CHAPTER 68

FORMS OF EROSION AND ACCRETION ON CAPE COD BEACHES

by

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Abstract

Frequent measurements of beach profiles have been made at sixteen areas between Maine and Long Island since September 1965 by members of the Coastal Research Center of the University of Massachusetts. This research effort has resulted in the accumulation of approximately 2000 beach profiles along the New England coastline. The detailed analysis of profiles from Monomoy Island and Nauset Spit on Cape Cod has revealed the following erosion-accretion characteristics:

1. The most active areas of the beach profile in terms of sand transport are at the low-tide, neap high-tide, and spring high-tide zones. The center of the beach face is relatively inactive.
2. An exception to this behavior occurs during severe storms when large volumes of sand are removed from the entire beach face, producing a concave upward profile shape.
3. During periods of relatively low wave activity there is much interaction in terms of sand movement between these three zones, resulting in the formation of distinctive profile shapes.
4. These profile shapes tend to maintain themselves through sand movements which cause the berm to migrate back and forth along the profile.
5. This activity is often accomplished with little or no net sand erosion or accretion to the total profile.

These conclusions, combined with additional analyses, indicate that the traditional measurements of total beach width and high tide beach width (i.e., to the berm) are not a reliable indication of sand volume changes on beaches.

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INTRODUCTION

Measurements of beach profiles have been made at sixteen areas between Maine and Long Island since September 1965 over various time intervals by members of the Coastal Research Center of the Department of Geology at the University of Massachusetts. This research effort has resulted in the accumulation of approximately 2000 detailed beach profiles along the New England coastline. Analysis of these profiles, along with other data, has provided a considerable store of information on the nature of coastal processes and the development of coastal morphology along the depositional portions of the New England coast (1,4). More specifically, these measurements have provided a means for the precise determination of sand volumes added to or removed from beaches under a wide variety of climatic conditions (2).

The characteristic response of a beach, in terms of volumetric changes and strandline migration, should be regarded as essential to the evaluation, planning, design, and operation of any coastal engineering project. It is the purpose of this paper to illustrate the type of information which is available from a detailed analysis of beach profile data and to show that the results so obtained are not always consistent with intuitive beliefs or "classical" patterns of beach behavior.

MONOMOY ISLAND AND NAUSET SPIT

Located on the "elbow" of Cape Cod, Massachusetts, Monomoy Island and Nauset Spit form a dynamic barrier island complex which originated in Holocene time (Figure 1). For a period of three years, beginning in June 1968, twelve beach profiles on Monomoy Island and four profiles on Nauset Spit were measured at intervals varying from two weeks to several months, depending upon the apparent beach activity. Very early in this study it was noted that the beach at various profile locations reacted in strikingly different manners to apparently similar beach-shaping mechanisms (5). A particular storm would cause considerable erosion at one profile location but comparatively little erosion would occur at another location as close as one mile away. This observation prompted an increased surveillance at certain locations, resulting in the collection 393 beach profiles over the twelve-mile stretch of coastline (Table I). The number of profiles measured at any single location is generally indicative of the relative activity (i.e. erosion/accretion) of the beach at that location.

