

Characterization of the Macro-Infauna of the
Lower Beach at Assateague Island, Maryland
Before and After Dredged Material Disposal

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Abstract

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This study was undertaken to describe the macro-infauna inhabiting the lower beach at Assateague Island, Worcester County, Maryland, before and after deposition of 50,000 cubic yards of sandy dredged material in the surf zone. Bottom samples were taken in July, August and November 1990 with a simple coring device at points from the swash zone to a water depth of three feet. The infaunal survey revealed a low diversity community composed of the mole crab (*Emerita talpoida*), the coquina clam (*Donax fossor*), a spionid worm (*Scolelepis squamata*), and two haustoriid amphipods (*Amphiporeia virginiana* and *Hauastorius canadensis*). No gross impacts were evident on the lower beach community three weeks after the dredged material was deposited.

Keywords: beach fauna, beach nourishment, Assateague Island

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Introduction

This study was initiated in conjunction with a U. S. Army Corps of Engineers project to deposit sandy dredged material from the Ocean City Inlet channel at a location along the Assateague Island ocean shoreline in Worcester County, Maryland. Although similar disposal operations had been conducted periodically in past years, there had never been any studies to characterize the benthic fauna which would be impacted. Since it was expected that additional sand deposition operations would be performed in the future for dredged material disposal and/or beach replenishment purposes, the National Park Service, which administers the area, requested that pre- and post-deposition benthic organism surveys be conducted. This report presents the results of surveys of the general benthic community. Surveys were also made to provide information on a State endangered tiger beetle (*Cicindella dorsalis media*). These results will be presented in a separate report following completion of the field surveys in the summer of 1991.

