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Dune Retreat and Shoreline Change on the Outer Banks of North Carolina

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ABSTRACT

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Barrier islands are popular recreational areas of economic importance and are constantly undergoing change. Costly efforts are made to maintain beaches and stabilize dunes within this dynamic environment. Light detection and ranging data collected in September 1997 and 1998 along a 175-km stretch of the Atlantic coast of the Outer Banks, North Carolina, provide the basis for quantitative determination of the changes in beach morphology. The 1998 survey was conducted just after the passage of Hurricane Bonnie. During the 1-year study interval, beach widths throughout the study region tended to decrease. Maximum dune retreat was determined for each 1-m bin of 1997 beach width. For comparable beach widths, maximum dune retreat increased from south to north. The maximum dune retreat was greatest for supratidal beaches with widths of ~20 m. For wider supratidal beaches, from 20 to 60 m, the associated maximum dune retreat gradually decreased. There was no further decrease in maximum dune retreat for beaches wider than ~60 m. Relatively little change in beach width, dune height, and dune base position occurred along the less developed beaches of the Core Banks. The greatest morphological changes occurred on Ocracoke Island and Hatteras Island. Of the geomorphic parameters examined, preexisting beach width and the dune base elevation were the best indicators of vulnerability to dune retreat.

ADDITIONAL INDEX WORDS: *Coastal change, subaerial coastal erosion, beach profile, Hurricane Bonnie.*

INTRODUCTION

Coastal light detection and ranging (LIDAR) surveys were conducted in late September 1997 and early September 1998 along the Atlantic coast of the Outer Banks, North Carolina, between Cape Lookout and Oregon Inlet (Figure 1). Hurricane Bonnie crossed the mainland of eastern North Carolina on August 27, 1998, on a track parallel to the coastline. Data for 1998 were collected September 1 and 7 after the passage of Hurricane Bonnie. The entire 175-km length of surveyed coastline was located at approximately the same distance from the storm track. Thus, the proximity of storm landfall is not a dominant factor controlling variations in morphological response because of the hurricane. Comparison of these two LIDAR surveys allows quantification of the net morphological change that occurred over this 1-year period. These changes were caused by Hurricane Bonnie, five other major storms, smaller storms, day-to-day natural processes, and human modification and stabilization activities. Our goal is to identify geomorphic parameters that are indicators of vulnerability to dune retreat, as documented by these two surveys.

DUNE EROSION

Dunes are recognized as being the primary barrier separating developed property from high waves and water levels during storms. When dunes are breached or overtopped, significant life and property losses can occur. Because of the importance of dunes to protecting coastal property, numerous methods have been developed to predict the effects of storms and wave energy on dunes. These models have been extensively reviewed by JUDGE, OVERTON, and FISHER (2003) and LARSON, ERIKSON, and HANSON (2004). One approach is based on the concept of an equilibrium profile in which changes in beach morphology (both subaerial and subaqueous) adjust in time to an equilibrium shape (BRUUN, 1962; DEAN and MAURMEYER, 1983; EDELMAN, 1972; KOBAYASHI, 1987; KOMAR *et al.,* 1999; KRIEBEL, 1991; KRIEBEL and DEAN, 1985; LARSON and KRAUS, 1989; VELLINGA, 1983). A second approach has been to model wave impact, wherein erosion from each individual swash is used to determine horizontal dune erosion (FISHER and Overton, 1985; FISHER, OVERTON, and CHISHOLM, 1987; NISHI and KRAUS, 1996; OVERTON, FISHER, and FENAISH, 1987; OVERTON *et al.,* 1994). A test of these models conducted by JUDGE, OVERTON, and FISHER (2003) examined a series of 110 pre- and poststorm cross-shore profiles, spaced at 300-m intervals, collected at Topsail Island, North Carolina. JUDGE, OVERTON, and FISHER (2003) found that dune height did not effectively predict dune vulnerability, whereas other morphological parameters related to cross-sectional area were somewhat successful. Using a larger study area in a different location with 4595 cross-shore profiles at 20-m intervals, we analyze the relationships between morphological parameters and dune erosion.

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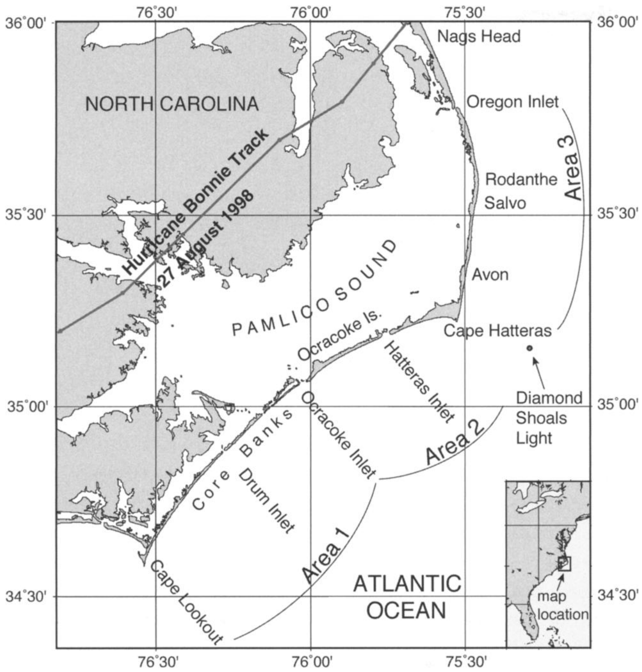

Figure 1. Map of the study region. Area 1 is the Core Banks. Area 2 is Ocracoke Island and Lower Hatteras Island. Area 3 is Hatteras Island north of Cape Hatteras. The center of Hurricane Bonnie passed inland of the Outer Banks, as shown.

