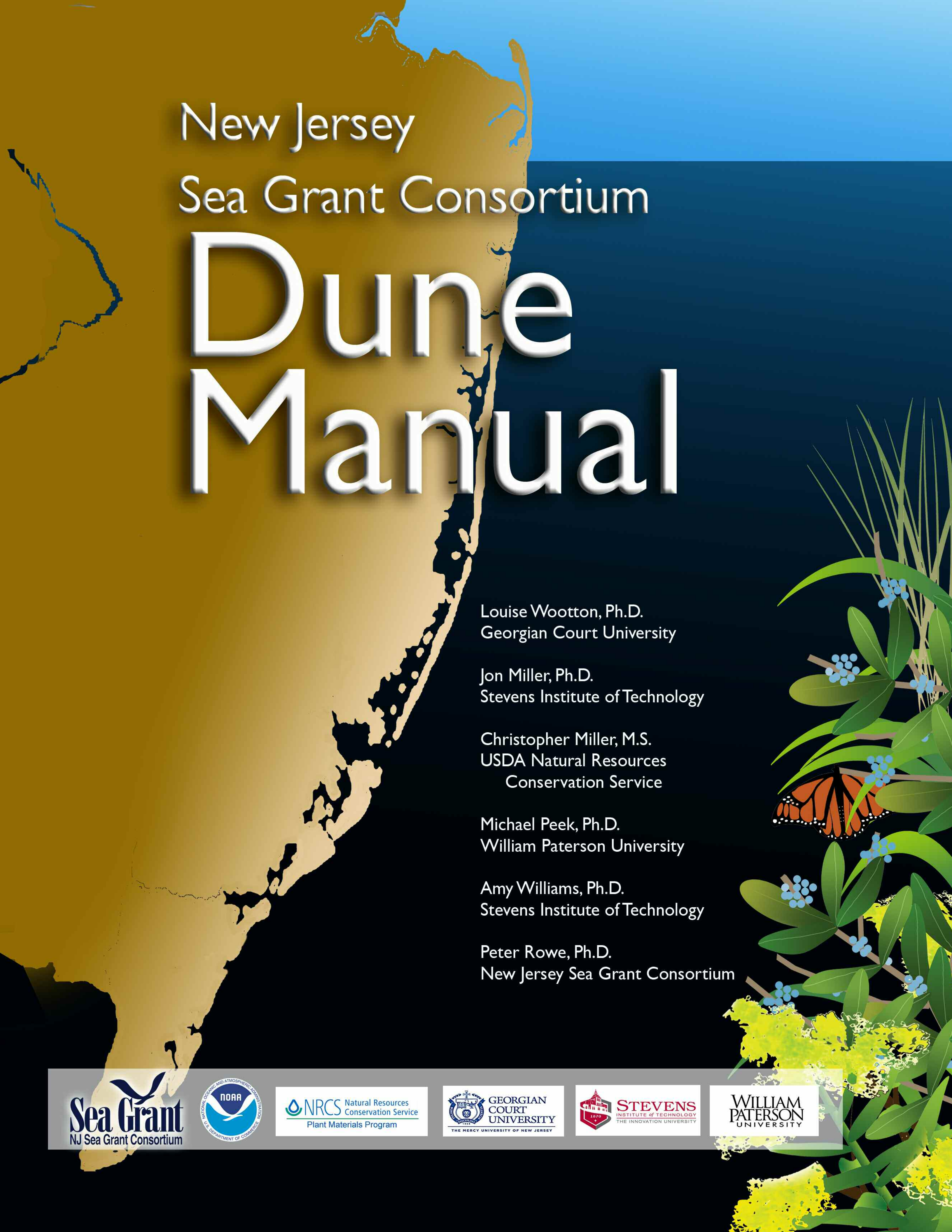

New Jersey Sea Grant Consortium

# Dune Manual


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Additional copies of this manual can be obtained by contacting the NJSGC at 732-872-1300 x 10 or laromando@njseagrant.org. The manual is also available digitally at njseagrant.org/dunemanual/

Published November 2016 by New Jersey Sea Grant Consortium, first edition.

# Introduction

New Jersey Sea Grant Consortium and its partners – Stevens Institute of Technology, U. S. Department of Agriculture - National Resources Conservation Service (USDA NRCS), Cape May Plant Materials Center, Georgian Court University, and William Paterson University – have developed this dune manual with the intended audience of New Jersey's coastal mayors, town planners, public works departments, OEM managers, environmental commissions, and other coastal stakeholders.

The purpose of the manual is to educate communities about dunes in the wake of natural disasters, sea level rise, and storm surge, by providing background information on the coastal ecosystems, their processes, and how they can mitigate the impacts of coastal storms. The information in the manual is intended to enable users to make informed decisions on coastal resilience by incorporating beach and dune dynamics with suitable plantings. The manual will first discuss basic information on the physical characteristics of dune establishment, growth, and erosion and highlight some of the important considerations related to dune management. It will then discuss the ecology of dune systems and introduce some of the management challenges of these unique ecosystems from a biological perspective. The next section will discuss the variety of plant species that are best suited for restoration plantings in New Jersey dune ecosystems, best practices in planting the species, and the science behind the plant species that are available. Lastly, the manual will discuss information about why a mix of species is important in dune stabilization and ecosystem function.

## Acknowledgements

New Jersey Sea Grant Consortium (NJSGC) wishes to thank the many persons and institutions that contributed to the preparation of this manual. Their shared technical knowledge, experience, and perspectives have produced a tool that will be of significant value to community leaders and other coastal stakeholders

Special thanks are extended to the authors who collaborated in the preparation of the manual: Dr. Louise Wootton (lead author), Dr. Jon Miller, Christopher Miller, Dr. Michael Peek, Dr. Amy Williams, and Dr. Peter Rowe. Sincere appreciation is extended to content editor Dr. Louise Wootton, copy editors Sandy Varone, Joe Varone, Rebecca Nagy and Claire Antonucci and graphic designer, Rory Joyce. In particular, the authors and editors of this document appreciate the reviews of the draft manual by Todd Pover (Conserve Wildlife Foundation of New Jersey), Wendy Walsh (United States Fish and Wildlife Service), Lynn M. Bocamazo (United States Army Corps of Engineers, New York District) and Jeff Gebert (United States Army Corps of Engineers, Philadelphia District). Their review and evaluation of the draft document significantly improved the quality of the manual. In closing, the authors and editors wish to thank the locations where workshops on the draft manual were hosted. Their hospitality and outreach activities were integral to the production and promotion of this document. Host sites were New Jersey Natural Gas, various branches of the Ocean and Cape May County Libraries, Stockton University, and the City of Cape May and Cape May Convention Hall.

This manual is the result of work sponsored by the New Jersey Sea Grant Consortium (NJSGC) with funds from the National Oceanic and Atmospheric Administration (NOAA) Office of Sea Grant, U.S. Department of Commerce, under NOAA grant number #NA10OAR4170075 and the NJSGC. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the NJSGC or the U.S. Department of Commerce. NJSG-16-903





Donna Swiatek photo

# Getting Started with Dunes

Sand dunes are important coastal features that provide a variety of ecosystem services, such as habitat for coastal species and protection for infrastructure and communities landward of them. Dunes can be found along beaches all over the world and range in size from small piles of sand to dunes in excess of 900 feet tall, such as those found on Moreton Island in Australia. In New Jersey, recent storms such as Sandy (2012), Joaquin (2015), and Jonas (2016), have helped to highlight the importance of a healthy beach and dune system to coastal resilience. The official dune definition adopted by the State of New Jersey in Title 7 of the New Jersey Administrative Code is as follows:

> ". . . wind or wave deposited or man-made formation of sand (mound or ridge), that lies generally parallel to, and landward of the beach and the foot of the most inland dune slope. "Dune" includes the foredune, secondary or tertiary dune ridges and mounds, and all landward dune ridges and mounds, as well as man-made dunes, where they exist."
> (N.J.A.C.7:7E Coastal Zone Management Rules)

Dune modification in New Jersey is regulated by the New Jersey Department of Environmental Protection (NJDEP). Individuals and communities are encouraged to contact the NJDEP prior to commencing projects intended to create or modify an existing dune. Care must also be exercised (in coordination with the Endangered and Non-Game Species Program (ENSP) and Fish and Wildlife Service representatives) to ensure that proposed activities do not degrade habitats for rare, threatened, or endangered species.

Natural coastal dunes are dynamic geologic features that are created as wind-blown sand is deposited primarily along the back beach (Figure 1). As the sand deposits grow, it is typical for vegetation to colonize the dune. Vegetation helps stabilize the dune and promotes dune growth by trapping additional windblown sand. Naturally established dunes are irregular and often contain multiple layers of ridges and valleys with a variety of sediment, vegetation, and wildlife. In contrast, man-made dunes are typically linear and often lack the complexity found in natural dune systems, which limits their habitat value. In some cases, poorly designed dunes can even degrade habitats for certain rare, threatened, and endangered species. Fortunately, it is possible with careful design, to engineer artificial dunes that can be compatible with the habitat needs of native species.

**Figure 1. Coastal sand dunes with established vegetation (landward of the fence) and newly accumulated areas of windblown sand (along the fence).**

# Basic Dune Physical Characteristics

## New Jersey's Beach and Dune Characteristics

Dunes in New Jersey are mainly confined to a narrow strip of land between the beach berm and upland development. While there are a few locations in which the sand supply and beach width are adequate for dunes to reach their full form (Island Beach State Park, for example) most dunes are limited in height and width by the sand available from the beach berm area and the infrastructure landward of the beach. As a result, on most New Jersey beaches only a single line of dunes exists.

The shape of the beach on any given day is the result of a complex set of interactions between the air, the land, and the sea. Some of the more important factors include the:

- wave heights and water levels experienced at site during the recent past
- present wave and water level conditions
- characteristics of the sand
- underlying geologic conditions at the site
- presence of any artificial structures.

Throughout much of New Jersey and the Mid-Atlantic, present-day dune heights reach 8 to 15 feet above the flat part of the beach known as the berm (Hamer et al. 1992; Psuty and Ofiara 2002). This height has been found to be related to the limit of the ability of the wind to move sand higher on the dune and deposit it on the back or lee side of the dune (Hamer et al. 1992). Dunes have the potential under ideal conditions to grow in height up to 4 feet per year, although growth rates of less than 2 feet per year are more typical.

In a typical beach configuration, known as a *beach profile* (Figure 2), the dune is located along the back part of the sandy beach. The line of dunes closest to the water is called the *foredune* or *primary dune*. These primary dunes are particularly susceptible to erosion, overwash, and breaching during extreme storms. Dunes located landward of the foredune are numbered consecutively and are referred to as the *secondary dune*, the *tertiary dune*, and so on. Along developed coasts, the natural dunes are sometimes enlarged with artificially placed sand or replaced altogether with a structure such as a seawall, bulkhead, or revetment.

Seaward of the dune is the *beach berm*, which is the flat, dry section of the beach that is normally used by recreational beach users and by several species of wildlife and plants. Some of these include rare, threatened, and endangered species. Beyond the berm is a sloped area known as the *foreshore* which leads into the water. This foreshore is exposed to constant wave action and generally shifts shape and slope between seasons and storm events in response to changes in wave action.

The beach profile continues under water. The area closest to the dry sand is called the *nearshore*. Like the foreshore, the nearshore is constantly affected by the energy of the breaking waves. The nearshore generally takes one of two shapes. During calm periods, the beach slopes off uniformly into deep water and generally takes on a characteristic shape known as an *equilibrium beach profile* (Dean 1977). During stormy periods, however, sand eroded from the dry beach collects in nearshore sand bars which form near the point at which the majority of the waves are breaking. The part of the beach between the breakpoint and the area that is constantly dry is sometimes referred to as the *surfzone*. The area beyond the breakers is generally referred to as the *offshore portion* of the beach profile.

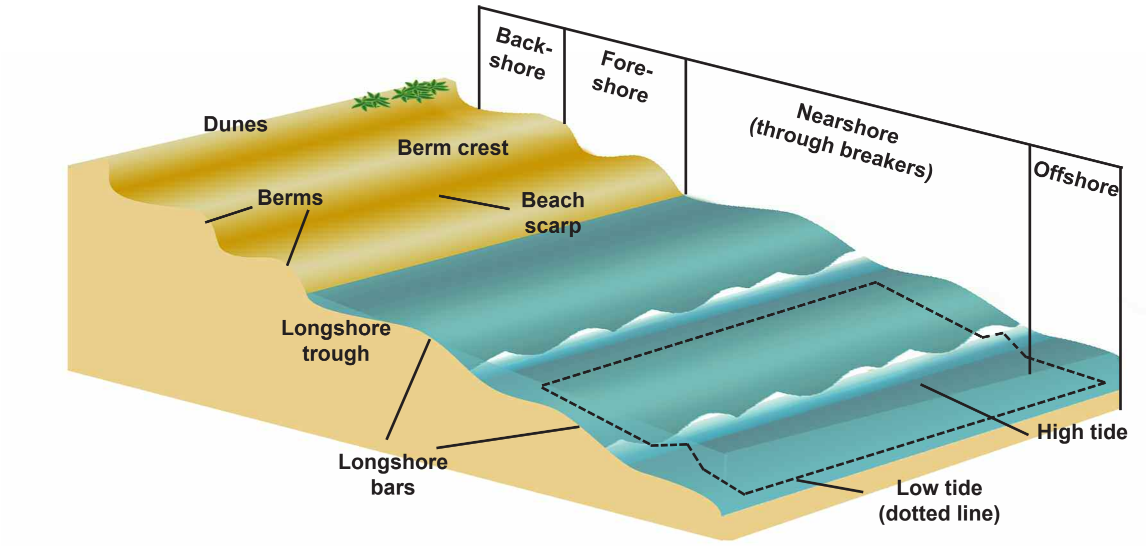



**Figure 2. Example of a typical beach profile.**

Dunes are constantly changing in response to both short- and long-term environmental processes at a given location. Dunes are sometimes referred to as reservoirs of sand. Their size fluctuates in response to the amount of available sand on the beach berm, the strength and duration of the wind, and the storm surge and wave action. Dunes can either be erosional or depositional depending on the interaction between these processes. Sand loss from wind- and wave-generated erosion can impact the dune directly or indirectly by decreasing the supply of sand available to build the dune. During large storms, high water levels may allow waves to erode the base of the dune and create a vertical cut or scarp (Figure 5A, B). Typically, the sand eroded from the dune gets swept into the surfzone, where it becomes a part of the active littoral transport system until it is deposited offshore in a bar or on a downdrift beach.

Winds play an important role as well, with offshore winds blowing sand from the dune onto the beach, and onshore winds blowing the sand back into the dune. Vegetation plays a critical role both in trapping sand blown towards the dune and in limiting the sand blown off the dune. These dynamic environmental conditions cause dunes to shift between erosive and accretional phases. On many beaches, the dune shifts landward during the winter in response to erosive conditions and seaward in the summer in response to accretional conditions (Figure 3). On a stable coast, the forces building the dune are balanced out by the forces acting to erode the dune.

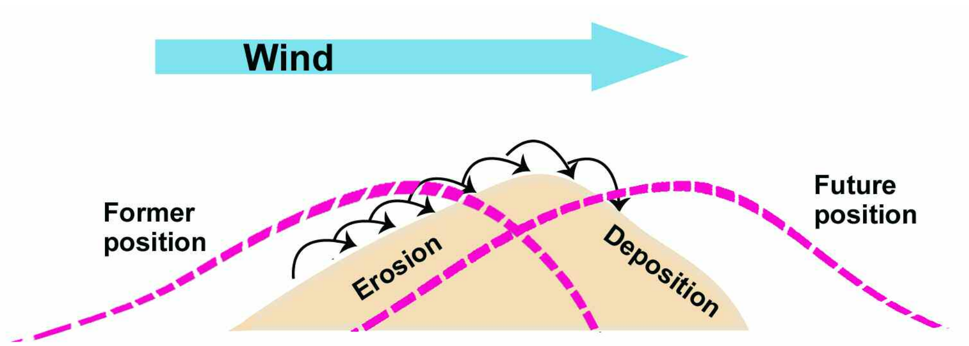



**Figure 3. Dune migration due to sand movement from wind.**

# Long-Term Dune Evolution

Historically, sea level rise has had the greatest impact on the shape of our coastlines. At the end of the last glacial period (approximately 20,000 years ago), sea level was about 450 feet lower than it is today, and the shoreline was located approximately 100 miles seaward of its present-day position (Psuty and Ofiara 2002). As the earth's temperature increased and the glaciers began to melt, sea level rose rapidly and continued to do so until about 2,500 years ago, when it slowed significantly. Geologists generally agree that the barrier island shoreline of New Jersey at this time was low and narrow, with poorly developed beaches and dunes that were frequently overwashed during large storms (Psuty and Ofiara 2002). During this time the coastal landscape was extremely dynamic. As the rate of sea level rise decreased to approximately its current rate, the waves and currents began to move the sediments that were originally flooded during the period of rapid sea level rise onto New Jersey's barrier islands. The rate of sand transfer was sufficient to accumulate large quantities of sediment, increasing the width and height of the barrier islands (Psuty and Ofiara 2002). As the barrier islands became more stable, vegetation began to grow and coastal dunes began to develop landward of the beach berm (Figure 4). Within the last 500 years or so, New Jersey's barrier islands entered a new phase in their evolutionary development as the once bountiful supply of offshore sand dwindled, causing a transition from a period of relative stability to one of gradual loss (Psuty and Ofiara 2002). As surges and large waves associated with coastal storms began to inundate the beaches on a more regular basis, the dunes began to erode and migrate landward. More recently, human alterations to the environment, such as shoreline armoring, have further reduced the natural supply of sediment to the coast. Without a natural source of sediment and to compensate for sand removed from the system during storms, beaches and dunes struggle to survive.

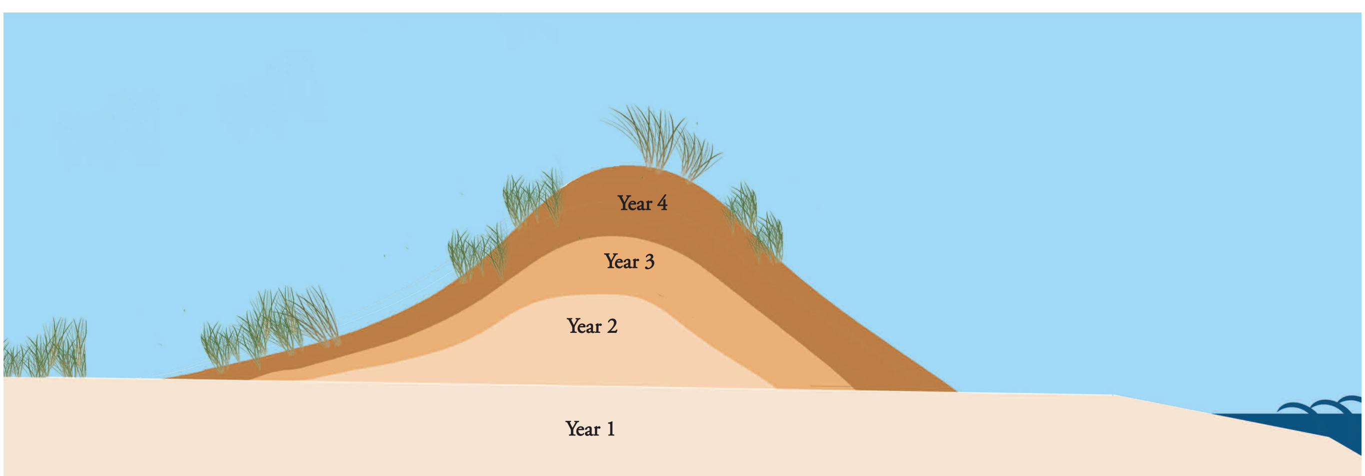



**Figure 4. Dune width and height increase over time and migrate in a seaward direction (Rogers and Nash 2003).**

On eroding coastlines, dunes respond by shifting landward as the beach erodes. The existence of dunes along eroding shorelines is an indication that sand is intermittently being transported into the dunes. On natural dunes, as sand is lost on the seaward side, it is typically deposited on the crest and landward side of the dune (Psuty and Ofiara 2002) during overwash. Along developed coastlines, however, there is typically limited space for the dunes to shift inland, which exposes the dunes to increased wave attack and scarping (vertical erosion) that threatens to destroy the dune system (Figures 5A, B).


**Figure 5A. Dunes eroded by Hurricane Ida in New Jersey. Figure 5B. Eroded dune base resulting from strong wave action during a severe storm.**

## Short-Term Evolution

### Sediment Deposition for Dune Growth

Wind is the main force responsible for the establishment, growth, and maintenance of coastal dunes. When a strong wind blows across a sandy beach, it picks up grains of sand which then move by sliding, rolling, or even hopping past one another. Lighter grains of sand are capable of being moved more easily and can travel farther, while the heavier grains are left behind. Natural and artificial obstructions on the beach cause the wind to slow down, which results in depositional areas in select locations. On a natural beach, vegetation is the most common obstruction, while on developed beaches, snow fencing or sand fencing is frequently installed to mimic the effect of vegetation and accelerate dune growth (Figure 1). The rate at which the wind can supply sand to a dune depends on the strength of the wind and the availability of a sand source. A beach with a wide berm typically provides an adequate sand source and will allow the dune to grow; however, if the beach is narrow, there may be an insufficient sand supply, which limits dune growth. On naturally narrow beaches, beach nourishment projects represent an opportunity to encourage dune growth that might not occur otherwise.

As a dune grows, it becomes asymmetrical in shape, with a steep seaward face and a mildly sloping landward tail. As the dune becomes taller and the vegetation becomes denser, the backdune is sheltered from the wind. Under these conditions, growth landward of the crest is reduced, while seaward of the crest, growth remains steady. On wide, depositional coastlines, it is possible for several distinct dune features to develop. If more than one line of dunes exist, the landward line must be established first.

Otherwise the line closest to the shoreline will trap sand, preventing it from reaching the original dune. Generally, the seaward-most dune will continue to grow seaward until the toe of the dune reaches the landward limit of seasonal beach fluctuations. If the toe of the dune reaches the mean high water line, beach use for both humans as well as rare, threatened, and endangered species can be inhibited. Healthy beach and dune systems require both a dune and a fronting beach, which may require periodic beach nourishment projects in areas where natural sediment sources have been compromised.

## Sand Grain Size

The size of sand grains on a beach influences the rate of sand transport and dune growth. On a natural beach, a given sample of sand will contain particles of varying sizes, each of which respond differently to a given set of wind and wave conditions. Fine-grain sands will move more easily, remain in motion longer, and therefore travel farther than coarse-grain sands. The result is a tendency for wind and waves to sort beach sediment. Fine-grain sand is more easily removed from the beach face and is commonly found in dunes and offshore in deeper water. Once the initial layer of fine sand is removed from the beach, the remaining larger grains armor the ground surface, making it more difficult to transport additional sand. Higher wind speeds or larger waves are then required to continue the transport process after the fine surface materials have been removed. On most beaches, the sand found at the bottom of the foreshore slope, near the location of most intense wave action, is typically the coarsest sand.

## Vegetation

Vegetation is an important part of the evolution of dunes, as it serves multiple ecological and physical purposes. Vegetation slows the wind, causing some of the trapped wind-blown sand to settle to the ground. The heavy grains fall out first, as more energy is required to keep them suspended. As the wind deposits the sand, it accumulates around the vegetation, initiating the creation of a new dune or contributing to the growth of an existing one. The accumulating sand promotes the growth of vegetation uniquely adapted to dune environments. Both the vegetation and the dune grow in elevation simultaneously as the roots of the vegetation strengthen and help reinforce the base of the dune. While barriers such as sand fences can recreate the trapping efficiency of vegetation, they cannot grow with the dunes like vegetation and therefore require maintenance over time.