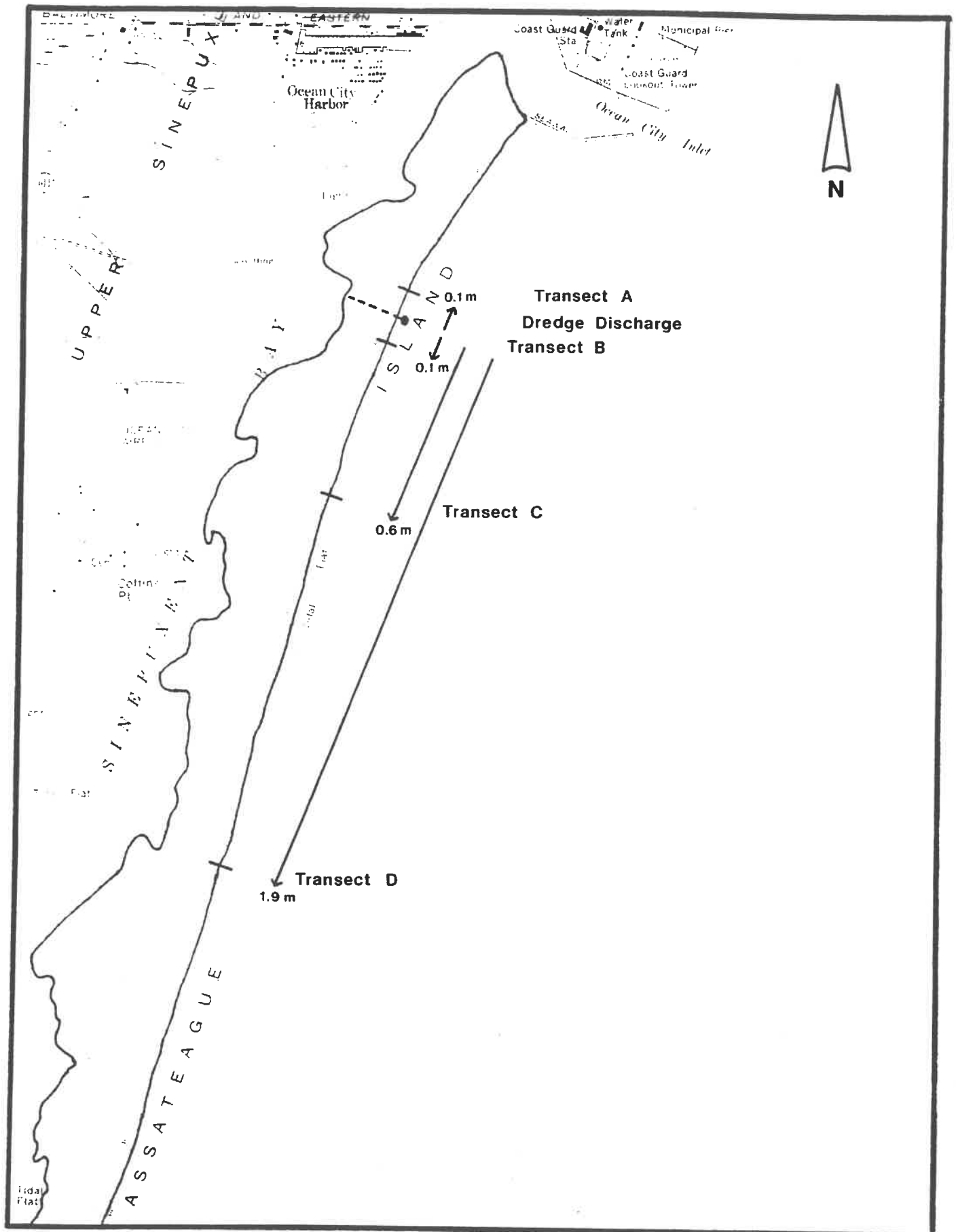
Methods

A pre-deposition infaunal survey was conducted on July 31 and August 1, 1990. The deposition of approximately 50,000 cubic yards of sandy dredged material took place from September 23 to October 9, 1990. The material was discharged from a hydraulic pipeline dredge at a point in the surf just seaward of the mean low water shoreline. A post-deposition survey was conducted on November 1 and 2, 1990.

Because of the difficulty in sampling the surf zone (Cox 1976), the study design was intended simply to characterize the lower beach infauna and to detect gross impacts resulting from the deposition of the dredged material. Four benthic sampling transects (A-D) were established (Figure 1). Transects A and B were located 0.1 miles north and 0.1 miles south, respectively of the dredge discharge point. Transects C and D were located 0.6 and 1.9 miles, respectively, south of the discharge. The transects were aligned with Corps of Engineer survey markers in the dunes to provide reference points. Transect A was located at marker A1-2, transect B at A1-3, transect C at A1-5, and transect D at A1-10.

Each transect had three sampling stations which were positioned according to the depth of the water. Station 1 was in the swash zone, the area of the beach that is alternately covered with water by wave up-rush and exposed to air during wave down-rush. Station 2 was located where the water was approximately 1.5 feet deep and station 3 was located where the depth became approximately 3.0 feet deep. The latter depth represented the greatest depth that could be effectively

Figure 1. Location of the study transects.



sampled by wading. The actual station locations were dependent on the stage of the tide, which has a mean range of 3.5 feet in this area (U. S. Department of Commerce 1989). Because of logistical limitations, such as the length of time needed to conduct the sampling, the tidal stage varied over the collection periods.

Bottom samples were taken with a simple coring device, a can with a height of 13.5 cm and a diameter of 10 cm. A core was taken by pushing the can vertically down into the sand. Before removal, one hand was used to dig alongside and cover the open end. Three cores were pooled to make one sample covering 0.024 m² of bottom. Two samples were taken at each station. The samples were washed through a 1.0 mm mesh sieve. The organisms retained on the sieve were preserved in a 10% formalin solution with the exception of the larger mole crabs, which were counted and released. The organisms in the preserved samples were subsequently identified and counted under laboratory conditions.