STUDY REGION

In this work, we examine shoreline change along the Atlantic coast of the North Carolina Outer Banks from Cape Lookout to Oregon Inlet (Figure 1). We divide the study region into three areas on the basis of strike of the coast and dune stabilization history. Area 1 southwest of Ocracoke Inlet includes the less developed Core Banks with low-lying dunes. Area 2 extends from Ocracoke Inlet to the bend at Cape Hatteras. Area 3 extends from Cape Hatteras to Oregon Inlet. The dunes in areas 2 and 3 were actively stabilized by Works Progress Administration and Civilian Conservation Corps workers beginning in 1937 (Berkemeier, Dolan, and Fisher, 1984). A continuous vegetated line of dunes was created from Ocracoke Inlet to the Virginia state line with dune heights ranging from 3 to 8 m and dune base widths from 25 to100 m (Berkemeier, Dolan, and Fisher, 1984). The dunes were then planted with grass, trees, and shrubs. Stabilization efforts continued at irregular intervals throughout areas 2 and 3 until the mid-1970s (Berkemeier, Dolan, and Fisher, 1984). All three areas continue to experience artificial beach and dune modification (*e.g.,* bulldozing of sand) at irregular spatial and temporal intervals.

DATA

The LIDAR data were collected using the National Aeronautics and Space Administration (NASA) Airborne Topographic Mapper (ATM) as part of a collaborative project between NASA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey. The ATM can survey beach topography along hundreds of kilometers of coast in a single day with data densities that far exceed traditional survey technologies. Each swath is typically 375 m wide and continuous along the aircraft flight line. The aircraft pitch, roll, and heading were obtained with an inertial navigation system. The position of the aircraft was determined with kinematic Global Positioning System (Krabill and Martin, 1987).

The LIDAR instrument transmits light to a target, where it is reflected/scattered back to the instrument (*e.g.,* Flood and Gutelius, 1997). The travel time is measured and used to determine the distance to the target, from which a topographic map can be created. Sallenger *et al.* (2003) made over 40,000 intercomparisons between individual ground-based measurements and LIDAR ATM measurements and found a room mean square vertical variation of roughly 15 cm. The footprint of the laser is about 0.5 m, with a geographic (*i.e.,* latitude and longitude) location accuracy of roughly 1 m (Sallenger *et al.,* 2003).

In September 1997 and 1998, ATM LIDAR surveys were conducted along major portions of the eastern United States, including the study region. Data for 1997 were collected in the study region on September 26, 27, and 29. No major storms immediately preceded the 1997 survey. Data for 1998 were collected on September 1 and 7.

In the year between the two LIDAR surveys, five major storms in addition to Hurricane Bonnie occurred along the Outer Banks. Major storms are defined as days when the measured significant wave height exceeds 4.0 m at the Diamond Shoals Light off Cape Hatteras (Figure 1) or exceeds 2.8 m at the nearshore NOAA data buoy located at Duck, North Carolina (Nelson, 2001). In area 1, the Core Banks, the dunes are sufficiently low lying that the largest storm waves during the study interval apparently overwashed portions of the island (Nelson, 2001). North of Ocracoke Inlet, it appears that the largest storm waves reached the seaward side of the dunes but did not overwash the dunes (Nelson, 2001).

Data Processing

The ATM obtained irregularly spaced measurements that were referenced spatially to the World Geodetic System 1984 (WGS84) ellipsoid model. The data were converted from WGS84 to North American Datum 1983 (NAD83) with subroutines provided by NASA/Wallops and the National Geodetic Survey of NOAA. NAD83 is referenced to the Geodetic Reference System of 1980 (GRS80) ellipsoid. With the use of Interactive Data Language (IDL), the data were filtered to remove all points higher than 20 m, which is taller than any dune elevation and probably represented return signals off birds, clouds, and tall buildings. The data were subdivided into 5-km sections along the coast and gridded at 1 m^2 with the Delaunay triangulation function in IDL. A three by three median box filter was then applied to remove isolated high and low values. Gridded data points that differed by more than ± 1 m vertically from the filtered values were replaced by the filtered values. The 0.8-m contour line was taken as a

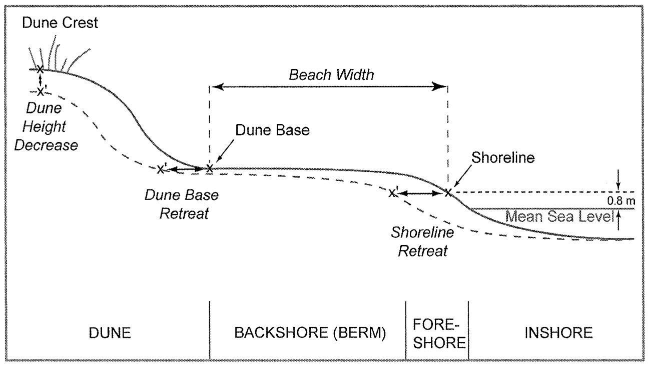

Figure 2. A sample beach profile illustrating the morphological parameters analyzed in this work. The shoreline is taken as the position of the 0.8-m contour line. Dune position is the location of the seaward break in slope at the base of the most seaward dune. Beach width is the horizontal distance from the 0.8-m contour line to the base of the most seaward dune. Dune height is the vertical distance from mean sea level to the top of the most seaward dune. X and X′ are examples of positions in 1997 and 1998, respectively (modified from Nelson [2001]).

