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PRELIMINARY INVESTIGATION OF THE SHORT-TERM EFFECTS OF STORMS ON SEDIMENTARY CHARACTERISTICS AND THE NEARSHORE FAUNA USING THE SEDIMENT PROFILING CAMERA SYSTEM

by

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A pilot study was conducted to investigate the short-term effects of disturbance by storms on nearshore sandy-bottom habitats at Duck, N. C., in October 1986. Sedimentary characteristics and benthic faunal composition were assessed using a sediment profiling camera system and a traditional benthic sampling technique. Technical problems precluded benthic sampling during the prestorm period. Poststorm sampling at five stations showed that the nearshore benthic fauna can be divided into two disturbance/faunal zones on the basis of faunal composition and sedimentary characteristics. The first zone (four inshore stations, ranging in depth from approximately 4 to 12 m) was characterized by low faunal abundance and was numerically dominated by amphipods and a diverse assemblage of polychaetes. The second zone (the farthest offshore station at a depth of approximately 14 m) was characterized by high faunal abundance and was numerically dominated by

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capitellid polychaetes. The sediment profiling camera system did not provide much insight into benthic community responses to short-term disturbance in this sandy environment. This study and another study in the SUPERDUCK program were carried out simultaneously, demonstrating that when equipment needs and goals are similar and with proper planning and communication, physical and biological studies can be conducted concurrently in a cost-effective manner. Additional studies may give insight into the short-term effects of human disturbances such as dredging and disposal operations on sedimentary characteristics and the benthic community characteristic of this habitat.

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Preface

This report describes work performed by the Coastal Ecology Group (CEG), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Sta- Program. The DOTS Program is sponsored by the Headquarters, US Army Corps of Engineers (USACE), and is managed by the Environmental Effects of Dredging Programs (EEDP) of the EL.

This report was written by Ms. Christine A. Miller-Way and Mr. David A. Nelson, CEG, Environmental Resources Division (ERD), EL. The authors acknowledge the assistance of the following people: Mr. Jeffrey A. Adair, CEG; Ms. Leslie Fields, Research Division, Coastal Engineering Research Center (CERC), WES; Ms. Linda Schaffner and Dr. Robert Diaz, Virginia Institute of Marine Science, Gloucester Point, Va., and the CERC Field Research Facility Field Crew for field assistance.

Technical review of this report was provided by Mr. John Lunz, Dr. Jurij Homziak, and Dr. Doug Clarke, CEG, and by Mr. Jim Clausner, Engineering Development Division, CERC.

Dr. Robert M. Engler was Program Manager, EEDP; Mr. Thomas R. Patin was the DOTS Coordinator. Monitor for the work was Mr. David B. Mathis, Dredging Division, USACE. The report was prepared under the direct supervision of Mr. Edward J. Pullen, Chief, CEG. Dr. Conrad J. Kirby was Chief, ERD, and Dr. John Harrison was Chief, EL. This report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

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Contents

PRELIMINARY INVESTIGATION OF THE SHORT-TERM EFFECTS OF STORMS ON SEDIMENTARY CHARACTERISTICS AND THE NEARSHORE FAUNA USING THE SEDIMENT PROFILING CAMERA SYSTEM

Introduction

1. This study was one of a number of experiments designed to develop a better understanding of nearshore coastal processes under a variety of environmental conditions. These experiments, known as SUPERDUCK, were conducted at the US Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (CERC) Field Research Facility located at Duck, N. C. The SUPERDUCK experiments occurred in three phases: a low-wave energy phase, a storm-wave energy phase, and an all-weather phase.

2. The objectives of this study were to: (a) investigate the effectiveness of a sediment profiling camera system (Rhoads and Germano 1982) in studying storm events and benthic community characteristics in nearshore sandy substrates, (b) determine if the study of storm events will give insight into the potential effects of dredged material disposal and benthic response, and (c) examine the feasibility of conducting concurrent physical and biological studies. This study was conducted in coordination with a study by L. L. Weishar and M. L. Fields of the CERC, entitled "Application of the System for Evaluation of Sediment Transport Using Fluorescent Tracers."

Methods

3. Investigations of benthic community characteristics were conducted during the low-wave energy phase (hereafter referred to as prestorm) and the storm-wave energy phase (hereafter referred to as poststorm) of SUPERDUCK. Benthic community characteristics were indirectly investigated using a sediment profiling camera system (Figure 1) and directly investigated with a traditional benthic sampling method, Smith-McIntyre grab sampler (Figure 2). Samples were collected and photographs taken along a transect perpendicular to the shoreline, beginning at a depth of 14 ft (4.3 m) (the shallowest possible station at which sampling from the study vessel could be conducted) and continuing at 8-ft (2.4-m) depth intervals to a depth of 46 ft (14 m). The farthest offshore site was selected as a reference site, since this was the

shallowest depth at which sediment transport was considered unlikely during a storm of moderate strength (Birkemeier et al. 1985). Station coordinates were located with a microwave positioning system, and depths were recorded with a fathometer. The station array was taken to represent a continuum of decreasing frequency of sediment disturbance and thus would allow a determination of possible disturbance effects on the benthic communities of the nearshore zone off Duck, N. C.

