

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 (Alsiidae) 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



Tire tracks.

Jeanne Heuser photo

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).



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 (*Sterna 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 (<i>Charadrius melodus</i>), threatened	Least tern (<i>Sterna antillarum</i>) endangered	Common tern (<i>Sterna hirundo</i>)
Red knot (<i>Calidris canutus ruia</i>), threatened	Black skimmer (<i>Rynchops niger</i>), endangered	American oystercatcher (<i>Haematopus palliatus</i>)
Northeastern beach tiger beetle (<i>Cicindela dorsalis dorsalis</i>), threatened	Seabeach knotweed (<i>Polygonum glaucum</i>), endangered	Horned lark (<i>Eremophila alpestris</i>)
Seabeach amaranth (<i>Amaranthus pumilus</i>)	Seabeach sandwort (<i>Honckenya</i>), threatened (<i>Peploides</i>), endangered	Seabeach evening-primrose (<i>Oenothera humifusa</i>)
		Sea-milkwort (<i>Glaux maritima</i>)
		Seabeach purslane (<i>Sesuvium maritimum</i>)

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.

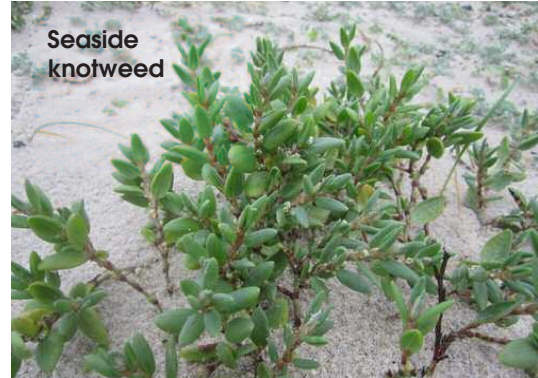
Several other rare and threatened plants and animals depend on the narrow strip of sand between the dunes and the ocean for habitat. Northeastern beach tiger beetles used to be very common on New Jersey beaches, but were very sensitive to human uses of the beach, including use of off-road vehicles. As 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 (*Polygonum 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 caroliniae*) 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 sasserii*), 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.



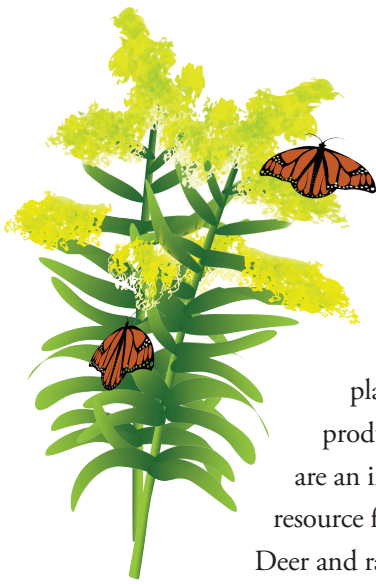
Asiatic sand sedge (*Carex kobomugi*)

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 (*Ammophila 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.