proxy for the shoreline. During data collection, the highest tide never exceeded 0.76 m above mean sea level; thus, 0.8 m was the lowest elevation that could approximate the shoreline. A baseline roughly parallel to and landward of the shoreline was created and colocated for both years for each 5-km section. Cross-shore profiles were sampled every 20 m along the baseline. Dune base position was identified as the seaward break in slope at the base of the most seaward dune. For each profile, the dune base position was determined by a computer algorithm that detected the break in slope. Each break in slope was visually verified to be associated with a dune. Dunes are not present everywhere along the coast. The 4595 profiles that contain dunes in both 1997 and 1998 were analyzed further.

Figure 2 illustrates the parameters analyzed. The distance from the baseline to the 0.8-m contour was measured for each profile for each year. The difference in this distance between the two years yields the cross-shore change in shoreline position. Beach width is defined as the horizontal distance from the 0.8-m contour line to the dune base position. Dune height is the vertical distance from mean sea level to the top of the most seaward dune. X and X′ are examples of positions in 1997 and 1998, respectively, for a location that experienced erosion (Figure 2). Differences between measurements from one year to the next on each profile represent the net change that occurred between the two surveys.

OBSERVATIONS

We analyzed the beach width, dune height, and dune base elevation for the 1997 and 1998 surveys. Figure 3 illustrates these parameters for the 1997 survey. Mean beach width, dune height, and dune base elevation for each study area for 1997 and 1998 are reported in Tables 1 and 2. Table 1 provides the standard deviation for each parameter, which indicates the spread in values about the mean and can be used to compare distributions. Table 2 provides the standard error of the mean, which measures the confidence in the reported value of the mean (*e.g.*, PRESS *et al.*, 2001) and enables comparison of the mean values between different areas. Because the standard error of the mean is the standard deviation divided by the square root of the number of measurements, the standard error of the mean decreases as the number of measurements increases. The standard error of the mean will be less than the standard deviation of the measurements and may be less than the sampling error for each measurement. Change in shoreline position (Figure 4a), beach width (Figure 4b), dune base position (Figure 5a), and dune height (Figure 5b) are determined for each area. Mean change for each area is reported in Table 3, along with the standard error of the mean. Negative values indicate decreases in the measured parameters (*i.e.*, erosion).

Beach Widths

The 1997 and 1998 mean beach widths for areas 1, 2, and 3 are reported in Table 1. The 1997 beach width is shown in Figure 3a, wherein it is evident that beach width is highly variable over short distances within each region. The 1997 and 1998 beach width distributions for the three areas have similar standard deviations (Table 1). However, the mean values of the distributions differ significantly (Table 2). Between the surveys of 1997 and 1998, mean beach width decreased significantly in all three regions (Table 2).

The shoreline tended to retreat between the surveys of 1997 and 1998 (Figure 4a). Areas 1, 2, and 3 experienced an average of 7.54, 13.4, and 9.26 m of shoreline retreat, respectively (Table 3). The standard error of the mean of these average values is 0.26 or less (Table 3), indicating that the means are significantly different. The Core Banks (area 1) experienced the least change in shoreline position. Ocracoke and Lower Hatteras (area 2) experienced the greatest mean erosion (Table 3). The greatest variability in shoreline change occurred in area 3, which had some regions of extreme accretion (over 20 m) and some regions of extreme erosion (over 30 m) (Figure 4a).

Dune Height

The 1997 mean dune heights for areas 1, 2, and 3 were 4.21, 5.64, and 6.50 m, respectively (Table 1). Dunes along the Core Banks are generally lower than dunes that had been artificially stabilized on Ocracoke and Hatteras islands (Table 1 and Figure 3b). The standard deviation of dune height distributions increases from south to north, indicating greater variability in dune heights toward the north. Increases in dune height and dune height variability are also evident from visual inspection of 1997 dune height (Figure 3b).

Changes in dune height between 1997 and 1998 are reported in Table 3 and illustrated in Figure 5b. The dunes of the less developed Core Banks experienced little change in height between the two surveys (change of 0.06 ± 0.01 m). The dunes north of Ocracoke Inlet experienced a mean loss in height, with the average dune height decreasing by 0.19 ± 0.01 m in area 2 and by 0.24 ± 0.01 m in area 3 (Table 3). To determine whether the changes in dune height were greater in areas 2 and 3 simply because the dunes there were