4. Prestorm sampling was conducted on 9 October 1986. The storm began on the morning of 10 October and lasted 3 days. Maximum storm conditions occurred on 11 October. Winds were from the northeast and reached a maximum of 16 m/sec. Maximum wave height was 3.5 m. These conditions describe a storm of moderately strong intensity. Poststorm sampling was conducted on 29 October 1986. Sampling occurred at five stations along the transect at depths of 14, 22, 30, 38, and 46 ft (4.3, 6.7, 9.1 11.6, and 14 m), approximately 304, 610, 1,067, 1,448, and 2,286 ft (93, 186, 325, 441, and 697 m) offshore, respectively. Samples obtained are summarized in Table 1. Sediment profiling system pictures were obtained during both phases of the experiment. The parameters examined from computer analyses of sediment profiling images and the insight into benthic community processes that each parameter provides are outlined in Table 2.

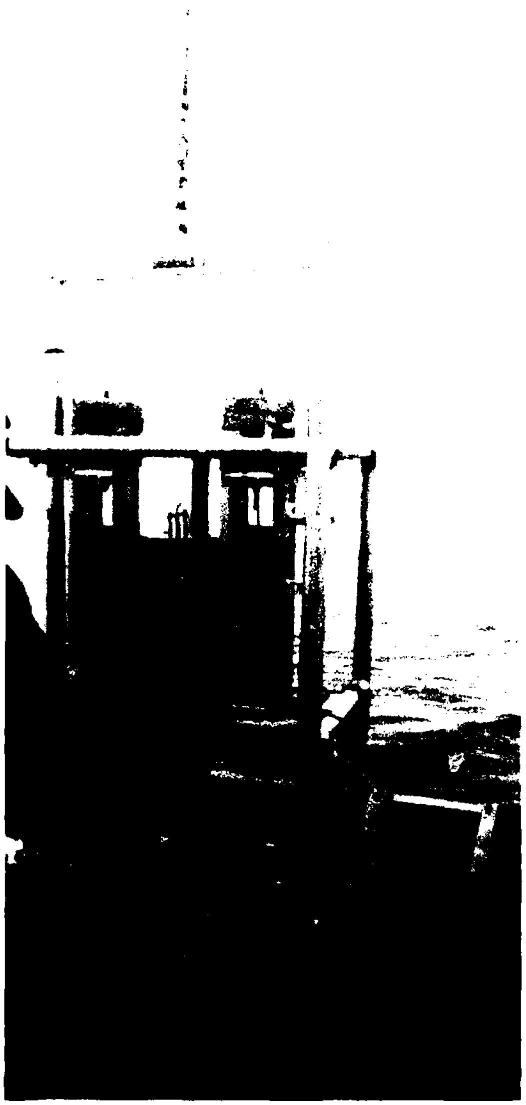

Figure 1. Sediment profiling camera system

5. Due to operational difficulties with the vessel, benthic grab samples were obtained only during the poststorm period. Three replicate benthic grab samples were taken with a small Smith-McIntyre grab sampler (sampled

area: 0.10 m^2) at each of the five stations. Samples were sieved through a 0.5-mm sieve, preserved in 10-percent formalin, and stained with Rose Bengal. In the laboratory, samples were sorted to major taxa (polychaetes were sorted to family), and individuals comprising each taxon were enumerated. Additionally, numerically dominant species were identified to the species level.

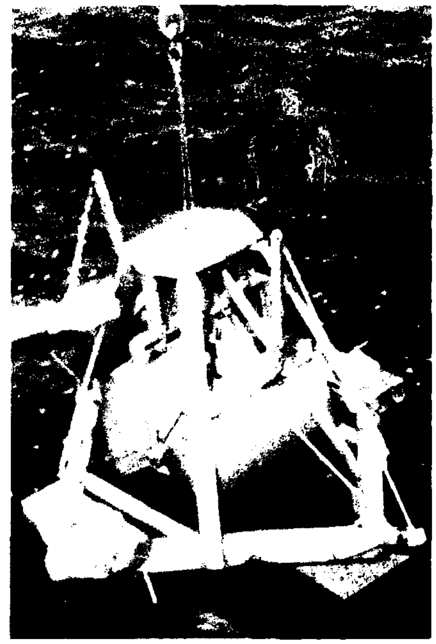

Figure 2. Smith-McIntyre grab sampler

6. Statistical analyses of the faunal data consisted of univariate correlations between taxa and cluster analyses (using squared Euclidean distances as the similarity measure and average linkage between groups as the clustering method). One-way analyses of variance were conducted to identify possible differences between stations, and Duncan's multiple range tests were used to determine which stations differed. Statistical analyses were conducted using the SPSS/PC statistical package. Data were log-transformed for the analyses of variance to better meet the assumptions of these procedures.

