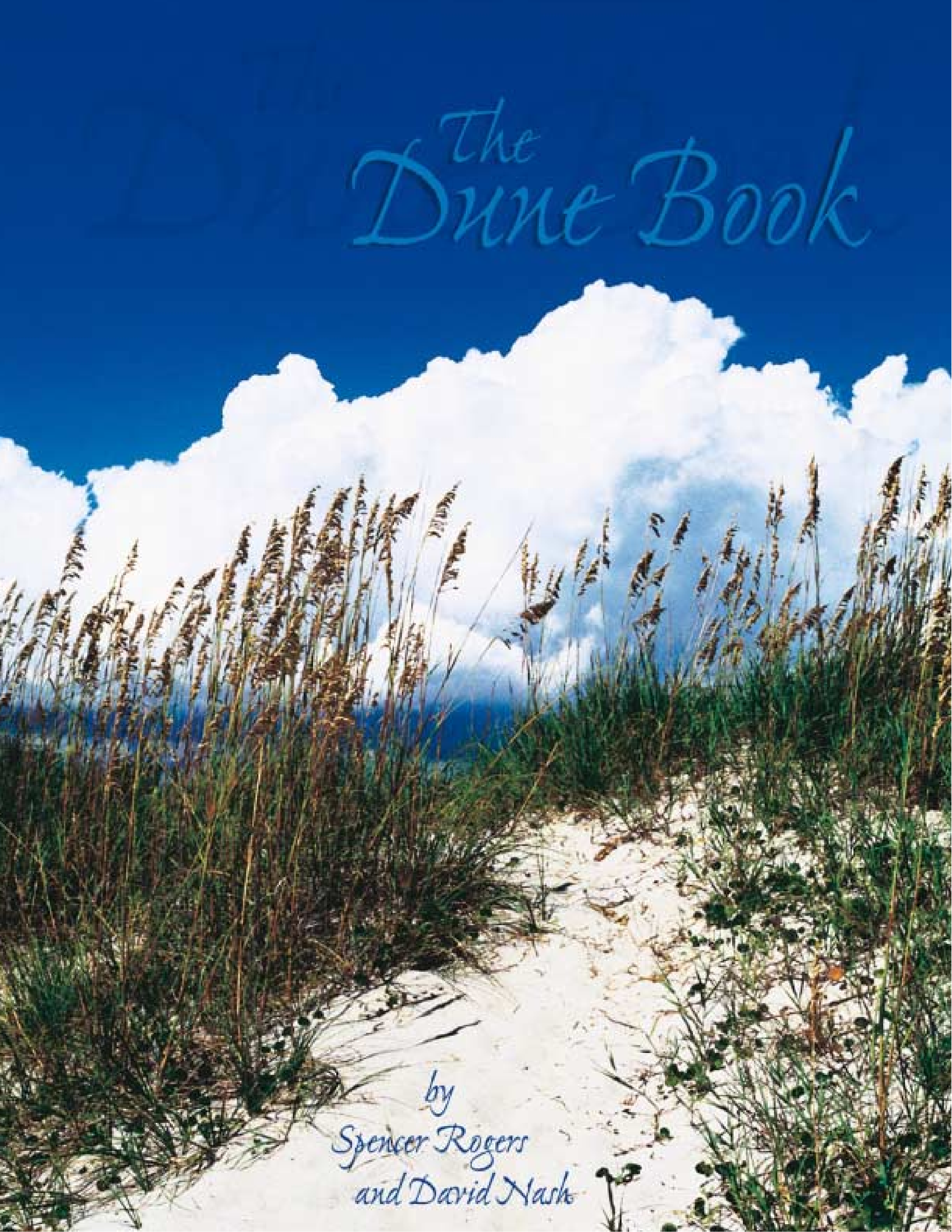
The Dune Book



by

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North Carolina Sea Grant, September 2003

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TABLE OF CONTENTS

Chapter 1:
Introduction

Thirty years ago, sand dunes and dune vegetation often were considered nuisances to be flattened before starting coastal development. Fortunately, times have changed. Dune vegetation is now recognized as an important asset for providing protection from natural hazards and aesthetic benefits. Although property owners and communities are doing a much better job of protecting the dunes, the functions, benefits and limitations of dunes are often misunderstood.

This booklet will describe what dunes and dune vegetation can and cannot do, cutting through some of the well-established myths. We will discuss how nature builds and destroys dunes and why they are so important. We will look at how we can manipulate the natural processes for the better and sometimes, if we are not careful, for the worse. The best dune grasses for the North Carolina coast are described and tips are given on how to plant and grow them. We also will discuss the best ways to use sand fences and other sand traps.

We will give the reader a general view of the best dune management practices along developed shorelines. The booklet includes plant species, common development practices and regulations in North Carolina. The general management approaches will apply on any developed shoreline where people, buildings and roads are already in place. However, the practices are not intended to be applied to undeveloped shorelines where wildlife or natural area management is the primary goal. In areas where the dunes and dune vegetation interact with other inland grasses, trees and shrubs, different management approaches may be needed.

What Is a Dune?

Ocean sand dunes are geologic features that are in a constant state of change — somewhere between building in elevation with wind-trapped sand and getting flattened in an extreme storm or hurricane. Attempts to define a dune for regulatory purposes have proven quite difficult due to the wide range of evolving features.

In this booklet, we will take the broadest view. Dunes are defined as any area landward of the active beach where dune grasses are the dominant plants. It might be a classic dune shape that rises 40 feet in height and is covered with sea oats, a recent overwash terrace flattened by a hurricane where the buried dune grasses have yet to pop up through the new sand, or anywhere in between.

Chapter 2:
How the Beach Works

To understand the dunes, you must first understand how the beach works.

Ocean waves dominate the beach. Waves absorb energy from the wind. Stronger winds and larger storms create larger waves. That energy is transmitted across the water surface by the waves to the coast where the waves break, unleashing that energy on the beach. Wave forces are very misleading. Most people avoid hurricane winds of 120 miles per hour. Yet the force of a single 2-foot wave breaking on a solid, vertical wall is at least three times more powerful than the winds of a major hurricane. Fortunately, our relatively thin bodies let the forces go around us, allowing people to play in the surf.

The most important protective feature of the beach and dune system is the submerged offshore slope. As a wave moves into shallower water, friction-like factors internally affect the wave form, slowing the base of the wave but having less effect on the crest or top of the wave. The decreasing depth causes the wave to increase in height, slow in speed and become much steeper. At some point, the crest of the wave is moving too fast for the bottom of the wave form to keep up. Then the wave becomes unstable and breaks, dissipating part of its energy before reforming into a smaller wave.

This depth-induced breaking is a relatively predictable wave phenomenon that can be measured on any beach or reproduced in the laboratory wave tank. This description assumes the wave will break when the water depth is roughly equal to the wave height. More precisely, the waves break when the wave height (crest to trough distance) is about 78 percent of the water depth, as shown in *Figure A*.

Storm winds blowing across large ocean areas can generate very large waves. Waves taller than 40 feet have been measured in deep water off the North Carolina coast during passing hurricanes. One of the largest waves ever measured was a height of 112 feet during a Pacific typhoon.

Photo 1: Wave height is easiest to observe on fishing piers.

Just one of these large waves would be devastating for houses and other development near the coast. Fortunately, our relatively flat continental shelf provides protection from the largest waves. A 40-foot wave will break in roughly 40 feet of water several miles offshore, even in the middle of a hurricane. This breaking effect will occur repeatedly as the wave approaches the beach. By the time the waves get to buildings on the shoreline, they are usually smaller than 6 feet, even in a hurricane. Therefore, the offshore slope protects the beach and any coastal development from the largest waves.

A good place to observe wave effects is on a fishing pier *(Photo 1)*. During a small storm, the seaward end of the pier may get 6- to 10-foot waves. To estimate the wave height, look at the pier pilings, following the waves to the beach where you can see them break once or twice before finally running up the beach face. At low tide, the last wave break may only be a foot or two in height.

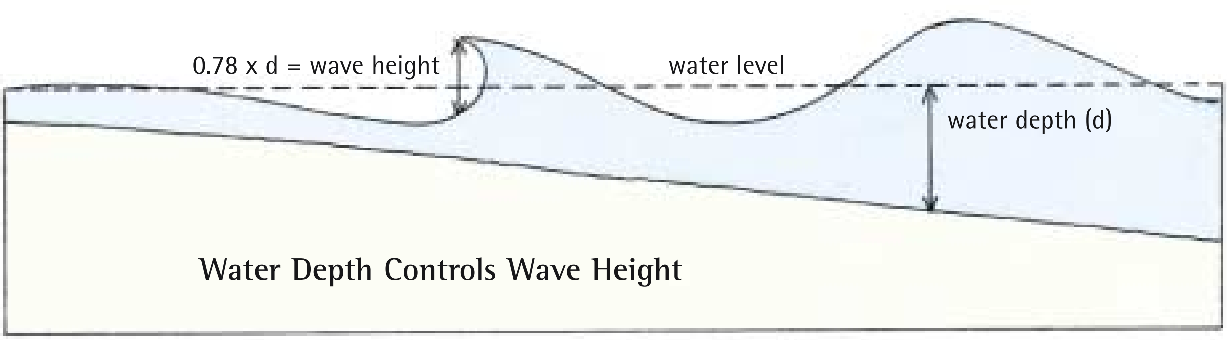


Figure A: Maximum wave height is controlled by water depth. Shallow water causes the wave to break.

Beach Shape

The shape of the beach is no accident. It is rearranged constantly by changes in the waves. *Figure B* shows the primary parts of the beach. The dune is the vegetated area. The berm is the dry, sandy beach where you can place your beach blanket. The beachface is the steeper sloped area leading to the water, where the waves are constantly running up. The offshore underwater area is in constant motion also extending at times to deeper than 30 feet and more than a mile offshore.

The primary factors that affect the beach shape on most days are:

- the wave height during the last week or so;
- the water level, including astronomical tide conditions and recent storm surges; and
- the grain size of the sand.

Higher waves shift sand from the berm into deeper water, flattening the beachface. Smaller waves move sand back to the berm and steepen the beachface.

When higher astronomical tides or small storm surges raise the water level, smaller waves can cause as much erosion as larger waves at normal water levels. Wider tide ranges tend to create flatter beachfaces. Areas with small or no astronomical tides tend to have steeper and shorter beachfaces.

The sand's grain size varies with location across the beach profile. The finest sands are in the dunes and farther offshore in deep water. The sands in the berm and beachface are coarser, with the coarsest found under the break point at the bottom of the beachface. On any individual beach, the grain size distributions are relatively constant – but can change significantly from beach to beach. Fine sands result in flatter beaches. Coarse sand results in a steeper beachface. Variations in sand size occur due to the source of the sand, most often resulting from the underlying or adjacent geology that is being reworked by the waves.

If ocean conditions were ever constant, the shape of the beach would approach a relatively constant or equilibrium shape. In nature, wave height and water level are constantly changing. The tide is rising and falling. Changing wind conditions are constantly varying the wave height. The shape of the beach cannot reach equilibrium, but it continues to move toward that shape for the present conditions. The adjustments in the beach shape are critical in providing storm protection for coastal development and are second in importance to the wave protection provided by the offshore slope.

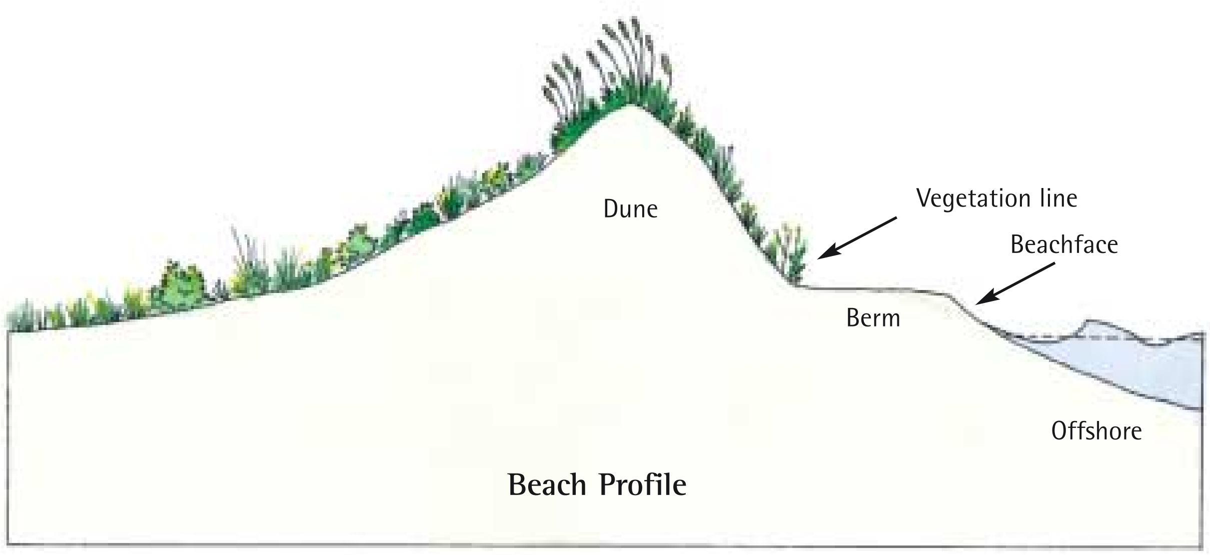


Figure B: Beach components are illustrated above.

Chapter 3:
Erosion Types

Beaches are products of erosion. They exist because of the erosion and recovery of sand as the shorelines adjust to the forces that shape them. There are many levels and causes of erosion. To help people understand erosion, it is separated into four types or causes: seasonal fluctuations, storm-induced erosion, long-term erosion and inlet erosion. To make the best dune management decisions, it is critical to understand what type or types of erosion are occurring. Building dunes and planting vegetation can be very effective in treating some types of erosion but totally ineffective for others.