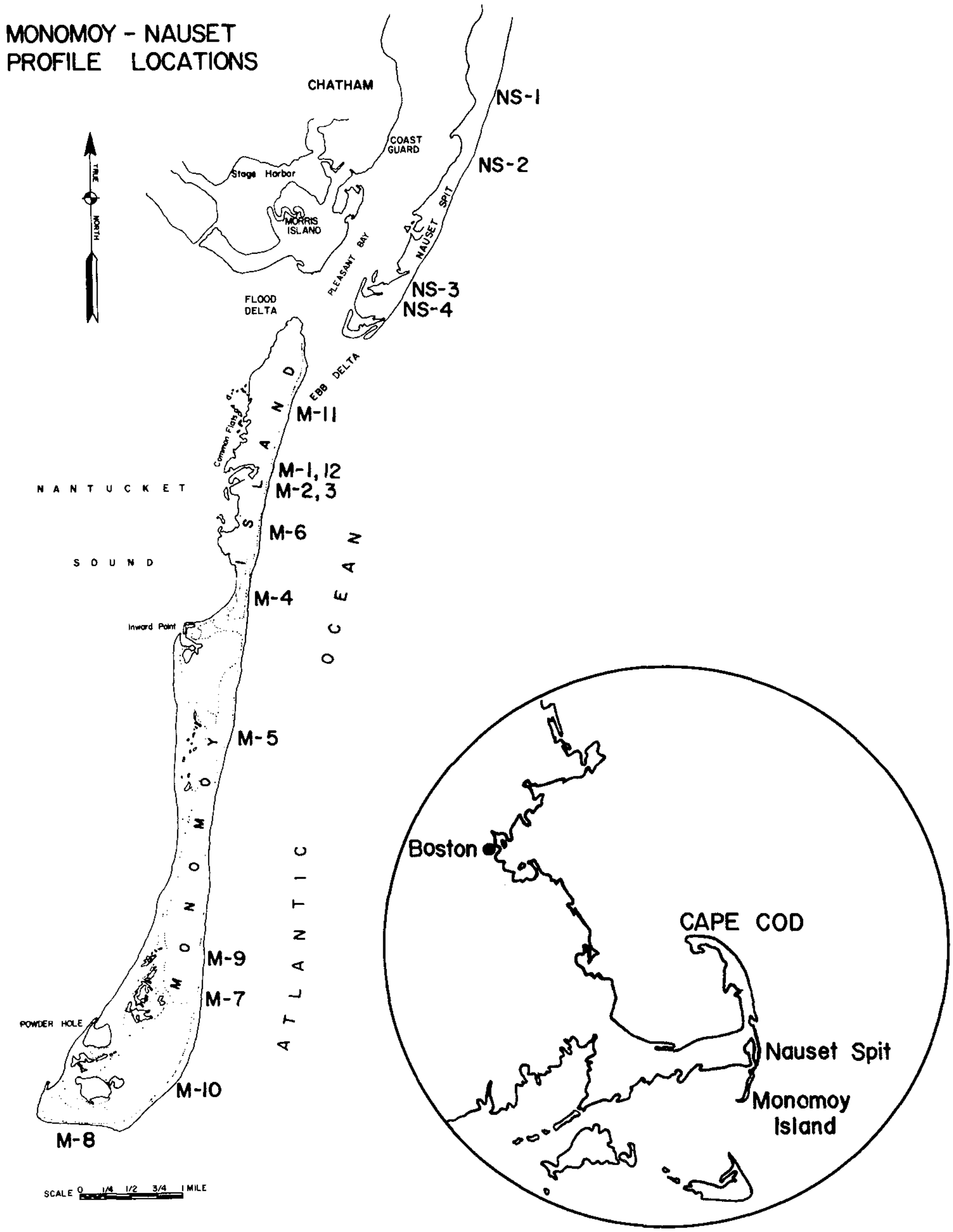

Figure 1. Location map for Monomoy-Nauset beach profile stations.

MONOMOY ISLAND

Profile Location	1	2	3	4	5	6	7	8	9	10	11	12
Number of Profiles	40	26	15	30	33	41	9	25	5	16	18	3

NAUSET SPIT

Profile Location	1	2	3	4
Number of Profiles	30	35	28	28

TABLE I. Beach profiles measured on Monomoy Island and Nauset Spit, 1968-1971. See Figure 1 for profile locations.

ANALYSIS OF BEACH PROFILE DATA

The 393 Monomoy-Nauset beach profiles were measured by means of a standard profiling technique (3). Each profile line extends seaward from a permanent stake in the foredune ridge perpendicularly across the beach to the low tide line. Vertical measurements are made at horizontal intervals of ten feet along the profile line, or at even shorter intervals when there occurs a distinctive morphological feature such as a beach ridge, an erosional scarp, or other significant break in the beach slope. The accuracy of this method is estimated to be ± 0.1 feet vertically over the total profile length.

Field data obtained by this beach profiling technique were punched on computer cards in essentially the same form as they appear on the original data sheets. These data were then converted to an x-y coordinate representation of the profile, the results being punched automatically on cards or written on magnetic tape for subsequent analysis and permanent storage. A comparative analysis of the Monomoy-Nauset profiles was made to determine detailed changes along any given profile with time.

The analysis of the beach profile data is basically a computation of changes in the total sand volume at a given profile location over the time period between measurements. By computing the areal change in a vertical cross-section of the beach at the profile location, the amount of sand that was added to or removed from the beach is estimated. These volume estimates are properly stated in the units of cubic feet of sand per lineal foot of beach (i.e. parallel to the shoreline) but, for the sake of brevity, such results are hereafter given simply in terms of cubic feet of sand. This analysis allows not only the determination of the net change to the beach as a whole, but also provides useful information on the re-distribution of sand within the beach profile. Correlation of these results with changes in beach shape and strandline migration form the substance of this discussion.

A detailed analysis of the Monomoy Island-Nauset Spit profiles, which are typical of other New England beach profiles, has revealed several distinctive erosion-accretion characteristics. These characteristics are illustrated by Figures 2 through 7, each of which is a set of profile comparisons selected to exemplify the observations listed below.

1. The most active zones of the beach profile in terms of sand transport are at the low-tide zone, neap high-tide zone, and spring high-tide zone. The center of the beach face tends to be relatively inactive (Figures 2 and 3).