Results

Sediment profiling camera images

7. Measurements from the sediment profiling system images are summarized in Table 3. Examples of prestorm and poststorm sediment profiling camera images are given in Figure 3. Analyses showed that prism penetration ranged from 0.5 cm to a maximum of 9.0 cm, with most values falling between 4 and 5 cm. Penetration values (based only on replicated transect images, Stations 1 and 2) were higher on the poststorm sampling date, 29 October, than on the prestorm date, 9 October, suggesting less sediment compaction, possibly due to storm-induced sediment turbulence and transport. An inadequate number of images prohibits the statistical comparison of sediment compaction before

Table 1

Summary of Samples Obtained from the Sediment Profiling Camera System and Benthic Sampling in the Nearshore Zone at Duck, N. C., October 1986

Phase	Station	Film Type	Number of Images or Samples
	Sediment Profiling Camera System		
Prestorm	1 - Inshore	B/W	1
		Color	1
	2	Color	3
	3	Color	1
	4	B/W	1
	5 - Offshore	B/W	1
Poststorm	1 - Inshore	Color	5
	2	Color	5
	3	Color	5
	4	Color	5
	5 - Offshore	Color	5
	Smith-McIntyre Grab Samples		
Prestorm			None
Poststorm	1 - Inshore		3
	2		3
	3		3
	4		3
	5 - Offshore		3

and after the storm. The penetration data do not show a trend with depth for either sampling period (Table 3).

8. Surface relief of bed forms was greatest at Station 1 on the poststorm date and the bed was smoothest at Station 1 on the prestorm date (Table 3). Relief during the prestorm period tended to be low and hummocky. Average surface relief during the study was less than 2 cm (range: 0.22 to 2.32 cm) (Table 3).

9. The depth of the redox potential discontinuity (RPD) was at a minimum of 0.31 cm at Station 4 (11.6-m ft depth) on the poststorm sampling date. The maximum depth of the RPD could not be recorded as it exceeded the penetration depth of the camera prism. This occurred at Station 1 during the

Table 2

Physical/Chemical Parameters Measured by the Sediment Profiling Camera System (after Schaffner et al. 1987)

Parameter	Method	Information Gained
Depth of penetration	Average of maximum and minimum distance from sediment surface to bottom of prism window	Indicator of degree of sediment compaction
Surface relief	Maximum minus minimum depth of penetration	Indicator of small-scale bed roughness
Depth of redox potential discontinuity (RPD) layer	Area of oxic layer divided by width of prism window	Indicator of dissolved oxygen conditions in the sediment. In muddy sediments, indicates the degree of bioturbation. In sandy sediments, indicates porosity and the degree of turbulence
Color contrast of RPD	Contrast determined from density slicing of the digitized image	Establishes the RPD boundary. Degree of boundary convolution indicates the dominance of physical or biological processes
Area of anoxic layer	Area determined from conversion of pixel number below boundary between oxic and anoxic layers	Indicator of processes controlling RPD dynamics when combined with measurement of area of oxic layer
Area of oxic layer	Total area of image minus area of anoxic layer	Indicator of processes controlling RPD dynamics when combined with measurement of area of anoxic layer
Sediment grain size	Determined from comparison of image to images of known grain size	Indicates approximate grain size and sediment layering

(Continued)

Table 2 (Concluded)

Parameter	Method	Information Gained
Area of voids	Number counted, depth from surface measured, area determined from conversion of pixel number	Indicator of deep-living fauna
Other inclusions (methane bubbles, mud clasts, shells)	Number counted, depth from surface measured, area determined from conversion of pixel number	Indicates recent physical and biological processes
Burrows and infauna	Number counted, area delineated, species determined if possible	Burrows indicate deep-living infauna. Area provides a rough estimate of faunal density
Surface features		
Tubes	Number counted, species determined if possible	Qualitative indicator of species present and density
Epifauna	Number counted, species determined if possible	Qualitative indicator of species present and density
Pelletized layer	Thickness and area determined from conversion of pixel number	Indicator of the degree of bioturbation and sediment transport
Successional stage	Interpretation of key image features listed above	Measure of biological community development

