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Impact of Beach Nourishment on Distribution of *Emerita talpoida*, the Common Mole Crab

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Introduction

Since the passage of the National Environmental Policy Act of 1969, the determination of the ecological impact of engineering projects involving alteration of the natural landscape has become both a practical and legal necessity. The widespread occurrence of shoreline recession (9) has precipitated many engineering projects designed to check "beach erosion." Beach nourishment, sea walls, breakwaters, and groin construction are currently underway in several coastal locations. Of the four erosion-control techniques, beach nourishment is particularly attractive in that the character of the shoreline is little changed (6); however, the ecological impact of discharging thousands of cubic yards of sand onto the beach is little known.

In 1972, under the sponsorship of the National Park Service, the writers were contracted to assess the ecological and physical impact of a large beach-nourishment program at Cape Hatteras, N.C. The location of the nourishment site is shown in Fig. 1. Since all aspects of the beach-face ecology could not be monitored, it was decided to concentrate on the common mole crab. As an inhabitant of the swash zone, *Emerita talpoida* is vulnerable to beach-face modification and thus likely to exhibit a response to such activity. In addition, *E. talpoida* is an important link between subaqueous and subaerial food chains; it feeds on plankton in the swash zone and, in turn, is subject to predaceous shore birds. Significant disruption of *E. talpoida* populations could have ecological implications to the barrier-island ecosystem.

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History of Cape Hatteras Erosion and Beach Nourishment Project

It has long been recognized by coastal engineers that beach erosion becomes a serious problem only when man-made structures are threatened by shoreline recession. Public concern about recession along the Outer Banks of North Carolina can be traced back to the early development of the beach-front property during the late 1930's and 1940's. Serious problems were inevitable as the erosional forces along the mid-Atlantic are highly variable and time-dependent; and the line of development, once it had been established along the Outer Banks, remained fixed.

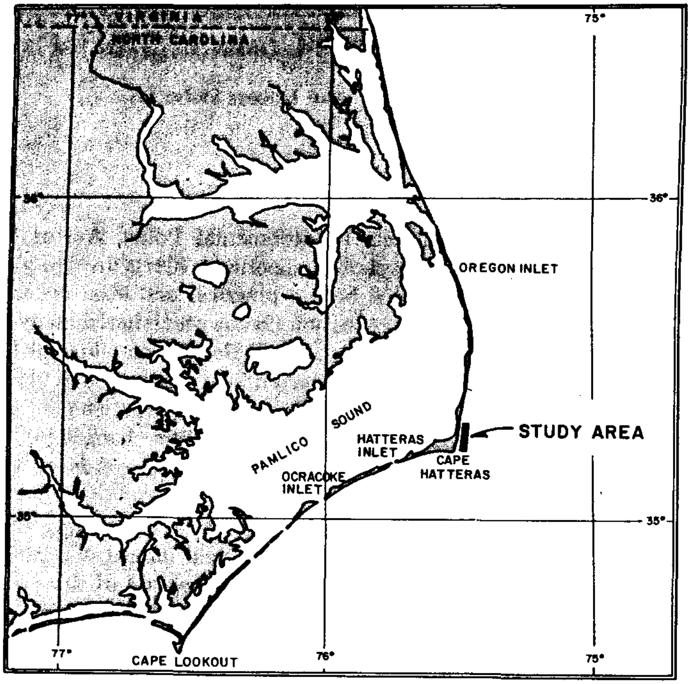

FIG. 1.—Location Map: Study Area on Barrier Islands of North Carolina

Narrowing of the distance between the line of development and the active surf zone at Cape Hatteras reached a critical point during the mid-1960's. Large segments of the man-made barrier dunes which had been constructed in the late 1930's were lost and oceanic overwash became a constant threat. The distance between the Cape Hatteras Lighthouse and the surf zone reached 256 ft (78 m) in 1966, as shown in Fig. 2. With reversal of this trend unlikely and relocation of the shoreline developments virtually impossible, the National Park Service contracted a beach-nourishment project in which 312,000 cu yd (239,000 m^3) of sand were placed along the beach areas of greatest concern.