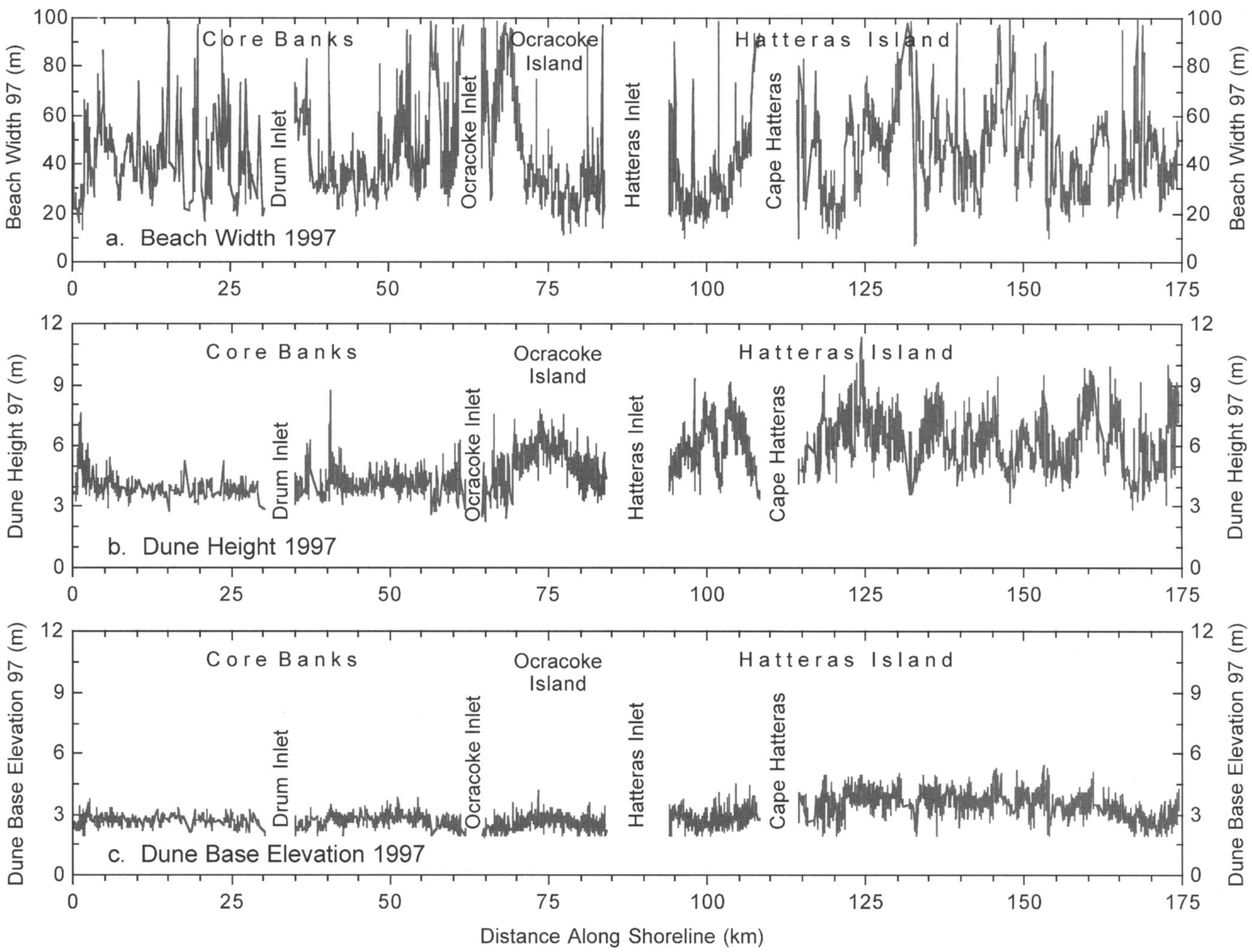

Figure 3. The 1997 measurements of (a) beach width, (b) dune height, and (c) dune base elevation. The horizontal axis extends from Cape Lookout (0 km) to Oregon Inlet (175 km).

higher, we examined the fractional change in dune height. Fractional change in dune height is the change in dune height divided by the dune height in 1997. Mean dune height increased slightly (<2%) in area 1 and decreased approximately 3% in both areas 2 and 3 (Table 3). Thus, areas 2 and 3 experienced both a greater absolute change in dune height and a greater percent change in dune height than area 1.

Table 1. *Mean beach width and dune height with standard deviation of the distribution.*

	Mean Value (m)		
	Area 1 Core Banks	Area 2 Ocracoke and Lower Hatteras	Area 3 Upper Hatteras
Beach width 1997	41.7 ± 15.4	37.6 ± 18.1	44.6 ± 16.7
Beach width 1998	34.5 ± 15.2	25.4 ± 15.2	37.5 ± 16.0
Dune height 1997	4.21 ± 0.65	5.64 ± 1.14	6.50 ± 1.30
Dune height 1998	4.27 ± 0.61	5.45 ± 1.09	6.25 ± 1.27
Dune base elevation 1997	2.71 ± 0.30	2.69 ± 0.36	3.52 ± 0.63
Dune base elevation 1998	2.71 ± 0.30	2.69 ± 0.36	3.52 ± 0.63

Dune Base Elevation

The dune base is the location of the change in slope at the base of the most seaward dune (Figure 2). Mean dune base elevation for 1997 was 2.71 ± 0.01, 2.69 ± 0.01, and 3.52 ± 0.01 m for areas 1, 2, and 3, respectively (Table 2). The reported errors are one standard error of the mean, indicating that the mean dune base elevation of area 3 is significantly greater than the means of areas 1 and 2. The standard deviation of dune base elevations increases from south to north, with the standard deviation of area 3 being twice that of area 1 (Table 1). The increase from south to north in dune base elevation and its variability are also evident from visual inspection of the 1997 dune base elevations (Figure 3c). Mean dune base elevation did not change in any of the three areas between 1997 and 1998 (Table 1).