Table 3

Results of Analyses of Sediment Profiling Camera System Photographs

Station	Date	Prism Penetration cm	Surface Relief cm	RPD Depth cm	Sediment Type	Notable Features
1	10/9	3.14	0.46	3.05	Medium/fine sand	Feeding void
1	↓	5.99	0.41	5.96	Medium/fine sand	
2	↓	4.03	0.96	4.06	Fine sand	
2	↓	3.82	1.83	1.32	↓	Onuphid tube
2	↓	2.39	0.50	2.44	↓	*Owenia* tube
3	↓	2.00	0.82	2.04	↓	
4	↓	8.59	0.78	4.51	↓	
5	↓	4.88	0.64	3.89	↓	
1	10/29	4.80	1.69	4.53	Medium/fine sand	Mineral banding
1	↓	4.51	1.18	4.74	↓	Mineral banding
1	↓	4.03	1.50	3.98	↓	Mineral banding
1	↓	1.66	2.32	1.45	↓	Mineral banding
1	↓	4.12	1.23	4.20	↓	Mineral banding
2	↓	5.83	1.18	4.24	Fine sand	Fecal pellets *Mellita*
2	↓	5.15	0.64	2.97	↓	
2	↓	4.67	1.96	2.62	↓	Fecal pellets *Mellita*
2	↓	4.96	1.55	2.17	↓	
2	↓	5.05	0.73	2.17	↓	
3	↓	4.58	1.50	2.20	↓	
3	↓	3.87	0.36	3.77	↓	Fecal pellets *Mellita*
3	↓	3.32	1.65	0.91	↓	
3	↓	4.03	0.78	3.04	↓	Fecal pellets *Spiochaetopterus*
3	↓	4.92	1.10	3.90	↓	
4	↓	3.91	0.37	3.25	↓	
4	↓	3.89	0.69	2.81	↓	
4	↓	3.66	0.77	2.68	↓	
4	↓	4.17	1.50	2.55	↓	
4	↓	4.83	0.72	3.55	↓	
5	↓	4.73	0.73	3.20	Fine sand/silt	
5	↓	3.89	0.87	2.54	↓	Feeding void
5	↓	2.68	0.91	1.19	↓	
5	↓	3.94	1.32	1.43	↓	Unidentified worm tube
5	↓	3.87	2.00	1.48	↓	

a. 9 October 1986

b. 29 October 1986

Figure 3. Prestorm and poststorm sediment profiling images (Duck, N. C., Station 2, 6.7-m depth) (contrast-stretched image)

poststorm phase (maximum prism penetration, 5.7 cm) and at Station 1 during the prestorm phase (maximum prism penetration, 6.2 cm). The average depth of the RPD was greatest inshore and lowest offshore, coinciding with offshore sediment fining; the RPD was generally greater than 3 cm inshore and less than 3 cm offshore (Table 3).

10. Sediments along the transect were typically fine to medium sands (Table 3). Inshore station sediments were fine to medium sands with shell fragments; with increasing depth, sediments became finer with traces of shell fragments, but were typically less than 1-percent silt (Schaffner et al. 1987). Mineral banding was observed at Station 1 on both sampling dates, but was not observed at other stations (Schaffner et al. 1987).

11. Sediment data from the data base that has been compiled by the CERC (Birkemeier et al. 1985) for Duck, N. C., corroborate the above results. In

general, fine sands dominate except very close to shore, and silt content is typically less than 1 percent at the depths considered in this study. Grain size distributions show that the sands are typically well sorted and not markedly skewed.

12. Images from the camera system revealed no fauna or biological features with the exception of a single feeding void at Station 1 during the prestorm period (Table 3). Flocculent detrital material was observed at all stations except Station 1 (Schaffner et al. 1987). During the prestorm phase, fecal pellets were observed at Station 5; during the poststorm phase, fecal pellets were observed at Stations 2, 3, and 4. Evidence of a tubiculous fauna was noted for Station 2 during the prestorm phase and for Stations 3 and 5 for the poststorm phase. Species that could be identified from the sediment profiling images included the polychaetes *Owenia fusiformis* and *Spiochaetopterus oculatus* (Stations 2 and 3) and the echinoderm *Mellita* sp. (Station 2).

Benthic grab sampling

13. The most apparent observation is an increase in total faunal abundance at Station 5 (14-m depth) (Figure 4). The inshore Station 1 was numerically dominated by amphipods; in contrast, other stations were numerically dominated by polychaetes (Figure 5). The intermediate stations were numerically dominated by a diverse assemblage of polychaetes whereas the offshore station was numerically dominated by capitellid polychaetes.