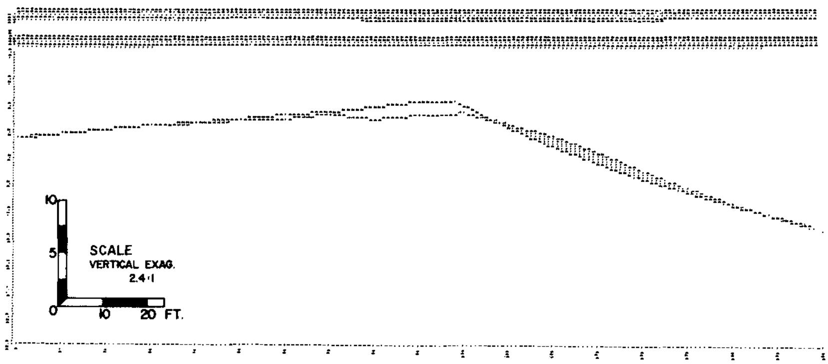

Figure 2. Comparison of the September 27, 1969, and the November 1, 1969, M-4 beach profiles, on Monomoy Island. Volumetric changes are indicated by the dark areas (erosion) and the light areas (accretion) between the two profiles. This comparison shows that 34 cubic feet of sand was removed from the beach face and 39 cubic feet of sand was added to the berm crest, resulting in a net total profile accretion of 5 cubic feet despite a neap berm retreat of 20 feet and a change in profile shape from convex to concave upward.

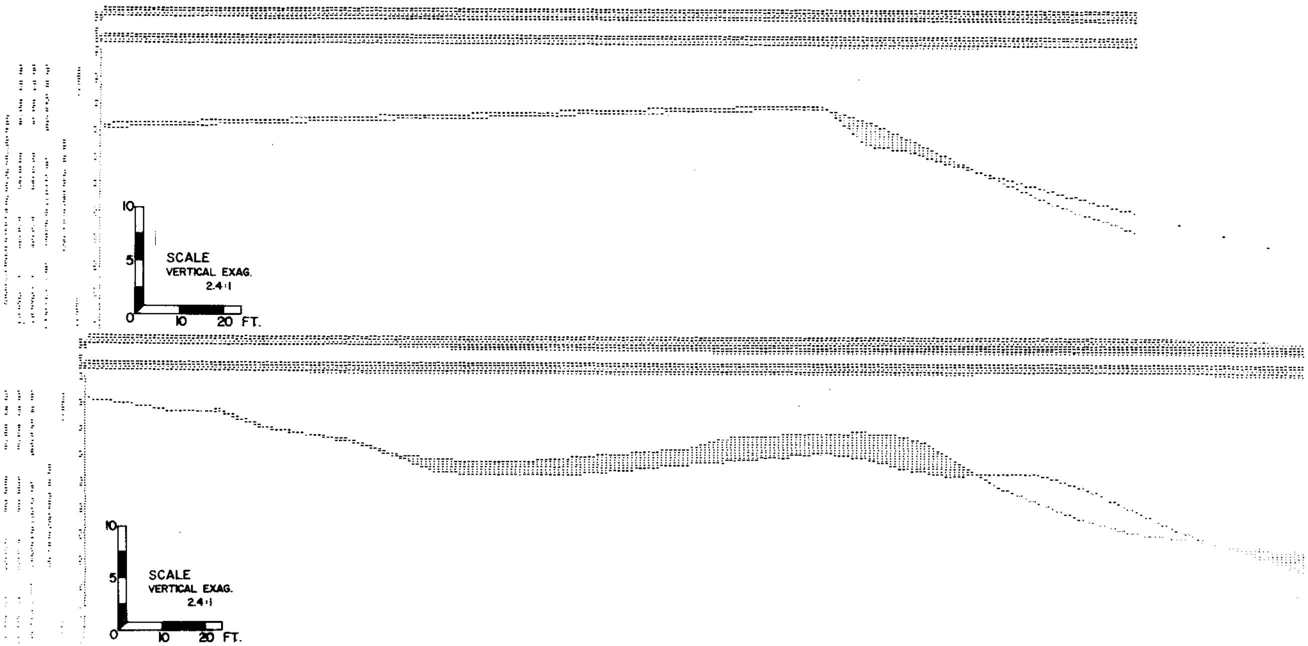

Figure 3. Comparisons between the November 1, 1969 and December 4, 1969, M-5 beach profiles (top), and July 14, 1969, and August 10, 1969, M-1 profiles (bottom), on Monomoy Island. Volumetric changes are indicated by the dark areas (erosion) and the light areas (accretion) between the two profiles. The most active areas of the profile (i.e., volumetric changes) are the low tide, neap high tide and spring high tide zones. In the upper comparison the cumulative volumetric change in these three zones was the accretion of only five cubic feet of sand. In the lower comparison, the cumulative volumetric change in these three zones was the loss of 55 cubic feet of sand. Note the changes in profile shape from convex to concave upwards.