Table 2. *Mean beach width and dune height with standard error of the mean.*

	Mean Value (m)		
	Area 1 Core Banks	Area 2 Ocracoke and Lower Hatteras	Area 3 Upper Hatteras
Beach width 1997	41.7 ± 0.50	37.6 ± 0.48	44.6 ± 0.35
Beach width 1998	34.5 ± 0.49	25.4 ± 0.40	37.5 ± 0.34
Dune height 1997	4.21 ± 0.02	5.64 ± 0.03	6.50 ± 0.03
Dune height 1998	4.27 ± 0.02	5.45 ± 0.03	6.25 ± 0.03
Dune base elevation 1997	2.71 ± 0.01	2.69 ± 0.01	3.52 ± 0.01
Dune base elevation 1998	2.71 ± 0.01	2.69 ± 0.01	3.52 ± 0.01

Horizontal Change in Dune Base Position

Figure 5a illustrates the cross-shore change in dune base position between 1997 and 1998. There was little cross-shore change in dune base position along the beaches of the Core Banks (Table 3 and Figure 5a). Changes were greater along the beaches of Ocracoke and Hatteras islands, with a mean dune retreat of 1.30 ± 0.08 and 2.17 ± 0.08 m in areas 2 and 3, respectively (Table 3). Variability in the change in dune base position was also greater in areas 2 and 3 (Figure 5a).

DISCUSSION

Coastal Erosion Classification

Various geomorphic process-response types have been identified to describe patterns of coastal erosion (*e.g.,* McBride, Byrnes, and Hiland, 1995; Storms *et al.,* 2002). As stated by McBride, Byrnes, and Hiland (1995), the appropriate classification varies as a function of temporal and spatial scale. For instance, the process-response type for a 50-km barrier island can be classified as "landward rollover," whereas the 2.5-km stretches of shoreline at either end of the island can be classified as "lateral movement." For this work, we found a significant change in the mean dune base position, with dune erosion in all three areas (Table 3). However, at smaller spatial scales, the patterns of change are highly variable (Figure 5a). It has been shown that the variability of shoreline position (Figure 4a) is a persistent self-affine signal (Tebbens, Burroughs, and Nelson, 2002), further indicating that classification will depend on location and spatial scale.

Maximum Dune Retreat

To determine which geomorphic factors most influence coastal change, we analyzed the relationships between the measured parameters. Of the parameters measured, only preexisting beach width and dune base elevation were found to be successful indicators of dune vulnerability to erosion.

To compare beach width with its associated dune retreat for each profile, we grouped beach widths into 1-m bins and determined the maximum dune retreat that occurred in each bin (Figure 6). In all three areas, the greatest dune retreat occurred for beach widths of approximately 20 m. A beach width of 20 m corresponds to a beach slope of approximately 10%, which is the maximum slope expected for a stable beach (Inman and Dolan, 1989). The maximum dune retreat systematically decreased for beaches from 20 to 60 m wide. For beaches wider than approximately 60 m, the maximum dune retreat was consistently less than ~7 m in all areas. Thus,

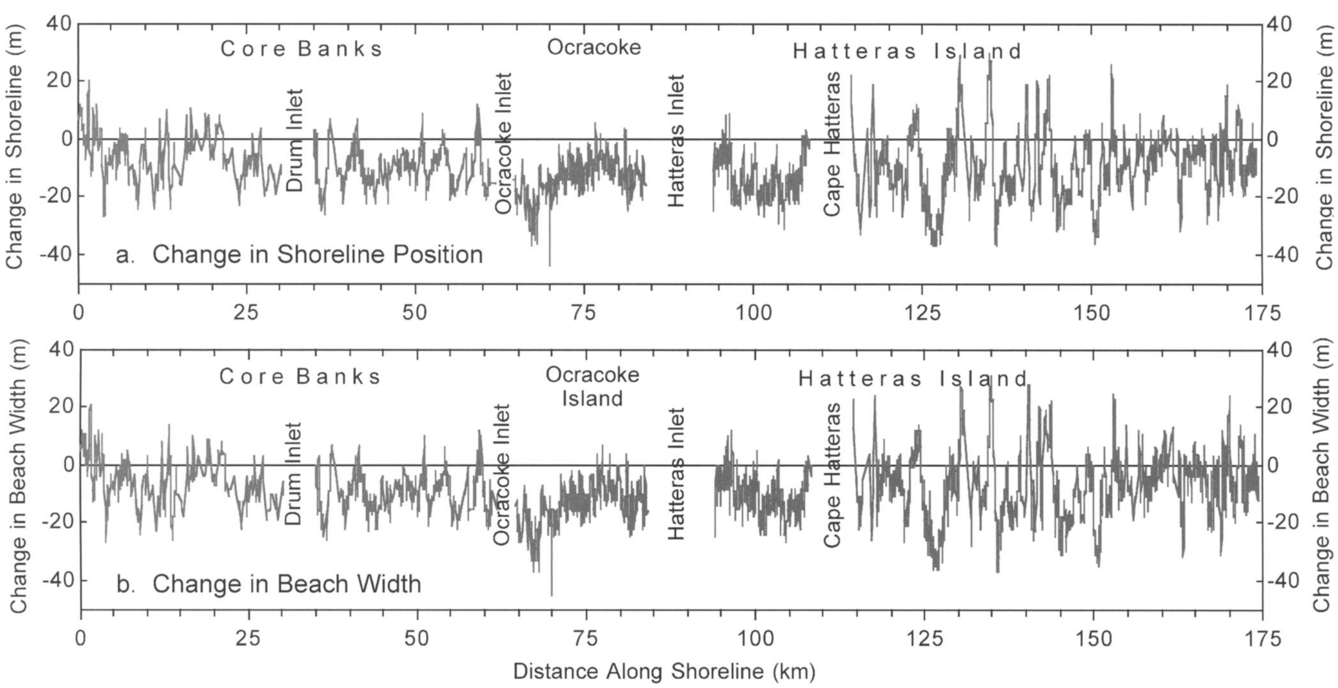

Figure 4. The change between the surveys of 1997 and 1998 in (a) shoreline position and (b) beach width.