14. The benthic fauna sampled was similar in species composition to that previously found in this region (Dexter 1969, Matta 1977, Diaz and DeAlteris 1982). In this study, the bivalve *Donax variabilis* was common at the inner two stations (Stations 1 and 2); the bivalve *Ensis directus* was common at the most offshore site (Station 5). The offshore site was numerically dominated by the capitellid polychaete *Mediomastus* sp. Species common at the intermediate stations included the polychaetes *Magelona rosea* and *O. fusiformis*.

15. Species that were collected by the Smith-McIntyre grab and were also observed in the sediment profiling images included the polychaete *S. oculatus*, the echinoid *Mellita quinquiesperforata*, and the asteroid *Luidia clathrata* (Table 3).

16. No significant correlations were observed between the abundances of the individual taxa. The results of the cluster analysis indicated two groups (Figure 6). The first cluster included the three replicates from the station

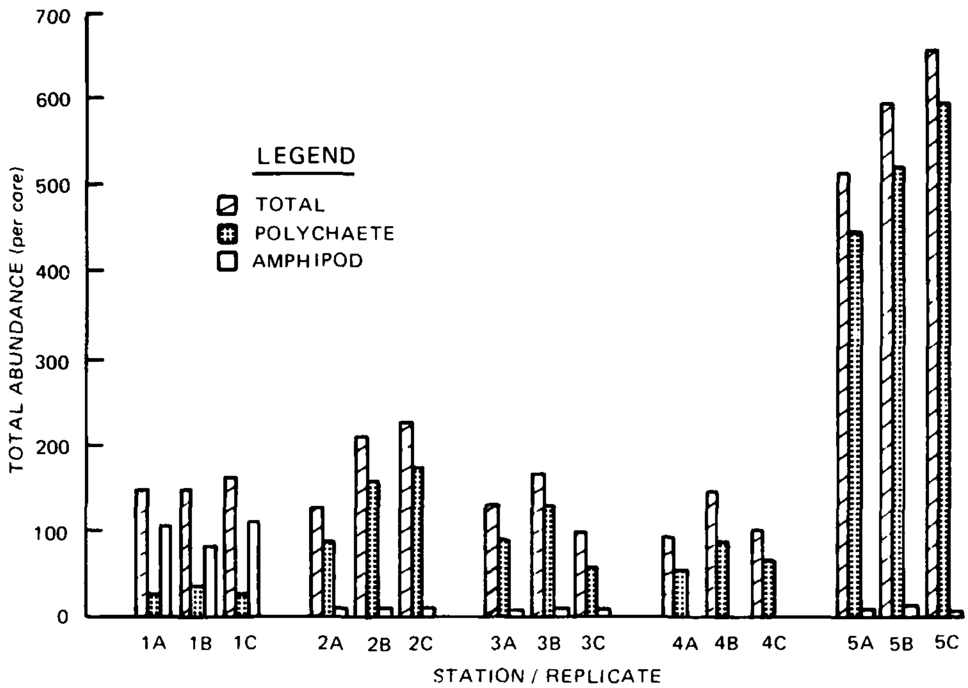

Figure 4. Abundance of benthic fauna at Duck, N. C., by major taxa

farthest offshore (Station 5). The second cluster included the three replicates from the most inshore station (Station 1) and the intermediate stations (Figure 6). Analyses of variance showed significant differences between depths with respect to total faunal abundance ($F = 27.08$; df = 4, 10; $P < 0.001$), total polychaete abundance ($F = 40.50$; df = 4, 10; $P < 0.001$), and total amphipod abundance ($F = 55.53$; df = 4, 10; $P < 0.001$). Range tests indicated that the most offshore station (Station 5) had a total faunal abundance that was significantly greater than the other stations (Table 4); total polychaete abundance was significantly less at Station 1 and significantly greater at Station 5 than at the intermediate stations (Table 4); and total amphipod abundances at Stations 1 and 4 were significantly different from the remaining stations (Table 4).

Discussion

17. The transect sampled by this study appeared to represent two discrete disturbance zones and associated faunal assemblages. The first zone, Stations 1, 2, 3, and 4, was characterized by relatively high levels of

