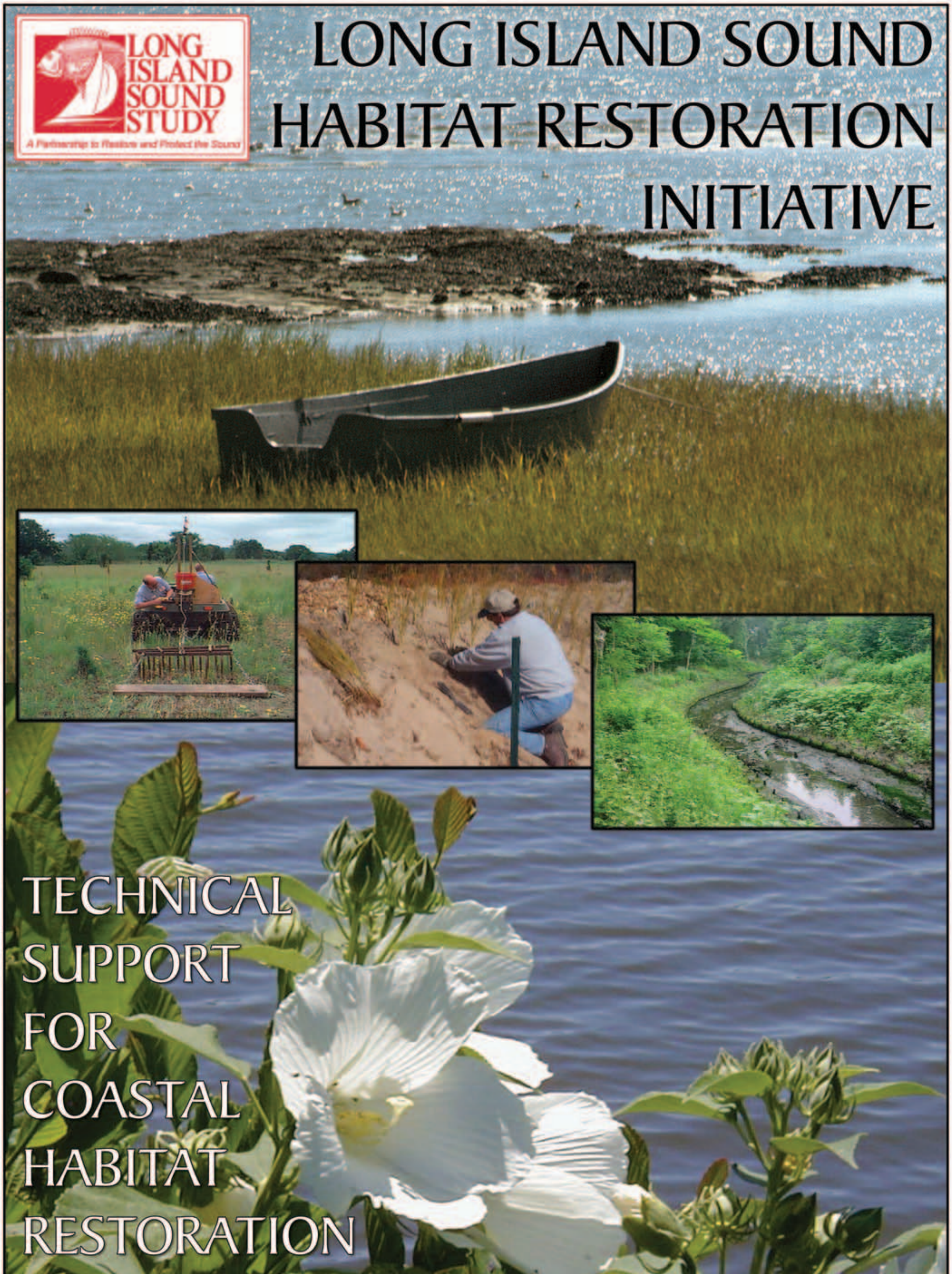
LONG ISLAND SOUND STUDY
A Partnership to Restore and Protect the Sound

LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE



TECHNICAL SUPPORT FOR COASTAL HABITAT RESTORATION

LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

Technical Support for Coastal Habitat Restoration

FEBRUARY 2003

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INTRODUCTION

This document has been prepared as part of the implementation of the Long Island Sound Study Comprehensive Conservation and Management Plan (CCMP) approved in 1994. The CCMP states that of all the problems facing Long Island Sound's living resources, habitat loss and degradation are of grave importance. The Sound's habitats collectively represent a unique and highly productive ecosystem supporting a diverse array of living resources. These living resources range from microscopic plants and animals that drift with the currents, to economically important finfish, shellfish, and crustaceans. Other living resources such as birds, sea turtles, and marine mammals spend all or part of their lives in the Sound, on its shores, or in its watershed. While there is still significant healthy habitat in and around Long Island Sound, the overall abundance and diversity of habitats have been diminished by incompatible human uses of the Sound and its resources for the last 200 years.

Interest in the field of restoration science is growing rapidly. While legislation has protected some habitats and many individual species of plants and animals from new damage, minimal regulation has been devoted to correcting past injuries. Wetlands, for example, have been protected since the early 1970s with the passage of the federal Clean Water Act and state wetland protection laws. Protective legislation has become effective in prevention of outright loss and other direct impacts on the habitat, but past damage by ditching and indirect, effects like nonpoint source pollution and habitat fragmentation, continue to degrade habitats. Existing legislation has halted the major losses, but cannot reverse the past damage without additional intervention by natural resource management agencies and concerned citizens. Additionally, many ecologically important habitats are not explicitly protected by legislation and may be legally altered or lost due to human activities, leaving remaining parcels of that habitat to support the fish and wildlife resources dependant on them. In order to maximize the populations of living resources within the Sound's ecosystem, it is of vital importance to return remaining habitats to the highest function possible.

This document contains a series of reports produced through the Habitat Restoration Work Group of the Long Island Sound Study (LISS). It is designed to provide basic technical information about the subject habitat and its restoration for persons interested in planning and pursuing a restoration project. Topics covered include ecological descriptions of the plant and animal communities associated with the habitat, the natural history and effects of human influence on the habitat, and the state of the science in restoring the habitat. Included at the end of each section is a list of the literature cited. The reader is strongly urged to investigate these source materials further to achieve a fuller understanding of the ecology and issues related to the subject habitat. The reader is also encouraged to contact the state and federal agency representatives of the Habitat Restoration Work Group for technical advice.

Twelve priority habitat types have been identified by the Work Group as particularly important to sustaining the living resources of the Long Island Sound ecosystem. ***Table 1*** lists the habitat types and shows the status of the documentation on each habitat type as of the printing of this manual. Each section within this manual is designed to be useful by itself, but all the sections taken together provide a fuller picture of the Long Island Sound ecosystem. In some cases, the recovery of a particular habitat is closely linked to ancillary issues like water quality improvement or land use. Some of these habitats may be the subject of a white paper rather than a full volume.

TABLE 1. Status of the Documentation on Each Long Island Sound Habitat Type

HABITAT TYPE	VOLUME TYPE	STATUS
Tidal Wetlands	full volume	Section 1 of this Manual
Freshwater Wetlands	full volume	Section 2 of this Manual
Submerged Aquatic Vegetation	full volume	Section 3 of this Manual
Coastal Grasslands	full volume	Section 4 of this Manual
Coastal Barriers, Beaches, and Dunes	full volume	Section 5 of this Manual
Riverine Migratory Corridors	full volume	future section
Intertidal Flats	full volume	future section
Estuarine Embayments	full volume	future section
Coastal and Island Forests	full volume	future section
Shellfish Reefs	full volume	future section
Cliffs and Bluffs	white paper	future section
Rocky Intertidal Zones	white paper	future section

GUIDING PRINCIPLES

The members of the Work Group have reached consensus on the definitions of several key terms to help guide the entire Habitat Restoration Initiative under the LISS. They are defined as follows:

Habitat Restoration

The intentional alteration of a site to attempt to reestablish the approximate biogeophysical conditions that existed in the predisturbance ecosystem or habitat.

Creation

To bring into existence a habitat that was not historically supported at the site in question. Creation requires the destruction or conversion of the existing habitat in favor of a new habitat.

Enhancement

The intentional alteration of habitat to improve one or a very limited number of functions of the existing habitat type.

In order to determine which habitats need restoration, the working group also defined its version of ecological degradation. ***Webster's Third New International Dictionary*** defines degraded as ***"…characterized by degeneration of structure and function."*** This can be applied to the natural world in an ecological sense by examining the "ideal" undisturbed workings of an ecosystem. For the purposes of this report, discrete portions of the Long Island Sound ecosystem are examined. For each portion, or habitat type, goals have been set that may be achieved within the scope of the LISS and without duplicating current efforts of federal, state, and local agencies. In the context of habitat definition, degradation can be broken down into several criteria. This allows a site to be objectively evaluated relative to an undisturbed "textbook" example of that habitat.

Loss of carrying capacity for fauna

The subject site will no longer support the desired animal species or will not support historical population sizes. Factors influencing this state can include loss of food source, lack of connection to complementary habitats, and loss of essential habitat features.

Loss of physical area

In a single habitat area, simple acreage reduction will reduce the absolute productivity level of a habitat. Relative value can remain unchanged, but the available area for primary production will be reduced, thereby reducing the size of consumer populations the habitat is able to support.

The change in size may also shift other factors influencing the function of a particular habitat. For example, in a salt marsh with significant freshwater input, reduction of the overall tidally-influenced area may cause the salt-adapted vegetation to be out-competed by freshwater species. The resulting shift in vegetation type will reduce the value of the wetland for marine finfish nursery area, while making it more valuable for migratory waterfowl.

It is important to recognize that not all habitat changes are detrimental, nor should or can every restoration site be returned to an exact historical state. As human development along the Sound has progressed, the habitat needs of the faunal populations have changed and some populations have been drastically reduced in size. The restoration should be aimed at allowing reestablishment of plant and animal diversity that can readily co-exist with the human population and its attendant development.

Reduced ecological function

- Loss of groundwater recharge ability
- Loss of nutrient cycling ability
- Loss of refuge or cover area
- Loss of pollutant-sequestering substrate
- Loss of migratory conduits

Aside from the food sources and living space provided to wildlife species by a habitat, components of the landscape provide beneficial functions. The combination of geological substrate and plant communities allow wetlands to aid in filtration of pollutants and recharge of aquifers. Rivers provide pathways for anadromous fish to reach their spawning habitat. These are examples of the chemical and spatial elements provided by a habitat.

Detrimental shift in vegetative cover

- Invasion by non-native or undesirable species
- Shift in ecosystem classification
- Change in hydrology

As discussed above, not all changes in an ecosystem are detrimental. The shift in vegetation should be closely analyzed for its relative merit before a decision to restore is made. If a tidal wetland becomes a brackish pond, the existence of the brackish pond may be valuable or desirable in and of itself. However, if the brackish pond is becoming invaded by common reed (***Phragmites australis)***, it may be more appropriate to restore the native brackish water plant community. Considering resource management goals, the brackish pond may be needed to support or reintroduce displaced historical populations.

Isolation of habitat from similar or complementary adjacent habitats

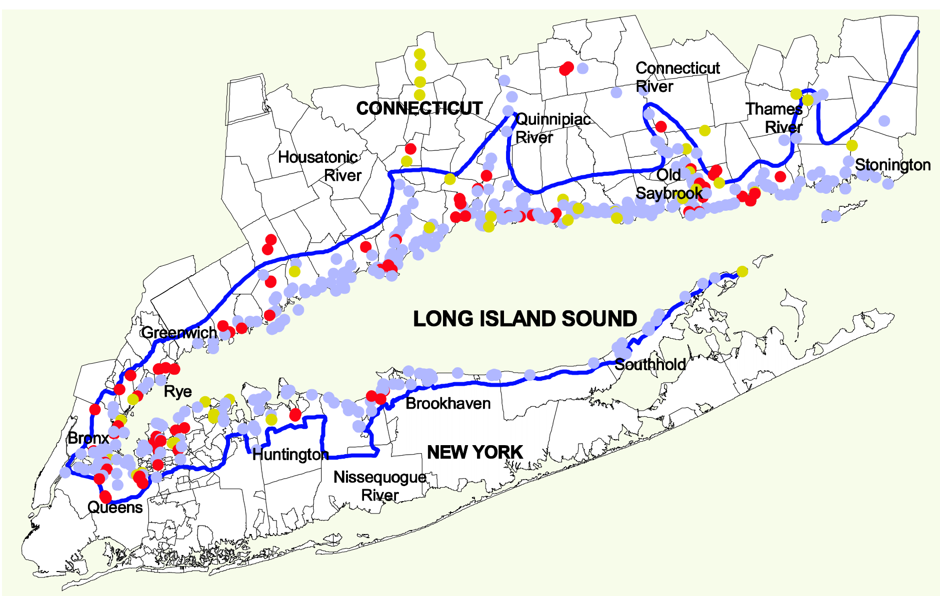
There is a growing awareness of the importance of habitat corridors in developed areas. If recent development or other human activity has cut off traditional roaming areas for animals, the human population becomes impacted by so-called “nuisance” wildlife. The habitat is degraded by losing its carrying capacity for the traditional faunal populations, or it may become undesirable to certain species that require multiple habitat types to complete their life cycles. For example, several species of amphibians need upland areas as habitat during the adult portion of their life, but require standing water to reproduce and develop their young. If a population of amphibians becomes isolated in one or the other of the required habitats, then it will not survive.

At present the Habitat Restoration Initiative Work Group has chosen to focus exclusively on habitat restoration. There are various existing programs that focus on enhancement and creation, but a need exists for habitat restoration in Long Island Sound and its coastal watershed.

PROJECT BOUNDARY

The focus of the restoration efforts falls within a project boundary. This boundary is based on climatological and topographical features, and political jurisdictions. In Connecticut, the boundary is the coastal hardwoods zone ecoregion described in Dowhan and Craig (1976). The northern extent of this ecoregion represents the inland extent of coastally-influenced vegetation. In New York, the project boundary follows the Harbor Hill moraine through Queens, Nassau, and Suffolk Counties. The western extent of the project boundary is the Triboro Bridge span that crosses the East River from Queens to the Bronx. The project boundary in Bronx and Westchester Counties is drawn to follow a portion of the Bronx River and the Hutchinson River Parkway.

Figure 1. Study Sites and Project Boundary



SITE IDENTIFICATION AND RANKING

In 1996, the Work Group solicited input from agency staff, municipal governments, scientists, citizens' groups, and the general public for degraded areas in need of restoration. This solicitation resulted in the identification of more than 400 sites, which were reviewed and ranked by the Work Group. Of the nominations, several were set aside because the project as proposed did not fit into the definition of habitat restoration used for the Habitat Restoration Initiative. Some additional proposals have not been ranked because more information about the site and its history is needed. In other cases, the project is not currently feasible due to a major obstacle, for example, an unwilling landowner, presence of hazardous waste, etc. The remaining proposals were ranked using specific criteria (see ***Appendix A***). The complete list of sites indicating those that have been ranked as a high priority, with the habitat type proposed for restoration at the sites, is updated periodically by the Work Group staff and published separately. A copy may be obtained by contacting:

EPA Long Island Sound Office
Stamford Government Center
888 Washington Boulevard
Stamford, Connecticut 06904-2152
(203) 977-1541
(631) 632-9216

LITERATURE CITED

Dowhan, J.J. and R.J. Craig. 1976. Rare and endangered species of Connecticut and their habitats. State Geol. Natur. Hist. Surv., CT Dept. Environmental Protection, Rep. Invest. No. 6, 137pp.

ACKNOWLEDGEMENTS

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U.S. Fish and Wildlife Service
U.S. Army Corps of Engineers
U.S. Department of Agriculture Natural Resource Conservation Service
National Oceanographic and Atmospheric Administration National Marine Fisheries Service
Connecticut Sea Grant
New York Sea Grant
New York Department of State
New York City Department of Environmental Protection
New York City Department of Parks and Recreation
Audubon New York
Save the Sound, Inc.

The authors and the Habitat Restoration Work Group would like to express their appreciation to all the knowledgeable people who patiently reviewed and re-reviewed this document in all its incarnations. Unfortunately there are far too many people involved to list them all here individually. It is, in part, through the dedication of these fine professionals that we are able to restore Long Island Sound's habitats effectively.

APPENDIX I-A

RANKING CRITERIA

Sites nominated for restoration through the Habitat Restoration Initiative have been ranked according to the criteria below. The ranking is used to help the Work Group members set annual planning and funding priorities. In addition to the ranking, many factors influence the order in which projects move forward. The presence of a local sponsor, an existing restoration design, or available funding can move a project forward more quickly, and the Work Group members are available to provide technical advice to local project sponsors on any project regardless of rank.

ECOLOGICAL CRITERIA

- Size of site restored
- Benefits of the site to trust* species
- Potential to restore ecological functions
- Potential to restore a diversity of plants and animal species at a site

LOGISTICAL CONSIDERATIONS

- Technical probability of success
- Community support
- Cost per acre of project
- Implementation readiness
- Extent of required maintenance

PUBLIC AND ECONOMIC BENEFITS

- Access and open space
- Environmental equity
- Economic benefits
- Recreational opportunities
- Educational opportunities
- Associated surface and groundwater improvements

* Trust species are those for which there is a legal mandate to protect or manage by the state or federal government. These include endangered and threatened species, migratory waterfowl, and managed fisheries, among others.

LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

SECTION 1: TIDAL WETLANDS

Technical Support for Coastal Habitat Restoration

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SECTION 1: TIDAL WETLANDS

DESCRIPTION

The textbook tidal wetland is the salt marsh of the estuarine shoreline. There are also brackish and fresh tidal marshes, which support reeds, bulrushes, and even shrubs and trees. Healthy tidal wetlands are dynamic systems subject to constant changes in elevation and vegetation patterns in response to natural events such as erosion, sedimentation, and sea level rise. The occurrence of tidal wetlands is determined by the geology and resulting topography of Long Island Sound and its shoreline. For example, the shoreline in Connecticut and Westchester County is more conducive to the formation of these marshes than Long Island's Sound shoreline east of Port Jefferson. The reason for this phenomenon is the Sound's glacial history; as the last glacier retreated from the Long Island Sound basin 19,000 years ago, it left a recessional moraine atop the scoured-out coastal plain wedge of Long Island's north shore. In the eastern section, this moraine directly borders the Sound. The resulting high, sandy bluffs erode easily. This erosion produces a straight shoreline and prevents the development of wetlands.

In the western section of Long Island, the moraine is set back further from the shore. Instead of following the moraine, the shoreline follows the edge of the ancient coastal plain. The coves and bays in this region are the result of north flowing rivers and streams carving valleys into the coastal plain. Tidal wetlands are found in these coves and bays.[1]

The coves and inlets of the Connecticut and Westchester County coast are defined by underlying bedrock. This geology, as well as the overlying substrate, is conducive to the formation of tidal wetlands; fine-grained sediments, as deep as 43.7 yards, were deposited by the melting glacier along much of the coast. These deltaic deposits support most of the Sound's major tidal wetland complexes.

SALT MARSHES

The most abundant and best known type of tidal wetland is the salt marsh. The soil salt content ranges from approximately 18 to 30 parts per thousand (ppt). These grassy communities represent the "climax" vegetation on these tidal shores since there are no temperate zone trees or shrubs that can tolerate regular flooding with salt water. Four grasses dominate this marshscape: black grass (***Juncus gerardii***), spike grass (***Distichlis spicata***), salt meadow cordgrass (***Spartina patens***), and saltwater cordgrass (***Spartina alterniflora***). Saltwater cordgrass is dominant in the low marsh zone, which is flooded twice daily by the tides. This zone occurs along the seaward edges, creeks, and ditches of the wetland. Black grass, spikegrass, and salt meadow grass occur on the higher elevations of the marsh known as the high marsh zone, which is irregularly flooded (***Figure 1-1***). The upland border zone of the wetland, flooded only several times a month, contains plants such as switchgrass (***Panicum virgatum***), marsh elder (***Iva frutescens***), and groundsel tree (***Baccharis halimifolia***).

The high marsh zone may contain permanent ponds and depressions called pannes. The ponds often contain widgeon grass (***Ruppia maritima***), a submerged aquatic vegetation important in the diet of waterfowl. Pannes may be devoid of vegetation or may support stunted cordgrass and/or saltwort (***Salicornia*** spp.).

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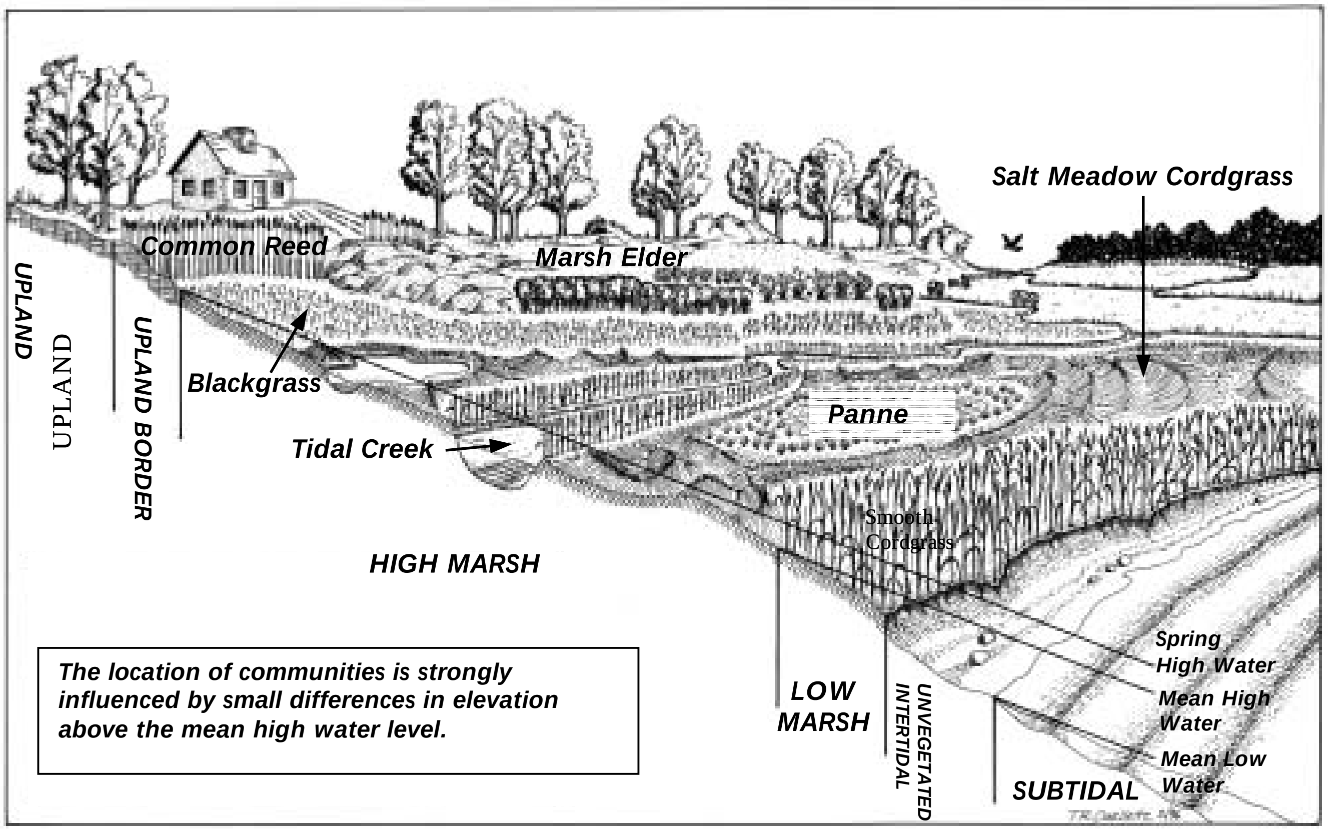
[1]It is interesting to note that, because of the slope of these ancient valleys, homes were not built adjacent to the wetlands, but at higher elevations. This unique situation enabled these marshes to escape being mosquito-grid ditched because mosquitoes were not an immediate threat to coastal homeowners.

FIGURE 1-1. Generalized Zonation of Plant Communities in a Typical Long Island Sound Salt Marsh



Common reed (***Phragmites australis***) may be present on the upland border of salt marshes. Since the plant cannot tolerate salinity levels greater than approximately 18 ppt (Rhodes and Simmers, 1978), or high sulfide levels (Chambers ***et al***., 2001), it does not invade salt marshes. However, degraded marshes that have had their salinity lowered to less than 18 ppt are subject to invasion.

The invertebrate animal communities found among the salt marsh plants and in the creeks and ditches include crabs, snails, shrimp, mussels, insects, and spiders (Olmstead and Fell, 1974). These species may be found in zones similar to those of the plant communities. For example, the mud snail (***Nassarius obsoletus***), is commonly found in creeks and ditches; the rough periwinkle (***Littorina saxatilis***) is found in the saltwater cordgrass of the low marsh; and the saltmarsh snail (***Melampus bidentatus***) is found in the high marsh. Other low marsh fauna include ribbed mussel (***Geukensia demissa***), fiddler crabs (***Uca*** spp.), striped sea anemone (***Haliplanella luciae***), and the common clamworm (***Nereis virens***) (Warren and Fell, 1996). In addition to the saltmarsh snail, high marsh invertebrates include isopods (***Philoscia vittata***) and amphipods (***Orchestia grillus***).

Because of their high productivity, tidal wetlands provide critical spawning and nursery habitat for a wide variety of fish species. These species, in turn, are important prey for valuable commercial and recreational fish species such as striped bass (***Morone saxatilis***), blue fish (***Pomatomus saltatrix***), and winter flounder (***Pleuronectes americanus***). Fish species found in the creeks and ditches include common mummichog (***Fundulus heteroclitus***), striped killifish (***Fundulus majalis***), the sheepshead minnow (***Cyprinodon variegatus***), American eel (***Anguilla rostrata***), Atlantic silverside (***Menidia menidia***), and young-of-the-year winter flounder.

Common birds of the tidal marsh include osprey (***Pandion haliaetus***), herons, egrets, rails, swans, shorebirds, ducks, and two species of marsh sparrow. Although there is much overlap in avifaunal use of salt, brackish, and freshwater marshes, there are some important differences in the distribution of bird species. The distribution of marsh breeding bird species can often be linked to change in vegetation from salt to freshwater marshes. Species that are habitat specific for ***Spartina*** spp.-dominated marsh (salt and mesohaline brackish) are seaside sparrow (***Ammodramus maritimus***), saltmarsh sharp-tailed sparrow (***Ammodramus caudacutus***), willet (***Catoptrophorus semipalmatus***), and clapper rail (***Rallus longirostris***). These species decrease in abundance with increasing distance from the mouth of the river. Marsh wren and swamp sparrow, on the other hand, build nests in tall reedy vegetation and are most abundant in oligohaline brackish marshes where cattail and ***Phragmites*** are the dominant plants (Benoit and Askins, 1999). Although no studies have directly linked freshwater marsh vegetation to any breeding bird species, a number of species, including wood duck (***Aix sponsa***) (Benoit, 1997; Craig, 1990), sora rail (***Porzana carolina***), song sparrow (***Melospiza melodia***), spotted sandpiper (***Actitis macularia***) and American bittern (***Botaurus lentiginosus***) (Craig, 1990), are found almost exclusively in freshwater habitats.

Many wading birds, wetland generalists that use marshes for foraging rather than nesting, can usually be found in tidal marshes throughout the range of salinities. However, even these non-marsh breeders can exhibit a preference for marsh type: snowy egret (***Leucophoyx thula***) and great egret (***Casmeroduis alba***) are much more common in salt and brackish wetlands, while great blue heron (***Ardea herodias***) prefer freshwater areas.

BRACKISH MARSHES

Brackish marshes occur in embayments and tidal rivers where the waters of Long Island Sound are significantly diluted by freshwater. In these wetlands, the salt content of the soil ranges between 0.5 and 18 ppt (oligohaline to mesohaline). At the upper salinity range, black grass, spike grass, and salt meadow grass may be dominant. Salt marsh aster (***Aster tenuifolia***) and silverweed (***Potentilla groenlandica***) grow in this area as well, reaching a greater abundance here than in the salt marsh. The distinction between this community, referred to as brackish meadows, and the superficially similar salt marsh community was first recognized by Nichols (1920). The difference between the two is important to recognize when determining restoration techniques and establishing restoration goals.