2. An exception to the behavior noted above (#1) occurs during severe storms when large quantities of sand are removed from the entire beach face, producing a concave upward profile shape (Figure 4).
3. During periods of relatively low wave activity there is much interaction in terms of sand movement between these three zones (listed in #1), resulting in the formation of distinctive beach profile shapes (Figures 5 and 6).
4. These profile shapes tend to maintain themselves through sand movements which cause the berm to migrate back and forth along the profile (Figures 5 and 6).
5. The beach activity noted above is often accomplished with little or no net sand erosion or accretion to the total profile (Figures 2 and 7).

The observations enumerated above, supported by additional analyses, suggest that the traditional measurements of total beach width and high tide beach width (i.e., to the berm) are not necessarily a reliable indication of sand volume changes on beaches. Intuitively, one expects accretion to be accompanied by a seaward migration of the strandline and erosion to be associated with a landward migration of the strandline. Figure 8 shows that such intuitive conclusions would have been correct for about two-thirds of the 154 beach profiles represented in that illustration. It is also readily apparent from Figure 8 that the application of any general formula for estimating volumetric changes corresponding to a given strandline migration would be inappropriate for the Monomoy-Nauset beaches. For example, the U.S. Army Corps of Engineers estimation rule (6, p. 216), "... one square foot of change in beach surface area equals one cubic yard of beach material ...", fails to indicate even the trend of the beach volume change associated with strandline migration. The Monomoy-Nauset conditions, typical of other Cape Cod beaches, are obviously not amenable to such simple formulations.

Additional attempts to correlate beach volume change with strandline migration led to examination of the ratio of the former to the absolute value of the latter. Figure 9 shows the frequency of occurrence of various values of this ratio during the three-year study of the Monomoy-Nauset beaches. The significant feature of Figure 9 is the