Study Area Results

The Assateague Island beach faces east southeast and is exposed to considerable wave energy from the Atlantic Ocean. The mean tidal range is 3.5 feet, and the spring range is 4.2 feet (U. S. Department of Commerce 1989). A 1990 Corps of Engineer beach profile survey indicated that the beach slope in the intertidal area was on the order of 3 to 5 degrees. The sand grain size was not measured, but a survey at the nearby Ocean City beach found the mean grain size, excluding gravel, to be 1.45 phi (0.37 mm) which is classified as medium sand (U. S. Army, Corps of Engineers 1989).

Pre-Deposition Survey

The results of the pre-deposition survey are shown in Table 1. Only five species were collected. Overall, the mole crab (*Emerita talpoida*) was the most abundant organism (234 individuals), followed by the polychaete, *Scolelepis squamata* (214), an amphipod, *Amphiporeia virginiana* (127), a bivalve, *Donax fossor* (97), and a second amphipod, *Haustorius canadensis* (32). With the exception of *Scolelepis*, most of the organisms were collected at stations 1 and 2. *Scolelepis* was most common in the deeper water at station 3.

Except for the lack of *Amphiporeia* at transect C, all five species were found at each transect. Abundance, however, was generally variable. *Donax* was substantially more abundant at transects A and B, and a particularly high number of

Table 1. Species and numbers of organisms collected in each sample (0.024m²) from the pre-deposition survey (7/31-8/1/90).

<u>Transect A</u>	<u>1a</u>	<u>1b</u>	<u>2a</u>	<u>2b</u>	<u>3a</u>	<u>3b</u>	<u>Total</u>
<i>Donax fossor</i>	17	9					26
<i>Emerita talpoida</i>	45	10	7	4			66
<i>Haustorius canadensis</i>	1	2	1	1			5
<i>Amphiporeia virginiana</i>	9					1	10
<i>Scoelepis squamata</i>					38	32	70
<u>Transect B</u>							
<i>Donax fossor</i>	61	2		2			65
<i>Emerita talpoida</i>	19	6	6	7			38
<i>Haustorius canadensis</i>	1		1	1			3
<i>Amphiporeia virginiana</i>	13		95			1	109
<i>Scoelepis squamata</i>					13	63	76
<u>Transect C</u>							
<i>Donax fossor</i>	5						5
<i>Emerita talpoida</i>	43	34	2	1			80
<i>Haustorius canadensis</i>	4	4			1	4	13
<i>Amphiporeia virginiana</i>							0
<i>Scoelepis squamata</i>			1		10	9	20
<u>Transect D¹</u>							
<i>Donax fossor</i>	1						1
<i>Emerita talpoida</i>	10	4	14	22			50
<i>Haustorius canadensis</i>	10		1				11
<i>Amphiporeia virginiana</i>	2	3		2	1		8
<i>Scoelepis squamata</i>				10	21	17	48

¹Only 2 cores were collected in sample 2b.

Amphiporeia was found at transect B. The abundance of these two species even varied considerably within a distance of only a few feet, as evidenced by the widely differing counts for the two samples taken at each station.

Post-Deposition Survey

The post-deposition survey was conducted 23 days after the pumping ceased. The only obvious physical evidence of the dredged material was a large shallow shoal visible in the surf zone at low tide where the material was discharged. The post-deposition infaunal survey revealed the same five species that were found previously (Table 2). The most noticeable difference between the pre and post surveys was the scarcity of *Donax*; only three were found as compared to 97 in the pre-deposition survey. The decline in their abundance was most apparent at transects A and B since these transects contained the highest numbers in the pre-deposition survey.

The abundance of *Emerita* at transect A was quite low compared to the numbers found at the other transects and compared to the pre-deposition abundance. The numbers of *Haustorius* were low in transects A and B (1 individual) compared to transects C and D (24) or to the numbers in the pre-deposition survey (8). The opposite trend occurred with *Amphiporeia*, which was rare at transects C and D (1 individual), but remained relatively common (40) at transects A and B.

