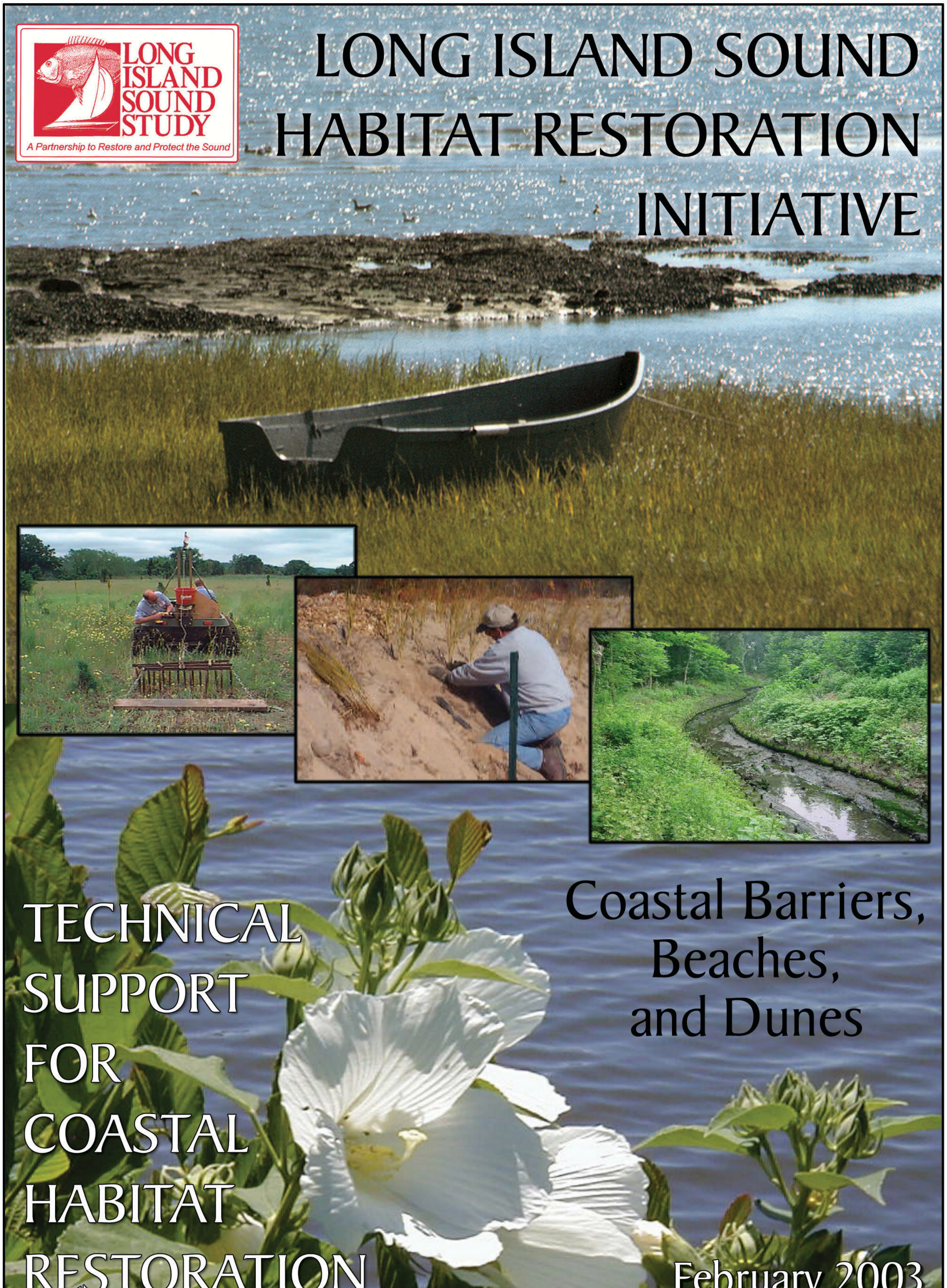
LONG ISLAND SOUND STUDY
A Partnership to Restore and Protect the Sound

LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE



TECHNICAL SUPPORT FOR COASTAL HABITAT RESTORATION

Coastal Barriers, Beaches, and Dunes

February 2003

LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

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DESCRIPTION

Coastal barriers, beaches, and dunes occur along the shoreline of Long Island Sound and are formed by a delicate balance of erosion, water currents, and wind currents. The presence or absence of sand along the shores of Long Island Sound is the result, in part, of Southern New England's glacial history. About two million years ago, during the Pleistocene epoch, glacial ice sheets formed in Canada, Northern Europe, and Siberia. These ice sheets advanced to cover the area that is now Long Island and Connecticut during the most recent period of glaciation, called the Wisconsin glacial age. The mechanics of the ice movement created different geology in mainland Connecticut and New York from that found on the land form of Long Island.

The advancing ice scraped rocks, dirt, and sand from the underlying land and carried them along in the ice sheet until atmospheric warming caused the leading edge of the glacial ice to melt and retreat. The point of furthest advance of a glacier results in a ridge of the scraped material called a terminal moraine. The Wisconsin glaciation deposited two moraines on Long Island. The southernmost moraine is called the Ronkonkoma moraine and forms a land ridge extending from Lake Success to Montauk Point. The Wisconsin ice sheet is thought to have receded after depositing the Ronkonkoma moraine, then advanced again for a short period of time. When the ice retreated once more, the Harbor Hill moraine was deposited. The Harbor Hill moraine extends from Queens to Orient Point on Long Island, but is part of a continuous moraine line that runs through Plum Island, Fishers Island, and Watch Hill in Rhode Island. It is the Harbor Hill moraine that supplies the sand to Long Island's north shore beaches. Radiocarbon studies and pollen analyses indicate that this ice retreat occurred approximately 19 to 20 thousand years ago (Flint and Gebert, 1976).

The shoreline of Westchester County, on mainland New York, and Connecticut, by contrast, consists largely of Paleozoic bedrock thinly overlain by salt marsh peat and beach sand (Koppelman et al., 1976). In some areas this bedrock is exposed. Bedrock has also been exposed in some portions of westernmost Long Island, specifically Astoria and Long Island City, Queens. The solid nature of the majority of the northern shoreline of the Sound makes it much less prone to erosion than the shores of Nassau and Suffolk Counties in New York.

In Long Island Sound, beach development in general is inhibited by the absence of significant wind and wave action, and by the small amount of available erodable sand in Connecticut (Koppelman ***et al.***, 1976). Nonetheless, beaches do form and the two most prevalent beach development processes in the Sound are barrier spit development and deposition resulting directly from headland erosion.

Headland erosion is the dominant type of beach development on the southern shore of the Sound in Nassau and Suffolk counties in New York. Here, towering bluffs of sand and cobbles, the eroded remains of the Harbor Hill moraine, are constantly eroded by runoff, waves, and wind to form narrow strips of beach at the bluff base. These bluffs erode at an average rate of one to two feet of recession annually (New England River Basins Commission, 1975), and are a locally important source of the sand budget for Long Island Sound beaches (Koppelman ***et al.***, 1976). The sand and silt from these bluffs may be carried away by waves and currents and deposited elsewhere as barrier spits or sand shoals and intertidal flats in a process known as longshore drift. The net movement of sand along the south shore of the Sound is generally east to west (New England River Basins Commission, 1975).

In the formation of coastal barriers, sand is carried by longshore currents and is deposited in long strips that build parallel to the shoreline. These beaches often extend across the mouths of rivers and bays resulting in a reduced opening to the Sound. As these barriers grow in length and width, dunes may be formed by wind. The specific ecological communities found on these two beach types are described in further detail below.

All coastal beach habitats are very harsh environments for plants and animals alike. The soils are composed of siliceous sand, quartzite gravel and rock, or a mixture of the two. These soils are often acidic, excessively well-drained, and subject to huge fluctuations in temperature on a daily basis, or even within a tidal cycle. The sand is extremely unstable and plants must be able to adapt to rapid exposure and burial. Salt spray is another important controlling factor in plant distribution. In order for any vegetation to become established on this substrate, it must be tolerant of salt spray, which is toxic to most terrestrial plants.