The material for this restoration program was extracted from a large tidal delta that had been deposited by an inlet during the storm of March 6-8, 1962.

However, the borrow material was too fine to remain as part of the subaerial beach system and the quantity too small to have significant impact on the inshore bar-trough system.

This initial experiment in nourishment proved to be ineffective; by 1967, continuous erosion had placed the Cape Hatteras Lighthouse and the U.S. Naval facility at Buxton in positions vulnerable to wave and surge forces. Following

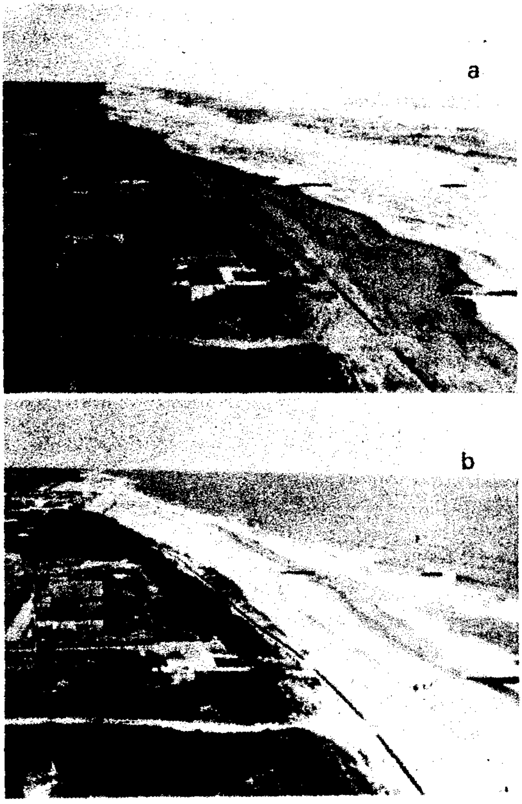

FIG. 2.—Views from Cape Hatteras Lighthouse: (*a*) Prenourishment: Jan., 1973; (*b*) Postnourishment: Sept., 1973

the recommendations of the Coastal Engineering Research Center, Army Corps of Engineers, the Navy contracted to have three permanent groins constructed during the summer of 1969 within the problem area, as shown in Fig. 2.

The groins, which required several adjustments in design, did provide protection for the Navy facility and the Lighthouse; however, the shoreline adjacent to the north and south of the groin field continued to recede at rates equal to or in excess of those recorded earlier. The National Park Service continued a "hold-the-line" strategy using sand bags and spot-dune construction.

During the winter of 1970, the erosion problem north of the Cape Hatteras Lighthouse became so severe that another beach-nourishment project was planned

TABLE 1.—Comparison of Sediment

Measurement of sediment (1)	Types of Beach: Native beach[a] (2)	Borrow site[b] (3)	Nourished beach[a] (4)
Grand mean, in millimeters	0.376	0.369	0.357
Standard deviation, in millimeters	0.220	0.215	0.233

[a]Before nourishment (115 samples) collected at midtide point of beach face over period of several weeks.

[b]Based upon 60 samples extracted from pits within borrow area ranging in depth from 2 ft–6 ft (0.61 m–1.8 m).

[c]Based upon 900 samples collected in vicinity of discharge point.