The most effective dune systems in both promoting habitat and providing storm protection are those in which the appropriate vegetation is encouraged in each

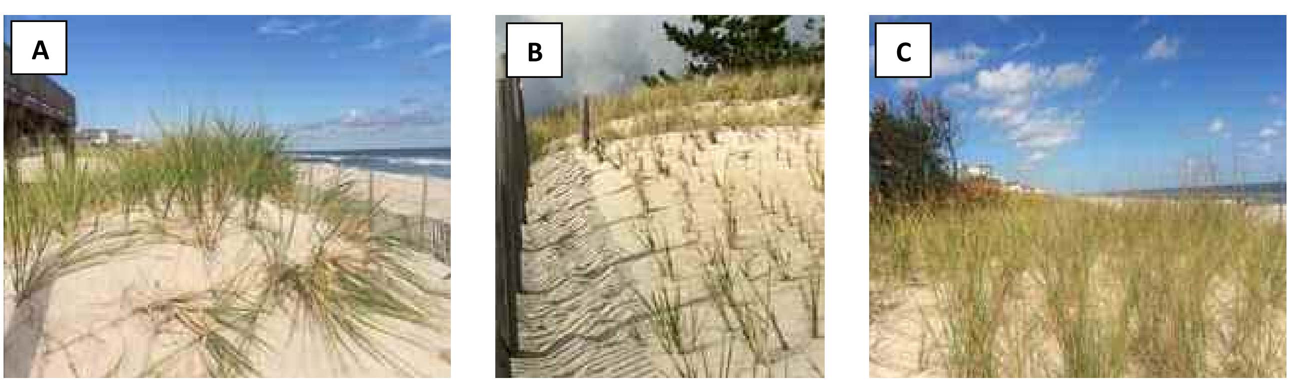



**Figure 6A, B, C. American beachgrass on dunes on Long Beach Island, New Jersey.**


**Figure 7A, B. Multiple species of dune plants that colonize along the landward side of an established dune.**

zone. ‘Cape’ American beachgrass *(Ammophila breviligulata)* is the primary plant species found on foredunes (or pioneer zone) in New Jersey (for more information, see the dune planting section of this guide) (Figure 6A-C). American beachgrass thrives on windblown sand deposits and collects sparse nutrients from the incoming sand, stimulating growth and reproduction. American beachgrass establishes quickly and spreads rapidly, making it a favorite among communities undertaking dune restoration projects. Trapping rates of 2 to 4 feet per season have been observed along densely cultivated dunes.

In natural dune systems, as growth progresses, multiple species of plants will begin to colonize areas landward of the foredune. In New Jersey, typical species are rugosa rose (*Rugosa rosa*), bayberry (*Morella pensylvanica*), and goldenrod (*Solidago sp.*) (Figure 7A, B). Species diversity is important for dune stabilization because each plant type has a different capacity to retain sand through its roots and above-ground vegetation. One of the most common mistakes communities make when undertaking a dune restoration project is planting a single species (most often American beachgrass) everywhere within the dune complex. Within the dune system, dense and diverse native herbaceous plants in the appropriate zones can provide habitat to pollinators and other wildlife. In the beach berm zone, the appropriate vegetation is native, herbaceous, and very sparse (<10% cover). More information on the type of vegetation appropriate for each zone is covered in subsequent chapters; however, dune planting should always be consistent with a community’s beach management plan and should be coordinated with the ENSP to ensure that habitat provisioning is not compromised.

## Sand Fencing

Sand fencing or snow fencing is often used as a means of accelerating or controlling the growth of dunes. Sand fencing performs a role similar to the stems of the vegetation on a natural beach. By slowing the wind to a point below that which is required to keep sand grains entrained, deposition is encouraged. Sand accumulates around the base of the sand fence, similar to the way snow accumulates around a snow fence in colder climates. Fencings of various materials and densities have been utilized. However, experiments have found that the typical wire-bound, wood-slat fencing with a width roughly equal to the spacing between slats (50% porosity) traps about as much sand as other, more costly materials (Manohar and Bruun 1970) (Figure 8A, B). Due to the relative cost effectiveness of this type of fencing, it is the type most frequently used in New Jersey.

In terms of effectiveness, it has been found that sand will accumulate and eventually reach a level about three-fourths of the exposed height of the sand fence (Hamer et al. 1992), depending on factors such as limitation of space and sediment supply. In Dover Township (now Toms River Township), New Jersey, a 4-foot-tall sand fence placed in a straight line parallel to the ocean was observed to trap concave sand


**Figure 8A, B. Examples of dune fences with sand accumulation.**

deposits 40 feet wide and 3.5 feet high (Herrington 2004). Although there are some subtle differences in sand-trapping ability, the most important factor is the total length of fence in a given area. Studies have shown that where windblown sand is abundant, installing twice as much fence (one row about 40 feet behind the first) traps about twice as much sand, regardless of fence alignment (Hamer et al. 1992).

Sand fencing is also commonly used for several other activities related to dune building in New Jersey. Several coastal communities deploy sand fencing seasonally to reduce the amount of wind-blown sand deposited in the street and/or on private property during the winter months. Typically, this material is redistributed on the berm during the spring. Some communities also try to use sand fencing to create desired dune geometries. By strategically placing fencing, dune characteristics such as height, width, and uniformity can be controlled. Although these practices are not advocated, if they are conducted they should be included in a community's beach maintenance plan and should be coordinated with the NJDEP to ensure that the beach/dune system (including habitat provisioning) is not compromised during the process.

## Seasonal Variability

On stable or eroding coastlines, the seasonal fluctuation in the beach profile limits the seaward extent of the coastal dune system. Pioneer dune grasses typically encroach on the berm during the summer, advancing the dune seaward. During the winter, this summer growth is subsequently cut back by storms that erode the berm and cut into the dune toe. Where fully established dune systems exist, the berm will typically be eroded back to the seaward line of dune vegetation. This seasonal process gives rise to the relatively clear, straight vegetation lines found on many natural beaches (Rogers and Nash 2003) which represent the landward limit of wave-induced erosion during the last several storm seasons.

In New Jersey, seasonal weather patterns cause dynamic changes in the beach profile. During periods of high wave energy, the foreshore slope is flattened as sand erodes from the berm and moves offshore. Typically, much of the sand is stored relatively close to shore in underwater sandbars. If the storms are severe enough, the erosion may extend all the way across the beach berm and impact the base of the dunes. This causes an avalanching processes known as *beach scarping,* which can result in large vertical cuts in the seaward dune face. During periods of reduced wave energy, the New Jersey coast is exposed to smaller, less frequent storms and long-period ocean swell that transports sand from offshore back onto the dry beach. During this process, the foreshore region is steepened and the widest beaches of the season (typically during the late summer/early fall) are formed. Overall, these seasonal fluctuations can add up to 75 to 100 feet of horizontal and 2 to 5 feet of vertical change.

## Storms and Recovery

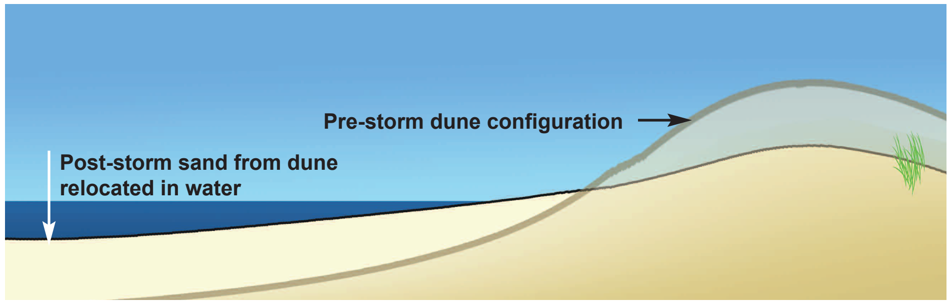



**Figure 9. Relocation of sand after a storm.**

Small storms typically only impact the beach/berm system and leave the dunes intact. The pre-storm beach width, elevation, and presence/absence of vegetation will affect the severity of the erosion experienced during a storm. In addition, if the beach has been left vulnerable by previous storms, increased erosion is likely. In fact, the cumulative effects of two closely spaced minor storms can often exceed the impact of a single severe storm.

Dune recession typically only occurs during larger, more infrequent storm events. During these strong storm events, the berm erodes first, which exposes the foredune to direct wave impact. As the waves erode the base of the dune, the front face eventually becomes unstable and collapses. During routine storms, most of the eroded sand is temporarily stored offshore in sandbars that migrate onshore during calm weather. The beach berm can recover to its pre-storm width and elevation in a matter of months. Depending on the extent of the erosion, post-storm dune recovery can take much longer. While the dune begins to recover almost immediately, it typically takes several growing seasons for the beach, dune, and vegetation to return to pre-storm conditions. In some cases, it has been found that full recovery from the most extreme storms can take up to a decade (Rogers and Nash 2003). In the wake of severe storms, emergency beach nourishments are often utilized as a way to rebuild the beach and accelerate dune recovery.

## Breaches

Storms like Sandy that generate extreme water levels and intense wave action can generate breaches in undersized sand dune systems. Breaches can occur either from the land side or the bay side, depending on the relative elevation of the water. On undeveloped coastlines, breaches and overwash are natural processes that contribute to barrier island migration and refresh important habitats. On developed barrier islands, however, breaches represent one of the most destructive short-term erosion hazards as swift currents can create deep channels capable of carrying away anything in their paths. During Superstorm Sandy, multiple breaches were formed in the Borough of Mantoloking, resulting in extensive damage to the community (Walling 2015). When they occur in developed areas such as Mantoloking, breaches are typically closed manually through sand placement or structural means; however, when they occur on natural coastlines, breaches may be left to evolve naturally.

# Engineering of Dunes

## Protection Benefits of Coastal Sand Dunes

In addition to providing habitat for a variety of species, coastal sand dunes are an integral part of a well-planned coastal defense system. Coastal sand dunes act as reservoirs of sand that help the beach maintain its equilibrium and preserve the ability of the beach to respond naturally to storm events. Beaches evolve during a storm by taking on a more dissipative state that causes waves to break farther offshore, reducing the wave energy near the shoreline. During this transition, the beach slope is reduced and one or more sand bars may form. The bars are formed as sand is transported offshore during the peak of the storm and is deposited near the region of most intense wave breaking. During smaller storms, the waves don't reach the base of the dune, and the erosion is limited to the beach face (berm) itself. The dunes only become active during moderate to large storms when the dissipation created by the bars is insufficient to prevent the waves from attacking the base of the dune. As a dune erodes, it releases a portion of its built-up reservoir of sand into the littoral system, where it contributes to bar formation and the development of a more dissipative profile, ultimately reducing damage to inland infrastructure. Larger dunes can withstand more wave activity and therefore provide more protection to areas behind them. In the simplest terms, the sand stored in a dune buys time and provides protection from severe storms.

## FEMA Dune Standards

Although dunes of nearly any size are beneficial, in order to be considered as a barrier to coastal flooding for flood insurance purposes, coastal sand dunes need to meet the size criteria established by the Federal Emergency Management Agency (FEMA). Based on an analysis of hurricane-related dune erosion, FEMA identified the amount of sand stored within the cross-sectional area of the frontal half of the primary dune above the 100-year stillwater elevation (Figure 10A) as the critical parameter for protection against a 100-year storm event. It has been established that a dune that is predominantly below the 100-year stillwater elevation will be rapidly overwashed and eroded and will not provide significant protection. As the dune erodes, sand is transported both seaward into the littoral drift and landward into the backdune, resulting in a landward migration of the dune. Along developed shorelines, this process will ultimately cause the loss of the dune. A dune that is only slightly above the 100-year stillwater elevation will typically undergo significant erosion and will deflate, reducing in height and width. Studies by Hallermeier and Rhodes (1986) and by Dewberry & Davis, LLC (1989) found that 540 cubic feet of sand per linear foot of dune (equivalent to 20 cubic yards per foot) was required to resist the 100-year storm. FEMA's current V-zone mapping procedures (FEMA 1995) are based on these observations and require this quantity of material be present in the cross-sectional area of the frontal half of the primary dune, above the 100-year stillwater elevation (Figures 10A and 10B), to be considered substantial enough to withstand erosion during a base flood event. This criterion is commonly referred to as the *FEMA 540 rule*.

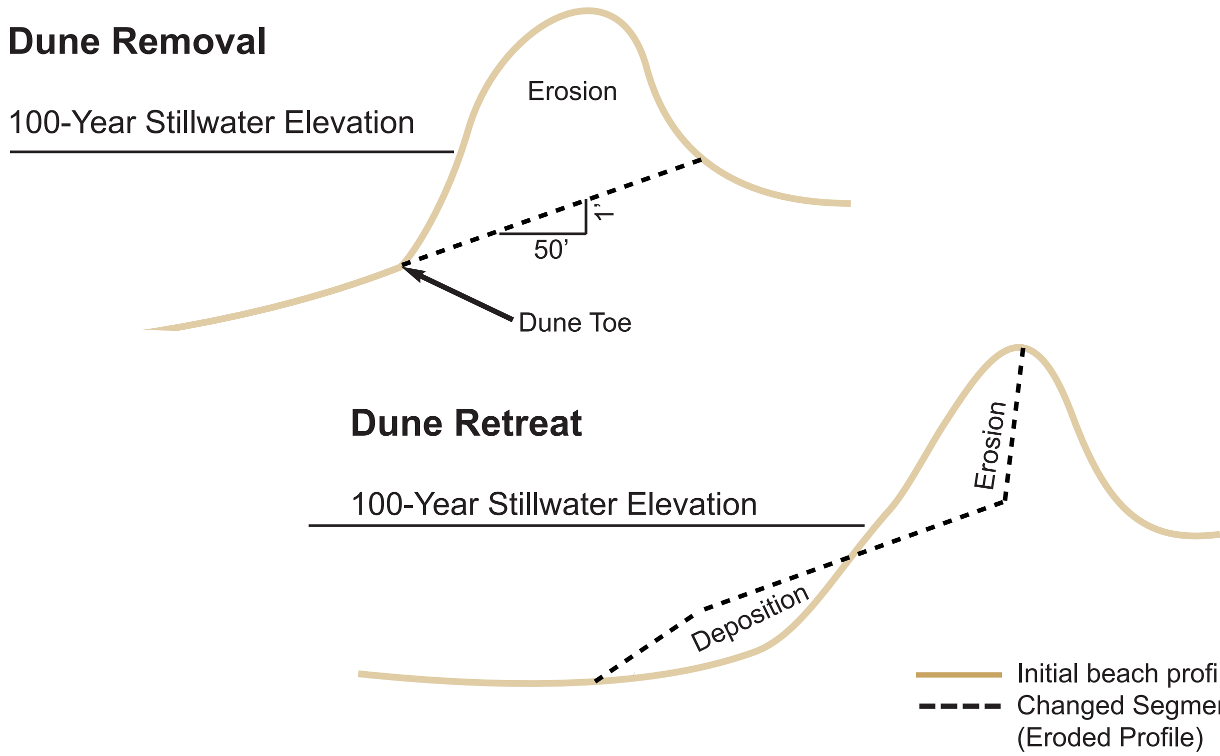



**Figure 10A. FEMA's current determination of dune retreat and removal.**

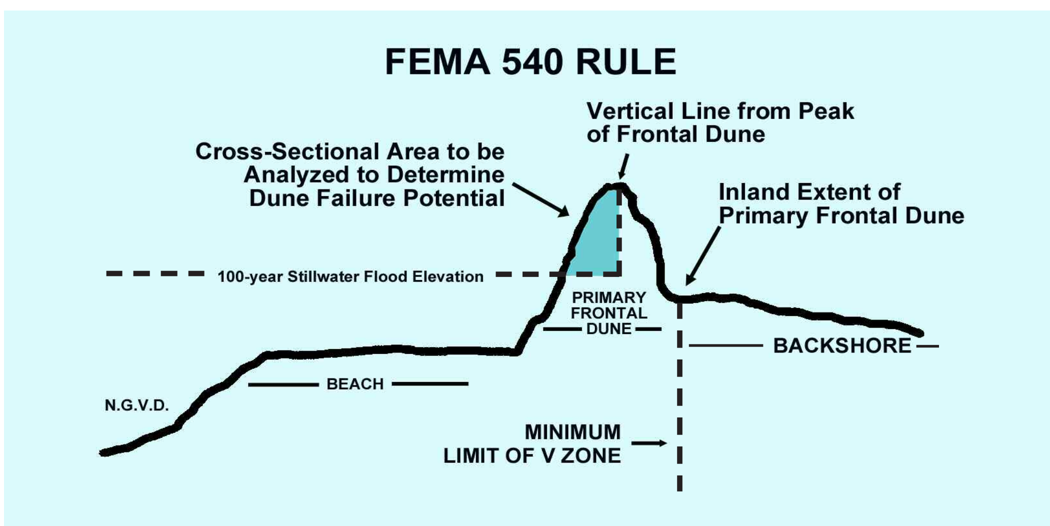



**Figure 10B. Factors to be considered in determining dune failure and V-Zone mapping.**

More recently, post-storm surveys have indicated that an even larger volume of sediment is necessary to withstand significant erosion events. The revised FEMA Coastal Construction Manual (FEMA 2000) recommends a minimum frontal dune volume (measured the same way as the 540 rule) of 1,100 cubic feet per linear foot (equivalent to 40.7 cubic yards per foot) above the 100-year stillwater level. Since the National Flood Insurance Program (NFIP) regularly encourages communities to establish standards above the minimum NFIP standards, New Jersey has taken the proactive step of referencing this higher standard in its Coastal Zone Management Regulations, although it is not yet required in the rules. Currently, very few communities in New Jersey even meet the lower standard. However, federal beach nourishment programs are authorized for the majority of New Jersey's Atlantic coast communities. In Ocean, Atlantic, and Cape May counties, the approved federal projects include construction and maintenance of dunes of specific dimensions, with the dune crest typically 12 to 22 feet above sea level (U.S. Fish and Wildlife Service 2005). These approved dunes, along with the associated beach berm, have been determined by the Army Corps of Engineers to provide sufficient storm protection. Projects to enlarge or modify a Corps-built dune should be reviewed by the ENSP and the U.S. Fish and Wildlife Service before starting any work. Likewise, any proposals for dune building in Monmouth County should be reviewed by the ENSP and the U.S. Fish and Wildlife Service, since the Corps-approved beach nourishment program in Monmouth County does not include any dunes.

## Human-Induced Modifications of Dune Systems

The ability of a dune to withstand the extreme forces of a severe storm event can be either enhanced or diminished by human modifications to the dune system. Dunes are dynamic features that naturally erode during extreme storm events and then recover when storm conditions subside. Although robust dunes have been shown to be extremely effective in minimizing damage during even very large storm events (Barone et al. 2014), several New Jersey communities have sought to supplement the protection provided by these natural systems by incorporating a non-erodible core to their existing or planned dunes. Some of the materials that have been utilized and/or proposed include geotextile cores, rock, and steel/vinyl sheet pile. The objective is to combine the aesthetic and habitat benefits of a dynamic beach and dune system with the robust storm protection provided by a structural core.

Although constructing a dune core can have significant benefits from a storm-protection standpoint, there are several important factors that must be considered. Hard structures that are routinely exposed to wave activity have been shown to accelerate erosion in front of and along the edges of the structure; therefore, dunes with a structural core must be properly maintained. After storm events, the beach fronting a dune with a structural core should be restored as soon as possible to ensure that the exposed core does not create additional erosion. When constructed on eroding beaches, dune cores should only be considered within the context of a larger beach management strategy that addresses the long-term sustainability of the beach in front of the dune, including the potential impacts to habitat for rare and listed species (evaluated in coordination with the ENSP and the U.S. Fish and Wildlife Service).

## Examples of Engineered Dune Stabilization Methods

### Geocore

Geocore refers to one of several approaches in which the natural beach sand is encased in a geotextile fabric. Geotextile is a synthetic woven product that is used in many soil-stabilization projects to increase the strength of the soil and maintain proper drainage. The two most popular forms of geocores used in beach stabilization projects are geotubes (Figure 11) and geocubes (Figure 12). In both cases, the geotextile containers are manufactured offsite and are shipped to the installation location where they are filled mechanically with sand from the beach on which they are being deployed. Geocores are frequently viewed as a quasi-soft approach to shoreline stabilization and in some locations may be preferred over rock and/or sheetpile.

Geotubes come in a variety of shapes and sizes; however, the most common for dune-core applications is an oval-shaped tube with a diameter of between 4

**Figure 11. Exposed geotube after Superstorm Sandy in Ocean City, New Jersey.**

and 8 feet. The geotube casing is typically filled by pumping a water and sand mixture, known as a slurry, into the casing through a fill port. As the geotextile material is porous, the water percolates through the fabric, leaving behind a large-diameter, sand-filled tube. Geotubes have been used in several locations in New Jersey, including Strathmere, Atlantic City, and Ocean City on the ocean coast, and at Mordecai Island in Barnegat Bay. The installation in Ocean City was completed just prior to Sandy, and although the most severe impacts of the storm were experienced well north of the project site, the geotube core performed its intended function and successfully absorbed the wave impacts.

Geocubes are a relatively new and less commonly used approach for stabilizing coastal dunes.  A single geocube consists of a series of interconnected rectangular compartments that can be filled with an excavator (Figure 12). The manufacturer of the product suggests that one of the advantages of the product compared to geotubes is that if a single unit or compartment fails, the integrity of the structure as a whole is generally preserved. Currently, the only known geocube installation in New Jersey is an experimental system deployed in Ocean City after Superstorm Sandy.

**Figure 12. Trapbag geotextile (geocube) container installation in Ocean City.**

## Rock

**Figure 13. Exposed dune rock core after Superstorm Sandy in Bay Head, New Jersey.**

Generally, rock dune cores are constructed as rock revetments backing an already existing beach. The structures are usually covered in sand, and in some cases, planted with dune grass to improve the overall aesthetic appeal of the project. Current practice is to design rock cores independently as traditional revetments in the event they become exposed during a storm. Design guidance for revetments can be found in both the Coastal Engineering Manual (U.S. Army Corps of Engineers 2002) and the Rock Manual (CIRIA; CUR; CETMF 2012). After Superstorm Sandy, many communities in New Jersey pointed to the effectiveness of Bay Head's relict rock seawall in protecting the community (Walling et. al. 2014; Irish 2014) as rationale for their own proposed dune enhancements. During the 2015-2016 winter, several sections of the Bay Head seawall were undermined, illustrating a potential shortcoming in the traditional design philosophy and highlighting the importance of maintaining a wide beach in front of proposed dune core projects.

## Sheet Pile/Bulkhead

**Figure 14. Sheet pile dune core (picture taken shortly after installation, before it is capped and buried by the dune), in Brick Township, New Jersey.**

Most modern sheet pile dune core projects are constructed using steel or vinyl sheet pile; however, in New Jersey there are many older timber bulkheads that essentially perform the same function. Steel/vinyl sheet pile is typically used due to its durability and ease of construction. Similar to other dune core stabilization approaches, the intent of the sheet pile wall or bulkhead is to function as a last line of defense during severe storms. The sheet pile technique has been incorporated at several shoreline locations in New Jersey, including Sandy Hook and Mantoloking. The Mantoloking bulkhead was constructed in response to the breach that occurred during Sandy that compromised a major coastal evacuation route. The project successively resisted the erosive forces associated with the 2015 Joaquin nor'easter and winter storm Jonas, however, the beach in front of the wall eroded significantly. In several places, 15 to 20 feet of wall were exposed after the storms, highlighting the importance of maintaining a wide beach in front of the structure.

## Beach Nourishment and Dunes

In New Jersey, beach nourishment projects have been designed and constructed both with and without dunes. Projects that include a dune generally specify a trapezoidal cross-section with regularly spaced plantings (typically American beachgrass). Such a dune provides

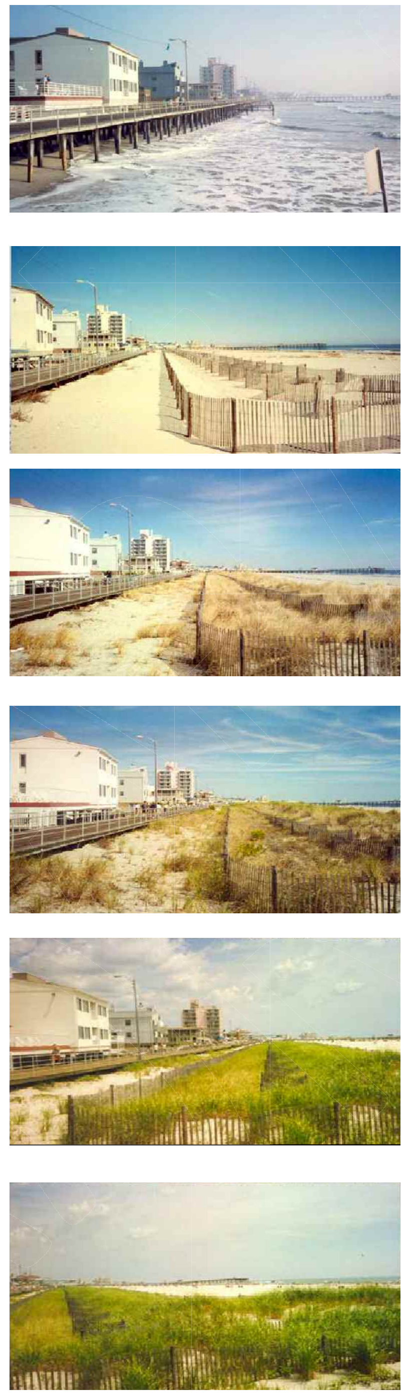


**Figure 15. A photo set showing the development of a dune system after a nourishment project at a severely eroded beach.**

uniform storm protection at the expense of the creation of more natural dune forms. While there has been some discussion recently about modifying project design specifications to allow for the creation of more natural features, there has been no formal adoption of these suggestions. Beach nourishment projects designed without a dune typically have higher and wider berms to compensate for the absence of the dune. These berms, which can be 150 to 300 feet wide, often provide a unique opportunity for dune development in areas where the natural sediment supply is scarce and the beaches are naturally narrow (Figure 15). The rate at which the dunes will grow on these constructed beaches depends on the rate at which the placed sand is transported onto the dune from the beach berm and on the effectiveness of the vegetation, fencing, and/or the dune itself in retaining the sand.