Discussion

The exposed ocean beach is a rigorous, physically demanding environment that severely limits benthic faunal diversity. The sand substrate is continually shifting as a result of the breaking waves. During storm conditions tremendous quantities of sand can be removed or deposited on the beach within a few days. The species found at Assateague are all typical occupants of this habitat and have been reported in various other faunal surveys on East Coast exposed beaches (Pearse 1942, Dexter 1967 and 1969, Croker 1967 and 1970, Croker et al. 1975, Matta 1977, Leber 1977, Knott et al. 1983, and McDermott 1983).

Emerita talpoida is one of the most common and conspicuous benthic inhabitants of wave-swept coast beaches from Massachusetts to Florida (Efford 1976). It is essentially restricted to the intertidal zone, except during the winter when it moves into deeper water (Edwards and Irving 1943, Gosner 1971, Leber 1977, Reilly and Bellis 1978). It can swim but is morphologically adapted primarily for burrowing. It

Table 2. Species and numbers of organisms collected in each sample (0.024m²) from the post-deposition survey (11/1-11/2/90).

<u>Transect A</u>	<u>1a</u>	<u>1b</u>	<u>2a</u>	<u>2b</u>	<u>3a</u>	<u>3b</u>	<u>Total</u>
<i>Donax fossor</i>							0
<i>Emerita talpoida</i>	1	2					3
<i>Haustorius canadensis</i>							0
<i>Amphiporeia virginiana</i>	23	11					34
<i>Scoelepis squamata</i>	61	10	2	1	18	7	99
<u>Transect B</u>							
<i>Donax fossor</i>							0
<i>Emerita talpoida</i>	5	26					31
<i>Haustorius canadensis</i>				1			1
<i>Amphiporeia virginiana</i>	5	1					6
<i>Scoelepis squamata</i>	12	3	2	1	17	18	53
<u>Transect C</u>							
<i>Donax fossor</i>	2	1					3
<i>Emerita talpoida</i>	30	36				2	68
<i>Haustorius canadensis</i>		9			7	2	18
<i>Amphiporeia virginiana</i>			1				1
<i>Scoelepis squamata</i>				5	3	37	48
<u>Transect D</u>							
<i>Donax fossor</i>							0
<i>Emerita talpoida</i>	16	59					75
<i>Haustorius canadensis</i>			1		5		6
<i>Amphiporeia virginiana</i>							0
<i>Scoelepis squamata</i>	7	15	10	5	5	6	48

migrates up and down the beach slope with the tide by emerging from the sand, often in large groups, and riding the wave wash before rapidly burrowing back into the sand (Cubit 1969). In a similar manner *Emerita* moves laterally along the beach with the longshore currents (Dillery and Knapp 1970). It has a tendency to occur in aggregations, which seems to be primarily due to subtle variations in wave patterns and beach morphology (Efford 1965, Bowman and Dolan 1985).

Emerita feeds by passively filtering the water with its feathery antennae (Efford 1966). Reproduction occurs throughout the summer and involves the production of planktonic larvae (Hunter 1972, Sandifer 1973). There are six zoea stages and a megalops (Shield 1973). The megalops eventually washes onto the beach where it molts into the adult form. The males are precociously mature. They become sexually active soon after arriving on the beach from the plankton and are often attached to older, much larger females (Efford 1967). The males live for approximately one year, while the females survive a few months longer (Pearse 1942).

Donax fossor is a small, filter-feeding bivalve that inhabits surf exposed sandy coastlines from Nags Head, North Carolina to New Jersey, and intermittently to the south shore of Long Island, New York (Morrison 1971). There has been disagreement among researchers on whether *D. fossor* is a distinct species or whether it is simply a northern variation of *D. variabilis*. Both names appear in the literature in reference to the single species occurring north of the mouth of Chesapeake Bay. At Assateague it inhabits the intertidal beach from the second half of June to November (Chanley 1969). It is thought to reproduce during the summer based on the presence of mature gametes and the appearance of larvae in summer zooplankton collections (Grant 1979).