Seasonal Fluctuations

Varying weather and storm patterns that reoccur every year cause seasonal fluctuations in the beach width. Between late fall and early spring, a series of storms with higher velocity winds from the northeast or "northeasters" occur across the North Carolina coast. These massive offshore storms cause larger waves and small storm surges that — at least on east-facing beaches — erode the berm. Although no single storm may be particularly noteworthy, they come frequently enough that the berm does not have time to recover during the periods of smaller waves that occur between storms. In contrast, the summer season has fewer and smaller storms, and the berm is usually wider than during late fall to early spring.

Because most visitors usually go to the beach in the summer season, they expect to see a wide flat berm. If you could watch the changes in the beach every day of the year, there would be a day when closely timed or more severe storms caused all of the berm to be eroded back to the seaward line of dune vegetation *(Figure C)*. It is no accident that the berm is usually backed by a relatively clear and straight line of vegetation.

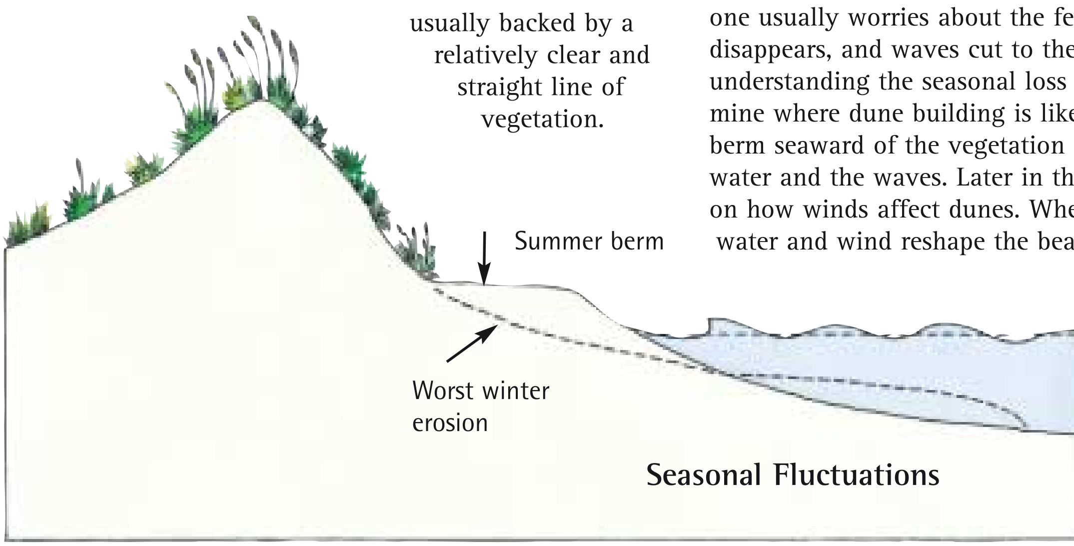


Figure C: Seasonal fluctuations in the berm are due to seasonal changes in wave height and storm frequency.

Photo 2: The vegetation line is established by seasonal fluctuations.

Dune grasses grow into the berm all summer. However, during the stormy season, wave-induced erosion reaches the vegetation, undermining plants that are trying to grow farther seaward *(Photo 2)*. Therefore, the vegetation line represents the landward limit of wave-induced erosion during the last one or two storm seasons.

On summer days, it is hard to imagine that the berm is temporarily eroded almost every year. On a typical North Carolina beach, the waterline moves about 75 to 100 feet every year due to seasonal fluctuations. Seasonal fluctuations also cause dramatic changes in the elevation of the beach. When most beaches are at the widest, usually in the summer, you can stand at the seaward edge of the berm at the top of the beachface, and the beach elevation under your feet typically had been 6 to 8 feet lower following the worst storms of the previous year.

Although relatively large in scale, the seasonal fluctuations in the beach width are usually not considered to be erosion. As long as the sand returns for the summer, no one usually worries about the few days when the berm disappears, and waves cut to the vegetation line. However, understanding the seasonal loss helps homeowners determine where dune building is likely to be successful. The berm seaward of the vegetation line is controlled by the water and the waves. Later in the book, there is a section on how winds affect dunes. When the competing forces of water and wind reshape the beach, the water always wins,

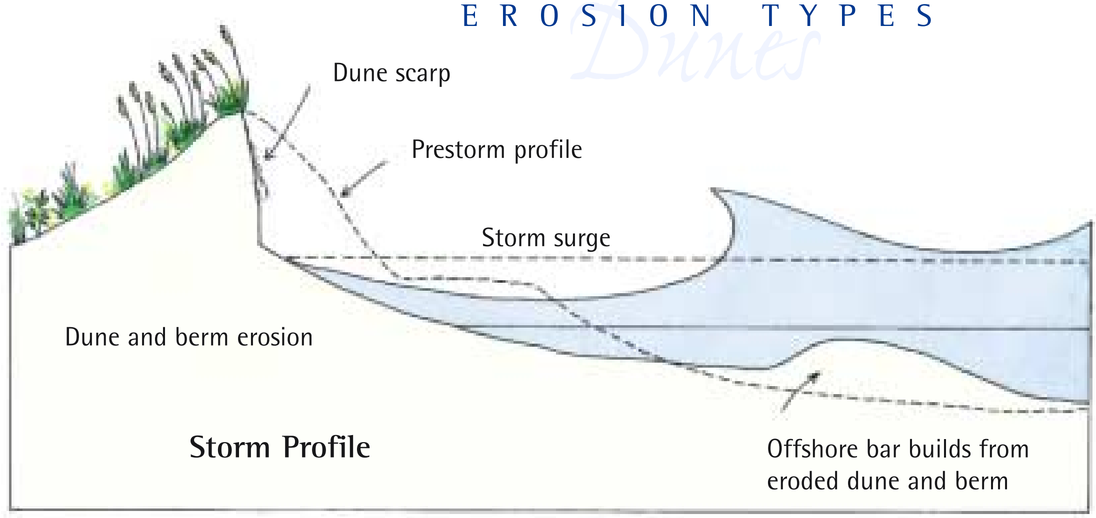


Figure D: Storm-induced erosion is caused by a single, infrequent but severe storm or hurricane.

taking whatever it wants. The wind works with the remaining sand to build the dunes, making it pointless to try to build dunes or plant vegetation on the seasonal beach. Next year's fluctuations are certain to remove it.

Storm-Induced Erosion

For our purposes, storm-induced erosion is defined as the erosion caused during infrequent, but very severe storms, including the worst hurricanes. Large waves are accompanied by a rise in water level or storm surge. The changes in the beach are shown in *Figure D*. The breaking waves create currents along the bottom that move sand from the visible beach to submerged areas farther offshore. The average slope of the beach is flattened, spreading out the incoming breaking waves. Initially the berm is eroded, but since the conditions are much worse than the typical annual storm, erosion occurs in the dunes.

As with seasonal fluctuations, the overall beach slope tends to flatten by moving sand in the upper beach to shallow water just offshore. A comparison of the "before and during shapes" in the figure shows that as the storm begins, relatively deep water extends to the shoreline, allowing large waves to reach the berm and causing rapid erosion. As more sand is moved offshore, the depth gets shallower, forcing the waves to break farther offshore and gradually slowing the erosion.

Storm waves frequently form offshore sand bars. As the waves move into shallower water, currents moving in opposite directions are created along the bottom. Sand is pushed toward the crest of the bar from both directions. The larger the waves, the larger the bar and the farther offshore it forms. Many beaches have one or more rows of offshore bars all year. In those areas, the storm moves the bars farther offshore as sand erodes from the berm and dune, increasing the bar's size.

Conveniently, the bars, with their sand-efficient shapes, cause the waves to break. As the storm continues, the bar builds in height above the original depths. Thus, the water depth over the bar is reduced by the sand supplied by the upper beach. Remember that the water depth controls the wave height. As the bar height builds, even smaller waves are forced to break on the growing bar. Wave heights reaching the upper beach are diminished. Smaller waves result in a slower rate of erosion. The bars act as an increasing filter for the largest waves.

Like the seasonal fluctuations, the storm moves the sand toward an equilibrium beach shape, which after some period of time, experiences little additional erosion. In the real world, most storms are far too brief to approach a stable shape. But even in the middle of a hurricane, the beach still moves toward that stable shape.

A principal benefit for anyone living near the shoreline is that the dune acts as a storage reservoir for

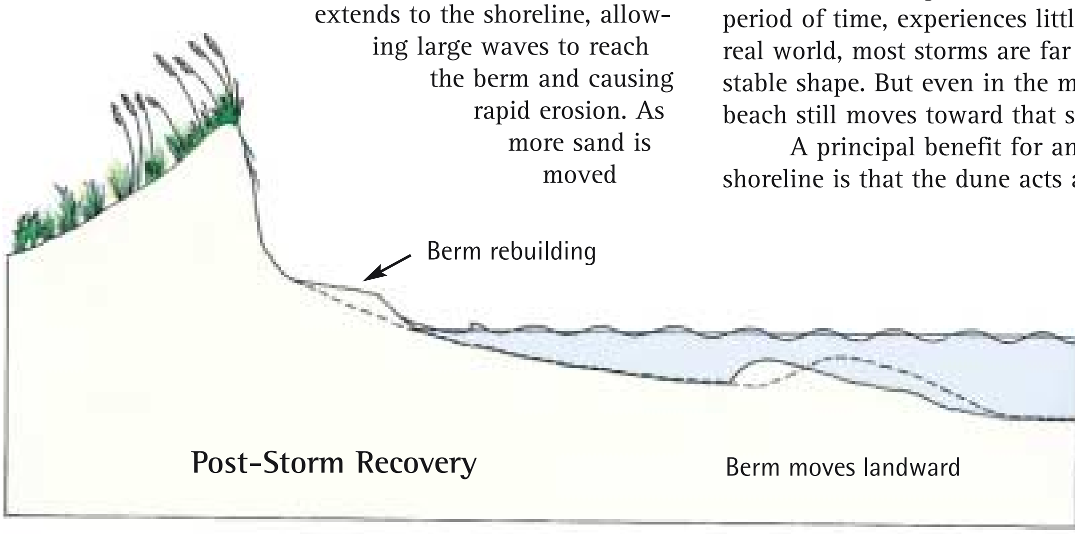


Figure E: Berm recovery begins immediately following a severe storm.

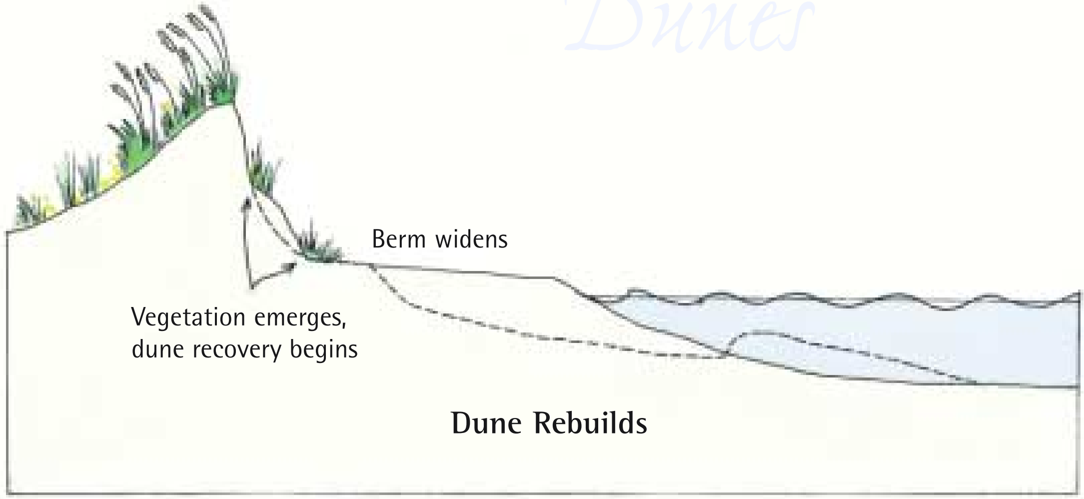


Figure F: Post-storm berm recovery is complete with dune recovery beginning.

sand that is made available during infrequent but severe storms. The larger the dune, the more time it takes to be eroded by the waves, and the more protection it provides to areas farther landward. If the dunes are large enough, the waves and storm surge are prevented from washing across the barrier island. Flooding may still occur from the backside of the island but not directly from the ocean. Even if the dune is breached and the shoreline is overwashed, the sand stored in the dunes and eroded by the storm reduces the incoming wave heights compared to areas without dunes.

Both natural and man-made dunes provide significant protection from storm-induced erosion that occurs during infrequent but extremely severe storms, such as a hurricane. Sand dunes provide **storm** protection. By using the techniques described in this booklet, you can manage dunes and dune grasses and improve the storm protection on your shoreline.

Post-Storm Recovery

If the offshore sand transport was a one-way path, ocean shorelines would disappear extremely rapidly. Fortunately, most of the sand eroded from the berm and dune is moved only a short distance offshore. As the waves and storm surge subside, the beach shape is again out of equilibrium. However, this time the offshore is too shallow. The smaller waves on the post-storm beach shape induce currents along the bottom that push sand back toward the shoreline.

Initially, the bar crest begins to move landward, and the berm begins to reform *(Figure E)*. Eventually, the lost sand is pushed back into a new and wider berm. With more time, the dune recovery begins *(Figure F)*.