As the soil halinity decreases, blackgrass, spike grass and salt meadow grass decrease in abundance and are replaced by locally dominant species such as common three-square (***Scirpus americanus***), bulrush (***Scirpus robustus***, ***Scirpus paludosus*** v. ***atlanticus*** and ***Scirpus cylindricus***), water hemp (***Amaranthus cannibina***), big cordgrass (***Spartina cynosuroides***), slough grass (***Spartina pectinata***), and common reed. Nichols (1920) notes that brackish reed marshes "are usually occupied by a dense growth of cattails (especially ***Typha angustifolia***) or of the reed (***Phragmites australis***), together, particularly in the drier situations (as, for example, on marginal embankments)." Narrow-leaved cattail (***Typha angustifolia***) is the dominant species in many of the brackish reed marshes although in very low salt environments the dominant cattail is a hybrid known as ***Typha*** X ***glauc***a. Narrow-leaved cattail is a species that prefers alkaline areas and thus is probably present in brackish marshes not because of the salt content but because of the alkaline nature of the soils.

Many animal communities of the salt marsh may also be found in the brackish marsh. Differences include the absence of the ribbed mussel and the fiddler crab (***Uca pugnax***) from the brackish marsh. Conversely, species not found in the salt marsh, but found in the brackish marsh, include the high marsh snail (***Succinea wilsoni***) and the red-jointed fiddler crab (***Uca minax***). Brackish high marsh areas provide important foraging habitat for a variety of fish species (Weisberg and Lotrich, 1982; Fell ***et al***., 1998). These species, in turn, provide an important trophic link between the highly productive marsh and near shore estuarine waters (Kneib and Stiven, 1978).

TIDAL FRESH MARSHES

Fresh tidal marshes occur in areas where the tide rises and falls but the waters have no detectable concentration of salt. Technically, these marshes are not considered a part of the estuary. Fresh tidal marshes are the most diverse tidal wetland type and support a great variety of plants such as wild rice (***Zizania aquatica***), arrow arum (***Peltandra virginica***), river bulrush (***Scirpus fluviatilis***), sweetflag (***Acorus calamus***), and broad-leaved cattail (***Typha latifolia***). Nichols (1920) reported common reed as an associated or local dominant with cattail. Tidal fresh marshes have 25 to 40 species growing intertidally, and 60 to 100 species in sections of the marsh that are flooded infrequently (Odum, 1984).

The wild rice community in the lower/mid-tidal flats is often associated with pickerelweed (***Pontederia cordata***), arrowhead (***Sagittaria*** spp.), marsh purslane (***Ludwigia palustris***), false pimpernel (***Lindernia dubia***), and golden club (***Orontium aquaticum***). The sweetflag community in the mid-tidal range is associated with three-way sedge (***Dulichium arundinaceum***), common beggar's tick (***Bidens frondosa***), a sedge (***Carex stricta***), water horsetail (***Equisetum fluviatile***), spotted jewelweed (***Impatiens capensis***), yellow iris (***Iris pseudacorus***), water smartweed (***Polygonum punctatum***), water duck (***Rumex verticillatus***), bur-reed (***Sparganium eurycarpum***), and rice cutgrass (***Leersia oryzoides***). Wild rice, pickerelweed, and some bulrush species are also found in this tidal range. The regularly-flooded zone often contains a community of arrow arum, river bulrush, and cattail. Many of the mid-tidal range species are also found in this zone. Common reed, though it does not expand as rapidly compared to brackish marsh, can outcompete freshwater vegetation to form monocultures.

While these patterns of dominance exist, there is no distinct zonation such as that found in salt marshes. The tidal fresh marsh also differs from the salt marsh in that it usually has numerous co-dominant species as opposed to one species growing in a certain zone, such as saltwater cordgrass dominating the low zone of the salt marsh.

The faunal community of the tidal fresh marsh is similar to that of the salt marsh, but composed of different species. The invertebrate community contains amphipods, especially ***Gammarus fasciatus***, oligochaete worms, freshwater snails, and insect larvae. Copepods, cladocerans, and freshwater shrimp (***Macrobrachium*** spp.) may also be found in the tidal fresh marsh (Mitsch and Gosselink, 1986). Numerous juvenile and adult fish, including killifish (***Fundulus*** spp.), bluegill (***Lepomis macrochirus***), largemouth bass (***Micropterus salmoides***), sunfish (***Lepomis*** spp.), and shad (***Alosa*** spp.), are found in these areas. Some of the same bird species that use the salt marsh also use the tidal fresh marsh. In addition to these species, sparrows, finches, blackbirds, wrens, and other ground and shrub birds may be abundant.

While tidal fresh marshes are diverse and ecologically important, they comprise only a small percentage of the tidal wetlands within the Habitat Restoration project boundary. For this reason, the tidal wetlands chapter will focus on brackish and salt marshes where salt concentrations become the major factor in restoration efforts.

VALUES AND FUNCTIONS

Wetlands are ecologically, economically, and socially valuable. The health and productivity of a wetland depend on the intricate interactions of marsh organisms, both plant and animal.

Wetlands are an important source of food for fish and wildlife. The primary productivity of wetlands rivals that of rainforests and high yield agricultural fields. Above-ground production of salt marsh angiosperms along the Connecticut coast ranges from 650 $g/m^2/yr$ to 2000 $g/m^2/yr$ (Niering and Warren, 1980). Many species of wildlife, particularly waterfowl, directly consume the wetland plants and their seeds. An even greater number of species, including zooplankton, shrimp, snails, clams, worms, and forage fish eat the detritus from decaying plants or the bacteria, fungi, diatoms, and protozoa growing on plant surfaces (Crow and Macdonald, 1979; de la Cruz, 1979). These species become the primary food for commercial and recreational fishes, including bluefish, striped bass, flounder, and weakfish. The marshes' high productivity contributes to it being an important feeding ground for migrating waterfowl, raptors, shorebirds, and wading birds.

Wetlands also provide critical habitat as spawning and nursery areas for finfish. ***Table 1.1*** lists finfish species commonly captured during Connecticut Department of Environmental Protection surveys in and around Connecticut coastal marshes from 1990-1996.

TABLE 1-1. Finfish Using Connecticut Marshes and Adjacent Open Water for Spawning and Nursery Grounds (Species in bold type have commercial and/or recreational importance)

Species	*Spawning*	*Nursery*
American eel		*
American shad		*
anchovy	*	
Atlantic tomcod	*	*
blueback herring	*	
cunner		*
four-beard rockling	*	*
grubby	*	*
hogchoker	*	*
menhaden	*	
northern puffer	*	*
northern kingfish	*	
oyster toadfish	*	*
rock eel (gunnel)	*	*
smooth flounder	*	
striped searobin		*
Summer flounder	*	
tautog (blackfish)		*
windowpane flounder		*
winter flounder	*	*

There are more than 40 plant and animal species of special concern, threatened, or endangered status that depend on the presence of tidal marshes for one, or many, of their life stages. The diamond-back terrapin (***Malaclemys terrapin***) is found only in brackish and salt water marshes. Seaside and saltmarsh sharp-tailed sparrows, both species of special concern in Connecticut, nest in salt marshes and, to a lesser extent, brackish meadow marshes. The stunted cordgrass areas, found in pannes of the high salt marsh, are critical foraging habitat for these sparrows. See ***Table 1-2*** for a partial list of other trust species (New York, Connecticut or federal) using the marsh.

TABLE 1-2. Partial List of Other Trust Species (New York, Connecticut or federal) Using the Marsh

Common Name	Scientific Name
least shrew	***Cryptotis parva***
American bittern	***Botaurus lentiginosus***
least bittern	***Ixobrychus exilis***
willet	***Catoptrophorus semipalmatus***
king rail	***Rallus elegans***
osprey	***Pandion haliaetus***
golden club	***Orontium aquaticum***
Eaton's beggar-tick	***Bidens eatonii***
sea-coast angelica	***Coelopleurum lucidum***
Parker's pipewort	***Eriocaulon parkeri***
salt marsh bulrush	***Scirpus cylindricus***

There are also a number of species featured in state and federal management plans that depend on tidal wetlands. For example, a priority recommendation in the North American Waterfowl Management Plan is to protect tidal marshes for the declining population of American black duck (***Anas rubripes***). The black duck and species such as willet ***(Catoptrophorus semipalmatus***), clapper rail (***Rallus longirostris***), marsh wren (***Cistothorus palustris***), mallard (***Anas platyrhynchos***), and Canada goose (***Branta canadensis***) use tidal wetlands for nesting. Non-trust species frequenting the marsh include fox, racoon, deer, turtles, snakes, frogs, beavers, muskrats, and voles.

Tidal wetland values are not limited to food production and habitat. Wetlands function to maintain water quality, filter nutrients and pollution, and remove sediments from water. The roots of tidal wetland vegetation and underlying substrate remove nutrients, especially nitrogen and phosphorus, from surface runoff. Studies on the Tinicum marshes near Philadelphia reported a 50-70 percent reduction in nitrogen and phosphorus after wastewater had passed through the marsh (Grant and Patrick, 1970). As the vegetation and soil filter out nutrients, they also remove pesticides, heavy metals, and other chemical constituents. The marsh not only acts as a filter for these pollutants, but it also functions as a settling basin (Bastian and Benforado, 1988). Vegetation acts as a buffer to slow water velocity, increasing settling time for suspended and particulate matter.

Other wetland values involve the protection of adjacent shoreline from flood and wave damage and erosion. As waves, storm surges, and currents move through the marsh, their energy is deflected by plant stems and leaves (Knutson, 1988). A reinforced root system helps to stabilize the marsh and resist erosion. The dissipation and absorption of energy by the marsh increases the potential for sediment deposition and decreases the potential for shoreline erosion. Also, the ability of wetlands to quickly absorb and then slowly release flood waters helps prevent flood damage.

Wetlands also provide aesthetic values and direct and indirect economic benefits as important sites for recreational fishing, waterfowl hunting, canoeing, nature observation, hiking, photography, and boating.

STATUS AND TRENDS

Current estimates place the acreage of all Long Island Sound tidal wetland types at 20,820 acres. Eighty-five percent of these wetlands occur in Connecticut. Prior to the implementation of current tidal wetland regulations, an estimated 25 to 35 percent of the Sound's tidal wetlands were destroyed by dredging, filling and development (Long Island Sound Study, 1994). Examples of specific activities that led to wetland loss include: dredging to create open water for commercial shipping lanes and recreational marinas; disposal of municipal waste (***i.e.*** landfills); and the placement of fill or disposal of dredged sediment to create upland transportation facilities (roads, railroads, and airports), or commercial, industrial, and residential development. In Connecticut, annual permitted wetland losses due to these types of activity currently average 0.25 acres.

Other activities may not destroy a marsh, but instead impair its functions and values. For example, many marshes are grid-ditched, drained, impounded, or impacted by stormwater runoff. Approximately 90 percent of the Sound's marshes have been grid-ditched, an activity that has had a negative impact on water levels in the marsh, resulting in declines in muskrat abundance (Stearns ***et al***., 1940) and changes in species composition of bird communities. An on-going, natural form of degradation involves the spread of common reed into brackish marshes at a rate of 1-2 percent per year (Warren, 1994).

Human activities that destroyed marshes contributed to an estimated 30 percent loss in Connecticut. Estimates of historical acreage range from 23,360 acres (Niering, 1961) to 26,500 acres (Goodwin, 1961). Presently, there are approximately 17,610 acres[2]. The average annual loss rate was 125 acres. The estimate of a 30 percent loss was supported by a recent analysis that compared a limited geographic area from 1880s Coast and Geodetic Charts to the same geographic area in 1974. There is a distinct geographic trend with wetland losses diminishing from west to east, corresponding to the trend from the most urbanized to the most rural area of the coast. Specific wetland losses in acres for individual counties ranged from 2.4-57.4 percent (***Table 1-3***).

TABLE 1-3. Wetland Losses (in acres) for Four Connecticut Counties

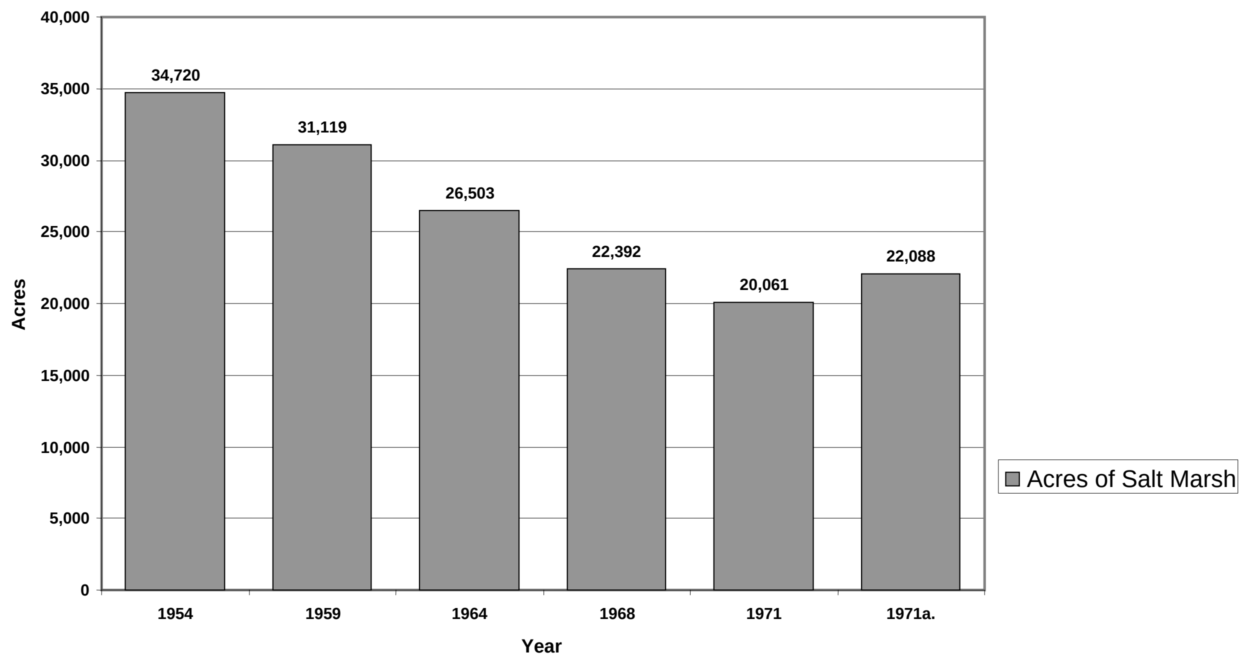
	Fairfield	New Haven	Middlesex	New London
1880s	5423.5	7653	4023	3762.6
1970s	2111.8	5733.6	3101.5	3670.7
Acres Lost	3111.7 (57.4%)	1919.4 (25.8%)	921.5 (22.9%)	91.9 (2.4%)

In New York State, tidal wetland losses have been fairly well documented from the 1950s to the 1970s. Unfortunately these inventories were conducted using varying methodology and did not differentiate between water bodies. Therefore, it is difficult to make an accurate comparison over time, and not possible, from extant studies, to determine losses solely in New York's portion of Long Island Sound. The studies available examined, for the most part, large wetland complexes considered of high value to waterfowl and wildlife. It appears that all but one of these inventories may have underestimated the total amount of wetland by omission of fringing marshes, especially those so

[2] This figure is based upon Connecticut's tidal wetland mapping that was completed in the 1970s, and includes a 1994 revision for the Connecticut River. The original 1970s maps did not include all of the state's tidal wetlands and in certain areas such as the mouth of the Housatonic River, new wetland areas have formed. This figure, therefore, underestimates the tidal wetland acreage present in Connecticut.

prevalent along the exposed shorelines of the Sound. However, it is doubtful that these relatively small areas of fringing marsh would alter the overall trend over the twenty year period examined. ***Figure 1-2*** depicts the total salt marsh acreage of Nassau and Suffolk Counties in specific years from 1954 to 1971. The data indicate a 36 percent loss during this period (U.S. Fish and Wildlife Service, 1965; N.Y. State Office of Planning Services, 1972) when the studies of comparable methodology are considered. The data labeled "1971a." in ***Figure 1-2*** represents a more comprehensive inventory undertaken by O'Connor and Terry (1972) that includes the fringing marshes as well as large complexes in the two counties. Individual data for Bronx county, where the majority of that county's salt marshes bordered the Sound, indicate a 90 percent loss of large wetland complexes from 1954 to 1964 (U.S. Fish and Wildlife Service, 1965). The NYSDEC conducted a full inventory of tidal wetlands in 1974 as required by the passage of the Tidal Wetlands Act. At that time there were estimated to be 3,200 acres of vegetated tidal wetlands in the New York portion of Long Island Sound. This estimate includes the Long Island Sound shoreline and all the bays and harbors opening on the

Figure 1-2. Wetland Inventory Figures for Nassau and Suffolk Counties, NY 1954 - 1972



Sound in Bronx, Queens, Nassau, Suffolk, and Westchester counties.

In the subestuaries (i.e., tidal rivers) of central and western Long Island Sound (LIS), with a tide range of 5 to 8 feet, emergent tidal wetland, especially low marsh habitat, is converting to intertidal flat. This phenomenon was first noticed in the mid to late 1980s in the Fivemile River in Darien. The pattern of loss is not uniform within any particular subestuary. On average, the losses appear to be the greatest in the mid-estuary segments and maximum loss rates since 1974 are approximately 60 percent. The single greatest loss is occurring in the mid-section of the Quinnipiac River, affecting an area of brackish wetland of approximately 80 hectares. The biophysical changes in these marshes bear a striking resemblance to other eastern seaboard wetlands that scientists attribute to accelerated relative sea level rise. Initial investigations of marshes in the New York portions of the Sound have revealed similar losses in several areas. These losses also appear consistent with reports from other estuaries of the eastern United States.

Rates of sediment accumulation in marshes must equal or exceed rates of sea level rise if the wetland is to persist and not "drown". Historic rates of sea level rise over the last 1500 years averaged ~1 mm/year, but rates over the last 100 years in southern New England have been averaging 2.4 mm/year (Donnelly and Bertness, 2001), a modern day phenemenon that may be responsible for the patterns of wetland vegetation change and loss seen in the Sound. Preliminary analysis of tide data for the New London tide station shows sea level rise rates of 3.6 mm/year and 9.0 mm/year for the period 1970 to 2000 and 1989 to 2000 respectively (R. S. Warren, personal communication). In both Connecticut and New York, research is underway to assess trends of tidal wetland losses and impacts due to sea level rise. The New York State Department of Environmental Conservation is conducting a tidal wetlands trends analysis by digitizing and comparing wetland areas from historic and current aerial photographs. The goals are to identify specific areas of loss, determine reasons for loss, and then pursue remediation and restoration with partners. In Connecticut, a series of sedimentation erosion tables will be installed in a number of marshes in order to measure changes in marsh surface elevation. This will allow researchers to determine if marsh surface elevation is keeping pace with sea level rise.

The first law to protect coastal wetlands in New York State, passed in 1973, is under Article 25 of the New York State Environmental Conservation Law. This law, called the Tidal Wetland Act, establishes policy allowing for the protection of wetlands balanced with reasonable economic development for the state. Activities in or near wetlands are subject to a regulatory review process. The regulatory program, administered by the New York State Department of Environmental Conservation (NYSDEC), has been in effect since 1977. Article 15, the Protection of Waters Act, is also administered by NYSDEC. This law regulates the placement of structures, dredging and filling activities, and alteration of water courses in navigable waters of the state. Waters of the state have been defined to include bordering wetlands.

Connecticut passed its Tidal Wetland Act in 1969. This Act establishes a policy that requires the preservation of tidal wetlands and is executable through a regulatory program that requires permits in order to conduct activities in tidal wetlands. Activities that are inconsistent with the state's policy, which includes all of the policies and standards of the state's coastal management act, cannot be authorized.

In recognition of long-term and on-going tidal wetland degradation, the Connecticut Coastal Management Program of 1979 drafted a policy that "encourages the rehabilitation and restoration of degraded tidal wetlands." In 1980, the Coastal Area Management Program (now called the Office of Long Island Sound Programs) of the Connecticut Department of Environmental Protection (CTDEP) began a long-term program for restoring heavily degraded tidal wetlands.

DEGRADED MARSHES AND RESTORATION METHODS

Degraded and altered tidal marshes of Long Island Sound are grouped into the following categories:

- Grid-ditched
- Drained
- Buried/Filled
- Common reed-dominated brackish marshes
- Impounded
- Stormwater impacted

These categories are listed in the order of greatest to least amount of acreage impacted. Grid ditching has affected more acreage of salt and brackish marshes than any other type of degradation. Fortunately, its impacts on the marshes' value and functions are mild when compared to degradation such as filling, which completely eliminates all tidal wetland values and functions. The second most common form of degradation, draining, alters plant species composition dramatically and reduces some of the values and functions.

The categories of marsh degradation and some specific changes in the marshes' value and functions are discussed below. Methods of restoration for each type of degradation are also presented.

GRID-DITCHED MARSHES

In the early part of this century, the prevention of mosquito-spread disease was a major concern of health officials. The draining of intermittent shallow pannes and ponds on the marsh surface was the focus of efforts to eliminate salt marsh mosquito (***Aedes solicitans*** and ***Aedes cantator***) breeding habitat. Grid ditches were constructed in order to drain these areas. More than 90 percent of the short-grass meadow communities of salt and brackish marshes were ditched in the Sound region. These ditches were approximately 30 inches wide and 30 inches deep. Parallel ditches 100 feet apart ran perpendicular to the shoreline and to lateral ditches every 400 feet.

Ditches effectively lowered a marsh's water table by several inches, eliminating ponds and intermittent pools, as well as creating drier soil conditions. While salt meadow grass production improved, the stunted cordgrass associated with pannes disappeared. Other changes included the elimination of pools containing widgeon grass and an increase in the tall form of saltwater cordgrass. This change in plant species composition led to an overall decrease of values and functions. For example, studies have shown that avifauna species abundance and diversity is greatest on the natural marsh and significantly lower in ditched marsh habitats (Reinert ***et al***., 1981 and Clarke ***et al***., 1984).

Restoration Methods:

① <u>Abandoning the Maintenance of Grid-Ditching</u>: This method allows the ditches to naturally fill with sediment. When the ditch becomes sufficiently shallow, saltwater cordgrass will begin to grow. The rate at which this process occurs varies according to the marsh and the specific hydrologic conditions. For example, forty years after a dike was constructed at the Barn Island marsh in Stonington, Connecticut, a tidal creek that had been cut off from tidal flow had converted to vegetated marsh. Sixty years after the Great Meadow marshes in Stratford, Connecticut were ditched, the majority of never-maintained ditches received only partial tidal exchange and contained intermediate-height saltwater cordgrass. A smaller percentage of the ditches received full tidal exchange and supported tall saltwater cordgrass along their banks. Ten years after stopping the maintenance of grid ditching in Connecticut's Hammonasset State Park many of the ditches have filled with sediment (soupy substrate) and vegetation. There was also a dramatic increase in pannes and panne vegetation, which has led to increased wildlife utilization.

② <u>Ditch Plugs:</u> This method has been used to restore grid-ditched marshes in both Connecticut and New York. The placement of soil plugs into the ditch restores the high water table in the adjacent marsh almost immediately. Studies in Old Lyme, Connecticut, have shown that after only a year, a large expanse of pannes reappeared on the marsh surface. At another site in Westbrook, Connecticut, a dramatic increase in wildlife use was observed immediately after plugging.

Preventing scour of the plug during spring high tides requires the placement of fill in a 20-25 foot length of ditch where the peat is firm and a 50 foot length where it is soft. Marine plywood may be used to stabilize the ends of the plugs and prevent erosion, but the longevity of the structure is not known at this time. Due to the interconnected nature of these ditches, it is usually necessary to plug several of them in order to restore a section of marsh.

③ Pond Creation: This method may be used to enhance unditched salt marshes or to help restore ditched salt marshes. Unfortunately, most of the mosquito ditching was conducted prior to the first aerial surveys, so no exact blueprints exist as to the historic location and number of ponds.

To create ponds, small, irregularly-shaped areas are excavated on the marsh surface. These ponds are a minimum of 25 feet in diameter and have a shallow perimeter averaging 6-12 inches in depth. Greater depths are excavated in the middle, usually covering one-quarter of the pond's size. The shallow shelf provides access for wading birds such as shorebirds and egrets, while the deeper area provides permanent habitat for aquatic organisms such as killifish. It is common practice to use excavation material from the ponds to plug adjacent grid ditches. For this reason, pond locations are selected based on their proximity to ditches.

DRAINED MARSHES

Gate structures and culverts are the two most common types of tidal flow structures resulting in the restricted draining of a marsh. A common type of gate structure used along the coast for mosquito and flood control is the flapper or sluice gate (***Figure 1-3***). These gates are constructed from wood or metal, are hinged at the top and suspended on a frame. The gates are usually set so that the door swings out toward Long Island Sound. Thus, when the tide ebbs, water moves unrestricted from upstream to downstream. When the tide floods, the gate closes, reducing the tidal range to about a foot. Greater flows occur when the gates have not been maintained, have become wedged open with tidal debris, or have become warped.

FIGURE 1-3. One of Four Flap Tide Gates Open at Hammock River

One of four flap tide gates was opened at Hammock River in Clinton, Connecticut. If more than one gate was opened, it could cause flooding of low-lying residential properties built close to the wetland.

Culverts, if not properly sized or set at the wrong elevation, can reduce tidal flow volumes and tidal heights. When not well maintained, blockages and collapsed pipes will significantly reduce tidal flows.

If culverts are set at too high an elevation, they prevent the water level from reaching its natural low tide level. Salt marshes are further stressed when high culverts prevent freshwater from draining, thus diluting the incoming saltwater.

The restriction of tidal flow into a marsh by culverts or tide gates usually lowers the water table from one inch below the surface to one to four feet below the surface and results in the following: increase in oxygen content of the soil above the water table; increase in the rate of decomposition of the organic matter in the dry soil; subsidence; reduced salinity and sediment accumulation rates; anoxia or hypoxia during summer months; and decrease in pH levels from circum-neutral or slightly alkaline conditions (typical of estuarine waters) to highly acidic (pH 3 to 4).

In general, the lower water table causes the tidal wetland soils to become a source of nonpoint pollution. Under normal conditions, pyrite (iron sulfide) forms in salt and brackish marshes in the presence of wet, anaerobic soils with a high organic content. Oxidation of the soil caused by the lower water table converts the pyrite into sulfuric acid. This action leads to a change in the soil pH from neutral or circum-neutral to highly acidic. Acid sulphate soil is created (Dent, 1986). Soil acidity values as low as three to four have been reported. At these levels, the aluminum found in natural clay particles is mobilized. Aluminum is generally very toxic to aquatic organisms at low concentrations. The water quality is further degraded by soil changes affecting dissolved oxygen levels. Following rainfall events, marsh leachate contains compounds that compete for oxygen, thus increasing the likelihood of a hypoxic event (Portnoy, 1991).

These chemical and physical changes are often accompanied by changes in the biological community. There may be a general loss of aquatic organisms such as salt marsh snails, amphipods, ribbed mussels, blue crabs, and killifish. Plant species composition can also be dramatically altered. If the soil salinity falls below 18 ppt, a drained salt marsh becomes open to invasion by common reed.

Restoration Methods:

Reintroduction of tidal flow is the principal technique used to restore salt marshes degraded by tide gates and undersized culverts. It is also applicable for achieving some fresh and brackish marsh restoration goals. The following information is required in order to determine the appropriate tidal elevation:

- tidal data (downstream and upstream of the structure)
- marsh elevation (downstream and upstream of the structure)
- baseline vegetation (high marsh, low marsh, common reed, etc.)
- creek and soil salinity (downstream and upstream of the structure)
- elevations of lowest lying structures (***i.e.*** homes, property, etc.)

If restoration has the potential to create flooding problems, then either special flood protection measures need to be incorporated into the project (***e.g.***, raising house elevations, construction of dikes around the upland perimeter) or tidal flow must be restored to the extent that flooding problems are not exacerbated. However, partial restoration of tidal flow may result in only partial restoration of the wetland. The following restoration activities are presented in the context that no flooding problems will ensue.

Planting of wetland vegetation is not recommended for this type of restoration. The natural stock of native plant species will spontaneously reestablish themselves. It usually takes several years for undesirable species to die-off. Saltwater cordgrass can often establish a dense cover in a year or two.

① Culvert Replacement: The decision to replace or eliminate a culvert is based on the size of the marsh system, the original reason for the culvert, and the amount of subsidence. If the marsh system is large and has been drained through a single, small culvert, excessive subsidence may have occurred, which requires special design considerations (see discussion below under manual tidal gate management). In small marsh systems, undersized culverts do not usually result in subsidence significant enough to require special engineering and detailed hydrological studies and modeling. If the culvert is associated with a structure such as a road, eliminating the culvert with the intent of restoring an open channel would not be an option. However, there are some locations where the undersized culvert can be removed and the original open channel restored.