It moves up and down the beach slope with the tide, utilizing the wave wash to move over the sand. It extends its foot as a drag to slow its movement and is often seen briefly exposed on the beach as waves recede before rapidly digging into the sand (Turner and Belding 1957). Its movement also appears to have a lateral component along the beach (Loesch 1957). It often displays a patchy distribution and large annual fluctuations (McDermott 1983, Reilly and Bellis 1983, Loesch 1957). It moves offshore as the temperature drops in the fall. Large numbers have been found in January and April collections from Maryland coastal waters out to a depth of five meters (Mihursky et al. 1985, U. S. Fish and Wildlife Service unpublished data). It has a life span of approximately two years (Morrison 1971).

Amphiporeia virginiana is an haustoriid amphipod inhabiting exposed coastal beaches from Nova Scotia to South Carolina (Dexter 1967). It is most common in the lower half of the intertidal zone, extending a short way subtidally (Croker 1970, 1975, and 1977, Fox and Bynum 1975, McDermott 1983, Knott et al. 1983). Although basically a burrowing species (Bousfield 1970), it is not as restricted to infaunal living as other haustoriids. It is often found swimming in the surf and actively moves up and down the beach with the tide. It is classified as a filter-feeder. The breeding season extends from January to September and, as is typical of amphipods, it broods its eggs and young. The brood size varies from 4 to 21. The life span is from 6 to 12 months.

Haustorius canadensis is a large burrowing haustoriid amphipod which is distributed from the Gulf of St. Lawrence to the mouth of Chesapeake Bay (Bousfield 1973). A similar long rostrate form extends southward to Georgia (Croker 1967a). It inhabits surf exposed or semi-protected beaches, almost exclusively within the intertidal zone. It tends to occur higher on the beach slope in the warmer months and lower in the winter (Sameoto 1969a, Croker 1977). Most of its existence is spent within the sand, but it may enter the water column for brief periods at night possibly for mating purposes (Sameoto 1969a). It usually occurs in the top 5 cm of sand, but occasionally may be as deep as 12 cm or more (Dexter 1967a, Sameoto 1969a). It has been found to maintain its distribution on the beach even after severe storms altered the beach morphology (Croker 1968).

Haustorius can burrow and feed only when the sand is saturated. It is a highly developed filter-feeder that strains detritus and associated organisms from the interstitial water (Croker 1967b, Bousfield 1970). The tidal and wave circulation is important in renewing the interstitial water for feeding, as well as maintaining sufficient oxygen levels (Sameoto 1969b). The protracted reproductive season begins in the spring and continues through summer. The eggs and young are brooded, with the brood size varying from 4 to 25 (Croker 1977). The life span is approximately 12 months (Sameoto 1969a).

Scoelelepis squamata is a spionid polychaete that inhabits sandy littoral habitats along the coast from northern New England to the southeastern states (Dexter 1969, Croker 1977). It occurs on both exposed and protected beaches, reaching its greatest abundance in the lower intertidal and shallow subtidal region (Croker 1970, Matta 1977, McDermott 1983, Knott et al. 1983). During the winter it is lower on the beach, occupying a position just below mean low water. It is a surface deposit feeder that resides within a loosely built tube (Fauchald and Jumars 1979). The worms are often

dislodged by the waves, but are able to quickly burrow back into the sand. The reproductive cycle involves production of pelagic larvae.

Emerita, *Donax*, *Amphiporeia*, *Haustorius*, and *Scolecopsis* share several noteworthy characteristics. They are not widely distributed in the marine environment, but are restricted to the coastal fringe where they prefer areas of clean sand. They are proficient burrowers that can accommodate the inherent substrate instability. They are relatively mobile and can quickly reposition themselves in the bottom after being dislodged by the waves. They have a short life cycle and repopulate rapidly after periods of decline. While the individual populations can be expected to fluctuate substantially over time and space, the community as a whole is relatively stable in terms of species composition.