Ever wonder why the berm is so flat? The berm is a feature of the post-storm recovery during average waves and tides. Returning sand is pushed up the beachface, where the water percolates into the surface, depositing the sand it carries. At high tide, daily wave runup pushes sand to its maximum elevation, resulting in a flat berm.

As noted earlier, the water and the waves control the berm and offshore area. So how does the sand get back into the dunes? The dunes are too high and too far landward to be reached by daily waves. Dunes are features of the wind, making use of those areas not regularly rearranged by the waves. On most days at the beach, the wind speeds are too slow to move much sand. However, as the wind speed increases above a certain threshold, the sand starts to move. The threshold on a particular beach depends on the grain size and composition of the sand. The finer and lighter the sand, the lower the wind speed necessary to move it. That is why dunes tend to have finer grain sizes than wave-dominated parts of the beach.

Sand moves by rolling and bouncing along the surface. The wind energizes an individual sand grain, temporarily knocking it into the air. However, in just a few feet, gravity bounces the grain back to the surface, where it helps knock another grain up into the wind. Most of these hops take place within 6 inches of the beach surface. When the wind speed increases above the threshold necessary to move the sand, a layer of moving sand is formed within 6 inches of the surface *(Photo 3)*. If you visit the beach on a windy day, notice that — while your ankles are getting sandblasted — only a few grains make it as high as your face.

Photo 3: Wind-blown sand moves just above the sand surface.

Sand dunes are formed when several features are present. First, there must be a supply of dry sand for the wind to pick up. The post-storm berm is an ideal sand source. An onshore wind must exceed the velocity threshold to move the local sand. The sand must be transported to a relatively stable location of beach, landward of the seasonal fluctuations. Finally, to form a dune, there must be some barrier to slow the wind speed below the threshold needed to move the sand 6 inches just above the sand surface. When the wind speed is reduced, the wind drops the sand, gradually accumulating into a growing dune.

This is when the dune vegetation becomes very important. The stems of the dune vegetation slow the wind near the surface, trapping the wind-blown sand. When the dune plant traps sand, it stimulates growth through the accumulating sand that would kill many other plants, ensuring that the plant remains a continuing sand trap for building the dune elevation. Sand fences and other wind barriers trap sand in the same way, but these barriers are unable to expand with the dune as does other vegetation.

Returning to our post-storm beach recovery in *Figure F*, the wide-recovered berm is a good source of sand. The eroded dune area is rarely reached by waves. The surviving vegetation spreads to initiate reconstruction of the dune.

Summarizing storm-induced erosion: Infrequent but very severe storms take sand stored in the dunes and temporarily fill the submerged beach. This helps to knock down the worst of the storm waves. After the storm, smaller daily waves push the sand back to the berm. The waves cannot reach the dune area, but the wind — with a little sand trapping assistance from the dune vegetation — rebuilds the dune.

The time required for the onshore and offshore movement of sand depends on the severity of the storm. The previously defined seasonal fluctuations remove and replace the berm every year and form the relatively uniform vegetation line establishing the seaward edge of the dune. A hurricane may cause severe dune erosion in as little as a few hours, but the sand may take several years to get back to the berm. The slow dune recovery by the wind may take as much as a decade following the worst storms. However, most of the sand eventually returns. Therefore, this booklet's simplified definition of storm-induced erosion assumes that all of the erosion is temporary and will eventually recover.

In the simplest terms, sand stored in the dunes buys time and protection from the worst storms. It takes time for the waves to move sand offshore. The bigger the reservoir of sand, the more time it takes for the waves to consume the dune. By carefully encouraging larger and properly placed dunes, the storm protection can be improved for more landward, natural and man-made features on your beach.

Long-Term Erosion

The next type of erosion is long-term or chronic erosion. Over a period of decades or longer, many shorelines gradually change — either eroding landward or accreting farther seaward. As long-term erosion continues, the berm width and seasonal fluctuations of the beach remain about the same, but the dune is eroded and retreats landward. By definition, long-term erosion is permanent erosion occurring over longer periods of time *(Figure G)*.

There are many different causes of long-term erosion. In the worst storms, a portion of the rearranged sand may be carried into water too deep for waves to return it to the beach. On low shorelines, storms sometimes push beach sand over the island and bury the estuary, with no way for overwash sand to return to the active beach.

Sand moves on and offshore as depicted in the drawings and also moves along the shoreline. This longshore transport of sand may benefit some sections of beach, usually at a cost of long-term erosion elsewhere. Sand is regularly lost into natural inlets. Man-made inlet improvements for navigation can affect the long-shore distribution of sand transport — and in some cases can

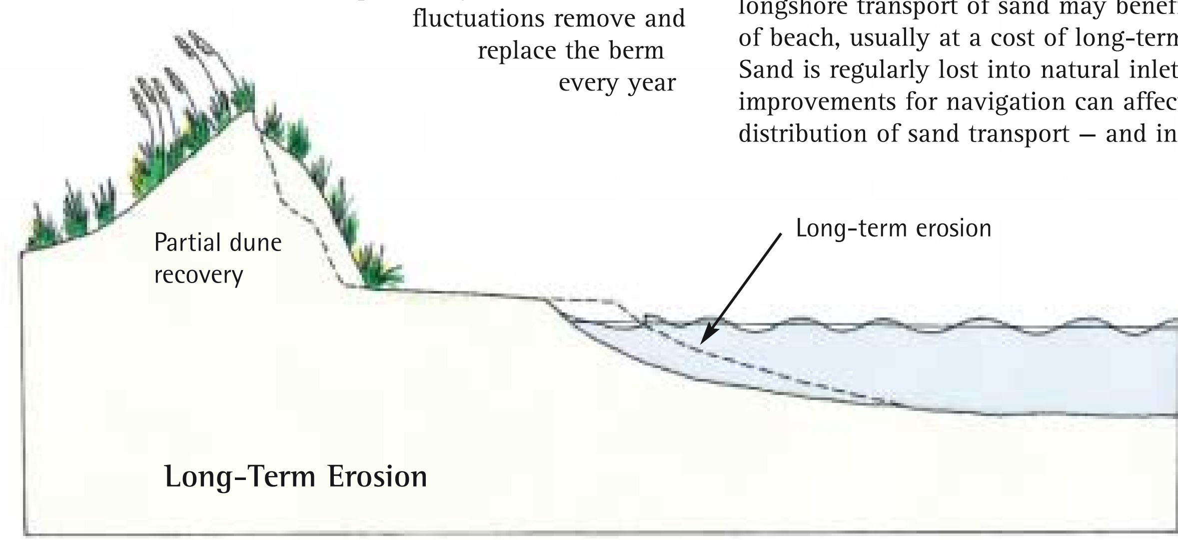


Figure G: Post-storm berm and dune recovery is completed, but long-term erosion deficit moves the berm and dune farther landward.

dispose of dredged sand in locations where it cannot return to the beach.

A less obvious cause of long-term erosion is rising sea level, often presumed to be a constant. In reality, up to a century of tide gage records have measured sea-level rises in North Carolina to be between .5 and 1.5 feet per century, depending on the gage location. On average that is around 0.01 feet higher each year, an imperceptible change.

However, as sea-level rise accumulates over the decades, the changes are seen as long-term erosion. On the average beach in North Carolina, historical rises in sea level are thought to account for about half of the long-term erosion. Many people are concerned that man-made actions may result in a gradual global warming and an accelerated rise in sea level. Such long-term changes are difficult to prove or disprove until well after the change has started. If global warming raises sea level faster than historical conditions, long-term erosion can be expected to increase. Climate warming and sea-level rise predictions vary widely. However, the most likely predictions should not result in catastrophic increases in erosion.

It is convenient to measure and discuss long-term erosion as annual averages over a period of decades. The average rate of long-term erosion over the last 50 years on North Carolina beaches is about 2 or 3 feet per year. Rates vary widely along the coast. Some areas have been losing more than 20 feet per year, while others have been gaining sand, accreting at rates of several feet per year. To evaluate long-term erosion at a specific site, you must look at local conditions. Statewide averages are irrelevant.

Focusing on annual averages can be somewhat misleading. Erosion is a weather-driven phenomenon. Like other weather factors, erosion varies widely from year to year, above and below the average.

Consider rainfall. How often do you have average rainfall in a year? Most years seem to bring either a drought or a flood. Shoreline change in any given year is similar. In a bad year, the beach and dune might lose 5 or 10 feet, followed by a couple of years of widening beaches and growing dunes. In an extreme storm or hurricane, the dune can erode 50 to 100 feet, even on shorelines that are not experiencing long-term erosion. Therefore, long-term erosion rates are most useful when considering issues over periods of a decade or longer. However, much wider short-term changes are normal and should be expected.

For example, the average erosion rate can be very important in locating houses, roads or in dune-building efforts. Just expect a wide range of changes from year to year. Do not be misled by a few years of growing berm width and dune building. Likewise, do not panic following a single extreme storm. On most beaches, a substantial recovery of the eroded beach and dunes can be anticipated. Consider the long-term average annual erosion rates for long-range planning but expect frequent reversals of erosion and accretion.

Inlet Erosion

The fastest-changing shorelines are usually found near unstabilized tidal inlets where there are volatile balances of tidal currents — which are trying to open the channels deeper and wider, and opposed by wave-transported sand attempting to close the hole in the islands. This results in a complex series of shoals and channels in the ocean and inside the inlet.

Each inlet behaves a little differently but usually can be grouped by the way it moves. Some inlets swing back and forth around a general location. Many inlets migrate in a single direction, sometimes at very rapid rates. However, a few inlets migrate in one direction for a decade or more — only to jump back to their starting places during a severe storm, then repeating their migration paths. In addition, there are some inlets that have existed near the same location for centuries. A few have recently opened in a hurricane, and a few have recently closed when the wave-transported sand finally overcame the tidal currents.

A common characteristic of inlets is that their shorelines and adjacent ocean beaches change far more rapidly than the shorelines beyond the influence of the inlet. The inlet shorelines of the barrier islands usually make the quickest shifts. Over a decade or two, most of the unstabilized inlets in North Carolina move at average rates between 50 and 150 feet per year. The fastest averaged more than 1,000 feet per year for an extended period.

As the inlets move, they drag the offshore tidal shoals and channels with them. These features cause the adjacent ocean beaches to fluctuate at faster rates than locations farther from the inlet. Even without extreme storms, rapid changes occur along shorelines near tidal inlets. For more information on local inlets, see *Shifting Shorelines: A Pictorial Atlas of North Carolina Inlets*, a North Carolina Sea Grant publication.

Science Versus Myth:
Do Dunes Help Stop Long-Term Erosion?

After almost a century of promoting dune preservation and planting by coastal scientists and managers, most beachgoers understand that dunes are important features. In practice, sand dunes have repeatedly

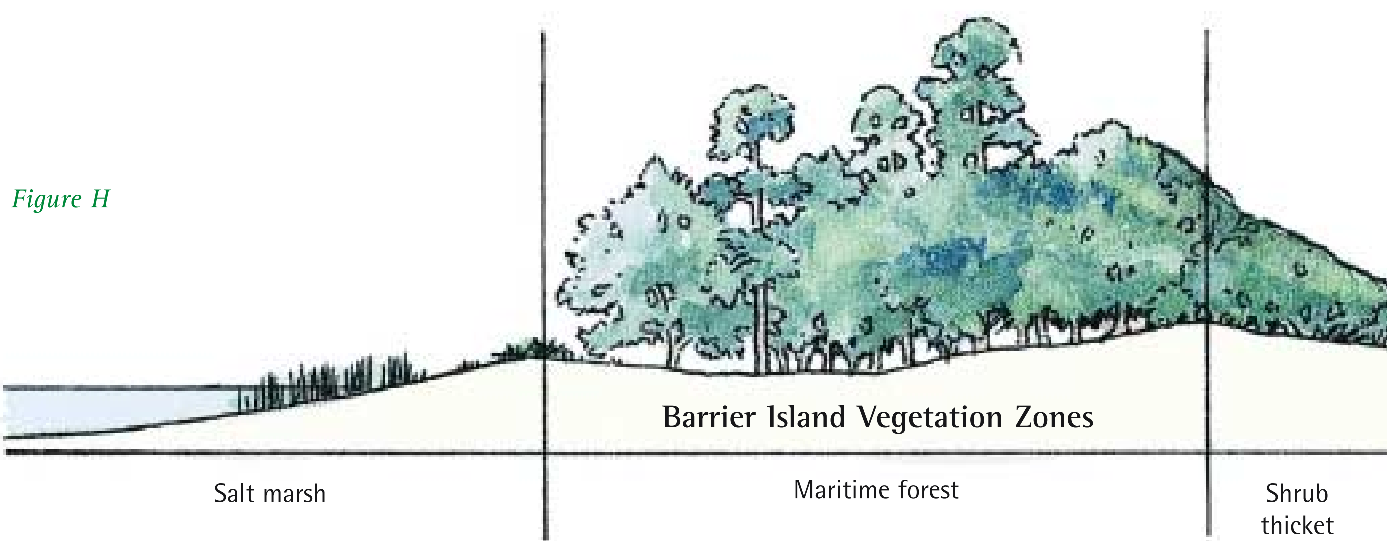
Photos 4 and 5: Although dunes provide storm protection, they aren't effective in preventing long-term or other types of chronic erosion.

proven to provide protection from waves and storm-induced erosion during infrequent but severe storms such as hurricanes. For that reason, protecting — and at times enhancing — the dune and dune vegetation is a noble if not necessary cause. Unfortunately, a myth has evolved that sand dunes are a cure for all types of erosion. In the real world, sand dunes are very poor protection from long-term erosion, inlet changes and even seasonal fluctuations in the beach.