Both primary and secondary dune features (multiple dune lines) have been found on nourished beaches because of the enhanced sediment supply (Nordstrom and Mauriello 2001). As an example, a 6.6 million cubic yard beach-fill project that created a 100-foot-wide berm in Ocean City, New Jersey, successfully re-established the natural cycle of dune growth (Nordstrom and Mauriello 2001). By following a carefully crafted protocol that allowed the dune to develop naturally, both a primary and a secondary dune were developed within 5 years in regions where only small foredunes previously existed.

## Considerations to Dune Engineering

### Walkways/Crossovers

Although stabilized dunes with no gaps degrade habitats for rare, threatened, or endangered (RTE) species, the protective value of a coastal dune for human infrastructure is maximized when the dunes are continuous. Any break or gap in a dune becomes an area where the erosive power of storm surge and waves are concentrated. Typically, water seeks the path of least resistance and is funneled toward any gap or low spot in a dune. Unfortunately, since natural dunes are made of erodible material, the concentration of the flow accelerates erosion along the flow path. In order to avoid creating this hazardous condition, dune walkovers are considered the preferred means of beach access, since they allow the dune line to remain continuous.

Dune walkovers are typically timber structures consisting of stairs and/or ramps on both the front and backside of the dunes, with a flat deck-type structure across the dune crest. Ideally, the walkover structure is constructed in such a manner that it does not interfere with natural dune processes, including the movement of sand and the growth of dune vegetation. Dune walkovers are often used in areas where there is heavy foot traffic, and typical dimensions are dependent on the intended use of the structure. Guidance for constructing walkover structures in New Jersey can be found in the New Jersey Coastal Zone Management Rules, section N.J.A.C.7:7E. In general, for multiple family or public beach accesses, the walkover structure must not exceed 6 feet wide in overall dimension, and


**Figure 16A. Wooden dune walkover (preferred method); B. angled walkway through dune; C. shore-perpendicular walkway through dune (least preferred method).**

must meet a minimum clearance of 3 feet 10 inches above the dune crest. Walkovers for single family use are limited to 4 feet wide and require a minimum of 3 feet of clearance above the dune crest. Structures are intended to pose the least possible amount of disruption to the natural dune, and thus are required to terminate at either 10 feet seaward of the line of permanent beach dune vegetation or at the toe of the frontal dune. Support posts are not to be encased in concrete, should have a minimum soil penetration of 5 feet, and should allow for the erosion of sand during a storm event (Beach and Dune Walkover Guidelines).

Although dune walkovers are preferable from a coastal protection standpoint, there are some locations and situations where they are not possible or necessary, such as areas of minimal dune development, sparse vegetation, low foot traffic, or critical habitat value. In these cases, there are several alternatives that may be used to provide access at grade. The least preferred method is a shore-perpendicular street-end cut. Shore-perpendicular entrances provide minimal resistance to waves and surge, and they provide a conduit for funneling high-velocity flow directly inland. If beach access must be provided at grade, two preferable alternatives, which provide at least some additional storm protection, include angling the entrances to at least 45 degrees with respect to the shoreline, or incorporating a small blockading feature to deflect the surge from flowing straight through the access way. In both cases, the intent is to deflect or divert the potential storm surge. State regulations require that on-grade footpaths be limited to 6 feet in width, and be constructed of materials other than solid concrete or stone, which may become dangerous projectiles in a storm event. The use of geotextile fabrics or cabled wood planks is reviewed on a case-by-case basis. An alternative that has been utilized with some success in Avalon, as well as in several other communities, is the construction of a mixed-sediment footpath. The mixed sediments are selected to be more resistant to erosion than the native sand, provide a stable base, preserve natural aesthetics, and have a relatively minor ecological impact. The mixed-sediment approach can also be used to construct footpaths over existing dunes when walkovers are not possible. On-grade footpaths are not considered appropriate in locations where an escarpment exists between the dune structure and beach berm (Beach and Dune Walkover Guidelines).

In addition to their effects on the storm protection functions of the dune system, dune crossings are important in managing human disturbance and trampling of rare, threatened, and endangered species, because human density is strongly and inversely correlated with distance from access points on recreational beaches (Tratalos et al. 2013). The number, spacing, and locations of dune crossings should be carefully evaluated for their individual and cumulative effects to rare, threatened, and endangered species.

## Environmental Concerns

Any hard structure introduced into the beach environment is likely to degrade habitat for wildlife in general, but specific concerns about rare, threatened, and endangered species are necessary to address. Proponents of such projects should contact Endangered and Non-Game Species Program (ENSP) and U.S. Fish and Wildlife Service representatives early in planning. Even in areas that do not currently support rare, threatened, or endangered species, hard structures are likely to preclude the formation of the most optimal habitats during future storm events. In some locations, hard structures may be the only cost-effective alternative to safeguard human lives and property from future storms. However, the adverse effects of such structures in precluding the formation of optimal habitats for federally listed species must be accounted for under the Endangered Species Act through coordination with the U.S. Fish and Wildlife Service. For example, for the recent installation of sheetpile in Mantoloking, project proponents (in consultation with Service representatives) provided offsite compensatory mitigation.

All developed portions of the New Jersey coast designated as piping plover nesting areas, including all “protected zones” and “precautionary zones,” are

**Figure 17. Portions of the New Jersey coast designated as piping plover nesting areas. Based on FWS NJ map.**

delineated in the Beach Management Plans (BMPs) (Figure 17). ENSP and the U.S. Fish and Wildlife Service also recommend the following general conservation measures as means for achieving the habitat targets listed in Table 1. Where they are deemed essential to protection of beachfront developments or other infrastructure (and where overwashes or blowouts have not formed), sand fences should be placed as far landward as possible to minimize the amount of sparsely vegetated and gently sloping beach that will be replaced with steep dunes and dense vegetation. The number of rows of sand fence should be minimized to decrease the extent of habitat loss. Beach managers should work with ENSP staff on site-specific sand fence configurations. Only native herbaceous vegetation should be planted, and the areal extent and density of plantings should be minimized.

| Dune Characteristic | Target |
|---|---|
| Dune slope | ≤ 13% (management intervention at ≥ 17%) |
| Dune height | ≤ 1.1 m (management intervention at ≥ 1.6 m) |
| Vegetative cover: primary dune | 13% (management intervention at ≥ 22%) |
| Vegetative cover: back beach | ≤ 10% (management intervention at ≥ 17%) |
| Shell/pebble cover: back beach | 17-18% |

**Table 1. Management targets for Dune Characteristics in all developed portions of the New Jersey coast designated as piping plover nesting areas (Figure17), including all “protected zones” and “precautionary zones” (based on Maslo et al. 2011). Typically, these targets are best achieved by leaving the beach/dune system to evolve on its own without any vegetation planting or sand fencing.**

Adverse effects can be further reduced if conservation commitments include periodic thinning of planted beach grass (see targets in Table 1). Both mechanical and chemical (herbicidal) thinning treatments can be considered during those times of year when rare, threatened, and endangered species are not present. Managers should also avoid creating dunes that would provide suitable den or burrow sites for predators such as foxes (*Vulpes vulpes*) and ghost crabs (*Ocypode quadrata*), and avoid installation of solid posts or other structures that provide perches for avian predators such as crows (*Corvus spp.*) and gulls (*Laridae spp.*). Woody species should not be planted in or near rare, threatened, and endangered species areas (not even in backdune areas), as they provide perches for avian predators.

Section 7(a)(2) of the Endangered Species Act (ESA) requires Federal Agencies that authorize, fund, or carry out projects within coastal ecosystems to consult with the U.S. Fish and Wildlife Service if a proposed action may affect any federally listed species. Section 9 of the ESA applies to both Federal and non-Federal activities and prohibits unauthorized taking of listed species, including significant habitat modification or degradation that results in the killing or injury of listed wildlife by significantly impairing essential behavioral patterns, such as breeding, feeding or sheltering. The U.S. Fish and Wildlife Service and the ENSP assist local beach managers in complying with the Endangered Species Act and related laws and regulations. Most municipalities have worked with the ENSP and the U.S. Fish and Wildlife Service to develop a BMP for rare and listed species.

# Dune Ecology: Beaches and Primary Dunes

Dunes are dynamic and constantly changing ecosystems that form a natural buffer between sea and land. Depending on conditions, they can either accumulate sand from the beach, growing the dunes and storing sand, or they can form a source of sand to the beach as the dunes erode. The ecology of these ecosystems plays a key role in mediating many of the functions of dunes, including their growth and stabilization. Similarly, the physical environment of this unique habitat strongly shapes the ecology of the organisms living there.

## Lower Beach and Wrack Line

In the lower portion of the beach where sediments are covered frequently by water, aquatic organisms thrive. However, in the areas at and just above the high tide zone, conditions are particularly harsh. The lack of water makes life nearly impossible for aquatic or terrestrial organisms, and the dry sand is easy to heat and cool, resulting in strong swings in temperature from too hot to walk on during a sunny summer day to bitterly cold during winter. The sand in this area is moved by both wind and waves, creating a highly dynamic system in which the sand is in near constant motion. In oceanfront dunes, this high beach area also experiences strong swings in salinity, from highly salty conditions during dry weather caused by salt spray being concentrated by evaporation, to being washed almost free of salt during intense rains. As a consequence, except in specialized habitats (such as the wrack line, where rotting organic material forms both food and a mechanism for water storage), very few animals and no true plants can live in this zone.

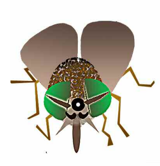
**Wrack line**

*Jeanne Heuser photo*

In this area of beach (the base of what is known as the *supratidal zone*), the strand or wrack line forms a small oasis of life in the otherwise dry and relatively barren sand. Here in the wrack line, the debris left by the high tide forms a narrow band along the shore. As many a beachcomber will testify, all kinds of items can be found here, from human garbage to seashells, animal remains, decomposing seaweed, sea grasses, and other natural materials. The rich organic content of this area provides a reservoir of water and food for the animals found in this area. One common animal in this zone are talitrid amphipods (*Talorchestia longicornis),* often known as beach fleas or sand hoppers. These animals live in burrows under or near the wrack line. The burrow helps hold water to keep them moist as well as forming a chamber where they can lay their eggs without them being washed away by the tide. These largely nocturnal crustaceans feed on the decomposing organic materials in the wrack line. Tiny white worms that are cousins of the earthworm (Enchytraeidae *Enchytraeus albidus*) are other common residents here. Carrion beetles as well as the larvae of tethinid or carrion flies (*Tethina parvula; Sarcophaga carnaria*) may also often be found under the decaying carcasses of fish, horseshoe crabs, and other larger animals found in the wrack line. In the past, the brightly metallic-colored northeastern beach tiger beetle (Cicindela *dorsalis dorsalis*) would also have been abundant here, especially on the warmest summer days. Unfortunately, these animals have become critically endangered in recent years and are either absent or extremely rare on

New Jersey's beaches today, despite several attempts to reintroduce them to the beaches and dunes at Sandy Hook. While the diversity of wrack-line organisms is low, their abundance can be really high. Attracted by the abundance of food, lycosid spiders *(Arctosa littoralis)* hunt here, their pale color helping to camouflage them in the sand. Robber flies (Alslidae) also patrol this area looking for carrion flies to eat, swooping in with their characteristically curved attack paths whenever they detect their prey. The rich supply of arthropods and worms makes the strand line a favorite foraging area for waders and beach-nesting birds like piping plovers, particularly for unfledged plover chicks that often lack access to their preferred feeding areas (back bay tidal flats) due to human development. In addition, it is common to see swallows swooping low over the strand in search of robber flies and other insects drawn to this area (http://www.vliz.be/imisdocs/publications/139188.pdf). The wrack line is also an important microhabitat for seabeach amaranth, where plants are less numerous but tend to grow larger and, therefore, produce more seeds (U.S. Fish and Wildlife Service 2007; Hancock 1995; Weakley and Bucher 1992).

Ghost or sand crabs *(Ocypodidae)* make deep burrows 3 to 4 feet into the sand toward the top of the beach or into the edges of the dunes, and spend most of the day in these cool, damp hiding spots. Like many beach residents, their shells are sand colored, which, combined with their tendency to be seen in moonlight, contributes to their ghostly appearance. They can grow to about 2 inches across the shell and can run sideways remarkably fast as they move across the beach in search of clams, insects, detritus, and even other crabs to eat. While they spend much of their lives on land, ghost crabs must periodically return to the sea or to the water at the bottom of their tunnels to wet their gills. The female carries her eggs on her undercarriage, and these too must be periodically submersed in water to keep them moist. The larvae are also released into the ocean when they hatch, spending a brief period as fully aquatic animals before metamorphosing and moving to the land as juveniles.



Unfortunately, ghost crabs can prey on the eggs and chicks of beach-nesting birds such as terns and piping plovers. Thus it is important to avoid habitat modifications that favor ghost crabs in or near areas that support populations of rare, threatened, or endangered beach species (Barnegat Bay Shellfish 2013; NPS 2015).

Many beachgoers will testify to the fact that the beach often plays host to a variety of biting insects, particularly greenheads and stable flies. As may be guessed by its name, the salt marsh greenhead fly (*Tabanus nigrovittatus*) breeds in salt marshes that are often found near beaches, especially in the barrier island and peninsula systems that dominate the New Jersey shoreline. Larval greenflies eat a wide variety of invertebrates found in the decomposing thatch of the salt marsh. They overwinter as pupae and then metamorphose to adults in late spring. Adult flies mate in the marsh areas, and the female lays her first batch of eggs without need of a blood meal. However, to fuel additional laying, she needs to obtain energy and protein by biting warm-blooded prey. Blown from the marshes to the beaches by the west winds, their strong bite and persistence can make them a serious pest for beach-loving humans in the summer. Stable flies are another familiar bane of summer beachgoers. These flies look similar to house flies, but they have a very similar life cycle to greenheads, with the larvae feeding and maturing in the rotting thatch of the salt marsh and the adults feeding on the blood of warm blooded animals (Cilek 2008; Hansens and Race 2008).

The use of off-road vehicles can have significant negative effects on this habitat. Vehicles can crush ghost crabs when not in their burrows, and vehicle traffic has also been found to decrease the numbers of invertebrates within the strand lines (Steinback and Ginsberg n.d). It has also been suggested that off-road vehicle use on ocean beaches was a key reason for the precipitous decline in populations of the northeastern beach tiger beetle in the past century (Hill and Knisley 1994). In addition, wrack removal, which is often done via beach raking to increase the aesthetics of beaches to bathers, strongly lowers the diversity and abundance of beach invertebrates in both wrack and on open sand (e.g., De la Huz et al. 2005; Dugan et al. 2003). Beach rakes also remove wrack material as well as rare plants and their seed banks (Kelly 2014).

**Tire tracks**

*Jeanne Heuser photo*

**Dune raker**

*Jim Birkitt photo*

## High Beach and Embryonic Dunes

Moving up the beach, away from the water, conditions stabilize a little and life becomes possible. Organisms living in this zone must have a high tolerance for being blasted with and buried by the constantly moving sand. This sand has little or no organic material in it, which means that nutrient supplies for plants are low. Without organic materials to absorb water, rain drains rapidly through the coarse sand grains after a storm, so plants must have a strategy for obtaining water rapidly when it is available and storing it within their tissues for later use. They must also have strategies to deal with the often high amounts of salt in their habitats.

At the very front of the living dune, a small number of highly specialized species with high tolerances to the conditions that this environment presents eke out an existence. Many of the plants and animals in this zone, such as piping plover (*Charadrius melodus)*, seabeach amaranth *(Amaranthus pumilus),* and seaside knotweed *(Polygonum glaucum)* are endangered due to habitat loss from coastal development, beach stabilization, and (for bird species) high levels of predation associated with human activities. In addition, these species are highly intolerant of being trampled or disturbed by the foot or vehicular traffic that commonly occurs there. Making things worse for such species is the increase in flooding frequency resulting from rising sea levels and the encroachment of the invasive Asiatic sand sedge *(Carex kobomugi),* which grows further down the front of the dune toward the ocean than native dune species.

The narrow strip of beaches along New Jersey's Atlantic coast supports a considerable number of rare, threatened, and endangered species, including federally-listed, state-listed, and other rare, declining, or imperiled species (Table 2). Iconic among these is the piping plover, a small, sand-colored shorebird with dark bands across its forehead and around its neck and bright orange legs. These birds breed on beaches throughout the Atlantic coast and on lake shores and river sand bars in the interior of the United States. They winter in the southern Atlantic and Gulf coasts and even northern Mexico, as well as in the Bahamas. These birds create nests that are little more than scrapes in the sand on the high beach. They prefer to nest in flatter areas with sparse vegetation to allow maximum ability to detect approaching predators. The adult plovers and their chicks are visual predators eating small crustaceans and marine worms in the intertidal zone and wrack line, as well as foraging for insects and other food in the dunes, dune swale ponds, and back bay areas. When their nests or young are threatened by a predator, adult plovers will often put on elaborate displays, feigning a broken wing and crying loudly to try to draw the threat away from their young. Piping plovers are solitary nesters, defending their territories from other plovers, though they often nest in or near colonies of other birds such as terns. Piping plover chicks are mobile shortly after hatching and follow their parents to feeding areas. These small, flightless chicks are camouflaged and highly vulnerable to threats such as predators attracted to human trash, human disturbance that prevents them from getting enough to eat, being run over by vehicles, and even getting stuck in vehicle ruts.

**Nesting terns** *Kevin Knutsen photo*

Common and least terns also nest in the high beach areas of New Jersey's coasts. Although visually similar (with light grey and white body plumage as adults and black caps on their heads) the least tern *(Sternula antillarum)* is much smaller than the related common tern *(Sterna hirundo)* and has a yellow rather than orange beak. Smaller and more delicate than gulls, terns have the distinctive habit of hovering over water and then plunging down to pick up a small fish or other prey item from just below the water's surface. Like piping plovers, both least and common terns nest at the top of sandy beaches in areas with little or no vegetation, above the normal high water line. Both birds tend to nest in colonies, which provide some protection from predation from gulls and other predators (Kaufman n.d.). Two very different black and white birds also nest on New Jersey beaches. With its distinctive long orange beak and haunting cry, the American oystercatcher *(Haematopus palliatus)* was almost wiped out in the nineteenth century by hunters and egg collectors. Oystercatchers use their long beaks to search for bivalves in shallow water and to crack them open. When in low densities, as in current-day New Jersey, oystercatchers often mate for life, whereas at high densities they may form trios with one male and two females tending one or two nests (Kaufman n.d). The black skimmer *(Rynchops niger)* gets its name from its distinctive black and white coloration and its method of feeding, which is to glide along the water's surface with the lower mandible skimming the water until it hits a

| Federally Listed | State Listed | Other Species of Concern |
|---|---|---|
| Piping plover (*Charadrius melodus*), threatened | Least tern (*Sterna antillarum*) endangered | Common tern (*Sterna hirundo)* |
| Red knot (*Caldris canutus ruia*), threatened | Black skimmer (*Rynchops niger*), endangered | American oystercatcher (*Haematopus palliatus*) |
| Northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*), threatened | Seabeach knotweed (*Polygonum glaucum*), endangered | Horned lark (*Eremophila alpestris*) |
| Seabeach amaranth (*Amaranthus pumilus*) | Seabeach sandwort (*Honckenya),* threatened *(Peploides*), endangered | Seabeach evening-primrose (*Oenothera humifusa*) |
| | | Sea-milkwort (*Glaux maritima*) |
| | | Seabeach purslane (*Sesuvium maritimum*) |

**Table 2: Rare, Threatened, and Endangered Species that depend on New Jersey's coastal beaches for habitat (Courtesy of FWS NJ)**

fish, at which point the beak slams shut (Meyers n.d.). Like terns, skimmers nest in colonies, and all of these (terns, plovers, oystercatchers, and skimmers) nest in overlapping areas and have experienced similar population declines as a result of habitat loss due largely to the incompatibilities between their nesting requirements and the management of dunes and beaches for human use and protection of human infrastructures.

Several other rare and threatened plants and animals depend on the narrow strip of sand between the dunes and the ocean for habitat. Northeastern beach tiger beetles used to be very common on New Jersey beaches, but were very sensitive to human uses of the beach, including use of off-road vehicles. As a result, they were wiped out from the state in the early 1900s until being reintroduced at Sandy Hook in the mid-1990s. As larvae, the beetles live in burrows in parts of the intertidal zone that are regularly inundated by tides and hunt for prey such as amphipods near the entrance of their burrows. Larvae metamorphose into adults after two years, and adults are formidable predators, capturing amphipods, flies, and other arthropods with their long mandibles (USFWS NJ 2014).


Seabeach amaranth *(Amaranthus pumilus)* is another species that was wiped out from New Jersey's coastal ecosystems for much of the twentieth century. It is believed to have been restored to the state from seeds in sand pumped onshore during beach replenishment activities in 2000. This annual plant has red stems and small, bright green, fleshy leaves. It grows as a rosette close to the sand and is often quite small (just a few inches in diameter). It starts flowering in early summer and continues producing flowers and seeds until it dies in late fall or early winter. Although it grows in the high beach, lower foredunes, and overwash areas where competition with other plant species is low or absent, it is limited in how far down the beach it can grow by a strong intolerance to even occasional tidal inundation.


Seaside knotweed *(Polygonal glaucoma)* is another low growing annual plant found in the high beach area. It has blue-green needle-shaped leaves that are covered with a waxy coating and tiny white to pale pink flowers. Its shiny dark-brown seeds get larger as the season progresses, from about 2.5mm at the start of the season to as much as twice that by the end of the fall (NHESP 2015). Other imperiled plants of this habitat include seabeach sandwort, seabeach evening primrose, and seabeach purslane. All of these, along with the beach-nesting birds described earlier, are threatened by a number of human activities, including beach stabilization (and especially beach armoring such as sea walls and riprap), intensive recreational use, and mechanical beach raking, as well as natural predation (which can also be intensified by human activities in some cases).

Another distinctive, but much more common, species growing in the high beach at the dune edge is sea rocket *(Cakile edentula)*. Its lobed, fleshy leaves help keep it moist in the hot dry sand. It has yellow or white 4-petaled flowers and forms bulbous seed pods that stay on the stem after the leaves drop. Both the flowers and green pods are edible, and are both salty and spicy in flavor (it is a member of the mustard family). The most seaward sea rocket plants tend to grow largest and most vigorously. They also tend to


make the most seeds. Sea rocket seed pods consist of two sections. The larger, distal area of the pod is designed to break off, and its cork-like structure allows it to float well, allowing for long distance dispersal, colonizing new areas, and replacing seaward populations. By contrast, the lower part of the pod tends to stay attached to the mother plant, and seeds from it disperse locally. These seeds tend to be blown landward by the prevailing wind, putting them into suboptimal habitats where their growth is lower and herbivore stresses are higher. Such inland sea rocket populations tend not to replace themselves, but instead are replaced by seeds blown inland from plants at the front of the dune (Davy et al. 2006). Interestingly, this two-part seed dispersal strategy is also found in seabeach amaranth (Weakley and Bucher 1992).

Off-road vehicle use, as well as foot traffic, can do significant damage to this ecosystem. Vehicles and pedestrians can crush the delicate and often relatively unobtrusive plants that grow in this area. They can also crush the eggs of beach-nesting birds, as well as frighten birds from their nests, opening the eggs to predation and lowering hatching success. Thus human activity in these areas is strongly correlated with decreases in the abundance of federally endangered species such as piping plover and seabeach amaranth. As they drive or walk on the front of the dunes, pedestrians and drivers alike can also crush the expanding dune grasses as they spread seaward, preventing the growth of the dunes and increasing erosion (Steinback and Ginsberg n.d.).

Because many of the species in this habitat are threatened or endangered, effective management of these areas is particularly important. Activities that affect or change the natural processes of sand accretion and movement, such as sand fencing, installation of jetties, beach raking, or other such practices, can have strong impacts on these species and should be avoided when possible. Off-road vehicles and mechanical beach rakes can crush bird eggs and chicks; create ruts that can trap unfledged chicks; disturb nesting, roosting, and foraging birds; crush the prey items used by shorebirds; and crush rare plants. In addition to removing wrack material, mechanical beach raking can directly remove rare plants and their seed banks from the beach. As a result, beach raking is generally restricted in the "protected zones" and "precautionary zones" delineated in the Beach Management Plans. On beaches where dune erosion is a concern, managers should also consider suspending any ongoing mechanical beach-cleaning activities. Hand picking anthropogenic trash and leaving the wrack will foster the natural dune development process. This practice will also conserve wrack material, which is an important foraging habitat for piping plovers and other shorebirds and an important microhabitat for seabeach amaranth.