If culvert replacement is an option, the original creek dimensions can be used to gage the appropriate size. When there is no potential to increase the risk of flooding to low lying properties, the culvert can be oversized to guarantee a natural flow of water. Another consideration for culvert replacement may be to set the bottom elevation so that at low tide, the upstream creeks and ditches retain some water as permanent habitat for aquatic organisms such as fish.

② Tide Gate Removal: This technique can be used successfully if marsh subsidence is not extreme. Under the appropriate conditions, gate removal can result in the formation of a low marsh system. Connecticut has successfully restored several marshes using this technique; examples include Branford River, Farm River, and Gigamoque Creek. It is projected that the low marsh may eventually turn into a high marsh over decades or centuries. A benefit associated with restoring to a low marsh type is that mosquito breeding will be minimal or non-existent.

In cases where marsh subsidence has been extreme, the likelihood of successfully restoring a marsh by removing the tide gate is minimal. In the early 1950s a hurricane destroyed tide gates that had been draining the Great Harbor and Lost Lake marsh complexes in Guilford, Connecticut. Prior to the destruction of the tide gates both these subsided areas supported a high marsh community complex. When full tidal flow was reestablished several months after the destruction of the tide gates, marsh vegetation was dramatically altered; there was an immediate 80 percent reduction in plant growth. The increased tidal flow over the subsided marsh created a condition that was too wet to support vegetation. After a forty-year period, the unvegetated portion of Great Harbor had been colonized by tall saltwater cordgrass. The Lost Lake area has almost no emergent vegetation and in light of the rapid rate of sea level rise, will probably never support vegetation. At low tide, it is an exposed peat flat.

③ Manual Tide Gate Management: Tide gate management is used to establish a suitable hydrology to maximize the amount of emergent marsh without creating a “Lost Lake” condition. Where there are two or more tide gates, individual gates can be opened to study the effect of increased tidal flow upon marsh vegetation. Monitoring will help to determine whether additional gates require opening. This approach is being used on the Hammock River marsh in Clinton, Connecticut. In 1985, one tide gate was opened resulting in the replacement of reeds by the native salt marsh grasses throughout a large area of marsh. However, there were significant areas where reeds were tall and persistent, prompting a second tide gate to be opened.

Another method used to determine the required number of open tide gates is a two-dimensional tidal hydrology model. Unfortunately, these computer simulations do not take into account the physical barrier that reed presents to the movement of water across the marsh surface. The interior of a reed patch will often be dry even though the surface elevation is below that of the water level in adjacent tidal creeks. The water that cannot penetrate the reed remains in the creek and creates an artificial high water level. As restoration proceeds and reed is converted to short-grass meadow, water spreads across the marsh surface more quickly and the water levels in the creek drop. It may be necessary to open an additional gate to compensate for the drop in water level. Computer models cannot predict this situation.

Flooding problems caused by major storm events such as hurricanes and Nor'easters are most appropriately dealt with through the use of manual gates. In advance of these storm events, the gates can be closed to prevent flooding and reopened after the storm has passed.

④ <u>Automatic Gates:</u> The use of automatic gates is most appropriate when the flooding of low-lying structures occurs so frequently that manual gate operation becomes expensive and impractical. Some automatic gates have electric water level sensors that close the gates when a critical level is reached. A potential problem with this type of gate is the power failures associated with major storm events.

A second type of automatic gate, called a self-regulating tide gate, uses a mechanical means to sense the water level. One or more adjustable floats are attached to the tide gate. When the water level reaches a predetermined critical elevation, the gates close.

IMPOUNDED MARSHES

Raising mean water level elevations through the construction of a dike or dam at the mouth of a cove or tidal river is referred to as an impoundment. The two types found in the Long Island Sound are millponds and wildlife impoundments. In a typical wildlife impoundment, the top of the dam is higher than the wetland surface, so little or no tidal water flows into the site. Freshwater, that would otherwise flow into the Sound, collects and forms a pond over the marsh reducing salinity levels and causing a die-off of the emergent salt marsh vegetation. These areas remain flooded in the spring to attract migrating waterfowl and shorebirds. Water, drawn down in late spring to allow annual plants to grow on the marsh surface, is replaced when the marsh is reflooded in the fall to provide waterfowl with shallow water habitat and easy access to submerged annual plants.

A type of impoundment unique to western Long Island Sound was the tidal millpond. Dikes in combination with tide gates (installed on the upstream side) allowed the millpond to fill with water during the flood tide. On the ebb tide, the gates closed and water returned to the Sound via a sluiceway or channel containing a waterwheel to drive the mill. Although the tidal range was decreased in the pond, daily fluctuations were still encouraged for the mill's operation. The high tide elevation remained more or less the same, but the low tide elevation was raised. When mills were abandoned, the sluiceways were often eliminated and the tidal fluctuations were significantly reduced. Little or no water returned to the Sound during the ebb tide cycle. The prolonged flooding cycle of the wetland surface resulted in the conversion of vegetated wetland to unvegetated intertidal flat or shallow subtidal wetland. The tidal wetland zone contracted and persists today only as a narrow fringe around the tidal pond. When water levels are not managed in a millpond, the pond becomes a large settling basin that allows for a rapid accumulation of sediment.

Restoration Methods:

① <u>Culvert Installation At Wildlife Impoundment Sites:</u> The only wildlife impoundments in the Sound were located at Barn Island in Stonington, Connecticut. Most of these have been restored through the installation of culverts to restore tidal flow. Subsidence values appear to be less than six inches and the vegetation is a mix of high and low marsh communities.

② <u>Tidal Flow Restoration To Millponds:</u> No millponds have been restored to natural conditions in Connecticut as abutting property owners prefer to see open water rather than emergent wetland. Unfortunately, these open water ponds require maintenance. For example, in some Connecticut millponds, the dams have been raised to restore shallow water habitat that was lost due to excessive sedimentation. Since the maximum dam height is dictated by peak flood tide elevation, a point will be reached where the only remedy for sedimentation is dredging.

In theory, the millpond gates and associated structures can be opened or removed to restore tidal flushing. In many places, the bottom elevations are such that within several years, most of the ponds will support low marsh vegetation.

FILLED/BURIED MARSHES

When tidal wetlands were perceived to be mosquito infested wastelands, it was a common practice to fill them in or use them as disposal sites for sediments dredged from navigation channels. Dikes were constructed with marsh sediments and the dredged sediments were hydraulically pumped into the containment area. Wetlands were also commonly filled for sanitary landfills and airports. Unfortunately, the opportunity to restore this type of degraded marsh is limited because most fill sites support various types of development including residential, commercial, and industrial. On sites that have not been developed, common reed is usually the dominant plant in response to the low salt or fresh nature of the soil.

In filled or buried marshes, all the functions and values of the former tidal wetland have been lost. In some cases, the resulting degradation may not be totally undesirable. For example, the sandy dredged sediments that were disposed on Nott Island in the Connecticut River are functioning as critical nesting habitat for diamond back terrapins (***Malaclemys terrapin***). Also, it may be possible to manage these sandy soils to promote the establishment of little bluestem (***Schizachyrium scoparium***) grassland habitat, a rare habitat type. In these cases, the value and uses of the filled marsh must be weighed against the cost and benefit of restoring a tidal wetland.

Restoration Methods:

① Excavation: Excavation is a technique used to remove fills placed over former tidal wetlands (***Figure 1-4***). The goal is to remove the amount of fill necessary to obtain a tidal hydrology

Figure 1-4. Mumford Cove Marsh Restoration

Photo on left shows Mumford Cove marsh restoration site during excavation of fill. The restored marsh, shown on right, has naturally revegetated and now serves as a nursery for Spartina alterniflora plugs used in other restoration projects.

appropriate for emergent wetland vegetation. It should be noted that excavation is one of the more expensive marsh restoration techniques on an area basis.

Fill can cause the underlying peat to be compressed. If compression is minimal, all of the overlying fill can be removed. Wetland peats, due to their fibrous nature, tend to resist excavation. Thus, the blade of a bulldozer or grader will usually pass over the old soil surface and easily locate the contact between the two soil types. This soil variation eliminates the need for continuous checking of the grades to establish a suitable final elevation. Excavated materials are usually disposed on the adjacent uplands.

② <u>Creek Restoration</u>: Aerial photography of pre-disturbance conditions can greatly aid in finding the location of the original creek system. Once a location has been established, sediments are removed with an excavator and subsequently transported to the upland. Monitoring the project site will identify the areas of persistent reed monocultures. Additional distribution channels can be added in these areas to increase the soil salinity.

③ <u>Pond Construction</u>: Either aerial photography or shallow surface depressions can be used in determining restoration sites. As in the case of creeks, the excavated material is transported to the upland. See grid-ditched marsh section for general pond design parameters.

④ <u>Planting</u>: Planting of native wetland vegetation is a restoration option used in combination with other techniques. In general, planting is usually not necessary because marsh vegetation can spontaneously reestablish itself through seeds already present in the fibrous peat soil or seeds transported by the tides from local marshes. If planting is chosen as a restoration option, it is most appropriately used for filled marshes because a natural supply of plant material in or adjacent to the site may not be readily available. Successful planting is based upon the individual tidal elevation requirements of the marsh vegetation. Since the depth and frequency of flooding (hydroperiod) varies across the marsh surface, it may be difficult to determine the most appropriate location for a particular species. Detailed elevation and hydrologic data may be necessary. Unfortunately, this information is not usually immediately available and can be expensive to obtain.

Plant stock should be indigenous to the Long Island Sound region. These plants will be adapted to local climate and tidal hydrology. The use of indigenous stock helps prevent the development of genetic hybrids that may be less desirable than the native species. Ideally, a number of wetland nurseries should be created in the Sound for the express purpose of providing transplant material. These types of nurseries assist in preventing localized degradation of neighboring healthy wetlands during plant extraction. Another option would be to cultivate plants in pots from seeds collected in the field. This method is more costly than transplanting. Additionally, plugs may be purchased from a small number of commercial nurseries in Connecticut and New York that grow native Long Island Sound tidal wetland plants.

BRACKISH MARSHES INVADED BY COMMON REED

Many natural brackish marshes in Connecticut and New York are experiencing rapid displacement of native vegetation by common reed. Although believed to be native to North America, the common reed was not described as an invasive, pestiferous species by Nichols (1920) in tidal fresh, brackish, or salt marshes. This description does not apply to today's common reed population which is spreading at a rate of one to two percent per year in ecologically-sensitive areas like the lower Connecticut River (Warren, 1994). One hypothesis suggests that an invasive strain of common reed may have been introduced from Europe. Recent research supports this hypothesis (K. Saltonstall, 2002). This invasive type of common reed forms a monoculture, reducing marsh value and functionality. Adverse changes in function and value include:

- Reduction in wildlife use by forming an almost impenetrable cover;
- Loss of scenic vistas;
- Increases in fire frequency in direct response to the woody nature of common reed, which can quickly produce a large amount of combustible material; and
- Reduction in plant species richness.

The most important variables that distinguish common reed-dominated from common reed-free areas are water depth and frequency of flooding (Warren et al. 2002) and porewater salinity and sulfide concentrations (R. Chambers, pers. comm.) In areas where these parameters do not meet some threshold level to prevent common reed expansion, the invasion of the non-native strain will continue. To restore some functions and values lost as a result of common reed expansion, a number of actions can be taken to reduce the amount of this plant and encourage other marsh vegetation.

Restoration Methods:

① Mowing: The purpose of mowing is to impose a physical stress on the plant that depletes the rhizomes of their nutrient reserves. The plant will no longer be capable of generating healthy new shoots. There are several theories regarding the best time of year to mow. Winter cuts have produced stunted growth the following season. One reason for this inhibited growth may be that the cut stems allow an entrance point for water, which interferes with the uptake of oxygen, a process identified in ***Typha***.

A more traditional theory promotes spring cuts. These cuts immediately follow the growth of the shoots in the spring, before the shoots have sufficient time to send surplus energy to the rhizome. The resulting new shoots are stunted and at a low density. This initial spring cut, in addition to several summer cuts over a two or three year period should greatly reduce the area of reed.

An example of this cutting routine occurred at a farm site in East Haven, Connecticut. One side of a wet meadow split by a fence supported tall, dense reed. The other side of the fence, which contained cattle, supported wet meadow vegetation with some sparse, very stunted reed plants. The grazing cattle successfully controlled the reed. Unlike the farm, mowed sites will need routine monitoring to identify problem areas and to determine mowing schedules.

Experimental mowing and herbiciding procedures undertaken in the brackish marshes of the lower Connecticut River have shown that mowing just once is an ineffective control of Phragmites. The most effective control was achieved through a combination of spraying with herbicide followed three to six months later with mowing.

② Prescribed Burning: Prescribed burning is a management technique similar to mowing. One of the major constraints to burning is that there must be a significant supply of dry combustible material. Prescribed burning is only effective at reducing the cover of common reed if it is done during the growing season when live shoots can be burned. In order to burn this fresh, wet vegetation, there must be sufficient dry combustible material present. This requirement presents a drawback because dead shoots from a previous year must be available; burning can only be conducted every other year after an intervening period where the grass is allowed enough recovery for dead shoots to accumulate.

Winter burning is not recommended. It can actually increase the rate of spreading. The elimination of shade over the marsh surface and the exposure of burned soil allow the ground to warm up earlier in the spring. The growth of reed may be further enhanced by the ash providing a source of nutrients. In general, winter burning provides only a temporary (several months) removal of this vegetation.

Prescribed burning opportunities along Long Island Sound are limited due to the extensive nature of development on adjacent uplands. On certain islands, this technique might be coupled with the use of herbicide instead of mowing to remove dead shoots.

③ Herbicide: The use of herbicides has been shown to significantly reduce the amount of reed growth and allow for accelerated restoration of native plant communities. The herbicide functions by killing active roots and rhizomes so that no new shoots can be produced. The most commonly used herbicide has the active ingredient known as glyphosate. While this is a broad spectrum herbicide (it kills all plants it comes in contact with), glyphosate has been shown through laboratory and field studies to have minimal impacts upon aquatic organisms. Additionally, glyphosate biodegrades quickly into natural products including carbon dioxide, nitrogen, phosphate, and water. Applications must be coordinated closely with weather patterns to minimize and prevent drifting of the spray onto non-target plants.

Most glyphosate applications are conducted in the late summer/early fall when all of the plants have been pollinated. Studies have shown these applications are most effective if the reed is mowed after the shoots turn brown. If dead Phragmites shoots are not removed, they persist upright for several years and inhibit native plant growth with a combination of shade and physical exclusion. Mowing, on the other hand, exposes the soil surface to sunlight and allows for colonization by native plants or, if there is an understory, competitive release of the shorter marsh grasses.

④ Ditch Plugs: As described previously under “Grid-ditched Marshes”, creating ponds and plugging mosquito ditches can enhance fish and wildlife habitat. However, these same techniques are currently being tested by the Connecticut DEP for effectiveness in reducing common reed. Previous work has shown that plugging ditches inhibits drainage, makes the area wetter, and causes linear pools to form in the plugged ditches. These hydrological changes, which increase flooding and hence increase root exposure to salinity and sulfides, are expected to reduce reed in localized areas. Additionally, it is hypothesized that combining the ditch plug treatment with either herbicide and mulching or mulching alone will be the most effective treatment for reed control.

STORMWATER IMPACTED MARSHES

Human activities on land can significantly impact the circulation of water in the hydrologic cycle. These changes may influence the development of wetlands. Under normal conditions, a percentage of precipitation that falls on undeveloped or unpaved land never reaches adjacent waters or wetlands. Processes such as evaporation, transpiration by plants, and absorption by soil particles all act to prevent a portion of the rainfall from reaching the closest body of water. These processes are accelerated with increased air temperature. This acceleration may occur to such an extent that there will be no precipitation transferred from upland sites to adjacent wetlands during low-volume summer rainstorms. Rainfall over paved project sites or road surfaces is channelized into storm drains. This stormwater is discharged directly into the nearest watercourse or wetland, by-passing the natural soil and vegetation complex that would otherwise store, evaporate, or transpire a significant percentage of this water. The resulting stormwater discharge into the wetland occurs faster and in greater quantities than rainfall transferred from undeveloped uplands to their wetlands. This discharge results in the deposition of sediment upon the wetland surface. The elevation increase results in a more aerobic soil, thus increasing the opportunity for the spread of common reed.

In the case of salt or brackish marshes, the discharge can radically reduce (***i.e.*** dilute) the soil salinity. Summer precipitation becomes a special concern because it is during this growing season that wetland plants are most sensitive to soil chemistry. This too favors the spread of common reed.

The impact of stormwater discharge into a tidal wetland can be extremely localized. But, it can also affect an entire wetland. In very developed urban and suburban areas, there may be multiple stormwater discharges into the water body. The resulting dilution or sediment deposition may influence large expanses of tidal wetlands.

Restoration Methods:

① Retention Retrofits: The goal of retention retrofitting is to retain high frequency, low-volume rainfall on-site. The general design storm in Connecticut is a one-inch rainfall event. This volume projection captures approximately 85 percent of all rainstorm events in a given year. (Most stormwater designs for flood protection target 10 to 25 year storm events.) Stormwater management manuals contain numerous techniques for stormwater retention. The technique of choice depends on specific site conditions, which may include soil type and depth to water table.

② Sediment Controls: Stormwater management manuals contain methods of best management practices to aid the prevention of sediment deposition. Catch basins, while commonly incorporated into a stormwater system, frequently fail to capture a significant percent of sediment, even coarse sand. The system of choice depends on specific site conditions.

MARSHES IMPACTED BY SEA LEVEL RISE

Rates of sea level rise over the past century have more than doubled compared to historic averages of 1mm/year. The accelerated rate of sea level rise may be causing changes in marsh vegetation, as in the conversion of high marsh to ***Spartina alterniflora***-dominated low marsh, and may be responsible for significant losses of tidal wetland acreage. In southwestern Connecticut and Westchester County, New York, there are numerous accounts of the conversion of low marsh to unvegetated tidal flats.

Conversion of high marsh to low marsh will eliminate the habitat functions for nesting birds as well as other fauna that use the high marsh for breeding and foraging. Also, a decrease in plant diversity would occur when the assemblage of high marsh graminoids is replaced by ***S. alterniflora***. Conversion of vegetated marsh to peat flat or open water will result in the loss of all functions and values for plants and animals of tidal wetlands.

Restoration Methods:

① Coco-fiber Logs and Mats: Biodegradable Coco-fiber logs and mats may be used to increase elevation, trap sediments and hence promote marsh restoration in limited areas. Expense of the materials may preclude use in extensive areas. This method has been used with limited success in one site in New York, and will be tested at a site in Conecticut.

② Beneficial Use of Dredge Sediments: This method of restoration involves placement of clean sediments in drowned marshes to create an elevation that will support tidal wetland vegetation. Although use of dredge sediments for marsh restoration and creation is increasingly common in other parts of the country, particularly Gulf Coast states, it has never been used in the Sound. The potential to use this method in the Sound is limited by cost and by the logistical problems associated with transporting sediments from the dredge site to the restoration site.

SPECIFIC RESTORATION OBJECTIVES

Restoration is used here in the general sense to mean that a former salt marsh complex is restored to salt marsh as opposed to brackish marsh. The restored marsh should support similar functions and values as the pre-disturbed marsh even though the restored wetland does not precisely duplicate the original. Precise restoration of the pre-existing vegetation community is not possible for several reasons. First, there are no historic maps that show the distribution of low marsh, high marsh, pools and ponds, and the complex of vegetation types present throughout the high marsh. Without such blueprints, it is impossible to restore all of the original habitats and microhabitats to their original extent and at their precise historic location. Second, the activities that have caused the degradation often have changed the physical characteristics of the marsh and its soils. For example, several feet of soil may have been lost in drained salt marshes. This subsidence may reduce wetland elevations such that restoration of historic tidal flow alters the duration of tidal flooding and the types of plants that can grow under present day conditions. However, understanding the salinity regime and target hydrological conditions at the restoration site may help to predict the resulting plant and animal communities.

Specific restoration goals for tidal wetlands include the following:

RESTORE HABITAT FOR FEDERAL AND STATE PROTECTED SPECIES

Increases in the occurrence of the following species in tidal wetland complexes is a restoration goal:

Animals

Diamond-backed terrapin (***Malaclemys terrapin***)
Saltmarsh sharp-tailed sparrow (***Ammodramus caudacutus***)
Osprey (***Pandion haliaetus***)
American bittern (***Botaurus lentiginosus***)
Least bittern (***Ixobrychus exilis***)
Seaside sparrow (***Ammodramus maritimus***)
King rail (***Rallus elegans***)
Willet (***Catoptrophorus semipalmatus***)
Great egret (***Casmerodius albus***)
Snowy egret (***Egretta thula***)
Little blue heron (***Egretta caerulea***)
Glossy ibis (***Plegadis falcinellus***)

Plants

Lesser sand-spurrey (***Spergularia canadensis***)
Bulrush (***Scirpus cylindricus***)
Bulrush (***Scirpus paludosus var. atlanticus***)
Goldenclub (***Orontium aquaticum***)
Mudwort (***Limosella subulata***)
Arrowleaf (***Sagittaria subulata***)

RESTORE BIOLOGICAL PRODUCTIVITY AND BIODIVERSITY

These two functions are directly related to each other. Biological productivity is the amount of organic material produced per unit time. A healthy tidal wetland supporting maximum populations of plant, wildlife, and marine organisms will be high in biological productivity. In degraded tidal marshes, the species richness (biodiversity) decreases, contributing to an overall decline in productivity. Restoration would, therefore, increase productivity and biodiversity.

REDUCE COMMON REED COVERAGE

The impenetrable cover formed by common reed monoculture reduces the habitat value for many types of wildlife. Aesthetic value is also decreased through elimination of scenic vistas. The goal of restoration is to improve both wildlife use and scenic coastal vistas.

ELIMINATE FIRE HAZARDS

Fires are a common problem in degraded tidal wetlands dominated by common reed. Although fires may occur in brackish and freshwater tidal wetlands dominated by cattail or bulrushes, these marshes do not pose fire hazards as great as those posed by common reed-dominated marshes. Fires are of particular concern where homes are built to the edge of the marshes. By restoring a common reed-dominated marsh to its pre-disturbed condition, the fire hazard will be greatly reduced.

RESTORE WATER QUALITY RENOVATION FUNCTIONS

Healthy tidal wetlands help to filter pollutants from industrial and residential runoff. When tidal wetlands become degraded this beneficial function is greatly reduced or eliminated. This is because the water/soil interface in degraded wetlands is often confined to the primary creeks and channels, rather than to the marsh surface where plants serve as a sink for pollutants. This surface area limitation reduces the ability of the wetland soils to capture pollutants contained in coastal waters and runoff. Restoration of tidal flow to degraded wetlands returns the wetlands' functional value as a pollution filter.

ELIMINATE NONPOINT SOURCE POLLUTION

In drained tidal wetlands, the oxidation of peat can create a variety of water quality problems. Tidal flow restoration will reestablish anaerobic conditions throughout the soil. When this happens, the conversion of pyrite to sulfuric acid and the attendant nonpoint source problems emanating from the wetland soils are eliminated.

RESTORATION SUCCESS AND MONITORING

Depending on the type of degradation and the chosen restoration technique, successful restoration may require the use of equipment that is specifically designed to operate on the organic and compressible soils of tidal wetlands. Most conventional excavation and grading equipment cannot operate on these types of soils and certainly not without causing extensive damage in the form of ruts. Since many restoration projects require equipment access across healthy tidal wetlands, it is imperative to avoid damage caused by conventional equipment. In certain instances, without specialized wetland excavation equipment, temporary haul roads would need to be constructed. Such an approach would make many wetland projects cost prohibitive. Additionally, if the road can only be constructed across healthy wetland, the impacts might be unacceptable under the regulatory permitting process.

Specialized, low-ground pressure equipment exerts a ground pressure of two pounds per square inch or less. Amphibious machines are particularly important for accessing remote wetlands or islands that require water access. CTDEP owns several pieces of this specialized equipment, including a bulldozer, an excavator with grading blade, amphibious excavator, amphibious rotary ditcher, and an amphibious mulcher.

Tidal wetland restoration activities should be evaluated for both short- and long-term goals. The short-term assessment considers the immediate response of the hydrological and biological features. A study of six long-term restoration sites in Connecticut has shown that reintroducing appropriate tidal flow will set a degraded marsh on a trajectory towards restoration of ecological attributes and functions (Warren ***et al***., 2001). However, different attributes, such as vegetation and populations of macroinvertebrates, fish, and birds, recover at different rates (Fell ***et al***., 2000; Warren ***et al***., 2001). Also, due to the dynamic nature of tidal marshes, success in the early stages of restoration does not guarantee overall long-term success. The periodic monitoring of a site can assist with achieving long-term goals by catching design flaws and keeping the project on course. If available, aerial photography provides a method of tracking long-term changes for wetlands of large areal extent. A less expensive, but very useful method for monitoring includes a series of photo stations within or around the marsh.

Two recent publications provide general guidelines for monitoring biotic (vegetation, fish, invertebrates, birds) and abiotic (salinity, tidal regime, soil organic content, etc.) parameters of marsh restoration projects: New York State Salt Marsh Restoration and Monitoring Guidelines (Niedowski, 2000), and Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine (Neckles and Dionne, 1999). The parameters to be measured and the methods suggested represent the baseline information generally required to adequately monitor the generic salt marsh restoration project. Depending on restoration goals and site-specific details, the suggested protocols can be tailored to individual projects.

Overall success depends on the extent to which the original restoration goals are met. Whichever value and functions are identified as being priorities for a particular site are the ones that should be the focus of

long-term monitoring. Annual monitoring of a combination of the following characteristics may help determine restoration success:

- extent of percent cover vegetation versus bare ground
- plant species composition (total list present)
- percent reduction of common reed
- plant cover (percentage) and height (for each common species)
- invertebrate species composition and abundance
- bird use (especially threatened species)
- fish species composition and abundance; use of creeks and high marsh.

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LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

SECTION 2: FRESHWATER WETLANDS

Technical Support for Coastal Habitat Restoration

SECTION 2
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SECTION 2: FRESHWATER WETLANDS

DESCRIPTION

The term "freshwater wetlands" is used collectively to describe the diverse range of non-saline ponds, bogs, fens, swamps, and marshes found in the world. The U.S. Fish and Wildlife Service wetland classification system created by Cowardin ***et al.*** (1979) categorizes freshwater wetlands in the United States as palustrine, lacustrine, or riverine systems. The classification system also addresses deep water habitats where the substrate is predominantly non-soil and flooding is permanent, but those types of wetlands are generally not included in the Long Island Sound Study Habitat Restoration Initiative.

Wetlands display a very distinct set of soil characteristics that make it possible to identify even degraded wetlands by the underlying soil profile. These are known as hydric soils. The U.S. Department of Agriculture's Natural Resources Conservation Service, formerly the Soil Conservation Service, has defined hydric soils as saturated, ponded, or flooded for a sufficient time during the growing season to develop anaerobic conditions in the upper part of the soil (Metzler and Tiner, 1992).

Wetland plant species have adapted to grow in these stressful conditions, whereas most upland plants cannot. Non-submersed wetland plants are able to move oxygen from the air above the hydric soil to the root system embedded in the hydric soils. Those wetland plant species that are found exclusively in saturated soil conditions are known as obligate wetland hydrophyte species. Plants that usually grow in saturated soil conditions, but may occasionally be found outside wetlands, are known as facultative wetland plants. It is predominantly these wetland-dependant plant species, along with soil profiles, that are used to identify and delineate wetlands for regulatory purposes at the state and federal level.

It is important to note that the plant communities in wetlands are highly variable even within similar climatic regions. The descriptions of plant communities that appear here are generalized to the Long Island Sound Study Habitat Restoration Initiative project area around Long Island Sound. Typical species associations are emphasized. The reader should consult the inland wetland programs or Natural Heritage Programs in each state for more specific community descriptions in a given location.

Palustrine wetland systems are defined by Cowardin ***et al.*** (1979) as non-tidal wetlands dominated by trees, shrubs, persistent emergents[1], emergent mosses or lichens; or they may be nonvegetated, shallow water areas (less than six feet deep) with no wave formed or exposed bedrock shoreline features. In order to be considered palustrine, these non-vegetated areas must be less than 20 acres in size.

Riverine communities are defined by Cowardin ***et al.*** (1979) as "all wetlands and deep water habitats contained within a channel", except those that are dominated by persistent emergent vegetation, trees or shrubs (palustrine), or have more than 0.5 ppt ocean derived salinity (estuarine, marine). Community types are classified by the rate of water flow which in turn dictates the substrate composition and faunal and vegetation types present. This system also includes tidally influenced

[1] Persistent emergent plants are those that leave all or a visible portion of their foliage above the saturation zone or water surface during the dormant season. Conversely, non-persistent emergents are those plants that leave no portion of their foliage visible during the dormant season.

freshwater non-persistent emergent riverbank vegetation like wild rice. More information on tidally influenced freshwater wetlands can be found in ***Section 1: Tidal Wetlands***.

