+
Isopoda		
Cyathura polita	+	+
Edotea triloba	+	+
Decapoda		
Callinectes sapidus	+	
Insecta		
Chironomidae	+	+
Tabanidae	+	
Cerotopogonidae	+	
Hirudinea		
Glossiphonid		+

appeared in 1981. Six crustaceans occurred in both studies. One freshwater form *Cambarus* sp. and one estuarine form *Callinectes sapidus* did not occur in 1981, and one estuarine species *Corophium* sp. occurred in 1981, but not 1976. Overall there were 16 taxa in 1976 and 17 in 1981. Of the five dominant species, four were the same in both studies (oligochaetes, *Scolecolepides viridis*, *Lepidactylus dysticus*, and chironomids). In 1976 *Monoculodes* sp. was dominant, but not in 1981. In 1981 the *Laeonereis culveri* was dominant but not in 1976.

In 1976, oligochaetes were not as abundant as in 1981, averaging 1,660 per square meter in 1976 and 2,290 per square meter in 1981. For both studies densities for transect IV were higher than the other two transects (the only exception was in March 1976). In 1976 *Scolecolepides viridis* tended to occur at stations farther offshore (stations 5 to 8) and averaged 69 per square meter for the study. In 1981 it averaged 500 per square meter for all collections, but *Scolecolepides viridis* became very abundant in April 1981 when salinity increased over 5 parts per thousand. In November 1980 and January 1981 it averaged 260 per square meter and in April and July 1981, 750 per square meter. *Laeonereis culveri* occurred only five times in 1976, in July, at low abundances. In 1981 it was the second numerically dominant species and occurred at almost every station.

The *Lepidactylus dysticus* was common and abundant in 1976, averaging 540 per square meter. It increased in abundance by a factor of two from October 1975 (300 per square meter) to July 1976 (700 per square meter). In 1981 *Lepidactylus dysticus* was abundant, averaging 1,025 per square meter. The trend in this species is consistent with the increased salinity. *Monoculodes* sp. was much more abundant in 1976 than in 1981. In 1976 it was a dominant species occurring at 75 percent of all stations over the entire study. In 1981 *Monoculodes* sp. was uncommon occurring at only 22 percent of the stations. In 1976 it averaged 392 per square meter and only 151 per square meter in 1981. The decline in abundance of *Monoculodes* sp. is not related to the salinity change. It is an estuarine genus that should have been favored by the higher salinity.

The chironomid larvae were widespread and abundant in 1976, occurring at almost all stations. They averaged 435 per square meter. By 1981 their importance had declined, occurring at 67 percent of all stations with an average abundance of 206 per square meter. While it is not known which chironomid species were abundant in 1976, the species present in 1981 were salt tolerant (Roback, 1974). The decline in chironomid, and possible shift to salt-tolerant forms, from 1976 to 1981 appears to reflect the increased salinity level.

Species diversity (H') for both studies was low. The range of diversity for 1976 was 0.33 to 2.33, compared with 0.00 to 2.52 in 1981. These ranges seem typical for low salinity habitats (Boesch, 1972; Diaz, 1977). Low diversity was due to both low evenness and richness. In 1976 Matta (1977) identified three communities in the sound. However, with the possible exception of a marsh area on transect IV in 1976 there did not seem to be three distinct communities. There was an overlap of the dominant species between the delineated community boundaries. With the low species number that occurred in the sound it is likely that they formed one basic low salinity community. In 1981, while salinity had increased there was still a single community in the sound. The marsh area on transect IV had receded shoreward of the first sampling site leaving all three transects with a very uniform physical environment. However, in 1981, transect IV did have higher abundances of individuals compared with the other transects. This is most obvious in the November collections and may be a relic condition associated with the marsh that was once present on the nearby existing marsh or both. There was a gradual shifting of the sound community in 1981, which attributed to increasing salinity. The major taxonomic dominants in both 1976 and 1981 were the same, but several of the species did change.

V. SUMMARY

1. Ocean Beach.

The ocean beach environment at CERC's FRF, Duck, North Carolina, was found to be typical of ocean beaches along the east coast in both physical and biological aspects. The macrofauna formed a single community unit that showed signs of migrating on and off the beach with the seasons.

Comparing the long-term changes that occurred from 1976 to 1981 (5 years), there were no substantial changes in the carbonate or organic content of the sediments, or the grain-size distributions. The small differences observed from 1976 to 1981 in the physical environment were well within the range of natural variation that open coast systems experience.