A number of studies have yielded information on the role that these species play in the coastal marine food web. Stomach analyses and observations by Loesch (1957) demonstrated that *Donax* spp. were eaten by various birds (willet, black bellied plover, and sanderling), fish (kingfish, spot, and drum), and crabs (blue, ghost, and spotted). Leber (1977) found *Donax* in the stomachs of pompano, and *Emerita* in southern kingfish and summer flounder. He also observed plovers and sandpipers feeding on *Emerita*, portunid crabs (*Arenaeus* and *Ovalipes*) feeding on *Donax*, and ghost crabs feeding on both *Emerita* and *Donax*. Wolcott (1978) determined that *Emerita* and *Donax* comprised more than 90% of the diet of ghost crabs.

McDermott (1983) found that *Scolecopsis* was a major component in the diet of certain shore zone fishes (silverside, spot, and northern kingfish). The fishes also utilized *Donax*, *Emerita*, and *Amphiporeia*. His work disclosed that *Scolecopsis* and *Donax* were important in the diet of the lady crab (*Ovalipes*), and that *Emerita* and *Amphiporeia* were eaten by another portunid crab (*Arenaeus*).

Pearse et al. (1942) observed plovers and sandpipers feeding on *Emerita*, *Donax*, and other small infaunal organisms. Mueller (1976) reported on several unusual occurrences of common terns feeding on *Emerita*. Croker (1967a) reported that large numbers of shorebirds fed on a Georgia beach where haustorid amphipods were abundant. Sameoto (1969a) observed blacked-bellied plovers and sandpipers regularly feeding on a Cape Cod beach where haustorid amphipods were the presumed prey.

Effect of Dredged Material Deposition

The post-deposition survey did not reveal any broad depression in the benthic infauna community that could be attributed to the dredged material disposal operation. Good numbers of *Scolecopsis* and *Amphiporeia* were present at the transects in the deposition vicinity. The sparsity of *Donax* in all of the post-deposition samples coincided with their seasonal migration offshore. Although there was some reduction in the numbers of *Emerita* and *Haustorius* in the post-deposition samples near the deposition area, the sampling program was not intense enough to resolve these potential effects. The low numbers of *Emerita* at one of the two transects in the deposition area could have been due to effects of the dredged material deposition, but natural patchiness in the distribution could also be responsible. Although *Haustorius* was virtually absent from the post-deposition A and B transects, little significance can be ascribed to this since the numbers in the pre-deposition survey were so low (8).

Studies on beach nourishment have indicated various impacts to the beach invertebrate fauna depending on the compatibility of the beach and nourishment material, time of year, magnitude of the project, and species present (Thompson 1973, Hayden and Dolan 1974, Reilly and Bellis 1983, Mihursky et al. 1986, Nelson and Pullen 1990). At Assateague Island the dredged material was discharged below the mean low water shoreline so the intertidal zone, where most of the sampling was conducted, was not within the main deposition area. The volume of material was relatively small, 50,000 cubic yards. The material was virtually all sand, although likely somewhat smaller in grain size than the existing beach material (Robert Blama, Corps of Engineers, pers. commun.). The beach fauna was composed of species which are adapted to the natural shifting sand conditions of the turbulent surf environment. They would be expected to have good survival outside the primary impact zone and be capable of rapid repopulation of the disturbed area. These factors are all entirely consistent with the finding that no substantial impact on the beach fauna was evident three weeks after the discharge ceased.