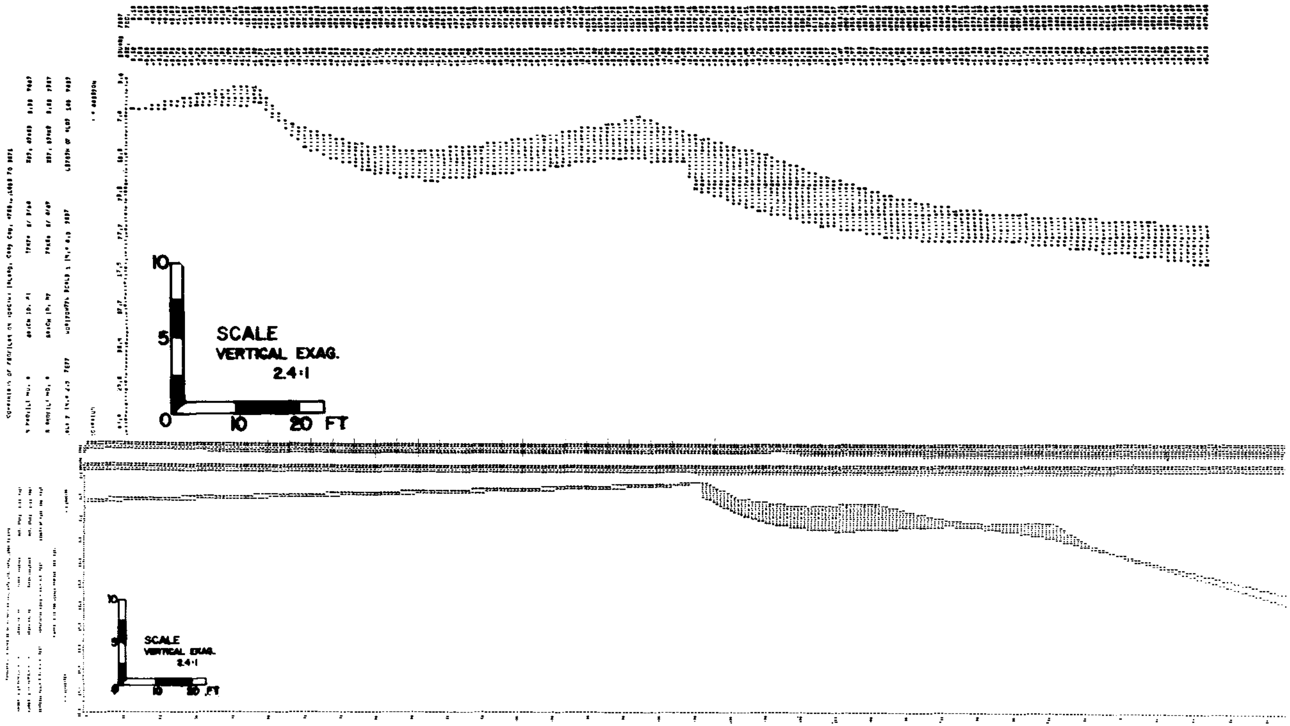

Figure 4. Comparisons between the August 3, 1969, and August 9, 1969, M-8 beach profiles (top) and the August 13, 1968, and November 14, 1969, M-5 beach profiles (bottom), on Monomoy Island. In both comparisons severe erosion had occurred through the intertidal portion of the profiles, and in both comparisons the beach was well underway towards recovery at the time the second profile was made as indicated by its convex upward shape. Nevertheless, there remained a net loss of 347 and 122 cubic feet of sand at the M-8 and M-5 profiles, respectively.

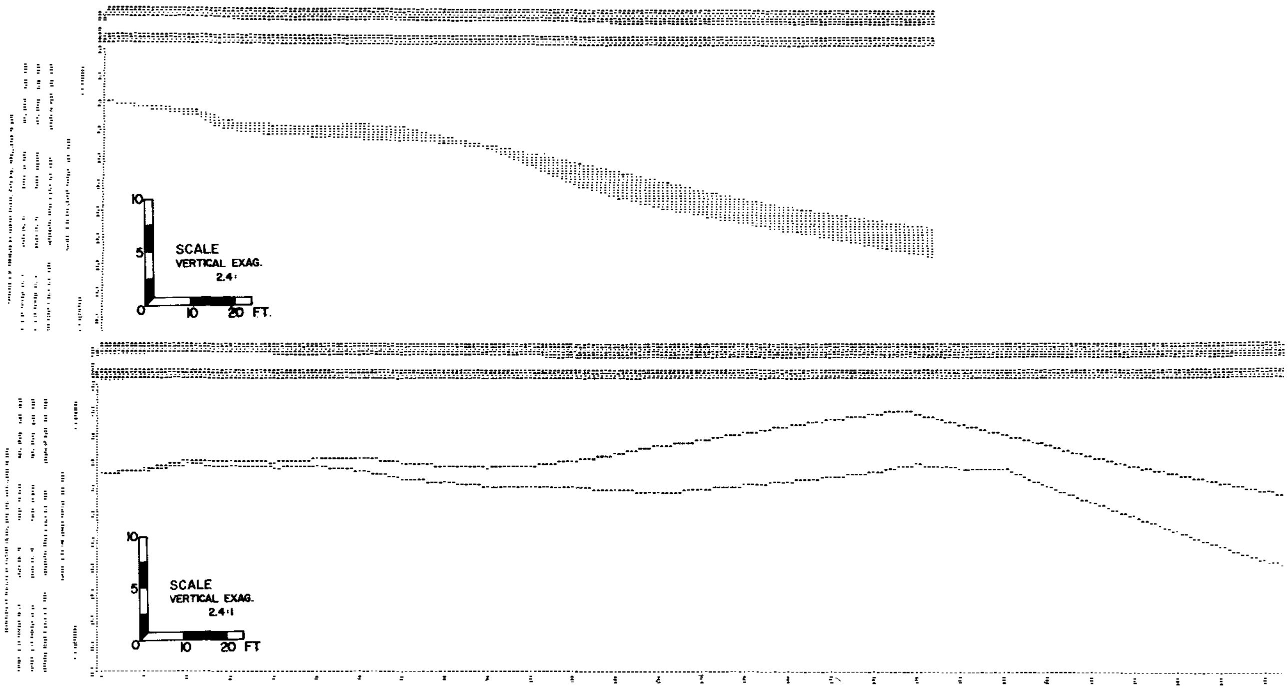

Figure 5. Comparisons between the May 9, 1970, and June 17, 1970, M-6 profiles (top) and the July 4, 1969, and August 3, 1969, M-10 beach profiles (bottom), on Monomoy Island. Volumetric changes are indicated by the dark areas (erosion) and the light areas (accretion) between the two profiles. In the upper comparison 267 cubic feet of sand was removed from the total profile, yet the berm moved 20 feet seaward. In the lower comparison 1070 cubic feet of sand per lineal foot of beach was added to the total profile, yet the berm migrated landward approximately 25 feet, resulting in an apparent narrowing of the beach. Note the similarity of the beach profiles before and after erosion (upper) and accretion (lower).