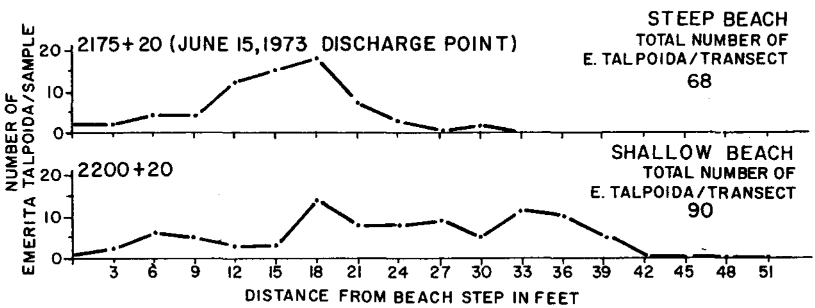

FIG. 3.—Results of Beach-Face Samples Analysis—Numbers 2175 + 20 and 2200 + 20 Refer to Discharge Location Along Beach

and implemented in the fall of 1971. Instead of returning to the 1966-project borrow site, the Pamlico Sound tidal delta, sand was extracted from the Cape Point spit.

This nourishment was effective in that the material remained on the beach for a longer time than the 1966 nourishment did. Although the 500,000 cu yd (390,000 m^3) added during the 1971 project were nearly double the amount added in 1966 [312,000 cu yd (239,000 m^3)], the beach system was still proportionately too large for the amount of material added. The present project is designed for a sufficient volume of material [1,250,000 cu yd (956,000 m^3)] to have much greater impact on the beach-energy system.

The Cape Point spit borrow site has proven to be an excellent source of nourishment material. Analysis of more than 2,500 sediment samples, collected from the discharge points and from sites reflective of natural conditions, indicates that it is virtually impossible to separate the nourishment material from the natural beach sands (see Table 1).

Emerita talpoida—Habitat Characteristics and Sampling Techniques

Emerita talpoida is the east-coast sand or mole crab. It is a crustacean and is a common inhabitant of the beach-face swash zone. While little is written about *E. talpoida*, the west-coast species, *E. analoga*, has received more attention. Seasonal variations are examined by Barnes and Wenner (1) and Cox and Dudley (2). The larval stage in the life cycle of *E. analoga* is palegic while juvenile and adult forms are intertidal. Efford (5) notes that the biographic distribution of *E. analoga* is largely controlled by offshore currents and countercurrents which transport the larvae along the coast. Dillery and Knapp (3) note that movements along the beach of juvenile and adult *E. analoga* by swash action averages 47.6 ft (1.45 m) per day. According to Efford (5), more rapid movement of adults and juveniles along the shoreline is mediated by nearshore currents and eddy-circulation cells. Burrowing backwards into the sand, it feeds by extending large, feathery antennae just above the sand to intercept food materials during the swash backrush. As the tides change, the crabs must move up or down the beach to remain in the location where the duration of backrush is greatest (8). This movement occurs en masse and usually on a single-wave uprush. Since the position of the *E. talpoida* population on the beach face is a function among other things of tidal stage, wave height, wave direction, and beach slope, the design of proper sampling procedures required analysis of population densities across the beach face.

Sand surface samples of 77.5 sq in. (500 cm^2) and a depth of 6 in. (150 mm) were taken during the day at 3-ft (0.9-m) intervals from the beach berm to the most seaward point of exposed sands on swash backrush. Adult forms larger than 0.25 in. (6 mm) were counted. Both a steep and a shallow beach face were sampled. The results of these analyses are presented in Fig. 3. On the steep beach, a single population-density maximum was observed approx 18 ft (5.5 m) from the most seaward sample point. On the flat beach, a population-density maximum was observed in the same vicinity; however, two lesser maximums were also observed which might relate to the complexity of approaching waves as reflected in distinct swash areas of the shallow beach. In order to assess the impact of beach nourishment on *E. talpoida*, it was decided that samples should be taken in the center of the most active swash area of the beach. While fewer organisms were found on the shallow beach than on the steep beach, density at the point of population maximums differed little.