There are a few different strategies that have evolved in the plant kingdom to deal with salt spray. The first is succulence. Some plants like saltwort (***Salsola kali***) store water in their tissues and are able to dilute the salt spray that may seep through the waxy skin of their leaves. This reduces the toxicity of the salt water to the plant.

Other plants, like dusty miller (***Artemesia stellariana***), are covered by dense hairs that prevent salt spray from reaching the leaf tissue at all. A thick epidermal layer or skin on some plants like beach pea (***Lathyrus maritimus*** and ***L. japonicus***) also prevents salt spray from reaching more sensitive cells in the plant. And, finally, some plants just grow low to the ground, like seaside spurge (***Euphorbia polygonifolia*),** thereby reducing the surface exposed to the wind and the salt spray it carries.

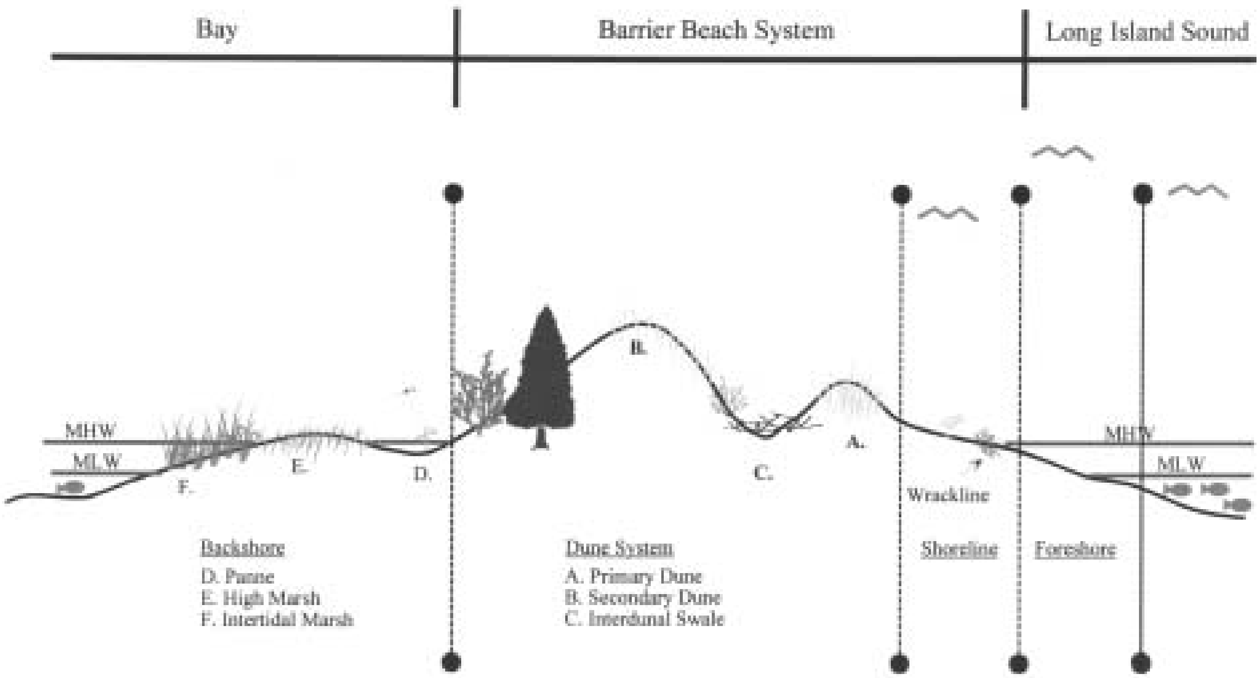
COASTAL BARRIERS

Coastal barriers are composed of sands and gravels deposited across bay mouths by longshore currents traveling parallel to the shoreline. Occasionally this morphology is seen within long, narrow, and shallow harbors formed as river valleys became drowned by the rising sea level. Two examples of mid-bay barrier beaches are found in Hempstead Harbor and Cold Spring Harbor in New York. Several individual community types are found associated with barrier beach systems as shown in the generalized cross section in ***Figure 5-1***.