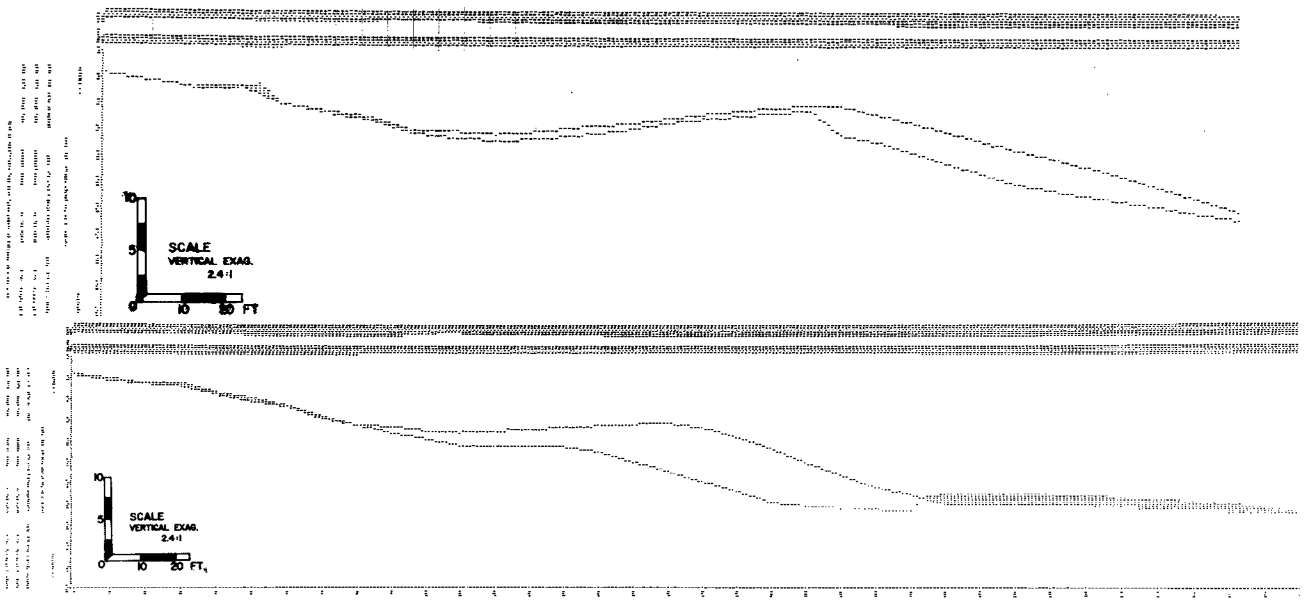

Figure 6. Comparisons between the September 26, 1969, and the October 18, 1969, NS-1 beach profiles (top) and the January 3, 1970, and April 14, 1970, NS-1 beach profiles on Nauset Spit. Volumetric changes are indicated by the dark areas (erosion) and the light areas (accretion) between the two profiles. In both comparisons, increases in beach volume (292 and 493 cubic feet, respectively) are associated with seaward berm migrations (10 and 40 feet). In the lower comparison the accretion occurred in the form of onshore ridge and runnel migration, with the ridge eventually welding onto the upper part of the beach face. Migrating intertidal ridges are typical of post-storm beach recovery on many New England beaches (1, pp. 245-265).