Impact of Beach Nourishment on *E. talpoida*

In order to assess the impact of beach nourishment on *E. talpoida*, four samples of 77.5 sq in. (500 cm^2) each were taken at the center of the zone of active swash at 36-ft (11-m) intervals up and down the beach from the point of sand discharge. The results of this survey are presented in Fig. 4. This sampling procedure was repeated for three different sand-discharge locations. At each of the three sites, population densities were preferentially depressed to one side of the point of discharge. In the cases of the June 18, 1973 and July 20, 1973 discharge points, the population densities were depressed to the south of the discharge sites while at the June 15 site, population densities were depressed on the north side. On the days preceding the June 18 and July 20 samples, waves were from the northeast with a southward longshore current. On the days preceding the June 15 samples, the waves were out of the southeast and the longshore current moved to the north. Thus, the impact on *E. talpoida* was restricted to the downcurrent side of the point of sand discharge.

The magnitude of the population depression due to discharge varied. On June 15, population densities on the impacted side were 59% of those on the nonimpacted side; on June 13, 53%; and on July 20, 17%. Although the nonimpacted side population densities were considerably higher on July 20, the magnitude of the impact was also much greater. Field observations taken

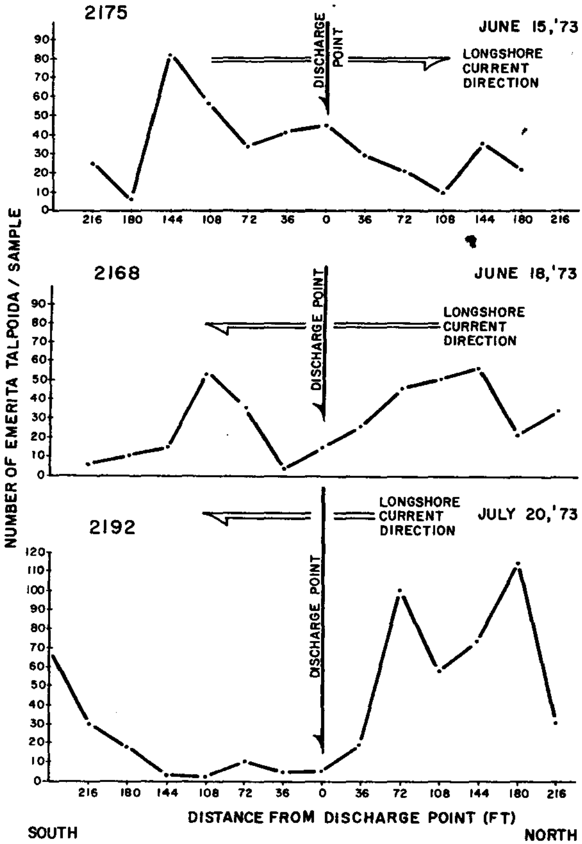

FIG. 4.—*Emerita talpoida* Densities Along Beach Adjacent to Sand Discharge Point—Numbers 2175, 2168, and 2192 Refer to Discharge Locations Along Beach (All Samples Collected During Daylight Hours)

on the days preceding July 20 indicated that large quantities of organic matter from the borrow pit, not observed previously or subsequently, were incorporated in the discharge water material.

In order to insure that the observed impact along the beach was not due to sampling error with respect to population positions across the beach, samples at 3-ft (0.9-m) intervals across the beach were taken 36 ft (11 m) north and south of the June 18 discharge point. At the time of the June 18 discharge, the longshore current was out of the north with the steep beach to the south and the flatter beach to the north.

Note that the population structure was unimodal to the south of the discharge point and trimodal to the north. Despite this difference, the depression in

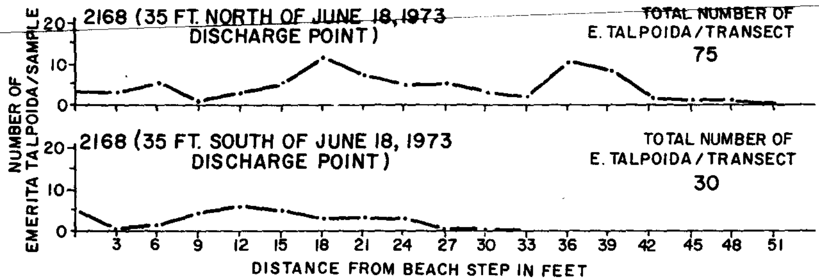

FIG. 5.—*Emerita talpoida* Densities Across Beach Adjacent to Sand Discharge Point—Number 2168 Refers to Discharge Location Along Beach