Foreshore Community

The foreshore community is found on the foreshore area of beaches facing Long Island Sound. It is also called a marine intertidal gravel or sand beach, and it occurs between the highest and lowest tide zones. There typically are no rooted plants found on the foreshore. Any vegetation present is in the form of wrack, material that has washed on shore and has been pushed to the high tide line by waves. In the eastern portions of the Sound, broken eelgrass (***Zostera marina***) blades are the dominant component of this margin of the community, but other species of plants, algae, and floating debris are found here throughout the Sound. The animal community associated with the foreshore area is characterized by benthic invertebrate fauna, such as polychaete worms (***e.g., Nereis virens, Scalibregma inflatum, Glycera americana)*** and amphipods. During spring and fall migratory seasons, sanderling (***Calidris alba***), semi-palmated plovers (***Charadrius semipalmatus***), and many other species of shorebirds are found feeding along the swash zone to refuel on their trip between interior and arctic North American breeding grounds and wintering grounds in South America and the Caribbean.

FIGURE 5-1. Barrier Beach Profile



Maritime Beach Community

Maritime beach communities are found between the primary dune and mean high tide and have sandy or gravelly substrate similar to the foreshore area. This segment of the beach is modified by wind erosion and storm waves. The plant community is well adapted to the extremely dry and salty conditions and constant burial in shifting sand. American beachgrass (***Ammophila breviligulata***) may begin to establish here at the foot of the primary dune. There are many other plant species that make their home on this section of the beach including sea rocket (***Cakile edentula var. edentula***), spearscale and seabeach orache (***Atriplex patula, A. arenaria***), seabeach sandwort (***Honckenya peploides***), saltwort, seaside spurge, and seaside knotweed (***Polygonum glaucum***). These accompanying species often occur interspersed with the beachgrass or in single, small clumps on otherwise bare patches of sand.

The maritime beach community supports nesting by several shorebird species including piping plover (***Charadrius melodus***), American oystercatcher (***Haematopus palliatus***), and black skimmer (***Rhynchops niger***). Three species of terns, least tern (***Sterna antillarum***), common tern (***S. hirundo***), and roseate tern (***S. dougalli***) construct nests on the bare sand above the high tide line. All of these bird species are federally- or state-listed species. Other rare species found in this beach community include the federally-endangered seabeach amaranth (***Amaranthus pumulis***) and Northeastern beach tiger beetle (***Cicindela d. dorsalis***). In addition, horseshoe crabs (***Limulus polyphemus***) lay their eggs at the spring high tide line into shallow depressions in the sand.

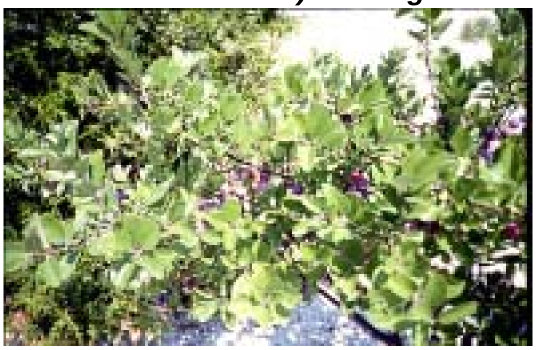
Maritime Dunes

Maritime dunes are described by their level of maturity and relative stability. The most seaward of the dunes are known as primary dunes. These are in constant motion and depend on the establishment of American beachgrass to stabilize them. Plant species like dusty miller, beach pea, sedge (***Carex***

silicea), seaside goldenrod (***Solidago sempervirens***), Virginia rose (***Rosa virginiana***), and pasture rose (***Rosa carolina***) are also well adapted to the dry conditions on the dunes and colonize soon after the pioneering beachgrass. Many of these species may also be found in upper dry beach areas where there are no dunes present. The beach at Flax Pond in New York is an example of a high-relief barrier beach without dunes.

Secondary dunes occur immediately landward of the primary dunes and are more stable than the primary dunes. Here species diversity increases in part due to more protection from salt spray, as well as more stable substrate. Herbaceous species include beach heather (***Hudsonia tomentosa***), seaside goldenrod, bearberry (***Arctostaphylos uva-ursi***), Cyperus (***Cyperus polystachyos var. macrostachyus***), beach pinweed (***Lechea maritima***), poison ivy (***Toxicodendron radicans***), and joint weed (***Polygonella articulata***). Typical shrub species landward of the primary dunes include beach plum (***Prunus maritima***) (***Figure 5-2***) and bayberry (***Myrica pensylvanica***). Species diversity in dune plant communities generally increases as protection from salt spray increases. In Connecticut there is an unusual colony of beach plum known as Graves' beach plum, growing entirely as vegetative clones. This colony has been classified as a separate variety named ***Prunus maritima var. gravesii***, and is thought to occur only in that single location. Typical birds associated with the dune community are the gadwall (***Anas strepera***) and short-eared owl (***Asio flammeus***).