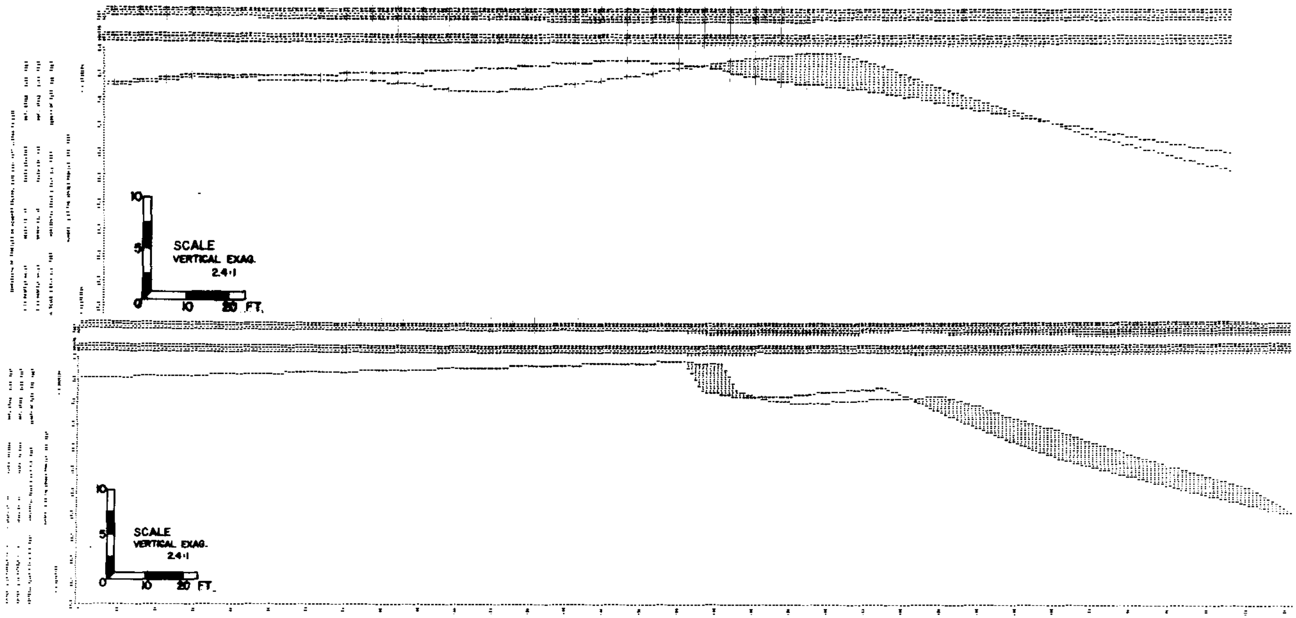

Figure 7. Comparisons between the October 19, 1969, and the December 19, 1969, M-10 beach profiles (top) and the June 19, 1969, and the July 4, 1969, M-5 beach profiles (bottom), on Monomoy Island. Volumetric changes are indicated by the dark areas (erosion) and the light areas (accretion) between the two profiles. In both locations sand was eroded from the upper beach face and berm-crest portions of the profile and was partially redeposited on the back beach portion of the profiles. This resulted in an increase of 49 cubic feet of sand in the upper comparison, and a decrease of 214 cubic feet in the lower comparison; however, at both locations the berm crest migrated landward and the profile shape changed from convex upward to concave upward.

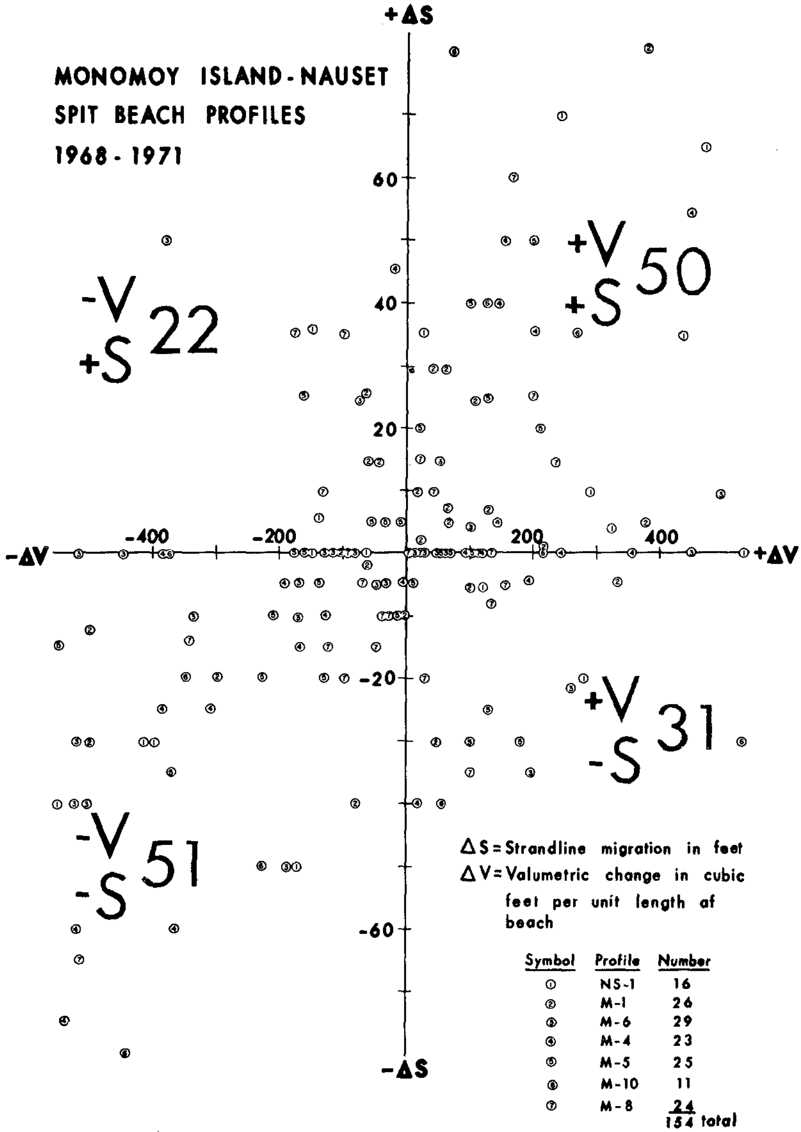

Figure 8. Graph of strandline migration versus volumetric change per unit length of beach. Large numerals indicate the number of profiles represented in each quadrant of the graph.