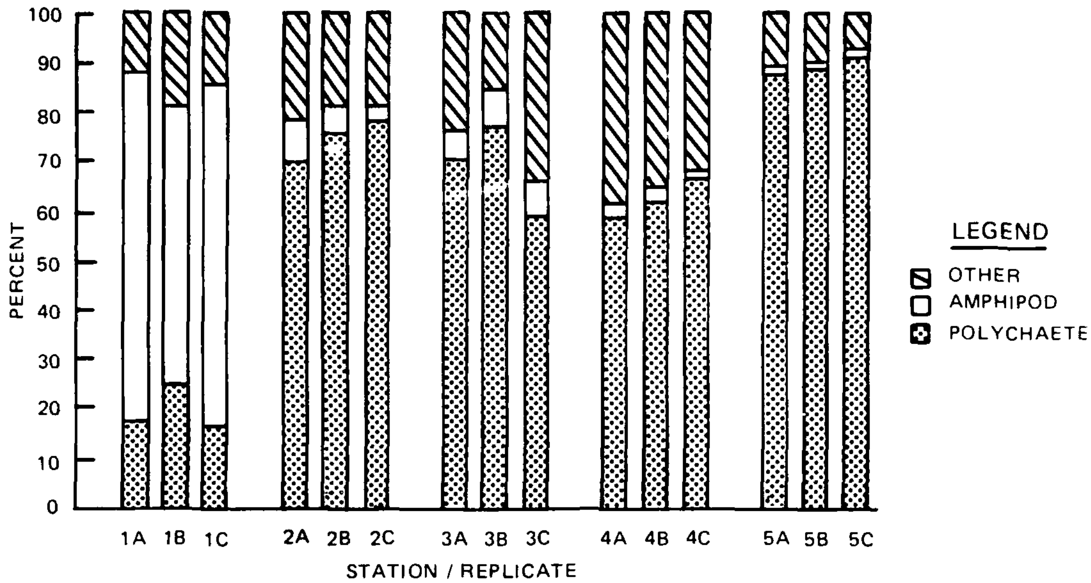

Figure 5. Percent numerical composition of taxa at Duck, N. C.

disturbance due to wave action. Within this zone, benthic samples were similar in faunal abundance and taxonomic composition. However, Station 1 and the intermediate stations were dissimilar in some respects. As depth increased within this zone, there was a shift in numerical dominance from amphipods to polychaetes. Sediment profiling photographs from Station 1 indicated an absence of animals and biological features. The effects of physical processes (due to wave action) at Station 1 were evidenced by photographs detailing a coarser sediment composition, pronounced mineral banding, and the absence of fecal pellets and flocculent material. Maximum RPD depth, maximum prism penetration, and maximum surface relief were observed at this station, indicating the possible dominance of physical processes. The fauna characterizing this station consisted of mobile species that are adapted to relatively high levels of disturbance. Haustoriid amphipods were the numerically dominant taxon. The feeding mechanisms of these amphipods is efficient only when interstitial water moves freely and the organic content of interstitial spaces is continually renewed with each tidal cycle (Holland and Dean 1977). These conditions are unlikely to be met in areas other than surf zones. The surf clam, *D. variabilis*, was also common at Station 1. This species is characteristic of littoral/surf zones and feeds on suspended particulate material. These and