Figure 5-2. Beach Plum (Prunus maritima) Bearing Fruit



Backshore Beach

In fully-developed barrier beach systems that front a bay or harbor, there may be a further community progression as one moves to the bay side of the barrier (***Figure 5-3***). Annual herb species are typically found on the upper shore of the backshore beach in bare sand above the wave and tide zone. These plants include pitseed (***Chenopodium macrocalycium*),** sea rocket**,** saltwort**,** seaside spurge**,** and seaside goldenrod. The seeds of these annual plants are redistributed by wind and waves during the winter causing variability in the distribution of the community from year to year. These same plant species are also typical on overwash fans[1] produced when storm-driven waves in the Sound breach the dunes into the harbor behind the beach.

The upper limit of the backshore beach may also include perennial herbs dominated by seabeach sandwort and interspersed with sea rocket and beachgrass. This community assemblage is rare in Connecticut. This habitat is used for breeding by the northern diamondback terrapin (***Malaclemys terrapin***).

Figure 5-3. The Back Shore of the Barrier Beach at Flax Pond, NY

Bayside Beach Wrackline

Continuing toward the bay side of the barrier beach system, the bayside beach wrackline is encountered next. This zone is typified by the accumulation of vegetation debris composed of eelgrass blades, and during the late fall and winter, smooth cordgrass (***Spartina alterniflora***) leaves and common

[1] Overwash fans are areas of sand carried into bays landward of barrier beaches during storm events that cause waves to overtop the beach. They typically display a fan shape when viewed frm above.

reed (***Phragmites australis***) stalks and leaves. Typical herbaceous species found in this area include seaside goldenrod, beach grass, seabeach atriplex (***Atriplex patula*** var. ***hastata***), hedge-bindweed (***Calystegia sepium***), and tall lettuce(***Lactuca canadensis***).

HEADLAND BEACHES

Headland beaches are those beaches that occur at the toe of headlands and bluffs along the Long Island shoreline of the Sound. These beaches are formed when the sand and glacial till that composes the bluffs is eroded by wind, rain, and waves and is deposited at the base of the bluff in a narrow strip. The average grain size of beaches from Queens to Eastern Suffolk County, New York, ranges from fine-grained sand to gravel and larger cobbles. At the foot of the bluffs of eastern Suffolk County, New York, more cobble beaches are seen than the sand beaches typical further to the west. In mid-Suffolk County, coarse sand and gravel are more typical of the beach substrate. There is greater fluctuation in grain size on headland beaches than on barrier beaches due to the mechanics of sand transport. There is a maximum particle size, that can be carried for any distance in the longshore currents of the Sound. This means that larger particles like gravel and cobble will remain close to their origin, while finer grains of sand are carried longer distances around the Sound or may be deposited into deeper waters offshore.

The grain size of the beach is a factor in determining which plant and animal communities will utilize the area. Fine-grained sand normally produces a similar community to those found in the maritime beach communities described earlier. Where vegetation does occur, American beach grass and other herbaceous species dominate the landscape. The typically narrow configuration of headland beaches prevents most dune formation.

On headland beaches composed of large cobble, there is a much sparser plant community. One species of note is scotch lovage (***Ligusticum scothicum***). This species occurs in both New York and Connecticut and is associated primarily with rocky beaches. It grows most frequently in the wrackline area, using the deposited vegetative material as a substrate for establishment. This species is at the southern extent of its range in the Sound and is listed as rare by Connecticut's Natural Heritage Program and is listed as state endangered in New York.

VALUES AND FUNCTIONS

As mentioned in the community descriptions above, beaches and dunes serve as critical habitat for several species of rare, threatened, and endangered species. Shorebirds are adapted to feed along sandy shorelines and would be at a competitive disadvantage without access to beaches for food.