In the macrobenthic community the dominant species were identical from 1976 to 1981. The only long-term differences were found in the occurrence of the rare species. Differences observed in the abundance of species were all within natural population variations. There are no changes in the physical or biological nature of the study area that could be attributed to the FRF pier. The fauna present (1981 conditions) were typical for a high energy ocean beach and the data collected did not exhibit any effect of the pier on the beach.

2. Sound Beach.

The sound beach environment was found to be biologically similar to other low salinity estuarine habitats along the east coast. The macrofauna community gradually changed throughout the course of the study in response to the increasing salinity (from 3 to 8 parts per thousand) over the year. Salinity was the only physical variable measured that changed significantly throughout the study. During any one season there appeared to be a single community present. Abundances of individuals on transect IV were generally higher than the other two transects, but the species were the same. Higher abundances may be attributed to either the relic marsh or the nearby existing marsh or both.

In comparing the long-term changes that occurred from 1976 to 1981 (5 years) the major change in the physical environment was the salinity. Other changes in the sediments and depths were difficult to quantify and probably did not have any biological significance. Despite the fact that a marsh was present at transect IV in 1976 and had receded by 1981, there was no change in the organic content of the sediments from 1976 to 1981.

In the macrofauna community there were changes in the dominant species from 1976 to 1981. The amphipod *Monoculodes* sp. was dominant in 1976, but not in 1981. The polychaete *Laeonereis culveri* was dominant in 1981, but not in 1976. Among the less common species there were more changes with several not occurring in the 1976 and the 1981 collections. The community structure measures for both years were about the same and do not reflect any of the changes that occurred at the species level. Overall, the changes observed in the macrofauna over the 5 years were related to the increased salinity in 1981.

3. Sample Design.

The sample design employed in this study and by Matta (1977) was identical. This allowed for the best comparison of conditions through time at the selected transect locations. Considering the physically controlled nature of both the ocean and sound beaches, any environmental impact that could be detected by fixed, widely spaced transects would have to be large and widespread. Thus, fixed transects would likely not detect any changes that were very localized. Most importantly, in physically controlled environments the impact has to be very severe (with the possible exception of toxic substances, which are not at issue here) in order to be detected in the background noise of high natural variability that the physical environment imparts to the fauna.

On the ocean beach, considering the biology and physical environment, it is unlikely that any reasonably executable sampling scheme could be developed to detect the pier effects at the site sampled in the intertidal and subtidal (out to 60 meters) beach. Any effects of the pier are far overshadowed by changes in the wave climate.

On the sound beach, salinity is the main factor controlling the biological community and, in order to understand the changes in the community, salinity changes have to be incorporated into the sampling design. This could be accomplished by more frequent sampling.

Should a major impact occur in either the sound or ocean beaches, the transects as established would provide the necessary background data for assessing the impact. They also give useful detail on the long-term variation of the two systems.

VI. CONCLUSIONS

1. Ocean Beach.

No changes in the physical or biological environment from 1976 to 1981 could be attributed to the pier. Any differences documented were well within the natural variability that ocean beaches experience. Considering this large natural variability, it does not seem that a reasonably executable sampling scheme could be developed to find the pier effects in the intertidal or subtidal beach.

2. Sound Beach.

Salinity in 1981 was higher than in 1976. This increase in salinity caused most of the changes in the macrofauna. There were no noticeable effects of the marsh on any transect, except transect IV, which generally had higher numbers of individuals than the other two transects. Considering the fluctuating nature of salinity, any future monitoring of the sound beach should include consideration of a long-term salinity record.

LITERATURE CITED

BOESCH, D.F., "A New Look at the Zonation of Benthos Along the Estuarine Gradient," *Ecology of Marine Benthos*, B.C. Coull, ed., University of South Carolina Press, Columbia, S.C., 1977, pp. 245-266.

BOESCH, D.F., "Application of Numerical Classification in Ecological Investigations of Water Pollution," *Ecology Research Series*, EPA, 600/3-77-033, 1977.

BOESCH, D.F., "Species Diversity of Marine Macrobenthos in the Virginia Area," *Chesapeake Science*, Vol. 13, 1972, pp. 206-211.

BOWMAN, M.L., "The Relationship of *Emerita talpoida* to Beach Characteristics," M.S. Thesis, University of Virginia, Charlottesville, Va., 1982.

BRINKHURST, R.O., and COOK, D.G., "Aquatic Earthworms (Annelida: Oligochaeta)," *Pollution Ecology of Freshwater Invertebrates*, C.W. Hart and S.L.H. Fuller, eds., Academic Press, New York, 1974, pp. 143-156.

CARVER, R.E., *Procedures in Sedimentary Petrology*, Wiley-Interscience, New York, 1971.