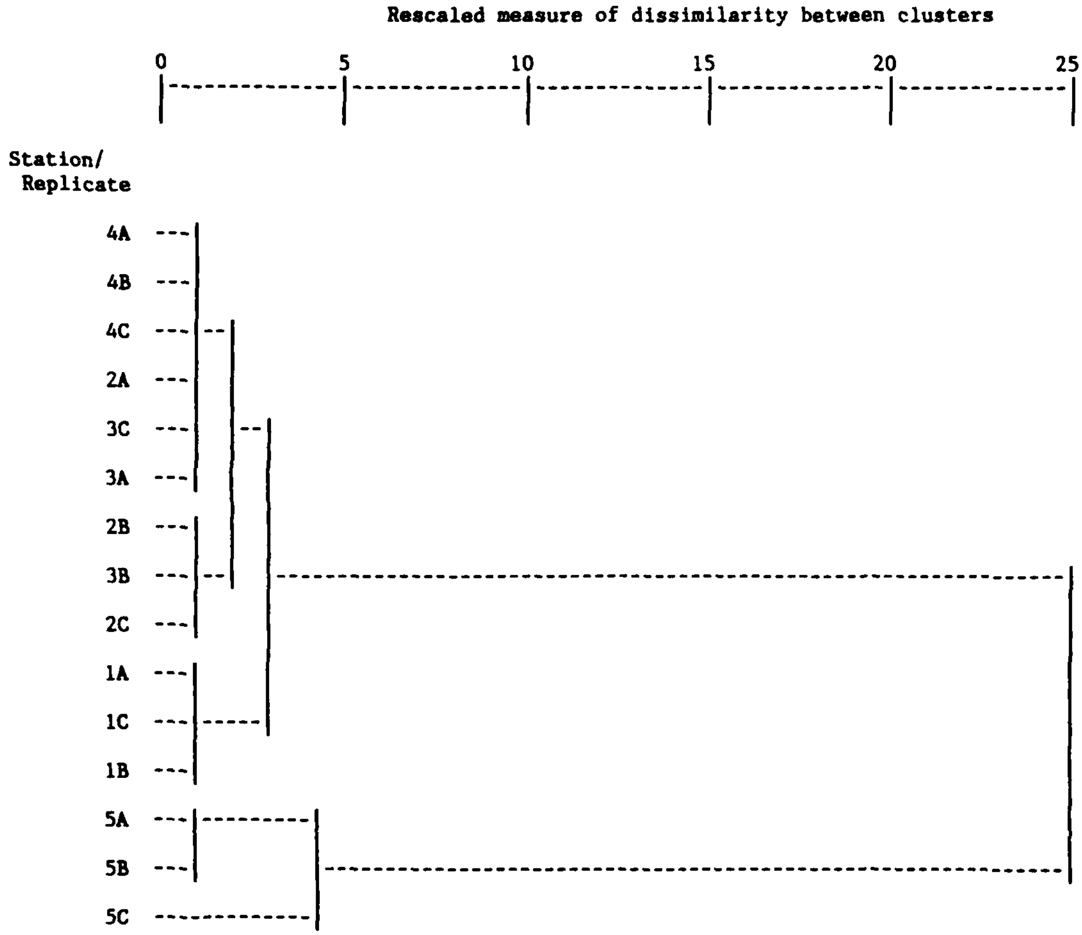

Figure 6. Dendrogram illustrating the results of cluster analysis

other species collected at this station do not produce obvious structures that could be observed with the sediment profiling system.

18. Stations 2, 3, and 4 appear to be in an area of lower wave action than Station 1. The sediment was primarily fine sands, no mineral banding was observed, and surface relief was less than that at Station 1. Polychaetes were the numerically dominant taxa at all three stations. The polychaete assemblage was typical of fine sand fauna, consisting of magelonids, oweniids, nephtyids, glycerids, and onuphids. The magelonid polychaete, *M. rosea*, and the oweniid polychaete, *O. fusiformis*, were especially common. These species have been classified as tentaculate surface-deposit feeders (Fauchald and Jumars 1979). *Owenia fusiformis* is tubiculous and is categorized as a non-motile species (Fauchald and Jumars 1979). Magelonid polychaetes, however,

Table 4

Results of Duncan's Range Tests for Total Faunal Abundance, Total Polychaete Abundance, and Total Amphipod Abundance During Poststorm Conditions*

Depth m	Faunal Abundance $\bar{x}$	Faunal Abundance SE	Polychaete Abundance $\bar{x}$	Polychaete Abundance SE	Amphipod Abundance $\bar{x}$	Amphipod Abundance SE
4.3	152.67 A	4.67	29.00 A	3.51	100.00 A	15.13
6.7	185.33 A	31.01	138.33 B	26.62	10.67 B	0.88
9.1	131.00 A	19.08	91.33 B	19.64	9.33 B	1.86
11.6	112.33 A	15.96	69.33 B	9.96	3.33 C	0.88
14	583.33 B	41.13	516.00 C	42.72	9.33 B	1.45

* Means (N = 5) with the same letter are not significantly different ($\alpha = 0.05$).

are good burrowers and are believed to be motile (Fauchald and Jumars 1979). Sediment movement and the consequent lack of deposited material for food may exclude these species from the surf zone.

19. The second disturbance/faunal zone is represented by Station 5. At this site, the level of disturbance appeared to decrease sufficiently for the establishment of a different species assemblage. The fauna in this zone was numerically dominated by a capitellid polychaete, *Mediomastus* spp. Capitellid polychaetes are generally recognized as being motile deposit-feeders (Fauchald and Jumars 1979). The lack of significant quantities of deposited material (food) would likely exclude them from areas with higher levels of sediment disturbance. The razor clam, *E. directus*, was also collected at this site. This species forms a tubular, permanent burrow from which it emerges to feed (Stanley 1970). The energetic demands of burrow construction would probably preclude its establishment in sites with high disturbance levels. Data from the sediment profiling camera photographs indicated no distinct differences between this station and Stations 2, 3, and 4. More detailed analyses of sediment particle size distribution, specifically with regard to percent silt, may reveal the reasons for the distinct species assemblages in the intermediate and the offshore zones.

20. A previous study in this area (Diaz and DeAlteris 1982) also observed distinct faunal assemblages with distance offshore. They identified three distinct faunal communities: a community characterized by the presence of the mole crab, *Emerita*, which extended from the swash zone to the inner surf zone; a *Scolelepis* (spionid polychaete) community that extended from the surf zone to approximately 50 m offshore; and a community dominated by the haustoriid amphipods, *Parahaustorius* spp., which extended from 50 m to approximately 61 m offshore, the offshore limit of their study. Although the most inshore station in the study reported herein was much farther offshore than the offshore limit of the study of Diaz and DeAlteris (1982), the latter community appears to correspond with the most inshore station identified in this study. Bathymetric charts indicate the depth at approximately 50 to 60 m offshore to be less than 3 m (Birkemeier et al. 1985).