Photos 4 and 5 show an Outer Banks house on a 30-foot sand dune that is higher than most of the ocean-front dunes in North Carolina. Two weeks later, during a small northeaster, the house fell to the beach. The long-term erosion rate of 8 feet per year is not apparent in the photos. The dunes are features of the wind and remain stable only in areas that aren't regularly reworked by waves. The volume of sand in the dune is small compared to the volume of sand in the berm and offshore area. Under constant wave assault, the dune can be redistributed thinly over the entire beach profile. Even the largest dunes are poor protection from long-term or chronic types of erosion.

The effective protection provided by the dunes during the worst storms is a wonder of nature. With a better understanding of what protection the dune can and cannot provide, you can better understand management techniques to improve protection or accelerate dune recovery following a severe storm.

Figure H



Chapter 4:
Dune Vegetation

Only a few species of plants can adapt to the dunes closest to the ocean and beach, where high levels of salt spray, continuous winds, large amounts of wind blown sand, and other environmental factors continuously impact these "pioneer zone" species. Coastal dune plants must be able to survive in soils that are low in nutrients and moisture and have extreme fluctuations in temperature and ocean overwash. Dune species thrive in this harsh environment because they are highly adapted to tolerate the extreme conditions.

Vegetation aids in forming the dune and plays an important role in the coastal dune ecosystem. Plants trap blowing sand, causing the formation of sand dunes and the stabilization of barrier island soils. As the dune field grows, multiple dunes line the beach, providing habitat for animals, birds, amphibians and reptiles.

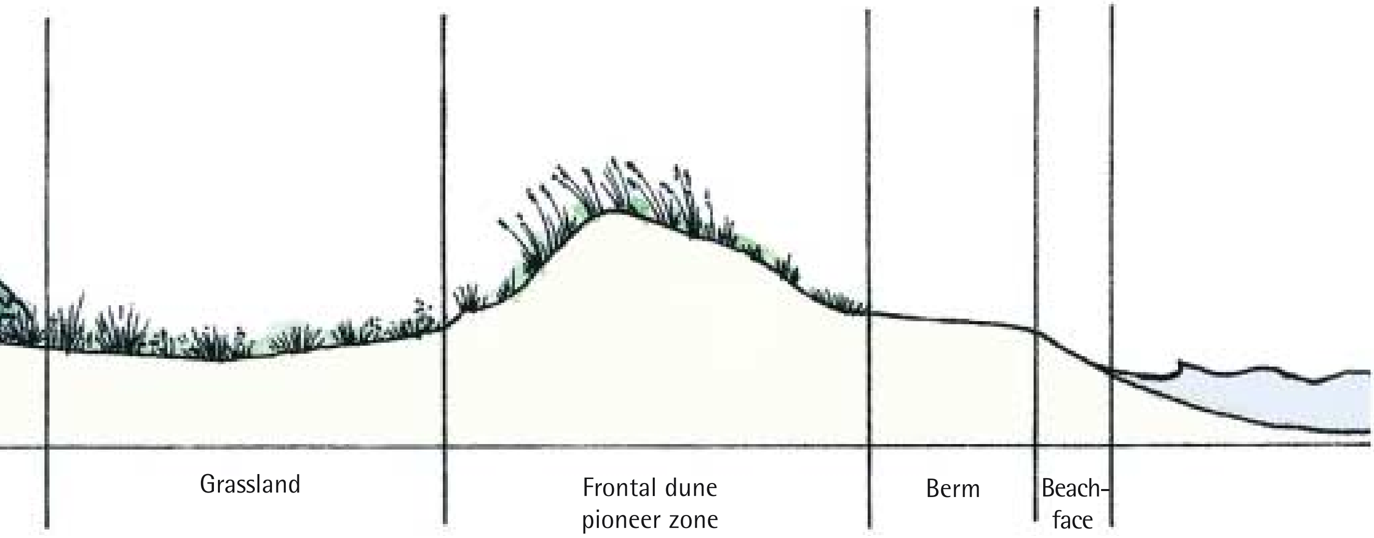
Salt spray and blowing sand are the two main factors contributing to the zonation of plant species across the barrier island, as shown in *Figure H*. When waves break on the ocean shoreline, salt spray is tossed into the air in high concentrations. Regular onshore winds push the spray inland, coating everything in its path. The highest salt concentrations occur on the beach, gradually decreasing with distance. Most plants have a low tolerance for salt in the soil or on their leaves. Dune plants tolerate the highest levels of salt spray and even an occasional overwash by sea water.

Most plants have a low tolerance for burial over their stems and roots. In contrast, dune plants thrive on wind-blown sand deposits, and collect sparse nutrients from the incoming sand, stimulating growth and reproduction. The harsh conditions in the pioneer zone allow the dune vegetation to grow without competition from less tolerant plants.

Inland from the shoreline and behind the shelter of the dunes, the conditions moderate to allow a wider variety of moderately tolerant grasses, shrubs and trees, resulting in distinctive plant zones forming across barrier islands — from the ocean to the estuary. The older dune ridges are farthest from wind-blown sand and salt spray. Plant species with less tolerance for salt spray and other adverse conditions may thrive in the back dune zone, where other plants and dune ridges block the sand and salt spray carried by the wind.

The typical vegetation zones from the ocean to the sound are: pioneer dune plants, grassland species, shrub thicket and maritime forest as shown in *Figure H and Photo 6*.

Photo 6: Maritime forest and shrub thicket canopy are shaped by salt spray.



Influence of Climate

Climate is the primary factor limiting the geographic range of pioneer zone coastal plant species. Along the mid-Atlantic coast, the dunes between the Chesapeake Bay and Cape Lookout are the approximate transition zone for several species. For example, sea oats prefer the warmer climate found south of this area and appear to be limited in their northern range by cold temperatures. American beachgrass is the dominant pioneer zone species north of the transition zone, tending to die back when stressed by the hot, dry conditions found farther south. Both species are excellent sand trappers and dune stabilizers. Each species should be utilized in the climate regions where they are best adapted.

While the native geographical range of a coastal species may extend for hundreds of miles along the coastline, plants from one end of the native range may not adapt well at the other end of their native habitat. For example, sea oats are native from the Virginia Cape all the way south to the tip of Florida and along the beaches in states bordering the Gulf of Mexico. However, research has demonstrated that the genetic makeup of sea oats — which influences the plant's hardiness, vigor, seed production, temperature tolerance, growth rate and reproduction — differs from one population to another.

Since local plants take years to evolve, they are usually best adapted to the climate where they were first grown. For example, South Florida sea oats do not adapt as well in the cooler climate of North Carolina as they do in Florida, and American beachgrass from New Jersey is not well suited to North Carolina's warmer climate.

Therefore, it is always best to obtain dune plants grown from seeds or parent material originating as close as possible to the beach where they will be planted. When possible, acquire seedlings or transplants that were grown from seeds or cuttings originating within a 100-mile radius of your beach.

Whether patching the frontal dune adjacent to a beach cottage or planting several miles of a beach nourishment project, the primary goal is likely to be the same: to trap and stabilize the blowing sand so that it will repair or enhance the storm protection provided by the dunes.

Coastal dune plantings also help build new ecosystems. This is best accomplished by using native indigenous species adapted to the pioneer zone. It is widely accepted that species diversity lends stability to an ecosystem. The difference between environmental restoration and landscape gardening is an important distinction that must be recognized when coastal dune revegetation projects are planned. Whenever possible, include several pioneer zone species in a dune revegetation project. The five species discussed below provide different options for dune revegetation and ecosystem restoration in different climate regions and planting seasons along the North Carolina coast.

Dune Plant Species

SEA OATS *(Uniola paniculata)*

Sea oats *(Photo 7)* are the "signature plant" on North Carolina's coastal dunes. As the name implies, the seed head has an oat-like appearance. The plant's tall stems, with their seed heads blowing in the ocean breeze, are a favorite sight for coastal visitors and residents. Sea oats are aesthetically pleasing and also are an important food source for wildlife, including birds and other creatures that depend upon the dune ecosystem for their survival.

This plant provides the best long-term stability for coastal dunes when planted in its native range, which includes the entire North Carolina coast. Sea oats readily tolerate the harsh conditions of the pioneer zone and are capable of trapping large quantities of sand during their first growing season. The plant's extensive root system helps stabilize the dune while weaving its way through the sand to absorb the limited supplies of water and nutrients. The root system also is the primary means by which sea oats spread and reproduce. From its roots, the parent plant sends out underground rhizomes that sprout as new plants — which in turn send out more rhizomes, gradually colonizing surrounding areas.

Although some new plants can grow from fallen seeds, the germination rate of the seeds in nature is quite low. For commercial production, the seeds can be treated to raise the germination to high levels before planting in the greenhouse. Seeds are collected in the fall before the seed heads drop.

Sea oat seedlings occasionally establish naturally from seeds, where they trap sand forming embryonic

Photo 7: New dunes form around sea oats.

dunes that will eventually become the frontal dune ridge. Sea oats are not limited to the frontal dune and are often found in older dune ridges several hundred feet landward of the ocean beach.

Planting Tips

Because sea oats are a warm-season perennial grass, seedlings may be planted during the warmer months of April through September.

Healthy seedlings that are between 15 and 24 inches in height can be obtained from local nurseries *(Photo 8)*.

Seedlings should be placed at least 8 inches deep in moist sand. Don't worry about planting the seedlings too deep. Planting too shallow often results in poor survival.

The best time to plant sea oats is after a rain when the sand is moist.

When planted in the spring and early summer months, seedlings will grow vigorously if properly fertilized and, if necessary, watered at planting.

Including one level teaspoon of a time-release (18-6-12 Osmocote or similar type) fertilizer in the planting hole will boost growth and expansion of the new plant (Use only time-release fertilizers in the planting hole because ordinary soluble fertilizers may damage the seedlings' root).

Photo 8: Sea oat seedlings should be placed deep in moist sand.

AMERICAN BEACHGRASS *(Ammophila breviligulata)*

American beachgrass *(Photo 9)* is a cool-season perennial grass native to the north and mid-Atlantic coasts along the eastern seaboard. Cape Hatteras is

Photo 9: A dune is covered with American beachgrass.

considered to be the approximate southern limit of its native range. Although American beachgrass is best adapted to the northern region of the mid-Atlantic coast, it has been planted extensively throughout the coastal areas of North and South Carolina to stabilize dunes.

Several factors contribute to making American beachgrass an effective plant for dune building and stabilization. It establishes quickly and spreads rapidly by underground rhizomes, effectively trapping sand during its first season of growth. American beachgrass sprigs also are less expensive than most other dune stabilization plants because they can be field grown by commercial nurseries, making it a favorite for large-scale plantings such as beach nourishment projects. Because it is the only cool-season perennial grass used in North Carolina for coastal sand dune stabilization, American beachgrass has a different planting season than other dune stabilization plants. The beachgrass can be planted from November through March, offering a winter planting window unique to this species among dune stabilization plants used here.

When planted south of its native range, American beachgrass can experience serious problems. Southern plantings are negatively impacted by hot and dry conditions. Frequently, the plants do not thrive behind frontal dunes, often dying out when the available supply of blowing sand is intercepted by more seaward plants and dunes. Also, seed heads — which are normally produced by American beachgrass plants growing farther north — rarely develop when planted to the south of its native range.

In addition, American beachgrass can become infected with a disease known as Marasimus blight, and attacked by the soft-scale insect pest, Ericoccus carolinae. Despite these disadvantages, extensive plantings of American beachgrass have been used to stabilize new dunes along the coasts in North and South Carolina, where conditions are better suited to other dune species.

In warmer climates, avoid using a pure stand of American beachgrass. Including sea oats within the beachgrass allows the sea oats to become the primary vegetation if the beachgrass begins to have problems. You also can randomly mix bitter panicum and seashore elder with the beachgrass.

Planting Tips

To avoid planting American beachgrass too shallow, the seedlings should be placed 8 to 10 inches deep in moist sand.

Apply fertilizer in March or April of the first year following winter planting. Broadcasting 30-10-0 fertilizer over planted areas at the rate of 4 pounds per 1,000 square feet will help the plants establish quickly.

Do not fertilize in the peak hot season when the plant is heat stressed. Also overfertilizing can make the plants more susceptible to die-offs.

BITTER PANICUM *(Panicum amarum)*

A warm-season, perennial grass, bitter panicum *(Photo 10)* occurs naturally from New England to Mexico. Its stout stem and wide, blue-green leaves add unique color and texture to the dune environment. Bitter panicum, sometimes referred to as "running beachgrass," also is a very effective sand trapper and stabilizer, spreading by underground rhizomes or "runners." The dune plant works well in combination with other dune species and should be included in dune revegetation projects.

Photo 10: This is a well-established stand of bitter panicum.

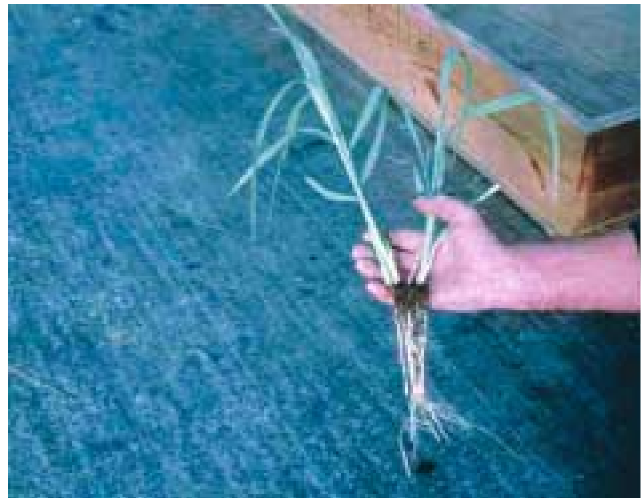


Photo 11: A rooted cutting of bitter panicum is ready to plant.