Native or invasive vegetation, such as beach grasses and Asiatic sand sedge, compete with rare, threatened, and endangered species of plants and often make the habitat unsuitable for nesting birds. As a result, any fencing or planting activities should be carefully coordinated with wildlife managers and carried out only as prescribed in the approved Beach Management Plan for that area. To prevent disturbance to beach- nesting birds, areas used by them for breeding or foraging are often fenced off to restrict access to foot and vehicular traffic during the nesting season (March 15 through August 31). Similarly, beach raking that removes wrack materials within the strand line that form an important foraging resource for beach-nesting birds should also be avoided. Predators including foxes, raccoons, feral cats, and even visiting dogs can be another important source of disturbance and mortality. Predator control plans and restrictions on dog walking may thus also be required in areas where beach nesting birds are active (USFWS NJ 2015).

In all developed portions of the New Jersey coast that currently or potentially support rare, threatened, or endangered species, Endangered and Non-Game Species (ENGS) and Fish and Wildlife Service representatives should be consulted before any changes in management are implemented. Managers should work with ENGS and FWS representatives to develop effective Beach Management Plans that balance the need for storm protection and other human uses of this area with the requirements of the rare, threatened, and endangered species that depend on this narrow band of habitat for their survival.

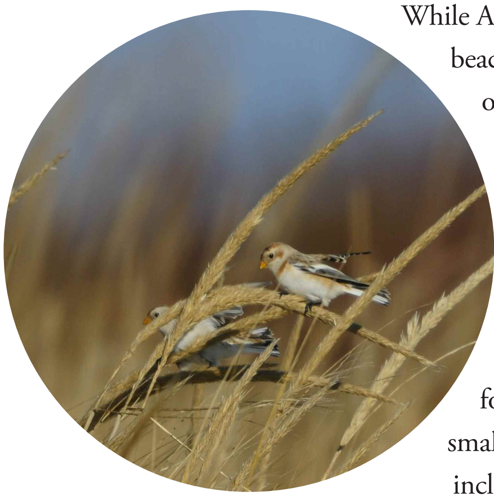
## Primary Dunes


American beachgrass

Moving inland from the high beach, the soil tends to be made up of smaller sand grains that are easier for the wind to pick up and transport from the beach. The smaller grains help improve the ability of soil to hold water. This, combined with the high humidity of this habitat when winds are blowing onshore and the fact that few species can survive the salt, heat, and water stresses of this habitat, means that the few species that can grow there have few competitors and can grow quite abundantly. In New Jersey, one plant species in particular tends to dominate the first fully vegetated areas of the dune (the primary dune). American beachgrass *(Ammophila breviligulata)* is uniquely suited to life in this habitat in a number of ways. For example, while burial is usually a negative factor for many typical terrestrial plants, sand burial is actually stimulatory to the growth of this and many other primary dune species. The constant supply of fresh sand that characterizes the primary dune brings nutrients (attached to the sediment grains) and is pathogen free, having been sterilized by the ocean, so it reduces the density of parasites and disease-causing organisms in the soil (Maun 2004). To save water, the stomata (pores used for gas exchange in plants) are located in deep grooves on the leaf surface, and the long narrow leaves can be rolled or folded and held in such a way as to minimize exposure to wind (USDA 2006a). Another adaptation to this habitat is the beach grasses' extensive system of roots and rhizomes (underground stems) that form a complex horizontal network that can extend 20 feet deep below the dune and at least as far out horizontally. The horizontal rhizomes connect related plant shoots, while the roots allow the plant to access water reserves deep in the sand. The root can also access moisture near the surface from brief rain events that don't provide enough moisture to infiltrate deep into the dune.

Despite all of these challenges, American beachgrass grows rapidly – as much as 6 to 10 feet a year. It can also grow as many as 100 stems per clump each year (USDA 2006). The leaves of American beachgrass have deep grooves on their top surface but are smooth underneath. Arising from a relatively short stem, the straight, stiff leaves are relatively narrow (1/4 to 1/3 inch) but can grow to several feet in length, and tend to stand upright rather than drooping. The leaves of American beachgrass act as filters that intercept blowing sand. As the sand grains hit the plants' leaves, air currents slow and sand grains fall to the dune surface where the plants' roots and rhizomes help to hold them in place, building and stabilizing the dune.

American beachgrass flowers are clustered into spikes that grow from a central stem in early summer. Although the plant does set seed in late summer, in New Jersey the seeds it forms are not highly fertile, and the plant spreads primarily through vegetative propagation via horizontal rhizomes. In the front of the dune, these rhizomes can be eroded by waves during storms and dispersed to other areas via water transport (USDA 2014).



**Buntings on beachgrass**
*Kevin Knutsen photo*

While American beachgrass seeds often have relatively low germination rates, they are still an important food source for birds and small mammals, including snow buntings and the endangered Ipswich sparrow. In addition, many other species, including snowy and short-eared owls and a number of gull species, use American beachgrass for habitat (Eastman 2003). Beach-nesting birds such as piping plover are restricted to habitats with very sparse (<10% cover) beachgrass and other vegetation (Eastman 2003).

Part of the reason that American beachgrass is able to survive the challenging conditions of the primary dunes is that it usually grows in association with mycorrhizal fungi (Koske et al. 2004). These fungi obtain water and nutrients from the soil and provide them to plants in return for sugars and other organics from the plant roots. In one study of another dune grass (sea oats or *Uniola paniculata)* in Florida, the ratio of hyphae (the fungus equivalent of roots) to plant root was found to be over 45,000:1. Clearly, these fungal extensions massively increase the surface area through which nutrients and water can be absorbed for use in growth by the plant. Not surprisingly, studies show that dune plants with mycorrhizae grow better (get taller, make more leaves, etc.) than those without, especially under drought stress. Mycorrhizal associations can also increase salt tolerance and help plants ward off parasites (Koske et al. 2004). When plants disperse via rhizomes, they actually travel with mycorrhizal spores, so that when they get to their new destination, both the plant and its associated fungal partner can sprout together. Typically, dune soils contain a variety of different species of mycorrhizal fungi. The more spores there are of those fungi in the soil, the more likely they are to be encountered by a sprouting seed to help with its growth and survival. Not all mycorrhizal fungi work equally well, although American beachgrass plants grow better when inoculated with spores from fungi collected from dunes rather than those from other sites.

Compaction, such as that caused by humans driving or trampling on the dunes, can destroy the root-like hyphae of the mycorrhizal fungi, which can impair plant growth (Koske et al. 2004). In addition, coping with the stressful environment of the dunes leaves dune grasses little energy in reserve to dedicate to mounting a response to infection. When humans walk or drive on the dunes, their weight crushes the delicate rhizomes running just below the surface of the sand. Such damage creates a pathway for pathogenic bacteria and fungi to enter the tissues of the plant, sickening or killing it. In addition, since each of the clumps of beachgrass is connected to others through the rhizomal network, once one plant becomes infected, the pathogen can spread rapidly to interconnected clumps, creating a widespread dieoff. This is why it is so important to avoid traveling through dunes in areas where dune grass is growing (Nickerson and Thibodeau 1983).

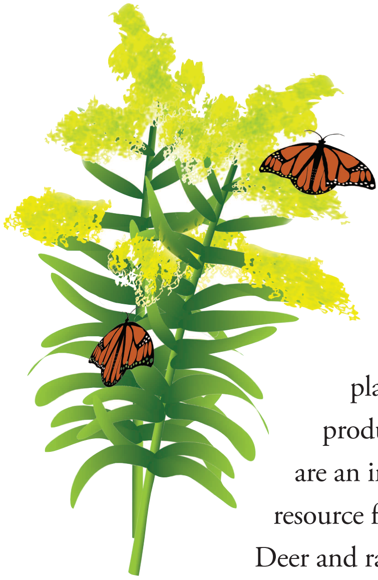
As mentioned earlier, American beachgrass needs a constant supply of sand accumulation to remain healthy. Away from the dune front, the species starts to lose vigor and becomes susceptible to infection by diseases such as *Marasimus* blight caused by a fungal infection. This disease creates characteristic circular dead patches in the grass (USDA 2014). Insects are the primary herbivores in dunes, with grasshoppers, aphids, and the soft-scale insect *(Ericoccus carolinae)* becoming increasingly common with distance from the ocean, feasting on the plant's tissues. Similarly, rabbits, deer, and other herbivores that graze on beachgrass leaves become increasingly common with distance from the water. Nematode worms, like the root-knot nematode *(Meloidogyne sasseri),* are another culprit, attacking dune grass roots (Rogers and Nash 2003). As a result, growth of American beachgrass becomes increasingly sparse behind the dune crest.

**Asiatic sand sedge** ***(Carex kobomugi)***

*Louise Wootton photo*

An increasingly common sight in the primary dunes in New Jersey is Asiatic sand sedge *(Carex kobomugi).* This invasive species, as its name suggests, has its origins in coastal areas around the Sea of Japan. Like American beachgrass, this species has a high tolerance for salt spray and heavy winds. It typically grows to about a foot tall in large, dense beds. Its usual color is bright green to yellow-green, although yellow and brown leaves are more common in the spring and fall. The relatively stiff, grass-like leaves curl over the plant, giving it a low profile. On the edges of the leaves are small, spiny ridges that make the leaf edge feel like a serrated steak knife. The plant forms many flowers on a single stem. Each stem contains either male or female flowers. The male flowers form distinctive white pollen tubes during the early spring but die after pollen production ends. The female flowers are relatively unobtrusive in spring, but by fall they develop into a large seed head characterized by a triangular set of spikes attached to a long stem with distinctive brown scales. Below the ground, Asiatic sand sedge forms spike-tipped rhizomes that spread out quickly from the plant. It also builds long roots that can grow several feet into the sand. While the species does produce numerous seeds each fall, the viability of those seeds seems to be low, and the plant is believed to spread largely through creation of new clumps along its rhizomes, some of which can break off and be transported to new habitats by wind, erosion, or transport by ocean waves and currents. Unlike American beachgrass, this species is relatively resistant to damage from trampling. Being non-native, few species recognize Asiatic sand sedge as potential prey and do not attempt to eat it. It also tends to be resistant to pathogens. These characteristics, along with its sharp seeds and rhizomes that form a natural deterrent to pedestrian traffic, caused this species to be planted in New Jersey's dunes for several decades. Unfortunately, the species' tendency to form a monoculture – outcompeting the native species and significantly changing the biology and geomorphology of the dunes – resulted in discontinuation of its use for dune restoration by the late 1980s. However, the species still spreads through natural propagation, and it is rapidly becoming the dominant species within many primary dunes in New Jersey and beyond.

Moving up the dune and away from the ocean, the improving soil quality and decreasing stress from salt spray and sand scour mean that other species are able to thrive. One such species is seaside goldenrod *(Solidago sempervirens).* Seaside goldenrod is a perennial, meaning the same plant grows back year after year. Its broad leaves are arranged alternately on the stem, which grows as much as 3 feet tall. The fleshy leaves store water and have a shiny wax coating to protect the leaf from evaporative water loss and the drying effects of the salt spray. In late summer and early autumn, seaside goldenrod produces large clusters of bright yellow flowers at the top of its stems. The individual flowers in these clusters are larger than those of other New Jersey goldenrods. Seaside goldenrod pollen grains are heavy and sticky, so the species is largely insect-pollinated. The heavy pollen also means that, contrary to common perceptions, this plant is not responsible for the misery of allergy sufferers in the fall. Ragweed, a plant with unobtrusive flowers that create pollen designed for air dispersal, is the real villain in this regard. The sugary nectar of seaside goldenrod is an important food source for migrating monarch butterflies, the common buckeye



butterfly, and others such as the silver-bordered fritillary. Each flower cluster gives rise to seeds that look similar to the fuzzy parachuted seeds of a dandelion. These seeds are food for mice and songbirds. The plant hosts a number of gall-producing insects, which in turn are an important winter food resource for birds like chickadees. Deer and rabbits will also occasionally graze its leaves. As well as increasing the species diversity of the dunes, goldenrod – like American beachgrass – can be one component of a suitable habitat for bird species such as killdeer *(Charadrius vociferous),* common terns *(Sterna hirundo),* and black skimmers *(Rynchops niger)* (Safina and Burger 1983).

Together, American beachgrass and goldenrod make up 90 to 95% of the plants in the foredune. A small number of other species is also present, including sea rocket, seaside spurge, panicgrass, purple sandgrass, saltmeadow hay, beach pea, trailing wild-bean, and the non-native dusty miller (Hosier 2003). Beach pea and trailing sand bean plants, like other legumes, have a symbiotic relationship with nitrogen-fixing bacteria within swollen "nodules" in their roots. These bacteria are able to take atmospheric nitrogen (which is not usually available to plants) and turn it into ammonia (the same ingredient found in store-bought fertilizers). This is particularly important in the nutrient-poor soils found in sand dunes. Beach peas have pretty pink or purple flowers reminiscent of those of cultivated sweet peas. The flowers are important nectar sources for bees and butterflies, and once pollinated, form seed pods filled with small peas which are eaten by deer, mice, birds, and a number of insects (Mass.gov. 2015). Burrowing under the roots of the grass to escape the heat and foraging for plant material and any carrion they can find are a variety of ant species. Similarly, the dunes are home to numerous burrowing wolf spiders. These spiders' deep burrows (up to 3 feet deep) create a refuge from the daytime heat. The wolf spider hunts mostly at night and preys on other dune insects. Another common dune species, the seaside grasshopper, is exquisitely camouflaged to look like sand. These animals are one of the few insects that prey on American beachgrass, which forms their major food source. This warmth-loving insect sometimes buries itself under the sand at night with just its head exposed in order to make use of the heat stored in the sand grains of the dune. On a warm day, the chirps made by the males rubbing their legs against their wings in order to attract females may be heard throughout the primary and secondary dune systems (Hammond 2009).

**Seaside grasshopper** *Louise Wootton photo*

The fact that there seems to be sand everywhere on a dune makes it look like a very uniform habitat to the casual observer. However, the direction and strength of the wind and the supply of sand from the beach make for strong differences between sites. The height of the dune also varies. This in turn can affect the temperature by varying the timing and amount of shade experienced by plants on the dune surface, as well as affecting access to water supply from ground water. Even small depressions in the dune can make an important difference to the plants growing there by collecting organic material (which holds water and forms a nutrient source as it decomposes), as well as providing a shaded area that may be an important nursery area (Garcia Novo et al. 2004). Similarly, the shade provided by beachgrass and goldenrod can help promote germination and establishment of seeds in the sand below. Consequently, beachgrass may be planted along with other species in areas behind the dune crest, even though it is unlikely to persist there long term, because its presence can help promote the establishment of the other plants sown along with it.

Coastal dunes form sand reservoirs that can play an important role in maintaining sand for the beaches in front of them as well as in protecting the communities behind them. In storms, wave erosion can become focused on one area of dune and can overwhelm the stabilizing effects of the dune vegetation. The sand released helps replace sand lost from the beach, but allows the ocean waters to flood landward, creating areas of flat sand known as *overwash fans*. Although overwash fans as well as blowouts (gaps in the dunes caused by wind erosion) can be problematic for human infrastructure (because they provide pathways for flood waters to move landward behind the dunes' defenses), they form an important habitat for many threatened and endangered species. In particular, they create safe nesting and foraging areas for beach-nesting birds, being well above the usual high tide mark but lacking in vegetation that may provide habitat and cover for their predators.

Where they occur, wide, dynamic, and complex natural dune systems support a diversity of native plants and animals. They provide a rare habitat type that is fully compatible with rare, threatened, and endangered (RTE) beach species. However, the dunes themselves are not the primary habitats for any of New Jersey's RTE beach species, which thrive more in the strip of beach between the water's edge and the edge of the vegetated dune, although many RTE species will utilize dune blowouts or washovers when they are present. Even natural, dynamic dune complexes are only a secondary habitat for RTE beach species, and stabilized dunes are not habitat at all. Unfortunately, few beaches in New Jersey support natural dune systems (e.g., northern Sandy Hook, Edwin B. Forsythe National Wildlife Refuge, North Brigantine Natural Area, and Stone Harbor Point). These few natural areas support the overwhelming majority of nesting piping plovers in the state, as well as important concentrations of other RTE species. Along developed coastlines, there is typically

**American beachgrass *(Ammophilia breviligulata)***

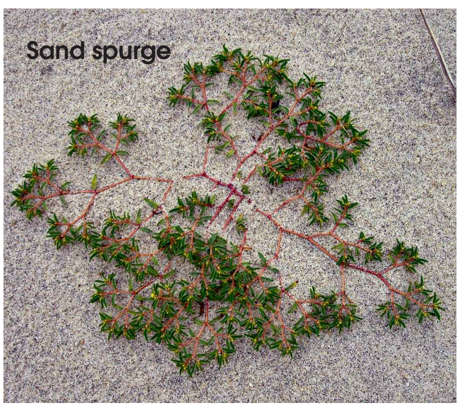
*Juliana Pollara photo*

limited space for dunes to shift inland, limiting the potential for the development of a secondary dune. Instead, much of New Jersey's coast features steep, stabilized dunes that are maintained by human activities such as bulldozing, sand fencing, and vegetation planting, as well as by direct placement of dredged sand during project construction or renourishment. While such activities may be necessary for protection of human infrastructure in many areas, they often reduce habitats for RTE species, promoting the formation of heavily vegetated berms and dunes that replace gently sloping and sparsely vegetated foredunes. Besides the direct effect of making habitat less suitable, these activities also indirectly affect RTE species. For example, stabilized dunes can exacerbate conflicts with recreational beach users by restricting both RTE species and people to a narrowed beach berm. Stabilized dunes can also facilitate predation of RTE birds by providing vegetative cover for predators, creating predator den sites or perches, and promoting a narrow linear band of nesting habitat that is easily searched by predators.

# Dune Ecology: Secondary Dunes and Beyond

## Secondary Dunes and Dune Swales

Behind the first or primary dune in natural areas are usually a series of additional or secondary dunes. In most coastal areas this and the nearby landward communities have been lost to human developments such as boardwalks, homes, and roads. However, in the few remaining undeveloped areas, such as northern Sandy Hook, Island Beach State Park, Edwin B. Forsythe National Wildlife Refuge, North Brigantine Natural Area, Stone Harbor Point, and Cape May National Wildlife Refuge, this zone is home to a wide variety of communities. Secondary dunes that are relatively close to the dune front tend to have similar vegetation to the primary dunes, although the beach grass tends to be much less dense and healthy in these areas. Seaside goldenrod is common in this habitat, as are sand spurge and even the occasional sea rocket.




Between the dune crests are low-lying areas called *dune swales*. In these areas, the "lens" effect created by reflection of sunlight from the dune banks surrounding them concentrates the sunlight, creating temperatures that can be 20$^0$F higher than those of the surrounding areas. This, in combination with the osmotic stress created by salt spray and the lack of a steady supply of fresh sand in these areas, means that dune swales often feature sparse ground cover with many areas of open sand. Scattered in small depressions and other areas where microclimatic features allow life, there is an array of dune plants, including beachgrass, goldenrod, little bluestem, panicgrass, pin-sedge *(Carex grayii)*, lichens *(Cladonia* spp.) (Hosier 2003), the occasional low-growing beach plum or baybush, and Eastern prickly pear cactus *(Opuntia humifussa).*

Little bluestem is a clump-forming grass found in a number of habitats, including dunes. It produces abundant seeds that are an important food source for songbirds, and its leaves form cover for ground birds and small mammals (Tober and Jensen 2013). Coastal panicgrass is a tall grass species that only grows once the sand has been stabilized by American beachgrass or other species. Once established, it creates a fibrous root system that further stabilizes the dune (USDA 2006b). The only cactus species native to New Jersey, the Eastern prickly pear, has virtually no leaves. Instead its stems are swollen into flat, green, fleshy pads that allow this plant to be extremely drought resistant. These pads do have some longer thorns, although it is the tiny bristles that occur in clusters on the pads that are perhaps its greater defense. While tiny, these bristles embed in the tissues of predators and careless humans, creating a painful irritation, and are hard to remove. The bright yellow flowers of the prickly pear cactus form at the margins of the pads, and each lasts only one day, but flowers are produced throughout early summer, forming yellow blooms that are extremely attractive to native, long-tongued bees. When pollinated, these flowers form the "pear"-shaped fruits that give the species its name. The pears turn from green to red when ripe and become quite sweet and juicy. They are an important food source for a number of bird and mammal species and can be eaten raw or made into jams, juices, and other foods by humans. The plant was also used by Native Americans in the preparation of a number of natural remedies.

While dune swales are usually thought of as dry habitats, blowouts and other erosional processes can actually lower the sand to a level lower than the groundwater surface. In many dune areas a "perched water table" exists in which groundwater is trapped above an impermeable clay layer, forming a lens near the soil surface that is saturated with fresh water. Since the soil is saturated with water, runoff from the surrounding dune areas during rain events can't drain, creating temporarily or semi-permanent wet areas such as dune swale ponds and marshes. Found within the wetland areas is an array of highly specialized, and thus often very rare, plant species. The plants found in these habitats are adapted to flooding and associated anoxic (low or no oxygen) conditions. The amount and salinity of the water in these systems strongly affects the community of plants growing there, but some of the plants found in dune swale wetlands include marsh fern (*Thelypteris palustris)*, rose mallow *(Hibiscus moscheutos)*, cattail *(Typha latifolia),* highbush blueberry, groundsel, large cranberry *(Vaccinium macrocarpon)*, marsh St. Johns-wort, panic grass, tickseed sunflower, sedges and bulrushes *(Carex, Cyperus and Scirpus* spp.), rushes (*Juncus* spp.), and common reed *(Phragmites australis)* (Hosier 2003). Birds, including red-winged blackbirds, golden-crowned kinglets, belted kingfishers (Breininger 1992), and green heron, as well as herpetofauna such as Fowler's toads and snapping turtles, are often found in and around these dune wetlands (NYNHP 2013).

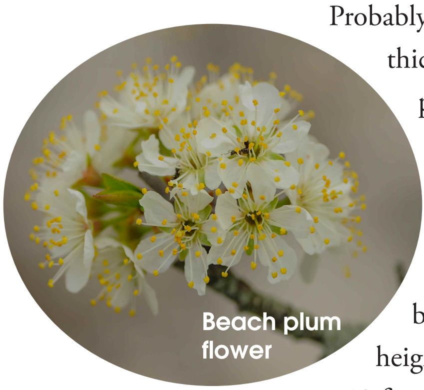
Dune wetlands also provide habitat for the larvae of mosquitos, dragonflies, and other insects. An unusual, and increasingly rare, inhabitant of dunes and dune wetlands is the eastern hognose snake. This thick-bodied snake prefers to feed on Fowler's toads and other amphibians, though it will also eat small mammals, birds, insects, and even carrion when amphibians are scarce. Hognose snakes are completely harmless to humans, but when threatened they will hiss loudly, which can be mistaken for the rattling sound of the venomous timber rattlesnake. They will also flatten and spread out their heads like cobras and make a series of fake strikes to try to scare off the animal creating the perceived threat. If this doesn't work, the hognose will go through an elaborate "fake death scene" in which it will throw up its last meal and proceed to seemingly writhe in agony with its mouth open and tongue sticking out. The snake will then defecate, flip over on its back, and play dead until the threat goes away. This death scene can be quite convincing. However, if you return the snake to its right side it will proceed to flip back over and continue to play dead, which rather ruins the effect (Vanek 2014)!

**Beach heather** *Louise Wootton photo*

In some higher-elevation backdune areas farther back from the ocean, woolly beach heather *(Hudsonia tomentosa)* commonly forms large patches. This plant gets its name from the white furry hairs on its leaves that help reflect light to prevent heat stress in the hot, dry backdune habitat. The leaves are also small and tend to be curled, and the plant grows close to the ground, all of which are adaptations to prevent water loss. Like some other dune species, dune heather's roots make associations with nitrogen-fixing bacteria in the soil, which provide the plant with much needed nitrogen-containing nutrients in return for sugars from the plant. For most of the year, wooly beach heather's low-growing pattern and dull grey-green leaves make it an unobtrusive plant. However, for a brief few weeks between late May and early July it creates a brilliant display with abundant bright yellow flowers being produced at the tips of each stem. Beach heather is extremely sensitive to trampling, so walking or driving on or near this plant should always be avoided.