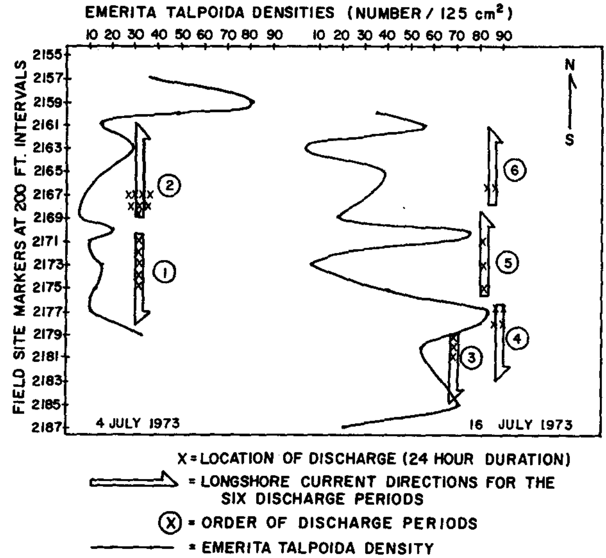

FIG. 6.—*Emerita talpoida* Densities Along Beach Following Consecutive Times of Discharge—Since All Field Measurements Were Taken in Feet, Markers Were Placed at 200-ft Intervals and Not 61-m Intervals

population density on the downcurrent side of discharge was clearly evident and is shown in Fig. 5. While the total number of organisms observed on the impacted south side was 30, 75 were observed on the north side. The 40% reduction in population density is consistent with the 53% observed for the along-the-beach sampling procedure.

While there is considerable evidence for a depression in population densities of *E. talpoida* immediately down beach from the discharge point of nourishment material, the fate of the impacted mole crabs remains uncertain. The lack of dead crabs on the beach-face in the impacted area suggests that they may not be subject to massive kills. It is known that, when stranded on the upper beach with the retreating tides, the mole crab will bury itself several inches into the sand and await the following rising tide (6). However, samples down to a depth of 1 ft (0.3 m) from the nourishment area indicated that the mole crab vacates the impacted beach rather than burrows into the sand. If a migration from the beach via the surf zone and subsequently onto another beach location does occur, it should be detectable. Samples taken at 200-ft (61.0-m) intervals suggest that this movement may be actual. The results of these analyses are shown in Fig. 6.

On six occasions sand discharges were accompanied by high population densities approx 600 ft–1,000 ft (18 m–31 m) down the beach from the discharge point. In three of the six instances, once preceding the July 4, 1973, population-density samples, and twice preceding the July 16, 1973 samples northeast waves and southward longshore currents occurred at the time of discharge; and, in the remaining three cases, southeast waves and northward longshore currents took place. In all six cases, the elevated numbers of *E. talpoida* observed were in the downcurrent direction at a distance of between 600 ft and 1,000 ft (18 m and 31 m). This dimension is consistent with shoreline meanders in the area and suggests that the mode of transport and reentry onto the beach face may be related to the crescentic-bar system and the cell-like inshore current.

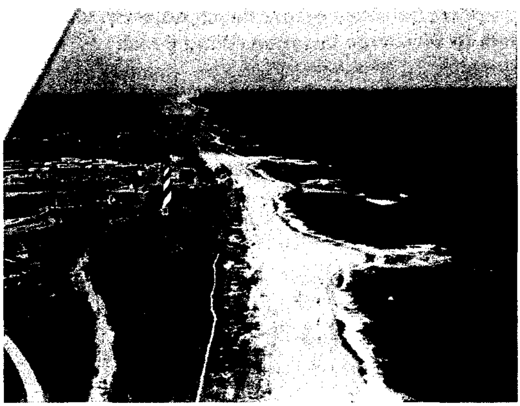

FIG. 7.—Air Photo of Shoreline in Area of Study Showing Well-Developed Shoreline Meanders