Literature Cited

- Bousfield, E. L. 1970. Adaptive radiation in sand-burrowing amphipod crustaceans. *Chesapeake Science* 11(3):143-154.
- Bousfield, E. L. 1973. Shallow-Water Gammaridean Amphipoda of New England. Comstock Publ. Assoc. Cornell University.
- Bowman, M. L. and R. Dolan. 1985. The relationship of *Emerita talpoida* to beach characteristics. *Journal of Coastal Research* 1(2):151-163.
- Chanley, P. 1969. Larval development of the coquina clam, *Donax variabilis* Say, with a discussion of the structure of the larval hinge in the Tellinacea. *Bulletin of Marine Science* 19(1):214-224.
- Cox, J. L. 1976. Sampling variation in sandy beach littoral and nearshore meiofauna and macrofauna. U. S. Army, Corps of Engineers, Coastal Engineering Research Center, Technical Paper No. 76-14.
- Croker, R. A. 1976a. Niche diversity in five sympatric species of intertidal amphipods (Crustacea: Haustoriidae). *Ecological Monographs* 37:173-200.
- _____. 1967b. Niche specificity of *Neohaustorius schmitzi* and *Haustorius* sp. (Crustacea: Amphipoda) in North Carolina. *Ecology* 48:971-975.
- _____. 1968. Distribution and abundance of some intertidal sand beach amphipods accompanying the passage of the hurricanes. *Chesapeake Science* 9(3):157-162.
- _____. 1970. Intertidal sand macrofauna from Long Island, New York. *Chesapeake Science* 11(2):134-137.
- _____. 1977. Macro-infauna of northern New England marine sand: long-term intertidal community structure. p 439-450. In B. C. Coull (ed.), *Ecology of Marine Benthos*. University of South Carolina Press, Columbia. South Carolina.
- _____. R. P. Hager, and K. J. Scott. 1975. Macroinfauna of northern New England marine sand. II. Amphipod-dominated intertidal communities. *Canadian Journal of Zoology* 53:42-51.
- Cubit, J. 1969. Behavior and physical factors causing migration and aggregation of the sand crab *Emerita analoga* (Stimpson). *Ecology* 50(1):118-123.

- Dexter, D. M. 1967. Distribution and niche diversity of haustoriid amphipods in North Carolina. *Chesapeake Science* 8(3):187-192.
- _____. 1969. Structure of an intertidal sandy-beach community in North Carolina. *Chesapeake Science* 10(2):93-98.
- Dillery, D. G. and L. V. Knapp. 1970. Longshore movements of the sand crab, *Emerita analoga* (Decapoda, Hippidae).
- Edwards, G. A. and L. Irving. 1943. The influence of temperature and season upon the oxygen consumption of the sand crab, *Emerita talpoida* Say. *Journal of Cellular and Comparative Physiology* 21(2):169-192.
- Efford, I. E. 1965. Aggregation in the sand crab, *Emerita analoga* (Stimpson). *Journal of Animal Ecology* 34:63-75.
- _____. 1966. Feeding in the sand crab, *Emerita analoga* (Stimpson) (Decapoda, Anomura). *Crustaceana* 10:167-182.
- _____. 1967. Neoteny in sand crabs of the genus *Emerita* (Anomura, Hippidae). *Crustaceana* 13(1):81-93.
- _____. 1976. Distribution of the sand crabs in the genus *Emerita* (Decapoda, Hippidae). *Crustaceana* 30(2):169-183.
- Fauchald, K. and P. A. Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. *Oceanography and Marine Biology, Annual Review* 17:285-346.
- Fox, R. S. and K. H. Bynum. 1975. The amphipod crustaceans of North Carolina estuarine waters. *Chesapeake Science* 16(4):223-237.
- Gosner, K. L. 1971. Guide to Identification of Marine and Estuarine Invertebrates, Cape Hatteras to the Bay of Fundy. John Wiley and Sons, New York.
- Grant, G. C. 1979. Middle Atlantic Bight zooplankton: second year results and a discussion of the two-year BLM-VIMS survey. Special Report in Applied Marine Science and Ocean Engineering No. 192, Virginia Institute of Marine Science, Gloucester Point, Virginia.
- Hayden, B. and R. Dolan. 1974. Impact of beach nourishment on distribution of *Emerita talpoida*, the common mole crab. *Journal of the Waterways, Harbors and Coastal Engineering Division* 100:123-132.
- Hunter, E. 1972. Spawning season, embryonic and larval life of *Emerita talpoida* (abstract). *American Zoologist* 12(4):726.