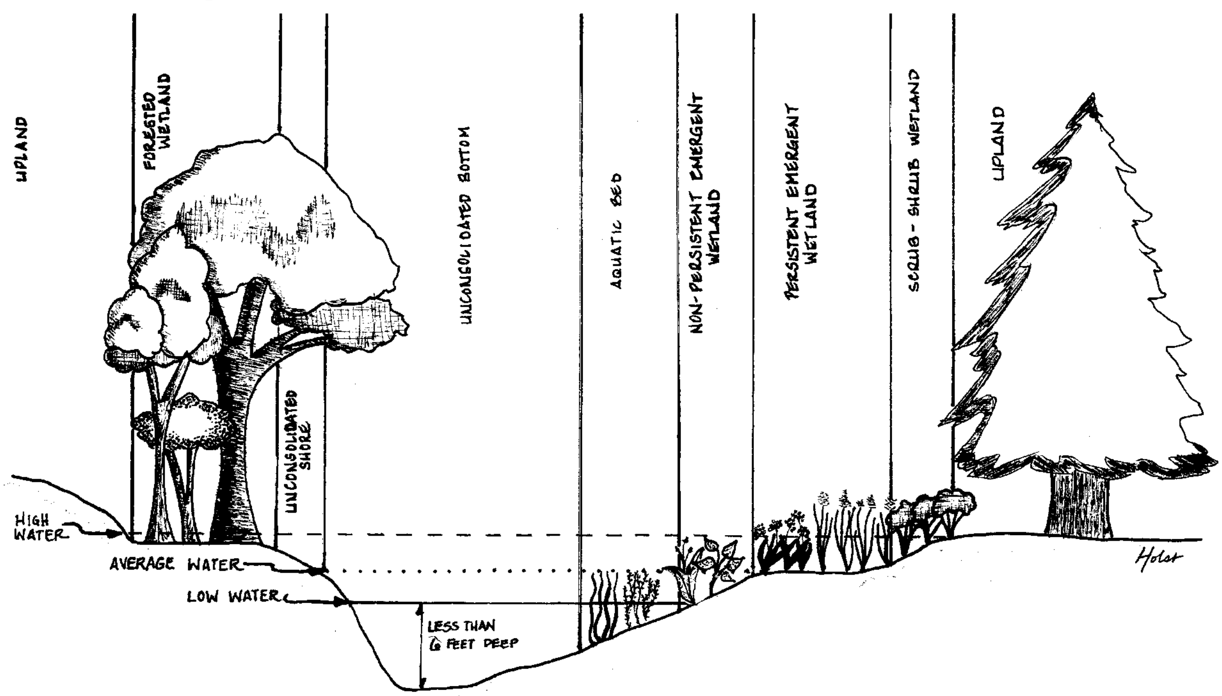
Lacustrine wetlands are wetlands and deep water habitats situated in a topographical depression or dammed river channel; lacking trees, shrubs, persistent emergent vegetation, emergent mosses or lichens with greater than thirty percent areal coverage; and with a total area larger than 20 acres. Certain wetlands smaller than 20 acres may be classified as lacustrine if there are active wave-formed or bedrock shoreline features making up all or part of the boundary, or if the deepest part of the basin exceeds 6.6 feet at low water (Cowardin ***et al.***, 1979). While lacustrine wetlands do occur within the project boundary in Westchester County and in Connecticut, for the purposes of this initiative, restoration will focus on the shorelines of these bodies of water where the classification shifts to palustrine.

PALUSTRINE WETLANDS

Palustrine wetland systems are divided into several classes; rock bottom, unconsolidated bottom, aquatic bed, unconsolidated shore, moss-lichen wetland, emergent wetland, scrub-shrub wetland, and forested wetland (see ***Figure 2-1***). There are also subclasses and dominance types used in the classification scheme. With so many defining features, palustrine wetlands are highly variable. The reader should consult the referenced paper by Cowardin ***et al.*** (1979) for the full range of classifications used by the U.S. Fish and Wildlife Service. The community descriptions in this chapter are arranged by plant dominance type.

Palustrine forested wetlands within the project boundary include the coastal plain Atlantic white cedar swamps and red maple-hardwood swamps found in both New York and Connecticut. These swamp areas are dominated by either Atlantic white cedar (***Chamaecyparis thyoides***) or red maple (***Acer rubrum***) which form over 50 percent of the canopy. Both of these communities may have highly variable associations of other plant species. The specific mix of associates is dependant on the soil type, water regime, and historic land use (Metzler and Tiner, 1992).

Figure 2-1: Typical Cross-Section of Palustrine Marsh Showing Zonation
Adapted from Cowardin ***et al.***, 1979.



Atlantic White Cedar Swamps

Atlantic white cedar swamps are considered an extremely rare community by the New York Natural Heritage Program, and are vulnerable to extirpation in New York. Of the statewide occurrences, only two are on mainland New York. The rest are found on Long Island, particularly in the southeastern portion. Atlantic white cedar swamps in Connecticut occur primarily east of the Connecticut River. The soils in these forested wetlands are semi-permanently or seasonally flooded in lowland areas, or saturated.

The Atlantic white cedar may form dense monospecific stands that dominate the tree, shrub, and herb layers of the community (Metzler and Barrett, 1996). If the tree layer is mixed with other species, greater diversity is found in the shrub and herb layer. In some parts of the project area red maple may occur as a co-dominant species in the tree layer. Less common associates in the tree layer include: white pine (***Pinus strobus***), yellow birch (***Betula alleghaniensis***), and eastern hemlock (***Tsuga canadensis***), although a mixed canopy association is reported in some Connecticut occurrences. The shrub layer may include sweet pepperbush (***Clethra alnifolia***), inkberry (***Ilex glabra***), northern bayberry (***Myrica pensylvanica***), and swamp-azalea (***Rhododendron viscosum***). In Connecticut the shrub layer is often dominated by highbush blueberry (***Vaccinium corymbosum***). Herb species may occur in sunny openings; these include cinnamon fern (***Osmundia cinnamomea***), marsh fern (***Thelypteris palustris***), and sundew (***Drosera intermedia***). The ground layer includes several species of ***Sphagnum*** mosses. The Massachusetts fern (***Thelypteris simulata***) and two species of sedges (***Carex atlantica, C. collinsii***) are herbs usually associated with this community throughout New England. While Massachusetts fern is found in Atlantic white cedar swamps within the project area, neither of the sedge species have been reported in New York recently (Metzler and Tiner, 1992; Reschke, 1990; Rozsa, pers. comm.).

Red Maple-Hardwood Swamps

Red maple-hardwood swamps are the most prevalent of the deciduous forested wetlands in the project area. These wetlands are found in lowland areas, depressions, and on spring-fed slopes. The soils are usually organic silt loam and mucky peat (Metzler and Tiner, 1992). Tree canopy cover is 50 percent or less and dominated by red maple, but there may be one of several species occurring as a codominant. Black ash (***Fraxinus nigra***) and black tupelo (***Nyssa silvatica***) are the most common in the New York portion of the project area. American elm (***Ulmus americana***), swamp white oak (***Quercus bicolor***), butternut (***Juglans cinerea***), and bitternut hickory (***Carya cordiformis***) may also occur in these swamps, but are uncommon to rare within the project area. Characteristic animals associated with red maple swamps are marbled salamanders (***Ambystoma opacum***), red-bellied woodpeckers (***Melanerpes carolinus***), and black-crowned night heron (***Nycticorax nycticorax***). A listing of bird species that commonly nest in forested wetlands is shown in ***Table 2-1***.

TABLE 2-1. Common Forested Wetland Nesting Bird Species

Common Name	***Scientific Name***
Wood duck	***Aix sponsa***
Acadian flycatcher	***Empidonax virescens***
Barred owl	***Strix varia***
Northern saw-whet owl	***Aegolius acadicus****
Northern waterthrush	***Seiurus noveboracensis***
Louisiana waterthrush	***Seiurus motacilla***

**** Species less common in New York***

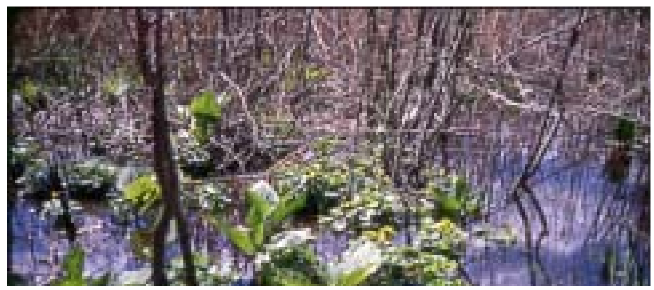
From Metzler and Tiner, 1992

Flood Plain Forest

An additional forested wetland type that occurs within the project boundary in both states is the flood plain forest community (**Figure 2-2**). These are hardwood forests occurring on mineral soils within the flood plain of rivers or on the river deltas. These areas are flooded in the spring and covered by standing water that usually disappears by summer. Sometimes they will flood again in late summer and early fall due to heavy precipitation associated with tropical storms. The soils are classified as alluvial deposits—soils deposited when river flood waters recede.

Typical dominant trees in this wetland type are silver maple (***Acer saccharinum***), red maple, and sycamore (***Platanus occidentalis***). Cottonwoods (***Populus deltoides***) are found on levees and riverbanks along the perimeters of the flood plain. In Connecticut, another species association has been identified by Metzler (unpub. data) in which the common dominant species are pin oak (***Quercus palustris***) and green ash (***Fraxinus pennsylvanica***). Additional dominant canopy species may include swamp white oak and tupelo (Rozsa, pers. comm.). The shrub layer of flood plain forests may include spicebush (***Lindera benzoin***) and dogwoods (***Cornus spp.***), and a ground layer comprised of Virginia creeper (***Parthenocissus cinquefolia***), jewelweed (***Impatiens capensis***), sensitive fern (***Onoclea sensibilis***), and common poison ivy (***Toxicodendron radicans)***. See **Figure 2-2** for a photograph of forested wetland community.

Figure 2-2. Skunk Cabbage and Marsh Marigold



Skunk cabbage and marsh marigold are shown growing within a stand of red maples along the Nissequogue River floodplain.

Scrub-Shrub Wetlands

Palustrine deciduous scrub-shrub wetlands or shrub thickets are also diverse within the project area in both states. The substrate is usually mineral soil or muck with a regular seasonal flooding regime or saturated conditions. These are wetlands dominated by shrubs rather than trees, although stunted trees may be present. One of several shrub species may be dominant: highbush blueberry, buttonbush (***Cephalanthus occidentalis***), swamp azalea (***Rhododendron viscosum***), or black willow (***Salix nigra***). Species like silky willow (***S. sericea***), dogwoods, meadow-sweet (***Spirea latifolia***), swamp rose (***Rosa palustris***), and mountain laurel (***Kalmia latifolia***) may occur in varying densities. Typical animals associated with these wetlands are the green frog (***Rana clamitans***), masked shrew (***Sorex cinerius***), and swamp sparrow (***Melospiza georgiana***).

When the hydrologic regime is extremely wet, the tree canopy may be reduced allowing willows (***Salix spp.***) to dominate the shrub layer. Moderate hydrological conditions favor low shrub layers of alders (***Alnus spp.***) and dogwoods. Other shrub species typically include spicebush, winterberry (***Ilex verticillata***), and highbush blueberry, among others. The herb layer may be dominated by several species of ferns like cinnamon fern, royal fern (***Osmundia regalis***), sensitive fern, crested wood-fern (***Dryopteris cristata***), and toothed wood-fern (***D. carthusiana***). Other herbaceous species characteristically present include skunk cabbage (***Symplocarpus foetidus***), sedges (***Carex spp.***), jewelweed, and skullcaps (***Scutellaria spp.***).

Black willow and buttonbush/silky willow communities are associated with areas of moving water. Black willow communities are found along riverbanks between the herbaceous bank vegetation and the low flood plain. There may be diverse annual vegetation associates in the ground layer, but usually fall panicum (***Panicum dichotomiflorum***), barnyard grass (***Echinochloa crusgalli***), beggar's ticks (***Bidens spp.***), and smartweeds (***Polygonum spp.***) can be found from year to year. A similar community dominated by buttonbush and silky willow are found on gentle slopes and fed by ground water. The hydrologic regime is very wet and the water table seldom drops below the soil surface. The herb layer usually includes ditch stonecrop (***Penthorum sedoides***), marsh fern, marsh purselane (***Ludwigia palustris***), and tussock sedge (***Carex stricta***).

Standing-water deciduous shrub thickets are dominated by either highbush blueberry or buttonbush. Swamp azalea is a common associate in both dominance types. The hydrologic regime is extremely wet with standing water above the substrate in spring and dropping slightly below the substrate by late summer. The soils are highly organic silt loams or muck. More acidic and undrained conditions such as perched water tables will favor highbush blueberry and swamp azalea. Herbaceous species and mosses are more sparse, generally appearing when the water table is lower.

Evergreen shrub thickets within the project area are dominated by leatherleaf (***Chamaedaphne calyculata***), with black spruce (***Picea mariana***) or sedge (***Carex utriculata***) as an associate. Black spruce will be the associate in glacial kettle holes and on the margins of oligotrophic ponds. Trees are rare, but white pine, swamp azalea, sheep laurel (***Kalmia angustifolia***), and highbush blueberry occur in the shrub layer. The herb layer usually contains small cranberry (***Vaccinium oxycoccos***) and pitcher plant (***Sarracenia purpurea***). Mosses may also be present.

Bogs

Sedge is found with leatherleaf in nutrient-poor minerotrophic basins and wet depressions called leatherleaf bogs. The herb layer covers up to 80 percent of the total wetland area. A few red maples and highbush blueberries may form a scattered shrub layer, if present. Herbs include three-way sedge (***Dulichium arundinaceum***), white beakrush (***Rhynchospora alba***), and tawny cotton-grass (***Eriophorum virginicum***). Mosses also cover 80 to 100 percent of the ground layer; of these, ***Sphagnum papillosum*** and ***S. fallax*** are the most common.

A variant description of this community described by the New York portion of the project area is the coastal plain poor fen. These wetlands are extremely rare in New York with only one occurrence within the project area on Long Island (New York State Dept. of Environmental Conservation, unpublished data). Coastal plain poor fens are dominated by ***Sphagnum*** mosses, but may include scattered shrubs, sedges, and stunted Atlantic white cedars and red maples. The waters supporting fens are slightly acidic and weakly mineralized. Characteristic shrubs include sweet pepperbush, water willow (***Decodon verticillatus***), leatherleaf, and sweet gale (***Myrica gale***). Typical herb dominants include swamp loosestrife (***Lysimachia terrestris***), fibrous bladderwort (***Utricularia fibrosa***), rose pogonia (***Pogonia ophioglossoides***), marsh St. John's-wort (***Triadenum virginicum***), and white water-lily (***Nymphaea odorata***) (Reschke, 1990).

Emergent Marshes

Freshwater emergent marshes are dominated by a variety of herbaceous plants; genera of grasses like ***Typha***, ***Panicum***, ***Cladium***, ***Carex***, ***Cyperus***, and ***Sagittaria sp***.; and floating aquatic herbs like ***Nymphaea***. These plants comprise hundreds of individual species that may occur in the freshwater marshes of the temperate Atlantic region (Mitsch and Gosselink, 1993). Dominant herbs vary according to the depth of the water above the substrate. In areas that are semi-permanently saturated (up to two yards deep), emergent aquatics like yellow pond-lily (***Nuphar luteum***), white water-lily (***Nymphaea odorata***), cattails (***Typha spp.***), bulrushes (***Scirpus spp.***), arrow arum (***Peltandra virginica***), and wild rice (***Zizania aquatica***) are typical.

In areas where the substrate is slightly better drained, but still saturated and only seasonally flooded, a different assemblage of plant species is found. The dominant species at these slightly higher elevations include bluejoint grass (***Calamagrostis canadensis***), reed canary grass (***Phalaris arundacea***), rice cutgrass (***Leersia oryzoides***), mannagrass (***Glyceria canadensis***), sedges, and bulrushes. These two emergent marsh communities are often found in intergrading patches covering large stretches of pond shore or riverbank. Both emergent marshes and shrub-dominated wetlands are home to the Eastern cottontail (***Sylvilagus floridanus***) and muskrat (***Ondatra zibethicus***).

The sand plain pond shore community is found at the margins of ponds and small lakes in sandy and gravelly glacial deposits along the Atlantic coast. The water level fluctuates both annually and seasonally, but the mucky soils of the drawdown areas are always saturated. These plant communities contain a high percentage of traditionally southern species. This is because the ocean moderates temperatures along the Connecticut coast sufficiently to enable survival of less hardy species at the Sound's northern latitude (Rozsa, pers. comm.).

The specific assemblages of plants in the coastal plain pond shore are quite different in Connecticut than in New York. The Connecticut community is dominated by wing-stem meadow-pitcher (***Rhexia virginica***), yellow hedge-hyssop (***Gratiola aurea***), and false pimpernel (***Lindernia dubia***). Other common species of this community in Connecticut include spatulate-leaved sundew (***Drosera intermedia***), rush (***Juncus pelocarpus***), common yellow-eyed grass (***Xyris difformis***), and spikerush (***Eleocharis flavescens*** var. ***olivacea***). The Long Island community, on the other hand, is dominated by pipewart (***Eriocaulon aquaticum***), sedge (***Carex walteriana***), horned rush (***Rhynchospora macrostachya***), panic grasses (***Panicum spp.***), spatulate-leaved sundew, and pink tickseed (***Coreopsis rosea***).

Palustrine Aquatic Beds

Palustrine aquatic beds are also highly variable within the project area. Shallow open water areas may support hydromorphic forbs. These are plants, either rooted or floating, which are structurally supported by the water column. Yellow pond lilies (***Nuphar variegatum***) and white waterlilies are floating plants found in association with one another where water depths are six feet or less. They occur in ponds, bogs, and fens with a wide range of pH values. If the lilies are not densely occurring, other submersed species may also be present. These include pondweeds (***Potamogeton spp.***), watershield (***Brasenia schreberi***), and little floating heart (***Nymphoides cordata***).

A palustrine submersed species association described in the Connecticut portion of the project area is formed by pondweeds, tapegrass (***Vallisneria americana***), and the naiad ***Najas flexilis***. There may also be free-floating forms present like bladderworts (***Utricularia spp.***) and hornwort (***Ceratophyllum demersum***) (CTDEP, 1982).

RIVERINE WETLANDS

There are four subsystems identified by Cowardin ***et al.*** (1979) that make up the riverine system; tidal, lower perennial, upper perennial, and intermittent. As mentioned earlier, tidally influenced freshwater systems have been covered in ***Section 1: Tidal Wetlands*** and will not be described here. Each subsystem is divided into seven classes; rock bottom, unconsolidated bottom, aquatic bed, rocky shore, unconsolidated shore, and non-persistent emergent wetland. Riverine wetlands within the project area may have all the subsystems and several of these classes over the entire run of the stream or river. Since the vegetation defines only the aquatic bed and non-persistent emergent wetland classes, the focus will be on these and the subsystem descriptions. Riparian areas and riverine systems as a whole are more fully covered in the Riverine Migratory Corridors volume of this series.

Marsh headwater streams are characterized by slow-flowing, cool water. These streams cut through a marsh, fen, or swamp prior to channelization of the flow. Typical submersed macrophytes in this type of stream include water milfoil (***Myriophyllum heterophyllum***), hornwort (***Ceratophyllum demersum***), pondweeds, duckweed (***Lemna minor***), waterweed (***Elodea nuttali***), and water stargrass (***Heteranthera dubia***). The overall substrate is gravel or sand, with silt, muck, peat, or marl deposits along the shoreline (Reschke, 1990). There may be springs present and deposition is minimal. The faunal community consists of small forage fish like the golden shiner (***Notemigonus crysoleucas***).

In the rocky portions of Westchester county and western Connecticut, the rocky headwater stream may be found. Here, the water is cold, flowing over eroded bedrock in a moderate to steep gradient channel. There may be alternating riffle and pool sections[2], and waterfalls and springs. The stream is usually well shaded by bordering trees that reduce primary production. The main source of nutrients to the stream is terrestrial in the form of leaf litter and other organic input. The resident faunal community may include creek chub (***Semotilus atromaculatus***), sculpins (***Cottus spp.***), or introduced salmonids like brown trout (***Salmo trutta***) and rainbow trout (***S. gairdneri***). Typically there will be mosses present along the stream bank, these may include ***Brachythecium rivulare***, ***B. plumosum***, and ***Hygroamblystegium tenax***.

Further along in the development of the waterway is the midreach stream. This is a section of the stream that has a well-defined series of alternating pools, riffles, and runs. There may also be springs and waterfalls providing other habitat features. The resident finfish species include pumpkinseed (***Lepomis gibbosus***) and shiners (***Notropis spp.***) occurring in pools. The riffle sections are home to sculpins and darters (***Etheostoma spp.***). Minnows (***Cyprinidae***) and suckers (***Catostomus spp.***) are typically found in run sections. Submersed vegetation includes waterweed and pondweeds.

Coastal plain streams are found along the coastal plain portions of the project area in Connecticut and Long Island. These streams are sluggish and often darkly stained from leaf litter. Submersed vegetation may be abundant, including species such as pondweeds, waterweeds (***Elodea spp.***), naiads (***Najas spp.***), bladderwort, duckweed, and the introduced watercress (***Nasturtium officianale***). Finfish species include the American eel (***Anguilla rostrata***), redfin pickerel (***Esox americanus americanus***), pumpkinseed, and swamp darter (***Etheostoma fusiforme***).

VALUES AND FUNCTIONS

The functions of wetlands in general have been defined hydrogeomorphically by the U.S. Army Corps of Engineers Waterways Experiment Station (***Table 2-2***). By utilizing these parameters, the relative "value" of a wetland or wetland system may be objectively quantified. It should be noted that this evaluation system is not based on the ecological assessment of wetlands, but by strictly functional attributes defined by physical parameters. As the term hydrogeomorphic indicates, the ability of a wetland or wetland system to perform any or all of these functions depends on the geological features in and around the wetland, the wetland shape and form, and the local hydrology. Wetlands have the potential to perform all of the hydrogeomorphic functions; however, not all wetlands do. The ability of an individual wetland to

Table 2-2. Functions of Freshwater Wetlands

- Modification of Ground Water Discharge
- Modification of Ground Water Recharge
- Storage of Flood and Storm Water
- Shoreline protection
- Hydrologic support
- Sediment and Particulate Retention
- Atmospheric Coupling
- Nutrient and Contaminant Retention
- Chemical and Detrital Export
- Maintenance of Characteristic Wildlife Communities

From Brinson, 1993

[2] ***Pool*** : Part of a stream with reduced velocity, commonly with deeper water than surrounding areas.
Riffle : Part of a stream where water flows swiftly over completely or partially submerged obstructions producing increased surface agitation.
Run : A slow moving relatively shallow body of water with moderately low velocities and minimal surface agitation.

perform a function may be precluded by natural or anthropogenic factors. The fact that wetlands are highly variable in their functions is part of what makes individual wetlands difficult or impossible to replace.

Modification of water quality by wetlands is extremely important in the watershed of the Sound. Wetlands are capable of trapping particulate matter in the vegetation or allowing it to settle in basins. They absorb and transform excess nutrients during the growing season. These nutrients are utilized by the wetland plant communities for growth and then transformed to other food sources like detritus. This transformation helps reduce nutrient enrichment in nearby lakes, ponds, and downstream water bodies, including the Long Island Sound. Metals and organic chemical compounds like hydrocarbons can be metabolized or transformed into less harmful components by the bacterial community within the wetland. Wetland plants are also involved in the uptake of metals, but little transformation takes place. Instead, the metals are simply sequestered in the plant material until it decays, which slows the exposure of biota to the metals.

Wetlands can modify groundwater discharges in two ways. They can sequester and transform chemical pollutants, and absorb and transform nutrients. Groundwater may contain nitrates, phosphates, and other nutrients, as well as trace metals like iron, and organic chemical contaminants. Wetland plant communities are able to modify groundwater recharge similarly, in that they sequester and transform surface pollutants before the water seeps into the underground aquifers. The layer of organic matter and fine sediments slows the recharge as well. This allows for more purification to take place than normally would on the sandy glacial soils of the project area. In many portions of the project area road runoff is required to be directed to constructed earthen recharge basins. Road runoff carries a heavy pollutant load that can be at least partially removed through filtration. The retention of precipitation and stream flow in pooled areas of surface water also helps to ensure areas of standing water in times of reduced precipitation.

Similarly, wetlands aid greatly in storage of flood and storm water. Wetlands can hold a significantly larger amount of flood water than an equal area of developed land. The flood water is then released slowly over a long period of time, which reduces flooding damage to surrounding properties. During times of heavy rainfall, storm water collected from streets and directed to vegetated and nonvegetated recharge basins is prevented from flowing directly into the Sound. Direct discharge of storm water is a nonpoint pollution source for the Sound (Long Island Sound Study, 1994).

Wetlands can also modify stream flow. This makes the in-water area more hospitable to fish and wildlife species. The wetland plants slow water currents and provide cover for juvenile finfish, invertebrates, and amphibians. These vegetated areas also curtail the rate of erosion caused by flowing water.

Wetlands contribute to the abundance and diversity of wetland fauna. Freshwater wetlands are "oases" of potable water for wildlife in an area dominated by salt water. Wildlife utilizing the Sound's resources must still have access to fresh water for survival. If these waters are inaccessible, polluted or destroyed, many fish and wildlife species will be forced to move out of the area to survive. Coastal development may exacerbate existing freshwater shortages by blocking coastal land and limiting animals' access to inland water supplies.

The use of the Long Island Sound area freshwater wetlands by migratory birds lends international significance to the health of these resources. The Long Island Sound watershed lies in the flight pathways of several neotropical migrant bird species during their semiannual move between the temperate and neotropical regions. Impairment of their resting and feeding areas affects the bird population of the entire hemisphere. Many bird species are already experiencing stress due, in part, to deforestation in Central and South America. If there is further loss of habitats in North America as well, existing impacts in southern latitudes will be compounded.

Amphibian species are directly affected by the impairment of freshwater wetlands. They must reproduce in fresh water, and the juvenile life stage is spent in shallow pools and among wetland plants. Without access to fresh water, therefore, frogs, salamanders, and toads will be unable to maintain populations within the project area. There are currently four species of amphibians listed as endangered, threatened, or of special concern within the project area in New York and Connecticut. The tiger salamander (***Ambystoma tigrinum***) is listed as endangered by NewYork State Department of Environmental Conservation (NYSDEC). Amphibian species of special concern in the New York project area are the southern leopard frog (***Rana utricularia***), Eastern spadefoot toad (***Scaphiopus holbrooki)***, blue-spotted salamander (***Ambystoma laterale***), and spotted salamander (***A. maculatum***). The blue-spotted salamander is also listed as a species of special concern in Connecticut.

Amphibians are considered excellent indicators of environmental stressors and their relative abundance can help to determine the health of an ecosystem. Amphibians respire through their skin, making them particularly sensitive to toxic substances and changes in water quality. Their absence or illnesses may indicate that a problem exists long before it manifests itself in mammals (including humans), fish, or birds. Additionally, amphibians and their eggs are an important food source for many other fish and wildlife species. Largemouth bass (***Micropterus salmoides***) and snapping turtles (***Chelydra serpentina***) eat frogs and tadpoles, as do the kingfisher (***Megaceryle alcyon***) and other wading and diving birds. The Eastern hognose snake (***Heterodon platyrhinos***), a species of special concern in both New York and Connecticut, eats primarily Fowler’s toads (***Bufo woodhousii***). Without that critical food source, Eastern hognose snakes will continue to decline in this region (Breisch, pers. comm.). Of the 290 animal species listed as federally endangered in 1986, one half were dependent on wetlands for all or part of their life cycles (Mitsch and Gosselink, 1993).

Freshwater finfish species also depend on wetlands for primary production, forage area, breeding and nursery habitat, refuge from predators, and resting areas. Many of these species form the basis of a healthy sportfish industry within the project area. The stream areas that connect with the Sound, in particular, support a diverse assemblage of species from the estuarine portions at the interface with the Sound to fresh headwaters miles inland. The Riverine Migratory Corridors volume discusses this aspect in more detail.