During earlier investigations of shoreline forms along the coast of North Carolina (4), sufficient data were accumulated from field studies and aerial photos to indicate that the shorelines of that area are seldom straight but consist of sinuous curves and bulges, with spits and bars protruding into the inshore zone (see Fig. 7). In the coastal nomenclature, these crescentic forms have acquired the descriptive names "sand waves," "shoreline rhythms," and "shoreline meanders" (4). Sonu (10) and Komar (7) have reported that these beach-face forms are a manifestation of the current patterns within the zone between the beach face and the inner bar. The morphologic and sedimentologic characteristics of the beach are associated directly with these rhythmic configurations. In that *Emerita* is dependent upon the uprush and backwash of the swash zone for feeding and movement along the beach (3) and on near-shore circulation patterns for movements along the shore (5), they would thus respond to the cell-like circulations within these shoreline meanders.

Conclusions

Although the studies reported here were essentially experiments of opportunity, sufficient data were assembled to construct a conceptual model for the impact of beach nourishment on *E. talpoida:*

1. On discharge of nourishment materials, the sands are transported across and down the beach via swash and longshore currents. (The nourishment is permitted to be redistributed after discharge by the natural processes of sand movement on the Cape Hatteras project.) In the area immediately downcurrent from the discharge point (0 ft–216 ft or 0 m to 65.9 m), population densities of *E. talpoida* are reduced due to their movement out of the stressed area.
2. *E. talpoida* move with the longshore current and reenter the swash zone some 600 ft–1,000 ft (180 m–310 m) down the beach, resulting in increased densities at that location.
3. On termination of discharge, the impacted area immediately downcurrent from the discharge point recovers rapidly. Movement of *E. talpoida* on the nonimpacted side of the discharge is up and down the beach face with the tides and horizontally with the swash with an overall component of motion in the direction of the longshore current. At the point of impact, *E. talpoida* numbers are returned to normal within 2 days to 3 days while the remainder of the impacted area becomes repopulated within a week or two.

Although a specific ecological impact of beach nourishment has been documented, it should be emphasized that the impact probably involves the redistribution of the mole-crab population rather than massive mortality. The magnitude of this impact is apparently greater when the discharge material contains a large amount of fine material or organic matter. The large depression in population densities at the time of high organic content of the discharge material may be due to high levels of hydrogen sulfide. Hydrogen sulfide is generally toxic to organisms found in highly aerated, oxygen-rich habitats. While hydrogen sulfide is the most causal agent, subsequent test for hydrogen sulfide were negative; however incidents of high organic content in the discharge material indicated by a black coloration of the discharge did not reoccur.

The severity of the impact of beach nourishment is tempered by the large number of *E. talpoida* along adjacent beach areas which can move into the impacted area resulting in the rapid recovery of *E. talpoida* following termination of nourishment. Thus the ecological impact on *E. talpoida* is of short duration and poses no impediment to the use of this form of shoreline protection as an engineering measure. While the impact of the beach fill on other swash-zone organisms was not monitored, no depression in feeding shore birds was observed as compared to adjacent non-nourished beaches. Observations of shore birds at active discharge locations indicated local reductions in numbers; however, this may reflect the presence of human activity rather than a depletion of forage materials.

Since the distribution of nourishment sands was left largely to the natural distributive mechanisms of the swash zone, large earthmoving equipment was not used on the beach surface. In a similar manner, the fate of the impacted mole crabs was controlled largely by the prevailing circulation patterns. *E. talpoida* population increases 600 ft-1,000 ft (180 m-310 m) downbeach are consistent in dimension with the size of large, shoreline meanders in the area. It is likely that the meanders in the longshore current associated with these shoreline forms also play a role in the redistribution of the impacted mole crabs.

Acknowledgment

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Appendix.—References

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