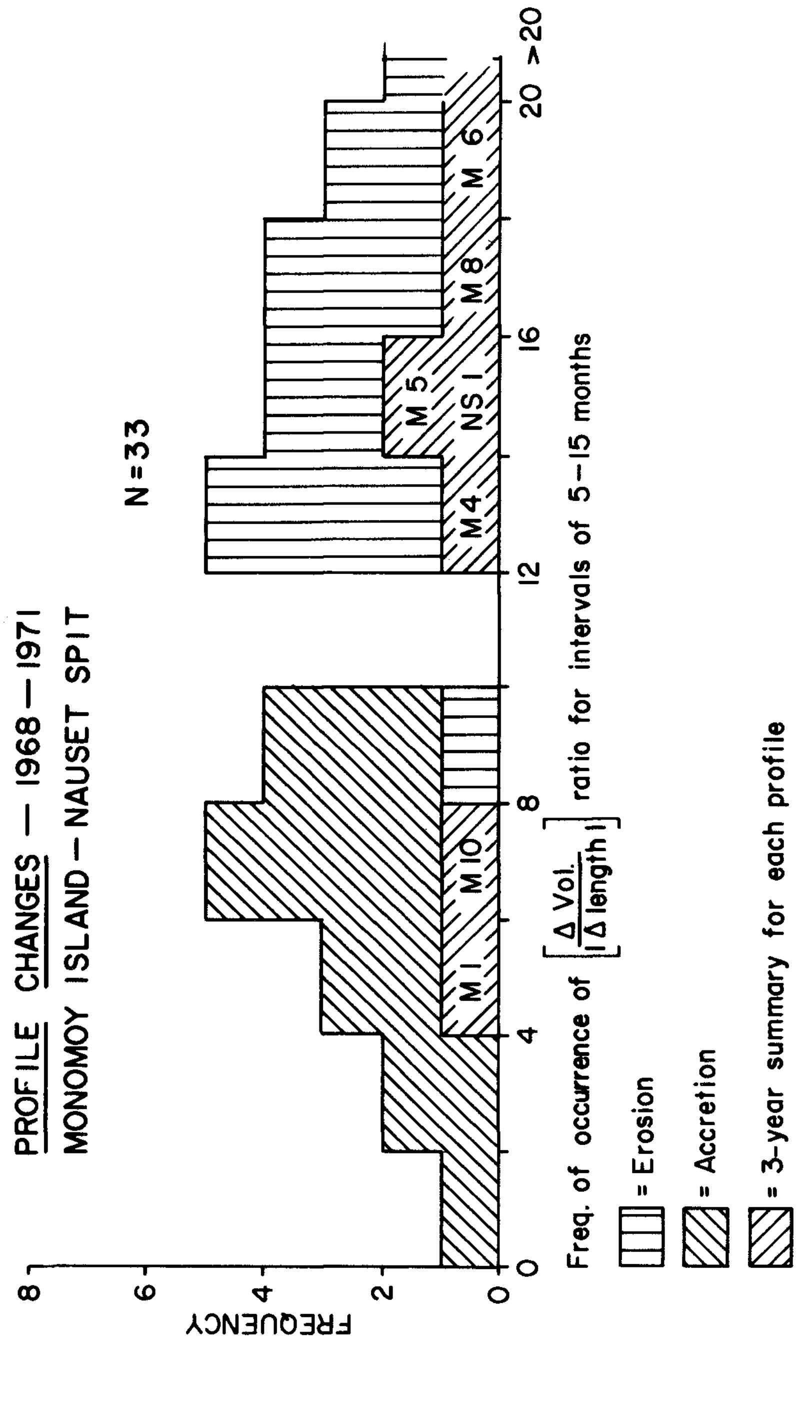

Figure 9. Ratio of change in sand volume to change in profile length at six profiles on Monomoy Island and one on Nauset Spit, for time intervals of five to fifteen months.

distinct separation of ratio values corresponding to erosional and accretional beach conditions; that is, the ratio was less than ten for accretional profiles and it was greater than twelve but less than 21 (except for one case of the 33 examined) for erosional profiles during the period of observation. The Corps of Engineers formula would predict a constant value of 27 for this ratio (i.e., 1 cu.yd./ft. = 27 cu.ft./ft.).

The three-year summary for each profile is also shown in Figure 9. The graph shows that more sand was removed per foot of beach profile (i.e., the ratio is higher) than was returned. This indicates a net dune erosion for the period, amounting from one-half to two-thirds of the sand composing the beach. Thus, it becomes even more apparent that observations of beach profile length alone can be quite misleading if the intention is to estimate beach changes in terms of sand volume.

CONCLUSIONS

An abundance of information is provided by the detailed comparative analysis of beach profiles as demonstrated by this study. Quantitative identification of erosion/accretion zones on the beach and precise determination of sand volume transport along the beach profile are facilitated by this technique. Traditional observations of beach profile length are not reliable for these purposes, as shown in the case of Monomoy Island-Nauset Spit beaches.

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