# Shrub Thicket

Moving away from the ocean, behind the secondary dune crests, a diverse community of shrubs and vines can be found that forms increasingly dense thickets as growing conditions improve. A few of the plants found in the thickets also grow in the swale between primary and secondary dunes, but their growth is usually stunted by exposure to wind-borne salt spray, so these plants have lower vitality in the dune swale than those growing further back from the ocean.



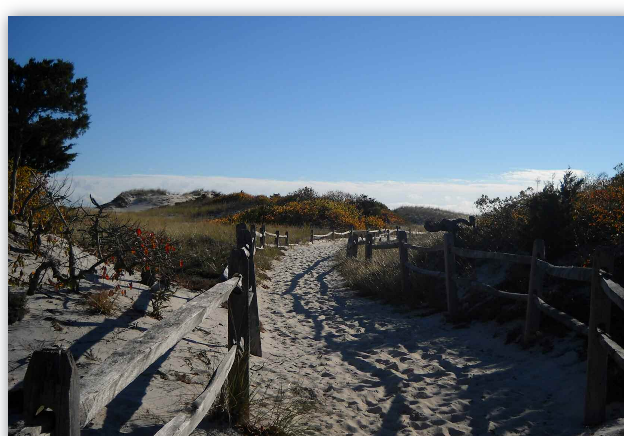
Kevin Knutsen photo

Probably the most familiar thicket plant is beach plum *(Prunus maritima).* In most areas of the dune, this plant grows to only 4-6 feet tall, but it can grow to a height of as much as 10-12 feet in inland, nutrient-rich soils. Before the leaves form each spring, beach plums produce an abundance of snow-white flowers that develop and ripen into purple-black fruits in late summer and fall. It can also reproduce asexually, with extensive colonies developing from a single plant when conditions for growth are favorable (USDA 2002). The fleshy, sweet fruits are an important food resource for many birds and dune animals as well as humans, and its branches form nesting habitat and refuge for many birds and mammals.

Another common plant of the shrub thicket is Northern bayberry (*Myrica pensylvanica).* This woody shrub is technically deciduous, but its fragrant leaves may stay attached to its branches for much of the winter. The flowers and fruits of this species are both inconspicuous, but its waxy berries are an important food resource for a variety of dune animals. As with many other dune species, the bayberry plant is host to nitrogen-fixing bacteria that help it to survive on soils which, though richer than those of the primary dunes, are still relatively nutrient poor (USDA 2002).

Poison ivy *(Toxicodendrum radicans)* is much hated by humans who, nearly unique among animals, react to some of the oils in these plants by forming a nasty, itchy rash. Most children learn to identify the plant from its leaves ("Leaves of three, let it be!") and hairy stems ("Stem like a rope, don't be a dope!"). In the spring, poison ivy leaves start out small and bright red, but enlarge and become a shiny, dark-green color. Then in fall, the leaves again change color to bright red before being shed for the winter. Poison ivy produces numerous grey berries that are eaten by a wide variety of birds (more than 40 species of bird have been observed to eat the seeds of this plant). The tangled branches of the poison ivy also form great nesting and hiding places for a variety of animals, and the plants' dense and tough roots help to stabilize the dunes. Thus, though people may not like this species, from a wildlife point of view this species is a highly desirable part of the dune plant community.

Often mistaken for poison ivy, Virginia creeper *(Parthenocissus quinquefolia)* is a woody, deciduous vine that has 5-part leaves rather than that the 3-part leaves of poison ivy. On dunes this plant can be found growing prostrate over the sand, but it will also climb any shrubs or trees in the habitat, using tendrils that have disks that can attach to whatever they are climbing. Like poison ivy, the leaves start out small and deep red, change to green during the growing season, and change back to red or yellow before being



L Peragino photo

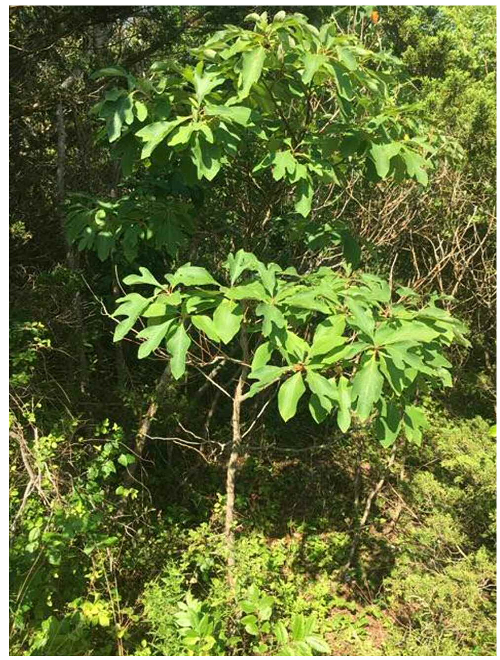
shed in the fall. This plant also helps stabilize dunes, both through its roots and through the dense network of stems that it spreads across the dune surface. In the fall it produces numerous blue berries that are a popular food for songbirds. Its leaves and branches also provide cover and nesting habitat for a variety of small birds and mammals (King and Henson 2005)

Eastern red cedar trees can grow as high as 40 feet, but usually they are much stunted when growing on dunes, rarely exceeding 10 feet tall. Its pyramid shaped branches and evergreen leaves form an important protective habitat, and its pale blue berries are eaten by a number of birds and mammals. The leaves, roots, and berries of the red cedar were used by Native Americans as a source for a number of natural remedies (USDA FS n.d.).

## Maritime Forest

As the distance from the ocean increases, the influence of salt spray lessens and soil quality increases, improving access to both water and nutrients. As this happens the dune thicket community transitions to maritime forest. Trees here tend to be smaller than their inland counterparts and often display a distinctive shape with a flat top and reduced growth on the side facing the onshore winds, giving them the appearance of being pruned. This is termed "salt spray pruning" because it results from reduced growth or death of those tree branches, leaves, and buds exposed to the salt spray carried by the onshore winds into these habitats. One of the most common trees in this habitat is American holly. The familiar bright red berries and green, shiny leaves with sharp pointed edges are a familiar sight during the winter holidays. While this species is evergreen, new leaves tend to replace old ones each spring, creating a rich carpet of decomposing leaves on the forest floor that helps contribute to improved soil quality. Holly trees have separate sexes, with male flowers forming on some trees – which will never set berries – and female flowers and fruits forming on others. Its dense branches and abundant leaves provide protection and habitat for a number of birds, many of which, along with mammals, feast on its berries.

Another common tree in the maritime forest is sassafras, with its distinctive aromatic leaves and deeply furrowed, reddish-brown bark. Each tree forms three different-shaped leaves – three-lobed and mitten-



**Sassafras** *Jeanne Heuser photo*

shaped when young or lower on mature trees, and unlobed at the top of mature trees (Burns and Honkala 1990). Sassafras forms small, yellow flowers in the spring, and like holly, there are separate male and female trees. The blue-black, oval fruits that form on long stems ripen in late summer and are eaten by a variety of birds, including species such as kingbirds and crested flycatchers that usually eat an insect-rich diet. Sassafras bark and roots have been used to make root beer and a variety of teas.

Many of the species seen in the shrub thicket, like eastern red cedar, beach plum, and bayberry, are also found in the maritime forest. Individuals in the forest often grow stronger and taller than their thicket counterparts in this less stressful habitat. The understory of the maritime forest is dominated by woody vines such as Virginia creeper, poison ivy, and greenbrier (Wetlands Institute 2005). Greenbrier *(Smilax rotundifolia)* gets its name from the sharp, curved thorns that grow along its green stems. The vine produces widely spaced round leaves with pointed tips and can grow tens of feet long as it climbs up trees and other plants in the forest. It produces small white flowers in summer and purple berries in fall on female plants (Chaney C. 2011).

Dune communities support a higher density of small mammals than other nearby habitats (Shure 1970). Cottontail rabbits, white-footed mice *(Peromyscus leucopus),* raccoons, skunks, and red foxes all use the thickets of the maritime forest and the forest itself for cover in the daytime and emerge at night to hunt for food in the forest and on the dunes themselves. Many birds, including mockingbirds and towhees, nest in the thickets and maritime forest while others, such as the scarlet tanager, yellow warbler, and rose breasted grosbeak, make use of the abundant supply of berries produced by the plants in this habitat to fuel their fall migration. The sight of thousands of tree swallows swooping low over the dunes in search of insects is a particularly memorable fall phenomenon. However, the real attraction of the dunes for these normally insect-eating animals is the bayberries. Migrating tree swallows have been found with more than 40 berries in their gut at any one time – quite a feat for such a small bird! Even in winter, dunes and the maritime forest host a number of bird species including the year-round resident yellow-rumped warbler and visitors such as snowbuntings (Wetlands Institute 2005). Attracted by the abundance of small birds and mammals, a wide array of predatory birds visits the dunes, including ospreys, Northern harriers, sharp-shinned hawks, American kestrels, peregrine falcons, and even snowy owls (in winter).

## Patterns of Species Diversity on Dunes

The series of somewhat predictable changes that happen over time in an entirely new habitat is called *primary succession.* Dunes are unusual in that the different steps in the process are often visible in one place at the same time. In areas where dunes are actively growing by accreting sand, the dunes nearest the ocean represent the youngest stages in the process with fresh sand delivered from the ocean, creating a brand new habitat. When the sand is first blown in from the beach, it is essentially sterile, though it may carry with it a small amount of nutrients held to each grain's surface by ionic bonds. The sand of the foredune is more or less pure mineral. Organic materials, which hold water like a sponge and provide a source of nutrients as they decompose, are more or less absent. The soil thus dries rapidly after storms and tends to heat and cool easily. The salt stress created by the constant rain of sea spray into this community, combined with the abrasive effects of the sand blowing onto the dune from the beach, makes this a very hard place to live. However, for the very small number of specialized species that live there, it provides some advantages, particularly in terms of lack of competition and relatively low levels of herbivory. Over time the dunes build out in front of the present-day community. What is today's foredune will eventually become a secondary dune and so on. Thus, as one walks inland on the dunes, one is generally moving into communities that were reclaimed from the sea longer and longer ago. Moving landward into these communities, the stresses created by salt spray and blasting from the windblown sand lessen. In addition, as the plants of the primary dune grow and die, their decomposing tissues are added to the soil, helping to build its organic content. As conditions improve, the species present help facilitate the establishment of others, and the diversity of species present increases. In addition, as soil richness and access to nutrients improve, the kind of plants present changes from grasses and short-lived plants to shrubs and eventually to long-living trees.

# Ecosystem Services of Dunes

Coastal dunes form the first line of protection for the communities behind them (e.g., uplands and wetlands such as interdunal swales and bayside tidal marshes) by reducing the energy of storm waves. Dunes play a vital role in protecting coastal areas from erosion, coastal flooding, and storm damage, as well as sheltering the properties and ecosystems behind them from wind and sea spray. Dunes also protect the tidal wetlands on the bayside of barrier islands and provide an important sand reservoir for the beaches themselves. Dune vegetation traps windblown sand, preventing it from being blown inland where it can a problem for homeowners and coastal infrastructure (roads, drainage, etc.) while helping build the dunes themselves.

In recent years the importance of coastal dunes in protecting the mosaic of natural and human communities behind them from the effects of projected climate change has been increasingly recognized (Nordstrom 2000). Expected relative sea level rise for the New Jersey coast between 1990 and 2100 is between 0.31 and 1.10 meters, with a median expected value for sea level rise in this region of about 0.71 meters (Cooper et al. 2008). If sea level rise occurs within the median range of this estimate, the result would be that 100-year storms (storms that statistically have a 1% chance of occurring in any given year) will happen 3 or 4 times more often in the future, and the resulting storm surges would inundate vast areas along the New Jersey coastline (Cooper et al. 2008, Lathrop and Love 2007). Other studies suggest that this would actually be at the low end of what we should expect. For example, Cooper et al. (2008) suggest "approximately 1% to 3% of the land area of New Jersey would be permanently inundated over the next century and coastal storms would temporarily flood low-lying areas up to 20 times more frequently." Similarly, Miller et al. (2014) suggest an expected rise in relative sea level of 1 meter along the New Jersey coastline, resulting in almost annual coastal floods. The presence of dunes significantly reduces coastal flooding, even during extreme storm events (Houser et al. 2008). Thus, careful management of healthy dunes can reduce the need for expensive and time-consuming rehabilitation in the future.

With careful management, dunes can be compatible with the habitat requirements of a variety of specially adapted plants and animals, including several beach species that are federally or state listed as threatened or endangered (e.g. seabeach amaranth and piping plover) and can act as a filter for rain and groundwater. In addition, dunes form habitat for a variety of animals, including migratory butterflies and song birds and a number of birds of prey. Dunes have a high aesthetic value for humans and have a rich cultural heritage both in terms of their use by native peoples and in modern times, as European colonization has its roots almost exclusively in coastal areas. Due to this, and their key role in protection of human infrastructure, in a recent economic analysis of different ecosystems (Costanza et al. 2006), dunes and coastal beaches were found to be, by far, the most valuable ecosystem in New Jersey on a per-acre basis.

# Vulnerabilities

## Reduced Genetic Diversity

New Jersey's coastal areas are typified by expensive multiuse infrastructure and high population densities. Consequently, dunes are managed to provide ecosystem services such as wildlife habitat and supporting services like flood and storm surge protection to the community. In most cases after significant coastal erosion, reconstruction of dunes occurs. The current practice is to pump sand from offshore to build beaches, which can further be bulldozed to form artificial dunes. Dune stabilization occurs through the placement of sand fences, other artificial barriers, or most commonly, planting with vegetation (Miller and Petersen 2006). Increasingly the goals of dune reconstruction for infrastructure protection and recreation have been linked with ecological restoration to provide a more functional, healthy, and sustainable dune.

**Failed dune planting** *Chris Miller photo*

Restoration, maintenance, and sustainability of barrier islands begins with a healthy dune system. The primary colonizer in this successional system is American beachgrass (*Ammophila breviligulata)*. Dunes, therefore, depend on the successful colonization and establishment of *A. breviligulata*. In situations where dunes are disturbed in anthropogenically developed areas, restoration efforts to reestablish stable dunes involve planting a single genotype of beachgrass identified as 'Cape' American beachgrass (Skaradek et al. 2003).

'Cape' American beachgrass was selected in the early 1970s by the USDA from a common garden and reciprocal transplant experiment with three other genotypes from the Eastern United States. 'Cape' was selected for its ease of propagation and aboveground performance compared to collections from Delaware ('Lewes' strain) and North Carolina ('Hatteras' and 'Bogue' strains). Overall, 'Cape' grew wider leaves and more culms than strains collected from Lewes, Delaware and Hatteras, North Carolina (Gaffney 1977). In virtually all maintenance and restoration activities along the natural range of *A. breviligulata,* from North Carolina to Canada and in the Great Lakes, 'Cape' is used to restore and maintain dune function (Skaradek et al. 2003; Miller and Petersen 2006). Often this variety performs very well, but not in all cases. For example, in the early 1990s dune restoration at Avalon, New Jersey resulted in the establishment of foredunes and the successful succession to maritime forest. However, in 1992, a dune restoration effort in Atlantic City, New Jersey, planted with 'Cape' experienced 100% mortality within two years of planting. Additionally, approximately one hundred other restoration sites along the Mid-Atlantic have experienced partial or complete mortality of 'Cape' plantings.

Mortality of 'Cape' plantings in a restoration setting can be attributed to several factors. First, timing of the planting is crucial, as noted in this manual and by the USDA planting guidelines (Miller and Peterson 2006). The timing of plantings corresponds to adequate soil moisture and favorable environmental conditions for bareroot plants to establish an adequate root system and mycorrhizal colonization. Secondly, sand-particle size can influence establishment. Dredged sand is often larger and not susceptible to movement, thereby limiting burial of the grass and reducing vigor (Maun and Lapierre 1984). Furthermore, sand-particle size is inversely related to water-holding capacity, so larger sand particles mean less water availability for bareroot plantings. The practice of artificially mounding sand into a dune to a height several meters above the water table further exacerbates the grass' ability to find water and establish a robust root system. Finally, other factors such as fungal endophyte and mycorrhizal infection, nematode root herbivory, and lack of genotypic diversity play roles in establishment (Emery and Thompson 2010; Emery and Rudgers 2011). Finally, the genotypic diversity of American beachgrass has the potential to affect all biotic and abiotic factors mentioned above, given the performance variation of different genotypes (Emery and Rudgers 2011).

Genetic diversity of American beachgrass in non-restored areas can be extensive. For example, plant populations in three locations spanning the entire coastline of New Jersey showed non-restored populations had high levels of genotypic diversity, whereas restored populations on constructed dunes had low diversity or only a single genotype.  Furthermore, 'Cape' was not found in native populations. Most foredune populations consisted of many small- to medium- sized clones. From a restoration perspective, genetically diverse plantings might increase restoration success. The current practice of genetic monoculture restoration does not mimic naturally occurring diversity and can result in reduced population performance, loss of community interactions, and altered ecosystem function.  Using locally sourced plants may influence the long- and short-term success of dune restoration.

## Invasive Species

The loss of dune habitats to human development means species specialized to these habitats are often already relatively rare.  Consequently, the additional threat posed by exotic and invasive species in these habitats is a matter of particular concern.  One such species in this regard is Asiatic sand sedge *(Carex kobomugi).* This species first arrived in New Jersey in the early 20th century and has spread rapidly, both through natural propagation and – for a period from the 1960s to the 1980s – deliberate propagation. In recent decades, the expansion of this species has been approximately exponential. For example, in 2008 there were 39.9 acres of dune infested by the sedge at Island Beach State Park – almost exactly double the amount that was present in 2002.  Similarly, there were 54 acres of the sedge at Sandy Hook – more than triple the area that was infested in that park in 2002. This sedge grows in extremely dense mats, with stem densities of over 600 stems per square meter and typical densities of 100-200 stems per square meter being observed. These densities are much higher compared to typical stem densities of American beachgrass with 40-50 stems per square meter observed. This dense growth rapidly crowds out other species. This results in the densities of native plants like American beachgrass and goldenrod being significantly reduced wherever the sedge grows. Many native plant species are completely absent from the dune once the

**Asiatic sand sedge monoculture** *Louise Wootton photo*

sedge invades. As the invasion matures, the plant forms more or less a monoculture on the dunes (Wootton 2003, Wootton et al. 2005, Burkitt and Wootton 2011).  Since native animals did not evolve with the sedge, few will eat it or use it for habitat. Thus, animals that depend on the native dune vegetation are likely to be negatively impacted by the decline in numbers and loss of the native plants from these areas.

Ecosystem resilience is defined as the ability of that system to maintain its function when faced with novel disturbance (Webb 2007). Biological diversity appears to be an important factor in determining the resilience of ecosystems and thus their ability to sustain themselves in the face of environmental challenges. The relationship between diversity and resiliency appears to derive from the apparent redundancy of species within healthy ecosystems (Peterson et al. 1998, Elmqvist et al. 2003). The presence of species with different but overlapping functions within an ecosystem, as well as of species operating at different scales, results in a variety of tolerances and responses to new conditions. The result is that, when diversity levels are high, at least some of the species are likely to be able to thrive and thus to maintain ecosystem services under whatever set of conditions prevail in that area at any point in time. A more biologically diverse ecosystem generally displays more resilience, or a greater ability to overcome a natural disaster or human-caused destruction (Naeem 1998). As previously discussed, invasion by Asiatic sedge decreases both the abundance and the number of native species (species richness and diversity) that characterize healthy dune ecosystems. Thus, invaded dunes are likely to be less resilient to future environmental changes or other challenges.

Because the sedge is able to grow farther into the beach than American beachgrass, the species also causes problems for beach-nesting birds such as piping plover (federally threatened) and least tern and black skimmer (state endangered). These species will only nest in open sandy areas between the high-tide mark and the vegetated portions of the dunes because the dense vegetation can provide places for their predators to hide. When the sedge pushes into the high beach, the birds will nest farther down the beach, putting their nests at higher risk of being lost to inundation during high spring tides and storms, and creating greater conflict with recreational beach users. In addition, plover chicks are known to use open, sandy corridors between vegetated dunes as pathways to more interior habitat suitable for foraging (Loegering and Fraser 1995). The dense growth pattern of the Asiatic sand sedge leaves few bare areas of dune, which cuts off these pathways for birds to move between habitats, which will further reduce survival of these already endangered species. The sedge can also compete with high-beach plant species such as seabeach amaranth (federally listed) and seaside knotweed (state listed).

As mentioned earlier, dune vegetation plays an important role in maintaining healthy dunes by trapping blowing sand and building the dune. Because the sedge is shorter in stature than native dune plants, it has been suggested that it might scavenge less sand at the front of the dune. Dunes invaded by this species may be wider and lower than dunes where native species thrive (Shisler et al. 1987, Pronio 1989). However, this is not well documented, and at least one recent study (Reo et al. in revision) suggests that dune heights may be similar in invaded dunes versus natively vegetated dunes.

The large-headed sedge *(Carex macrocephala)* has also started to move in to New Jersey's coastal dunes (Wootton 2007). Native to Asia and the Pacific coast of North America, this sedge seems to grow much less aggressively than the closely related Asiatic sand sedge, and thus is less of a threat to this habitat. Other non-native species in the primary dunes include dusty miller *(Artemisia stelleriana),* rugosa rose *(Rosa rugosa),* Russian thistle (*Salsola kali),* and crab grass *(Digitaria sangoinalis).* Dusty miller is a garden escapee species. Its leaves are covered with velvety white hairs that give them a grey green color. Even its yellow flower spikes are coated with a dense mat of white fur. The hairs help to protect the plant from wind, and thus help minimize loss of water to evaporation. Their light color also reflects light, helping to keep the plant cool in the intense heat of the summer. While exotic to New Jersey, this plant doesn't seem to be an aggressive invader of the dunes. Native to Asia, rugosa rose has attractive pink or white, fragrant flowers that are a source of pollen and nectar for a number of insect species, and the red rose hip fruits are a rich source of vitamins and sugars for birds and mammals. While this plant does have desirable properties, it is not as good at stabilizing dunes as the native shrubs that it often outcompetes, and thus is not a particularly desirable species in this community

**Large-headed sedge**
*Louise Wootton photo*

**Rugosa rose** *Louise Wootton photo*

(IPANE n.d.). Little is known about the ecological impacts of Russian thistle or crab grass in New Jersey dunes. However, these species have the potential to be a problem in the future, and their presence on dunes should be noted and monitored as a precautionary measure, especially in areas with known populations of threatened and endangered species.

Although not common on dunes, multiflora rose *(Rosa multiflora)* is of concern in the high dunes and maritime forest, since it is a truly invasive species. Multiflora rose forms dense thickets that exclude native plants through both above- and below-ground competition and can prevent the movement of larger animals. Like most roses, this plant has thorny stems and compound leaves. However, instead of creating individual larger blooms, this species forms clusters of sweet smelling white or pink flowers in summer. These flowers set to form small red fruits that are eaten by birds, spreading the plant to yet more habitats.

Within the maritime forest a few tree species, such as European privet *(Ligustrum vulgare)*, Japanese black pine, and autumn olive *(Elaeagnus umbellata)* can become invasive, outcompeting native tree species. However, it is the invasive vines that tend to be more problematic. Some common invasive vines include Japanese honeysuckle (*Lonicera japonica),* English ivy *(Hendera helix),* oriental bittersweet *(Celastrus orbiculatus),* and virgin's bower clematis *(Clematis flammula).* These vines smother the trees they climb, pulling down branches, and can lead to the entire tree being vulnerable to falling during wind events. They also create shade on the forest floor below, which can inhibit growth of native understory plants and germination and growth of seedlings of native trees. Other species such as garlic mustard *(Alliaria petiolata)* and porcelain berry *(Ampelopsis brevipedunculata)* invade the forest floor, competing directly with the native plants and tree seedlings.

## Human Impacts on Dunes

In 2000, New Jersey had the highest population density among the 50 states – 1,195 persons per sq mi in 2010 (NJ State Library 2012). The desirability of scenic ocean views combined with the high human population densities on the Atlantic Coast mean that coastal dunes and their associated maritime forests have been particularly impacted by development. Only 31.2 of the 130 miles of shoreline between Sandy Hook and Cape May Point have not been developed by humans (Farrell et al. 2013). Since many of the plant and animal species found in these habitats are found nowhere else, and often cannot survive in areas impacted by human development, contraction of these habitats means that those species are becoming increasingly rare.