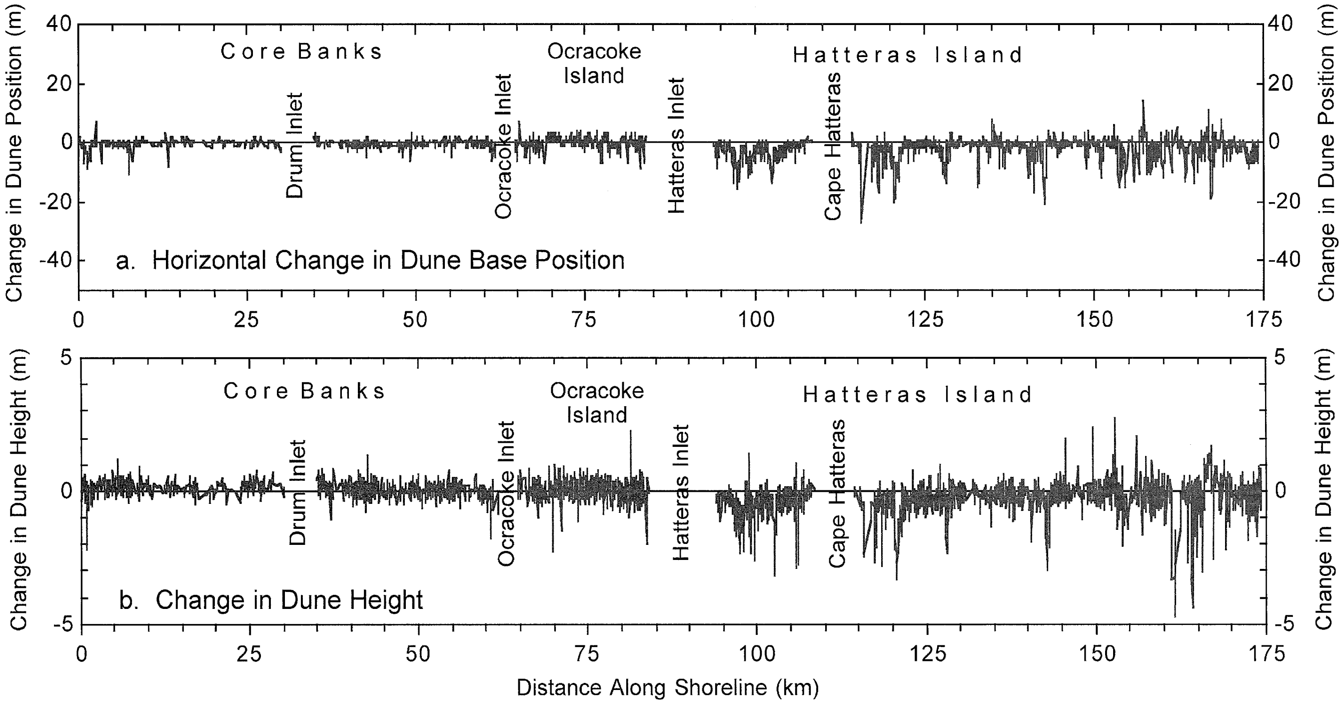

Figure 5. The change between the surveys of 1997 and 1998 in (a) horizontal dune base position and (b) dune height.

for the study region during the year examined, the amount of dune base erosion decreased as beach width increased from 20 to 60 m. For beaches wider than 60 m, maximum retreat of the dune did not decrease additionally.

Maximum dune retreat differs for the three areas. For a corresponding beach width, the maximum value of dune retreat tends to increase from south to north. For instance, for a 20-m beach, the maximum dune retreat in area 1 was ~11 m; in area 2 it was ~16 m, and in area 3 it was ~27 m (Figure 6).

A second parameter that influenced dune retreat was dune base elevation. Area 3 has the greatest range in dune base elevation. The data for area 3 are subdivided into three groups on the basis of dune base elevation. The maximum dune retreat in each 1.0-m bin for each elevation range is shown in Figure 7. For area 3 for a given beach width, higher dune base elevations are associated with less dune retreat.

Table 3. *Summary of changes with standard errors of the mean.*

	Mean Change (m)		
	Area 1 Core Banks	Area 2 Ocracoke and Lower Hatteras	Area 3 Upper Hatteras
Shoreline position	−7.54 ± 0.25	−13.4 ± 0.18	−9.26 ± 0.26
Dune base position	−0.37 ± 0.05	−1.30 ± 0.08	−2.17 ± 0.08
Beach width	−7.16 ± 0.26	−12.2 ± 0.19	−7.08 ± 0.26
Dune height	0.06 ± 0.01	−0.19 ± 0.01	−0.24 ± 0.01
Fractional dune height	0.018 ± 0.002	−0.030 ± 0.002	−0.032 ± 0.002

Therefore, for comparable beach widths, dunes retreated less where the beaches were steeper.