Additionally, beaches and dunes are the first line of defense against coastal storm events. Beaches and dunes absorb the impact of storm driven waves and high winds to protect bay side and landward development. As development on beaches increases, erosion, due to structures (***e.g.***, homes, bulkheads, groins) and the loss of stabilizing plants, increases greatly. The cost of alternative and usually temporary shoreline protection measures range from $100-$600 dollars per linear foot for sea walls to over one million dollars for beach nourishment per mile of shoreline (Pilkey ***et al.***, 1981). The value of a single barrier beach as storm protection is clear to anyone who has witnessed the power of a hurricane or winter Nor'easter. Costs associated with shore protection projects in progress in Long Island Sound total in the millions (U.S. Army Corps of Engineers, n.d.). The project planning and projected construction cost at Orchard Beach in the Bronx is estimated to total $840,000. The estimated project cost to protect the access road to the Village of Asharoken, N.Y. is $2 million. The estimated project cost to protect the residential areas of Bayville, N.Y. is $2.65 million. The estimated cost of a study to correct downdrift sand starvation at Mattituck Inlet in Southold, N.Y. is $400,000.

Beach related recreation provides millions of dollars to the Long Island Sound area economy. An economic study of the value of Long Island Sound commissioned by the Long Island Sound Study (Altobello, 1992) determined that beach swimming alone held a user value of $182 million. This figure is based upon beach users' "willingness to pay", a dollar amount users would be willing to pay per day if charged to use the beach. Further calculations determined that beach swimming generated $291 million in direct economic effects for the Long Island Sound region. The direct economic effect includes expenditures by beach users such as transportation costs, food purchased, etc. When other indirect effects such as the wages of lifeguards and beach attendants spent in the local economy are added to the direct effects, beaches can generate $661 million dollars in economic value. All of these figures are based on 1990 dollars and have presumably risen with inflation. These figures would also increase with the addition of other beach activities such as fishing and jogging to the calculation.

In addition to their direct value as habitat, recreational space, and shoreline protection, beaches and dunes perform another important function. It is behind these systems that estuarine embayments, coastal ponds, and harbors form. The wave attenuation afforded by barrier beaches provides a sheltered area of open water for waterfowl, juvenile fish, and other species to feed, grow, and rest. The damming function of a barrier beach across the mouth of a bay or river with significant freshwater input reduces the salinity of the bay water. This in turn lowers osmotic and metabolic stresses from salt on the plants and animals that utilize the bay. There is greater species diversity found in estuaries than on exposed oceanic shorelines due to this reduction of salt stress and wave energy.

There are several species of beach plants that provide valuable commodities to people as well as animals. Beach plum, prickly-pear cactus, and Virginia rose all provide edible fruits.

STATUS AND TRENDS

In the more than 300 years since European colonization of the United States, the general trend of habitation has been inexorably toward the coast. As more and more residences and recreational structures are built along the shore, the perceived need to stop the natural process of barrier beach roll-over and bluff erosion has grown. Technological advances in building equipment have allowed larger and more expensive facilities to be built along beaches where they are subject to the storm events of the summer, fall hurricanes, and winter Nor'easters. The construction of theses facilities has resulted in the outright loss of habitat on the beaches. But the attempt to alter the natural cycle of deposition and erosion of sand along the shoreline by construction of bulkheads, sea walls, groins, and jetties has interrupted the formation of new beaches in those areas.

Loss of beach and dune material also has occurred during sand and gravel mining operations. In areas like Port Jefferson harbor and Jamesport, New York, large amounts of sand and gravel were excavated for use as fill and cement binder for construction. This sand has been removed permanently from the Sound's sand budget.

DEGRADED BEACHES AND RESTORATION METHODS

Beach degradation happens for a variety of reasons and each reason has its own solution. Some are complex and challenge the ability of managers and regulators to correct. Some are quite simple and require only small modifications in regular management practices to achieve success. The causes of degradation and some proposed corrective measures are discussed below.