Wetlands contribute greatly to the diversity of plant species. Wetland communities like freshwater emergent marshes and riparian forests are highly diverse communities (Mitsch and Gosselink, 1993) containing hundreds of plant species within the project area. Because of the unique adaptations many wetland plants have made to survive in the saturated anaerobic conditions, they are not found outside of wetland systems. The disappearance of wetlands will cause the loss of these plant species and the support they provide to the animals that depend on them. In addition, approximately 43 percent of the plants statewide that appear on the New York State listing of endangered, threatened, and special concern species are found in wetlands (Young, pers. comm.).

An additional function that freshwater wetlands perform is the cycling of nutrients and atmospheric gases. Wetland plant species utilize carbon dioxide in the air and release oxygen into the soil layer surrounding the roots. Wetland plants and plants in other stressed environments display a metabolic adaptation that allows them to utilize carbon dioxide much more efficiently than their terrestrial counterparts. Carbon dioxide uptake is directly proportional to the rate of photosynthesis in the plant. In some cases the wetland plants display a photosynthetic rate five times greater than plants that have conventional metabolic processes (Mitsch and Gosselink, 1993).

Bacteria in the soils of freshwater wetlands are able to fix various forms of nitrogen into nitrate that is then cycled into the food web by primary producers. The combination of oxygenated soil and near neutral pH in freshwater emergent marshes allows for relatively rapid decomposition of plant material into detritus by bacterial decomposers.

STATUS AND TRENDS

Historically, Bronx and Queens counties had extensive areas of rich and productive farmland, far removed from the crowding and pollution of Manhattan. Vast coastal meadows with clear running freshwater streams were bordered by Long Island Sound on one side and dense upland forest on the other. As the boundaries of New York City expanded, both counties underwent major transformations to densely-developed urban extensions of the city.

Flushing Meadows-Corona Park in Queens County is best known today as the home of the U.S. Open tennis championships and one of the largest urban parks in the country. At the time of the Dutch settlement of New York, however, Flushing Meadows was thousands of acres of tidally-flushed and freshwater spring-fed wet meadows. During the construction of the 1939-40 World's Fair grounds, the vast majority of these wetlands were filled with material excavated from building foundations in surrounding areas of New York City.

The rivers of the Bronx have been channelized and used to support the industry along the southern waterfront. Failing bulkheads allow debris to fall into the waterway and cannot attenuate runoff containing industrial contaminants. These rivers have now become pollutant conduits into the Sound. Some natural areas remain in the upper Bronx River within the boundaries of the Bronx Zoological Park and the Botanical Garden, and restoration efforts are underway further downstream as part of the Bronx River Restoration project. The Hutchinson River has become degraded by storm water inputs from roads and the routing of the Hutchinson River Parkway through its floodplain.

Nassau and Suffolk counties have also been heavily developed, though not to the densities found in the boroughs of New York City. The freshwater seeps and artesian springs that gave Cold Spring Harbor its name have all but disappeared, and the major tributary stream of that harbor was first dammed in the 1700s. The Nissequogue River was also dammed for mill operation and almost every shoreline town on the Sound has a "Mill Pond" indicating the location of a dammed tributary stream. Mill Creek that flows into Port Jefferson Harbor is now channelized into roadside drainage ditches and the stream delta wetlands have been filled. The creek has also been contaminated by industrial solvents in the creek’s groundwater source.

In the past, large tracts of Connecticut’s wetlands were drained for agriculture, or altered to produce cranberry and blueberry bogs. According to Metzler and Tiner (1992), a large portion of the agricultural properties have been abandoned and the opportunity for restoration exists. Dahl (1990) estimates that 53 percent of the Nation’s wetlands were lost between approximately 1780 and 1983. The States of Connecticut and New York are thought to have lost 74 and 60 percent, respectively, of their wetlands from about 1780 to the time of the National Wetlands Inventory in 1983. Metzler and Tiner (1992) disputed Dahl's 1990 estimate for the loss of wetlands in Connecticut and offered a more conservative estimate of 40 to 50 percent loss for freshwater wetlands.

Loss of wetlands in this country appears to have hit a peak between 1954 and 1974 (Mitsch and Gosselink, 1993). Within the project area this is most likely due to the post-World War II housing boom. With the advent of mass construction techniques pioneered in places like Levittown on Long Island, housing in the suburbs of the New York metropolitan area expanded at an unprecedented rate. At that time, the prevailing attitude towards wetlands was one of exploitation or elimination. The highly organic soils of wetlands made fertile farm fields when drained. Areas that could not be exploited for lumber or farming were often filled. Wetlands in general were viewed as sources of disease and unhealthy atmosphere.

Sportsmen and hunters were among the first wetland preservationists. They valued wetland for waterfowl habitat. In 1934 the first federal "duck stamps" were issued to generate revenues for wetland preservation. Scientific research, interest by sportsmen and hunters, and popular support of the environmentalist movement in the United States caused a groundswell of support for wetland conservation in the early 1970s. Statistics have shown that as public awareness of the values of wetlands has increased, the rate of wetland loss nationally has decreased. Unfortunately, the rate of natural wetland formation and restoration efforts by agencies like U.S. Fish and Wildlife Service has not been able to keep pace with the overall losses (Dahl, 1990).

TABLE 2-3. Mapped Palustrine Wetlands of the Connecticut Project Area by County

County	*Acres*
Fairfield	14,563
Middlesex	12,031
New Haven	12,258
New London	30,770

The U.S. government passed the Clean Water Act in 1972. Section 401 of the Act ensures that federally permitted activities comply with the protective measures of the Act and water quality standards enacted by states. Section 404 of the Act regulates the discharge of dredged or fill material into the waters of the United States, including wetlands. Since the enactment of Federal legislation protecting and regulating wetlands, the national loss rate of all wetlands has been cut in half (Mitsch and Gosselink, 1993). A study by Dahl and Johnson (1991) indicates that between the mid-1970s and mid-1980s nationwide palustrine emergent marsh area showed a net increase of 0.9 percent.

TABLE 2-4. Mapped Freshwater Wetlands of New York Project Area by County

County	*Acres*
Bronx	3
Nassau	729
Queens	167
Suffolk	2403
Westchester	7572

The Connecticut State Legislature passed the Inland Wetlands and Waterways Protection Act in 1972. The goal of this law is to balance wetland preservation with compatible economic growth of the state, yet it has been estimated that 200 acres of wetlands are still annually encroached upon or filled (Council on Environmental Quality, 2001). According to the National Wetlands Inventory Maps completed in 1982, 69,622 acres of palustrine wetland were mapped within the project area of Connecticut. ***Table 2-3*** presents the acreage by county.

New York State passed Article 24, the Freshwater Wetlands Act, in 1974. This part of the Environmental Conservation Law regulates the alteration of non-tidal freshwater wetlands 12.4 acres or larger and their adjacent areas. Smaller wetlands may be included if they are deemed locally significant. These smaller wetlands have been included in Nassau and Suffolk counties. There is currently a permitted loss rate of less than one acre per year. New York State has currently mapped 10,874 acres of freshwater wetlands of all types within the project area. ***Table 2-4*** displays the acreage by county.

New York State also regulates wetlands to some extent under Article 15 of the Environmental Conservation Law, the Protection of Waters Act. This law provides for the regulation of activities like construction and maintenance of dams and impoundments, construction of docks and bulkheads, and dredging and filling in the waters of the state.

There are other programs that indirectly protect freshwater wetlands. The North American Waterfowl Management Plan provides for the management and restoration of waterfowl habitats in the U.S. and Canada. Preservation of endangered species and their habitats is mandated under federal and state laws. Many wetland plants and animals are on the federal and state listings of endangered species. Both New York and Connecticut have programs to manage the habitats of fish and wildlife species. Both states also have a Natural Heritage Program that identifies significant habitats for management, restoration and enhancement. New York State's Wild, Scenic, and Recreational Rivers program was developed to protect and preserve those rivers of the state which possess outstanding natural, scenic, historical, ecological, and recreational values. The Nissequogue River in Smithtown, New York has been designated as a Wild, Scenic, and Recreational River under this program. Connecticut also has a Rivers Management Program that protects and preserves critical riverine resources and provides for comprehensive river management plans.

DEGRADED WETLANDS AND RESTORATION METHODS

The major cause of wetland degradation is the alteration of the hydrology in the wetland system. This alteration may be caused by a number of activities such as draining, filling, and impounding. Other degradation may be caused by chemical inputs to wetlands, or invasion by exotic species. While degradation is caused by unique combinations of circumstances in each affected wetland, some general causes and restoration methods can be outlined.

DRAINED MARSHES

Freshwater wetlands were drained in the past for a variety of reasons. One of the most common uses for drained freshwater wetlands nationwide was agriculture. The highly organic soils of the wetlands are suitable for growing crops without the need for costly fertilizers. In other cases, wetlands were drained for development of homes, as in the densely populated suburbs of New York City.

Drainage of standing water in the wetland by digging channels causes a shift in seasonal as well as instantaneous hydrology. The vegetative community moves away from submergent and emergent obligate wetland plant species to facultative wetland species and upland plants tolerant of wet conditions. In extreme cases the plant community may shift entirely to upland species as the wetland soils are exposed to air and become oxygenated.

Wetland drainage may be an unintentional side effect of other activities by people. Groundwater-fed wetlands may suffer degradation due to the presence of water supply wells nearby. The extraction of groundwater from shallow aquifers for human consumption may eventually cause the aquifer to shrink, reducing the seepage to wetlands on the surface. The same may happen with deeper aquifers. The wetland hydrology shifts depending on the surface water and precipitation input, but in most cases the wetland shrinks in size and may become intermittent. The vegetation will reflect the infrequent flooding, and upland plants will begin to colonize the former wetland area.

In the past, surface water supplies to wetlands have been diverted for drinking water reservoirs, flood control projects, cooling of industrial plants, and irrigation of crops. Wetlands that are dependent upon surface water to maintain their water budget will suffer degradation from this loss.

Restoration Methods:

① The simplest way to reverse the drainage of wetlands is to fill or plug the ends of the drainage ditches and allow them to fill naturally. The former area of wetland should refill with water.

Once the hydrology is stabilized, the seed bank contained within the soil will naturally recolonize the site. The restored wetland's plant distribution may be different once it is re-flooded due to compaction and subsidence of the soils while it was drained. Once the wetland is drained the saturated soils become exposed to air and decomposition of organic matter takes place. If this has happened, the proportion of open water to emergent marsh may be greater than in the previously undisturbed wetland. This should be taken into consideration when setting restoration goals for the site and when measuring restoration success.

② In wetlands where the surface water has been diverted, replacement of that flow is the best method of restoration. If the original source of flow cannot be restored, an alternate source of water may be considered in its place. For example, diverted cooling water may be channeled back to the wetland, groundwater may be pumped into the wetland or stream to provide a surface flow, or the wetland deepened to intercept shallow groundwater pockets. In each of these methods, the hydrologic budget of the wetland must be carefully calculated to ensure adequate flow and/or saturation of the hydric soils. As with drained wetlands, the remaining seed bank in the soil may be sufficient to revegetate the site.

③ It is possible to help alleviate groundwater withdrawal related wetland degradation by redirecting storm water and sewage treatment plant effluent into recharge basins or by direct groundwater injection. This course of action is not to be taken lightly. It involves a great deal of engineering and construction, as well as multiple permits. Recharge basins are often a required component of new subdivisions and other types of construction. The complexity of the issue does not lend itself to detailed discussion here. State and municipal permitting authorities can provide further information about this topic.

FILLED MARSHES

Filling of wetlands with additional soils or garbage increases the elevation of the wetland and causes the plant community to disappear due to burial. This type of degradation was common until legislation outlawed siting of structures and municipal landfills on wetlands. A slower form of filling may occur due to silt runoff from disturbed upland areas. Gradually the wetland becomes shallower until it is converted to upland. Storm water from roads directed to wetlands with no treatment can also cause this problem.

Restoration Methods:

Restoration can be achieved by excavation of the fill materials to the level of the pre-existing peat or organic soils. Once the former elevations are restored, the hydrology should eventually reach equilibrium, provided that water budget calculations are accurate. The existing seed bank is then left to revegetate the wetland naturally. If the organic soil horizon has been disturbed, the area should ideally be reflooded early in the growing season. Since destruction of the organic soil horizon will have also disturbed the seed bank, recolonization will be somewhat slower. The area may have to be colonized by nearby wetlands. To compensate for this, annual emergents like wild rice may be seeded to stabilize the substrate until the natural colonization occurs. Alternatively, planting of permanent resident shrubs and other perennials may be done immediately. Shrubs and trees are slow to return to wetland areas, and if the habitat values they provide are desired, planting will ensure these values in the short term. Immediate planting or seeding of herbaceous species is also advisable in areas where invasion by purple loosestrife is likely.

IMPOUNDMENTS

Rather than hydrology modifications that result in a loss of water, wetlands may be degraded by influx of too much water. This type of degradation has been extensive on Long Island riverine wetlands and was reported as having been a regular practice in colonial times (State of New York, 1939).

Impoundments and dams increase the area of permanently flooded wetland, which results in a shift in vegetative cover. In areas where riverine wetland vegetation is dominant, the fringing vegetation becomes flooded. Impoundments and dams have traditionally been placed to provide power for hydroelectric plants and mills, and to provide artificial lakes for recreation.

Restoration Methods:

Lowering of the impoundment structure profile in order to reduce the flooded area may result in rapid recolonization by fringing wetland plants. The impoundment structure may be removed entirely, if feasible. Otherwise, installation of weir boards to allow for drawdown during wet seasons is a viable alternative when concerns of downstream flooding are present.

Replanting in these areas is seldom necessary. The lowering of the water level allows emergent vegetation to recolonize the newly drained area quickly from the remaining seed bank, or new seeds from adjacent populations. However, if invasive species are present on the project site, it is advisable to plant the desired species in densities sufficient to provide a competitive advantage over invasive species.

EXOTIC SPECIES INVASION

Throughout the northeastern United States, purple loosestrife (***Lythrum salicaria***) has become a pervasive invader of freshwater wetland systems. This plant is native to Europe and has flourished in the United States due to the absence of natural predators. Purple loosestrife is virtually uncontrollable without intense, hands-on management. Once it invades, purple loosestrife spreads quickly, forming dense monotypic stands. It reduces the diversity of the wetland plant community and provides reduced ecological value to the biota of the wetland. Fortunately, Long Island has not been invaded to the same extent as upstate New York, but control of any populations occurring there is vital to halting its spread within the project area.

A similar type of degradation is seen with the invasion of wetlands by the common reed (***Phragmites australis***). While common reed is a native plant, under some circumstances it too may form dense monotypic stands that reduce the vegetational diversity. The thick woody stems are less desirable for nesting to many animal species than other emergent wetland plants like cattails and bulrushes. The woody nature of the plant also makes it decay more slowly in the marsh, reducing its detrital export value. In areas where other degradation has already taken place, common reed can become invasive. Like purple loosestrife, it provides reduced food and cover value to the wetland biota.

Restoration Methods:

① Purple loosestrife and common reed are both difficult plants to remove from wetlands. Mechanical removal through mowing and excavation are labor intensive and often have limited success since remaining stands of the plants are quick to recolonize cleared areas. The restoration practitioner must be vigilant and remove all above and below-ground portions of the plants. The mechanical disturbance also has the potential to cause damage to the remaining wetland area. The excavation may cause increased turbidity of standing water areas in the wetland that can cause shading of submerged aquatic vegetation or reduce dissolved oxygen required by fishes.

② Herbicide application in wetlands is a somewhat controversial method of exotic species control. While there are herbicides that are designed to become inert when mixed in water, extreme care must be exercised when applying herbicides. Hand application is necessary to ensure that the herbicide kills only the target species. Some herbicides are toxic to juvenile stages of finfish, crustaceans, and other invertebrates and should not be used in or near wetlands. Persons involved in wetland restoration in areas with invasive species should familiarize themselves with the variety of herbicides used by restoration ecologists and learn the ecological impacts of each prior to undertaking this restoration method. When used properly, herbicide application has proven successful as a restoration and management tool. This is especially true in cases where mechanical removal may require several disruptive treatments over time.

③ Another method to control purple loosestrife is the introduction of insects to help reduce spread of the plant. There are three species of beetles that have been introduced in areas of the Hudson River, a project funded by New York's Clean Air/Clean Water Bond Act. These insects are a root-boring beetle (***Hylobius transversovittatus***), and two species of leafeating beetles (***Galerucella calamariensis***, and ***G. pusilla***). In Connecticut, releases of the two leaf-eating beetle species began in 1996, followed by releases of a flower-feeding ***weevil (Nonophyes marmoratus***) in 1998. In the Montezuma Wetlands in western New York, and in Connecticut release sites, initial introductions of these insects appear to be successful. The insects show high host fidelity, meaning that they are not eating plants other than the target species. If proven successful, this method of purple loosestrife control may be appropriate in the project area. This may prove particularly useful as a control on Long Island where purple loosestrife is less common than in wetlands of upstate New York and Connecticut and there is still opportunity to control its spread.

CHEMICAL CONTAMINATION

Some wetlands can become contaminated by pesticides like those used in controlling mosquitoes, by chemically contaminated groundwater, or by petroleum products and metals carried in stormwater runoff. A crucial first step in restoring the wetland is tracking down the source of contamination and abating it. If the contamination is severe enough, it may require specially trained personnel working under state and federal guidelines to protect the safety of the public, workers, and fish and wildlife species. Often disposal of the contaminated soils and water must occur at a specially licensed facility, and can be quite expensive.

- In some cases it may be possible to remove the contaminants contained in wetland sediments and plant material. Dredging the contaminated sediments and disposing of them properly will remediate the contamination. Vegetation should be replaced where necessary. Depending on the depth of excavation, the sediments may have to be replaced with clean material to prevent alteration of the plant and animal communities.

- In areas where excavation of the contamination is too costly or otherwise inappropriate, it may be possible to "cap" the contamination with clean material. This solution should be reserved for situations where the contamination poses an acute threat to wildlife and/or people since it will result in altering the depth of the wetland.

- In some places heavily contaminated wetland sites have been planted with species capable of not only tolerating the contaminated soils and water, but of extracting the hazardous substances and sequestering them. This practice is known as bioremediation. In many places around the country, plants have successfully been used to extract heavy metals from wetlands contaminated by mine tailings. Some plants possess this ability naturally, in other cases the plants have been specifically engineered to serve the purpose. Once the plants have extracted contaminants during the growing season, the foliage may be harvested and taken to a disposal facility that handles contaminated materials. This restoration option is fairly complex and will require the restoration project manager to engage in further investigation with state and federal authorities.

All of the above restoration methods require the restoration practitioner to do quite a bit of homework. Part of this homework is investigating what permits may be required of state, federal, and local agencies to engage in wetland restoration activities. It is also important to research the plant and animal communities found in the wetland prior to the disturbance that degraded it.

SPECIFIC RESTORATION OBJECTIVES

In setting restoration goals for freshwater wetlands, it is prudent to examine the body of scientific literature on the subject. As mentioned in the previous section, there is a wealth of information on successful techniques of emergent marsh and stream restoration, but very little is known about restoration techniques for other wetland types. By looking at historical records of lands that are still conducive to restoration efforts, the acreage available for restoration will become clear. Publicly owned parcels are desirable for restoration because their future use is more readily controlled. Alternatively, conservation easements, land donation, and outright purchase are potential mechanisms to pursue long-term restoration on private property.

Each of the hydrogeomorphic functions of wetlands should be considered when evaluating potential wetland restoration projects. Restoration projects should attempt to restore as many of the wetland's original functions as possible.

In addition, the restoration should be completed with the context of the habitats surrounding the wetland addressed to help correct fragmentation that has already occurred. For example, along with their need for wetlands in which to reproduce, amphibians require upland habitats adjacent to those wetlands as part of their adult habitat range. New York State's Article 24 provides a 100-foot regulated wetland adjacent area, however, the habitat range of the amphibians may extend up to 300 feet from the wetland. This makes amphibians particularly sensitive to habitat fragmentation. Restoration of buffer areas and corridors between freshwater wetlands and complementary upland habitats should be included as part of a freshwater wetland restoration. The restoration of upland buffers will benefit other fish and wildlife species as well.

The stabilization and restoration of stream bank buffer zones will contribute greatly to down stream water quality while, at the same time, providing improved wildlife habitat. River and stream corridors are important migratory pathways for many different fish and wildlife species. Using river and stream corridors to connect adjacent habitat types is an efficient means to reduce habitat fragmentation.

RESTORATION SUCCESS AND MONITORING

The measurement of the success in the restoration of freshwater wetlands should be based upon the functions that are designed to be returned to the restoration site. This may include measuring the pre- and post-restoration diversity and density of plant communities, level of use by fish and wildlife species, the appearance of endangered or threatened species in the restoration site, chemical and hydrological cycling, and persistence of the restored community. Often when restoration is performed for regulatory reasons, like correction of illegal filling, the regulatory agency involved only requires single parameter measurement of success. This is usually a requirement of a certain percentage of plant survival over a few growing seasons. For in-stream habitats, monitoring of finfish diversity, submersed vegetation, insect community, stream velocity, and temperature are all important. Little long-term monitoring has taken place for any of these parameters within the project area. Each restoration site is unique and a long-term monitoring plan should be developed that is site-specific.

Long-term monitoring is also pertinent when dealing with varying weather conditions such as droughts and floods. A drought or flood can drastically affect the presence of plant and animal species in a wetland, causing them to temporarily disappear or shift their zonation. In wetlands dominated by annual plants, a single drought or flood event can decimate the vegetation for that growing season.

The plants may take years to return to their former abundance. Similarly, the animal species dependant on that wetland and its plant community may be forced to relocate, or become stressed. Stress on the animals may negatively affect reproductive success, or even cause death. Therefore, animal populations may fluctuate as well as the plant communities. A wetland restoration judged solely on the basis of a single growing season will result in an unreliable conclusion.

In order to measure success of the project, it is necessary to set specific and measurable goals for the project. The first step in restoring the wetland should be an examination of the lost functions at the restoration site. Based on this information, the restoration planner needs to evaluate the possibility of returning all of those lost functions to the wetland. Most critical is an examination of the site hydrology. In many areas on Long Island, the shallow aquifers have been drawn down to provide drinking water and irrigation. If the draw down has been severe, there may not be a high enough water table to support the desired size wetland. A water budget must be calculated for the site.

In planning for the wetland restoration, it is also necessary to gather information about the soils on the restoration site. If the former wetland soils are in place, the project will have a higher likelihood of success. If the soil profile has been disturbed, then appropriate soils may need to be brought to the site, or project time frames lengthened to allow proper soil chemistry to become established. In the case of filled emergent marsh areas it will be useful to obtain soil borings. The borings will indicate where old marsh peat layers may reside under the current fill. The borings will also provide insight into the nature of the fill, grain size, and likelihood of contamination.

Measurements of success must be based on project goals. Selecting which functions of the degraded wetland can be restored under the current conditions is of primary importance. Progress toward these goals is the basic framework on which to base measurements of success. Useful measures may include vegetational diversity, biomass, and species richness, and animal community composition. Seasonal changes in both the plant and animal communities should be taken into account while developing the monitoring plan for the restoration site. Pre-construction baseline and post-construction follow-up measurements should, at a minimum, measure vegetation survival across five growing seasons utilizing the assumption that structure creates function. Vegetation forms the structure of the habitat, allowing it to perform the functions of animal habitat. Measurement methods can include aerial and ground-based photography, and transect and quadrant surveys.

Ideally, animal surveys and primary production should be included in determining the success of the restoration project. All of these measures should be compared to a nearby reference site that displays the functions and characteristics desired in the restoration site. While there are no “magic number” targets to shoot for, the comparison of the two sites as a start and an end point should allow the restoration planner to measure progress toward the desired end point. Published values of primary productivity and accounts of animal and plant community descriptions are available for both states. The U.S. Environmental Protection Agency and other federal programs are making monitoring data from completed restoration projects available on the World Wide Web.

As stated in the introduction to this document, the state Habitat Restoration Initiative staff and all the Habitat Restoration Workgroup members are available to provide guidance and technical advice with project planning, financing, permitting, and monitoring. It is highly advisable to contact them at the beginning of the restoration planning process to learn what resources are available to assist with any project.

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LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

SECTION 3: SUBMERGED AQUATIC VEGETATION

Technical Support for Coastal Habitat Restoration

SECTION 3
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SECTION 3: SUBMERGED AQUATIC VEGETATION

DESCRIPTION

Submerged aquatic vegetation (SAV) is a term used to describe rooted, vascular plants that grow completely underwater except for periods of brief exposure at low tides. The term SAV is generally used for marine, estuarine, and riverine angiosperms, and macrophytes. Most of these plants have leaves and stems with an extensive system of lacunal air spaces for buoyancy; thin cellulose walls for diffusion of gases, and high concentrations of chloroplasts in the epidermal layer for light absorption (Thayer and Fonseca, 1984).

Factors influencing SAV distribution and growth include light penetration, nutrients, substrate, temperature, current velocity, wave energy, and salinity. ***Table 3-1*** defines the terminology used to define salinity ranges in this section of the document:

TABLE 3-1. Terminology to Describe the Different Salinity Ranges (parts per thousand)

System	Salinity modifer	Salinity (ppt)
Marine	euhaline	>30.0
Estuarine (brackish)	polyhaline mesohaline oligohaline	18.0-30.0 5.0-18.0 0.5- 5.0
Riverine	fresh	<0.5

SAV commonly grows in beds. These beds can be dense or sparse and contain one species or many. Generally, species diversity increases as the salinity decreases. For example, while only two species (eelgrass and widgeon grass) grow in Long Island Sound's polyhaline waters, 17 species are found in the tidal freshwaters of the Connecticut River (Barrett ***et al.,*** 1997).

Studies conducted in the Chesapeake Bay have found other differences between tidal freshwater and more brackish or saline species. Freshwater SAV exhibit a shorter growing season and reduced biomass production when compared to marine and estuarine species. Some freshwater species can root at greater depths than salt and brackish species by forming surface canopies that allow light to be intercepted before it is attenuated in turbid, shallow water environments. This adaptation in some freshwater species allows for deeper maximum depth limits than the more meadow-forming species such as eelgrass and tapegrass. (Batiuk ***et al.,*** 1992).

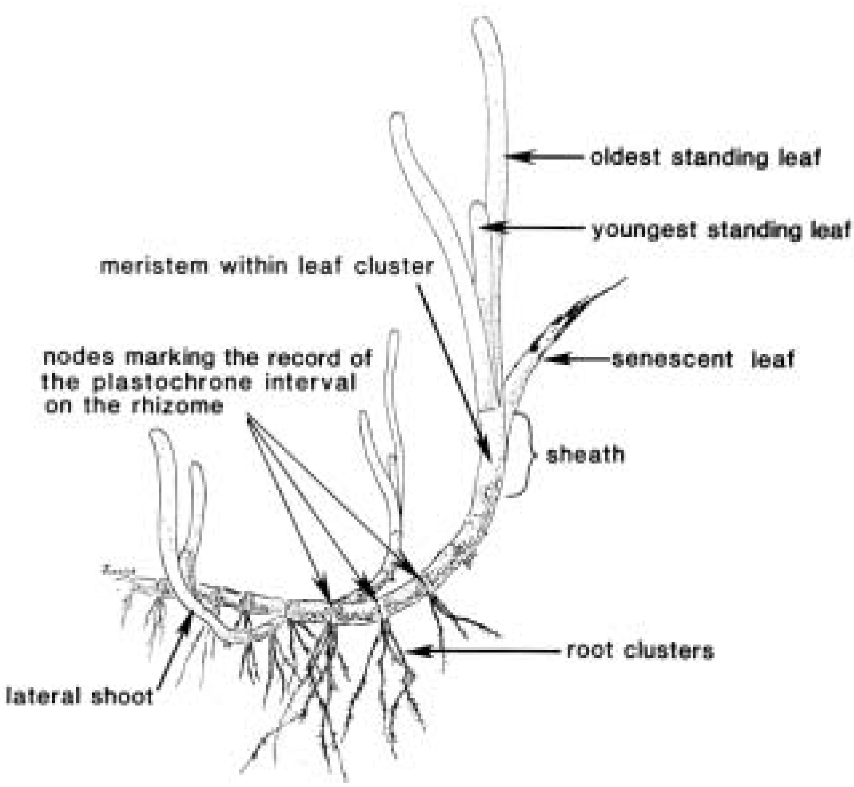
Mesohaline, oligohaline, and freshwater species of SAV have not been well studied in the Long Island Sound watershed. Until the status, trends, and water quality requirements of these species can be further researched, it is not possible to define goals for habitat restoration efforts. For this reason, restoration efforts under the Habitat Restoration Initiative will focus on eelgrass (***Zostera marina latifolia***), a polyhaline/marine species that has been more thoroughly researched.