Planting Tips

Bitter panicum is commercially available and may be purchased as stems and rhizomes or rooted cuttings.

When using rhizomes or "runners," plant them in a trench 6 to 8 inches deep, leaving about one third of the upper end of the shoot out of the sand. Rhizomes planted in the early spring have a better chance of survival than those planted during the heat of the summer.

For rooted cuttings of bitter panicum, plant from April through September. Like sea oats, rooted cuttings respond well to one level teaspoon of a time-release (18-6-12 Osmocote or similar type) fertilizer added to the bottom of the planting hole. Also, plant the rooted cuttings 8 inches deep in moist sand *(Photo 11)*.

SALTMEADOW CORDGRASS *(Spartina patens)*

A slender-stemmed grass, saltmeadow cordgrass *(Photo 12)* is less of a pioneer zone dune plant than the other species listed in the booklet. However, the grass is highly adapted to back dune areas that have less wind-blown sand. It also prefers moist sites but will grow in drier areas.

Saltmeadow cordgrass has the widest native range of the pioneer zone species in North Carolina, occurring naturally from Nova Scotia to Texas. The grass also has a very high salt tolerance, and the seeds will germinate in saline soils, where the seeds of other dune species will not survive. Saltmeadow cordgrass often colonizes in areas that have been washed over by storm events, leaving large areas of sandy washover flats that are low in elevation.

Photo 12: Saltmeadow cordgrass colonizes on a washed-over dune area.

It begins the dune-building process as the new plants trap blowing sand. Saltmeadow cordgrass may be planted in low areas subject to washover and flooding by salt water where other species may not survive.

Planting Tips

Seedlings of saltmeadow cordgrass may be obtained from wetland plant nurseries.

Because saltmeadow cordgrass is a warm-season perennial, plant it in the spring and summer. The cordgrass should be planted landward of the dunes and placed 8 inches deep in moist sand.

To get the plants off to a healthy start, use one level teaspoon of time-released (18-6-12 Osmocote or similar type) fertilizer incorporated when planting.

SEASHORE ELDER *(Iva imbricata)*

Seashore elder *(Photo 13)* is the only nongrass species recommended for trapping sand and stabilizing dunes in the pioneer zone along the North Carolina coast. This warm-season perennial has succulent leaves and woody stems. It is a very effective sand trapper. Seedlings often germinate in the wrack line where they begin the dune-building process. The shrubby habit of seashore elder builds round hummock-like dunes as it traps large amounts of blowing sand.

While seedlings are a common occurrence along the frontal dunes, commercially available transplants are often grown by rooting cuttings, as the seeds can be difficult to germinate under nursery conditions.

Planting Tips

Rooted cuttings may be transplanted to the dunes during the spring and summer months and grow well when planted 8 inches deep in moist sand.

When transplanting cuttings, use one level teaspoon of time-released (18-6-12 Osmocote or similar type) fertilizer.

Fertilizing Tips

As discussed earlier, warm-season seedlings should be fertilized when planted, using one level teaspoon of a time-released (18-6-12 Osmocote or similar type) fertilizer that will not burn plant roots when placed in the hole. This fertilization regime is important for stimulating growth and establishment of sea oats, bitter panicum, seashore elder and saltmeadow cordgrass.

The warm-season plants may benefit from maintenance fertilization in the years following establishment. Because dune sand does not hold nutrients very well, nitrogen may easily leach through the sand and pollute the ground water. Therefore, purchase and apply fertilizer that contains nitrogen in a slow-release form. This will protect groundwater supplies and ensure that the plants maximize the uptake of the nutrients applied.

If an established dune plant shows the need for fertilizer, apply 4 pounds of 30-10-0 or 7 pounds of 16-4-8 fertilizer per 1,000 square feet between April 15 and July 15. When healthy, vigorously growing sea oats, bitter panicum and other plants are established on the dunes, fertilizing on a regular schedule is not necessary.

When fertilizer is not supplied in the hole at planting — normally the case when planting American beachgrass in the winter months — nutrients should be

Photo 13: Seashore elder forms round, hummocky dunes.

added by broadcasting the correct amount of fertilizer at the proper time of year.

The first year following planting of American beachgrass, apply 4 pounds of 30-10-0 or 7 pounds of 16-4-8 per 1,000 square feet in March or April and again in September. The second year after planting, apply 4 pounds of 30-10-0 or 7 pounds of 16-4-8 per 1,000 square feet in March and again in September. It may not be necessary to fertilize stands of American beachgrass that are more than 2 years old, but if needed, apply 4 pounds of 30-10-0 or 7 pounds of 16-4-8 per 1,000 square feet in March. Again, using fertilizers containing slow-release nitrogen will stimulate plant growth and protect groundwater supplies.

Fertilizer and Irrigation

Dune plants are highly adapted to tolerate the harsh conditions in oceanfront dunes, where they easily outcompete other plants. To get new plants started or selectively stimulate areas where you need to trap sand, use limited fertilizer, applied at the right time of year for each species. A small amount of fertilizer at the right time can increase both growth and spreading rate.

Fertilizer increases the number of stems for each plant, improving the sand-trapping capacity and increasing the number of rhizomes. It also accelerates the spread rate of new plants. Since pioneer zone species are adapted to low-nutrient conditions found in dune sand, excessive fertilization may damage dune plant communities and increase the risk of plant diseases. Therefore, frequent fertilization is not required after seedlings have been established.

Excessive irrigation allows other species to compete with dune vegetation by rinsing the salt spray off the leaves and out of the soil. Therefore, regular irrigation or fixed irrigation systems are not recommended.

Dune Plant Communities

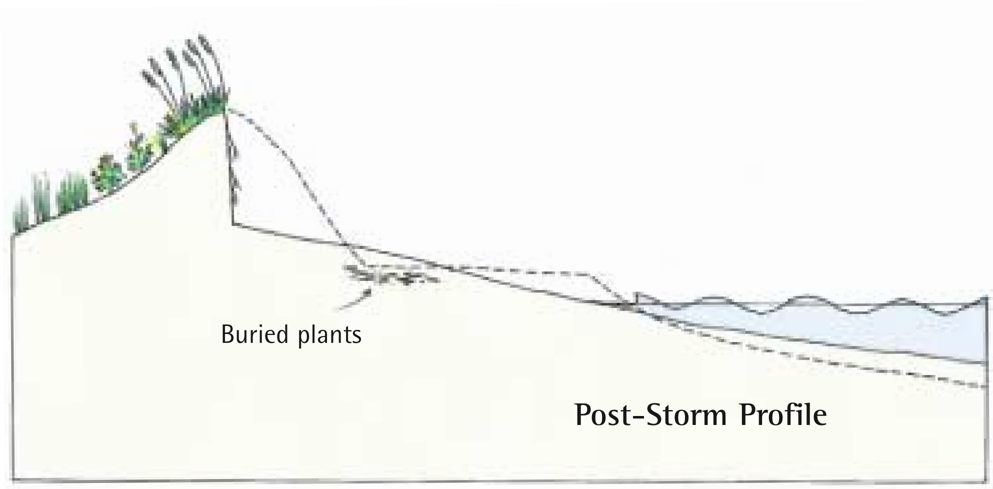
Native grasses and broadleaf plants stabilize pristine dune ecosystems, such as those found on the Cape Lookout National Seashore. Unfortunately, the dunes and plants in developed areas along the North Carolina coast are often destroyed by human impacts.

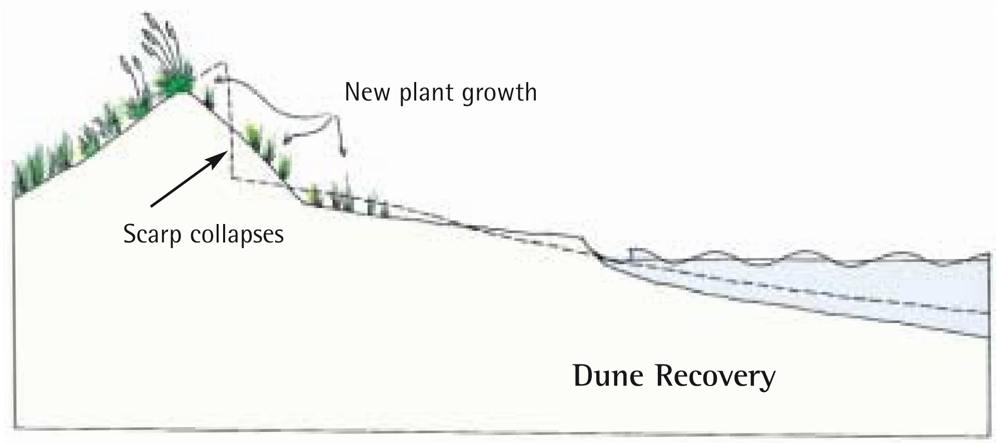
Planting three or more of the pioneer zone species in a dune revegetation project will increase the long-term stabilization of the blowing sand and help the ecosystem recover more quickly. Once the foundation of the pioneer zone species is established, other annual and perennial plants adapted to the dune environment will establish naturally. As the dune system stabilizes and provides food and shelter, birds, animals and reptiles will return to the recreated habitat.

Other Planting Suggestions:

When planted properly at the correct time of the year, the pioneer zone species discussed here will establish themselves and trap and stabilize sand on coastal dunes. The biggest problem associated with plant failure is improper planting. Therefore, remember these steps:

- Obtain healthy seedlings that have not been allowed to dry out.
- Plant at the correct season of the year. American beachgrass establishes best when transplanted early in its planting window — November, December and January. Likewise sea oats, bitter panicum, saltmeadow cordgrass and seashore elder will establish best when planted early in their planting windows — spring and early summer.
- Plant at the correct depth! Failure to plant deep enough is the main cause of plant death.
- Plant in moist sand, following a good rain. If the sand is dry when planting, irrigate the seedlings and surrounding sand as they are placed in the planting hole.
- In extremely hot and dry conditions following planting, apply irrigation water once a week to thoroughly moisten the sand to the planting depth. Once seedlings are established, additional irrigation is not necessary.
- Backfill the planting hole completely. Leaving an air pocket under the plant roots will result in death of the plant.
- Fertilize as recommended. When adding fertilizer at planting, use only time-released (Osmocote or similar type) fertilizer that will not burn plant roots.
- Do not overfertilize. The plants are adapted to low-nutrient, sandy soils.
- Keep foot and vehicular traffic off of the transplanted area. Dune plants cannot tolerate traffic from beach visitors or vehicles.





Figures I and J: Surviving plants slide down the face of the eroded dune as the scarp dries, and collapses where the plants take root.

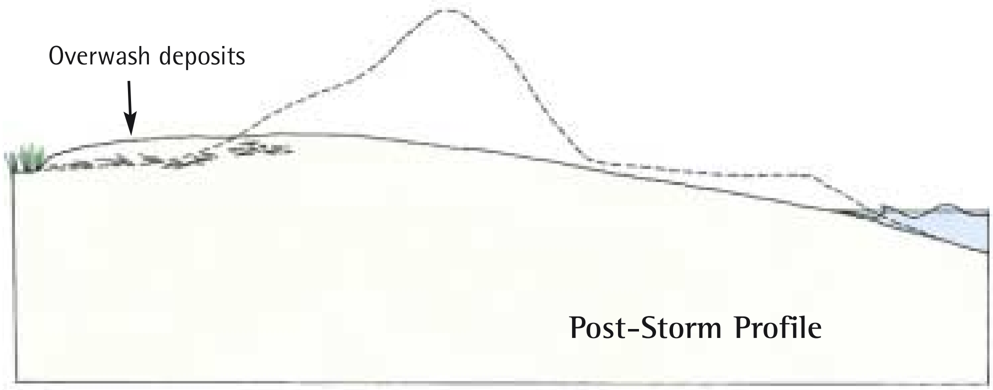
Science Versus Myth:
Do Dune Plants Stop Erosion?

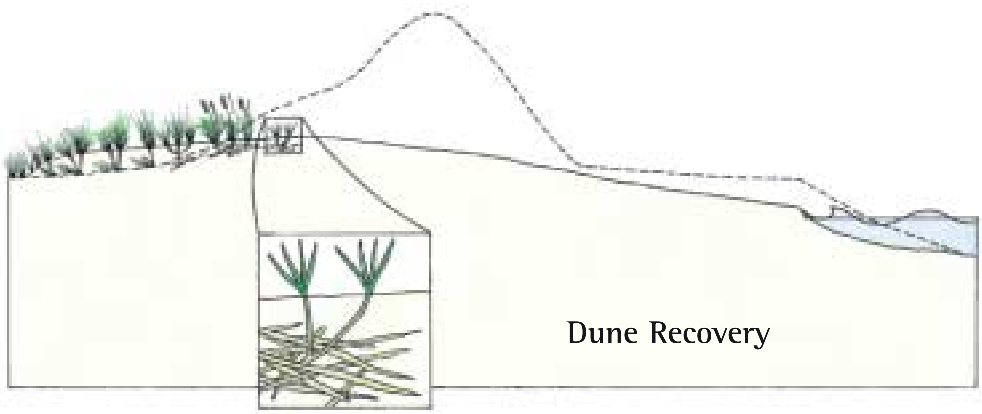
Another favorite dune myth is that the deep vertical roots of the dune plants provide protection from erosion, somehow reinforcing the strength of the dune and improving the storm protection. However, this isn't true.