- Knott, D. M., D. R. Calder, and R. F. Van Dolah. 1983. Macrobenthos of sandy beach and nearshore environments at Murrells Inlet, South Carolina, U.S.A. *Estuarine, Coastal and Shelf Science* 16:573-590.
- Leber, K. M. 1977. Seasonal community dynamics of macrobenthos on a high energy sandy beach in North Carolina. Master's Thesis, East Carolina University, Greenville, North Carolina. 89 p.
- Loesch, H. C. 1957. Studies on the ecology of two species of *Donax* on Mustang Island, Texas. *Publications of the Institute of Marine Science University of Texas* 4(2):201-227.
- Matta, J. F. 1977. Beach fauna study of the CERC Field Research Facility, Duck, North Carolina. U. S. Army, Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report No. 77-6.
- McDermott, J. J. 1983. Food web in the surf zone of an exposed sandy beach along the mid-Atlantic coast of the United States, p. 529-538. *In* A. McLachlan and T. Erasmus (eds.), *Sandy Beaches As Ecosystems*. W. Junk, The Hague, Netherlands.
- Mihursky, J. A., B. Millsaps, L. Ward, and J. Nussbaum. 1986. Benthic-animal-sediment assessment of Maryland's coastal waters from Maryland-Delaware State line to Ocean City Inlet. Report from the University of Maryland Center For Environmental and Estuarine Studies to Maryland Department of Natural Resources, UM CEES/CBL Ref. No. UMCEES-86-141CBL.
- Morrison, J. P. E. 1971. Western Atlantic *Donax*. *Proceedings of the Biological Society of Washington* 84(48):545-568.
- Mueller, H. C. 1976. Common terns feed on mole crabs. *Wilson Bulletin* 88:375-376.
- Nelson, D. A. and E. J. Pullen. 1990. Environmental considerations in using beach nourishment for dredged material placement, p. 113-128. *In* R. L. Lazor and R. Medina (eds.), *Beneficial Uses of Dredged Material*, Proc. of the Gulf Coast Regional Workshop, April 26-28, 1988. Galveston, Texas. Tech. Rpt. D-90-3. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Pearse, A. S., H. J. Humm, and G. W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. *Ecological Monographs* 12:135-190.

- Reilly, F. J., Jr. and V. J. Bellis. 1983. The ecological impact of beach nourishment with dredged materials on the intertidal zone at Bogue Banks, North Carolina. U. S. Army Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Report No. 83-3.
- Sameoto, D. D. 1969a. Comparative ecology, life histories, and behavior of intertidal sand-burrowing amphipods (Crustacea: Haustoriidae) at Cape Cod. Journal of the Fisheries Research Board of Canada 26:361-388.
- _____. 1969b. Physiological tolerances and behavior responses of five species of Haustoriidae (Amphipoda: Crustacea) to five environmental factors. Journal of the Fisheries Research Board of Canada 26:2283-2298.
- Sandifer, P. H. 1973. Distribution and abundance of decapod crustacean larvae in the York River estuary and adjacent lower Chesapeake Bay, Virginia, 1968-1969. Chesapeake Science 14(4):235-257.
- Shield, P. 1973. The chromatophores of *Emerita talpoida* (Say) zoeae considered as a diagnostic character. Chesapeake Science 14(1):41-47.
- Thompson, J. R. 1973. Ecological effects of offshore dredging and beach nourishment: a review. U. S. Army, Corps of Engineers, Coastal Engineering Research Center, Miscellaneous Paper No. 1-73.
- Turner, H. J., Jr. and D. L. Belding. 1957. The tidal migrations of *Donax variabilis* Say. Limnology and Oceanography 2(2):120-124.
- U. S. Army, Corps of Engineers. 1989. Atlantic Coast of Maryland Hurricane Protection Project. General Design Memorandum.
- U. S. Department of Commerce. 1989. Tide Tables 1990, East Coast of North and South America. National Oceanic and Atmospheric Administration, National Ocean Survey.
- U. S. Fish and Wildlife Service. 1979. Benthos survey of proposed ocean borrow sites for Ocean City. Unpublished data.
- Wolcott, T. G. 1978. Ecological role of ghost crabs, *Ocypode quadrata* (Fabricius) on an ocean beach: scavengers or predators. Journal of Experimental Marine Biology and Ecology 31:67-82.