COX, J.L., "Sampling Variation in Sandy Beach Littoral and Nearshore Meiofauna and Macrofauna," TP-14, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Sept. 1976.

CROKER, R.A., "Macro-infauna of Northern New England Marine Sand: Long-term Intertidal Community Structure," *Ecology of Marine Benthos*, B.C. Coull, ed., University of South Carolina Press, Columbia, S.C., 1967, pp. 439-450.

DAHL, E.,"Ecology and Zonation of Fauna of Sand Beaches," *Oikos*, Vol. 4, 1952, pp. 1-27.

DEXTER, D.M., "Comparison of the Community Structure in a Pacific and an Atlantic Panamanian Sandy-beach," *Bulletin of Marine Science*, Vol. 22, 1972, pp. 449-462.

DEXTER, D.M., "Sandy-beach Fauna of Pacific and Atlantic Coasts of Costa Rica and Columbia," *Revue Biology Tropics*, Vol. 22, 1974, pp. 51-66.

DEXTER, D.M., "The Sandy-beach Fauna of Mexico," Southwest, *Nature*, Vol. 20, 1976, pp. 479-485.

DIAZ, H., "The Mole Crab *Emerita talpoida* (Say): A Case of Changing Life History Pattern," *Ecological Monographs*, Vol. 50, 1980, pp. 437-456.

DIAZ, R.J., "The Effects of Pollution on Benthic Communities in the Tidal James River, Virginia," Ph.D. Dissertation, University of Virginia, Charlottesville, Va., 1977.

DIAZ, R.J., "Ecology of Tidal Freshwater and Estuarine Tubificidae (Oligochaeta)," *Aquatic Oligochaeta Biology*, R.D. Brinkhurst and D.G. Cook, eds., Plenum Publishing Corp., New York, 1980, pp. 319-330.

EDGREN, R.A., "Coquinas (*Donax variabilis*) on a Florida Beach," *Ecology*, Vol. 40, 1959, pp. 498-502.

FOLK, R.L., *Petrology of Sedimentary Rocks*, Hemphill, Austin, Tex., 1968.

HOLLAND, A.F., and DEAN, J.M., "The Community Biology of Intertidal Macrofauna Inhabiting Sandbars in the North Inlet Area of South Carolina, U.S.A.," *Ecology of Marine Benthos*, B.C. Coull, ed., University of South Carolina Press, Columbia, S.C., 1977, pp. 423-438.

KENNEDY, C.R., "The Life History of *Limnodrilus hoffmeisteri* Clap. (Oligochaeta: Tubificidae) and Its Adaptive Significance," *Oikos*, Vol. 17, 1966, pp. 158-168.

KNOTT, D.M., CALDER, D.R., and VAN DOLAH, R.F., "Macrobenthos of Sandy Beach and Nearshore Environments at Murrells Inlet, South Carolina, U.S.A.," unpublished manuscript, 1982.

LEPPAKOSKI, E., "Assessment of Degree of Pollution on the Basis of Macrozoobenthos in Marine and Brackish Water Environments," *Academy Aboensis*, Series B, Vol. 35, 1975, pp. 1-90.

MATTA, J.F., "Beach Fauna Study of the CERC Field Research Facility, Duck, North Carolina," MR 77-6, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Apr. 1977.

MIKKELSEN, P.S., "A Comparison of Two Florida Populations of the Coquina Clam, *Donax variabilis*, Say, 1822," *Veliger*, Vol. 23, 1981, pp. 230-239.

PEARSE, A.S., HUMM, H.J., and WARTON, G.W., "Ecology of Sand Beaches at Beaufort, North Carolina," *Ecological Monographs*, Vol. 12, 1942, pp. 135-190.

ROBACK, S.S., "Insects (Arthropoda: Insecta)," *Pollution Ecology of Freshwater Invertebrates*, C.W. Hart, Jr. and S.L.H. Fuller, eds., Academic Press, New York, 1974, pp. 313-376.

SHELTON, C.R., and ROBERTSON, P.B., "Community Structure of Intertidal Macrofauna on Two Surf-Exposed Texas Sandy Beaches," *Bulletin of Marine Science*, Vol. 31, 1981, pp. 833-842.

TENORE, K.R., "The Macrobenthos of the Pamlico River Estuary, North Carolina," *Ecological Monographs*, Vol. 42, 1972, pp. 51-69.

Diaz, R.J.
Long-term changes in beach fauna at Duck, North Carolina / by R.J. Diaz and J.T. DeAlteris--Fort Belvoir, Va. : U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Springfield, Va. : available from NTIS, 1982.
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Diaz, R.J.
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