Thus, two geomorphic indicators of dune erosion are beach width and dune base elevation. Both of these parameters affect the ability of waves to reach the dune and cause erosion. These results are consistent with JUDGE, OVERTON, and FISHER (2003), who found that parameters related to cross-sectional area are somewhat successful as dune vulnerability indicators. Cross-sectional area indicators are also used in some models of dune erosion (*e.g.,* HALLERMEIER and RHODES, 1988).

Regional Variability

We consider how the geomorphic patterns of change vary for the three different areas within the study region. If the Core Banks and Ocracoke Island behaved in one manner and the coast north of Cape Hatteras behaved differently, then the regional variations could be attributed to a change in strike of the coast. If the Core Banks exhibited one behavior and Ocracoke and Hatteras Islands exhibited a different behavior, then the regional variations could be due to the greater anthropogenic influences in areas 2 and 3.

Mean beach width decreased in all three areas in the year between the two surveys, but no clear systematic pattern between the different areas appeared.

The maximum decrease in mean beach width occurred in area 2, with areas 1 and 3 exhibiting smaller mean changes that were similar to each other. Thus, changes in beach width do not reveal systematic regional patterns attributable to

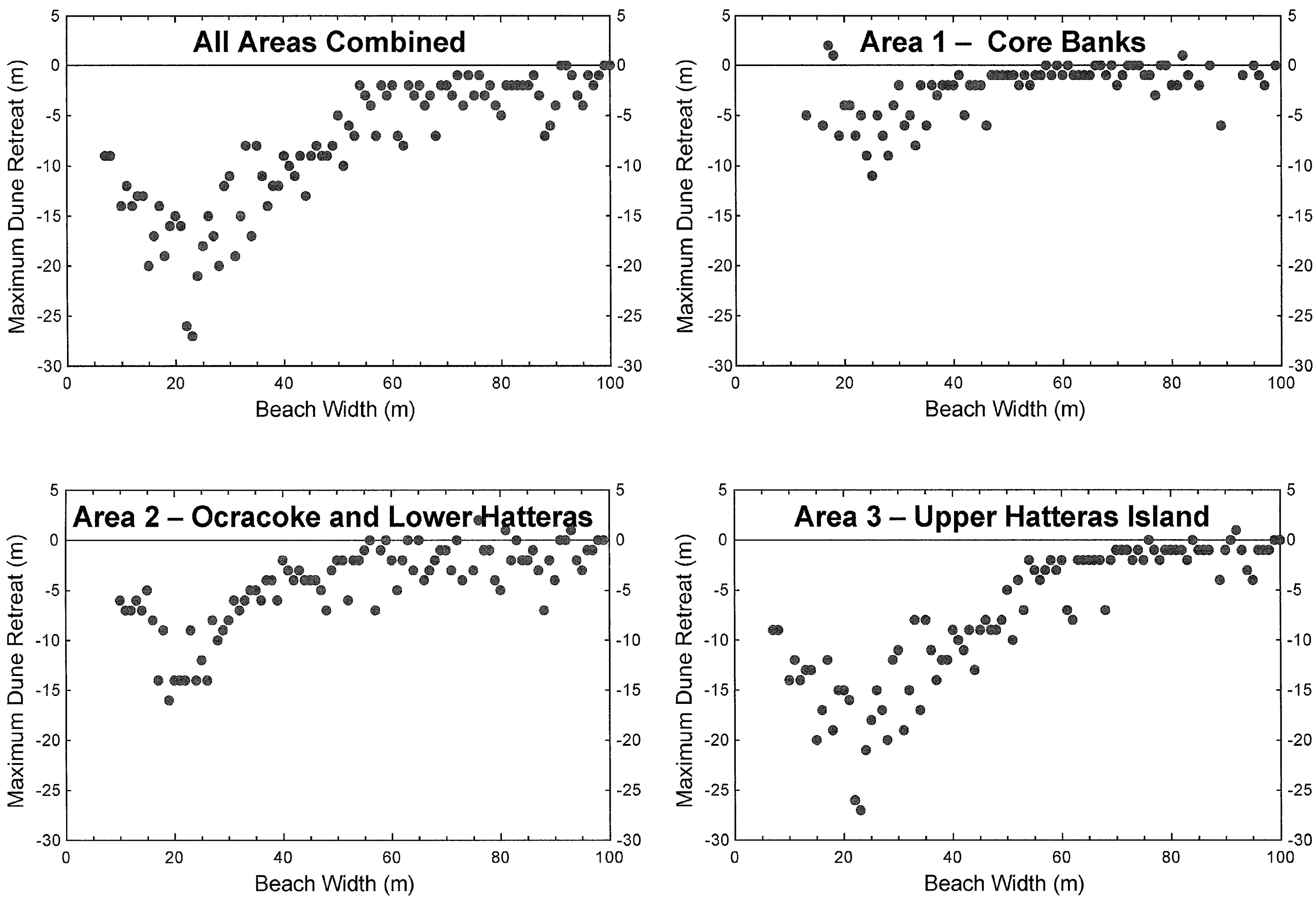

Figure 6. Maximum dune retreat in each 1.0-m bin of 1997 beach width for all areas combined and for areas 1, 2, and 3, as indicated. The maximum dune retreat corresponds to the most negative value in each 1-m bin. Dune retreat was greatest for beach widths of approximately 20 m. For comparable beach widths, maximum dune retreat increased from south to north.

change in strike of the coastline or to varying anthropogenic influences.