Another way humans can impact dunes is through foot and vehicular traffic. Many coastal recreational activities require travel across or near dunes. Bathers, beach fishermen, bird watchers, and many others are drawn to these areas for recreation. As noted earlier, many of the dune species are highly intolerant to compaction from vehicular or foot traffic. Thus, even in protected habitats, humans are at risk of irreparably damaging the specialized organisms that live in these areas through their activities. Driving, raking, or walking near the toe of the dune must be strongly restricted since this can prevent the normal and healthy expansion of dunes into the high beach, as well as potentially damaging or killing rare and endangered species such as seabeach amaranth growing there. Movements across the dunes should be limited to designated pathways, and despite the human desire to shorten the route toward any destination, these paths should not run perpendicular to the ocean, since such pathways form funnels for the ocean's energy, promoting erosion of dunes and flooding of the communities behind them. Education and outreach programs as well as policing of dunes are needed to limit people's movements to designated pathways and to keep traffic away from the active dune front. As mentioned earlier, use of off road vehicles and mechanical beach rakes should also be avoided.

# Building and Planting Coastal Sand Dunes: Dune Vegetation

## Introduction

Vegetation plays a vital role in dune formation and stabilization. On windy days, sand grains get picked up by the wind and blow around. When those airborne sand grains hit an object, they stop blowing and fall to the ground. The leaves of beach grass and other plants on a dune act as collectors for blowing sand. Once on the ground, the grass blades help protect the sand from the breeze, so the sand grains tend to stay where they land and start to pile up, forming a dune. As the plants grow, they send out lots of roots and rhizomes that further trap and stabilize the sand, helping to make the dune stronger and more resistant to erosion. As a result, dune plants are a key component of an effective dune restoration plan.

Many native coastal plant species play a major role in the formation of sand dunes and also protect shoreline areas from erosion. These plants often produce foliage and deep root systems that assist in the formation of a sand dune over time. The foliage of these species reduces wind velocity and filters sand from the wind, and their deep root systems help to anchor dunes to their foundation. For example, as filtered sand piles up around dune plant species, new roots develop on the buried stems and new shoots emerge from the sand's surface. The end result is a dense mat of vegetation that anchors the dune below its surface and traps more windblown sand.

There are generally three zones of vegetation that form on coastal dunes. Each of these zones is exposed to different levels of soil salinity, which determine the types of plant species that occur within each zone. The frontal dune zone, which occurs closest to the ocean, contains several grasses and other herbaceous plants that are able to tolerate high exposures to salt spray. The backdune zone is located behind the frontal zone and supports trees, shrubs, and vines as well as grasses and other herbaceous plants. These species generally have lower salt tolerance. Farthest from the ocean is the maritime forest zone, which supports pines and hardwoods.

Along much of our highly developed coastline, we generally don't see all three dune zones. We generally see one or maybe two zones, such as in constructed dunes (berms) that have a trapezoidal shape which has a front, a wide crest (top,) and a sloping backdune.

### A Word about American Beachgrass

American beachgrass *(Ammophila breviligulata)* is currently the species that is most often utilized in dune plantings in New Jersey and elsewhere in the Northeast. Unfortunately, this species has very specific growth requirements and tends to thrive best in actively accreting sands in the frontal dune. After a few years, when the sand has become stabilized, the *Ammophila breviligulata* usually dies, yielding to other species that provide long-term dune coverage, if present, or leaving bare sand if no alternative "volunteer" species have colonized the area or been planted there in the interim. Coastal communities with fixed sand dune maintenance and replenishment budgets often choose the short-term convenience of working with one species over long-term ecologically correct approaches. However, it is shortsighted to plant only American beachgrass.Unfortunately, the ease by which this species' planting units establish and its low cost and short-term effectiveness have made it difficult to persuade landowners and municipalities to consider the use of other plant species for sand dune restoration. However, over the past 25-30 years or so, it has been observed that throughout its native range beachgrass is susceptible to decline after three to six years, especially when established on dredged sand in Army Corps of Engineers beach replenishment projects. In response to this problem, the Cape May Plant Materials Center of the USDA-Natural Resources Conservation Service (NRCS) has been focusing on testing and releasing additional plant species for diversifying sand dune plantings to the commercial nursery industry rather than relying on traditional beachgrass monocultures. In addition, work is being done to make local New Jersey ecotypes of beachgrass available commercially to broaden genetics beyond the single clone of 'Cape'.

## An Idealized Dune Planting

American beachgrass *(Ammophila breveligulata)* is best adapted in the foredune where sands are constantly shifting and occasional overwash occurs. Interplanting other adapted species on the backside of the foredune provides a seed source of additional plants to assist in the successional process. These species may include grasses such as bitter panicgrass *(Panicum amarum),* coastal panicgrass *(Panicum amarum var. amarulum),* switchgrass (*Panicum virgatum),* saltmeadow cordgrass *(Spartina patens),* coastal little bluestem *(Schizachyrium scoparium var. littorale),* and dune wildrye *(Elymus glabriflorus).* Species of forbs (herbaceous flowering plants) include seaside goldenrod *(Solidago sempervirens)*, partridge pea *(Chamaecrista fasciculata)*, beach pea *(Lathyrus japonicus),* and trailing wild bean *(Strophostyles helvola).* Many of these plant species are available from specialized nurseries as potted and/or bareroot plants (see Plant Selection sections of this document). Seeding techniques are also being developed for many of these species. For instance, coastal panicgrass has been successfully seeded between rows of beachgrass on beach replenishment projects in the Mid-Atlantic. Within three to five years, coastal panicgrass dominates much of the backdunes and provides the primary stabilization where beachgrass has lost vigor. Once the primary vegetation is established, natural recruitment will take place and increase plant diversity over time.

For dunes where adequate width is achieved (greater than 100 feet) and some salt spray protection is afforded, shrubs such as bayberry *(Myrica pensylvanica)*, beach plum *(Prunus maritima),* winged sumac *(Rhus copallina),* and groundsel (*Baccharis halimifolia)* can be added for long-term stabilization. These species are generally planted as containerized material. Shrubs need not be planted on as tight a spacing as the herbaceous plants but rather scattered throughout the planting area in more natural groupings to provide a seed source. Again, it is noted that woody species should not be planted in or near rare, threatened, and endangered species areas (not even in backdune areas), as they provide perches for avian predators.

Sand dune restoration is not as simple as establishing a native community of plants, but involves managing the sand budget (the ocean gives sand and takes it away). True coastal dune restoration must consider the natural dynamics of this ecosystem. The plant species inhabiting certain niches have evolved and adapted to these locations and require specific environmental conditions to survive establishment and persist.

As mentioned earlier in this manual, in all developed portions of the New Jersey coast designated as piping plover nesting areas, including all "protected zones" and "precautionary zones" (Figure 17), it is important that only native herbaceous vegetation be planted and that the areal extent and density of plantings be minimized to avoid conflict between plantings and the habitat needs of beach-nesting species. In such areas, periodic thinning of planted beach grass may be needed to maintain plant densities compatible with the use of those areas by rare, threatened, and endangered species (see targets in Table 1).

## Choosing and Acquiring Plant Materials

When choosing plant materials, consider using plant releases developed by the USDA-NRCS Plant Materials Program. These plant releases have been tested and found to establish successfully along the Mid-Atlantic coast. If NRCS plant releases are not available through specialty conservation plant suppliers, many commercial growers produce the desired species needed for dune plantings. For a list of commercial producers growing coastal vegetation, please see Appendix. This list will be posted/updated on the website of the USDA-NRCS Plant Materials Program at the following link: http://www.nrcs.usda.gov/wps/portal/nrcs/publications/plantmaterials/pmc/northeast/njpmc/pub/.

Although a fair number of plant species occur in natural dune systems, a smaller subset of those species is commercially available for projects. These are the species that are focused on in this document. Once the primarily vegetation is established, natural recruitment will take place and will increase plant diversity over time. However, it is most important to first establish those keystone plant species to provide stabilization and vegetative cover to catch sand and jump-start the successional process. These commercially available species are listed below:

**Frontal Dune Species** (* limited commercial availability)

- American beachgrass (*Ammophila breveligulata*)
- bitter panicgrass (*Panicum amarum*)*
- Potential future species for New Jersey: Sea oats (*Uniola paniculata*)* is a native, indigenous plant south of New Jersey in Maryland and Virginia. A cold-tolerant selection is being developed by the Cape May Plant Materials Center and will be available to growers.

**Secondary (Backdune) Species** (* limited commercial availability)

- coastal panicgrass (*Panicum amarum var. amarulum*)
- saltmeadow cordgrass (*Spartina patens*)
- coastal little bluestem (*Schizachyrium littorale*)*
- seaside goldenrod (*Solidago sempervirens*)*
- beach pea (*Lathyrus maritima*)*
- trailing wild bean (*Strophostyles helvola*)

# Building and Planting Coastal Sand Dunes: Frontal Dune Species

## 'Cape' American beachgrass (*Ammophila breviligulata*)

**Figure 18. 'Cape' American beachgrass *(Ammophila breviligulata)***

American beachgrass (*Ammophila breviligulata*) (Figure 18) is a native, cool-season grass also known as dune grass that grows most prolifically in the zone of accretion in the foredune area. Once the sand becomes stabilized, American beachgrass loses vigor and yields to other species that provide long-term cover and stabilization. However, it should still be a component of backdune plantings as a quick cover or nurse crop.

Foredune areas (essentially from the dune crest seaward) should be planted with 'Cape' American beachgrass (*Ammophila breviligulata*) culms in late winter to early spring, to maximize plant survivability and productivity. Culms should be planted in groups of two in a staggered pattern and should be planted 6 to 8 inches in depth depending on the length of the dormant stem. Ideally, three fourths of the length of the stem should be placed in the sand. The spacing of planting units will depend in the location in the dune profile of the planting. The densest plantings (12") should be in the most landward part of the dune. The mid-dune plants should be approximately 18 to 24 inches apart and the frontal dune plantings more widely spaced. This type of plant spacing results in a wider dune with a gentler slope in the front (O'Connell 2008) (Figure 19).

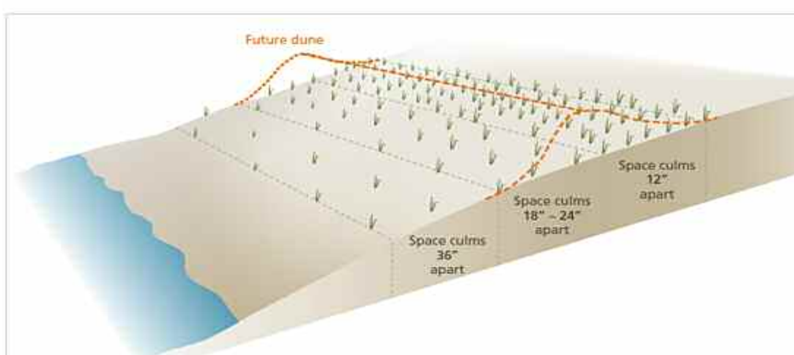



**Figure 19. Staggered spacing for American beachgrass dune planting.**

## Assessing Beachgrass Plant Quality

The growth of bare root beachgrass plants is not dependent on the presence of roots, but rather the little "node" or growing point located at the bottom of the plant. When you squeeze the bottom end of the culm, it should be hard, not soft. A hard stem indicates sufficient energy stored to facilitate the growth of the plant. Spindly and soft stems should either be discarded or combined with a good stem in a common planting hole (Skaradek, et al. 2003).

**Planting date:**
Bareroot-November to April
Plugs-November to June
**Method of establishment:** Transplants using 2 live stems placed bare-root or 1 multi-stemmed containerized plants. Use a dibble bar or similar tool.
**Material size:** > 8-12 inches in length.
**Planting depth:** Insert plant stems to a depth of 6 inches, pack soil firmly around the plant.
**Plant spacing outside of areas that support or are set aside as habitat for rare, threatened or endangered species:** 12-18 inches apart. Spacing will depend on how quickly complete coverage is needed.

***Notes:***

- If you are planting later in the season (past the dormant planting season), greenhouse-produced plugs are a good alternative. These are more expensive than a bare root stem (culm), but they may be planted into early June. Plants need to be installed deeply for better survival. For instance, beachgrass stems should be planted so two-thirds of the stem is in the sand. Planting 2 stems per hole is sufficient (the old recommendation was 3 stems). This is referred to as a planting unit.
- The planting densities recommended above are likely to degrade rare, threatened, and endangered (RTE) species' habitats over time, as dense stands of dune vegetation move down into the back beach. As a result, these planting practices should not be adopted in RTE species areas. Instead, dune creation and management in RTE species areas should follow the approved BMP if there is one, as well as guidelines in Maslo et al. (2011). Both of these will be superseded by the RTE dune guidelines, once complete. Dune management in RTE species areas should be guided by the site-specific recommendations of the Breeding and Nesting Bird program staff at New Jersey's Division of Fish and Wildlife Services.

The 'Cape' variety of beachgrass is currently the only commercially available beachgrass that is adapted to the northern Mid-Atlantic and Northeast. For more information on 'Cape' American beachgrass, consult the Plant Brochure and Plant Guide at the links below:
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/njpmcrb12116.pdf

http://plants.usda.gov/plantguide/pdf/pg_ambr.pdf

## Additional Beachgrass Genetic Material that is Commercially Available

**Bogue Germplasm** - This beachgrass material was originally collected in the Bogue Banks of North Carolina and was propagated and producted by a grower in North Carolina. This plant material has never gone through any variety-release program but it is available commercially from a few select growers in the Mid-Atlantic. It performs best in Virginia and the Carolinas and has fair to good performance in New Jersey. It can be a suitable substitute for 'Cape' if that material is not available.

**Vans Great Lakes ecotype** - This material is not recommended for planting in New Jersey since its origin is a freshwater environment along the Great Lakes in Michigan.

# Bitter Panicgrass (*Panicum amarum*)

**Figure 20**

Bitter panicgrass (*Panicum amarum*) (Figure 20) is a native, warm-season grass, closely related to upright coastal panicgrass but much more horizontal in its growth habit. This species is less adapted to accreting sand than beachgrass, so it is better adapted to secondary dunes or the backside of primary dunes. It is rather slow to establish from vegetative culms, but should at least be a small component in backdune plantings. Unlike coastal panicgrass, it does not produce a large quantity of viable seed in the Mid-Atlantic region.

Bitter panicgrass is a perennial warm-season grass with a horizontal growth habit that spreads slowly from short, strong rhizomes, initially forming open clumps. Over time these clumps can fuse to form a dense mat of vegetation. Since this grass produces little viable seed, it must be planted vegetatively.

**Planting date:** November to May.
**Method of establishment:** Potted and bare-root plants are available commercially. Freshly dug root tillers (sprigs) or rooted stem cuttings can also be obtained from vigorous stands.
**Material size:** $\geq$ 6 inch stem length with a minimum 2 nodes.
**Planting depth:** Place sprigs at a 45 degree angle in an 8 to 10 inch hole or slit leaving the top 6 to 10 inches of stem exposed. Plant tillers (sprigs) so the roots are well distributed in moist soil and the crowns are covered with one half to 1 inch of soil. Pack soil firmly.
**Plant spacing outside of areas that support or are set aside as habitat for rare, threatened, or endangered species:** Tillers (sprigs) should be planted in rows 6 to 8 feet apart and spaced about 18 inches apart in the rows.

**'Northpa' –** This is an NRCS plant release from the Brooksville, Florida, Plant Materials Center. The origin of this genetic material is North Carolina. No other commercial sources adapted to New Jersey are available for this species.

For more information on 'Northpa' bitter panicgrass consult the Plant Release and Planting Guides at the links below:
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/flpmcrb5053.pdf

http://plants.usda.gov/plantguide/pdf/pg_paam2.pdf

# Sea Oats (*Uniola paniculata*)

**Figure 21**

Sea oats (Figure 21) is a southeastern U.S. native perennial. It is an erect, rhizomatous, and colonizing grass that produces an extensive underground root system. This species is the most important plant on frontal dunes along the southeastern coast. From Virginia into Maryland, it intergrades with American beachgrass. It flourishes best where sand is drifting and accumulating. It persists as a perennial cover after the sand has stilled but dies back to the ground over the winter. Very little to no seed is produced by most seed heads; what little is produced is readily eaten by birds. Only rarely is reproduction by natural germination of seed observed.

**Planting date:** April to June (late spring-early summer)
**Method of establishment:** Potted plants and bare-root stock are available commercially and form vigorous stands. Hand planted.
**Material size:** $\geq$ 30-inch stem height.
**Planting Depth:** Plant 2 inches below the nursery grown depth.
**Plant Spacing outside of areas that support or are set aside as habitat for rare, threatened, or endangered species:** Use an 18 to 36 inch row spacing with plants placed 18 inches apart within a row.

***Note:*** Currently, commercially available genetic stock of this species from growers in the Carolinas would not be adapted long term to our climate in New Jersey. It may live one season or for a few seasons but would most likely die in the first harsh winter. The Cape May Plant Materials Center is testing a cold-tolerant strain that should be available in a few years for planting in our climate. Consequently, in future years an adapted sea oats should be released to the nursery industry for planting in Maryland, Delaware, and southern New Jersey.

# Building and Planting Coastal Sand Dunes: Backdune Species

## 'Atlantic' Coastal Panicgrass (*Panicum amarum var. amarulum*)

**Figure 22**

Coastal panicgrass (Figure 22) is a warm-season bunch-like grass that is a post-stabilization species thriving from the crest of the frontal dune to inland sites. It is the only dune stabilization species that has been directly seeded onto sand dunes successfully. Potted plants and stem divisions can also be successfully established on these severe sites. The annual foliage emerges from a deep fibrous perennial root system with short lateral rhizomes. The seed is eagerly sought by doves and quail. Volunteer seedlings occasionally occur when the soil is undisturbed.

**Planting date:** March to May
**Method of establishment:** Transplant using single bare-root or containerized seedling or division; 12 to 18 inches tall, planted by hand. By seed, it can be hand broadcast/incorporated or planted using a garden seeder (single row, push-type), mechanically operated drill, or drop seeder.
**Material size:** 12 to 18 inches tall seedlings or rooted divisions
**Planting depth:** Plant tillers (sprigs) so roots are well distributed in moist soil and the crowns are covered with one-half to 1 inch soil. Pack soil.
**Plant spacing and seeding rates:** Tillers (sprigs) should be planted in rows 6 to 8 feet apart and spaced about 18 inches apart in rows. About 5,000 tillers per acre are required for this type of planting

***Note:*** In areas where the height of the vegetation is not a concern, coastal panicgrass (up to 4 ft. tall) may be seeded into the sand with a single row, garden type planter. With seed, use 5 to 8 lbs/acre drilled. The seed must be placed at a 1.5 to 2 inch depth for optimal germination. Ernst Conservation Seeds in Meadville, Pennsylvania, sells coastal panicgrass seed. For a list of commercial producers growing coastal vegetation, please see Appendix. This list will be posted/updated on the website of the USDA-NRCS Plant Materials Program at the following link: http://www.nrcs.usda.gov/wps/portal/nrcs/publications/plantmaterials/pmc/northeast/njpmc/pub/

For more information on 'Atlantic' coastal panicgrass consult the Plant Release and Planting Guide at the links below: http://www.nrcs.usda.gov/Internet/ FSE_PLANTMATERIALS/publications/njpmcrb12119.pdf

http://www.plant-materials.nrcs.usda.gov/pubs/njpmcbrpaam2.pdf

# ‘Avalon’ Saltmeadow Cordgrass (*Spartina patens*)

**Figure 23**

Although typically associated with tidal salt marshes, saltmeadow cordgrass (Figure 23) also naturally occurs in the secondary and backdune areas. Predominately inhabiting inter-dune troughs and low blow-out areas, it is dominant in these micro-sites since most other sand dune species cannot tolerate wet to saturated soil conditions. The trailing rhizomes of saltmeadow cordgrass are slender but form dense mats near the surface. It is vegetatively established on normal sites using freshly harvested stems (culms) or containerized plants on severe locations. It does not require the sand accumulation that beachgrass does and in fact will not tolerate too much deposition. It is one of the species that invades dune overwash areas after storm events.

**Planting date:** May 1 to June 15

**Method of establishment:** Transplant using 3 to 5 live stems placed bare-root or containerized; can be hand placed or planted with vegetable planter.
**Material size:** ≥ 12 inches.
**Planting depth:** Plant 2 inches below the nursery grown depth.
**Plant spacing:** Use 18 to 36 inch spacing, depending on the severity of the planting site.

***Note:*** The origin of the ‘Avalon’ release is Avalon, New Jersey.
For more information on ‘Avalon’ saltmeadow cordgrass consult the Plant Fact Sheets at the links below:
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/njpmcrb12127.pdf

http://plants.usda.gov/plantguide/pdf/pg_sppa.pdf

# ‘Dune Crest Germplasm’ Coastal Little Bluestem (*Schizachyrium littorale*)

Coastal little bluestem (Figure 24) is a native, warm-season, perennial grass that spreads by seed and short rhizomes. Found in scattered open clumps in the back dunes, it rarely forms a solid stand, but is found mixed in with other species such as partridge pea, beach heather, and beach pea. This bluestem also provides habitat for small mammals, shorebirds, and migratory birds.

**Planting date:** March to May.
**Method of establishment:** Transplant single potted plants and hand place or plant with vegetable planter.
**Material size:** ≥ 2 inch plug
**Planting Depth:** Place root ball 2 inches below the nursery grown depth.
**Plant spacing:** Container grown or bare-root plants should be planted on 2 to 5 foot centers on the primary dune ridge and back sides and the more stable dune and swale areas behind the primary dune. Coastal little bluestem may be interplanted with coastal panicgrass, saltmeadow cordgrass, seaside goldenrod, or partridge pea to enhance habitat diversity and conservation effectiveness.

**Figure 24. Coastal little bluestem close up.**

**Coastal little bluestem in Avalon backdune**

Coastal little bluestem is a coastal variant of the inland little bluestem. It only occurs in backdune areas where the sand has been stabilized. Because it is a bunch-type grass (unlike the three species described above), it usually occurs in open stands with bare sand between the clumps. Maximum height is 1.5 to 2 feet tall. A Mid-Atlantic ecotype was released by the USDA-NRCS, Cape May Plant Materials Center in 2007, but although supplies have been growing with time, it is not available in large quantities through commercial nurseries.

http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/njpmcrb12124.pdf

http://plants.usda.gov/factsheet/pdf/fs_scli11.pdf

## ‘Monarch Germplasm’ Seaside Goldenrod (*Solidago sempervirens*)

**Figure 25. Seaside goldenrod**

Seaside goldenrod (Figure 25) adds color and variety to a dune planting. This perennial forb is a major food source on the fall migration of the monarch butterfly. From its inconspicuous green basal leaves from winter into early summer arises a brilliant yellow flower cluster in early fall. Although often blamed for causing allergies, it is actually an insect-pollinated plant. Ragweed is the real culprit of these allergies.

**Date:** March 1 to May 15

**Planting Unit:** One bare-root or potted plant

**Depth:** Two (2) inches below the nursery grown depth

**Method:** Hand placed or vegetable planter

**Size:** ≥ 12 to 18 inch stem

**Spacing:** 24 to 36 inch row spacing with plants placed 24 inches apart within a row. Plant in the backdunes where sand is stable. May be interplanted with switchgrass, coastal panicgrass, saltmeadow cordgrass, and beach pea or partridge pea.

http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/njpmcrb12132.pdf

http://plants.usda.gov/plantguide/pdf/pg_sose.pdf

## Partridge pea (*Chamaecrista fasciculata*)

Partridge pea (Figure 25) is a native, warm-season, annual legume. This plant reseeds itself for one to three years, but will gradually disappear without maintenance. Soil disturbance is necessary to maintain this species. This species is commonly found on backdunes, and its seeds are particularly important to wildlife because they remain in a sound condition throughout the winter into early spring.

**Figure 26**

**Planting date:** March to June
**Method of establishment:** seed
**Material size:** N/A
**Planting depth:** One half inch
**Planting rate:** Drill 4 lb/acre of scarified seed.
For more information on partridge pea consult the link below:
http://plants.usda.gov/plantguide/pdf/pg_chfa2.pdf

## Additional plants that have limited commercial availability

The following is a list of supplemental plant species that are difficult to find from commercial sources. However, the Cape May Plant Materials Center is making an effort to eventually make these plant species more readily available from commercial sources.

### Beach Pea (*Lathyrus maritimus*)

Beach pea is a native, perennial, leguminous vine. It is often found interspersed with grasses on the backside of the frontal dune or in backdune areas. Its flowers vary in color from purple to magenta and are produced throughout the growing season from June to September. The primary means of spread is by rhizomes, although some seeds are produced in pea pods. This species ranges no farther south than coastal New Jersey. Only plants are available commercially; however, it has the potential to be included in dune seeding mixtures in the future.