STRUCTURAL ALTERATION

Beach and dune habitats become degraded when facilities for recreation and housing are located directly in the habitat. Beaches and dunes are naturally highly dynamic systems that constantly shift and adapt to the cycles of wind, tide, and storms. Development of permanent structures represents an attempt to halt these processes, which can lead to loss of vegetation and outright covering of habitat with structures. Sometimes when structures are placed in the dune system or landward of it, the dune is cut down to improve the view from the structure. This inevitably leads to increased erosion and loss of large areas of dune habitat. In addition, the presence of people and their pets in and around beach habitats can disrupt the breeding activity of many beach dependent animals. This is discussed in further detail later on.

Attempts to alter the natural cycle of deposition and erosion of sand by construction of bulkheads, sea walls, groins, and jetties interrupt the formation of new beaches. An added adverse impact of beach stabilization structures is the loss of the dynamic habitats that support many plant and animal species. For example, piping plovers nest on non-vegetated but stable areas of beaches. These areas of the beach are ephemeral by nature and shift in response to seasonal and episodic disturbances by waves and storms. Shoreline protection structures attempt to eliminate the effects of wind and waves on beaches and succeeds in reducing these dynamic shifts in habitat.

Restoration Methods:

① Removal of outdated or abandoned structures: Structures placed in and on beaches should be relocated or removed wherever possible. In some locations groins, jetties, bulkheads, docks are no longer in active use. The landowner should be contacted to assess their interest in cooperation. Federal and state grants may be available to assist in defraying the costs of restoration on private property. If the landowner is a government or public entity, the managing authority should be approached for cooperation in removal or relocation of the structure. In some states and on some federal lands, funds have been set aside to purchase homes built within the beach and dune area as landowners decide to move away from the area. Such measures should be explored in the Long Island Sound region as a long term restoration strategy. One such project is being studied by the U.S. Army Corps of Engineers at Mattituck Inlet where the dredging of the inlet and construction of jetties has contributed to downdrift erosion of the beach.

② Restoration of damaged dunes: In locations where dunes have been graded or removed, there may be opportunity to restore them around the existing structure. Placement of additional sand seaward of the existing structure may be possible if site conditions and applicable regulations allow it. The rebuilt dune should be planted with stabilizing vegetation as soon as possible. American beach grass is relatively inexpensive and readily available from nurseries and soil and water conservation districts. The beachgrass should be ideally planted during the months of March and April in a planting scheme of plugs spaced 12 inches on center. Site selection for candidate sites should include an analysis of prevailing wind and wave direction and intensity; measurement of the beach width seaward of the structures or existing dunes; and examination of the coarseness of the existing available sand. The restored dunes should be of sufficient height and breadth to trap available wind borne sand, and placed far enough landward on the beach to withstand the average storm wave run-up. Following either replanting the dunes or rebuilding and planting them, a common practice is to place a line of snow fence around the perimeter of the dune. This discourages foot and vehicular traffic as well as serving to trap additional sand. An estimate from the Connecticut Department of Environmental Protection for dune rebuilding projects indicates that the average cost per acre is approximately $10,000.

A more passive approach utilizes construction or snow fencing to trap wind-borne sand. The fencing may take several seasons to build a dune depending on the volume of airborne sand in the restoration area. Vegetation will often colonize newly formed dunes naturally, though accelerating the process through active planting will not hurt, either.

VEHICLE TRACKS AND FOOT PATHS

Often, the most convenient foot and vehicle access to the water is across dunes and beaches. Beach vegetation is delicate and not tolerant of trampling. American beachgrass, in particular, has a very rigid and brittle stem that snaps easily under the weight of foot traffic. Wearing of ruts and footpaths through the dunes also serves to accelerate erosion of the dunes by wind. Tire ruts on the beach also pose a serious threat to bird chicks who get trapped in them and may starve or become crushed by other vehicles.

Restoration Methods:

① Placement of Exclusion Fencing and Signage: The simplest method of beach and dune restoration in sandy areas is to redirect or exclude pedestrian and vehicle access through vegetated areas. American beach grass is well adapted to the sand beach environment and will grow back on its own, although supplementary planting will augment the recovery. This method of “passive” restoration is best suited to areas where damage has been minimal.