In other uses of vegetation for erosion control, the plants' root systems significantly reinforce the soil. Examples include turf grasses used to control erosion caused by surface water run off and marsh grasses that develop dense root mats, which can prevent erosion on estuarine shorelines. However, the roots of dune plants are widely spaced throughout the dune. As erosion progresses, wave-induced losses create a near vertical erosion scarp or bluff in *Photo 2, page 5*, exposing the roots. The moisture in the soil — and not the roots — support the scarp. As the exposed sand dries, the eroded scarp begins to collapse, eventually becoming a flatter, more stable slope. Although the dune plant roots do not provide soil reinforcement, they are critical to the survival of dune plants in harsh conditions near the beach.

Natural Dune Recovery

Dune recovery following a storm usually evolves in several ways, depending on the remaining topography and severity of the storm. During typical seasonal fluctuations in the berm width, the seaward edge of the vegetation sends rhizomes a few feet into the back edge of the berm during the growing season, only to get pruned during the season's worst erosion.





Figures K and L: After storm conditions flatten the dune and overwash deposits bury vegetation, some plants grow through overwash deposits and begin dune recovery.

In severe storms — where the dune is not overtopped but a significant volume of sand is removed from the dune — vegetation recovery is usually initiated at one of the three points where remaining vegetation may survive as shown in *Figures I and J*.

The most severe storms may leave remnants of surviving vegetation near the old vegetation line, initiating the most seaward pioneer plants in the next growing season. The near vertical erosion scarp created by the erosion is highly unstable. In the days to weeks following the storm, the moist sand in the scarp dries, and the scarp gradually collapses, becoming a flatter, more stable slope.

As the scarp collapses, vegetation from the top of the dune is carried with it. Some of the vegetation survives the slide to the toe of the dune, initiating the recovery over the new slope. Remaining vegetation at the top starts the recovery from above. Therefore, on high dunes, vegetation recovery following storms can begin at three locations: surviving plants on the dune top; plants sliding seaward with the collapsing scarp colonizing the toe of the dune; and sometimes, the old vegetation line, if the erosion isn't too deep.

On shorelines where the dunes are low and overtopped by the waves, a storm can flatten everything as shown in *Figures K and L*. The old vegetation line and the dune are eroded, and the vegetation is lost. The waves push overwash sand further inland, behind the original dune. Farther back, the overwash deposits stop, and the original grasses remain exposed.

Dune vegetation has the ability to survive varying depths of burial by overwash. Although the plants seem to disappear following a storm, they can pop up out of nowhere at the beginning of the next growing season and initiate the dune recovery. Buried too deep, the vegetation will not survive, and recovery must start farther landward.

Dune plants colonize bare sand primarily by spreading rhizomes or runners from a parent plant. Storms can leave debris deposits or wrack lines that contain a few viable seeds or plant remnants and help jump start the dune recovery. Post-storm recovery and cleanup operations on the beach can have an impact on the natural dune recovery processes addressed in a later section.

Once the vegetation has been initiated, the dune-building process can commence. Dune building needs a sand supply, fast winds and a wind barrier to trap the sand. As the recovering dune evolves, these processes are altered.

The post-storm berm is the primary source of dune-building material. Onshore winds blow the dry sand landward, where it is trapped by the emerging vegetation. The densest clumps of vegetation trap the most sand and are stimulated to grow denser and spread even faster.

As the dune grows in height and vegetation density, the area farther landward begins to be affected. By trapping most of the sand in the first dense vegetation, the sand supply to more inland areas is reduced. As the seaward dune height increases, dunes farther landward lose their sand supply and become more sheltered from the wind speeds necessary to deliver the sand.

Over time, most dune growth — in both width and height — occurs in the seaward direction as shown in *Figure M*. Notice that during each season, the seaward edge of the dune grows farther seaward, followed by the rising dune crest. In contrast, the landward side of the dune captures very little sand.

Dunes grow from landward to seaward. However, at some point the seaward growth is halted when the vegetation line reaches the landward limit of seasonal berm fluctuations. As the slope of the dune face steepens, future increases in dune height slow considerably. Understanding the way that dunes grow in width and height — and their effect on the growth of more landward dunes — is critical in applying the dune and vegetation management strategies featured in the next chapter.

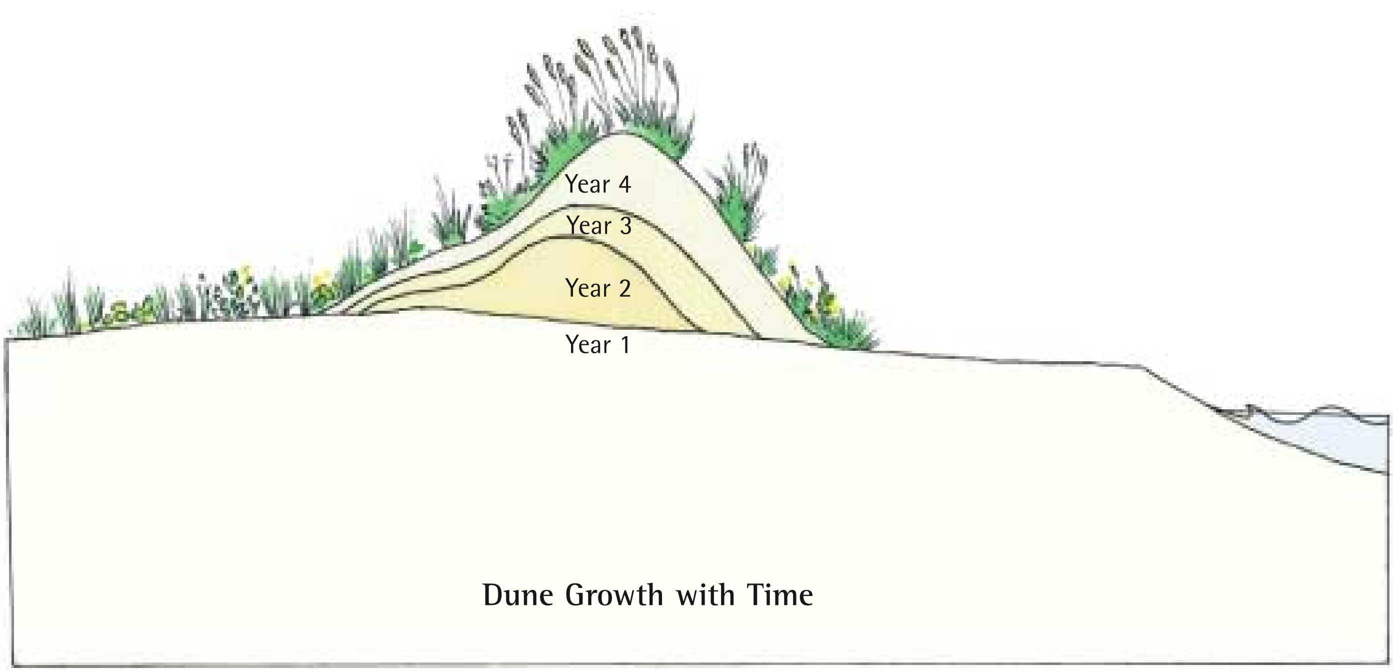


Figure M: Dune width and height increase each season in a seaward direction toward the source of blowing sand. Vegetation and dune height prevent sand from reaching the rear of dune.

Chapter 5:
Dune Management Practices

When starting a dune project, the first question to ask is: "What type of erosion is occurring on the shoreline?" Use the simplified definitions of erosion in Chapter 3. On most shorelines, several types of erosion may be present. But recent beach conditions are usually dominated by a single type of erosion.

Areas subject to seasonal fluctuations are unlikely to be good places for new dunes. In areas experiencing long-term or inlet erosion, storm-protection enhancements should include plans for the berm and vegetation line to retreat with time. Dune-building efforts should concentrate on areas well landward of the present vegetation line. If you start too close to the water, you may lose your storm protection to chronic erosion before the big storm hits. However, if you have recently had a direct hit by a major hurricane and lost 50 to 100 feet of dune, you are likely to have a wide, recovering area on which to work. Because storms come in all sizes and severities, there are always uncertainties about the severity of last season's erosion and how much recovery is likely.

Faced with recent dune erosion, most people have a strong desire to return the dune to its previous location. However, that can be a mistake. The two most common errors when building dunes are: trying to stop long-term erosion and starting the dune too far seaward. If you avoid these mistakes, you will end up with a better dune. It is best to build a dune as far landward as possible.

Here are some general rules of thumb that will help ensure the best possible storm protection from your dunes:

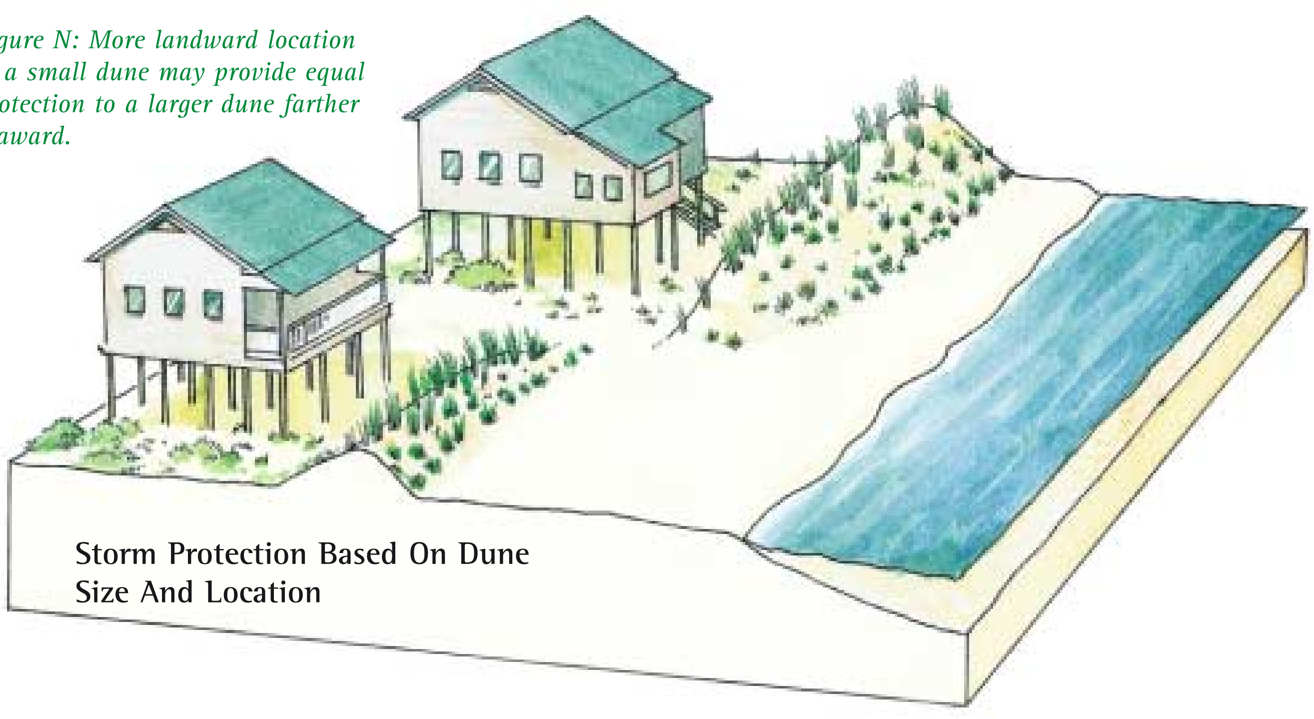
- Because more landward dunes are less likely to lose sand to long-term erosion, plan the dune for future shoreline conditions.
- Because storm protection increases with the volume of sand, start the dune farther landward, allowing it to grow taller and wider over time.
- Landward dunes always provide better storm protection than the same size dune placed farther seaward (*Figure N)*.
- To maximize the size of the dune, start your dune building as close to what you want to protect as possible.
- Because overwash deposits during a storm can jump start the dune-building effort in low areas landward of the original dune, if feasible, leave the deposits in place and start the dune on the top of the new sand.

Plant Spacing Guidelines

The density of the planting will directly affect the amount and location of blowing sand trapped by the plants. Using a closer spacing of plants will require more plants but will trap and stabilize more blowing sand. Here are some plant-spacing guidelines described in *Figure O*.

Usually start planting on the unvegetated dune face if the scarp has collapsed, at the toe of the dune scarp if one exists, or on flat, overwashed areas as far landward as possible.

Figure N: More landward location of a small dune may provide equal protection to a larger dune farther seaward.