### Bearberry (*Arctostaphylos uva-ursi*)

Bearberry serves a dual role on sandy soils: as a beautification plant and a critical area stabilizer. The thick, horizontal, vegetative mat and evergreen character are what make bearberry a very popular ground cover. It is often planted around home sites, sand dunes, and sandy inland slopes. The fruit it produces is eaten by a few species of songbirds and game animals.
http://plants.usda.gov/factsheet/pdf/fs_aruv.pdf

### Beach Heather *(Hudsonia tomentosa)*

Beach heather is a low, spreading shrubby plant with scale-like leaves that resemble a cedar tree and are densely covered with short, whitish hairs. It rarely grows over a foot tall and prefers backdune areas where the sand is stilled. Difficult to propagate from cuttings.
http://plants.usda.gov/factsheet/pdf/fs_huto.pdf

### Trailing Wild Bean or Fuzzy Bean (*Strophostyles helvola*)

Trailing wild bean is a native, annual trailing vine that has a characteristic bean flower and is leguminous. It may be instrumental in jump starting the plant successional process on dunes, even though it has a low capacity for stabilizing sand. It is being investigated for its use in a sand stabilization seed mixture.
http://plants.usda.gov/plantguide/pdf/cs_sthe4.pdf

### Prickly pear cactus (*Opuntia compressa*)

This is the only cactus found in New Jersey. It often forms spreading mats and in summer produces big pale yellow flowers with red centers and reddish fruits which are edible in the fall.

### Dune wildrye (*Elymus glabriflorus*)

Dune wildrye is a native, short-lived, upright cool-season grass that grows in somewhat protected areas of the backdune. The seed head looks like the agricultural small-grain rye plant. It is tolerant of dry alkaline soils. Because of its good seedling vigor, it has the potential to be used as a nurse crop for dune plantings/seeding. However, a commercial seed source is not available and will need to be developed. http://plants.usda.gov/plantguide/pdf/pg_elgl3.pdf

## Recommended Plant Specifications for Specific Coastal Species

Using vegetative transplant materials is considered one of the most economically effective ways to obtain planting stock for restoration projects. Vegetative transplant materials are described as the production and establishment of new plants by means other than seeds. Vegetative transplant materials commonly used for coastal restoration include bare-root slips and plugs, rooted and unrooted stems, rhizomes, and stolons (runners).

When considering the use of vegetative materials for restoration projects, the following information should be considered.

### Plant Materials

Determining the type of plant materials needed is directly related to the plant species and the targeted restoration site. In general commonly used plant materials include:

**Bare-root slips or plugs**

These include a single or multi-stem plant pulled from a donor stand. Materials are usually bare-root with little or no soil remaining around the roots. Bare-root plugs should have a root mass of not less than 2 inches in diameter at the root crown with a minimum of 4 roots per plug.

**Rhizomes and stolons (runners)**

Rhizomes are horizontal underground stems that can send out both shoots and roots at nodes and buds. Stolons are stems that grow horizontally above the ground and may produce roots and shoots at the nodes or buds. Rhizomes and stolons should have a minimum of two nodes or buds to be considered planting material. Sprigging is a commonly used term when referring to the planting of rhizomes and stolons to establish a site.

**Rooted and unrooted stems**

These include above ground aerial stems that when placed in contact with the soil have the ability to root at stem nodes. Rooted and unrooted stems should have a minimum of two healthy nodes or buds to be considered planting material.

Vegetative materials for restoration are usually obtained from two types of sites, the first being an existing donor native site (wetland, dunes, etc.) and the second being from an established commercial nursery pond or field. Removing vegetative plant materials from a donor native site (wetland, dune, etc.) is not recommended but may be an option if commercial supplies are limited. Removing plants from natural sites regardless of the care taken in frequency, spacing, and location of plant removal will eventually affect the health and vigor of the donor stand. In addition, removal without applicable permits may be in violation of state and federal regulations.

Harvesting vegetative materials from a commercial nursery site (ponds and fields) is recommended due to multiple benefits including the following:

- donor plants are usually an improved variety with proven traits
- sites are more easily accessible
- they have increased health and vigor
- less chance of insect or disease problems
- harvest numbers are more easily obtained
- will not damage or impact natural communities

In order to establish a commercial nursery site, propagation material is needed in the form of starter transplants. Starter transplants may be in any of the vegetative forms described above. Starter transplants may also be obtained from a donor native site (wetland, dune, etc.) or from an existing established commercial wetland pond or field. It is recommended that starter transplants needed for the establishment of a commercial nursery site also be obtained from an existing commercial nursery site.

To supply adequate quantities and quality of materials, donor sites need to be established for a period of time for the parental donor plants to develop adequate top growth and below-ground root mass. Most vegetatively harvested materials are harvested from the new growth of the original transplants. Plants must be viable and actively growing when removed from the donor site. In addition, plants need to be free of defects, disfiguring, sun scalding, disease, insects, insect eggs, and insect larvae or other forms of infection or infestation.

Refer to Table 3 for recommended specifications for commonly produced vegetative transplant materials for use in coastal restoration.

## Salt Hardening

If planting in an area with high salinity, it is recommended that plants be salt hardened. Salinity hardening levels will vary according to planting site conditions. However, hardening plants to 12 parts per thousand (ppt.) is a general rule when working in brackish to lower-saline conditions. Plants should be salt hardened to a minimum level of 12 ppt for at least 14 consecutive days under ponding conditions. Plants need to stay salt hardened at the minimum salt level and the minimum hardening duration to within three weeks prior to delivery and planting.

## Shipping and Handling

Vegetative material should not be dug or harvested earlier than 48 hours prior to time of delivery. Plants should be packed for delivery in such a manner as to ensure protection against climatic, seasonal, or other injuries during transit. A variety of methods for packing includes wrapping with burlap, sphagnum moss, or paper; dipping in water absorbing gels (polymers); or a combination of materials. Special care should be taken for prompt delivery and careful handling in loading and unloading. Plants need to be transported in an enclosed truck or trailer, or they may be moved in an open trailer if sufficient wind protection (netting) is provided to prevent damage to sensitive leaves.

Plants may be cut to facilitate transportation but stems should not be cut shorter than half the normal mature plant height. Stems should not be broken or physically damaged during transport. In addition, plants should not show signs of water stress such as displaying dry wilted leaves and/or stems. Plants need to maintain their stem and leaf rigidity at all times, indicating adequate moisture and low stress. Vegetative materials should be planted within 24 hours following delivery unless proper storage conditions (wet, cool) are provided.

## Plant Form Descriptions

**Bare root –** these are plants that are field dug with most of the native soil shaken off for easy transport to the planting site. Bare-root materials are generally cheaper than pot grown material; however, they show decreased survival especially when planted later than recommended. American beachgrass is commonly planted as bare-root stems (culms) but is increasingly available as plugs. See an example below.

**2 x 2 inch plugs –** these are the nursery standard plugs generally grown in flats of 32. These plugs are rooted in a potting medium and are 2 inches deep and 2 inches across diagonally. This product is intermediate in cost between bare root and deep plugs.

**Book planters/Deep plugs -** these plugs are grown in inserts that open like a book for easy retrieval. Plugs generally range 4 to 7.5 inches deep.

**Figure 27**

Nursery-grown container stock is generally the most reliable and ecologically appropriate way to obtain plant materials for restoration projects. When obtaining container-size plant materials, following the information in Table 3 should be considered.

Table 3

## Recommended herbaceous species for coastal dune restoration outside of areas that support or are set aside as habitat for rare, threatened, or endangered species

| Species/Planting Zone | Recommended Planting Material | Comments/Considerations |
|---|---|---|
| **American Beachgrass**<br>*Ammophila breviligulata*<br><br>Plant through dune planting area,<br><br>Will persist and thrive best on frontal dune | Field grown bare-root culms (stems): plant only during dormant season (November to March).<br><br>Nursery grown plugs: may be planted into June as long as some soil moisture is present, | Recommended plant spacing: Generally 1 to 1.5 ft. centers within a row. There should be a spacing of 1.5 ft. between rows with staggered plant spacing except where plover nesting is present or has the potential for nesting.<br><br>Variety recommended: `Cape'<br>Origin: Cape Cod, Massachusetts |
| **Bitter Panicum**<br>**Bitter Panicgrass**<br>*Panicum amarum*<br><br>Plant on mid-upper areas of backdune, | Nursery grown rooted cuttings<br><br>Dormant bare-root stems | Recommended plant spacing: 2 – 3 foot center. Plant with beachgrass due to soil binding abilities and to form stable dune matrix.<br><br>Recommended planting percentage of 20% bitter panicgrass, 80% American beachgrass<br><br>Variety recommended `Northpa'<br>Origin: North Carolina |
| **Sea Oats**<br>*Uniola paniculatata*<br><br>Plant on mid-upper areas of frontal and back dunes. | Plant rooted containerized material for best success, | Currently not available for planting in New Jersey. However, a cold-tolerant variety may be available in the future. |
| **Coastal Panicgrass**<br>*Panicum amarum var amarulum*<br><br>Plant on dune crest to backdune areas. | Dormant bare root propagules<br><br>Nursery grown plugs or containers<br><br>Seed may be drilled between rows of vegetatively planted beachgrass. Seed should be place 1.5" to 2.0" in depth. | Recommended plant spacing: 2 foot centers.<br><br>Drill seed at 5 to 8 lbs./ac.-1.5 to 2.0 inches deep in the sand<br><br>Variety recommended: Atlantic<br><br>Origin: Virginia |
| **Saltmeadow Cordgrass**<br>*Spartina patens*<br><br>Mid to upper areas of frontal and backdune, as well as coastal bay shorelines | Dormant bare root propagules from November to March only<br><br>Plant nursery grown plugs or containers, | Recommended plant spacing:<br>2 to 3 foot centers interspersed with American beachgrass<br><br>Recommended variety: Avalon<br><br>Origin: New Jersey |

| Species/Planting Zone | Recommended Planting Material | Comments/Considerations |
|---|---|---|
| **Coastal Little Bluestem** *Schizachyrium littorale*<br><br>Plant on backdune areas only. Will not tolerate accumulating sand. | Plant nursery grown plugs or containers. | Plant on three foot centers interspersed with American beachgrass, coastal panicgrass, and saltmeadow cordgrass.<br>Selection recommended: Dune crest germplasm<br>Origin: New Jersey, Delaware |
| **Seaside Goldenrod** *Solidago sempervirens*<br><br>Upper areas of frontal dune and backdune | Plant nursery grown plugs or containers. | Plant plugs of nursery grown material. Successful seeding has not been accomplished yet.<br>Selection recommended: monarch germplasm<br>Origin: New Jersey, Delaware |
| **Partridge Pea** *Chamaecrista fasciculata*<br>**Trailing Wild Bean** *Strophostyles helvola*<br>**Beach Pea** *Lathyrus maritima*<br>Dune crest and backdune | These species are most likely only available commercially as seed.<br><br>Limited availability | These species should be interplanted in the backdune area to increase plant diversity and improve soil health as they are leguminous, nitrogen fixing plants. Seeding techniques haven't completely been worked out yet. |

## Environmental Considerations

In or near rare, threatened, or endangered species habitats, beach management goals supporting recreation and tourism and providing storm and flood protection to human communities and infrastructure need to be balanced with the need for maintenance of habitat for rare/listed species. As noted earlier in this manual, Section 7(a)(2) of the ESA requires federal agencies that authorize, fund, or carry out specific projects (such as projects that implement recommendations in the Manual) to consult with the U.S. Fish and Wildlife Service if a proposed action may affect any federally listed species. Section 9 of the Act applies to both federal and non-federal activities and prohibits unauthorized taking of listed species. This includes significant habitat modification or degradation that results in the killing or injury of listed wildlife by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. Consequently, in areas that support or are set aside as habitat for rare, threatened, or endangered species, dune plantings should only be undertaken when clearly needed for storm protection and, when needed, should be designed to avoid the creation of over-stabilized dunes and the encroachment of dense vegetation into the high beach zone. Dune plantings should avoid creating cover, den sites, or perches for predators in both foredune and backdune areas. For example, woody species should not be planted in or near habitats for rare/listed species. Managers planning dune restoration projects in such areas should contact the Endangered and Non-Game Species Program (ENSP) and the U.S. Fish and Wildlife Service early in the planning process to develop and implement appropriate Beach Management Plans (BMP) for these areas, including the nature and densities of the plants used in the dune restoration or enhancement project.

# Building and Planting Coastal Sand Dunes: Trees and Shrubs on Backdunes

Over time, as sand dunes become stabilized, shrubs and trees begin to colonize backdune areas. On the barrier islands of the Mid-Atlantic coast, maritime forests infrequently occur behind primary and secondary dune zones. The major function of tree and shrub vegetation on sand dunes is permanent structural stabilization. The USDA-NRCS Plant Materials Program has released a few coastal shrub cultivars to the growers industry. In addition, a few other commercial growers readily supply coastal shrub and/or tree species. For a complete list of plant vendors supplying needed species, please consult the Seed & Plant Vendors Guide at the following website address: http://www.nrcs.usda.gov/wps/portal/nrcs/main/plant materials/pmc/northeast/njpmc/

## Woody Plants for Secondary Dune Stabilization

In addition to plantings of grass and forbs, where there is suitable habitat (largely secondary and tertiary dunes) in areas that are not used or set aside as habitat for rare, threatened, or endangered species (RTE), randomly distributed shrub clusters should also be planted about 25 feet apart from one another as habitat features allow. Ideally, clusters should comprise three to six shrubs planted within 5 feet of one another, and include species such as "Wildwood" northern bayberry *(Morella pennsylvanica)* and "ocean view" beach plum *(Prunus maritima).* Woody species should not be planted in or near RTE species areas, as they provide perches for avian predators.

Many woody plants are adapted to secondary coastal dunes. Where humans or storms have not destroyed the vegetation, trees, shrubs and vines flourish and collectively provide excellent erosion protection. The permanent vegetation on areas other than the frontal dune will most certainly contain woody species. The most abundant native woody plants along the Mid-Atlantic coast are bayberry, wax myrtle, beach plum, highbush blueberry, inkberry, native roses, and choke cherry. The woody species recommended for planting are bayberry, wax myrtle, beach plum, winged sumac, and eastern red cedar. The survival rate for woody seedlings transplanted in dune sand is often lower than when planted in the general landscape. Growth may also be poor, unless efforts are made to enhance the environment into which the seedlings are transplanted and must live.

Desiccation of the plants during the establishment period undoubtedly accounts for some of the loss. The following steps are recommended to reduce desiccation and improve survival when transplanting adapted woody species onto sand dunes.

Woody plants provide protection from the wind. This is best accomplished by planting into established stands of ‘Cape’ American beachgrass or other herbaceous plants. Protection provided by buildings is also useful. Erection of a low barrier such as wood shingles around each plant is also effective.

Another step to reduce desiccation is altering the composition of the sand into which the seedling will be planted. This is accomplished by mixing one half gallon of organic material such as peat moss with about twice as much sand. To do this, dig a hole about 8 x 8 x 8 inches, place the organic material in the hole, and mix it with the sand as the hole is filled. This can be done at planting time or well in advance of the planting date.

Place the plant in the center of this amended hole slightly deeper than the plant grew in the nursery. Late fall or early spring is the best time to plant. The use of container-grown plants is highly recommended and may eliminate the need for organic amendments. Fertilizer at planting time is not recommended since it may reduce the survival rate.

## General Guidelines for Planting Trees and Shrubs

**Planting date:** March 15 to April 30
**Method of establishment:** Transplant 1 or 2 year bare-root seedlings or containerized transplants.
**Material size:** $\geq$ 12 inches tall
**Planting depth:** Plant 2 inches below the nursery grown depth.
**Plant spacing:** Space 4 to 6 feet apart; off-set (stagger) rows for maximum protection.

***Note:*** To ensure establishment (first two years) all competing vegetation must be removed from within 2 feet of each plant; it is important not to fertilize surrounding vegetation that could potentially out-compete the tree or shrub.

### SHRUBS

#### Bayberry (*Morella pensylvanica)*

Bayberry is an upright, salt-tolerant woody shrub forming thickets 6 to 7 feet in height, less in exposed seashore conditions. The aromatic dark-green leaves, 2.5 to 4 inches long, may hang on the twigs through most of the winter. The clusters of waxy gray-white fruit develop from inconspicuous flowers, which bloom in the early spring from second-year stems. The fruit ripens in October and remains on the plant well into winter. This species is dioecious, meaning there are separate male and female plants. Once this shrub has become well established, it will slowly creep with rhizomes forming dense thickets. This plant fixes atmospheric nitrogen which helps it survive in stressed environments such as sand dunes and other sterile soil conditions.

Both common bayberry and the 'Wildwood' variety are commercially available.
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/njpmcrb12118.pdf
http://plants.usda.gov/factsheet/pdf/fs_mope6.pdf

A related species is wax myrtle (*Morella cerifera*), an evergreen shrub. Southern New Jersey is the northernmost extent of this species. It has many of the same attributes as bayberry.
http://plants.usda.gov/factsheet/pdf/fs_mypu.pdf

#### Beach plum (*Prunus martima)*

Beach plum is a low-spreading shrub that is generally only a few feet high due to wind pruning but may reach heights of 15 feet in a more sheltered area. Snowy white flowers are produced in late April to early May with fruit ripening in late August to early September. The fruit is prized by wildlife and humans alike. It is suitable for making jams and jellies.

Common beach plum and the 'ocean view' variety of beach plum are commercially available.
http://www.nrcs.usda.gov/Internet/FSE_PLANTMAT

**Beach plum** *Louise Wootton photo*

ERIALS/publications/njpmcrb12123.pdf

http://plants.usda.gov/factsheet/pdf/fs_prma2.pdf

### Winged sumac *(Rhus coppallina)*

Winged sumac is a native, deciduous, large shrub that rarely exceeds 10 feet in height. It has alternate compound leaves 16 to 24 inches long with a winged leafstalk. Compact clusters of greenish-yellow flowers bloom from July to September. Fruits mature later in the fall. The fruiting head is a compact cluster of round, red, hairy fruits called drupes. Sumac also makes good ornamental plantings and hedges because of its brilliant red fall foliage. It is best used on drastically disturbed sites where pioneer species are desirable.
http://plants.usda.gov/factsheet/pdf/fs_rhco.pdf

### Virginia rose (*Rosa virginiana)*

Virginia rose is an upright shrub growing between four to six feet tall. The glossy dark green foliage develops excellent yellow to red fall color. This species bears fragrant pink flowers that are 2 to 3 inches in diameter and occur in clusters of five to eight. It is a good alternative to rugosa rose, which is a non-native rose that has invasive tendencies.
http://plants.usda.gov/plantguide/pdf/cs_rovi2.pdf

## Trees on Dunes

**Sassafras** *Jeanne Heuser photo*

In a highly developed and expansive dune system, a maritime forest can exist that has predominantly tree and shrub species. This unique ecosystem occurs in New Jersey at Sandy Hook, Island Beach State Park, and as a small fragmented forest in Avalon, New Jersey. Some species that occur in the maritime forest include eastern red cedar *(Juniperus virginiana),* American holly *(Ilex opaca),* hackberry *(Celtis occidentalis),* black cherry *(Prunus serotina),* sassafras *(Sassafras albidum)*, pitch pine *(Pinus rigida),* and loblolly pine *(Pinus taeda)* in extreme southern New Jersey.

# Prohibited Species: What NOT to Plant

The new NJDEP Coastal Management Zone Regulations specify that dunes in New Jersey will be planted with native species only. What follows is a list of non-indigenous and/or non-native plant species that should **NOT** be planted on dunes.

**European beachgrass** (*Ammophila arenaria*) – While this is not available locally, it is available online and from catalogs for import from California and Oregon but would be devastating to the local ecology if planted here.

**Dunegrass** *(Leymus mollis)* – This is a native species to North America but is not indigenous as far south as New Jersey. It occurs from Massachusetts through the Canadian Maritimes and in the Pacific Northwest. This plant would not be adapted to our hot, dry summers and would not thrive locally.

**Blue lyme grass** (*Leymus arenaria)* – This is a non-native, ornamental, coastal landscaping grass that is not an appropriate plant species for dune stabilization. It has blue-green leaves and is grows horizontally. It appears similar to bitter panicgrass, a native coastal stabilization grass.

**Northern sea oats** *(Chasmanthium latifolium*) – This speces is also known as wood oats. Although the common name implies that it grows on the dune, this species is actually a forested, floodplain species that needs some shade and moisture to survive. It gets its name from the likeness of its seedhead to sea oats. Once a genetically adapted species is made available for New Jersey, sea oats *(Uniola paniculata)* would be an appropriate species. Currently, sea oats is not permitted due to the lack of commercial availability of a cold-tolerant variety of this species that could survive New Jersey winters.

**Rugosa rose** *(Rosa rugosa)* – While many people love this species for its pretty pink and magenta blooms and large red rose hips, this is a non-native plant and should be avoided when restoring native dunes. Beach plum and bayberry are native plants with high habitat value that would be better choices for planting in areas in where rugosa rose is being considered. An alternative rose would be Virginia rose (*Rosa virginiana).*

**Salt cedar** *(Tamarisk sp.)* – Its extreme salt tolerance makes it a common choice for shore gardeners. While this plant is not too invasive in dry areas, it is a real threat in riparian areas and planting it should be avoided.

**Shore juniper** *(Juniperus conferta)* – This species is a non-native, creeping evergreen groundcover and is used primarily as an ornamental landscaping foundation plant.

**Japanese Black Pine** *(Pinus thunbergii)* – Japanese black pine is highly used by landscapers in coastal communities due to its tolerance to salt and poor soil. Unfortunately, it creates a monoculture of one species and low genetic diversity. Monocultures in general – and this species in particular – are susceptible to predators and diseases and are short-lived. An alternative in a sheltered coastal site would be the native pitch pine *(Pinus rigida).*

**Asiatic and large headed sedges** *(Carex kobomugi* and *C. macrocephala)* – Neither of these is available at nurseries locally, but again they are available via the internet and mail order. Both of these species are non-native and *C. kobomugi* is highly invasive in New Jersey. Both are low-growing sedges that do not catch sand as well as native beach grass, resulting in long, low dunes that are less able to protect the communities behind them from flooding. It also decimates plant diversity on the dunes and reduces habitat value for many shore animals.

# Planting Amendments and Dune Maintenance

**1. Fertilizer** – A slow release fertilizer such as Osmocote® (analysis varies depending on release time) or an organic product such as Ocean Gro (5-5-0) that supplies a small amount of nitrogen and moderate amount of phosphorus would be beneficial. While older protocols did suggest broadcast fertilization of beach grasses, dunes are now considered environmentally sensitive buffers to aquatic habitats, and broadcast fertilizer applications in such habitats are no longer acceptable because the nutrients from such habitats often leach rapidly from there into the nearby water, causing pollution. In areas that are not used or set aside as habitat for rare, threatened, or endangered (RTE) species, it is recommended that a small amount of fertilizer be added to the hole as the plants are installed. Initial fertilization is best done at planting with a complete slow release fertilizer, such as Osmocote® 14-14-14, placed under the plant at a rate of 1.5 grams per plant. Initial fertilization may also be provided with 200 to 300 pounds of mineral 10-10-10 per acre, broadcast six weeks after planting. Other commercial fertilizers of the same analysis with a slow release formulation may also be used. Fertilizers and other amendments should not be used on dunes in or near RTE species areas, as they promote high densities of dune vegetation that are incompatible with RTE species' habitat requirements.

**2. Compost/seaweed** – Adding organic materials such as compost is helpful from a water-holding standpoint, but any of these materials should also be mixed in with some sand to prevent a water barrier (zone of discontinuity between different-sized pore spaces) from being created between the roots and the pure sand substrate. Similarly, if one plants a containerized shrub growing in Promix (high organic potting soil) into a hole surrounded by pure sand, this will create a discontinuous water barrier between sand and Promix. To help the plant thrive, it is important to back fill the hole with a mixture of Promix and sand (about a 50/50 ratio).

**3. Terra-sorb and similar water absorbing gels** – Terra-sorb is one of a suite of similar products that keep roots moist when transplanting bare-root seedlings and helps maintain water absorption to roots during dry periods. In addition, the establishment of bare-root and stem cuttings can be assisted by using fertilizer combined with water absorbing granules called hydrogel. This material is extremely water absorbent and has the ability to absorb hundreds of times its weight in water. Hydrated hydrogel combined with fertilizer can be placed in the planting hole just prior to plant placement. Absorbed water and fertilizer is then slowly released back into the root zone for use by the plant. It is good insurance and adds minimal cost to the planting. One pound of crystalline product, which costs $6.00-$7.00, added to about 30 gallons of water will treat 15,000 bare-root seedlings.

**4. Mycorrhizae fungi** – Mycorrhizal fungi promote plant vigor, add disease resistance, and can increase survival while improving soil for future plantings. A 3-lb. jar of Bio/Organics Mycorrhizae Inoculum will treat about 1,500 plants at a cost of $80.00. This adds about 5¢ per plant to the cost of the planting. The jury is still out on the effectiveness of the commercially produced mycorrhizal inoculant. If an additional 5¢ per plant is not a problem from a project budget standpoint, it won't hurt to add the inoculum at planting time.