How the change in beach width occurred in the three areas was different. Because beach width is defined to be the distance between the shoreline and the base of the dune, a change in the position of either of the end points will result in a change in beach width. All three areas experienced a mean shoreline retreat, with less mean retreat in area 1 than in areas 2 and 3 (Table 3 and Figure 4a). Along the Core Banks, dune retreat was minimal (Table 3 and Figure 5a), so the change in beach width was caused almost entirely by shoreline retreat. On Ocracoke and Hatteras Islands, dune retreat and shoreline change both contributed to the observed changes in beach width.

Several geomorphic parameters exhibit systematic variations from south to north across the study region. The cross-shore change in the dune base position shows an increase in dune retreat from south to north, with minimal change in area 1 and greater changes observed in areas 2 and 3 (Table 3 and Figure 5a). The change in mean dune height was minimal in area 1, whereas areas 2 and 3 both exhibited decreases in mean dune height (Table 3 and Figure 5b). For comparable beach widths less than 60 m, maximum dune retreat increased from south to north (Figure 6). Areas 2 and 3 experienced greater changes in dune base position, dune height, and maximum dune retreat than area 1. The dunes of the less developed Core Banks experienced minimal change in dune height and dune base position. The greatest changes occurred in areas 2 and 3, where greater efforts have been made to maintain beaches and stabilize dunes.

An ultimate goal of coastal studies is to determine the processes that lead to the observed changes in morphology. THIELER *et al.* (2000) found that many models of coastal processes that are based primarily on morphology contain inaccurate assumptions and are not valid. We therefore do not attempt to infer coastal process with the use only of morphology. Additional factors to consider when understanding dune erosion processes are water levels, wave energy, and duration of exposure of dunes to waves (*e.g.,* JUDGE, OVERTON, and FISHER, 2003; VELLINGA, 1983). In this work, we identified morphologic parameters associated with dune retreat for a 1-year interval in one region. Future work is needed to incorporate this knowledge into a better understanding of the dynamic processes of coastal systems.

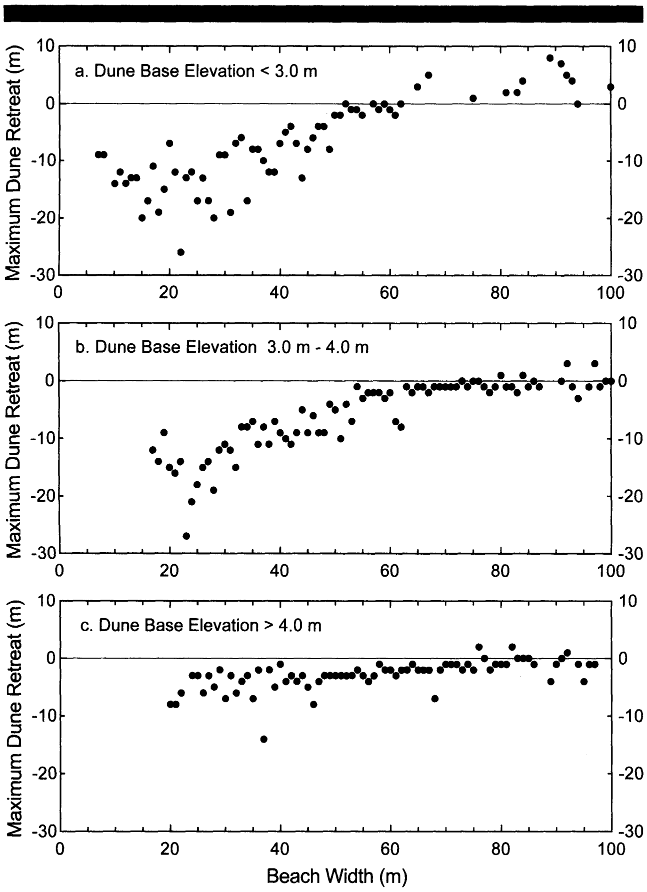

Figure 7. Maximum dune retreat in each 1.0-m bin of beach width in area 3 for dune base elevations of (a) less than 3 m, (b) between 3 and 4 m, and (c) greater than 4 m. Lower dune base elevations are associated with greater maximum dune retreat. If the data in these three graphs are combined, then only the most negative value in each 1-m bin will be displayed, as seen in Figure 6 (area 3).

CONCLUSIONS

The major conclusions of this paper are:

- Supratidal beach widths generally decreased along the Outer Banks between the surveys of 1997 and 1998.
- Along the Core Banks, changes in beach width were primarily caused by shoreline retreat. For Ocracoke and Hatteras Islands, changes in beach width were caused by both shoreline retreat and dune base retreat.
- For comparable beach widths, maximum dune retreat increased from south to north.
- Maximum dune retreat was greatest for beach widths of approximately 20 m. The maximum dune retreat systematically decreased for beaches 20–60 m wide. For beaches wider than 60 m, maximum dune retreat did not decrease additionally.
- The Core Banks experienced minimal changes in dune base position and mean dune height.
- The greatest changes in beach width, dune height and dune base position occurred on Ocracoke and Hatteras Islands.

Our work builds on the results of JUDGE, OVERTON, and FISHER (2003), who found that cross-sectional area parameters are indicative of dune vulnerability. In this work, we examined coastal change in a different region, over a larger area, and at a finer resolution. Of the geomorphic parameters examined, those that best indicate vulnerability to dune retreat are preexisting beach width and dune base elevation.

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