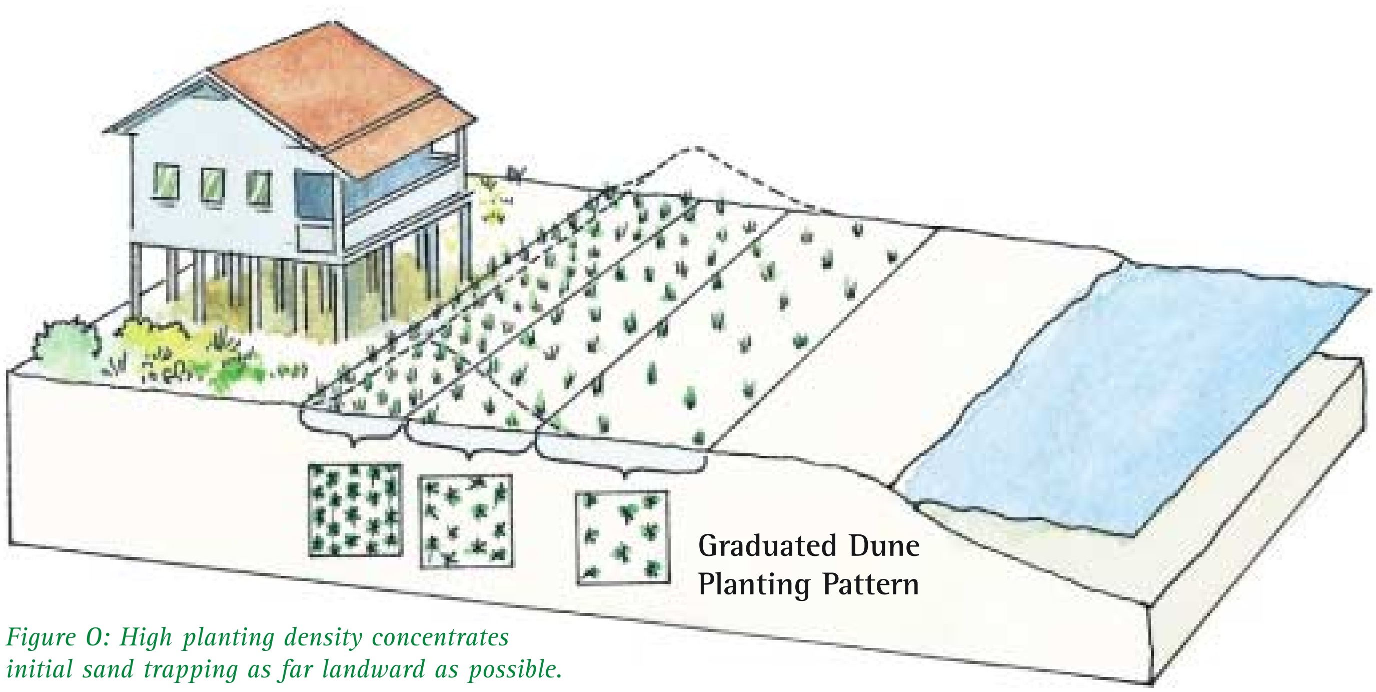


Figure O: High planting density concentrates initial sand trapping as far landward as possible.

- Space the first few rows of plants in a 12-by-12-inch grid and arrange the plants in a staggered pattern from row to row.
- After planting several rows with this spacing, increase the plant spacing and row width to 18 to 24 inches for three or four more rows and stagger the plants from row to row.
- Increase the plant spacing and row width to 36 inches for the last two or three rows closest to the ocean.
- Remember that all plants should be planted well landward of the high-tide line and seasonal beach fluctuations.

Because the available blowing sand supply comes from the dry sand beach between the high-tide line and the area to be planted, this graduated spacing pattern allows more sand to blow through the wider spaced rows and accumulate in the tighter spaced plants where the volume of sand provides the most protection.

If scattered dune plants are already on the site, the same effect can be achieved by selectively applying fertilizer to only the most landward plants. As described previously, fertilizer increases the stem density in each clump, making it a better sand trap, and also increases the number of root runners spreading from each plant. A few new plants may be needed to augment the existing plants.

Sand Fences

Sand fences can be useful in trapping sand but are better used for pedestrian and vehicular traffic control where vegetation alone is not adequate. Like the stems of the dune plants, sand fences slow the wind velocity near the surface until it can no longer move the sand. Sand accumulates around the base of the fence, similar in function to snow fences in colder climates. Fencing is available in various materials and densities. Experiments have found that the typical wire-bound, wood-slat fencing that has a width roughly equal to the spacing between slats (50 percent porosity) will trap about as much sand as other materials.

The fences are usually supported by 3-inch poles or 2x4 posts. The materials have a limited lifetime when installed near the beach. The wood rots, and the wire corrodes. If fence and plants are installed at the same time — by the time the fencing begins to fall apart — the vegetation should be covering the area.

If you travel the coast and talk to people who install sand fences, it seems everyone has a theory on the best way to place the fence: parallel to the shoreline, perpendicular to the shoreline, perpendicular to the wind, zigzagging, Ws, Xs, Zs, or another personal alphabetical choice.

Although there are some subtle differences in sand-trapping ability, the most important factor is the total length of the fence. Studies have shown where wind-blown sand is abundant, installing twice as much fence traps about twice as much sand, regardless of the alignment.

Like dune plants and dunes in general, sand fences function with the wind and are subject to the whims of the waves. Placed too far seaward and subject to season beach fluctuations or long-term erosion, the fences and any accumulated sand will be quickly washed away. Unlike the vegetation, destroyed sand fences leave debris on the beach that can be a nuisance to clean up, making it more important to install them far enough landward.

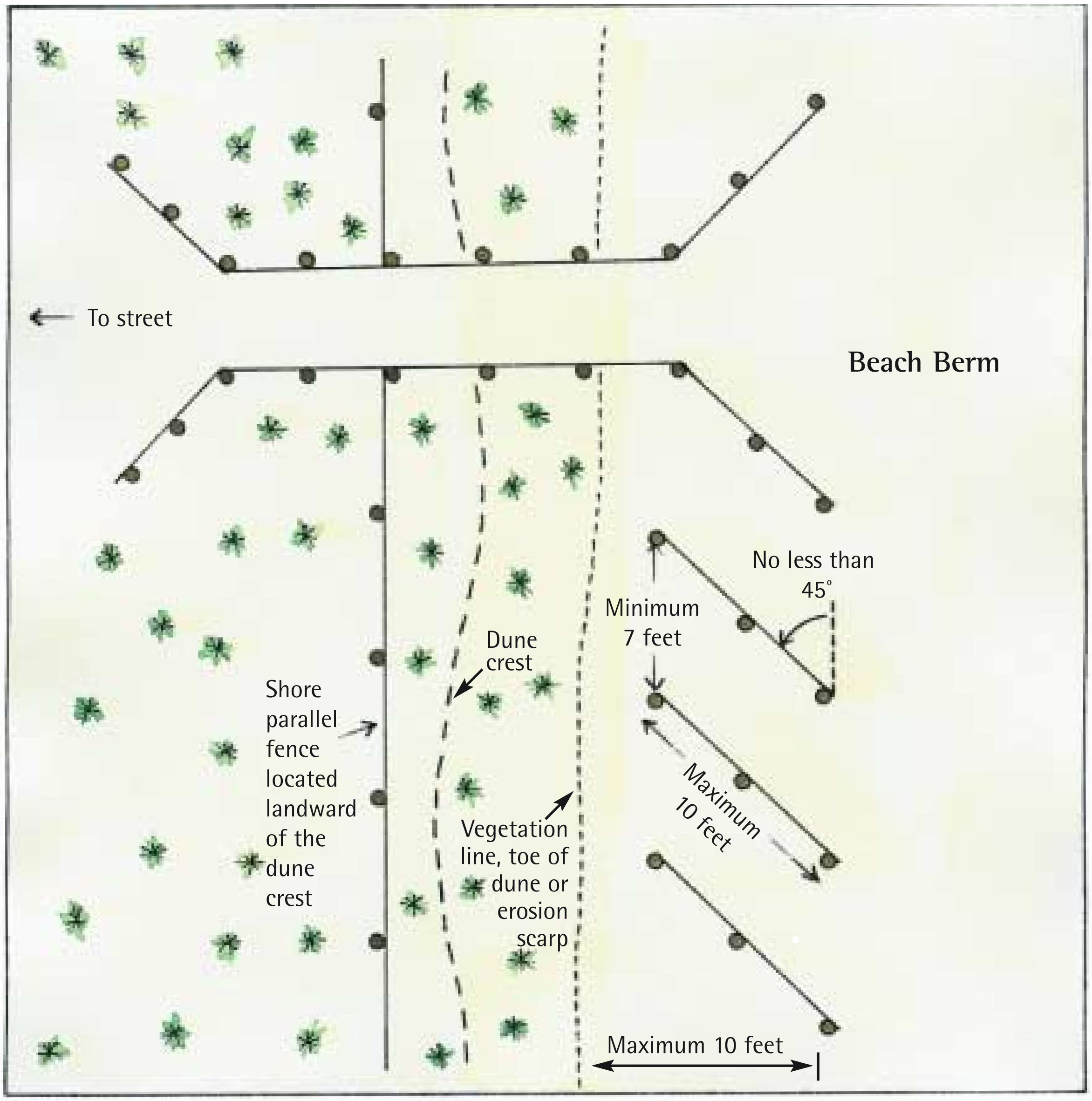


Figure P: Examples of sand fence installations are shown that may be allowed under state and federal regulations. The shore parallel fence is located landward of the dune crest.

In recent years, concerns have increased over the fact that some sand fence alignments may affect the nesting of sea turtles. After several recent hurricanes, a few property owners got a little carried away with the number of fences and where they placed them on the beach. As a result, the N.C. Division of Coastal Management (DCM) may require a permit for sand fences.

A permit exemption can be obtained for certain installations similar to those shown in *Figure P*. To avoid affecting turtle nesting on the seaward face of the dune, continuous fences parallel to the shoreline must be located landward of the crest of the dune. To trap sand or funnel beach access traffic, fences may be installed farther seaward as shown in the figure. Other designs and purposes may be allowed if you get the proper permit.

Before installing a sand fence, check with the permit department in your town hall or a DCM field office. If you follow the rules, getting permission to install sand fences is usually easy.

Although it is easy to get permits for sand fences, sand fencing is often overused and frequently installed in the wrong places. Most dune-building projects should invest in planting more vegetation rather than fences. As the stem density of the plants increases, and their runners spread out, the vegetation becomes better sand traps than fences. Plants need little maintenance compared to fences. Also, there is no debris to clean up if the plants are washed out.

Photo 14; An unimproved walkway with sand fences can funnel pedestrians.

Advantages of Fencing

There are a few exceptions where sand fencing is useful, particularly when managing pedestrian traffic. A few people randomly walking through dunes do not significantly harm dunes or vegetation. However, dune vegetation is not tolerant of repeated trampling. Once the vegetation is lost, wind and repeated use will often lower the dune elevation or prevent the path from keeping up with the growth of the adjacent dunes. If the pathways get to be more than 3 feet lower than the adjacent dunes, it is time to consider additional dune protection.

Sand fences can be useful in limiting traffic to narrower paths and encouraging the use of elevated dune walkways *(Photo 14)*. The fences are useful funnels to direct beachgoers to the desired accessways. On a few beaches, public use is so heavy that the vegetation line gets trampled along the entire shoreline as well as near the accessways. To protect vegetation from crowds, building a continuous, shore-parallel sand fence just seaward of the vegetation may be the only effective way to prevent trampling. As noted earlier, a permit will be required.

It is seldom desirable for dune building to install a fence along the vegetation line. By trapping sand too far seaward, the fence will retard the growth of a more stable dune farther landward. Fortunately, few North Carolina beaches are crowded enough to need a fence seaward of the vegetation line.

Rope Fencing

In high-use areas, rope fencing is an alternative to using sand fences. A single rope is strung between widely spaced posts. The rope is placed high enough to easily duck underneath and is not a barrier to sea turtles. Rope fencing has been surprisingly effective in managing the bare sand on shorebird nesting sites near the beach. This type of fencing also reminds people to protect the area. The rope fences are less expensive to install and last longer than sand fences. They also do not restrict wind-blown sand from reaching the vegetation farther landward. *(Photo 15)*.

If trampling is occurring from an overcrowded beach, try the rope fences first. In some cases, the posts leftover from deteriorated sand fences can be used to string an equally effective rope fence. In the most crowded areas, a full fence may be required to protect the dune elevation and vegetation.

Christmas Trees

Once a year, around the New Year, an abundant supply of sand traps becomes available — discarded Christmas trees. After the decorations are removed, the trees can be placed on their sides and secured by kicking sand over the lower branches or staking. The dense needles are effective at trapping sand. Needles fall off in the first year, with the branches decaying during the following year or two. Like sand fences, Christmas trees are temporary sand traps that must be used with existing or planted vegetation when building a dune. Trees can also be useful in patching pedestrian and vehicular pathways, where they both trap sand and act as a visual barrier, discouraging further traffic.

Several public programs that recycle Christmas trees

Photo 15: Rope fences are less expensive to install than sand fences.

Photo 16: Avoid direct beach pathways that are more than 3 feet lower than adjacent dunes.

have been extremely popular. People of all ages have been willing to drive trees several miles to a site and then drag their trees hundreds of yards to the dunes and place it themselves, with only minimal supervision. This can be a fun activity, even on a winter day.

Protecting Beach Accessways

In most communities, the level of public beach use requires some management strategy to avoid damaging the dunes where people come and go to the beach. Most oceanfront high-rise or commercial buildings and many individual houses may need plans for beach access. Direct pathways to the beach that are more than 3 feet lower than the adjacent dune should be avoided *(Photo 16)*.

The amount of protection needed for a beach access varies with the level of use and local dune conditions. Walkway improvements are considered expendable, and their only purpose is to protect the dune and vegetation that are both constantly changing. To protect the vegetation and dunes, keep the improvements to a minimum.

When building walkways with heavy pedestrian use, there are several options, including ground cover such as mulch, gravel, marl or paving stones, on-grade wooden walkways, and elevated wooden walkways, with or without handrails. Elevated walkways are the most common but not always necessary *(Photo 17)*. Let local conditions be your guide. In areas with very wide, irregular dunes, it may be possible to choose a winding path to the beach. It is best to avoid pathways perpendicular to the beach because they can become a direct path later for storm-induced erosion.

Photo 17: This is a good example of an elevated walkway with handrails.

In higher-use areas, use rope or sand fences to guide pedestrians along the chosen path. Along shorelines with high inland ground elevations and/or high berm elevations, a direct, unstabilized pathway may be acceptable. In many back dune areas that have little sand deposition, the landward end of the accessway can be stabilized with mulch, gravel, marl or paving stones.

For moderately stable areas behind the dune crest, on-grade wooden walkways that don't have posts or handrails have been successfully used. If the walkways become partially buried by wind-blown sand, they can be lifted in sections and replaced on the higher grade. When dune elevations vary more than 3 feet or are actively growing in elevation with time, an elevated wooden walkway on posts will probably be necessary. For walkways close to the ground, handrails may not be necessary. However, for walkways above certain heights, the building code may require handrails for safety. The Americans with Disabilities Act sets standards for handicapped access ramps. So check on the rules before starting construction *(Photo 17)*.