Even the best-vegetated dune will not remain that way unless a reasonable maintenance program is followed. Some considerations include:

## Control of Foot and Vehicle Traffic

Primary dune vegetation cannot tolerate trampling. Traffic must be **prohibited**! However, dunes must be crossed to reach the beach. At selected sites, mechanical crossovers must be installed. Elevated walks, paved paths, and sandy surfaces are satisfactory. Walkways, except elevated ones, should be curved to reduce wind erosion. The secondary dune must also be protected from pedestrian and vehicular traffic. All walkways should be fenced to channel traffic across the dune. The front and back faces of the dune should be fenced to prevent ingress, particularly from the beach. In RTE species' habitats, symbolic (string and post) fences should be used instead of sand fences to channel public use away from sensitive vegetation or wildlife habitat. Where temporary use of sand fences is deemed necessary for public use management, adverse effects can be minimized by prompt removal. Sand fences placed for public use management in suitable rare/listed species habitat should not be allowed to become buried. They should always be removed before September 1. If natural processes do not restore beach topography to pre-installation elevation and profile, remedial mechanical re-grading to restore the pre-fencing topography should be conducted before March 15.

## Vegetation Maintenance

Generally little maintenance is required after coastal plantings are performed. It is important to fertilize plantings during the first two years after plantings. This enables plantings to become established more readily. Foot traffic should also be minimized on newly planted areas, and debris should be removed on a regular basis.

Vegetation is maintained with applications of fertilizer applied as needed to keep desired density. A maximum annual application of 20 pounds of nitrogen per acre should be applied. Replanting of areas where vegetation has been destroyed is an essential annual maintenance requirement. This should be accomplished at the first window of opportunity. Woody plants need a maintenance fertilizer program beginning in the second year after planting.

Fertilizers and other amendments should not be used on dunes in or near the rare/listed species areas. Further, vegetation thinning should be conducted to maintain rare/listed species habitats within recommended targets (Table 1).

## Maintenance of Dune Line

A dune system, like a chain, is no stronger than its weakest link. Consequently, to receive maximum protection from dunes, a strong and uniform dune line must be maintained in areas not occupied or set aside for RTE species. In areas being managed for protection of human infrastructure, blowouts, washouts, or other natural or human-produced damage must be repaired quickly or it will weaken the entire protective dune systems. However, sand dunes are dynamic formations. They tend to move oceanward during periods of relatively calm weather and landward after severe storms. Our task in such areas is to assist nature to maintain and restore the dunes.

Blowouts in a dune system can be repaired by placing a sand fence between the existing dune parts. One or more fences may be required. It is essential to tie the ends of the fence into the existing dune to keep the wind from whipping around the ends.

Maintenance of a uniform dune line is likely to degrade RTE species habitats over time, particularly in areas where human activities alter natural dune blowouts or overwashes. Thus, the practices described above should not be adopted in rare/listed species areas. Instead, dune creation and management of RTE species areas should follow the approved Beach Management Plan if there is one, as well as Maslo et al. (2011). Both of these will be superseded by the forthcoming dune guidelines for use in habitats for use in rare/listed species habitats. Dune management in rare/listed species areas should be guided by the site-specific recommendations of NJDEP Beach Nesting Bird program staff.

## Building the Dune with Vegetation and Fencing

Where blowing sand is available, a simple, relatively inexpensive and successful method for building dunes is to plant American beachgrass. It consists of planting strips of beachgrass parallel to the coastline. As the airborne sand moves landward, the velocity decreases. The sand falls to the surface to begin the natural cycle of dune formation. The row closest to the ocean should be at least 100 feet from the mean high tide line. If space permits, plant a 40 to 50 foot wide strip, but no less than 20 feet. Such plantings will trap windblown sand, particularly during the growing season. American beachgrass will continue to grow through the newly trapped sand. Large quantities of sand deposited on the beach by winter storms may quickly exceed the capability of the grass to trap and hold it. Some of this unstabilized sand may be blown to the backdune areas or returned to the beach and then the ocean.

## Sand Fences (Snow Fence Material)

A sand fence is effective for trapping and holding sand. The material is readily available in the form of snow fence. It may be more expensive than building dunes with vegetation alone but is less expensive than using machinery. Where a sand source is available and the wind comes from the desired direction, a sand fence will build a dune much faster than vegetation alone.

To build a barrier dune in areas not occupied or set aside for RTE species, erect two parallel sand fences 30 or 40 feet apart. The fences should be roughly parallel to the water line and be as nearly as possible at a right angle to the prevailing winds.

Where this is not possible, erect a single line of fence parallel with the ocean at least 140 feet from the Mean High Tide line. Attach 30 foot long perpendicular spurs at 40 foot intervals along the water side of the fence to trap lateral drift. These spurs form pockets to trap sand as it drifts laterally along the fence.

As the pockets fill with sand, additional sets of fence can be placed over those filled units until the barrier dune has reached the desired height. As a general rule, sand will only fill to a level about three-fourths of the depth of the sand fence height.

To widen an old dune, the fence line should be erected oceanward at a distance of 15 feet from the base of the old dune.

The sand fencing configurations recommended in this section are likely to degrade RTE species habitats over time. As a result, these fencing practices should not be adopted in rare/listed species areas. Instead, dune creation and management in rare/listed species areas should follow the approved Beach Management Plan – if there is one – as well as Maslo et al. (2011). Both of these will be superseded by the forthcoming dune guidelines for use in rare/listed species habitats.

## Sand Fence Specifications

Use standard 4 foot wood slatted (snow) fence. The wood should be sound and free of decay. The fence should have no broken wire or missing or broken slats. An alternate fence material is the polyvinyl type that has at least 50 percent porosity.

Wood posts for fence support should be black locust, red cedar, white cedar, or other wood of equal life or strength. They do not need to be chemically treated. The posts should have a minimum length of 6.5 feet and a minimum diameter of 3 inches. Standard fence posts are usually 7 to 8 feet long and can be used when available and meet the minimum standards.

Four wire ties should be used to secure the fence to the wood posts. Install the fence so alternate posts will have fence on the ocean side of them. Tie wires should be no smaller than 12 gauge galvanized wire.

Posts will be set no more than 10 feet apart and at least 3 feet deep. This method makes the fence more resistant to changes in wind direction.

## Sand Fence plus Vegetation

The combination of these two approaches may be more effective than either of the two alone. The sand fence should be placed as outlined above. Strips of vegetation should then be planted parallel to the fence on the landward side of the landward fence and the oceanward side of the oceanward fence as shown in Figure 3. Each strip of vegetation should be about 20 feet wide and located 10 to 15 feet from the sand fence. As the sand fills between the two fences, additional fence can be erected in the area between the fences. The area can be planted as shown in Figure 4. Such a combination can trap more windblown sand crossing the dune area than either fence or beachgrass alone. This method can produce a broader based dune than either approach alone.

## Height of Dune

The length of time required to build a dune varies with weather conditions, available sand, and the method used to build the dune. If the sand fence/vegetation combination is used and ample quantities of sand are brought onto the beach by storms, 4 feet of dune elevation can be built in a season. If vegetation alone is used the dune will be no higher than the vegetation is capable of growing in a season.

The dunes' eventual maximum height, which will be influenced by the installation of additional sand fence or vegetation and available sand, is about 12 feet to 15 feet. At this height range, the wind's energy is either unable to lift the sand above this elevation or the sand is carried over the top of the dune and deposited on the back side. To maintain this height requires a vigorous maintenance program. Maintenance includes replanting, protection from traffic, fertilization, and a diversity of plant species.

Care should be taken to ensure that local residents are aware of any interference the dune height will have on their scenic vistas. This may influence the maximum height to which the dune is built.

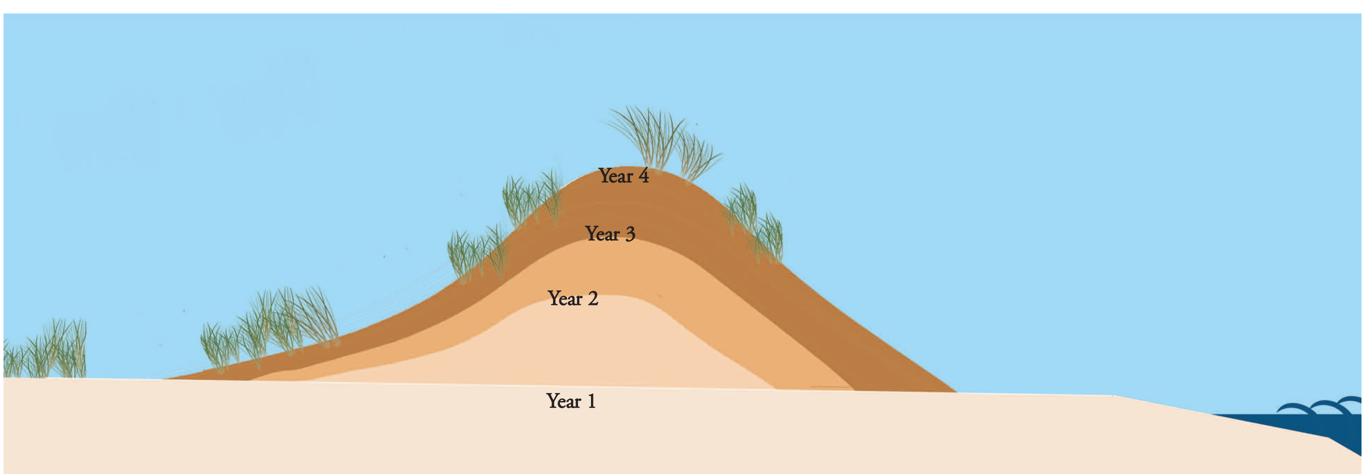



**Figure 4. Dune width and height increase over time and migrate in a seaward direction (Rogers and Nash 2003).**

# Conclusion and Next Steps

Coastal sand dunes make up a very important feature of our beaches. They have the ability to provide significant protection from severe coastal storms and, with careful design, dunes can be compatible with habitats for native plants and animals, including rare, threatened and endangered species. Artificially enhanced dune systems have the potential of providing even greater protection than naturally forming dunes, if properly designed and maintained. However, both natural and human-made dunes are part of a dynamic system, and will constantly change shape based on the environmental factors present at the site. In order to properly design and maintain a healthy beach and dune system, it is important for coastal communities interested in doing so to thoroughly understand the geomorphic processes of coastal dunes, the need to manage for wildlife and endangered species, and the need to protect human coastal infrastructure. The information presented in this report is intended to help communities become more aware of the functions of coastal dunes and gain an insight of possible artificial dune design and restoration alternatives.

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# Cape May PMC Plant Suppliers List

| Vendor ID | GROWER | ATLANTIC coastal panicgrass | AVALON saltmeadow cordgrass | CAPE beach grass | BOGUE beach grass | NORTHPA bitter panicgrass | MONARCH seaside goldenrod | DUNE CREST coastal little bluestem | HIGH TIDE switchgrass | SOUTHAMPTON prairie cordgrass | WILDWOOD bayberry | OCEANVIE beach plum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT01 | Colonial Seed | | | | | | X | X | | X | | |
| DE01 | Cape Farms | | | X | | | | | | | | |
| DE02 | Delaware Department of Corrections | | | X | | | | | | | | |
| | | | | | | | | | | | | |
| FL01 | Aquatic Plants of Florida | X | X | X | | X | | X | | | | |
| | | | | | | | | | | | | |
| GA01 | Adams-Briscoe Seed | X | | | | | | | | | | |
| | | | | | | | | | | | | |
| MA01 | Cape Cod Organic Farm | | X | X | | | | | X | X | X | X |
| MA02 | Cape Coastal Nursery | | | X | | | | | | | | |
| MA03 | Sudbury Nurseries-West | | | | | | | | | | X | |
| MA04 | Plymouth County Beachgrass | | | X | | | | | | | | |
| MA05 | New England Wetland Plants | | | X | | | X | X | | | | |
| MA06 | Sylvan Nursery | | | X | | | | | | | | |
| MA07 | Quansett Nurseries | | | X | | | | | | | | |
| MD01 | Harper Farms | | | X | | | | | | | | |
| MD03 | Bluemel Nurseries | | | X | | | | | | | | |
| MD04 | SMGC Seed | X | | | | | | | | | | |
| MD05 | Chief Mountian Farms | X | | X | | | X | | X | | X | |
| MD06 | Signature Horticultural Services | | X | X | X | | | | | | | |
| MD07 | Environmental Concern | | | | | | | X | | | | |
| MD08 | Chesapeake Horticultural Services | | | X | | | X | | X | | | |
| ME01 | Western Maine Nurseries | | | | | | | | | | X | X |
| ME02 | Pierson Nurseries | | | X | | | | | | | | |
| ME03 | Burnt Meadow Nursery | | | X | | | | | | | | |
| MI01 | Cold Stream Farm | | | | | | | | | | X | |
| MI02 | Van Pines Nursery | | | X | | | | | | | | |
| NC01 | Drake Farms/Edwards Nursery | X | X | X | X | X | | | | | | |
| NC02 | Cape Fear Farm and Nursery | X | | X | X | | | | | | | |
| NC03 | Simmons Agriculture/Nursery | X | | X | | | | | | | | |
| NC04 | Coastal Transplants | | | | X | X | | | | | | |
| NC05 | Lumber River Native Plants | | | | | | | X | | | | |
| NJ01 | Church's Nursery | | | X | | | | | | | | |
| NJ02 | Coastal Native's Nursery | X | X | X | | | | | | | X | X |
| NJ03 | Old Cellar Creek Farms | | | X | | | X | | | | | |
| NJ04 | Pinelands Nursery | X | X | X | | X | | | | | | |
| NJ05 | Winslow Conservancy | | | X | | | | | | | | |
| NJ06 | Cumberland Nurseries | | | X | | | | | | | | X |
| NJ07 | Clemenson Native Nursery | X | X | X | | X | X | X | | X | X | X |
| NJ08 | New Moon Nursery | | X | X | | X | X | X | | | | |

# Cape May PMC Plant Suppliers List

| Vendor ID | GROWER | ATLANTIC coastal panicgrass | AVALON saltmeadow cordgrass | CAPE beach grass | BOGUE beach grass | NORTHPA bitter panicgrass | MONARCH seaside goldenrod | DUNE CREST coastal little bluestem | HIGH TIDE switchgrass | SOUTHAMPTON prairie cordgrass | WILDWOOD bayberry | OCEANVIEW beach plum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NJ09 | Tuckahoe Nurseries | | | X | | | | | | | | |
| NJ10 | Cicconi Farms Inc. | | | X | | | | | | | | |
| NJ11 | McKittrick Nurseries | | | | | | | X | | | X | X |
| NJ12 | Walt Surran | | | X | | | | | | | | |
| NY01 | Peat & Son | | | X | | | | | | | | |
| NY02 | Country Garden Nursery/Long Island Natives | | | X | | | | | | | | |
| NY03 | North Fork Boutique Gardens | | | X | | | | | | | | |
| NY04 | Greenbelt Native Plant Nursery | | | X | | | | | | | | |
| PA01 | Ernst Conservation Seeds | X | | | | | | | X | | | |
| PA02 | Sylva Native Nursery | X | | | | | | | | | X | X |
| PA03 | Musser Forest Nursery | | | | | | | | | | X | |
| PA04 | Wetland Supply Company | | | | | | | | | | | X |
| VA01 | Cullipher Farms | X | X | X | | | | | | | | |
| VA02 | Ralph Williamson | X | | | | | | | | | | |

# Grower Addresses

| Vendor ID | Vendor Name | Street 1 | City | State | Zip | Telephone | Vendor website/notes |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| CT01 | Colonial Seed | 28 School St. | East Granby | CT | 06026 | (413) 355 - 0200 | http://colonialseed.com/ |
| DE01 | Cape Farms | RD#1, Box E-134A | Lewes | DE | 19958 | (302) 945-1840 | http://www.capebeachgrass.com/about.html |
| DE02 | DE Department of Corrections | Rt. 6, Box 700 | Georgetown | DE | 19947 | (302) 856-5790 | |
| FL01 | Aquatic Plants of Florida | 8120 Blaikie Court | Sarasota | FL | 34240 | (941) 378-2700 | http://apofl.com/ |
| GA01 | Adams-Briscoe Seed | P.O. Box 19 | Jackson | GA | 30233-0019 | (770) 775-7826 | www.abseed.com |
| MA01 | Cape Cod Organic Farm | 3675 Main Street, P.O. Box 93 | Barnstable | MA | 02630 | (508) 362-3573 | http://www.capecodorganicfarm.org/About-the-Farm.html |
| MA02 | Cape Coastal Nursery | 225 Sandwich Road | Falmouth | MA | 02535 | (508) 398-1743 | http://capecoastalnursery.com |
| MA03 | Sudbury Nurseries-West | 81 Ben Hale Road | Gill | MA | 01354 | 413-863-9898 | http://www.sudburynurserieswest.com/ |
| MA04 | Plymouth County Beachgrass | 34 North Carver Rd | West Wareham | MA | 02576 | (508) 295-3254 | www.plymouthcountybeachgrass.com |
| MA05 | New England Wetland Plants | 820 West Street | Amherst | MA | 01002 | 413-548-8000 | http://www.newp.com/ |
| MA06 | Sylvan Nursery | 1028 Horseneck Road | Westport | MA | 02790 | 508-636-4573 | www.sylvannurseries.com |
| MA07 | Quansett Nurseries | 794 Horseneck Road | South Dartmouth | MA | 02748 | (800) 636-6931 | http://www.quansettnurseries.com/index.php |
| MD01 | Harper Farms | 4645 E.N.M.-Rhodesdale Road | Rhodesdale | MD | 21659 | (410) 943-4173 | |
| MD03 | Bluemel Nurseries | 2740 Greene Land | Baldwin | MD | 21013 | (800) 498-1560 | http://www.kurtbluemel.com/ |
| MD04 | SMGC Seeds | PO Box 144 | Centreville | MD | 22617 | (410) 991-1419 | http://smgcwildlife.com/ |
| MD05 | Chief Mountian Farms | 116 Chrief Mountain Lane | Port Deposit | MD | 21904 | (410) 658-7331 | http://www.chiefmountainfarms.com/ |
| MD06 | Signature Horticultural Services | 19960 Gore Mill Road | Freeland | MD | 21053 | (410) 329-6466 | http://www.signaturehort.com |
| MD07 | Environmental Concern | 201 Boundary Lane, P.O. Box P | St. Michaels | MD | 21663 | (410) 745-9620 | www.wetland.org |
| MD08 | Chesapeake Horticultural Services | 8859 Mistletoe Drive Suite A | Easton | MD | 21601 | (410) 924-5847 | http://chesapeakehort.com/ |
| ME01 | Western Maine Nurseries | 4 Nursery lane | Fryeburg | ME | 04037 | (800) 447-4745 | www.wmnurseries.com |
| ME02 | Pierson Nurseries | 24 Bizzell Road | Biddeford | ME | 04005 | (207) 499-2994 | www.piersonnurseries.com |
| ME03 | Burnt Meadow Nursery | 25 Spring St. | Brownfield | ME | 04010 | (207) 890-7403 | http://burntmeadow.com/ |
| MI01 | Cold Stream Farm | 2030 Free Soil Rd. | Free Soil | MI | 49411-9752 | (231) 464-5809 | http://www.coldstreamfarm.net/ |
| MI02 | Van Pines Nursery | 7550 144th Ave. | West Olive | MI | 49460-9707 | (616) 399-1620 | http://www.vanspinesnursery.com |
| NC01 | Drake Farms/Edwards Nursery | 317 Drake Farm Road | Pinetops | NC | 27864 | (252) 903-8274 | www.edwardsnursery.com |
| NC02 | Cape Fear Farm and Nursery | 634 Olde Point Road | Burgaw | NC | 28425 | (910) 2597925 | |
| NC03 | Simmons Agricultural Nursery | 6869 Kingtown Road | Ash | NC | 28420 | (910) 754-7800 | seagrass@atmc.net |
| NC04 | Coastal Transplants | 1509 George II Hwy SE | Bolivia | NC | 28422 | (910) 431-9814 | http://www.coastaltransplants.com/ |
| NC05 | Lumber River Native Plants | 7000 Livingston Road, P.O. Box 42 | Gibson | NC | 28343 | (336) 601-8787 | www.ncnativeplants.com |

# Grower Addresses

| Vendor ID | Vendor Name | Street 1 | City | State | Zip | Telephone | Vendor website/notes |
|---|---|---|---|---|---|---|---|
| NJ01 | Church's Greenhouse & Nursery | 522 Seashore Rd. | Cape May | NJ | 08204 | (609) 884-3927 | http://www.churchsbeachgrass.com |
| NJ02 | Coastal Native Plants Nursery | P.O. Box 42 | Mauricetown | NJ | 08329 | (856) 785-1102 | Bryan Alcox |
| NJ03 | Croshaw Nursery | P.O. Box 339, Mill Lane | Columbus | NJ | 08022 | (609) 298-6388 | http://www.croshawnursery.com/ |
| NJ04 | Old Cellar Creek Farms | 1423 South Shore Road | Palermo | NJ | 08223 | (609) 390-3384 | Mike Dubruille |
| NJ05 | Pinelands Nursery | 323 Island Road | Columbus | NJ | 08022 | (609) 291-9486 | http://www.pinelandsnursery.com |
| NJ06 | Winslow Conservancy | 303 Messina Avenue | Hammonton | NJ | 08037 | (609) 313-0660 | http://hankmcneil.wordpress.com/winslow-farms-conservancy-hank-mcneil-philadelphia-henry-mcneil/ |
| NJ07 | Cumberland Nurseries | 1521 Bridgeton-Millville Pike | Millville | NJ | 08332 | (856) 451-2508 | www.cumberlandnurseries.com |
| NJ08 | Clemenson Farms Native Nursery | 108 Linwood Ave. | Estell Manor | NJ | 08319 | (609) 476-3903 | http://clemensonfarmsnativenursery.com/ |
| NJ09 | Eric Demitroff | 534 Main Ave. | Vineland | NJ | 08360 | (856) 794-9606 | |
| NJ10 | New Moon Nursery | 975 Barretts Run Road | Bridgeton | NJ | 08302 | (888) 998-1951 | http://www.newmoonnursery.com/ |
| NJ11 | Tuckahoe Nurseries | PO Box 576 | Tuckahoe | NJ | 08250 | 609-861-0533 | www.tuckahoenurseries.com |
| NJ12 | Cicconi Farms Inc. | 1005 Farmingdale Road | Jackson | NJ | 08527 | 732-363-1420 | http://www.cicconifarms.com/stat/Home.html |
| NJ13 | McKittrick Nurseries | 62 Squankum Road | Colts Neck | NJ | 07722 | (732) 542-5005 | http://mckittricknurseries.yolasite.com/ |
| NJ14 | Walt Surran | 223 Main Street | Corbin City | NJ | 08270 | (609) 628-2467 | |
| NY01 | Peat & Son Nursery, Inc. | 32 Old Country Rd. | Westhampton | NY | 11977 | (631) 288-3458 | http://www.peatnson.com/ |
| NY02 | Country Gardens Nursery | 220 Old Country Road | Eastport | NY | 11941 | (631) 325-1522 | www.countrygardensnursery.com |
| NY03 | North Fork Boutique Gardens | 2450 Elijah's Lane | Mattituck | NY | 11952 | (631) 734-6832 | http://nfbgi.com/ |
| NY04 | Greenbelt Native Plant Nursery | 3808 Victory Boulevard | Staten Island | NY | 10314 | (718) 370-9044 | http://www.nycgovparks.org/greening/greenbelt-native-plant-center |
| PA01 | Ernst Conservation Seeds | 9006 Mercer Pike | Meadville | PA | 16335 | (800) 873-3321 | www.ernstseed.com |
| PA02 | Sylva Native Nursery and Seed | 3815 Roser Road | Glen Rock | PA | 17327 | (717) 227-0486 | http://www.sylvanative.com/ |
| PA03 | Musser Nursery | P.O. Box 340, Route 199 North | Indiana | PA | 15701-0340 | (724) 465-5685 | http://www.musserforests.com/default.htm |
| PA04 | Wetland Supply Company | 194 Goodview Drive | Apollo | PA | 15813 | (724) 727-3772 | http://wetlandsupply.com/ |
| VA01 | Cullipher Farms | 2088 Jarvis Rd. | Virginia Beach | VA | 22456 | (757) 721-7456 | http://cullipherfarm.com/ |
| VA02 | Ralph Williamson | 2393 Berryville Road | Chatham | VA | 24531 | (804) 927-5772 | http://www.southernstates.com/storelocations/11765/index.aspx |