EELGRASS

Historically the most abundant SAV species in Long Island Sound, eelgrass was widely dispersed in the eastern, central, and western sections. Its current distribution in the Sound is limited to the eastern shoreline of Connecticut. The ecological importance of eelgrass is derived from its productivity and the substantial habitat it creates. Eelgrass may form extensive meadows or patchy beds interspersed with bare areas, and the location of these beds can shift over time.

Eelgrass, a kind of seagrass, is the only true marine SAV found in Long Island Sound. Seagrasses are characterized as having linear, grass-like leaves and an extensive root and rhizome system. An eelgrass plant is composed of 3-7 strap-like leaves bound together in a sheath attached to an underground rhizome (***Figure 3-1***). The rhizome is produced by the basal meristem, which also produces new leaves and lateral shoots. Root clusters from rhizome nodes function as anchors and as the primary sites for nutrient uptake. The base of the lateral shoot pushes through the sediment as the plant grows

FIGURE 3-1. Major Features of the Morphology of *Zostera Marina* ***(From Thayer and Fonseca, 1984)***



(Costa, 1988). The plants may reproduce vegetatively by lateral shoots or sexually through flowering, pollination, and seed germination. Eelgrass is perennial, but annual populations do exist in shallow areas where ice scouring, freezing, or other stresses exist. These environmental factors, as well as genetics, may contribute to a high incidence of flowering in these populations (Costa, 1988). Successful sexual reproduction is dependent on a number of conditions. For example, even though flowering and seed production may occur, seedling recruitment may be absent in areas of high currents (Fonseca ***et al***., 1985).

Eelgrass grows in areas of specific, though diverse, environmental conditions. Substrate requirements range from sand and gravel to mud. Morphologic flexibility among populations is responsible for this species' ability to occupy such a wide range in habitats, including variations in wave/current energy and nutrient content of sediments. For example, Costa (1988) noted that plants growing in shallow, wave-swept bottoms tend to have short narrow leaves, grow in high densities (fewer than 95 shoots per square foot), and produce dense root and rhizome clusters; whereas plants growing in deeper water have longer broader leaves, grow in lower densities (less than 20 ft^{-2}), and produce less root and rhizome material.

The maximum depth of eelgrass growth is determined by the maximum depth of sufficient light penetration necessary for photosynthesis. The degree of light penetration is dependent upon amounts of phytoplankton chlorophyll ***a*** (CHLA), total suspended solids (TSS), color, dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorous (DIP) in the water column (Batiuk ***et al.***, 1992; Hurley, 1991). Levels of nitrogen and phosphorous indirectly affect light attenuation by controlling the growth of phytoplankton and algal epiphytes, which can significantly shade SAV leaves.

In Long Island Sound, eelgrass is found at depths between 1.8 and12 feet below mean low water (Koch and Beer, 1996). There are, however, historical accounts of specimens collected in water just over five yards deep from Bushy Point Beach in Groton, Connecticut (New England Botanical Society, 1970). The historical maximum depth record in the western Sound is negative one yard mean low water in Cold Spring Harbor (Johnson and York, 1915). The upper limit of growth is determined by physical factors such as wave action, ice scour, and desiccation.

Faunal species associated with eelgrass beds include protozoans, nematodes, polychaetes, oligochaetes, hydroids, bryozoans, molluscs, decapods, barnacles, and fish (Thayer and Fonseca, 1984) (see ***Table 3-2***).

TABLE 3-2. Partial Listing of Species Associated with SAV Beds

mudsnail	***Ilyanassa obsoleta***	sand shrimp	***Crangon septemspinosa***
northern lacuna	***Lacuna vincta***	blue mussel	***Mytilus edulis***
common periwinkle	***Littorina littorea***	blue crab	***Callinectes sapidus***
lunar dovesnail	***Mitrella lunata***	hermit crab	***Pagurus longicarpus***
bay scallop	***Argopecten irradians***	horseshoe crab	***Limulus polyphemus***
northern quahog	***Mercenaria mercenaria***	bluefish	***Pomatomus saltatrix***
softshell clam	***Mya arenaria***	striped bass	***Morone americana***
common clamworm	***Nereis virens***	winter flounder	***Pleuronectes americanus***
isopod	***Idotea triloba***	lobster	***Homarus americanus***

VALUES AND FUNCTIONS

Eelgrass beds rank among the most productive of marine and estuarine plant habitats. Under optimum growing conditions in August, leaf production near Woods Hole, Massachusetts was reported to range from 292 - 730 g C m^{-2} yr^{-1} (Dennison and Alberte, 1982). One reason for this high productivity is that old leaves are shed and replaced by new leaves on a three-week cycle. The timing of peak biomass production corresponds with peak epiphytic algae and bacteria production. Other secondary biological productivity includes the support of eggs, barnacles, and bryozoans that attach to the surface of plant leaves and stems. Some of these organisms and others that live among the plant roots in the sediment are grazed upon by snails, worms, and other invertebrates that, in turn, provide food for fish and larger invertebrates. For example, winter flounder feed on shrimp and sandworms living within the beds.

Beds of eelgrass are also important as a food source for several species of birds. Waterfowl consume the nutritious seeds and tubers, as well as the root stalks. Species such as Atlantic brant, Canada geese, and many species of ducks eat eelgrass leaves and seeds as a principal food source (Buchsbaum, 1987). Small prey fish associated with the beds create concentrated feeding areas for predatory birds such as terns, osprey, and cormorants (Buchsbaum, 1995; Colarusso, pers. comm.).

Eelgrass beds not only supply food, but also provide shelter to a number of organisms. Studies have shown that eelgrass beds have a consistently greater diversity and abundance of marine organisms than adjacent unvegetated areas (Kenworthy ***et al.***, 1988; Heck ***et al***., 1989). The dense underwater canopy with vertical and horizontal complexity is highly attractive to marine organisms. For example, some fish species lay their eggs on the surface of eelgrass leaves; newly-molted crabs and lobsters seek refuge in eelgrass beds while their shells harden; and juvenile and larval stage bay scallops (***Argopecten irradians***), starfish, snails, mussels, and other creatures attach themselves to eelgrass leaves (Prescott, 1990; Orth, 1992). Other species that use the beds for food or shelter include killifish, silversides, sticklebacks, northern pipefish, scup, tautog, rock crabs, and green crabs.

Eelgrass leaves are a critical source of attachment for juvenile bay scallops, a species whose population has plummeted in the Sound. The Chesapeake Bay suffered a similar loss of its scallop fishery in the 1930s, corresponding with a demise of eelgrass. One of the best populations of scallops in the Sound was found in Niantic Bay, Connecticut, an area which also historically contained dense eelgrass beds.

Other economically important species benefiting from the presence of eelgrass include winter flounder, menhaden (***Brevoortia tyrannus***), blue crab, American lobster, hard-shell clam or northern quahog, bluefish, and striped bass.

The presence or absence of eelgrass beds can be excellent indicators of water quality (Dennison ***et al.***, 1993). Inventories of eelgrass distribution and abundance function as long-term monitoring tools of an estuary's health. For example, studies conducted in the Chesapeake Bay indicated that nutrient enrichment and increased turbidity were associated with a decline in eelgrass as well as other SAV (Kemp ***et al.***, 1983 and Batiuk ***et al.***, 1992). In Massachusetts, a study found housing developments and increased groundwater nitrogen loading resulted in a significant decrease of eelgrass habitat (Short and Burdick, 1996). Resource managers can use this information as guidelines in the establishment of conservation goals.

Eelgrass and other SAV contribute to chemical processes such as nutrient absorption, oxygenation of the water column (Hurley, 1991), and assimilation of certain contaminants (Levine ***et al.***, 1990). Dense beds may buffer water currents, thus reducing shoreline erosion and resuspension of bottom sediments. Roots and rhizomes further help to reduce ambient turbidity by binding sediments.

STATUS AND TRENDS

There are three convenient reference periods for summarizing the status and trends of eelgrass populations in the Sound: pre-1931, 1931–1995, and present day.

PRE-1931

Historical information indicates that eelgrass was once "common" along the entire coastline of the Sound and in sheltered bays, harbors, rivers, and creeks. This observation was reconstructed, in part, from the following historical botanical and vegetation literature of the Connecticut coast:

- Berzelius Society (1878) – "Abundant along the coast"
- Bishop (1885) – "Common on coast" (***i.e.***, within 30 miles of Yale University)
- Graves ***et al***., (1910) – "Common along the coast in bays, salt rivers and creeks, growing on muddy or sandy bottoms."

- Nichols (1920) – "The most distinctive plant of muddy bottoms along the seacoast is eelgrass . . . this also grows on sandy bottoms but it never attains there the luxuriance, which it exhibits where growing on muddy bottoms. ... So prolifically does it thrive in the shallow waters of protected harbors and coves that at low tide large areas of muddy bottom here will be almost completely hidden by its cluster of long, slender leaves." [Note: the description is accompanied by a photograph showing eelgrass growing on the shallow subtidal flats at the mouth of the Oyster River on the border of West Haven and Milford, Connecticut.]

The distribution of eelgrass in the New York portion of the Sound is poorly known except that there are several key references that establish the historical presence of this species in western Long Island Sound:

- Transeau (1913) – "in tidal creeks, such as that on the east side of Center Island or the north side of Lloyds Neck, the Eel Grass Formation is dominant"
- Johnson and York (1915) - This report describes the relationship of estuarine plants to tide levels within Cold Spring Harbor. The investigation notes that eelgrass "gives character to large areas of the harbor bottom" and that "the densest stands of Zostera seen in the harbor are that east of the channel to the Outer Harbor . . . On these areas there may be from 500 to 2,000 leaf clusters of Zostera to each square yard of bottom." Johnson and York also reported the average lower limit of eelgrass as -3.0 feet mean low water with extremes to -4.5 feet mean low water.

The historical documentation from New York and Connecticut is supported by herbaria collection specimens and by other forms of documented observations, such as coastal survey maps (***Appendix 1***).

1931 - 1995

Beginning in 1931, eelgrass experienced a massive die-off all along the Atlantic Ocean in both Europe and North America. Both sides of the Atlantic were believed to have lost at least 90 percent of existing eelgrass populations (Thayer and Fonseca, 1984; Costa, 1988). Losses in some areas were even higher; for example, there were estimates of less than 0.1 percent of the original population remaining in Buzzards Bay, Massachusetts. By the summer of 1931, eelgrass leaves became somewhat darkened, broke from the roots, and washed ashore in great windrows from New England to North Carolina (Cottam, 1935).

Although the cause of this catastrophic decline is not certain, it is referred to as a wasting disease in most literature. The most often cited culprit of wasting disease is ***Labyrinthuyla macrocystis***, a fungus that attacks the leaf surfaces of eelgrass. Although originally thought to be the primary cause of the decline, it is now more commonly suspected of being a symptom. According to Thayer and Fonseca (1984), "***bacteria, fungi, commercial harvesting of fishery organisms, pollution, and competing species have been implicated as possible causative agents in the decline, but they have never been conclusively shown to have contributed to the 'wasting disease' event***." More recently, Rasmussen (1973, 1977) presented evidence that the decline in Denmark (and possibly elsewhere) was associated with a period of warm summers and exceptionally mild winters. Another theory suggests that extremes of low and high precipitation levels may have played an important part in the decline and in five prior documented declines (Martin, 1954).

The decline prompted concerned fish and wildlife biologists to make eelgrass population surveys a priority for the next two decades. The results of these surveys showed evidence that rhizomes persisted for many years and that eelgrass populations returned where water quality was suitable. The following references support this theory:

> ". . .in most of the Chesapeake Bay section of Virginia and Maryland, the plant has returned to almost normal condition...In general, the best return of the plant has been restricted to areas of reduced salinity, such as the more inland coastal bays and estuaries and mouths of large rivers" (Lewis and Cottam, 1936)

> "The situation has been most variable and sporadic since the initial destruction of eelgrass in 1931 to 1932. Little or no improvement could be detected for several years after 1931. Often some recovery was noted, only to be wiped out again . . . Along most of the Atlantic Coast of the United States and Canada, the situation is now somewhat better than it has been since 1931. Local units may be called fully recovered; other areas still are almost completely[1] without eelgrass. During the first half of the summer of 1944 a most gratifying recovery was noted in the majority of areas along the coast. In August, however, the disease reappeared in a number of areas, especially along the Massachusetts coast, so that the situation in part of this area was considerably less favorable than it had been during the preceding two or three years. The situation along the United States coast is perhaps least favorable in the more open bays and estuaries of New Jersey and Maryland, and most favorable in the sandy loam areas of reduced salinity of Chesapeake Bay, Long Island, and part of the Maine coast. Though the situation in any local area is highly variable and unpredictable, the trend is toward restoration of the plant in all favorable areas along the coast." (Cottam, 1945)

This trend, established along the rest of the coast, occurred in Long Island Sound (LIS) as well. While some local populations returned, other areas of the Sound supported no eelgrass. Records of eelgrass following the 1931 decline include locations listed in ***Appendix 2***.

A report by Muenscher (1939) on aquatic vegetation of Long Island made no references to eelgrass in any of the north shore harbors that were surveyed. Cottam (1945) recorded the observations of Dr. W. S. Bourn, a biologist with the U.S. Fish & Wildlife Service, after a visit to the Connecticut shore in 1944; while rough waters prevented a survey by boat, Bourn watched for drift and found it only in the Barn Island area where he observed a "***considerable windrow of healthy eelgrass plants that had been obviously dug up by feeding waterfowl***." He added that "***the individual plants appeared healthy and were approximately four feet in length***."

Addy and Johnson (1947) reported on the success of several transplant attempts in Connecticut with eelgrass taken from Niantic Harbor:

Location	Survival
East Lyme, Patagausett Cove	not checked
Old Lyme, Black Hall River	successful
Branford, Hotchkiss Grove Beach	successful
Norwalk, Norwalk River	failed

The same survey reported a failed attempt at transplanting eelgrass on the south shore of the Sound in Huntington Harbor. Both the stock plants and, consequentially, the transplant beds showed symptoms of the wasting disease.

In 1954, Cottam and Munro reported the following about the north shore of the Sound:

> "Though eelgrass is perhaps less abundant in this state than along most of the New England coast, the plant has shown encouraging improvement. In a few coves and bays, notably Stonington Harbour, Mystic, Poquonock, and Niantic Rivers, it is now regarded as abundant.

[1] This remark may suggest that viable rhizomes were still present.

> Yet, in some adjacent areas beds are scarce or even nonexistent. Eelgrass is said to be ***practically absent***[2] near New Haven, Milford Harbour, Southport, and Rowayton. Reestablishment on Long Island's north shore is noticeably poorer than that on adjoining coastal areas."

PRESENT DAY DISTRIBUTION

After the dramatic decline of eelgrass during 1931 to 1932, populations rebounded somewhat in the eastern Sound but not along the western Connecticut coast. Currently, along the Connecticut coast, beds occur from the Rhode Island border at Stonington west to Clinton. Mapping of these beds was completed in 1996 by a team of researchers from the University of Connecticut (C.Yarish, University of Connecticut, pers. comm.). A number of factors may limit the return of eelgrass to western LIS including high nitrogen levels and the much higher tidal range, which reduces light availability and restricts the vertical distribution of eelgrass (Koch and Beer, 1996).

There are no known eelgrass populations along the north shore of Long Island (Black, pers. comm.; NYSDEC surveys). ***Figures 3-2 and 3-3*** show historical and current locations of eelgrass in Long Island Sound.

[2] "Practically absent" suggests that eelgrass was present in the central and western Long Island Sound, but bed recovery was poor.

FIGURE 3.2.   Historical Eelgrass Distribution

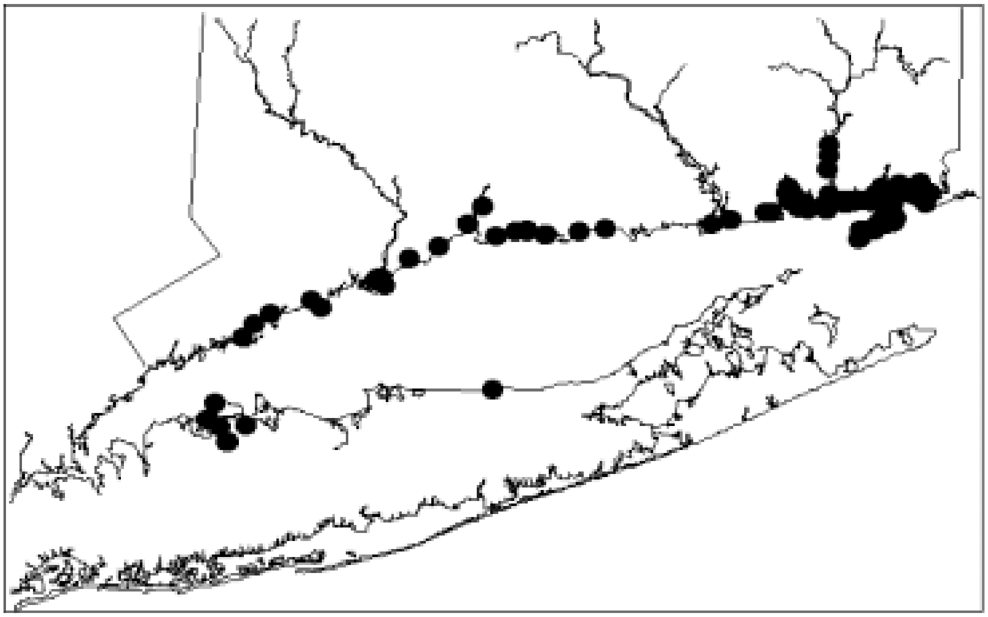
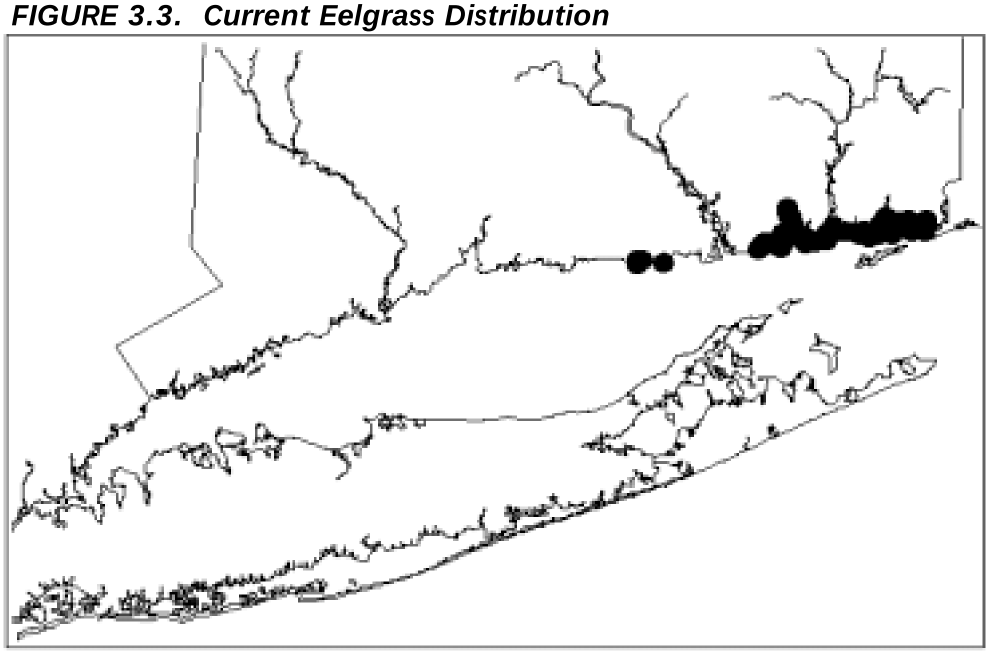


FIGURE 3.3.   Current Eelgrass Distribution



REGULATIONS PROTECTING SAVS

SAV is broadly protected under the Connecticut Coastal Management Act. Activities subject to regulation pursuant to the Act are reviewed for consistency with applicable coastal policies and assessed for adverse impacts to coastal resources. Adverse impacts to SAV are defined pursuant to C.G.S. Sec. 22a-93(15)(G) as those impacts "***degrading or destroying essential wildlife, finfish or shellfish habitat through . . . significant alterations of the natural components of the habitat.***"

The Act also establishes policies to preserve and enhance coastal resources. Eelgrass in estuarine embayments is a resource protected by the Act. This policy is

> "to manage estuarine embayments so as to insure that coastal uses proceed in a manner that assures sustained biological productivity, the maintenance of healthy marine populations and the maintenance of essential patterns of circulation, drainage and basin configuration; to protect, enhance and allow natural restoration of eelgrass flats except in special limited cases most notably shellfish management, where the benefits accrued through alteration of the flat may outweigh the long-term benefits to marine biota, waterfowl, and commercial and recreational finfisheries" [C.G.S. Sec. 22a-92(c)(2)(A)].

In the Spring of 1997, the Atlantic States Marine Fisheries Commission adopted an SAV policy that calls on states to protect existing beds, reduce pollution to promote comebacks, and set quantifiable SAV recovery goals. Specifically, member states are responsible for: monitoring programs at 1-5 year intervals; evaluating current regulatory program effectiveness and recommending improvements; setting SAV restoration goals; educating the public; and supporting SAV research.

DEGRADED EELGRASS BEDS AND RESTORATION METHODS

In many cases of eelgrass bed degradation, there is a combination of stresses. For example, a widespread problem such as impaired water quality may be coupled with localized physical disturbances. It is important to note that bed density, size, and distribution naturally fluctuates. In areas where stressed beds exist, growth may appear sparse, leaf blades may be short and narrow, and seed production may be sporadic (Koch ***et al.***, 1994).

BEDS IMPACTED BY IMPAIRED WATER QUALITY

Studies conducted in Chesapeake Bay (Kemp ***et al***., 1983; Orth and Moore, 1983) have shown that degraded water quality is the most significant cause of eelgrass declines. Poor water quality not only degrades or destroys healthy beds, but also prevents the reestablishment of beds at historical locations. Light availability, the most important parameter, is measured with special light meters or derived from water clarity measurements with a Secchi disk. The reduction or attenuation of light in the water column occurs in a number of ways (***Figure 3-4***), and is most greatly influenced by nutrient enrichment.

The Comprehensive Conservation and Management Plan (CCMP) of the Long Island Sound Study (LISS) ide[illegible]acting water quality. Excessive amounts of nitrogen encourage phytoplankton and epiphytic growth, thus increasing the amount of material in the water column and on the leaf surface. This material shades the eelgrass and prevents or inhibits growth. Nitrogen loading can also favor macroalgae growth at the expense of eelgrass resulting in dramatic changes to the food web (Deegan ***et al***., in press). At locations where eelgrass beds were converted to macroalgae-dominated sites or to unvegetated bottom habitat, fish abundance, biomass, and richness decreased (Deegan ***et al***., in press; Hughes ***et al***., in review) and decapod abundance and biomass decreased (Deegan ***et al***., in press).

Considerable efforts have been directed towards understanding the water quality requirements for SAV. In the Chesapeake Bay these efforts involved extensive water quality sampling where SAV beds occurred and where they were absent. Water quality data at restoration sites (successes and failures) have been further used to refine these requirements. Similar but more stringent habitat parameters were identified for SAV in Long Island Sound (***Table 3-3***). The more conservative values are based on the findings that regenerating eelgrass beds require better conditions than those needed for simply maintaining existing beds (Okubo and Slater, 1989). The Chesapeake studies have shown that if several of the water quality requirements are not met, eelgrass is usually not present.

FIGURE 3-4. Conceptual Model of SAV/Habitat Interactions

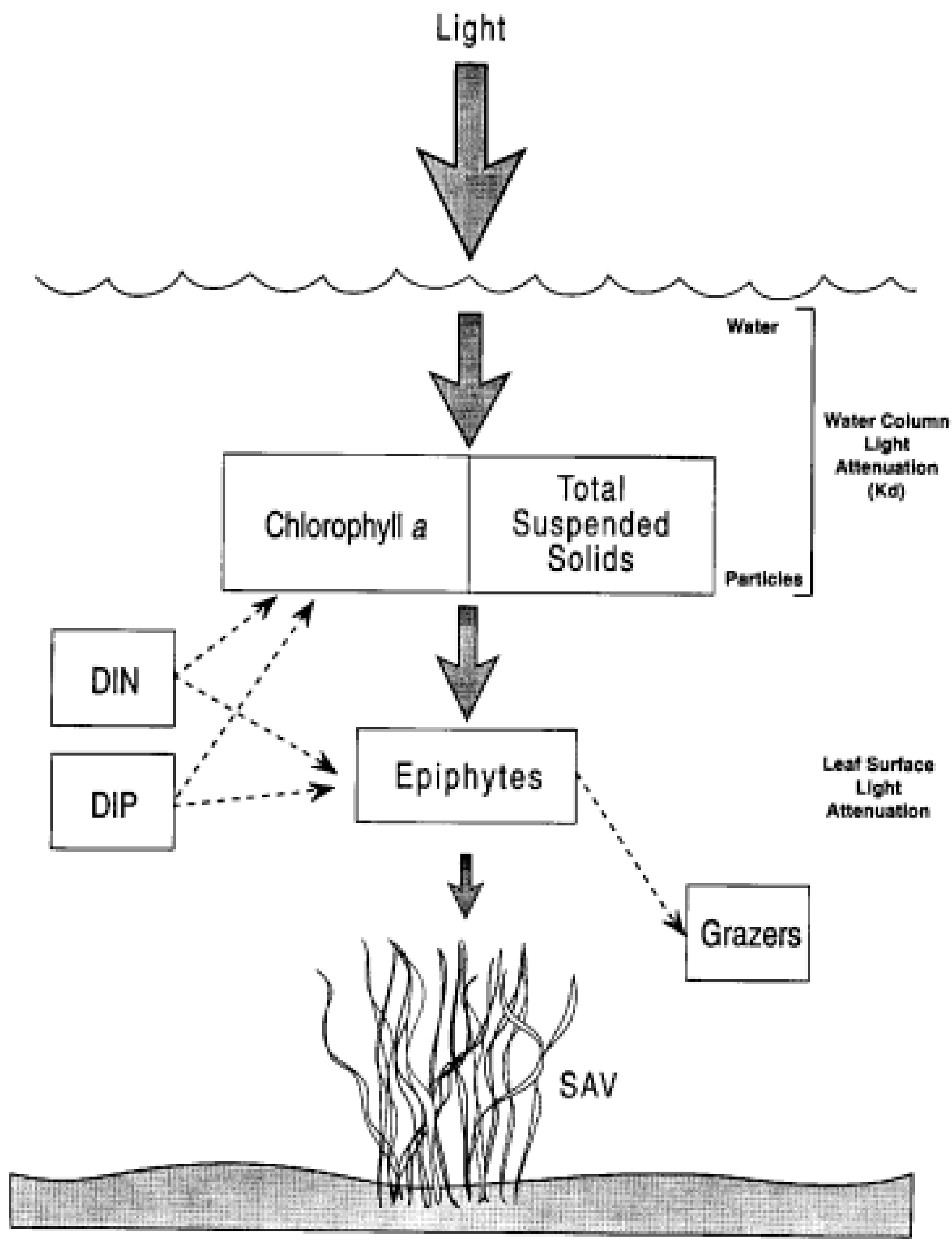
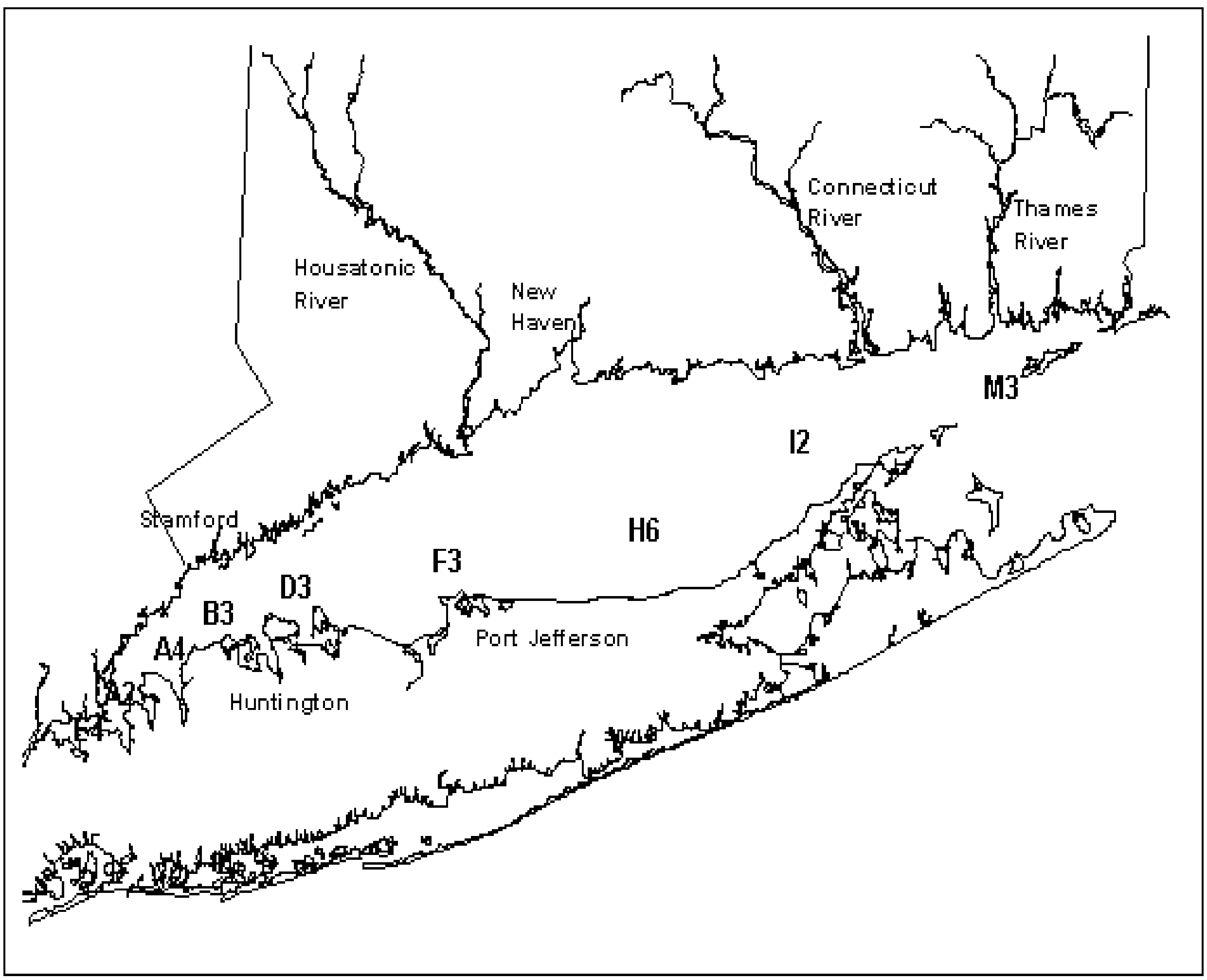


TABLE 3-3. Suggested Water Quality Criteria for Eelgrass. Parameters are based upon environmental data collected at three seagrass sites in Long Island Sound over 18 months (Koch et al., 1994).