21. Other studies (Pearse, Humm, and Wharton 1942; Dexter 1969; Holland and Dean 1977; Shelton and Robertson 1981) have reported the dominance of haustoriid amphipods in high-energy sandy environments. However, few studies have investigated the subtidal nearshore faunal communities in these areas. Additional studies examining the location of and the reasons for faunal transitions should be conducted to assess the generality of the findings of this study.

22. The lack of faunal data for the prestorm period precludes assessment of the short-term effects of storms on the benthic community. However, hypotheses regarding possible effects can be proposed using data from the sediment profiling camera photographs and the poststorm faunal data. As the zones designated in this study appear to be typical of high-energy sandy beaches (Pearse, Humm, and Wharton 1942; Shelton and Robertson 1981; Diaz and DeAlteris 1982), it is possible that the locations of the zones, with respect to the beach, shift offshore with the occurrence of storms. Storms cause the depth at which sediment movement occurs to shift offshore; the greater the power of the storm, the greater the depth to which storm waves reach and cause sediment motion. Thus, species assemblages that typically occur in areas with little sediment motion would find similar conditions farther offshore with the passing of a storm. The time frame in which this inshore/offshore shifting would occur cannot be assessed with the results of this study due to the lack of prestorm samples. However, recolonization studies conducted in similar environments (McCall 1977, Grant 1981, van Blaricom 1982, Bell and Devlin

1983) suggest that changes might occur within a period ranging from a few hours for very mobile species to a month for the burrowing forms.

23. In conjunction with the interpretation of sediment profiling camera photographs, Rhoads and colleagues (Rhoads, Aller, and Goldhaber 1977; Rhoads, McCall, and Yingst 1978; Rhoads and Germano 1982) have proposed a successional paradigm to explain changes that occur in sediment characteristics and species assemblages with disturbance and recolonization. This paradigm has not been adequately evaluated for sediment types other than fine-grained sediments (muds and mud-dominated sediments). The proposed sequence of recolonization following disturbance events includes several distinct stages. The first phase of recolonization, stage I, is characterized by low species diversity and the dominance of opportunistic and tubiculous species such as capitellid polychaetes. The RPD is generally shallow, surface relief is typically low, and sediment reworking rates by organisms typically low. Stages II and III represent a progressive "infaunalization" of the species assemblage. Stage II is identified by the presence of infaunal species such as tubiculous amphipods or shallow-dwelling bivalves. Stage III, the "equilibrium" community, is characterized by high species diversity and K-selected species.* Infaunal, "head-down, conveyor belt" deposit-feeders, possibly including maldanid, orbinid, and nephtyid polychaetes, and deep-burrowing species such as heart urchins dominate the species assemblage. These assemblages are associated with sediments that are deeply oxygenated, have high faunal sediment reworking rates, and relatively high biogenic surface relief.

24. The sediment profiling camera system appears to be less instructive in sand as opposed to mud environments. The faunal transition that occurred between the intermediate and the most offshore stations was not reflected by changes in parameters measured by the camera system. Many of the changes in the successional sequence proposed by Rhoads, McCall, and Yingst (1978) appear to be a consequence of sediment chemistry in fine-grained sediments, particularly sediment oxygen levels. In high-energy, sandy environments, sediment chemistry does not vary to the extent that it does in muddy sediments and appears to be controlled primarily by physical processes. It may therefore be a less important factor to consider when evaluating faunal recolonization

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* These species, also called "K-strategists," are competitive, long-lived individuals that have stable populations and produce relatively few young.

patterns. Additional studies are needed before this successional paradigm can be adequately evaluated for sandy environments.

25. Effective coordination between the concurrent physical and biological studies in this segment of SUPERDUCK was achieved. The sediment profiling camera system provided data critical to both studies, and the simultaneous use of the equipment and research vessel provided cost efficiency. However, detailed planning, closely allied goals, and efficient communication were found to be necessary for effective coordination.

Conclusions

26. Conclusions derived from this study are presented below.

a. As presently designed, the sediment profiling camera system has limited usefulness in evaluating benthic community processes in sand environments. Limited penetration in sand by the camera system and the dominance of physically controlled animal-sediment interactions preclude obtaining useful insights into benthic processes with this system.

b. The short-term effects of disturbance on benthic community characteristics were not adequately evaluated by this study. Additional studies on the short-term effects of natural disturbances, such as storm events, would give greater insight into the effects of man-made disturbances, such as dredged material disposal, in sand environments.

c. Studies on physical and biological processes can be conducted concurrently and cost effectively when equipment needs are similar. However, efficient planning and communication are necessary for effective coordination.

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