There are many ways to design elevated walkways. Most communities seem to have local preferences. The structure should be kept lightweight to minimize potential storm debris. 4-inch posts buried between 4 and 5 feet below grade are usually adequate. Some municipal or commercial walkways may require larger piling foundations and /or deeper embedments.

If dune growth is expected, elevate at least 3 feet above the dune, allowing for future elevation increases. It is common for some dunes to eventually grow above the walkway elevation. In some cases, the dune may begin to bury the walkway. It does not hurt to bury the walkway if its access purposes are still met. However, if the dune elevations rise more than 3 feet above the accessway, consider rebuilding the walkway higher.

When planning a walkway, the trickiest decisions are locating the steps or access ramp relative to the vegetation line and the elevation of the step or ramp in relation to the beach profile. Below are some tips to follow:

- Because either seasonal fluctuations, storm-induced erosion or long-term erosion can easily reach the seaward end of a walkway, drop the walkway to the

Photo 18: This is an on-grade walkway without railings.

Photo 19: The steps were intentionally buried at the time of construction.

berm elevation near or just seaward of the vegetation line.

- To keep the walkway and steps usable throughout the year, design the last few steps to be buried below the berm elevation or add a few steps after a winter storm *(Photo 19)*. Remember to expect some occasional wave damage to the seaward steps or end of the ramp.
- On shorelines with long-term erosion, be prepared to shorten the walkway back to the new vegetation line after moderate storms.

Local governments have different requirements for homeowners building dune walkways. Some communities require a walkway for every home. Other towns prohibit individual walkways, requiring homeowners and vacation renters to use nearby public walkways. To build a walkway, you usually need a permit from the local government, DCM and in some cases the U.S. Army Corps of Engineers. The permits are usually easy to obtain. Before starting construction, always check with the local building inspector for exact permit requirements.

Vehicular Ramps

Some beach towns allow recreational vehicles on the beach seasonally or year-round. Even where public beach driving is restricted, most communities need one or more access points for emergency or maintenance vehicles. Even moderate vehicle use will kill the dune vegetation, and lower the dune elevation quickly. Where dune width is adequate, angle the trail to the beach so that the dunes overlap, avoiding a low path perpendicular to the shoreline. When a vehicle access must be perpendicular to the shoreline, consider installing a flexible wooden ramp on the dune surface, preventing the loss in elevation.

Plans are available for the ramps, known locally as "Hatteras" ramps because of their long-time use in the Cape Hatteras National Seashore. If repairing an already damaged vehicle access, consider raising the dune elevation with sand from an outside source before constructing the ramp. As for other accessways, a permit may be required.

Science Versus Myth:
Is Beach Scraping Useful for Building Dunes?

In North Carolina, beach scraping or beach bulldozing is a historically common practice used to build or repair dunes. The method excavates sand from the berm and beachface, pushing it landward to restore the eroded dune or to rebuild a dune that has completely washed away. Since mining sand from the beach has the potential to increase everyone else's long-term erosion, DCM requires a permit that restricts when the beach can be scraped, how much sand can be excavated and how far landward the sand can be moved.

The benefits of beach scraping are considered another dune myth. Regulations limit moving the sand to locations seaward of the vegetation line, minimizing the damage to adjacent beaches but ensuring that beach scraping has little or no benefit. Beach scraping only temporarily rearranges the shape of the beach.

As discussed earlier, the beach shape is controlled primarily by the waves, water levels and sand size, always moving toward some equilibrium shape. As soon as the beach is scraped, it starts moving back to its prior shape. The vegetation line identifies the landward limit of the seasonal beach fluctuation. Therefore, it can be expected that the deposited sand will be rearranged by small storms, redistributing it to prescraped conditions. Limited studies have confirmed that beach scraping is ineffective in providing erosion protection.

In most cases, it is not recommended to plant dunes constructed with beach-scraped sand. The practice is most often used on shorelines experiencing long-term erosion. When combined with seasonal fluctuations in the beach width, the material is extremely likely to be lost in less than a year, sometimes in only a few days. Planting dune grasses in the temporary fill will not improve its stability. The plants are very likely to be washed out, and the planting effort is wasted.

The only observable benefit of beach scraping is making property owners feel better. Although a temporary feature, the new pile of sand may seem visually comforting. The major harm caused by beach scraping is that it wastes funding and effort that could be better spent on other activities.

For anyone who feels compelled to consider beach scraping, there is an alternative. A better investment is purchasing beach quality sand from an inland source. With a permit, the truck-hauled sand can be placed landward of the vegetation line. The benefits of the added sand will be maximized if the sand is placed as close as possible to the protected areas. Unlike beach-scraped sand, planting is recommended at the more landward location.

Like all dunes, the small amount of new sand will not be effective if placed within areas of seasonal fluctuations or is subject to long-term erosion. However, the new sand will provide a measurable improvement in protection from storm-induced erosion for approximately the same investment as beach scraping.

The one situation where beach-scraped dunes should be planted is following infrequent but severe storms. In some cases, a beach-scraping permit may allow the sand to be placed landward of the seasonal fluctuations and initiate the rebuilding of the dune. Like planting dense vegetation too far seaward, pushing up a small dune may retard more landward dune growth and may not be the best management approach for storm protection.

A more serious issue is the effect of beach scraping on the surviving dune vegetation that usually initiates natural dune recovery. Note the points of normal recovery in *Figure J on page 17*. Where dunes remain with a vertical erosion scarp, beach scraping results in excavation of any plants that survive at the old vegetation line. By preventing the plants at the top of the scarp from collapsing to the toe, the seaward recovery of the vegetation is retarded.

When overtopped, as in *Figure L on page 18*, the vegetation line is difficult to identify, and scraped sand is placed on top of the surviving vegetation. The added sand is likely to bury the remaining vegetation so deep that it doesn't survive. If beach scraping occurs after an extreme storm, it appears to retard the natural recovery processes of the dune vegetation. Therefore, after temporary storm-induced erosion where scraped sand is piled in areas expected to be landward of the next year's seasonal fluctuations, it is important to plant at least a few rows of dune vegetation to replace what was killed by the beach scraping.

Permits

Permit requirements are mentioned several times throughout the booklet. Planting dune vegetation does not require a permit. However, a permit may be required for other dune construction projects, including sand fences, dune walkways, vehicular ramps, removing vegetation, lowering dune elevation, or moving any sand with heavy equipment.

For more information about permits, contact your town hall and/or the N.C. Division of Coastal Management at 919/733-2293, 888/4RCOAST; or *www.nccoastalmanagement.net.*

Chapter 6: *Summary*

In addition to their obvious aesthetic benefits, sand dunes and dune vegetation can provide substantial protection from storm-induced erosion. For that reason, protecting the existing dunes and building larger dunes with dune vegetation are useful shoreline management practices.

Remember that erosion has many causes — and dunes do not provide protection from seasonal fluctuations, long-term erosion or inlet erosion — no matter how large the dune. Determine what is causing your erosion before planting or dune building.

Wave forces dominate the beach. In contrast, wind shapes the dunes' features. Whatever the water wants, it takes. Plan your dunes and planting accordingly.

The larger the volume of sand in a dune when a storm hits, the more protection it provides. The location of a dune relative to the shoreline is another important factor affecting storm protection. For any size dune, you will always get better protection if you locate it farther landward. Future growth in dune height and width will be in the seaward direction from where you start building a dune. Therefore, to get the most protection, initiate your dune building as far landward as possible and as close to what you want to protect as feasible.

When building dunes, it is a good idea to buy and install healthy local dune plants adapted to your climate. Failure to plant deep enough is the main cause of new plant death on the dunes. Be certain to plant dune plants at the correct depth, the recommended times and under conditions appropriate for each species.

Sand fences are usually not needed for dune building. Dune plants are just as effective and need little or no maintenance. However, sand fences can be useful in managing pedestrian and vehicular damage. When pedestrian traffic is heavy, try rope fences as a lower-cost and lower-maintenance alternative.

Protect your dunes from pedestrian damage by choosing the appropriate accessway materials for local conditions. If the accessways are more than 3 feet lower than the adjacent dunes, look at modifying the present accessway. Consider the walkways expendable but necessary to protect the dunes. Plan for future maintenance when the inevitable erosion occurs.

If you feel the urge to spend money on beach scraping, consider buying and planting some truck-hauled sand, placed farther landward where it will do more good.

And don't forget to check if you need a permit.

Enjoy the beach. It is a wonderful place to work and play.

Related Reading

Shifting Shorelines: A Pictorial Atlas of North Carolina Inlets by William Cleary and Tara Marden, available from North Carolina Sea Grant (UNC-SG-99-04), $15.

Rip Currents brochure available from North Carolina Sea Grant (UNC-SG-00-01), up to 30 brochures are free; bulk orders are 20 cents each.

Rip Currents video, available from North Carolina Sea Grant (UNC-SG-98-03), $6.

Glossary

Accretion: deposition of sand on the beach or dune, the opposite of erosion.

Beachface: the steeper sloping section of the beach, where the waves run up and wash into the beach.

Berm: the flat, dry sand beach where you put your beach blanket.

Broadcast: uniform application of fertilizer at recommended rates over the soil surface and/or plants.

Dune: the vegetated area landward of the berm.

Overwash: Storm waves that wash over the island and deposit sand in low elevation areas in and behind the dunes.

Scarp: the near vertical bluff created when the dune or berm is eroded by the waves.

Vegetation line: the seaward limit of dune vegetation formed by the landward limit of the seasonal fluctuations in the berm.

Wrack line: natural debris deposits, including washed out dune plants, marsh debris and seaweed that is left by waves near the vegetation line following storms.

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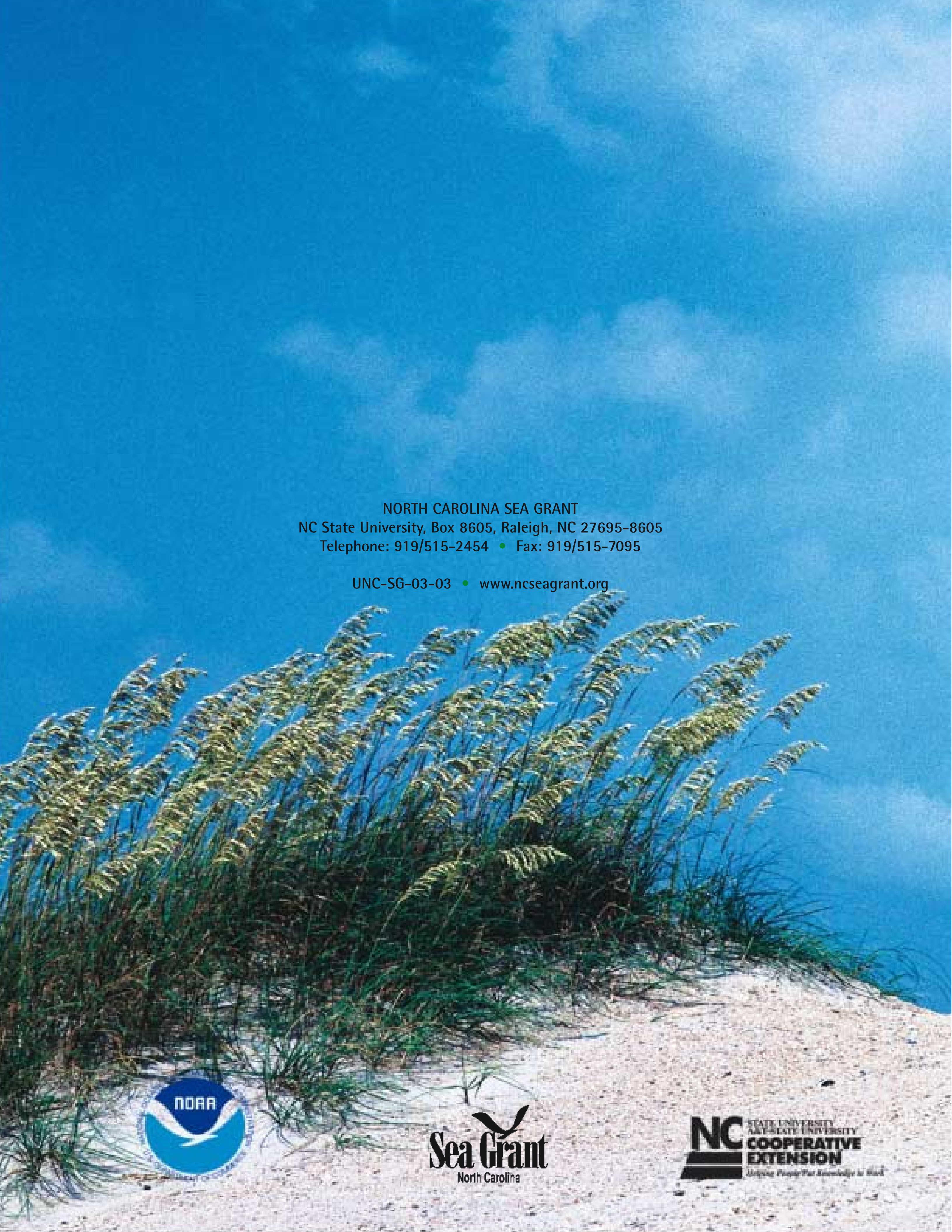
Front cover, back cover and photos on page 2 and 27 by Scott D. Taylor. Other photos by Spencer Rogers and David Nash.

Illustrations by David Williams
Design by Kathy McKee
Editing by Ann Green



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