Parameter	LIS	Chesapeake Bay
Light attenuation coefficient, Kd (m^{-1})	<0.7	<1.5
Total suspended solids, TSS (mg/L)	<30.0	<15.0
Chlorophyll ***a***, CHLA (***u***g 1^{-1})	<5.5	<15.0
Dissolved inorganic nitrogen, DIN (mg/L)	<0.03	<0.15
Dissolved inorganic phosphorous, DIP (mg/L)	<0.02	<0.02
Sediment organic matter (%)	<3.0	
Secchi depth (m)	>0.7	>0.8

FIGURE 3-5. Long Island Sound Offshore Water Quality Sampling Locations. Data from CTDEP and NYCDEP monitoring programs.



Monitoring stations in the Sound (***Figure 3-5***) indicate that the maximum allowable level of several water quality parameters for eelgrass are being exceeded: dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorous (DIP), and chlorophyll ***a*** (CHLA). Five years (1992, 1994, 1996, 1998, and 2000) of offshore data are presented in ***Appendix 3***. In general, the graphs show impaired water quality following an east to west trend with the least favorable eelgrass conditions occurring in western LIS. For each parameter, a horizontal line represents the maximum acceptable level for eelgrass growth.

Water column attenuation, measured as a light attenuation coefficient (Kd), results from absorption and scatter of light by particles in the water (phytoplankton is measured as chlorophyll a; total organic and inorganic particles are measured as total suspended solids) and by absorption of light by water itself. Leaf surface attenuation, largely due to algal epiphytes growing on SAV surfaces, also contributes to light attenuation. Dissolved inorganic nutrients (DIN and DIP) contribute to the phytoplankton and epiphyte components of overall light attenuation, and epiphyte grazers control accumulation of epiphytes. (From Batiuk ***et al***., 1992.)

While eelgrass does not grow near the offshore stations, it was necessary to use this data for lack of consistent nearshore data collection. Offshore water quality is generally not as impaired as nearshore water quality due to increased mixing and dilution of point and nonpoint source pollution. Thus, the offshore data represents a conservative water quality estimate when used to graph trends in impaired water quality.

Restoration Methods:

It is important to consider water quality for all possible restoration sites, even when the original cause of degradation may be an obvious localized activity. For example, removal of fill from a former eelgrass site in the western Sound would be pointless if the maximum acceptable water quality levels are exceeded.

① <u>Public Education:</u> At a Long Island Sound watershed level, the on-going public education efforts that originated under the LISS have been successful and should continue. At a local level, where isolated areas such as coves are experiencing water quality problems, adjacent homeowners can be made aware of possible causes of degraded SAV habitat. For example, where septic systems contribute to nutrient enrichment and algal blooms, homeowners may be educated as to the impacts of septic system failure on the ecosystem and encouraged to correct the problem by repairing or upgrading their systems.

   Additionally, homeowners can be educated about the effects of nitrogen runoff from lawn care products and encouraged to use sustainable practices to maintain their yards. This includes such techniques as using grass clippings to add nutrients to lawns and reducing chemical fertilizer use on their property. Also, topsoil runoff contributes to turbidity, so erosion prevention could be encouraged.

② <u>Educating Policy-Makers</u>: The large-scale issue of impaired water quality is being addressed under a separate component of the LISS Comprehensive Conservation and Management Plan (CCMP). Thus educational efforts aimed at informing policy-makers of the need for improved water quality necessary for the successful reestablishment of eelgrass habitat must be developed.

③ <u>Eelgrass Restoration through Transplantation or Seeding:</u> In undertaking any eelgrass restoration effort, water quality is one of the most important factors in selecting the most favorable restoration sites. The conservative water quality parameters established by Koch ***et al***. (1994) may be used as a guide for selecting sites. Sites being considered for restoration should be tested with experimental plantings to ensure water quality is adequate before embarking on any major restoration efforts. Experimental plot recommendations include an 11 x 11 yard area with predator control cages or nets made of material, such as inch-gill net (Short, 1995). While these cages prevent destruction by animals such as horseshoe crabs and green crabs, they will not prevent species such as clamworms from negatively impacting a bed. The cages must be checked frequently to remove algae or debris that will otherwise accumulate and shade the bed. These cages can be removed after three to four months; the shoot production of plants in established beds is substantial enough to prevent the bed from being impacted by predators.

A more rigorous model for determining appropriate restoration sites has been developed by Short and Kopp at the University of New Hampshire. Their model, called the Preliminary Transplant Suitability Index (PTSI) and the Transplant Suitability Index (TSI), take into account numerous ecological variables that can effect whether a site is conducive to eelgrass restoration (http://marine.unh.edu/jel/fred/siteselection01.html). For the PTSI a numerical ranking is given to the following variables:

- Historical eelgrass distribution
- Current eelgrass distribution
- Bathymetry (-2’ to –5’ MLW gets highest ranking)
- Water quality data (calculate a eutrophication index based on DO, DIN, TON, Secchi, and phytoplankton pigments)
- Sediment distribution
- Wave exposure
- Bioturbation
- Proximity to natural eelgrass beds

Test transplants of eelgrass are done concurrently with the development of the PTSI. The recommended method, called TERFS (Transplanting Eelgrass Remotely with Frame Systems), was developed by Short and Kopp (unpublished data). The TERFS method consists of tying eelgrass shoots to a metal checkerboard frame that is lowered into the water until it rests on the bottom. Once the eelgrass has rooted and the paper ties have dissolved the metal frames are retrieved. At the conclusion of the test transplantation, the final TSI is calculated to determine the best sites for full-scale eelgrass restoration. The TSI is calculated using the following parameters: PTSI, light, bioturbation, test transplant survival, and growth and leaf nitrogen content of test transplants.

Transplantation: Transplanting eelgrass involves harvesting mature plants from healthy donor beds. Transplantation should occur within several hours of being picked during which time the fragile plants are rinsed free of sediments and kept wet, cool, and intact (Fonseca, 1992 and Thayer ***et al***., 1988). Transplanting techniques may include the use of: sod potters; plant bundles bound with edged metal staples; biodegradable plant staples; some other type of temporary holdfast; or the TERFS system. Intertidal areas are usually accessible during low tides, while work in deeper waters may require divers. One benefit of the TERFS method is that divers are not needed (see above description). The TERFS system shows promise as an efficient and low cost method of transplanting eelgrass.

The cost of transplanting is site and method specific and can vary dramatically. An estimate from a transplantation project in New Hampshire using divers is approximately $100,000/acre (Colarusso, EPA, pers. comm.).

Seeding: Based on the preliminary results of studies conducted in Long Island Sound, the recommended technique consists of harvesting seeds from donor sites and spreading (or broadcasting) the bare seed into the areas to be restored (C.Yarish, University of Connecticut, pers. comm.). This technique is preferred over transplantation because it is less destructive to the donor site and less expensive. Depending on springtime conditions, seeds may be harvested from mature plants from the end of June to early July. Preliminary findings indicate the seeds should not be spread until mid-September to achieve the best germination. A parallel study of the Sound's eelgrass suggests the germination rate of seeds is roughly 70-80 percent (C.Yarish, University of Connecticut, pers. comm.). Alternatively, an experimental method of seeding eelgrass, currently under development at the University of Rhode Island, uses a boat-drawn sled to inject seeds suspended in gelatin into the sediments (http://ciceet/unh.edu/additional/spotlight).

BEDS IMPACTED BY FISHING AND VESSEL RELATED ACTIVITY

Fishing gear dragged through seagrass beds can break apart leaves or tear up the plant from its roots. Large unvegetated swaths can be left in the middle of an otherwise healthy bed. Most damaging to the beds are trawls, nets, lobster traps, and, historically, scallop dredges. An example of this type of disturbance occurred in Connecticut's Niantic River. Once a productive scallop area, the estuary was lined with scallopers' boats. Six-inch wide metal frames covered with chicken wire were attached to the end of 16-20 foot long poles and dragged along the bottom. Studies conducted on larger-scale scallop operations in North Carolina have shown that harvesting techniques not only damage the eelgrass beds, but may also have further negative impacts on the scallop fishery (Fonseca ***et al***., 1984).

Vessel-related disturbances to eelgrass beds can be substantial. Motorboat propellers cutting through seagrass beds or digging into the sediment can leave long scars that persist unvegetated for years (Zieman, 1976). Turbulence from propeller wash and vessel wakes can dislodge sediments, break off seagrass leaves, or uproot plants (Lockwood, 1990). Also, mooring chains swinging around their mooring blocks can denude circular patches within eelgrass meadows (Short ***et al***., 1991; Short ***et al***., 1993; Burdick and Short, 1999).

Restoration Methods:

① Natural Restoration: Fishing and vessel related disturbances may affect isolated patches within a bed. Considering the resiliency of eelgrass, these beds have the potential to recover if the activity is not repeated on a regular basis. The likelihood of this natural restoration is elevated with increased proximity to beds with flowering plants. Mature seeds are dispersed by sinking, free floating stalks or waterfowl (Lamounette, 1977).

It should be noted that once a bed has been stressed by having a trawl or net dragged through it, poor water quality may prohibit its recovery.

② Public Education: To avoid repeated impacts upon eelgrass habitat, public education is imperative. To assist in public awareness and education campaigns, special buoys may be placed over eelgrass beds warning boaters to avoid the area. In addition, literature can be dispersed to those persons actively involved with the recreational and industrial use of the marine environment.

WATERFOWL AND STORM-RELATED DAMAGE TO BEDS

Feeding by herbivores can play a significant role in the reduction of eelgrass bed density. Non-migratory Canada geese (***Branta canadensis***) and the introduced mute swan (***Cygnus olor***) have been known to overgraze beds, leaving only chopped blades or rhizomes. Studies in Chesapeake Bay estimated that during the winter of 1978-1979, Canada geese consumed about 21 percent of the standing crop of seagrasses in the shallow portion of the lower Chesapeake Bay (Wilkins, 1982). Connecticut's resident goose population, increasing from 1,000 in 1970 to approximately 35,000 today, has the potential to negatively impact eelgrass beds. Submerged aquatic vegetation of tidal estuarine waters may be especially vulnerable to waterfowl damage since the beds become more accessible to such foragers at low tide.

The mute swan population in the Atlantic Flyway increased from 200 in 1954 to 12,500 in 1999. More than 50 percent of the population was found in Connecticut and New York (Allin ***et al***., 1987). Studies on penned molting swans found the average consumption of eelgrass and sea lettuce (***Ulva lactuca***) per swan over 24 hours to be 3.66 kilograms and 4.03 kilograms wet weight, respectively (Mathiasson, 1973).

Other natural disturbances to eelgrass beds include damage caused by catastrophic storms, periodic storms, sediment transport, and ice damage. While these disturbances have not been well-documented in the Sound, studies in southeastern Massachusetts have shown that, of all the natural disturbances, severe climatological events have had the greatest impact on eelgrass abundance (Costa, 1988).

Restoration Method:

Providing that these natural disturbances have not permanently altered the physical characteristics of a site, the eelgrass beds have the potential to regenerate without restoration. Population management of certain waterfowl species (***e.g.***, mute swan and resident Canada geese) may be warranted if over grazing has degraded eelgrass beds. Reduction of nuisance waterfowl numbers may decrease grazing of eelgrass and allow for natural restoration.

BEDS IMPACTED BY SHORELINE EROSION CONTROL STRUCTURES

Structures that affect wave energy or currents can degrade or destroy eelgrass beds. Bulkheads, seawalls, and riprap "harden" the shoreline and reflect wave energy. The process of constructing or installing these structures creates temporary sediment plumes, thus reducing light penetration. The long-term negative impacts include changes in localized wave attenuation, longshore currents, and sedimentation patterns (Kurland, 1994). Beds can grow at sustained current velocities up to 59 inches sec^{-1} and may tolerate brief exposure to higher velocities (Fonseca ***et al***., 1982a). If the structure increases current velocity above this point for extended periods or if the point of wave breaking is shifted, the eelgrass bed may become weakened and degraded. In addition to these problems, the increased energy will contribute to greater turbidity. Jetties and groins similarly impact eelgrass beds.

Restoration Method:

Shoreline structures are created for the protection of property. Therefore, the removal of these structures for the sake of eelgrass restoration is, in most cases, not practical. However, if beach/shoreline restoration is being considered, eelgrass restoration may be an option. Refer to restoration techniques under the section "Beds Impacted by Impaired Water Quality."

SHADING OF BEDS

Docks, floats, and piers alter environmental conditions by reducing available sunlight, creating shaded areas. Shading decreases photosynthetic efficiency, flowering and vegetative density of eelgrass beds (Dennison 1987).

Restoration Method:

Height/orientation recommendations for dock building may be considered as a function of maintenance, reconstruction of dilapidated structures, or permitting new docks. For example, the greater the clearance above marine bottom, the less impact. For this reason, fixed-timber piers two yards above water are preferred over floating docks. Axis of orientation is also important; north to south running docks shade less of an area than do east-west oriented docks (Short, 1995).

BEDS IMPACTED BY DREDGE ACTIVITIES

Dredging for the purposes of marinas, docks, pipeline crossings, and navigation channels physically removes eelgrass and its substrate, increasing water depth. Light availability in these deeper waters may be insufficient for bed reestablishment. Recolonization in the dredged basins and channels is further hindered by maintenance dredging or accumulations of organic matter. The dredging process indirectly impacts other beds in an area by creating turbidity that reduces the productivity of grasses and, if severe enough, eventually kills them.

Restoration Methods:

Sand and gravel dredge sites are more likely candidates for restoration than areas dredged for the purpose of boating/shipping. Restoring eelgrass near the edge of deep channels can help stabilize the area and possibly reduce the need for frequent dredging. But, in more shallow dredge sites, the presence of eelgrass may actually create conflicts by contributing to sediment deposition and shoaling (Colarusso, pers. comm).

<u>Preliminary restoration steps:</u> Eelgrass restoration at a dredge site is an option if the area can be filled to its former bathymetry. The determination of appropriate sites should be based on an assessment of various environmental variables using one of the methods described under the section “Beds Impacted by Impaired Water Quality.”

BEDS IMPACTED BY FILL

Eelgrass beds were completely destroyed by the historical placement of fill or dredge sediments in vegetated shallows to create dry land. This practice was common when waterborne commerce was the main mode of transportation and upland area was needed for uses such as boat yards or cargo ports. Relatedly, dredge sediments from navigation channels were often disposed of in shallow waters or cast alongside the channel. As with dredging, filling may have short-term impacts on other beds in an area because of increased turbidity.

In aquaculture practices, fill was added to provide a cultch base for settling oyster larvae. Around the turn of the 20th century, the tremendous boom in offshore oyster harvest and production spawned numerous inshore oyster operations or aquaculture projects. The nearshore water areas were often carved up into grids and individual parcels were leased to prospective oystermen. Oysters were relayed to nearshore sites for brief periods of time and then harvested and transported back to deep waters. The actual impacts of such operations are difficult to quantify but undoubtedly some amount of eelgrass habitat was lost through direct placement of live oysters and cultch, and indirectly through attempts to remove sediment in coastal embayments.

Restoration Method:

Removing fill, in most cases, is an extremely difficult and impractical option, especially if the site has been developed. If the cost of fill removal is not a deterrent and if pre-disturbance bathymetric conditions are known, eelgrass restoration is possible. Refer to restoration techniques under the section “Beds Impacted by ImpairedWater Quality.”

SPECIFIC RESTORATION OBJECTIVES

The general goal is to restore eelgrass beds to historical locations as dictated by acceptable water quality. Specific goals include:

IMPROVE FISH AND WILDLIFE HABITAT

Eelgrass provides forage, shelter, and nursery habitat for marine life. Restoration will increase the overall productivity of shallow coastal embayments. Focus species will include: bay scallop, winter flounder, menhaden, blue crab, American lobster, hard-shell clam, bluefish, and striped bass.

MAINTAIN / IMPROVE WATER QUALITY

Eelgrass beds filter estuarine waters by removing suspended sediments and dissolved nutrients and by assimilating certain contaminants. In areas where water quality is suitable for restoration, further nutrient reduction goals should be established.

INCREASE EROSION CONTROL AND SEDIMENT STABILIZATION

Eelgrass roots and rhizomes help to bind sediments, while the three-dimensional canopy structure can act as a baffle and substantially reduce wave energy, further enhancing sediment stability. The loss of a bed can threaten other beds in the area by re-suspending sediments and contributing to increased turbidity. Restoring beds to disturbed areas with the goal of improving sediment stabilization may help maintain the health of local beds.

RESTORATION SUCCESS AND MONITORING

Fonseca ***et al***., (1982b) suggest transplantation is basically successful if it survives and has increased its coverage after two growing seasons. But the definition of “success” varies. Vegetation may survive and persist, but restoring one acre with the goal of a fully functioning one-acre bed is not probable. In general, the long-term success of restored eelgrass habitat has not yet been well documented. To increase the chance of a successful restoration project one of the methods of assessing suitable restoration sites (either Koch ***et al***., or Short and Kopp) should be used.

Factors to consider for monitoring may include the following:

a. Water quality
b. Coverage - density, leaf area, continuity of bed
c. Persistence
d. Functional equivalence

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APPENDIX 3-A

HISTORICAL (PRIOR TO 1931) EELGRASS DISTRIBUTION

Locations are listed from west to east.

Location	Source	Observation / Collection Date
New York		
Fishers Island	St. John, 1920	1920
Wading River	Brooklyn Botanical Garden	1873, 1914
Center Island, east side	Transeau, 1913	
Lloyds Neck, north side	Transeau, 1913	
Cold Spring Harbor	Brooklyn Botanical Garden	1890
Inner Harbor	Johnson and York, 1915	1905-1913
Connecticut		
Fairfield	G. Safford Torrey Herbarium	1915
Stratford, Housatonic River	U.S. Coast and Geodetic Survey Chart, 1892	1884-1887
Milford/West Haven Oyster River	Nichols, 1920	
Branford, Stony Creek	U.S. Coast and Geodetic Survey Chart, 1918	1833-1916
Madison	G. Safford Torrey Herbarium and Yale Herbarium	1874
East Lyme, west Watts Island	U.S. Coast and Geodetic Survey Chart, 1925	1917-1918
East Lyme/Waterford Niantic River	U.S. Coast and Geodetic Survey Chart, 1925	1917-1918
Waterford, Indian Cove	U.S. Coast and Geodetic Survey Chart, 1925	1917-1918
Groton: -Thames River, n. of sub base - Bluff Point	U.S. Coast and Geodetic Survey Chart, 1933 G. Safford Torrey Herbarium	1917-1933 1930

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APPENDIX 3-B

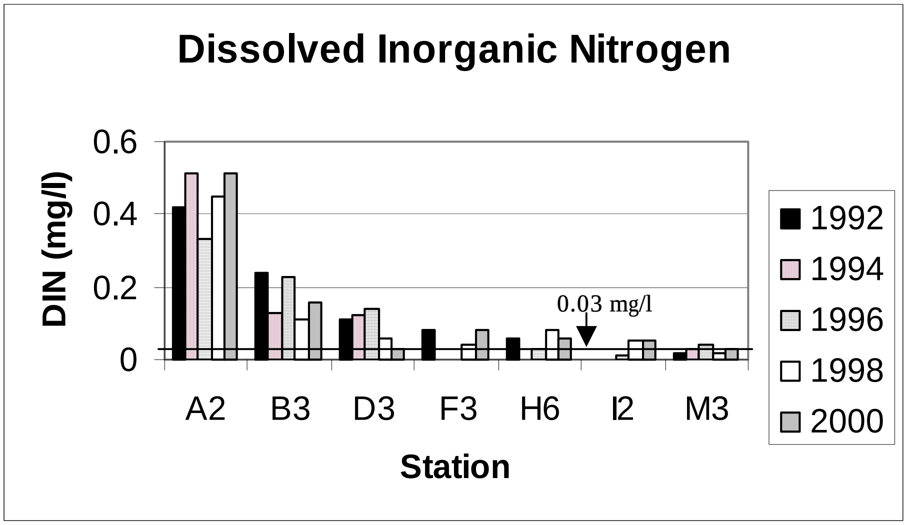
EELGRASS LOCATIONS 1931 - 1992

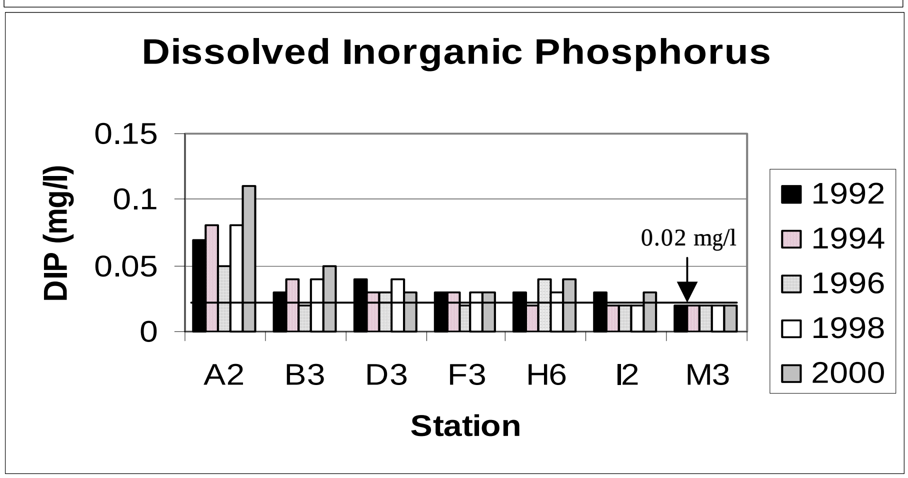
Location	Source	Observation/ Collection Date
New York		
Fishers Island - West Harbor -South Beach	U.S. Coast and Geodetic Survey Chart, 1958 New York State Museum collection #5539	1958 1990
Wading River	Brooklyn Botanical Garden	1950
Connecticut		
Rowayton	Cottam and Munro, 1954	1954
Westport, Longshore Beach	Barske, 1993, pers. comm.	1947
Southport	Cottam and Munro, 1954	1954
Stratford, Frash Pond	Knapp, 1995, pers. comm.	1935-45
Milford, Milford Harbor	Cottam and Munro, 1954	1954
New Haven, Quinnipiac River	Addy and Johnson, 1947	1947
East Haven River	Lynch and Cottam, 1937	1936
Branford, Hotchkiss Grove	Beckley, 1982	1982
Guilford, Great Harbor	Barske, 1993, pers. comm.	1947
East Lyme, -Rocky Neck	Barske, 1993, pers. comm.	1947
East Lyme and Waterford -Niantic River and Bay -Niantic Bay	Cottam and Munro, 1954 Northeast Utilities Service Company, 1996; Lynch and Cottam, 1937	1954 1985-1996 1936
Waterford: -Jordan Cove and Bay -White Point	Northeast Utilities Service Company, 1989 Knight and Lawton, 1974	1985 1974
Waterford and New London Alewife Cove	Conn. College Herbarium	1945
New London, Alewife Cove	Lewis, 1995, pers. comm.	1963-1969
New London and Groton, Thames River	Welsh, 1984	1984
Groton: -Shennecosett Beach -Pine Island Bay -Jupiter Point -Poquonock River -Bushy Point Beach -Mumford Point	Welsh, 1984 Barrett,1991 NOS NOAA Nautical Chart, 1985 Cottam and Munro, 1954 CT Botanical Society NOS NOAA Nautical Chart, 1985	1984 1991 1985 1954 1970 1985

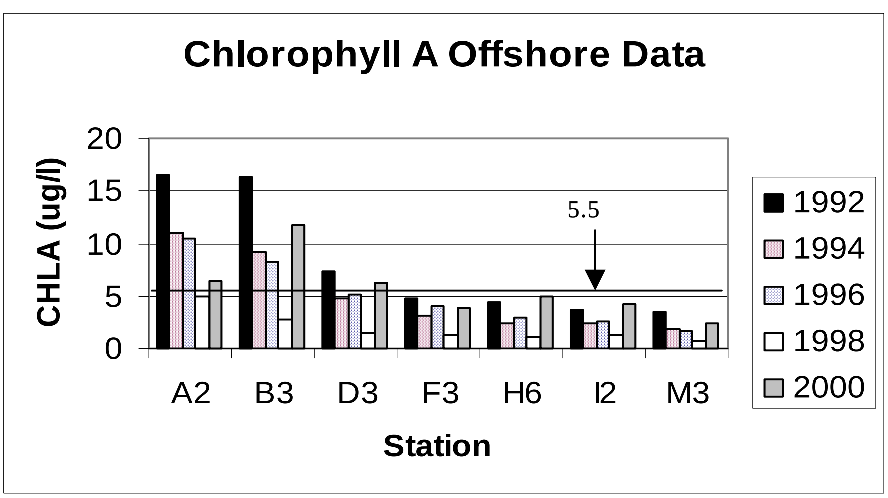
Location	Source	Observation/ Collection Date
Stonington:	Barrett, 1991	1991
-Ram Island	U.S. Coast and Geodetic Survey Chart,	1958
-S.E. of Ellis Reef	1958	1954
	Cottam and Munro, 1954	1932; 1945
-Mystic River	Uhler, 1932; Cottam, 1945	1991
-Mystic Cove	Barrett, 1991	
-Dodges Island	Lynch and Cottam, 1937; Renn, 1937;	1936; 1989
-Quiambog Cove	Crawford, 1989	1991
	Barrett, 1991	1958
-Lyddy Island to Lords Point	U.S. Coast and Geodetic Survey Chart,	1954; 1991
-N.W. Stonington Harbor	1958	
	Cottam and Munro, 1954; Barrett, 1991	1991
-Stonington Harbor	Barrett, 1991	1958
-Bay bounded by Stonington,		1958
Sandy and Edwards Points	U.S. Coast and Geodetic Survey Chart,	1936; 1989
-Elihu Island	1958	
	U.S. Coast and Geodetic Survey Chart,	
-Wequetequock Cove	1958	
	Lynch and Cottam, 1937; Crawford, 1989	
-Barn Island area		

APPENDIX 3-C

GRAPHS OF WATER QUALITY DATA FOR FIVE OFFSHORE SAMPLING STATIONS







LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

SECTION 4: COASTAL GRASSLANDS

Technical Support for Coastal Habitat Restoration

SECTION 4
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SECTION 4: COASTAL GRASSLANDS

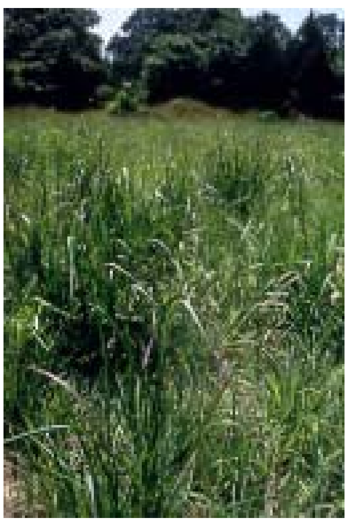
DESCRIPTION

The grassland communities described in this chapter occur on the rolling glacial outwash plains of Connecticut and Long Island. These areas are extremely well drained, nutrient-poor, sandy soils. Three grassland community types occur in the vicinity of Long Island Sound and are described below.