② Planting of Deterrent Vegetation: In some places, planting of denser vegetation that is less prone to trampling may be appropriate. Shrub species like beach plum and poison ivy hold sand with their roots and provide a less attractive pathway for pedestrian traffic. Alternate pathways should be provided and clearly marked.

③ Construction of Permanent Pathways: Many public beach facilities have benefitted from installation of raised boardwalk paths over sensitive dune areas. In high traffic areas, this may be an appropriate course of action when combined with restoration of trampled spots.

④ Seasonal or Other Restrictions to Vehicular Access: Beach access for four wheel drive vehicles is a popular recreational activity. Regulation of vehicle access must take into account beach breeding species so that chicks do not become trapped or crushed.

INVASIVE SPECIES

Non-native plants may become established on beach and dune areas. A typical invader is the salt spray or Japanese rose (***Rosa rugosa***). This plant is well adapted to the harsh environment of the beach and, as its name indicates, it is well able to tolerate salt spray. Where it has become established, salt spray rose forms dense thickets that exclude all other plant species.

Other invasive plants frequently found in the sand dunes of Connecticut include the trees black locust (***Robinia pseudoacacia***) and Tree-of-Heaven (***Ailanthus altissima***); and the vines honeysuckle (***Lonicera spp.***), Asiatic bittersweet (***Celastrus orbiculatus***), and black swallow-wort (***Vincetoxicum nigrum***). An increasingly prevalent invader is common reed (***Phragmites australis***). The nesting habitat value of beaches is reduced when domestic animals like dogs and cats have unrestricted access to the shoreline. They may attack nesting sites and eat chicks or eggs.

Restoration Methods:

① Cutting, pulling and herbicide application: Invasive plant species can be controlled through a combination of cutting, herbicide application, and removal of new plants. This method is labor intensive and requires annual monitoring of control areas. Specific information on controlling each of the invasive plant species listed above can be obtained from U.S. Department of Agriculture Soil and Water Conservation District offices, state environmental protection agencies, and non-governmental organizations like The Nature Conservancy. Factors like timing of herbicide application or cutting must be determined for each plant. In areas where removal of invasive vegetation will destabilize dunes, appropriate native vegetation should be planted in its place.

② Domestic animal control: Domestic animals can be controlled by their owners and local animal control officers and shelters. Dogs and cats owned by people living near the beach should not be allowed to roam freely during the nesting season of sensitive species like piping plover or terns. Dogs brought to the beach by their owners should be leashed and kept away from nesting wildlife.

③ Exclosures and exclusion fencing: A method of protection employed on piping plover nesting beaches is fencing. Exclosure fences are built around plover nests to protect them from predators like red foxes. The exclosures are built after nest site selection by the adult pair and left in place until the young plovers fledge. They are usually constructed of welded wire mesh fencing completely enclosing the nest site, even across the top. Typical dimensions of an exclosure is five feet in diameter and three feet high. The exclosure allows the parent plovers to enter and exit the nest site through the mesh, while keeping predators out.

SPECIFIC RESTORATION OBJECTIVES

Restoration objectives for coastal barriers and beaches should be consistent with the Long Island Sound Study Comprehensive Conservation and Management Plan (Long Island Sound Study, 1994) goals for living marine resources. These goals are to "increase the abundance of species listed by the states and/or federal government as endangered, threatened, or of special concern." Active management of these species includes restoration of critical habitat. In areas where infrastructure like paved roads, bath houses, groins and jetties are no longer serving their intended function, those structures should be removed or relocated landward. Invasive species invasion should be controlled and reduced through vigilant management of public beaches and education of private landowners.

RESTORATION SUCCESS AND MONITORING

Measurement of coastal barrier and beach restoration success is less straightforward than in many of the habitats addressed in the other sections. Beaches and dunes are not static habitats and are functioning properly if they move and change from season to season. Measures of success must be tied to specific goals that consider the non-static nature of beach habitats. Things that may be measured in aggregate, like overall acreage of invasive plants, need to be monitored and coordinated across agencies. Abundance and breeding success of endangered birds like piping plover and the three species of terns that nest on the shoreline of the Sound are already measured by the U.S. Fish and Wildlife Service and the state environmental protection agencies. Annual measures of factors like vegetation density and community composition can be used to help determine restoration success.

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