MARITIME GRASSLANDS

Maritime grasslands are found within the coastal zone and are influenced directly by spray from the ocean and strong onshore winds. This community differs from the dune grass communities in that the landscape is more gently rolling and the substrate is more stable. However, the soils are still characteristically sandy or gravelly and very well drained. The vegetation of the maritime grassland community is dominated by grasses like little bluestem (***Schizachyrium scoparius***) (***Figure 4-1***), common hairgrass (***Deschampsia flexuosa***), and poverty grass (***Danthonia spicata***). Other characteristic species include Atlantic golden aster (***Pityopsis falcata***), the New York State threatened bushy rockrose (***Helianthemum dumosum***), Pennsylvania sedge (***Carex pensylvanica***), and Indian grass (***Sorghastrum nutans***).

Figure 4.1. Newly Seeded Little Bluestem



Newly seeded little bluestem, Schizachyrium scoparius, after three months' growth at Orient Point County Park, NY

Maritime grasslands often occur in a mosaic-like distribution interspersed with maritime heath lands. These heath areas will have populations of dwarf shrubs like bearberry (***Arctostaphylos uva-ursi***), beach plum (***Prunus maritima***), beach heather (***Hudsonia tomentosa***), bayberry (***Myrica pensylvanica***), and black huckleberry (***Gaylussacia baccata***). Although there are grasses and forbs present in the heath land patches, they compose less than 50 percent of the ground cover and do not form a turf (Reschke, 1990).

The most extensive maritime grasslands and heathlands in New York currently occur outside of the project area in the Montauk Downs and Shinnecock Hills areas of the south fork of Long Island. Taylor (1923) describes the dominant vegetation species at the Montauk Downs as being little bluestem, Greens' rush (***Juncus greenei***), common hairgrass, Indian grass, toothed white-topped aster (***Aster paternus*** [***Sericocarpus asteroides***]), plantain-pussytoes (***Antennaira plantaginifolia***), and sand-plain agalinis or sandplain gerardia (***Agalinis acuta***). Additional small patches of maritime grassland can be found along the Connecticut coast such as the restoration project completed by the Connecticut Department of Environmental Protection at Nott Island.

SAND PLAINS

Sand plain grassland communities are found on outwash plain soils ranging from medium-grained sand to coarse gravel. There are reports of the water table being just a few inches below the soil surface in some places in the New Haven area sand plains (Britton, 1903). The characteristic plant species display xerophytic tendencies due to the extremely rapid drainage characteristics of the soil. Like the maritime grasslands, the dominant grass species on sand plains is little bluestem, but this community is characterized by higher elevations and little to no salt spray influence. There is often a habitat mosaic found in the sand plain areas of Connecticut with bare ground, lichens (***Cladonia spp.***), and grass cover interspersed with black oaks (***Quercus velutina***) and pitch pines (***Pinus rigida***).

Olmstead (1937) described three distinct zones of vegetational dominance in the Quinnipiac sand plains. There are areas of "savanna" where the soil is almost completely covered by little bluestem grass, lichens, and other non-woody vegetation. There may be scattered trees and shrubs present in the midst of these grassy stretches. Other areas are dominated by woody scrub vegetation or forest. Dominant trees include pitch pine, black oak, grey birch (***Betula populifolia***), and eastern red cedar (***Juniperus virginiana)***. Areas dominated by forest cover are often devoid of ground cover vegetation, resulting in bare soil between the tree trunks. A third zone is characterized by the lack of plant cover altogether and are designated as barrens. Olmstead (***op. cit.***) speculated that the barren areas may represent localized disturbance due to human farming activities like plowing and animal grazing. The pre-disturbance climax community was most likely a tall grass savannah with scattered oaks.

In addition to floristic attributes, Olmstead (***op. cit.***) described three distinct soil "habitats" based on observations of disturbed soil profiles in areas that had been farmed in the past and were then abandoned. Type 1 is characterized by relatively undisturbed soil profiles. Type 2 consists of areas where the "A" horizon of the soil is entirely removed and at least some of the "B" horizon is likewise eroded. Type 3 is characterized by intact "A" and "B" horizons and additional sand deposition at the surface in ridges and hummocks of varying depth.

Further, Olmstead (***op. cit.***) described distinct species communities occurring in specific zones of the soil habitats. In Type 3 habitats, orange grass (***Hypericum gentianoides)*** is found chiefly on the windward slope of wind formed ridges and hummocks of the "A" horizon. It grows interspersed with sand rush, (***Bulbostylis*** [***Stenophyllus***] ***capillaris***). These species are then invaded by little bluestem and lichens.

In Type 2 habitats, blue curls (***Trichostema dichotomum***), an annual weedy species, and little bluestem are prevalent. These are important pioneering species, since all the humus in these sand plains is contained in the "A" horizon. The "B" horizon is largely devoid of nutrients to sustain plant growth.

A similar type of sand plain habitat occurred on an estate encompassing High Hill in Huntington, N.Y. The description of the site (Blizzard, 1931) is similar to the descriptions of the Connecticut sand plains. The dominant grass was little bluestem occurring in clumps separated by exposed patches of sand and gravel. The spaces between clumps of little bluestem contained lichens (***Cladonia*** spp.) and mosses. Blizzard particularly noted the lack of diversity in this grassland as compared with the nearby Hempstead Plains, especially the absence of false indigo (***Baptisia tinctoria***) and wildflowers.

Conard (1923) noted a similar successional assemblage of plants on the disturbed right-of way along the Cold Spring Harbor line of the Long Island Rail Road. The disturbed areas displayed more invasion by non-native plants than seen in the Connecticut or High Hill communities, mainly along the border of developed and cultivated neighboring properties. A dominance of little bluestem was noted in flat areas and those areas with gravel soils.

HEMPSTEAD PLAINS

The Hempstead Plains have been described as the only true prairies east of the Allegheny Mountains. They are dominated by grasses like little bluestem and switchgrass (***Panicum virgatum***). Seasonal dominants include many wildflowers. May blossoms are dominated by several species of violets (***Viola lineariloba, V. pedata*, *V. fimbriatula***). Summer flowers included false indigo and unicorn root (***Aletris farinosa***) in June; yellow-fringed orchis (***Habenaria ciliaris***) in July; and various asters (***Aster***

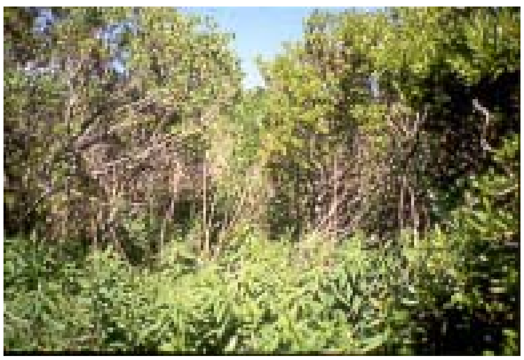
linariifolius, A. ericoides, A. multiflorus) and goldenrod (***Solidago tenuifolia***) in August (Conard, 1935).

The plant diversity of the Hempstead Plains is well documented. As late as 1968, a survey of the vegetation in a preserved plot at Mitchell Field Park identified 147 species of wildflowers, 27 species of shrubs and vines, and 13 species of grasses (Neidich, 1984). The Hempstead Plains community is a mature and stable community rather than an intermediate stage between bare ground and forest cover. It is theorized that the thick turf formed by the dense root system of ***Andropogon*** species of grasses, in combination with fires, have prevented succession to a forest cover on these plains. Olmstead (1937) drew similar conclusions about the sandplain communities of Connecticut.

OLD FIELD GRASSLANDS

Old field successional grasslands, otherwise referred to as post-agricultural or ruderal grasslands, are found on abandoned farm and pasture lands (***Figure 4-2***). Frequently these lands were converted from forest cover to cropland or grazing area. Once active agriculture or grazing ceases on a plot, nearby grasses and forbs quickly colonize it. Bluegrasses (***Poa sp.***), goldenrods (***Solidago sp.***), New England aster (***Aster novae-angliae***), and quackgrass (***Agropyron repens***) are some characteristic herbs. Shrubs and trees like the silky dogwood (***Cornus amomum***) and eastern red cedar (***Juniperus virginiana***) may also be present in small patches (Reschke, 1990). In contrast to the Hempstead Plains community, these grasslands will succeed to forest and shrub cover relatively quickly if not managed. As with many disturbed habitats they are also quite susceptible to invasion by non-native species. While old field habitats are not, strictly speaking, native habitats, they represent an excellent opportunity for grassland management and may be used as surrogate habitat by grassland dependent species.

Figure 4-2. Farm Field with Common Reed, Shrubs, and Invasive Vines



An abandoned farm field has become overgrown with common reed (Phragmites australis), shrubs, and invasive vines.

VALUES AND FUNCTIONS

Grassland habitat is the home of many bird species like the grasshopper sparrow (***Ammodramus savannarum***)[*$], Eastern meadowlark (***Sternella magna***), Northern harrier (***Circus cyaneus***)[$+*], upland sandpiper (***Bartramia longicauda***)[$], and savannah sparrow (***Passerculus gramineus***)[$], which nest, breed, and forage there. Raptor species like the American kestrel (***Figure 4-3***) (***Falco sparverius***), rough-legged hawk (***Buteo logopus***), red-tailed hawk (***Buteo jamaicensis***), common barn owl (***Tyto alba***)[$], and the

Figure 4-3. Juvenile American Kestrels in Nest Box

Photo by Bob Parris, USFWS

[+] Denotes federally protected species including federally endangered or threate
[*] Denotes state protected species including endangered, threatened, or of special concern in New York.
[$] Denotes state protected species including endangered, threatened, or of special concern in Connecticut.

bobolink (***Dolichonyx oryzivorus***) depend on grasslands for feeding.

Raptors use their keen eyesight and hearing to locate prey found in grasslands. Rodents like the meadow vole (***Mictrotus pennsylvanicus***), deer mouse (***Peromyscus maniculatus***), white-footed mouse (***P. leucopus***), and the nocturnal meadow jumping mouse (***Zapus hudsonius***) are principal components of the raptors' diets and are abundant in the open grassland areas. The raptors also feed on the Eastern cottontail rabbit (***Sylvilagus floridanus***), which once browsed in the little bluestem-dominated areas of the Hempstead plains. Due to their heavy dependance on visual cues in hunting, the American kestrel and Northern harrier must hunt in areas mostly free of dense woody vegetation. Other raptors like the short-eared owl (***Asio flammeus***)[$] and hawks use open coastal grasslands as overwintering habitat.

Natural Heritage Program priority vertebrate species associated with northeastern United States grasslands include the big brown bat (***Eptesicus fuscus***), spadefoot toad (***Scaphiopus holbrooki***)*[$], and eastern hognose snake (***Heterodon platyrhinos***)[$*]. Federally-endangered invertebrate species dependant on grasslands as their primary habitat include butterflies like the regal fritillary (***Speyeria idalia***)[+$] and the American burying beetle (***Nicrophorus americanus***)[+$].

One important feature of the grasslands described above is that they are able to withstand periods of drought that severely stress other plant communities. The vegetation found in Hempstead Plains and Sand Plain grasslands grow extensive root systems that comprise up to two-thirds of their biomass. The massive root system is extremely efficient in absorption and utilization of water. This ensures that even during the driest summers or periods of fire, the deep and wide reaching root system of the grasslands is able to survive until the following growing season. This fact plays an important role in soil conservation. Olmstead (1937) discusses the effect of plowing some areas of the Quinnipiac sand plains:

> "An effect much more harmful to reestablishment of the natural vegetation than soil depletion was the actual soil destruction, which occurred on many of the areas soon after plowing. The loose sand...must have been subject to wind erosion almost as soon as the original vegetation was destroyed."

He goes on to describe historical accounts of vast depressions created by wind scour over denuded areas of the sand plains.

Several state- and federally-endangered plant species are found only in grasslands. One of these is sand-plain agalinis. In New York this flowering annual is only known to exist in two sites in Suffolk County. A 1950 edition of <u>Gray's Manual of Botany</u> describes sand-plain agalinis as only occurring at Cape Cod, Massachusetts, western Long Island, Providence County, Rhode Island, and Hartford County, Connecticut. This is truly a plant of specialized habitat that is unlikely to reestablish in any great quantity without human intervention. Sand-plain agalinis and the previously mentioned bushy rockrose are two of 14 plant species listed as rare by the New York Natural Heritage Program supported by Hempstead Plains grassland communities. The U.S. Fish and Wildlife Service is currently managing remnant populations of sand-plain agalinis on Long Island. It is hoped that the plant may be reintroduced to additional sites in the future.

STATUS AND TRENDS

Hicks (1892) quotes accounts from the diaries of colonial settlers of the Native American tribes using grasslands as hunting grounds and maintaining them by deliberately setting fires to remove woody vegetation. The colonists later maintained the grasslands as common pasturage for livestock. During the late 19th century the Long Island Rail Road continued to burn the remaining Hempstead Plains to maintain the fields' value for livestock and farming while maintaining rail line rights-of-way (Hicks, 1892).

Maritime grasslands are not found within the boundaries of this project on Long Island, Bronx, Queens, or Westchester Counties. The North Fork area of Long Island is the most likely area for them to have occurred, but farming has remained the predominant land use in that area since the late 17th century, and such activities would have destroyed the natural plant community and soil profile. Suitable soil and atmospheric conditions exist along the flatter areas near Southold to have supported maritime grasslands and likely could do so again. The North Fork area is in a continuous line of Wisconsin glacial moraine deposits which include Nantucket, Block Island, Martha's Vineyard, and the Elizabeth Islands. These areas along with Cape Cod, southern Rhode Island and southeastern Connecticut are part of the same biogeographic region which support similar characteristic grassland communities. The islands of Nantucket and Martha's Vineyard, and Block Island are still known to support maritime grassland communities.

In Connecticut, sand plain communities are nearly extirpated. In his description of the North Haven sand plains, Britton (1903) writes that "A large portion of this land has been improved..." but no estimate of the original extent of these sand plains is made other than the two small specific plots he studied. Those two plots encompassed roughly 120 acres according to Britton's estimates. Olmstead (1937) investigated the same areas cited by Britton, as well as additional areas nearby. His description of the entire sand plain area reads, "One of the most noteworthy of these terraces extends along the east side of the Quinnipiac River in the towns of North Haven and Wallingford, for a distance of 15 to 16 miles, between New Haven and Meriden, Connecticut, with and average width of 1 to 1½ miles." Using this description of the then current extent of the Quinnipiac sand plains, the area of sand plain habitat can be crudely calculated at 15,360 acres. The description of these plains in Olmstead, Britton, and Nichols (1914) all describe a tract to the east of the Quinnipiac between New Haven and Meriden. The historical acreage can be inferred if not quantified by the statements in the previously cited papers. For example, Olmsted (1937) says "When not used for urban or industrial purposes, they are covered with various xerophytic types of natural or semi-natural plant communities..." This would seem to indicate some level of loss or degradation of this habitat that was at one time "a conspicuous feature of the central lowland of Connecticut." (Nichols, 1914).

On Long Island, the Hempstead Plains once covered more than 60,000 acres. The Hempstead Plains grasslands were first purchased by the Dutch from Native Americans in 1640 as part of the county of Queens. English settlers from New Haven purchased the "Great Plains" in 1643 and settlement began the following year. The settlers thought the plains were unsuitable for tillage and retained approximately 17,000 acres as common pasturage (Neidich, 1984).

More intensive development on the plains began in 1869 with Alexander T. Stewart's purchase of 7500 acres, which was to become Garden City, Long Island. After the Wright brothers historic flight at Kitty Hawk, N.C. in 1903, small airfields began to spring up all over the plains for both military and civilian use. Large portions of the Hempstead plains were converted to agriculture as the urban centers of Queens expanded.

Following World War II, the neighborhood called Levittown heralded the birth of suburbia with the construction of 17,000 cheap, mass-produced homes for returning soldiers. This was the largest single development effort on the plains. As of 1984, only 44 acres of the original 60,000 was preserved. This represents less than one tenth of one percent of the original known coverage of this habitat (Neidich, 1984).

Due to the glacial action that formed these grasslands, no new "natural" grasslands are expected to form in Connecticut or New York. Today, the existing upland grassland communities are mostly limited to those created through anthropogenic activities. Golf courses, airports, corporate parks, utility rights-of way, and abandoned agricultural lands have filled an ecological niche. The lack of regulatory protection of grasslands leaves them particularly vulnerable to development. Management of grasslands on areas already developed has been successfully achieved at Brainard Field Airport in Connecticut and Floyd Bennett Field in Brooklyn as well as other sites across New England. The New York Natural Heritage Program is currently managing a 19-acre open area at Nassau Community College on Long Island. This remnant tract of the Hempstead Plains is surrounded by dense development, nonetheless it appears to be the best representative acreage of the undisturbed community.

DEGRADED GRASSLANDS AND RESTORATION METHODS

The most prevalent cause of degradation in grassland communities is development. Placement of structures in grassland areas reduces the overall area of grassland cover. An additional indirect effect of the development is fragmentation of the remaining undisturbed grassland tracts. Studies on grassland bird population dynamics indicate that species like the Bobolink, savannah sparrow, grasshopper sparrow, and Henslow's sparrow only nest in grasslands greater than 25 acres in size. Upland sandpipers and Northern harriers prefer ranges 74 acres or larger (Askins, pers. comm.).

Fire suppression policies in the remaining grassland areas is an equally important factor in their degradation. Low diversity shrub cover steadily invades making the area unsuitable for grassland specialized species. Fire suppression increases with development of an area. Suppression of natural fire events has been recognized as contributing to community degradation of many forest types as well as the detrimental effects on grasslands (Clapham, 1983).

A historic cause of degradation to the sand plains in Connecticut, and possibly the North Fork of Long Island, was plowing of the grasslands for agriculture. The action of farming the soils caused the destruction of the upper layer of the soil profile. After the initial physical disturbance by plows, the soils became extremely erodible by wind and water. Colonists also planted trees along the fence rows separating the agricultural plots in the New Haven sand-plain region, facilitating the spread of woody vegetation into the grassy areas.

There are several restoration techniques described in the literature for grassland communities. The most extensive body of research has been done on the tallgrass prairies of the Midwestern United States. Due to the close ecological similarity of the Hempstead Plains, sand plain communities, and these prairies, the techniques developed in the Midwest are appropriate to use on the East Coast. Generically, these techniques could be used on almost any grassland restoration site, and the most important component of these restoration techniques is long-term maintenance.

Restoration Methods:

① Prairie preserve restorations in Illinois have been successful using combinations of plowing, disking, and planting along with natural revegetation from the existing seed bank (***Figure 4-4***). An example of this technique can be found at the Fermi National Laboratory

Figure 4-4. Preparation of a Grassland Restoration Site

Standard farm tractors can be used to prepare grassland restoration sites for replanting.

on the land inside the accelerator ring. This technique combined with a seed drill designed for use with warm season grass seeds has been successfully employed at Orient County Park in Orient, New York. The site must first be cleared of any woody vegetation, and will still require follow up mowing or burning to maintain the grasses.

② A grassland management and restoration technique utilized by the Natural Heritage Program is controlled burning (***Figure 4-5***). Also called prescribed burning, this technique has been shown to favor native grass species like little bluestem while stunting or eliminating woody vegetation and non-native forbs. This technique has been utilized on all of the grassland types discussed in this chapter with much success (The Nature Conservancy, 1994). The major advantage to using this technique is that it takes advantage of the natural fire adaptations of the grassland plant communities. The disadvantages include the long time period for vegetation to reestablish itself, and the need for maintenance of the site for long periods of time, possibly in perpetuity. The natural grass community may take years to fully develop, while requiring biennial or annual burning to reduce invasive species competition.

Figure 4-5. Controlled Burning

A U.S. Fish and Wildlife Service staff member uses a drip torch to burn a managed grassland in New York.

③ Mowing or cutting the grass at regular intervals will also help to discourage invasion of woody growth in grassland areas. Mowing will cut the leafy parts off of newly sprouted seedlings. Once the food stored within the seed itself is expended, the seedling becomes completely dependant on photosynthesis to survive. If the upper leafy portion of the tree or shrub is removed, the young plant will die. The mowing must also be timed to prevent disturbance to nesting birds. Grass cuttings should also be removed following mowing to reduce the leaf litter. Some studies suggest that buildup of leaf litter may enable invasion by non-native and woody species.

This method of grassland restoration and management is often used in developed areas where burning is unsafe. For example, corporate parks and airports are often attractive to grassland birds due to the maintenance of level, grassy areas that are less prone to pedestrian disturbance. While the plant community of a managed grassland may not be as diverse as the natural community, many of the same habitat features may exist on the managed grassland to attract birds to colonize it. The lawn areas of large corporate office parks and airports are less intensively landscaped, and may have a variety of grasses and wildflowers. Because the grassy areas at an airport must be regularly mowed to control possible navigation hazards, this provides an excellent partnership opportunity. Once a management plan is implemented in cooperation with appropriate state and federal agencies, the work schedule of the maintenance crew can be adjusted easily to accommodate the birds' nesting season.

SPECIFIC RESTORATION OBJECTIVES

Coastal grasslands are the most rare of the 12 habitat types chosen as priorities by the Habitat Restoration Workgroup. Any and all opportunities to restore areas of grassland should be taken. It is useful to remember that some of the important functions of grasslands as habitat for birds and other animal species require a minimum parcel size of as much as 50 acres. It may be necessary to acquire additional land to be able to restore large tracts of grasslands or to use managed areas like airports and industrial parks to act as surrogates for open grassland areas. There are other areas of public land where large lawn areas can be managed for warm season grasses. Fields at several New York City parks in Queens and the Bronx are being restored and managed for warm season grasses in the midst of a densely-populated urban area. Any parkland with unused or passive fields can be adapted to grassland management.

Due to the lack of legislative protection of grasslands, the best restoration strategy for these communities, other than outright acquisition, is to cooperatively manage them with the private owners. In the case of airports the maintenance of an ***Andropogon spp.*** dominated meadow not only attracts grassland breeding birds, but discourages use of the area by nuisance bird species like gulls (Robert Askins, pers. comm.). These larger birds can potentially cause severe jet engine damage in the case of a bird - plane collision.

An additional set of goals would include restoration of endangered, threatened, and special concern species. Plant species can be propagated from seeds, while invertebrates could be captive bred and released into the restored area once the plant community becomes established. Vertebrate species could be expected to colonize from nearby sites or could be trapped and released onto the restored site. The U.S. Fish and Wildlife Service is working to expand the population of sand-plain agalinis on Long Island. Additional sites to establish populations would help maintain the fragile status of this endangered plant.

Overall increase of grassland dependant and associated species should be a generic goal and measured as part of site monitoring. Setting specific goals for individual species will be in part determined by the size of the grassland site. Extensive literature exists regarding the minimum acreage requirements of grassland breeding birds, raptors, and other vertebrates. Goal setting will also be influenced by the available management techniques for the site. A site managed through controlled burning may have different restoration targets than a site managed by mowing. A restoration project manager must research the different needs of plants and animals which may utilized the restored site and plan accordingly.

RESTORATION SUCCESS AND MONITORING

A standard measure of restoration success in grassland restorations is to examine the species diversity and wildlife usage of the area. In areas like the Hempstead Plains, accurate records of the species occurring there prior to significant disturbance make an excellent benchmark for restoration efforts. The same is true in the sand plain communities of Connecticut’s central lowlands. Using these records and the attributes of remaining grassland areas such as Montauk Downs in New York, and the grasslands on Nantucket and Martha’s Vineyard islands in Massachussets, a target profile of a restored grassland can be built. It may take several growing seasons to achieve full species diversity in the plant community. Intensive management may be required in the first several growing seasons following restoration to suppress unwanted vegetation.

Measurement techniques for this habitat include vegetation transects and quadrat surveys to determine species abundance, diversity, and richness. Also important in determining the success of a grassland restoration is bird, mammal, and insect censussing, again making the same abundance, diversity, and species richness determinations. Seasonal and diurnal patterns of use should be considered when planning sampling. For example, nesting species may not be found at times of the year other than breeding season, and nocturnal species like owls may not be seen if all surveys are done in daylight.

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LONG ISLAND SOUND HABITAT RESTORATION INITIATIVE

SECTION 5: COASTAL BARRIERS, BEACHES, AND DUNES

Technical Support for Coastal Habitat Restoration

SECTION 5
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SECTION 5: COASTAL BARRIERS, BEACHES, AND DUNES

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.

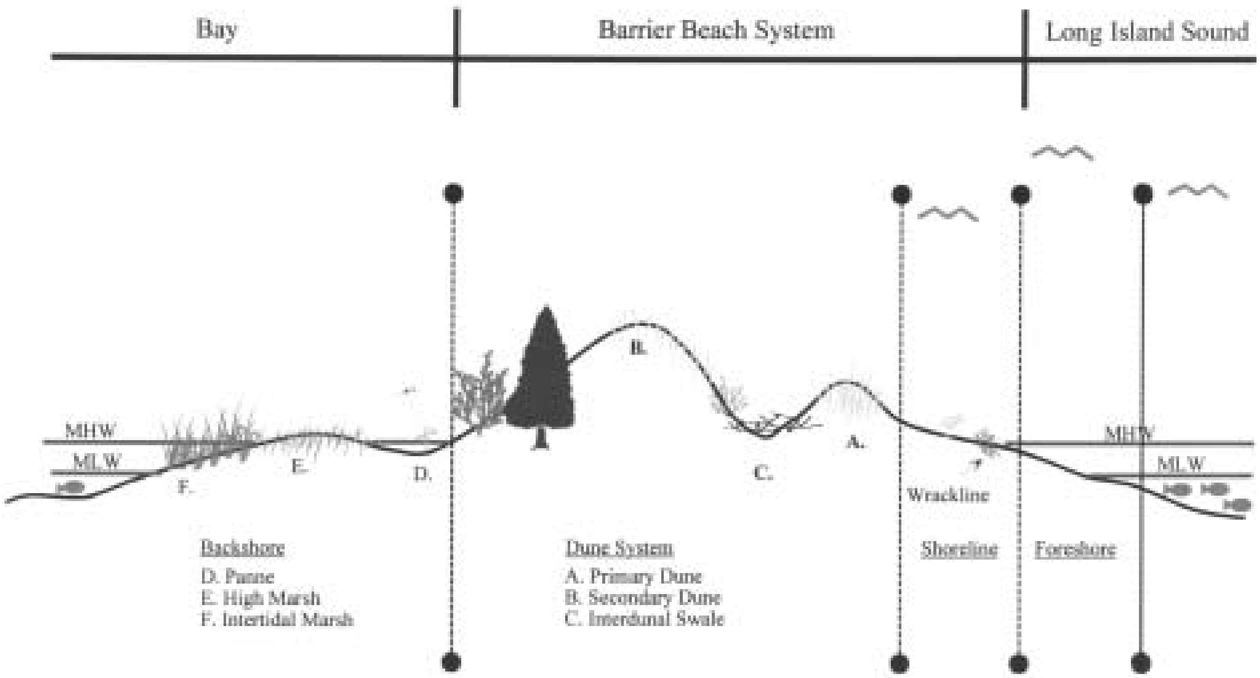
COASTAL BARRIERS

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.

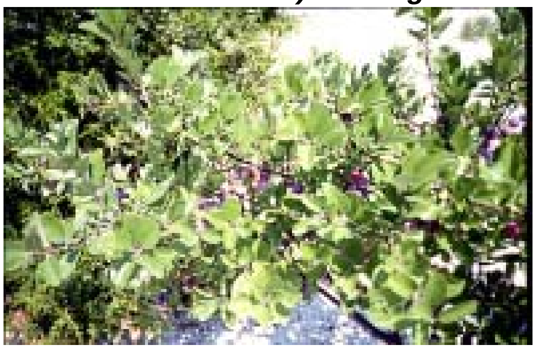
Maritime Dunes

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 <u>Removal of outdated or abandoned structures:</u> 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 <u>Restoration of damaged dunes</u>: 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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